calcite crystals (600 microns). In places, it contains amorphous cement (1 mm x 2.5 mm). Opaque minerals are rare (53304). Fossils are poorer in this rock, compared to those in the muddy limestone. If any, they are merely small fragments and are not well preserved.

Fine grained crystalline limestone is distributed mainly in the southern part of the surveyed area, containing insertions of above-mentioned sandy limestone and calcareous dolostone. Sparitic calcite and detrital quartz fragments are contained,and also 30 to 40 % of micritic calcites are contained in places. The lower muddy limestone is fossiliferous and the following fossils in it are determined. (Determination by Prof. Masafumi Murata, Kumamoto Univ., A. I-6)

	Sample No.
Gastropods ----------------------	L728
Cardiliidae Gen et Sp. indet.	
Shell of bivalves --------------	L748
Peclinidae Gen. et indet.	

② Stratigraphical correlation

In Vol.VI of the report of the survey in 1977, it is stated as for the Pucara Group that the IV member and the V member are well developed in the San Roque area. Following this result, correlation of the lithofacies and the stratigraphy were conducted in detail, through the surveys of trenching and diamond drilling. Illustration of the stratigraphical correlation in the San Roque area (Fig. I-4 (1)) shows the summary of the information, including the results of consideration on the geological structure. The stratigraphical correlation of the Pucara Group in the central part is shown in Fig. I-4 (4). In the present year's survey, the IV member has been divided into A, B and C submembers and the V member into D and E submembers, for the consideration of the stratigraphy. The stratigraphical correlation of the core of the drill hole 52-1 has been changed to be correlated to further upper part in this year's survey, different from the previous correlation performed in the report, Vol. VI in 1977. The characteristics of each submember are described hereunder. The sequences from the III member to A submember and from A submember to E submember are all conformable.

i) III member, thickness +100 m*

There is no surface exposure of this III member in the San Roque area. This member is the lowest of the beds confirmed in the cores of the drill holes No. 53-MJ3, No.52-3,and No.52-4. The III member is composed of grey to dark grey,fine to medium grained crystalline limestone, with the intercalations of calcareous dolostone. Generally this member is poor in fossils, though the fragments of Echinoid are found in the lower part. No indication of mineralization has been found, but the content of zinc is rather high to show as much as 200 to 500 ppm.

ii) A submember of the IV member, thickness 160 m

The A submember is rather thick in the southern part and thin in the northern part of the San Roque area. It is composed, from the lowest, of muddy limestone, grey to dark grey fine to medium grained crystalline limestone and sandy limestone containing foraminiferas. In places, lenticular dolostone are intercalated in the upper part.

The lower muddy limestone is rich in fossils of Echinoid, and contains 40 to 50 % of terrestrial detrital quartz and feldspars (52312).

The grey to dark grey,fine to medium grained crystalline limestone is characterized with veinlets of calcite and spotted dots of calcite.

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* The thickness confirmed in the San Roque area.

The intercalated layer of dolomite, found on the slope of the San Roque valley near the drill hole No. 52-4, is grey, micritic and partly calcareous.

iii) B submember of the IV member, thickness 150 m.

This submember is composed, from the lowest, of muddy limestone, dark grey fine grained crystalline dolostone and dark grey fine grained limestone.

The distinct feature of this submember is what contains many fossils, such as mainly Echinoids, Brachiopods, Crinoids, and Bryozoan, forming fossil enclosures in places. Muddy limestone contains lenticular intercalations of calcareous dolostone and muddy dolostone in the southern part. In the cores of the drill hole No. 53-3, shells of Brachiopod are abundantly contained, and the rock is observed to be rather silty. Dark grey fine grained crystalline dolostone is poor in fossils, and is poorly extended laterally. The dark grey fine grained limestone of the uppermost of the B submember is composed mainly of sparite, though partly micrite can be found, and contains many fossils of Brachiopods, Crinoids, Bryozoan and Echinoid. Disseminated galena is associated with it (53304, 53305 etc.).

iv) C submember of the IV member, thickness 120 m

The C submember is mainly constituted by muddy limestone and is generally rather homogeneous without remarkable intercalation, although there are some layers of sandy fine grained limestone contained in the upper part. No mineral indications have been recognized. This submember extends quite well laterally and has been employed as a key bed for the stratigraphical correlation. The muddy limestone in this submember is dark grey, partly black in color and bituminous in places. This rock would be called sparmicrite. The thickness increases in the northern part. Fossils are poor in this submember except for the beds in the lowermost part.

v) D submember of the V member, thickness 400m

This submember is composed of muddy dolostone, medium to fine grained crystalline dolostone, sandy dolostone, muddy limestone, and sandstone, and these rocks are presumed to have been accumulated thickly in the central to northern part. The muddy dolostone is hard and compact, grey to brownish grey, and in this rock, parallel fractures are partly developed perpendicular to the bedding plane. It contains many fragments of detrital quartz and fossils, and the mineral indications of sphalerite associated with some galena have been recognized. Crystalline dolostone is grey, pale grey, and dark grey in color and is observed as thin layers (thickness 10 to 20 m) in the muddy dolostone. Sandy dolostone is found to be intercalated as lenticular layers in the muddy dolostone, and the thickness is rather thin (±10 m). Lithofacies are gradually changing from the muddy dolostone to this sandy dolostone. The muddy dolostone has been found as lenses in places, and it is observed to be micrite under microcope. Sandstone is cherty to a certain degree, and is intercalated as lenticular layers, 0.5 to 1 meter thick and 1 to 5 meters long, along the bedding planes of the muddy dolostone (L713).

In the D submember at the drill hole No. 52-1, there is a thin layer of siltstone, which is thought to be the lithofacies changed from the muddy dolostone, although it is uncertain on the surface.

vi) E submember of the V member, thickness + 50 m

This submember occupies the uppermost of the Pucara Group in the San Roque area, and is found around the uppermost part of the trench T-2. This submember consists of calcareous sandstone, partly dolomitized. It is composed of micritic calcite (5 - 10 microns) and microspherical quartz. The ratio of quartz reaches about 50 %. Poor in fossils, and opaque minerals are seldom contained.

vii) Summary

A) Although the submembers A, B, and C (the IV member) are mainly composed of limestone and the submember D is constituted mainly by dolostone, change of lithofacies is remarkable as is seen in the fact that limestone is predominant in the southern part.

B) Muddy rocks are well developed in B to C submembers and in parts of the D submember distributed in the northern part.

C) Lead ore indications are restricted in the B submember, while zinc ore indications are limited to rather upper part of the D submember.

D) Fossils are abundant in the B submember and in the lower part of the C submember.

E) The dolostone does not extend laterally in the surveyed area.

(3) Igneous rocks

Quartz porphyries and granite porphyries are found in the west of the area where the Pucara Group is distributed. The age of their intrusion into the Pucara Group is thought to be at the end of the Cretaceous Period. Under microscope, these rocks are composed of the groundmass of microcrystalline quartz (30 to 40 microns) and the phenocrysts of potash feldspar or corroded quartz of 0.2 to 0.4 mm (L808) in size. As flow structures have been observed in places, it is thought that part of the rocks would have been formed as lava flows.

(4) Geological Structure

Synclinal structure is notable with the axis of roughly north-south direction, plunging gently to the north, though it has a swell in middle part. In the north of the San Roque area, where mineral indications have been detected by the present survey, synclinorium can be seen. The bounds between the Mitu Group and the Pucara Group are thought to be fault in every point.

(5) Indication of mineralization

The first indication of mineralization in the San Roque area was discovered along trench T-4. Also, high grade lead ores were found along trench T-2, though this sample was a float rock. For the purpose to pursuit the extension of the indication found along trench T-4, the additional trenches T-28 and T-29 were worked, which led to make a good discovery of the largest scale indication in the surveyed area (Table I-1). The ores are mainly "amber sphalerite" associated with small amount of galena, which is seen to have filled fractures developed in the muddy and rather crystalline dolostone. The maximum width so far observed of the fracture filling with such sphalerite is about 3 cm but fractures of about 1 cm in average are generally seen. The samples collected along a channel 5 meters long in the trench T-28, show the ore grade of Pb 0.87% and Zn 2.35% in average, while an assay of a piece sample there taken along a line of 20 cm reaches the grade of Pb 0.15% and Zn 20.72 % (L783). The mineralization is observed to develop in veinlets at both sides extending from the boundary plane where it is most remarkably concentrated, between the muddy dolostone and the fine grained crystalline dolostone belonging to the D submember. The ore minerals are seen in grains associated partly with chalcedonic quartz. This sphalerite has been fairly replaced by calamine and smithsonite (S725, S783, L784 etc.).

On the contrary of the indications of this fracture filling type, all the indications found in the surveyed area till the year before,are those of the disseminated type, in which sphalerite and/or galena crystals of the grain size of 0.1 to 5 mm are scatteringly emplaced in the carbonate rocks. The ores caught by the drill hole No. 52-1 in 1977 are also proposed to this disseminated type, in which sphalerite grains are seen impregnated, surrounding fossils.

To summarize the indications of mineralization in this area, followings are noted.

① The indications are confined to the beds belonging to B and D submembers of the Pucara Group, and are bound within the strata.

② The indications found in the B submember are of the disseminated type of galena emplaced in limestone.

③ The indications found in the D submember are of the disseminated type,and of the fracture filling type of sphalerite, emplaced in muddy dolostone and fine grained crystalline dolostone.

④ The ore grade of indications of a disseminated type is very low, while indications of a fracture filling type include parts of high grade ore, associated with small amount of galena.

2-3-2 Tambo Maria Area

This area is located about 18 km south-south-east of the city of Oxapampa. The Pucara Group is distributed along the both banks of the Honda river. In the present year's survey, in which dolostone was marked, works of 13 trenches and 2 holes of diamond drilling were completed around the indications, found in the survey carried out in 1976, and detailed stratigraphical correlation was performed.

(1) Pucara Group

The Pucara Group in the area, where the present survey was carried out, is composed, from the lowest, of black to dark grey muddy limestone, black bituminous calcareous sandstone, fine to medium grained crystalline dolostone,and light brown sandstone. In the dolostone, what is called zebra-structure develops well, which is constituted by fine bandings.

① Characteristics of the lithofacies

Black to dark grey muddy limestone is composed of fine fragments of detrital quartz, sparry calcite,and amorphous material originated from organic matter. Partly it is sandy or bituminous, where dissemination of very fine grained pyrite can be recognized. Foliation develops well, which plane is slant at 30 degrees to the horizontal level.

Black bituminous calcareous sandstone is distributed in the northern part of this surveyed area, and lies, as lenticular masses, in the upper part of the above-described limestone. It is pretty fine grained and partly is silty. Foliation develops well, which dips 30 to 40° to the west. Fossils as Psiloceras, Bivalves, Bryozoan and Algal debris etc. are contained. They are observed mostly in the upper part near dolomite. Under microscope, sparry calcite (0.02 to 1.5mm) forming fragments of fossils, and micritic calcite and detrital quartz of the groundmass are recognized (53215).

Most of the dolostone exposing in the surveyed area is fine to medium crystalline dolostone. It has well-recrystallized coarse grained mosaic texture and microscopically dolomite occupies as much as 80 to 90 %, associated with small amount of calcite, opaque minerals and clay minerals. The crystal grains of the dolomite are 50 microns to 1.5 mm in size and sometimes they contain subhedral or anhedral dolorhombs.

In this crystalline dolostone, what is called zebra-structure can be recognized as lenses or thin layers. The zebra-structure is a sort of stripe pattern of dolomite, like zebra, in which dark grey fine grained dolomite and white sparry dolomite (size of crystal is about 1.5 mm) are composing rhythmical alternation with the width of 0.3 to 2 cm. The zebra-structure is of various sizes from fistsize to rather extensive one. This structure is observed to lie in relatively lower part of this crystalline dolostone bed, in scale of the thickness (or width) of 5 to 10 m and of the maximum extension of approximately 500 m. Sandy dolostone and muddy dolostone are also found as intercalated layers in this crystalline dolostone, which is recognized between about 80 m and 180 m, in the drill hole No. 53-MJ2.

The uppermost sandstone is light brown in color and pretty calcareous. In place, alternation of sandstone and limestone is observed. The boundary to the overlying bed has not been made certain.

② Stratigraphical correlation

As was the result of the survey up to 1977, the dolostone is correlated to the III member of the Pucara Group, and the lower sandy to muddy limestone is correlated to the II member of it. Also, the upper calcareous sandstone is corresponded to the IV member (Fig. I-4(2), I-4(4)). Accordingly, they occupy lower part than the beds in the San Roque area, and the III member can be correlated to the ore horizon of the San Vicente ore deposits.

(2) Indications of mineralization

There has been no new discovery of the indication in this year, but the outcrops of banded sphalerite ores found in the dolostone in 1976, although slight mineralization of Zn 1.9 % accompanying pyrite was found in the cores at the depth of 190.5 m of the drill hole No. 53-MJ2. To summarize the indications of mineralization in the Tambo Maria area, the followings are noted.

① The indication lies in the dolostone belonging to the III member of the Pucara Group. Especially, the concentration of sphalerite is observed in the bandings formed with recrystallized dolomite, which is called zebra-structure. The ores can be said to have tendency to concentrate in brecciated parts.

② The ore grade is rather low. (Samples collected along a channel 3.2 m long show Zn 4.4 %. Refer to Vol.VI). Most sphalerite is observed being replaced by smithsonite. The highest grade of a piece sample is Pb 0.022 % and Zn 25.90 %.

③ Scale of the ore deposits is very small and their extension is limited.

2-4 Geology and Ore Deposits in the Chaglla Area

The area is positioned at the southwestern part of the syncline structure composed of the Pucara Group, which axis is plunging to the north in this area and in the northern part. The area is composed of sedimentary rocks belonging to the Mitu Group, the Pucara Group,and the Sarayaquillo Formation. Of them, the Pucara Group is distributed most extensively in this area. No igneous rock has been recognized.

(1) Mitu Group

The Mitu Group is distributed in the northeastern part of this area and at the east of Patio, and is composed of volcanic pyroclastic rocks such as tuff, greenish grey tuffaceous sandstone and andesitic tuff breccia. The Mitu Group is overlain by the Pucara Group, unconformably.

(2) Pucara Group

The Pucara Group are extensively distributed from the northern part to the southern part of this area, and are divided into, from the lowest, lower limestone bed, dolostone —— limestone bed, sandstone bed, and upper limestone bed. The total thickness is up to 1,900 m.

The lower limestone bed overlies the Mitu Group unconformably, and is proposed to the lowest bed of the Pucara Group in this area. This limestone distribution is seen in the northeastern part as well as in the southeastern part of the surveyed area. It is mainly composed of well-bedded grey to dark grey micritic to muddy limestone, with intercalated layers of dark grey fine grained calcareous sandstone and grey fine grained thin crystalline dolostone. The limestone is called, under microscope, micrite containing small amount of detrital quartz. The calcareous sandstone found around Patio contains micrograins of pyrite sporadically, and in place it forms alternation with thin black bituminous shale.

The limestone of the upper part is dolomitic. The following fossils have been confirmed from this bed. (Determination by Mr. Rangel, Instituto de Geología y Minería, Republic of Peru. A. I-7)

			Sample No.
Psiloceras	cf.P. reissi	(TILMANN) ---	N 759, D1
Pentacrinitis	cf.P. jurensis	(QUENSTEDT) ---	D1

This bed is correlated to Hettangian series of the Jurassic Period, by these fossils. The thickness is about 700 m in the vicinity of Patio.

The dolostone — limestone bed consists of dolostone and limestone, and is distributed around Tambo de Vaca in the central part of this surveyed area, around Huarao Grande in the southern part and around Monopampa in the northern part. There are two layers of dolostone in the lower part of this bed. Of them, the lower dolostone develops well. The thickness of the upper dolostone is 75 m and that of the lower is 300 m. It is grey fine to coarse crystalline dolostone and microscopically mosaic texture is observed so it can be classified as sparry dolomite. In the dolostone, close to the limestone in the upper part, small lenticular greyish white cherts are intercalated. Cross-laminae can be recognized in this bed at Huarao Chico. In this dolostone, zebra-structure develops well, and each band of that is 0.5 to 2 cm wide generally forming stripe pattern. The trends of the stripe pattern are mostly parallel to the bedding plane but sometimes are seen to be oblique. The size of crystals of the white coarse crystalline dolomite reaches 2 to 3 mm in places, and the development of druse is conspicuous. The zebra-structure is observed to lie lenticularly parallel to the bedding plane and maximum thickness reaches up to 10 m, but the extention to the elongated direction is not so remarkable. In the grey fine grained crystalline dolostone found around Huarao Grande and Huarao Chico, indications of lead mineralization have been recognized.

The limestone develops in the upper part of this bed. Two layers have been confirmed --- one is between the above-mentioned dolostone layers, and the other is along the upper horizon against them. It is grey and fine grained with unaided eye. There is an oolitic limestone in the Tambo de Vaca area, and this limestone contains many fossils. Microscopically, pelsparite containing pellets has been recognized (N701). Also, nodules of greyish white cherts are observed. The thickness of the upper limestone is 100 m, and that of the lower is 80 m. Indication of lead mineralization associated with calcite has been found in this limestone at Huarao Grande.

The following fossils have been found in the dolostone --- limestone bed (Determination by Mr. Rangel, Instituto de Geología y Minería,Perú. A. I-7).

	Sample No.
Rimirhynchia cf. R. rinosiformis BUCKMAN ---	N 752
Pentacrinites cf. P. jurensis (QUENSTEDT)---	N 752, D3
Polifera ind. ----------	P 705
Rhynchonella sp. ----------	D 2
Rhynchonella cf. R. tetraedra SOW ----------	P 710
Rhynchonella cf. R. Wanneri TILMANN -------	P 710
Rhynchonella sp. Cyclostomata ind.----------	P 1

From these fossils, this bed is correlated to the lower to middle part of the Lias Series.

The sandstone bed is distributed in the area from Tambo de Vaca to Muña, and around Monopampa. Its exposure is also recognized at Huarao Chico. It is dark grey in color, though brownish in case weathered, fine grained calcareous sandstone with thin intercalated layers of black bituminous shale and dark grey fine grained limestone. Micrograined pyrite has been recognized in this sandstone.

Carbonaceous matter is observed in this bed at Tambo de Vaca. The following fossils have been found in this bed. (Determination by Mr. Rangel, Instituto de Geología y Minería, Republic of Peru. A. I-7).

	Sample No.
Vermiceras cf. V. stubel, TILMANN -----	N 768, D 5
Arnioceras ceratitoides (QUENSTEDT) -----	S 712, D 6
Arnioceras cf. A. angusticostatus TILMANN---	D 5, D 7
Schlotheimia cf. angustisulcata GEYEY -----	D 6
Arnioceras sp. ----------	P 7

This bed is correlated to the Sinemurian Series. At Tambo de Vaca, this bed is overlain by the conglomerate of the Sarayaquillo Formation, and the thickness is as thin as about 20 m but at Muña to the west of it, the thickness is estimated to be more than 120 m.

The upper limestone bed is distributed from Tambo de Vaca to the north of Gungapa. It consists mainly of light grey to grey fine grained limestone, with thin layers of grey fine grained crystalline dolostone in parts. Under microscope, it is micrite containing detrital quartz a little. This bed is overlain unconformably by the conglomerate of the Sarayaquillo Formation in the north of Tambo de Vaca. It becomes more thick toward the north, and the thickness at Gungapa is estimated to be more than 500 m.

By the characteristics of the lithofacies and by the contained fossils, the above-described beds are correlated as follows: the lower limestone bed to the II member, the dolostone - limestone bed to the III member, the sandstone bed to the IV member and the upper limestone to the V member. The details are described more definitely in the section 1 of the Chapter 3 (Fig. I-4(3)).

(3) Sarayaquillo Formation

This formation is distributed only at the top of mountains found in the area from Tambo de Vaca to Gungapa, with the very low-angulated unconformity to the Pucara Group. It consists of conglomerate carrying sub-angular pebbles. Pebbles are mainly grey fine grained limestone but small amounts of them are grey fine grained dolostone and dark grey fine grained calcareous sandstone. The matrix is brownish grey calcareous sandstone. The thickness is confirmed about 50 m.

(4) Quaternary sediments

The Quaternary sediments are well developed near Gungapa, composed of rounded pebbles of granodiorite, chert, sandstone, shale, and granules of siliceous rock, and of quartz sands. They are almost unsorted and unconsolidated, therefore they are thought to be flood sediments.

(5) Geological structure

The strata show the general trend of N45°-70°E, with the dip of 10°-30° NW in the central part, forming gentle monoclinic structure in general, though slight waving with the axis of NE direction can be recognized. In the northern part, they form steep monocline with the strike of NS and the dip of 45°-70°W.

As for faults, NNW-SSE system is presumed to exist at Monopampa, and NWW-SEE system at Patio. The NNW-SSE system is parallel to the main tectonic orientation in the central part, and it is considered that the NNW-SSE system would have played a great role for the block movement of uplift and subsidence by dividing this area into blocks with other faults of NNE-SWW and NWW-SEE systems.

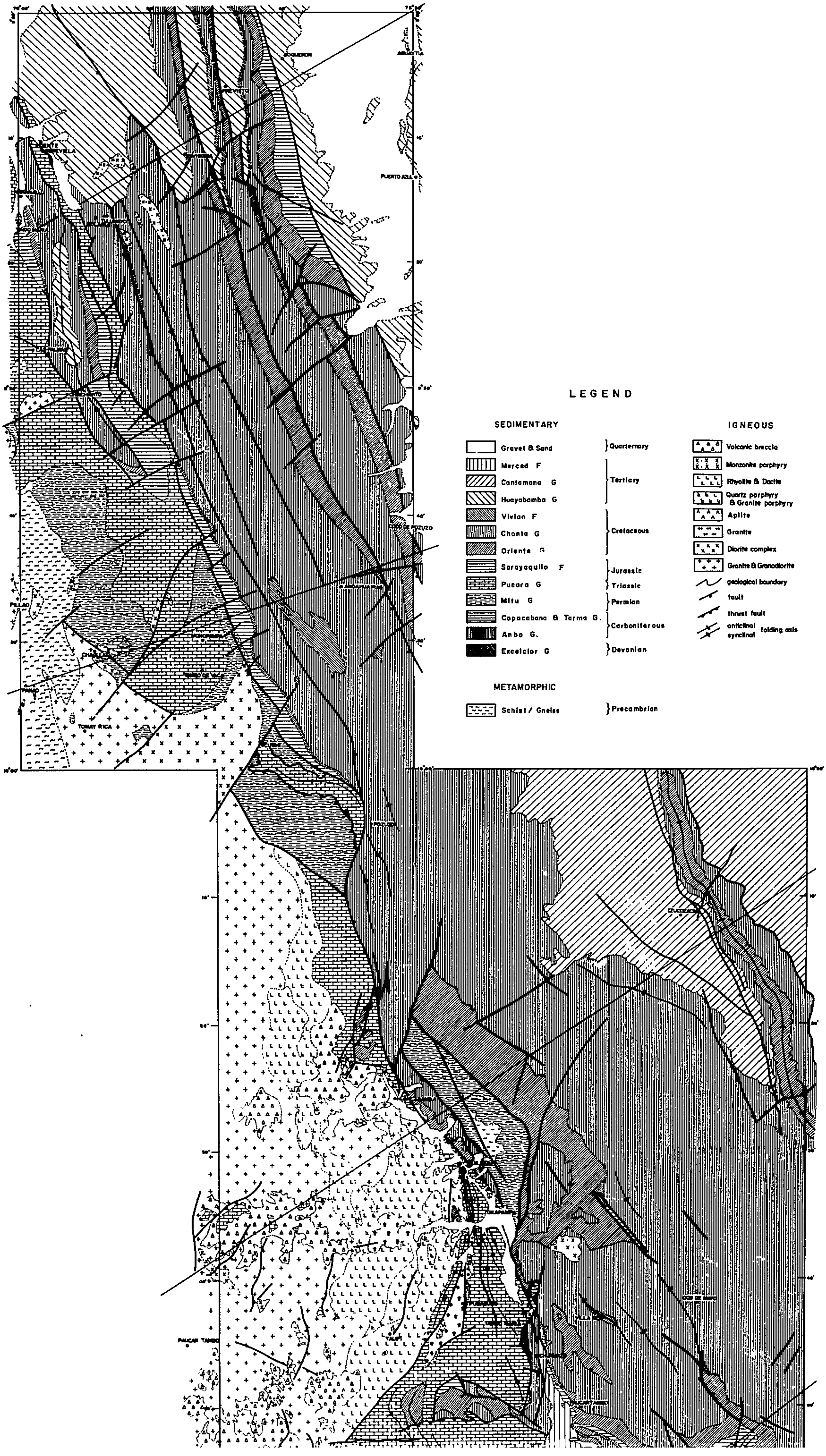
(6) Indication of mineralization

In this area, there are indications of lead mineralization in the dolostone - limestone bed of the III member, at Huarao Chico and at Huarao

Grande (Table I - 1). No sphalerite mineralization has been found megascopically, but for microscopic evidences. The lead mineralization at Huarao Chico is recognized in light grey fine grained crystalline dolostone, in which coarse grained irregular aggregates of calcite and small amount of fluorite are recognized. The galena is observed in aggregates, like bean-stalk, of coarse crystals 5 - 10 mm. in size. The dolostone surrounding the aggregates of calcite and fluorite is light brown in color, and coarse grained and crystalline. Assay result of a piece sample collected from the indication is Cu 20 ppm, Pb 4.33 %, Zn <0.01 %,and Ag 18 g/t (N746).

The indications of mineralization at Huarao Grande are found in two separate exposures --- one is in dolostone and the other is in limestone. The indication of lead mineralization found in dolostone is similar to that found at Huarao Chico, in which galena looks like bean-stalk or like amoeba, associated with calcite and fluorite contained in grey fine grained crystalline dolostone. The assay result of a piece sample collected from this indication is Cu 8 ppm, Pb 25.80 %, Zn 0.11 %,and Ag 74 g/t (A752).

Meanwhile, the indication of lead mineralization in limestone is found as small lenticular mass, associated with small amount of calcite, in somewhat upper horizon than the above-mentioned dolostone. The assay result of a piece sample taken from this indication shows Cu 70 ppm, Pb 23.68 %, Zn 0.04 %,and Ag 62 g/t (P807). In the limestone around this mineral indication, euhedral sphalerite of about 30 microns has been recognized a little, under microscope (P800).


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

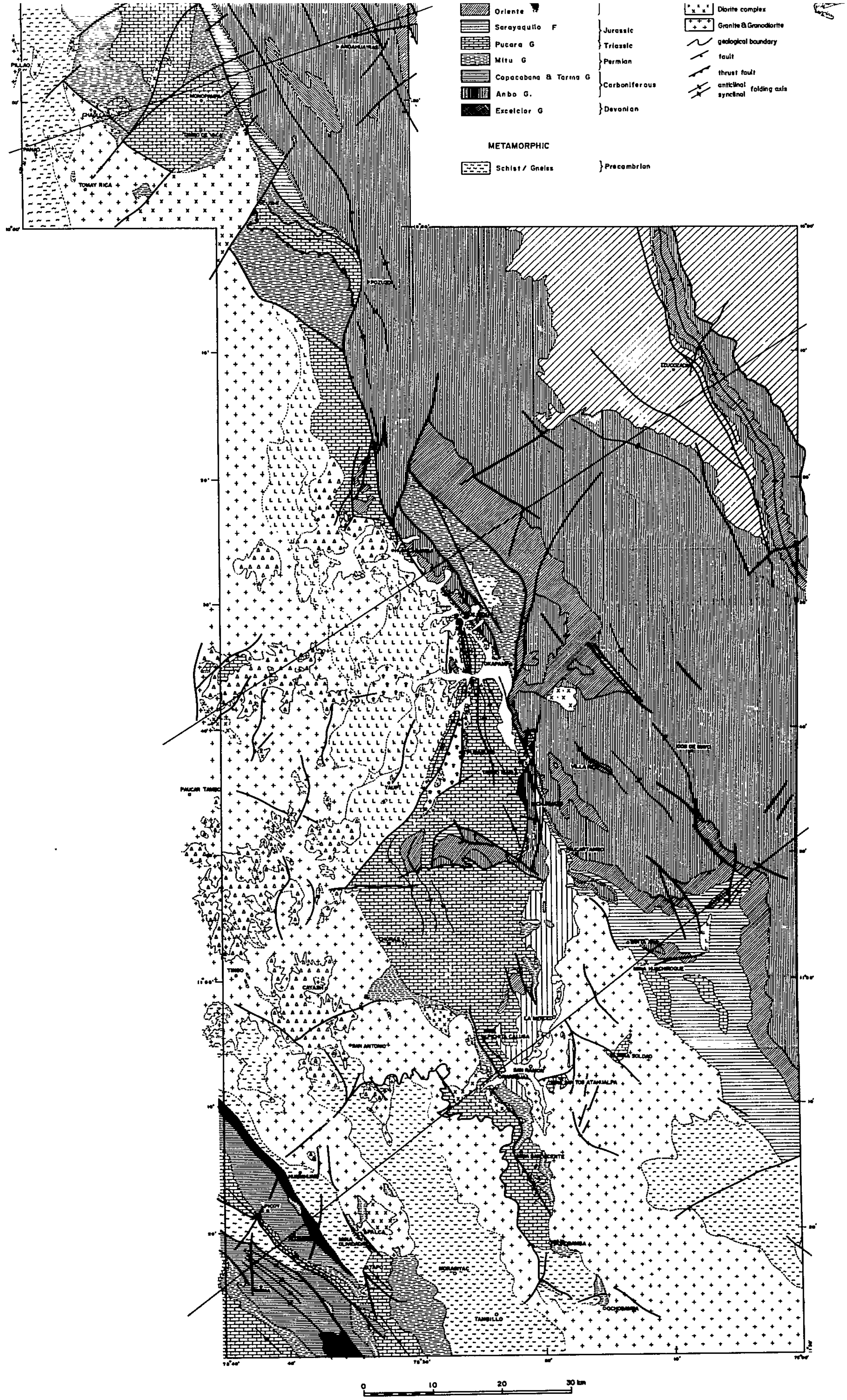
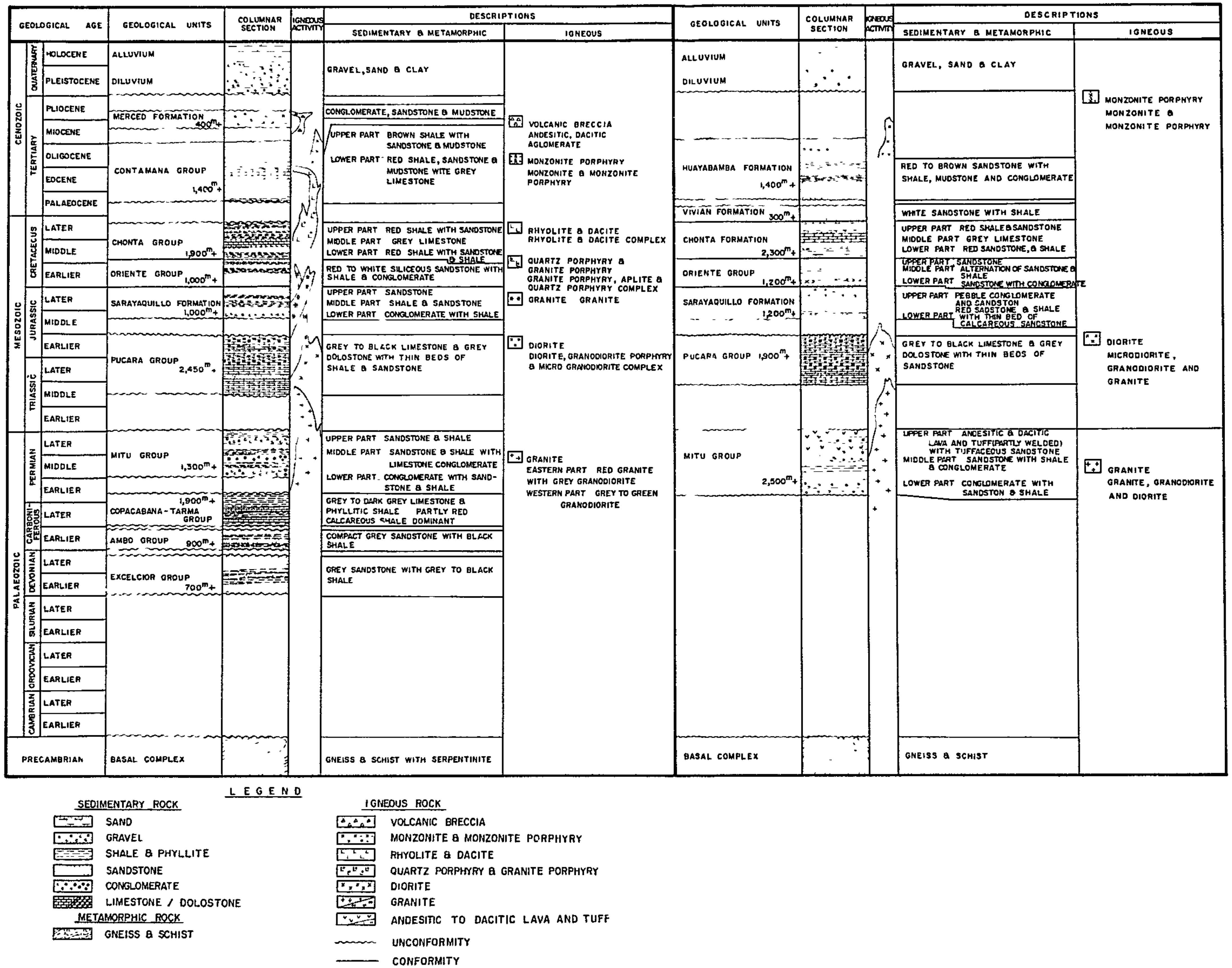
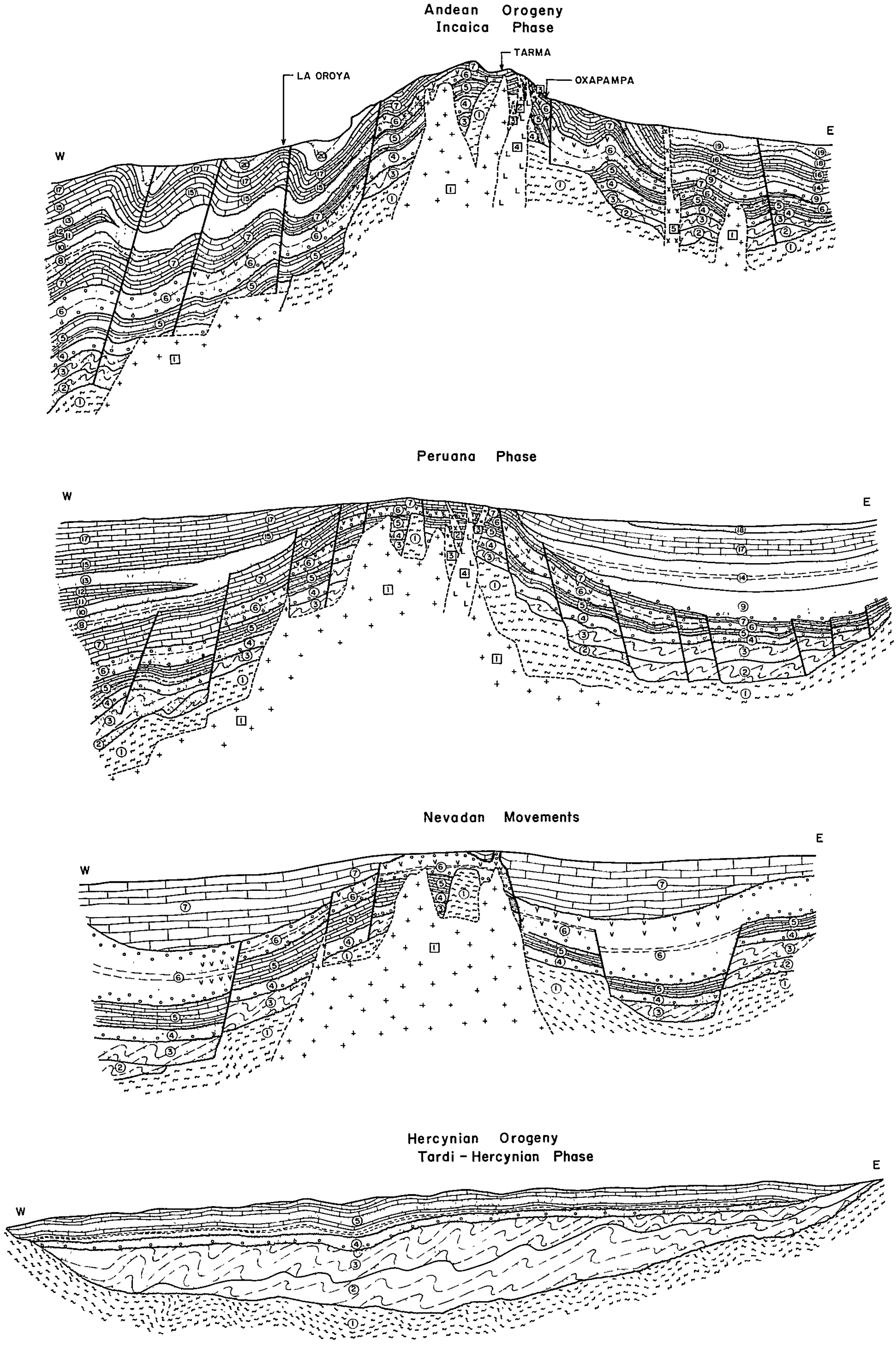


Fig.I-1. Generalized Geological Map of the Surveyed Area

Fig. I-2. Generalized Geological Columns of the Entire Surveyed Area

Southern Block | Northern Block




Andean Orogeny
Incaica Phase
TARMA
LA OROYA
OXAPAMPA
W
E
Peruana Phase
W
E
Nevadan Movements
W
E
Hercynian Orogeny
Tardi - Hercynian Phase
W
E
SEDIMENTARY ROCKS
IGNEOUS ROCKS

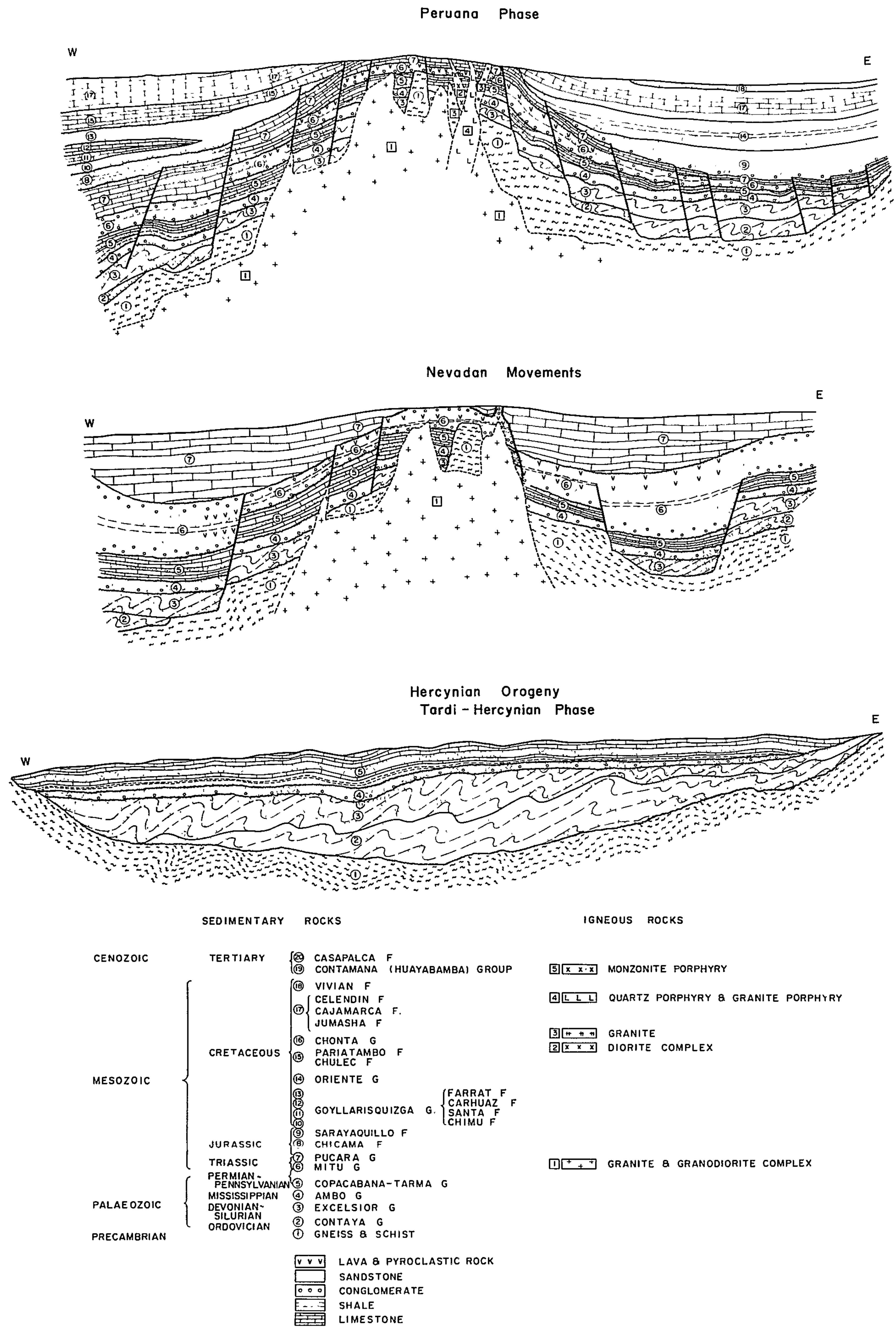
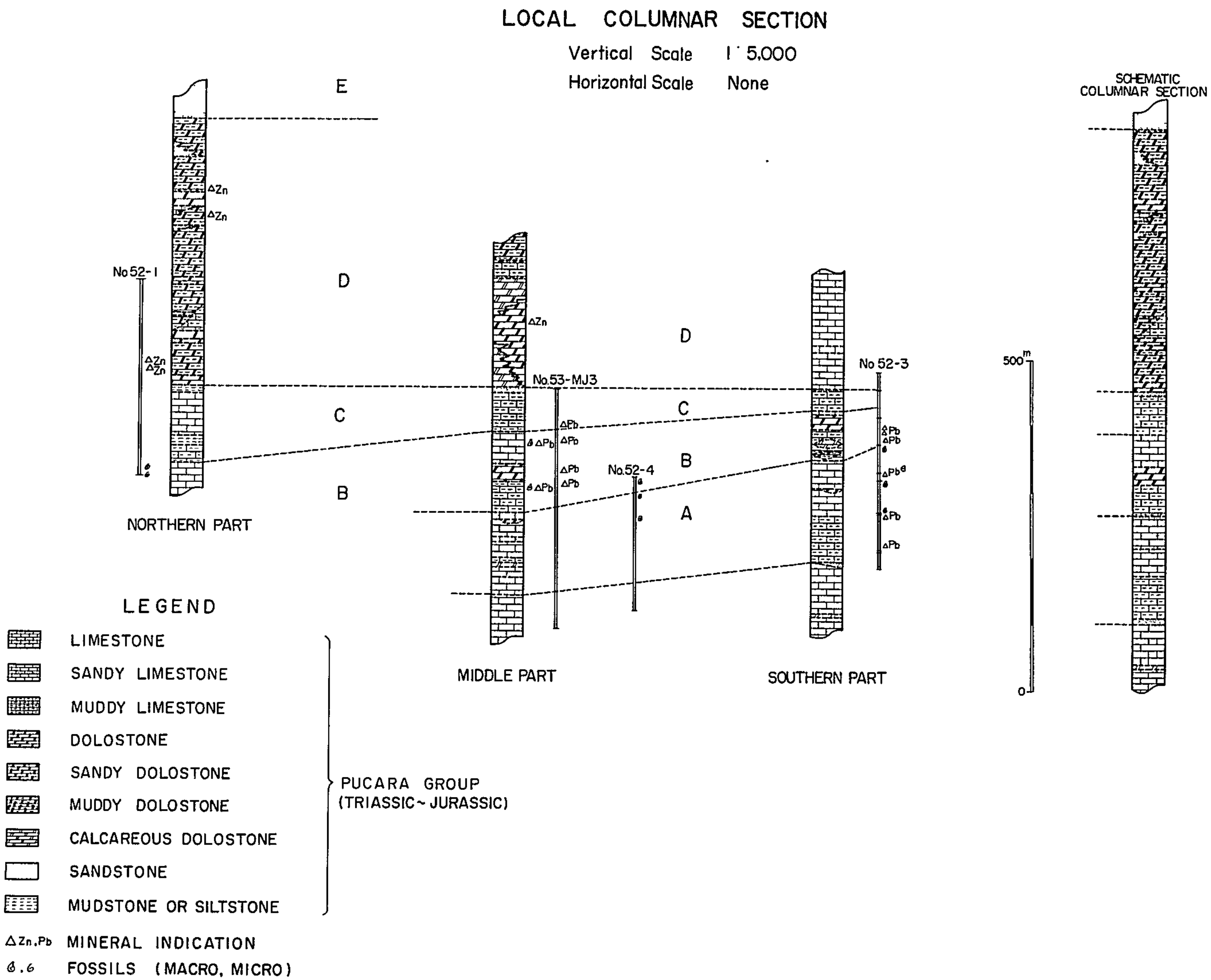
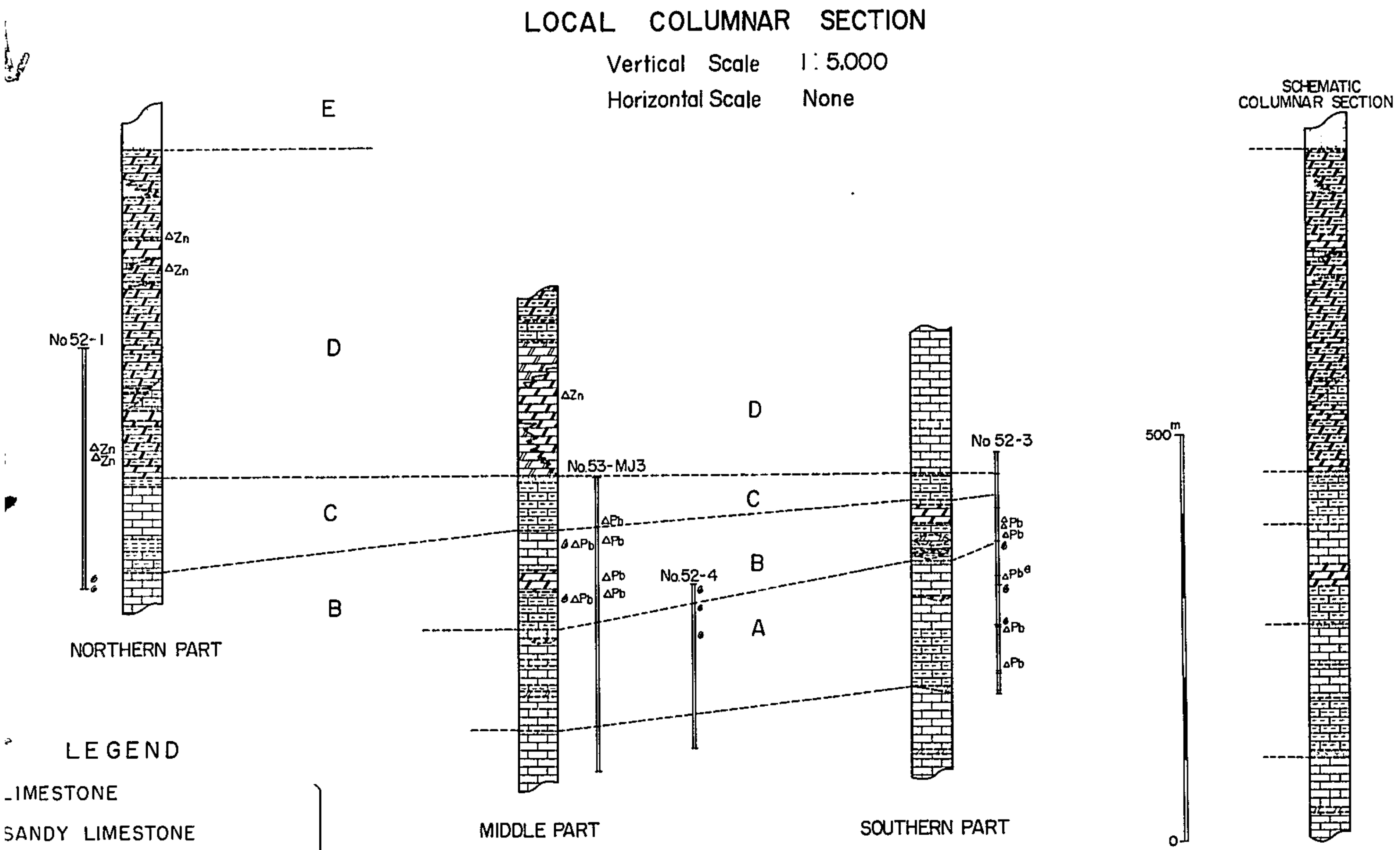


Fig. I-3. Scheme of Orogenic Cycle in the Surveyed Area



MEMBER		LITHOLOGY	T
V	E	Dolomitic Sandstone, micritic, very fine grained, quartzose, light brownish grey	
	D	Muddy Dolostone; micritic, very fine grained, grey to brownish grey, hard. Dolostone, crystalline, fine to medium grained, grey to light brownish grey Muddy Limestone, micritic, fine grained Sandstone ; fine to medium grained, light grey	20
IV	C	Muddy Limestone, fine grained, black to dark grey Sandy Limestone, fine grained, grey	3
	B	Muddy Limestone; biomicritic, fine grained, dark grey Limestone; crystalline, biomicritic, fine grained, dark grey Dolostone, crystalline, fine grained, dark grey	
	A	Limestone, crystalline, medium grained, grey Muddy Limestone; micritic, fine to very fine grained, dark grey to black Sandy Limestone, fine to medium grained, brownish grey	
III		Limestone, crystalline, medium grained, grey	

Fig. I-4. Generalized lithological distribution and correlation of the Pucara Group
(1) San Roque area



LEGEND

LIMESTONE
SANDY LIMESTONE
MUDDY LIMESTONE
DOLOSTONE
SANDY DOLOSTONE
MUDDY DOLOSTONE
CALCAREOUS DOLOSTONE
SANDSTONE
MUDSTONE OR SILTSTONE

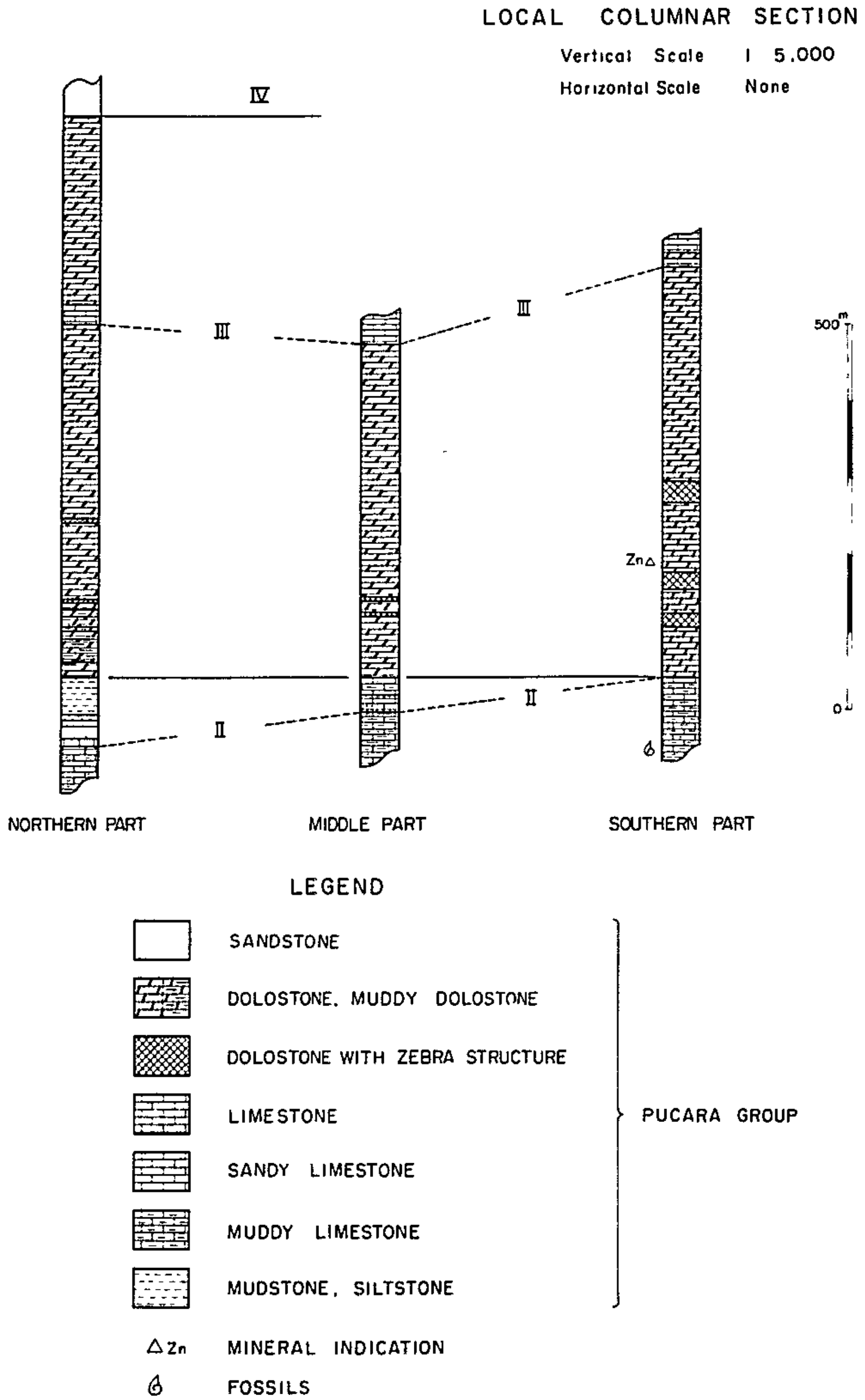
} PUCARA GROUP (TRIASSIC ~ JURASSIC)

MINERAL INDICATION
FOSSILS (MACRO, MICRO)

MEMBER		LITHOLOGY	THICKNESS	REMARKS
V	E	Dolomitic Sandstone, micritic, very fine grained, quartzose, light brownish grey	+ 50m	
	D	Muddy Dolostone, micritic, very fine grained, grey to brownish grey, hard Dolostone, crystalline, fine to medium grained, grey to light brownish grey Muddy Limestone, micritic, fine grained Sandstone, fine to medium grained, light grey	200m ~ 400m	△ Zn,Pb △ Zn,Pb △ Zn,Pb △ Zn,Pb
IV	C	Muddy Limestone; fine grained, black to dark grey Sandy Limestone; fine grained, grey	30m ~ 120m	
	B	Muddy Limestone; biomicritic, fine grained, dark grey Limestone, crystalline, biomicritic, fine grained, dark grey Dolostone, crystalline, fine grained, dark grey	75m ~ 150m	△ Pb △ Pb
	A	Limestone, crystalline, medium grained, grey Muddy Limestone, micritic, fine to very fine grained, dark grey to black Sandy Limestone; fine to medium grained, brownish grey.	160m	△ Pb
III		Limestone, crystalline, medium grained, grey		△ Pb

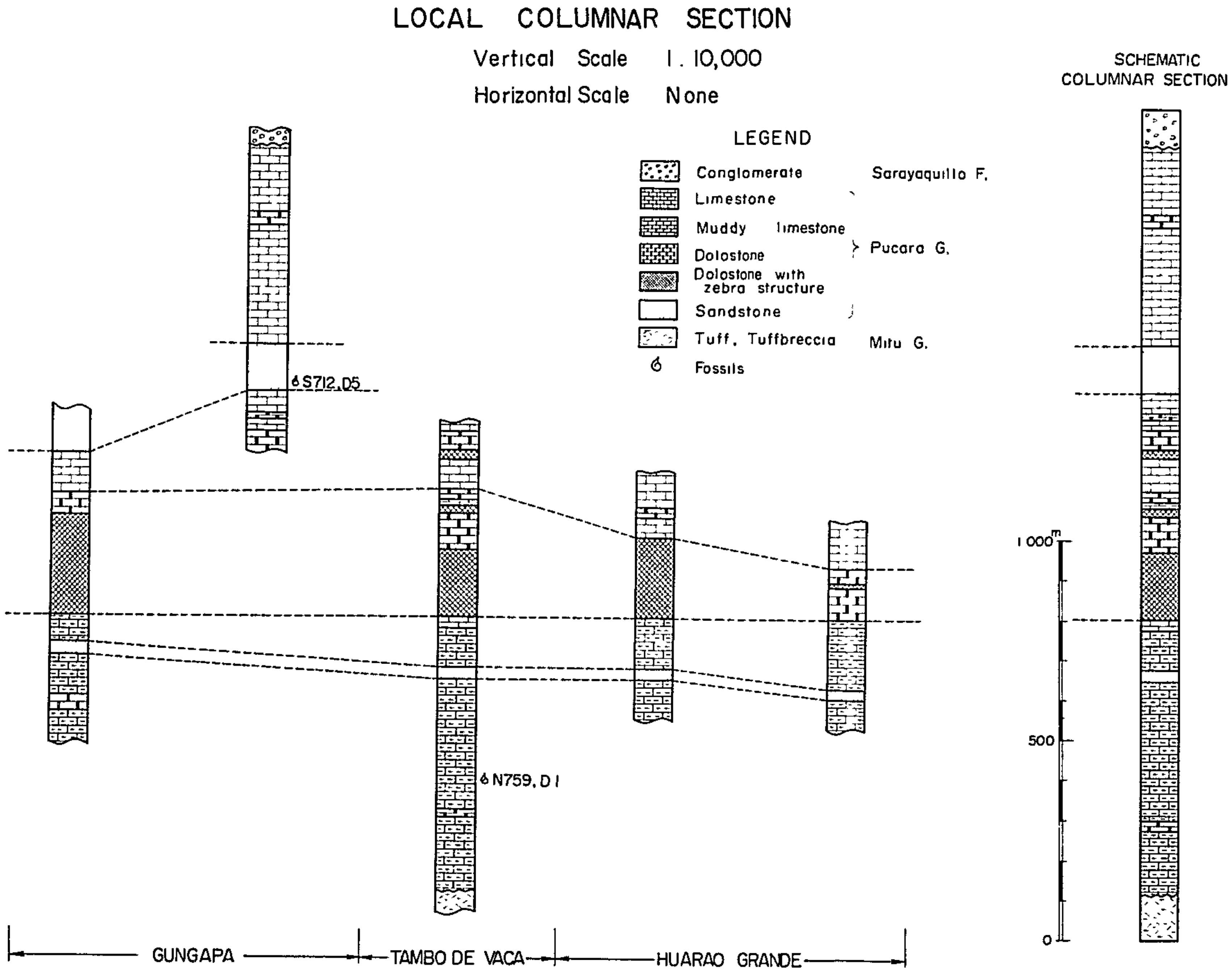
Fig. I-4. Generalized lithological distribution and correlation of the Pucara Group

(1) San Roque area



MEMBER	LITHOLOGY	THICKNESS	REMARKS
IV	Sandstone, Calcareous, fine grained to medium grained, light brownish grey to grey	+ 50m	
III	Dolostone, Well-crystalline to crystalline, fine grained to medium grained, light grey to dark grey, partly muddy, partly showing zebra structure, cross laminated to bedding plane Limestone, Aphanic to crystalline, very fine grained to fine grained, light grey to grey in color	820m	△ Zn
II	Mudstone, Bituminous, dark grey to black, partly calcareous, coexisted many pyrite, Observed only in northern part Siltstone, Partly calcareous, grey to dark grey, Observed only in northern part Sandy Limestone, Fine grained to very fine grained, brownish grey to dark grey Muddy Limestone, Partly bituminous, dark grey to black		6 psiloceras

Fig. I－4. Generalized lithological distribution and correlation of the Pucara Group
(2) Tambo Maria area



AGE		MEMBER	LITHOLOGY AND OTHERS
Up Jura	Sa. F.		Conglomerate, Pebble of limestone, dolostone and sandstone Matrix of brownish grey to reddish brown, calcareous sand and clay
Lower Jurassic	Pucara Group	V	Limestone, fine grained, light grey to grey, in lower part dolomitic Dolostone, fine grained, grey
		IV	Sandstone ; calcareous, fine grained, grey, pyrite-impregnated, intercalated with limestone (muddy, grey) and shale (coaly, black, containing ammonite fossils indicated Sinemurian age)
		III	Limestone, partly dolomitic, fine grained, grey and well cross laminated Dolostone, crystalline, fine to coarse grained, generally zebra structure developed, containing cherty nodules in upper part
		II	Limestone, muddy, partly dolomitic, fine to very fine grained, well-bedded, containing ammonite fossils indicated Hettangian age (N-759) Sandstone ; weakly calcareous, fine grained brownish grey to grey and well bedded
Perm	Mitu G		Tuff ; fine grained, greenish white Sandstone, tuffaceous, greenish grey Tuff breccia, andesitic

Fig. I-4. Generalized lithological distribution and correlation of the Pucara Group
(3) Chaglla area

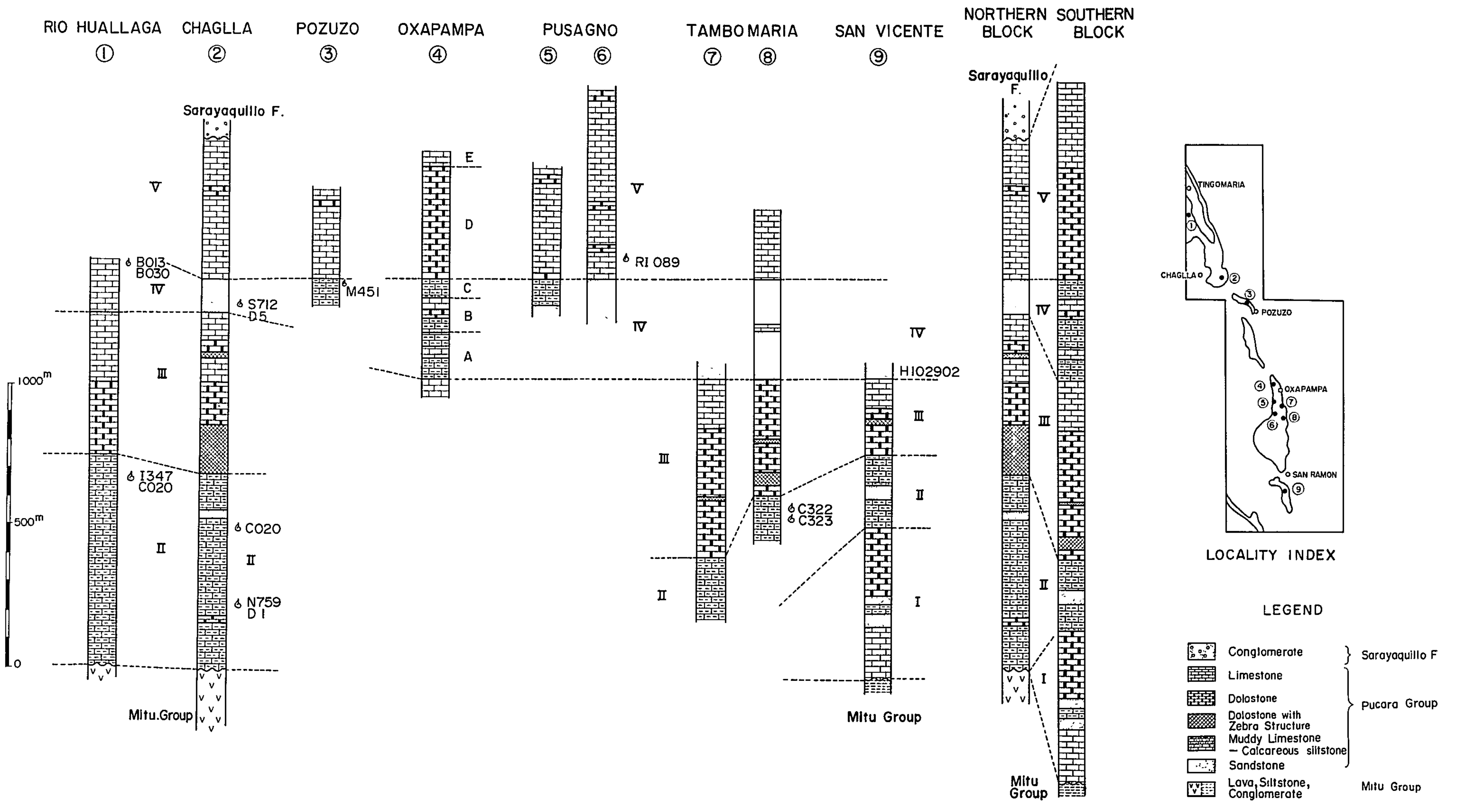


Fig. I-4. Generalized lithological distribution and correlation of the Pucara Group
(4) Entire surveyed area

Table I-1. List of mineralization in the surveyed area.

No.	Area	Location	Kind of Ore	Host Rock Group	Host Rock Rock	Alteration	Related Igneous Rock	Mode of Occurence	Scale of Mineraliza-tion	Direction of Mineraliza-tion	Amount of Unit Ore Body	Unit Ore body Scale	Unit Ore body Thickness Width	Unit Ore body Direction	Grade of Ore	Ore Minerals	Gangue Minerals	Structural Control	History	Note	Sample No.
1	SAN RAMON	SAN VICENTE	Zn, Pb, Cu	PU	Do, Ls	–	–	ba	3km×500m	N-S 20~50W	10	main 200m×200m	20m	N-S 45~50W	Pb 1% Zn 14%	Sp, Gn> Cp, Py	dol, cal	strata bound	worked product 1200T/D		
2	SAN RAMON	PICHITA CALUGA	Zn, Pb, Cu	PU	Ls	–	Di	ba	200m×75m	N50W NE	2	200m×75m	5m	N50W NE	Pb 5% Zn 15%	Sp, Gn> Cp, Py	dol, cal	strata bound	closed in 1969		
3	SAN RAMON	SANTOS	Zn, Pb, Cu	PU	Ls	Sk	Qp	diss	30m×	E-W S	1	30m×	max 1.5m	E-W S	Pb 1% Zn 18%	Sp, Gn> Py, Cp, Po	epi, gar	intrusive	exploited in 1974		S91202 S91204
4	SAN RAMON	SOLDADO	Zn Pb, Cu	PU	Ls	Sk	Qp	diss	100m×	N50W, S65 N40E, S50	2	100m×	max 5m	N40E S50	Pb 1% Zn 12%	Sp, Gn> Cp, Py	epi, gar	intrusive	closed		F103001
5	TARMA	LA OLIVIDADA	Cu	PU	Ls	Sil	–	net	50m×	NW-SE	1	50m×	max 3.5m	NW-SE	Cu 5%	Az, Mal> Sp	cal	NW-SE-fracture	worked product 9 T/M		T91902
6	OXAPAMPA	HONDA	Cu	PU	Ls	Sk	Mo	diss							Cu0.06%	Py, Cp	skarn	intrusive		Surveyed by Japanese Mission (1976)	K244
7	OXAPAMPA	HONDA	Cu	–	Mo	–	Mo	diss							Cu0.08%	Mt, Py> Ht, Cv		intrusive		Surveyed by Japanese Mission (1976)	K264
8	CHAGLLA	CHAGLLA	Cu, Pb	PU	Ls	–	–	vein							Cu0.24% Pb0.016% Zn0.066%	Mal, Gn	cal			Surveyed by Japanese Mission (1976)	A028 A024 A025
9	SAN RAMON	SOUTH PICHITA CALUGA	Cu, Zn	–	Do	epi chl	Di	vein					0.25m		Cu1.90% Zn0.18%	Mal, Cp Py, Sp	cal, qt epi, chl	fault		Surveyed by Japanese Mission (1976)	T008 I082 F072
10	OXAPAMPA	CHONTABAMBA	Pb, Zn	PU	Ls	–	–								Pb 28% Zn 8%	Gn, Sp			closed product 10T	Surveyed by Japanese Mission (1976)	A089
11	OXAPAMPA	SAN ROQUE VALLEY	Pb, Zn	PU	Ls	–	–	diss							Pb15.8% Zn0.68% (C416)	Gn	cal	strata bound		Surveyed by Japanese Mission (1976)(1977)	L319, C416 OF007, M494 OF017
12	OXAPAMPA	TAMBO MARIA	Zn	PU	Do	–	–	ba					3.2m		Cu0.02% Pb0.013% Zn4.12%	Sp, Sm	dol	strata bound		Surveyed by Japanese Mission (1976)(1977)	S024, S025 S346, S347 S350
13	OXAPAMPA	SAN ROQUE T-2	Zn, Pb	PU	Do	–	–	diss							Pb0.09% Zn0.35%	Sp, Gn	qt, dol	strata bound		Surveyed by Japanese Mission (1978)	L729
		SAN ROQUE T-4	Zn	PU	Do	–	–	diss & fr							Pb0.15% Zn20.72%	Sp	qt, dol	strata bound			S725
		SAN ROQUE T-10	Zn, Pb	PU	Do	–	–	fr							Pb6.56% Zn19.16%	Sp, He, Gn	dol	strata bound			S783
		SAN ROQUE T-28	Zn, Pb	PU	Do	–	–	fr					5m		Pb0.87% Zn2.85%	Sp, Gn	dol	strata bound			L783-1 L783-2 L783-3 L783-4 L783-5
		SAN ROQUE T-29	Zn, Pb	PU	Do	–	–	fr							Pb2.11% Zn11.06%	Sp, Gn	dol	strata bound			L815
14	CHAGLLA	HUARAO CHICO	Pb	PU	Do	–	–	diss								Gn	cal, flu	strata bound		Surveyed by Japanese Mission (1978)	N746
		HUARAO GRANDE	Pb	PU	Do	–	–	diss								Gn	cal, flu	strata bound			N752
		HUARAO GRANDE	Pb	PU	Ls	–	–	diss								Gn	cal	strata bound			D807

Group: PU : Pucara Group

Rock Name:
- Do : Dolostone
- Ls : Limestone
- Mo : Monzonite
- Di : Diorite
- Qp : Quartz porphyry

Alteration:
- Sil : silicification
- epi : epidotization
- chl : chloritization
- Sk : Skarnization

Ore Mineral:
- Az : Azurite
- Cp : Chalcopyrite
- Cv : Covelline
- Gn : Galena
- He : Hemimorphite
- Ht : Hematite
- Mal : Malachite
- Mt : Magnetite
- Po : Pyrrhotite
- Py : Pyrite
- Sm : Smithsonite
- Sp : Sphalerite

Gangue Mineral:
- cal : Calcite
- chl : Chlorite
- dol : Dolomite
- epi : Epidote
- flu : Fluorite
- gar : Garnet
- qt : Quartz

Mode of occurence:
- diss : disseminated
- fr : fracture filling
- ba : banded
- vein : vein type
- net : network

Chapter 3 On the Pucara Group

The dolostone belonging to this Pucara Group is important as the country rock of the lead-zinc ore deposits in this surveyed area. Accordingly, it has been regarded as one of the purposes of the surveys to confirm the characteristics of the lithofacies and to clarify the stratigraphical relation. In this chapter, a consideration on the Pucara Group, will be given by summarizing it collectively on the basis of the whole surveys' results.

3-1 Stratigraphy and Correlation

3-1-1 Stratigraphy

The Pucara Group in the surveyed area was divided into 6 members by the survey results in 1977 and they have been called the I to VI members. In the present year, as it has been ascertained through the surveys in the San Roque area that dolostone and limestone of the V and VI members should be treated as variation of an unit, these 6 members have been coordinated to be 5 members, from the I member, the lowest, to the V member, the uppermost. Description of the respective member is given hereunder. The basis of the correlation of them will be stated in the section 3-1-2.

(1) The I member (Lower dolostone-limestone bed)

The distribution of the I member is limited to the area around San Ramon and San Vicente in the southern part of the surveyed area. It has not been recognized in the northern area of San Ramon. The I member is composed of grey siliceous limestone or dark-colored limestone, dolostone and sandstone. Zebra-structure is associated with dolostone in places. The relation of this member against the underlying Mitu Group is unconformity, as confirmed near San Vicente. The thickness is approximately 530 m.

(2) The II member (Muddy-sandy limestone bed)

The II member has been found everywhere in the central part. It consists of limestones containing muddy or bituminous materials. The thickness varies in different localities, about 250 m in the south and 700 - 750 m in the north, but it has similar lithofacies all over. In the southern part, it lies on the I member, while it overlies the Mitu Group with unconformity in the northern part.

(3) The III member (Middle dolostone-limestone bed)

The distribution of this member is almost same as that of the II member. It is composed mainly of dolostone and limestone. Through the present year's survey, the detailed information on this member has been obtained in the Chaglla area and in the Tambo Maria area. The dolostone lying in the lower part of this member is crystalline and characteristically accompanied by zebra-structure. Especially, in the Chaglla area, prominent zebra-structure of the thickness over 100 m has been recognized in the dolostone. This dolostone is usually homogeneous in lithofacies but some are observed to form alternation with thin layers of calcareous sandstone and mudstone etc., as seen in San Vicente, which is thought to reveal variation of the sedimentary environment. The limestone overlying the dolostone is comparatively crystalline and in some places the lithofacies are transitional to the overlying IV member (Sandy limestone bed).

The lead-zinc ores found at San Vicente and at Tambo Maria are emplaced in the dolostone accompanying zebra-structure.

(4) The IV member (Sandy limestone bed)

The member is distributed in every part of the survey area with the thickness of 120 - 430 m. It is composed mainly of well-bedded dark brown medium to fine grained sandy limestone, though it becomes rather sandy in the north of Chaglla. Especially, in the Oxapampa area, the alternation of muddy limestone and limestone or dolostone is remarkable, and disseminated lead is associated with it, though slightly.

(5) The V member (Upper dolomite-limestone bed)

The member is distributed from the north of San Ramon to Chaglla area, though it has not been found around San Vicente and along the Huallaga River. It consists mainly of limestone but in places it has layers of intercalated dolostone. It is remarked that distinct alternations or interfingers of dolostone, limestone, and muddy to sandy dolostone are recognized only by several kilometers in diameter, in the vicinity of San Roque in the northwest of Oxapampa.

Disseminated - fracture filling type lead-zinc ore deposits at San Roque are emplaced in this dolostone bed.

The unconformity boundary between this bed and the overlying Sarayaquillo Formation (conglomerate) is recognized in the Chaglla area, though there is no other area, where the relation to the upper horizon has been confirmed.

3-1-2 Correlation

The above-mentioned evidences are shown collectively in Fig. I-4 (4) for the correlation. As it is impossible in the surveyed area to make stratigraphical correlation on continuous exposure without a break, the correlation has been performed by the stratigraphical position of the collected fossils and by employing rocks with characteristic lithofacies —— actually two layers of clastic rocks as key beds.

The muddy-sandy limestone of the II member, distributed extensively in the surveyed area, has been found to have common characteristics of being well-bedded, being bituminous and being bounded to the overlying dolostone with conformity. Also, the index fossils of Psilocerous genus ammonite, showing Hettangian Age of Jurassic Period, are found contained in it in the Chaglla area and in the Tambo Maria area. Based on these evidences, this dark-colored limestone can be treated as a key horizon for the stratigraphical correlation.

Although the sandstone bed of the IV member is also composed of calcareous or dolomitic sandstone, it can be distinguished from the above-mentioned dark-colored limestone by the relation to overlying or underlying beds and variation of the lithofacies, in the Tambo Maria area and in the Chaglla area. Among them, the sandstone (A, B and C submember) found in the Oxapampa area is thought to be correlated to the IV member (sandy limestone bed) by the evidences that it is not bituminous, that it can not be said to be so well-bedded as the II member (muddy-sandy limestone), and that no special phenomena can be seen of the upheaval of strata near Oxapampa while all the Pucara Group is plunging gently to the north structurally, although this correlation could not be definite because the exposure of this sandy limestone is seen only scatteringly and also no distinct index fossil has been detected.

By the results of the above-described, the overlying and underlying limestone and dolostone are correlated extensively and it can well be said that they are similar in lithofacies but for those belonging to the V member found at Oxapampa. From the above consideration the followings can be pointed out.

① The I member is corresponded to upper Triassic Period and can be correlated to the Chambara Formation at the standard localities.

② The II member is corresponded to lower Jurassic Period and can be correlated to the lower part of the Aramachay Formation at the standard localities.

③ The III member and the upper members are corresponded to lower to middle Jurassic Period and can be correlated to the Condorsinga Formation at the standard localities, but the boundary of the both formations has not been confirmed yet.

④ The thickness of the Pucara Group is about 1,900 m in the north and about 2,450 m in the southern part.

3-2 Dolostone of the Pucara Group and its Sedimentary Environment

There are two prominent dolostone layers in the surveyed area --- the one belonging to the III member which is distributed everywhere in the surveyed area, and the other belonging to the V member which is found in the San Roque area, though its development in the V member in any other area is weak. Other than those, a development of it can be recognized in the I member in the San Vicente area. The main lead-zinc ore deposits found in the surveyed area are emplaced in the dolostone of the III member and the V member, and it has been clarified that the formation and the sedimentary environment of the dolostone is very important in relation to development or concentration of ore deposits. Accordingly, the consideration is given in this section on a sedimentary environment and a mechanism of the formation of the dolostone belonging to the III member and the V member, which include mineralizations and constitute the main subject of the present surveys in this area.

3-2-1 Occurrence of the dolostone

The dolostone of the III member forms a remarkable alternation with layers of calcareous sandstone, calcareous mudstone etc. in the San Vicente area, but the dolostone found in the other areas is rather homogeneous with some intercalations of limestone, calcareous mudstone and calcareous sandstone. The dolostone is comparatively well-bedded and in the

Chaglla area a cross-laminae develops prominently. On the other hand, the dolostone of the V member, distributed in the San Roque area, is composed mainly of muddy dolostone and is characterized by the vaiation of the lithofacies and by the remarkable alternation of dolostone, muddy - sandy limestone and limestone.

The dolostone of the III member is generally crystalline state. Under microscope, the grain size of the crystals is 0.1 - 0.2 mm in average, but sometimes reaches 1 mm, and the crystal growth and purification by the recrystallization are recognized. Accompanying to the growth of dolomite crystals, the growth of sulphides, especially pyrites, from microframboidal spheres to cubic crystals can be recognized. On the contrary, the dolostone of the V member found in the north of San Roque is micritic and is composed mostly of the grains of under 0.01 mm in size. The fragments of Brachiopod, Echinoid, and algae are observed to be contained in it. Also, detrital quartz, chalcedonic quartz and terrigenous clayey materials are contained, which are seldom recognized in crystalline dolostone. As for sulphides, only small amount of spherical pyrite and sphalerite can be seen in micrograins (under 0.02 mm) in the micritic dolostone, but as the crystallization of dolomite advances, their grains grow as much as megascopically recognized.

The content of magnesium (Mg hereunder) in carbonate rocks has been analyzed on all the samples collected for the geochemical survey in this year. The histogram of the Mg assay is shown in Fig. I-6. More than half samples show under 3 % or over 10 % of the Mg content, and the samples of medium grade content is rare. This tendency may correspond to the distribution of the Mg content in the Paleozoic carbonate rocks shown by FAIRBRIDGE (1957). (This phrase from SHOJI (1971)). The samples containing more than Mg 10 %, are called dolostone, and some of them are composed of mud size grains (under 0.01 mm) in the San Roque are and some are composed of recrystallized dolomite 1 ~ 2 mm in size in the Tambo Maria area (L767 etc.). Therefore, there is no difference of Mg content among them, but it can be said that merely the degree of recrystallization is different. The samples shown the medium grade content of Mg are regarded as mixture of dolomite and calcite or as those containing such foreign materials as quartz and clay. JONES (1961) stated that there are no small crystals in the recent dolomite, because of the recrystallization, found in the Deep Spring Lake, California in U.S.A. (This phrase from FRIEDMAN (1967)). Also, FRIEDMAN (1967) stated as for the classification of dolomite that penecontemporaneous dolomite is accumulated in the form of micritic or fine crystals. Accordingly, the dolomite found in the surveyed area might well be regarded as penecontemporaneous dolomite as FRIEDMAN stated, viewing from the occurrences and the compositions of the dolomite.

3-2-2 Consideration of the sedimentary environment

(1) Impurities contained in the dolostone

① Strontium

For the information on paleo-environment in which carbonate rocks were accumulated, research on impurities has been thought to be effective and actually has been procecuted to bear results, by Europeans and Americans, for a long time. Consideration is given here on the sedimentary environment of the Pucara Group in the surveyed area, from the point of impurities contained in the carbonate rocks.

CHESTER (1975) stated, by analyzing strontium (Sr hereinafter) contained in the carbonate rocks of dolomite* and dolomitic limestone, which

* CHESTER represented dolostone by the word "dolomite".

genesis was well defined, distributed in Sturgeon Lake area in the northwestern part of Canada, that Sr is disposed to concentrate more in non-reef limestone, as the Sr content in the reef limestone is 67 ppm in average whereas that in the non-reef limestone is 553 ppm averagely. Also, WOLF et al. (1967) insisted, by quoting the reports on Sr by FLUGEL (1962) and by STERNBERG (1969), that the content of strontianite ($SrCO_3$) in non-recrystallized carbonate rocks is disposed to be extremely high in case of abysmally-deposited rocks further from reef envrionment as the results have shown that rocks deposited in back-reef environment are 60 to 150 ppm and rocks deposited in fore-reef environment are 50 to 420 ppm while those deposited in basin are 380 to 1,570 ppm (Converted to Sr, 40 - 100 ppm, 100 - 280 ppm, 250 - 1,030 ppm respectively), and that Sr content in recrystallized carbonate rocks is low.

The assay results of Sr contained in 53 samples of the carbonate rocks in the survey area of the present year, are shown in Table I-2 and Fig.I-5. The highest value of Sr content is 2,440 ppm (N804) of the sample of the muddy-sandy limestone of the II member underlying the dolostone found in the Tambo Maria area. The assay values of Sr of the other samples are 10-390 ppm. This fact is evident from the Sr assay results of the samples collected in the survey carried out in August, 1975 (Refer to Table 15, Vol. 5). In Oxapampa area, samples belonging to the II member show high values of Sr content and the samples of the V member collected in the area where limestones are predominant show a little higher values while Sr content in the other samples are 10-390 ppm.

The followings can be pointed out by the consideration on the basis of the reports by Chester and others.

i) The II member is composed of well-bedded muddy - sandy limestone, which contain fossils of ammonites. Therefore, they are regarded to be the limestone which were accumulated in a quiet basin of non-reef environment.

ii) The dolostones of the III member are remarkably recrystallized as found both in the Tambo Maria area and in the Chaglla area. It is seems to was accumulated in the reef environment. Therefore, as stated by WOLF et al. (1967), it is impossible to estimate the sedimentary environment exactly from the assay result of Sr content.

iii) The V member is composed of dolostone —— limestone. The dolostone found in the San Roque area contains many terrestrial detritus, showing reef-origin, but some of those found in the central to southern part are rather abyssal. It is thought that they were accumulated in rather variable environment.

② Barium

By CHESTER (1965), it is possible to estimate the sedimentary environment of carbonate rocks if it was reef-origin or non-reef origin by giving consideration to barium (Ba hereafter) content values, that is, by the evidence whether the content value is over 100 ppm or under, as a tendency can be seen that reef-origin carbonate rock reveals 9.5 to 137 ppm of Ba content whereas non-reef origin carbonate rock shows 133 to 1,350 ppm.

In the surveyed area, Ba contents are generally 600 to 3,000 ppm except for the samples (containing $BaSO_4$ 2.00 %) collected from the exposures of the lead-zinc (Pb, Zn hereinafter) ore indication in the San Roque area. In another words, the values are extremely higher than those shown by CHESTER. However, as STANTON (1972) pointed out, considering that large amount of terrestrial Ba was added with elements of Pb, Zn and other metals in the period of primary accumulation of the strata-bound ore deposits, it is impossible to apply CHESTER's conclusion. The fact that several times concentration of Ba exists, as is seen in the sample of mineralized zone at

San Roque, showing $BaSO_4$ 2.00 % (L787) would be taken to represent the existence of the environment of extensive evaporation.

③ Aluminium

Aluminium (Al) is contained in the form of alumina (Al_2O_3) as feldspars of terrestrial detritus and as its weathered products --- clay minerals. Generally, contents of Al are low, but some samples collected in the Chaglla area and in the Tambo Maria area show pretty high values (>5 %). The carbonate rocks of high contents of Al are considered to be the rocks originated in the environment in which terrestrial detritus were supplied.

(2) On the environment forming dolomite

① General consideration

There are many disputes among the geologists on the mechanism of the formation of dolomite, but it has been gradually accepted that dolomite would be formed by the replacement of already-formed calsium-carbonate in the existence of hypersaline brine.

It is thought that the dolostone found in the surveyed area was accumulated in the reef-environment where hypersaline brine was formed with the extensive evaporation, viewing from the distribution of Sr and Ba. This environment would be corresponded to the recent environment, as FRIEDMAN (1967) suggested, where dolomite is being formed. The examples are given --- the area separated far from the sea region as Coorong Lake in Australia, and the area of shallow-water environment with some tidal flow where saline water is concentrated especially along the shore line, as seen at Abu Dhabi in Perusian Gulf. As for reef environment, that represented by Abu Dhabi is the case in which the level of backreef, continental side of barrier reef, is lower than the sea level, while Coorong Lake is the case in which the level of the back reef is higher than the sea level.

It is insisted that dolomite rarely deposits directly from the solution, and that dolomite is formed mostly by the replacement by Mg in hypersaline brine after accumulation as calcium-carbonate. Hypersaline brine is formed by exhalation of water from porous rocks along sea shore, or by direct evaporation of sea-water. There is another case that it is formed by evaporation of fresh water in continental circumstances (FRIEDMAN 1967). In a closed water basin favorable for hypersaline brine to be formed, the increase of salinity and the replacement of calcium-carbonate by Mg can be said to occur easily, but it does not seem to have much chance that great amount of dolomite would be produced, because of the quantitative limitation of Mg or calcium-carbonate. In other words, supply of supplementary tidal flow is necessary in order to keep the salinity required for the precipitation of calcium-carbonate and for the propagation of algae (containing Mg) as one of the source material of calcium-carbonate, and to compensate Mg exhausted through the replacement of calcium-carbonate. As SCHNEIDER (1964) pointed out, the growth of barrier reef in reef environment and the existence of overlasting back-reef environment are necessary. In some water basin where tides are flowing into, residual evaporites are not always produced even if dolomites are formed, as is the case of Andros Island of Bahama (FRIEDMAN 1967). Accordingly, the existence of residual evaporites can be said to suggest closed environment where vaporization is extensive.

From the above-mentioned evidences, most of the dolostones belonging to the III member and to the V member in the surveyed area are well taken as the products formed in reef-environment, but the mechanism could not be so simple as SCHNEIDER (1964) suggested. It is considered that they were formed in the variable reef environment at the change of the times, that is, a time when the formation of dolomite was accerelated and residual evaporites were deposited, or when Mg was compensated by flowing in from open sea.

② Sedimentary environment in the San Roque area

In the San Roque area, the Mitu Group is distributed in the area where the Pucara Group develops, with the width of 100 to 400 m. The Mitu Group develops in NNW-SSE direction in this area, and some small-scale distributions are recognized in the Pusagno area about 30 km south of the San Roque area. In these areas, the distribution of the Pucara Group can be taken to be between the Mitu Group and the older rocks (granites and the Mitu Group etc.) developed in its west. Structurally, large scale geoanticlinal movement occurred in the direction of NNW-SSE, accompanied with igneous activities, from the early Paleozoic Era, along the Cordillera Oriental range, to the west of the surveyed area (Fig. I-3). The above-mentioned Mitu Group exists forming horst topography, faulted with the Pucara Group, running by 1 to 5 km east of the eastern margin of the geoanticlinal zone. As the basement to separate the sedimentary basin of the Pucara Group into eastern and western parts, the Mitu Group uplifted in relation to the geoanticlinal movement, leaving variable reef environment as described in the section 1. The horsted Mitu Group is accompanied by the same intrusive igneous rocks as found in the geoanticlinal zone in the west. Therefore, it is easily understood that the uplift was caused by the igneous activities related to the geoanticlinal movement.

The dolostone found in the San Vicente area, belonging to the III member, is known to contain residual evaporites in place, accompanying the Mitu Group in its east (Vol.II; KOBE (1977)). Accordingly, it is thought that this dolostone was formed in the same environment as that of the V member found in the San Roque area.

Schematic illustrations of the sedimentary environments from the A to D submembers of the IV and the V members around the San Roque area are given in the Fig. I-7. The effect of the Mitu Group as the basement of the barrier reef seems to be most remarkable in the north at the time of the sedimentation of the D submember, viewing from the variation of the composition in the sedimentary rocks, as evidences of the rapid formation of dolomite and the existence of residual evaporites are observed there. This tendency is recognized a little in the evidences at the time of the sedimentation of the B submember, but the tendency was not so apparent on the A and the C submembers.

③ Sedimentary environment in the areas of Tambo Maria and Chaglla

In the Tambo Maria area and in the Chaglla area, located far from the geoanticlinal zone, the Mitu Group is not recognized within the Pucara Group, and the residual evaporites is not also found in comparison with the San Roque area.

It would be a premature consideration to conclude in this area from the above mentioned that there have been no closed sedimentary basin bounded by barrier reef as seen in the San Roque area. Cross-beddings in the dolostone are remarkably developed in the middle of the III member found in the Chaglla area. This fact coincides with the elucidation by FRIEDMAN (1967) that cross-beddings are often observed as one of sedimentary structures of dolostone formed under tidal-flow environment. Therefore, it is thought that the shallows on the basement of the Mitu Group or others would have been formed along the west of the dolostone zone, then dolomite would have been formed receiving new sea water by tidal currents. Any trace of sedimentary structure has been not recognized in the Tambo Maria area because recrystallizations of dolostones are prominent. It is thought that the environment have been same as that in the Chaglla area.

3-3 Formation of Dolomite and on the Zebra-Structure

Consideration has been given in the preceding section on the sedimentary environment in which dolomite was formed, in the surveyed area. As for the formation of the dolomite, it was thought in the report of the survey in 1977 that dolomites have been formed by the replacement of accumulated Ca component by Mg contained in the sea water in the process of the diagenesis in which various processes would be occured from the sedimentation as limestone to the consolidation, though dolomitic rocks originated to biogenesis exist in the surveyed area. (Refer to the section 3 of the Chapter 2, Part I, Vol.VI). There is no change on the outline of this idea, but some comments are given here, based on the present survey.

To summarize the mechanism of the formation of dolomite elucidated by FRIEDMAN (1967), SHOJI (1971) and others, the followings can be said: In a reef condition, calcium contained in the sea water precipitates in various forms chemically and bio-chemically as aragonite, algae etc., when the pH and the salinity of the seawater reach to a certain level. The sediments are porous and are in a state to promote chemical reaction easily. While precipitation is in progress, evaporation takes place continuously in back-reef or in shallows, and it becomes to hypersaline brine containing Mg. This brine remains in the closed basin or in the shallows and permeates calcium-carbonate fore-precipitated at the bottom, flowing in reverse against the surface water. Mg in the hypersaline brine reacts with calcium-carbonate and high-magnesian calcite, protodolomite etc. are formed. In another words, it can be said that the foundation of dolomite is formed during the period of sedimentation or in the early stage of the diagenesis. Various chemical processes like transition, cementation, recrystallization, replacement, and dolomitization are promoted by the physical motives as compaction and dehydration in the period of diagenesis after the completion of sedimentation. Namely, high-magnesian calcite, protodolomite etc. are fixed as dolomite by the complex mechanism such as stabilization of unstable minerals, consolidation, recrystallization of grains and replacement with some components of brines in pores.

It is inferred generally that the dolomite in the surveyed area have been formed on the same processes as mentioned above. Among these processes, it should be perceived, in relation to dolomitization, that the volume is reduced as much as 12-13 % (maximum) when calcium-carbonate (including high-magnesian calcite) is replaced to dolomite (CHILINGAR, 1967; FAIRBRIDGE, 1967). Also, it is estimated that the space caused by this contraction of volume accelerates the dolomitization through the movement of unreacted high-Mg brine, and gives an effect to promote the crystal growth in the process of recrystallization. The formation of zebra-structure found in places in the dolostone of the surveyed area would be related largely to this loss of volume in the process of diagenesis. Dolomite is seen to have been formed even in the limestone containing less amount of Mg. The limestone of the III member represented by the sample P800 contains 1.3% of Mg in the Chaglla area. By the result of the X-ray micro-analysis (XMA), a little dolomite of rhombic microcrystals are observed among calcite grains (A. I-11). It can be said by this evidence that Mg has been stabilized as dolomite even if the content of Mg is very low.

It had been thought that directions of zebra-structure were formed by a tectonic movement related to a lateral pressure of NEE-SWW direction for the reason that this structure was conformable to the bedding planes and to the regional structure. At least, it is true in the Oxapampa area. Although, directions are concordant to the bedding plane dipped gently in the Chaglla area from the results of geological surveys, these directions could not be said to be in good harmony with the regional structure.

There may be some zebra-structures formed in relation to tectonic movement, but it would be much better to improve the former consideration to the idea that most of the zebra-structure was formed through the continuous gentle crystallization of dolomite in the space caused through the process of the dolomitization in the earliest stage of diagenesis. Considering in this way, the appropriate elucidation can be given on the breccia structure found in the San Vicente area and in the Tambo Maria area, that the compaction from the upper part took place when the space was formed. Around the brecciated structure, there are dolomite grains formed through recrystallization. They are thought to have been formed in the same process as the zebra-structure was formed. The filling temperature of the fluid inclusions in the dolomite with the zebra-structure was obtained to be 70°-150°C in the San Vicente ore deposits. (Refer to Vol. I). This would show the temperature of the crystallization of dolomite. And also, this temperature coincides with the filling temperature of 100°-150°C of the fluid inclusions contained in the strata-bound lead-zinc ore deposits, stated by STANTON (1972).

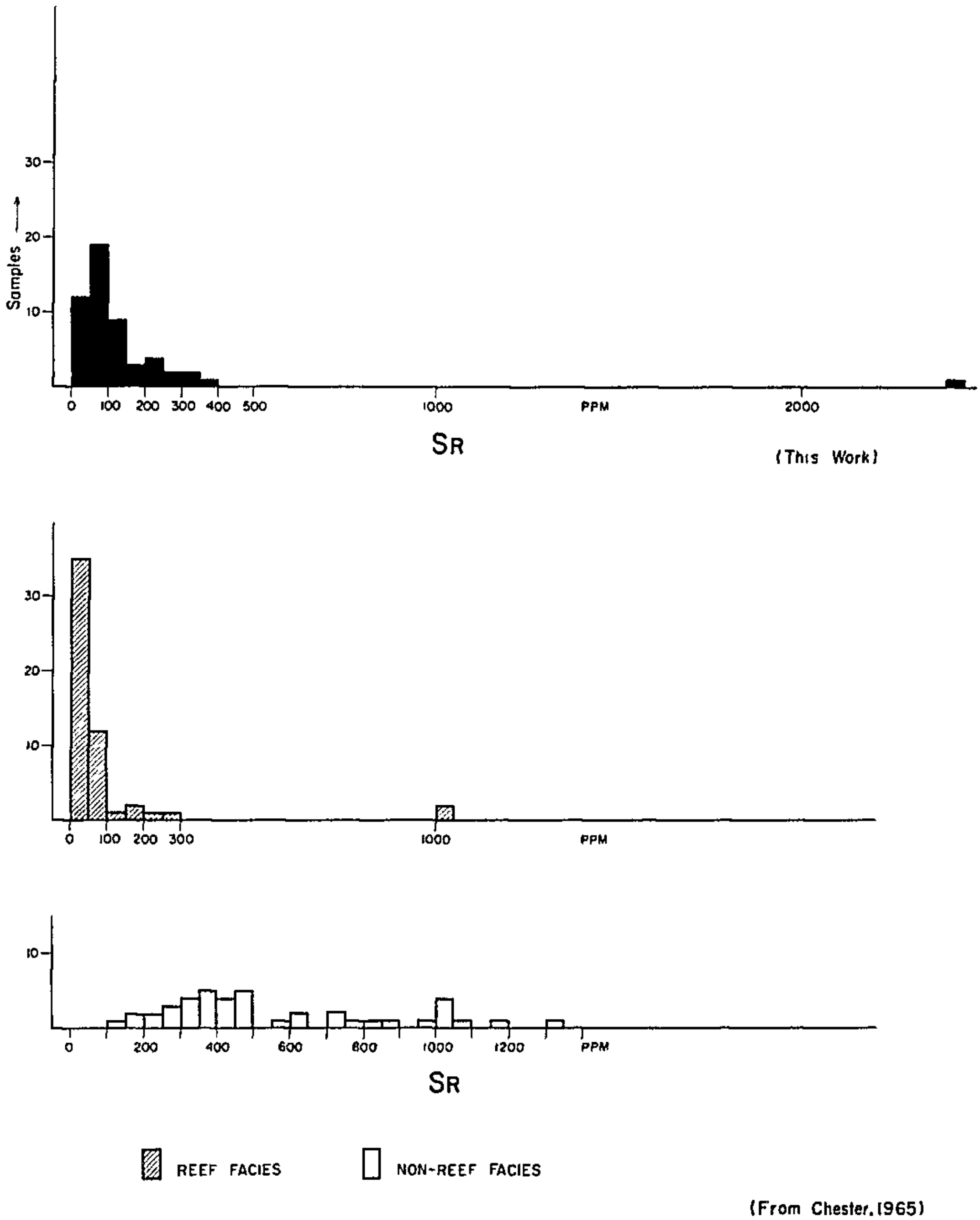


Fig. I-5. Histograms of Sr content on carbonate rocks

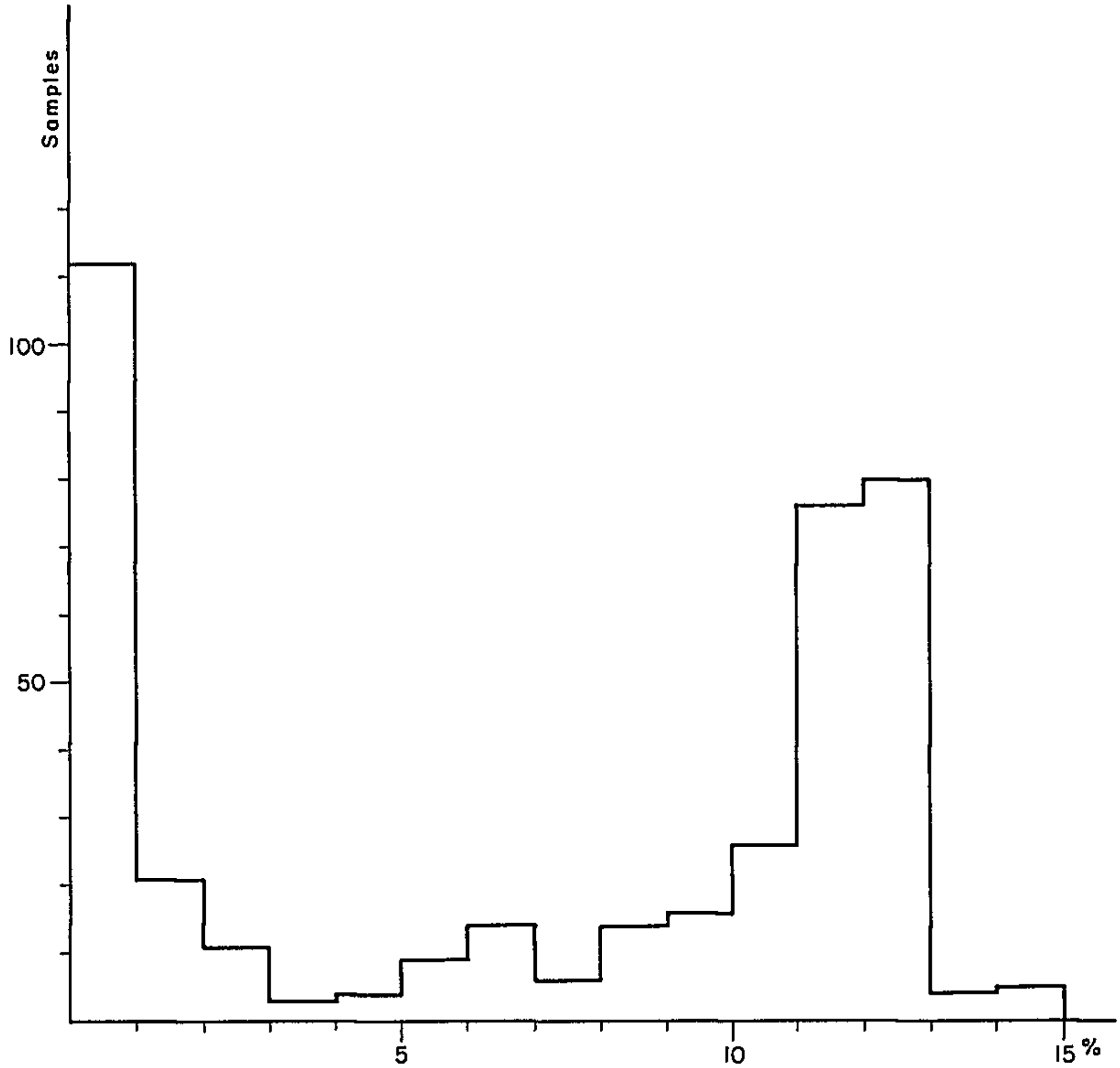


Fig. I-6. Histogram of Mg contents on carbonate rocks

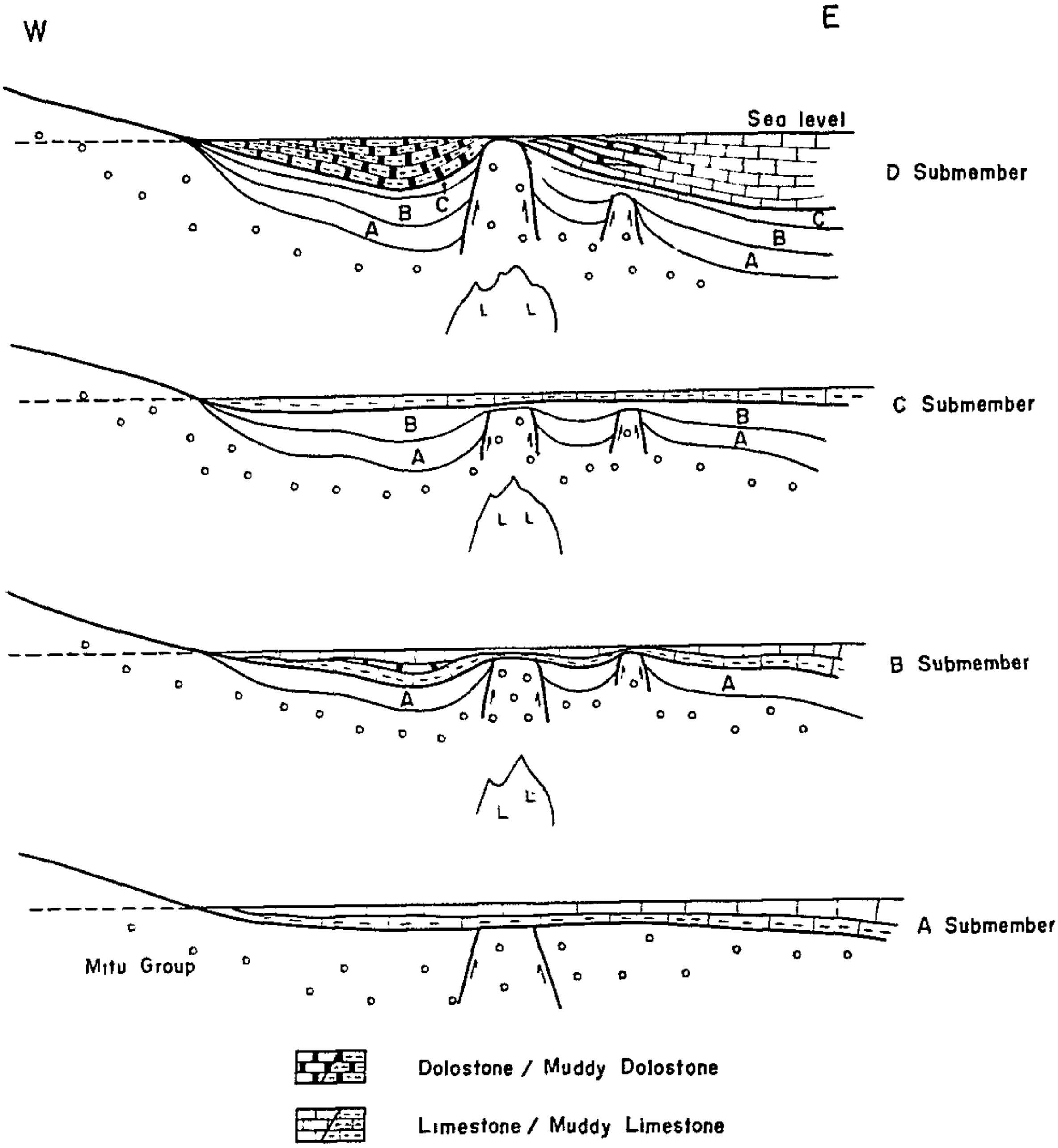


Fig. I-7. Schematic cross-sections of San Roque area during sedimentation of the Pucara Group

Table I -2 Contents and those relationship of minor elements on carbonate rocks in the surveyed area.

* cf. A. I-1. Geological Index; Location

Sample No.	Field No.	Location*	SiO_2(%)	Al_2O_3(%)	CaO(%)	$BaSO_4$(%)	Sr (ppm)	Mg(%)	Zn (ppm)	Ba(%)	Weight ratio Ba(ppm)/Sr(ppm)	Ca (%)	Molal ratio Mg/Ca
957	A755	HG	1.35	0.46			50	12.9	17				
965	A763	HG	0.05	0.50			30	12.8	6				
1004	L709	S.T-13	0.67	0.67	29.03	0.11	210	11.8	6120	0.06	2.9	20.75	0.94
1008	L713	S.T-2	94.75	3.45	0.35		10	0.1	146			0.25	0.80
1019	L726	S.T-2	16.11	1.74	23.31	0.49	120	9.2	207	0.29	24.2	16.66	0.91
1020	L727	S.T-2	23.93	1.65			140	8.6	195				
1026	L733	S.T-1	4.33	1.62	30.84		100	8.4	267			22.04	0.63
1032	L742	S.T-5	3.62	1.90			230	11.7	690				
1033	L744	S.T-5	4.27	1.02	28.53	0.24	310	11.3	570	0.14	4.5	20.39	0.91
1034	L745	S.T-5	8.57	1.54			140	11.2	495				
1035	L746	S.T-5	50.12	0.71	14.46	0.22	70	6.4	195	0.13	18.6	10.33	1.02
1047	L760	T.T-25	0.21	0.73			90	11.7	15				
1048	L761	T.T-25	0.11	0.68	28.64		80	13.6	19			20.47	1.10
1049	L762	T.T-25	0.06	0.93			80	13.2	8				
1051	L764	T.T-25	0.46	0.99			70	13.1	9				
1052	L766	T.T-24	3.24	1.41			90	23.9	16				
1057	L772	T.T-22	0.06	0.92	29.52		100	13.1	53			21.10	1.02
1075	L785	S.T-28	0.67	0.77	28.04	0.12	100	12.3	1380	0.07	7.0	20.04	1.01
1076	L786	S.T-28	42.99	1.00	17.04		60	6.8	257			12.18	0.92
1077	L787	S.T-28	61.23	0.79	10.78	2.00	50	4.5	235	1.18	236.0	7.70	0.97
1078	L788	S.T-28	3.59	0.82			100	11.4	760				
1079	L789	S.T-28	51.82	1.24			60	5.4	191				

Sample No.	Field No.	Location	SiO_2(%)	Al_2O_3(%)	CaO(%)	$BaSO_4$(%)	Sr (ppm)	Mg(%)	Zn (ppm)	Ba(%)	Weight ratio Ba(ppm)/Sr(ppm)	Ca(%)	Molal ratio Mg/Ca
1080	L790	S.T-28	7.32	1.05		0.24	80	11.0	778	0.14	17.5		
1082	L793	S.T-28	14.02	1.44	25.18	0.51	160	10.2	187	0.30	18.8	18.00	0.93
1084	L795	S.T-28	3.73	1.53			220	11.3	7160				
1085	L796	S.T-28	1.30	1.32	27.88	0.52	350	12.2	558	0.31	8.9	19.93	1.01
1086	L797	S.T-28	2.11	1.50		0.23	110	11.8	961	0.14	12.7		
1118	N703	TV	0.04	0.42	28.53	0.17	40	12.8	4	0.10	25.0	20.39	0.01
1134	N719	TV	0.05	0.34			40	12.8	3				
1140	N726	TV	0.16	13.58			30	12.9	7				
1155	N756	TV	0.97	1.65			80	12.8	6				
1174	N796	GG	0.07	0.65	29.25		50	12.8	9			20.90	1.01
1177	N804	T.T-16	4.31	9.27			2440	0.3	117				
1190	N833	T.T-20	1.56	2.60			110	21.4	20				
1193	N838	T.T-15	0.63	2.12			60	22.7	11				
1196	N843	T.T-15	0.22	0.85			50	12.2	275				
1197	N845	T.T-15	0.23	2.76	29.52	0.25	50	23.8	158	0.15	30.0	21.10	1.86
1198	N846	T.T-15	1.37	0.64	28.64	0.29	80	11.9	148	0.17	21.3	20.47	0.96
1256	P750	GG	0.59	0.79		0.12	70	1.9	398	0.07	10.0		
1257	P752	GG	4.47	8.01	30.07		50	11.0	125			21.49	0.84
1258	P753	GG	3.85	0.87		0.25	280	0.2	530	0.15	5.4		
1259	P754	GG	7.04	1.39	37.72		390	0.3	648			26.96	0.02
1285	P800	HG	5.41	1.19	38.49	0.23	150	1.3	1270	0.14	9.3	27.51	0.08
1319	S721	S.T-4	1.57	7.61			110	12.5	220				

Sample No.	Field No.	Location	SiO_2(%)	Al_2O_3(%)	CaO(%)	$BaSO_4$(%)	Sr (ppm)	Mg(%)	Zn (ppm)	Ba(%)	Weight ratio Ba(ppm)/Sr(ppm)	Ca (%)	Molal ratio Mg/Ca
1320	S724	S.T-4	7.98	1.76			120	11.2	440				
1322	S727	S.T-4	9.43	1.44			100	11.2	319				
1323	S728	S.T-4	42.32	1.09	16.11		70	7.2	172			11.51	1.03
1325	S730	S.T-4	16.95	2.10			260	10.0	231				
1326	S732	S.T-4	13.94	0.79		0.33	130	20.7	367	0.19	14.6		
1331	S746	S.T-6	5.12	1.30	27.49		160	10.7	153			19.65	0.90
1342	S761	S.T-9	0.34	0.38	30.18		190	11.6	2450			21.57	0.89
1357	S789	S.T-10	1.27	0.49			250	12.6	136				
1360	Z 4	HG	0.58	0.35		0.17	40	13.0	9	0.10	25.0		

Chapter 4 Geochemical Survey

4-1 Purpose and Method

The geochemical survey was carried out in regard to the rocks of the Pucara Group, at the same time of the geological survey, for the purpose to give consideration to the features of emplacement of the strata-bound lead-zinc ore deposits and to detect high potential areas where ore deposits are found. Samples were collected from the exposures coming across in the trenches or along the routes of additional geological survey. About 100 g of a sample was crushed to the grains under 80 mesh and prepared for 10 g sample to be analysed, by quartering method. They were brought back to Japan and analysed chemically as for three indication elements (Cu, Pb, Zn) and Mg, by atomic absorption method. Flow-sheet of the analysis is given in A. I-12, and the assay results are shown in A. I-13.

4-2 Analysis and Consideration of the Results

4-2-1 Analysis

Through the analysis of the geochemical survey on rocks carried out in 1977, it was ascertained that the frequency distribution is variable in the different areas according to the samples which were divided into the following three groups. ---

① The group of high values in average.

② The group of medium values in average.

③ The group of low values in average.

The group 1 was called San Roque type and the group 3 was called Tambo Maria type.

The present analysis has been performed for the total 867 samples, containing 466 samples, a part of the samples collected in the last year's survey in addition to 401 samples of the present survey. The samples were divided into group according to the areas where they had been collected. The results of treatment of the assay data are given in Table I-3. The average value of each group is as follows;

		Cu ppm	Pb ppm	Zn ppm
San Roque	Trenching	5.5	73.8	282.9
	Exposures	7.4	71.2	163.0
Tambo Maria	Trenching	3.1	34.2	16.1
	Exposures	6.0	31.4	23.0
Chaglla	Exposures	3.1	24.0	12.0
	Average	5.3	42.2	46.7

The frequency distribution is illustrated in Fig. I-7.

4-2-2 Consideration of the results

(1) Frequency distribution

Looking at the histogram, in the San Roque area, although there is a difference, which is thought to be the difference by the construction of the samples, between samples collected along the trenches and those along exposures, similar diagrams are obtained carrying two peaks. In both cases of Pb and Zn, the histogram represents dispersion of "excess of high values" type, showing the highest frequency to be at rather higher assay value than the average of the whole samples and the second-highest to be at further higher position.

On the contrary, in case of the Tambo Maria area, as well as in the Chaglla area, the peak of the frequency is at the lower value than the average of the assay of the whole samples, which is extremely different from the results obtained on the group of samples in the San Roque area.

(2) Background

As for background value (average value), though there is no difference about the background value of Cu, that of Pb and Zn varies among the three groups of samples of three different areas, that is, the value is higher of the group of samples collected in the San Roque area while lower in Tambo Maria area and in the Chaglla area.

There are many reports on the impurities contained in carbonate rocks. Among them, GRAF (1960) summarized the average to be Cu 14 ± 9 ppm, Pb 8 ± 4 ppm and,Zn 26 ± 5 ppm, and TUREKIAN (1961) reported Cu 4 ppm, Pb 9 ppm,and Zn 20 ppm (This phrase by FUJINUKI (1973)). The carbonate rocks distributed in the surveyed area show much higher values than those reported by them. It is not appropriate to compare the carbonate rocks in this area to those of the orginary development, because the high values of Pb and Zn in this surveyed area are thought to indicate special condition of the formation, under which lead and zinc would have been concentrated as much as to form ore deposits by the supply from outside open area. Be the matter what it may, there has been no report to suggest that Zn is lower than Pb as background value. Accordingly, in the cases of the Tambo Maria area and the Chaglla area, the results are thought to be suggesting, not that there would have been an environment in which less amount of Zn deposited than Pb, but that there would have been some movements after deposition. In the surveyed area, the sample group collected in the eastern part of the Pusagno area, carrying Cu 7 ppm, Pb 39 ppm,and Zn 66 ppm, was distinguished from others, as the group which contains many samples of the average values, at the stage of the consideration of the results in 1977. It is considered that they show average background values of Cu, Pb,and Zn contained in the carbonate rocks found in the central part, as there has been little change even by the results of the following survey.

(3) Types of the sample groups

Regarding the values of Cu 7 ppm, Pb 39 ppm,and Zn 66 ppm to be the background values, it is estimated that, about the sample group of the San Roque area, showing rather high background values as for Pb and Zn, the peaks of the high values of Pb and Zn are suggestive of the idea that they would have been formed by the movement to increase the contents of Pb and Zn. On the other hand, the sample group of the Tambo Maria area shows the phenomena that the average value of Pb coincides roughly to the background value while the average of Zn is lower as much as about 40 ppm (20 ppm against 66 ppm), and that Zn value is lower than Pb value. The same case is recognized as for the sample group of the Chaglla area. As it is not the fact that there is no higher value of Zn than that of Pb in these areas, it is thought that they would have experienced some movement to decrease Zn content in the rocks. Therefore, it is necessary to consider over high values as for the samples of the San Roque area and over low values as for those of the Tambo Maria area and the Chaglla area. Here the former is to be called San Roque type, while the latter is to be called Tambo Maria type, as was the case in the last year's survey.

(4) Threshold values

	Cu ppm	Pb ppm	Zn ppm	
San Roque type	17	171	489	($M + 1.5\sigma$)
Tambo Maria type	-	-	9.8	($M - 1.0\sigma$)

On the Tambo Maria type, consideration will be given only to Zn.

(5) Consideration on the anomalies

PL. I-7 (1), (2) and (3) show the anomalies extracted by the threshold values mentioned above.

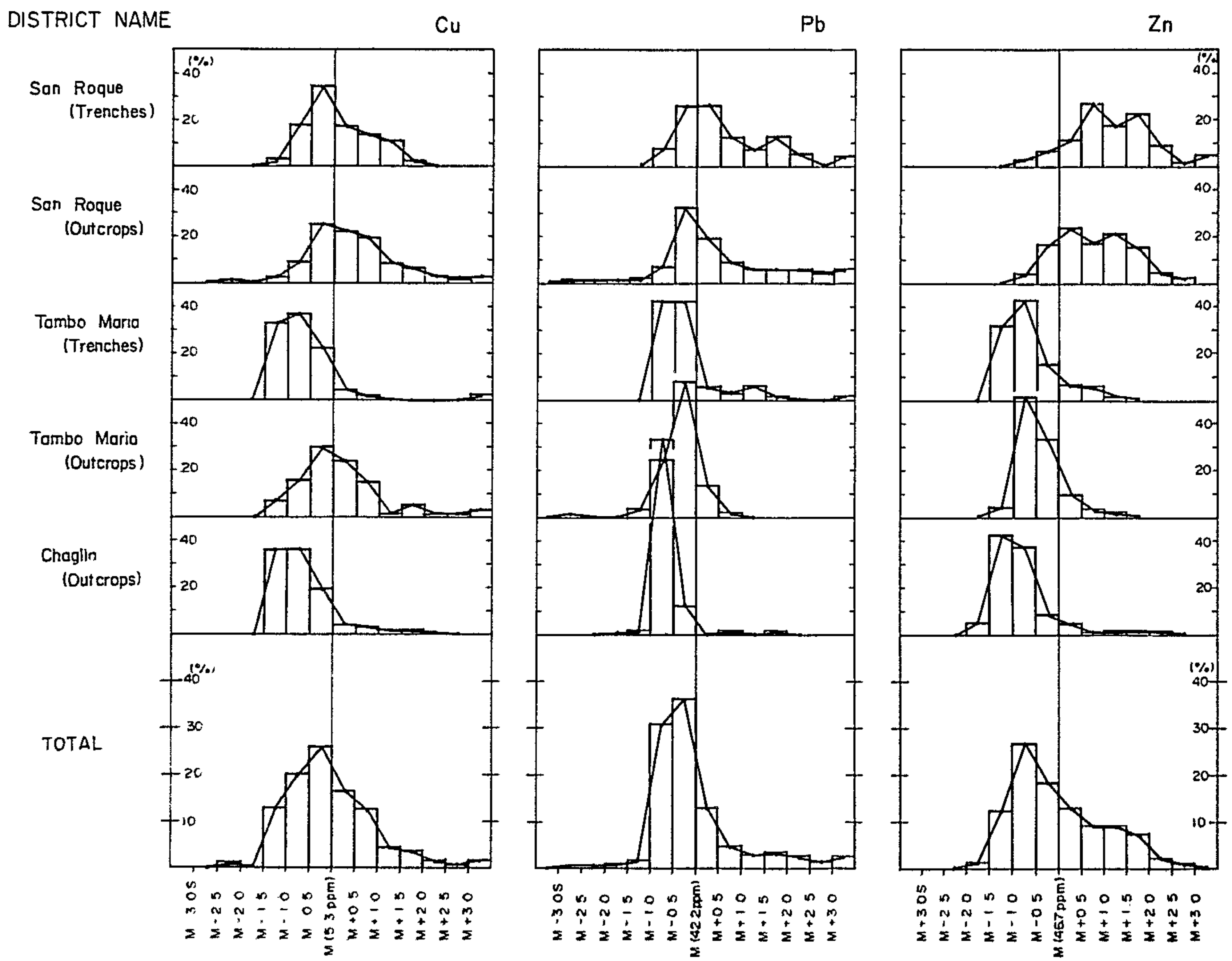
The followings are to be pointed out on the anomalies of the San Roque type. The distribution of most of the Pb, Zn anomalies is corresponded to the trends of the carbonate rocks. Sometimes they are duplicated, and sometimes they are neighboured. Pb, Zn anomalies are rarely recognized in the area occupied by the igneous rocks distributed in the west. In the northern part of the San Roque area, remarkable mineral indication of Pb and Zn has been found, but the surrounding anomalies, detected in the dolostone, are local and small-scaled. In the south of the mineral indication, anomalies are large-scaled along the area occupied mainly by the B and the D submembers, but only slight amount of Pb and Zn has been caught megascopically. Dolomitization is poor in this area. By the consideration of the results of the geochemical surveys carried out in 1976 and in 1977, it was concluded that the Pb, Zn anomalies in the San Roque area would show the result of rearrangement of the metal components by the intrusion of the igneous rocks, viewed from the distributional relation. Considering the presence of the igneous activity related to the horst structure, the above might be allowed, but it is true that the scale and the degree of the anomalies are dependent far more upon the mother rock, whether it is dolostone or limestone, rather than the igneous rocks. The dolostone is thought to be the product of transition and replacement of limestone after its sedimentation, as described in the chapter 3. It is suggested from this fact that ore minerals of Pb and Zn, originally deposited in limestone, would have been mobilized by dolomitization.

As for the anomalies of Tambo Maria type, they are distributed along dolostones both in the Tambo Maria area and in the Chaglla area, and mineral indication of Tambo Maria (Zn) has been found in the anomalies. Therefore, it is thought that Zn would have been mobilized and concentrated in the period of the formation of zebra-structure in dolostone, as was the conclusion of the results in 1977.

By the above-mentioned evidences, it can be said that geochemical survey for rocks is quite effective and appropriate for the exploration of strata-bound lead-zinc ore deposits. However, it is notable that attention should be given to lower values, not only to higher values than the average, on the interpretation of the results. The scales of anomalies are variable according to lithofacies and types of the emplacement of lead and zinc ores exposing on the surface, in the San Roque area where high values of anomalies are detected. It might be necessary to distinguish anomalies by the types of mineralization such as disseminated type anomaly, fracture filling type anomaly etc., to say things more in detail.

In each case of San Roque type anomaly or Tambo Maria type anomaly, dolomitization should not be ignored but be taken significant as the factor of rearrangement of the elements contained in the country rocks. In another words, concentration of ore minerals would not be expected, in the condition that the country rock is limestone with weak dolomitization, even if high values are detected geochemically. On the contrary, in case of geochemical low, if the value is far lower than the values of the samples collected in the surrounding area or along the same horizon, concentration of ore minerals would be well expected.

It is concluded therefore that the geochemical survey for rock samples is quite effective for the exploration of strata-bound lead-zinc ore deposits giving attention to the above-mentioned factors.



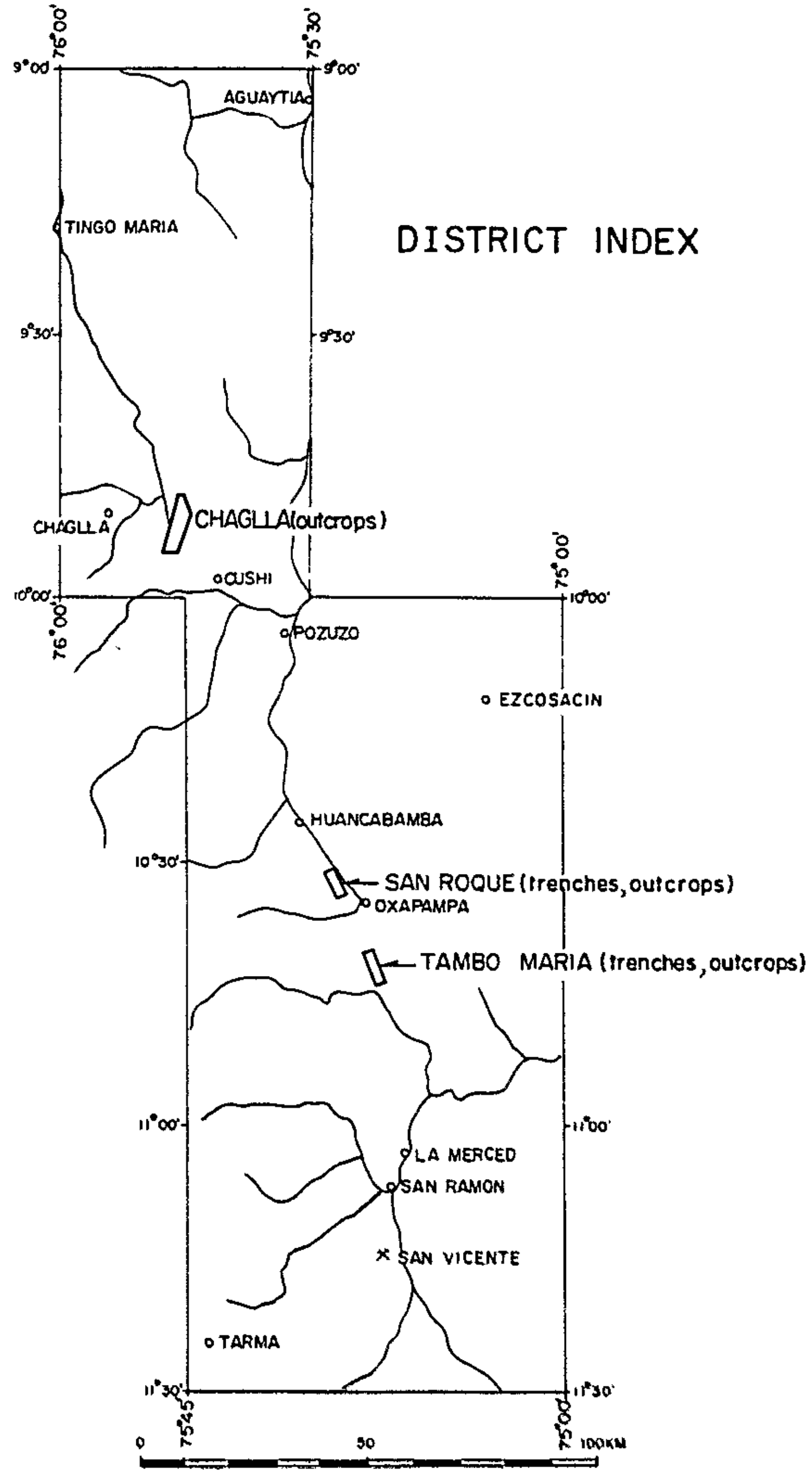


Fig. I-8. Histograms for Cu, Pb and Zn on rocks classified by each district in the surveyed area

Table I-3 Results of statistical analysis of geochemical samples.

(1) Detailed survey area, Trench and Outcrops (867 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	657	7,300	17,900
Minimum	1	3	3
Average (M)	5.3 (0.721)	42.2 (1.625)	46.7 (1.669)
Standard Deviation (σ)	- (0.3391)	- (0.4047)	- (0.6798)

(2) San Roque area, Trench (81 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	24	2,320	17,900
Minimum	2	18	13
Average (M)	5.5 (0.739)	73.8 (1.868)	282.9 (2.452)
Standard Deviation (σ)	- (0.2398)	- (0.4170)	- (0.5779)

(3) San Roque area, Outcrop (282 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	657	7,300	4,220
Minimum	1	3	14
Average (M)	7.4	71.2	163.0
Standard Deviation (σ)	- (0.3648)	- (0.5244)	- (0.5366)

(4) Tambo Maria area, Trench (67 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	62	1,500	275
Minimum	2	17	6
Average (M)	3.1 (0.491)	34.2 (1.534)	16.1 (1.207)
Standard Deviation (σ)	- (0.2198)	- (0.3067)	- (0.3783)

(5) Tambo Maria area, Outcrops (257 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	ppm (Zn-log)
Maximum	103	83	258
Minimum	2	3	6
Average (M)	6.0 (0.776)	31.4 (1.497)	23.0 (1.362)
Standard Deviation (σ)	- (0.2198)	- (0.3067)	- (0.3783)

(6) Chaglla area, Outcrops (180 samples)

	Cu	Pb	Zn
	ppm (Cu-log)	ppm (Pb-log)	Zn (Zn-log)
Maximum	32	222	1,270
Minimum	2	10	3
Average (M)	3.1 (0.490)	24.0 (1.381)	12.0 (1.079)
Standard Deviation (σ)	- (0.2100)	- (0.1310)	- (0.3931)

Chapter 5 On the Strata-Bound Ore Deposits

Strata-bound lead-zinc ore deposits associated with carbonate rocks are a common subject studied in the recent years. The ore deposits of this type are characterized by the fact that the distribution of sulphide ore minerals is confined to certain horizons of the country rocks. They assume stratiform, massive,and brecciated forms. Various ideas on the genesis of this type of ore deposits appeared in the past, and it is generally accepted that they would have been formed penecontemporaneously with the sedimentation of the country rocks at low temperature. (STANTON,1972 and others)

The mineral indication discovered newly in the surveyed area by the trenching in the present year is also thought to be the mineralization possibly of this type, after various research and discussion. Furthermore, the mineral indications at Tambo Maria and at San Roque found up to 1977's surveys, and the San Vicente ore deposits now in operation are all thought to be belonging to the strata-bound ore deposits.

5-1 Types and their Occurrences

The mineral indications found in the surveyed area are classified into the following three types, depending upon their characteristics concerning forms.

1. Banded type ore deposits
2. Fracture filling type ore deposits
3. Disseminated type ore deposits

To make sure, it will be added that the standard of this classification is strictly as for forms in the process of geological survey, and that they are all belonging to the strata-bound ore deposits, genetically.

5-1-1 Banded type ore deposits

This type of mineralization is represented by San Vicente deposits now in operation. The mineral indication at Tambo Maria found through the survey carried out in 1976 also belongs to this type.

The San Vicente ore deposits are located about 20 km south of San Ramon, and the deposits are composed mainly of banded sphalerite associated with dolostone carrying zebra-structure belonging to the III member of the Pucara Group. Mainly this sort of sphalerite has been worked at San Vicente mine. As the description of the San Vicente ore deposits was given in Vol. I, in Vol. VI and others, details are omitted here. In short, the most distinct characteristic is that the horizon of ore-emplacement is dolostone with many intercalated layers of muddy rocks.

The thickness of the dolostone bed found around the indication at Tambo Maria reaches as much as 450 m, which shows the largest scale in the Oxapampa area. It has been confirmed that the dolostone with zebra-structure bearing zinc ore minerals is not so thick as estimated in the survey carried out in 1977, and that the lateral extension of the dolomite is poor. There has been no further discovery of sphalerite associated with zebra-structure, even by the trenching and by the diamond drilling carried out in the present year. No spharelite has been found in the trenches T-24 and T-25, nearest to the exposure of the mineral indication, although dolostone with zebra-structure were founded. The assay results of them show also low value of Zn content (Zn 9-19 ppm). By these results, it has been ascertained that the lateral extension of mineral indication at Tambo Maria is poor. The characteristics of the ore deposits of this type are as follows;

(1) The ore deposits are associated with dolostone belonging to the III member of the Pucara Group. Especially, in the dolostone carrying zebra-structure ,the ores are concentrated.

(2) The zebra-structure occurs in lenticular form almost parallel to the bedding planes usually, but in places angled relation has been observed.

(3) The dolostone carrying zebra-structure comprises rhythmical band pattern of very coarse grained crystals of "white dolomite" (0.5 - 2 mm) and minor grained "dark grey dolomite" containing much of impure materials. Concentration of sphalerite is observed along the boundary planes between aforesaid white and dark grey dolomites.

(4) Concentration of sphalerite is further remarkable where zebra-structure is brecciated.

(5) Zn grade is 10-20 % whereas the grade of Pb is approximately 1 %.

5-1-2 Fracture filling type ore deposits

The only example belonging to this type is the newly discovered ore deposit in the San Roque area, by the trenching survey carried out as a part of the present year's survey. None has been found of this type ore deposit in other areas. This ore deposit is emplaced in the dolostone of the V member of the Pucara Group. Sphalerite is concentrated, in association with minor amount of galena, along the boundary planes between grey to bluish black fine grained crystalline dolomite and muddy dolomite (microscopically dolomicrite or micritic dololutite) and also concentrated in veinlets mostly in crystalline dolomite as if sphalerite had filled the fractures. The width of these veinlets reaches several mm to 3 cm and networks are observed in parts. They do not contain much of gangue minerals as dolomite, calcite, quartz,and others. Parts of sphalerite have been replaced by secondary minerals as hemimorphite or smithsonite.

The assay result of the sample collected by channel sampling 5 m long is Pb 0.87 % and Zn 2.35%. The analysis of the sample collected from the higher portion (20 cm) shows Pb 0.15 % and Zn 20.72 %. (L783)

Their forms in three dimensions are not certain. The parts where veinlets and networks are concentrated tend to lie along the bedding plane as a whole, although individually they oblique with the strikes of the country rocks.

The country rocks surrounding the mineral indication, the muddy dolostone and fine grained crystalline dolostone are not altered at all, and show the development of rather complexed geological structure, such as fractures and small-scale folding structure.

Sphalerite is also concentrated to a certain degree in the dolostone with chalcedonic quartz and colloform quartz, but the concentration becomes weaker in accordance with the increase of quartz component.

The characteristics of this fracture filling type ore deposits are summarized as follows;

(1) The ore minerals are observed to occur near and along the boundary planes between muddy dolostone and fine grained crystalline dolomite, belonging to the V member of the Pucara Group.

(2) Sphalerite accompanied by minor amount of galena is concentrated in veinlets and networks across the bedding planes.

(3) Lower grade of concentration of sphalerite is observed in the impure dolostone containing micro-grains of chalcedonic quartz.

(4) There is no dolostone which has been altered.

(5) Zn grade is about 3-4 %.

5-1-3 Disseminated type ore deposits

The mineralizations belonging to this disseminated type ore deposits are the lead indication at the old working in the San Roque area, the mineral indication caught in the core of the drill hole No. 53-1,and the mineralization found in the Chaglla area. They are emplaced in the muddy or fine grained crystalline carbonate rocks of the IV member or the V member of the Pucara Group. In each mineral indication, small amount of fine grained (several microns to several mm) galena and sphalerite are contained in muddy limestone, fine grained crystalline limestone, muddy dolostone,and fine grained crystalline dolostone. There are some indications of ore minerals which have been caught microscopically. The beds of the ore horizon contain many very well-preserved shallow-water fossils as Brachiopods, Echinoids etc. and often sphalerite and galena are seen surrounding such fossils (52113). Also, the ores associated with bituminous and silty carbonate rocks have been found. The grade of this type ore deposits is generally low. The highest assay result so far analysed is seen on the core of the drill hole No. 52-1, that is, the core of the depth between 129.35 m and 130.35 m shows Pb 0.088 % and Zn 4.9 % (52116),and the assay of the total core length of 7.7 m including the above shows Pb 0.235 % and Zn 1.1 %. The other indications show only values of several hundred ppm, rarely reaching as much as Zn 1 % or so. Characteristically, the country rocks are limestone, less dolomitized, or non dolomitized.

5-2 Characteristics of ores

Features of ores are described here mainly about the ores of the mineral indication discovered in the San Roque area through the present year's survey.

(1) Sphalerite and its secondary minerals

The ore minerals in the mineral indication found in the San Roque area are recognized to occur in the veinlet form or in fracture filling form. The ores in the Tambo Maria area and in the San Vicente area are seen in the banded form. While,those in the Chaglla area are recognized only under microscope. Amber to light brown in color, the sphalerite of the type is thought to be poor in iron content.

The sphalerite in veinlets or in fracture filling type composes aggregates of yellowish dark grey grains of the sizes of 400 microns to several mm, under microscope. Replacement of the sphalerite by smithsonite has been observed in the marginal part and along the cleavages (L783, L784). Fluid inclusion and exsolution of sulphides are not recognized. Internal reflection can be observed both in sphalerite and in smithsonite. The sphalerites outcropped in the San Vicente area and in the Tambo Maria area, have similar texture as mentioned above, and among them, fair amount of sphalerite found in the Tambo Maria area has been replaced by smithsonite or hemimorphite.

Sphalerite of the disseminated type ore deposits is anhedral and fine grained (several microns to several ten microns). No aggregate has been recognized, but sphalerites are filling the space among the dolomite or calcite grains or druse contained. Especially, in case of the mineral indication found in the Chaglla area, there is no megascopic zinc ore mineral, and the highest value of the assay results is merely as much as Zn 0.11 % (A752) and Zn 0.127 % (P800). The sphalerite in this case is micro-grained (several microns to 50 microns) and is filling the space amongst the calcite grains, in anhedral form. Similar occurrence has been recognized in the core at the depth of about 180 m. of the drill hole No. 52-3 in the San Roque area (52312, Refer to Vol.VI). On the contrary, rather coarse grained is the size of the sphalerite in the indication found in the core at the depth of about 130 m of the drill hole No.52-1 in the north of San Roque. There, sphalerite grains of the sizes of several hundred microns to several mm, occur surrounding fragments of brachiopods and algal debris (52113, 52116).

Sphalerite in the lead-zinc ore (S783) found at the trench T-10 in the San Roque area has all been replaced by hemimorphite, but almost no oxidation has been recognized in the other samples.

(2) Galena and its secondary minerals

Remarkable indications containing galena are occasionaly recognized in the San Roque area and in the Chaglla area. Such indications in the San Roque area are found around the old working surveyed in 1977, at the outcrop along the San Roque valley (near the drill hole No. 52-4), at the trench T-2, in the core of the drill holes No. 52-3,and No. 53-3, etc. At the trench T-2, very high grade massive galena (30 x 50 cm) has been found in muddy dolostone, though it is a float (L731). Although this sample consists of only galena megascopically, small amount of cerussite has been also recognized, by X-ray diffraction and under microscope.

Other galena found in the San Roque area is all scatteringly disseminated as euhedral single crystal 0.5 to 5 mm in size and as aggregates of several grains in muddy limestone, fine grained crystalline limestone, and muddy dolostone. Under microscope, most of them is galena, with very small amount of cerussite partly replacing the margin of galena (L783).

In the Chaglla area, the indications containing galena are recognized at two localities —— at Huarao Grande and at Huarao Chico. There, euhedral crystals of galena and their aggregates are observed in the forms of irregular beanstalk or amoeba. Many of them are massive aggregates of approximately 2 x 15 cm, but their sizes often reach as much as 10 x 50 cm (A752). These galena are partly replaced by cerussite. It is noted that fluorite and calcite are associated around galena crystals. In any case, galena mineralizations are all small-scaled and poor in extension. Some galena is accompanied by sphalerite ores of fracture filling type ore deposit (L783, L784, L820). This type of galena is observed around the trench T-28. In this galena, it is not the case that micro-grains of galena are scattered in the matrix of country rocks, but galena, of the grain size possible to be distinguished megascopically, are recognized to occur associated with sphalerite. Under microscope, they are euhedral to subhedral and either single crystals or aggregates of the size over 0.5 mm, and they are included in the sphalerite or found in the form of veinlets in dolomite. Galena is replaced by cerussite around the margin.

Silver is generally not much contained. At the galena indication of the disseminated type,in the Chaglla area, the silver is contained 74 g/t (A752, Pb 25.80 %). The silver content in the galena of fracture filling type,in the San Roque area, is shown 4-24 g/t.

(3) Pyrite and its decomposed products

Pyrite and its decomposed products are generally found around mineral indications in the forms of micro-spherical or cubic euhedral grains under microscope. Micro-spherical pyrites, that is, pyrites with framboidal texture (under 10 microns in size) were found in the sample 52108 of the core of diamond drilling carried out in 1977. In the present survey, they are recognized remarkably to occur around the ore minerals and also in the country rocks (L709, L761, L796 etc.). Also, textures of the aggregates of framboidal pyrite are remaining in widely distributed cubic pyrite (30-50 microns), which shows the process of the growth. In another words, there is pyrite in the process forming cubic euhedral crystals or big crystals of the size as much as 500 microns (L783, L795, 52109 etc.). These pyrite are replaced partly by goethite or lepidocrocite (FeO(OH)) and these cubes are commonly pseudomorphs. In the detailed observation, both microspherical and cubic pyrite wherever found, are composed of further ultra-microspherical grains of 1 to 5 microns (52108 etc.).

Most of the pyrite found in the Chaglla area is fine grained and less in amount, and it is replaced by goethite in most part. Pyrite's growth to cube is recognized at the only sample P800, and there, the pyrite is grown as much as about 70 microns in size. Also, it is confirmed by XMA that very small amount of Zn content is associated with pyrites (A. I-10).

Euhedral pyrite (0.1 - 0.2 mm) is observed to be concentrated extraordinarily in bituminous muddy rocks in and around the sample 53213 collected from the drill core No. 53-MJ2 located at Tambo Maria. The assay result of this sample is shown Zn 19,080 ppm, which is abnormally high, after that of the exposure of the mineral indication, in the Tambo Maria area. However, only small amount of sphalerite is recognized in this sample by naked eye. The pyrite distributed in the San Vicente area is recognized as a inclusion of micro-grain in sphalerite, and differs from those found in the Tambo Maria area and in the San Roque area.

5-3 Country Rock and Mineralization

As afore-mentioned, it is clarified that the ore minerals are controlled stratigraphically, and that lead and zinc ores are concentrated in such part where dolostone is seen to have recrystallized particularly in muddy carbonate rocks. It is considered, through these facts, that a degree and a scale on mineralization would be controled strongly by these country rocks, as is suggested the close correlation between country rock and concentration of ore minerals. The main mineralizations distributed in the central part are associated with the dolostone carrying zebra-structure of the III member in the Pucara Group, and with muddy dolostone and fine grained crystalline dolostone of the V member. Quite small numbers of mineralization are associated with other rocks as muddy limestone, fine grained crystalline limestone, as seen in case of Pb indications in this area.

(1) Relation between grain size of the country rocks, and the ore minerals.

The dolostone distributed in the present year's surveyed area is composed mainly of primary dolomicrite and crystalline dolomite (including dolostone carrying zebra-structure and brecciated dolostone). The dolostone found around the mineral indications in the San Roque area comprises alternation of dolomicrite or muddy dolostone and fine grained crystalline dolostone, in which grains of crystal have grown to a certain size in places through diagenesis. The sphalerite found in the matrix of dolomicrite is usually fine grained, but the sphalerite associated with rather coarse grained mineral dolomite is somewhat coarser. The sphalerite seems to have filled the space amidst the crystal grains of the crystalline dolostone. Therefore, it is thought that the growth of sphalerite crystals would have occurred in later stage than the crystallization of the dolomite (S783, L760 etc.). In addition, it is thought that the fracture-filling-type sphalerite would have been developed by linking themselves continuously connected. It is only along the parts where large crystals of the dolostone are found that the concentration of sphalerite is observed. Along the mineral indication at Tambo Maria, banded sphalerite is found in large crystals (1-3 mm in diameter) of the dolostone carrying zebra-structure of coarse grained dolomite.

In the dolomicrite found in the San Roque area, there are aggregates (1-5 cm) of quartz 0.5 to 1 mm in diameter composed of chalcedony forming colloform texture. The sphalerite grains surrounding these aggregates of large quartz crystals are rather coarser grained (100 to 500 microns) than those in the dolomicrite at a distance from those quartz aggregates, they are fine grained and less in amount (L721, S725). Also, in this area, some lenticular sandstone rich in cherty quartz are found in muddy dolostone.

None of lead-zinc indications has been found in these sandstones. According to the above-mentioned evidences, it has been ascertained obviously that the concentration or the growth of sphalerite crystals would have been associated with the crystallization of the country rocks.

(2) Relation of zinc to the components of the country rocks.

To mention about the sedimentary environment of the dolostones in the survey area, it is estimated that it would have been reef-environment of rather closed shallow-water basin, considering from the distribution of Sr and Ba, as stated in the section 3-2.

① Relation between Sr and Zn

Fig. I-9 is the diagram in which correlation of Sr values and Zn values is illustrated. The samples collected in the San Roque area show positive correlation between them. This is obviously seen on the samples taken along the trench T-28. The same fact can be recognized on the samples collected along the mineral indications in the Chaglla area. However, this relation can be seen rather indistinctly and the both values are rather low on the samples collected in the Tambo Maria area and on the samples taken in the non-mineralized part in the Chaglla area. In another words, it can be said that positive correlation is recognized between Sr values and Zn ones of the rocks (especially carbonate rocks) in mineralized areas, which suggests that the concentration behaviors of these elements would have been same in the process of diagenesis. It is possible to estimate that high Zn values are not likely to be expected Sr values where Sr values are under 100 ppm. But, it is thought to be because the recrystallization (growth of the crystal grains) would have been more advanced than in the San Roque area that the Sr values are low in the non-mineralized parts in the Tambo Maria area and Chaglla area, as mentioned in the Chapter 3. In addition, it is possible, as aforesaid, to estimate the sedimentary environment of the country rocks from the Sr values, which suggests that the features of primary concentration of Zn (background) could be inferred. The scale of remobilization of Zn element in the limited area close to the mineralized parts (500 to 600 m) could be estimated from the Sr values.

② Relation between Mg/Ca mol-ratio and Zn values (SHOJI, 1971)

Analysis of calcium (Ca) has been conducted on parts of the samples (calcareous dolostone, muddy dolostone, and dolostone), accompanying the calculation of Mg/Ca ratio (Table I-2). Comparing this ratio to Zn values, no correlation has been found. That is, there would be no relation between concentration factor of Zn and the Mg/Ca ratio, but the concentration of Zn element is thought to have been much more dominated by the sedimentary environment of the carbonate rocks. Also, it would not be likely that the limestones were dolomitized by some hydrothermal solution in later stage, viewing from the observation of the stained thin sections of dolostone samples. There are some dolostone which are composed of micritic dolomite, in the mineralized parts of the San Roque area. From the above evidences, it can be said that these kind ore deposits are quite different from the lead-zinc deposits associated with hydrothermally altered dolostone, in which Zn values are correlated to the Mg/Ca ratio.

③ Coexistence of fluorite

As the mineral assemblage, it has been confirmed, by X-ray diffraction etc., that fluorite is associated with galena as one of the gangue minerals, in the Chaglla area and in the San Roque area (N746, A752, L731). Fluorite is a common mineral which is generally associated with lead and zinc minerals of a strata-bound lead-zinc ore deposits, excepting its amount and its scale of distribution. (SCHNEIDER(1964), STANTON(1972)). Even looking from this evidence of the coexistence of fluorite, it is thought that the lead-zinc ore deposits in the surveyed area is quite likely to be strata-bound ore deposits.

(3) Summary

Characteristics of the carbonate rocks and the correlation of them to Zn have been clarified by the relation of the grain size of the dolomite to the ore minerals and by the composition of the country rocks. The impurity Sr is positively correlated to Zn, and suggests the same behavior as Zn in the process of the concentration of Zn at the mineralized areas. Also Sr contents are quite useful to estimate the sedimentary environment of the country rocks, namely the carbonate rocks. Therefore, Sr is one of the most effective index element for the consideration on this type of ore deposits.

5-4 On the Mechanism of Formation of the Ore Deposits

It can be said undoubtedly that the lead-zinc ore deposits associated with the Pucara Group in the central part are strata-bound deposits, from the following evidences, as aforementioned, —— that there is no alteration in the dolostones as the country rocks, that lead-zinc sulphides have filled the space amidst the grains of mineral dolomite, that framboidal pyrite is present, that gangue minerals such as quartz and calcite are rarely found, that there is no relation between Mg/Ca ratio and Zn content values, and that fluorite is associated with ore minerals.

The carbonate rocks, which comprise country rocks of the ore deposits, would have been accumulated in reef-environment, and it is thought that dolomite would have been formed through compaction and crystallization after replacement of low-Mg calcite or aragonite deposited directly from hypersaline brine in back reef basin by circulating Mg-bearing hypersaline brine. Consideration is given here on the mechanism how lead and zinc are gathered and concentrated with the abovesaid phenomena, from the data obtained and the literature concerned.

5-4-1 On lead and zinc as primary precipitates

Detailed studies have been conducted on the mechanism of concentration of heavy metal ions in strata-bound ore deposits, by SCHNEIDER (1964), LAFFITE (1967), STANTON (1972), ANDERSON (1973, 1975), RENFRO (1974), SKALL (1975), BEALES (1975), HOAGLAND (1976), and others.

Heavy metal elements are brought about with terrestrial material, remote (submarine) volcanic tephra, and hydrothermal solution along faults (even if they are located somewhere far away). It is thought that these metal ions would be dissolved into underground water, solution along faults, or hypersaline brine circulating in the surrounding rocks, and that they would have been precipitated with the carbonate rocks by the reaction with marine water. It has been said that the circumstance required for such precipitation of heavy metal ions at the time of sedimentation of carbonate rocks would be rather closed environment of warm sea basin. (NICOLINI, 1964) In the Pucara Group found in the surveyed area, almost no deriviation of volcanic activities has been recognized, and it would not be appropriate to allow existence of hydrothermal solutions along faults. Therefore, heavy metal elements would have been precipitated as metal ions after brought into with terrestrial material from the older rocks (Mitu Group etc.) now exposing mainly in the western area.

Considering about iron, lead and zinc elements, it is thought that they would have been precipitated as sulphides associated with low-Mg calcite and aragonite in weakly acidic to neutral condition with existence of CO_2 gas, after brought into marine water as salt or complex salt with SO_4 ion and Cl ion contained in solution. As for iron, the things would have been as this; SO_4 ions were resolved by sulphuric bacteria to release S ions in the static water environment where organic and sapropelic materials were accumulated, and FeS_2 were fixed on the cell wall, followed by their gathering and growth to form framboidal pyrite. The fact that there have been found micro-spherical pyrites with framboidal texture of under 10 microns in diameter in this year's samples, as well as in the core sample 52108 (Vol. VI) of the hole No. 52-1 collected in 1977 in the San Roque area, suggests the contemporaneous sedimentation of the pyrite with the country rocks after direct precipitation from the solution of sea water, and also indicates some closed environment of back reef basin.

As for zinc, it is thought that the precipitation would have been occurred by the process of following reaction, after brought into sea water as Zn ions. (STANTON, 1972; BARTON, 1967)

$CH_4 + ZnCl_2 + SO_4{}^{2-} + Mg^{2+} + 3CaCO_3 = ZnS + CaMg(CO_3)_2 + 2CA^{2+} + 2Cl^- + H_2O + 2HCO_3^-$. CH_4 in this reaction is methane gas originated from sapropelic organs, and the resolution from SO_4 ion to S would be further accelerated by sulphuric bacteria. As organic matter besides bacteria, floating algae (Dasycladacea etc.) and excrements (Faecal pellets etc.) have been taken to be. (SCHNEIDER, 1964; HAMADA, 1977, etc.) It has been thought that the environment in which methane gas and sulphuric bacteria would occur and primary sulphides would be deposited may be some sorts of depression (through, pocket etc.) where bituminous to calcareous siltstone would be accumulated (SCHNEIDER, 1964). In the San Roque area, fragments of algae and pellets which are thought to be excrements have been found in the cores of the drill hole No. 52-3 (52113, 53305, 53308 etc.). The sediments in this area show, as afore-mentioned, the closed environment of back reef basin, containing organic matters, corresponding roughly to that which SCHNEIDER (1964) stated.

Accordingly, it is thought that the deposition of zinc would have been

through reduction by methane gas or sulphuric bacteria. It has been confirmed by XMA that, though very small in amount, some zinc minerals are included in framboidal pyrites and their aggregates (P754, P800). This evidence suggests the contemporaneous deposition of zinc with framboidal pyrites.
Also, it is thought that the behavior of lead would be similar to that of zinc, and that the deposition of lead would have been contemporaneous with that of zinc or later.

Meanwhile, Zn and Pb ions dissolved in circulating hypersaline brine would have been carried in pretty great distance and to be mobilized in underground after the consolidation of carbonate rocks in some cases (SKALL, 1975; AMSTUTZ et al., 1964). In another words, it is thought that the hypersaline brine containing Zn ions would have circulated in the space amidst the crystals of dolomite and calcite and that some of these ions would have been deposited as sphalerite and galena, filling such space, by the reaction with organic impurities and HS ions released at the dolomitization. Some samples of the muddy or fine grained limestones show high content values (7×10^3 order) in Zn or Pb content, though nothing can be recognized megascopically. In such samples, very fine grained sulphides (10 to 30 microns) are recognized to be scattered in the matrix under microscope. They are thought to be the result of the precipitation of lead and zinc at the time of the primary sedimentation as well as the deposition from the hypersaline brine (P800, 52312, 52108).

5-4-2 Concentration in the process of diagenesis

Following the above-mentioned, the consideration is given on the process of the concentration of lead and zinc etc. through the geohistory up to this time, after their primary deposition. There is no actual theory or accepted elucidation to estimate clearly the mechanism of the concentration from primarily deposited lead and zinc to the economically valuable grades in the process of dehydration, compaction,and crystallization of the country rocks. However, carbonate rocks themselves have been studies remarkably in the field of petrological geology, and there are many reports on genesis, occurrence, and classification of carbonate rocks by CHILINGAR , BISSELL , FAIRBRIDGE (1967). Also, the process of diagenesis concerning carbonate rocks has been studied prominently for these years, but there are few studies in which such contents are related to the formation of lead-zinc ore deposits. AMSTUTZ (1964), BROWN (1967), STANTON (1972), BERNARD (1977) etc. have given exclusively the reports on the description and the genesis of the syn-depositional lead-zinc ore deposits associated with carbonate rocks. However, in each report, primary sedimentary environment is thought to be important, and the ore genesis is considered to be a circulating hypersaline brine through sea water and carbonate rocks. There are also brief comments that ores would be concentrated by crystallization after the crushing and the brecciation by underground water in the process of diagenesis.

The gathering and the growing of sphalerite etc. by inter-solid-phases reaction and the system of transportation → deposition → concentration of zinc contained in solution, would be pointed out as the factors of the concentration of ore minerals. That is to day, the conditions to form economically valuable ore deposits are two —— primary deposition and concentration, and secondary concentration in the process of diagenesis. By the secondary concentration in the process of diagenesis, the values of the lead and zinc content on the rocks distributed around the mineral indication or the center of concentration, would be lower than the background values at the time of the primary deposition. In the surveyed area, this phenomenon can be seen in the San Roque area and in the Tambo Maria area.

LAUNEY, ROUTHIER (1964) illustrated the tendency that Zn content values in the rocks around mineral indications are rather low. The mineral indication of fracture filling type which was found near the trench T-28 in the San Roque area, would be the result of the concentration of zinc through inter-solid-phase reaction. In this area, lead and zinc were precipitated at the order of n x 10^2 to n x 10^3 ppm in the shallow water basin of the back reef environment, at the primary deposition. The disseminated type ore deposits have remained as they were. A porosity by dolomitization would be increased when aragonite and Mg-bearing calcite were transitioned. (CHILINGAR, 1967; FAIRBRIDGE, 1967). Already-deposited sphalerite etc., which are thought to be impurites for the dolomitization, were extracted, transported, and concentrated in the processes of the gathering and the growing of crystals in the solid phase. The most favorable condition to form the space is thought to be on the plane where crystal growth starts. Therefore, the space produced along the boundary plane between impure dolomicrite and crystalline dolostone, and amidst the crystalline dolostone, would have supplied the favorable place for sphalerite and galena to be concentrated most abundantly. The sphalerite associated with zebra-structure would be produced through the continuation of the above process. In another words, it is thought that the sphalerite would have been transported and gathered in such space as to form zebra-structure continuously by brines exhausted in the compaction, and that the formation of banded ores and the crystal growth would have occurred by inter-solid-phase reaction. Individual orebodies in the San Vicente ore deposits are lenticular and almost conformable with zebra-structure. In the central part of each orebody, the thickness is greatest and the concentration is so prominent as sphalerites form aggregates. (Refer to the real-size photograph of the San Vicente ore,and to photomicrographs). But, in the marginal part, thickness and ore grade are decreased. These evidences indicate that sphalerite were transported and gathered along the zebra-structure contemporaneously as the zebra-structures were formed in the early stage of diagenesis, and that the sphalerite crystals were developed to coarser grains by inter-solid-phase reaction. In the sphalerite thus developed to be coarse grains, fine pyrite is recognized to be scattered as dots. Pyrite looks as if it were exsolution lamelae. But, through the observation of the San Vicente ore shown in A. I-5, it is presumed that the pyrite was locked in the gathering of sphalerite.

From above-mentioned, it is concluded that the strata-bound lead-zinc ore deposits found in the central part are genetically uniform whichever they may be, but that different types have been formed through the various processes in which scale and grade of ore deposits were specialized by the multifarious conditions of primary deposition and secondary concentration through diagenesis.

There are another types of concentration of ore minerals caused by the re-dissolution and re-concentration of Zn by solution, apart from such mobilization, gathering and inter-solid-phase reaction, in this central part. It is occured by the circulating underground water after the consolidation of carbonate rocks, and the concentration of zinc is accompanied by the mechanism of dissolution of carbonate rocks → formation of karst → collapse → recrystallization → filling. This type of concentration with collapse breccias tends to form large scaled ore deposits. For instance, Mississippi Valley type, Tri-state type and Apparachian type ore deposits are known as this type. (NOBLE, 1963; CALLAHAN, 1967; HOAGLAND, 1971, 1976; STANTON , 1972; HAGNI , 1976). This kind ore deposit concentrated with karst aquifer system, have not been found in the present survey, but the brecciated dolomite found in the drilling core of No.53-MJ1 in the Tambo Maria may be corresponded to this type, though the scale is very small. However no indication of mineralization has been found around here.

5-4-3 Summary of the strata-bound ore deposits

From the evidences as mentioned above, the followings have been ascertained about the strata-bound lead-zinc ore deposits in this surveyed area.

(1) The mineral indications, as those of strata-bound ore deposits, are associated with the carbonate rocks belonging mainly to the III member and the V member of the Pucara Group.

(2) The indications are classified into the following three types according to the degree of each concentration stage.

① Disseminated type ------ Keeping the feature of the primary deposition. No concentration is recognized.

② Fracture filling type --- Concentrated by inter-solid-phase reaction of ore minerals gathered in the space, after primary deposition.

③ Banded type ------ Continuously transported and concentrated in the space to form zebra-structure by hypersaline brine, after primary depostion.

(3) The environment in which primary lead and zinc were deposited with the sedimentation of the country rocks is a warm back-reef-basin and a rather closed inner-sea or shalllow basin, where organic matters like algae are abundant.

(4) The formation of the barrier reef is localized depending upon the paleotopography dominated by the basement of the Mitu Group.

(5) Ore minerals are concentrated especially in the dolostone among various carbonate rocks. They are found remarkably along the boundary plane between impure muddy dolostone and crystalline dolostone, or in rather crystalline dolostone. The banded type ore deposits associated with zebra-structure are derived from those phenomena continuously.

(6) There is no economically valuable ore deposits formed by the brecciation and the recrystallization accompanied by karst aquifer system in later stage.

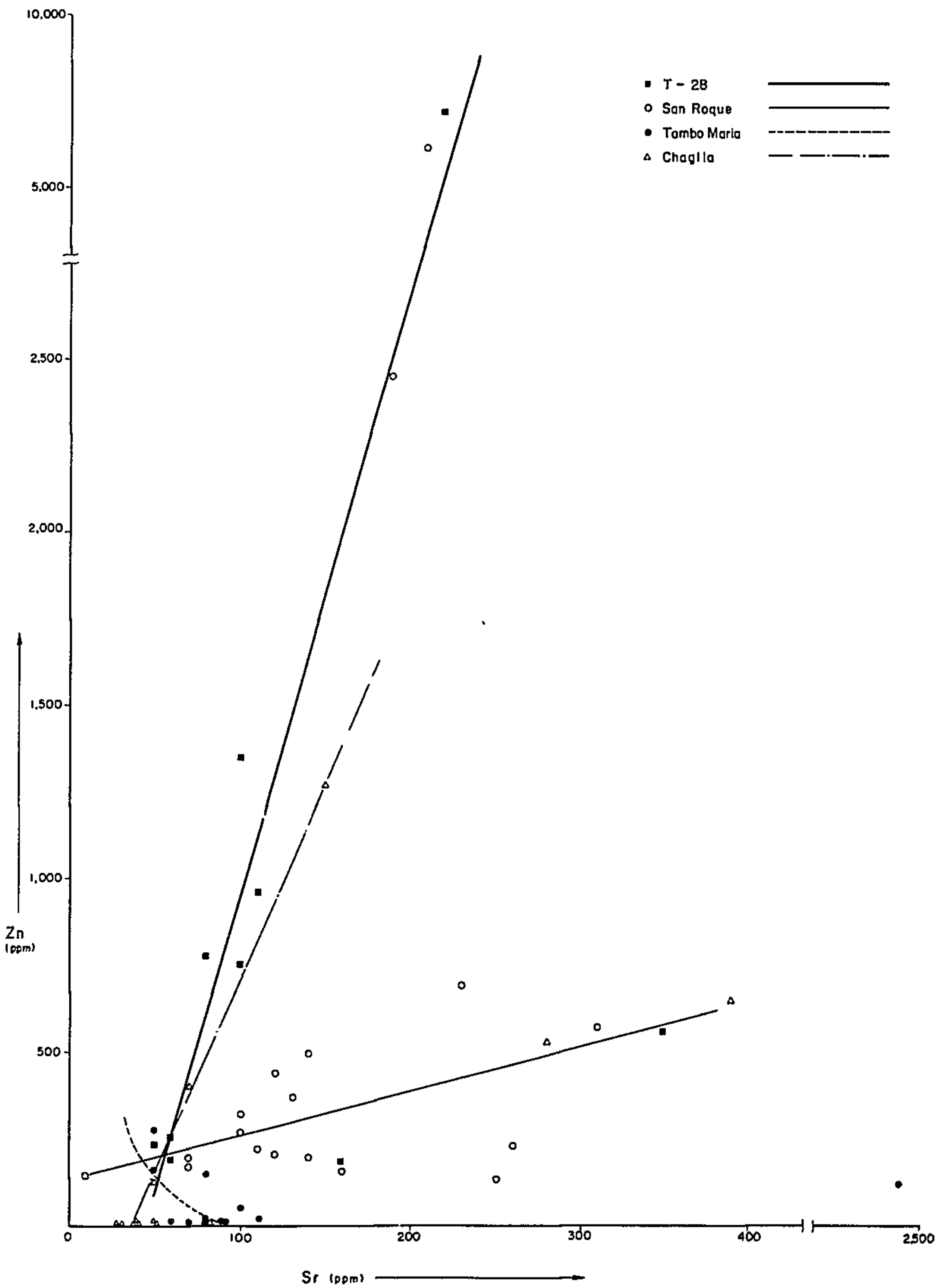


Fig. I-9. Correlation of geochemical values between Sr and Zn on carbonate rocks

PARTICULARS

PART II

Diamond Drilling

Part II Diamond Drilling

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Chapter 1 Introduction

1-1 Object of Drilling Survey

The geological survey which had been carried out until 1977 prospected the mineral indication of zinc and lead of disseminated and strata-bound type in the Pucara Group at San Roque and Tambo Maria.
Since it was observed that the mineralization was under control of formation, this diamond drilling survey was carried out for further clarification of mineralization and control of formation at both areas.

1-2 Outline of Drilling Survey

One chief engineer was dispatched in advance and arrived at Oxapampa on 18th, May, 1978 to prepare the access road for the first drill hole.
Other three engineers followingly arrived there on 9th, June, 1978.
A bulldozer (AD-7), a compressor (VT-3) and a jack-leg (RH-571-3L) were mobilized for the construction of access roads.
For diamond drilling survey, a drilling machine (TGM-2C), Two pumps (NAS-3C & MG-10) and a mixer (MCE-100A) were mobilized.

Drilling works, carried out under the wireline method, finished on 18th, September, 1978 in which the total hole length of 902.60m was drilled.

1-3 Organization of Drilling Survey Team

The drilling survey team consisted of one chief engineer, three engineer, one geologist (Japaneses), and one counterpart, nine drilling mates and fifteen general workers (Peruvians).

During the preparatory stage, drilling was carried out by one shift for ten hours a day and once drilling operation was started, it was carried out by three shifts in twenty four hours a day basis, where normal working time was almost ten hours a shift including commuting time from the camp to the holes and vice versa.

The engineers engaged in the survey were as follows.

Chief Engineer	Katsumasa Tanikawa	MESCO,Inc.
Engineer	Isamu Nakayama	"
"	Tadatoshi Nasu	"
"	Shigemitsu Watanabe	"
Geologist	Shin'ichi Doi	"

Chapter 2 Diamond Drilling

2-1 Location of Drill Holes

No.53-MJ 1 drill hole was located in Tambo Maria, 17km south to Oxapampa, at 1,609.1m above the sea level, aiming to drill through the dolomitic zone of the Pucara formation.

The distance from the camp in Oxapampa to the hole was 21km and it took about 60 minutes to go by car.

No.53-MJ 2 drill hole was located 1.6km north to No.53-MJ 1 hole, at 1,630m above the sea level to drill through the dolomitic zone of the Pucara formation.

No.53-MJ 3 hole was located in San Roque, 6km northwest to Oxapampa, at 1,910m above the sea level to drill through the limestone zone of the Pucara formation. The distance between the camp and the hole was 7km and it took 40 minutes to go by road.

2-2 Mobilization and Set-up of Drilling Force

1) Access Road Preparation

One of the team arrived at Oxapampa on 18th, May. He investigated the road way as an access to the drilling sites and, meantime, made necessary arrangements with land owners to rent their land for the sites, to tresspass their farm field for transportation and to repair or construct roads in their estates.

One bulldozer, one compressor and one jack-leg were hired and used for road works such as cutting rock blasting and backfilling.

The field works on the road to No.53-MJ 1 and No.53-MJ 2 holes were started on 22nd, May and 2,000m of the road was completed on 3rd, June.

Then, the working force was shifted to prepare the access road to

No.53-MJ 3 hole which was required to be ready promptly, so that the construction of the former road was suspended temporarily.

It was on 5th, June when works started on this second road. It was constructed as a new road by 551m and completed on 17th, June. The works involved excavation by bulldozer on a slope of 30 degrees and blasting of exposed rock.

After completion of this road, works resumed on 18th, June for the former road and finished on 7th, July with the remaining part of 2,700m completed.

2) Mobilization of Machienes and Equipment

Bentonite and additives were transported from Lima to Oxapampa by a big truck. From Oxapampa, they were delivered by a truck to a near place to the drilling sites, consigned with a drilling machine, pumps, a mixer, rods and trestles, casing pipes, etc. which had been stored there from the last year. There, they were shifted to a small truck to deliver them to the sites.

3) Order of Drilling Works

Due to the progress of the access roads construction and the drilling sites preparation, drilling was carried out in the order of No. 53-MJ 3, No.53-MJ 1 and No.53-MJ 2

4) Preparation of Drilling Stages

The drilling stage of No.53-MJ 3 sat on a field sloped by 35 degrees and was prepared by cutting the ground flat. Excavation was started manually but the base rock was soon exposed since the surface soil was relatively thin.

Then, a timber fence was made around the proposed drill hole and rock was blasted to fill inside of the fence to make a drilling stage. Machines and materials were delivered by a small truck to a near place to the stage.

From there to the site distanced 70m, heavy machines towed by universal rulling and lifting machine, meanwhile rods and casing pipes were transported by men.

No.53-MJ 2 hole was on a slope of 30 degrees and a road was running below where farmers were passing by frequently. A timber fence of 2m high was provided for the protection of rolling stones and the site was made by cutting the ground flat.

The distance between the road end and the site was 150m where stones were very likely to fall off on a slope so that timber fences were provided at the places where necessary. A timber gang way was framed there as an access on which heavy machines were towed by universal rulling and lifting machine and, rods and casing pipes were brought up by men.

The stage of No.53-MJ 3 hole was being prepared by a bulldozer but it got out of order when two-third of works had been finished, so that it was completed by men hands afterwards. All materials were transported by a small truck to the stage.

5) Drilling Water Supply

Water for drilling was supplied from an adjacent brook. Water was led by a pipeline from the brook to a near place to the stage from where it was pumped up to the stage.

For No.53-MJ 1 hole, water was led from a brook to a place below the stage by a polyethylene pipeline of 1-1/2" dia. laid by 650m and was pumped 80m up to the stage by a steel pipeline of 2" dia laid by 150m.

For No.53-MJ 2 hole, water was led from an adjacent brook by a polyethylene pipeline of 1-1/2" dia laid by 240m and pumped 180m up to the stage by a steel and polyethylene pipeline of 2" dia laid by 150m and 100m respectively.

For No.53-MJ 3 hole, water was pumped 60m up to the stage by 2" steel pipeline of 120m long followed by 1-1/2" polyethylene pipeline of 270m long. Since the water source was for domestic use of the adjacent village, water was cut down occasionally by accident and it caused temporary suspension of drilling work.

2-3 Drilling Works

1) No.53-MJ 1 hole (Vertical hole of 302.10m long)

0.00m~6.00m (The length corresponds the depth from the ground hereafter). The hole was drilled by a HQ bit to reach firm rock. It was reamed by a casing shoe bit of 112mm dia. and casing pipes of the same diameter were inserted. The rock facies was boulder and the hole wall was likely to fall off frequently.

6.00m~54.50m

HQ wireline was employed but, since mud water was lost completely from the hole at 6.50m,the casing pipe was extended by 1m additionally.
Then, drilling was continued by HQ wireline down to 54.50m. Since the rock facies was dolomite with many fissures, mud water tended to be lost quite frequently. Even mud water with cement or of high density was lost easily and it caused vibration on the drill rods.
Bentonite water and waste oil were poured into the hole to the rod surface to prevent the vibration. From 54.00m, the rods kept on vibrating more violently and drilling work was extremely deteriorated, so that NW casing pipes were inserted down to 54.50m.

54.50m~183.00m

NQ wireline was employed and the hole was drilled to 183.00m.
The rock facies was dolomite with many fissures which caused considerable loss of mud water. The extension of NW casing pipes was tried in vain due

to mud water loss.

Drilling was carried out preventing rod vibration by pouring bentonite water and waste oil into the hole but it became difficult increasingly and BW casing pipes were inserted to 183.00m

183.00m∿302.10m

BQ wireline was employed and drilling was continued to reach 302.10m in the same circumstance as above. Inner tubes were set between 6.00m and 302.10m by suspending them with wire.

2) No.53-MJ 2 (Vertical hole of 300.00m long)

0.00m∿60.00m

Drilling was started with a HQ bit to reach firm rock at 7.10m and the hole was reamed with a casing shoe bit of 112mm dia. to insert casing pipes of the same dia for the protection of unstable hole wall.

Then, drilling was continued with a HQ wireline bit down to 60.00m.

The rock facies was crushed dolomite and mud water was being lost continuously. Cement or additives for the prevention of water loss were used without much effect and rod vibration kept on getting fierce, so that bentonite water, "emale-20C" and waste oil were poured into the hole to continue drilling. However, this supplementary injection lost its effect completely around at 60.00m and NW casing pipes were inserted to 60.00m.

60.00m∿201.00m

NQ wireline was employed.

Mud water loss was slight until the hole reached 108.00m and there, mud water was lost completely. "Mud-seal" and "Tel-stop" were added into mud water to prevent water loss but it was not much effective due to the existance of many fissures in the rock. The rock facies was the alteration of muddy dolomite, sandy dolomite and calcareous dolomite with many fissures. The hole was drilled to 201.00m and BW casing pipes were inserted.

201.00m∿300.00m

BQ wireline was employed.

The rock facies down to 271.50m was the alternation of calcareous dolomite and shale. At 213.00m, 261.00m and 271.00m, mud water was lost completely and additives were used to prevent water loss. When the hole was reaching 272.00m, mud water was lost again. The hole was, therefore, inspected carefully and it was found that water loss was taking place at 201.00m. Mud water was kept at the hole bottom but not returned to the surface due to the water loss at 201.00m. This caused the rod vibration, so that waste oil was poured in the hole and drilling was continued to 300.00m.

3) No.53-MJ 3 hole (Vertical hole of 300.50m long)

0.00m∿4.10m

Drilling was started with a metal bit of 116mm dia. The hole reached the rock base at 3.00m but was drilled to 4.10m, where casing pipes of 112mm dia. was inserted to the same depth.

4.10m∿12.00m

HQ wireline was employed.

The rock facies was limestone with fissures and the complete loss of mud water took place frequently. Since it took too much time to mix and make mud water ready to cover the frequent water loss, it was decided that the casing pipes were to be extended one after another. NW casing pipes were inserted in such a way.

12.00m∿129.00m

NQ wireline was employed.

The rock facies was shaley and sandy limestone with many fissures and caves which caused frequent water loss in drilling. NW casing pipes were extended from 12.00m to 31.50m.

Below 31.50m, the zones where mud water was lost were cemented and drilling was continued. When the hole reached 72.40m, cementation lost its effect and more frequent water loss took place to cause the rod vibration. Drilling was eventually continued by applying grease and waste oil to the rods to prevent it. However, drilling was getting much more difficult to be continued and BW casing pipes were accordingly inserted to 129.00m.

129.00m∿300.50m

BQ wireline was employed to continue drilling.

Mud water was being lost due to the rock facies like muddy limestone with many fissures and BW casing pipes were extended from 129.00m to 168.50m. Mud water was still being lost below this depth but it was impossible to extend them. The additives to prevent water loss were used but they were unable to prevent it completely. Grease and waste oil were applied on the rods to prevent the vibration due to water loss. When the hole reached 300.50m, drilling was finished.

2-4 Demobilization of Drilling Force

When the drilling works at No.53-MJ 2 hole was finished, all machines and equipment were dismounted and transported back to Oxapampa. After they were overhauled there, they were packed in crates and sent back to Lima on 18th, September, and all the field works were finished.

2-5 Performance Record

1) Drilling

Number of holes	3
Total hole length	902.60m
Nominal drilling progress	6.31 m/one shift
Actual drilling progress	7.11 m/one shift