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REPUBLIC OF PERU

REPORT ON GEOLOGICAL SURVEY OF THE CORDILLERA ORIENTAL, CENTRAL PERU

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PREFACE

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

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

This year was for the fourth phase survey, and as for above-mentioned work, Geological-Geochemical Survey and Drilling Survey teams were formed consisting of eleven (11) members headed by Mr. Shigeaki Yoshikawa, MESCO, Inc., and sent to the Republic of Peru. The teams stayed there for one hundred forty-six (146) days from May 12, to October 4, 1978. During the period of their stays, the teams, in close collaboration with the Government of the Republic of Peru and its various authorities, were able to complete survey works on schedule.

This report submitted hereby summarizes the results of the Geological-Geochemical Survey and Drilling Survey performed for the fourth-phase survey in the area.

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

February 1979

Shinsaku Hogen
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

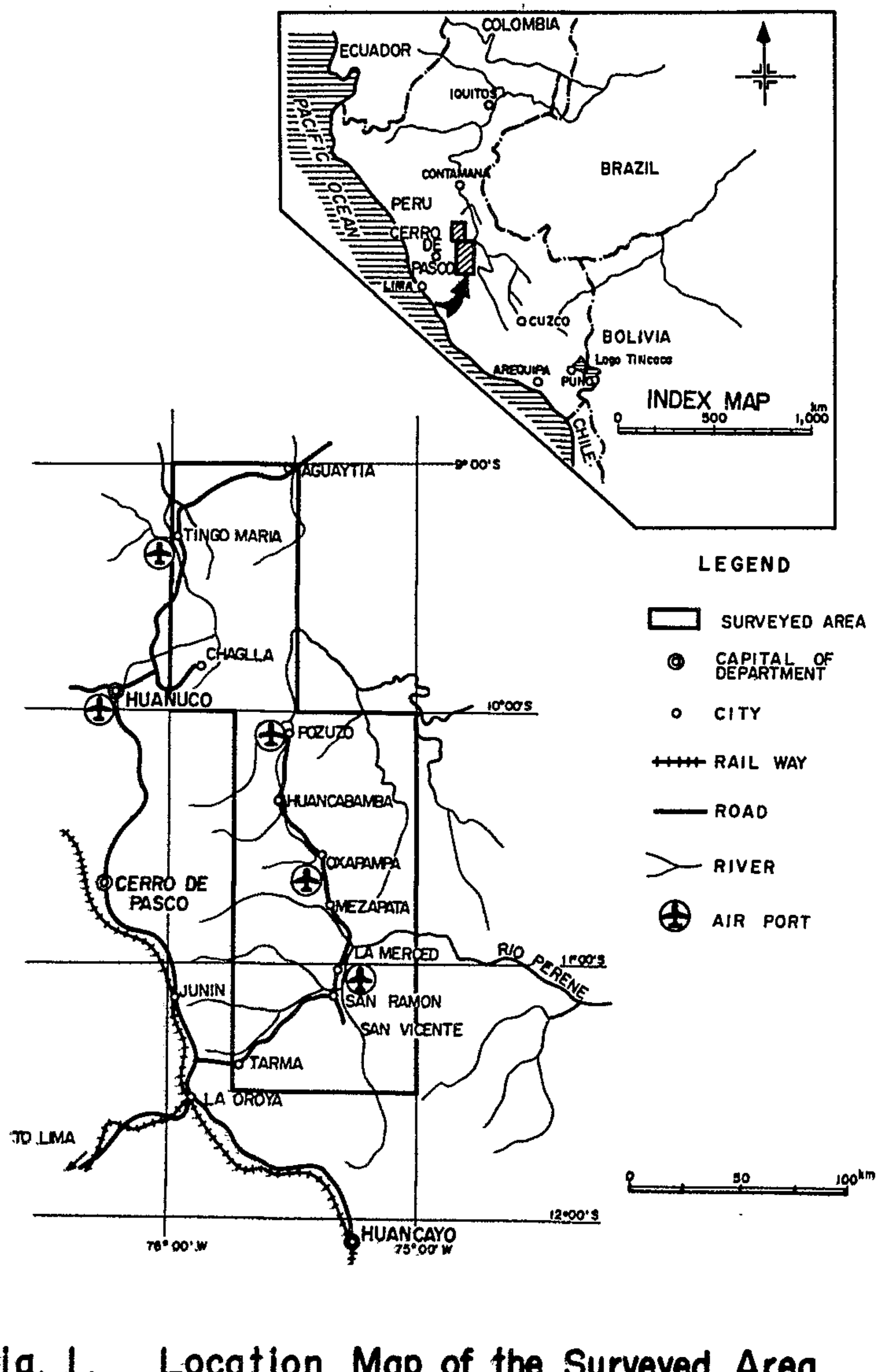

Fig. 1. Location Map of the Surveyed Area

Integrated Contents

SUMMARY

The present survey has been carried out comprising a part of the Basic Geological Survey for the Development of Mineral Resources in the central part of the Republic of Peru.

As the final year's program, geological survey, trenching, geochemical survey, and diamond drilling were completed in this year, in the areas of San Roque and Tambo Maria in the southern part, and in the Chaglla area in the northern part of the surveyed area, where the rocks belonging to the Pucara Group are distributed.

The survey has been carried out with the purpose of finding new indications of ore mineralization, of confirming the features of emplacement of ore deposits, and of considering mechanism and genesis of these ore deposits.

The field works were accomplished in the term from May to October, 1978, followed by the laboratory works down to February, 1979.

In the central part, Paleozoic to Cenozoic sedimentary rocks are distributed in the direction of NNW-SSE, except for its western highland, where metamorphic rocks and igneous rocks develop well.

The Pucara Group is distributed along the eastern margin of these igneous rocks, and is composed of carbonate rocks such as dolostone and limestone.

There are two sorts of the dolostone. The one is that formed in the rather closed reef environment, viewing from the impurities contained and from the distribution of residual evaporites. The other is the dolostone formed in the shallow-water environment where tidal flow was accompanied. The former-type dolostone is recognized in the areas of San Vicente and San Roque, and the latter type one is seen in Tambo Maria and Chaglla areas,

The dolomite is thought to have been formed in the process of the replacement by magnesium contained in sea water, in the early stage of the diagenesis. Also, the mechanism to form zebra-structure is now thought to be that gradual crystallization would have occurred along the narrow space caused by the reduction of volume through the dolomitization, instead of the idea in the past, that the recrystallization at the time of structural movement was the main cause to form the zebra-structure.

The strata-bound lead-zinc ore deposits in the Pucara Group are classified into three types —— dissminated type, fracture filling type and banded type. The ore grade of each type is, in average, n x 10^2 to n x 10^3 ppm, 3 to 4 % and 10 to 20 %, respectively in the order. The ores of the disseminated type are found predominantly in the limestone while those of fracture filling type and banded type are emplaced mainly in the dolostone.

By the result of the geochemical survey on the rock samples, the anomalies of lead and zinc are known to be of two types —— the one is San Roque type, which has higher content values than the average content, and the other is Tambo Maria type, which has lower content values than the average content. In the San Roque area, rather broad anomalies are found in the limestone area containing mineral indications of the disseminated type, and small anomalies are recognized in the dolostone accompanied by the mineral indications of the fracture filling type. On the other hand, about the Tambo Maria type, the distribution of the anomalies, in which zinc content values are lower than lead content values is recognized to coincide with the distribution of the zebra-structure in the dolostone area. The above facts are thought to indicate that lead and zinc would have been mobilized and concentrated through the formation of the zebra-structure and through the dolomitization.

The strata-bound lead-zinc ore deposits are thought to have been accumulated syngenetically with the sedimentation of the country rocks, and it is not likely that they were brought about with the igneous activities. The metal ions dissolved in the hypersaline brine would have been carried into sedimentary basins and precipitated there primarily as metal-sulphides. These sulphide minerals are thought to have been remobilized through the narrow spaces caused by the dolomitization of the country rocks and concentrated in the forms of the ore deposits of fracture filling type and banded type.

By the above-mentioned results of the various surveys, it becomes obvious that the process of the mineral concentration of the strata-bound ore deposits distributed in this central part would have been from the deposits of the disseminated type to those of the fracture filling type or banded type. The conditions required for this sort of concentration are as follows:

(1) Sedimentary environment where metal ions, once carried into, would have been kept trapped.

(2) Reducing environment where ions would have precipitated as metal-sulphides.

(3) The environment where dolomitization would have developed and zebra-structure would have been formed.

The geology of the San Vicente area is thought to be sufficiently provided with all these conditions. The primary environment of the San Roque area seems to be similar to that of the San Vicente area, but there are parts where dolomite has not been well developed, and even where dolomite is found, the development of the zebra-structure is poor in this area. On the other hand, although the geology of the Tambo Maria area and Chaglla area is thought to be sufficient for these conditions required for the concentration of the ore minerals, the accumulation of the primary metal-sulphides would have been less than that in the San Vicente area and in the San Roque area. Therefore, large scale mineralization is not likely to be found.

It is clear from the facts mentioned above that the area where economic ore mineralization is expected in the San Roque area after San Vicene area. Further surveys would be necessary in this San Roque area. To have a more wide perspective, the potentiality for the ore mineralization would be expected in the area from Chontabamba to Pusagno, in the area of the north-west of San Ramon, in the area of the northwest of Huancabamba, in the area of the west of La Palmas in the northern part.

For further exploration, geological survey, trenching, geochemical survey, gravity survey, impurity analysis of the carbonate rocks and diamond drilling are effective as for the methods.

GENERAL

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Chapter 1 Introduction

1-1 Purpose of the Surveys

The present surveys were carried out in the area of 20,000 km^2 in the eastern part of the three departments of Junin, Pasco and Huanuco, programmed as the Basic Geological Survey for the Development of Mineral Resources in the central part of the Republic of Peru (Fig. 1).

The purpose of the surveys is firstly to confirm the distribution and the geological structure of the Pucara Group in which strata-bound lead zinc ore deposits are expected to have been emplaced, and secondly to extract the area of high potentiality for the mineral resources. Also, it is thought to be a purpose to establish the most appropriate and effective methods for the exploration of this type of ore deposits.

1-2 Circumstances of the Surveys

The programmed area of 20,000 km^2 had been left rather undeveloped except for some areas in the southern part of it. In 1974, Ministerio de Energía y Minas of the Republic of Peru had a program of the Cordillera Oriental Development Plan, including the present survey area, and survey by Side Looking Airborne Radar (SLAR) was carried out to produce mosaic map, which was geologically analysed.

The present survey was commenced in 1975 in the aforesaid area, following this SLAR survey. The preliminary survey of the earliest stage of the present survey, in 1975 and 1976, was composed of the reconnaissance work to check the geological map produced on the basis of the SLAR mosaic map, and of the geochemical survey to collect fundamental information about mineral deposits.

As the results of these surveys, the distribution and the geological structure of the Pucara Group was ascertained well, and it became clear that this Pucara Group is important as country rock of the strata-bound lead-zinc ore deposits as seen in San Vicente.

In 1976, the survey was carried out limitedly in the southern part where the Pucara Group is distributed. In 1977, several areas such as San Roque and Tambo Maria were selected for a series of survey as geological survey, geochemical survey, geophysical prospecting (gravity survey) and diamond drilling etc. Through these surveys, it became evident that the location of the strata-bound lead-zinc ore deposits is controlled by the distribution of the dolostone* and the muddy carbonate rocks of the Pucara Group, and that such dolostone is developed dominantly in Oxapampa area.

In 1978, the surveyed area is confined to much smaller areas of San Roque and Tambo Maria, and geochemical survey, diamond drilling as well as the works for detailed correlation of the formations including trenching were carried out. Also, in the Chaglla area in the northern part, geological survey and geochemical survey were completed, taken as the effective methods to this area after applied and proved to be effective in the southern part.

Details of the works performed in this series of the survey are shown in Fig. 2 and Table 1.

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* In the reports of the present surveys, the word "dolomite" has been used for both meaning of rock dolomite and mineral dolomite. To avoid confusion, rock dolomite is called dolostone and mineral dolomite is named as dolomite, in this report.

1-3 Outline of the Surveys

1-3-1 Surveyed area

- Geological Survey

  Detailed survey accompanying trenching

  (San Roque area and Tambo Maria area) approx. 15 km^2

  Detailed geological survey (Chaglla area) approx. 45 km^2

- Trenching (San Roque area and Tambo Maria area)

  Total 5,626 m (29 lines)

- Diamond drilling (San Roque area and Tambo Maria area)

  Total 902.6 m (3 holes)

The surveyed areas are illustrated in Fig. 2 and the routes to these areas are shown in Fig. 3.

1-3-2 Methods and terms of the surveys

(1) Fieldworks

For the surveys in the San Roque area and in the Tambo Maria area, the base camp was stationed in the city of Oxapampa, and seven vehicles as trucks and jeeps were utilized through the term. All the works composing trenching as wood-cutting, digging and filling were completed by man-power.

As the Chaglla area was not accessible to vehicles, horses were the main facilities for the transportation of the materials, for the survey works themselves and for the movement from the base camp stationed in Chaglla town.

Sampling for the geochemical survey was done alongside with the geological survey.

As for the diamond drilling, some existing roads were improved and also new roads were constructed from the base in Oxapampa city for the transportation of the drilling machines.

(2) Analysis

Following these fieldworks, analytical works were carried out on the data obtained by these fieldworks and by the various works performed in the present series of the surveys. The analytical works were done in Japan except for some parts completed in the Republic of Peru. Mr. David Dávila joined the team for the analysis in Japan in this year, as the Peruvian counterpart.

The terms of the fieldworks and the analytical works in the present year are shown in the Table 2.

1-4 Members of the Survey Team

The fieldworks and the analytical works were performed by the members of MESCO, Inc. of Japan, in cooperation with Ministerio de Energía y Minas and Instituto de Geología y Minería (INGEOMIN) of the Republic of Peru.

The members of the survey team are as follows.

Leader:	Shigeaki Yoshikawa	MESCO, Inc.
General Affairs and	Mitsuru Suemori	JICA*
Liasons:	Tsuyoshi Konno	MMAJ**
	Kenji Sawada	"
Geologist:	Hiroshi Sato	MESCO, Inc.
	Yasumasa Fukahori	"
	Yukichi Tagami	"
	Shin'ichi Doi	"
	Masahiko Nohno	"
	Minoru Saito	"
Drilling Engineer:	Katsumasa Tanikawa	"
	Isamu Nakayama	"
	Tadatoshi Nasu	"
	Shigemitsu Watanabe	"

General Affairs	Benjamin Morales	INGEOMIN
and Liasons:	Alberto Pool	"
	Edgardo Ponzoni	"
	Gregorio Flores	"
Counterpart:	Oscar Palacios	"
	David Dávila	"
	César Vilca	"
	Alejandro Garro	"
	Luis Carrera	"
	David Zambrano	"

* Japan International Cooperation Agency

** Metal Mining Agency of Japan

Chapter 2 Conclusion and Recommendation to Future Program

2-1 Conclusion

In this year, the fieldworks such as geological survey, geochemical survey and diamond drilling were carried out in the central part of the Republic of Peru, and the analysis works were performed in Japan, of the data obtained through these fieldworks. Also, comprehensive analysis of the all-out data, including those obtained through this series of survey works up to 1977, was accomplished. To describe about the results of the above-mentioned various works in general, the followings are notable.

It is significant that, in San Roque area, remarkable outcrop of the lead-zinc ore mineralization of the fracture filling type was discovered. This is thought to be a strata-bound ore deposit contained in the carbonate rocks in the Pucara Group, —— same sort of the deposits as formerly discovered "disseminated type" or "banded type" ore mineralization. Mineralization of no other type but the disseminated type has been found in limestone belonging to the Pucara Group, and mineralizations of the other types are known to be emplaced in dolostone, which is thought to have been formed, in this area, through the process of diagenesis, in the highly evaporative reef environment, after the sedimentation. The dolomitization through this process would have played an important part in the concentration of ore minerals. It is concluded that banded ore associated with zebra-structure is the product of the highest concentration and, therefore, that it has the highest value economically.

The facts clarified through the various works in this year are summarized as follows.

(1) Stratigraphy of the Pucara Group

The Pucara Group develops well in a narrow band stretching NNW-SSE roughly in the central zone of the central part. The Group is composed of the sedimentary rocks such as limestone and dolostone, and it has three members mainly of dolostone and limestone, and two members dominantly composed of muddy or sandy limestones. They are called I to V member in the order from the lowest member, stratigraphically. Two dolostone layers are remarkable being III member and V member; the former is distributed in very broad area including San Vicente area, Tambo Maria area and Chaglla area, while the latter is distributed in the San Roque area. Rocks of the other members are not developed well. Dolostone belonging to the III member is notably alternated with ferrigeneous clastics layers in the San Vicente area, though it is homogeneous in the other areas. On the other hand, alternation with terrigeneous clastic layers and facies change to limestone is the characteristic of the V member.

The stratigraphical correlation of these carbonate rocks were attempted by the fossils available and by the features of the lithological facies. The Pucara Group has thickness of approximately 1,900 m in the northern part and about 2,450 m in the southern part. It is correlated to upper Triassic to middle Jurassic Age of the Mesozoic Era.

(2) Sedimentary environment of the Pucara Group

Viewing from the fact that the content of strontium in almost all carbonate rocks but muddy dark limestone belonging to the II member is 10 to 390 ppm. It is thought that most of these carbonate rocks, except for those of the II member, were accumulated in the reef environment of the shallow water, as was described by WOLF (1967) and CHESTER (1965). The II member, on the contrary, is thought to be the sediments in the rather abysmal environment, as many ammonite fossils are observed to be contained ubiquitously in the rocks of the II member.

The rocks of the II member contain 600 to 3,000 ppm of barium sulphate, which is extremely high compared to the figure shown by Chester (1965) as the average barium sulphate content of the rocks formed in the reef environment. Some samples show the content value of as high as even 2 %. In San Vicente area and in Pusagno area, gypsum has been found, in the rocks of this member, as the product of residual evaporites. It can be said that a highly evaporative environment is indicated, from the evidence that anomalous concentration of barium sulphate and gypsum coincides with the distribution of dolostone.

It is thought from the above-mentioned facts that the rocks belonging to the Pucara Group were accumulated in a shallow water reef environment, though these were two different conditions locally --- the one is a closed condition under which dolomite was formed and the other is a shallow water condition with tidal current.

The distribution of impurities can be used effectively for the consideration of the sedimentary environment of various carbonate rocks.

(3) Sedimentary environment viewing from the basement of the Mitu Group

The rocks of the Mitu Group are terrestrial sediments composed mainly of volcanic conglomerates formed at the end of Paleozoic Era. They are found on the horsts seen in the San Roque area to the Pusagno area in the zone where the rocks of the Pucara Group are distributed. There are differences of the sediments, as for rock facies or presence of residual evaporites, according to the position against the horst-like Mitu Group rocks, if they are in the eastern side or in the western side. It is thought that the rocks of the Mitu Group gave some sort of effects, as the basement of the barrier reef, for the setting up of the sedimentary environment of the Pucara Group, through the upheaval of parts of the Mitu Group, in connection with the tectonic movement to form geoanticlinal structure.

In another words, it is concluded that the basement of the Mitu Group played a great role to set up evaporative environment where dolomite was easily formed. It is possible to point out same environment's presence in the San Vicente area. But the basement of barrier reef or shallow water environment is not certain in the Tambo Maria area and in the Chaglla area, where there is no outcropping of the rocks belonging to the Mitu Group. The reason why this sort of analysis became possible lies in the facts that the rocks of the Mitu Group were found in the drill cores of the hole No. 52-2 in 1977 and that the distribution and the characteristics of these rocks were ascertained clearly in the geological survey carried out in the present year.

(4) Formation of dolomite and formation of zebra-structure

As for dolomite in the surveyed area, there are roughly two kinds of dolomite —— micritic dolomite and sparry dolomite. Little compositional difference has been noticed between the two dolomites, but the difference is merely about the size of the crystals. FRIEDMAN (1967) and SHOJI (1971) elucidated the mechanism of the formation of syngenetic dolomite in the environment as afore-described. It is thought about the dolomites found in the surveyed area that they were stabilized through the process of inversion, replacement and dolomitization in diagenesis following the formation of proto-dolomite by the reaction with hypersaline brine containing magnesium after the precipitation of calcium carbonate in marine water. There is a notable fact that the volume reduces as much as 12 to 13 % in maximum in the phenomenon of dolomitization, which has been pointed out by CHILINGAR (1967) and FAIRBRIDGE (1967). The volume reduction could give effects on the passage of hypersaline brine and on the successive dolomitization. Accordingly, it is said that zebra-structure was formed by the gradual crystallization in the spaces parallel to the sedimentary plane, caused by such volume contraction at the period of dolomitization through the diagenesis.

(5) Behavior of lead and zinc in carbonate rocks

As the results of the geochemical survey carried out in the present year, the high value anomalies of the San Roque type and the low value anomalies of the Tambo Maria type have been obtained, as was the result of the geochemical survey in 1977.

As for the anomalies of the San Roque type, there is a distinct difference of the character of the anomalies shown by the rock facies, that broad anomalies are found in the limestones containing disseminated type mineralization while merely small anomalies are seen in the dolostone containing mineralization of fracture filling type. On the other hand, the distribution of the anomalies of the Tambo Maria type corresponds well with the distribution of the zebra-structure contained in the dolostone, and the zinc content values are notably lower than those of lead in the anomalies of this type. The dolomite contained in the dolostone was formed after the accumulation as low-magnesian calcite or aragonite. It is thought that metal elements would have been remobilized through the process of the formation of dolomite by the replacement or the inversion from such calcite or aragonite.

It can be said from the above-mentioned evidences that further effective consideration can be possible if the differences of the country rocks are well noted, although the geochemical survey of the rocks is very effective by itself in the area where strata-bound lead-zinc ore deposits are expected.

(6) Types of strata-bound lead-zinc ore deposits

The strata-bound lead-zinc ore deposits in the Pucara Group are emplaced mainly in the carbonate rocks belonging to the III and V members.

Those indications of the mineralization are classified into the following three types.

① Disseminated type

② Fracture filling type

③ Banded type

(7) Mechanism of the formation of the ore deposits

These sorts of ore deposits are thought to have been formed through the processes of the precipitation of primary sulphides and the concentration of them.

The genesis of the primary sulphides has been elucidated by SCHNEIDER (1964), STANTON (1972) and others that the precipitation would have occurred through the reduction of the metal ions dissolved in the marine water by SO_4 ion and methane gas in the weakly acidic to neutral environment. Accordingly, the rate of the precipitation of the primary sulphides can be said to be dependant upon the amount of the metal ions flowing into sedimendary basin, and also upon the environment whether it was suitable to the precipitation.

The process of the concentration of the metals would have been associated with dolomitization. The spaces caused by dolomitization would have supplied passages for the hypersaline brine and rooms for the concentration of the primary sulphides. The rate of concentration would have been dependant upon the size of the spaces and upon the amount of the primary sulphides transported.

(8) Appraisal of the surveyed area

In the San Vicente area, all the aforesaid conditions required for the precipitation and the concentration to form the ore deposits of this strata-bound type are well satisfied —— such as inflowing of the metal ions, environment for the precipitation of the primary sulphides, environment for the formation of dolomite and the condition for the zebra-structure to be widely formed. As the result of it, banded type mineralization of the San Vicente ore deposit has been found.

In the San Roque area, the geological conditions are similar to those of the San Vicente area. However, no zebra-structure has been found, but only the mineralizations of disseminated type and fracture filling type are recognized. Accordingly, banded type mineralization could be expected in the places, if zebra-structure would be found.

On the contrary to the San Roque area, zebra-structure develops quite well in the areas of Tambo Maria and Chaglla. However, quite a little amount of the precipitation of the primary sulphides would have render the scale of concentration rather small.

2-2 Recommendation to Future Program

From the above-mentioned survey results, it can be said that the following conditions are required for the strata-bound lead-zinc ore deposits to be emplaced remarkably, in the central part,

① that large amount of metal ions such as lead, zinc, and so on flew into sedimentary basin,

② that such metal ions were not dispersed but kept reserved,

③ that there was a reducing environment in which they could precipitate as metal sulphides, and

④ that dolostone was formed, including part of zebra-structure, where metals were concentrated as the result.

In this central part, the followings have been picked up as the favorable areas for the existence of the ore deposits, which could possibly be found through the future survey (Fig. 4 (1), (2)).

① San Roque area

② The area from Chontabamba to Pusagno

③ Northwestern part of San Ramon

④ Northwestern part of Huancabamba

⑤ Western part of Las Palmas

In the San Roque area, surveys should be programmed for the discovery of zebra-structure. To realize it, geochemical survey, geological survey accompanying trenching and diamond drillings are thought to be effective.

In the other areas, it is recommended to ascertain distribution of dolostone, to confirm sedimentary environment, and to comprehend conditions of the precipitation of sulphides by the geological survey and the geochemical survey, followed by the diamond drilling. It would be effective to take up impurity analysis of the carbonate rocks for the consideration of the sedimentary environment and the gravity survey for the distribution of dolostone.

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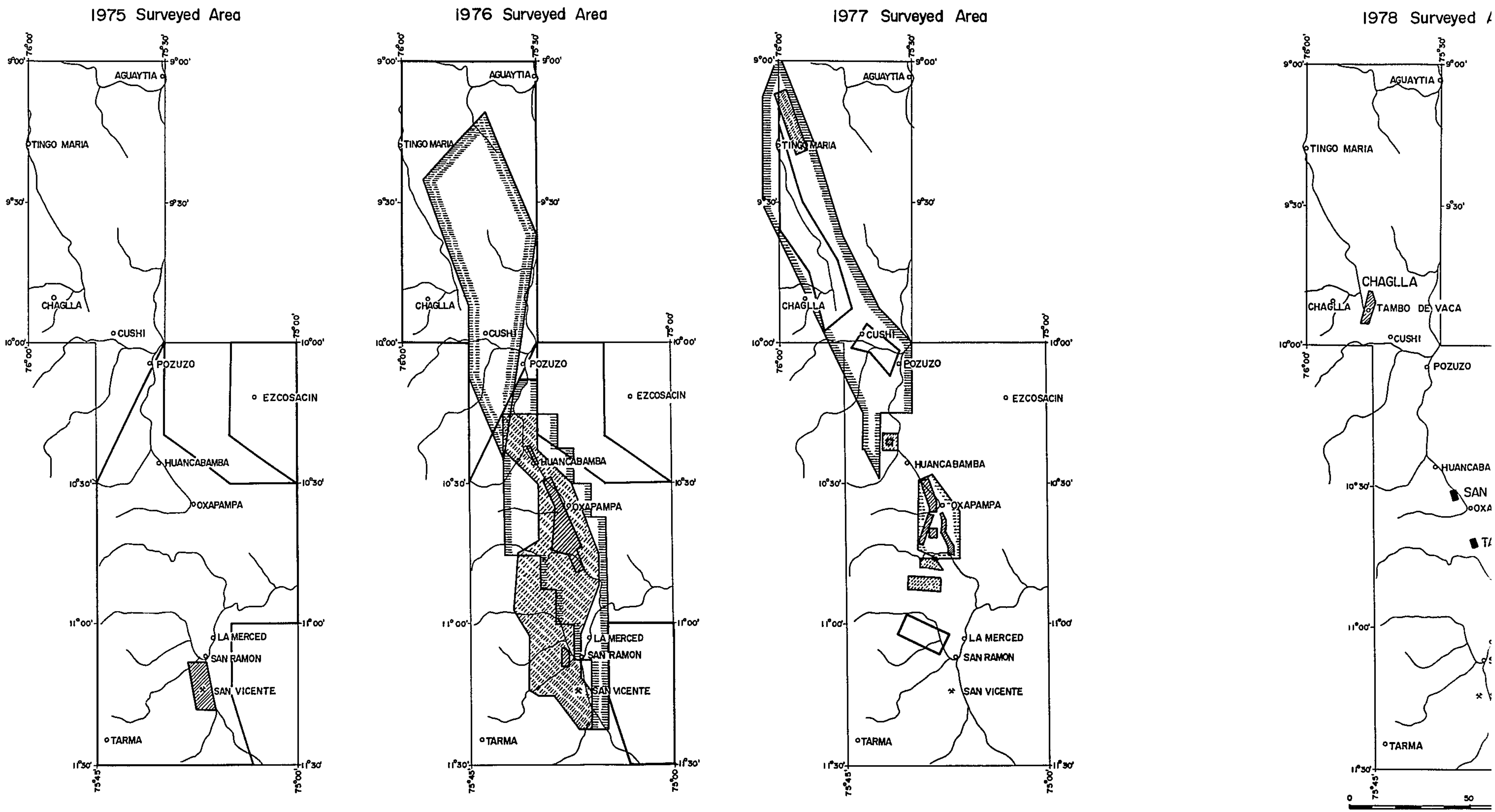


Fig. 2 Areas and methods of the field works carried out from 1975 to 1978

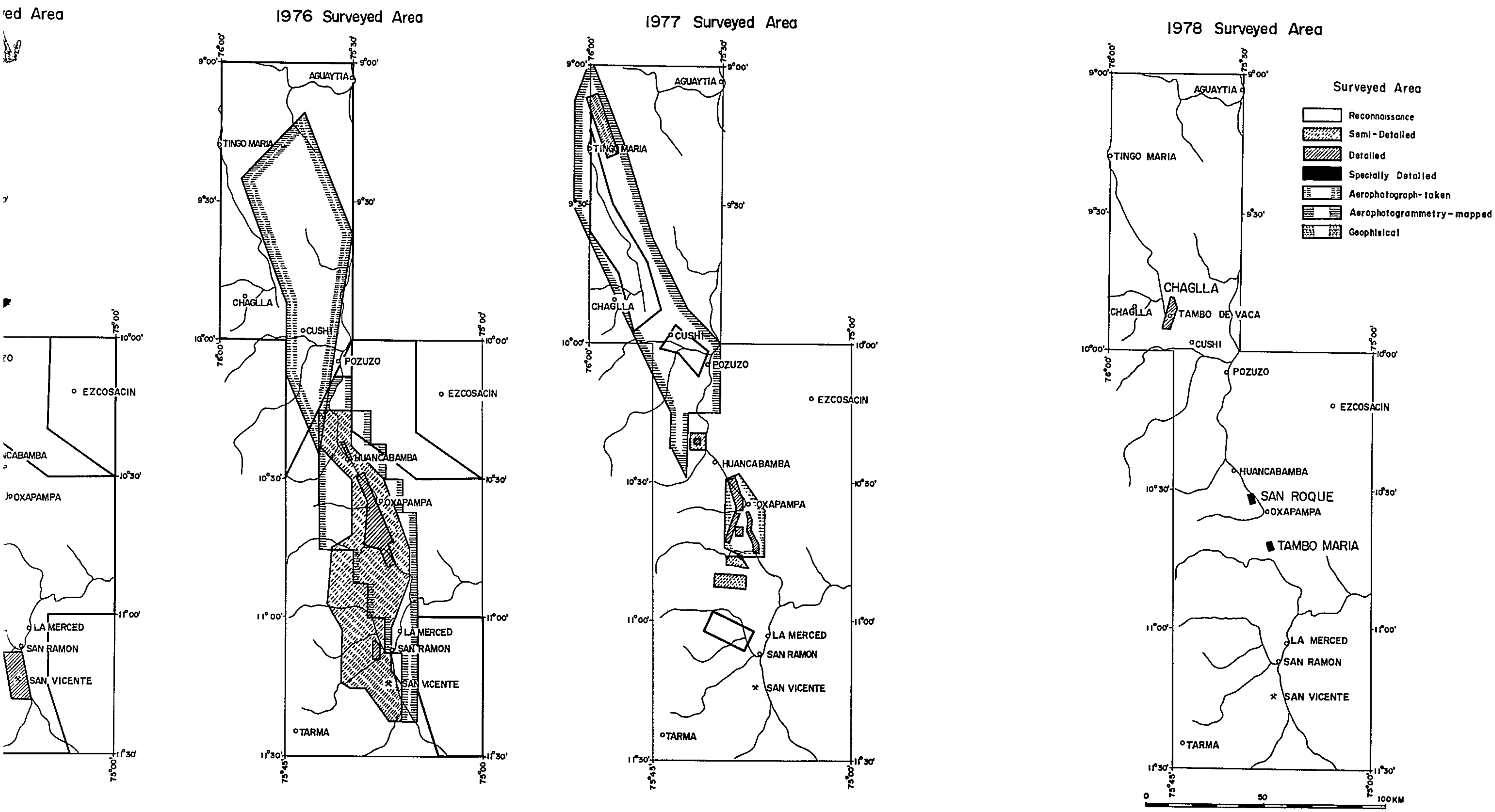


Fig. 2 Areas and methods of the field works carried out from 1975 to 1978

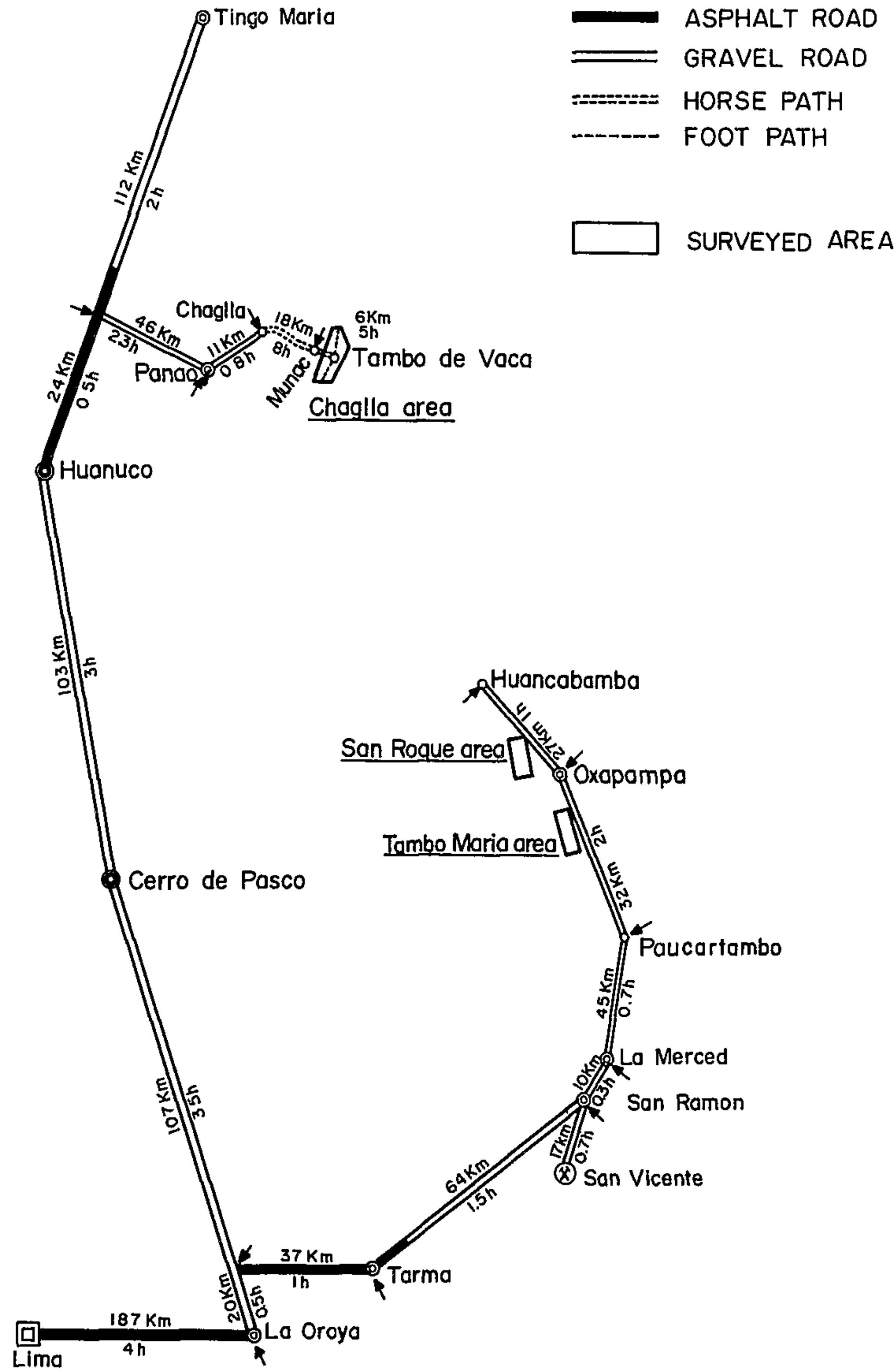
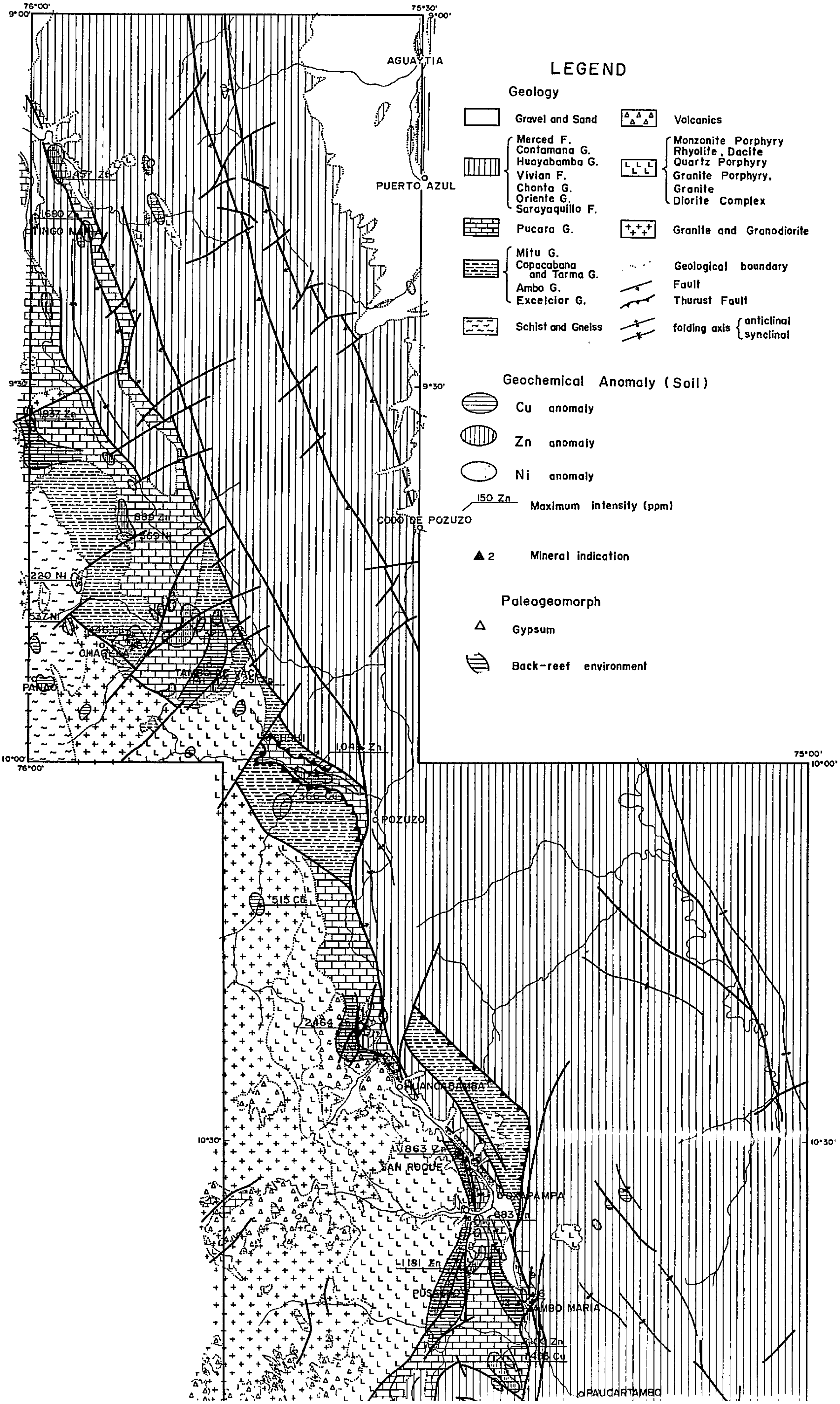


Fig. 3. Accessibility map of the surveyed area



LEGEND
Geology
Gravel and Sand
Merced F.
Contamana G.
Huayabamba G.
Vivian F.
Chonta G.
Oriente G.
Sarayaquillo F.
Pucara G.
Mitu G.
Copacabana and Tarma G.
Ambo G.
Excelcior G.
Schist and Gneiss
Volcanics
Monzonite Porphyry
Rhyolite, Dacite
Quartz Porphyry
Granite Porphyry,
Granite
Diorite Complex
Granite and Granodiorite
Geological boundary
Fault
Thurust Fault
folding axis
anticlinal
synclinal
Geochemical Anomaly (Soil)
Cu anomaly
Zn anomaly
Ni anomaly
150 Zn
Maximum intensity (ppm)
▲2 Mineral indication
Paleogeomorph
Gypsum
Back-reef environment
76°00'
9°00'
75°30'
9°30'
10°00'
75°00'
10°30'
AGUAYTIA
PUERTO AZUL
TINGO MARIA
CODO DE POZUZO
CHAGLLA
PANAO
POZUZO
HUANCABAMBA
SAN ROQUE
OXAPAMPA
TAMBO MARIA
PAUCARTAMBO
1690 Zn
1837 Zn
220 Ni
537 Ni
1,048 Zn
515 Cu
2,464
863 Zn
1181 Zn
1438 Cu

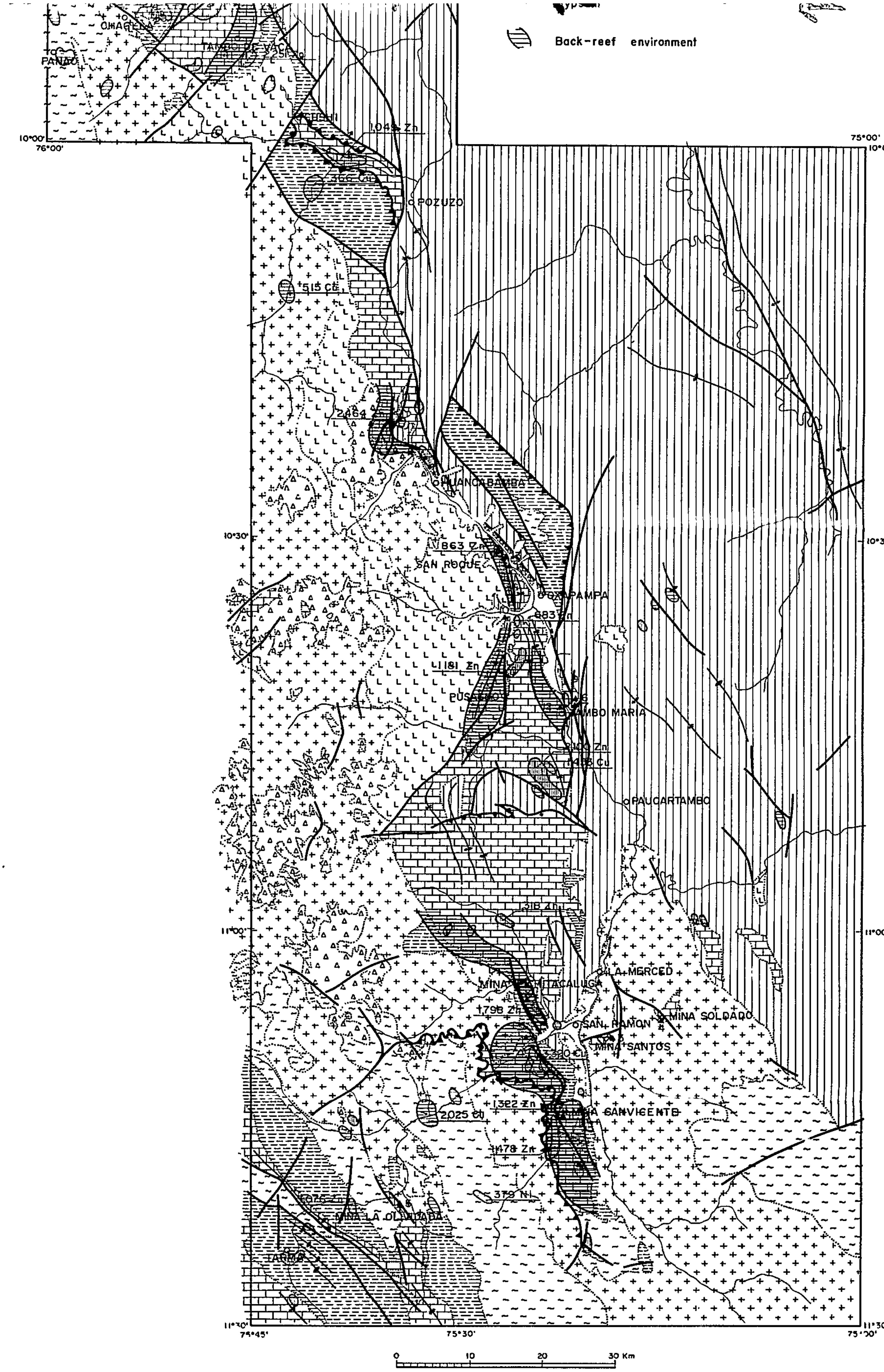


Fig. 4(1) Schematic Paleoenvironment Illustrating the Correlation to Geology, Geochemical Anomalies and Mineral Showings in the Entire Surveyed Area

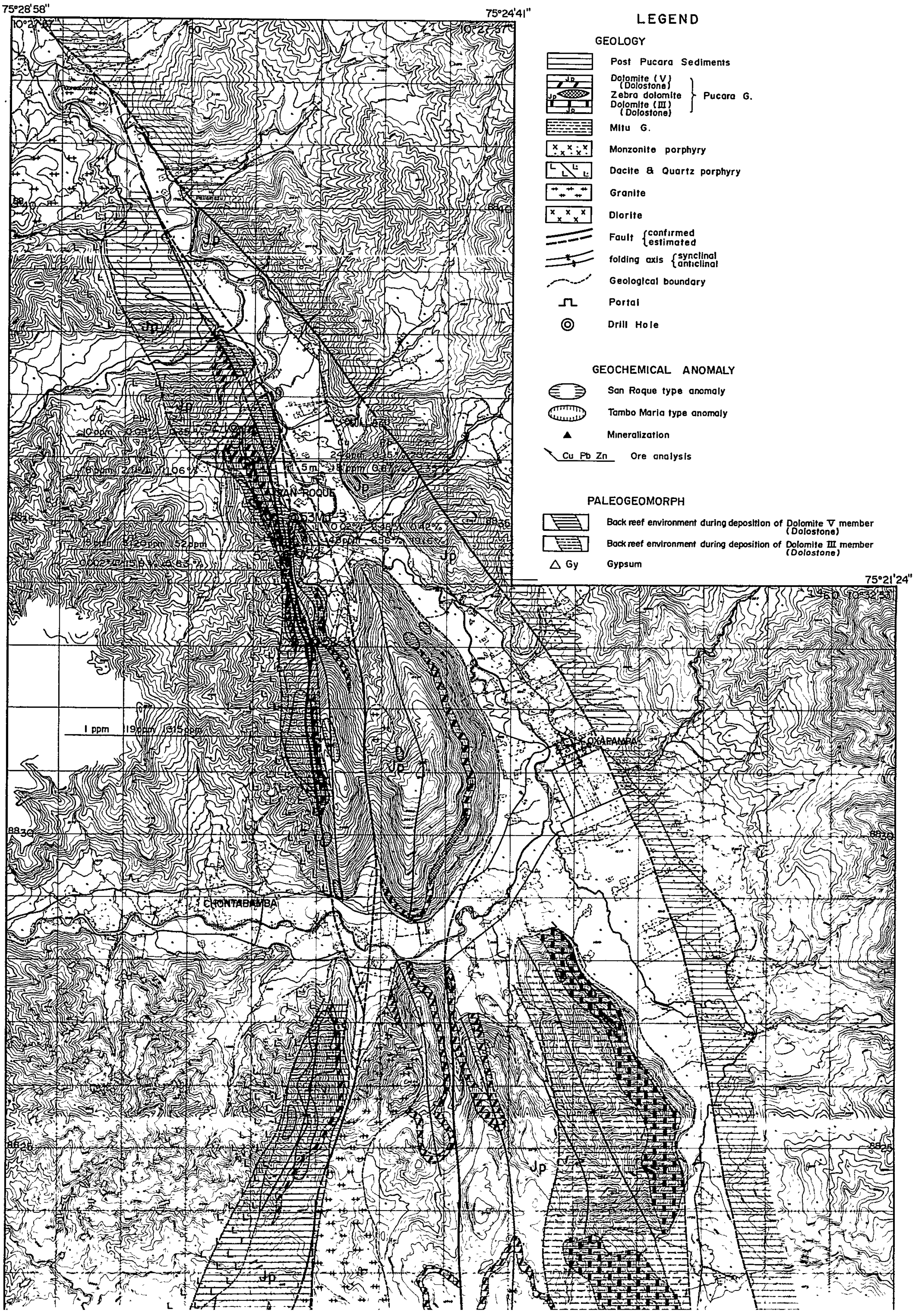

75°28'58"
75°24'41"
75°21'24"
LEGEND
GEOLOGY
Post Pucara Sediments
Dolomite (V) (Dolostone)
Zebra dolomite
Dolomite (III) (Dolostone)
Pucara G.
Mitu G.
Monzonite porphyry
Dacite & Quartz porphyry
Granite
Diorite
Fault {confirmed estimated
folding axis {synclinal anticlinal
Geological boundary
Portal
Drill Hole
GEOCHEMICAL ANOMALY
San Roque type anomaly
Tambo Maria type anomaly
Mineralization
Cu Pb Zn Ore analysis
PALEOGEOMORPH
Back reef environment during deposition of Dolomite V member (Dolostone)
Back reef environment during deposition of Dolomite III member (Dolostone)
Gy Gypsum
SAN ROQUE
CHONTABAMBA
OXAPAMPA
Jp
1 ppm 119ppm 515ppm

Fig. 4(2). Schematic Paleoenvironment Illustrating the Correlation to Geology, Geochemical Anomalies and Mineral Showings in the Oxapampa Area

Table 1 Entire field works carried out from 1975 to 1978 in the surveyed area.

Items	1975	1976	1977	1978
Geological Survey (Km^2)				
Reconnaissance	10,000	10,000	1,000	-
Semi-detailed survey	-	2,000	300	-
Detailed survey	100	259	100	45
Detailed survey combined with trenching survey	-	-	-	15
Trenching Survey (m)	-	-	187	5,626
Geochemical Survey (samples)				
Reconnaissance	2,595	1,702	262	-
Semi-detailed survey	-	2,622	315	-
Detailed survey	412	2,034	1,185	404
Geophysical Survey (Km^2)	-	-	400	-
Drilling (m)	-	-	(4 holes) 968.8	(3 holes) 902.6
Aerophoto Taking (Km^2)	-	3,000	-	-
Topographic Mapping (Km^2)	-	3,000	3,400	-

Table 2 Period of the surveyed works in 1978.

Items	1978								1979	
	5	6	7	8	9	10	11	12	1	2
Geological and geochemical survey	12 28			8	(89 days)					
Drilling	12					4	(146 days)			
Core logging			9		15	(69 days)				
Analysis and Interpretation				9						28 (204 days)

PARTICULARS

PART I

Geological Survey

Particulars

Part I Geological Survey

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Chapter 1 Outline of the Survey

1-1 Purpose of the Survey

In the central part of the Republic of Peru, the Basic Geological Survey for the Development of Mineral Resources carried out in the term from 1975 to 1977 has clarified the distribution and the structure of the Pucara Group in the surveyed area and has detected new indications of the mineralization of lead and zinc contained in the Pucara Group, at Tambo Maria and at San Roque in the southern part of the surveyed area.

In 1978, the present year, the geological survey accompanying trenching and the geochemical survey were adopted in the areas of Tambo Maria and San Roque in the southern part of the programmed area, based on the results of the previous surveys completed in and before 1977. These surveys were carried out on the purpose to find out new indications of mineralization and to clarify their stratigraphical position and the features of strata-bound deposits, as well as to give consideration to the mechanism of formation of the ore deposits.

On the other hand, in the Chaglla area in the northern part of the programmed area, the same methods of geological survey and geochemical survey as adopted in the southern part have been employed, and it has been aimed to confirm the geology and the geological structure of the Pucara Group distributed in this area and to give consideration to the potentiality of the existence of ore deposits.

1-2 Fieldworks

Trenching was carried out in the areas of San Roque and Tambo Maria. Total 5,300 meters of 27 lines had been planned along the routes carefully selected, based on the results of the previous surveys, to ascertain the stratigraphy and the geological structure and to comprehend the relation between geochemical anomalies and the mineralized zones. The actual works included the wood-cutting to remove the thick vegetation and the digging work to obtain outcrops of the base rocks. In the San Roque area, two more lines were added as they were thought to be necessary for the analysis of the geology and the mineralization.

Following these actual works, geological mapping along the trenching lines were completed in the scale of 1 to 500, utilizing small compasses. Also, the supplementary geological survey was done around the trenching in the San Roque area, based on the topographical map of the scale of 1 to 10,000.

The geological survey in the Chaglla area was carried out along the routes of total approximately 53 km, selected in the direction of the cross-cut against the main structure of the surveyed area, using the topographical map of the scale of 1 to 25,000 prepared in 1977 from the airphotograph. Partly, line cutting was necessary for the geological survey.

Samples of the geochemical survey for the carbonate rocks were collected as a part of the geological survey, along the survey routes and along the trenching lines. The interval of the sampling was every 35 m along the trenching lines and every about 300 m along the routes of the geological survey.

The above-mentioned surveys were performed by 7 Japanese geologists and 5 Peruvian geologists.

1-3 Laboratory Works

Following the fieldworks, laboratory works including the results of the diamond drilling were carried out. All the indoor works but a part, which had been done in the Republic of Peru, were performed in Japan, the main items of which are as follows.

		Number of Sample		
		Geological survey	Diamond drilling	Total
(1)	Microscopy of thin sections	48	20	68
(2)	Microscopy of polished sections of ores	23	11	34
(3)	Chemical analysis of ores	30	-	30
(4)	X-ray diffraction	10	5	15
(5)	X-ray micro-analysis	5	1	6
(6)	Determination of fossils	23	5	28
(7)	Chemical analysis of the rock samples of the geochemical survey (Cu, Pb, Zn, Mg)	404	60	464
(8)	Impurities analysis (Sr, Ba, Si, Al, Ca)	53	-	53

Chapter 2 Geology and Ore Deposits

2-1 Outline of the Geology

In the central part of the Republic of Peru, various rocks of sedimentary rocks, igneous rocks and metamorphic rocks are distributed and the distribution is arranged in the main direction of NNW-SSE, which is shown by the general trend of the topography in this area.

The sedimentary rocks are distributed in the narrow area in the southwestern part and in the broad area in the central to northern part. In the southwestern part, Paleozoic to Mesozoic strata are well developed on the basement of metamorphic rocks, while, in the central to northern part, the sedimentary rocks are composed of mainly Mesozoic to Cenozoic strata, including the Pucara Group and the younger strata are developing eastwards mostly in the order of the age.

The igneous rocks are distributed also mainly in the direction of NNW-SSE along the Andean range, from near Tarma and San Ramon in the south to near Chaglla, through the western part of Oxapampa. The igneous rocks are composed of late Paleozoic intrusive rocks, Mesozoic diorites, granites, and porphyries, and Cenozoic Tertiary volcanic rocks and intrusive rocks.

The metamorphic rocks are distributed, as roof pendant, in the highland between Tarma and San Ramon in the southern part and also in the highland near Panao in the northern part. They are composed of gneisses and schists (Fig. 1-1, Fig. I-2).

Folding structure in the sedimentary rocks has the axis mainly of NNW-SSE direction. The folding is tight in the older sediments, but rather gentle in the younger sedimentary rocks.

As for fault structure, NNW-SSE system represented by Tingo Maria - La Merced Tectonic Line running in the Inter-Andean basin is the most remarkable, but other systems of NEE-SWW, NWW-SEE and NNE-SSW are seen developed.

The geological structure associated with the above-stated NNW-SSE system and the rock distribution in correspondence with the topography are thought to have been formed geohistorically in relation to the orogenic movements in the Andean region from Paleozoic to Cenozoic Era. For example, the intrusion of the late Paleozoic granites, representing the fore-running igneous activity in this region, was related to the geoanticlinal movement in the eastern margin of the Cordillera Oriental range, and the following igneous activities would have also been somehow in relation mainly to this granites. Also, the sedimentary rocks of the Mesozoic and later age were accumulated, to say about them in the eastern side, in the depression formed along the geoanticline and therefore the formation of geoanticline can be regarded to have played a great role on the distribution of the sedimentary rocks. It can be said that the structures of faulting and folding would have been formed and developed by the lateral pressure of NEE-SWW, almost in right an angle to NNW-SSE direction.

In the above geological setting, the surveyed areas of the present year are all located in the western side of the Tingo Maria - La Merced Tectonic Line, and are composed mainly of the rocks belonging to the Triassic to Jurassic Pucara Group of the Mesozoic Era. Among the present year's surveyed areas, the San Roque area is situated in one of the zones where the distribution of the Pucara Group is narrowest in the central part. In this area, the geology is complicated as is seen in the facts that the faults of N-S direction are well developed in the area of the distribution of the Pucara Group, and that along these faults there are distributions of Mitu Group (Permian System of the Paleozoic Era) and the igneous rocks in the west, activities of which were in late Mesozoic to Cenozoic Era.

2-2 Outline of the Ore Deposits

Many metal ore deposits and mineral indications have been detected in the central part through this series of the survey works performed by this time. Small scale gypsum deposits are known near Oxapampa as non-metal ore deposit.

2-2-1 Metal ore deposits

Metal ore deposits in the surveyed area are classified into the following four types, according to the ore species and the genesis (Table I-1).

(1) Strata-bound ore deposits in the Pucara Group (Lead and Zinc).

(2) Contact metasomatic ore deposits, formed along the contact zone between the intrusive rocks and the carbonate rocks of the Pucara Group (Copper, Lead and Zinc).

(3) Vein type ore deposits in the Mesozoic diorites etc. and in the Pucara Group (Copper, Lead and Zinc).

(4) Porphyry copper ore deposits in the Tertiary monzonite (Copper).

Strata-bound ore deposits are found mainly in the dolostone, as the country rocks, of the Pucara Group, and are represented by San Vicente ore deposits which are now worked and by Pichita Caluga ore deposits now out of operation, in addition to the indications of mineralization at Tambo Maria and San Roque. The ore deposits of this type are the most important in the region, as will be described in the Chapter 5 in detail.

Contact metasomatic ore deposits are found to lie along the contact zone between the limestone and the granite in the east of San Ramon. The limestone develops as roof-pendant and belongs to the Pucara Group, while the granite is the one which intruded in the late Paleozoic Era. Ore deposits of Santos and Soldado,which were once worked, are known as the deposits of this type, but they are very small and detailed mapping has not been conducted.

Vein type ore deposits are represented by La Olividada ore deposit (Copper), once operated in the east of Tarma, as well as by very small indications known near Chaglla and near San Ramon.

The only indication of the porphyry copper ore deposit is very small dissemination in the monzonite intrusion found in the east of Tambo Maria.

2-2-2 Non-metal deposits

Meanwhile, as the non-metal ore deposits, small scale gypsum ore deposits are found in the upper Cretaceous, Chonta Group of the Mesozoic Era, at the north of Oxapampa, and in the Pucara Group at the west of Pusagno.

2-3 Geology and Ore Deposits in the Oxapampa Area

In the Oxapampa area, the San Roque area and the Tambo Maria area were selected for the area where further detailed survey would be required, and detailed stratigraphical correlation and the investigation on the conditions of the emplacement of the ore deposits were performed through 3 diamond drillings and 29 lines of trenching. As the results of these works, stratigraphical position of the ore emplacement horizon has been confirmed clearly and also new lead and zinc indications have been discovered in the trenches T-4, T-28,and T-29 etc. The results are described as follows, including those of the diamond drilling.

2-3-1 San Roque area

In this area, situated about 8 km north-north-west of the city of Oxapampa, the Pucara Group is outcropping in a direction of almost north and south, along the western side of the Huancabamba River. Quartz porphyry and granite porphyry, which are thought to have intruded in the late Cretaceous Period, are distributed to the west of the area where the Pucara Group occupies. By the geological survey completed in 1977, it was clarified that, in the area where the Pucara Group is distributed, the rocks belonging to the Mitu Group are found existing with the sharp boundaries of faults. By the present year's survey, it has been further confirmed that the distribution of this group is more extensive.

In the eastside of the area occupied by the Pucara Group, where rocks are composed of the young sedimentary rocks such as Oriente Group, Chonta Group etc., description is ommitted here, as no addition of the information has been obtained in the present year's survey.

(1) Mitu Group

The Mitu Group has been found on lines of two rows of NNW-SSE direction, the one is in contact with the quarts porphyry and granite porphyry in the west, and the other is intercalated between the Pucara Group as if they were intruded into the Pucara Group. Their width is about 100 meters in southern part but it extends to approximately 400 meters in the north. The rocks of the Mitu Group are mostly volcanic conglomerate composed of pebbles of acidic volcanic rocks and granite, and of red tuffaceous matrix. Reddish-brown well-foliated tuff which looks like tuffite is found in the trench T-3, and rhyolitic tuff has been recognized in the west of the trench T-29. Under microscope, the tuffite-like tuff is consituted by splinters of quartz and feldspar and very fine grained quartz which has been devitrified. Also, this tuff has rather coarse grained fragments of quartz, sized 5 to 100 microns, in the matrix which is contituted by fragments of quartz and feldspar with very fine grained devitrified quartz (Sample No. L740). In the rhyolitic tuff, remarkable flow structure has been observed. It is composed of vitreous material and feldspar with phenocrysts of quartz (A770).

Bedding planes are uncertain in the rocks of the Mitu Group, and in the volcanic conglomerate there are various species of pebbles which are not well sorted. No distinct sedimentary structure inside the rocks has been seen. It is thought that the uplift of the Mitu Group occurred correlatively to the Pucara Group, as the rocks of the Mitu Group form a horst structure caused by block movement. The formation of this horst structure is very important in relation to the accumulation of the Pucara Group, which will be described in the Chapter 3.

(2) Pucara Group

The Pucara Group is composed of alternation of muddy dolostone, fine grained crystalline dolostone, muddy limestone, fine grained crystalline limestone and sandstone. The thickness is about 1,000 meters at maximum in this region.

① Characteristics of various lithofacies

Dolostone is usually grey, dark grey to yellowish brown-grey in color, and is divided into several species as sandy dolostone, muddy dolostone or fine grained crystalline dolostone, by grain sizes or composition.

Sandy dolostone is constituted by micritic dolomite and microspherical quartz of 50 to 100 microns in diameter. The ratio of quartz to dolomite is approximately 1 to 1. It is distributed in the northern area of the trenches T-1, T-2, T-4 and T-28 (L712).

Muddy dolostone is compact muddy rock grey to yellowish brown grey with the unaided eye, and develops remarkably in the vicinity of the trenches T-2, T-4, T-5,and T-28. Microscopically, most of the rock is occupied by micritic dolomite, containing some fine grained detrital quartz (10 to 20 microns). In this muddy dolostone, chalcedony of 1 to 5mm in diameter can be observed sometimes along the bedding planes, presumed to have been consolidated from gel-like quartz distinctly visible with the naked eye. Especially, around the chalcedony found in the trenches T-2 and T-4, micro grains of galena and sphalerite are associated (L718, S725). Quartz is also found in places as lenticular intercalations, 0.5 to 1 meter wide and 1 to 5 meters long, in the cherty siliceous sandstone (L809).

There are two sorts of the fine grained crystalline dolostone --- the one is that gradually changed from muddy dolostone and the other is lenticular layers sitting in the muddy limestone. Their lateral extension is poor. This rock is grey to dark grey or bluish dark grey dolosparite, with the mosaic texture composed of anhedral to subhedral grains of 10 to 15 microns in diameter. Rarely well crystallized dolostone is recognized, as those crystals are distinctly visible with the naked eye (L709).

As for the limestone, there are grey to dark brownish grey muddy limestone, fine to medium grained sandy limestone,and fine grained crystalline limestone. Muddy limestone is partly bituminous. Microscopically, it can be called as biosparmicrite or skeletal detrital limestone, containing many fragments of fossils (algae, Bryozoan etc.) as well as 20 to 25*% of detrital quartz fragments. The matrix is composed of micritic calcite, in which 30-40 % of sparry calcite is contained (Sample No. 53305, 53308). In the surveyed area, four layers of the muddy limestone are recognized, among which C submember was employed as a key bed for the correlation of the lithofacies in the San Roque area, as it well extends laterally.

The sandy limestone is thinner than the muddy limestone --- 20 to 30 meters in average, and it sometimes lies as lenticular body. It contains about 25% of detrital quartz fragments and also pretty coarse

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* The percentage shows the ratio of the area occupied under microscope.