REPUBLIC OF PERU

REPORT ON GEOLOGICAL SURVEY OF THE CORDILLERA ORIENTAL, CENTRAL PERU

VOL. I

JULY 1976

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.

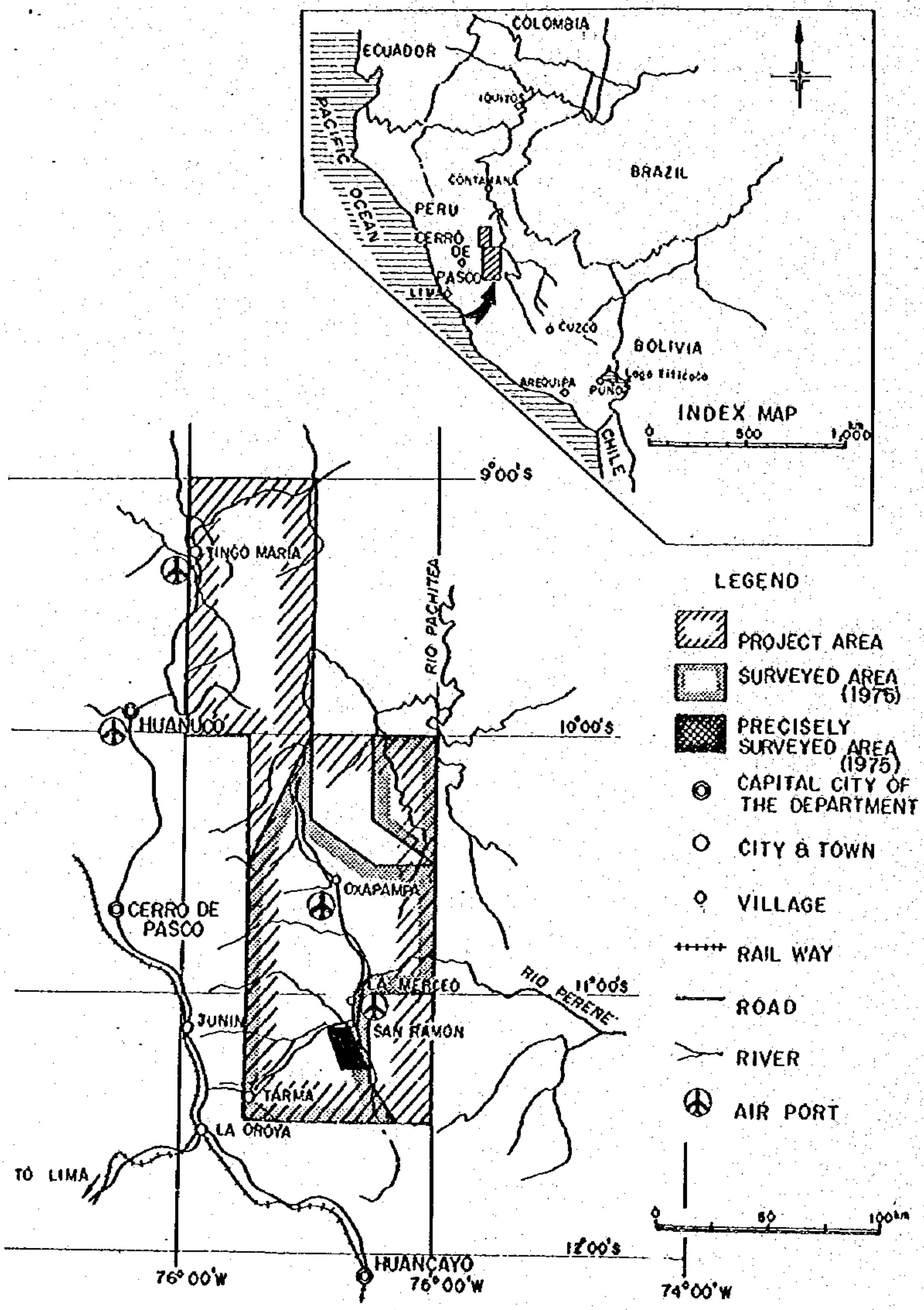
This year was for the first phase survey, and as for this current year, a Geological-Geochemical survey team was formed consisting of six (6) members headed by Mr. Shigeaki Yoshikawa, Mitui Kinzoku Engineering Service Co., Ltd., and sent to the Republic of Peru on September 2, 1975. The Team stayed there for seventy-one (71) days from September 2, 1975 to November 14, 1975. 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 performed for the first and second-phase survey.

I wish to take this opportunity to express my 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.

July 1976

Shinsaku Hogen
President
Japan International Cooperation
Agency



Location Map of the Cordillera Oriental, Central Peru

GENERAL CONTENTS

A B S T R A C T

Present survey was performed as a part of the operations of geological survey for mineral exploration in the central part of the Cordillera Oriental of the Republic of Peru.

The purpose of this survey was

(1) to make clear the distribution of the Pucara Group in which the emplacement of ore deposits was anticipated, and to extract some areas of higher possibility of ore existence, and

(2) to establish the most appropriate methods of exploration for the bedded lead-zinc deposits anticipated in the Pucara Group.

The field works were carried out from September to November of 1975, and indoor data analysis was performed from December 1975 to May 1976.

The rocks exposed in the area of present survey consist of the Pre-Cambrian metamorphic rocks, the sedimentary formations ranging from Devonian Period to Tertiary Period, the late Paleozoic granitic rocks of batholith forms, the middle Mesozoic dioritic rocks, the early Cenozoic porphyries and volcanics, and the late Cenozoic volcanic rocks.

The metamorphic rocks, granitic rocks, and older sediments are distributed in the southwestern part of the surveyed area, the porphyries and volcanics are in the central part, and the later sediments in the northeastern part. These formations are so distributed, as a whole, that they become younger from southwest towards northeast.

The major tectonic lines, though showing NW-SE in the southwestern part, generally show the direction of NNW-SSE. Anticlines and synclines

are developed with their axes of the said direction and the thrust faults of similar strike with westward dip are distinctly observed. In addition, the faults in WNW-ESE and NNE-SSW systems cutting the thrust faults are also developed.

The known metallic ore deposits are these copper-lead-zinc veins emplaced in the granitic and metamorphic formations in the southwestern part, and the bedded lead-zinc deposits in the Pucara Group, in which the latter have much more economical importance.

The bedded lead-zinc deposits are embedded conformably to the bedding planes of the layers of dolomite and dolomitic limestone of Chambara formation in the lower part of the Pucara Group. San Vicente and Pichita Carga are representative as the known deposits of this kind, around which are developed the layers of banded dolomite and breccial dolomite. Such formations of dolomite and dolomitic limestone are widely distributed not only around the sites of the known deposits, but also in the central and northern parts of the surveyed area, though their distribution has not been clear enough.

Where the dioritic rocks are intruded in the vicinity of these lead-zinc deposits, the galena-calcite veins are recognized cutting across the bedded lead-zinc deposits, and intense pyrite impregnation and copper indications are observed in the dioritic rocks themselves, too.

The skarn type deposits of copper-lead-zinc are formed for some extent near the contacts of stocks and dykes of the dioritic rocks penetrating the carbonate rocks of the Pucara Group.

The results of geochemical survey conducted in the present area have revealed that zinc is most effective elment for prospecting the bedded lead-zinc deposits and copper and nickel for classifying lithofacies as well as for recognition of some sorts of mineral indications, because not only some remarkable anomalies of zinc have been detected in the Pucara Group, but also copper anomalies have been detected in some dioritic rocks and porphyries and nickel anomalies in the metamorphic rocks.

The precise geological survey around the San Vicente deposits has made clear such relation of geological structure and ore deposits as stated above. Regarding an origin of the deposits of San Vicente type, it may be interpretted that they once had been formed by similar process as those lead-zinc deposits of the Mississippi Valley type, and migration and addition of components were induced by the effects of later intrusion of dioritic rocks and porphyries.

As stated above, geological survey and its data analysis have shown that the effective ways of exploration of the bedded lead-zinc deposits anticipated in the Pucara Group are as follows;

(1) establishment of the stratigraphy of the Pucara Group, especially zoning of the dolomite layers,

(2) finer stratigraphical and structural survey of the dolomite layers,

(3) distributional and structural survey of the Jurassic dioritic rocks and the Paleogene porphyries, and

(4) geochemical survey by Cu, Zn, Ni, and Pb, and detection of minor elements in the carbonate rocks.

As the principles of the forthcoming surveys for the Second Year Phase and thereafter, the following items are desirable to be put into practice;

(1) for the entire area projected, similarly to the present reconnaissance,

1. general reconnaissance of geological structure,
2. distributional and structural survey of the Pucara Group, the Jurassic dioritic rocks, and the Paleogene porphyries, and
3. geochemical survey by Cu, Zn, and Ni,

(2) further, within the distribution of the Pucara Group,

1. stratigraphical survey of the Pucara Group, especially the zoning of the dolomite layers,
2. geochemical survey by Cu, Zn, and Pb, and
3. magnetic survey for the purpose of structural analysis of the deeper zones of the Pucara Group,

(3) in the locations of higher possibility of ore existence in the Pucara Group,

1. finer stratigraphical and structural survey of the dolomite layers,
2. geochemical survey by Zn and Pb in grid patterns, and
3. electrical survey (IP method) for the purpose of extraction of mineralized zones.

GENERAL

CONTENTS

GENERALS

Chapter 1. Conclusion

1-1 Results of Geological Reconnaissance in the Southern Block of the Projected Area

Followings are the general summaries of the results of geological data analysis on the survey of the Southern Block of the Projected Area (to be described A & B Areas hereafter) practiced in the First Year Phase, and the results of chemical analysis of geochemical samples and their indoor researches in the succeeding geochemical survey.

(1) The southwestern part of the said area is occupied mostly by the igneous rocks and the northeastern part is mostly by the sedimentary formations, and the area is covered by these formations approximately 40% in sedimentary formations, 10% in metamorphic rocks, and 10% in the younger sediments.

(2) General trend of geological structure and their distribution coincides with the general structural trend of NNW-SSE in the central part of Peru.

(3) Macroscopically, the sedimentary formations are zonally distributed extending in NNW-SSE, being younger towards northeast and older towards southwest.

(4) The sedimentary formations consist of the repeated deposits of the geosynclinal sediments such as limestone and dolomite of transgressional period and the sediments of regressional period such as lutite and conglomerate, and judged by these sediments, the center of geosyncline seems to have migrated from southwest towards northeast.

(5) The sedimentary formations have been deposited intermittently since Devonian Period of Paleozoic Era till Tertiary Period of Cenozoic Era, with the intermissions of sedimentation accompanied by the orogenic movements in

1. Triassic Period of Mesozoic Era,

2. Jurassic Period of Mesozoic Era, and

3. Early Tertiary Period.

(6) The Pucara Group, deposited from Triassic to Jurassic Periods of Mesozoic Era, can roughly be divided into two groups; the one is the formation zonally distributed in NNW-SSE in the central part of the area, and the other is the formation zonally arranged in NW-SE in the southwestern part. The central group, being partly intruded by the Paleogene porphyries, is in contact with the granitic rocks by a thrust fault in the west, and is overlain by the younger sediments in the east. The southwestern group is in contact with the Paleozoic metamorphic rocks by a normal fault on the southwestern side, and covers unconformably the Mitu Group of its lower horizon on the northeastern side.

(7) The Pucara Group in the area may mostly be correlated to the Chambara Formation, although a part of the upper section of the southwestern group may be correlated to the Aramachay Formation.

(8) The Pucara Group contains the member mainly composed of dolomite or dolomitic limestone, lying conformably both to its upper and lower limestone layers. This member is widely distributed in the central and southern parts, emplacing the deposits of San Vicente and Pichita Carga, as well as distributed zonally in the northern part.

(9) The igneous rocks can be classified as

1. the granite and granodiorite, intruded from Permian Period of Paleozoic Era to Triassic Period of Mesozoic Era and forming the basement of this region,
2. the porphyritic diorite and granodioritic rocks of Jurassic intrusion in Mesozoic Era,

3. the Paleogene intrusives and effusive volcanic rocks, and

4. the Tertiary effusive volcanic rocks.

(10) Among the granite and granodiorite intruded from Permian to Triassic Periods, the granite prevails in the east, while the granodiorite in the west. Both are intermingled in the central part and the granite is observed to cut through the granodiorite locally. Dykes of meta-andesite cutting both of them are also observed.

(11) The porphyritic diorites and granodiorites intruded in Jurassic Period of Mesozoic Era are distributed in the form of stocks in the areas of granites and sediments of the western and central parts.

(12) The igneous rocks of Paleogene activity, Cenozoic Era, are widely distributed in the central and northern parts, which are roughly classified into intermediate igneous rocks of earlier activity and acidic igneous rocks of the later activity. The intermediate rocks are abundant in the eastern side in the forms of stocks and dykes, while the acidic rocks are in the west side as batholiths and lava flows. Stocks of acidic rocks are also scattered in a part of the central area.

(13) The Neogene volcanic rocks, Cenozoic Era, are scattered in the granitic rocks of western part, consisting of tuff-breccias and andesitic lava flows.

(14) The metamorphic rocks are distributed zonally stretching in NW-SE, which consist mostly of schists and gneisses intercalating serpentine and granitic rocks.

(15) Anticlinal and synclinal foldings extending in the direction of NNW-SSE are predominant in the area, forming the fundamental geological structure of the region. There are developed the westerly dipping thrust faults of similar NNW-SSE direction to the folding structure and the faults of

WNW-ESE and NNE-SSW systems formed by the compression of ENE-WSW that caused the thrust faults.

(16) The main metallic ore deposits and remarkable mineral indications in the area as follows;

1) bedded lead-zinc deposits in the Pucara Group,
2) cobalt-nickel deposits related to the ultrabasic rock in the metamorphic region,
3) skarn-type deposits replacing the carbonate rocks in the Pucara Group,
4) vein type deposits of copper-lead-zinc in the granitic rocks and metamorphic rocks,
5) indications of copper mineralization detected around the Paleogene porphyries.

(17) The major lead-zinc deposits of bedded type are embedded in the dolomite formation, especially developed dominantly in the structurally disturbed portions of banded and breccial structures. Such structures are observed often in the surrounding areas of the known ore deposits in the Pucara Group of the southern part.

(18) The ultrabasic rocks hosting cobalt-nickel deposits are distributed only in the limited areas, and the deposits so far reported are in small scale.

(19) The skarn type deposits of copper-lead-zinc are pyrometasomatic deposits formed at the contact of the Pucara limestones, overlying the basement of granitic rocks as roof pendants, and dykes of the Paleogene porphyries penetrating the limestones. The ore holding limestones are all narrowly patched, and the known deposits are all small.

(20) In some of the stocks of intermediate intrusives among the Paleogene porphyries, there are observed intense hydrothermal alteration with impreg-

nation of pyrite. The geochemical survey has detected intense anomalies of copper (to be described Cu hereafter).

(21) According to the geochemical survey in the area, the location of zinc (to be described Zn hereafter) anomalies are limited in the distribution of Pucara Group and, moreover, they coincide to the distribution of dolomite or dolomitic limestone.

The Cu anomalies show higher intensities in the areas where (16)-4) and -5) are distributed, but the distribution of Cu anomalies on -5) has not been analysed thoroughly due to the handicapped geographical conditions.

Relation of nickel (to be described Ni hereafter) anomalies to mineralization or to geological structure has not been clarified.

(22) In view of the results of geochemical survey, the prospecting for the bedded lead-zinc deposits may be limited within the areas where the Pucara Group is distributed. It has also been made clear that the copper anomalies have intimately related to some of the intermediate intrusive bodies.

1-2 Results of Precise Geological Survey in the San Vicente Area

The general summaries of the results obtained through the Precise geological survey in the area around the San Vicente Mine in the First Year Phase are as follows;

(1) Igneous rocks are distributed in the east and west parts of the San Vicente Area, and the central part is consisted mostly of sedimentary formations.

(2) The distribution and structure of these formations are similar to the prevailing trend of NNW-SSE direction in this Area.

(3) The sedimentary formations are so distributed as the Pucara Group in the west side and the lower seated Mitu Group in the east side.

(4) The Pucara Group is in contact with the granodiorite by thrust fault

on its west side, while it overlies the lower seated Mitu Group and granite with unconformity.

(5) The entire Pucara Group is correlated to the Chambara Formation, of which middle part is consisted mostly of dolomite and dolomitic limestone, and the upper and lower parts are consisted mostly of limestone.

(6) The middle member, mainly of dolomite and others, is distributed along the axial part of synclinal structure with the axial trend of NNE-SSW in the central part of the area, and is distributed along the eastern wing of anticlinal structure with the axial trend of NNW-SSE in the northern part of the area.

(7) The middle horizon of the middle member includes a few layers of banded crystalline dolomite, and layers of breccial dolomite in the upper horizon indicating structurally disturbed zone.

(8) Igneous rocks of the area consist of

1) the granitic rocks which intruded during the period between Permian, Paleozoic Era and Triassic, Mesozoic Era, and constitute the basement of the area, and

2) the stocks of porphyries intruded in Jurassic Period, Mesozoic Era.

(9) Among the granitic rocks of Permian to Triassic intrusion, the white granite (Granito blanco) or white granodiorite called Tarma granite predominates in the western part of Pucara Group, while the red granite (Granito rojo) or called San Ramon granite predominates in the eastern part of the Group.

(10) Most of the dioritic rocks of Jurassic intrusion are intermediate porphyries, being distributed as stocks in the north and south of the area. They show intense variation of lithofacies, but generally speaking, they are tonalitic or granodioritic in the centers and dioritic in the margins of the stocks.

(11) The axis of synclinal structure in the center of the San Vicente Area is extended in the direction of NNE-SSW and has a gentle plunge towards SSW. The west side of this syncline is cut by a thrust fault of which strike is N-S and dipping to the west, while east side is cut by normal faults, striking in N-S or NNE-SSW with westward dips.

(12) The lateral compression in the direction of ENE-WSW which caused the said thrust faulting also formed many of the faults of WNW-ESE and NNE-SSW systems. Because later ones caused dislocation of the San Vicente ore bodies, they seem to be the important fissures in ore prospecting.

(13) Aside from the ore deposits worked by the San Vicente Mine, many of the bedded lead-zinc deposits are known around the Mine. And copper bearing pyrite impregnation can be recognized in some of the dioritic stocks.

(14) The main ore bodies of the San Vicente Mine are embedded in the middle member, consisting of dolomite and others, of the Pucara Group, and they have been enriched at the structurally disturbed zone where the banded dolomite (Zebra dolomite) and breccial dolomite are developed. And the deposits emplaced in the limestone of the lower member are all located near the stocks of dioritic rocks.

(15) The deposits embedded in the middle member consist mostly of fine-grained massive sphalerite, while the deposits embedded in the lower member consist of slightly coarser-grained sphalerite with many of local concentrations of galena and chalcopyrite and with many galena-calcite veins cutting across the massive handed sphalerite, too.

(16) The X-ray diffraction on the host rocks of San Vicente deposits has shown none of the alteration mineral which is inferable to the mineralization to have formed the bedded lead-zinc deposits.

(17) According to the microscopic observation of ore minerals, the deposits

away from the dioritic rocks are mostly consisted of fine-grained sphalerite with less contents of other sulphides, but on the contrary, those closer to the stocks are consisted of slightly coarser-grained sphalerite with more association of galena and chalcopyrite, though locally. Two stages of mineralization may be estimated in case of the latter, and iron content in the sphalerite is higher than the former, which may suggest the higher temperature circumastances.

(18) The determination of fluid inclusions in the host rocks of ore deposits has shown the filling temperatures of 70^{o} ~ $150^{o}C$ with only one exception near the dioritic stock, which are very close to the values of lead- zinc deposits of so-called Mississippi Valley type.

(19) The geochemical survey has revealed that Zn content in the stream sediments and soils is higher in the area covered by the middle member of the Pucara Group, consisting of the dolomite formation in which the major bedded deposits of lead-zinc are embedded, while Cu content is higher around the dioritic stocks. Pb content is specially high near the bedded lead-zinc deposits.

(20) Zn in the carbonate rocks is generally high near the known ore deposits, and especially higher around the deposits nerar the dioritic stocks. its, and especially higher around the deposits near the dioritic stocks. The proportions of Zn and sulphur (to be described S hereafter) especially increase near the known ore deposits, and similar tendency is recognized in the ore bearing dolomites.

1-3 Future Aspects

Although the relation between genesis and structure of the bedded lead-zinc deposits of San Vicente type, which is the main subject of the present survey, have not been fully clarified, such valuable facts as described below have been understood, which may serve as guidance for the forthocoming surveys, that

1) the dolomite formation in the Pucara Group is important for the emplacement of ore deposits,

2) the major parts of the bedded lead-zinc deposits of San Vicente type have the features much resembling to those deposits of so-called Mississippi Valley type,

3) in the lead-zinc deposits near the stocks of dioritic rocks penetrating the Pucara Group, the younger mineralization rolated to their intrusion seems to have been overlapped,

4) remarkable indications of copper, lead, and zinc mineralization are recognized in some of the stocks and dykes of Paleogene porphyries.

The following methods of exploration have been considered effective for the bedded lead-zinc deposits to be expected in the Pucara Group through the precise geological survey around the San Vicente Mine Area, through geological reconnaissance of southern block of the Area, and through data analysis ever published about the present problems.

(1) The stratigraphical investigation of the Pucara Group, especially the zoning of its dolomite and dolomitic limestone formations is highly effective way for exploration, because the bedded lead-zinc deposits are emplaced in the dolomite or dolomitic limestone layers concordantly.

(2) The stratigraphical zoning and structural investigations of the dolomite formations are also important, because the bedded lead-zinc deposits are predominantly developed of all the dolomites in the structurally disturbed portions where the recrystallized banded structures and breccial structures are well developed.

(3) As the genetical condition of the bedded lead-zinc deposits of San Vicente type are considered similar to those of the bedded lead-zinc deposits of so-called Mississippi Valley type, it is necessary to inquire

the genetical conditions to control the localization of mineralization such as the existence of permeable dolomite, existence of thick overlying layers of impermeable shales, and existence of near-by permeable beds like sandstone.

(4) It is as well important to investigate the distribution and structure of dioritic stocks of Jurassic intrusion, as the bedded lead-zinc deposits are overlapped by the younger mineralization derived by these stocks in their vicinities.

(5) It is necessary too, to survey the structure and distribution of the Paleogene porphyries and to clarify their relation to mineralization, as the porphyries, being intruded as stocks in some parts of the Pucara Group and the younger sediments, have derived the skarn type deposits at their contacts with carbonate rocks as well as parts of the stocks where intensely impregnated by pyrite.

(6) The geochemical survey on the stream sediments and soils in the surrounding areas of bedded lead-zinc deposits has clearly indicated the correlation between the deposits and Zn geochemical anomalies. It has also been made clear that Cu geochemical anomalies are correlative to some of the Jurassic dioritic rocks and Paleogene porphyries and are also correlative to the bedded lead-zinc deposits which had been overlapped by the later mineralization inferable to their intrusion.

Thus, it has been concluded that the geochemical survey by Cu and Zn is effective for the regional reconnaissance and such survey by Zn and Pb is effective for the specified survey in the zone of the bedded lead-zinc deposits extracted through the foregoing regional reconnaissance.

Based upon the above statements, the followings are recommended as the principles of the forthcoming exploration.

(1) As the operations of the first stage for the entire projected area,

1) geological reconnaissance to make clear the distribution and structure of the Pucara Group and stratigraphic zoning of its dolomite formations,

2) geological survey on the distribution and structure of the Jurassic dioritic rocks and Paleogene porphyries,

3) geochemical survey by Cu and Zn.

(2) As the operations of the second stage for the extracted areas through the oprations of the first stage,

1) establishment of stratigraphy of the Pucara Group with special reference to precise stratigraphic zoning of its dolomite formations,

2) geological survey to make clear the relation of the geological structure of the Jurassic dioritic rocks and Paleogene porphyries to mineralization,

3) geochemical survey by Zn and Pb in the soils of distributed areas of the bedded lead-zinc deposits, inspection of minor elements of Zn and S in the carbonate rocks of dolomite formations, and geochemical survey by Cu and Zn in the soils of surroundings of the intrusives carrying mineralization indications.

(3) As the operations of the third stage for the extracted areas through the operations of the second stage,

1) investigation of mineralization indications and tracing up the variations of components and structures of the host rocks,

2). geochemical survey in grid pattern by Cu, Zn, and Pb in the soils,

3) investigation to trace up the specified dolomite by structural borings.

In the geophysical operations, it is advisable to apply the magnetic survey in the second stage and electric survey (IP method) in the third stage.

Chapter 2. Brief Summary of Survey

2-1 Purpose of Survey

Present survey was performed as the geological operations of First Year Phase for the mineral resources development in the central part of the Cordillera Oriental. The operations consisted of the geological reconnaissance in combination with geochemical survey in the area of about 10,000 km^2 (A and B areas), which was the southern half of the entire projected area of about 20,000 km^2, and precise geological survey and geochemical survey in the area of about 100 km^2 including the San Vicente Mine, through which was aimed to make clear the following problems;

(1) In the A and B areas, to make clear the distribution of the Pucara Group where the emplacement of ore deposits are anticipated through the geological reconnaissance and geochemical survey, as well as the data analysis by inspecting various data concerning to the Side Looking Airborne Radar (SLAR), and to obtain the data to extract the areas of higher possibility of ore emplacement.

(2) In the San Vicente area, to make clear how the Pucara Group is situated and distributed in the regional geological structure, through the practice of the precise geological survey and geochemical survey with the references to the available geological data ever published.

(3) To establish the most effective system for the exploration of the said areas by data analysis of the geological survey, geochemical survey, and SLAR, as well as the analysis and compilation of geological data for the exploration of bedded lead-zinc deposits.

2-2 Outline of Operation

2-2-1 Operation Territory

(1) Projected Area

The entire projected area is a terrain of about 20,000 km^2 within a polygon demarcated by the following 8 points.

($9^0 00'S$, $75^0 30'W$) ($9^0 00'S$, $76^0 00'W$) ($10^0 00'S$, $76^0 00'W$) ($10^0 00'S$, $75^0 45'W$) ($11^0 30'S$, $75^0 45'W$) ($11^0 30'S$, $75^0 00'W$) ($10^0 00'S$, $75^0 00'W$) ($10^0 00'S$, $75^0 30'W$)

(2) Areas of Geological and Geochemical Reconnaissance for the First Year Phase, (1974) (A and B Area)

The area of geological reconnaissance for the First Year Phase, 1974, is a terrain of about 10,000 km^2 within a polygon demarcated by the following 8 points.

($10^0 00'S$, $75^0 00'W$) ($10^0 00'S$, $75^0 30'W$) ($10^0 30'S$, $75^0 45'W$) ($11^0 30'S$, $75^0 45'W$) ($11^0 30'S$, $75^0 10'W$) ($11^0 15'S$, $75^0 15'W$) ($11^0 00'S$, $75^0 15(W)$ ($11^0 00'S$, $75^0 00'W$)

from which an area made by the following 6 points is subtracted.

($10^0 00'S$, $75^0 15'W$) ($10^0 00'S$, $75^0 30'W$) ($10^0 20'S$, $75^0 30'W$) ($10^0 30'S$, $75^0 15'W$) ($10^0 30'S$, $75^0 00'W$) ($10^0 20'S$, $75^0 15'W$)

(3) Area of Precise Geological and Geochemical Survey for the First Year Phase, (1974) (San Vicente Area)

It is an area of about 100 km^2 involving the San Vicente Mine located at $11^0 18'S$, $75^0 23'W$.

2-2-2 Methods and Period of Survey

(1) Field Operations

Geological and geochemical reconnaissance survey by the stream sediment and soils were practiced in the A and B areas, and in the San Vicente area, precise geological and geochemical survey in combination with geochemical survey by the steam sediments and soils. The SLAR mozaic of scale 1:100,000 and aerial photographs were used in the field works of A and B areas because of the lack of published topographical maps. In the San Vicente area, the published maps of scale 1:25,000 were used. The field works required 74 days from September 2 to November 14, 1975.

(2) Comprehensive Data Analysis

Through the compilation of the field data and the various pre-existing data, general analysis was attempted to make clear the geological structure and mineral resources of the A and B areas, and at the same time, it was investigated how to establish the most effective system of the exploration. Compilation and analytical works required 7 months from December 1975 to June 1976.

2-2-3 Organization of Survey Team

The field operations and data analysis was executed by the Mitsui Kinzoku Engineering Service Co., Ltd. with the cooperation by the Geological Survey, the Republic of Peru (Institute de Geologia y Mineria).

Members of the survey team are as follows;

Leader	Shigeaki Yoshikawa	Mitsui Kinzoku Engineering Service Co., Ltd.
General supervision and liaison	Hiroaki Niki	Japan International Cooperation Agency
"	Shinsei Terashima	Metal Mining Agency of Japan
"	Akio Hoshino	"
Members (Geological survey)	Yasumasa Fukahori	Mitsui Kinzoku Engineering Service Co., Ltd.
"	Nobuo Saito	"
"	Yukichi Tagami	"
"	Ikuhiro Hayashi	"
"	Masataka Oochi	"
General supervision and liaison	Sigfirido Narvaes L.	Geological Survey, the Republic of Peru
Counterparts	Salvador Mendivil E.	"
"	Carlos Guevara R.	"
"	Julio Caldas V.	"
"	Edgar Valdivia V.	"
"	Julio Cezar Zedano C.	"

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Geological Geochemical Reconnaissance Survey in the Southern Block (the A & B Areas)

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Chapter 1. Outline of Survey Operations

1-1 Purpose of Survey

In the geological operations of the First Year Phase for the mineral resources development in the central part of Peru, geological survey in combination with geochemical survey was performed mostly in the A and B Areas of 10,000 km^2 which occupied the southern part of the entire projected area of about 20,000 km^2. The purpose of operations was to make clear the distribution of the Pucara Group in which the existence of ore deposits was anticipated and to extract the areas of high possibility of emplacement of the deposits.

It was aimed not only to extract the areas of high potentiality for mineral resources, but also to establish the most effective system of prospecting the bedded lead-zinc deposits, through the careful analysis of all the field data from geological and geochemical surveys together with the results of chemical examinations on the geochemical samples obtained through the said operations.

1-2 Field Operations

1-2-1 Geological Geochemical Reconnaissance Survey

The area of geological reconnaissance covers about 10,000 km^2 (the A Area) which occupies nearly southern half of the entire projected area for the survey of Central Peru. The routes of survey were so arranged in principle that they would intersect perpendicularly to the major lines of geological structure. The interval of the routes was fixed at 10 km as a rule in the area of about 2,800 km^2 which involved the Pucara Group (the B Area), and at 20 km in the rest of about 7,200 km^2. Along with the ground survey, aerial photos were used to confirm the ground locations and SLAR photo mosaics for geological recording.

Accessibility of the A and B Areas was extremely deficient except for the central part. The ground survey had mostly to depend on foot, especially in the slopes of western highland where the auto-roads were almost unavailable and even the survey of horse back was allowed only in the limited parts due to the extremely steep topography. The eastern jungle also lacked land trails where light aeroplane and motor-boat were only the facilities to access, although some pastures were scattered along the major rivers. The survey of the jungle area experienced the extreme hardships, as most of the area was entirely unexplored land and any data to avail the recognition of position was entirely lacking.

The field operations were performed in 62 days from September 6 to November 6, 1975. Considerable trouble was experienced during the period in the central and northern parts due to traffic interruption caused by unusual floods.

1-2-2 Geochemical Survey

This survey was practiced on the stream sediments and soils for the purpose to obtain the informations regarding to the ore deposits in the vast projected area. The stream sediments were collected whenever the geological survey encountered rivers and tributaries. The soils were collected from the B_1 bed on each of the survey route. Sample collection was tried as much as possible so that two samples either from sediments or soils at every one km on route the geological survey.

1-3 Indoor Works

Followings were the indoor works exercised to examine the data and samples obtained from the field operations.

1-3-1 Chemical Analysis of Ores

Chemical analysis was made on 12 samples by atomic absorption method, which were collected from the ore deposits and ore indications.

1-3-2 Chemical Analysis of Rocks

Chemical analysis was made on 6 samples of igneous rocks, which were subjected to age determination, to examine their chemical compositions.

1-3-3 X-ray Diffraction

X-ray diffraction method was applied for 2 clay samples for the identification of clay minerals.

1-3-4 Microscopic Examination of Thin Sections of Rocks.

Microscopic examination was made on 144 thin sections of the representative rocks.

1-3-5 Microscopic Examination of Polished Sections of Ores

Microscopic examination was made on 16 polished sections of the representative ores.

1-3-6 Age Determination

Age determination was made on 6 samples of the representative igneous rocks to make clear the ages of intrusion.

1-3-7 Identification of Fossils

25 specimens of collected fossils were identified to determine the geological ages of sedimentary formations.

1-3-8 Geological Interpretation by Aerial Photos and SLAR Mosaics

These were done to clarify the geological structure.

1-3-9 Chemical Analysis of Geochemical Samples

Chemical analysis by atomic absorption method was made on 2,595 geochemical samples (1,500 from soils and 1,095 from stream sediments) to detect 3 indicative elements of Cu, Zn, and Ni, which were considered effective for prospecting ore deposits.

1-3-10 Chemical Analysis of Minor Elements in the Carbonate Rocks

Two indicative elements of Zn and S were analized quantitatively on the samples of carbonate rocks, in order to find out the relation between mineralization and minor elements contained in the carbonate rocks.

1-3-11 Pollen Analysis

Pollen analysis was tried on 10 rock samples to verify therir geological ages.

1-3-12 Determination of Magnetic Susceptibility

This was done on 100 rock specimens to investigate the adaptability of magnetic survey.

1-3-13 Determination of Filling Temperatures of Fluid Inclusions.

The filling temperatures of fluid inclusions in five ore samples were determined for the guidance to consider the genesis of the bedded lead-zinc deposits of San Vicente type.

Chapter 2. Geographical Environment

2-1 Location

The Areas A and B cover a region full of topographic Varieties, extending from the East Andes through inter-Andean basins and the Sub-Andes towards Amazonian low lands, with total range of 10,000 km^2 as already stated.

The region belongs to the administrative divisions of Departamento Junin in the south, Departamento Pasco in the north, and Departamento Huanuco at a part of extreme north.

The published topographic maps cover the southwestern part only, and the aerial photos so far available are not the ones systematically taken.

2-2 Accessibility

The accessibility from the City of Lima, the Capital of Peru, to San Ramon, located a little south of the center of the region, is availed by regular flight service of domestic air line once a week, or by regular bus service of several trips every day following National Highway No. 20 across the Andes. Distance from Lima to San Ramon is 308 km which is cruised by car in about 7 hours.

The traffic condition of the Areas is extremely deficient except the district of inter-Andean basins. Many auto-roads are spread on the highland near the Junin Pampa in the west, but the eastern slope has scarcely none of auto-road.

Many auto-roads are spread in the inter-Andean basins near San Ramon and Oxapampa constructed for agricultural and forestry developments, but most of them are not so well-maintained that become unpassable except a part time of dry season. No road is available to reach to the northeastern jungles, where mountain trails are seen only partly with scarcely none of the inhabited

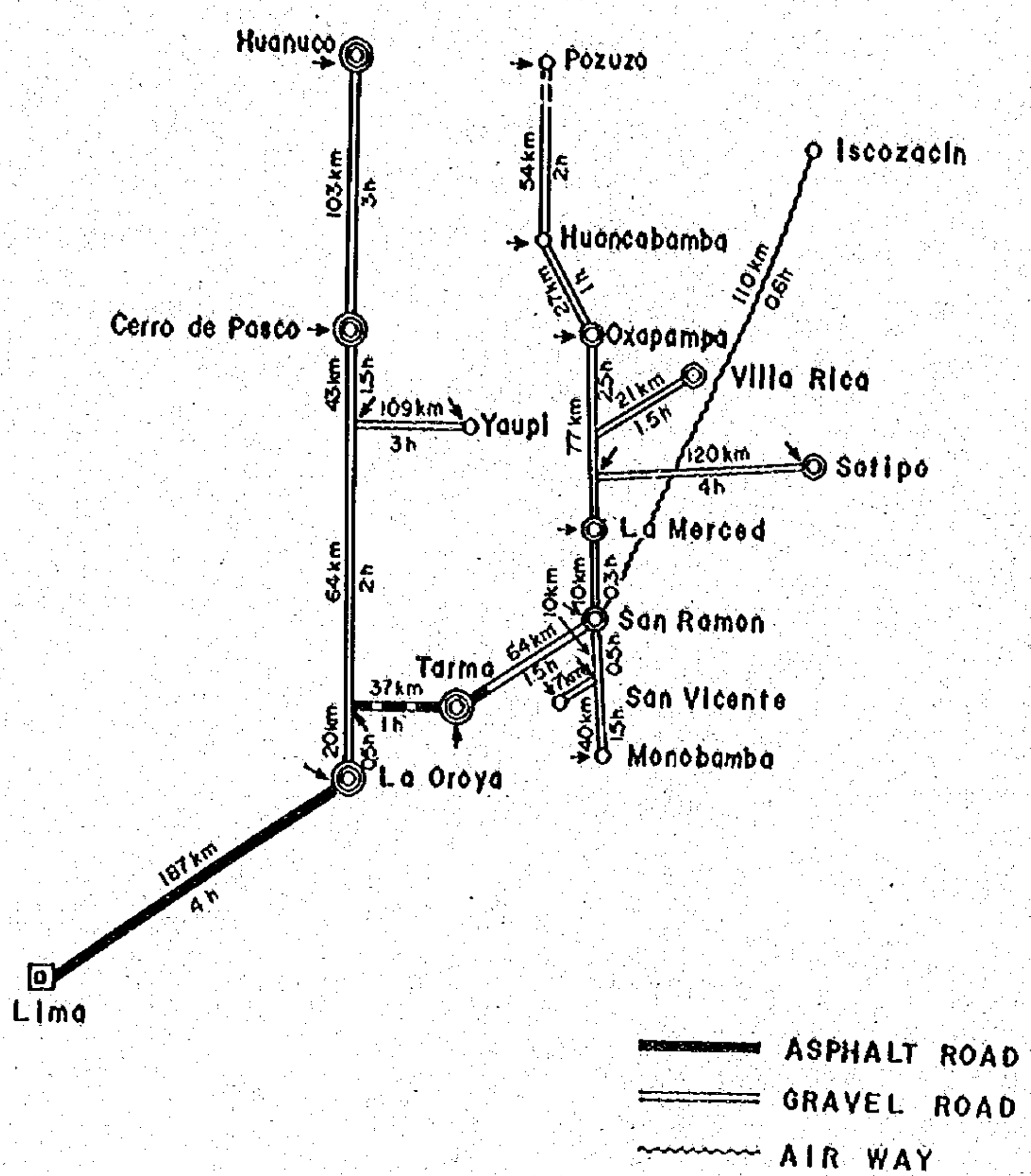

Fig. I Accessibility Map of Surveyed Area cottage. The traffic in the jungles is so deficient that boats are the only available traffic facilities, though along big rivers partly.

The main traffic systems and accessible times in the Area are shown in Fig. 1.

2-3 Climate

Climate of the Area may be classified into cold-mountain type in the west, wet-subtropical type in the inter-Andean basins, and wet-tropical type in the northeast. The western highland of cold-mountain type has dry and wet seasons by the influence of monsoon. Difference of altitude also affects much to the difference of temperatures in day and night, but generally speaking, its climate resembles to that of late fall in the central Japan. Dry and wet seasons are distinct in the inter-Andean basins of wet-subtropical climate. It has been said that the dry season continues from April to September and the wet season from October to March next year, though with considerable local variations. This terrain is so located that heavy rain is discharged from the front of wet air stream flown up from the Amazonian low lands to collide with the Andes. Almost always the terrain is thickly clouded, and especially in the wet season when the Paciffic pressure becomes lower, couldy days will continue. The highest daytime temperature during the dry season reaches as high as 30° C, but it descends as low as 13° C or so in the night. Humidity is always high and generally speaking the climate resembles to that of early summer in the southern Japan. It is hot throughout the year in the northeastern district of wet-tropical type, with average temperature of about 28° C. Humidity is also extremely high and especially it becomes hotter with more humidity from October to April next year when the rain fall is increased.

2-4 Vegetation

In the westren district of the cold-mountain type climate, the highland above 4,500 m S.L. is mostly waste land with sparcely grown weeds. The land below 4,500 m is the pampas with sporadic growth of tall trees like eucaliptus along the streams. In the land below 4,000 m S.L., potatoes fitted for the cold terrain are cultivated and the pampas are used for pastures. The inter-Andean basins are grown mostly by the forests of broad leaf trees, among which those along the roads are cut down to be sent to Lima. The land covering mountain foots and flat lands are cultivated for the orchards of banana, papaya, pineapple, and orange, being the important supply center of fruits to be consumed in Lima.

The northeastern district of the wet-tropical type climate is thickly covered by jungles, which are entirely the primeval forests except some patches along the streams opened for pastures.

Chapter 3. Topography

3-1 Topographic Provinces

The region involving the Area may be classified into the topographic provinces of the western highland, the inter-Andean basins, and the northeastern low land. Each of the province has its own geological and topographic history to have been developed, of which features will be given below.

3-2 Western Highland

The western highland can be divided into the terrains of eastern margin of the East Andes and steeply sloped terrain developed between the East Andes and inter-Andean basins. The East Andes consists of Paleozoic formations, which is sharply dissected into narrow and long ranges by a group of streams flowing into the River Amazon. The Kars and crater lakes of younger volcanism are recognized in the highland above 4,000 m S.L. The valleys between these ranges are filled up by Neogene volcanics and glacial deposits, some of which present peneplains. In the steeply sloped terrain between the East Andes and inter-Andean basins, stream erosion is extremely intense so that the V-shaped valleys are well developed in the granitic terrain with wedge like summits by the dendric stream system. In the terrain of metamorphic and sedimentary rocks, the topography is generally gently sloped on top with steep cliffs on sides. Especially in the limestone terrain, the U-shaped valleys are developed with many steep cliffs.

3-3 Inter-Andean Basins

The inter-Andean basins can be divided into the East Andean slope, medial basins, and the sub-Andes. The East Andean slope consists of Mesozoic sediments mostly of limestone, and the U-shaped valleys are well developed with steep cliffs in the limestone terrain.

The basins are consisted of coarse-grained granite, conglomerate, and sandstone, presenting more or less gentle topography. River terraces are well developed along the main stream which flows in the central part from south to north, and especially, three staged terraces are developed near San Ramon. The gentle slopes and flat lands are cultivated for agricultural plantation.

The terrain of the sub-Andes consists of granitic rocks and Mesozoic sediments intercalating limestone, and its topography is specially steep in the limestone and younger intrusive territories, where the land is so well vegetated as to leave sparce rock exposures.

3-4 Northeastern Low Land

The land is mostly occupied by the low land of less than 1,000 m in altitude, and especially the northeastern corner is covered by thick jungles where the land is flat and the river is meandering. Some parts of the terrain of Mesozoic sediments show considerably steep topography, while the terrain of Cenozoic sediments shows the hilly topography with gentle slopes. Between these terrains, river terraces and fans are locally developed along the major streams.

Chapter 4. General Geology of Surveyed Area

4-1 *Geology (cf. Fig. 2)*

The pre-Paleozoic metamorphic rocks are scattered like roofpendants in the district covering the East Andes and the up-stream of the River Amazon, specially in the East Andes. The trend of their distribution is in the direction of NNW—SSE, being coincident to the general trend of geological structure of this region.

The oldest sediments in this region is the middle and upper Ordovicean formations mostly consisted of submarine lutite. Covering them with parallel unconformity, there overlies the formarion of thick layers of lower and middle Devonian lutite, sandstone, and quartzite. The Ordovicean and Devonian sediments are widely distributed all over the East Andes.

The upper Paleozoic formations are also distributed, covering widely from the East Andes to Sub-Andes, which are represented by the Ambo Group, consisting of lower Carboniferous sandy and argillaceous sediments of terrestrial origin, and the Copacabana-Tarma Group, consisting of upper Carboniferous to lower Permian lutite, marl, and limestone. After the deposition of them, upheaval caused erosion of them, of which clastics supplied themselves to build up the Mitu Group widely distributed in this region. The Pucara Group of upper Triassic to lower Jurassic is mostly consisted of carbonate rocks, which deposited over the Mitu Group with a very short time lag. The later transgressions and regressions gradually removed towards east, which are represented by the regressional formations of Sarayaquillo and Oriente Groups and the transgressional Chonta Group, being distributed in the direction of NNW—SSE over the East Andes located in the east of this region. In the district of Amazonian low land, the Contamana Group of Tertiary clastic rocks, composed mostly of sandstone and lutite, is widely distributed, which was deposited by erosion of successively upheaved lands.

Quarternary sandstone and conglomerate of alluvial and lake sediments are deposited along the valleys and in the inland depressions.

Among the igneous rocks, the granitic rocks presumably of late Paleozoic intrusion are widely distributed in this region in the form of batholiths, and the dioritic rocks of middle Mesozoic intrusion and the porphyries of late Cretaceous to early Tertiary activities are distributed in the forms of stocks, apophyses, and lava flows. The volcanic rocks of middle to late Tertiary volcanisms are also scattered in the East Andes.

4-2 Geological Structure and History

The East Andes is composed mostly of Paleozoic formations. Complicated foldings and faultings either of normal or reverse are widely developed, but the general structural trend is extending in the direction of NNW—SSE. Many faults are developed in the front zone of the East Andes, or the zone ranging from the Andes to the Amazonian low land through the Sub-Andes, some of which are shown by the steep fault scarps of several hundred meters high. Many foldings are observed from the East Andes to Sub Andes, but the ups and downs of the folding become gentler towards east from them and the formations lie almost flat near the Brazilian border.

The surveyed area is the part of intense folding and many of the foldings are asymmetrical ones of which axial planes dip to the east and are cut by the westerly dipping reverse faults. The metamorphic rocks observed mostly in the East Andes are said to have been formed during the cycle of sedimentation and orogeny took place in pre-Paleozoic or early Paleozoic Era.

Orogenic movement took place twice during Paleozoic Era, and the formation composed mostly of submarine lutite was deposited in relation to the first movement in early Ordovicean Period. Sedimentation continued from Devonian to late Permian Periods though intermittently.

Dominant transgression took place from late Paleozoic to Mesozoic Eras and sedimentation continued till late Cretaceous, resulting in the repeated deposition of clastic rocks such as lutite and thick layers of limestone.

After the orogeny from late Mesozoic to early Cenozoic Eras, erosion continued till the end of Tertiary, resulting in the wide deposition of clastic rocks mostly of lutite.

4-3 Mineral Resources

The mineralization which derived the metallic ore deposits in Peru is related to the orogenic movements to have built up the Andes Mountains and associated volcanisms. During Paleozoic Era, two cycles of sedimentation took place under geosynclinal environments where the present Andes sits on, and they ceased upon the activation of deformation and volcanisms. The first cessation was in late Devonian and the second was in middle Permian. The ore deposits derived form such activities of deformation and volcanisms are scattered in the East Andes. In late Triassic Period, the Andes geosyncline was performed in the similar area.

After a short period of deformation and volcanisms in middle Jurassic Period, this geosyncline was further developed, but sedimentation was ceased upon the activation of orogeny and volcanisms which took place from late Cretaceous to Tertiary Periods. The ore deposits related to the orogeny of this epoch are the most important ones around the Andes region.

Many of the deposits in the East Andes are fissure-filling type, but those of replacement and disseminated types are also found. Main metallic minerals are of gold, silver, copper, lead, and zinc. It has been made clear recently that the pre-Paleozoic metamorphics contain basic rocks in which the deposits of chromium, cobalt, and nickel are emplaced. And it is also being clarified that not only the bedded lead-zinc deposits are embedded in the Mesozoic limestones, but also the contact deposits of copper, lead, and zinc have been formed at their contacts with intrusive rocks.

Chapter 5. Geology of the Southern Block (the A and B Areas)

5-1. General View of Geological Setup

The main constituents in the western part of the region are the Pre-Cambrian metamorphic series, the sediments deposited from middle Paleozoic to early Mesozoic Eras, and the batholothic granites of Paleozoic intrusion penetrating some of the sediments. There are also found the dioritic rocks of Jurassic intrusion and Tertiary porphyries and volcanics of intermediate to acidic nature, penetrating the said formations.

In the central part, the sedimentary formations deposited from late Paleozoic to Mesozoic Eras overlie the basement composed of the said batholithic granites. These sedimentary formations contain some of the thick layers of limestone. There are dioritic rocks of Jurassic intrusion penetrating the granites and some of the said formations.

In addition to them, intermediate to acidic porphyries and volcanics of middle Tertiary are distributed in the northern part.

Sedimentary formations deposited from late Mesozoic to middle Cenozoic Eras are widely distributed in the eastern part.

5-2. Metamorphic Rocks

Most of the metamorphic rocks are distributed in the southwestern highland where they occur like roof-pendants and form a belt extending in NNW-SSE. The metamorphic rocks are composed mostly of gneisses and schists, associating basic or ultrabasic intrusives and granites occasionally. Gneisses are dominant in the east, consisting mostly of grayish-white biotite-gneiss in association of mylonitized two-mica granite and metamorphosed granite.

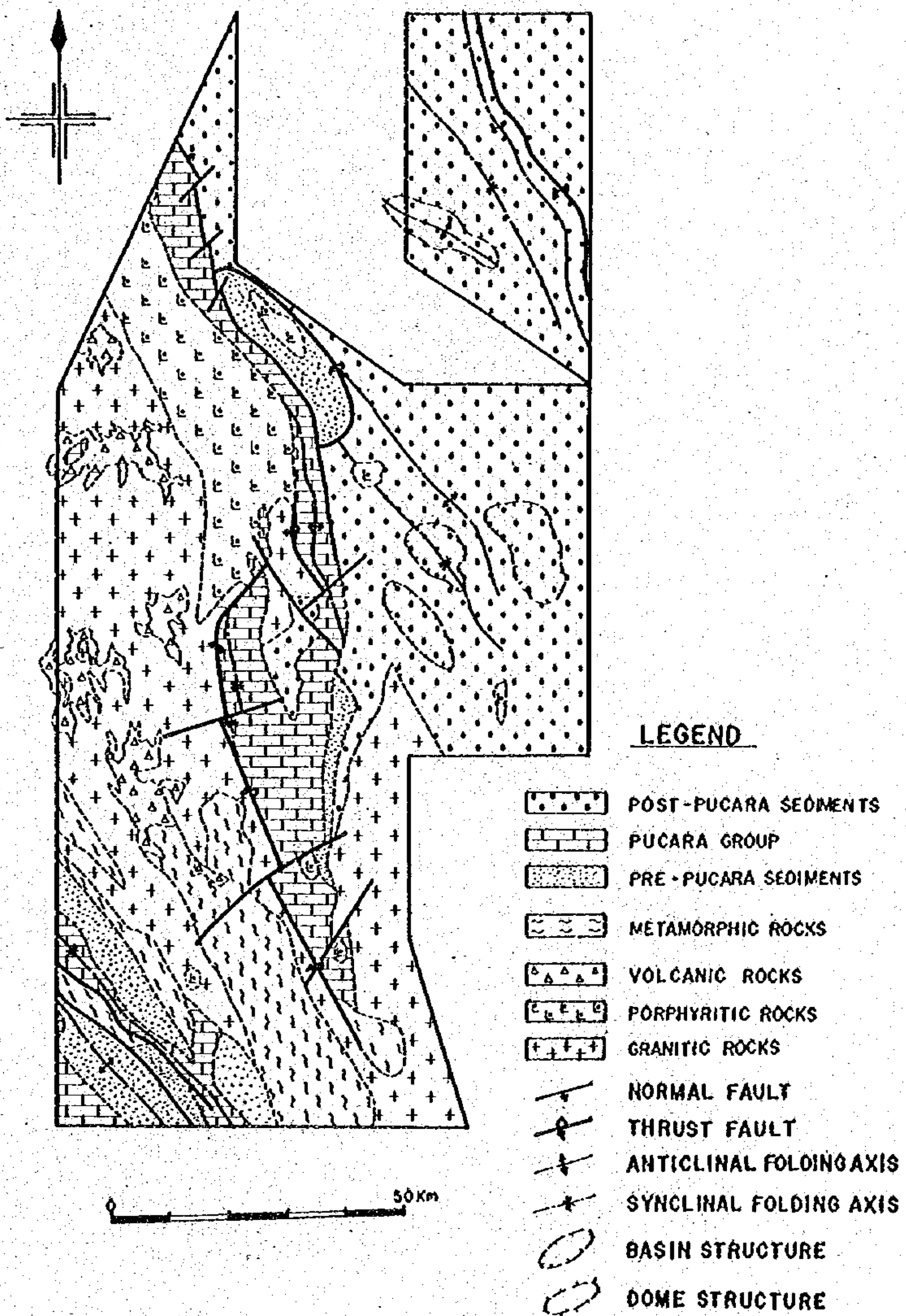

Fig.2 Structural Map of the Surveyed Area

Table. I Generalized Geological Column of the Surveyed Area

AFTER BELLIDO, E.(1969)
LEVIN, M & SAMANIEGO, A(1975)

GEOLOGICAL AGE			GEOLOGICAL UNITS	COLUMNAR SECTION	IGNEOUS ACTIVITY	DESCRIPTIONS: SEDIMENTARY & METAMORPHIC	DESCRIPTIONS: IGNEOUS
CENOZOIC	QUATERNARY	HOLOCENE	ALLUVIUM			GRAVEL SAND & CLAY	
		PLEISTOCENE	DILUVIUM				
	TERTIARY	PLIOCENE					
		MIOCENE				UPPER PART : BROWN LUTITE WITH SANDSTONE & MUDSTONE	VOLCANIC BRECCIA
		OLIGOCENE	1,400m+			LOWER PART : RED LUTITE, SANDSTONE & MUDSTONE WITH GREY LIMESTONE	ANDESITE, RHYOLITE & DACITE
		EOCENE	CONTAMANA GROUP (LOURDES FORMATION) → (400m+)			(PARACAS FORMATION) CONGLOMERATE, SANDSTONE & MUDSTONE	
		PALAEOCENE					DIORITE-PHOPHYRITE, QUARTZ-PHOPHYRY, GRANITE-PHOPHYRY & APLITE
MESOZOIC	CRETACEOUS	LATER	CHONTA GROUP 1,900m+			UPPER PART : RED LUTITE WITH SANDSTONE MIDDLE PART : GREY LIMESTONE LOWER PART : RED LUTITE WITH SANDSTONE & SHALE	
		MIDDLE					
		EARLIER	ORIENTE GROUP 1,000m+			RED TO WHITE SILICIOUS SANDSTONE WITH LUTITE & CONGLOMERATE	
	JURASSIC	LATER	SARAYAQUILLO FORMATION 1,000m+			UPPER PART : SANDSTONE MIDDLE PART : LUTITE SHALE & SANDSTONE LOWER PART : CONGLOMERATE WITH LUTITE	
		MIDDLE					DIORITE & GRANODIORITE COMPLEX
		EARLIER	PUCARA GROUP 1,400m+			GREY TO BLACK LIMESTONE & GREY DOLOMITE WITH THIN BEDS OF LUTITE & SANDSTONE	
	TRIASSIC	LATER					
		MIDDLE					PORPHYRITE & ANDESITE
		EARLIER					
PALAEOZOIC	PERMIAN	LATER	MITU GROUP 1,300m+			UPPER PART : SANDSTONE & LUTITE MIDDLE PART : SANDSTONE & LUTITE WITH LIMESTONE CONGLOMERATE LOWER PART : CONGLOMERATE WITH SANDSTONE & LUTITE	GRANITE EASTERN PART : RED GRANITE WITH GREY GRANODIORITE WESTERN PART : GREY TO GREEN GRANODIORITE
		MIDDLE					
		EARLIER					
	CARBONIFEROUS	LATER	COPACABANA - TARMA GROUP 1,900m+			GREY TO DARK GREY LIMESTONE & PHYLLITIC SHALE. PARTLY RED CALCAREOUS SHALE DOMINANT	
		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					
PRE-CAMBRIAN			BASAL COMPLEX			GNEISS & SCHIST WITH SERPENTINITE	

LEGEND

SEDIMENTARY ROCK
- SAND
- GRAVEL
- LUTITE, SHALE & PHYLLITE
- SANDSTONE
- CONGLOMERATE
- LIMESTONE

METAMORPHIC ROCK
- GNEISS & SCHIST

IGNEOUS ROCK
- VOLCANIC BRECCIA
- ANDESITE, RHYOLITE & DACITE
- DIORITE-PHOPHYRITE, QUARTZ-PORPHYRY, GRANITE-PHOPHYRY & APLITE
- DIORITE
- PORPHYRITE & ANDESITE
- GRANITE

UNCONFORMITY
CONFORMITY

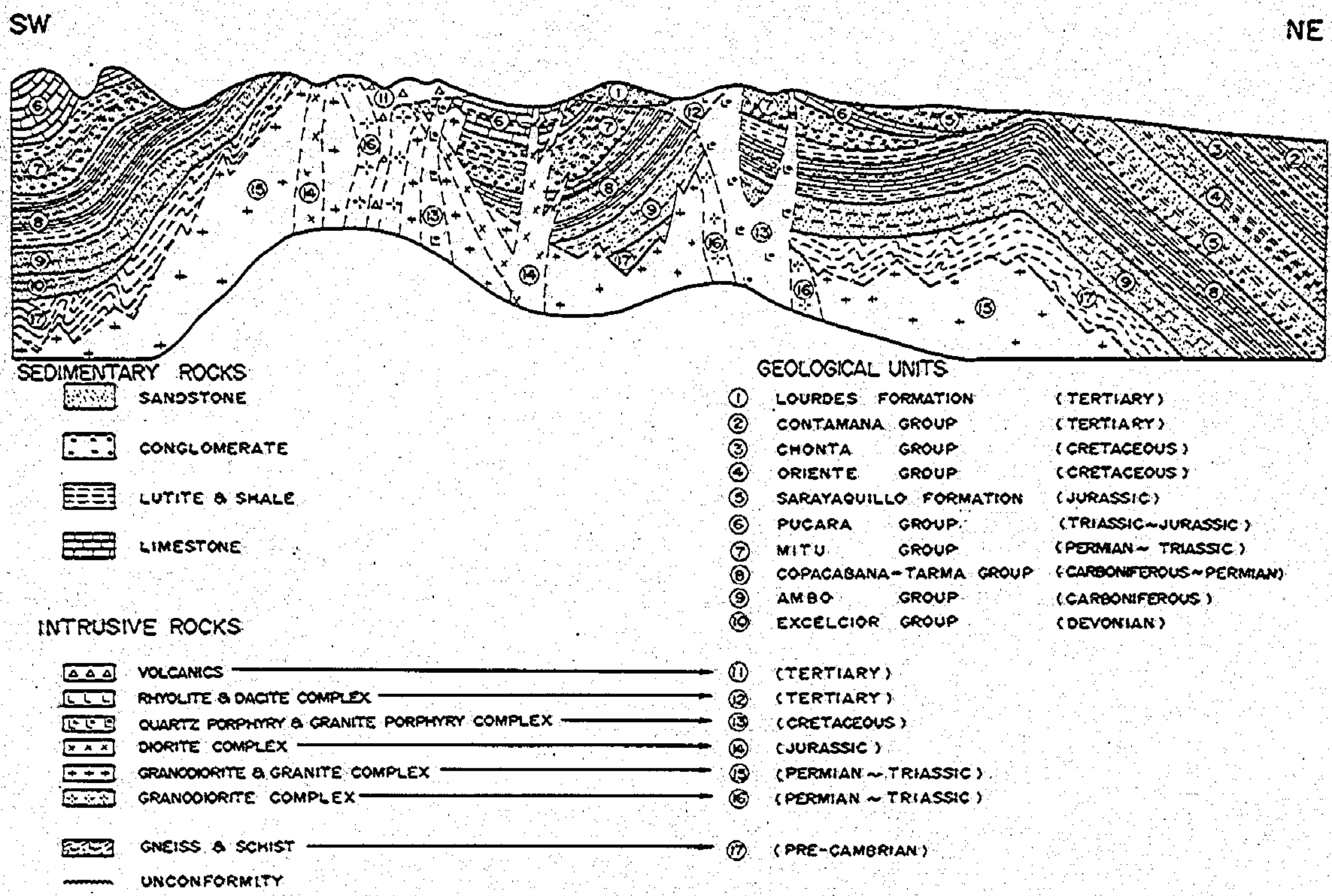

Fig. 3 Schematic Geological Profile of the Surveyed Area

Schists are dominant in the west, which are mainly hornblende-quartz schist, muscovite-quartz schist, and chlorite schist. Quartz contained in these schists show distinct wavy extinction, and hornblende and biotite are more or less altered into chlorite.

Basic or ultrabasic intrusives are found in the metamorphic series but serpentine is the major, of which principal mineral is chrysotile, though considerable parts are altered into clay minerals.

Folding structure of the metamorphic series is rather complicated, but the folding axes of the major structure indicate the direction of NNW-SSE in many cases. (Fig. 2)

5-3 Igneous Rocks

5-3-1 Permian to Triassic Granites

The granitic rocks occupy almost the western half of the A and B Areas. The west side of the central sedimentary formations is occupied mostly by granodiorite which is called Tarma granite or "Granito blanco". This is, as a whole, medium- to coarse-grained, holocrystalline, white rock, but its feldspars are greenish and locally reddish in the west, and white in the central part.

Principal minerals are quartz, plagioclase, potassium feldspar, biotite, and hornblende, and the potassium feldspar is perthitic microcline. In their compositions, the plagioclase decreases and potassium feldspar increases towards the east, and quartz is less with more hornblende in the west.

Normative composition calculated from chemical analysis of the greenish granodiorite in the west has shown 55.5-63.7% in plagioclase, 21.6-26.6% in quartz, and 14.7-17.9% in biotite. While, the east side of the sedimentary series is widely occupied by fine-granied and holocrystalline granite called San Ramon granite or "Granito rojo".

Principal minerals are quartz, orthoclase, plagioclase, and a little amount of biotite, and perthitic structure is seen in the orthoclase.

As seen in the samples of Nos. 18, 93, and 212, the results of chemical analysis show that they are rich in SiO_2. In the samples Nos. 18 and 212, the proportion of $K_2O + Na_2O$ against $MgO + FeO$ is as high as more than 90%. The white granite of sample No. 93 is an acidic rock rather rich in FeO. The three samples are plotted on the attached ternary diagram of normative minerals of Quartz-Plagioclase-K-feldspar as shown by Fig. 4, which indicates that the three are well gathered in a definite area of the domain of quartz monzonite, and are homogeneous in their chemical compositions.

The results of chemical analysis of "Granito rojo" in the San Vicente Mine area has shown that 34.9% of plagioclase, 26.8% of orthoclase, 35.1% of quartz, and 3.6% of biotite. This "Granito rojo" penetrates "Granito blanco", and the pebbles of "Granito rojo" are found in the basal conglomerate of the Mitu Group. Moreover, some parts of "Granito rojo" contain xenoliths of sediments probably of the Copacabana-Tarma Group of Paleozoic.

According to the results of age determination of these batholithic granites by K-Ar method, "Granito blanco" is intruded in middle Permian (224 m.y.), while "Granito rojo" is in late Triassic (195 m.y.) penetrating the former. But they are interpretted to be of co-magmatic origin, as the facies of transional composition of the two are found locally, too. It is also considered that intermediate dykes (216 m.y.) intruded into already formed batholiths in the later stage of this magmatic activity.

5-3-2 Jurassic Diorites

The Jurassic diorites are scattered as stocks of a few kilometers diameters in the western and central parts of the A and B Areas, penetrating the sedimentary series and granites. Several stocks consisting of fine grained diorite and granodiorite porphyry are found near the San Vicente

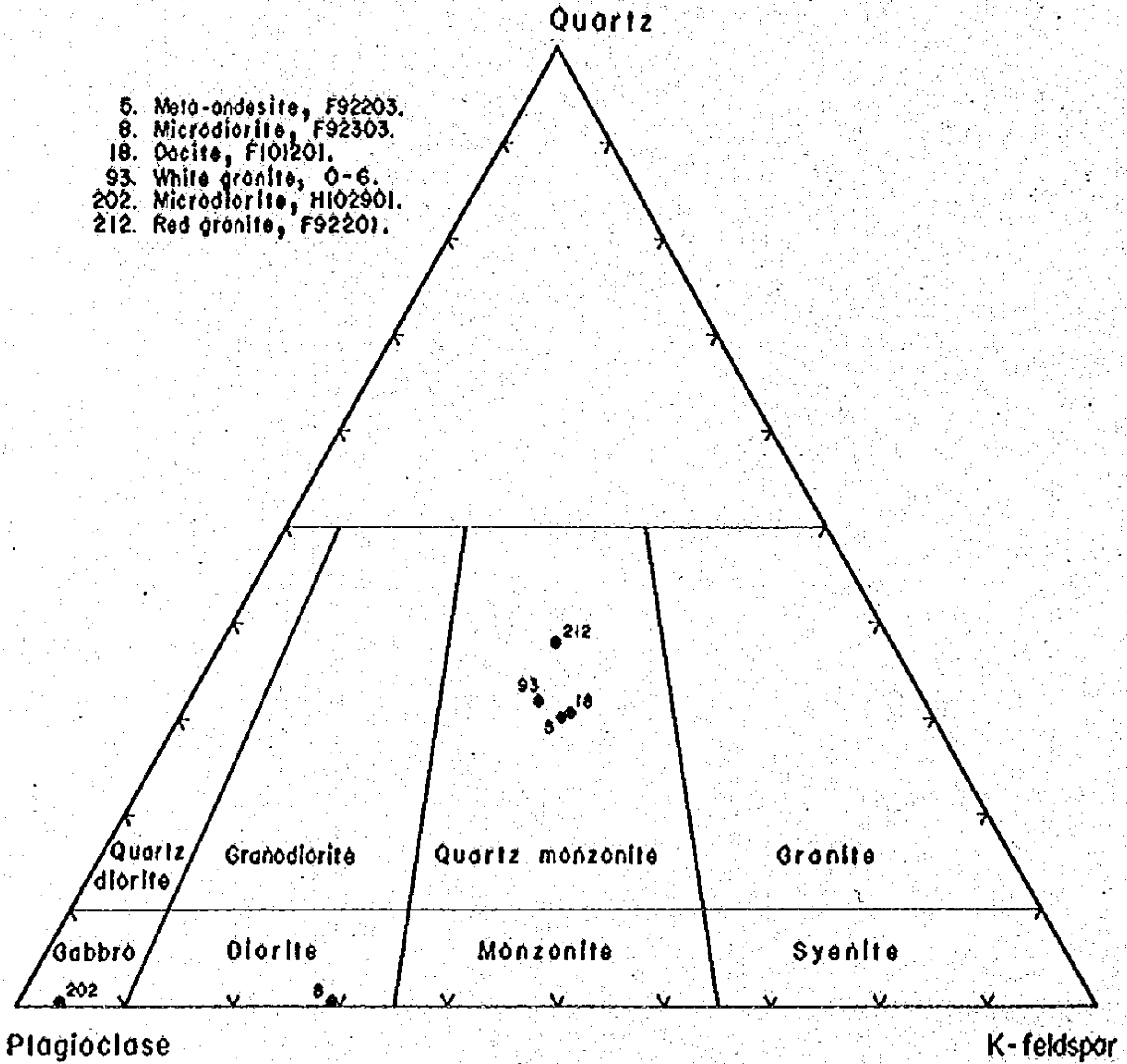

Fig. 4 Ternary Diagram of Normative Quartz-Plagioclase-K-feldspar calculated from Chemical Analysis.

Mine, and each of them shows a tendency to be dioritic in the margin and granodioritic in the center. Stocks of coarse grained and homogeneous diorite are found in the north of Villa San Luis, and many occurrences of diorites with various lithofacies are known in the western highland, penetrating the batholothic granites, but the present survey actually visited only some of them.

In many cases, each stock differs in its lithofacies, and within a single stock facies are so variable as to be fine-grained diorite, granodiorite, and fine-grained granodiorite, but generally speaking, they are intermediate hypabyssal rocks of porphyritic texture. Any of them are holocrystalline with fine- to medium-grained granitic texture, bright gray or dark gray, and often their dark minerals are arranged linearly.

Principal minerals of the diorites are hornblende and plagioclase, and a little amount of biotite, quartz, apatite, and opaque minerals, are contained. Some parts of biotite and hornblende are altered into chlorite, and plagioclase is into sericite, too. Biotite, quartz, and plagioclase are faintly deformed.

As seen in the samples of Nos. 5, 8, and 202, the results of chemical analysis show that they are less in SiO_2, which may indicate rather basic rocks comparatively richer in MgO and FeO. The three samples are plotted on the ternary diagram of normative Quartz-Plagioclase-K-feldspar as shown by Fig. 4, which indicates that the sample No.8 belongs to diorite, No.5 to quartz monzonite, and No. 202 is classified to be gabbro. As far as this diagram is concerned, the Jurassic diorites are heterogeneous in composition, and chracteristic is that Nos. 8 and 212 are lacking normative quartz.

5-3-3 Paleogene Intrusives

The Paleogene porphyries consist of the acidic intrusives of batholithic occurrence, extended in the direction of NNW-SSE in the central part of the A and B Areas, and the intermediate intrusives in the forms of stocks or dykes in the east of the acidic intrusives.

The acidic intrusives occur as batholiths with some of them as stocks, penetrating the pre-Mesozoic sedimentary formations and the batholithic granites. But in the "Granito blanco", it is difficult to distinguish it clearly from the acidic intrusives.

They consist mostly of such porphyries as granite porphyry, aplite, quartz porphyry, etc., and the batholiths and stocks are composed of the combinations of such various rock facies. Fine-grained aplitic rocks are distributed in the west of the batholithic porphyries in the form of stocks.

Granite porphyry is leucocratic and holocrystalline rock, of which dominant mafic mineral is biotite, though occasionally altered intensely.

Quartz porphyry has the phenocrysts of quartz, potassium feldspar, plagioclase, and biotite, with its groundmass composed of quartz, plagioclase, and potassium feldspar. The plagioclase is partly altered into sericite and the potassium feldspar is characterized by microclinal or perthitic structure. Some biotite is altered into chlorite and epidote.

The intermediate porphyries, penetrating the pre-Mesozoic sediments, consist of granodiorite porphyry and diorite porphyrite, but there are found locally the monzonitic facies which shows the intermediate facies between the acidic intrusives and the said dioritic porphyries.

The granodiorite porphyry shows not much difference in its texture from granite porphyry, but contains less potassium feldspar and biotite and more plagioclase and hornblende than the latter.

Diorite porphyrite has porphyritic texture, containing plagioclase, hornblende, and quartz as principal minerals, in association with a little amount of pyroxene, titenite, and magnetite. Sericite, epidote, chlorite are recognized as secondary minerals.

Monzonite has porphyritic texture, too, and has phenocrysts of plagioclase and potassium feldspar with its groundmass consisted of plagioclase and quartz. Mafic mineral is found as chloritized hornblende. The rock is subjected to intense alteration partly where sericite and such opaque minerals as magnetite and pyrite are abundantly contained.

The Paleogene porphyries are intruded into the Chonta Group of middle to later Cretaceous, and the age determination of them has revealed the epochs of their intrusion are both Eocene; 45 m.y. in the intermediate intrusives and 40 m.y. in the acidic intrusives. The field observation has also recognized the cases when the intermediate intrusives are cut by the more acidic ones.

5-3-4 Paleogene Volcanics

Similarly to the younger porphyries, the younger volcanics consist of the acidic volcanics distributed in the central part of the A and B Areas, and the intermediate volcanics distributed in small scale in the east of the acidic intrusives.

The acidic volcanics consist of rhyolite, quartz porphyry, acidic tuff, etc., and they occur complicatedly intermixed.

The rhyolite is porphyritic and has the phenocrysts of quartz, potassum feldspar, and a little amount of plagioclase and biotite. Recognized are sericite altered from plagioclase, and opaque minerals such as magnetite and pyrite as secondary minerals.

Quartz porphyry does not differ much from what is found amoung the intrusives.

Acidic tuff has the crystals of quartz and plagioclase scattered like phenocrysts, which are cemented by calcite and vitreous substance. Epidote, tourmaline, and opaque minerals are recognized as accessory minerals.

The intermediate volcanics consist of dacite, andesite, and andesitic tuffs, which occur complicatedly intermixed.

Dacite is porphyritic with microcrystalline groundmass, and its phenocrysts are plagioclase, quartz, and hornblende.

Andesite is porphyritic, too, containing the phenocrysts of plagioclase and hornblende, and its groundmass consists of microcrystalline plagioclase and quartz.

The Paleogene volcanics are more or less altered, and sericitization of plagioclase and chloritization and epidotization of colored minerals are commonly observed.

The Paleogene porphyries and volcanics occur intimately interrelated. Wide, batholithic acidic rocks and acidic volcanics are predominant in the west of Huancabamba, while the stocks of intermediate intrusives and volcanics are dominant in the east of Huancabamba.

They are more or less altered, especially some of the intermediate intrusives are intensely altered, where disseminations of pyrite and magnetite are recognized.

5-3-5 Neogene Volcanics

The Neogene volcanics occur to penetrate and to overlie the batholithic granites of the western highlands. Principal constituents are lavas, breccias, tuffs, etc., of andesitic, dacitic, and rhyolitic nature. They are greenish and reddish grey, and sediments like limestone are often exposed as inliers. In addition, some are intruded by the stocks and dykes of diorite and dacite.

The constituting proportions of these volcanics and intrusives in each of the rock facies differ widely by locations. The epoch of their intrusive and effusive activities is not clear, but it may be presumed to be of middle to later Tertiary, as they may be correlated to the volcanics widely distributed in the Andes Plateau.

5-4 Sedimentary Rocks

5-4-1 Classification of Sedimentary Rocks

The areas of sedimentary rocks are divided into two districts in the A and B Areas; the one is a comparatively narrow patch of distribution near Tarma in the southwest, the other is wide area covering the central and northeastern parts. The southwestern part is composed of the older or middle aged sedimentary rocks, while the central and northeastern parts are composed of a series of sediments from middle to younger ages.

As shown on Table 1, they are classified into the following groups and formations from the lower upwards;

Paleozoic,	Excelcior, Ambo, Copacabana-Tarma, and Mitu Groups,
Mesozoic,	Pucara Group, Sarayaquillo Formation, Oriente and Chonta Groups,
Cenozoic,	Lourdes Formation, Contamana Group and Quartornary sediments.

It was made a rule to follow the names of the groups and formations given by Bellido, E. B. (1969) in his works over the Departamentos of Junin and Pasco, but some exceptional names were picked up from the later reports of him in this region or newly given in the present survey.

5-4-2 Excelcior Group

(1) Distribution; It is extended in the direction of NW-SE with the width of 4 km in the southeast of Tarma.

(2) Constituents and Lithofacies; Grey sandstone is dominant in the upper and lower horizons, while the middle is composed of the alternation of well-stratified, dark grey to black, phyllitic shale and grey sandstone. The formation, as a whole, forms a grand anticline of which axial direction is NW-SE, which passes through Tarma, and accompanies several subordinate foldings of axial direction of NW-SE.

(3) Thickness; 700 m +

(4) Relation with the Lower Formation; Unconformable relation is infered at the type locality, although the present survey has not recognized the direct relation with the underlain matamorphic rocks.

(5) Fossils and Correlation; No fossil has ever been found in the present survey, but some Devonian fossils are reported to have been found outside the surveyed area. This Group may be correlated to E.B. Bellido's (1969) Excelcior Group of earlier or middle Devonian, in view of the overlying Copacabana-Tarma Group and resemblance of rockfacies of the constituents.

5-4-3 Ambo Group

(1) Distribution; Being exposed along the national highway about 2 km east of Acobamba, the formation extends in the direction of NW-SE in a belt of about 1 km wide, and its southeastern extension reaches as far as near Villa Tapo.

(2) Constituents and Lithofacies; This Group is composed of comparatively hard and compact, grey sandstone, with local alternation of grey sandstone and black and hard shale. It is found partially metamorphosed to schistose, near Acobamba, where sericite is formed abundantly.

(3) Thickness; 900 m +

(4) Relation with the Lower Formation; Clino-unconformity is recognized against the Pre-Cambrian formations, but the direct contact with the lower seated Excelcior Group has never been recognized. But it is said at the type locality that the relation to the Excelcior Group is clino-unconformity.

(5) Fossils and Correlation; No fossil has been found, but it may be correlated to E.B. Bellido's (1969) Ambo Group of earlier Carboniferous from the lithofacies and the overlying Copacabana-Tarma Group.

5-4-4 Copacabana-Tarma Group

(1) Distribution; This group is distributed in a zone extending in the direction of NW-SE near Tarma, as well as in small patches as "windows" in the low land along the Rio Perene near Puerto Yurinaki.

(2) Constituents and Lithofacies; It is consisted mostly of grey or dark grey limestone and phyllitic shale, in which the limestone near Acobamba is ill-stratified, compact, hard rock, while reddish calcareous shale is dominant in its southeastern extension.

Near the Rio Perene, it consists of well-stratified, hard and compact limestone, which is locally affected by intense dissemination of pyrite. There exists a large anticlinal structure near Tarma with the axial direction of NW-SE, which is occupied widely by the Copacabana-Tarma Group with the exception of partial exposures of the Excelcior Group at its saddle. Even in both wings of this large anticlinal structure, repetition of minor anticlines and synclines is observed. A large synclinal structure exists near Acobamba, where the Copacabana-Tarma Group occupies a part of its eastern wing and is extended as a zone in the direction of NW-SE.

(3) Thickness; 1,900 m +

(4) Relation with the Lower Formation; There is no distinct boundary to the underlying Ambo Group, but as the bedding planes of both Groups are parallel at very close approach, and as it has been said in parallel unconformity at the type locality, it may safely be infered to be in the relation of parallel unconformity in this district, too. The Group is in contact with the Pre-Cambrian metamorphic rocks but both are bordered by a fault of NW-SE direction.

(5) Fossils and Correlation; This Group may be correlated to E.S. Bellido's (1969) Copacabana-Tarma Group from the following evidences;

1) the late Carboniferous fossile have been found from the lower limestone of this Group near Acobamba,

2) it can be presumed to be in parallel unconformity with the underlain Ambo Group,

3) The Group is overlain by Mitu Group, presumably of Permian.

In the present survey, both groups are combined in one group, in view of the close resemblance of their lithofacies.

This Group contains the fossils of Fusulina, one of which was identified as

Fusulina peruana (Mayer)

(by Ass't. Prof. Hisayoshi Igoo, Tsukuba Univ. Japan)

which may indicate the middle Carboniferous, and be correlated to the upper Atokan Series of Pennsylvanian, USA.

5-4-5 Mitu Group

(1) Distribution; This Group is distributed not only in the Inter-Andean basins of the central part of this region in a zone of N-S direction, but also in a zone of NNW-SSE direction near Tapo of the southwestern part. It is also distributed over the granitic rocks like roof-pendants near Villa Yaupi on the slope of western highland.

(2) Constituent and Lithofacies; It consists of conglomerate, sandstone, and lutite, locally intercalating greenish purple pyroclastics and volcanic rocks. Proportion of conglomerate increases in the lower horizon, where thin layers of sandstone and lutite are intercalated. Various kinds of pebbles such as granitic rocks, metamorphic rocks, and sediments, are contained. Among the pebbles of granitic rocks, contained is the pebbles of "Granito rojo" which forms the basement of the area.
Not only sandstone and lutite, but also thin layers of sandstone containing calcareous pebbles are found in the middle horizon. The layer of calcareous conglomerate is typically seen near the San Vicente Mine, and as the layer is only the one of such kind as well as it has been fairly traced laterally, it may serve as a key bed.

(3) Thickness; 1,300 m +

(4) Relation with the Lower Formation; Although no fossil has been found, this formation may be correlated to E.B. Bellido's (1969) Mitu Group, as it is in relation of parallel unconformity or weak clino-unconformity with the overlain Pucara Group, as well as in clino-unconformity with the underlain Copacabana-Tarma Group, which will be supported by the lithofacies, too.

5-4-6 Pucara Group

(1) Distribution; It is distributed zonally extending in N-S in the central part of the region with its widest width near the Rio Oxabamba. It is also distributed near Tarma of the southwest, extending in the

direction of NNW-SSE in contact with the lower seated Mitu Group. Small patches like roof-pendants are seen over the western granitic rocks, too.

(2) Constituents and Lithofacies; It consists of limestone, dolomitic limestone, and dolomite, sometimes intercalating lutite, sandy limestone, and sandstone. Both limestone and dolomite are various in colors as bright to dark grey, black, etc., and this makes the megascopical distinction difficult, but can roughly be identified by the reaction with hydrochloric acid.

Mepard, F. (1968) classified this Group into three formations at its type locality in East Andes by its lithofacies and fossils. They are named from the bottom upwards as the Chambara, Aramachay, and Condorsinga Formations, of which lithofacies and structural features are given below.

1) Chambara Formation

It is mainly consisted of black limestone with intercalation of sandstone and lutite. A few layers of dolomite and dolomitic limestone are intercalated in the black limestone. Calacareous breccia is also found near the contact with Aramachay Formation. This formation occupies the greater part of the Pucara Group distributed in this region, and these ore deposits of San Vicente and Pichita Carga are embedded in the dolomite layers of this formation.

2) Aramachay Formation

It consists mostly of black limestone and sandy limestone but is clastic in many cases. This may suggest the formation to have been deposited in the basins derived from the orogenic zone. Part of this formation is observed in the west of Tarma, but its distribution is not clear in the central part.

3) Condorsinga Formation

It consists mostly of limestone and sandy limestone, intercalating lutitic sandstone, but no distribution is in the surveyed area.

(3) Stratigraphy;

		Surveyed Area	Type Locality
Chambara Form.	thickness	1,200 m +	1,500 m
Aramachay Form.	"	200 m +	600 m
Condorsinga Form	"	0 m	2,900 m

(4) Relation with the Lower Formation; It is in weak clino-unconformity with the underlain Mitu Group, and locally in parallel unconformity. The Pucara Group in the central part seems to be in parallel unconformity with the Mitu Group, but it is in contact with the granitic rocks, distributed to its west, by clino-unconformity or by faults. It can be seen in the west of Tarma where the Pucara Group overlies the Mitu Group with weak clino-unconformity.

(5) Fossils and Correlation: As no index fossil is available in the Pucara Group of this region, and is ill-preserved if any, the geological age of this Group has not been determined satisfactorily. The Group may be correlated to E.B. Bellido's (1969) Pucara Group from the points that the Group is in parallel unconformity with the upper seated Sarayaquillo Formation, and in parallel- or clino-unconformity with the lower seated Mitu Group, and from the points of discovery of Triassic and Jurassic fossils and the constituents' lithofacies.

The eastern part of the Pucara Group near Tarma is correlated to the Aramachay Formation from its contained fossils and lithofacies of constituents, and all the rest to the Cambara Formation, but no zoning has been tried in this report. The Chambara Formation contains the fossils of bivalves and ammonites, which have been identified as follows;

Bivalves, (by Prof. Minoru Tamura, Kumamoto Univ., Japan)

Bivalve, Gen. & sp.

Pectinid ? Gen. & sp.

Schafhautlia astartiformis munster

Petria cfr. obtusa (Bittner)

Petria cfr. cassiana (Bittner)

Although they are not enough to indicate what subdivision of Triassic or Jurassic Periods, they are considered to indicate Ladinic to Carnic in comparison to the previous data and European affinities.

Ammonite found is identified as

Psiloceras sp. (by Prof. Tadashi Sato, Tsukuba Univ., Japan)

which seems to indicate Lower Hettangian of Lower Jurassic.

5-4-7 Sarayaquillo Formation

(1) Distribution; It has comparatively wide distribution covering the area of the Rio Perene, which flows in the central to eastern parts, and the district towards Paucartambo. Small patches of its distribution are also found near Raymondi and near the Rio Chacos, east of Oxapampa.

(2) Constituents and Lithofacies; The formation is composed of three members, which will be called lower, middle, and upper members for the sake of convenience.

1) Lower Member; This is the basal conglomerate of the Sarayaquillo Formation, which can be observed near the Rio Chacos, east of the Rio. Perene. It is mainly composed of sub-breccias of granitic rocks cemented by the clastics containing the particles of clay size, light to dark purplish in color, and derived from the granitic rocks and limestone. Its thickness and details in the

structure are not clear, but it does not exceed 100 m near the Rio Perene with repeated minor foldings and ill persistence.

2) Middle Member: It is dominantly distributed on the Rio Perene-Paucartambo and near Raymondi. It consists of reddish brown to reddish purple lutite, and the alternation of shale and reddish, fine to medium grained calcareous sandstone, but generally speaking, lutite is more. In the red lutite and red sandstone of this member, are dominantly developed the stringers of gypsum which is the most remarkable feature of the Sarayaquillo Formation.

3) Upper Member; It is consisted of white to light reddish, fine grained sandstone which is best observed near Paucartambo..

(3) Thickness; 1,000 m +

(4) Relation with the Lower Formation; It is in parallel unconformity with the underlying Pucara Group.

(5) Fossils and Correlation; No fossil has been found but it may be correlated to E.B. Bellido's (1969) Sarayaquillo Formation by its well developed occurrence overlying the Pucara Group and lithofacies of the constituents.

5-4-8 Oriente Group

(1) Distribution; It is widely distributed in the area surrounding the Sarayaquillo Formation on the Rio Perene, east of Oxapampa, and in the Sub-Andes east of Iscozacin, and near Raymondi.

(2) Constituents and Lithofacies; It consists mainly of red or light red to white, calcareous sandstone, which partially intercalates red or green lutite and red, quartzose, fine conglomerate.

(3) Thickness; 1,000 m +

(4) Relation with the Lower Formation; This Group overlies the Sarayaquillo Formation conformably.

(5) Fossils and Correlation; Rhynchonellidae (Brachiopoda) has been found from the sandstone of this Group and identified by Prof. Minoru Tamura, Kumamoto Univ.,Japan. But it does not deserve to determine the age. It is considered to be correlated to the Oriente Group, from the points of its conformable development over the Jurassic Sarayaquillo Formation, and from its lithofacies rich in quartzose sandstone. Especially, as its lower member is consisted of white to light red, loose, and coarse grained sandstone, it is considered to correspond to the Cushabatay Formation of the lower member of the Oriente Group.

5-4-9 Chonta Group

(1) Distribution; It is widely distributed in the area covering from the Rio Pozuzo in the north of the region, through Villa Rica, towards the north of the Rio Perene in the east. It is distributed in the Sub-Andes of the northeastern part, and small distribution is found in the west of Raymondi, too.

(2) Constituents and Lithofacies; This Group of this region is composed of three formations, which will be classified for the convenience into the lower, middle, and upper formations in ascending order, of which lithofacies are so characteristic as will be mentioned below.

1) Lower Formation; It is consisted mostly of red lutite with intercalated white, quartzose sandstone and grey shale, and rarely in association with andesite sheets.

2) Middle Formation; It is consisted mostly of bright to dark grey, cleavable limestone with homogeneous appearance, intercalating, though rarely, thin layers of white quartzose sandstone.
It is distributed along the Rio Pozuzo and on the upstream of the Rio Iscozacin. It is in contact with the Pucara Group by faults on the Rio Pozuzo, while it forms a dome structure on the upstream

of the Rio Iscozacin where oil has once been prospected.

3) Upper Formation; It consists of red or reddish brown lutite and fine to medium grained sandstone, accompanying white quartzose sandstone locally, though the red lutite is exceeding quantitatively.

Being composed of the above three formations, this Group can be observed along the auto-road from Paucartambo to the Rio Yocas via Villa Rica continuously from the lower to the upper ones. The boundary between the middle and upper formations is distinctly marked on the surface due to the difference of susceptability of erosion and weathering.

(3) Thickness; 1,900 m +

(4) Relation with the Lower Formation; It overlies the Oriente Group conformably.

(5) Fossils and Correlation; Fossil of Bivalve, Anomia Argentaria was identified from the limestone of the Middle Formation, (identified by Prof. Minoru Tamura, Kumamoto Univ., Japan) which is to belong to the Upper Cretaceous and may serve as an evidence, together with the lithofacies, to cerrelate the Group to the Chonta Group widely distributed in Peru.

5-4-10 Lourdes Formation

(1) Distribution; This Formation is distributed in an elongated zone of 2-4 km wide, extended from the north of the San Vicente Mine towards the west of Paucartambo, passing through the west of San Ramon, and is distributed in Villa Lourdes, too.

(2) Constituents and Lithofacies; It consists of conglomerate containing medium to large sized pebbles, coarse grained arkose sandstone, and grey mudstone. The pebbles consist of all kinds of basement rocks such as granitic rocks, limestone, and metamorphic rocks. Matrix is granitic sand of mal-solidity.

Coarse grained arkose sandstone is contained in a lenticular form in the conglomerate. The Formation is gently folded in general, but locally are found some acute folding structures.

(3) Thickness; 400 m +

(4) Relation with the Lower Formation; It overlies the Mesozoic sediments unconformably.

(5) Fossils and Correlation; Plant fossil of Dictyledon was found in the mudstone, but did not serve for the age determination. (identified by the Dep't. of Paleontological Research, National Science Museum, Tokyo) But it may be presumed to be the sediments of earlier to middle Tertiary from its unconformable relation to the Mesozoic sediments, its mal-solidity, and the contained pebbles. As the distribution of this formation has been made clear by the present survey, the name Lourdes Formation has been given after the village name of type locality of this formation, to which any formational name had not been given.

5-4-11 Contamana Group

(1) Distribution; This Group is widely distributed in the low land around the Sub-Andes in the northeast of the surveyed area.

(2) Constituents and Lithofacies; It consists of Molasse deposited in the vast basin on the east of the Andes Mountains and it can be divided into two formations in this region.

The lower formation is composed mostly of lutite, intercalating sandstone and mudstone, and presents dark reddish color as a whole. The lower part of this lower formation sometimes presents green or yellow color, while the upper part of it presents grey and purple colors, and consists mainly of sandstone and mudstone, intercalating lutite with well developed laminae.

The lower formation intercalates grey or cream colored thin layers of limestone locally.

The upper formation consists mostly of lutite and sandstone, which intercalates mudstone. Its lower part is red or purple in general, while its upper part is in maroon color.

(3) Thickness; 1,400 m +

(4) Relation with the Lower Formation; Though not definite, it seems to be in parallel unconformity or weak clino-unconformity with the underlain Chonta Group.

(5) Fossils and Correlation; It has been made clear that this formation is Tertiary from the pollen analysis. The results of such pollen analysis as well as the intercalation of calcareous layers sandwiched between the lower member called "red bed" and the upper member called "maloon bed", and their lithofacies are enough to correlate this Group to the Contamana Group, which was described by Bellido, E.B. (1969) and was typically developed at Contamana in the north of the region.

5-4-12 Quarternary Sediments

Large basins and terraces are developed numerously along the major rivers like Rio Perene, Rio Santa Cruz, etc. The sediments to constitute them are river or lake deposits, consisting of gravels, sands, and clays, lying almost horizontally.

The river terraces are three staged near San Ramon, and each surface is almost flat except the uppermost being inclined gently. Large scaled talus deposits are found on the slopes joining to the flat lands facing to the major rivers.

Chapter 6. Geológical Structure and History

6-1 Folding Structures

All the structural trends in these areas, such as major folding axes, strikes of faults, elognation of large scaled intrusives, and distribution of volcanic rocks, are in the direction of NNW--SSE. The repeated orogenic movements during Paleozoic and Mesozoic Eras and their associated magmatic activities which derived these regional structures, are considered to have been caused by the lateral compression of ENE--WSW.

The metamorphic and sedimentary formations of southwestern part occupy a part of the structural zone where the anticlines and synclines are repeated, and the major structures indicate the direction of NW--SE. Near Tarma, a synclinorium with axial direction of NW--SE is seen in its east, and an anticlinorium of similar direction is in its west. And the combination of these structures build up the zonal distribution of those formations of metamorphics and sediments, ranging from Pre-Cambrian to early Paleozoic. The volcanic rocks consisting of lavas and tuff breccias, distributed in the western highlands, are scattered in the direction of NNW--SSE, and their distribution seems to be controlled by structural lines reaching to the deeper portion of the granitic rocks.

The structure of the central part is built up by a large synclinal structure in the western part of the Pucara Group and by a large anticlinal structure in its eastern part as a whole, where many anticlines and synclines are repeatedly formed in the Pre-Cambrian metamorphic rocks and in the sedimentary formations deposited from Paleozoic to middle Mesozoic Eras. Most of the axial palnes of these foldings are nearly vertical. In the northern extension of such large anticline and syncline, there are distributed acidic porphyries and volcanic rocks extended in almost NNW--SSE.

The structure of eastern part is controlled by a synclinal structure in the west side and an anticlinal structure in the east with axial direction of NNW--SSE, where Molasse type sediments from middle Mesozoic to Cenozoic Eras are gently folded in repeated anticlines and synclines. The wings of these foldings are gently dipping on each side, and some of the basin structures are seen along the bottoms of synclines, too. Stocks and dykes mainly of intermadiate porphyries and volcanic rocks are intruded near the folding axes of these anticlines and synclines.

The sedimentary formations from late Mesozoic to Cenozoic, which are distributed in the northeastern part, are generally dipping gently to east or west, where the dome and basin structures are seen, except the area of steeper dipping in a large anticlinal structure with axial direction of NNW--SSE and located along the ridge of the Sub-Andes.

6-2 Faulting Structures

The major faults in this region are either of those thrust faults having the strikes of NNW--SSE system and westerly dips or the high - angled faults of WNW--ESE and NNE--SSW system, which are derived by the lateral compression in the direction of ENE--WSW.

Among them, the thrust faults are well developed, and the major ones are seen at the boundary between the Pucara Group and the thrusted-up granitic rocks in the central part, at the boundary between the Oriente Group and the upthrusted Mitu Group in the northern part, and the contact of Contamana Group with the upthrusted Chonta Group in the northeastern part. These thrust faults are all located at equal interval with the thrust planes having the strikes of NNW--SSE.

The high-angled faults of WNW--ESE and NNE--SSW systems in their strikes and cutting the thrust faults are generally observed, but large scaled ones are few. Many of such high-angled faults are found near the San Vicente Ore Deposits, and the ore deposits are often dislocated by them.

Large scaled, high-angled faults with the strikes of NW--SE system are developed to form the horsts and gravens in the southwestern part.

In the erstern highland, the Jurassic dioritic rocks are intruded as stocks as well as the Neogene volcanic rocks are scattered, and all of them are arranged in the direction of NNW--SSE. This may suggest that the intrusion and extrusion of these porphyries and volcanic rocks are controlled by the structural lines reaching to the deeper zones.

As regards to the Paleogene porphyries and volcanic rocks, the batholiths are elongated in NNW--SSE, and the stocks are scattered in NNW--SSE, too. This may be enough to presume the existence of deep-reaching structural lines to have controlled such intrusion and extrusion.

6-3 Geological History

In this region are distributed various kinds of rocks such as Pre-Cambrian metamorphic rocks, sedimentary formations deposited intermittently since Devonian to Tertiary Periods, volcanic rocks of Paleozoic, Mesozoic, and Cenozoic activities, etc.

The metamorphic rocks are considered to have been performed during the course of Pre-Cambrian orogeny, but an alternative interpretation is to have been formed during the course of sedimentation and orogeny in early Paleozoic Era. The similar metamorphic rocks accompany the red granite somewhere in southern Peru, and the absolute age of the granite has been reported 460 m.y.*

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* by Bellido, E.B. (1969)

In the middle of Paleozoic Era, the Excelcior Gourp, which consists of sandstone and shale of Molasse type, was deposited in a geosyncline developed at the western fringe of Brazilian schield parallelly to the present Andes Mountains. The Excelcior Group was subjected to weak metamorphism and folding by the later weak crustal movements.

In late Paleozoic Era, the Ambo Group, mainly consisted of sandstone and shale including lutite, was deposited, and during the succeeded epoch of transgression, deposited was the Copacabana-Tarma Group mainly consisted of fossiliferous limestone and shale. This submarine sedimentation ceased when the orogenic movement was activated in the middle of Permian Period. Upon the commencement of this orogenic movement, the magmatic activity was accelerated from Permian to Triassic Periods, which derived the intrusion of granitic rocks to form most of the basement of this region. Among the granitic rocks, "Granito blanco" with less potassium feldspar intruded in the earlier stage in the western part of the region, and "Granito rojo" with more potassium feldspar gradually incresed to intrude in the later stage, and the sites of intrusion also migrated eastwards. Porphyrite and andesite intruded in the form of dykes in some parts of the granitic rocks.

The orogenic movement and magmatic activity of these Periods caused these formations to have build up the mountains. The granitic rocks already intruded and the older metamorphic rocks and sediments were eroded and the materials were deposited in such depressions like basins, resulting in to perform the Mitu Group of Molasse type mainly composed of conglomerate.

A geosyncline was again performed in this region in late Triassic Period, and there deposited was the Pucara formation which was mainly composed of limestone and dolomite accompanying lutite.

In the middle of Jurassic Period, orogenic movement was again activated in some parts of the region with association of magmatic activity. As related to the magmatic activity of this epoch, stocks of the intermediate rocks were intruded in the western highland and others.

The mountains built up by these orogeny and magmatic activity was eroded to have resulted in the deposition of the Sarayaquillo Formation, consisting of conglomerate, sandstone, and lutite.

Late Jurassic Period was an eqoch of subsidence; the transgression caused the deposition of the Oriente Group consisting mostly of sandstone in the early part of Cretaceous Period, and the deposition of the Chonta Group containing the deeper submarine limestone in the middle or later part of Cretaceous Period.

The first stage of the Andean orogeny was activated from the later part of Cretaceous to the earlier part of Tertiary Periods, and intrusion of the intermediate porphyries and volcanic rocks took place in the early part of Tertiary Period. Along with the evolution of magmatic activity, the activities of acidic porphyries and vlocanic rocks were made dominant in the middle of Tertiary Period. The mountains, built up by these orogeny and magmatic activity, were eroded to have resulted in the deposition of the Contamana Group, consisting of conglomerate, sandstone, mudstone, and lutite. At the same time, the Lourdes Formation, consisting of conglomerate and sandstone of lake and river sediments, was deposited in the highland basins.

The deposition of such clastic rocks had ceased upon the activation of the second stage of the Andean orogeny in the middle of Tertiary Period. The magmatic activity accompanied by the second stage of orogeny derived the effusion of volcanic rocks mostly along the weak structural lines in the western highlands. The rapid erosion, started with the second stage of orogeny, has been continued till present.

Chapter 7. Metallic Ore Deposits in the A and B Areas

7-1 General Remarks of Metallic Ore Deposits

Many metallic ore deposits have been known in the A and B Areas, but most of them, except a few, have not been studied geologically. They are classified as follows according to the genesis and types;

(1) bedded lead-zinc deposits embedded in the Pucara Group of early Mesozoic,

(2) contact deposits of copper, lead, and zinc emplaced at the contacts of intrusive rocks with carbonate rocks of the Pucara Group,

(3) fissure filling deposits of gold, silver, copper, lead, and zinc, developed in the western part, and

(4) Vein-like deposits of chrome, cobalt, and nickel found in the basic rocks intercalated in the Pre-Cambrian metamorphic rocks.

Aside from these deposits, there are known the deposits of radio active minerals in the basal conglomerate of the Mitu Group, and the deposits of manganese peroxide of unknown genesis.

In the present survey, five deposits among them were investigated, which were under the operation or had been operated till recently. They are

San Vicente Deposits	bedded lead-zinc deposits
Pichita Carga Deposits	" " "
Santos Deposits	contact deposits of copper, lead, and zinc
Soldad Deposits	" " " " "
La Olividada Deposits	fissure filling deposits of copper.

7-2 San Vicente Deposits (cf. Fig. C - 3)

The deposits are the most representative and important among what are distributed in the area of the present survey, and on this account, the specified area including the San Vicente Deposits and other deposits of similar type has been surveyed precisely. They are, therefore, described in details in Particulars II in this report.

7-3 Pichita Carga Deposits

(1) Location and Accessibility

The deposits are located near the summit of a peak 2,040 m S.L., about direct distance of 8 km northeast of San Ramon. The location can be reached 20 km along the mine road, branched out northwards from the national highway from San Ramon to Tarma. The road surface is very rough, as it has passed 6 years since the mine had been closed.

The deposits were stoped mainly by open pit, and concentrates after flotation had been sold, but the mine was closed about 1969 upon the exhaustion of ore from the main deposit.

(2) Geolog and Ore Deposits

1) Geology

Limestone and dolomite of the Pucara Group and lutite and conglomerate of the Mitu Group are widely distributed around the ore deposits (Fig. 7). The Pucara and Mitu Groups repeat the gentle folding of axial direction of NW--SE. Fissures of NW--SE system are developed around the deposits, and there are recognized the blockwise depressions of the formations by these faults (Fig. 7). A dioritic stock of probably middle Jurassic intrusion is found about 4 km northwest of the deposits.

2) Ore Deposits

They are embedded either in dolomite or in dolmitic limestone, and the main ore body is in the dolomitic limestone directly above the underlain lutite. They were stoped by open pit, and breccial ores are found abundantly in the stock piles.

The deposits are considered to be embedded concordantly to the bedding planes, judged from the worked-out pit. Comparatively coarse grained sphalerite is the main ore mineral, but the ore contains more galena, chalcopyrite, and pyrite than the San Vicente Deposits. Under the microscope are recognized green liveingite ($5PbS.4As_2S_3$) and some other affinities, and the X-ray fluorescent analysis has revealed that this mineral contains minor amount of Fe, Cu, and Zn aside from Pb, Bi, and As.

Considering from the occurrences and ore natures, the deposits have close resemblance, as those of San Vicente, to the lead-zinc deposits of Mississippi Valley type, but the overlapped mineralization related to the later dioritic rocks may be possible as in the cases of the Siete Jeringas and Llanco Ceteador Ore Bodies of San Vicente Deposits.

3) Ore Natures, Dimensions, and Grades of Deposits

The ore is complex ore consisting mainly of sphalerite and galena with accompanying chalcopyrite and pyrite, and abundantly are seen such oxides as cerussite and calamine on the surface.

Judging from the dimension of the abandoned open pit, the dimension of the deposit may be estimated about 200,000 tons (200 m, elongation x 75 m, width x 5 m, thickness x 3.0 sp. gr.). The other deposits are only explored by tunnelling partially, and the details

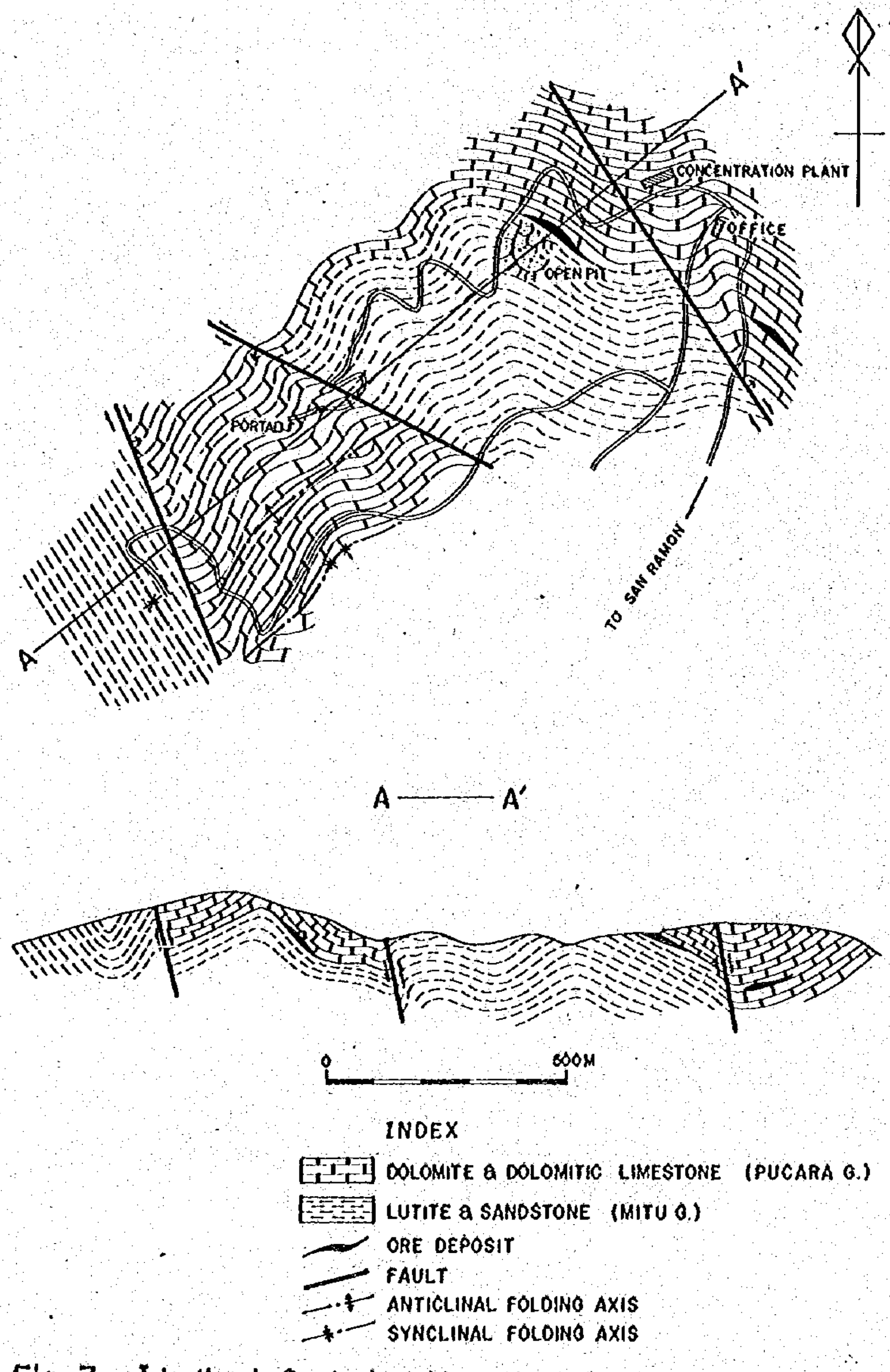


Fig. 7 Idealized Geological Map of the Pichita Carga Mine

are not clear.

Considering from the stock piles, the grade of ore is estimated approximately 5% Pb and 15% Zn.

7-4 Santos Deposits

(1) Location and Accessibility

It is located on the mountain slope of 1,200 m S.L. about 3.5 km in direct distance east from San Ramon. The mine is accessed in about 12 km from San Ramon along the local road and mine road.
The development of this mine was commenced in 1974 and the operation was started in 1975 after the construction of auto-roads. The outcrop was worked in a small scale in the beginning, but the crosscutting was undergone beneath the outcrop at the time of present survey. About 500 tons of ore have been mined since the beginning of operation, and the ore is sold to the Mantaro Mill in Huancayo after handsorting.

(2) Geology and Ore Deposit

Permian granitic batholith is widely distributed around the deposit, and the alternation of sandstone and shale of the Pucara Group of later Triassic to earlier Jurassic is locally distribrted like roof-pendant. (Fig. 8).
A dyke of porphyritic intrusive rock, having the strike of E--W and high angled dip to the south, is intruded in dirct contact with the ore deposit.

(3) Ore Deposit

It is the pyrometasomatic deposit emplaced at the contact of limestone of the Pucara Group with dyke of porphyritic intrusive rock.
The ore minerals are mostly sphalerite and galena, but pyrite, chalcopyrite, and pyrrhotite, are also contained. Epidote and garnet occur as skarn

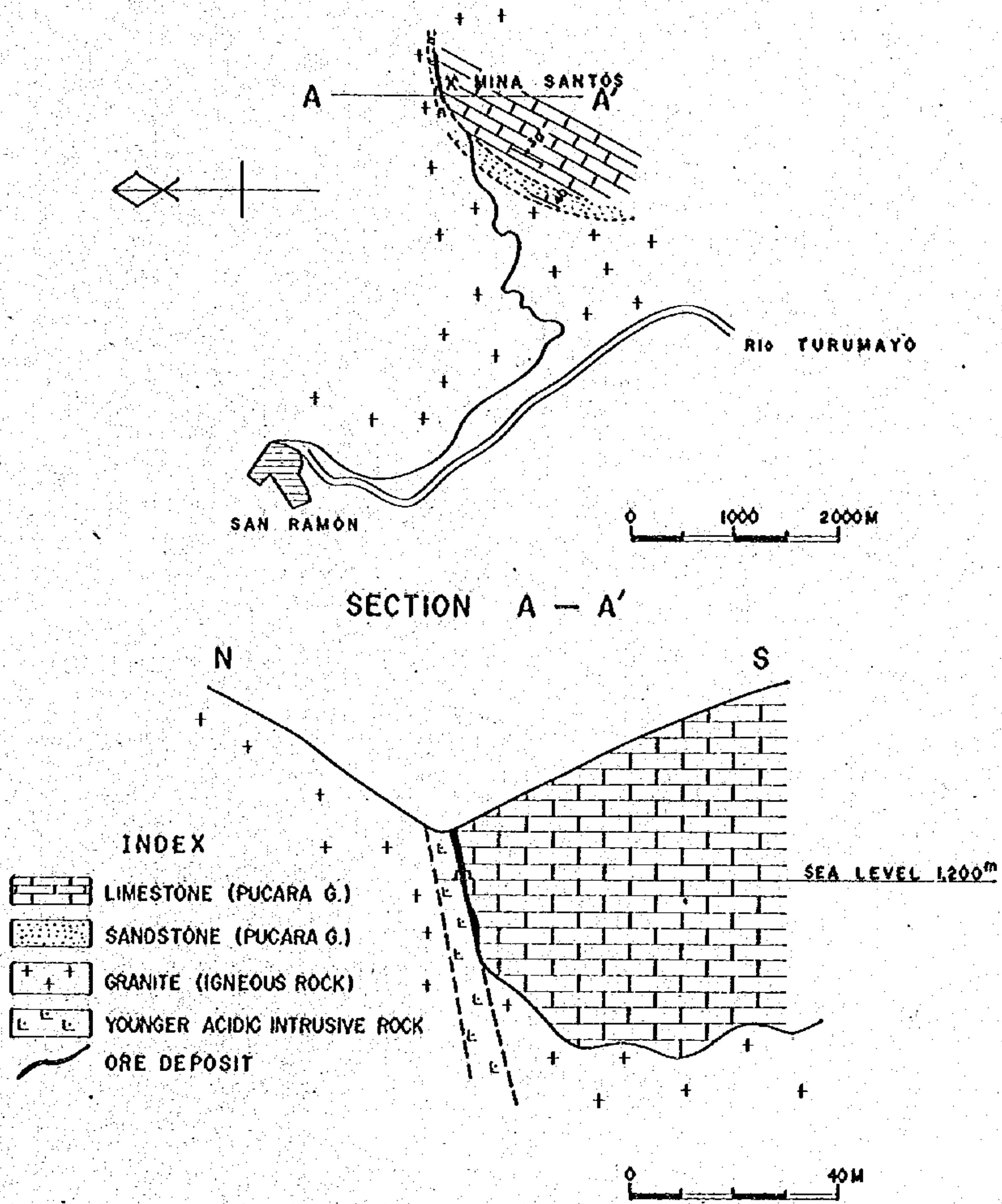


Fig. 8 Idealized Geological Map of the Santos Mine

minerals. Minute dots of chalcopyrite are recognized in sphalerite, but minor in amount.

(4) Ore Natures, Dimension, and Grade of Deposit

The ore is consisted of sphalerite and galena of comparatively coarse grained, which are scattered in the skarn minerals of epidote and garnet, but the ore minerals are sometimes compactly concentrated.
The deposit is considered to consist of a series of lenticular shoots of repeated swell and pinch, with maximum width of 1.5 m and 30 m in elongation in each shoot, although only one shoot has been ascertained. It has about 1,000 tons of reserve with about 1 % Pb and 13 % Zn.

7-5 Soldad Deposits

(1) Location and Accessibility

They are located on the mountain slope about 10 km in direct distance east from La Merced. The location can be accessed with about 40 km in entire distance by following a logging road branched out from the national road from Sam Ramon to La Merced. As the surface of the logging road is so rough, that the mined ore is stock piled at the mine site, and the improvement of the road is now planned for the transportation of ore.
The deposit was once worked by open pit but the operation has been tentatively suspended due to the transportation problem of ore.

(2) Geology and Ore Deposits

1) Geology

A granitic batholith is widely occupies the area of the ore deposits, with scattered roofpendants of the Pucara Group consisting of limestone and sandstone (Fig. 9). Fissures of NW--SE and NE--SW systems traversing the said formations are predominant. There is

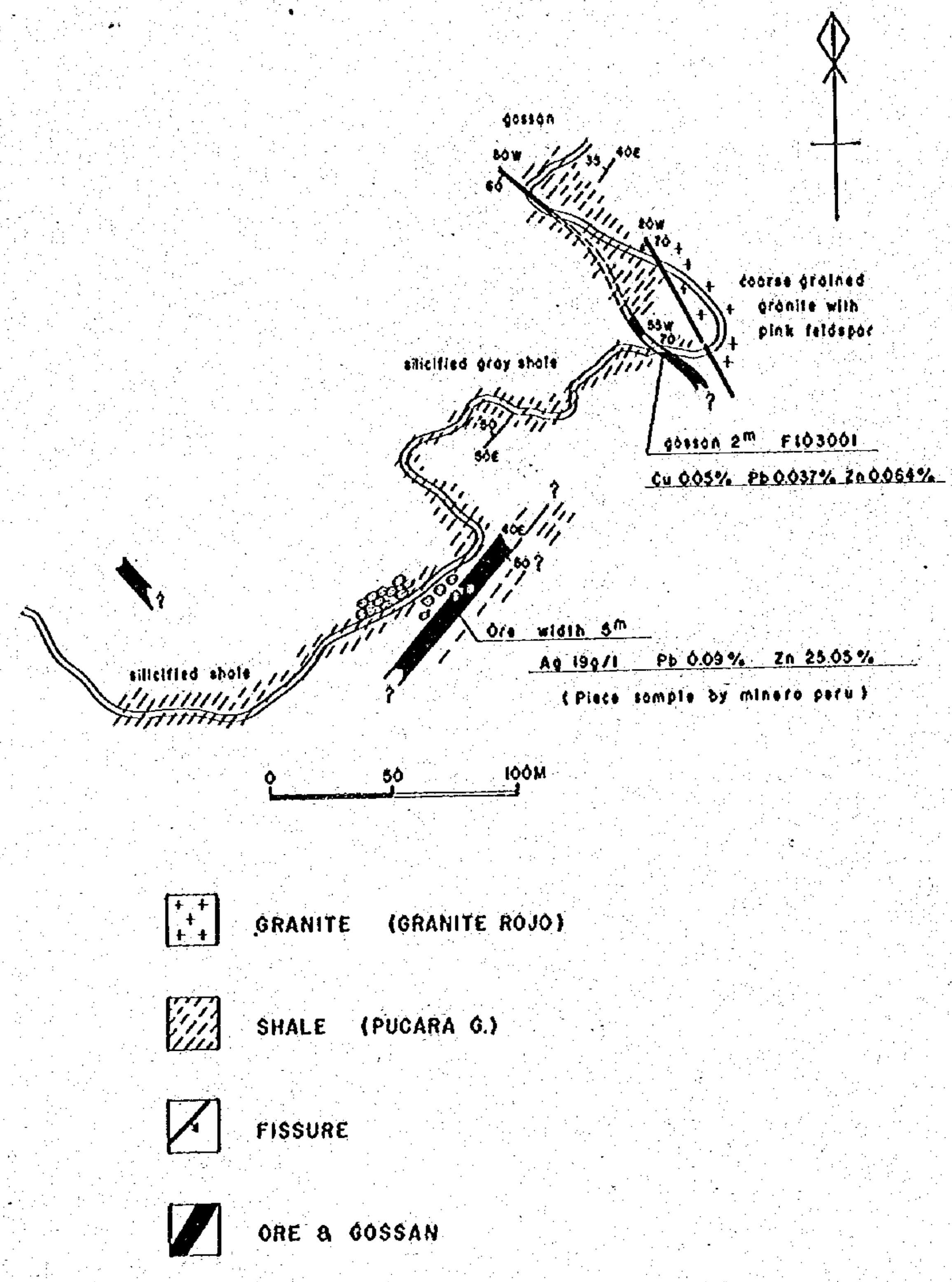


Fig.9 Idealized Geological Map of the Soldad Mine

none of the intrusive rock penetrating the said formations in the surrounding area of the deposits.

2) Ore Deposits

They are the pyrometasomatic deposits, replacing the limestone layers in the Pucara Guoup. In view of the geological environments and natures of ore, the deposits are considered to be of similar type with the Santos Deposit located 8 km soughwest of them, being the pyrometasomatic deposits related to the younger porphyries. Main ore minerals are sphalerite and galena, and chalcopyrite and pyrite are contained, too. Spharelite is considered to have been deposited by twice of mineralization judged from the modes of occurrence; the first mineralization is the pyrometasomatic one which derived sphalerite simulaneously with galena and skarn minerals, and the second is the hydrothermal mineralizarion which derived sphalerite in stringers traversing the minerals of the first mineralization.

3) Ore Natures, Dimensions, and Grades of Deposits

In the representative ore, comparatively coarse grained sphalerite and galena are scattered in such skarn minerals as epidote and garnet, and thick but local concentrations of ore minerals are also seen.

The deposit is a lenticular mass, with elongation of 100 m ±, width of 5 m ±, and its reserve may be estimated about 40,000 tons by taking sp. gr. 3.0. Estimated grades of this deposit are 1 % Pb, and 12 % Zn. Chemical analysis of ores collected in the site is shown as below.

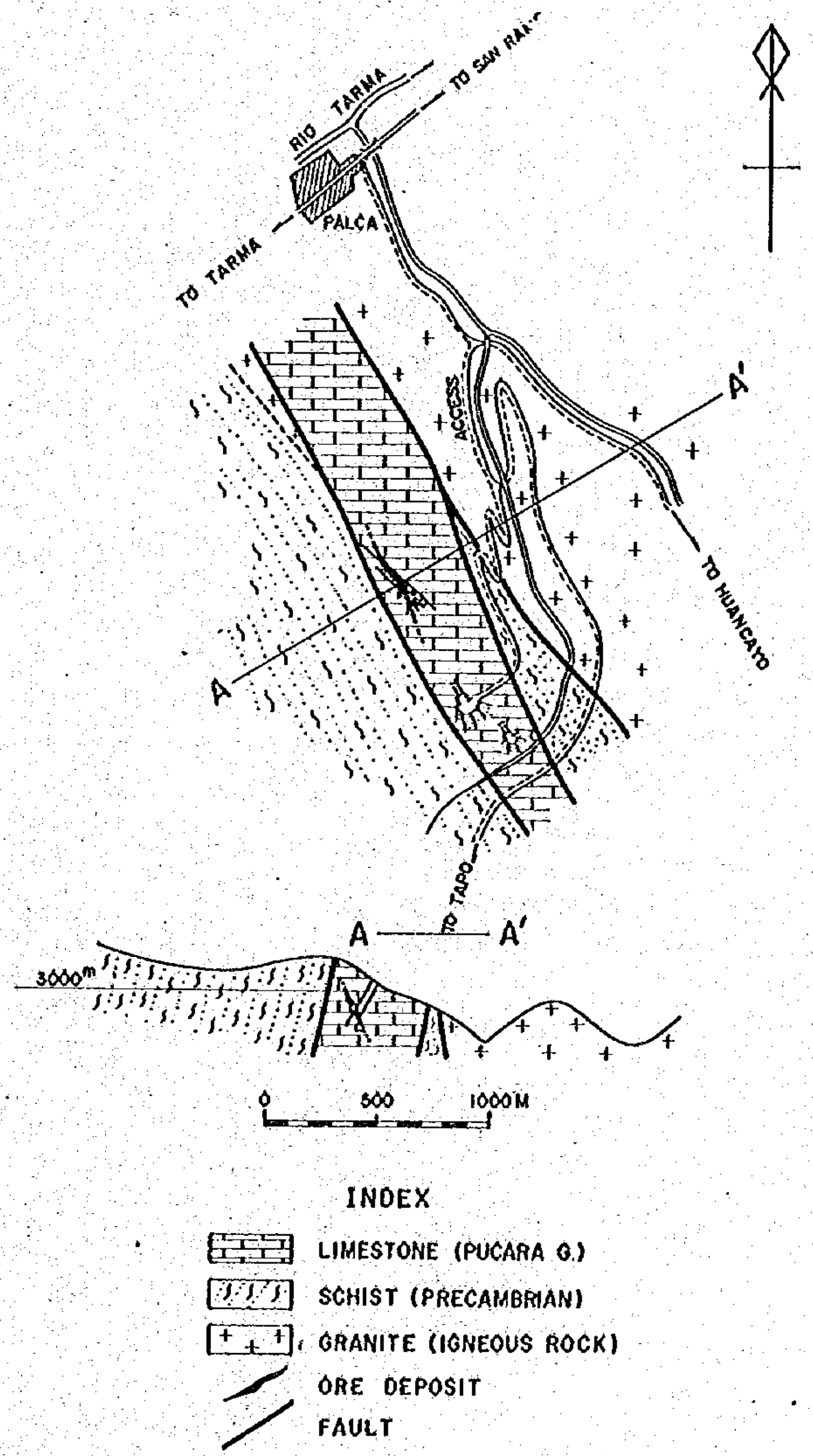


Fig. 10 Idealized Geological Map of the Olvidada Mine

Zn ore; 0.6 oz/t, Ag, 0109 % Pb, and 25.5 % Zn.

Mn ore; 4.5 pz/t, Ag, 0.26 % Pb, and 14.15 % Mn.

(Analyzed by Banco Minoro, Huancayo, by the request of Sr. Juan Sanchez, resident of the mine)

Two more mineral indications exist, but they are all in low grade.

The Soldad Deposit is limitedly distributed, as it occurs in the from of replacement to the limestone in a roof-pendant of the Pucara Group. The patches of roof-pendants of the Pucara Group are scattered in fairly wide area, and similar indications have been known around them, which may suggest the necessity to consider a systematic investigation of them including the Santos Mine.

7-6 La Olividada Deposit

(1) Location and Accessibility

It is located on the mountain slope about 15 km east of Tarma in direct distance. In order to reach to the mine, one can follow the national road till Palca on the way from Tarma to San Ramon. By taking an auto-road branced out from Palca to Tape for about 1.5 km, one comes to the junction of mine road. The mine site is accessed by following up the mine road for 1.2 km. As the road is narrow and steeply graded, it is impossible for the larger cars to pass, though it is passble by jeeps or smaller cars.

(2) Geology and Ore Deposit

1) Geology

Batholithic granite occupies the east side of the deposit and Pre-Cambrian muscovite schist occupies the west (Fig. 10). Near the border between the two, the Pucara Group is distributed in a zone depressed like a graven by the faults of NW--SE system.

No younger intrusive is found near the deposit.

2) Ore Deposit

It is a net-work deposit in limestone of the Pucara Group, brecciated by the finssures of NW--SE system.

It is considered to be a hydrothermal deposit, which is judged by the development of net-work stringers of calcite in the host rocks in association of weak silicification.

Ore minerals are mostly those oxide minerals of copper as covellite, malachite, and chrysocolla, and a little amount of sphalerite is contained, too.

3) Ore Natures, Dimension, and Grade of Deposit

As the ore is mostly composed of oxide copper minerals, the mine is worked underground by hand stoping, yielding at the rate of 9 tons a month at the time of present survey. The ore is sold after hand picking near the portal.

Size of the deposit is 3.5 m of max. width with elongation of about 50 m. Taking 50 m for depth and 2.8 for specific gravity, the reserve is estimated as much as 12,000 tons with ists estimated grade of 5 % Cu.

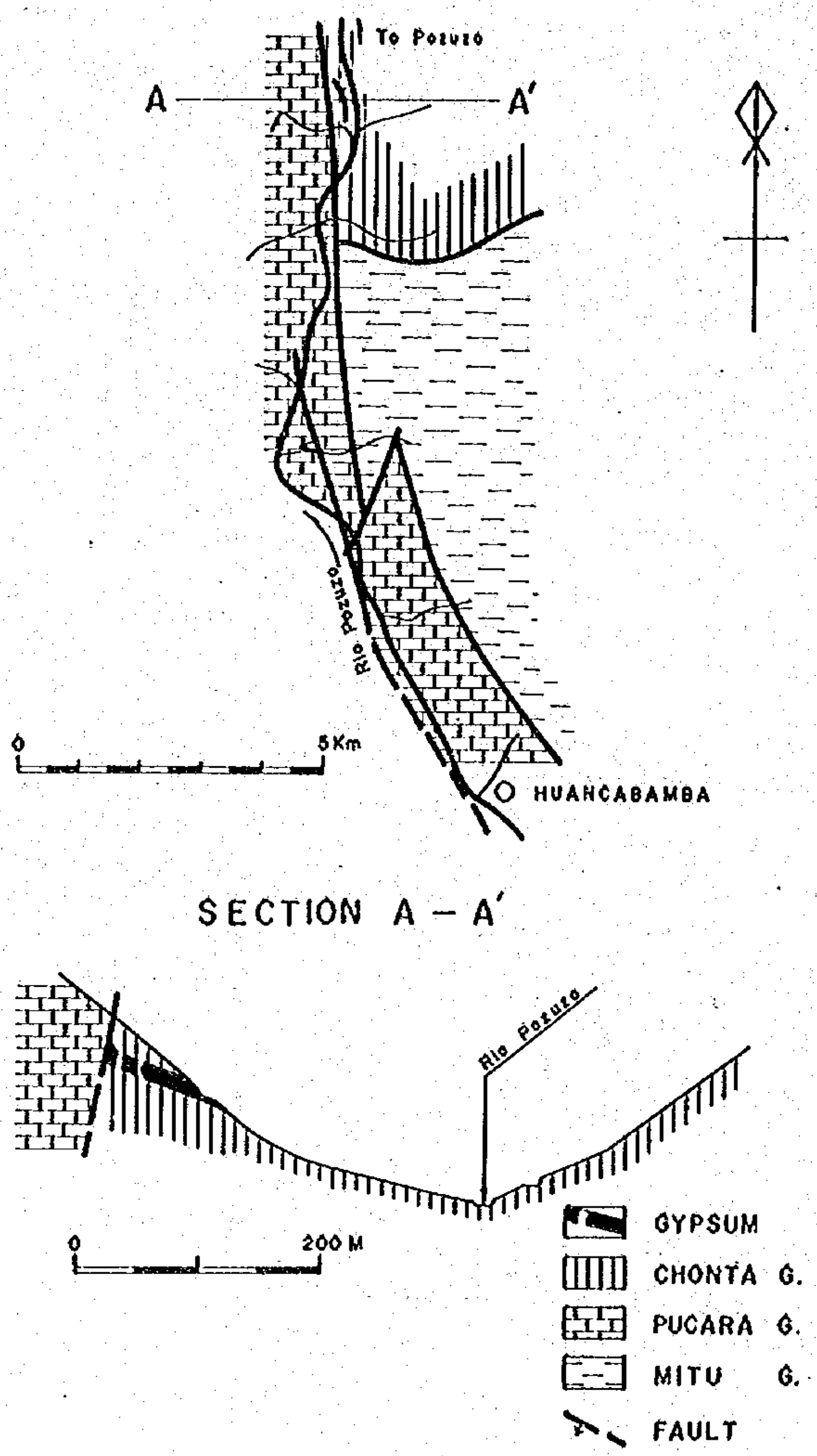


Fig. 11 Idealized Geological Map of the New Gypsum Deposit

Chapter   Non-metallic and Other Kinds of Mineral Resources

8-1 General Remarks

Almost none of survey has been made on the mineral resources of non-metallic and other kinds in the Area because of extremely handicapped topographic conditions, except for the prospecting works for oil in the northeastern jungles. This prospecting was attempted to a dome structure of the middle formation of the Pucara Group exposed on the surface on the upstreams of the Rio Iscozacin, but it has not secured any reservoir of economic size.

Radioactive minerals are also known near Oxapampa, but no investigation on geology and ore deposits has ever been done.

Aside from them, present survey has met with a gypsum deposit of high purity, located about 12 km of direct distance north from Huancabamba.

8-2 Gypsum Deposit

(1) Location and Accessibility

It is located on the mountain slope of 1,850 m S.L. By following the road leading to Pozuzo from Huancabamba for about 12 km, one comes to the junction with a logging road. The location of the deposit is reached by following up this logging road for about 3 km. The road has recently been constructed, and the deposit has been exposed freshly on the surface of a road-cutting. The deposit has not been attempted of exploration and development since it has been discovered during the raod construction.

(2) Geology and Ore Deposit

1) Geology

The formation which contains the deposit corresponds to the middle formation of the Chonta Group, consisting mostly of bright to dark grey limestone intercalating calcareous red shale and grey sandstone. Nearby to the west of the deposit, the Pucara Group is distributed, being bordered by a fault (Fig. 11).

2) Ore Deposit

The deposit is emplaced in the alternation of grey sandstone and calcareous red shale of the Chonta Group parallelly to the bedding plane of the formation with the strike of NNW-SSE and westward dip of 15°. Grey stripes are observed in the deposit, too, and their dip and strike are also parallel to the bedding plane.

The deposit is clearly bordered by the sandstone and shale of the host rocks, in which none of the sign of alteration is recognized. This may suggest the deposit of sedimentary origin.

3) Ore Natures, Dimensions, and Quality

The ore is essentially composed of fine grained white crystals with occasional association of groy stripes. X-ray diffraction has not detected any other mineral but gypsum, which may be enough to anticiparo the extreme purity.

The deposit has a width (or thickness) of about 10 m and vorified extension of 50 m on the outcrop, but it may be expected to extond for several hundred meters as numerous boulders of gypsum are scattored on its supposed extension without any structural disturbance.

Chapter 9. Geochemical Survey of the A and B Areas

9-1 Purpose and Method

This survey was attempted to obtain necessary informations about the ore deposits distributed in the vast projected area of the Central Peru by examining geochemically the stream sediments and soils. The stream sediments were collected during the ground geological survey whenever the rivers and tributaries were met with, and the soil samples were from the B_1 bed on the routes of ground survey. The sample collection was so arranged that two samples, either from stream sediments or soils, would be collected at one kilometer along the surveyed routes.

Total samples collected in the A and B Areas amounted to 2,595 (1,095 samples from stream sediments and 1,500 samples from soils).

The stream sediments were collected in principle from where the finer sediments were concentrated near the bottom of streams. The sediments collected were screened at the spot by 80 mesh sieve. About 100 gr of the undersize was picked up and was reduced to about 10 gr of it for assay by repeated quartering. About 1 kg of soils were collected from the B_1 bed directly under the humus and were screened by 80 mesh sieve after drying under the natural air. About 100 gr of the undersize was picked up and was reduced to about 10 gr of it for assay by repeated quartering.

The prepared assay samples were analized by atomic absorption method on the three indicative elements of Cu, Zn, and Ni which were considered effective for the survey of ore deposits in the A and B Areas through the experience of geochemical survey in the C Area.

Table 15 is the flow sheet to explain the analytical system of the three elements.

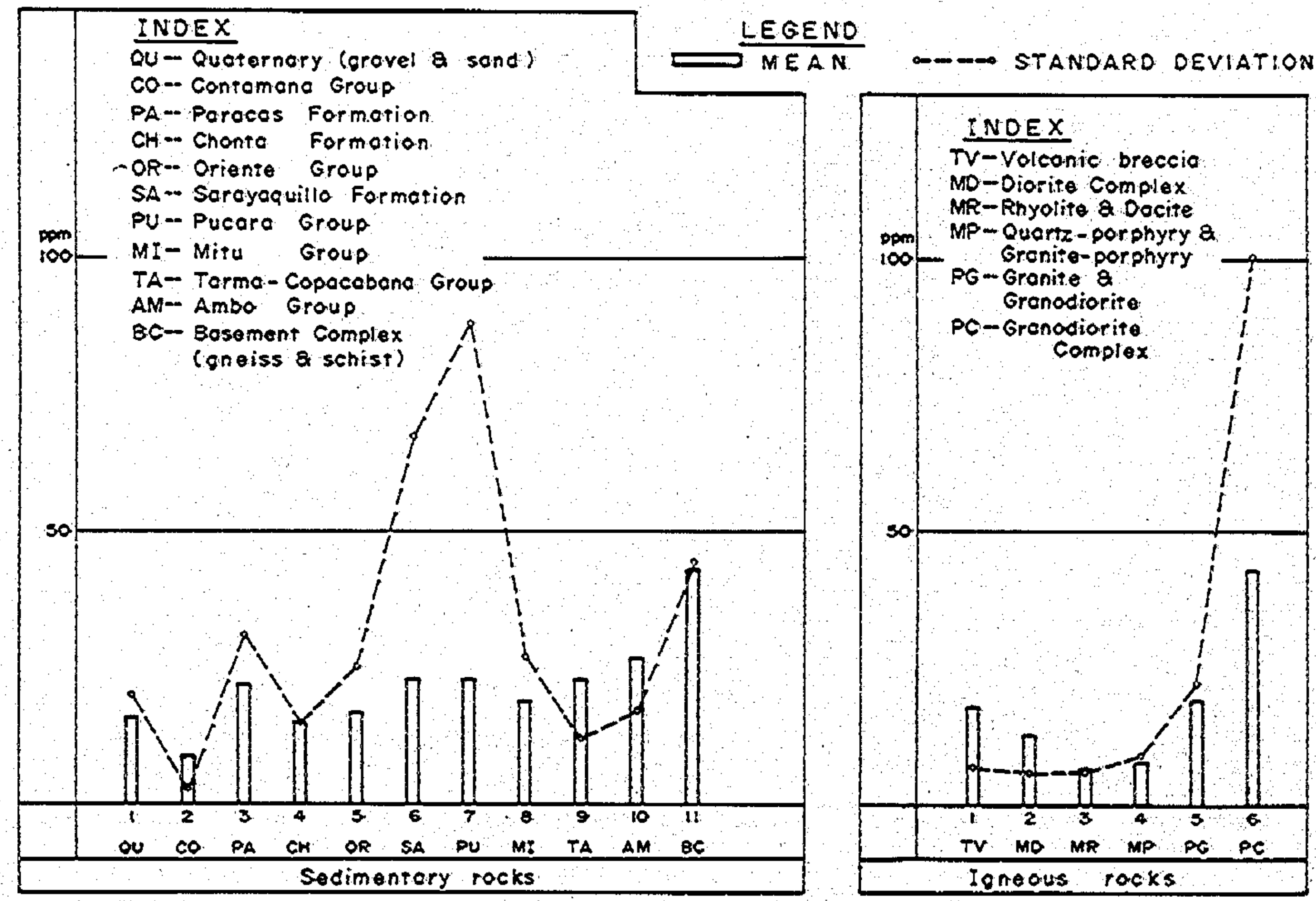


Fig.12-A Mean Value & Standard Deviation of Cu - Chemical Analysis

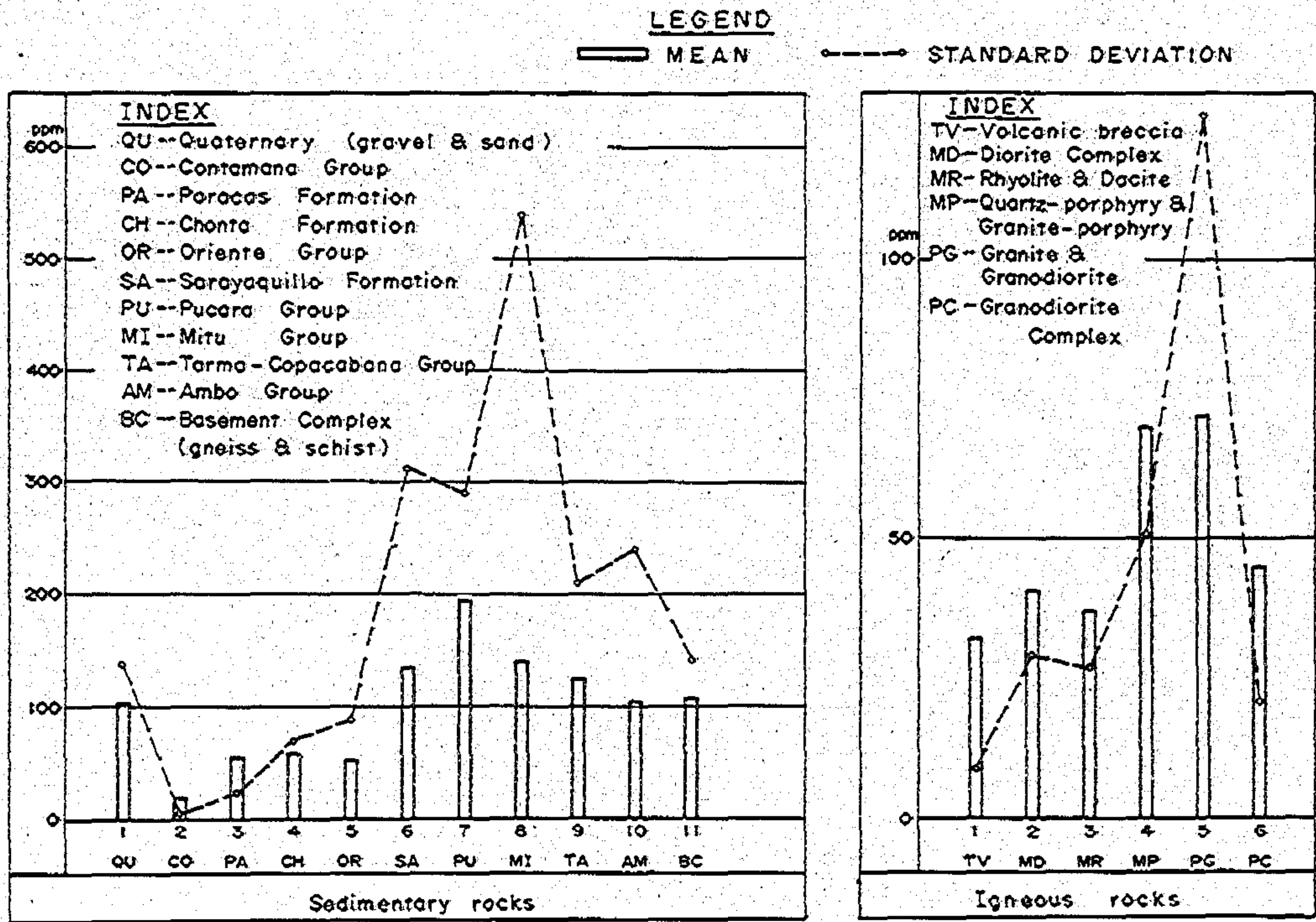


Fig.12-B Mean Value & Standard Deviation of Zn-Chemical Analysis

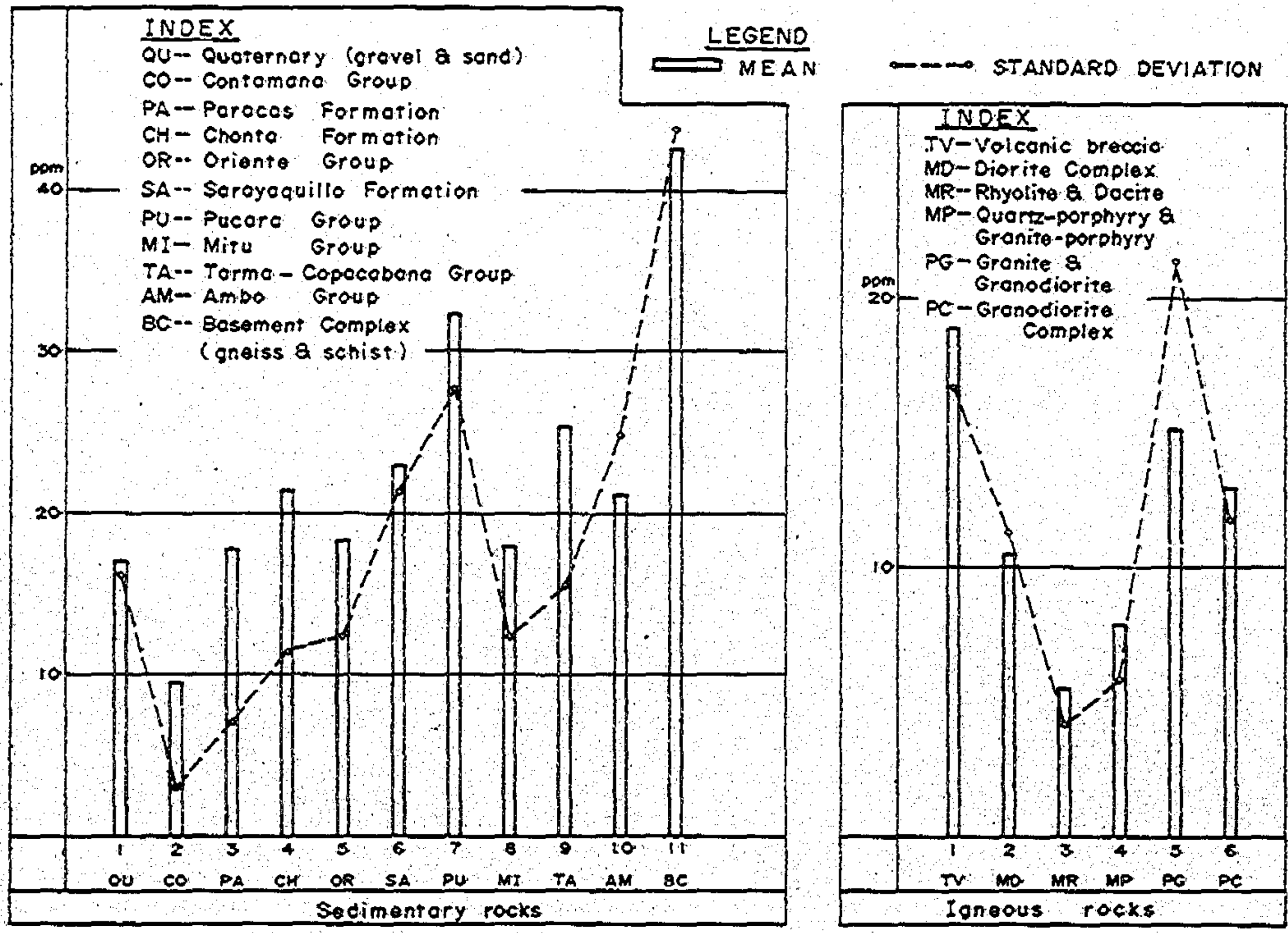


Fig.12-C Mean Value & Standard Deviation of Ni - Chemical Analysis

Table.2 Statistical Analysis of 3 Elements of Geochemical Samples in the Surveyed Area

[ ] is a number of treated samples

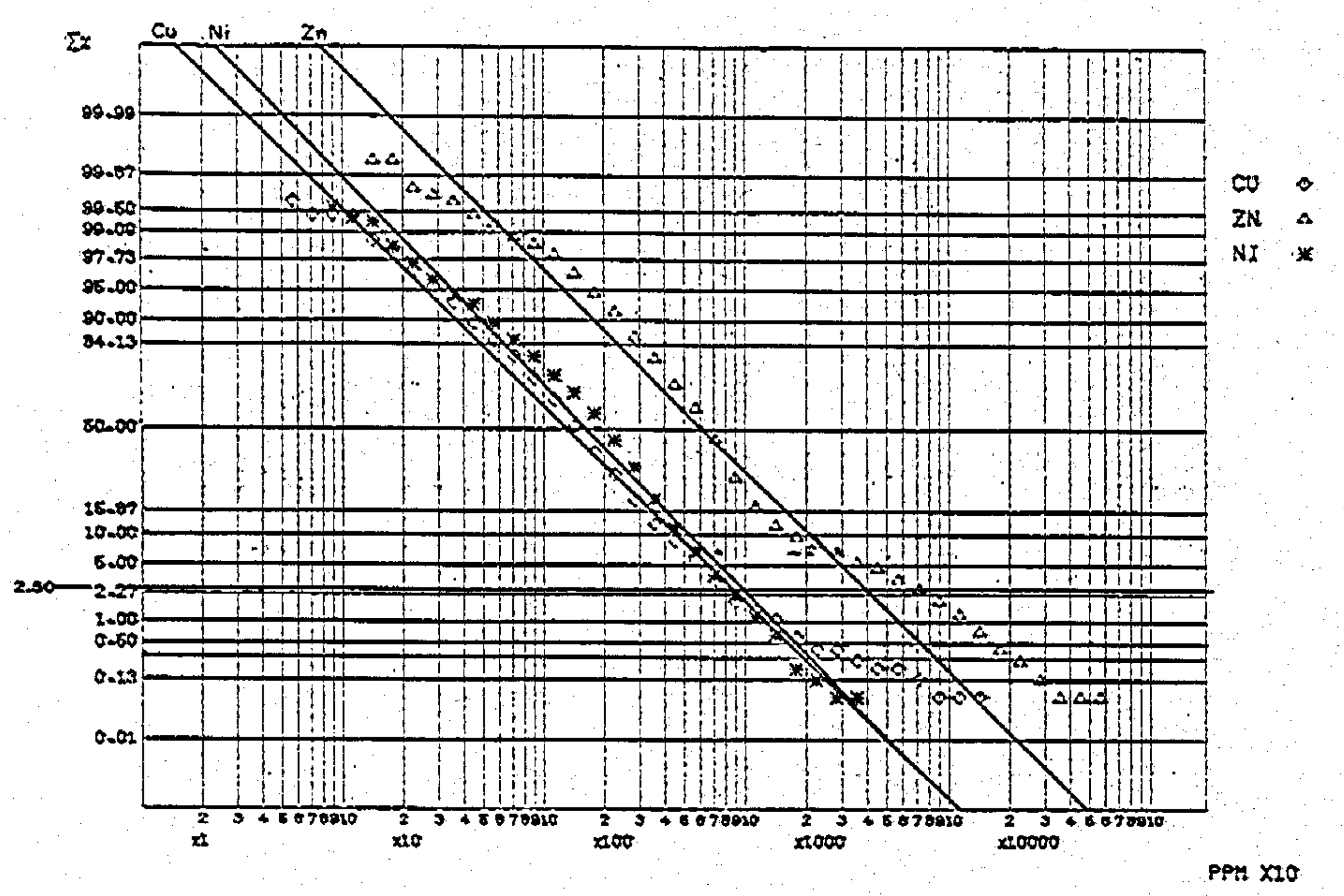
Stream Sediment [1090]

	Cu ppm	Zn ppm	Ni ppm
Maximum	156.0	2,064.5	101.0
Minimum	0.0	0.0	0.0
Average	14.2	56.6	14.5
Standard deviation	13.5	104.0	10.4
Numbers	1,090	1,090	1,090

Soil [1500]

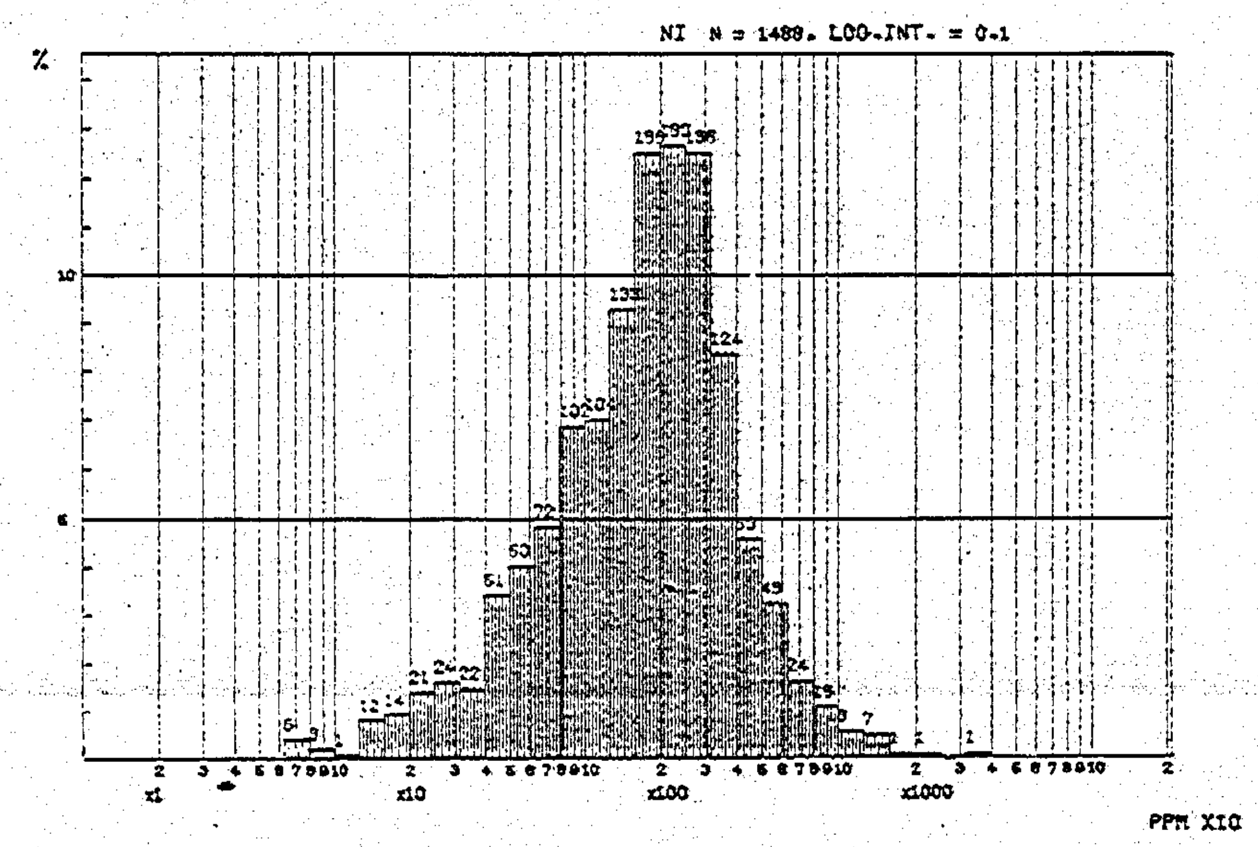
	Cu ppm	Zn ppm	Ni ppm
Maximum	1,452.6	5,192.9	378.8
Minimum	0.0	0.0	0.0
Average	20.2	106.0	22.7
Standard deviation	49.0	241.2	22.2
Numbers	1,500	1,500	1,500

CUMULATIVE FREQUENCY DISTRIBUTION FOR CU AND ZN AND NI (T)

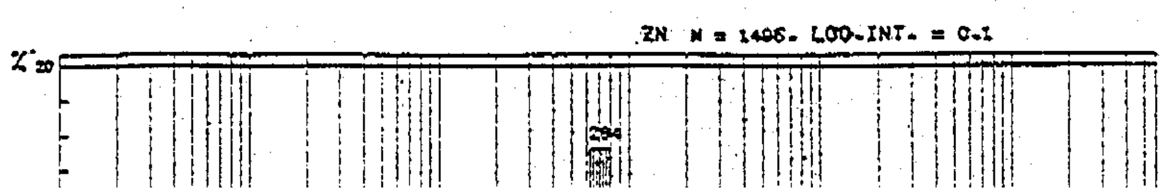


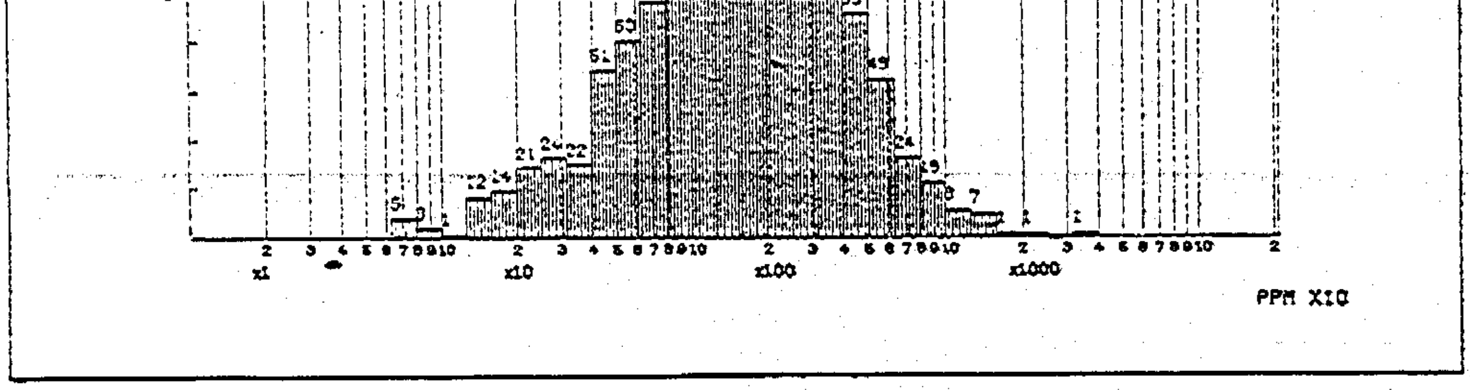
		Back ground	Anomaly
◇	Cu	13	90
△	Zn	60	400
✱	Ni	17	100

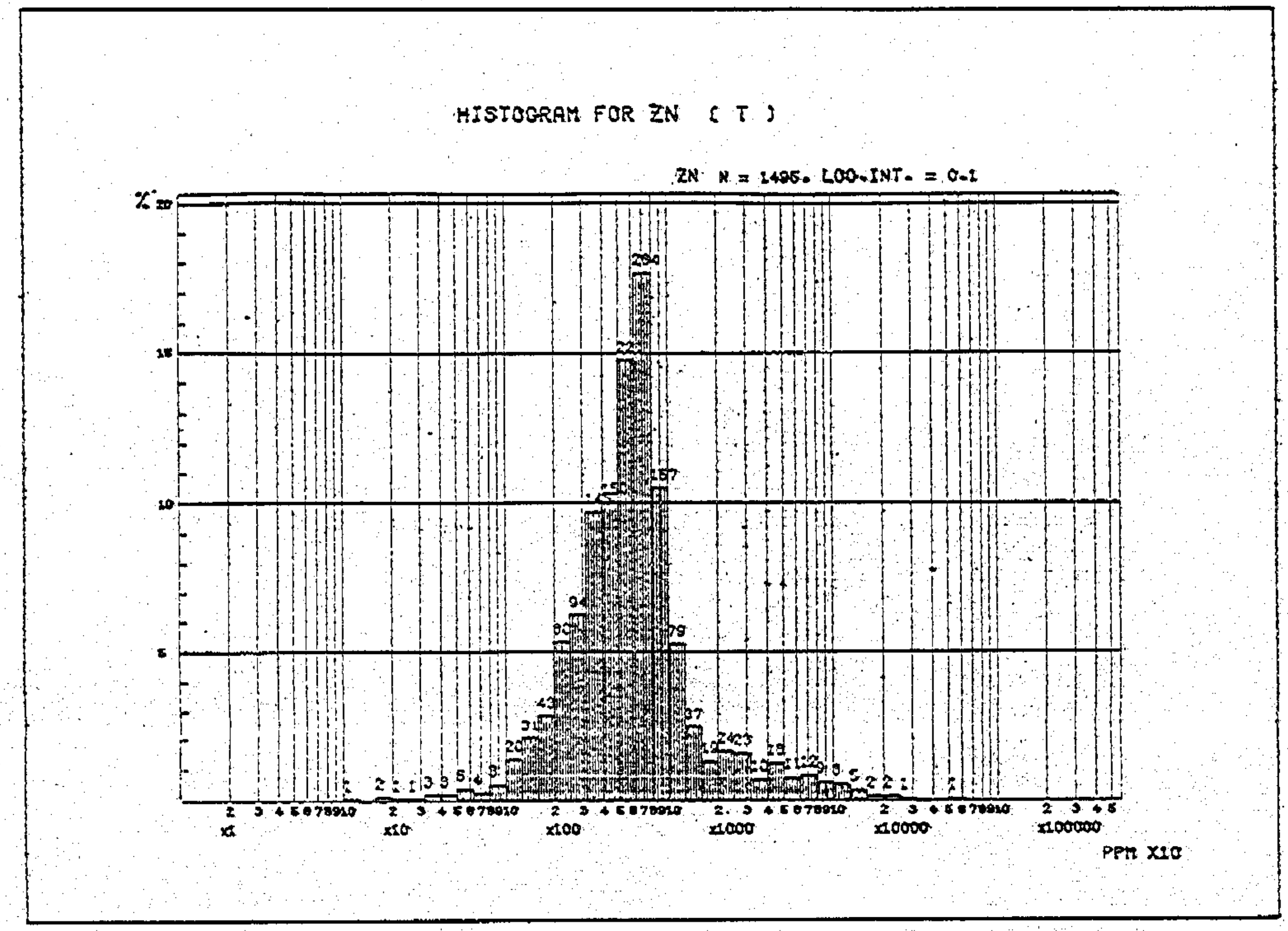
HISTOGRAM FOR NI (T)



HISTOGRAM FOR ZN (T)







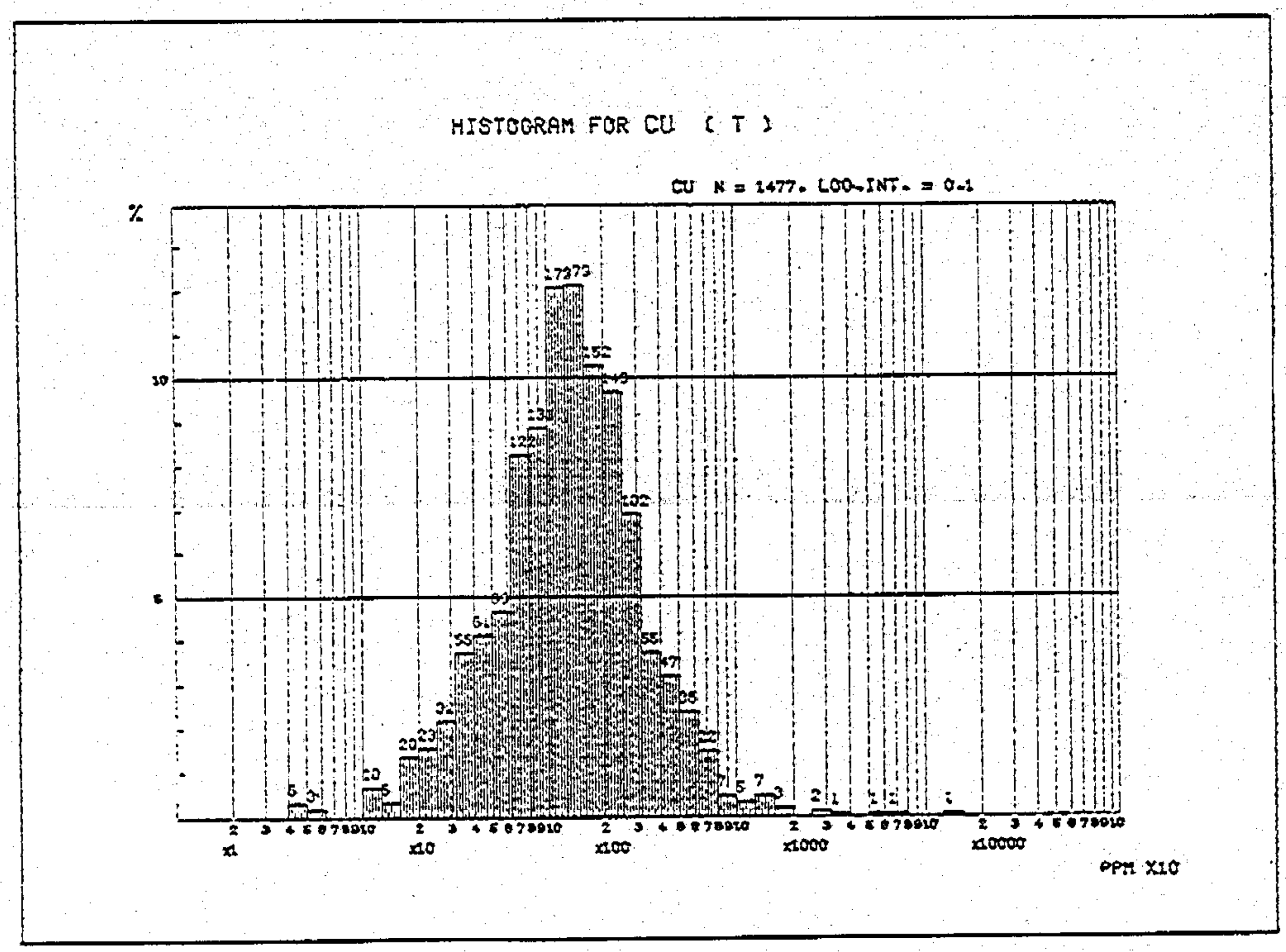
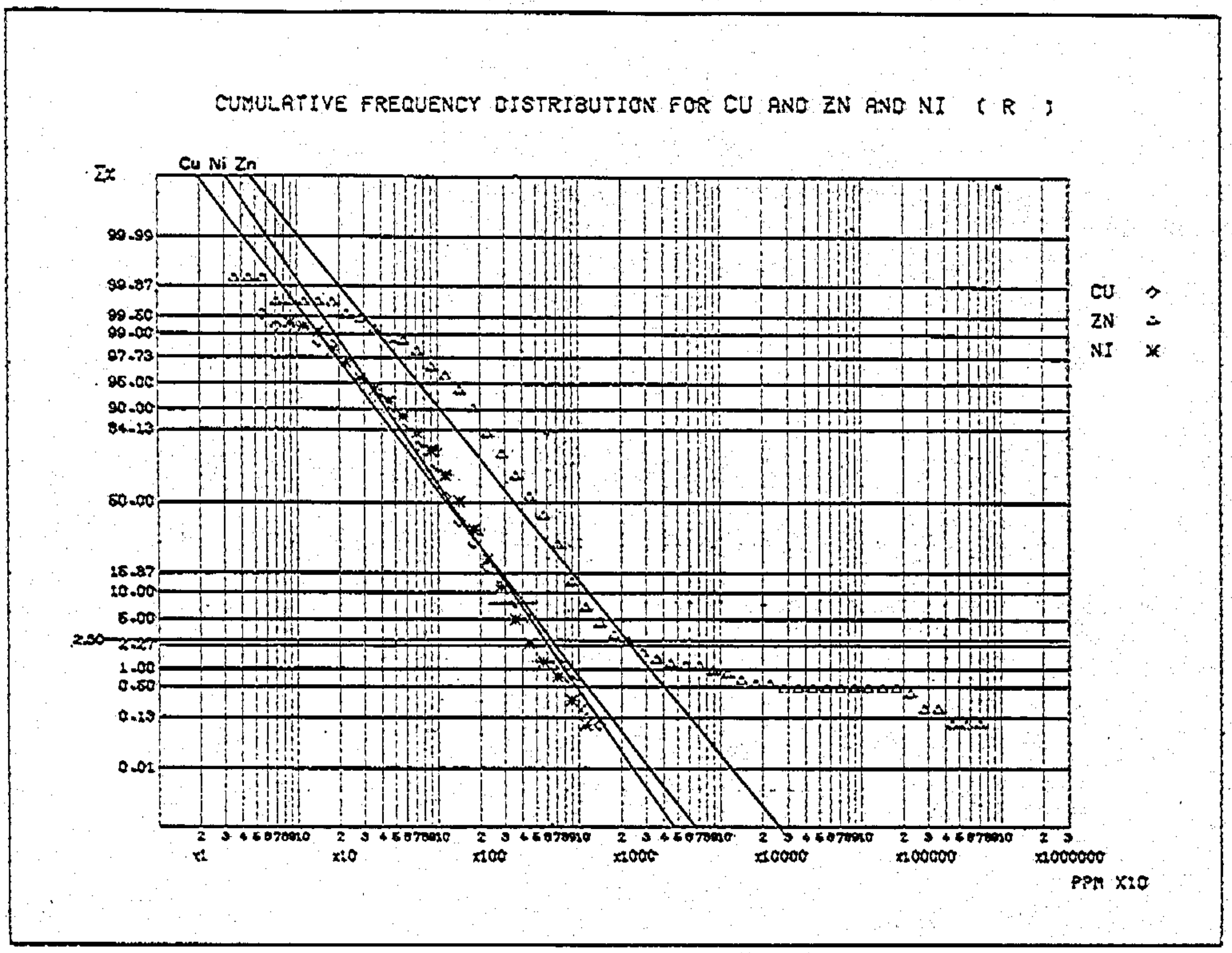
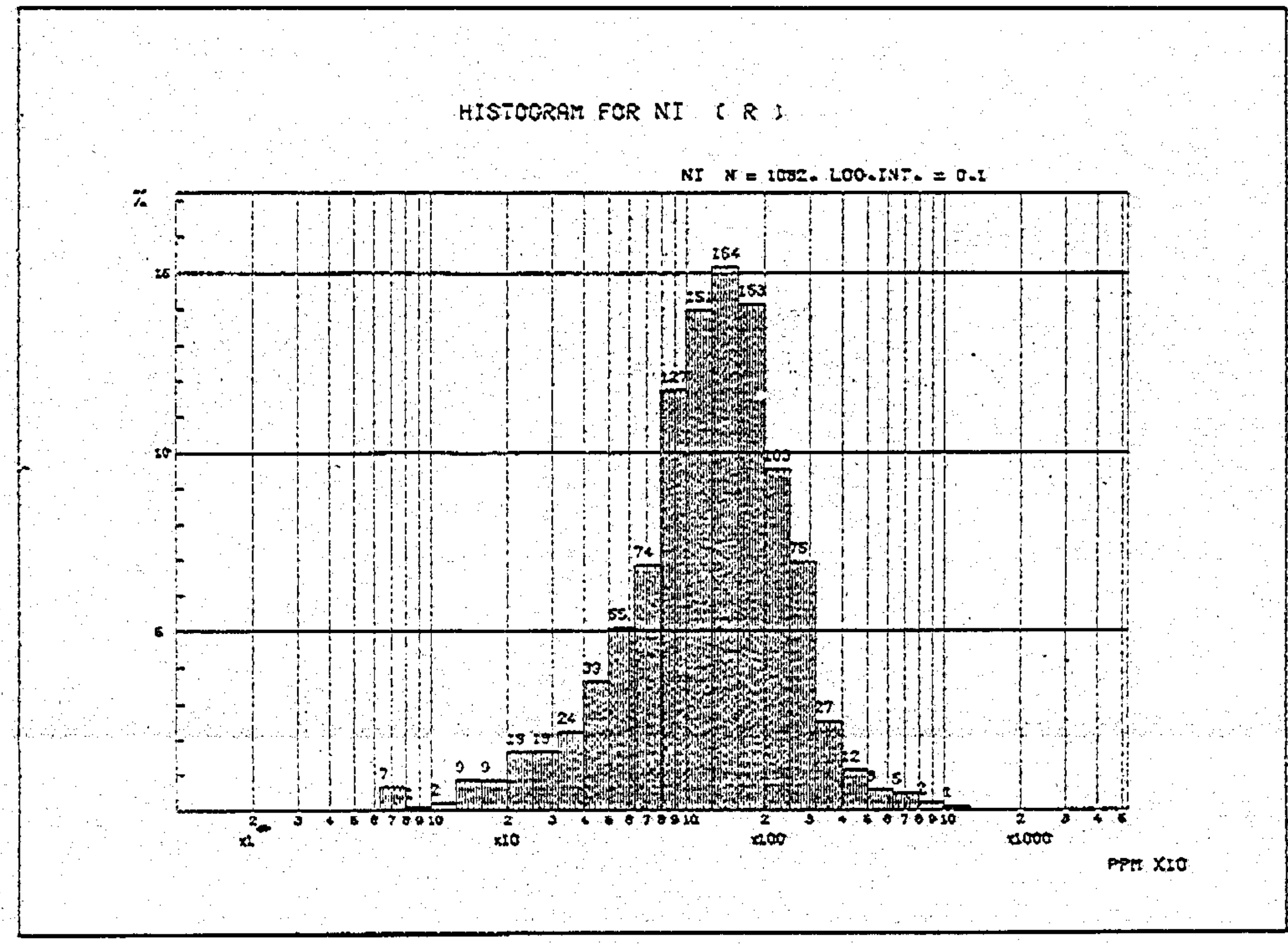
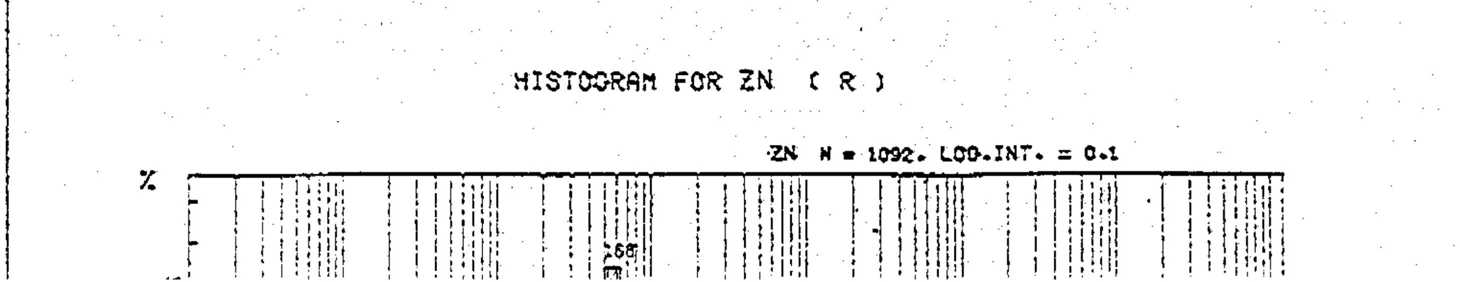


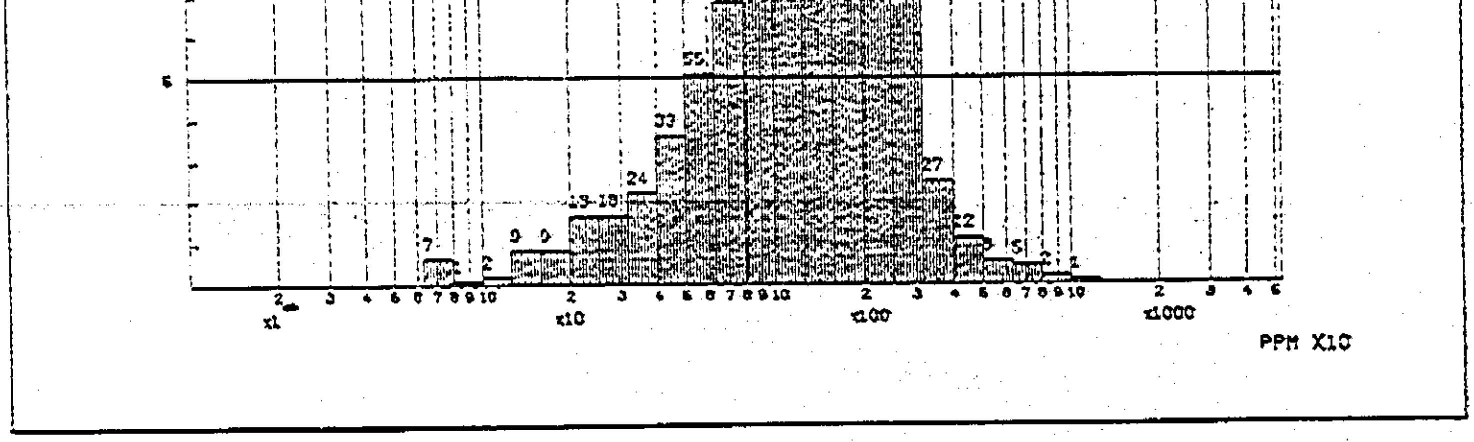
Fig. 13 Cumulative Frequency Diagram & Histgram for Cu, Zn & Ni of Soil of The Surveyed Area

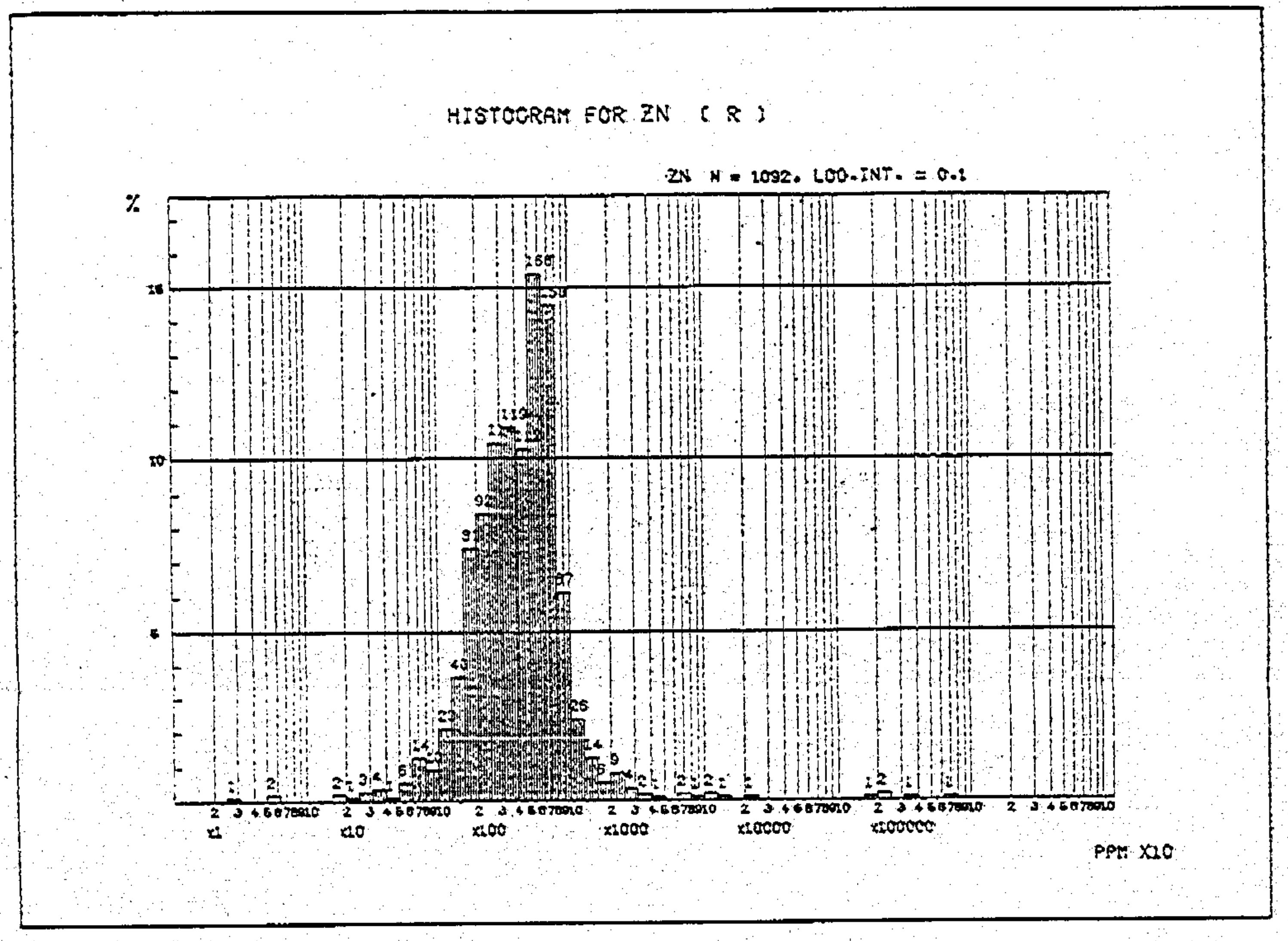


	Back ground	Anomaly
◇ Cu	12	65
△ Zn	35	225
✱ Ni	12	56









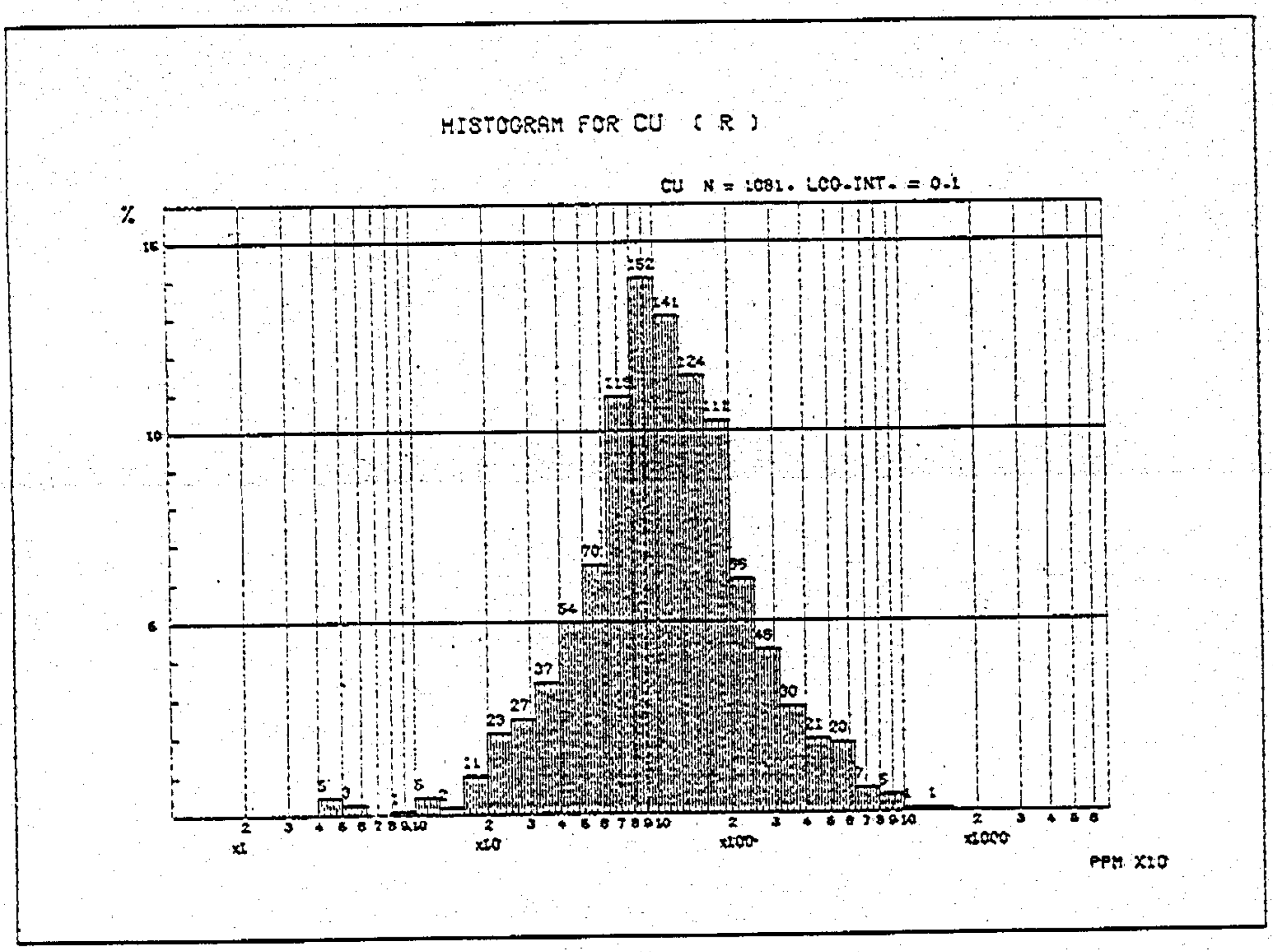
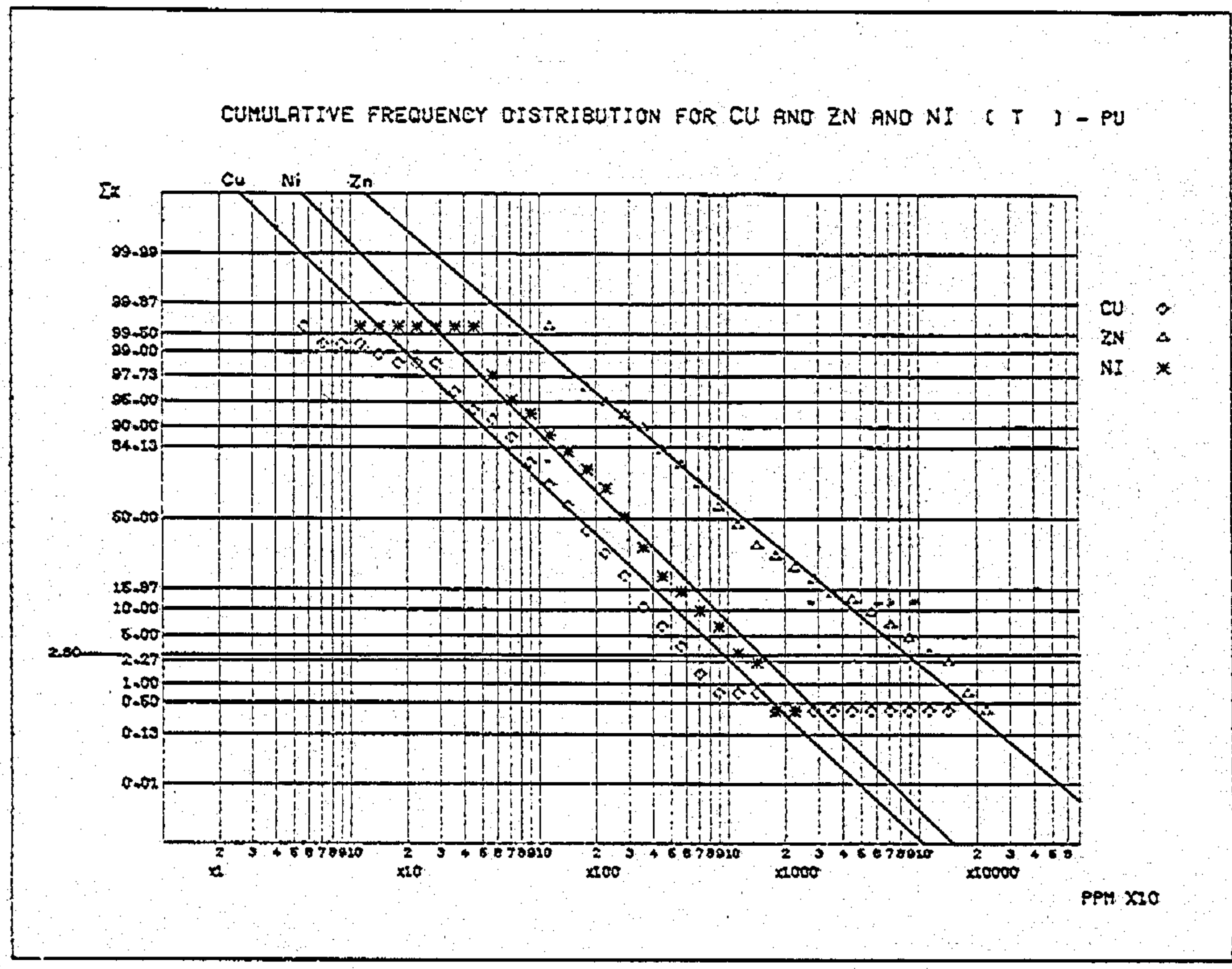
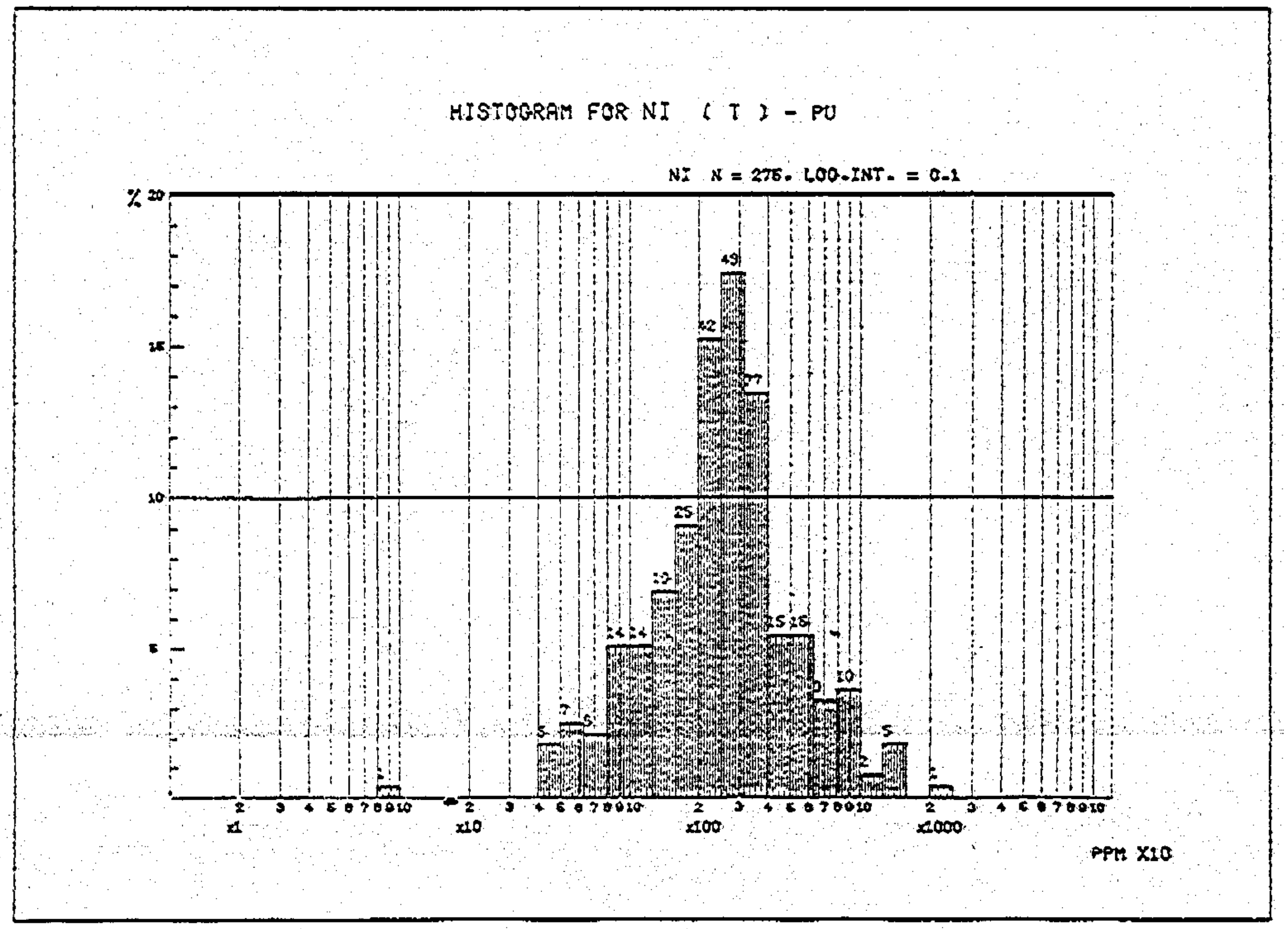
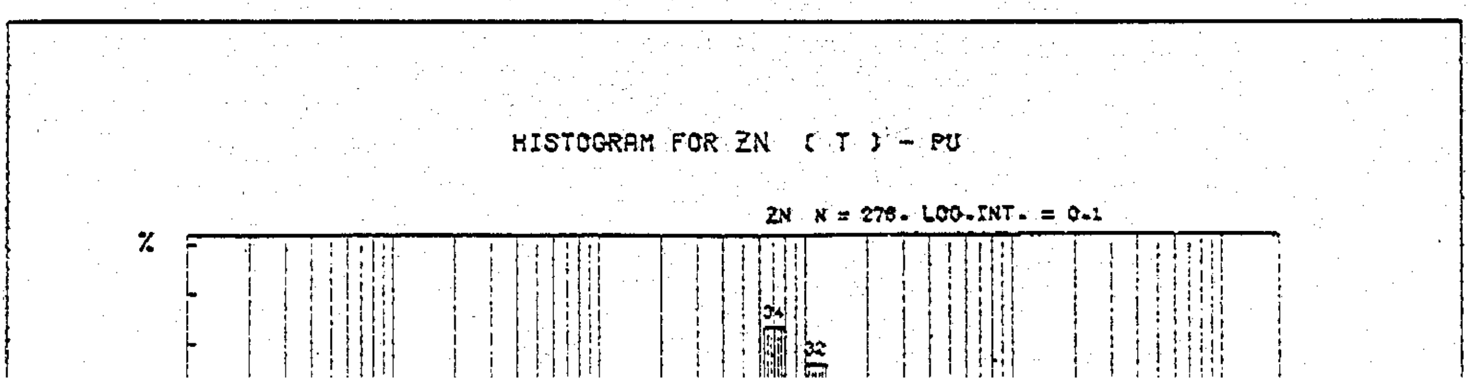


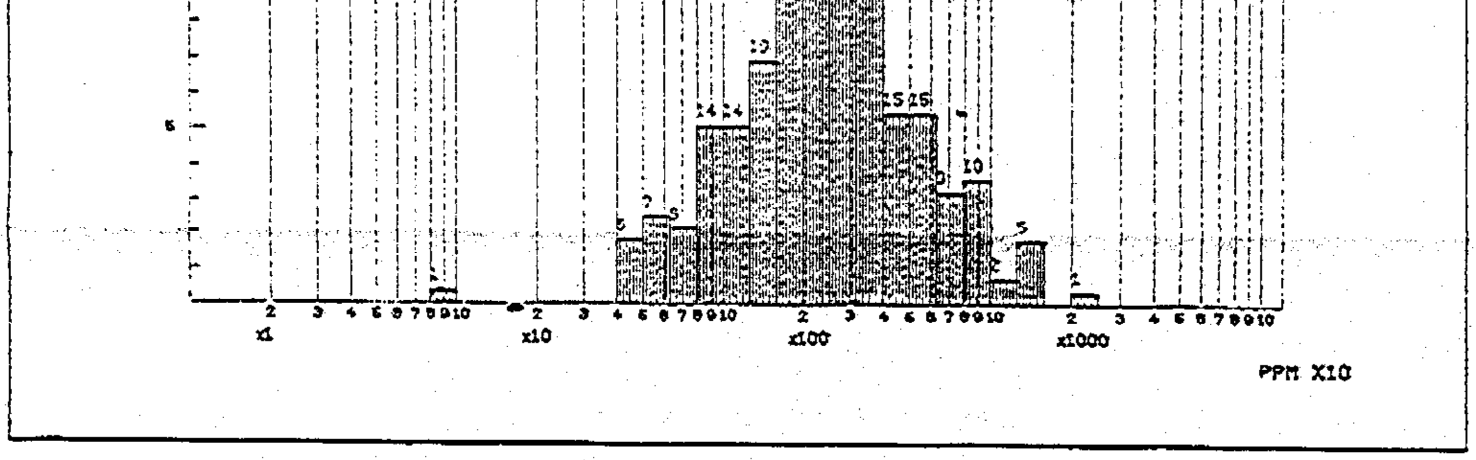
Fig.14 Cumulative Frequency Diagram & Histgram for Cu, Zn & Ni of Stream Sediment of The Surveyed Area

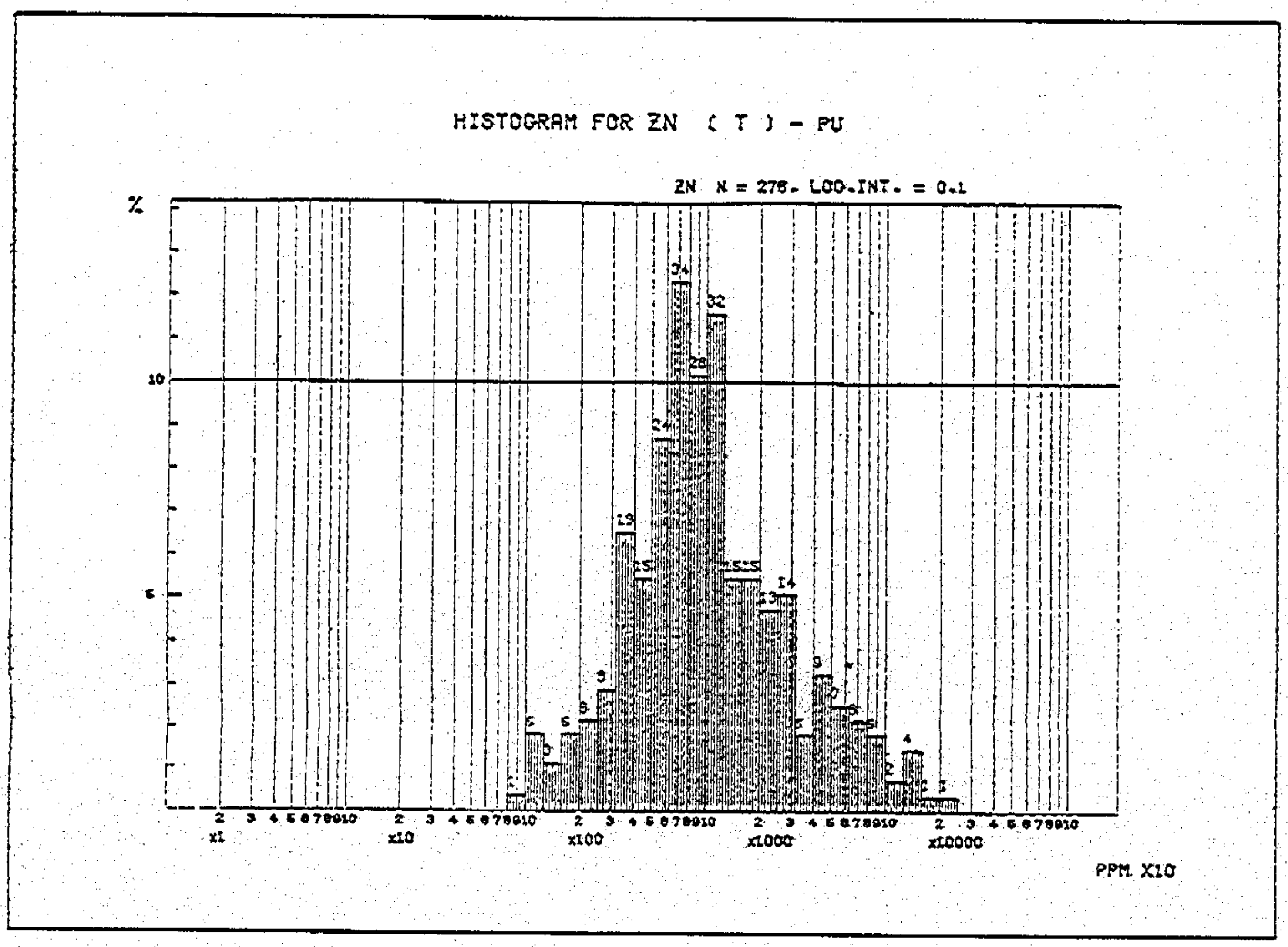


	Back ground	Anomaly
◇ Cu	17	95
△ Zn	130	850
✳ Ni	29	160









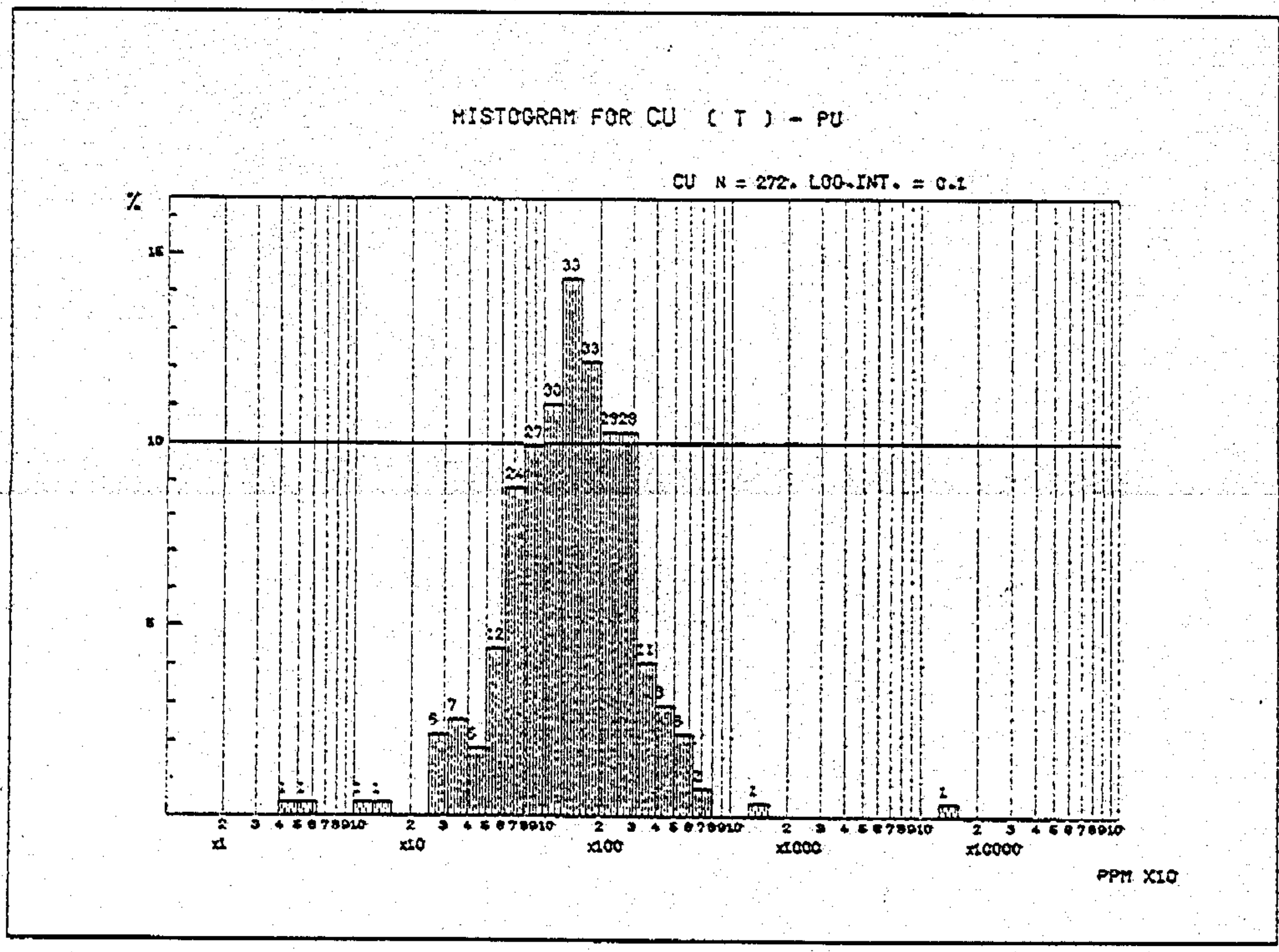


Fig.15 Cumulative Frequency Diagram & Histgram for Cu,Zn & Ni of Soil of The Pucara Group

In addition to the three, cobalt (Co), chrome (Cr), manganese (Mn), and lead (Pb), were also chemically examined on 60 samples selected from the entire samples of 2,595, as they were thought applicable to the prospecting in the A and B Areas. Table 15 shows the flow sheet of chemical analysis for these 4 elements.

9-2 Results of Geochemical Survey

Minor amounts of metallic elements are contained in the rocks in the natural state quite free from mineralization. The contents are different by rock types, and some special rock will show so high contents as the extraction of mineralized zones are prevented. The assay results on each element were compared to the geology of the spot where the sample was collected in the A and B Areas. As most of the stream sediments did not reflect honestly the geology of collected spot, the assays of soils were used for the correlation with geology.

As is shown on Table 19, the results have revealed that

(1) the mean value of Zn is specially high in the Pucara Group, and so with the overlying Sarayaquillo Formation and the underlying Mitu Group, too (Fig. 12). It also seems slightly higher in the Copacabana-Tarma Group which contains limestone layers,

(2) the mean value of Cu has not shown any tendency to become higher as a whole in some specified layer or rock mass, but some high concentrations are recognized in some parts of the Mesozoic dioritic rocks and Paleogene porphyries, though the distribution of the highs has not been studied thoroughly,

(3) the mean value of nickel shows a tendency to be slightly high in the metamorphic rocks, but the difference by layer or rock mass is small (Fig. 12).

In view of the difficulty to correlate the stream sediments to the geology of collected spots, whole of their assays were treated as one population. The results of statistical analysis thus performed on Cu, Zn, and Ni, are shown on Table 2. The geochemical anomalies were extracted by the following basis.

Threshold Values	Cu ppm	Zn ppm	Ni ppm
Transitional zone ($\bar{x}$)	14.2 (20)	56.6 (60)	14.5 (20)
Weak anomaly ($\bar{x} + \sigma$)	27.7 (30)	160.6 (200)	24.9 (30)
Strong anomaly ($\bar{x} + 2\sigma$)	41.2 (40)	264.6 (300)	35.3 (40)

( ) shows adopted value.

In addition to the above, there is a method by probability logarithmic diagram, by which the background and anomalies are obtained as follows;

	Cu ppm	Zn ppm	Ni ppm
Background	12	35	12
Anomaly	65	225	56

By applying either of the methods, the obtained values showed close approximation, but in the present report, the background (threshold value of transitional zone) and anomaly (threshold value of anomalies) are classified by applying the combined values of mean value ($\bar{x}$) and standard deviation (σ).

The followings are the results of factor analysis of stream sediments by computer in which the whole are treated as one population.

Factor 1	Ni (96.4)	Cu (31.4)	Zn (7.2)
Factor 2	Zn (99.4)	Cu (8.6)	Ni (8.1)

This will suggest that the three elements of Cu, Zn, and Ni, are appropriate for the indicative elements in the regional geochemical survey, because the correlativity between each element in each factor seems not so high and they seem to be controlled by different factor each other.

As regards to the soil samples, not only they were treated as one population statistically, but also treated differentiatedly by layers or rock masses, as they are more reasonably correlated to the geology of collected spots.

The Pucara Group was investigated by treating the samples concerned to this Group as one population, too, as the Group showed very high mean and standard deviation in Zn compared to the case of treating the whole as one population.

Table 2 shows the results of statistical analysis on Cu, Zn, and Ni, by taking the whole as one population, from which the anomalies are extracted on the following basis.

Threshold values	Cu ppm	Zn ppm	Ni ppm
Transitional zone ($\bar{x}$)	20.2 (20)	106.0 (100)	22.7 (20)
Weak anomaly ($\bar{x} + \sigma$)	69.2 (70)	347.2 (300)	44.9 (40)
Strong anomaly ($\bar{x} + 2\sigma$)	118.2 (120)	588.4 (600)	67.1 (70)

The anomalies and background are obtained as follows by propability logarithmic diagram as a means to pick up the geochemical anomalies;

	Cu ppm	Zn ppm	Ni ppm
Background	13	60	17
Anomalies	90	140	100

By either of the methods, fairly close values are obtained, but in the present report, the values obtained by the combination of mean value ($\bar{x}$) and standard deviation (σ) are adopted to that of background (threshold value of transitional zone) and that of anomalies (threshold values of anomalous zones).

The followings are the results of factor analysis of soil samples by computer in which the whole is treated as one population.

Factor 1	Cu (98.4)	Ni (14.1)	Zn (10.8)
Factor 2	Zn (98.7)	Ni (12.4)	Cu (10.8)
Factor 3	Ni (98.2)	Cu (14.1)	Zn (12.2)

( ): correlation coefficient to the factor

The three elements of Cu, Zn, and Ni, may be said as appropriate indicative elements in the regional geochemical survey, as the above results show clearly that each of them are controlled by different factor.

Fig. 12 shows the results of statistical analysis in terms of geological formations or rock masses, in which the followings are the results to have investigated on the Pucara Group.

The geochemical anomalies in the Pucara Group were extracted by the following basis.

Threshold values	Cu ppm	Zn ppm	Ni ppm
Transitional zone ($\bar{x}$)	22.6	194.0 (200)	32.3
Weak anomaly ($\bar{x} + \sigma$)	110.1	480.6 (500)	60.0
Strong anomaly ($\bar{x} + 2\sigma$)	197.6	767.2 (800)	87.7

( ) shows adopted value

Values of geochemical anomaly and background obtained by probability logarithmic method are shown as follows;

	Cu ppm	Zn ppm	Ni ppm
Background	17	130	29
Anomaly	95	850	160

They are close to those values obtained by the method afore mentioned.

Table. 3 Statistical Analysis of 7 Elements in Selected Geochemical Samples

[ ] is a number of treated samples

Stream Sediment [30]

	Cu ppm	Zn ppm	Ni ppm	Co ppm	Cr ppm	Mn ppm	Pb ppm
Maximum	40.5	1,430.0	65.6	8.2	2.6	781.0	30.6
Minimum	6.0	8.1	0.7	0.3	0.0	141.5	0.0
Average	12.5	109.7	14.4	1.2	0.6	372.6	2.2
Standard deviation	8.7	257.8	11.9	1.4	0.7	153.7	6.1
Numbers	30	30	30	30	29	30	11

Soil [30]

	Cu ppm	Zn ppm	Ni ppm	Co ppm	Cr ppm	Mn ppm	Pb ppm
Maximum	79.0	207.0	54.0	5.6	10.7	2,867.9	14.9
Minimum	3.5	4.6	2.0	0.4	0.0	22.6	0.0
Average	19.5	68.5	20.1	1.5	1.3	715.6	2.0
Standard deviation	18.0	51.2	14.6	1.3	2.1	571.4	3.1
Numbers	30	30	30	30	26	30	21

Fig. 16 shows the distribution of obtained geochemical anomalies on Zn through the statistical analysis by taking the samples of the Pucara Group as one population.

The followings are the results of factor analysis of soil samples in which the whole of the Pucara Group are taken as one population.

Factor 1	Cu (97.2)	Zn (23.8)	Ni (7.8)
Factor 2	Ni (97.7)	Zn (21.3)	Cu (7.9)
Factor 3	Zn (94.8)	Cu (22.3)	Ni (19.6)

( ): correlation coefficient

The above will show that Cu, Zn, and Ni, in the Pucara Group are fairly controlled by different factors each other.

Table 3 shows the statistical analysis of the assays of 60 samples which were assayed on Co, Cr, Mn, and Pb in addition to Cu, Zn, and Ni.

Factor analysis on them by computer;

on 30 samples of stream sediments,

Factor 1	Ni (87.5)	Cu (80.6)	Cr (80.5)	Mn (71.6)
Factor 2	Pb (96.0)	Zn (95.9)		
Factor 3	Co (94.)			

on 30 samples of soils,

Factor 1	Ni (89.1)	Cr (85.7)	Co (65.5)	Cu (53.0)
Factor 2	Pb (89.7)	Zn (79.1)	Cu (51.1)	

According to the above results, Ni, Cr, and Co seem to be controlled by the common factor, while Zn and Cu by different factor. Part of Cu seems to be related to the factor which controls Ni, Cr, and Co on one hand, and on the other, to be related to the factor which controls Pb and Zn. Mn is too divergent to be accepted of showing certain tendency, as several factors are possibly considered on its genesis. Therefore, in the regional geochemical survey, it is most reasonable to select each one of the indicative element from Pb-Zn and Ni-Cr-Co groups, snd Cu as the element related to both of the groups.

In the geochemical survey at present stage, of which main purpose is to extract the mineralized zones containing Ni, Cr, and Co, and those containing Pb and Zn, it is necessary to investigate the behavior of each element contained in the mineralized zones, as the elements may behave differently each other in each of them ineralized zones.

9-3 Geological Considerations on Geochemical Results

Geological considerations have been made on the geochemical anomalies by soils and stream sediments in terms of each element, which says:

(1) Cu anomalies by soils are higher around the fissure filling deposits, which are developed in the metamorphic and granitic rocks in the southwestern part, and the predominant anomalies all exist near the minearl indications found near Villa Huasahuasi and north of Villa Palca. While in the southern part, the predominant anomaly coincides with a part of the Jurassic dioritic rocks which intrudes like a stock near the San Vicente Deposits.

In the central part, anomalies were found near the border of the Pucara Group and Oriente Group in the northwest of Villa Paucartambo, but no intrusive body has ever been assertained. A remarkable anomaly exists in the Oriente Group in the north of Villa Rica, which is considered to be related to intrusives, as the nearby existence of intrusive has been anticipated through the aerial photometric interpretation.

(2) In addition to the anomalies indicated by soils, those by stream sediments have been detected distinctly in the east of Huancabamba. The district has not been surveyed enough geologically due to the jungles, but as the existence of stock of the Paleogene porphyries is anticipated through the photo-geological analysis and the scattered boulders, the geochemical anomalies afore mentioned may be related to this intrusives.

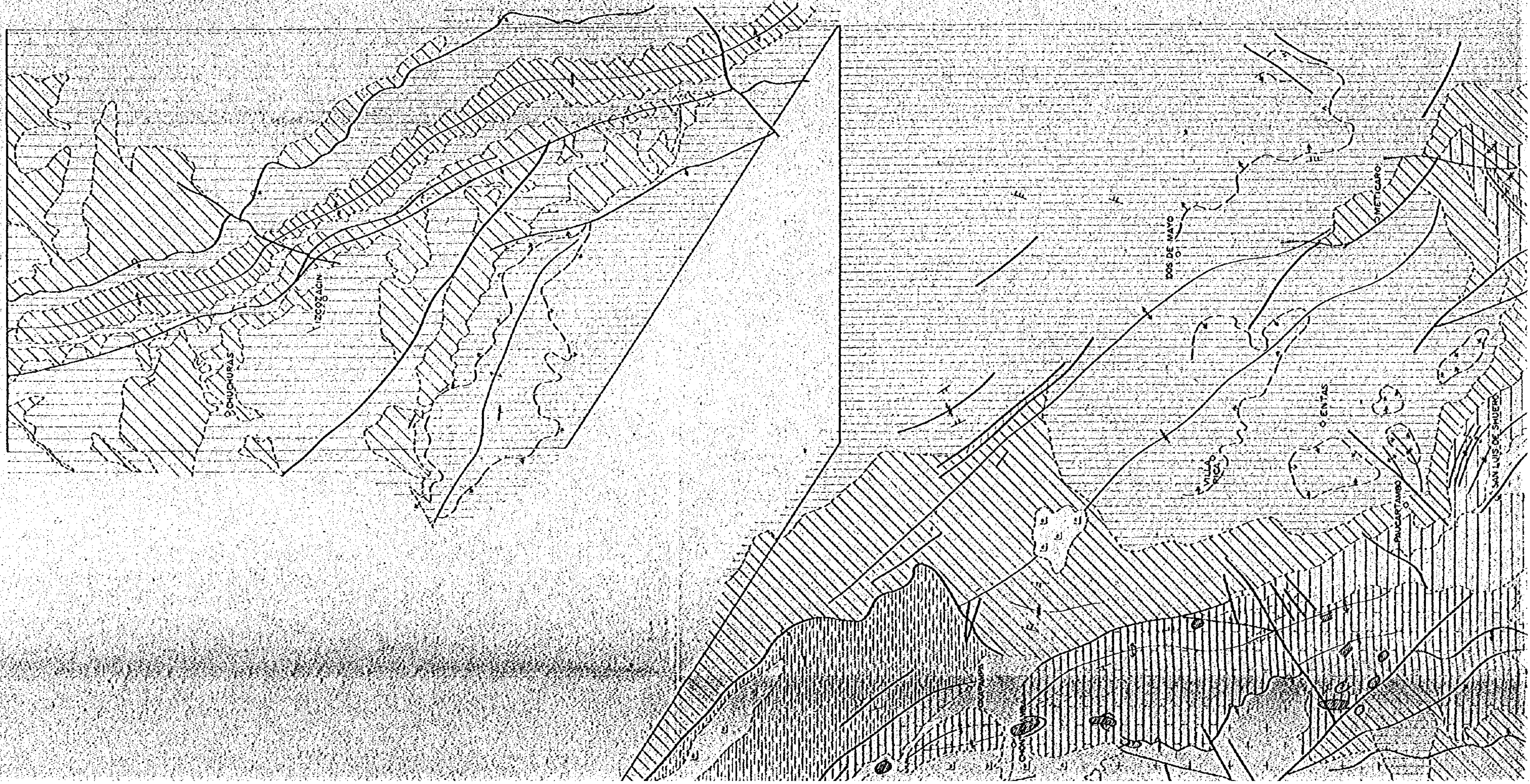
(3) All the anomalies of Zn by soil samples have been detected in the Pucara Group, except those which are related to the zone of fissure filling deposits in the southwestern part (Fig. 16).

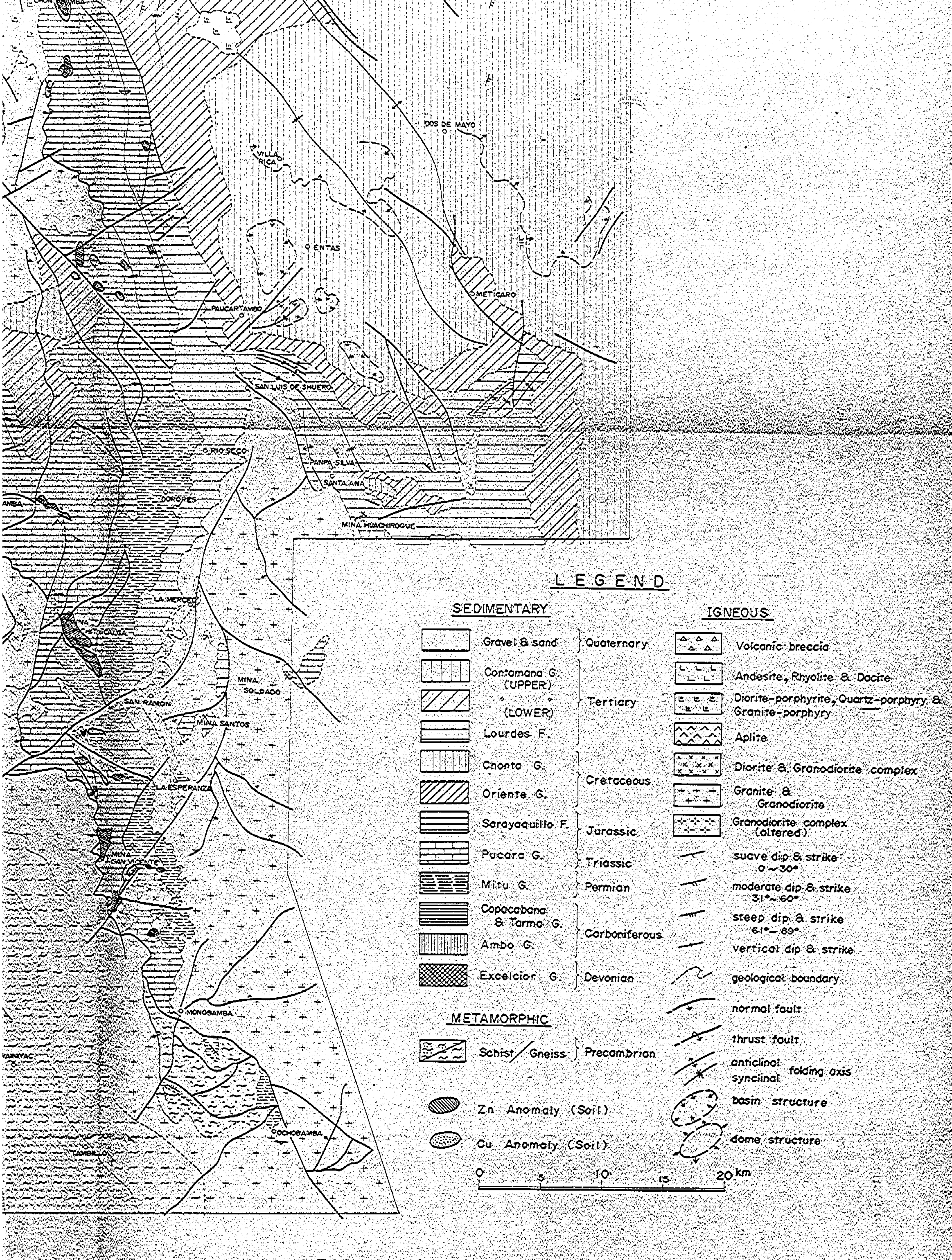
The predominant anomalies in the Pucara Group exist not only around those known deposits of San Vicente Deposits and Pichita Carga Deposits, but also exist in the nothwest of Paucartambo, southwest of Oxapampa, and northwest of Huancabamba in the central part. The sizes and relation to the geological structure of the anomalies are not clear, except the surroundings of the San Vicente Deposits where precise geological survey and geochemical survey have been exercised, but there seems a tendency that the anomalies are distributed near dolomite or dolomitic limestone.

(4) The anomalies of Zn detected by stream sediments are distributed near the anomalies detected by soils, or else on their downstreams.

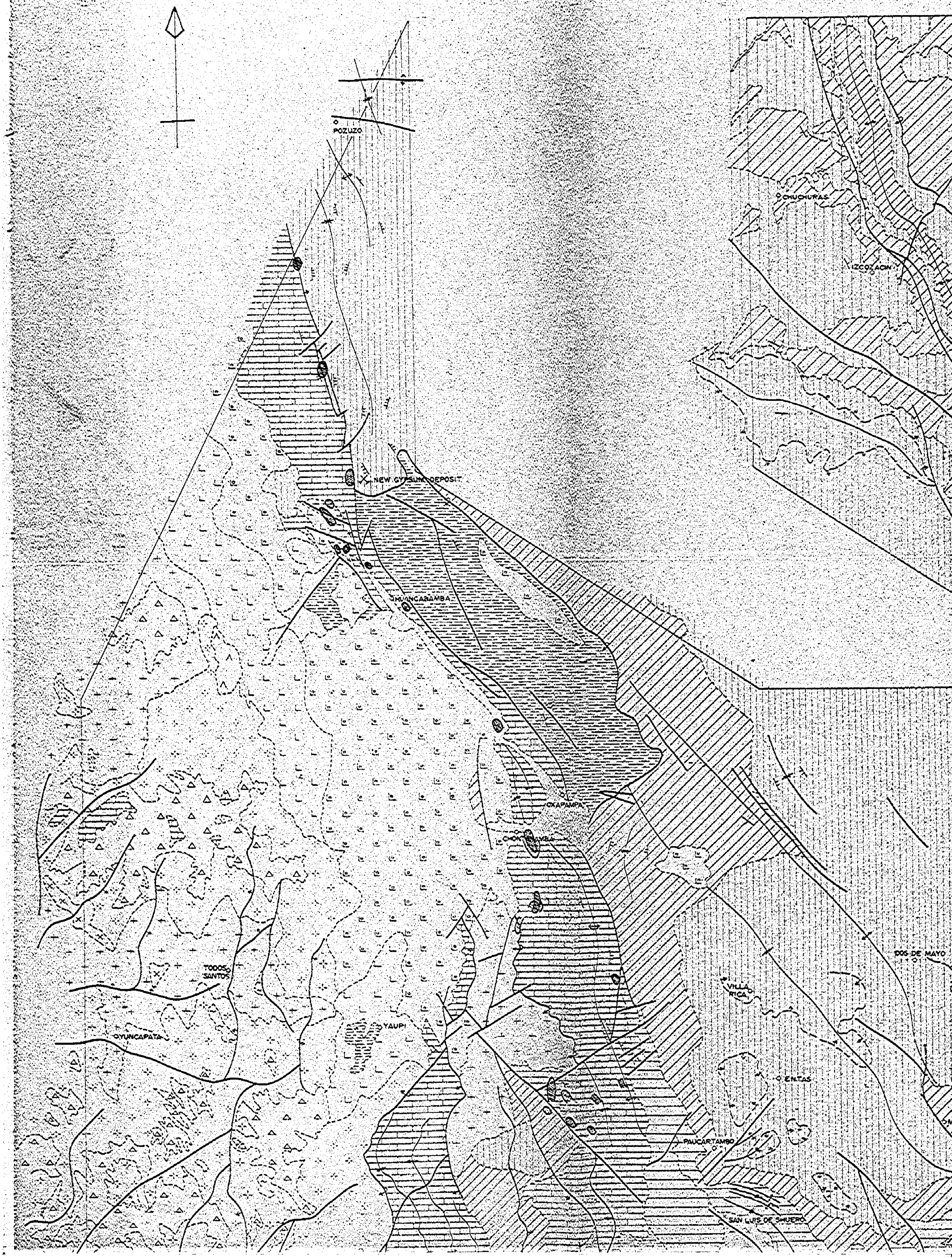
(5) Ni anomalies by soils coincide with the metamorphic rocks in the southwestern part with some predominant ones, and weak anomalies are scattered throughout.

(6) Ni anomalies by stream sediments more or less coincide to those by soils, but no remarkable ones are recognized except those found near the metamorphic rocks.


CHUCHURAS
IZCOZACIN
DOS DE MAYO
METICARO
ENTAS
VILLA RICA
PAUCARTAMBO
SAN LUIS DE SHUARO



Geochemical Anomaly in Pucara Group



POZUZO
CHUCHURAS
NEW GYPSUM DEPOSIT
OXAPAMPA
TODOS SANTOS
OYUNCAPATA
YAUPI
VILLA RICA
DOS DE MAYO
PAUCARTAMBO
SAN LUIS DE SHUERO

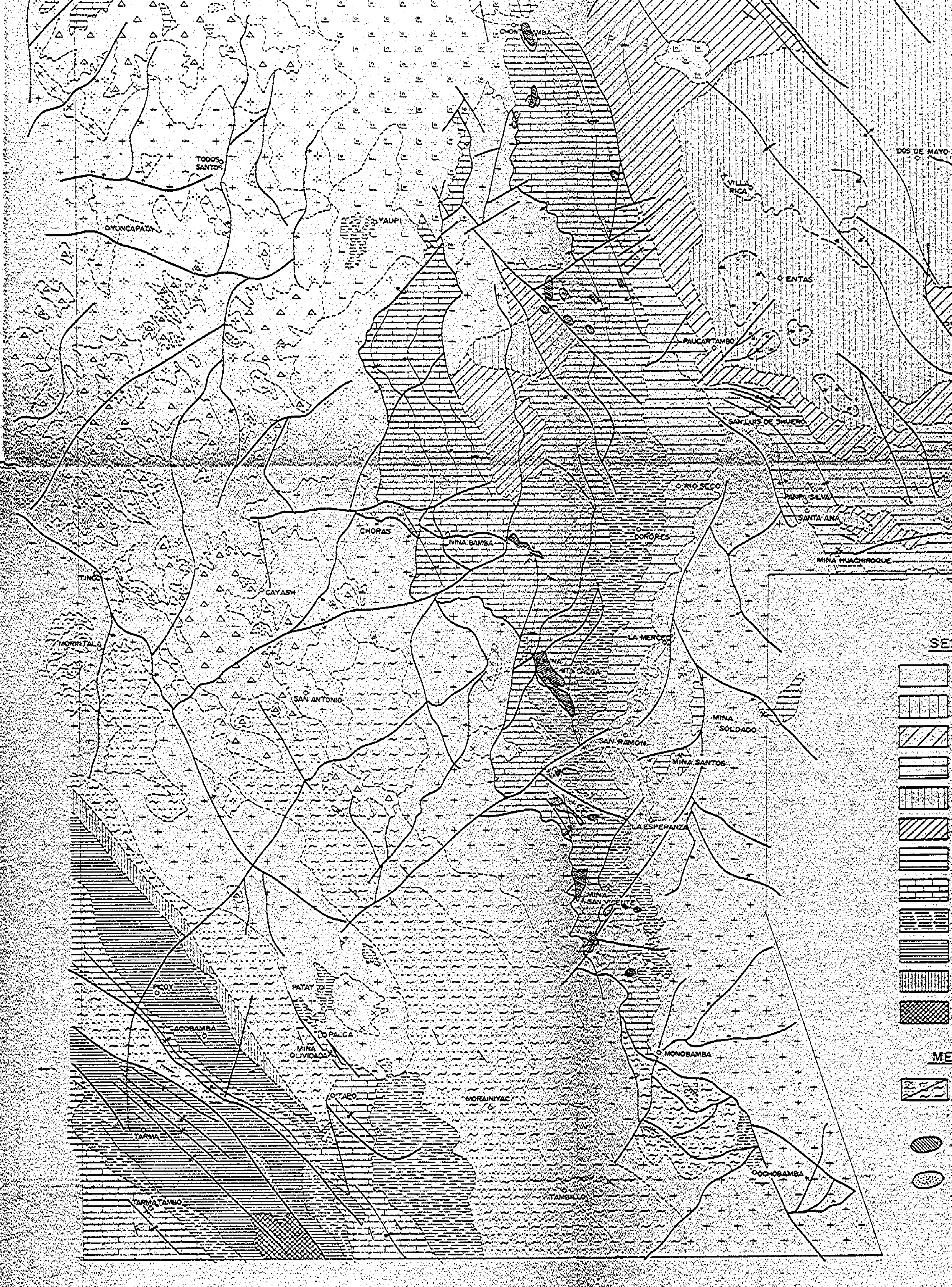


Fig. 16 Schematic Map of Geochemical Anomaly in Pucara Grou

Chapter 10. Measurement of Magnetic Susceptibility

One hundred rock samples were collected from the entire area surveyed and their magnetic susceptibilities were measured. Rock samples were classified by their rock types and geological ages.

10-1 Measuring System of Magnetic Susceptibility

Followings are the specifications of measuring system of magnetic susceptibility used.

Model : Magnetic Susceptibility System, Model 3101A,
Bison Instruments, Inc.

Sensibility : 1×10^{-6}------1×10^{-1} e.m.u.c.g.s.

Dimension : 15cm x 30cm x 26cm

Weight : 4.5 kg

10-2 Measurement

Rock sample is smashed into even grains under 60 mesh and put in a cylindrical palstic container with a known capacity to be measured for the magnetic susceptibility. In order to obtain a real magnetic susceptibity, the packed density of samples is measured simultaneously for correction, as the apparent magnetic susceptibility is proportional to the volume of container of the sample to be measured. In addition repeatability is examined by repeated measurements.

10-3 Results of Measurements

The results of measurements are shown on Fig. 17 classified by rock types and formations.

It is recognized that magnetic susceptibilities of each rock type and formation vary widely. Apparently from Fig. 17, the distribution of logarithmic magnetic susceptibility tends to show difference of rock types. Therefore, variance of logarithmic magnetic susceptibilities were analyzed.

10-4 Results of Analysis

Rocks were classified into 33 rock types, of which results of variance anslysis are given on the following tables.

(1)

element	errorisum of squares	degree of freedom	unbiased variance	test of significance
A (getw. 33 rock types)	12.5	32	0.3859	*95 %
e (residual)	13.33	67	0.1989	
T (total)	25.68	99	0.2594	

(2)

element	errorisum of squares	degree of freedom	unbiased variance	test of significance
A' (betw. macro rock types)	2.43	2	1.22	**99 %
A'' (within sed. rocks)	4.25	9	0.471	*95 %
A''' (within ign. rocks)	3.43	10	0.343	
A'''' (within ss)	1.46	5	0.293	
A (rest)	0.78	6	0.131	
e	13.33	67	0.1989	
T	25.68	99		

When the rocks are classified into three macroscopic groups of sedimentary rocks, ore, and igneous rocks, difference of magnetic susceptibilities between sedimentary and igneous rocks is recognized. But on the other hand, significant difference of magnetic susceptibilities between age groups of any rock types can not be recognized.

For checking the measurement errors, 16 samples were randomly chosen out of one hundred original samples, which were resmashed and remeasured. The results of variance analysis of remeasurement are shown below.

element	errorisum of squares	degree of freedom	unbiased variance
W (betw. samples)	8.261	15	0.551
e	0.708	16	0.044
T	8.969	31	

S/N is calculated from the data above, as

$$\frac{\sigma W^2}{\sigma M^2}=\frac{\frac{1}{2}(0.551-0.0442)}{0.0442}=5.72$$

$$S/N=10 \times \log_{10}\left(\frac{\sigma W^2}{\sigma M^2}\right)=7.58 \text{ db}$$

As S/N is generally considered satisfactory to be more than 5--7 db, the present measurement may be said accurate enough.

10-5 Simulation

By using the measured magnetic susceptibilities of rock samples (Fig. 17), the assumed magnetic field, possibly induced by the actual geological set-up, was calculated. An underground magnetic model was produced from geological section along the measuring line B, where the Pucara Group near the central part exposed out, of which results is shown by Fig.18.

Magnetic susceptibilities were assumed as follows;

Rock Type	Magnetic Susceptibility
Limestone, Pucara Group	1.5×10^{-4}
Sandstone, Pucara Group	1.2×10^{-4}
Gneiss	2.5×10^{-4}
Granite & Granodiorite	4.0×10^{-4}
Diorite	1.0×10^{-3}

If aerial magnetic survey is done over this area by a precision total field magnetometer, its effects may generally be considered, from the results of simulation, to contribute to the interpretation of structures from deeper to shallower zones of the igneous rocks and the basement composed of gneisses, as well as to make possible to assume the deeper distribution of the Pucara Group.

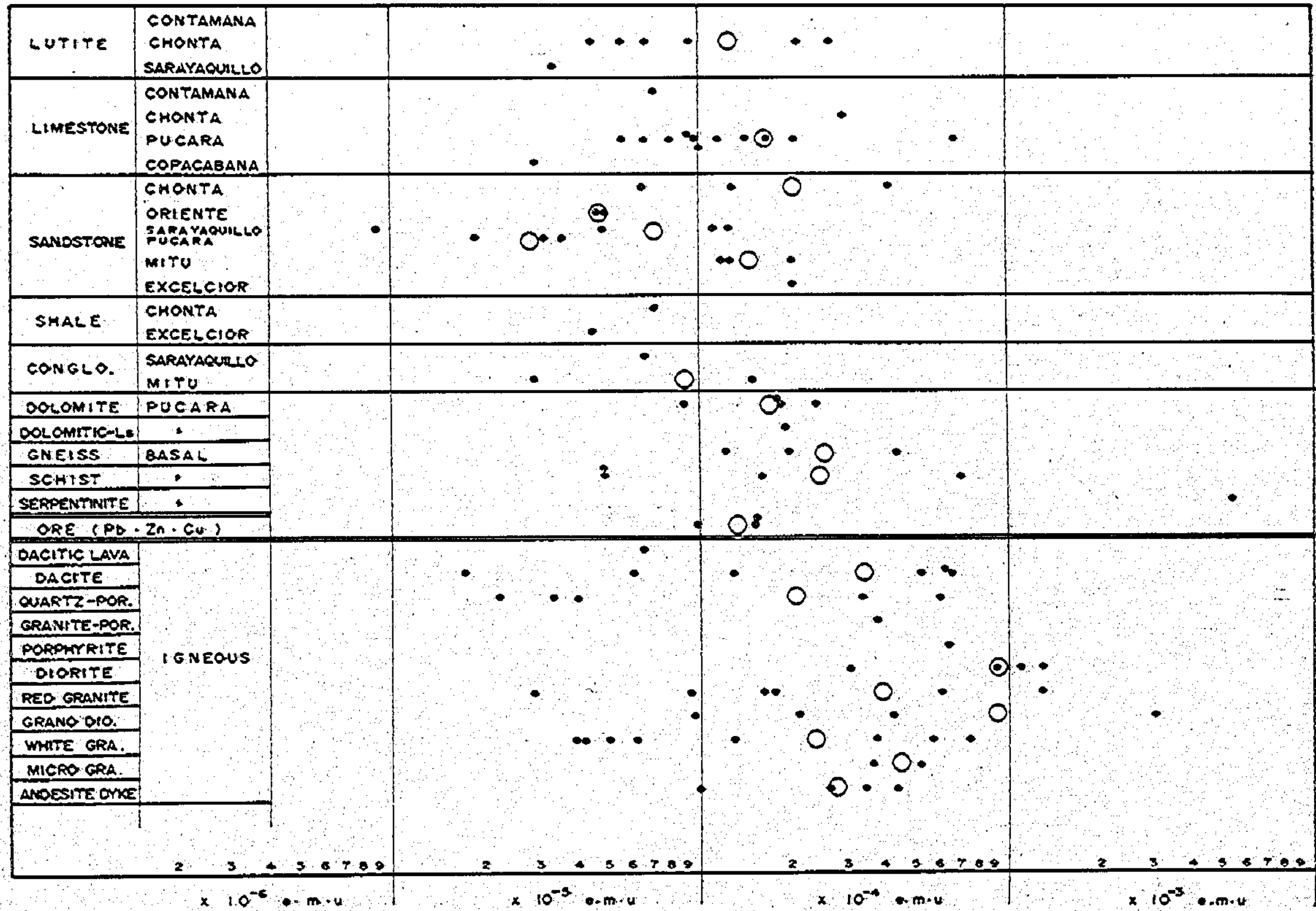


Fig. 17 Result of Magnetic Susceptibility Measurement

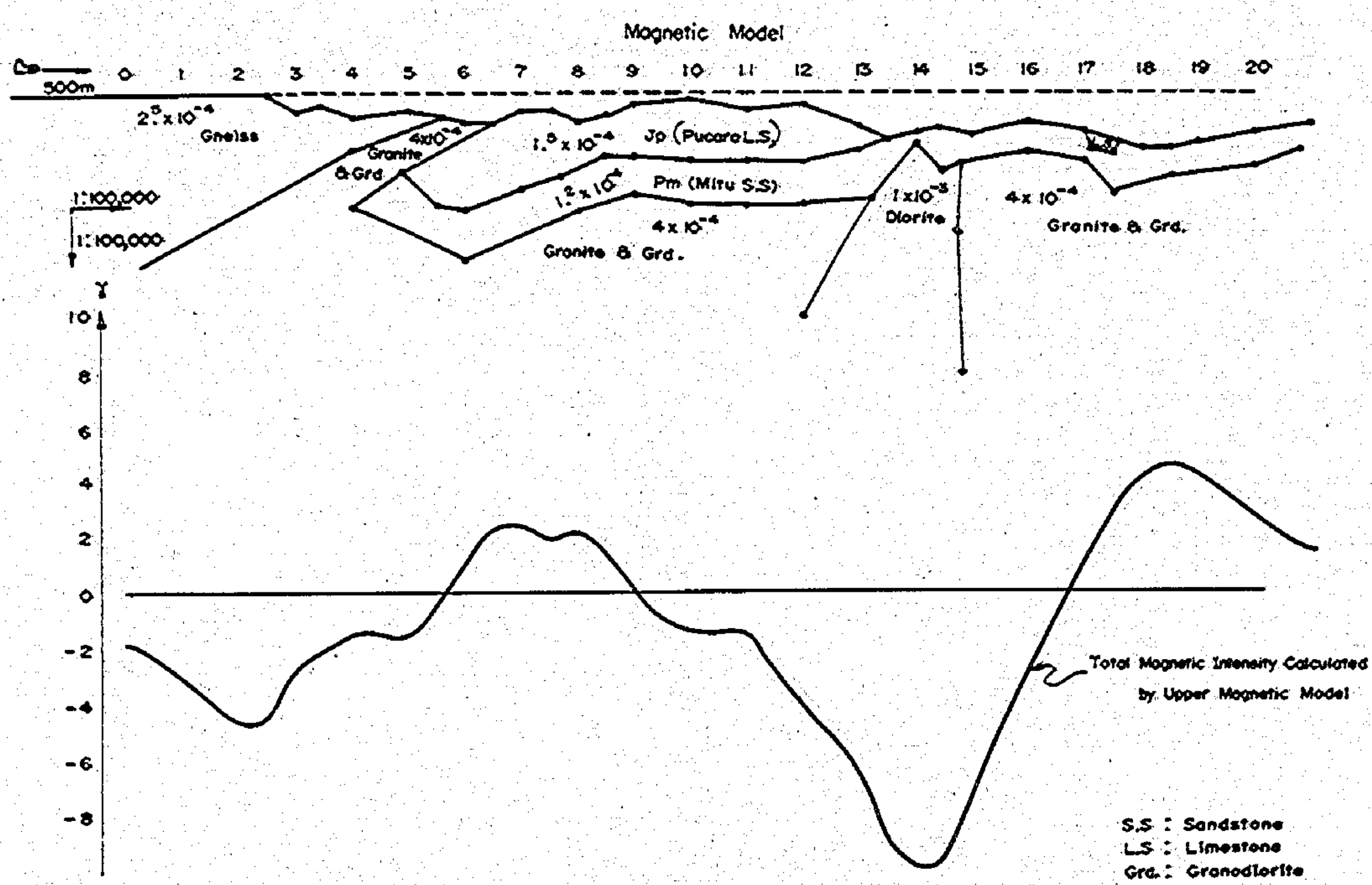


Fig. 18 Model Study of a Magnetic Section with Electronic Computer