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REPORT ON GEOLOGICAL SURVEY OF THE CORDILLERA ORIENTAL, CENTRAL PERU

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METAL MINING AGENCY
JAPAN INTERNATIONAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

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 second phase survey, and as for this current year, a Geological-Geochemical survey team was formed consisting of sixteen (16) members May 25 headed by Mr. Shigeaki Yoshikava, Mitsui Kinzoku Engineering Service Co., Ltd., and sent to the Republic of Peru on May 25, 1976. The Team stayed there for one hundred fifty-five (156) days from May 25, 1976 to October 23, 1976. During the period of its stay, the team, 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 Reconnaissance survey in a northern half of the area, and of the Geological-Geochemical Detailed Survey in a central part of a southern half of the area, and Aerial Photo-taking performed for the second-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.

March 1977

Shinsaku Hogen
President
Japan International Cooperation Agency

Yasuaki Hiratsuka
President
Metal Mining Agency of Japan

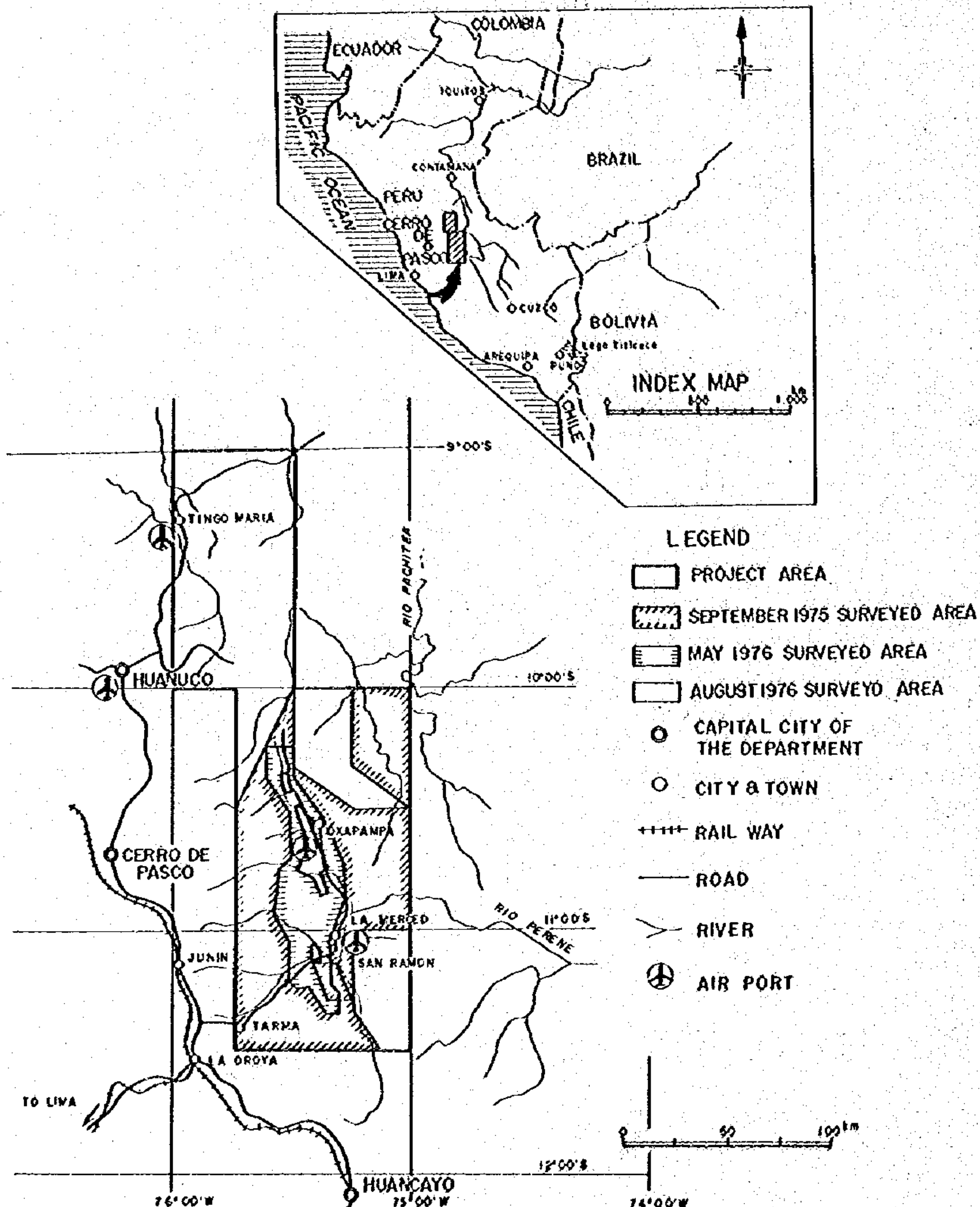


Fig. 1 Location Map of the Surveyed Area

GENERAL CONTENT

A B S T R A C T

Present survey was carried out as a part of the project of geological survey for mineral resources development in the central part of the Republic of Peru. Purpose of the survey lied in

(1) to extract some terrains of higher possibility in ore existence through clarifying distribution of the Pucara Group in which emplacement of bedded deposits of lead and zinc are anticipated, and

(2) to establish the procedures and principles of prospecting such kind of ore deposits.

Field operations consisted of geological survey, geochemical survey, and aerial photo taking, and they were performed during the period from August to October 1976, and indoor analytical works were fulfilled from November 1976 to March 1977.

Geological formations distributed in the surveyed area consist of Pre-Cambrian metamorphic rocks, sedimentary rocks deposited intermittently from Devonian Period, Paleozoic, to Tertiary Period, Cenozoic, and igneous rocks by the intermittent activities from late Paleozoic to Tertiary through Mesozoic Era. These formations have their principal structural direction of NNW-SSE, and the igneous and metamorphic rocks are distributed mainly in the western area, while the sedimentary rocks are in the eastern area. Among the sedimentary formations, the Pucara Group is mostly distributed in the east side of the igneous zone in the surveyed area. This direction of NNW-SSE is the principal direction of geological structure in this area and synclinal and anticlinal structures are developed with their folding axes of said direction, Moreover, there are developed faults of similer direction (normal and reverse), and

faults of NWW-SEE and NNE-SSW systems, traversing the folding structures, are also developed.

Mostly in the southern part of the surveyed area, there exist bedded lead-zinc deposits, mineral indications of disseminated lead, copper-lead-zinc deposits of skarn type, copper-lead-zinc deposits of vein type, and indications of porphyry copper type mineralization. Among them, the most important are the bedded deposits and the disseminated mineral indications in the Pucara Group. Both of them are contained along dolomite layers of the Pucara Group; mineralizagion of bedded type are recognized in the Chambara Formation, lower member of the Pucara Group, which are represented by the deposits of San Vicente, Pichita Caluga, and indications in Tambo Maria, while mineralization of dissemination type in Oxapampa is recognized in the Aramachay Formation, middle member of the Pucara Group. These mineralizations are characteristically recognized in such parts of dolomite where banded (zebra) or breccia structures are developed.

From the study of percentage of copper, lead, and zinc, (to be called *-ratio hereafter) as minor contents in such carbonate rocks as limestone and dolomite, it has been made clear that the Pucara Group generally presents the values of copper, lead, and zinc indicating approximately definite ratios, while the carbonate rocks where the mineral indications were found near Tambo Maria in the southern part of the surveyed area and the carbonate rocks near Pusaguno have the values of which ratios are anomalously deviated from the said definite ratio. This fact may suggest the migration of elements, especially of copper, lead, and zinc, and in regard to the factors of migration, influences of such tectonic movements as the formation of folding structures of the

Pucara Group, faulting structures, and nearby intrusions of igneous rocks may not be ignored. This results have served effectively in establishing accurate principles of future survey and in extracting the terrains in which further detailed survey is needed.

Results of geochemical survey on soils in the surveyed area have revealed that zinc anomalous zones have been detected distinctly in the Pucara Group, copper anomalies have been detected over diorite, porphyry, and vein type deposits, and nickel anomalies have been found where metamorphic rocks and diorite are distributed. Consequently, it has been made clear that zinc is effective for prospecting the bedded lead-zinc deposits, and copper and nickel are effective for distinction of rock facies and for examination of some kinds of mineral indications.

Through the keen analysis of the results of survey as stated above, west part of Oxapampa and surroundings of Tambo Maria and Pusaguno in the southern part of the surveyed area have been extracted as the terrains of higher possibility in the existence of the bedded lead-zinc deposits in the Pucara Group, and in the northern distriot too, it has been made clear that neighbourhoods of Tingo Maria and Monopampa, where zinc anomalies have been detected by geochemical survey, may become hopeful terrains depending upon the results of future survey. It also has been clarified advisable to apply the following procedures in prospecting these terrains above mentioned;

(1) Stratigraphical and structural survey of the Pucara Group, especially zoning of dolomite layers,

(2) Geochemical survey for copper, lead, and zinc, especially examination of minor elements in the carbonate rocks,

(3) Geophysical surveys to understand subsurface geological structure,

especially its relations to igneous rocks (gravity and magnetic surveys).

Principles of future survey, therefore, may be stated as follows;

(1) For Oxapampa, Tambo Maria, and Pusaguno, where the possibilities in existence of concealed ore deposits have become higher,

1. geological survey and detection of distribution of minor elements,

2. gravity and magnetic surveys,

3. structural boring,

should be practiced,

(2) For the northern area, on the other hand, any survey activity should be suspended until coming out of the best procedures of prospecting expectable through the results of surveys mentioned in the paragraph (1).

GENERAL

CONTENTS

Chapter 1 Conclusion

1-1. Results of Geological Reconnaissance

Following are the results of comprehensive data analysis and compilation of findings including present survey practiced mostly in the northern part of the projected area and all the surveys previously made.

1-1-1. Geology

(1) In the surveyed area, igneous and metamorphic rocks are distributed mostly in the western part, and sedimentary rocks are distributed in the eastern part.

(2) Distribution of these formations conforms to the general direction of NNW-SSE in the geological structures of central part of Peru.

(3) The metamorphic rocks consist of schists and gneisses, forming the basement for the sedimentary rocks mainly in the western part of the surveyed area, and they are distributed as roof pendants over the granitic rocks of late Paleozoic intrusion.

(4) The igneous rocks distributed in the western part consist of granitic rocks of late Paleozoic intrusion, dioritic rocks and granitic rocks of Jurassic intrusion along eastern margin of the late Paleozoic granitic rocks, porphyries such as granite porphyry and quartz porphyry of late Cretaceous intrusion in Mesozoic Era around the eastern margin of Paleozoic granitic rocks, and Tertiary volcanic rocks in Cenozoic Era mostly effused within the area of distribution of the Paleozoic granitic rocks. There are Tertiary monzonitic rocks too, penetrating the sedimentary rocks and intruding along a fault which passes in a direction of NNW-SSE at the eastern side of the Pucara Group distributed in the central part.

(5) Macroscopically, the sedimentary rocks of older ages tend to be distributed in the western part, and those of younger ages tend to be distributed towards east.

(6) The sedimentary rocks have been deposited intermittently since Devonian Period of Paleozoic Era till Tertiary Period of Cenozoic Era, but interruptions of sedimentation took place for three times as shown below accompanied by orogenic movements; prior to middle Triassic, Mesozoic Era, prior to middle Jurassic, Mesozoic Era, and during Paleogene, Cenozoic Era.

(7) The Pucara Group which was deposited from Triassic to Jurassic Period, Mesozoic Era, is distributed in a direction of NNW-SSE nearly in the central part of the surveyed area, forming a slender zone and overlying the Mitu Group unconformably. The western side of it is generally penetrated by the younger igneous rocks, though it is partly in contact with the older granitic rocks by faults. The eastern side of it is in contact with the younger sedimentary formations by faults or unconformities.

(8) The Pucara Group is classified into the Chambara, Aramachay, and Condorsinga Formations, and is composed mainly of such carbonate rocks as limestone intercalating shale and sandstone, dolomitic limestone, and dolomite.

(9) 5 layers of dolomite are recognized in the southern area; 2 in the Chambara Formation, 2 in the Aramachay Formation, and 1 in the Condorsinga Formation. A few layers of dolomite were recognized in the northern area too, but their stratigraphical relation could not be determined. The dolomite layers in the Chambara Formation emplace the San Vicente Deposits, Pichita Caluga Deposits, and Tambo Maria mineral indications.

(10) Structures of anticline and syncline are developed with their

folding axes in a direction of NNW-SSE in the surveyed area, which build up the principal geological structure in this area. Faulting structures are characterized by the faults of similar direction to the folding structures, either as normal or reverse fault, and by the development of fractures in NWW-SEE and NNE-SSW systems, which are related to lateral compression in a direction of NEE-SWW.

1-1-2. Mineralization

In the southern part of the surveyed area, there were recognized such ore deposits or mineral indications as bedded lead-zinc deposits and indications of disseminated lead in the Pucara Group, skarn type deposits of copper, lead, and zinc, replacing the carbonate rocks in the Pucara Group, vein type deposits of copper, lead, and zinc, in the Pucara Group and granitic rocks, and indications of porphyry copper type accompanied by the Tertiary porphyries.

But in the northern part, indications of only feeble veins of copper, lead, and zinc were found. The bedded lead-zinc deposits emplaced in the Pucara Group are the most important among them.

1-1-3. Geochemical Survey

(1) Cu anomalies were detected near the vein type deposits in the Pucara Group and granites, and near the localities where indications of copper mineralization were found in such rocks as Jurassic dioritic rocks and Tertiary monzonitic rocks.

(2) Zn anomalies were detected almost limitedly within the distribution of the Pucara Group, and they were recognized to conform with the distribution of dolomite or dolomitic limestone.

(3) High values of Ni were found to have been gathered where gneisses and Jurassic diorites were distributed.

(4) It has been made clear through the results of geochemical survey,

that the survey for the purpose of pursuing the bedded lead-zinc deposits in this area should be practiced within the distribution of the Pucara Group.

1-2. Results of Detailed Geological Survey

Followings are the results of field operations and data analysis in the detailed geological survey.

1-2-1. Geology

(1) Sedimentary rocks occupy the greater part of the surveyed area among those distributed in it, and igneous rocks are distributed along the westerm margin. Among the sedimentary rocks, the Pucara Group is distributed nearly in the central part, while younger sediments of post Pucara Group are distributed in the eastern side of the area.

(2) Igneous rocks consist of Jurassic dioritic rocks in Mesozoic Era and Cretaceous granitic rocks, which are distributed in Pichita Caluga district, Jurassic dioritic rocks and granitic rocks, late Cretaceous porphyries of Mesozoic Era, and Tertiary monzonitic rocks, which are distributed in Oxapampa district. But no igneous rock is distributed in Huancabamba district.

(3) The Pucara Group consists of 8 members, which are 2 layers of black limestone members, 3 layers of limestone-dolomite members, and 3 layers of sandstone members.

(4) Fossil, indicating Hettangian Epoch of Jurassic Period, was found from the dolomite-limestone member overlying the lower sandstone layer, and this discovery made it possible to correlate the ore-bearing horizon of the San Vicente Deposits with corresponding horizon in the surveyed area in general. And another fossil, indicating Sinemurian Epoch of Jurassic Period, was discovered from the middle sandstone layer.

Consequently, the layers from the lower sandstone to the middle limestone-dolomite member under the middle sandstone could be correlated to the Aramachay Formation which is the middle member of the Pucara Group.

(5) The limestone-dolomite member consists mainly of limestone, dolomitic limestone, and dolomite, and 4 layers of dolomite were confirmed in the surveyed area (cf. previous paragraph). And the zebra structure and breccia structure were found to have been developed in some parts of the dolomite layers.

(6) The carbonate rocks such as limestone and dolomite were interpreted as organic origin, and the dolomite was considered to have been formed by diagenesis after its deposition. Mg contents in dolomite are 10--14%, and the lowermost layer among the 4 was found most homogeneous but the rest 3 were found a little heterogeneous.

(7) An anticlinorium with folding axes in the direction of NNW-SSE (partly N--S) is recognized in the surveyed area, which forms the principal geological structure of this area. In regard to faulting structures, there are faults not only of similar direction to the folding structures but also of NEE-SWW and NWW-SEE systems.

1-2-2. Geochemical Survey

(1) Pb and Zn contents in soils of the surveyed area were as high as 121 ppm and 329 ppm in average respectively, and most of anomalies were maldistributed on the west side. Such distribution more or less conformed to the distribution of the dolomites, and the anomalies were found to have been elongated strikewise.

(2) But the mineral indications of Tambo Maria could not be extracted out in the present geochemical survey. This may suggest that Zn once leached out of the host rock was dispersed away due to topographic influence.

(3) High values of Cu were recognized around the terrain in which vein type mineralization was found like Pichita Caluga and Churumazu.

1-2-3. Mineralization

(1) Following mineralizations were recognized in the surveyed area; bedded mineralization in the Pucara Group, mineralization of dissemination type in the Pucara Group, pyrometasomatic mineralization and mineralization of porphyry copper type accompanied by Tertiary monzonite, and vein type mineralization.

(2) The bedded mineralization of Pb and Zn recognized near Tambo Maria was spread in a patch of 30 cm in average width and about 2 m in length, occurring near the boundary between the banded dolomite and breccial dolomite. The ore mainly consisted of sphalerite was found to occur on the side of white dolomite in the banded structure of white dolomite and gray dolomite.

(3) Average contents of Cu, Pb, and Zn, in the carbonate rocks were 37 ppm, 121 ppm, and 329 ppm respectively and maximum contents were 2,785 ppm, 1,873 ppm, and 5,528 ppm respectively. Especially among them, anomalous values of Pb and Zn were distributed around the mineral indications along the dolomite layers.

(4) Ratios of the 3 components are almost similar in spite of their contents and they were found constant in the upper and lower layers throughout the surveyed area. Around such mineral indications as Tambo Maria and Oxapampa, however, high anomalies in Zn proportion and low anomalies in Zn proportion (high Pb) coexisted closely, and it was considered that migration of elements, especially of Pb and Zn, might have been the cause.

(5) Around anomalous samples in the ratios of 3 components, intrusions of igneous rocks were recognized and from this fact, influence from

igneous rocks was considered to have had much to do with migration of Pb and Zn.

(6) Since it was so interpreted that the banded dolomite (zebra dolomite) had been formed along pores generated during structural movements, the migration of Pb and Zn might have occurred during the movements to form the banded dolomite.

(7) Geochemical survey on soils is only to indicate dispersed distribution of elements after leaching, while such survey on the carbonate rocks will convey their distribution fixed in host rocks, and to compare their values and ratios of samples each other may enable to assume migration of elements. At the same time, the indications in Tambo Maria, once had not been detected anomalies by the survey on soils, was extracted as anomalies by the survey on the carbonate rocks. From these facts, geochemical survey on the carbonate rocks is considered more effective method.

1-3. Future Aspects

Followings are the important points as the guides for future survey. They have been clarified through several surveys hitherto have been done regarding to the bedded deposits of San Vicente type, the main object of these surveys.

(1) Dolomite layers are important hosts for emplacement of the ore deposits.

(2) Ratios of Cu, Pb, and Zn, contained in the carbonate rocks, are generally constant, but mineral indications have been found where the anomalous ratios were detected.

(3) Factors of such anomalies may be infered to migration of elements primarily contained in the carbonate rocks and later additional effects of elements by igneous activities.

It may otherwise be said as follows:

(1) Geochemical anomalies by soils and anomalies of ratios in 3 elements contained in the carbonate rocks appeared generally along the layers of dolomite, and ore deposits were also found to have been emplaced where such structural disturbances as the banded structure and beccia structure were developed. Therefore, stratigraphical survey of the Pucara Group for the purpose to fix the startigraphical positions of dolomite layers was very fruitful survey in determining the ore bearing horizons.

(2) Geochemical survey on soils was effective for some extent to understand the state of distribution of each element clearly, but the survey on the carbonate rocks to acquire the distribution of minor elements contained is considered to be much more effective as it enables to locate possible areas of ore emplacement.

(3) It has been pointed out that igneous rocks would play an important roles even in the mineralization of deposits of San Vicente type. The possibility has been upraised through the present survey too, and it has become important to determine their structural positions and modes of intrusion. In view of this, it is considered effective not only to determine their geological ages and chemical compositions, but also to examine their minor components and to practice the gravity and magnetic surveys.

(4) The banded structure and the breccia structure in dolomite are interpreted to have been derived by structural factors. The ore deposits of San Vicente type, mainly concentrated in the banded structure, is also interpreted to have been emplaced during this epoch of structural events. Considering these views, importance has been perceived to make clear the roles played by the regional tectonic movements in relation to the igneous activities.

(5) It is necessary to acquire systematically the reasonable relation whether behaviors of minor contents of Cu, Pb, and Zn in the carbonate rocks would conform to the ore deposits of San Vicente type. Comparative study with the San Vicente Deposits is considered useful from such stand points.

(6) The carbonate rocks in this area contain more or less uniform proportion of Cu, Pb, and Zn, of which contents were also as high as 120 ppm Pb and 330 ppm Zn. Mineralogical determination in what states and from what origins they are contained in the carbonate rocks may also be important in solving the problems of ore genesis as well as to presume the explorable terrains. In view of what have been stated above, the desirable surveys to be practiced in the future will be given hereafter (Fig. 2).

As it has been pointed out by the report of May 1976 survey, possibility in existence of concealed ore deposits has been upraised in such locations as the surroundings of Tambo Maria and Pusaguno, west of Oxapampa, in the southern part of the surveyed area. In response to these, following surveys should be practiced for these locations in order to make clear the structure of ore-bearing formations.

Geological survey:	geological survey to interpret the results of gravity and magnetic surveys and structural boring, determination of distribution of minor elements.
Gravity survey & Magnetic survey :	determination of subsurface structure of ore-bearing formations, an area of about 200 km^2 (200 stations) including Maria Tambo and Pusaguno, west of Oxapampa.

Structural boring: establishment of stratigraphy and determination of structure of ore-bearing formation, a few holes of deep boring in the west of Oxapampa and Tambo Maria.

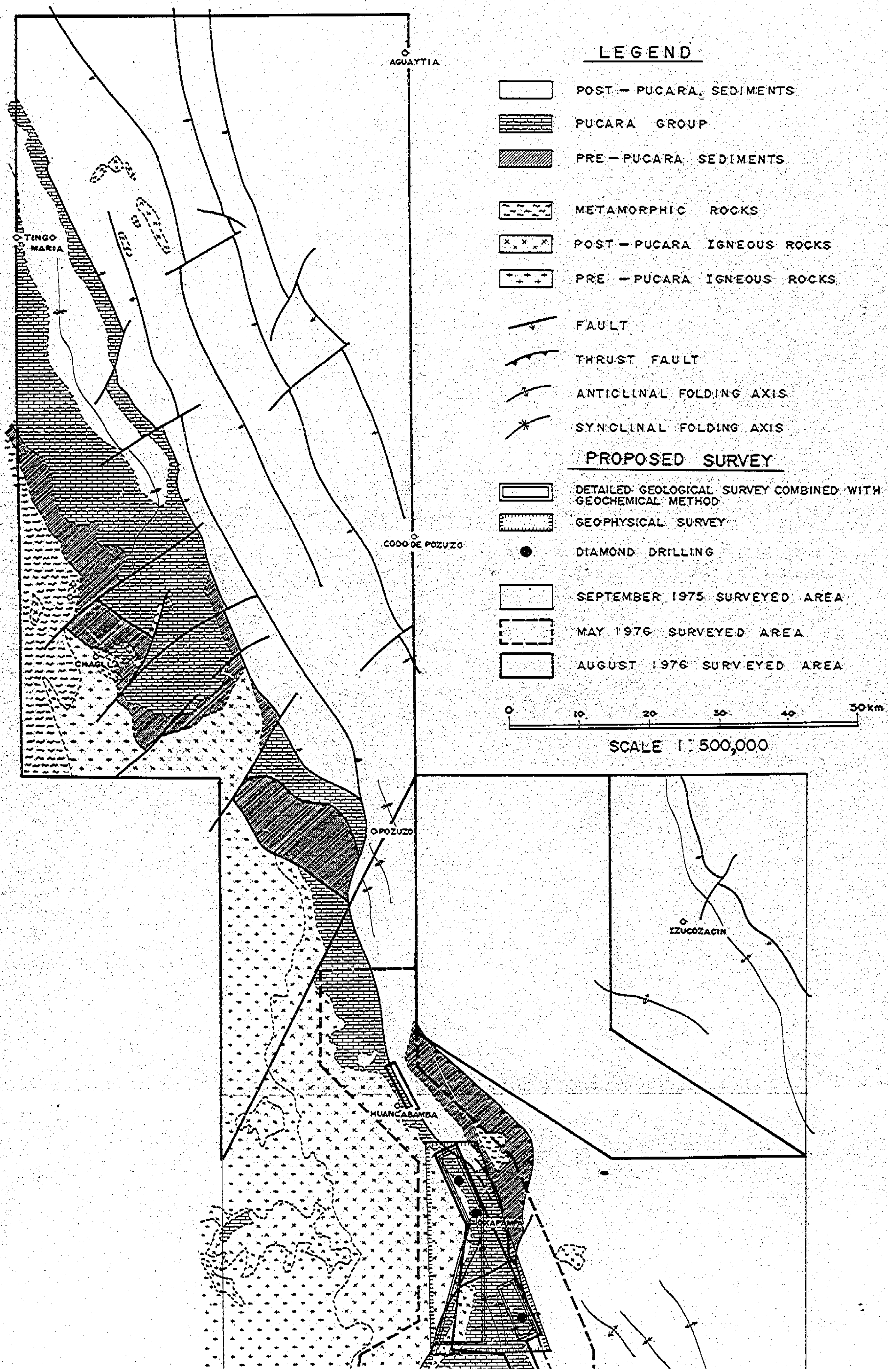
In the northern part of the surveyed area, on the other hand, in spite of some anomalies detected by geochemical survey, any instant movement for the next step should be suspended until the most effective way of prospecting will be found by practicing ahead the survey in the south. Followings are, however, desirable procedures to be taken in early period of survey.

(1) The first stage:

Determination of distribution and structure of dolomite layers, the ore-bearing formation, and zoning of dolomite layers.

(2) The second stage:

Survey in the north in this stage should follow the most effective procedures to be expected to come out through the survey in the shouth.



LEGEND
POST - PUCARA SEDIMENTS
PUCARA GROUP
PRE - PUCARA SEDIMENTS
METAMORPHIC ROCKS
POST - PUCARA IGNEOUS ROCKS
PRE - PUCARA IGNEOUS ROCKS
FAULT
THRUST FAULT
ANTICLINAL FOLDING AXIS
SYNCLINAL FOLDING AXIS
PROPOSED SURVEY
DETAILED GEOLOGICAL SURVEY COMBINED WITH GEOCHEMICAL METHOD
GEOPHYSICAL SURVEY
DIAMOND DRILLING
SEPTEMBER 1975 SURVEYED AREA
MAY 1976 SURVEYED AREA
AUGUST 1976 SURVEYED AREA
0 10 20 30 40 50km
SCALE 1 : 500,000
AGUAYTIA
TINGO MARIA
CODO DE POZUZO
POZUZO
HUANCABAMBA

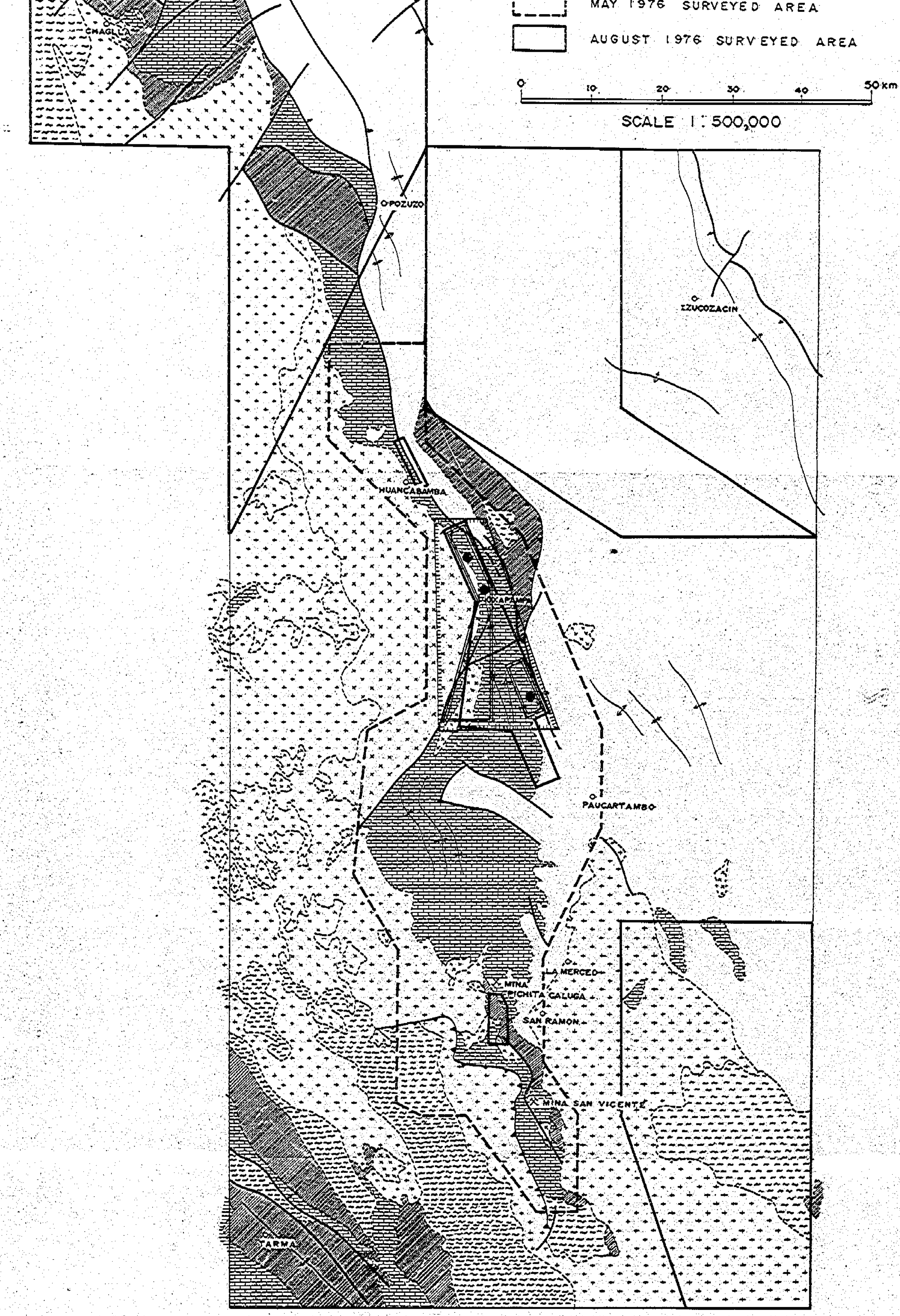


Fig. 2. Geological Structure and Recommendation Map of the Surveyed Area

Chapter 2 Introduction

2-1. Purpose of Survey

This survey was carried out as a part of the project of geological survey for mineral resources development in the central part of the Republic of Peru, which had been laid out to be practiced in the eastern parts of these Departments (Departmentos) of Junin, Pasco, and Huanuco, covering an area of about 20,000 km^2 (Fig. 1). The operations consisted of geological and geochemical field surveys, in which reference was made to data about the Side Looking Air-borne Radar (SLAR) furnished by the Geological Survey of the Republic of Peru (Instituto de Geologia y Mineria) for thier re-examination. Purpose of these works lied in to extract some areas of higher possibility in mineral existence by making clear the distribution of the Pucara Group, and to establish the most appropriate methods of prospecting bedded lead-zinc deposits anticipated to exist in the Pucara Group.

2-2. Progress of Surveys

The survey was commenced in 1975. The survey of 1975 consisted of geological reconnaissance for the area of southern half of the projected area covering about 10,000 km^2 and detailed geological survey in combination with geochemical survey for an area of 100 km^2 around the San Vicente Mine. This survey was performed during the period of September to October 1975 (to be called September 1975 survey hereafter).

In 1976, detailed geological survey and geochemical survey were performed in an area of 2,000 km^2 centering around the distributed area of the Pucara Group, which had been mapped out clearly in the southern half of the area covered by the September 1975 survey. This survey took from May to July 1976 (to be called May 1976 survey hereafter).

Moreover, since after August 1976, detailed geological survey was made for the highly concentrated parts by zinc in the Pucara Group, which were extracted through the May 1976 survey, and at the same time, geological reconnaissance was made for a part of the southern area (to be called August 1976 survey hereafter).

Present report has attempted to compile mainly results of the August 1976 survey, but as it has come to the stage completing the survey for entire projected area, the report also deals with comprehensive data analysis including the results of surveys of September 1975 and May 1976.

2-3. Outline of Survey

2-3-1. Range of Surveyed Area (Fig. 2)

The entire projected area for survey is an area of about 20,000 km^2 surrounded by the following 8 points;

1. (9° 00' S, 75° 30' W)	5. (11° 30' S, 75° 45' W)
2. (9° 00' S, 76° 00' W)	6. (11° 30' S, 75° 00' W)
3. (10° 00' S, 76° 00' W)	7. (10° 00' S, 75° 00' W)
4. (10° 00' S, 75° 45' W)	8. (10° 00' S, 75° 30' W)

Geological works in the August 1976 survey consisted of geological reconnaissance practiced mostly in the northern part for an area of about 10,000 km^2. This area consisted of 3 separate districts, and the coordinates to surround each of them will be given below. In addition, some supplementary survey was also made outside these areas.

District 1, about 7,000 km^2, surrounded by the following 6 points;

1. (9° 00' S, 75° 30' W)	4. (10° 00' S, 75° 45')
2. (9° 00' S, 76° 00' W)	9. (10° 30' S, 75° 45')
3. (10° 00' S, 76° 00' W)	8. (10° 00' S, 75° 30')

District 2, about 1,570 km^2, surrounded by thefollowing 6 points:

8. (10° 00' S, 75° 30' W) 12. (10° 30' S, 75° 00' W)

10. (10° 20' S, 75° 30' W) 13. (10° 20' S, 75° 15' W)

11. (10° 30' S, 75° 15' W) 14. (10° 00' S, 75° 15' W)

District 3, about 1,430 km^2, surrounded by the following 5 points

15. (11° 00' S, 75° 15' W) 6. (11° 30' S, 75° 00' W)

16. (11° 15' S, 75° 15' W) 18. (11° 00' S, 75° 00' W)

17. (11° 30' S, 75° 10' W)

Detailed geological survey in the August 1976 survey in 3 separate districts of which total areas comes to 259 km^2. The coordinates to surround each of these districts will be given below.

District 1, about 12 km^2 surrounded by the following 4 points:

(10° 22' 07" S, 75° 31' 51" W), (10° 22' 32" S, 75° 32' 34" W),
(10° 26' 28" S, 75° 30' 26" W), (10° 26' 07" S, 75° 29' 43" W),

District 2, about 226 km^2, surrounded by the following 9 points:

(10° 28' 41" S, 75° 27' 00" W), (10° 29' 32" S, 75° 28' 46" W),
(10° 35' 04" S, 75° 26' 22" W), (10° 44' 48" S, 75° 27' 27" W),
(10° 45' 08" S, 75° 23' 28" W), (10° 49' 28" S, 75° 21' 36" W),
(10° 48' 42" S, 75° 19' 47" W), (10° 44' 11" S, 75° 21' 42" W),
(10° 43' 46" S, 75° 20' 33" W),

District 3, about 21 km^2, surrounded by the following 5 points:

(11° 05' 24" S, 75° 24' 10" W), (11° 05' 24" S, 75° 25' 16" W),
(11° 09' 24" S, 75° 25' 16" W), (11° 09' 24" S, 75° 23' 37" W),
(11° 06' 30" S, 75° 23' 37" W),

2-3-2. Procedures and Periods of Survey

(1) Field Works

In the field works of geological reconnaissance mainly in the northern part, the survey was depended upon the SLAR mozaics in a scale of 1:100,000 due to a lack of the published topographic maps, and was supplemented by aerial photos previously taken and newly taken before the commencement of the present survey for the confirmation of accurate ground positions.

In the areas of detailed survey, topographic maps of 1:25,000 and 1:100,000 either published or provisionally made for the present survey were used. The field works required 81 days from August 8 to October 27, 1976.

(2) Comprehensive Data Analysis

Comprehensive review of all the data obtained through the field survey as well as related data ever published was made, and the most effective and more accurate procedures for future survey were considered. The works of data compilation and analysis required 5 months from November 1976 to March 1977.

2-3-3. Organization of Survey Team

The field works and data nalysis were performed by Mitsuikinzoku Engineering Survice Co., Ltd., with cooperation of the geological Survey of the Republic of Peru (Instinuto de Geología y Minería).

Members of field survey team are listed below.

Leader	Shigeaki Yoshikawa	MESCO*
General Affairs	Hironao Hagiwara	Japan International Cooperation Agency
and Liaison	Nobutaka Miyazoe	Metal Mining Agency of Japan
Members	Hiroshi Sato	MESCO
	Nobuo Saito	"
	Yukichi Tagami	"
	Ikuhiro Hayashi	"
	Yosuke Fujioka	"
	Nobuhiro Fukuzako	"

* : Abbreviation of Mitsui Kinzoku Engineering Service Co., Ltd.

	Yoshiaki Shibata	MESCO
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	Tetsuo Sato	"
	Kazuyasu Sugawara	"
General Affairs and Liaison Counterparts	Benjamin Morales A.	Geological Survey, the Republic of Peru
	Salvador Mendivil E.	"
	Carlos Guevara	"
	Julio Caldas	"
	Victor Pecho	"
	Oscal Palacios	"
	Javier Barreda	"
	David Davila	"
	Oscal La Torre	"
	Felix Portilla	"

2-4. General Features of Surveyed Area

2-4-1. Location

The surveyed area is located in the central part of the Republic of Peru and is full of topographical variations, including the ranges of Eastern Andes and Sub-Andes, interstitial basins, and Amazonian plain physiographically.

Admistratively, the area spreads over 4 Departments (Departamentos) of Loreto, Huanuco, Pasco and Junin, from the north. Published topographic maps are available only to cover partially the southwestern part of surveyed area, and the rest of the area was so lacked in aerial photos, which were taken systematically, that the photos had to be taken in a part of the northern area provisionally for the survey in 1976.

2-1-2. Transportation and Accessibility (Fig. 3)

It is the commonest way to access the surveyed area by car from Lima, the Capital City. It is 308 km from Lima to San Ramon, the important city in the southern area, through La Oroya City on the Andean plateau, and it requires about 7 hours. On the other hand, it is 545 km from Lima to Tingo Maria City in the northern area, which can be accessed by following a route on the Andean plateau northwards from La Oroya and then following a trans-Andean route towards Amazonian plain, and it requires about 13.5 hours. Regular flights are also available from Lima to both of the cities.

Within the surveyed area, there is only a main highway stretching longitudinally along the median basins (or interestitial basins) in the southern area from San Ramon to Pozuzo village via Oxapampa City for a distance of 168 km and a few roads are branched out of it, but the rest of the area is not facilitated by roads.
Transportation facility is extremely deficient especially in the northern area, as there is only a trans-Andean road from Tingo Maria to Aguaytia village for a distance of 117 km. Densities of development of supplementary trails for men and horses are quite divergent according to degrees of population and industrial developments, and some area is left unexplored for more than 3,000 km^2 as seen in the central part of northern area.

To the interior of Amazonian plain like Izucozacin and Codo de Pozuzo, air flights either regular or irregular are available from the bases of San Ramon and Tingo Maria, but to the rest of the area partial sails by boats along big streams are only available facility of transportation.

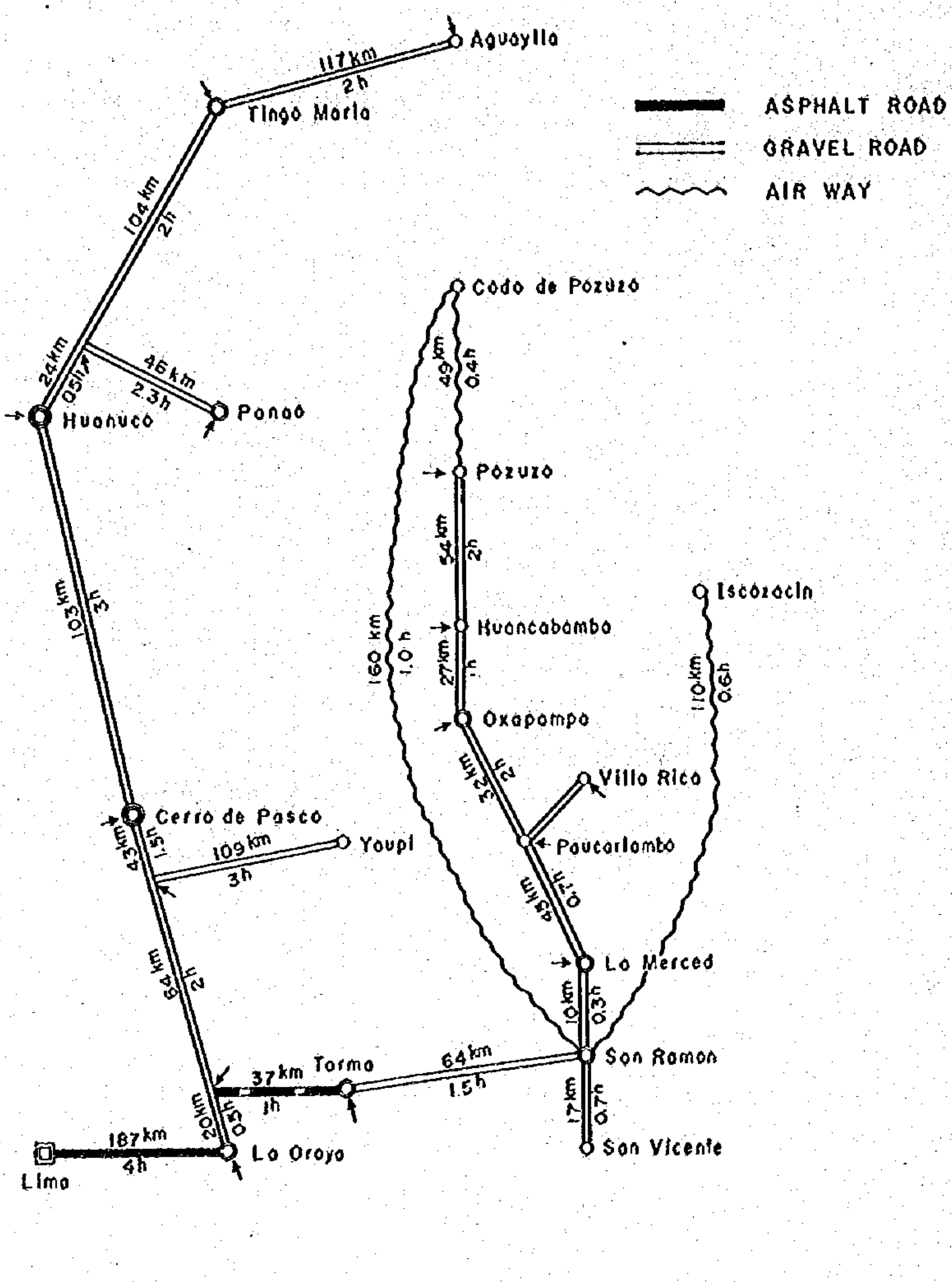

Fig. 3 Accessibility Map of the Surveyed Area

2-1-3. Climate

Types of climate in the surveyed area can roughly be classified into cold highland type in the west, wet sub-tropical type around the median basins, and wet tropical type in the east, which conform more or less to the topographical environments as will be stated later.

The western highland of cold highland type has wet and dry seasons by the influence of monsoon. Difference of temperatures is distinct not only between topographic altitudes but also between day and night, but the climate resembles to that of late fall in the central Japan as a whole.

The area of median basins of wet sub-tropical type has also dry season from April to October and wet season from November to March, but the distinction between the two is not so clear as the cold highland type and duration of each season differs considerably by places. Moreover, there is a period of abundant rain falls around September, which is called a minor wet season, and the September 1975 survey and August 1976 survey so happened to be in this wet period, that the field operations were greatly hadicapped. This district is where the air of high humidity, flown from Amazonian plain, collides against the Andes and discharges a great amount of rain in its front. Consequently amount of clouds is always much, and cloudy weather lasts long especially during the wet season when the atmospheric pressure from the Pacific Ocean becomes lower. The maximum temperature in daytime during the dry season is about $30^{\circ}C$, while temperature drops as low as $13^{\circ}C$ in the night. The climate, with specially high humidity resembles to that of early summer in the southern part of Japan as a whole. It is hot throughout a year in the northeastern part of wet tropical type with an average temperature of about $28^{\circ}C$. Humidity is also extremely high, and especially between October to April of abundant rain falls it becomes hot and very humid.

2-4-4. Vegetation

In the western part with cold highland climate, the highland above 4,500 m S.L. is almost waste land with sporadical growths of weeds. Grass fields are developed below 4,500 m S.L. and tall trees like eucalyptus are seen along streams sometimes. The terrains below 4,000 m S.L. are cultivated for potato and others suited for cold lands and grass fields are used for pasturage. Forests mainly of broad-leaf trees grow in the district of median basins of wet sub-tropical climate. Among these forests, those growing along the roads are logged to be transported to Lima. Piedmonts and flat lands are cultivated for orchards of banana, papaya, pineapple, and orrange, being an important supplying center of the fruits consumed in Lima.

The northeastern area of wet tropical climate is thickly covered by jungles and most of them are left as primeval forests except for some patches along big rivers which have been cleared to use for pasturage.

2-4-5. Topography

(1) Topographical Division

From geomorphological features, the surveyed area can roughly be divided into western highland, median basins, eastern highland, and eastern lowland. Each of the topographical divisions has been formed according to its geological and geomorphological history. Characteristics of them will be stated below.

(2) Western Highland

The western highland can be divided into the part forming eastern fringe of the East Andes and the part of steep slopes developed between the East Andes and the median basins. The former consists of Paleozoic rocks and is dissected sharply by the streams flowing into the River

Amazon to be formed in a slender chain of mountains. In the part above 4,000 m S.L., recognized are many kars as well as crater lakes of younger volcanoes. Some of valleys between these redges are filled up with Neogene volcanic rocks and glacial deposits to be formed into peneplains. Stream erosion is extremely intense in the part of steep slopes between the Wast Andes and median basins, and V-shaped valleys of dendric stream system are developed in granitic terrains, by which acute angled ridges are formed. Topography of mountain surrounded by steep cliffs but having gentle slopes on top is commonly observed in the terrains of metamorphic rocks and sedimentary rocks. Especially, in limestone terrains, U-shaped valleys are developed and steep cliffs are often formed.

(3) Median Basins

The district of median basins can be divided into the slopes connecting to the East Andes, basins, and the slopes connecting to the Sub-Andes. The first part is consisted of Mesozoic sediments mainly of limestone, and steep cliffs are formed and steep U-shaped valleys are developed in the terrains of limestone.

The basin district is consisted of granitic rocks, conglomerate, and sandstone, with gently sloped topography. Development of river terraces are recognized along a big river flowing north-southward in its central part, but around Chagalla corresponding to the ridge of the surveyed area, no median basin is formed as the East Andes and Sub-Andes intersect there. Flat lands and their continual gentle slopes in the basin district are cultivated for forestry and agriculture.

The slopes connecting to the Sub-Andes is consisted of Mesozoic sediments mainly of limestone and granitic rocks, and steep cliffs are formed in the limestone.

(4) Eastern Highland

The portion of Sub-Andes consists of Mesozoic and Cenozoic sediments, and characteristic V-shaped valleys due to comparatively high angled layer of Mesozoic sandstone are developed in the direction of NNW-SSE. Rain falls are abundant and plant growth is thick in this division, and rock exposures are few.

(5) Eastern Lowland

Greater part of this division is occupied by lowlands below 500 m S.L., and is thickly covered by jungles in which rivers are meandering. Some parts consist mainly of Cenozoic and Mesozoic sediments and present more or less steeper topography.

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PARTICULARS

PART I

Geological Reconnaissance

CONTENTS

Chapter 1 Outline of Survey

1-1. The August 1976 survey was performed as a part of the project of geological survey for mineral resources development in the central part of the Republic of Peru, succeedingly to the geological survey of 1975 in the southern part of projected area. Present survey consisted of geological and geochemical surveys in the northern area and in a part of the southern area, and re-examination of the SLAR data for the entire pjojected area. The purpose of survey was to make clear the distribution of the Pucara Group in which emplacement of ore deposits are anticipated and to extract some terrains of higher possibilities in existence of the bedded lead-zinc deposits.

1-2. Field Operations

(1) Geological Reconnaissance

This reconnaissance was practiced in the northern part and in a part of the southern part of the entire projected area. Survey routes were so laied out that they intersect perpendicularly to the principal direction of geological structure in this area. In the survey along these routes, aerial photos were used for confirmation of ground positions and SLAR mozaics were used for geological description.

As stated before, the road facilities in the areas of present survey are extremely deficient. The trans-Andean road between Tingo María and Aguaytia and others accessible near Panao and Pozuzo, outside of the area, are only the facilities, and there is none of road accessible to the central part. Supplementary trails for men and horses are also limited along the Rio. Huallaga and between Panao-Chaglla and Pozuzo districts. The central highland, being handicapped by such natural conditions as steep topography, thick begetation, extremely wet climate and others, has been left as quite unexplored land, and the field operation experienced extreme hardship by these conditions, which made any approach impossible except into a part of this land. Survey in the Amazonian plain, boat was used along some streams, but difficulties accompanied because of high water during the wet season.

(2) Geochemical Survey

This survey was performed on soils and stream sediments to obtain informations regarding to ore deposits in such vastly projected area in the central Peru. Soil samples were collected from the B_1 bed along survey routes and samples of stream sediments were collected from rivers and streams met along with gorund survey of geology. Effort was made to collect the samples at a rate of 2 samples for 1 km along survey route.

1-3. Indoor Works

(1) Microscopic observation of thin sections of rocks	105 pcs.
(2) Chemical analysis of ores	9 "
(3) Microscopic observation of polished sections of ores	9 "
(4) X-ray diffraction tests	14 "
(5) Identification of Fossils (in which 7 were collected during detailed geological survey)	14 "
(6) Pollenological analysis	5 "
(7) Age determination	6 "
(8) Complete analysis of rocks	6 "
(9) Chemical analysis of geochemical samples (soils: 2,892. stream sediments: 1,405)	4,297 "
(10) Analysis of minor elements in the carbonate rocks	31 "
(11) Geological analysis on aerial photos and SLAR mozaics	

Table I. Generalized Geological Columns of the Entire Surveyed Area

AFTER BELLIDO, E (1969)

Southern Block

Geological Age			Geological Units	Descriptions: Sedimentary & Metamorphic	Descriptions: Igneous
Cenozoic	Quaternary	Holocene	Alluvium	Gravel, sand & clay	Volcanic breccia: Andesitic, dacitic aglomerate
		Pleistocene	Diluvium		
	Tertiary	Pliocene	Merced Formation 400m+	Conglomerate, sandstone & mudstone	Monzonite porphyry: Monzonite & monzonite porphyry
		Miocene	Contamana Group 1,400m+	Upper part: Brown shale with sandstone & mudstone	
		Oligocene		Lower part: Red shale, sandstone & mudstone wite grey limestone	
		Eocene			Rhyolite & dacite: Rhyolite & dacite complex
		Palaeocene			
Mesozoic	Cretaceous	Later	Chonta Group 1,800m+	Upper part: Red shale with sandstone	Quartz porphyry & granite porphyry: Granite porphyry, aplite & quartz porphyry complex
		Middle		Middle part: Grey limestone; Lower part: Red shale with sandstone & shale	
		Earlier	Oriente Group 1,000m+	Red to white silicious sandstone with shale & conglomerate	
	Jurassic	Later	Sarayaquillo Formation 1,000m+	Upper part: Sandstone; Middle part: Shale & sandstone; Lower part: Conglomerate with shale	Granite: Granite
		Middle			
		Earlier	Pucara Group 2,740m+	Grey to black limestone & grey dolomite with thin beds of shale & sandstone	Diorite: Diorite, granodiorite porphyry & micro granodiorite complex
	Triassic	Later			
		Middle			
		Earlier			
Palaeozoic	Permian	Later	Mitu Group 1,300m+	Upper part: Sandstone & shale	
		Middle		Middle part: Sandstone & shale with limestone conglomerate	
		Earlier		Lower part: Conglomerate with sandstone & shale	
	Carboniferous	Later	Copacabana-Tarma Group 1,900m+	Grey to dark grey limestone & phyllitic shale. Partly red calcareous shale dominant.	Granite: Eastern part: Red granite with grey granodiorite; Western part: Grey to green granodiorite
		Earlier	Ambo Group 900m+	Compact grey sandstone with black shale	
	Devonian	Later	Excelcior Group 700m+	Grey sandstone with grey to black shale	
		Earlier			
	Silurian	Later			
		Earlier			
	Ordovician	Later			
		Earlier			
	Cambrian	Later			
		Earlier			
Precambrian			Basal Complex	Gneiss & schist with serpentinite	

Northern Block

Geological Age			Geological Units	Descriptions: Sedimentary & Metamorphic	Descriptions: Igneous
Cenozoic	Quaternary	Holocene	Alluvium	Gravel, sand & clay	
		Pleistocene	Diluvium		
	Tertiary	Pliocene			Monzonite porphyry: Monzonite & monzonite porphyry
		Miocene			
		Oligocene	Huayabamba Formation 1,400m+	Red to brown sandstone with shale, mudstone and conglomerate	
		Eocene			
		Palaeocene			
Mesozoic	Cretaceous	Later	Vivian Formation 300m+	White sandstone with shale	
		Middle	Chonta Formation 2,300m+	Upper part: Red shale & sandstone; Middle part: Grey limestone; Lower part: Red sandstone, & shale	
		Earlier	Oriente Group 1,200m+	Upper part: Sandstone; Middle part: Alternation of sandstone & shale; Lower part: Sandstone with conglomerate	
	Jurassic	Later	Sarayaquillo Formation 1,200m+	Upper part: Pebble conglomerate and sandston; Lower part: Red sadstone & shale with thy bed of calcareous sandstone	
		Middle			
		Earlier	Pucara Group 4,400m+	Upper part: Grey to black limestone with dolomite & dolomitic limestone; Middle part: Bituminous limeston, shale and alternation of calcareous shale & sandstone; Lower part: Grey to black limestone with dolomite & shale	Diorite: Microdiorite, granodiorite and granite
	Triassic	Later			
		Middle			
		Earlier			
Palaeozoic	Permian	Later	Mitu Grout 2,500m+	Upper part: Andesitic & dacitic lava and tuff (partly welded) with tuffaceous sandstone	Granite: Granite, granodiorite and diorite
		Middle		Middle part: Sandston with shale & conglomerate	
		Earlier		Lower part: Conglomerate with sandston & shale	
	Carboniferous	Later			
		Earlier			
	Devonian	Later			
		Earlier			
	Silurian	Later			
		Earlier			
	Ordovician	Later			
		Earlier			
	Cambrian	Later			
		Earlier			
Precambrian			Basal Complex	Gneiss & schist	

LEGEND

SEDIMENTARY ROCK
- SAND
- GRAVEL
- SHALE & PHYLLITH
- SANDSTONE
- CONGLOMERATE
- LIMESTONE

METAMORPHIC ROCK
- GNEISS & SCHIST

IGNEOUS ROCK
- VOLCANIC BRECCIA
- MONZONITE & MONZONITE PORPHYRY
- RHYOLITE & DACITE
- QUARTZ PORPHYRY & GRANITE PORPHYRY
- DIORITE
- GRANITE
- ANDESITIC TO DACITIC LAVA AND TUFF

UNCONFORMITY

CONFORMITY

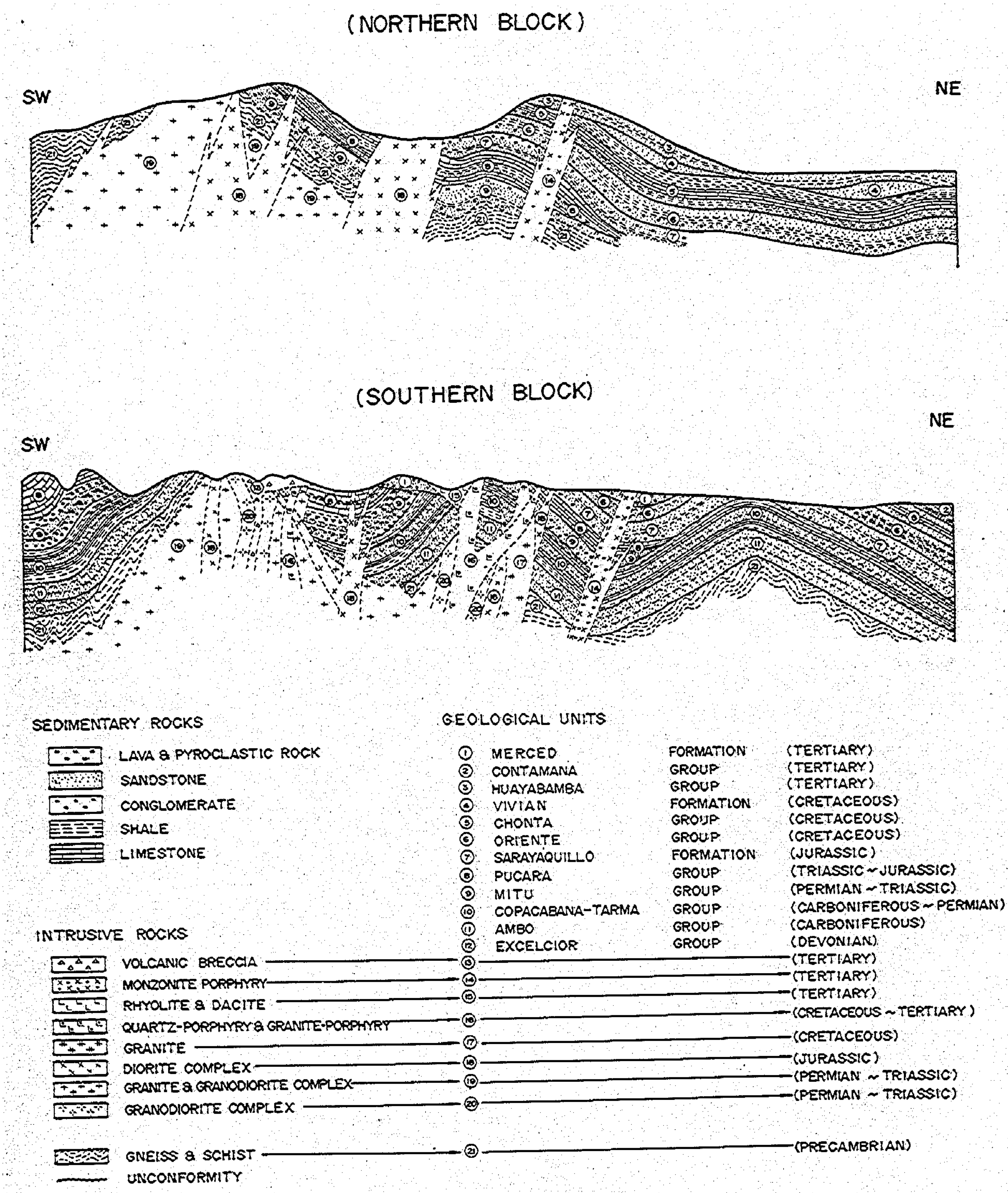

Fig. 4. Schematic Diagrams of Geological Relation in the Reconnaissance Area

Chapter 2 Geology and Geological Structure

2-1. Outline of Geology (Fig. 2, 4; Table I; PL. I-1, I-2, I-3)

Roughly observed, geologic set-up of the surveyed area may be said to be strongly controlled by the direction of NNW-SSE possessed by the gneral topography and geological structure in this area. That is to say, the eastern ridge consists mainly of upper Paleozoic sediments over the basement of gneisses. Sediments prior to middle Mesozoic are distributed from the eastern ridge towards the median basins, and post-middle Mesozoic and Cenozoic sediments are distributed from the eastern margin of the median basins, through the eastward Sub-Andes, towards Amazonian plain. It may otherwise be summarized that, being bordered by a distinct tectonic line in the direction of NNW-SSE running from the east of Tingo Maria to the east of La Merced via Oxapampa (to be called Tingo Maria-Merced line hereafter), its west side is occupied by the sediments from Paleozoic to middle Mesozoic and the east side is occupied by the sediments of post-middle Mesozoic and Cenozoic.

The Mesozoic Pucara Group, which is one of the main objects of present survey among the sedimentary formations, is recognized to be distributed in the direction of NNW-SSE centering around the median basins in the west side of the Tingo Maria-Merced line, and only a few distribution of it has been observed in the east side of the line.

Igneous rocks are also distributed mostly in the Sub-Andes, which are evidenced to have been derived by the intermittent activities since late Paleozoic till Tertiary. But in the east side of the Tingo Maria-Merced line, younger igneous activities from late Cretaceous to Paleogene have been recognized only scatteredly.

2-2. Metamorphic Rocks

Metamorphic rocks are distributed as roof pendants over granitic rocks in the highlands between Tarma and San Ramon in the southwestern part, and near Panao in the northern part, while they are distributed in small scale near Oxapampa in the central part and near San Ramon. They build up the basement in this area.

The metamorphic rocks consist of gneisses and schists, and often they are associated with intrusives of basic or ultra-basic rocks and with granitic rocks. The gneisses consist mainly of biotite gneiss and muscovite gneiss, and are associated sometimes with mylonitized tow-mica granite and schisttose granite. The schists mainly consist of hornblende-quartz schist, muscovite-quartz schist, and chlorite schist in the southwestern part, while they consist of quartz schist and chlorite-quartz schist in the northern part. Especially in the southwestern highland, ultra basic intrusives are recognized in the metamorphic rocks.

2-3. Igneous Rocks

Igneous rocks in the surveyed area are distributed in the direction of NNW-SSE along the East Andes, starting from nearby Tarma and San Ramon in the south and passing through the west of Oxapampa towards Chaglla. They are classified into late Paleozoic intrusives, Mesozoic dioritic rocks, granitic rocks, and porphyries, and Tertiary volcanic and intrusive rocks of Cenozoic Era.

2-3-1. Late Paleozoic Intrusives

They are exposed in a form of batholith from around Tarma and San Ramon in the south, through the west of Oxapampa, till around Chaglla in the north, shwoing the widest distribution among the igneous rocks in this area.

The granitic rocks which are exposed from Tarma towards west of Oxapampa are called Tarma granite or "white granite" (granito blanco). They are generally white, coarse to medium grained, and holocrystalline, of which principal minerals are quartz, plagioclase, kalium feldspar, biotite, and hornblende, and amount of colored minerals are less than that of salic minerals. Near San Ramon there is exposed "red granite" (granito rojo) in contrast to the "white granite", which is otherwise called San Ramon granite. Similarly to the white granite, the rock is coarse to medium grained, holocrystalline rock, consisting of pinkish kalium feldspar, quartz, plagioclase, with minor amount of biotite and hornblende.

The granitic rocks exposed along the Rio Santa Cruz towards Chaglla in the north, on the other hand, vary from granite to granodiorite or diorite, having generally a little less orthoclase and a little more mafic minerals. Variation of facies seems stronger as compared to the granitic rocks in the south. Near Chaglla, the rock is leucocratic, medium grained, and contains principal minerals of quartz, plagioclase, kalium feldspar, biotite, and hornblende. The mafic minerals often occur as aggregates, shwoing schistose texture sometimes. Lithological variation is specially intense along the Rio Santa Cruz, appearing as granodiorite, diorite porphyry, microdiorite, etc. In some parts of granodiorite, enclaves of microdiorite or microgabbro are recognized like xenoliths.

Such lithological varieties are clearly shown by their chemical compositions (Table 9); they are considered rather homogeneous in the south but heterogeneous in the north. That is to say, amount of SiO_2 is more in the south but less in the north, and proportion of $Na_2O + K_2O$ to $MgO + FeO$ is so big as to exceed 90% in the south, except for sample No. 93, while in the north, both MgO and FeO are increased. Being plotted on a ternary diagram of normative quartz-plagioclase-kalium feldspar (Fig. 5),

SAMPLES OF SEPTEMBER 1976 SURVEY.

SAMPLE NO.	ROCK NAME
5	META ANDESITE
8	MICRODIORITE
18	DACITE
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

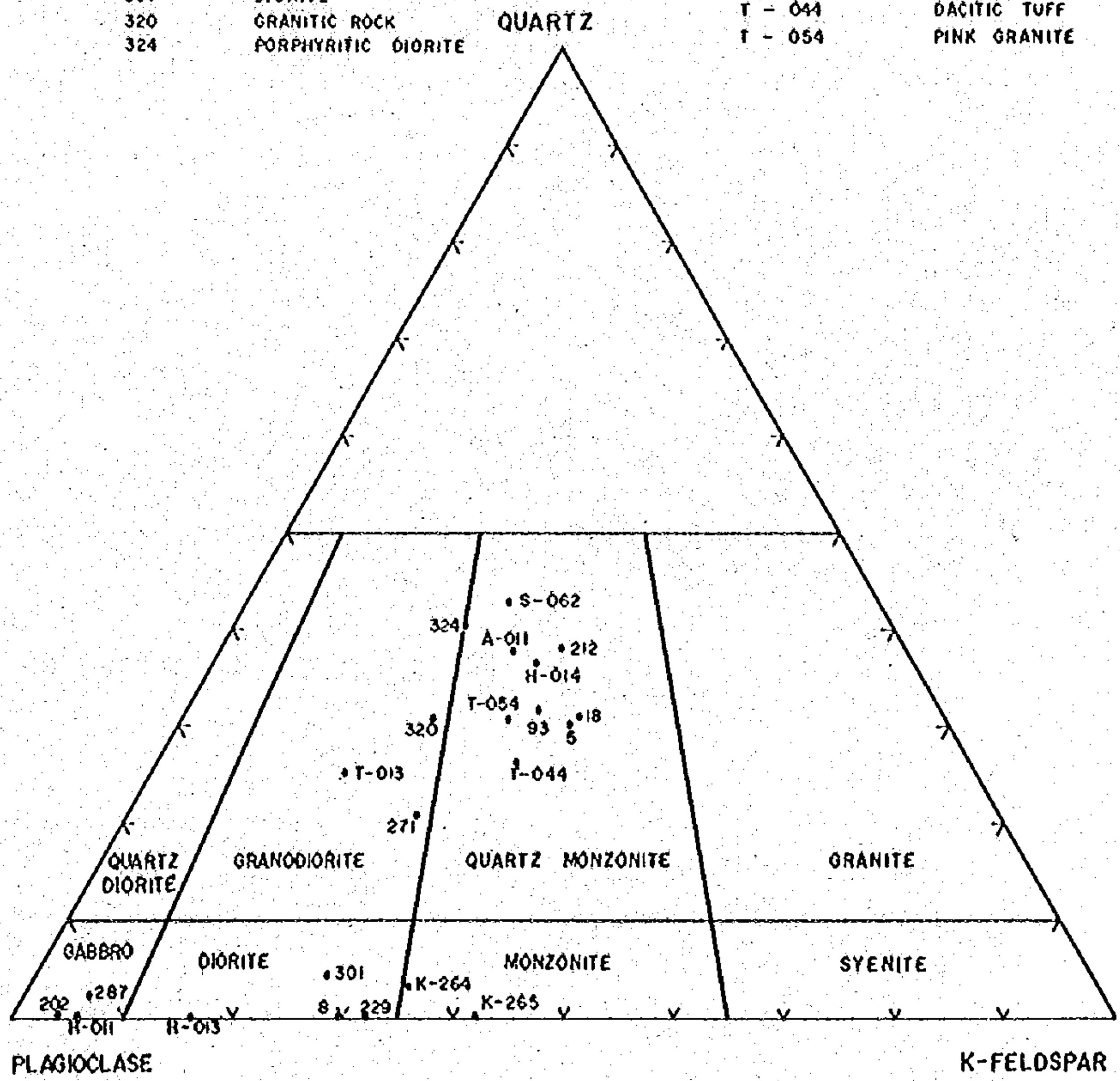

Fig. 5 Ternary Diagram of Normative Quartz-Plagioclase-Kalium Feldspar

all the granitic rocks in the south are concentrated in the range of quartz monzonite, while those in the north are deviated to granodiorite, and moreover there is found a gabbroic one (sample No. 287).

According to age determination by K-Ar method (Table 10), the white granite indicates middle Permian, Paleozoic (244 m.y.), the red granite indicates late Triassic, Mesozoic (195 m.y.), and the granitic rocks in the north indicate that their intrusion ranges from early Permian, Paleozoic (282 m.y.) to late Permian (208 m.y.). Moreover, the red granite has been evidenced in the field to penetrate the white granite, and andesite dyke penetrating the red granite in the south of San Ramon indicates late Permian (216 m.y.). From these facts, the granitic rock are interpreted to have been formed by the intermittent magmatic activities ranging mostly from early Permian to late Permian, and partly to Triassic Periods.

2-3-2. Mesozoic Intrusives

Thick sedimentation took place on both sides of the east range during Mesozoic Era, and about this time also, igneous activities occurred mainly along eastern margin of the Paleozoic intrusives. These igneous rocks are classified into 3 rock groups of granitic rocks, dioritic rocks, and prophyritic rocks such as quartz porphyry, granite porphyry, etc., according to their periods of activity and rock facies.

(1) Jurassic Dioritic Rocks

They are exposed in the forms of stocks and dykes around Chaglla and Pillao in the north, around Oxapampa in the central part, and around the San Vicente Mine in the south. They are generally coarse to medium grainted, consisting mostly of plagioclase and hornblende with a little amount of biotite, quartz, and kalium feldspar. But their rock facies vary so much as they are microdiorite and granodiorite in the north, quartz diorite and granodiorite in the central part, and diorite and gabbroic diorite in the south, and it is also a general characteristic that they have captured xenoliths of ultra basic rocks and hornblendite.

Chemically speaking, they are generally poor in SiO_2 but richer in MgO and FeO. Being plotted on a ternary diagram of normative quartz-plagioclase-kalium feldspar, they are dispersed over the ranges of granodiorite, diorite, and gabbro, which shows that they are very heterogeneous in their chemical compositions. In addition, diorite in the east of Tomay Rica in the north is that to be classified in the late Paleozoic granitic rocks from its chemical composition, its mode of occurrence and the result of age determination, but it has been classified into Jurassic intrusives as a variety of diorite. This is one of the problems to be discussed through future survey, although the rock nature is obliterated wherever supergene alteration is intense.

According to age determination by K-Ar method, the rocks in the north indicate 170 m.y., those in the central part which penetrate Mesozoic granitic rocks (125 m.y.) indicate 115 m.y., and these in the south indicate 155 m.y., from which they may be estimated of the magmatic activity in Jurassic Period. Granodiorite exposed in the south of San Ramon has indicated 239 m.y., but it has been confirmed in the field that the rock has penetrated Mesozoic formation.

(2) Jurassic-Cretaceous Granitic Rocks

They are exposed along the eastern margin of late Paleozoic intrusives centering around Oxapampa. They are coarse to medium grained and generally appear pinkish. Principal minerals are quartz, kalium feldspar, and plagioclase, and accessory minerals are biotite and specularite. Their petrographical natures and features in chemical compositions resemble to the late Paleozoic intrusives, but age determination has indicated the ages of 125 and 130 m.y., by which they have been classified into the

Jurassic-Cretacenous granitic rocks.

(3) Porphyritic Rocks; granite porphyry, quartz porphyry, etc. (Cretaceous) They are slightly fine grained porphyritic rocks distributed from Oxapampa towards northwest of Huancabamba, intruding along the eastern margin of the Paleozoic intrusives in the form of stocks. Under the microscope, they show porphyritic or seriate texture. Principal minerals are quartz, kalium feldspar, and a little amount of plagioclase, and accessory minerals are biotite and hornblende, but mineral compositions vary slightly by localities, occurring as rhyolite, quartz porphyry, granite porphyry, and monzonite porphyry. Although they appear in transitional relation each other, this poin has to be confirmed further.

No age determination has been done on these porphyritic rocks this time, but the time of their intrusion is considered sometime between post Cretaceous Period, Mesozoic, to early Tertiary Period, Cenozoic, by the facts that they are in close transitional relation with the Jurassic granitic rocks afore mentioned, and they penetrate the Oriente Group in the northwest of Huancabamba and in the west of Oxapampa.

These intrusive bodies give skarnization and marblization, though faintly, against limestone, and give the effect to turn tuffaceous rock in the Oriente Group into fornfels though faintly.

2-3-3. Cenozoic Intrusive Rocks

They are exposed in small stocks near Oxapampa and Tingo Maria, penetrating the Mesozoic Chonta Group (middle Cretaceous) and being partly overlain by the Tertiary Merced Formation. (Direct relation with the Huayabamba Formation could not be confirmed this time.) Megascopically, they are medium to fine grained rocks with principal minerals of plagioclase, kalium feldspar, and hornblende, and showing faint porphyritic texture. Under the microscope, they are identified as monzonite or monzonite porphyryr with accessory minorals of blonzite, soda pyroxene, biotite, and chlorite.

Characteristics in chemical compositions are that they are much richer in alkalis ($Na_2O + K_2O$) against silica and poorer in total iron and magnesium. It is one of their features that their distribution is limited only in the east side of the Tingo Maria-Merced line.

Age determination by K-Ar mothod has indicated ages of 14 m.y., 22 m.y., and 27 m.y., suggesting they are of intrusion in Miocene Eposh, Tertiary Period, Cenozoic Era. Their features in chemical compositions, their youngest age among igneous products in this area, and their limited distribution, may suggest the igneous activity was such as particular in this area related to the formation of the Tingo Maria-Merced line.

Another feature of them is their contact metamorphic effect and their additional effects of heavy metals against the host rocks at the time of their intrusion, which will be described below.

(1) At Tambo Maria, south of Oxapampa, monzonite has given skarnization with associated dissemination of Cu and Zn to the host rocks where it has intruded into the Pucara Group, and the monzonite itself is also disseminated with Cu.

(2) Near Pozuzo, a dyke of monzonite porphyry with 3 m width has intruded into the red sandstone of the Chonta Group, giving weak contact metamorphism to the country rocks.

(3) Near Tingo Maria too, small stocks of monzonite porphyryr have intruded into the Chonta Group, where weak contact metamorphism has been recognized. Geochemical survey on soils detected the samples high in Cu and Zn only around this area but it is uncertain if such wore the effects by these monzonite porphyry.

The monzonite has penetrated the Chonta Group in the east of Oxapampa, but the effects against the host rocks are uncertain.

2-3-4. Cenozoic Volcanic Rocks

Tertiary volcanic rocks consist of acidic effusive rocks and acidic pyroclastic rocks, penetrating or overlying the older formations such as older granitic rocks.

(1) Acidic effusive rocks are exposed centering around the district from the west of Oxapampa to Yaupi in its southwest. They are dacitic and mostly lavas in the north but mostly pyroclastics in the south which partly contain welded tuffs.

Under the mocroscope, the pyroclastics contain sub-angular or rounded fragments of rhyolite and dacite and phenocrysts of plagioclase and quartz, and vitreous groundmass shows clear lineation of flow structure. Quartz grains are crushed and corroded. The age of effusion of them has been determined as Eocene Epoch, Tertiary Period, Cenozoic Era (46 m.y.). For reference, age of dacite dyke penetrating the Paleozoic intrusives has been reported 40 m.y. by the survey of previous year.

(2) Acidic Pyroclastic Rocks

This formation is distributed mainly in the East Andes which occupies the western part of surveyed area. Constituent rocks are andesitic and dacktic pyroclastic rocks and tuffaceous sediments. They, as a whole, present greenish gray and reddish gray colors in which sediments such as limestone are exposed out as inliers locally. They cover all the igneous rocks in this area and are the products of the last stage of igneous activities. The time of their formation is estimated during Neogene from the evidences that they overlie the Merced Formation and that they are correlated to the volcanic rocks distributed throughout the Andean highland.

2-4. Sedimentary Rocks

2-4-1. Classification of Sedimentary Rocks

Sedimentary formations in the surveyed area are distributed in a narrow area of the southwestern part and in a vast area covering northern and central parts. Paleozoic and Mesozoic formations are distributed in the southwestern part, while a series of sediments from Mesozoic to Cenozoic are distributed over the central and northern parts except for some patches of Paleozoic formation.

These sedimentary formations are classified as follows in ascending order as shown on Table 1;

Paleozoic formations,	Excelcior Group
	Ambo Group
	Copacabana-Tarma Group
	Mitu Group
Mesozoic formations,	Pucara Group
	Sarayaquillo Formation
	Oriente Group
	Chonta Group
	Vivian Formation
Cenozoic formations,	Contamana Group
	Huayabamba Group
	Merced Formation*
	Quarternary Sediments

Names of these Groups and Formations are followed after the names given by Bellido, E.B. (1969) in his geological study over Junin, Pasco, and Huanuco Departments. But some are followed after the later reports

* Called the Lourdes Formation in Vol. 1.

and others have been given the names in the present survey.

Nothing will be mentioned about Excelcior, Ambo, and Copacabana-Tarma Groups, as they have been described in the report of September 1975 survey.

2-4-2. Mitu Group

(1) Distribution: This formation is distributed in a direction of NW-SE near Tarma, in a direction of N-S near San Ramon, in a state of "window" between the neighbours of Oxapampa and Pozuzo, and in a direction of NNW-SSE near Chaglla in the north.

(2) Constituents and Rock Facies: Consisting of conglomerate, sandstone, and shale of reddish brown or brown, locally associating with volcanic rocks (lavas and pyroclastics). Classified into 3 formations lithologically.

The lower formation consists mainly of conglomerate and locally intercalates sandstone, being distributed all over the area. The conglomerate contains relatively well rounded pebbles of granitic rocks, metamorphic rocks, and a minor amount of sediments, of which size varies from fists to human heads. Amount of sandy material of reddish brown or brown is generally little.

The middle formation consists mainly of sandstone with intercalation of a few layers of shale and conglomerate, and is distributed in the west of Pozuzo in the north, and around the San Vicente Mine in the south. The sandstone is medium to fine grained with dark brown or light brown color, well stratified, and locally tuffaceous. A layer of conglomerate is distributed near Monopampa east of Chaglla which resembles to the lower formation, but it is considered a lateral transition of the middle formation.

At the upper part of this middle formation, it graduates to the upper formation consisting of reddish brown to greenish andesitic lavas and tuffs. The upper formation is distributed mainly over Rio. Santa Cruz and Chaglla in the north.

At Rio. Santa Cruz, it is mostly composed of dacitic tuffs which are welded wide over.

Andestic rocks near Chaglla consist mostly of lavas, but variation of rock facies is so much as to occur as keratophyre with abundant albite, andesite, and dacite. Andesite tends to occur upper, while keratophyre to occur lower. Megard, F. (1968) has pointed out the Mitu Group in Huancayo district in the Andean plateau has intense lateral variation in rock facies and thickness, and lacks volcanic rocks locally. Similar tendency as Huancayo district has also been recognized in this survey too, for example, the upper formation is thin, if any, in the south among the area of present survey, and in the middle formation near Monopampa, conglomerate is dominant.

(3) Thickness: Southern part 1,300 m +

Northern part 2,500 m +

(4) Relation with Underlying Formation: It overlies the Copacabana-Tarma Group with clino-unconformity in the south and in the north from Oxapampa it overlies the Pre-Cambrian metamorphic rock in a relation of clino-unconformity.

(5) Fossils and Stratigraphical Correlation: No fossil has been found from this formation, but this formation may be correlated to the Mitu Group described by Bellido, E.B. (1969) and Megard, F. (1968) because of 2 points, one is that it is covered by the Pucara Group unconformably and overlies the Copacabana-Tarma Group in a relation of clino-unconformity, and the other is its rock constituents.

2-4-3. Pucara Group

(1) Distribution: It is distributed in the central part of the surveyed area in a direction of N-S in the south and in a direction of NNW-SSE in the north. In the south, it is exposed in some divided areas, which are arranged linearly in one line, showing the maximum width of 20 km in the south of Oxapampa, but getting narrower towards north from Oxapampa and thinning out locally. Near Tingo Maria, it is distribted in 2 separate zones because of the overlying sediments of post Pucara Group. Near Tarma of southwest, it also is distributed in a direction of NW-SE.

(2) Constituents, Rock Facies, and Stratigraphical Correlation: It is a calcareous formation mainly consisted of limestone, dolomitic limestone, and dolomite, containing minor amount of sandstone and shale.

Limestone is bright gray, dark gray and black, and full of variation in facies such as bituminous, siliceous, and sandy. Dolomite too, is in similar color tones and contains banded structure (zebra structure) and breccia structure locally. Discrimination of limestone and dolomite is not easy in the field but approximate distinction is enabled by specific gravity and reaction with hydrochloric acid. It has been made clear that there are 5 layers of dolomite intercalated, as 4 layers have been confirmed to exist in the detailed survey near Oxapampa, and another one has been known to exist at the footwall side of the San Vicente Deposits (2-3, Part II). Others were also recognized at Tingo Maria, along the Rio. Huallaga, and near Monopampa in the north, but their stratigraphical positions could not be determined.

Several studies on the Pucara Group have been made in such type localities as Huancayo and Cerro de Pasco districts by Megard F. (1968), Szekely, T.S. et al. (1972), etc. The Pucara Group, according to them, has been classified into three formations from their facies and produced fossils, which are, in ascending order, the Chambara Formation, Aramachay Formation, and Condorsinga Formation. Followings are their summarized features.

1) Chambara Formation

1. Consisting of limestone, shale, bituminous limestone, etc.
2. Late Triassic
3. Thickness is 2,930 m near Cerro de Pasco but thinned towards east.
4. Homogeneous as a whole, deep sea facies.

2) Aramachay Formation

1. Consisting of bituminous limestone, sandstone, and siliceous limestone.
2. Early Jurassic (lower Lias Series)
3. Thickness is 600 m near Lake Junin but thinned outwards.
4. Considered to have been deposited in deep sea sedimentary basin with varied environments of deposition,

3) Condorsinga Formation

1. Consisting of limestone, calcareous shale, clastic limestone, cherty limestone, etc.
2. Early Jurassic (upper Lias Series)
3. Thickness is 1,500 m in Huancayo district and 1,200 m in Tarma district but thinned towards east and north.
4. Homogeneous, shallow sea facies.

According to the previous surveys, layers of bituminous limestone and shale are distributed along the Rio Huallaga in the north with thickness of 100 m to 400 m, near Oxapampa in the south too, a formation intercalating sandstone and shale is distributed continuously at about 600 m in thickness.

These horizons contain and fossil of Psiloceras planorbis, an index fossil of Hettangian Stage, has been discovered in the south (No. 581). By such evidences, these formations can be correlated to tho Aramachay Formation described by Megard, Szekely, and others. Therefore, the overlying formations are to correspond to the Condorsinga Formation and the underlying to Chambara. But present survey in the north was not enough to enable definite zoning.

(3) Thickness:

	South	North
Chambara Formation	1,060 m +	
Aramachay Formation	600 m +	
Codorsinga Formation	1,080 m +	
Total	2,740 m +	4,400 m +

(4) Relation with Underlying Formation: The Pucara Group is in a relation of faint clino-unconformity or locally parallel unconformity with the underlying Mitu Group, and in contact with late Paleozoic intrusives (granitic rocks) with clino-unconformity or with faults.

(5) Fossils (Table 11, Fig. 13)

Fossiles ever discovered in the previous survyes will be mentioned hereafter.

Bivalves are : (identified by Prof. Minoru Tamura, Kumamoto Univ.)

Bivalva Gen. & sp.

Pectinid ? Gen. & sp.

Schafhautlia astatiformis muster

They are not the ones which deserve to determine what epoch of Triassic or Jurassic Priod they indicate, but comparing with some similarities in Europe, they are estimated of Ladinian Epoch-Carnian Epoch.

With regard to ammonite (identified by Prof. Masabumi Murata, Kumamoto University),

Psiloceras planorbis (Soverby)

was discovered in the south of Oxapampa (by the August 1976 survey) and west of the San Vicente Mine (by the September 1975 survey).

Moreover,

Euasteroceras ? sp.

Metophiceras sp.

Arnioceras

Epammonites cf. latislatus (Quenstedt)

were found along the Rio Huallaga in the north.

Among them, Psiloceras is known as an index fossil to indicate Hettangian Epoch of Jurassic Period, and others are considered to be of Sinemurian Epoch. Consequently, these ammonite-bearing layers were confirmed to correspond to the Aramachay Formation of lower Jurassic Period, and this was very fruitful in stratigraphical correlation.

In addition, fossils of crinoids, nautiloids, and brachiopods were collected, but to which epoch and age of Jurassic Period could not be determined.

2-4-4. Sarayaquillo Formation

(1) Distribution: This formation is distributed zonally from Tingo Maria to Pozuzo and around Previsto in the north, while in the south, it is distributed from the Rio Perene basin, which flows to east in the central part of the south, towards around Paucartambo.

(2) Constituents and Rock Facies: It is composed of 3 members, which will be called lower member, middle member, and upper member for convenience.

The lower member is basal conglomerate which is distributed east of Rio Perene in the south, and no distribution in the north. Pebbles consist mostly subangular granitic rocks and are cemented with clastic materials of clay-sized partcles of light or deep purple color, derived from granite and limestone. Thickness on Rio Perene is about 100 m, and the formation is gently undulated but not persistent.

The middle member is distributed in the north, and from Rio Perene to Paucartambo in the south. Its lower part consists of fine grained sandstone and shale of reddish brown - reddish purple, partly associating with calcareous sandstone. Its upper part consists of faulse bedded, fine grained sandstone with white-light red to reddish brown (mainly in the north) color, locally intercalating shale and conglomerate. This member is developed thickest in this formation, reaching to 900 m in the south and 1,000 m in the north.

The upper member is developed only near Previsto in the north. It consists mainly of conglomerate and intercalates thin layers of sandstone. Pebbles vary from the size of fists to a half of human body, but are more or less well rounded. Rocks of pebbles are mostly granitic rocks and limestone, but other igneous rocks and sedimentary rocks are recognized, too. Thickness is about 200 m.

(3) Thickness:	In the south	1,000 m +
	In the north	1,200 m +

(4) Relation with Underlying Formation: in parallel unconformity with the underlying Pucara Group.

(5) Fossils and Stratigraphical Correlation: No fossil has been found, but from its relation of parallel unconformity with undelying Pucara Group and its rock constituent, this formation can be correlated to the Sarayaquillo Formation of late Jurassic, named by Bellido, E.B. (1969).

In addition, pollenological analysis was tried on the mudstone in this formation near Tingo Maria in the north. According to the analysis (Table 12), it contains spores of Mesozoic, which have never recognized in Tertiery rocks, and yet none of them characteristic in Jurassic has been found. A doubt arises if it is of Cretaceous, but there is nothing to determine definitely. Therefore the formation has been treated as late Jurassic in this report.

2-1-5. Oriente Group

(1) Distribution: This formation is distributed surrounding the distributed area of the Sarayaquillo Formation from the Rio Perene basin towards Paucartambo and is distributed around Oxapampa, and further, it is distributed in a zone of NNW-SSE over Izcozacin in the east towards Tingo Maria and Prevista in the north.

(2) Constituents and Rock Facies: This group consists mainly of calcareous sandstone with white, light red or red colors and is divided into 3 formations.

The lower formation is essentially grayish white, coarse grained sandstone rich in quartz grains, intercalating medium grained conglomerate and thin layers of yellowish gray shale. Thickness is 800 m in the south and 600 m in the north.

The middle formation consists mainly of well stratified yellowish gray or greenish gray shale, and locally alternates with grayish white, fine grained sandstone. Thickness is about 200 m.

The upper formation is mostly distributed in the north, which is grayish white, coarse to medium grained quartzose sandstone, intercalating gray shale. The sandstone rarely contains quartz grains about 1 cm big. Thickness is about 400 m.

(3) Thickness: In the south: 1,000 m +

In the North: 1,200 m +

(4) Relation with Underlying Formation: Conformable to the underlying Sarayaquillo Formation.

(5) Fossils and Stratigraphical Correlation: Rhynchonellidae (brachipod) (identified by Prof. Minoru Tamura, Kumamoto University) is contained in sandstone of this group, but it does not deserve to determine geological age. Considering from, however, the conformable relation with underlying Jurassic Sarayaquillo Formation and from the rock constituent mainly of quartzose sandstone, it is considered to be correlated to Bellido's (1969) Oriente Group, and further, its lower formation is correlated to the Cushabatay Formation, the middle formation to the Aguanuya and Esperanza Formations, and the upper formation to the Agua Caliente Formation.

2-4-6. Chonta Group

(1) Distribution: It is distributed widely in the eastern half of the surveyed area.

(2) Constituents and Rock Facies: It is the formation consisting red or reddish purple shale, sandstone and gray limestone, and it is characteristic that sandstone and shale generally contain abundant calcareous matrices. In the surveyed area, this group can be classified from rock facies into three formations of lower, middle, and upper.

The lower formation consists mainly of red or reddishbrown, fine or medium grained sandstone and shale, intercalating coarse grained sandstone and white quartzose sandstone, both containing a small amount of limestone fragments of indefinite shapes, and locally associated with andesite sheets.

The middle formation consists mainly of bright gray or dark gray, homogeneous limestone and locally intercalates white quartzose sandstone or alternates with dark gray to grayish green, quartzose sandstone and shale.

The upper formation consists of red or reddish brown shale and fine or medium granied sandstone, accompanying locally white calcareous sandstone.

This Chonta Group, consisting of the above 3 formations, can be observed continuously along the car road from Paucartambo in the south to Vocas through Villa Rica and between Tingo Maria and Aguaytia.

(3) Thickness: It is more than 1,900 m in the south, while it reaches to 2,300 m in the north because of thicker upper formation.

(4) Relation with Underlying Formation: In transitional relation with the underlying Oriente Group.

(5) Fossils and Stratigraphical Correlation: Fossil of bivalve was found from the limestone of middle formation in the south, which is Anomia Argentaria (indentified by Prof. Minoru Tamura, Kumamoto Univ.) belonging to upper Cretaceous. Fossils of bivalves, echinoids, brachiopods, etc. belonging to upper Cretaceous, were found from the limestone and calcareous shale of middle member. Definite epoch could not be determined by them, but this group may be correlated to Bellido's (1969) Chonta Group from its rock constituents.

2-4-7. Vivian Formation

(1) Distribution: It is distributed in a slender zone in a direction of NNW-SSE near Provisto in the north, and in the north of Pozuzo it is locally distributed occupying topographically higher parts.

(2) Constituent and Rock Facies: It is white or brownish white quartzose sandstone, intercalating very few thin layers of light green shale.
From rock facies, it resembles to the upper formation of Oriente Group, but the Vivian Formation can be distinguished from others by its feature

that this is more quartzose and sometimes contains stripes of concentrated biotite.

(3) Thickness: 300 m +

(4) Relation with Underlying Formation: No direct relation with underlying Chonta Group can be recognized, but they are in concordant relation, and they are said to be so in the type locality, too.

(5) Fossils and Stratigraphical Correlation: No fossil was discovered in the present survey, but from its position to overlie the Chonta Group and from its constituents, this formation can be correlated to E.B. Bellido's (1969) Azucal sandstone formation. In this report, however, it is named Vivian Formation which is popular in northeastern Peru.

2-4-8. Contamana Group

(1) Distribution: This is widely distributed in the lowland near Izcozacin.

(2) Constituents and Rock Facies: The formation is molasse type deposited in the east side of the Andes and can be divided into two, upper and lower. The lower part consists mainly of shale, intercalating sandstone and mudstone and appears dark gray as a whole. Upper part of the lower formation is principally sandstone and mudstone with gray or purple color, partly intercalating thin layers of gray limestone. Upper formation consists mainly of sandstone and shale of which lower part is generally red or purple and upper part is brown to light brown.

(3) Thickness: 1,400 m +

(4) Relation with Underlying Formation: Though not distinct, it seems to be in a relation of parallel unconformity or faint clino-unconformity with underlying Chonta Group.

(5) Fossils and Stratigraphical Correlation: This Group has been determined to be the sediments of early Tertiary of Cenozoic Era by

pollonological analysis. From its overlying position on the Chonta Group and form lithological features, this group can be correlated to E.B. Bellido's (1969) Contamana Group.

2-4-9. Huayabamba Group

(1) Distribution: It is distributed from Tingo Maria to Aguaytia in the north and in the east of Las Palmas on the Rio Huallaga.

(2) Constituents and Rock Facies: It consists mainly of reddish brown or grayish brown, fine sandstone, intercalating thin layers of quartzose fine sandstone. Most of the fine sandstone is enriched with grains of quartz and muscovite. Near Tingo Maria, it is locally alternated with fine to medium grained conglomerate.

(3) Thickness:

(4) Relation with Underlying Formation: Although no direct relation with the underlying Vivian or Chonta has been recognized, they are considered to be in unconformable relation, as it is discordant to the underlying Mesozoic formations.

(5) Fossils and Stratigraphical Correlation: It has been made clear by pollenological analysis on the muddy part of this group, that the formation is early Tertiary sediments. Therefore, this may have to be called Contamana Group, but on account of no observable direct relation between the two and slight difference in rock facies between the two, this formation has been correlated to the Huayabamba Group of which type locality is the northern part of surveyed area. For reference, fossils of spores, which is considered to belong to Paleogene, have been detected by the pollenological analysis.

2-4-10. Merced Group

(1) Distribution: It is distributed in a zone from San Ramon towards Tambo Maria in a direction of N-S.

(2) Constituents and Rock Facies: It consists of conglomerate containing medium to large sized pebbles, coarse grained arkose sandstone, and gray mudstone. Its pebbles are all kinds of rocks of the basement such as granitic rocks, andesite, limestone, and metamorphic rocks, and matrix consists of granitic sands of weak consolidation. Most of coarse grained arkose sandstone is intercalated in the conglomerate as lenses. This Group is locally high angled, but generally low angled and folding structure is developed.

(3) Thickness: 400 m +

(4) Relation with Underlying Formation: It is in unconformable relation with underlying Mesozoic sediments.

(5) Fossils and Stratigraphical Correlation: Mudstone contains plant fossils, one of which is Dictyledon (identified by Paleontological Research Department, National Science Museum) but it does not deserve for age determination. In view of its unconformable relation with Mesozoic sediments, weak degree of rock consolidation, and underlying position against the acidic pyroclastics of Neogene, Cenozoic, near Huancabamba, this group is considered the sediments a little older than the pyroclastics.

2-4-11. Quarternary Sediments

They are developed in the Amazonian plain and along big rivers such as around Aguaytia and Tingo Maria in the north and around San Ramon and Oxapampa in the south. They are river and lake deposits, consisting of pebbles, sands, and clay, and are deposited horizontally. On the slopes from highland to the valleys of big rivers, large scaled talus deposits are observed.

2-5. Geological Structure and Geological History

2-5-1. Folding Structure

The regional structures in surveyed area such as major folding axes, direction of faults, elongation of intrusive bodies, and distribution of volcanic rocks are all showing the direction of NNW-SSE. These regional structures are considered to have been formed by orogenic movements for several times which took place in Paleozoic, Mesozoic, and Cenozoic Eras, having been caused always by lateral compression in the direction of NEE-SWW.

Metamorphic rocks and older sediments distributed in the southwest occupy a part of structural zone in which anticlines and synclines are repeated and all of their major structural lines are showing the direction of NW SE. Near Tarma, a synclinorium with folding axes of NW-SE is observed in east side, and an anticlinorium with folding axes of similar direction is on the west side. By the combination of such structures, the sediments from Pre-Cambrian to Paleozoic are distributed in such a way as to be arranged zonally.

In the sedimentary formations from Paleozoic to middle Mesozoic distributed in the central part, many of anticlinal and synclinal structures are developed, but a great synclinal structure of the Pucara Group in the west and a great anticlinal structure in the east are controlling the entire structures. The former structure, though it extincts for a while near Pozuzo, is such a large scaled one as to continue farther north from around Tingo Maria in the northern part. Sediments of molasse ranging from middle Mesozoic to Cenozoic are distributed in the east, which are also folded to form repeated anticlines and synclines. Dominant are the synclinal structure in the west side and the anticlinal structure in the east side, both having axes in the direction of NNW-SSE. Among them, the syncline in the west side continues from the south to the north of the area. Both wings are so gently dipping, that basin structures are often formed along axial zone of syncline.

Dips of those sediments from late Mesozoic to Cenozoic Eras, distributed in the northeastern part of south area, are generally gentle towards east or west, except for the steeper dips observed around an anticlinal structure located at the ridge of the East Andes, east of Izcozacin.

Amidst such folding structures of fundamental direction of NNW-SSE, large scaled intrusive rocks and volcanic rocks took their activities along similar direction, and principal ones among them are distributed along the eastern margin of the East Andes, which are considered to have been controlled by a deep-reaching tectonic line and also related to the anticlinal structure of Jurassic Period in the west side of it.

2-5-2. Faulting Structure

Principal faults in the surveyed area were formed in relation with lateral compression of NEE-SWW direction, of which examples are;

1) reverse or thrust faults of NNW-SSE system, dipping westward,
2) normal faults of NNW-SSE system, dipping eastward with high angles
3) high angled faults in NWW-SEE and NNE-SSW systems,
4) high angled faults of NEE-SWW system.

Among the faults of NNW-SSE, several of reverse faults which control the geological structure dominantly in this area, are developed between Tingo Maria and Boqueron in the northern part, and thrust faults are observed near San Ramon where the granitic rocks had thrusted over the Pucara Group, and near Oxapampa and Pozuzo where the Mitu Group had thrusted over the Mesozoic formations. Moreover, the normal fault is such a large scaled one as to continue from the east of Tingo Maria towards Oxapampa and is supposed to be extended to the east of Merced of farther south, and it is controlling not only the distribution of the Pucara Group but also that of the igneous rocks. (called Tingo Maria-Merced line in this report)

These faults of NWW-SEE and NNE-SSW systems, intersecting the faults of NNW-SSE system, are widely distributed, but large scaled ones are few.

High angled faults are developed in the southwestern part with strikes of NW-SE system, forming horsts and grabens. They are considered to have been formed to be accompanied by geoanticlinal movement of this area during Jurassic Period.

In the eastern margin of the East Andes, igneous activities took place intermittently during a long duration of time since Paleozoic Era till Cenozoic Era, but most of the igneous rocks are arranged scatteredly in the direction of NNW-SSE, which may suggest that the activities took place in relation to the regional tectonic line of NNW-SSE direction as discussed in previous paragraph (2-3-3).

2-5-3. Geological History

Various types of rocks are distributed in the surveyed area such as Pre-Cambrian metamorphic rocks, sedimentary rocks deposited intermittently from Devonian to Tertiary Periods, and Igneous rocks intruded in Paleozoic, Mesozoic, and Tertiary. The metamorphic rocks are considered to have been formed during the course of Pre-Cambrian orogenic movement, but an alternative is to estimate it to have been formed during sedimentation and organic movement in early Paleozoic Era. Results of age determination on the red granite associated with similar group of metamorphic rocks in the south of Peru has been reported 460 m.y.,* and a pegmatite in the gneisses near Huancayo in the west of surveyed area also has been reported 467 m.y..**

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* by Bellido, E.B. (1969)

** by Dalmayrac, B

In this report, however, it will be treated Pre-Cambrian after Bellido, E.B. (1969).

Paleozoic formations in the southwestern part were deposited over the basement of metamorphic rocks formed by the Pre-Cambrian orogenic movement. The Excelcior Group of Devonian Period began to be deposited in a geosyncline formed in Ordovicean Period, and the sedimentation of such formations as the Ambo Group and Tarma-Copacabana Group continued untill early Permian Period of Paleozoic Era when the orogenic movement was activated. In association with this orogeny, an igneous activity took place and the granitic rocks forming the basement of this area were intruded. According to age determination by K-AR method, this igneous activity is considered to have continued intermittently till late Triassic Period.

The orogeny in early Permian constructed the foundation of principal direction of NNW-SSE in this area, and on account of later upheaval by blocks and faulting movements, the middle Permian Mitu Group was deposited through erosion.

In Triassic Period of Mesozoic Era, a geosyncline was formed, in which marine sediments of the Pucara Group were deposited. Later on, formation of a geoanticline was begun in the west highland of East Andes, and sedimentary basin for the Pucara Group was begun to be divided into two; one is in the west side (Cerro de Pasco-Huancayo sedimentary basin) and the other in the east (Tingo Maria-Oxapampa sedimentary basin).
In the middle of Jurassic Period, orogeny was locally activated which followed by intrusion of dioritic rocks. Mountain range formed by this orogeny and igneous activity was erroded and the Sarayaquillo Group was deposited.

The formation of geoanticline of the East Andes had been completed in late Jurassic Period, and geosynclines were formed on both sides of it. In the eastern geosyncline the Oriente Group of relatively shallow sea sediments were deposited in early Cretaceous Period, and the Chonta Group of relatively deep sea facies in middle to late Cretaceous Period. In late Cretaceous Period, the sedimentary basin was turned from marine to terrestrial environment, and the sedimentation of Mesozoic Era had been terminated by deposition of the Vivian Formation in the north as the last.

Getting into Cenozoic Era, an intense orogeny accompanying igneous activity took place in the Andean districts in the west of the area, while in the east, subsidence continued, accompanying activity of acidic porphyries only, which made the Contamana Group and Huayabamba Group of Paleocene-Oligocene, Tertiary to be deposited in parallel along Cretaceous system. About from Oligocene to Miocene, the second activity of Andean orogeny was activated in this area, by which sedimentation was terminated, but folding and faulting took place in stead, and during Miocene Epoch, activity of acidic pyroclastics took place in the eastern margin of the East Andes, and intrusion of alkali rocks occured along the Tingo Maria-Merced line.

Chapter 3 Ore Deposits

3-1. Metallic Ore Deposits

Mostly in the southern part of surveyed area, metallic ore deposist are known to be distributed in some localities, but most of them have not been discussed geologically except for one or two deposits. In the northern part on the other hand, only two localities of mineral indications have been discovered through present survey. In the May 1976 survey, which was practiced upon the conclusions of the September 1975 survey, mineral indications were newly found around Oxapampa and others. These ore deposits are classified as below according to their genesis and kinds of ore.

(1) Bedded lead-zinc deposits in the Pucara Group.

(2) Lead-zinc deposit of dissemination type in the Pucara Group.

(3) Pyrometasomatic (contact) deposits formed at the contact between the carbonate rocks of the Pucara Group and intrusive rocks.

(4) Vein type deposits of copper, lead, and zinc in the Pucara Group and Mesozoic diorites.

(5) Porphyry copper type deposits in Tertiary monzonites. As these deposits have been described in details in Chapter 8, Vol.1 and in Chapter 4, Vol.4, generallized remarks will be given here to avoid duplication. Regarding to the bedded lead-zinc deposits in the Pucara Group, the most important deposits in this area, will be mentiond precisely in Part II in this report.

3-1-1. Bedded lead-zinc Deplsits Emplaced in the Pucara Group

Examples of this type of deposits are the San Vicente and Pichita Caluga deposits in the south, and Tambo Maria indication was also found by the May 1976 survey. A summary of findings of previous survey on these deposits will be given as follows:

(1) Distribution of ore zones is limited in the dolomite layers in the Pucara Group, and ore bodies are well developed in such structurally disturbed zones where the banded dolomite (zebra dolomite) and breccia dolomite are developed.

(2) Igneous rocks ranging from Jurassic Period of Mesozoic Era to Tertiary Period of Cenozoic Era are intruded around the mineralized zones, but it has been made clear either by megascopical observation and X-ray diffraction test, that these igneous rocks have not given any alteration effects to the carbonate rocks. Although veinlets of sphalerite of probably epigenetic origin are recognized in the Siete Jeringa ore body among the San Vicent Ore Deposits, liquid inclusions in sphalerite and dolomite have indicated the filling temperatures between 70° and 150°C, suggesting the orgin under alkaline low temperature conditions, even if there should be any relation with igneous rocks.

(3) Ore minerals are essentially sphalerite and a little amount of associated galena and chalcopyrite. Pyrite is very little in amount, which was found as inclusions in sphalerite around the center of the San Vicente Deposits, but scarcely none of it was found in sphalerite at Tambo Maria and recognized as lenticular aggregates on the contrary. Such relation between sphalerite and pyrite in their occurrences will suggest epigenetic mineralization of lead and zinc (cf. Chapter 4 Vol.4).

(4) As stated above, the mineralization is what was brought about under considerably low temperature conditions and natures of deposits resemble to the Mississippi Valley type deposits of lead and zinc. They, however, may otherwise be said to be a type of deposits in which effects from igneous activity can not be ignored.

3-1-2. Lead-Zinc Deposit of Dissemination Type in the Pucara Group

This means the newly found mineral indication in the west of

Qulliazu by the May 1976 survey. It is a disseminated deposit mainly of lead which may be considered to have been derived by porphyries and granitic rocks of post-Cretaceous, Mesozoic, which are distributed in the west side, but its relation to the bedded lead-zinc deposits stated in 3-1-1 is necessary to be paid for attention. About this matter will be discussed in 4-4, Part II (cf. Chapter 4, Vol. 4).

3-1-3. Other Mineralizations

(1) Pyrometasomatic deposits of copper, lead, and zinc have been formed at the contacts between Permian granitic rocks and the Pucara Group occurring as roof pendants in the east of San Ramon of the southern area. The Santos and Soldad Deposits have been known, which are pyrometasomatic deposits formed along porphyry dykes in a small scale, intruded near the contacts between the two. Main skarn minerals are garnet and epidote. Both are laid off at present, but the Soldad Deposit has a dimension of 5 m wide and 100 m long and many roof pendants of limestone are found in its surroundings. In view of such, it will be necessary to attempt a systematic survey including these deposits.

(2) Vein type deposits of copper, lead, and zinc are all small scaled, and aside from the La Olovidada Deposit in the east of Tarma, there are indications of Chaglla and south of Pichita Caluga which have been newly found by the present survey. The La Olividada Deposit is the one which is associated with network veinlets of calcite developed in the limestone of Pucara Group, carrying mostly oxide copper minerals such as covellite and malachite (Chapter 8, Vol. 1).

Near Chaglla in the northern area too, association of minor amount of malachite and galena was found in calcite veinlets of 2-3 cm wide at two locations in the limestone of Pucara Group. And in the south of Pichita Caluga, there was observed in Jurassic diorite a quartz vein of

25 cm wide in which minor amounts of chalcopyrite and pyrite were recognized. In the north of Pichita Caluga and near Churmazu too, veins of quartz, calcite, and clay accompanying hematite stains with maximum width of 20 cm and very little amounts of Pb and Zn were detected but not recognizable megascopically. These mineralizations are all weak and thought to have scarce possibility to be developed in large deposits.

(3) Near Tambo Maria the Onda mineral indications were found by the May 1976 survey. As it has been stated in 4-2, Vol. 4, Tertiary monzonite accompanies faint skarnization at the contact with the Pucara Group and copper mineralization is also recognized in the monzonite itself. The copper mineralization in this rock body, though very faint, has its importance to have evidenced the existence of mineralization accompanied with the Tertiary monzonite.

3-2. Non-metallic Deposits

Non-metallic deposit in the surveyed area is as few as a gypsum deposit has been known in the north of Huancabamba (cf. Chapter 9, Vol.1).

Chapter 4 Geochemical Survey

4-1. Purpose and Procedure

This survey was practiced for the purpose of getting informations regrading to ore deposits in the surveyed area on soils and stream sediments. Soil samples were collected along the survey routes and samples of stream sediments were collected from rivers and streams along with survey on the routes.

Total samples collected amounted to 4,297, in which 2,595 were collected during the September 1975 survey and 1,702 during the August 1976 survey (soil samples, 2,892; samples of stream sediments, 1,405). A soil sample was collected from the B_1 bed along the survey routes at a rate of about 1 kg for each, and sample of stream sediments was collected as a rule from stream bottoms rich in fine sands whenever met with during geological survey. A sample, after being dried under open air, was classified by 80 mesh sieve and about 100 g. of its undersize was extracted, which was further reduced for 10 g. for assay sample by quartering.

The geochemical samples prepared for assay were analysed in Japan by means of atomic absorption method on 3 indicator elements* of Cu, Zn, and Ni, which were thought effective for prospecting ore deposits in this area. Flow sheet of chemical analysis on the 3 elements are shown by Table 14 and assay results are shown on Table 16A.

4-2. Data Analysis (Table 2A, 3A; Figs. 6A, 6B, 6C; PL. I-4, I-5, I-6)

Data of chemical analysis were treated statistically by an electric computor (IBM 370-145). As soil samples are considered to be a group

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* cf. p. 41, Report of the September 1975 Survey.

Table 2A. Statistical Analysis of Geochemical Samples (Cu, Zn, Ni) in the Reconnaissance Area

Soils (Numbers of treated samples : 2,892)

	Cu-log (ppm)	Zn-log (ppm)	Ni-log (ppm)
Maximum	3.162 (1,453)	3.715 (5,193)	2.730 (537)
Minimum	-0.301 (1)	-0.301 (1)	-0.301 (1)
Average (M)	1.099 (13)	1.805 (64)	1.273 (19)
Standard Deviation (σ)	0.4270	0.3919	0.3985

Stream Sediments (Numbers of treated samples : 1,405)

	Cu-log (ppm)	Zn-log (ppm)	Ni-log (ppm)
Maximum	2.193 (156)	3.315 (2,064)	2.155 (143)
Minimum	-0.301 (1)	-0.523 (0)	-0.301 (1)
Average (M)	1.008 (10)	1.618 (41)	1.085 (12)
Standard Deviation (σ)	0.3893	0.3456	0.3542

Table 3A. Numbers of Anomalous Samples on Soils Classified by Each formation and Lithology in the Reconnaissance Area

	QU	ME	CO	HU	VI	CH	OR	SA	PU	MI	TA	AM	EX	BC	TV	TM	TR	MP	CG	MD	PG	PC	TOTAL
Cu (ppm)																							
0 - 34	222	26	9	87	9	769	119	106	550	137	44	3	0	75	29	17	31	28	27	54	187	15	2544
35 - 57	5	0	0	3	0	23	5	3	56	19	9	1	0	32	0	4	0	1	0	4	22	6	195
58 - 94	1	0	0	1	0	17	5	1	17	8	1	1	0	23	0	1	0	0	0	7	10	2	95
95 - 155	1	0	0	1	0	3	2	2	9	4	0	0	0	3	0	1	0	0	3	2	1	0	32
156 - 257	2	0	0	0	0	1	1	1	1	2	0	0	0	2	0	0	0	0	0	2	2	0	14
258 over	0	0	0	0	0	0	0	1	4	2	0	0	0	3	0	0	0	0	0	0	1	1	12
TOTAL	231	26	9	94	9	813	132	114	637	172	54	5	0	138	29	23	31	29	30	69	223	24	2892
Zn (ppm)																							
0 - 157	222	23	9	91	9	801	124	110	422	154	47	3	0	128	26	23	31	27	29	66	214	24	2583
158 - 247	1	0	0	1	0	2	1	0	45	5	1	0	0	3	0	0	0	0	0	0	5	0	64
248 - 388	5	0	0	0	0	5	3	3	73	7	1	1	0	3	2	0	0	1	0	1	0	0	105
389 - 609	3	3	0	1	0	3	1	0	43	1	3	0	0	3	1	0	0	0	0	1	1	0	64
610 - 956	0	0	0	1	0	1	1	0	30	0	1	0	0	0	0	0	0	1	0	1	1	0	37
957 over	0	0	0	0	0	1	2	1	24	5	1	1	0	1	0	0	0	0	1	0	2	0	39
TOTAL	231	26	9	94	9	813	132	114	637	172	54	5	0	138	29	23	31	29	30	69	223	24	2892
Ni (ppm)																							
0 - 47	223	24	9	87	9	786	125	102	431	144	48	4	0	91	29	23	31	28	27	59	214	23	2517
48 - 74	4	1	0	6	0	21	6	9	114	20	6	1	0	32	0	0	0	1	0	2	7	1	231
75 - 118	2	1	0	1	0	4	1	3	59	4	0	0	0	10	0	0	0	0	2	1	2	0	90
119 - 186	1	0	0	0	0	2	0	0	28	1	0	0	0	2	0	0	0	0	0	3	0	0	37
187 - 294	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	1	3	0	0	12
295 over	1	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	1	0	0	5
TOTAL	231	26	9	94	9	813	132	114	637	172	54	5	0	138	29	23	31	29	30	69	223	24	2892

Geological Index

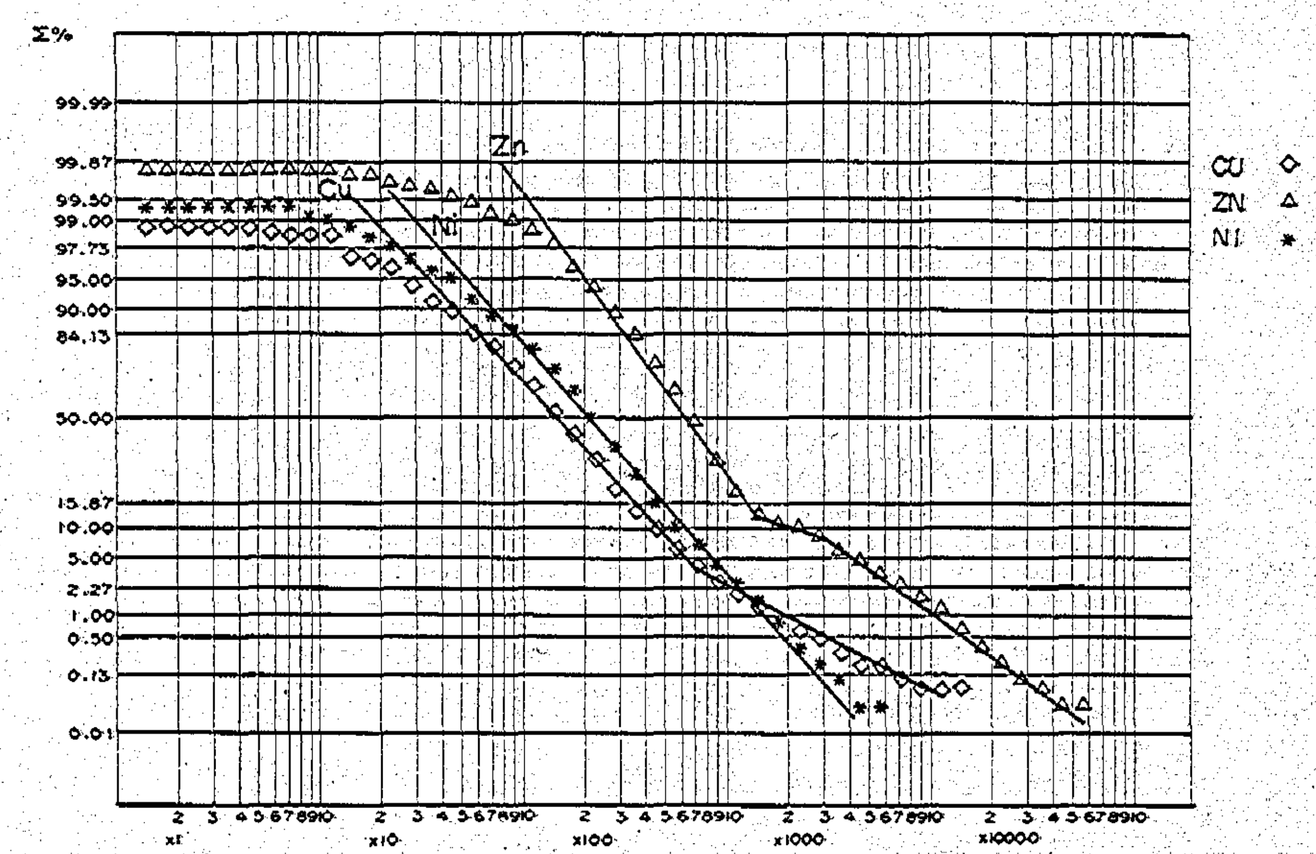
Sedimentary rocks

- QU: Quarternary (gravel & sand)
- ME: Merced Formation
- CO: Contamana Group
- HU: Huayabamba Group
- VI: Vivian Formation
- CH: Chonta Group
- OR: Oriente Group
- SA: Sarayaquillo Formation
- PU: Pucara Group
- MI: Mitu Group
- TA: Copacabana - Tarma Group
- AM: Ambo Group
- EX: Excelcior Group
- BC: Basement Complex (gneiss & schist)

Igneous rocks

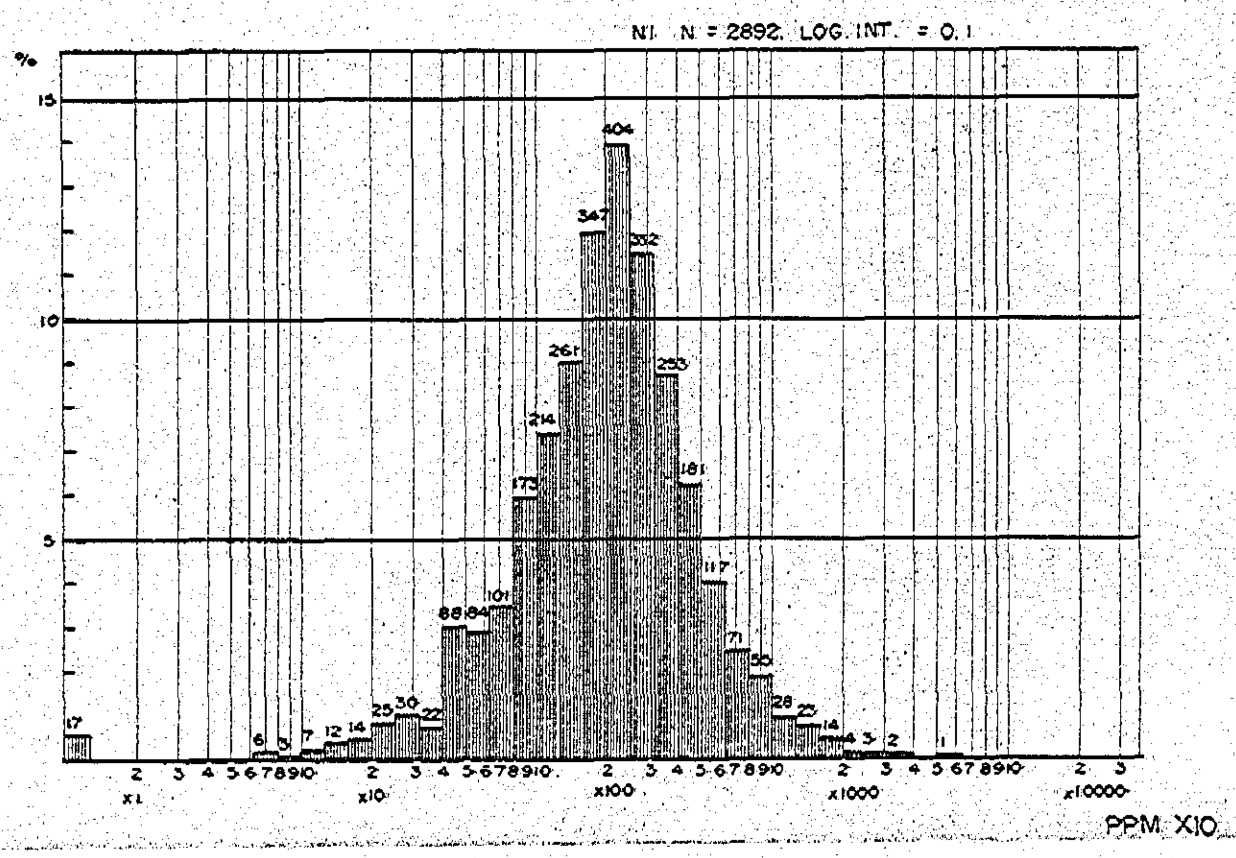
- TV: Tertiary — Volcanic breccia
- TM: Tertiary — Monzonite porphyry
- TR: Tertiary — Phyolite & Dacite
- MP: Tertiary — Quartz - porphyry & Granite - porphyry
- CG: Cretaceous — Granite
- MD: Jurassic — Diorite complex
- PG: Permian - Triassic — Granite & Granodiorite
- PC: Permian - Triassic — Granodiorite complex

CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, ZN AND NI (Soil)

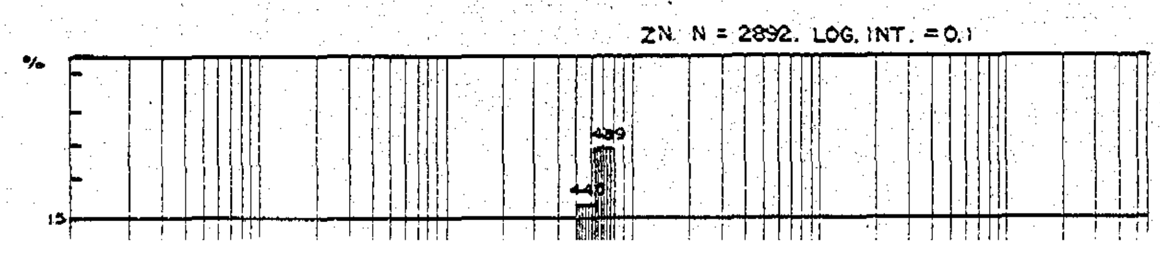


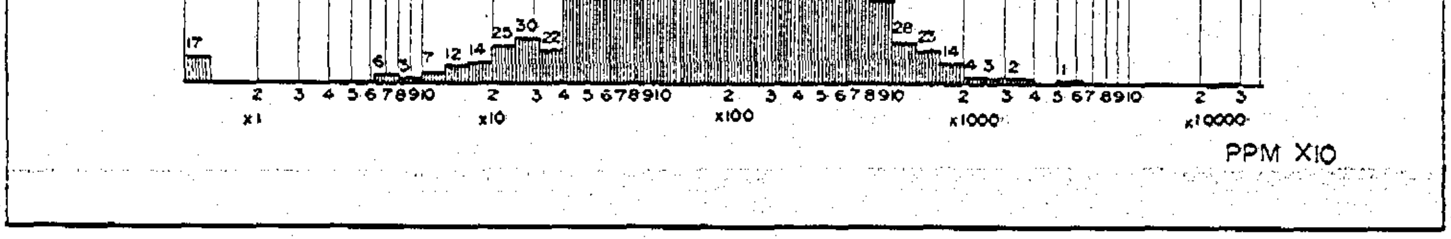
Threshold by Cumulativive Freguency Line: Cu 70, Zn 200, Ni 105 (ppm)

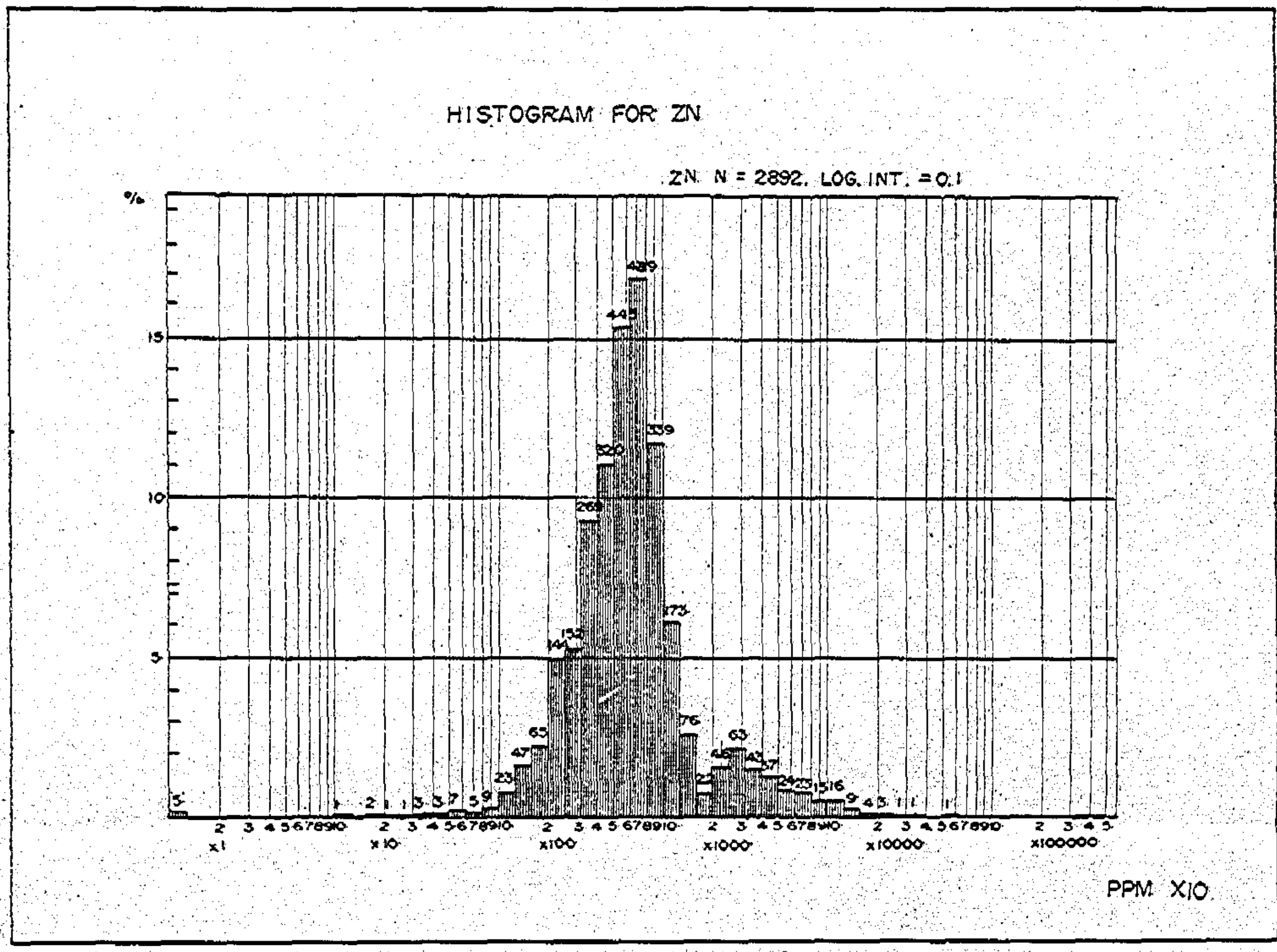
HISTOGRAM FOR NI



HISTOGRAM FOR ZN







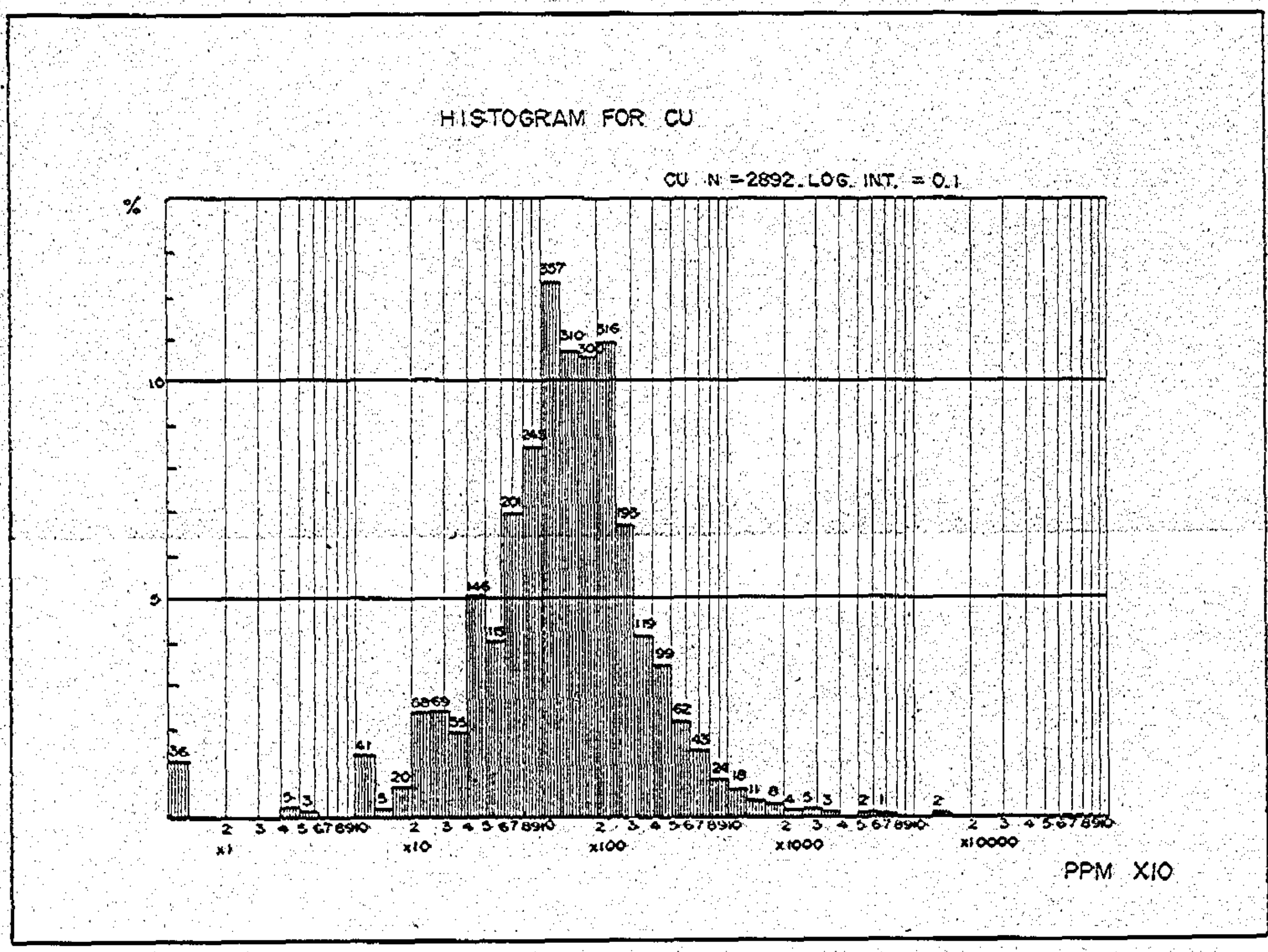
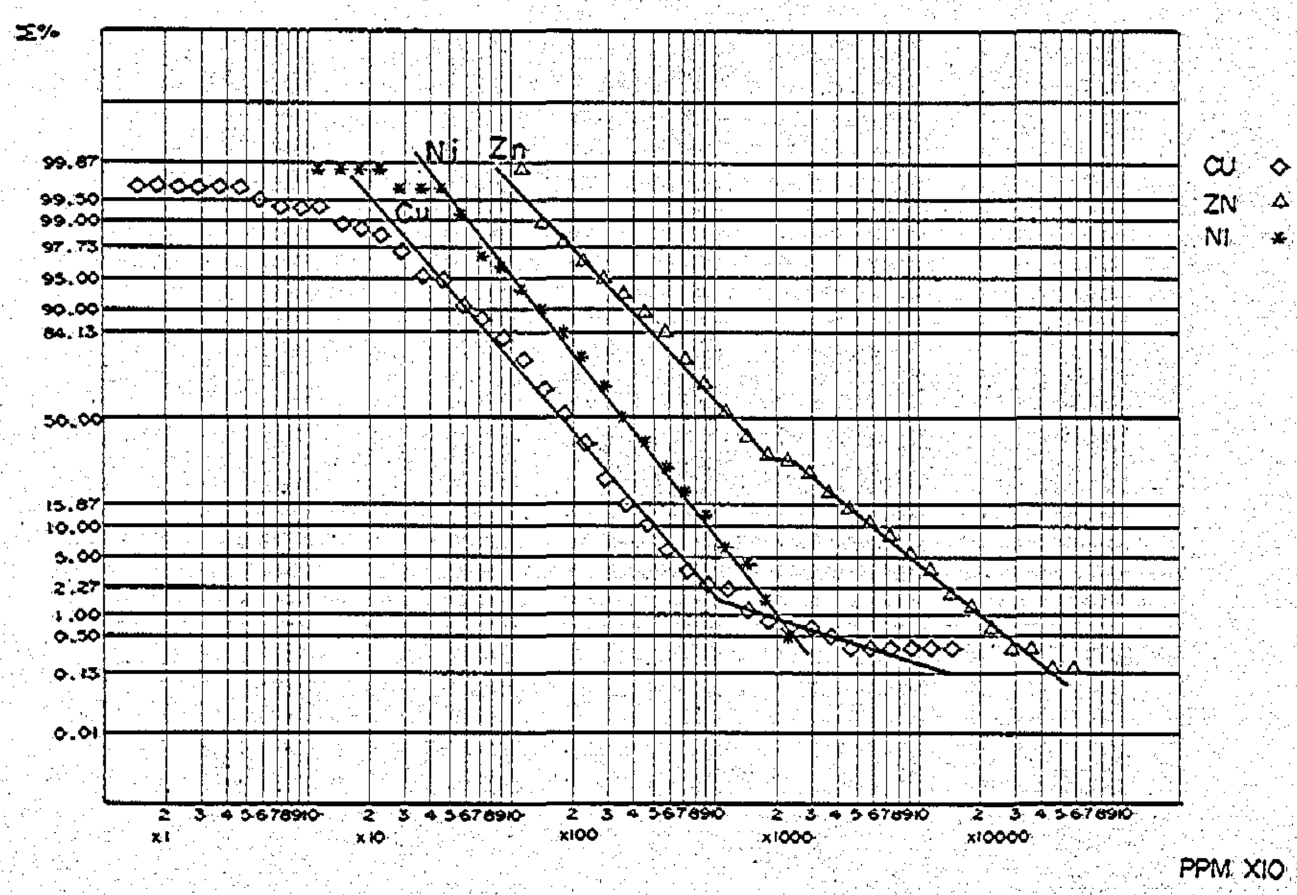


Fig. 6A. Cumulative Frequency Diagram and Histogram for Cu Zn and Ni on Soils in the Reconnaissance Area

CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, ZN AND NI (Soil-Pucara Group)



HISTOGRAM FOR NI

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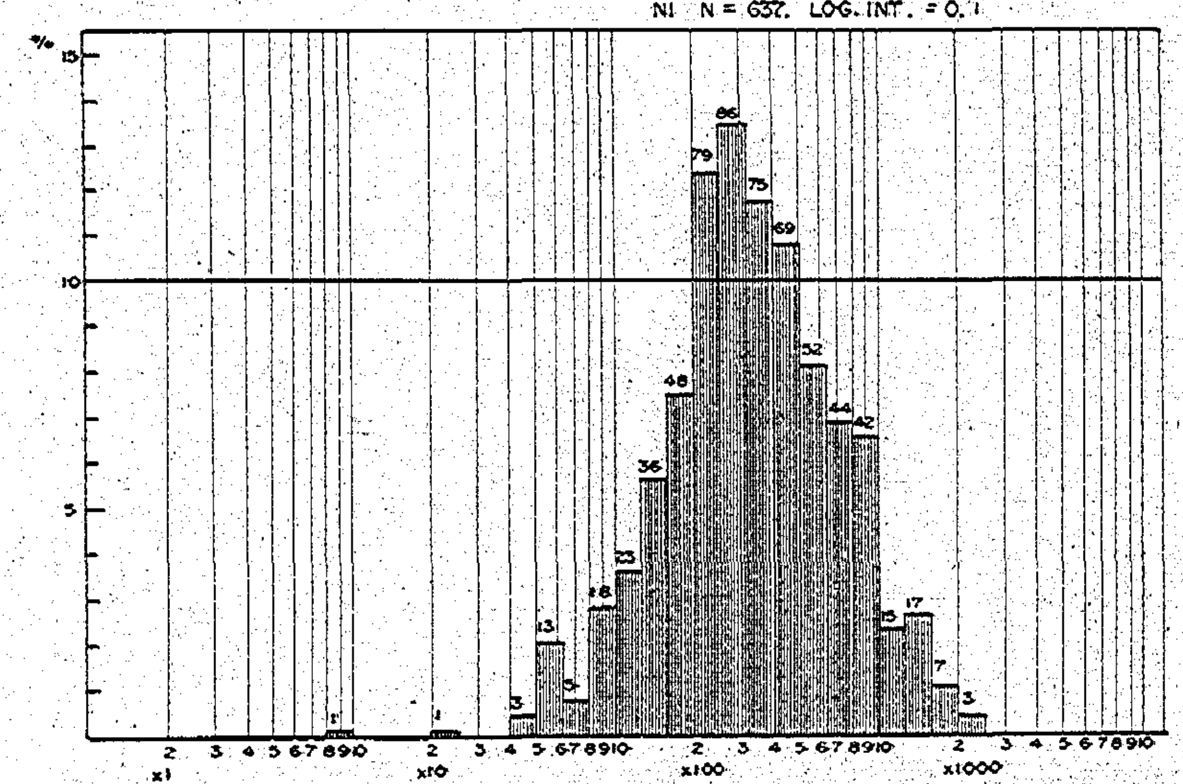

HISTOGRAM FOR ZN

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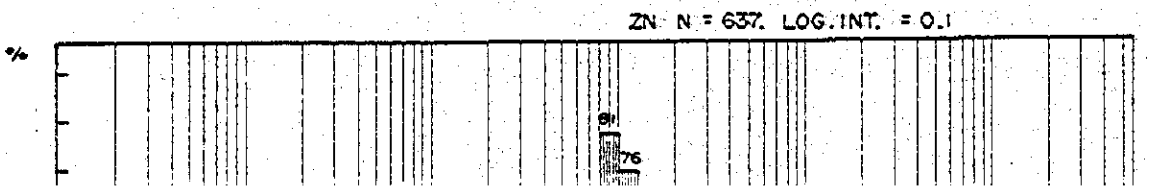
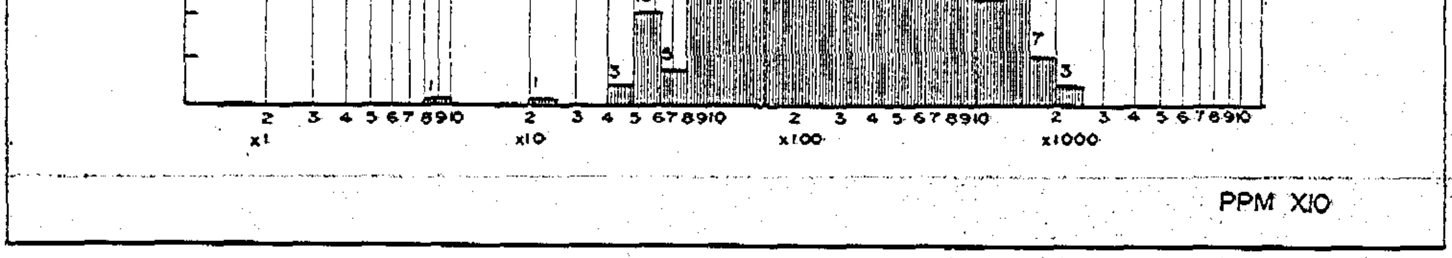
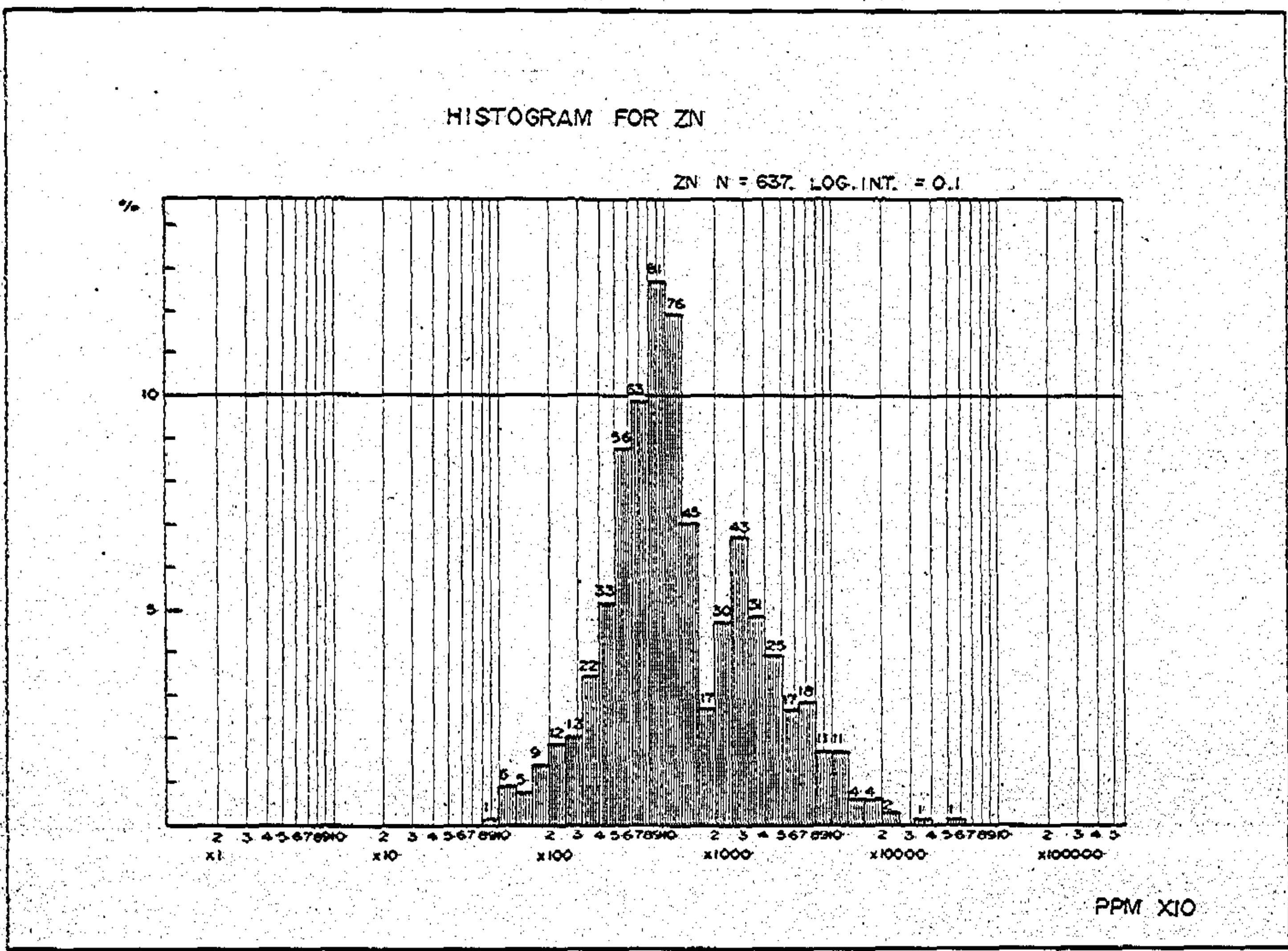






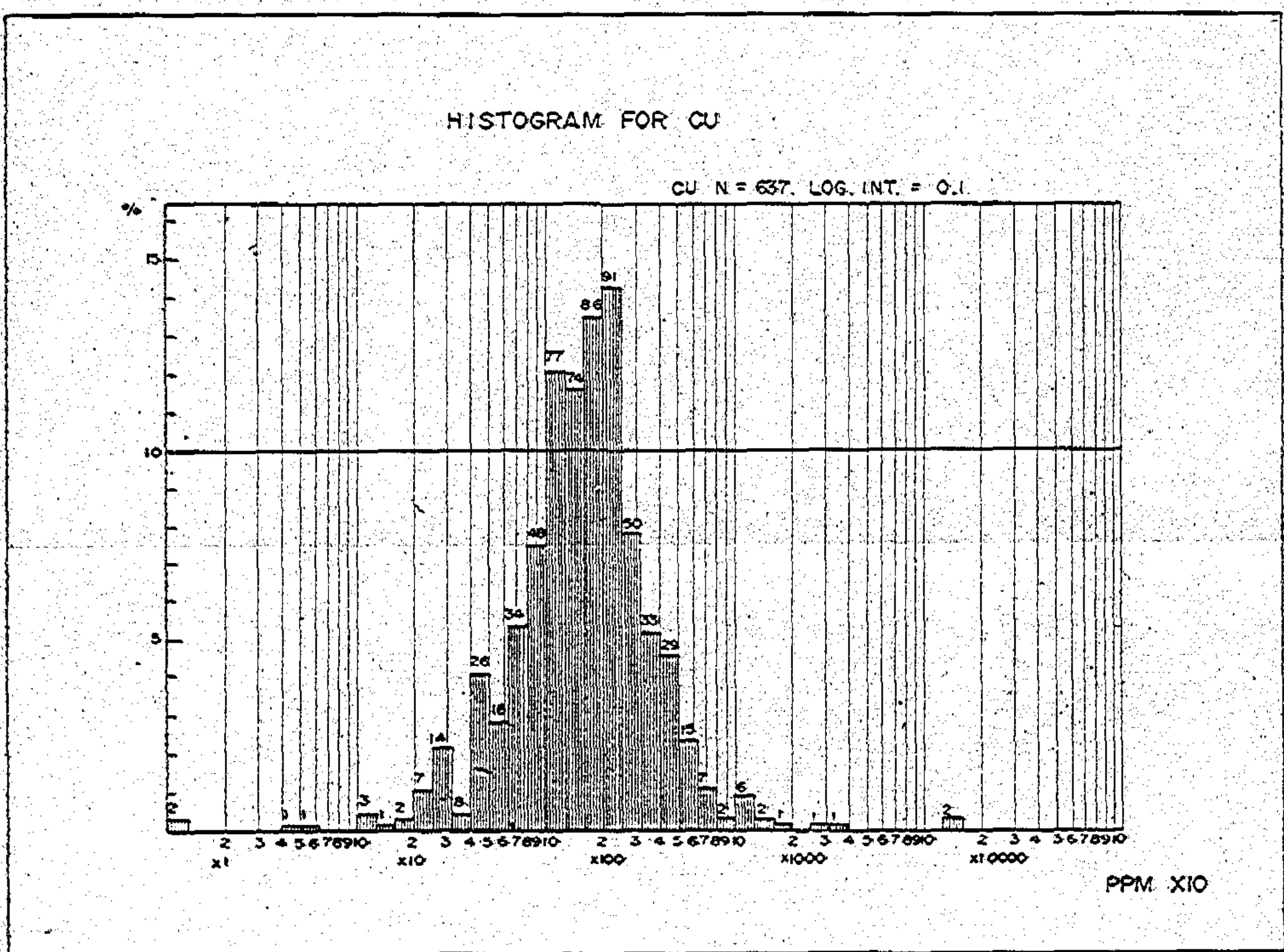
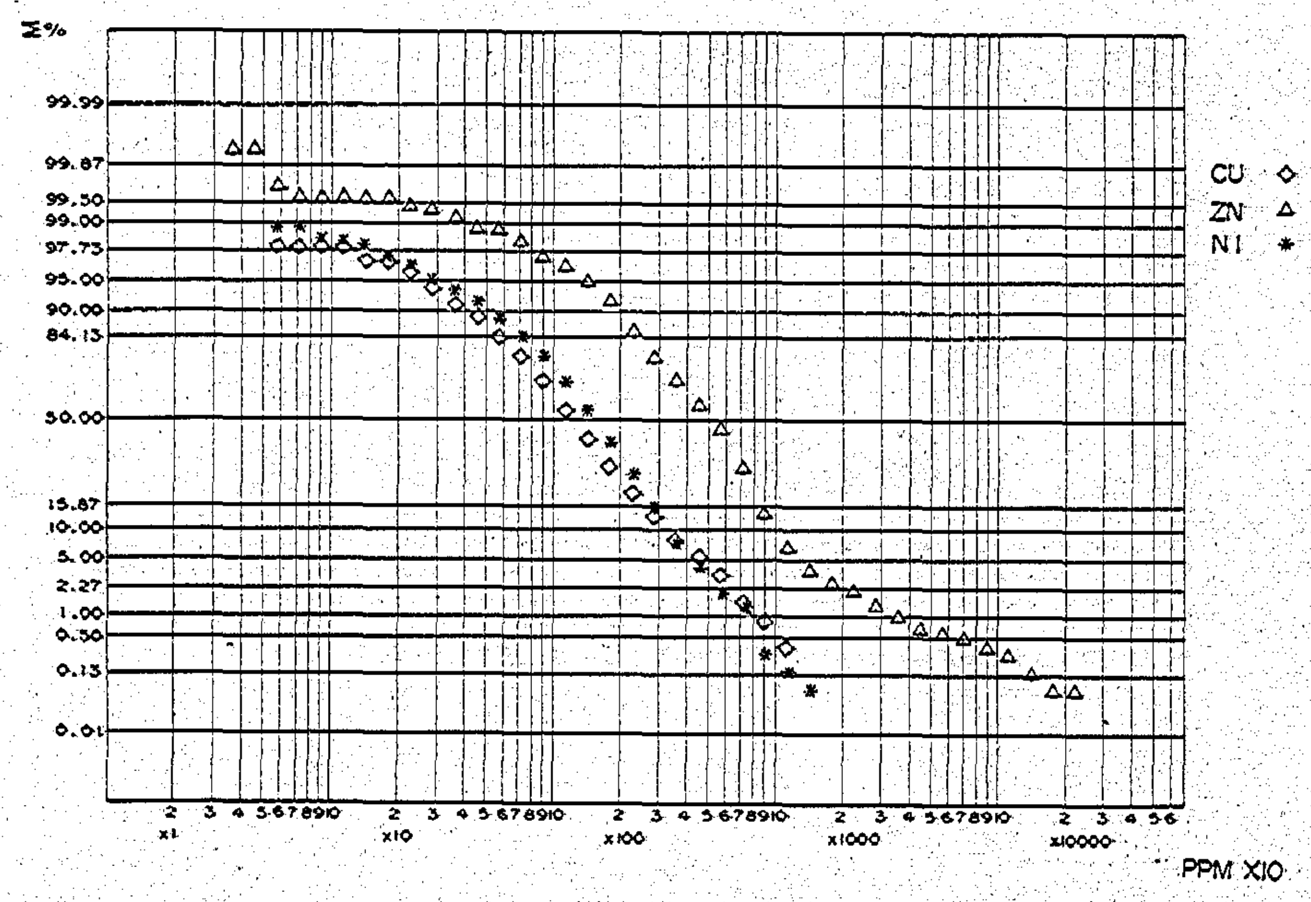
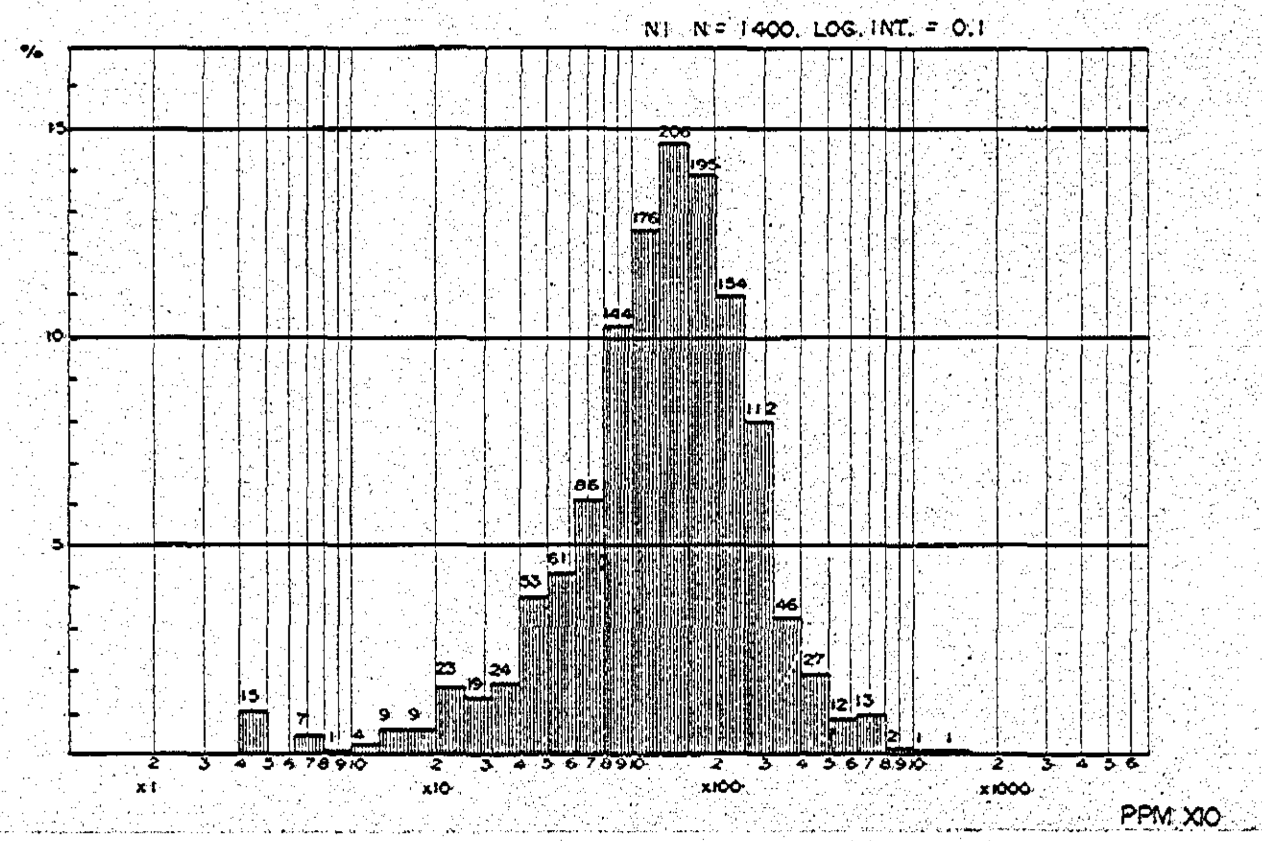


Fig 6B Cumulative Frequency Diagram and Histogram for Cu Zn and Ni on Soils in the Pucara Group

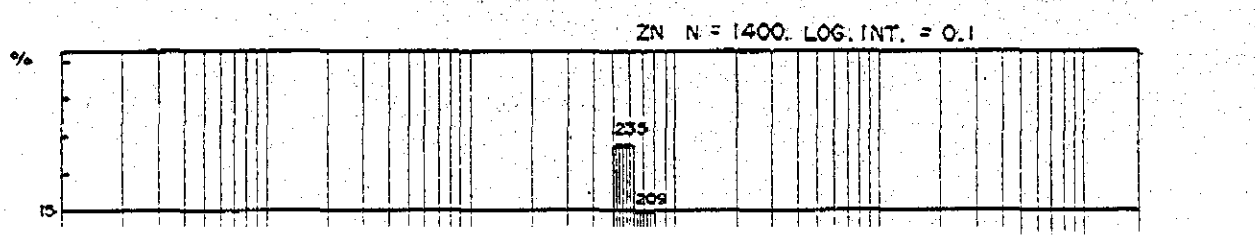
CUMULATIVE FREQUENCY DISTRIBUTION FOR CU, ZN AND NI (Stream Sediments)

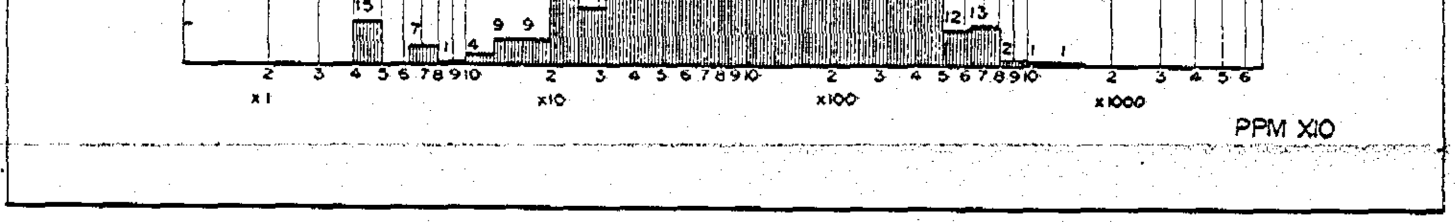


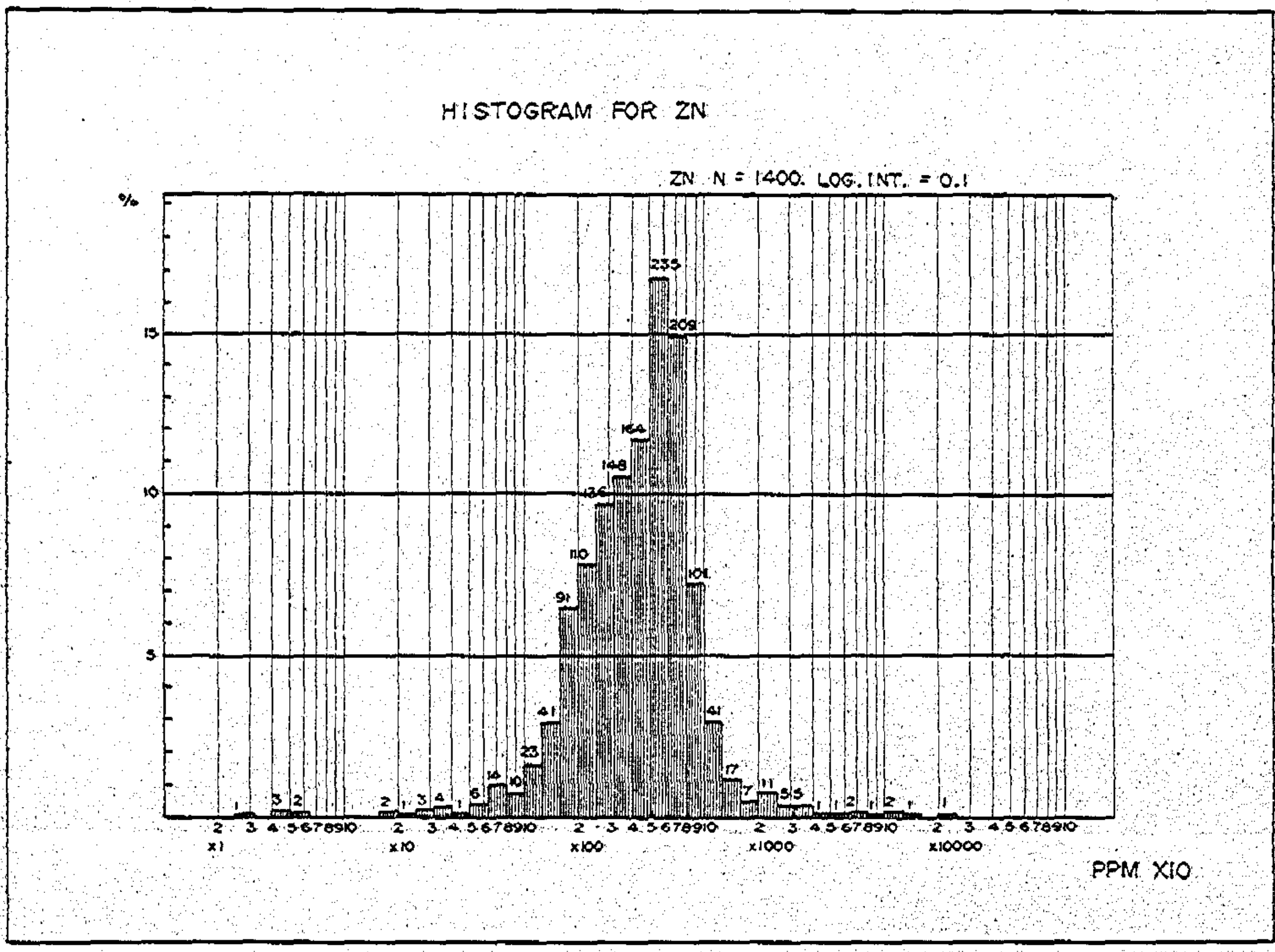
HISTOGRAM FOR NI



HISTOGRAM FOR ZN







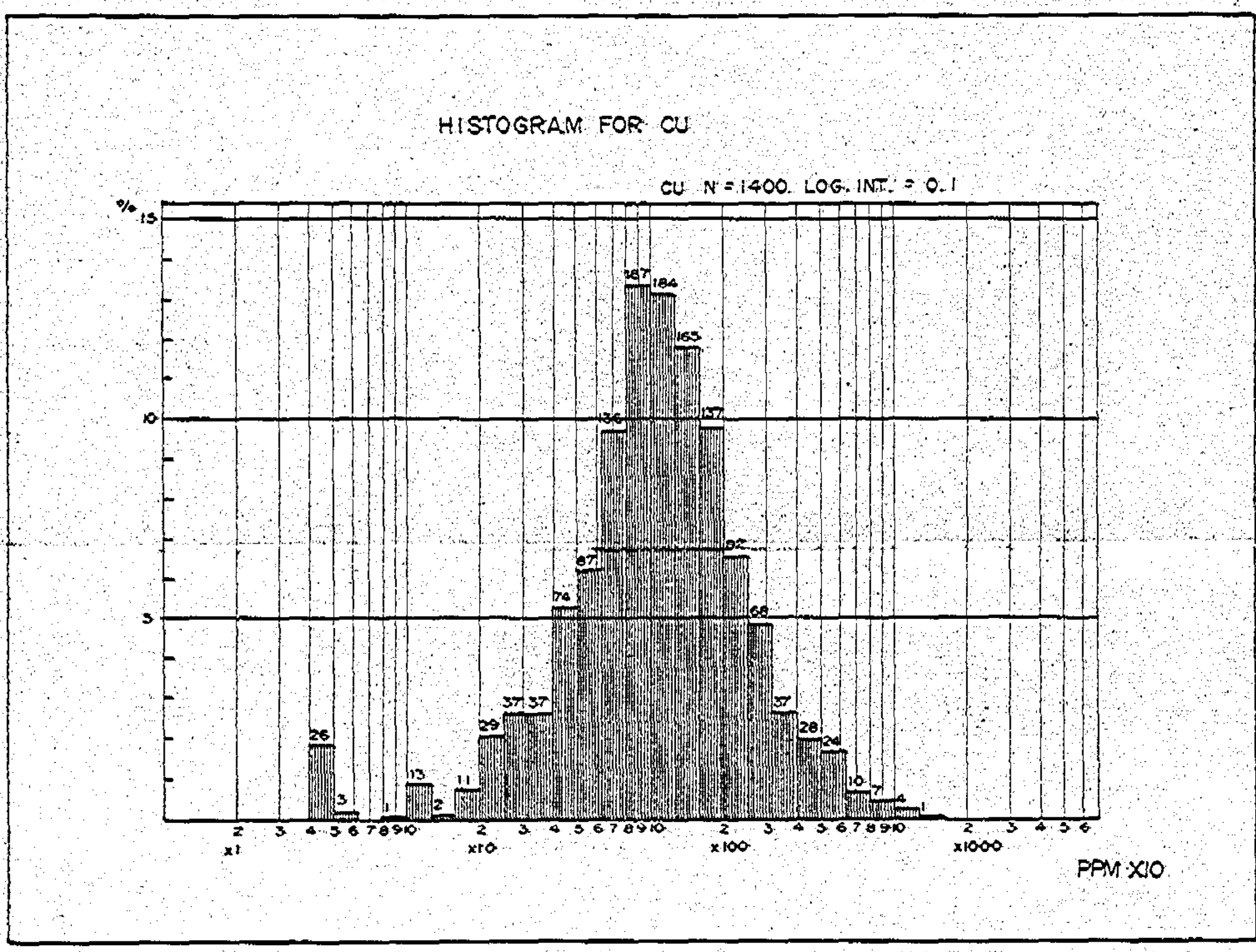


Fig. 6C. Cumulative Frequency Diagram and Histogram for Cu, Zn and Ni on Stream Sediments in the Reconnaissance Area having chemical values reflecting geology of sampled spots, the entire samples (2,892 samples) were treated as one population, and they were further classified according to geological formations and rock facies. No geological correlation was attempted on the stream sediments, because many of them would not be correlated directly to geology of the sampled spots. Data analysis was made following after the method by Lepeltier, C. (1969).

(1) Soils: Table 2 shows mean values, deviations, etc, in taking the entire samples as one population. Figs.6 A show histograms for examination of dispersion patterns and a cumulative frequency distribution on a logarithmic chart.

It has been made clear that values of Ni is plotted nearly on a straight line to show logarithmic normal distribution, but those of Cu and Zn are plotted in combinations of 2 or 3 straight lines, by which they are estimated to consist of 2 or 3 groups.

Cumulative frequency curve of Cu is converted towards higher grades at the point of 70 ppm, presenting high grade anomaly type. This is due to multi-existence of higher values in the population, and the conversion point is considered to express some anomalous factors contained in the population. As is clear on the histograms, on the other hand, Zn seems to consists of two patterns; those up to 130 ppm are normal, and those between 130 ppm and 300 ppm are in anomalous pattern, a mixture of both patterns. In such a case, it is appropriate to select the threshold values, from the cumulative frequency curves, of the conversion point for Cu and of the central value in the mixed pattern for Zn, by which the following figures will be obtained:

	Cu ppm	Zn ppm	Ni ppm
Background Values (M)	14	63	23

Threshold Values of Anomalies (t)	70	200	105

Statistical treatment was also attempted on soil samples by classifying them according to geological formations and rock facies, and histograms and cumulative frequency distribution on the Pucara Group, the ore-bearing formation, (Fig. 6B) show the patterns quite conformable to those in the case of single population on Cu, Zn, and Ni. From these data, the following figures have been read out.

	Cu ppm	Zn ppm	Ni ppm
Background Values (M)	19	105	34
Threshold Values of Anomalies (t)	125	200	150

In extracting geochemical anomalies, therefore, the following classification was adopted, in consideration that most of the anomalous values are concentrated in the samples taken from the Pucara Group.

	Cu ppm	Zn ppm	Ni ppm
Background Values (M)	20 (x)	100 (x)	30 (x)
Threshold Values of			
Weak Anomalies (t)	70	200	100
Strong " (2t)	140	400	200
Strongest " (3t)	-	600	-

(x): Figures are not plotted on geochemical maps.

In addition, Table 3A shows the dispersed patterns of anomalies by formations and rock facies.

(2) Stream Sediments: Mean values and deviations of samples of stream sediments are shown by Table 2A. And cumulative frequency distribution is shown on a logarithmic chart in Figs. 6C. According to them, Cu, Zn, and Ni, seem to show logarithmic normal distributions each other.

On this basis, the following classification was adopted in extracting anomalous values among the samples of stream sediments.

	Cu ppm	Zn ppm	Ni ppm
Background Values	10 (x)	41 (x)	12 (x)
Threshold Values of	61 (60)	204 (200)	62 (60)
Weak Anomalies (t)	122 (120)	408 (400)	124 (120)
Strong " (2t)			

Figures in ( ) are adopted values; (x) means unindicated value on geochemical maps.

4-3. Discussion of Geochemical Results (PL. I-7)

(1) Comprehensively observed in regard to Cu anomalies in soils (table 3A), many high values are found in the samples of Pre-Cambrian gneisses, and high values are also found spottily in granitic rocks, Jurassic dioritic rocks, and in the Pucara Group, but these are scarcely found in the acidic igneous rocks of post Mesozoic except for Tertiary monzonite porphyries.

Comparing such features with the results of geological survey, copper anomalies by soil samples have their higher values around the vein type deposits developed in the granitic rocks and metamorphic rocks, and distinct ones among them are recognized around Huasahuasi, Palca, and Chaglla mineral indications in the southern area. High values are also found in Jurassic dioritic rocks, especially in the stocks of diorite around San Vicente. Although possibilies look scarce in these anomalies to be developed into the ore deposits, the May 1976 survey has discovered a mineralization of porphyry copper type in monzonite porphry which had never been found, and this finding is necessary to be kept in mind for a problem to be discussed in future.

Copper anomalies by the samples of stream sediments, on the other hand, are mostly related to the localities where Cu anomalies were detected by soil samples. In the east of Huancabamba, a weak anomalous zone is extended widely, and it is caused by Cu originally contained in the gneisses or in the Mitu Group, but not by copper derived from the mineralized stocks of porphyries against an anticipation arisen through the previous survey.

(2) Most of high values in Zn are concentrated in the Pucara Group, and a few in the gneisses and Mitu Group, and some local highs are in the Chonta Group.

The representative geochemical anomalies in the Pucara Group recognized where high values are concentrated are as follows;

	States of Distribution	Maximum Values ppm
Around San Vicente	4 or 5 or strongest anomalies	2,027
Around Piehita Caluga	2 of strongest anomalies	5,193
West of Paucartambo	scattered high anomalies	2,190
West of Oxapampa	3 of strong anomalies	1,336
Around Huancabamba	scattered high anomalies	2,464
Around Monopampa	3 or 4 strongest anomalies	3,217
Tingo Maria	scattered strong anomalies	1,680

All the values excluding the maximums were more or less 1,000 ppm in these anomaly zones, and almost all of the anomalies have been assured to conform to the distribution of dolomite or dolomitic limestone in the Pucara Group, but relations of anomalous zone, consisting of some anomalies, with ore deposits could not be clarified by the previous reconnaissance. But the later precise survey has discovered Zn indications and detected some additional anomalies. As they have been revealed to be distributed along dolomite layers, it is desirable to continue some more surveying actions for such strong anomalies as described above.

Other Zn anomalies except in the Pucara group are mostly related to the vein type deposits in the south.

Anomalies by stream sediments are distributed around those detected by soil samples or in their downstreams.

(3) Strong anomalies of Ni by soil samples are concentrated in the gneisses and Mitu Group, and in igneous rocks, slightly high values are found along the exposures of Jurassic dioritic rocks. In the Pucara Group, weak anomalies of Ni are distributed in conformity with Zn anomalies in the northern area.

From the samples of stream sediments, nothing remarkable has been found except a weak anomaly found in the gneisses of the south, as they are generally low graded.

(4) Consequently, it has been made clear that Zn is effective for prospecting the bedded lead-zinc deposits, and Cu and Ni are effective in discriminating rock facies and for investigation of some kinds of mineral indications.

PARTICULARS

PART II

Detailed Geological Survey

CONTENTS

Chapter 1 Outline of Survey

1-1. Purpose of Survey

Detailed geological survey, a part of the August 1976 survey, was practiced for the districts remarked in paragraph 2-3-1 of the part, General, in the southern part of the projected area. This survey was practiced succeedingly to the reconnaissance in September 1975 and geological reconnaissance and geochemical survey for the Pucara Group in May 1976 and operations were taken in the 3 districts which had been extracted as the most important ones through the previous surveys, especially the May 1976 survey. Purpose of survey was to clarify the states of emplacement of the bedded lead-zinc deposits in these districts; practically speaking, it lied in to make clearer the distribution, stratigraphy, and structure of dolomite layers in these districts, to acquire accurate state of distribution of elements of heavy metals and its relation with the stratigraphy and geological structure, and to establish principles and procedures for the future surveys.

1-2. Field Operations

(1) Detailed Geological Survey

This survey covered total area of 259 km^2 in the 3 districts, which consisted of Huncabamba district of 12 km^2, Oxapampa-Churmazu district of 226 km^2, and Pichita Caluga district of 21 km^2.

Survey routes were so arranged that they would intersect perpendicularly to the principal direction of geological structure in those districts, NNW-SSE or N-S. The surveyed districts can be accessed along the road running longitudinally between San Ramon-Oxapampa-Pozuzo. To get into the interiors of surveyed districts, only a few logging roads were available and supplementary trails for men and horses existed only partially.

In such conditions, the survey had to be proceeded mostly by clearing primeval forests. Moreover, topography was so steep wherever the Pucara Group was distributed and it so happened to be in the minor rainy season, that the survey had to be practiced under extremely severe conditions.

In geological observation along the survey routes, the pre-arranged topographic maps of scale 1:10,000 and 1:25,000 were used.

(2) Geochemical Survey

Geochemical survey in these districts were made on soils as well as on the carbonate rocks. Soil samples were collected from the B_1 bed directly under humus, and samples of the carbonate rocks were collected from exposures whenever met with. They were so tried as to be collected about 10 per 1 km^2.

1-3. Indoor Works

Following indoor works were performed for examination and analysis of data obtained through the field operations.

(1)	Microscopic observation of thin sections of rocks	62 pcs.
(2)	Chemical analysis of ores	32 "
(3)	Microscopic observation of polished sections of ores	23 "
(4)	X-ray diffraction tests	130 "
(5)	Chemical analysis of minor elements in carbonate rocks (Mg, Zn, Sr, & F)	296 "
(6)	Analysis of geochemical samples (Cu, Pb, & Zn) soils	1,840 "

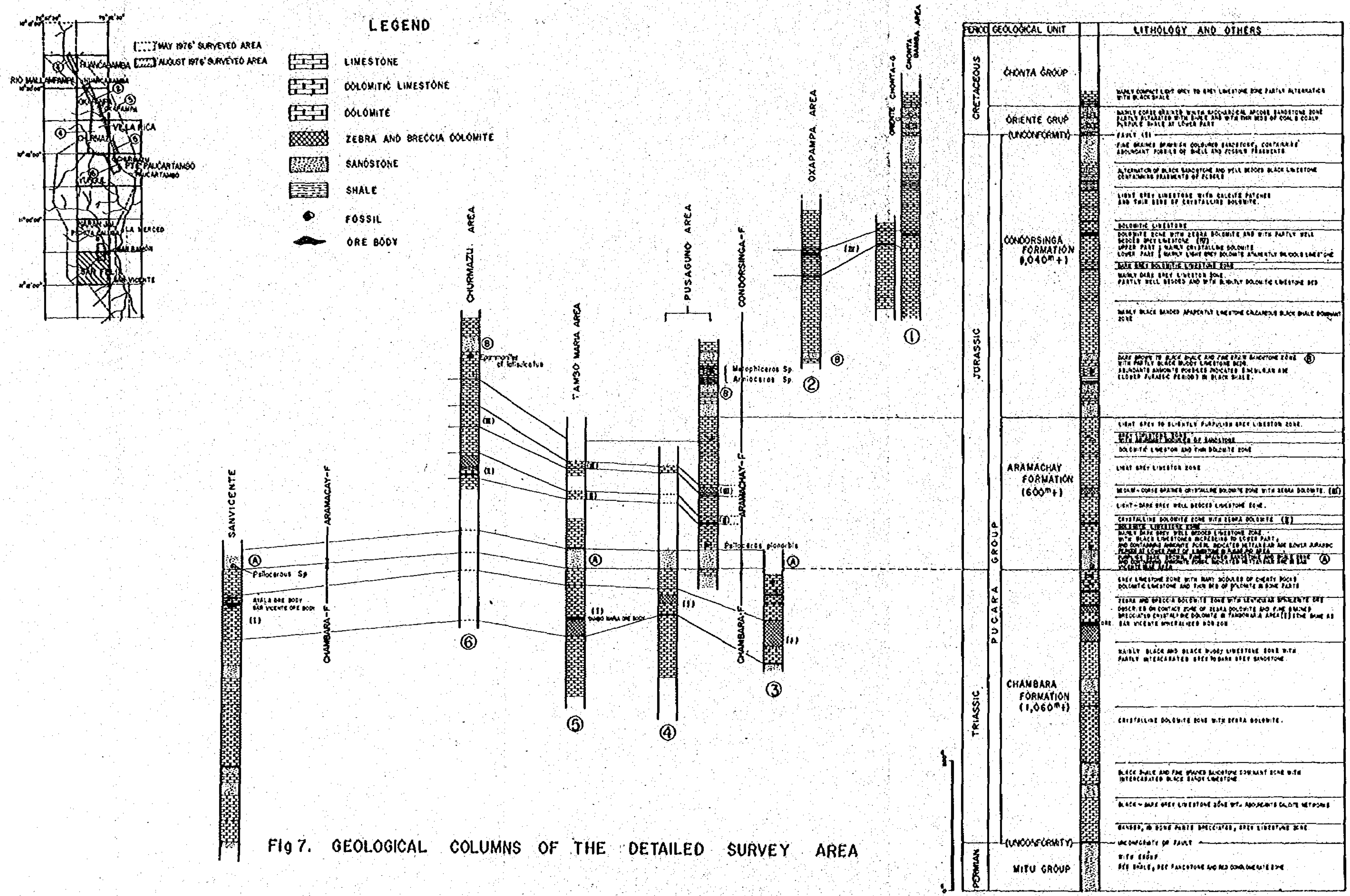


Fig 7. GEOLOGICAL COLUMNS OF THE DETAILED SURVEY AREA

Chapter 2 Geology and Geological Structure

Geological survey in the August 1976 survey was performed to clarify the stratigraphy and structure of the Pucara Group, which was one of the main purposes of the said survey. Upon this, the survey was mostly concentrated in the areas where the Pucara Group was distributed. In this chapter, therefore, description will be made chiefly upon the stratigraphy and structure of the Pucara Group, and upon sedimentary rocks and igneous rocks, summaries only will be mentioned here, as details were mentioned in the report of the May 1976 survey and in Part I in the present report. Results of present survey are shown by Fig. 7, PL. II-1, II-2, II-3, and others.

2-1. Outline of Geology

The surveyed districts are located in the median basins in the geomorphological classification (General, 2-4-1), and they are located along the Rio. Huancabamba, Rio. Paucartambo, and Rio. Chanchamayo, which flow longitudinally in these districts in the direction of NNW-SSE. Roughly speaking, sedimentary rocks after the Pucara Group are distributed on the east side of these rivers, the Pucara Group, main object of present survey, is in the central part, and igneous rocks are on the west dide of the Pucara Group. These formations are arranged generally in NNW-SSE or N-S and Tingo Maria-Merced line is running along the rivers above mentioned, which borders the Pucara Group and the sediments deposited after the Pucara Group. Aside from this line, faults in NEE-SWW, and NNE-SSW which intersect the Pucara Group are recognized.

2-2. Igneous Rocks

(1) Mesozoic Dioritic Rocks

They are distributed in the districts of Pichita Caluga and Oxapampa, and around Pusagno. They are so exposed on both sides of the River Tarma as to have penetrated the Mitu and Pucara Group near Pichita Caluga. Diorite in the north is a gabbroic rock slightly more basic than those in the south.

Near Pusagno, on the other hand, it is medium or fine grained gabbroic rock, distributed as a slender zone in a direction of N-S along the margin of Cretaceous granitic rocks to be mentioned later. Around here, it is observed to occur penetrating the Pucara Group and Cretaceous granitic rocks.

From the results of age determination by K-Ar method (2-3-2, Part I), they are considered to be the products differenciated from a single original magma for a long time, principally occupied by Jurassic Period in between the duration.

(2) Cretaceous Granitic Rocks

They are what have been called Pusagno granite bodies by the May 1976 survey, being exposed near Pusagno and northwest of Quillazu. They are coarse grained and contain abundant pinkish kalium feldspar, and other component minerals of quartz, plagioclase, and biotite, penetrating the Pucara Group, and locally contain xenoliths of limestone of the Pucara Group.

Age detrmination by K-Ar method indicates late Jurassic or early Cretaceous Period (125 & 130 m.y.). Sometimes they are intruded by the dioritic rocks as mentioned in the previous section.

(3) Cretaceous Granite Porphyry and Quartz Porphyry

They are what have been called Oxapampa intrusives by the May 1976 survey. In the surveyed area, they are granite porphyry and quartz porphyry in the west of Oxapampa, and granite porphyry near Pichita Caluga. Mineralization of disseminated lead in the Pucara Group are located in the neighborhoods of these porphyries and granitic rocks afore mentioned.

(4) Tertiary Intrusives

They are monzonites or monzonite porphyry intruding into the Pucara Group and Chonta Group as stocks near Tambo Maria. Age determination has indicated 22 m.y. which is about Miocene Epoch of Tertiary Period, which means the youngest igneous rocks in the surveyed area. As it has been stated in Part I of this report, they have given weak skarnization and copper mineralization to the surrounding Pucara Group (2-3-3, Part I), about which will be mentioned in Chapter 4.

(5) Tertiary Acidic Pyroclastics

They are exposed sparcely in the west of Quillazu, but lithologically they are conglomerate here, containing medium or grand pebbles. This may be interpreted as one of the partings of conglomerate intercalated in this pyroclastic formation. In other words, the present area of detailed survey may contain only such member of the pyroclastic formation.

2-3. Pucara Group

2-3-1 Stratigraphy

The Pucara Group in the surveyed area will be classified as below in ascending order.

Lower black limestone layer
" limestone-dolomite layer
" sandstone layer
Middle limestone dolomite layer
" sandstone layer
Upper black limestone layer
" limestone-dolomite layer
" sandstone layer

(1) Lower Black Sandstone Layer

This layer corresponds to the lowermost of the Pucara Group in this surveyed area, and is distributed in Oxapampa district, and from the south of Oxapampa through Tambo Maria and left side of the Rio Santa Cruz towards Pusagno, forming the fringe of topographic depressions. It consists mostly of black limestone including muddy parts, intercalating partings of gray limestone, and it seems to be more muddy towards lower part. Thickness is about 250 m in the surveyed area.

(2) Lower Limestone-dolomite Layer

It overlies the lower black limestone layer and is distributed from around Pusaguno towards Rio Santa Cruz. It is not well exposed but seems to be distributed continuously in this district, judging from distribution of its boulders and from the relation with overlying formation.
Its lower part right above the underlying lower black limestone layer is dolomite of about 150 m thick, and above this part is limestone. The dolomite (I-bed) is mostly recrystallized and banded structure (zebra structure) and breccia structure are recognized scatteredly. Sphalerite in lenticular banded forms has been recognized around Tambo Maria near the border of the banded and breccia structures. Fossils of bivalves have also been found in the upper part of this dolomite. Limestone in the upper part consists mostly of gray limestone of 100--150 m thick, and around Oxapampa, it contains many nodules of cherty substance and fragments of bivalves and ammonites.

(3) Lower Sandstone Layer

Overlying the lower limestone-dolomite layer, it is developed well continuously with thickness of about 70m. It consists mostly of fine grained arkose sandstone of white or light gray and intercalates a few shale.

(4) Middle Limestone-Dolomite Layer

It is distributed in the south from Oxapampa, and is well exposed near

Pusaguno and Churumazu, but not so well exposed near Tambo Maria. It consists mostly of well stratified limestone of gray or locally dark gray color, containing many sandy nodules in its uppermost part.
Characteristic of this layer is to intercalate dolomite or dolomitic limestone. There are 2 beds of dolomite in the lower part (dolomite II-bed and III-bed), which are crystalline and contain local developments of the banded structures with light gray and white stripes. The braccia structures are also recognized near Churumazu. The upper dolomitic limestone contains a few breccia structures but is generally gray or darkgray compact rock.
This layer seems to be richer in lithological variation, locally containing tuffaceous sandstone near Pusagno. Each of the 3 beds of dolomite or dolomitic limestone has thickness of 50 ~ 70 m and total thickness of this member reaches about 500 m. Fossil of Psiloceras planorbis, which is the index fossil of Hettangian Epoch of lower Jurassic has been discovered from the lowermost limestone near Pusagno. By the discovery of this fossil, the lower sandstone layer has been assured to belong to the lowermost of the Aramachay Formation.

(5) Middle Sandstone Layer

This is distributed in a slender zone in a direction of NNW-SSE or N-S, occuping the topographical highs from around Oxapampa towards the east of Pusaguno and along the road between Oxapampa and Quillazu. It also represents the lowermost part of the Pucara Group in the north from Oxapampa.
It consists mainly of dark brown shale and sandstone, intercalating partings of black muddy limestone, and is in transitional relation with the overlying black sandstone bed. In the east of Pusagno, where this formation is best developed, its lower part consists of an alternation of sandstone and black limestone, middle part is dominated by bituminous shale, and its upper part consists of fine sandstone. Its middle part contains Ammonites of Sinemurian

Epoch of lower Jurassic abundantly in Pusaguno and Oxapampa. The lower part of this member in Churumazu contains banded dolomite locally. Thickness of this member is about 250 m.

(6) Upper Black Limestone Layer

Overlying the middle sandstone layer, this member is distributed mostly in the north from Oxapampa and in Huancabamaba district, and occupying the topographical uppermosts in the south from Oxapampa.
Consisting mostly of black or dark gray limestone, its upper part is dark gray or bright gray, compact, and partly dolomitic. In the south from Oxapampa, there exists the lower black limestone which resembles lithologically to this member, but it could be discriminated clearly by the stratigraphical relation with the fossil-bearing sandstone layer discovered near Pusaguno. Thickness of this member is about 200 m.

(7) Upper Limestone-dolomite Layer

It is distrinuted in Huancabamba and north from Oxapampa, overlying the upper black limestone. Consisting mostly of well stratified gray limestone, it intercalates gray, compact dolomite (IV-bed) in its middle part. Being slightly different from the lower dolomite, this dolomite seems to be less crystalline though the banded structures are recognized spottily. The upper limestone is also gray and compact. Thickness of this member is about 450 m.

(8) Upper Sandstone Layer

Corresponding to the uppermost part of the Pucara group distributed in the surveyed area, this is developed in the northernmost part of Huancabamba district. Its lower part is an alternation of black sandstone and black limestone, which graduates into fine sandstone of the upper part. Fossils of bivalves are found abundantly from the sandstone of this member in Pusagno, in the south of Oxapampa and around Quillazu.

In addition, the Pucara Group in Pichita Caluga district consists of dark gray and compact limestone, in which dolomites containing the banded structures are recognized here and there. Although it could not be determined to which member in the above classification would it correspond, it is considered to belong in certain member among the lower members.

2-3-2 Correlation of the Pucara group in the surveyed area

Each member afore memtioned has been classified through correlation by the fossils found in the 2 layers of sandstone and limestone (Table 11, Fig. 13) and their stratigraphical relations. Refered to these fossils and the reports by Megard and Szekely, the lower sanstone layer or the lowermost of middle limestone-dolomite layer which contains the fossile of Psiloceras planorbis, an index fossil of Hettangian Epoch can be correlated to the lower part of the Aramachay Formation, and the middle sandstone layer which contains varous ammonites of Sinemurian Epoch can be correlated to the lowermost of the Condorsinga Formation. As the Aramachay Formation consists of bituminous limestone, sandstone, etc. in its type locality, by which the variation of sedimentary environments have been estimated, these members from the lower sandstone layer to the middle limestone-dolomite layer in this area could be correlated to the Aramachay Formation in view of its variety in the sedimentary facies.

In addition, as stated before, the Psiloceras found in the lower part of the middle limestone-dolomite layer was also found by the September 1975 survey in the uppermost part of the Pucara Group near the San Vicente Mine. Therefore, the lower limestone-dolomite layer around Oxapampa could be correlated to the limestone-dolomite formation in which the San Vicente Deposits were emplaced. In view of this, the Pucara Group distributed around the San Vicente Mine is considered to be represented mostly by the Chambara Formation.

Consequently, thickness of the Pucara Group in the surveyed area was estimated to reach to 2,740 m in total, in which thickness of the Chambara Formation amounted to 1,060 m near the San Vicente Mine, that of the Aramachay Formation to 600 m+ around Pusagno, and thickness of the Condorsinga Formation, situated upper than the upper black limestone, reached to 1,040 m + around Oxapampa and Huancabamba.

2-3-3 Distribution and Genesis of Dolomite

Ther are 4 beds of dolomite recognized in the surveyed area, which are one in the Chambara Formation, two in the Aramachay Formation, and one in the Condorsinga Formation, in addition to them, dolomitic limestone and thin dolomite layers distributed as thin partings and lenses. Furtheremore, existence of one more ded of dolomite is assured near San Vicente, underlying the dolomite of the Chambara Formation, and thus, the dolomite beds in the Pucara Group are counted five in all.

Dolomites are usually crystalline and accompany the banded structure (zebra structure) and breccia structure in most cases. Field distinction of dolomite and limestone was made by the differences in the reaction to hydrochloric acid and specific gravity. In order to check the field results, X-ray diffraction tests were tried and contents of magnesium (to be described Mg hereafter, strontium (to be described Sr hereafter), and fluorin (to be described F hereafter) were analysed on 327 samples, of which results are shown by Tables 13 and 15 and Figs. 14 and 17. Following considerations were made through the results of Sr and F contents.

(1) Dolomite I-bed: It is comparatively homogeneous, and especially the horizon from Oxapampa towards Tambo Maria contains usually from 10% to 14% of Mg and does not show a big fractuation. But around the west of Pusagno, it is a little heterogeneous, showing less than 10% of Mg locally. Mg content around the exposure of Zn ore in Tambo Maria shows 6%, but excluding Zn contents (average; 29.2%) and recalculating in proportion to rock forming

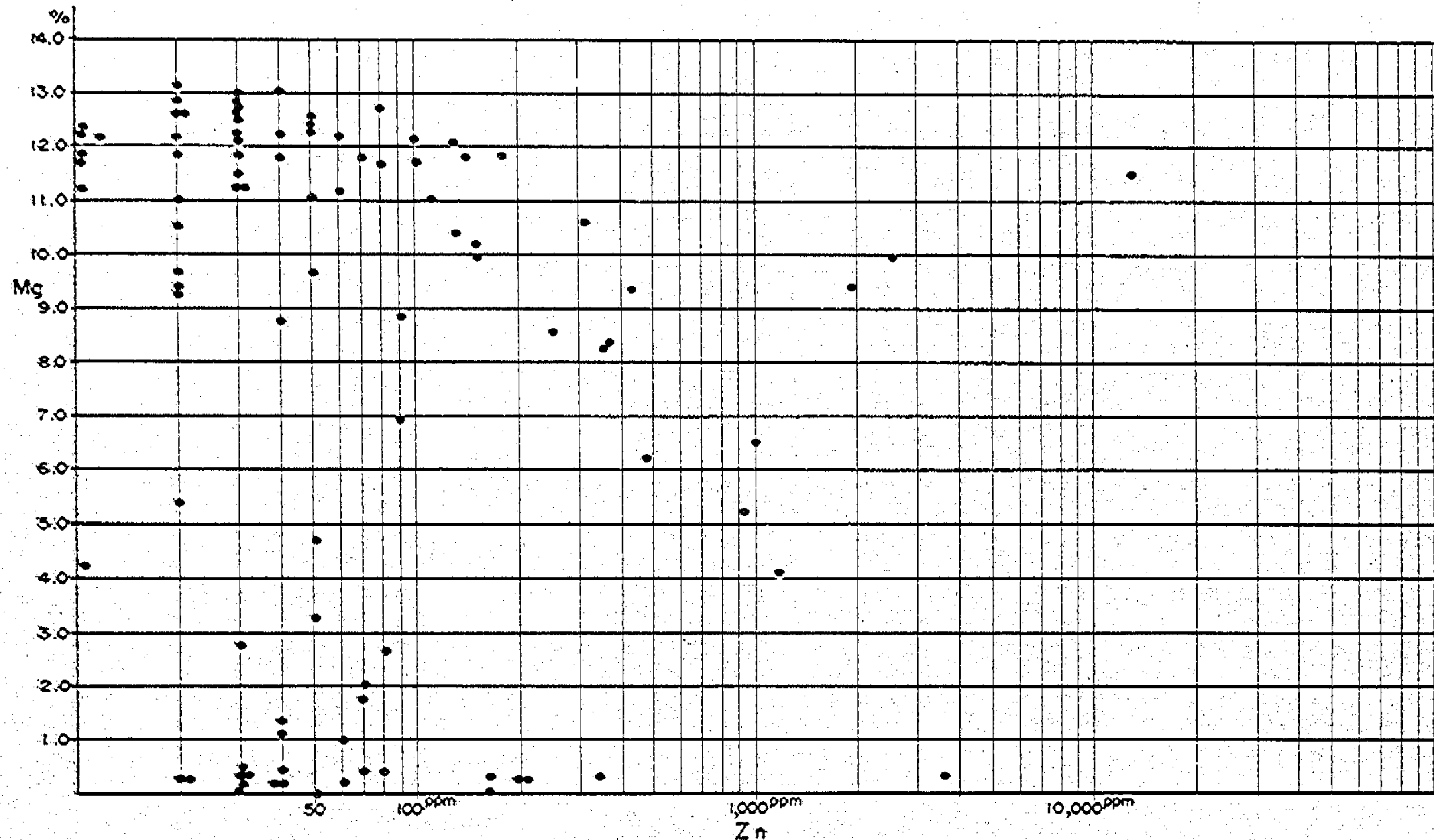


Fig. 17A Relation of Geochemical Values between Mg and Zn contents on Carbonate Rocks

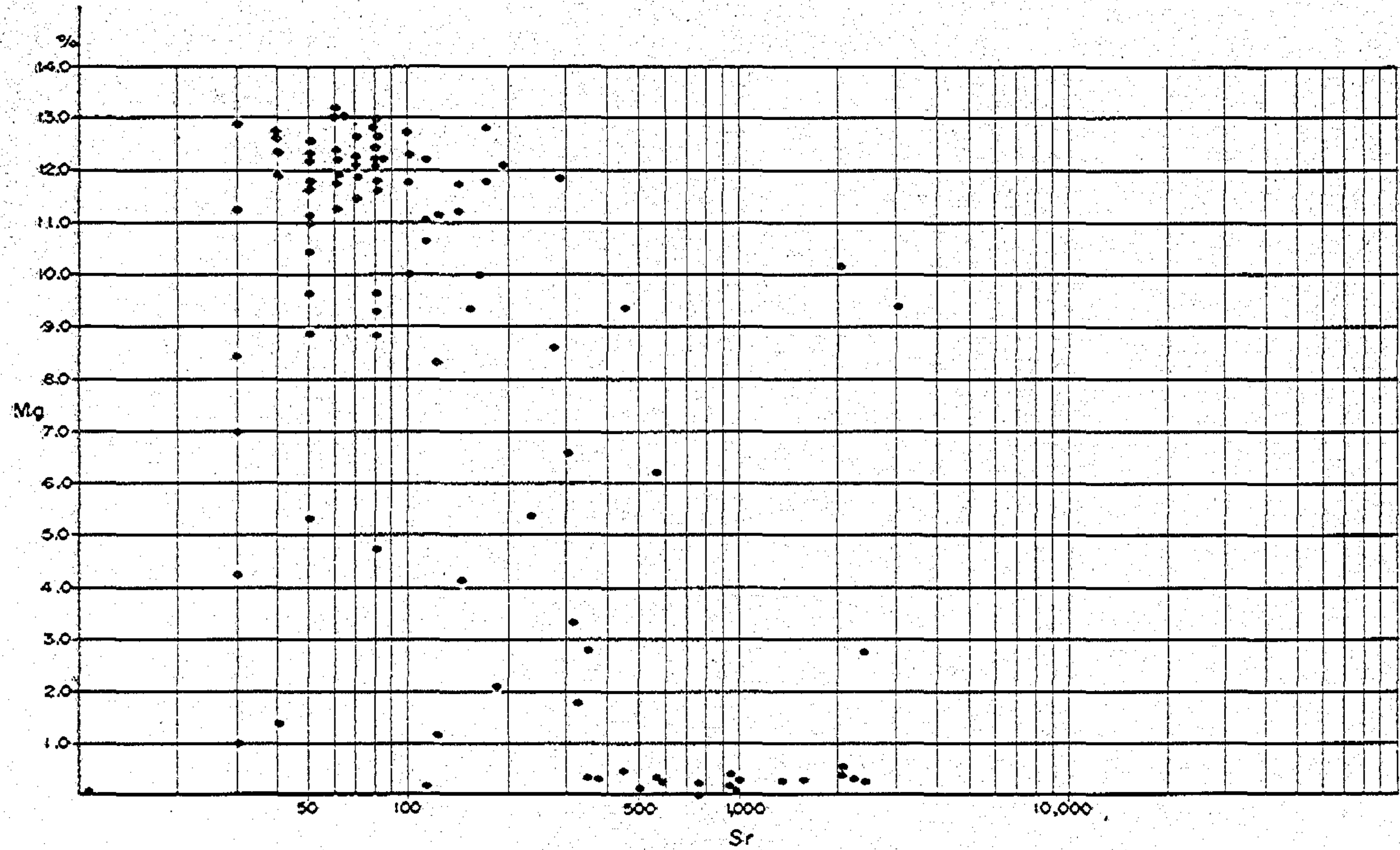


Fig. 17 B Relation of Geochemical Values between Mg and Sr Contents on Carbonate Rocks

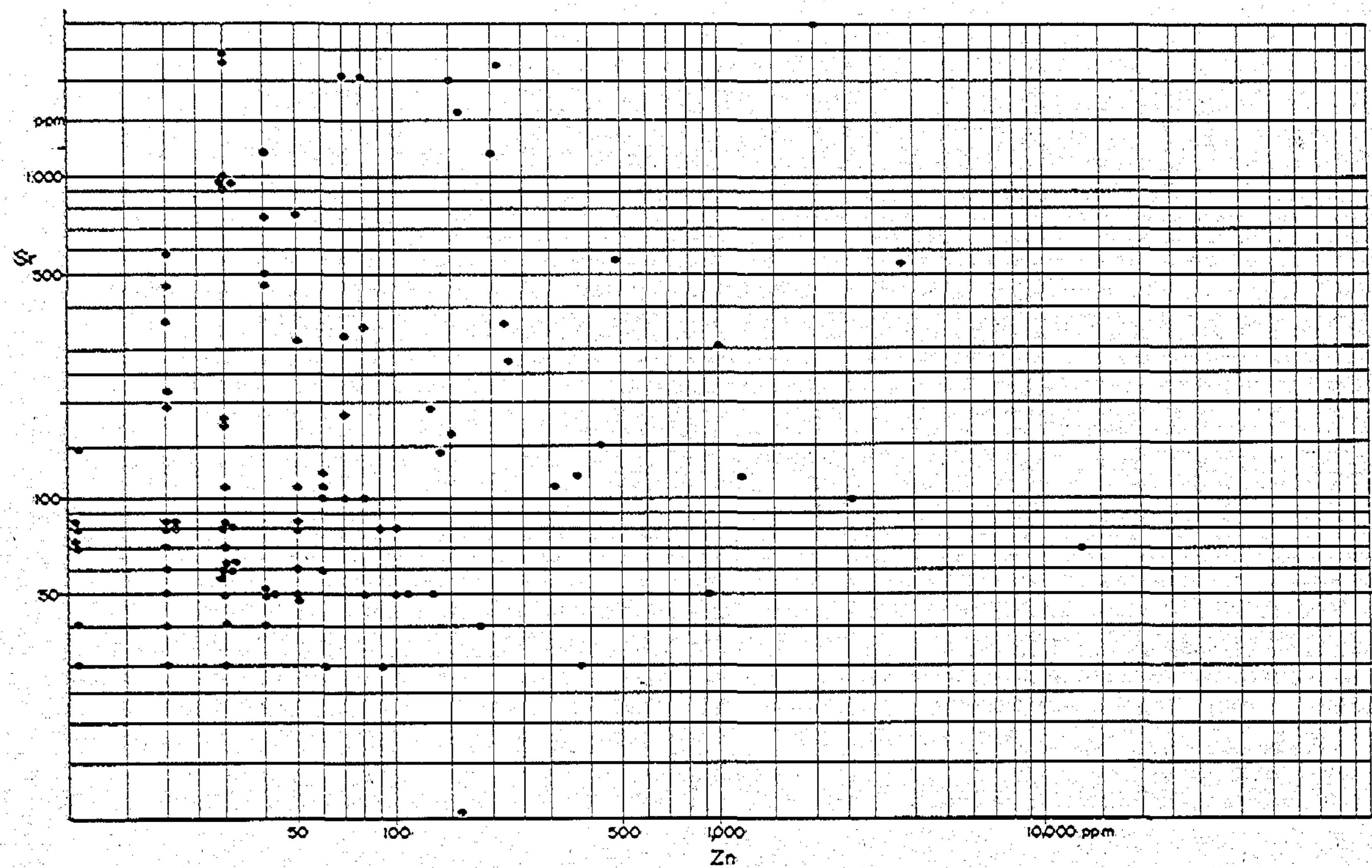


Fig. 17C Relation of Geochemical Values between Sr and Zn Contents on Carbonate Rocks

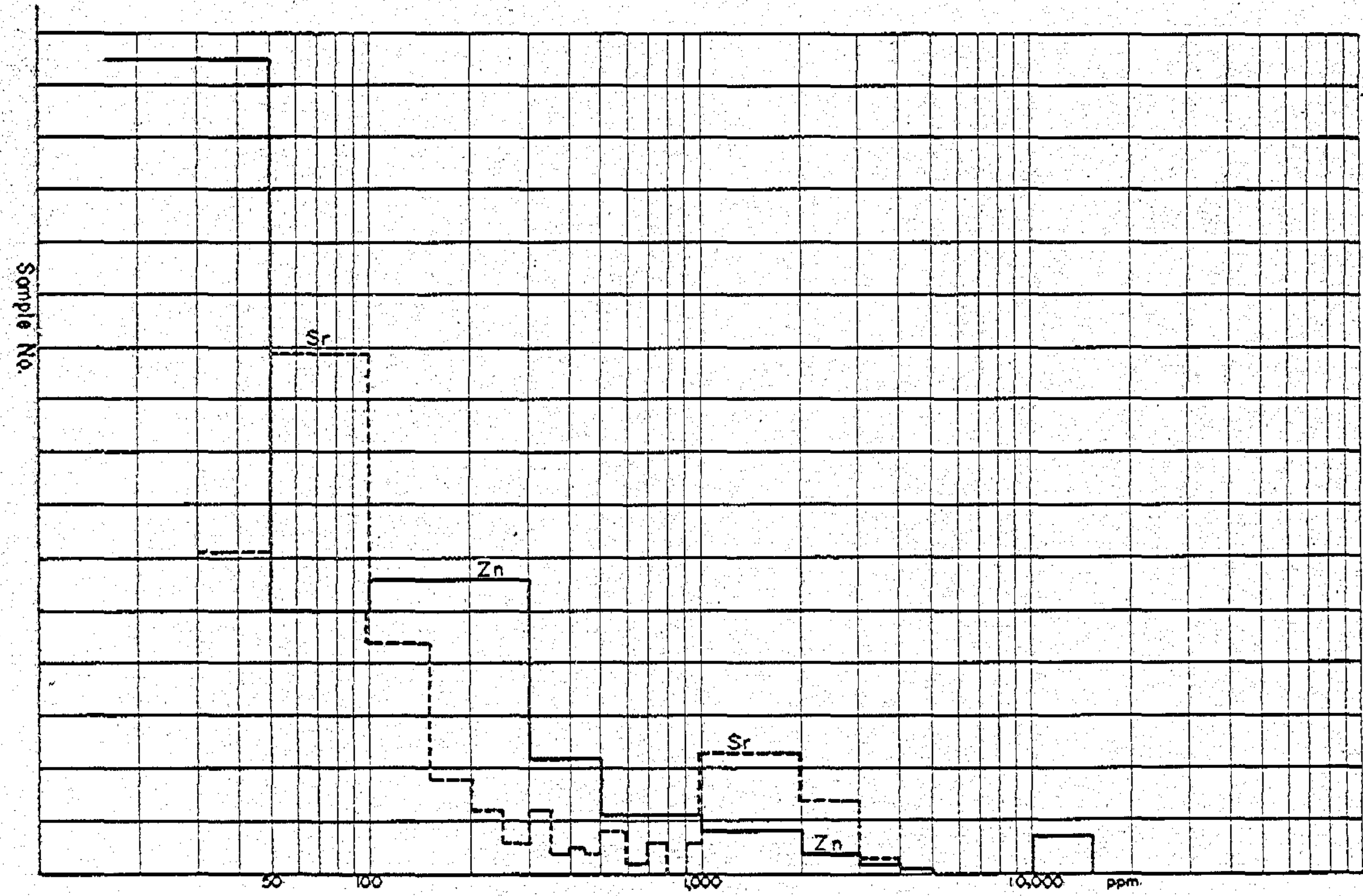


Fig. 17D Histogram of Zn and Sr Contents on Carbonate Rocks

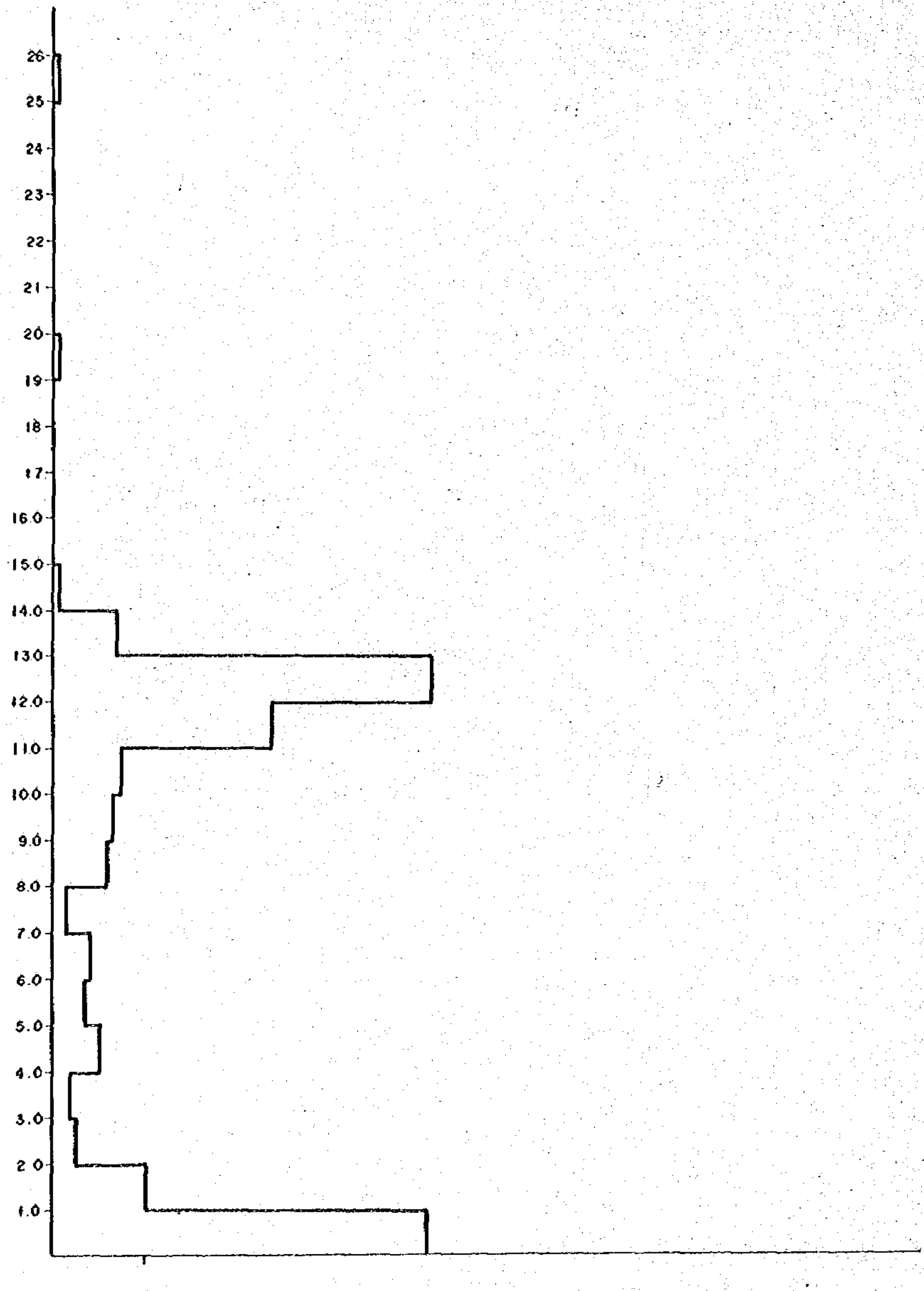


Fig 17E Histogram of Mg Contents on Carbonate Rocks minerals, the Mg content is adjusted to 11.7% and gets into the variation range above mentioned, by which the dolomite may be said more or less homogeneous.

(2) Other dolomites from II-bed to IV-bed contain a little less Mg than I-bed, and are heterogeneous, especially so in the north from Oxapampa.

(3) Both hanging and foot walls of the dolomites from I-bed to IV-bed are limestone which contains some parts containing 10%--12% of Mg.

On the other hand, microscopical observation, of which results are shown on Table 6, has revealed that micrite texture is dominant in the calcareous rocks and abundant fossils of organisms such as shell fragments, foraminifera, radiolaria, and algae are contained, and from some of the dolomites Mg of 10% ± have been detected by chemical analysis. Therefore, dolomite is considered to have been formed by metasomatic process between Mg component in sea water and Ca component in the sediments initially deposited as limestone of organic origin during the period of diagenesis till consolidation.

(4) Meanwhile, Sr shows maximum value of 3,200 ppm but cases less than 200 ppm occupies 68%, and similarly to Zn, majority tends to be gathered to lower side, while high values are dispersed. Mutual relation of the indicator elements of Mg, Sr, and Zn is shown in Figs. 17A, B, and C respectively, but any distinct correlation can not be found between Mg-Zn, Sr-Zn, and Mg-Sr each other. In this sense, Sr is not adequate as an indicator element in prospecting mineral indications.

2-4. Other Sedimentary Formations

(1) Mitu Group

It is distributed only in Pichita Caluga district in the surveyed area. It consists of red or reddish brown conglomerate and sandstone, which can be correlated to the lower formation of the Mitu Group. In this surveyed area, this Group is in contact with overlying Pucara Group by a fault in the east side, while in the west side, it underlies the Pucara Group unconformably.

(2) Sarayaquillo Formation

This is distributed a little in the south of Churumazu, and no distribution in the rest of surveyed area. Here it consists of reddish brown and medium grained sandsdone.

(3) Oriente Group

This Group in the surveyed area is distributed sparsely in Huancabamba district and around Quillazu and Churumazu of Oxapampa district.

It consists of white to grayish white and medium to coarse grained sandstone and is locally accompanied with thin layers of carbonaceous shale or grayish gray shale in its lower part.

No direct relation with the Pucara Group in the west could not be recognized, but around Huancabamba, the Sarayaquillo Formation is lacked and the Group is in direct cntact with the Pucara Group in unconformable relation, and it seems to be bordered by faults in the rest of localities.

During the May 1975 survey, a zone of abundant boulders of white and medium to fine grained sandstone was classified as the Oriente Group in the southwestern part of Oxapampa, but it was thought better to estimate the zone as a part of the Pucara Group from the point of stratigraphical relation of the Pucara Group and from the point of structural relation in this area. Consequently, this has been included into the Pucara Group in this report.

(4) Chonta Group

This formation is distributed in Huancabamba district and from around Tambo Maria towards Churumazu in Oxapampa district, occupying the west side of the Pucara Group. It consists of an alternation of red to reddish brown shale and sandstone, and its overlying limestone which is dark gray to grayish white and compact. It is in conformable relation with the Oriente Group regionally, but it seems to be in unconformable relation around Huancabamba, and is in contact with the underlying formation by faults in the rest of the area.

(4) Merced Formation

This is distributed from about Tambo Maria towards the west of Churumazu, being in contact with the Chonta Group by a fault. It consists of ill-sorted conglomerate containing the pebbles of medium to large sizes of various kinds of rocks such as granitic rocks, sedimentary rocks, etc.

2-5. Geological Structure

To speak regionally, the principal geological structures such as foldings and faults in the surveyed area generally show the direction of NNW-SSE, and as it has been stated already, the structures have been controlled by the orogenies took place for several times since Paleozoic Era till Cenozoic Era.

As for the Pucara Group which occupies most of the area, synclinorium structures are dominant, and anticlinal structures are developed in its eastern side in some parts of the area.

Axes of these foldings are all show the direction of NNW-SEE, except near Oxapampa where they show a direction of N-S, and fundamental structure continues towards north outside the surveyed area. Plunges of folding axes are generally horizontal or gently inclined to the north, by which the upper formations of the Pucara Group are exposed in the north of the surveyed area.

A fault which passes the eastern end of the area is most remarkable (Tingo Maria-Merced line) among the faulting structures, showing the movement of subsidence in its eastern side and upheaval in its western side. Moreover, it is accompanied with the faults in the directions of NWW-SEE and NEE-SWW, having resulted in the formation of blocked structure in this area.

Regionally speaking, faults in the direction of NNW-SEE are controlling the distribution of the Pucara Group and the younger sediments, while the other two kinds of faults tend to cause the subsidence of northern side, by which the tendency is stressed for the upper part of the Pucara Group in the north from Oxapampa to be more exposed.

Igneous rocks by the activities from Paleozoic to Cenozoic Eras are recognized in the western part of the surveyed area, and they are considered to have been controlled by the fractures in the direction of NNW-SSE which had caused the Paleozoic igneous activity. On the other hand, Cenozoic monzonite are intruded along the faults of NNW-SSE in the eastern side, and they are, as mentioned before, to be specially mentioned about its lithology and locations of intrusion.

Chapter 3 Geochemical Survey

3-1. Purpose and Procedure

This survey was practiced on soils and carbonate rocks along with geological survey in the area of detailed survey, for the purpose to extract the most promising area in emplacement of metallic ore deposits through obtaining informations regarding to the elements of heavy metals.

Soil samples were collected from the B_1 bed of sampling stations on survey routs, and the carbonate rocks were collected from its exposures. Numbers of samples collected amounted to 1,840 in soils and 193 in the carbonate rocks, of which total amounted to 2,033, and they were so collected as to amount about 10 samples for one square kilometer. Among the collected samples, soils (about 1 kg for 1 sample) were dried under open air and the carbonate rocks (about 200 gr. for 1 sample) were crushed, and then both were classified with 80 mesh sieve, of which undersizes were so prepared as to be reduced into 10 gr of assay samples by repeating quartering.

The prepared assay samples were analysed in Japan by atomic absorption method on 3 indicator elements of Cu, Pb, and Zn which were considered useful in prospecting ore deposits in this area. Flow sheets of chemical analysis on the 3 elements are shown on Table 14 and the assay results are on Table 15.

3-2. Data Analysis

In the present geochemical survey, two kinds of geochemical samples were collected, the one from soils and the other from the exposed carbonate rocks, and geochemical data of them were treated statistically on each kind of the samples.

Table 2B. Statistical Analysis of Geochemical Samples(Cu, Pb, Zn) in the Detailed Survey Area

Soils (Numbers of treated samples : 1,840)

	Cu-log (ppm)	Pb-log (ppm)	Zn-log (ppm)
Maximum	2.978 (950)	3.778 (6,000)	4.647 (44,370)
Minimum	0.0 (1)	0.477 (3)	0.301 (2)
Average (M)	0.974 (9)	1.509 (32)	1.994 (99)
Standard Deviation(σ)	0.4219	0.5645	0.6672

Soils of Pucara dolomite (Numbers of treated samples : 185)

	Cu-log (ppm)	Pb-log (ppm)	Zn-log (ppm)
Maximum	2.210 (162)	3.778 (6,000)	4.243 (17,500)
Minimum	0.0 (1)	0.699 (5)	0.301 (2)
Average (M)	1.043 (11)	1.915 (82)	2.343 (220)
Standard Deviation(σ)	0.3797	0.6253	0.7469

Soils of Pucara Limestone (Numbers of treated samples : 798)

	Cu-log (ppm)	Pb-log (ppm)	Zn-log (ppm)
Maximum	2.978 (950)	3.720 (5,250)	4.647 (44,370)
Minimum	0.0 (1)	0.477 (3)	0.301 (2)
Average (M)	1.002 (10)	1.616 (41)	2.184 (153)
Standard Deviation(σ)	0.4157	0.5688	0.6467

Carbonate Rocks (Numbers of treated Samples : 193)

	Cu-log	(ppm)	Pb-log	(ppm)	Zn-log	(ppm)
Maximum	3.445	2,785	3.273	1,873	3.743	5,528
Minimum	1.000	10	1.079	12	1.813	65
Average (M)	1.563	37	2.084	121	2.517	329
Standard Deviation (σ)	0.3421		0.2969		0.3593	

Pucara dolomite (Numbers of treated Samples : 113)

	Cu-log	(ppm)	Pb-log	(ppm)	Zn-log	(ppm)
Maximum	2.338	218	2.829	675	3.364	2,311
Minimum	1.000	10	1.398	25	1.813	65
Average (M)	1.508	32	2.044	111	2.449	281
Standard Deviation (σ)	0.2869		0.2548		0.3130	

Pucara Limestone (Numbers of treated Samples : 75)

	Cu-log	(ppm)	Pb-log	(ppm)	Zn-log	(ppm)
Maximum	3.445	2,785	3.273	(1,873)	3.748	5,528
Minimum	1.041	11	1.716	(52)	1.954	90
Average (M)	1.649	45	2.158	(144)	2.623	420
Standard Deviation (σ)	0.4030		0.3259		0.4036	

Table 3B. Numbers of Anomalous Samples on Soils Classified by Each Formation and Lithology in the Detailed Survey Area

	PDO	PLS	PSS	QU	ME	CH	OR	MI	TV	TM	MP	CG	MD	TOTAL
(ppm)														
0 - 25	153	671	126	118	27	158	98	30	11	1	74	82	8	1557
26 - 40	21	79	18	19	2	7	3	9	0	3	4	5	7	177
41 - 66	6	30	2	9	0	1	1	6	0	0	1	3	5	64
67 - 107	3	9	2	0	1	0	1	3	0	0	0	0	5	24
108 - 174	2	5	1	0	0	0	0	3	0	1	0	0	1	13
175 over	0	4	0	0	0	1	0	0	0	0	0	0	0	5
TOTAL	185	798	149	146	30	167	103	51	11	5	79	90	26	1840
Pb (ppm)														
0 - 118	122	644	132	138	30	161	102	44	9	5	63	87	24	1561
119 - 227	15	65	9	7	0	4	1	6	0	0	5	1	2	115
228 - 434	23	42	5	1	0	2	0	1	2	0	9	2	0	87
435 - 831	11	26	2	0	0	0	0	0	0	0	2	0	0	41
832 - 1592	10	10	1	0	0	0	0	0	0	0	0	0	0	21
1593 over	4	11	0	0	0	0	0	0	0	0	0	0	0	15
TOTAL	185	798	149	146	30	167	103	51	11	5	79	90	26	1840
Zn (ppm)														
0 - 458	118	632	138	137	30	159	102	50	9	5	71	88	24	1563
459 - 988	30	86	2	7	0	6	1	1	1	0	3	2	1	140
989 - 2130	13	48	6	2	0	2	0	0	0	0	5	0	1	77
2131 - 4592	19	18	3	0	0	0	0	0	1	0	0	0	0	41
4593 - 9899	3	8	0	0	0	0	0	0	0	0	0	0	0	11
9900 over	2	6	0	0	0	0	0	0	0	0	0	0	0	8
TOTAL	185	798	149	146	30	167	103	51	11	5	79	90	26	1840

Geological Index

Sedimentary rocks

PDO: Pucara Group – Dolomite
PLS: Pucara Group – Limestone
PSS: Pucara Group – Sandstone
QU : Quarternary (gravel & sand)

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

Igneous rocks

TV: Tertiary – Volcanic Breccia
TM: Tertiary – Monzonite porphyry
MP: Tertiary – Quartz - porpyry & Granite - porphyry
Cretaceous

CG: Cretaceous Granite
MD: Jurassic Diorite complex

(1) Soils

Results of data analysis have been shown on Tables 2B and 3B, and histograms and cumulative frecuency diagrams of Fig. 8A, which were made on the entire soil samples and on those samples collected from the spots where dolomite and limestone among the Pucara Group are distributed.

According to these data, dispersion patterns of Cu assay values generally show the logarithmic normal distribution, while those of Pb show a slightly curved patterns by which is perceived a tendency of high value excess type, but appear approximate to logarithmic normal distribution. Although Zn is also high value excess type, its curve is rather gentle and zig-zag type with many folds to positive and negative sides, and such may be said to show the distribution approximate to logarithmic normal distribution. Therefore, threshold values for anomalous values are obtained from the calculated values in Table 2B.

Mean values (M), threshold values of weak anomalies ($t' = M + 1\sigma$), and those of strong anomalies ($t = M + 2\sigma$) of the 3 elements will be obtained from Table 2B as shown below.

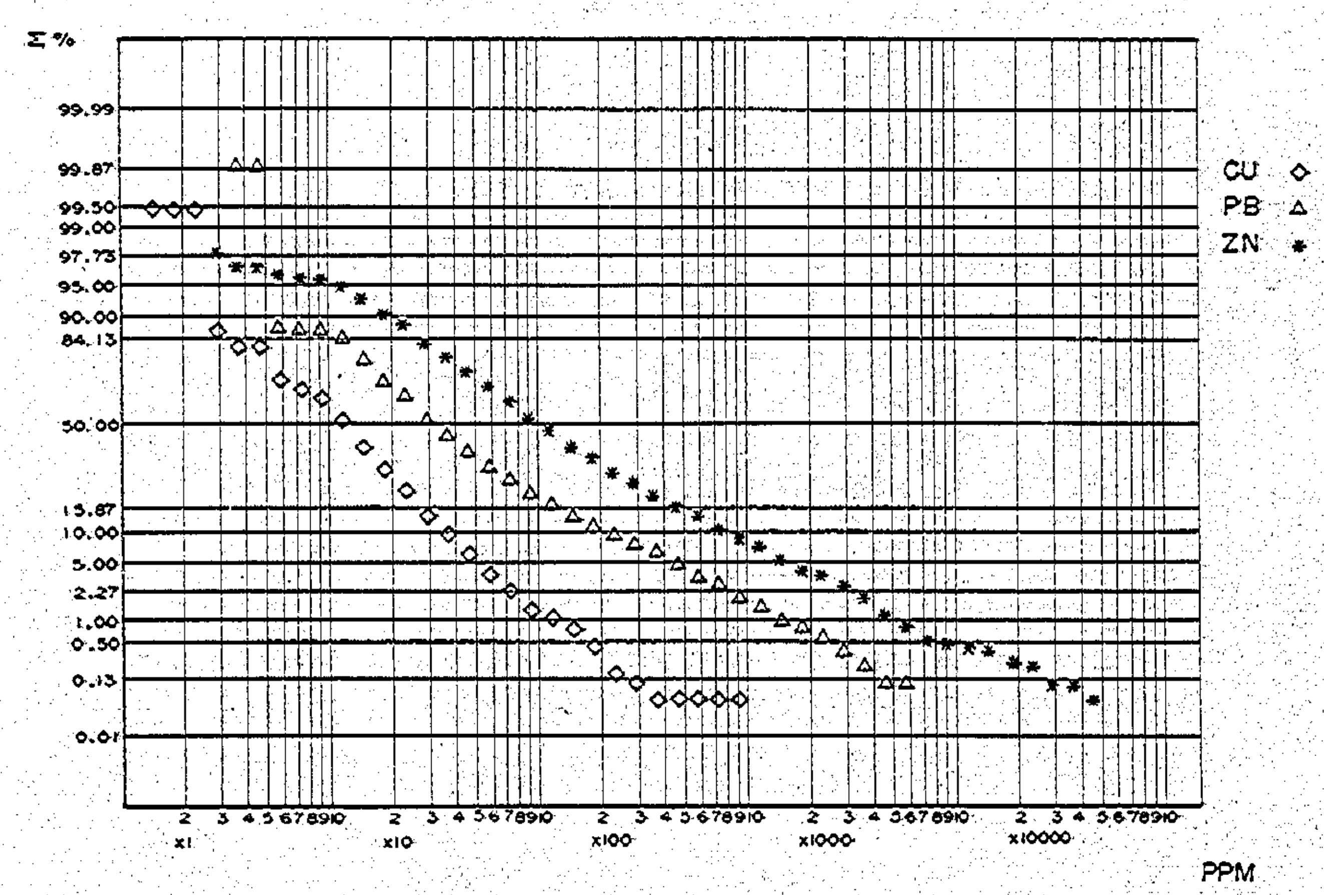
Entire Soils

	Cu ppm	Pb ppm	Zn ppm
Background (M)	9	32	99
Threshold of weak anomaly (t')	25	118	458
" of strong anomaly (t)	66	435	2,130

Soils from Pucara dolomite

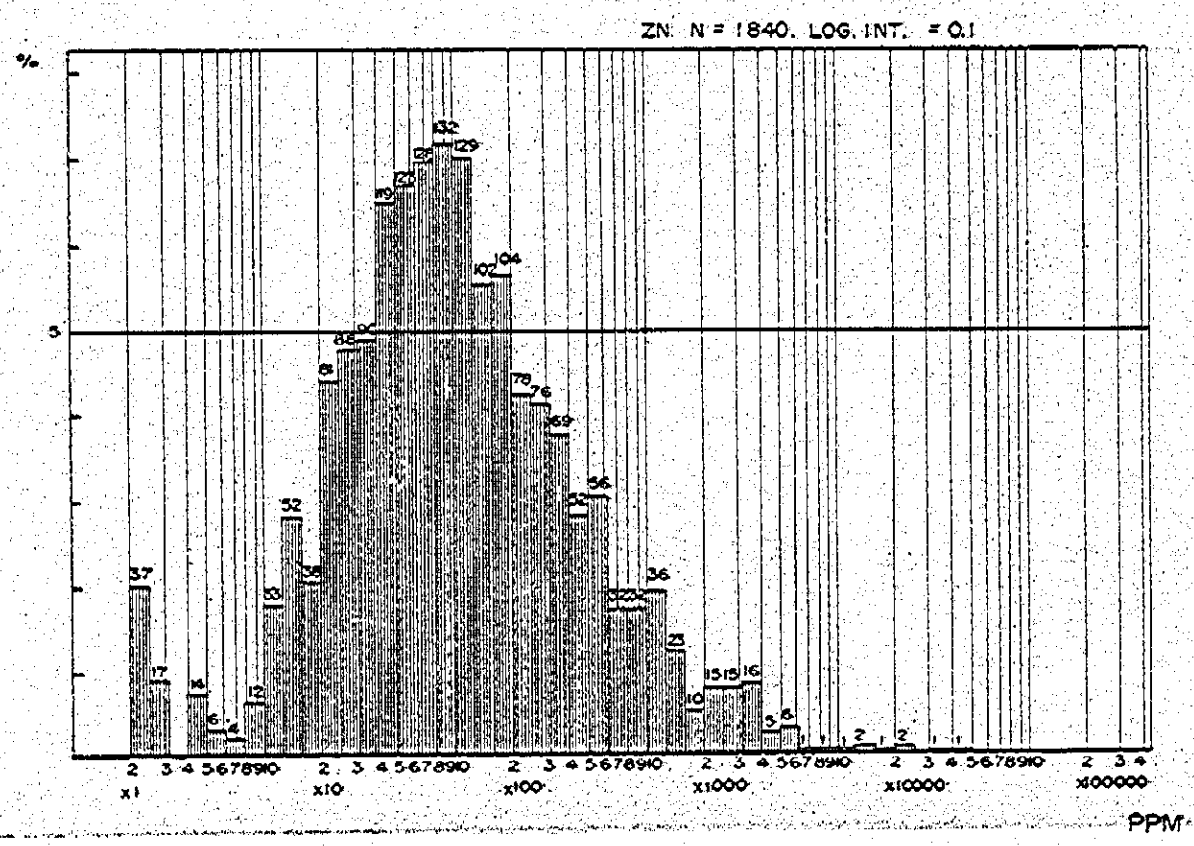
	Cu ppm	Pb ppm	Zn ppm
Background (M)	11	82	220
Threshold of weak anomaly (t')	26	344	1,330
" of strong anomaly (t)	63	1,464	6,866

CUMULATIVE FREQUENCY DISTRIBUTION FOR CU. PB AND ZN (Soils)



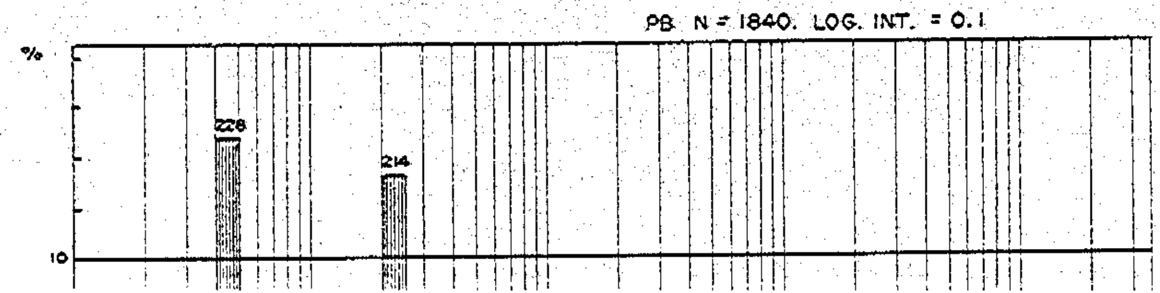
HISTOGRAM FOR ZN

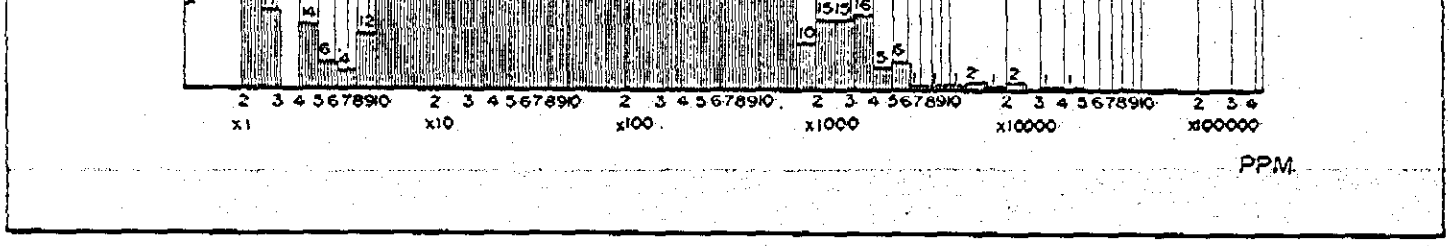
ZN N = 1840. LOG. INT. = 0.1

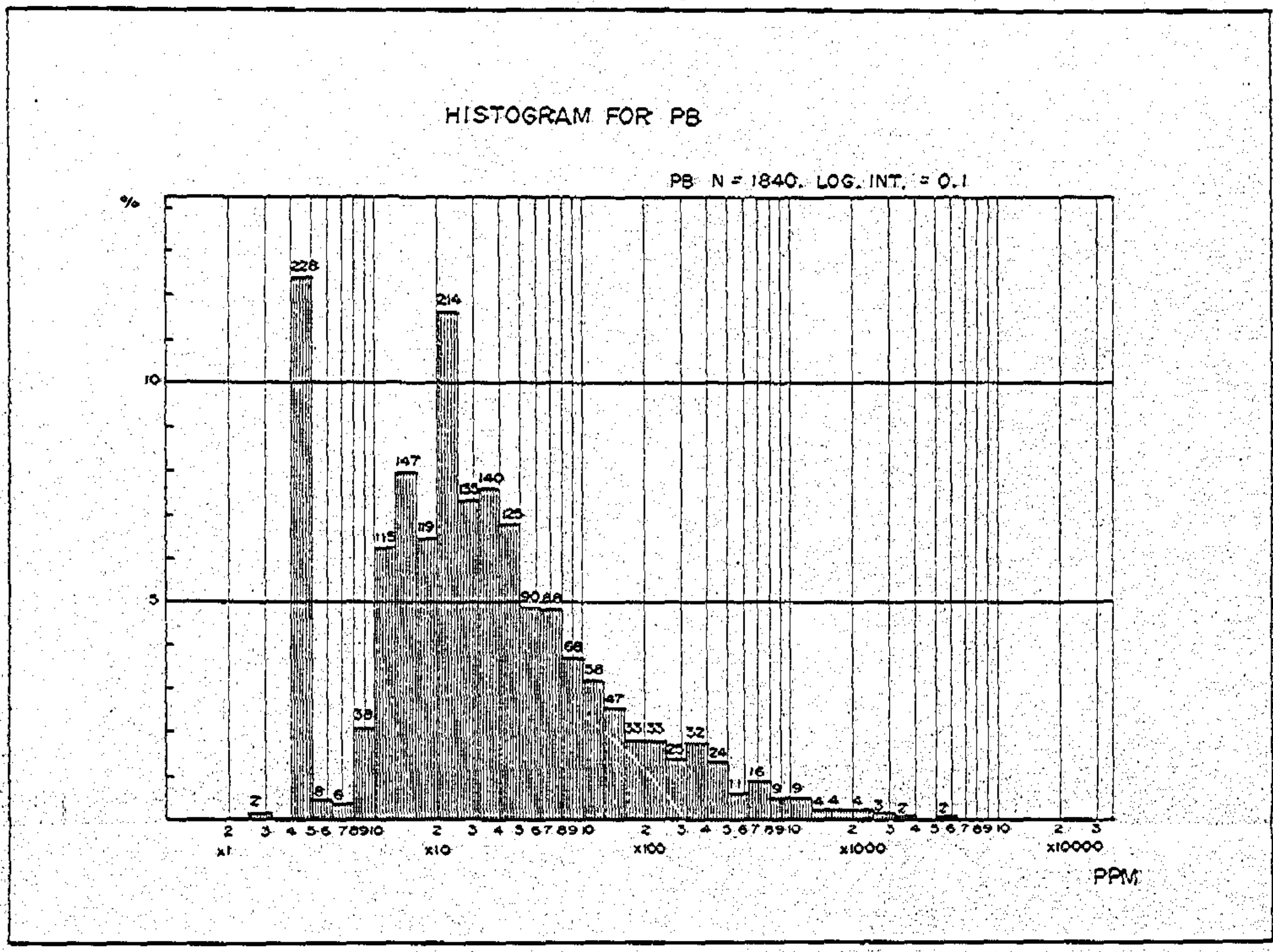


HISTOGRAM FOR PB

PB N = 1840. LOG. INT. = 0.1







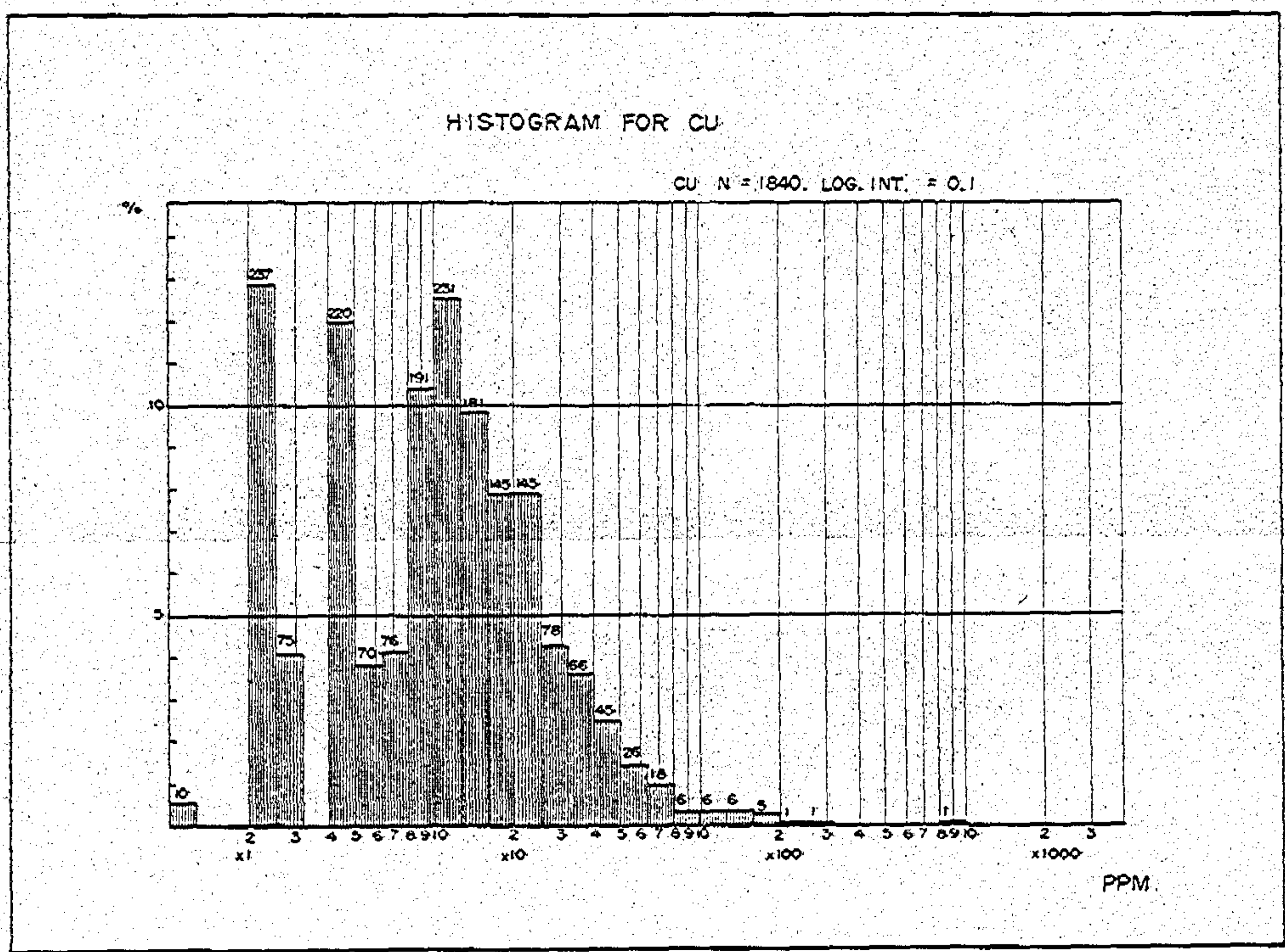
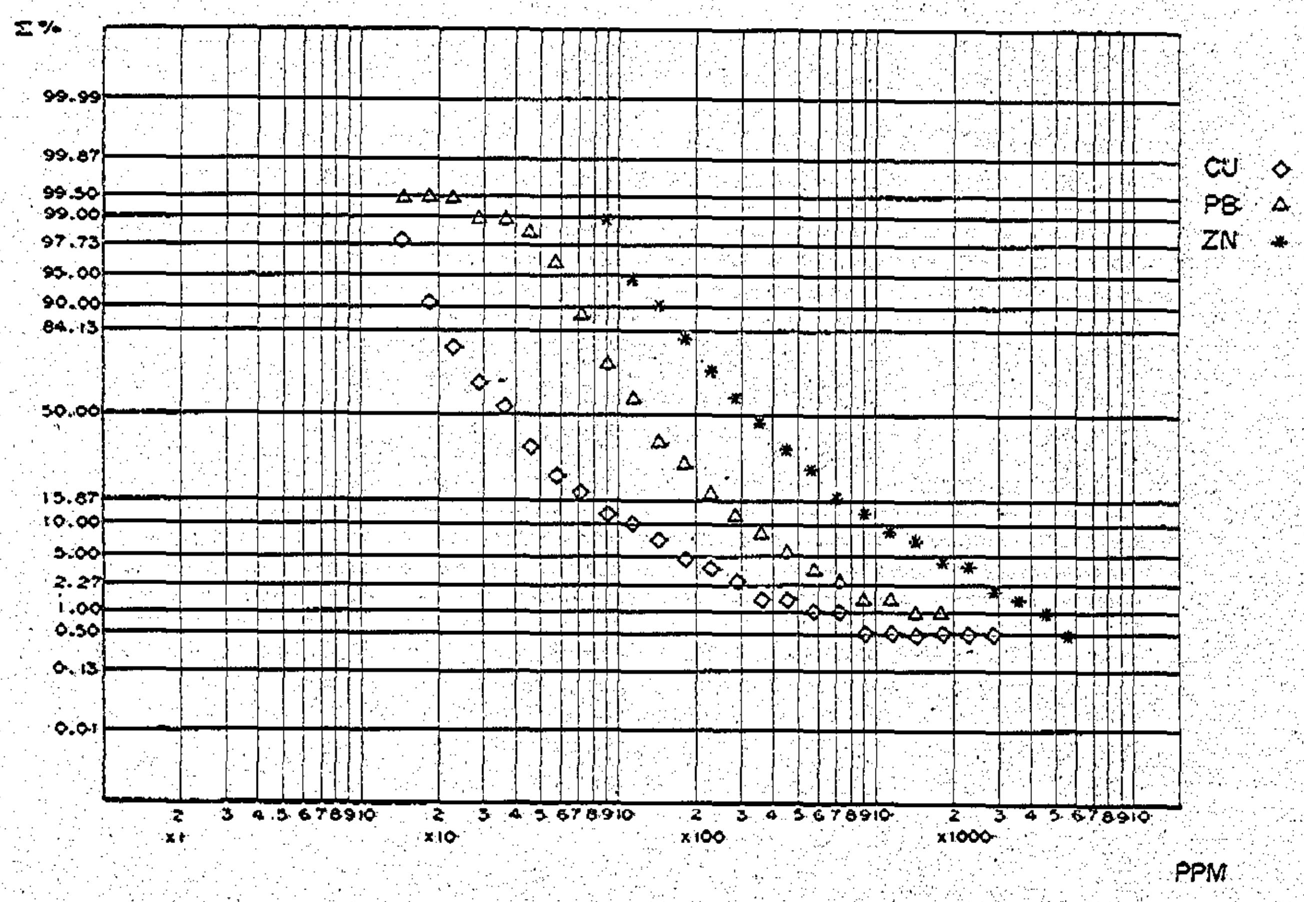
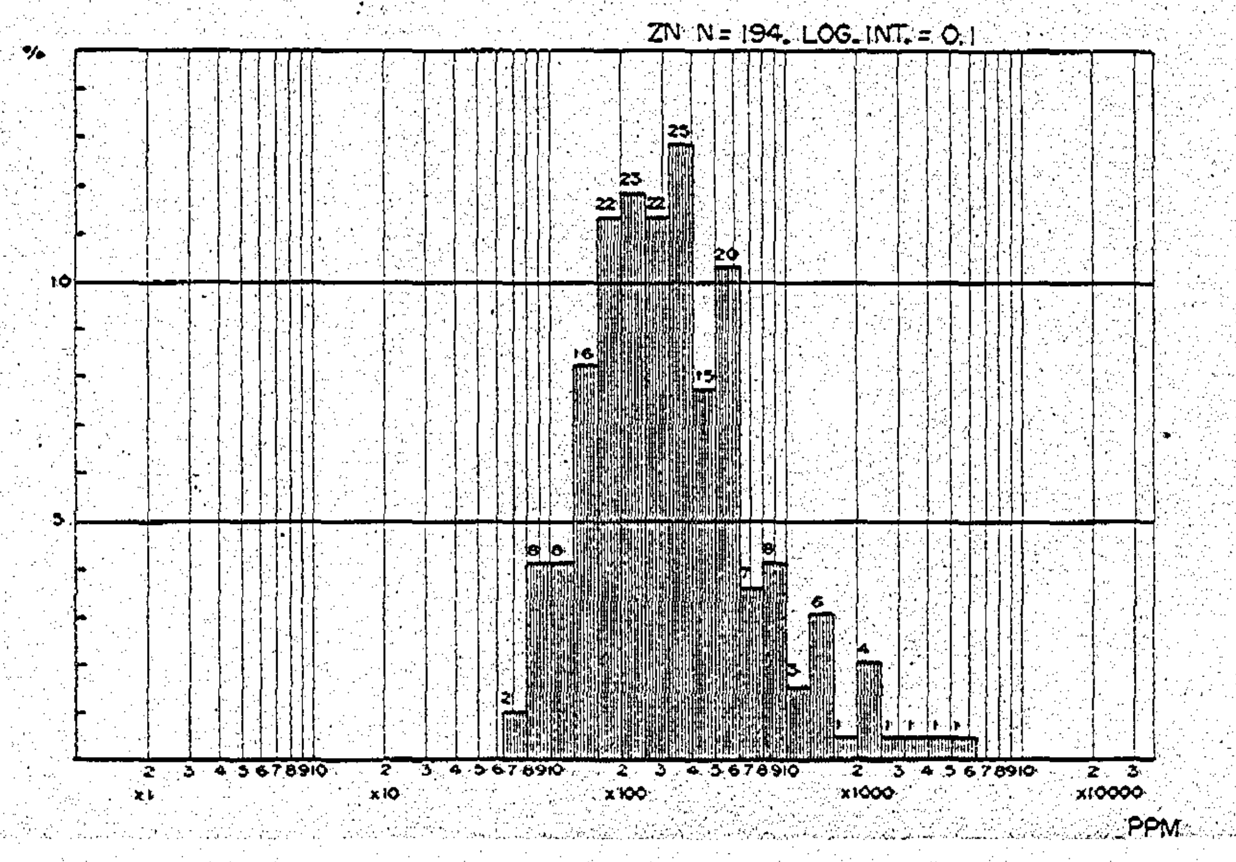


Fig. 8A. Cumulative Frequency Diagram and Histogram for Cu, Pb and Zn on Soils in the Detailed Survey Area

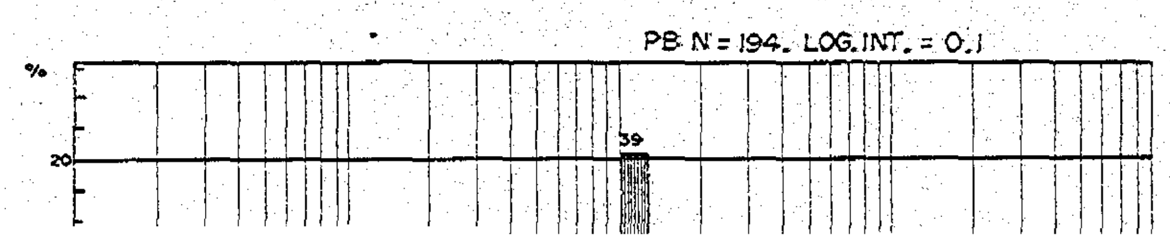
CUMULATIVE FREQUENCY DISTRIBUTION FOR CU. PB AND ZN (Carbonate Rocks)

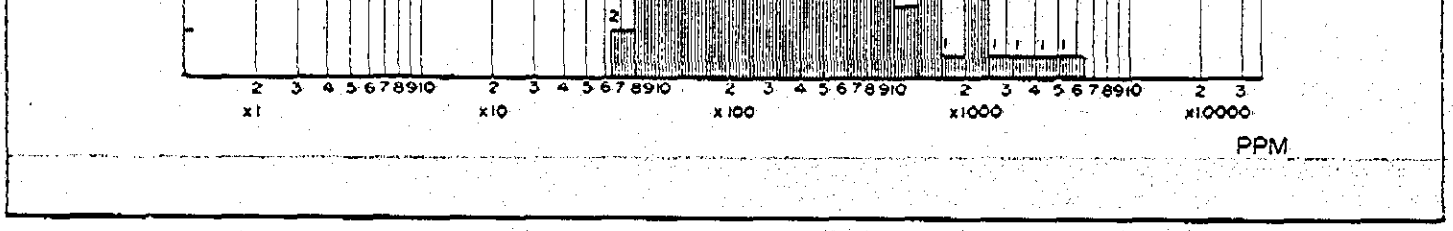


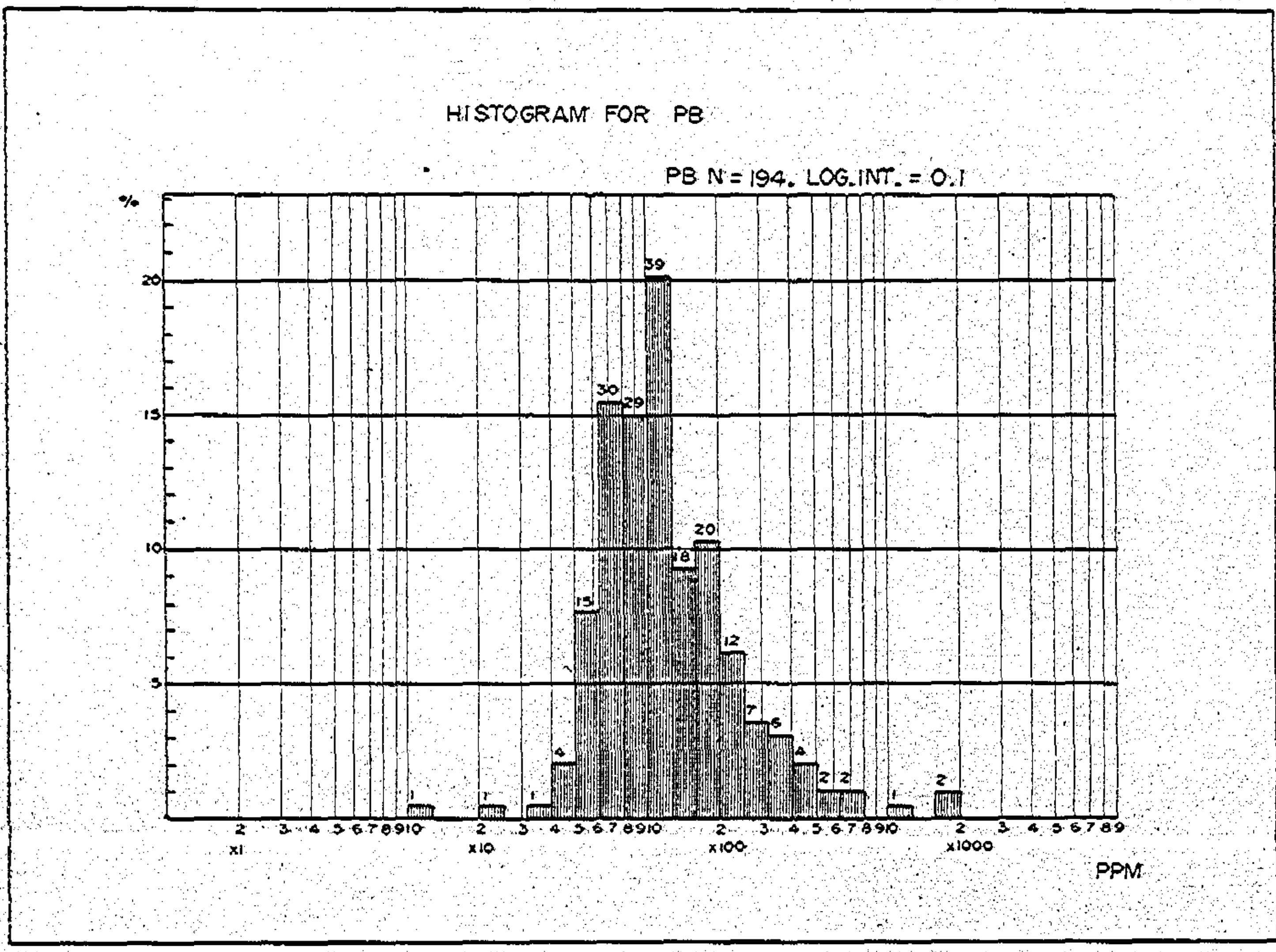
HISTOGRAM FOR ZN



HISTOGRAM FOR PB







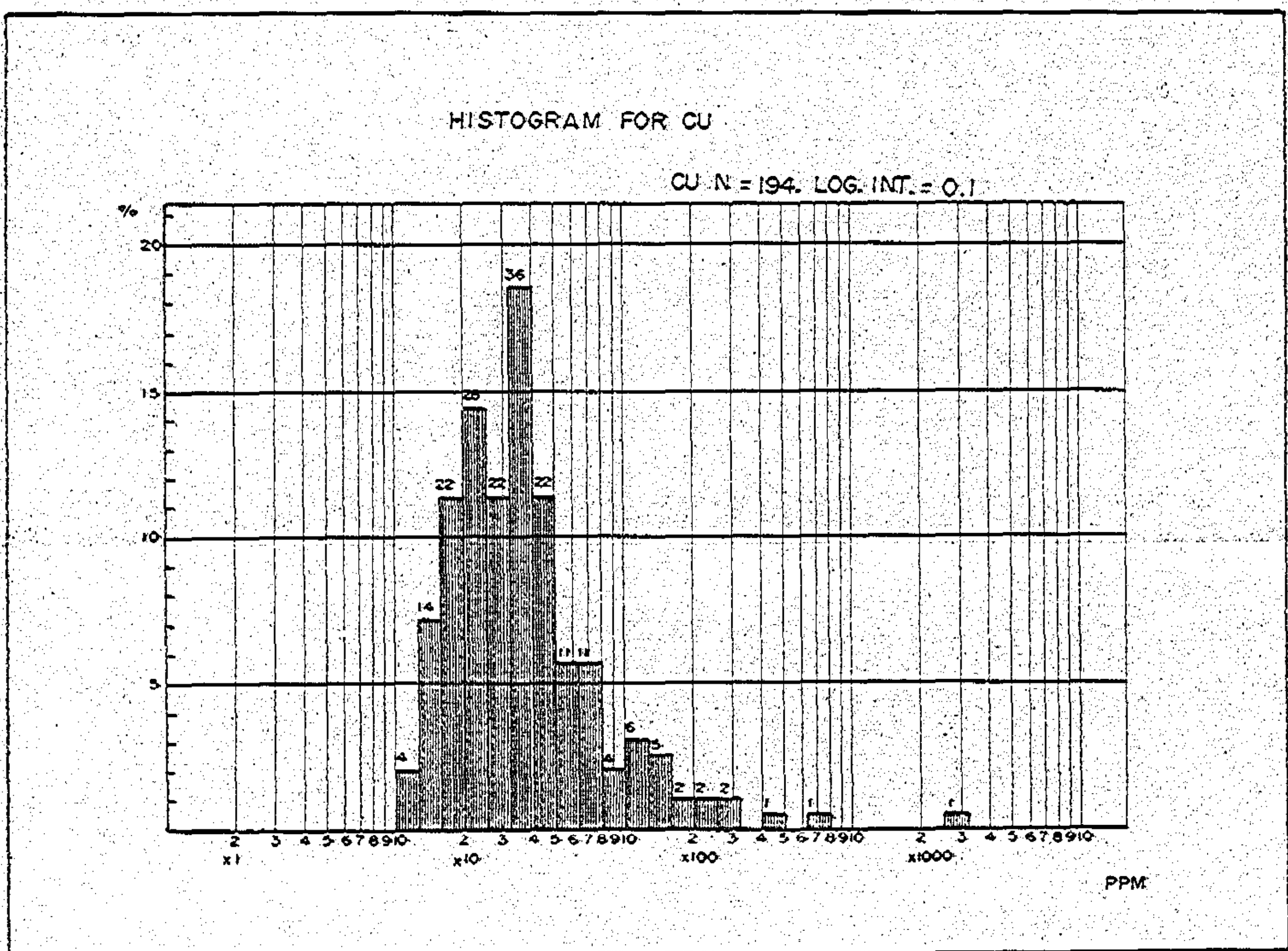


Fig. 8B Cumulative Frequency Diagram and Histogram for Cu, Pb and Zn on Carbonate Rocks in the Detailed Survey Area

Soils from Pucara limestone	Cu ppm	Pb ppm	Zn ppm
Background (M)	10	41	153
Threshold of weak anomaly (t')	26	153	677
" of strong anomaly (t)	68	567	2,802

Extraction of anomalous values were based upon the above tabulation and following values were adopted.

	Cu ppm	Pb ppm	Zn ppm
Threshold of weak anomaly (t')	30	120	400
" of strong anomaly (t)	70	450	2,000
" of special strong anomaly (2t)	140	900	4,000
Supplementary threshold (t")	-	-	1,000

The treshold of weak anomaly of Zn, 400 ppm, corresponds to that of strong anomaly adopted in the reconnaissances made in 1975 and 1976. The difference of threshold values between the reconnaissances and present detailed geological survey has been caused by the difference of sampled objects.

Supplementary thresholdod was prepared for Zn, which was 1,000 ppm' corresponding to $M + 1.5\sigma$.

For reference, distribution of anomalous values by geological formations and by rock facies are shown on Table 3B.

(2) Carbonate Rocks

Similarly to the soils, results of data analysis have been shown on Table 2B and Fig. 8B Tendencies of high value excess type are recognized on Cu and Pb especially in the Pucara limestone. Zn also shows high value excess type but is approximate to logarithmic normal distribution. Therefore, threshold values on the carbonate rocks were obtained from the cumulative frequecy diagrams.

Mean values, (M) and threshold values of weak and strong anomalies

Table 4. Geochemical Anomalous Areas by Soil Samples in the Detailed Survey Ares

Name	Cu				Pb					Zn					Remarks
	Classification	Area km2	Number of Anomalous Samples		Classification	Area km2	Number of Anomalous Samples			Classification	Area km2	Number of Anomalous Samples			
			> t	> 2t			> t'	> t	> 2t			> t'	> t	> 2t	
Huaocabamba	-	-	-	-	M	0.5	10	2	2	M	0.5	8	4	1	Dolomite IV.
Quillazu	-	-	-	-	S	0.8	10	5	2	M	0.9	11	3	-	Dolomite III.
Oxapampa - A	VW	0.2	1	1	S	1.6	31	10	5	M	0.8	18	9	-	Dolomite II, III.
" - B	VW	0.1	1	-	S	1.6	27	11	6	S	1.5	10	7	4	Between Dolomite II, III and quartz porphyry
" - C	-	-	-	-	S	1.4	26	12	8	S	1.4	22	12	8	Dolomite II
" - D	-	-	-	-	M	0.9	15	4	1	M	1.3	21	4	1	Dolomite IV
" - E	-	-	-	-	W	0.9	12	1	-	M	2.5	21	3	-	"
Pumaguno - A	-	-	-	-	S	2.6	23	7	4	M	0.5	15	5	1	Dolomite I, II and III.
" - B	-	-	-	-	M	0.4	4	2	1	W	0.2	3	2	1	Dolomite I
Churmazu	M	1.0	5	2	-	-	-	-	-	W	0.1	3	-	-	Along the mineralized fissure in Pucara Group
Pichita Caluga	M	1.5	8	6	M	1.1	17	4	1	W	0.4	12	1	1	"

S: STRONG ANOMALY
M: MODERATE ANOMALY
W: WEAK ANOMALY
VW: VERY WEAK ANOMALY

(M + 1σ and M + 2σ) were obtained from calculation table as described below.

Entire carbonate rocks

	Cu ppm	Pb ppm	Zn ppm
Background (M)	37	121	329
Threshold of weak anomaly (t')	80	240	752
" of stron anomaly (t)	177	476	1,720
Pucara dolomite			
Background (M)	32	111	281
Threshold of weak anomaly (t')	62	199	578
" of strong anomaly (t)	121	358	1,186
Pucara limestone			
Background (M)	45	144	420
Threshold of weak anomaly (t')	113	305	1,063
" of strong anomaly (t)	285	645	2,693

Extraction of anomalous values was based upon the above tabulation and following values were adopted.

	Cu ppm	Pb ppm	Zn ppm
Threshold of weak anomaly (t')	80	240	700
" of strong anomaly (t)	180	500	1,700
" of special strong anomaly (2t)	360	1,000	3,400

3-3. Geochemically Anomalous Areas

Geochemically anomalous areas were extracted by the threshold values of soil samples as stated before, and have been shown in PL. II-4,5,6, & 7, and Table 4. Weights in extracting the anomalous areas were laid out as follows according to the numbers of spots contained in each of the anomalous areas.

For Pb & Zn

	t	t'	2t
Strong anomalous area	10	5	2
Medium anomalous area	5	2	-
Weak anomalous area	3	-	-

For Cu

	t	t'	2t
Strong anomalous area	-	10	5
Medium anomalous area	-	5	2
Weak anomalous area	-	3	

In the case of Cu, however, as threshold value of weak anomaly (t'), 30 ppm, is inferior to that of (t) 70 ppm in the reconnaissance, extraction was made for those above the threshold (t) of strong anomaly.

3-4. Discussion of Results

(1) Majority of Cu anomalies by soil samples are assembled by these samples showing high values in the Pucara Group, and in other formations, slightly high values are recognized in the Mitu Group and Jarassic diorites (Table 3B).

Their distribution is seen always in the surroundings of Cu mineralization and gossans by mineralization. In the north of Pichita Caluga district, Cu mineralization of 20 cm wide is recognized along a fault in the Mitu and Pucara Groups, and boulders of vein typed Pb-Zn mineralization accompanying with Cu are found in its surroundings. And around Churumazu too, boulders of hematite stained are recognized in the surroundings of a fault in a direction of NNW-SSE. Therefore, high valued samples are considered to indicate an evidence of hydrothermal mineralization in this district. As mentioned before, around Tambo Maria, Tertiary monzonite is intruded into the Pucara Group and has given skarnization to the Group as well as the monzonite itself is accompanied with Cu, and high valued samples are recognized in and around this intrusive body. In the areas where Cu mineralization could not be found directly, slightly high values were recognized together with anomalies of Pb and Zn in the northwestern part where dolomite is distributed.

(2) As to the Pb and Zn anomalies, it has been made clear that high values are very many in the Pucara Group, and next to it, relatively high values are in the Cretaceous to Tertiary porphyries such as granite porphyry and quartz porphyry.

Compared with the results of geological survey, most of anomalies in the Pucara Group are omnipresent in the west side of the surveyed area, forming a relatively elongated distribution along the strike of dolomite in the north from Oxapampa, and in the south from Oxapampa the anomalous area composed of aggregated small anomalies are also distributed in the dolomite formations. Moreover, these anomalous areas are included in a zone within 2 km laterally away from igneous masses in their west side.

On the other hand, in the Zn indication discovered in Tambo Maria, most of the samples showed lower values than the threshold obtained through the data analysis on the present geochemical samples. This may be infered to very meager solubility of the metallic minerals in case outcrop is directly exposed, especially in case of less accompaniment with pyrite like the Tambo Maria indication, it may be infered to much more meager solubility. Or else, it may be infered to relatively steeper topography here which might not have allowed for the dissolved Zn to have been concentrated, on the contrary to more or less flat topography in the highly anomalous zone in the west part. Such can be said about the district of the San Vicente Mine, where the outcrops of ore deposits are contained and topography is steeper, being evidenced by the fact that in spite of a sample showing the maximum value of Zn of 1,322 ppm, average of the rest of 13 samples is only 89 ppm, if the area is limited over the ore deposits under operation.

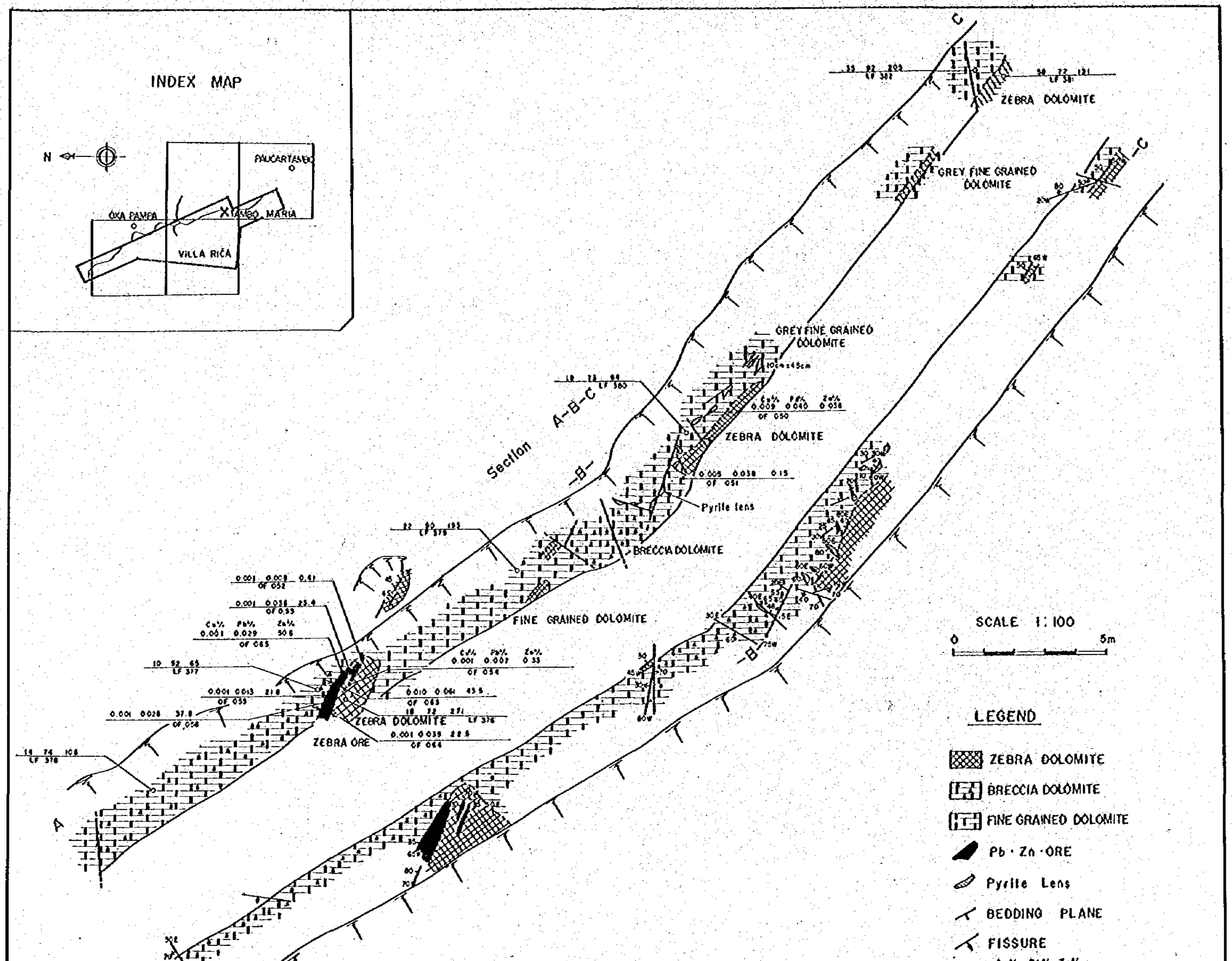


Fig.9. Geological Sketch of Mineral Indications (Pb, Zn) of the Tambo Maria District

Chapter 4 Mineralization in the Pucara Group

Types of mineralization in the surveyed area are (1) bedded type and (2) dissemination type both in the Pucara Group, as well as (3) porphyry copper type by Tertiary monzonite and (4) vein type mineralization in several localities. As the last type (4) has already been summarized in the Part I of this report, remarks will be made here about the rest 3 types (1), (2), and (3), by omitting (4).

4-1. Mineralization of Bedded Type in the Pucara Group

Mineralization of bedded type in dolomite layers was assured around Tambo Maria in the south of Oxapampa during the May 1976 survey, for which detailed survey was carried out in an area including it during the August 1976 survey (Fig. 9).

The bedded zinc ore around Tambo Maria was found to occur around the border of banded structure and breccia structure developed in fine grained dolomite and was also found to be concentrated rather in the side of banded dolomite with a dimension of 25--35 cm in width and about 2 m in length. The banded dolomite, which is otherwise called zebra dolomite, is crystalline dolomite with stripes of white and gray or dark gray. This zebra dolomite is not developed uniformly in the fine grained dolomite around this locality but locally developed spottily, which is sometimes elongated lenticularly, but it is developed massive in this place of mineral indication. Sphalerite is light brown, relatively coarse grained (2--3 mm), and concentrated in the side of white dolomite in the stripes of white dolomite and gray dolomite. Average assay of the ore zone (average width, 30 cm) runs 0.005 % Cu, 0.048 % Pb, and 32.1 % Zn.

And in the spot about 15 km away to the south from the Zn indica-

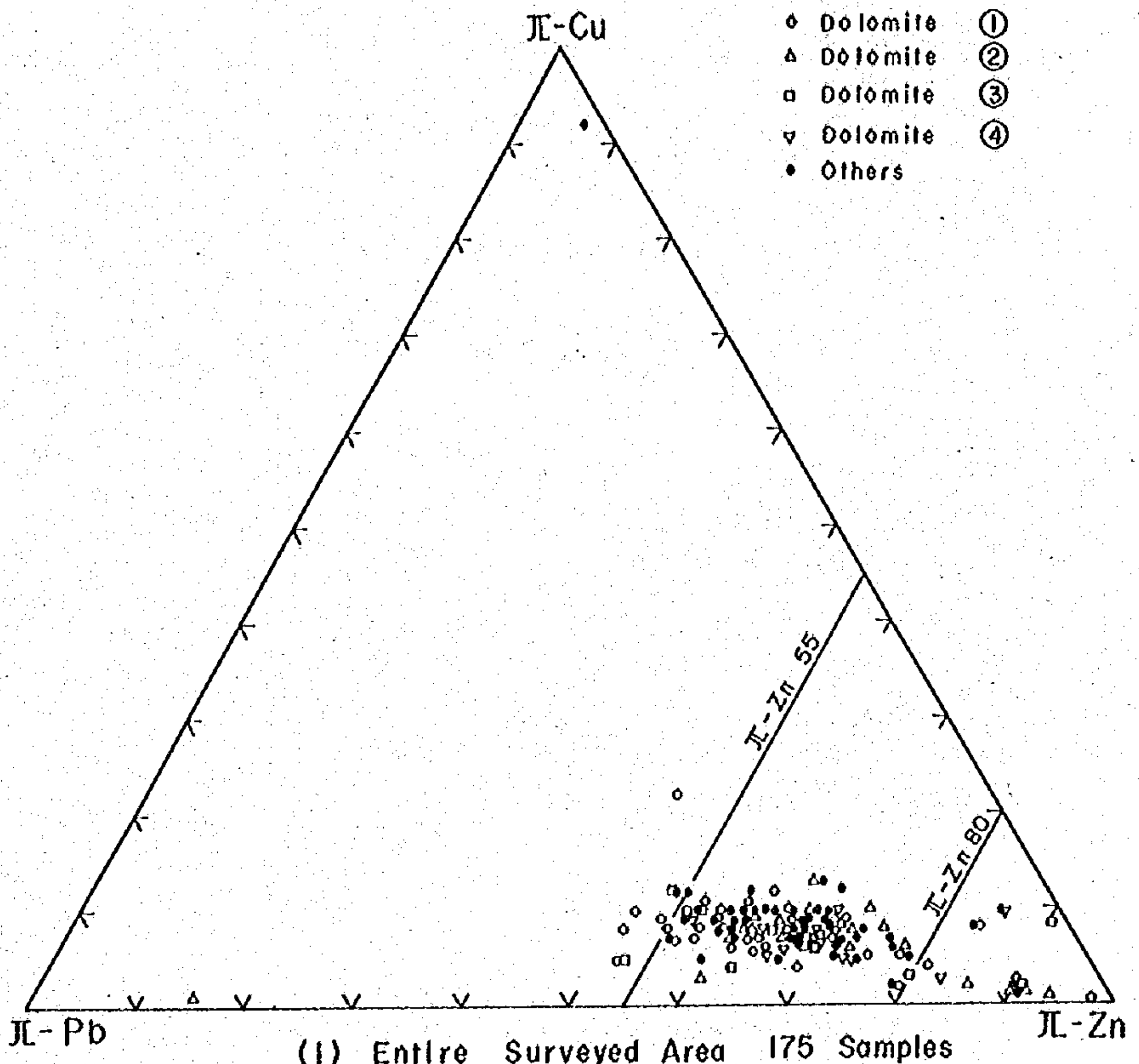
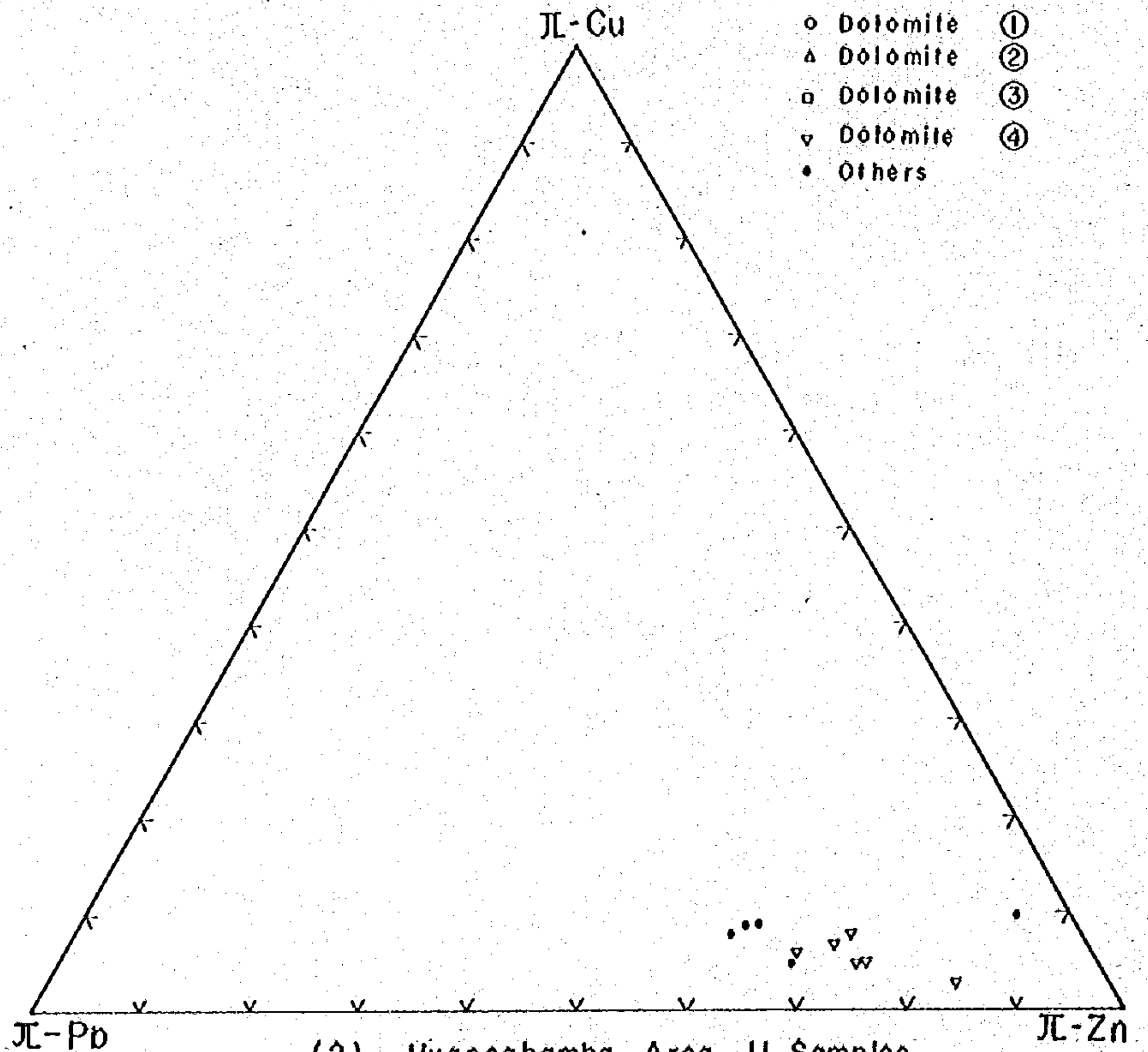
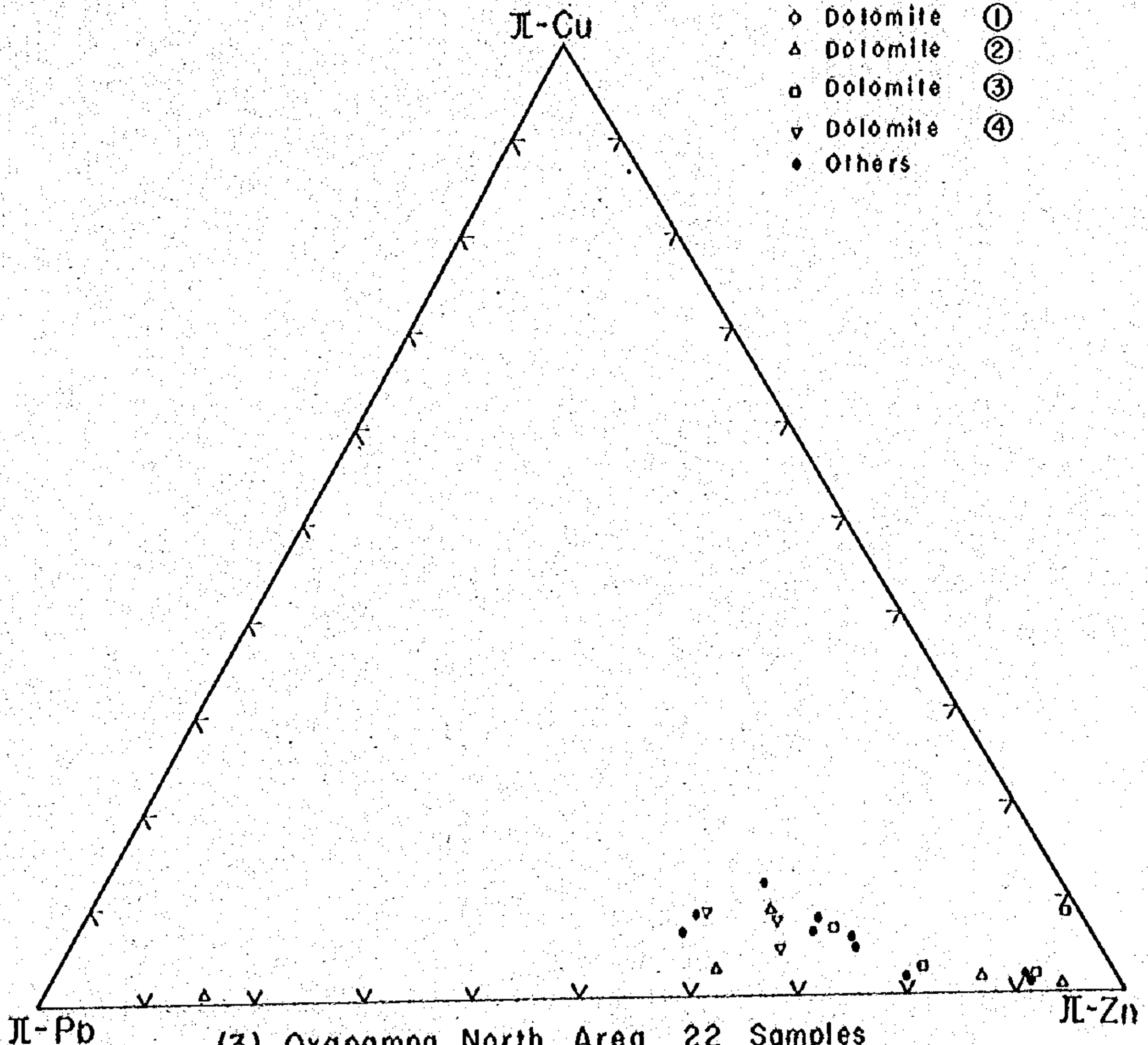


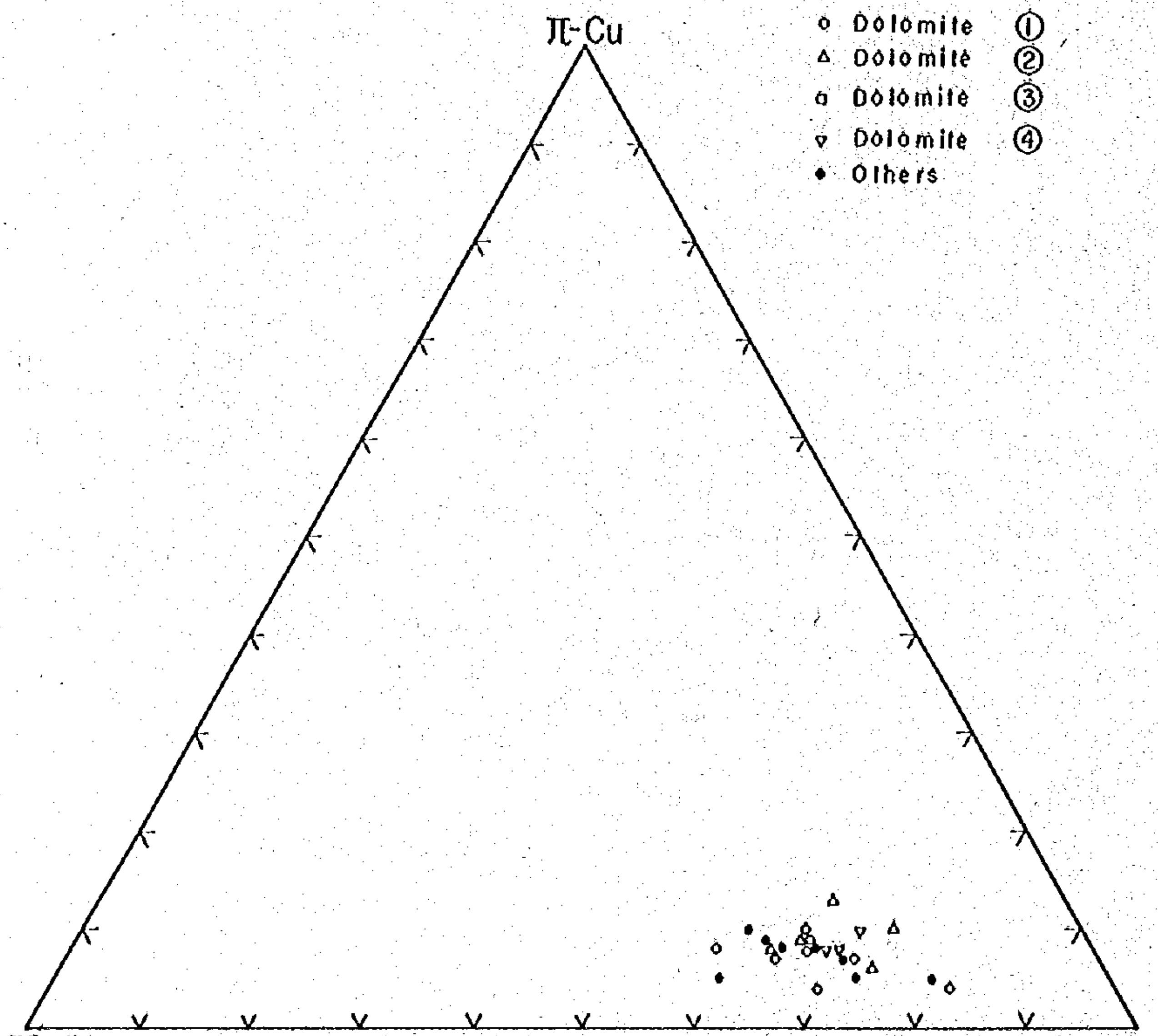
Fig.10 Ternary Diagrams of Minor Elements Ratio (π-Ratio) on Carbonate Rocks



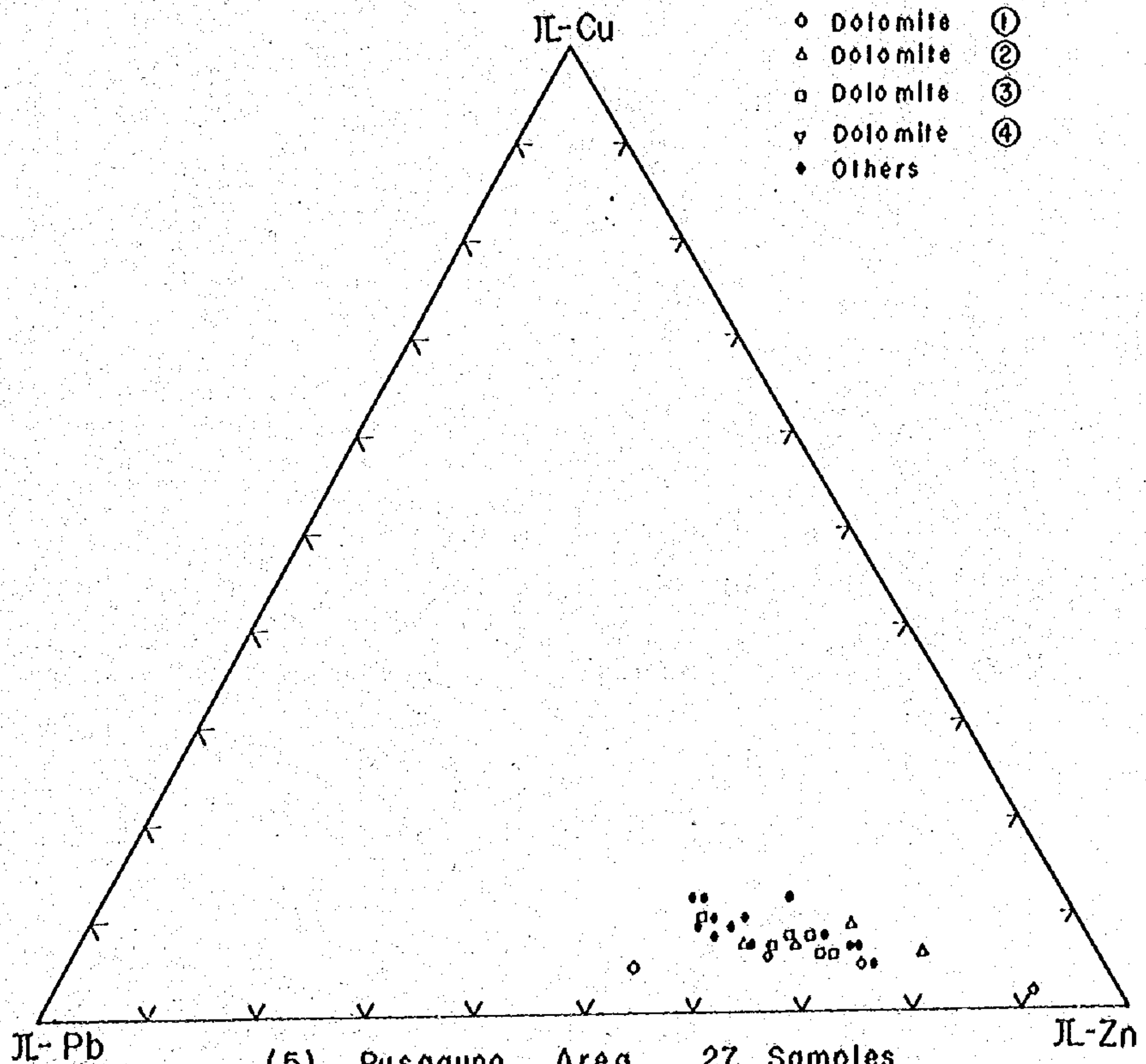
(2) Huancabamba Area II Samples



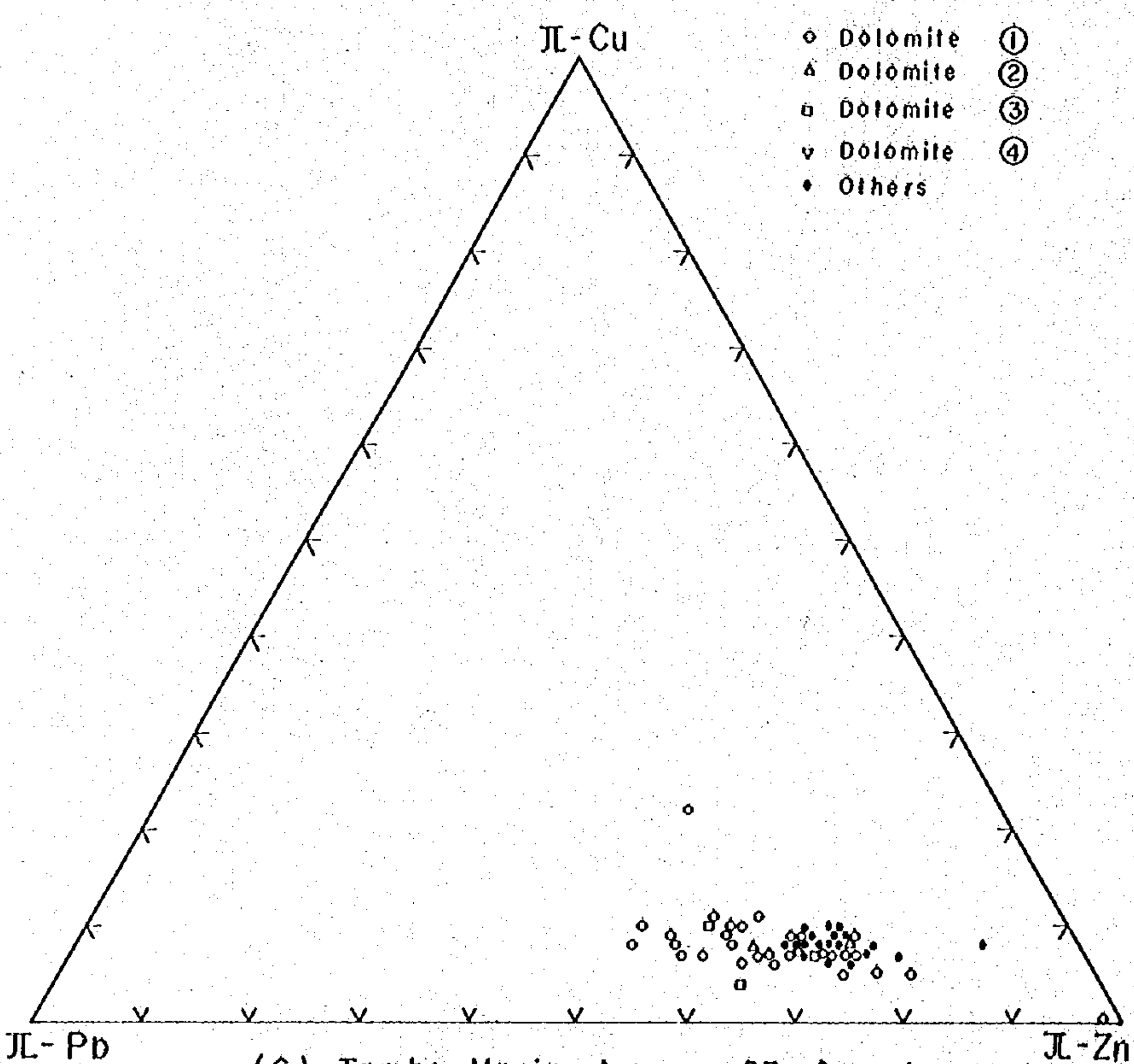
(3) Oxapampa North Area 22 Samples



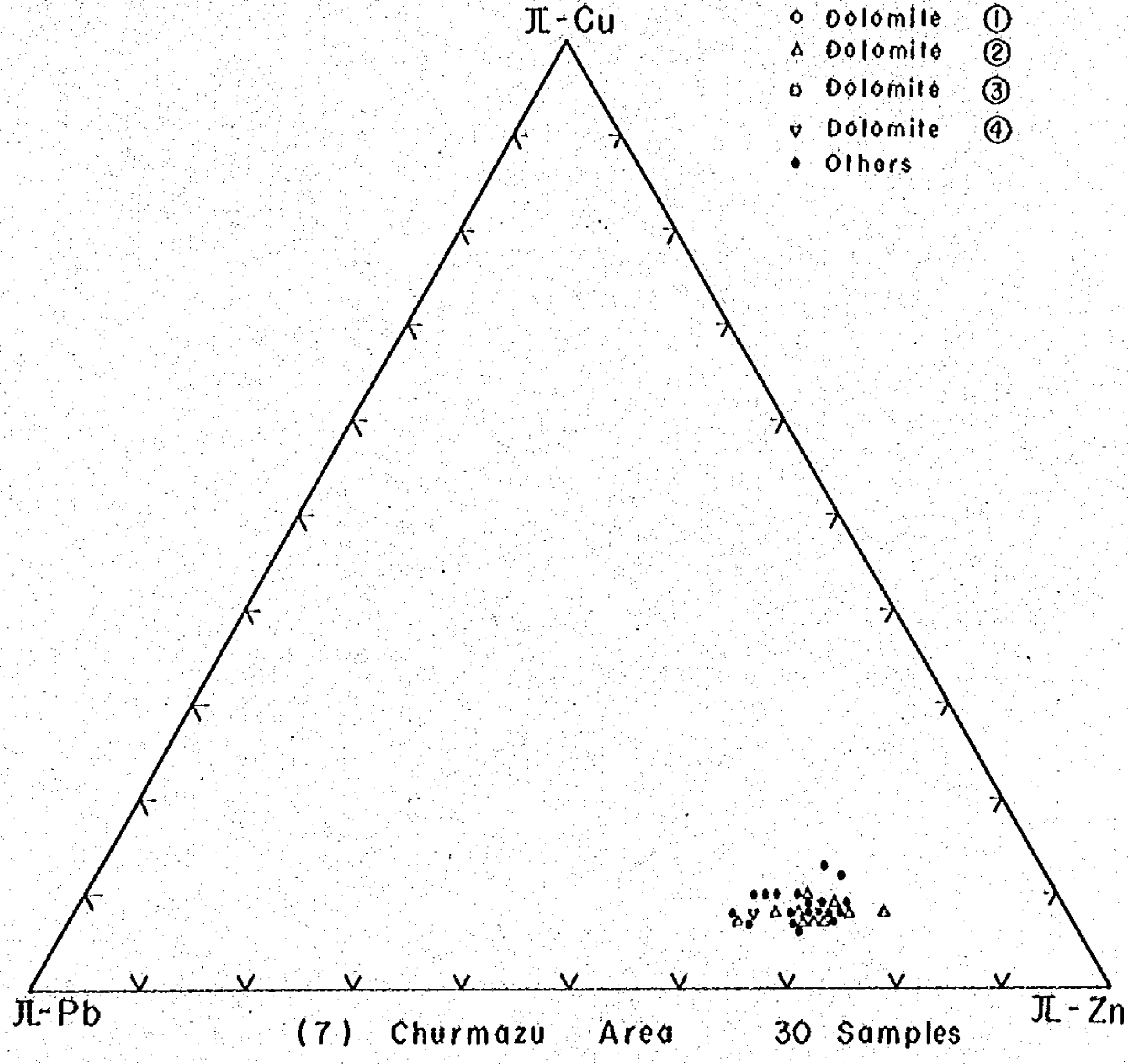
(4) Oxapampa South Area 24 Samples



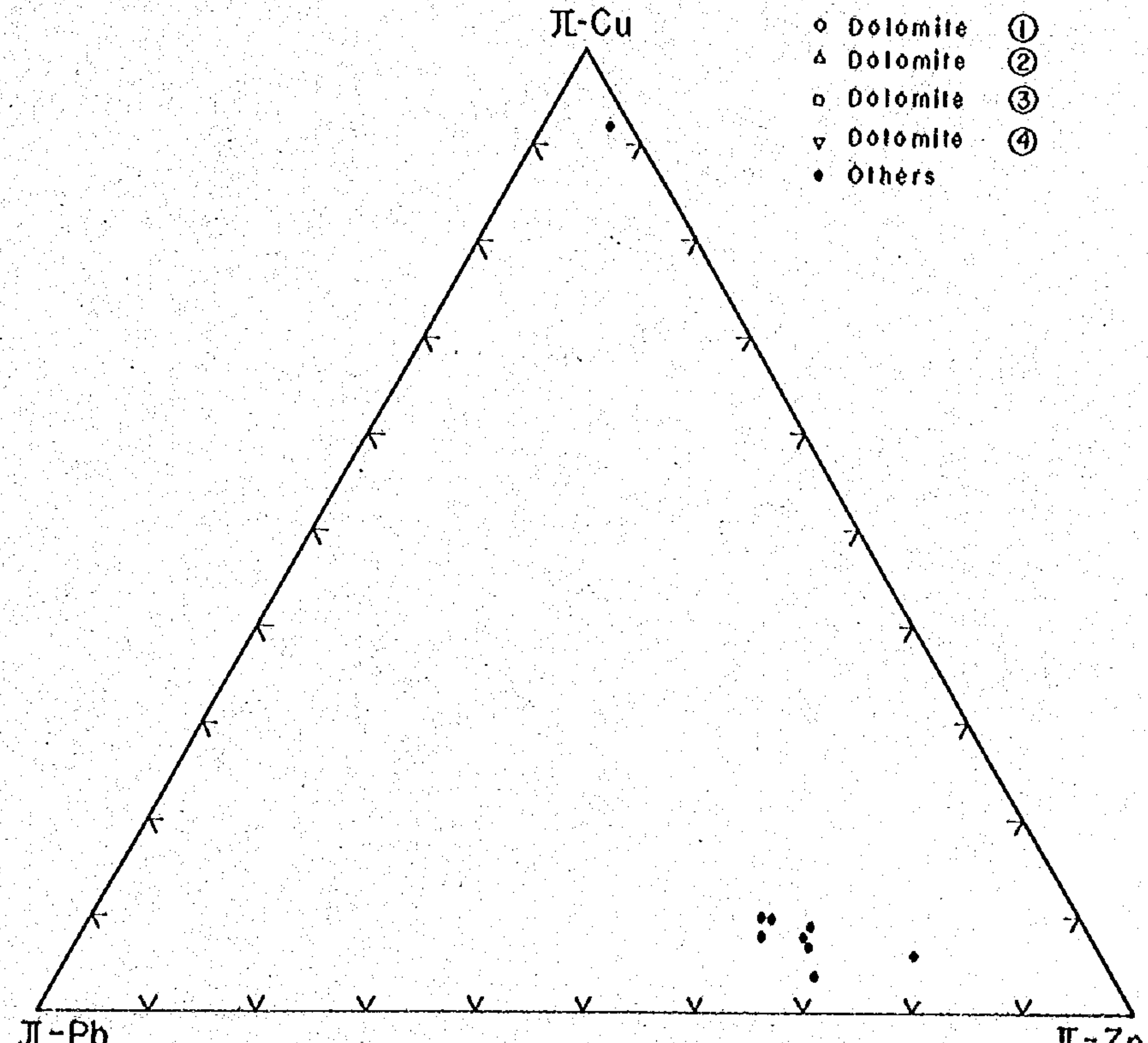
(5) Pusaguno Area 27 Samples



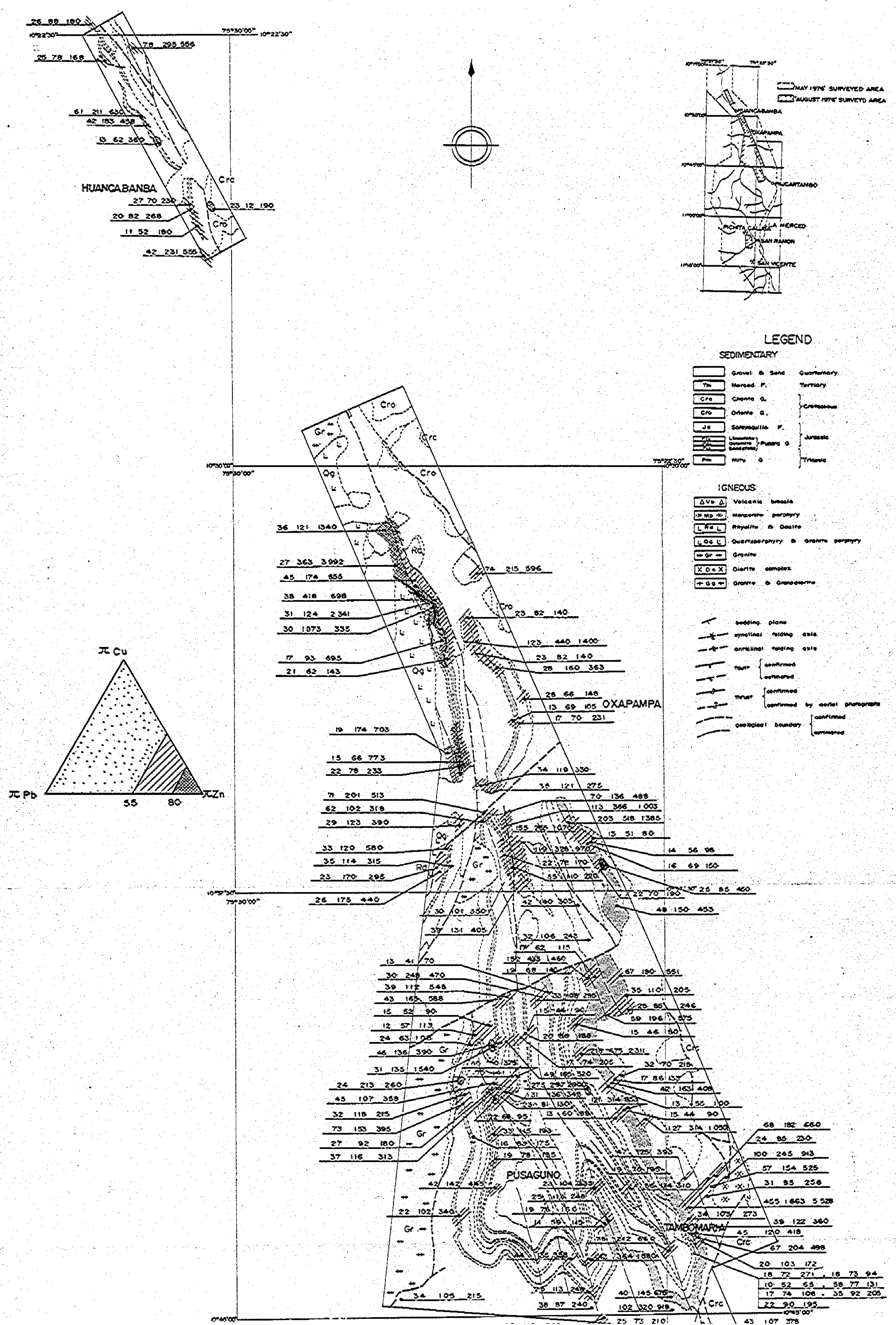
(6) Tambo Maria Area 53 Samples



(7) Churmazu Area 30 Samples



(8) Phichita Caluga Area 8 Samples


HUANCABANBA
OXAPAMPA
PUSAGUNO
TAMBOMARHA
LEGEND
SEDIMENTARY
Gravel & Sand Quarternary
Tm Merced F. Tertiary
Crc Chonta G.
Cro Oriente G. Cretaceous
Js Sarayaquillo F. Jurassic
Limestone Dolomite Sandstone Pucara G
Pm Mitu G Triassic
IGNEOUS
Vb Volcanic breccia
Mp Monzonite porphyry
Rd Rhyolite & Dacite
Qd Quartzporphyry & Granite porphyry
Gr Granite
Do Diorite complex
Gg Granite & Granodiorite
bedding plane
synclinal folding axis
anticlinal folding axis
fault confirmed estimated
thrust confirmed confirmed by aerial photographs
geological boundary confirmed estimated
MAY 1976 SURVEYED AREA
AUGUST 1976 SURVEYD AREA
HUANCABAMBA
OXAPAMPA
PUCARTAMBO
PICHITA CALUGA
LA MERCED
SAN RAMON
SAN VICENTE
π Cu
π Pb
π Zn
55
80

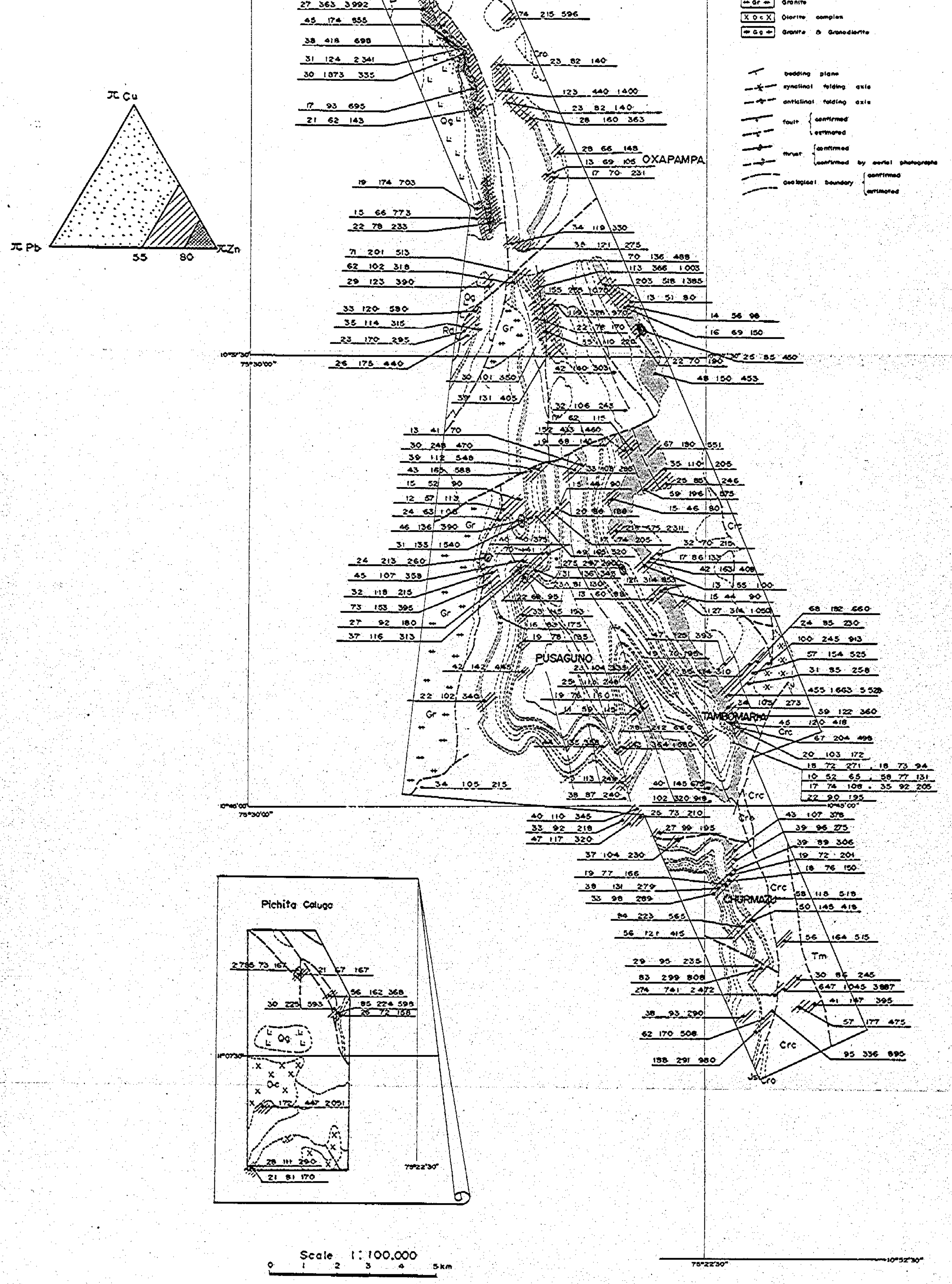


Fig. 11 Geochemical Anomalous Area of π-Ratios in the Detailed Survey Area

tion, a group of lenticular masses of pyrite (max. 45 cm x 10 cm) are found to occur in all directions in the fine grained dolomite and along minor cracks formed in it. No ore mineral such as sphalerite is found.

On the other hand, occurrence of ore in the San Vicente Deposits, which has been described precisely by the September 1975 survey, may be said in short to be slightly different from that of the Tambo Maria indication afore mentioned. Spharelite in the banded dolomite decreases its granularity towards dark gray dolomite from white dolomite, and occurs as fine dissemination in the central part of black dolomite. Different from the Tambo Maria indication, no pyrite is found near the ore body, but is only contained in sphalerite as inclusions.

4-2. Mineralization of Dissemination Type

Mineralized zones of this type in the surveyed area have been recognized in the Pucara Group surrounding those post-Cretaceous intrusives of porphyries such as quartz porphyry and granite porphyry and granitic rocks distributed from the west of Oxapampa to Pusaguno. In the west of Quillazu, indications mainly of galena have been recognized at the contact with granite porphyry and in dolomite a little away from it, which are all accompanied with veinlets and patches of calcite.

Even by such intrusion of igneous rocks, the Pucara Group as invaded formation has not been altered, and so with the limestone and dolomite in which mineral indications exist. In addition, boulders have been found to contain sphalerite associated with calcite veinlets. The locations of these mineral indications are generally along the dolomite bed-II and bed-III in the middle limestone-dolomite layer, and they are included in the heighest geochemical anomalies of soils in the surveyed area, but the mineral indications so far found are so feeble as stated above.

4-3. Mineralization of Porphyry Copper Type Accompanied with Monzonite

This mineralization is what has been found in the May 1976 survey near Tambo Maria, of which details have been stated in 4-2-1 of the report. This mineralization is of high temperature type with chalcopyrite and accessory sphalerite found at the contacts of the Pucara Group with Tertiary monzonitic rocks (2-3-3, Part 1), where the monzonites themselves are mineralized by magnetite and chalcopyrite with association of minor hematite and covelline.

Such monzonites were recognized in the east of Oxapampa as the stocks intruded into the Chonta Group, where mineralization and alteration could not be ascertained.

4-4. Minor Components in the Carbonate Rocks

4-4-1. Distribution Tendencies of Minor Components

Aside from the soil samples, geochemical samples were collected from the carbonate rocks mainly of the Pucara Group and chemical analysis was made on the 3 elements of Cu, Pb, and Zn, of which results are shown on Table 16B.

Behaviors of each element in the carbonate rocks are summarized as follows;

(1) Most of Cu assays are less than 80 ppm with only a few exceptional highs of more than 400 ppm.

(2) Pb assays are generally less than 200 ppm with a few sporadial highs of more than 600 ppm.

(3) As to Zn, the mineral indications around Tambo Maria show the highest average of 21.4 % Zn as well as some local highs of more than 1,000 ppm are recognized in Tambo Maria and west of Oxapampa, but the majority are less than 300 ppm.

Percentages of assays on Cu, Pb, and Zn, which are shown on Fig. 10, are calculated for the purpose to acquire the tendencies of distribution of the 3 minor elements in certain horizon and between upper and lower horizons of the carbonate rocks. The percentages of assay values on the 3 elements have been produced for an attempt to express the concentrations of each elements in a state of proportions instead of contents. The ratios will be called Cu, Pb, and Zn, hereafter.

Plotting the ratios of Cu: Pb: Zn on a ternary diagram, majority of samples are assembled in a definite range of oval shape of which major axis is expressed by the 2 points of ≠ (5 : 15 : 85) and (10 : 35 : 55), and this range will be called normal range hereafter. A few more than 10 samples are plotted outside the normal range either in higher or in lower sides of Zn, which will be called anomalous hereafter.

Local tendencies of the distribution will be given below (Fig 11);

(1) Around the indications of Tambo Maria, the Zn indication in the dolomite bed-I is in center of anomalies and low Zn is found a little away from the direct contact with hanging wall side of the indication.

(2) In the west of Oxapampa, on the contrary, no mineral indication has been found at the spot of maximum anomaly of Zn, but extreme highs of Zn of which assays are as high as 2,300 ppm and 4,000 ppm have been found in 3 spots and high Pb is associated with some of them, but any mineral indication like the one afore mentioned has been found nowhere. The samples of such anomalous ≠ are oncentrated in the dolomite bed-II and bed-III.

(3) Around Pusagno too, high anomaly of Zn is recognized at one sopt in the dolomite bed-I as well as low anomalies of Zn at 2 spots.

(4) Elsewhere as Huancabamba, Churumazu, and Pichita Caluga, majority

of samples are included in the normal range with only one exception of high π Cu.

4-1-2. Geological Considerations on the Distribution of Minor Components

Followings are geological interpretations on the distribution tendencies of Cu, Pb, and Zn, contained in the carbonate rocks.

(1) Majority of assay values of the carbonate rocks are included in the normal range of π-ratios. In spite of variety in quantities of heavy metals contained in the carbonate rocks in this area, the similarity in their ratios may be infered to their proper natures something like the background. Moreover, it is interesting to notice that in the area between Huancabamba and Pichita Caluga, for instance, these ratios are more or less constant, inspite of difference of distance for about 60 km and in spite of age difference between the hrizons of dolomite bed-I and bed-IV. Present survey, however, has not been able to make clear in what states the 3 elements will exist in the carbonate rocks.

(2) Most of the anomalies are superimposed over the distribution of the dolomite horizons. This may be infered to migration and selective reconcentration of the metallic elements mostly in the dolomites, in relation with such structural factors as to have caused the recrystallization in majority of the dolomite and the formation of banded structure and breccia structure, of which will be mentioned later.

(3) From the distribution of anomalies around Tambo Maria and Oxapampa, a tendency has been perceived for the elements of Pb and Zn to be arranged within a narrow range, similarly to the zonal distribution of ores. This findings will suggest the migration of elements of Pb and Zn, either of addition or of leaching, to have occurred around the area. This migration may be considered to consist of migration of Pb and Zn initially contained in the carbonate rocks and of additional migration from igneous activities.

In regard to the relation with igneous rocks, the September 1975 survey has suggested the enrichment in the San Vicente Ore Deposits given by the nearby intrusion of diorite. In Tambo Maria and Oxapampa too, igneous rocks are noticed to exist nearby the anomalies. Considering to the features above stated and to spacial relation with igneous rocks, influence by the igneous rocks will not be ignored. As stated before, monzonite near Tambo Maria is accompanied with distinct mineralization, and in Oxapampa too, dissemination of Pb has been recognized in contact with porphyries. These evidences will be enough to support the consideration of possible important roles played by the igneous rocks in the formation of ore deposits of San Vicente type.

Therefore, importance has been increased to acquire the behaviors of igneous activities and to anticipate the concealed existence, which may contribute for the discovery of new mineralization zone.

In any case, whether the behaviors of minor components in the carbonate rocks within a limited range can be related to the concealed existence of ore deposits or not, will be the problem to be put off for the future studies, and in this sense, it is also important to pursue for comparison what behaviors of minor components will be revealed by the known deposits of San Vicente.

In addition, as the existence of Pb veins has been known to intersect the banded ores of San Vicente deposits, the dissemination of Pb in Oxapampa may be infered to outward migration from certain deposit of Pb alone as its source during the formation of ore deposits of San Vicente type.

4-5. Considerations about Mechanisms in Ore Deposition

As it has been discussed in the report of May 1976 survey, the banded structure in dolomite has been formed during a course of diagenesis after its deposition, and it has a strong possibility to have been formed in the crevices generated during structural movements. Concentration of Pb and Zn as galena and sphalerite is considered to have been proceeded along the crevices and from the side of black dolomite which caused the banded structure. Origins of Pb and Zn have been considered to consist of those contained in the carbonate rocks and others added by igneous rocks. The additional elements from igneous rocks would have been deposited as sulphides. As to these elements contained initially in the carbonate rocks, occurrence of them can hardly be estimated accurately. But, if an imaginary inference is allowed on their occurrence like for instance to have replaced some parts of Ca in carbonates such as calcite and dolomite, the necessary sulphur for them to have been crystallized out as sulphides whould have been supplied from the sulphur initially contained in the carbonate rocks.

Chapter 5 Measurements of Physical Properties of the Carbonate Rocks

Mesurements of electrical resistivities and IP effects were made on the rock samples collected in the surveyed area, for the purpose to investigate the applicability of electrical survey as a means in the possible future prospecting for the mineralized zones in the surveyed area. Rock samples measured were 64 in all, which consited of 20 samples of dolomite, 30 of limestone, 7 samples of the carbonate rocks including the banded dolomite, and 7 samples of ore in the carbonate rocks including sphalerite almost free from iron content.

(1) Mesuring Method

In measuring the physical properties of rock samples, miniature IP transmitter and receiver were used in an arrangement shown in the attached figure. Frequencies of 2.5 Hz and 0.3 Hz and resistivity at 2.5 Hz were adopted in this measurements. The samples were measured after having been trimmed and dipped in city water for 24 hours. Advantage of this method is that measurements are made exclusively on the rocks themselves, without consideration of any other factors except the rocks. On the contrary, the samples have to be measured after having been removed from their natural states of occurrence and under much differed conditions from their initial states. In this sense, the method may be said disadvantageous. The physical data thus obtained have to be treated as relative values between the rocks for comparison.

(2) Results of Measurements

Values of resistivity and FE by rock types are shown on Fig. 15 and relation between resistivity and FE values by rock types are shown on Fig. 16. The results of measurements may be summarized as below;

1. As the values of resistivity are similarly very high in limestone, dolomite, and banded dolomite, it is difficult to distinguish these rocks by the resistivity values. Ore samples also showed so high values of resistivity that distinction between ores and carbonate rocks can hardly be made.

2. FE values are low throughout the samples examined except for the maximum FE value of 2.5 % in limestone; FE values are commonly low in ores and rocks containing sphalerite.

(3) Considerations on Measured Results

It may be suggested by the measured results that prospecting method to make use of electrical properties will be difficult to be applied in a teritory of such geological environment as the ores essentially consisting of sphalerite almost free from Fe content with very minor association of other kinds of sulphides. On the other hand, the high resistivity and low FE natures in the superficial rocks may suggest the area suited to be surveyed by electrical method, provided any other sulphides except sphalerite would exist concealedly below these formations.

As far as investigated to date, it seems inadequate to extract mineralized zones by electrical method, unless some additional new facts will be found, because the measured properties are those of representative rocks and ores in this area and they are, at the same time, the main units to constitute the geological setup of the area.

It is considered at present moment, however, that the mineralized zones in this area have not been reduced into certain promising parts, and the area is still in a stage of extracting more possible parts of mineral existence.

Since geological survey has revealed that relation between the mineralization in this area and intrusive rocks must not be ignored, if it is enabled to detect possible existence of concoiled intrusive bodies in the area vastly covered by sedimentary formations, by applying some methods other than electrical one, for instance by making use of density and magnetism, such will contribute most in locating promosing parts in the mineralized zone. It is advisable, therefore, to consider to apply gravity and magnetic methods in the future geophysical survey instead of electrical method.

Just for reference, results of mesurements of densities on the representative rocks collected in the surveys of May and August 1976 have been shown on Table 18. Fllowings are the values classified by rock types.

Effusive rock	porphyry	$\rho = 2.55$
Sedimentary rocks	sandstone	$\rho = 2.60$
	limestone	$\rho = 2.69$
	dolomite	$\rho = 2.79$
Intrusive rocks	granite	$\rho = 2.60$
	diorite	$\rho = 2.88$

A tendency is recognized for the densities to be increased in the order of effusive rocks, sedimentary rocks, and diorite (intermediate to basic intrusives). Besides, as magnetism of diorite is estimated stronger among these rocks, occurrence of diorite will be enabled to detect by applying gravity survey and magnetic survey combined.