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ESTADOS UNIDOS MEXICANOS
CONSEJO DE RECURSOS MINERALES

REPORT ON GEOLOGICAL SURVEY OF THE PACHUCA-ZIMAPAN AREA, CENTRAL MEXICO

PHASE III

GEOLOGICAL SURVEY
GEOCHEMICAL PROSPECTING
GEOPHYSICAL SURVEY

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METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

PREFACE

The Government of Japan, in response to the request of the Government of the Estados Unidos Mexicanos, decided to conduct the collaborative mineral exploration project in the Pachuca area of the State of Hidalgo, central Mexico and entrusted its execution to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

Between July 15th to October 11th, 1981, Metal Mining Agency of Japan dispatched a survey team headed by Mr. Motomu Koyokawa to carried out the Phase III work of the project.

The survey had been accomplished in close cooperation with the Government of the Estados Unidos Mexicanos and its various authorities.

This report is a compilation of the results of the Phase III work, and after the completion of the project the consolidated report will be submitted to the Government of the Estados Unidos Mexicanos.

We wish to express our appreciation to all of the organizations and members who bore the responsibility for the project; the Government of the Estados Unidos Mexicanos, El Consejo de Recursos Minerales (CRM) and other authorities, and the Embassy of Japan in Mexico.

February, 1982

Keisuke Arita
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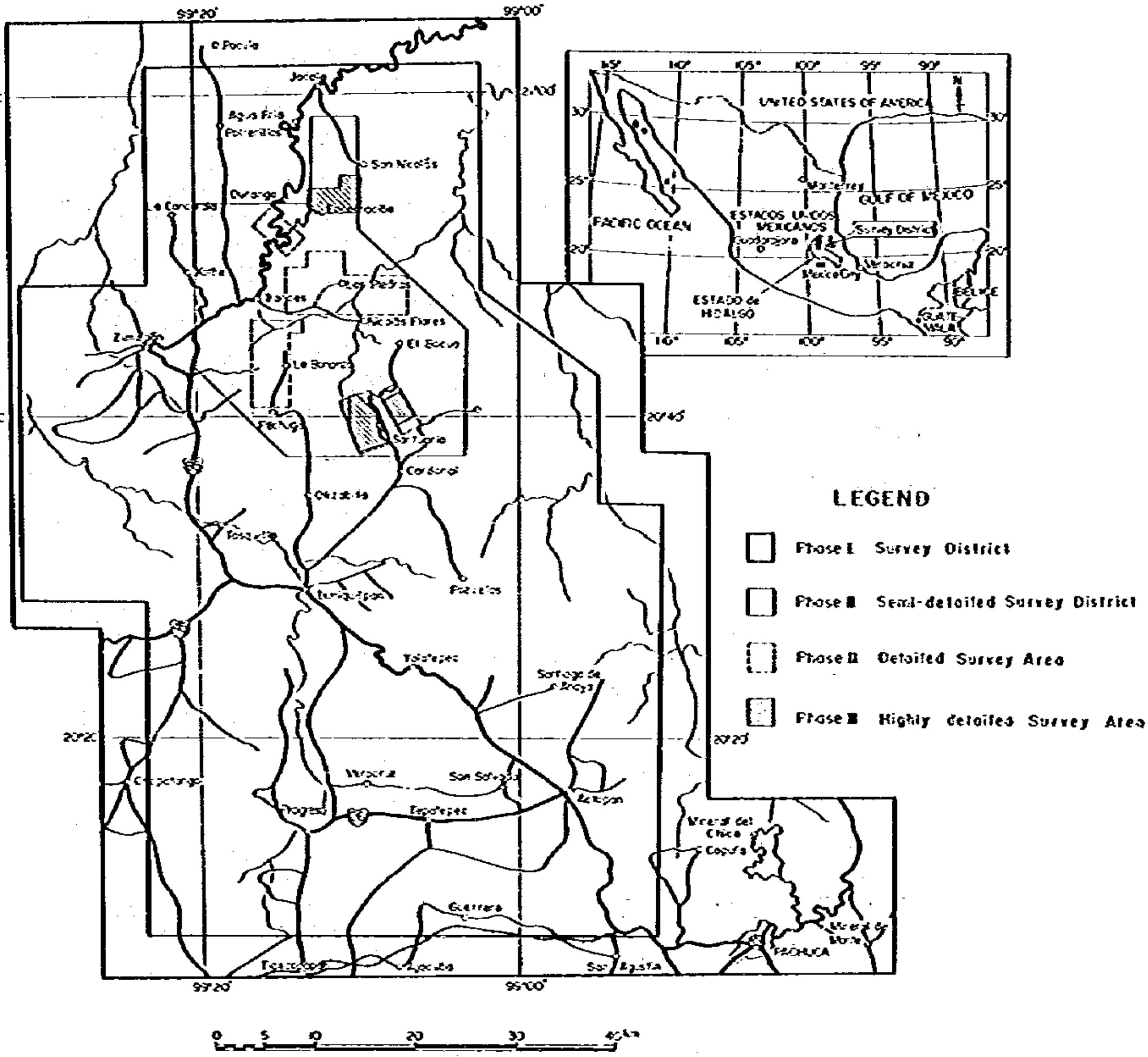

Fig. G-1 Location Map of the Survey District

ABSTRACT

This report summarizes a result of the third phase works of the collaborative mineral resources exploration project in the Pachuca district of the State of Hidalgo, central Mexico.

The field survey was performed by the Metal Mining Agency of Japan (MMAJ) in close cooperation with El Consejo de Recursos Minerales (CRM) during the period from July 15th to October 11th of 1981.

The main subject of this year's survey was to extract the promising mineralized zones as the target of exploration in future and to obtain more detailed geological and geochemical data from the El TEJOCOTE, the SAN CLEMENTE and the PROVIDENCIA areas which were selected on the basis of the result of survey carried out up to the second year.

For this purpose, IP electric survey was also carried out in the EL TEJOCOTE and the PROVIDENCIA areas beside the detailed geological and geochemical surveys carried out in the three areas above mentioned.

An epitome of the survey results is as follows.

(1) <u>EL TEJOCOTE Area</u>

The area is located in the northern part of the project district, and occupies anarea of 32 square kilometers. The small extent of 2.7 square kilometers among the area was especially selected as the target of geochemical prospecting and IP electric survey.

The main reason that the area was chosen as one of the target of this phase work, was to investigate the geochemical anomalies of lead and silver by stream sediments detected out in the second phase survey.

Geology of the area is characterized by a dominant distribution of the thick-bedded to massive limestone (Kdl) member of the El Doctor Formation and dioritic intrusive rocks intruded into the former.

At the contact between limestone of the Kdl member and the dioritic intrusive rocks, some skarn zones are intermittently formed, which are associated with the pyrometasomatic mineralization mainly composed of magnetite ore and accessary copper minerals.

Silver bearing lead and zinc ore deposits of hydrothermal vein to manto type are scatteringly arranged in the limestone on the outside of those contact zones mentioned above. Such distribution seems to indicate a zonal arrangement of mineralized zones formed by a series of mineralization.

The skarn type ore deposits are emplaced in skarn zones having the width from several meters to about 20 meters and the extension of about 100 meters, showing the forms of lens, irregular mass and vein, the maximum ore reserve, however, being several tens thousand tons. On the other hand, ores of hydrothermal type deposits have been completely oxidized and altered to the ore minerals such as limonite, hematite and jarosite.

High grade ores show such metal contents as Zn n∿n x 10%, Pb n%, Ag 20∿65 g/t, and Cu 0.n%, but a large majority of ores are of low grade.

Geochemical survey and IP electric survey were conducted in a small area of 2.7 square kilometers locarized in the area of distribution of hydrothermal ore deposits.

As the results, geochemically anomalous zones and IP anomalous zones of high chargeability were detected both in the northeastern part and in the southern half of the area.

The geochemically anomalous zone in the northeastern part is composed of an aggregate of B-class anomalies of lead and silver components. Although the zone has a relatively large extent, the A-class zones contained in those of above is rather small on a scale showing a tendency to continue northeastward beyond the limit of the area.

The A-class anomalies of lead component are in the range of 1,230 ppm and 1,500 ppm. Those of silver component are 8 ppm to 13 ppm and have been detected overlapped with lead anomalous zones.

The anomalous zones in the southern half of the area are formed by copper component and consist of B-class anomalies with relatively large extent and small-scale A-class anomalies. The highest value of A-class anomaly was 394 ppm.

On the other hand, the result of IP electric survey shows that the anomalous zones of high resistivity and high chargeability are distributed in the southern part of the area overlapping with the geochemical anomalous zones of copper component, and that those of low resistivity and high chargeability are scattered in the central and northern parts on a small scale, some of which are overlapped with the geochemical anomalous zones of lead and silver components.

The geological consideration leads to reach to the understanding that the anomalous zone in the southern part suggest the presence of iron and copper mineralized zone of contact metasomatic type associated with intrusive rocks and the latent body of intrusive rock, and that, on the other hand, those in the central part and the northeastern part indicate the presence of lead and zinc mineralized zone of hydrothermal type.

However, the investigation of the various measured values which constituted these anomalous zones of geochemistry and chargeability leads to be regarded that the anomalous zones are inferior to those detected in other two areas as mentioned below.

(2) PROVIDENCIA Area

Geology of the area which is situated in the southern part of the district surveyed in the second year, consists of dominant occurrence of Jurassic to Cretaceous sedimentary rocks such as the Las Trancas Formation (Jts), the El Doctor Formation (Kdl, Kdn and Kdf) and the Mendéz Formation (Kms), and small-scale Tertiary dyke rocks (Tirh and Tian) having intruded into those sedimentary rocks. Among these, the principal one is the Kdf member of the El Doctor Formation, which widely overlies the central part of the area. This member consists of medium-bedded limestone with rhythmical intercalation of thin-bedded black flint.

The silver bearing lead and zinc mineralized zones are observed as the outcrops of the ore deposits scattered in the Kdf member of the El Doctor Formation within an ellipse-shaped extent having the major axis of about 1,000 meters long extending in the NS direction and the minor axis of about 700 hundred meters long.

The ore deposits observed on the outcrops show the various shapes such as irregular mass, manto and vein, and almost all the deposits consist of oxide ores except only one outcrop of sulfide ore contained in quarts veins.

The dimension of outcrop of ore deposit seems to have been approximately several tens meters by several tens meters by 100 meters in the case of irregular massive type judging from the remains of old pits excavated for prospecting and mining.

In the medium-bedded limestone at the marginal zones of ore outcrops, no remarkable hydrothermal-alteration is confirmed, although some silicification and brecciation are observed locally.

Beside the oxide minerals, carbonates of lead and zinc are observed as ore minerals under the microscope.

The assay results of ore samples show the metal contents such as Pb n%, Zn n x 10%, and Ag n x 10~n x 100 g/t, with a very small amount of copper.

Geochemical prospecting and IP electric survey were carried out within the area of 1.5 km x 1.9 km which includes those mineralized zones mentioned in the above. As the result, a high-grade geochemically anomalous zone and a high charge-ability anomalous zone were detected. The outline of these anomalous zones are described in the following.

Geochemically anomalous zone

The central part of the mineralized zone which extends for about 1,000 meters in the NS direction, consists topographically of a ridge prolonging in the same direction with slopes on the eastern and western sides.

The high-grade geochemically anomalous zone continues along the eastern slope for about 1,000 meters in the NS direction. The width of the zone is about 200 meters in the southern part, being about 400 meters at a little northern side of the center.

The main component of the geochemically anomalous zone is lead, and the zone contains 21 points of high-grade anomalies of AA-class and A-class. The values of these anomalies are very high ranging from 0.3% to 9.8% in lead.

The anomalies of silver and copper components were detected in the central part of lead anomalous zone, though small on a scale. The values of silver and copper are shown to be 10 ppm to 100 ppm and 180 ppm to 500 ppm respectively.

High chargeability anomalous zone

A high chargeability anomalous zone with a form of irregular ellipse was detected having its center on the mountain ridge which is situated in the central part of the mineralized zone.

The result of analysis of the anomalous zone at each depth (100 m, 200 m and 300 m) shows that the chargeability increases with the increase of depth. The extent of the anomalous zone is 350 m x 500 m in average although some variation is found in each depth.

Since the positions of anomalous zones at each depth are almost overlapped each other, it seemed that the causative body of this anomalous chargeability has been emplaced on the whole in the chimney-form, although some irregular offshoots are found in place.

When looking out over the relation with the geochemically anomalous zone, the chargeability anomalous zone is positioned at the ridge in the central part of the mineralized zone, and the geochemically anomalous zone is found on the eastern mountain slope at the topographically lower place. It is, therefore, understood that they are closely related each other. The mineralized outcrops shows a positional relation that they are fringing the outer periphery of the chargeability anomalous zone at the 100-meter depth.

Since the high-grade and large-scale geochemically anomalous zone, numerous outcrops of ore deposit and high chargeability anomalous zone were detected showing a mutually close relation, it is concluded that the mineralized zone is to be ranked the first class for the future exploration, and that it is required that the emphasis of future exploration would have to be laid on the investigation of ore occurrence at the deeper part.

(3) SAN CLEMENTE Area

The survey of this phase consists of the detection of the gold and silver mineralized zone by means of rock sampling with 50-meter grid-spacing in the geochemically anomalous zones of gold and silver in alkaline rhyolite, and the detailed geological survey in rhyolite complex. The results are summarized as follows.

The form of rhyolite complex

Compact rhyolite which constitutes the main part of the San Clemente mountain mass has a form of lava dome which covers the lower formations in the eastern part of the mountain mass, being widened laterally with gentle dip, whereas it shows a relation to cut other formations with steep contact plane in the southwestern part. The gold and silver mineralized zones are located in the southwestern part of the complex which corresponds to the vent of the lava dome.

The scale and the grade of the mineralized zone

(Note: the grade is the total content of gold and silver, which was calculated by the formula "Au grade + Ag grade x 1/50")

The two mineralized zones of A and B were detected. The A-mineralized zone occupies an area of 300 m x 500 m, in which the six high grade places from A-1 to A-6 are included.

Those of A-1 to A-3 are located in the western part to form the western mineralized zone, A-4 to A-6 are in the eastern part to form the eastern mineralized zone, the central part between them being low grade.

The western part occupies an area of 200 m x 400 m including the low grade part, and the average grade of the whole zone is 3.06 g/t.

The principal ore mineral is tiny grains of gold bearing complex sulfosalts minerals (main components of Ag, Sb, Te, Pb and Cu with accessory components of Bi, Se, As, Ni and S), showing the occurrence to be disseminated in rhyolite.

The size of the grains is of about 0.1 milimeter across or less in general. It is, therefore, difficult to be observed unless the rock sample is pulverized up to about 200 mesh and separated by sluicing. The rate of silver content to gold in the mineralized zone is about 50.

The eastern mineralized zone has an extent of approximately 200 m x 250 m, and has the grade of about 1.5 g/t.

The reason that many remains of old test pits and mine workings are found in this zone, seems to be attributed to the fact that the main ore mineral is electrum which is close to native gold in composition, which made easy to discriminate it as gold grain at the time of prospecting. Accordingly, the rate of silver content to gold in the zone is as much as 1 to 2. Electrum is found as small grains of the size of about 0.1 milimeter attached, in many cases, on the hematite film filling the joints and fine fissures of country rocks, showing an occurrence a little more controlled by the fissure and joint system as compared with the western mineralized zone.

The B-mineralized zone is situated at about 200 meters to the south of the A-mineralized zone. Although the extent of the zone is approximately 150 m x 300 m, it is low grade as compared with the former.

<u>The grade of the gold deposit of dissemination type</u>

There are many examples of gold and silver deposits of dissemination type which have been or being operated in the United States and Canada, having been emplaced in the country rock of intrusive rock, volcanic rock and sedimentary rock (Boyle, R.N., 1976).

Although the crude ore of these deposits are variable in grade, the most of these are low grade (0.1 oz/t) and large scale.

Several examples of these deposits are listed in the following.

(1) Howey and Hasaga Mine, Red Lake, Ontario, Canada
Au 0.10 oz/t
Ag 0.05 oz/t

(2) Young-Davidson Mine, Matachewan, Ontario, Canada
Au 0.10 oz/t
Ag 0.02 oz/t

(3) Box Mine, Goldfilds, Saskatchewan, Canada
Au 0.05 oz/t
Au/Ag = 5

(4) Sunbeam Kirkland Mine, Manitoba, Canada
Au 0.23 oz/t
Au/Ag = 1

On the basis of the result of survey hitherto conducted, the gold and silver mineralized zone of the area is judged to have a great possibility to be grown into a low-grade and large-scale deposit. It is, therefore, concluded that the highly detailed exploration works should be required.

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CHAPTER 1 INTRODUCTION

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1-1 Foreword

The cooperative mineral resources exploration project in the Pachuca district of the Estados Unidos Mexicanos was started in 1979 as the first phase, and this year is the third phase of the project.

The survey in the first year were carried out putting an emphasis on elucidation of the regional geology and the geological structure of the district.

Accordingly, the field and indoor works were composed of preparation of topographical maps of the whole survey district, photogeological interpretation (5,250 km^2) and regional geological mapping, including reconnaissance to the metallic ore deposits located in the district.

As a result, the policy of exploration for the second year was concluded to be directed to (1) clarification of stratigraphy of the Cretaceous formations predominated in the district, (2) investigations to the ore deposits such as iron, copper, lead, zinc and silver of contact metasomatic to hydrothermal types scattered in the northern half of the district and gold ore deposit within the potash rhyolite body in the vicinity of San Clemente.

Based on the above conclusion, the following surveys were carried out as the second year's exploration;

(1) Semi-detailed geological survey and geochemical prospecting (stream sediments samples) for the northern half of the district (750 km^2).

(2) Detailed geological survey and geochemical prospecting (stream sediments and rock samples) for the five mineralized zones (147 km^2 in total) contained within the above district.

These exploration works resulted in to recommend the mineralized zones to be required of more detailed surveys, and several sub-areas in which mineralized zones were expected to occur. Among those, three areas of (1) EL TEJOCOTE, (2) PROVIDENCIA and (3) SAN CLEMENTE were selected as the most promising areas, and they were the targets of this year's survey.

The survey of this year consists of the detailed geological survey, geochemical prospecting (soil sampling with a definite interval) and IP electric survey in the EL TEJOCOTE and the PROVIDENCIA areas and detailed geological survey, geochemical prospecting (rock sampling with fifty meter's grid-spacing) in the SAN CLEMENTE area.

The field works of the geological survey and geochemical prospecting were performed by eight geologists among which four were dispatched from Japan and other four were from El Consejo de Recursos Minerales (CRM), being started on 15th July and completed on 11th October, 1981. The IP electric survey was conducted by a geophysical survey team of CRM with participation of one Japanese geophysicist.

Chemical analysis of the geochemical samples was conducted at the Ixmiquilpan laboratory of CRM for three elements in the soil samples such as Cu, Pb and Ag, and in Japan for two elements of Au and Ag in rock samples. All the survey data including the results of chemical analysis and IP electric survey were investigated, analyzed and arranged in Japan together with the result of laboratory examinations conducted thereafter, and those were compiled in this report.

1-2 Location and Access

Location and access of the EL TEJOCOTE, the PROVIDENCIA and the SAN CLEMENTE areas are as follows (Fig. G-1).

Location

Table 1-1 Location of the Surveyed Area

	EL TEJOCOTE Area	PROVIDENCIA Area	SAN CLEMENTE Area
Northern limit	N 20°55'44"	N 20°41'30"	N 20°41'02"
Southern limit	N 20°52'30"	N 20°39'28"	N 20°37'50"
Eastern limit	W 99°09'33"	W 99°06'14"	W 90°07'43"
Western limit	W 99°13'02"	W 90°08'02"	W 99°10'07"
Area	32 km^2	6 km^2	14 km^2
		Total	52 km^2

Access

EL TEJOCOTE Area:

The national highway No. 85 runs northward from Ixmiquilpan through Las Trancas Village to further north. A gravel road of about 4.5 kilometers leads from a crossroads about 15 kilometers to the north of Las Trancas toward east-northeast to Encarnación Village which is situated at the southern end of the surveyed area. This road extends further to the center of the area, and turns to the southeast to reach to the Delicias mine. Large size truck can be passable along it. An advance camp was required to be set at Encarnación Village during the field survey.

PROVIDENCIA Area:

A paved road leads northeastward from Ixmiquilpan to Cardonal Village for about 20 kilometers. At the crossroads along a gravel road about 2 kilometers to the north of Cardonal, a gravel road branches toward the east to reach to the Yonthe settlement at the distance of about 4.5 kilometers. A rough gravel road runs from the settlement to the eastern end of the area for about 10 kilometers, which is left in bad condition barely to permit the access of small truck.

SAN CLEMENTE Area:

A gravel road leads northward to the San Clemente settlement from Olivo settlement located along the paved road from Ixmiquilpan to Cardonal. Since this road runs about 1 kilometer southwest of the boundary of the southwestern end of the surveyed area, the access to the area should be on foot.

1-3 Kind of the Work

Table 1-2 and Table 1-3 show the various works and quantity of the laboratory examinations.

Table 1-2 Kind of Work

Surveyed area	Area of detailed geological survey (km^2)	Number of geochemical sample	Line kilometer of IP survey
EL TEJOCOTE	32	213 (soil)	15
PROVIDENCIA	6	230 (soil)	15
SAN CLEMENTE	14	302 (rock)	-
Total	52	443 (soil) 302 (rock)	30

Table 1-3 Laboratory Examination

Type of examination	Number of sample	Number of analized element
Chemical analysis of ore sample	52	Au....10 Ag....40 Cu....40 Pb....44 Zn....39 Fe....10 Mn.... 1 } 184
	36	Au....36 Ag....36 } 72
Chemical analysis of geochemical sample		
<u>soil sample</u>	443	Cu....443 Pb....443 Ag....443 } 1329
<u>rock sample</u>	302	Au....302 Ag....302 } 604
Check analysis		
<u>soil sample</u>	80	Cu.... 80 Pb.... 80 Ag.... 80 } 240
<u>rock sample</u>	10	Au.... 10 Ag.... 10 } 20
Microscopic observation of rock thin section	55	-
Microscopic observation of ore polished section	27	-
EPMA analysis	20	-
X-Ray powder diffraction	11	-
K-Ar radiometric age determination	2	-
Whole rock chemical analysis	3	13 components

1-4 Members of the Survey

The members engaged in conference for the survey plan and those participated in the field survey of this phase are as follows:

Members

Japanese counterparts	Mexican counterparts

Conference for the survey program (May, 1981)

Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ)	El Consejo de Recursos Minerales (CRM)
Yuzo Nakamura (Head of the mission, MMAJ)	Guillermo P. Salas (Director General)
Hideaki Mukai (JICA)	Jose L. Lee Moreno (Gerencia de Estudios Especiales)
Kenji Sawada (MMAJ)	Gustavo Camacho Ortega (Gerencia de Estudios Especiales)
Kenjiro Takehata (MMAJ, Mexico Office)	Cesar J. Villegas (Gerencia de Geofísica)
Motomu Kiyokawa (Sumiko Consultants)	

Field survey (15 July to 11 October, 1981)

Geological survey and geochemical prospecting

Motomu Koyokawa (Head of the mission, geologist)	Panfilo Sanchez Alvarado (Jefe de la Oficina de Ixmiquilpan, Ingeniero)
Kiyoharu Nakashima (Geologist)	Melitón Figueroa Palacios (Ingeniero)
Tetsuo Sato (Geologist)	Noel Arnold Reyes Reyes (Ingeniero)
Akio Abe (Geologist)	Luis Tarcisio Arteaga Pineda (Ingeniero)

Geophysical survey

Mitsuya Takahashi (Geophysicist)	Felipe Ramires (Ingeniero)
	Bulmaro Herrea (IP operator)
	Miguel Figueroa Salgado (Land surveyor)
	Guillermo Soto Martinez (Land surveyor)

1-5 Acknowledgments

We wish to express our appreciation of guidance and contribution to the survey of Dr. Hideo Takeda of Geological Survey of Japan, who was staying in Mexico for a short-term visit having been despatched from Japan International Cooperation Agency (JICA) and Mr. Akira Hirayama who is working for CRM despatched also by JICA. We are much indebted to Professor Yukitoshi Urashima of Kagoshima University for his guidance to EPMA identification of gold and silver minerals.

CHAPTER 2 GEOLOGICAL SURVEY

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2-1 Outline of Geology

EL TEJOCOTE, PROVIDENCIA and SAN CLEMENTE areas are located independently for each other and occupy small parts of the second year's survey district (Fig. G-1).

EL TEJOCOTE area (32 km^2) is situated in the northern part of the district, while PROVIDENCIA area (6 km^2) and SAN CLEMENTE area (14 km^2) are in the southern-central part being arranged in a row. The regional geological setting of the district including these three areas is summarized as follows (ref. Fig. 2-1-1, 2-1-2, 2-1-3).

Geology of the district consists of pelitic to calcareous sedimentary rocks of uppermost Jurassic to Cretaceous age, Tertiary formation composed mainly of volcanic rocks, Tertiary intrusive rocks, and Quaternary system. Among these, the sedimentary rocks of Jurassic to Cretaceous are dominantly distributed throughout the whole district, whereas Tertiary formations are partially scattered in the southern half of the district and Tertiary intrusive rocks are mainly observed as irregular stocks in the northern part.

Pre-Tertiary formations

Jurassic to Cretaceous formations are divided into the Las Trancas Formation (Jts, Jtc and Jtl members), the El Doctor Formation (Kdl, Kdf and Kdc members) and the Mendez Formation (Kms) in ascending order.

The Las Trancas Formation is mainly composed of the Jts member which consists of thin-bedded shale and partly intercalates the Jtc member consisting of sandy tuff and conglomerate, and the Jtl member composed of limestone. The formation is distributed from the western part to southern part of the district forming zone with a width of about 5 kilometers showing the trend of NW-SE. The time of deposition of the formation was from Tithonian of uppermost Jurassic to Neocomian of lowermost Cretaceous, and it is the lowermost formation exposed in the district.

The El Doctor Formation consists mainly of thick-bedded to massive limestone (Kdl member) and black flint-band-alternated, medium-bedded limestone (Kdf member), and the Kdl member intercalates small amounts of the Kdc member which consists of conglomeratic limestone and calcareous sandstone. The Kdl member is extensively distributed in the northern part of the district, and the Kdf member forms zones parallel to the zonal distribution of the Las Trancas Formation (Jts) on both sides of southwest and northeast. The Kdl and Kdf members are in the relation of contemporaneous heterotopic facies. The time of deposition of these members is from middle Albian to late Turonian.

The Mendez Formation (Kms) consists mainly of thin-bedded shale and a small amount of intercalations of thin-bedded sandy shale and marl. It is extensively distributed in the eastern part of the district and conformably or partly unconformably overlies the El Doctor Formation. The time of deposition of the formation is from late Turonian to Campanian.

In these Pre-Tertiary formations, a couple of overturned anticlinal and synclinal structures are found on a large scale with other many minor foldings, which made the geological structure very complicated.

[Tertiary]

With the exception of small local occurrence of the El Morro fanglomerate which is considered to be the Tertiary basal conglomerate, all the Tertiary formations consist of volcanic rocks. They are divided into basalt, andesite, dacite and rhyolite, which are further subdivided by the time of eruption. The main rocks which are distributed in the surveyed areas of this year are described in the following.

The earliest one among the basaltic rocks is olivine-pyroxene basalt lava belonging to Tba 1 which is rather extensively distributed in the western central part, central part and southern central part of the district, and directly covers the El Morro fanglomerate and pre-Tertiary formations. The Tba 1 is generally subjected to alteration mainly of argillization, and the time of activity has been inferred to be early Oligocene.

Among the rhyolitic rocks, a large scale and important one is alkaline rhyolite of Trhy2, which take the form of lava flow, lava dome and dyke, and show a limited occurrence in the southern-central part of the district. The ryolitic lava flow and lava dome form the prominent San Clemente mountain mass in southern center of the district, and the dykes are mainly distributed in the PROVIDENCIA area. K-Ar age determination indicates that the time of activity of these rocks was 26.5 ± 1.3 Ma, showing late Oligocene.

The rhyolitic rocks are rich in potassium and sodium and belong to alkaline rhyolite with total of both components being about 8 percent. They are closely related to the mineralization of both gold and silver of the SAN CLEMENTE area and lead and zinc of the PROVIDENCIA area.

[Intrusive rocks]

The main intrusive rocks scattered in the surveyed areas among those distributed in the district are quartz dioritic rocks (Tidi), diorite porphyry (Tidp) and dyke-form volcanic rocks.

The important rocks among these are quartz dioritic rocks (Tidi). These are mainly concentrated in northern part of the district showing a form of irregular stock with a tendency to be arranged in to two directions. These tendency is concordant with the direction of the major fault systems observed in the district. The rocks show holocrystalline, equigranular texture with gray to grayish white tints, consisting of hornblende, biotite and feldspar, sometimes showing variation to dioritic to grano-dioritic.

An absolute age determination by K-Ar method indicates approximately 47 Ma which corresponds to middle Eocene, and the intrusion appears to have taken place during the closing period of the Laramide orogeny.

These rocks intrude into the El Doctor Formation which consists of thick-bedded limestone in northern part of the district, and has had contact metamorphic effect on the intruded rocks having been accompanied by mineralization.

The typical localities of the rocks can be observed in the southern part of the EL TEJOCOTE area.

Exposures of diorite porphyry (Tidp) can be observed in the vicinity of Pechuga in the central part of the district surveyed last year, in the form of dyke, and a small occurrence can be found also in the SAN CLEMENTE area.

It is generally greenish gray to pale grayish brown. Under the microscope, large porphyritic crystals of plagioclase are characteristically observed, and the rock consists of plagioclase, quartz, hornblende and biotite with fine-grained holocrystalline texture. It undergoes generally chloritization and sericitization to a moderate degree. K-Ar age determination of the rock at Pechuga indicates 31.1 ± 1.6 Ma showing the time of Oligocene.

Beside these, several dykes which belong to the SAN CLEMENTE Alkaline rhyolite (Trhy2) can be observed in the PROVIDENCIA area.

Thus, general geology of the district is characterized by a dominant distribution of pre-Tertiary marly to calcareous sedimentary rocks and local distribution of Tertiary volcanic rocks which intrude or cover the sedimentary rocks, and in addition, various types of mineralizations can be observed in connection with the Tertiary igneous activities.

The EL TEJOCOTE area is situated in northern part of the district, in which the thick-bedded limestone (Kd1) member of the El Doctor Formation is predominant. Small distribution of conglomerate of the El Morro fanglomerate is merely found as the Tertiary rock. The Tertiary intrusive rocks such as dioritic rocks (Tidi), basalt (Tiba) and andesite (Tian) are observed. Among these, dioritic rocks (Tidi) are on a large scale, and are important because that contact metamorphic zones accompanied by mineralized zones of iron and copper are observed at the contact of the rock with limestone, and that minerazalizations of silver, lead and zinc are also found in the surrounding zones.

The PROVIDENCIA area is situated in the southeastern part of the district. The geology consists of the Las Trancas Formation (Jts), the El Doctor Formation (Kdl, Kdn and Kdf) and the Mendez Formation (Kms), and Tertiary intrusive rocks on a small scale. The pre-Tertiary formations show a reversal stratigraphic relation due to the overfolding structure. The mineralization is observed in the medium-bedded black flint-bearing limestone member (Kdf) as oxidized ore bodies containing silver, lead and zinc in the form of irregular massive to vein.

The SAN CLEMENTE area is situated to the southwest of the PROVIDENCIA area, where alkaline rhyolite (Trhy2) forms a prominent mountain which corresponds to the SAN CLEMENTE mountain mass. Small exposures of the Las Trancas Formation (Jts) and the El Doctor Formation (Kdf) are observed at the foot of the mountain, which is overlain by Tertiary basalt lava (Tba 1). These pre-Tertiary and Tertiary formations are covered and intruded by the alkaline rhyolitic rocks, forming the main part of the mountain mass. Among these rocks, gold and silver mineralization of hydrothermal dissemination type is observed in the country rock of compact rhyolite facies which belongs to Trhy2.

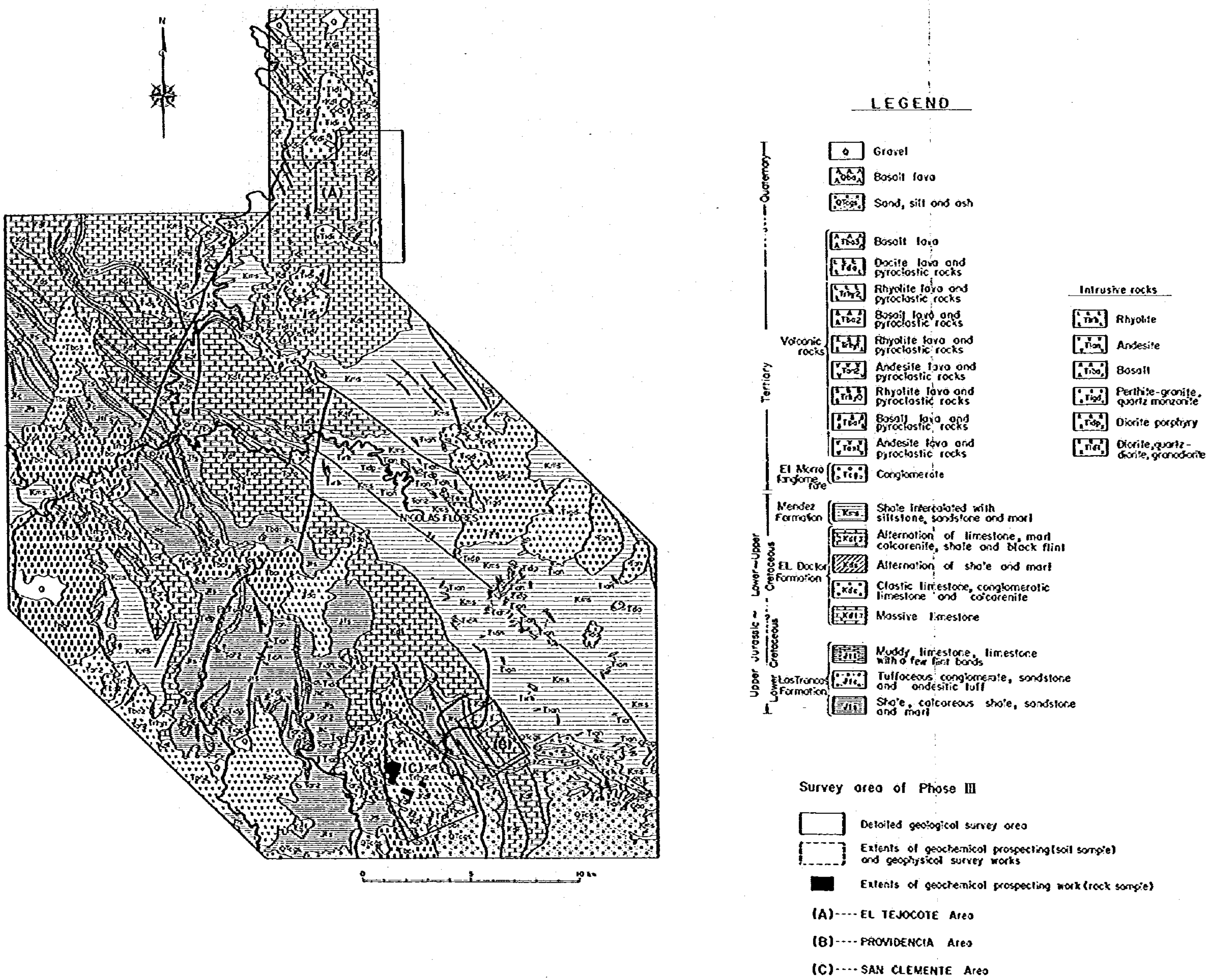
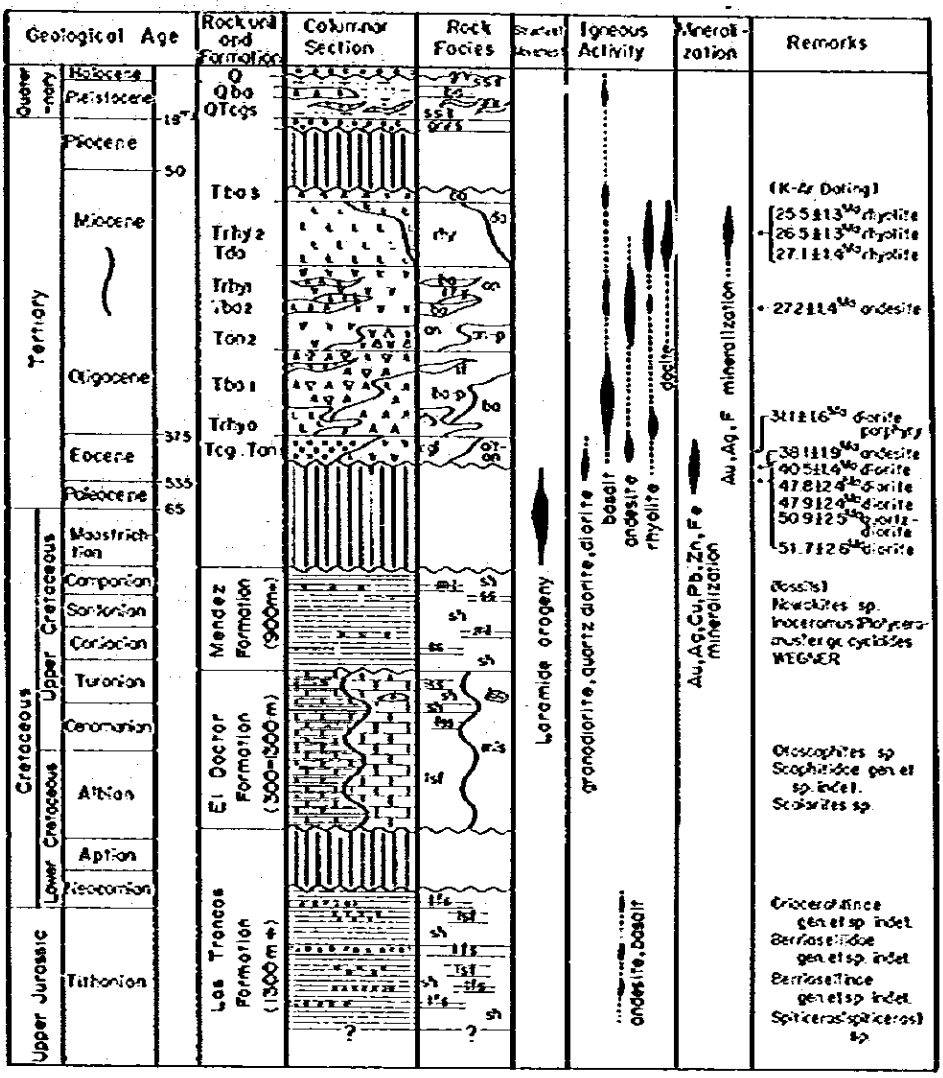


Fig.2-1-1 Geological Map of the Phase II Survey District



Abbreviations

grv	: gravel	alt	: altered
s	: sand	ml	: marl
silt	: silt	sh	: shale
bo	: basalt	ss	: sandstone
rhy	: rhyolite	lsc	: clastic limestone, limestone conglomerate
da	: dacite	lss	calcarenite
an	: andesite	lsf	: thin to medium-bedded limestone with black flint
p	: pyroclastic rocks	mls	: massive limestone
tf	: tuff	tfs	: tuffaceous sandstone, conglomerate, tuff
cgl	. conglomerate		

Fig.2-1-2 Generalized Stratigraphic Column of the Phosell Survey District
(after JICA and MMAJ 1981)

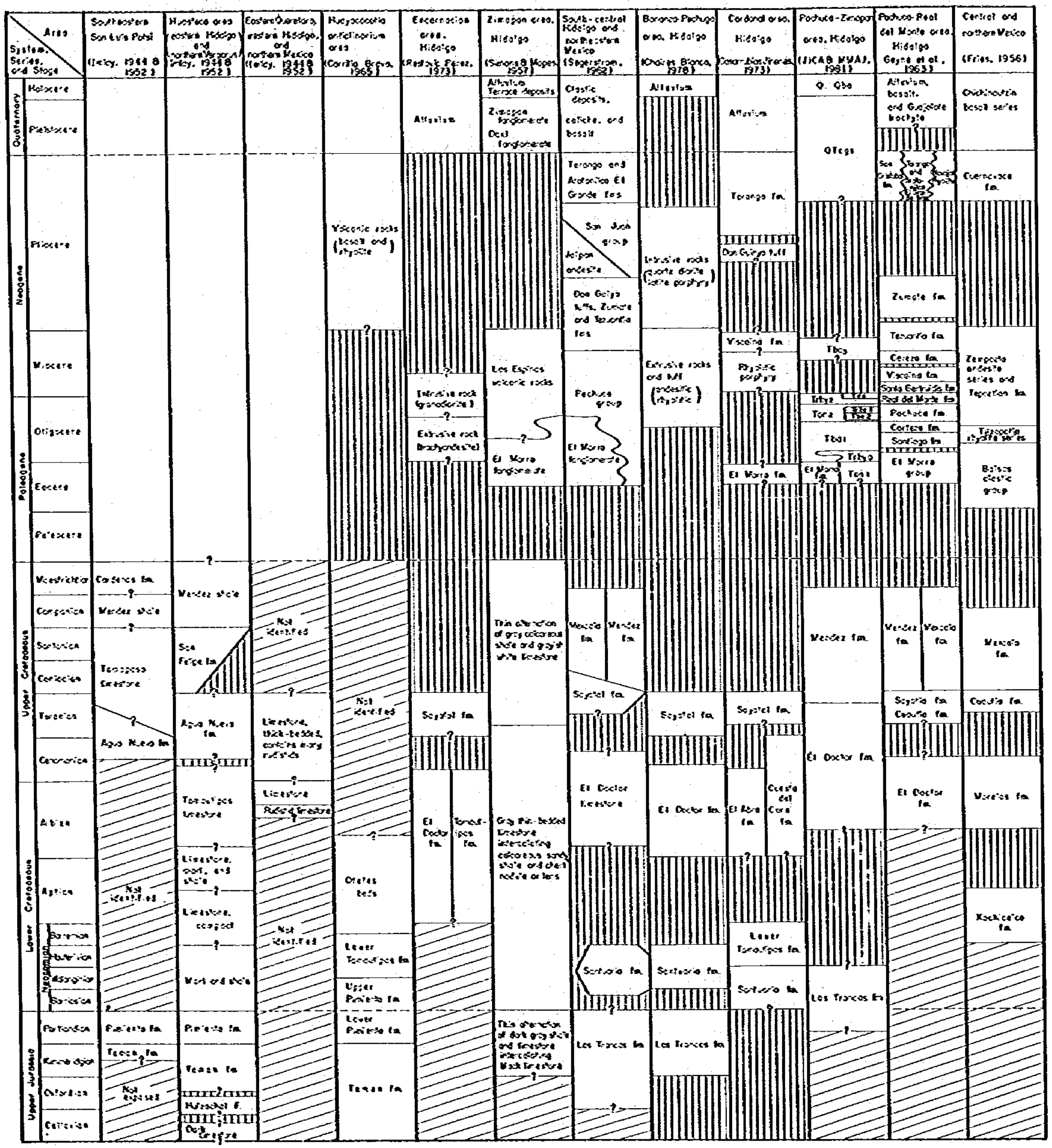


Fig. 2-1-3 Stratigraphic Correlation of Geological Units in the Sierra Madre Oriental (after JICA and MMAJ 1981)

2-2 EL TEJOCOTE Area

2-2-1 Location, Settlements, Topography and Vegetation

The EL TEJOCOTE area is 32 km^2 in area with the east-west extension of about 6.4 kilometers and north-south extension of about 5 kilometers, situated in the northern part of the project district. The area is generally mountainous with steep slope, partly with flat plateaus, where the small settlements such as Plomosas, Mesa de la Cebada, El Cobre, El Cedral, El Tejocote, Peña Blanca, Molino and El Salto as well as Encarnación, are scattered.

The whole neighborhood of Encarnación including the surveyed area is known as one of the places of iron production in Mexico from the middle of the 19th century to the beginning of the 20th century, and the remains of iron mill at that time is found in Encarnación. Although Encarnación has been the center of the neighboring area since that time, the present population is estimated to be about 300 or 400 having decreased with increase of emigrants to Zimapán City and Mexico City in these years. The number of houses is several tens in Plomosas and Mesa de la Cebada, about 15 in El Cobre and several houses for each in other small settlements.

The highest point in the area is the top of Cerro Cangandhó, which is 2,830 meters above sea level, and the lowest point is at the river bed near Barranca del Durazno, which is 1,125 meters above sea level, the maximum difference of altitude being 1,705 meters. Although the topography is steep in general, plateaus with gentle slope are found at Mesa de la Cebada and Plomosas. Dolines with the diameter of 30 to 100 meters are mainly found on these plateaus and some are found on the ridge. Such topography is attributable to limestone of the El Doctor Formation predominated in the area. On the other hand, somewhat irregular river system is developed in the neighborhood of El Cobre, which is attributable to grano-dioritic intrusive rock distributed in such area.

Vegetation mainly of shrubs is found on the ridges and slope of mountain of the area, and some cultivated lands and pastures are scattered. Plants mainly consists of tall trees of conifers, but xenophilous desert plants are also found. The farm products in the cultivated land is mostly the corn, and sometimes peach and apple.

2-2-2 General Geology

General geology of the EL TEJOCOTE area consists of the thick-bedded to massive limestone member (Kdl) and the calcirudite member (Kdc) of the El Doctor Formation which belong to Cretaceous, the Tertiary El Morro fanglomerate (Tcg) and Tertiary intrusive rocks. The Tertiary intrusive rocks mainly consist of dioritic rocks (Tidi), and small basalt (Tiba) and andesite dykes (Tian) (see Fig. 2-2-1, 2-2-2 and PL 2-2-1).

El Doctor Formation

The formation predominantly distributed throughout the whole area is divided into two members, among which the thick-bedded to massive limestone member (Kdl) is overwhelmingly predominant and the calcirudite member (Kdc) is only locally distributed.

The thick-bedded to massive limestone member (Kdl) is composed of pale gray to dark gray, massive and non-bedded to thick-bedded

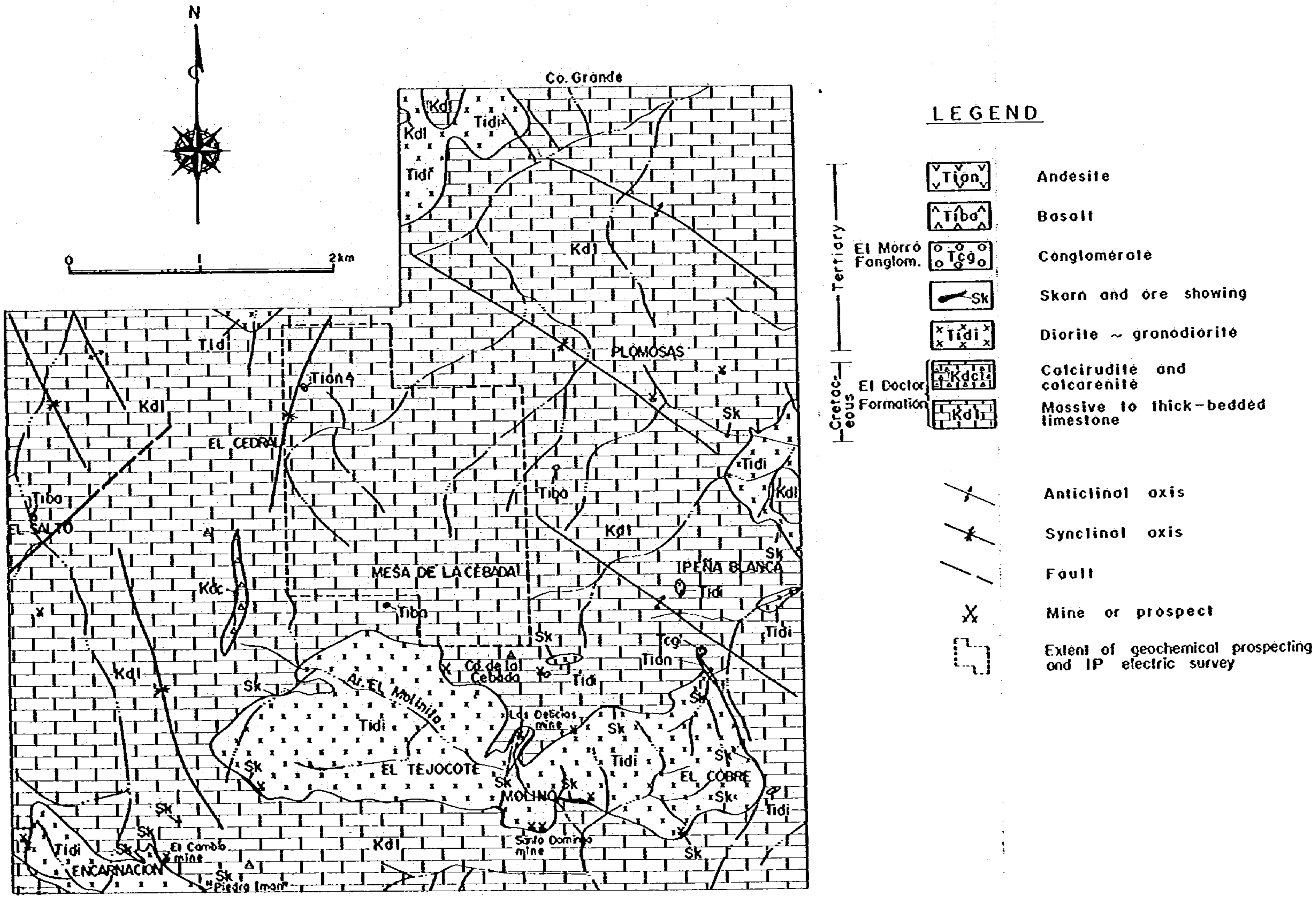
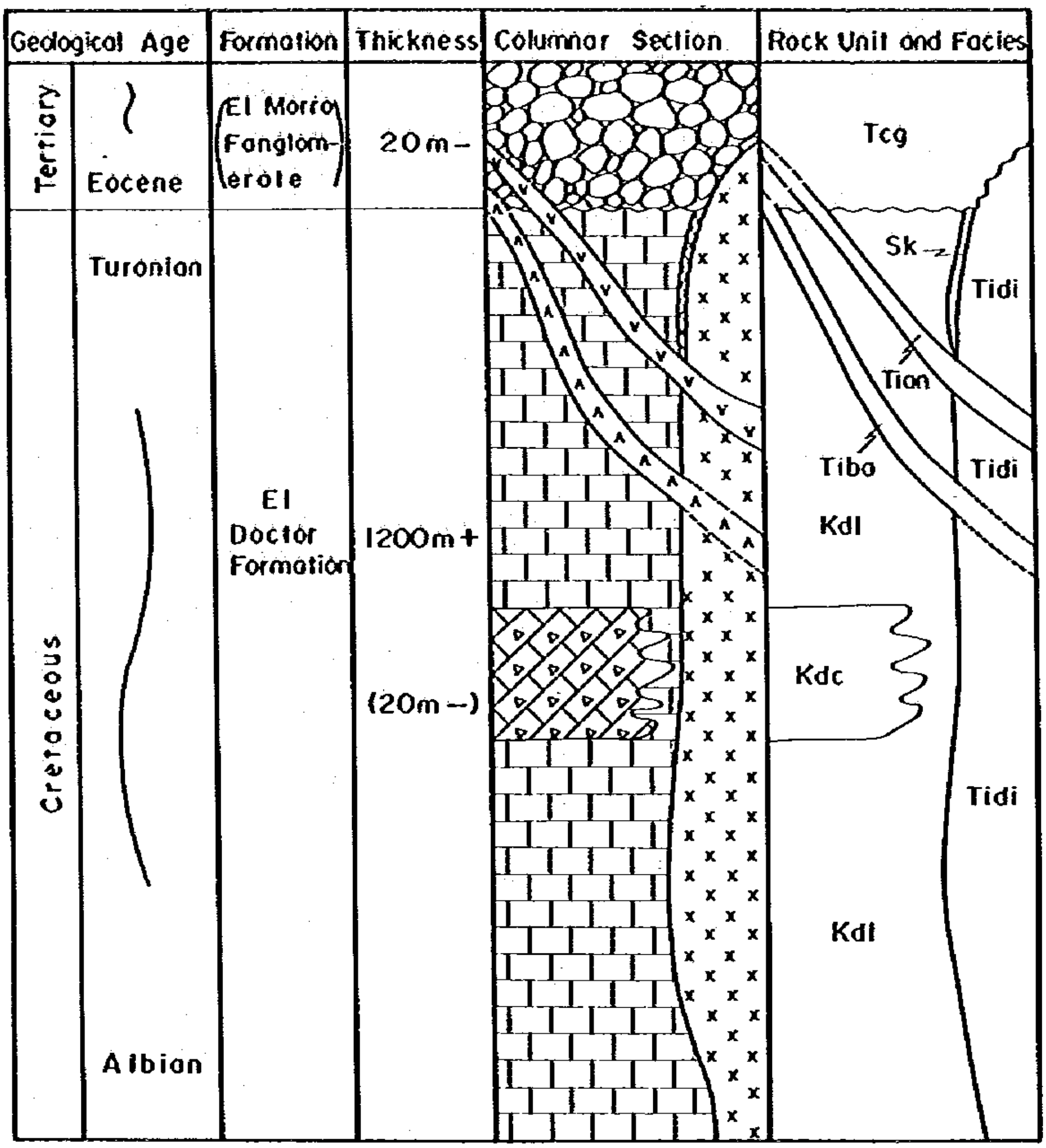


Fig. 2-2-1 Geological Map of the EL TEJOCOTE Area



Rock facies

Tian ,	andesite	Tcg ,	conglomerate
Tiba ,	basalt	Kdc ,	calcirudite and calcarenite
Tidi ,	diorite ~ granodiorite	Kdl ,	thick-bedded to massive limestone.
Sk ,	skarn and ore deposit		

Fig.2-2-2 Stratigraphic Column of the EL TEJOCOTE Area.

(0.4 ∿ 2 m) limestone (partly dolomitic), and it is estimated to be more than 1,200 meters in thickness. Limestone is generally micritic, but some parts are clastic with abundant medium-grained calcareous sand grains, partly containing fragments of rudistids etc. Most of the limestone have the odor of hydrogen sulfide and organic matter. The limestone is recrystallized in the surroundings of intrusive diorite to have become white saccharoidal. It has often been subjected to skarnization mainly of garnet and epidote at the contact with the intrusive rock to have been the place of emplacement of copper-bearing iron ore deposit. The calcirudite member (Kdc) is distributed in a lenticular form extending approximately in north-south direction in the vicinity of the road 1.3 kilometers to the west of Mesa de la Cebada, being in thickness less than 20 meters. Beside it, intercalations of calcirudite and calcarenite 1 to 3 meters thick are observed in limestone. These are, however, quite local and they were included in the limestone member on the geological map. The calcirudite is composed of breccia or subround pebble of gray limestone less than 10 centimeters in diameter, the interstices filled with gray calcareous matrix, being massive and non-bedded. Although no well-preserved fossil has been obtained in the area, the formation has been correlated to be from Albian to Turonian of Cretaceous by the regional geological survey until last year (JICA and MMAJ, 1980 and 1981).

El Morro Fanglomerate

The rock is exposed on a small scale in the hill side between El Cobre and Peña Blanca, the thickness being inferred to be less than 20 meters. The rock is composed of breccia or subangular breccia (less than 10 centimeters, commonly 0.3 ∿ 0.5 centimeters in diameter) of crystalline or non-crystalline, gray to pale gray limestone and pale reddish brown, limonitized limestone, cemented by brown calcareous matrix. The time of sedimentation seems to be later than the time of intrusion of dioritic rocks (Eocene), since the rock contains pebbles of crystalline limestone and of limonitized limestone, which leads to correspond to the El Morro fanglomerate exposed typically in the vicinity of Zimapán.

Tertiary Intrusive rocks

Dioritic rocks (Tidi) are most remarkable among the intrusive rocks on its scale of distribution. They are observed at eight places such as southwest of Cerro Grande, north of El Cedral, southeast of Plomosas, vicinity of Peña Blanca and the its east side, east of Cerro de la Cebada, the area from Arroyo El Molinito to El Cobre, and the vicinity of Encarnación. The largest one among these is distributed from Arroyo El Molinito to El Cobre extending in the east-west direction, having the extent of 1.3 kilometers in minor axis (maximum) and 4 kilometers in major axis. The exposures such as to the southwest of Cerro Grande and to the north of El Cedral are the both ends of the same rock body and the main mass is situated to the northwest of the area.

The rock exposed in the vicinity of Encarnación is a part of the main rock mass which is distributed to the southeast having the extent of 2.5 km x 2.5 km. These rocks are medium-grained quartz diorite composed of main component minerals such as augite, common hornblende, biotite, plagioclase, alkali-feldspar (orthoclase and perthite) and quartz, and accessory minerals such as apatite, titanite, rutile and magnetite. The lithofacies changes locally with places and rock bodies.

The MFA and alkali-lime index diagrams, and the ratio of Na_2O to K_2O based on the results of chemical analysis of rock samples taken from the five masses distributed in and around the area, show that the rocks belong to calc-alkali series (Table 2-2-1, Fig. 2-2-3).

Normative ratio of quartz-plagioclase-orthoclase of the rock mass in the southeast of Plomosas (A57DTC) shows that it corresponds to granodiorite, but other four masses are contained within the range of quartz monzodiorite (Fig. 2-2-4). The peripheral part of rock mass and some part of small stock and small dyke are fine-grained, and plagioclase and biotite display porphyritic texture. Also there found boulders of pale pink aplitic biotite granite and pale gray aplite dykes with 1 to 10 centimeters thickness which appear to be the products in the final stage of activity of the rocks. The aplite dykes are well exposed along the road near the Las Delicias mine. Although the alteration is generally weak excepting that by weathering, remarkable skarnization including epidotization is often observed near the contact with limestone.

The whole rock K-Ar age determination of the rocks showes 51.7 ± 2.6 ∿ 40.5 ± 2.0 Ma, which indicates early to late Eocene (Table 2-2-2).

Basalt (Tiba) is exposed as small stocks less than 3 meters thickness at El Salto, on the hill side about 1 kilometer to the southwest of Plomosas and to the south of Mesa de la Cebada. The rock at El Salto is dark gray, compact and fresh, but those found in other two parts are weathered, and rough and loose. The rock at El Salto is olivine-augite-common hornblende basalt.

Table 2-2-1 Chemical Compositions and CIPW Norms of the Dioritic Rocks in and around the EL TEJOCOTE Area

	Sample №	Cd134DTC	A57DTC	C102DTC	Cb1DTC	B500DTC
	Sample Locality	21Km WNW of Cerro Grande	2Km SE of Plomosas	Arroyo El Molinitno	0.9Km SE of Encarnación	3.8Km S of Encarnación
Chemical Composition	SiO_2 (%)	56.95	62.4	61.61	59.11	60.41
	TiO_2	1.34	0.76	0.83	1.00	0.83
	Al_2O_3	17.82	16.4	16.34	17.20	17.57
	Fe_2O_3	3.80	2.75	2.83	3.39	3.41
	FeO	3.59	2.50	2.73	2.80	2.03
	MnO	0.15	0.09	0.13	0.14	0.12
	MgO	3.36	1.76	2.44	2.58	2.00
	CaO	6.61	4.80	5.00	5.99	4.84
	Na_2O	3.25	3.50	3.48	3.83	4.14
	K_2O	2.02	2.46	2.99	2.78	3.54
	P_2O_5	0.31	0.39	0.39	0.45	0.32
	H_2O (+)	0.65	0.72	0.73	0.60	0.65
	H_2O (−)	0.10	0.51	0.51	0.11	0.48
	Total	99.95	99.04	100.01	99.98	100.34
Normative Composition	Quartz (%)	11.91	20.45	16.43	11.48	10.94
	Corundum	0	0.18	0	0	0
	Orthoclase	11.94	14.68	17.67	16.43	20.85
	Albite	27.51	29.90	29.44	32.41	34.91
	Anorthite	28.09	21.50	20.13	21.54	18.84
	Diopside	2.15	0	1.71	4.17	2.35
	Hypersthene	8.87	5.67	6.81	5.41	3.87
	Magnetite	5.51	4.03	4.10	4.92	4.51
	Hematite	0	0	0	0	0.29
	Ilmenite	2.55	1.46	1.58	1.90	1.57
	Apatite	0.71	0.91	0.90	1.04	0.73
	Salic tot.	79.45	86.71	83.67	81.86	85.54
	Femic tot.	19.79	12.07	15.10	17.44	13.32
	D.I.	51.4	65.03	63.5	60.3	66.7

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Table 2-2-2 K-Ar Whole-rock Ages of the Dioritic Rocks in and around the EL TEJOCOTE Area.

Sample №	Sample locality	K (%)	SCC$^{40}Ar^{R}$/mg×10^{-5}	$^{40}Ar^{R}$ (%)	Age (Ma)
Cd134DTC	2.1Km west-northwest of the Cerro Grande	1.76 1.75	0.269 0.290	74.8 74.2	*40.5±2.0
A57DTC	2Km southeast of Plomosas	2.06 2.06	0.413 0.426	87.8 84.6	51.7±2.6
C102DTC	Upstream of the Arroyo El Molinito	2.53 2.54	0.470 0.487	76.9 80.5	47.9±2.4
Cb1DTC	0.9Km south-southeast of Encarnación	2.29 2.29	0.458 0.460	79.5 80.2	50.9±2.5
B500DTC	3.8Km south of of Encarnación	2.96 2.99	0.556 0.567	81.8 79.3	47.8±2.4

$\lambda_\beta = 4.962\times10^{-10}\ yr^{-1}$, $\lambda_\varepsilon = 0.581\times10^{-10}\ yr^{-1}$, $^{40}K/K = 1.167\times10^{-4}$

All samples were analyzed in duplicate

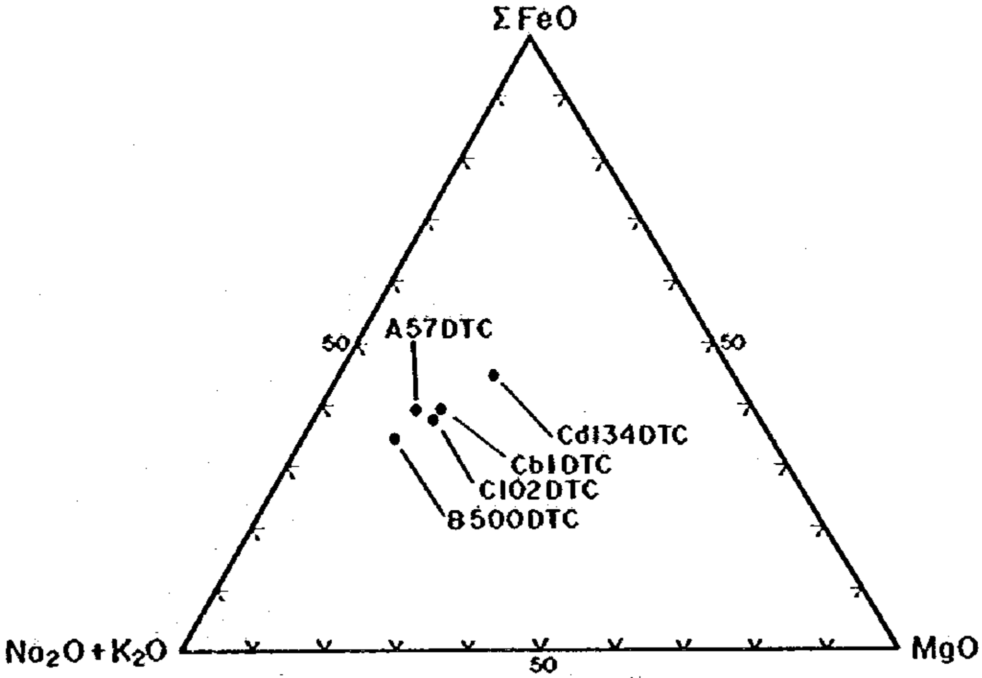
Cd134DTC: medium-grained augite-biotite-hornblende quartz diorite

A57DTC: medium-grained weakly porphyritic hornblende-biotite granodiorite

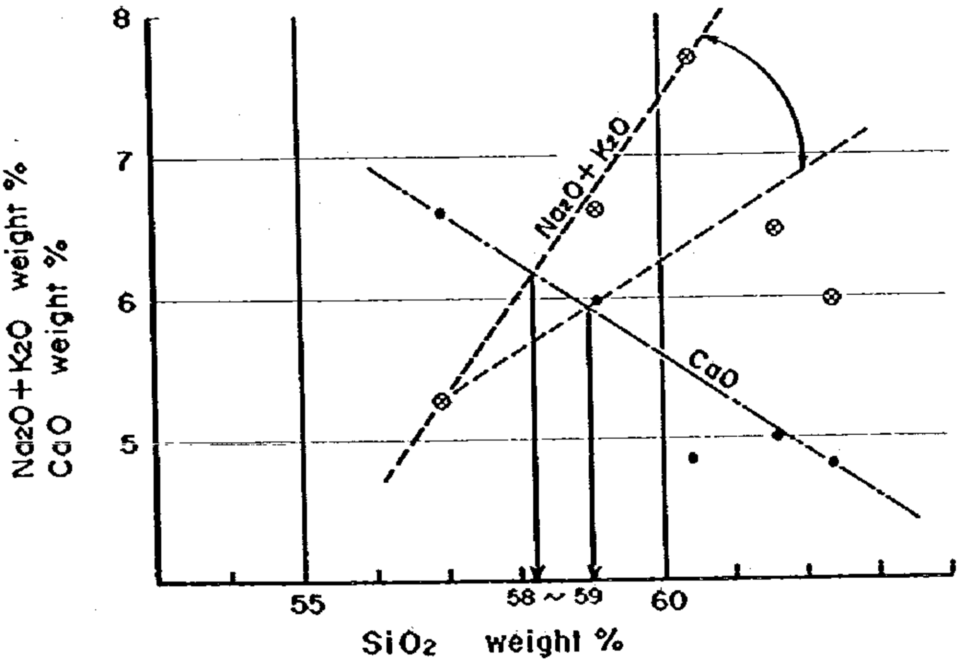
C102DTC: medium-grained biotite-hornblende quartz diorite

Cb1DTC: medium-grained augite-biotite-hornblende quartz diorite

B500DTC: medium-grained hornblende quartz diorite



MFA diagram (wt.% ratio)



Alkali-lime index diagram

Fig.2-2-3 MFA and Alkali-lime Index Diagrams for the Dioritic Rocks in and around the EL TEJOCOTE Area

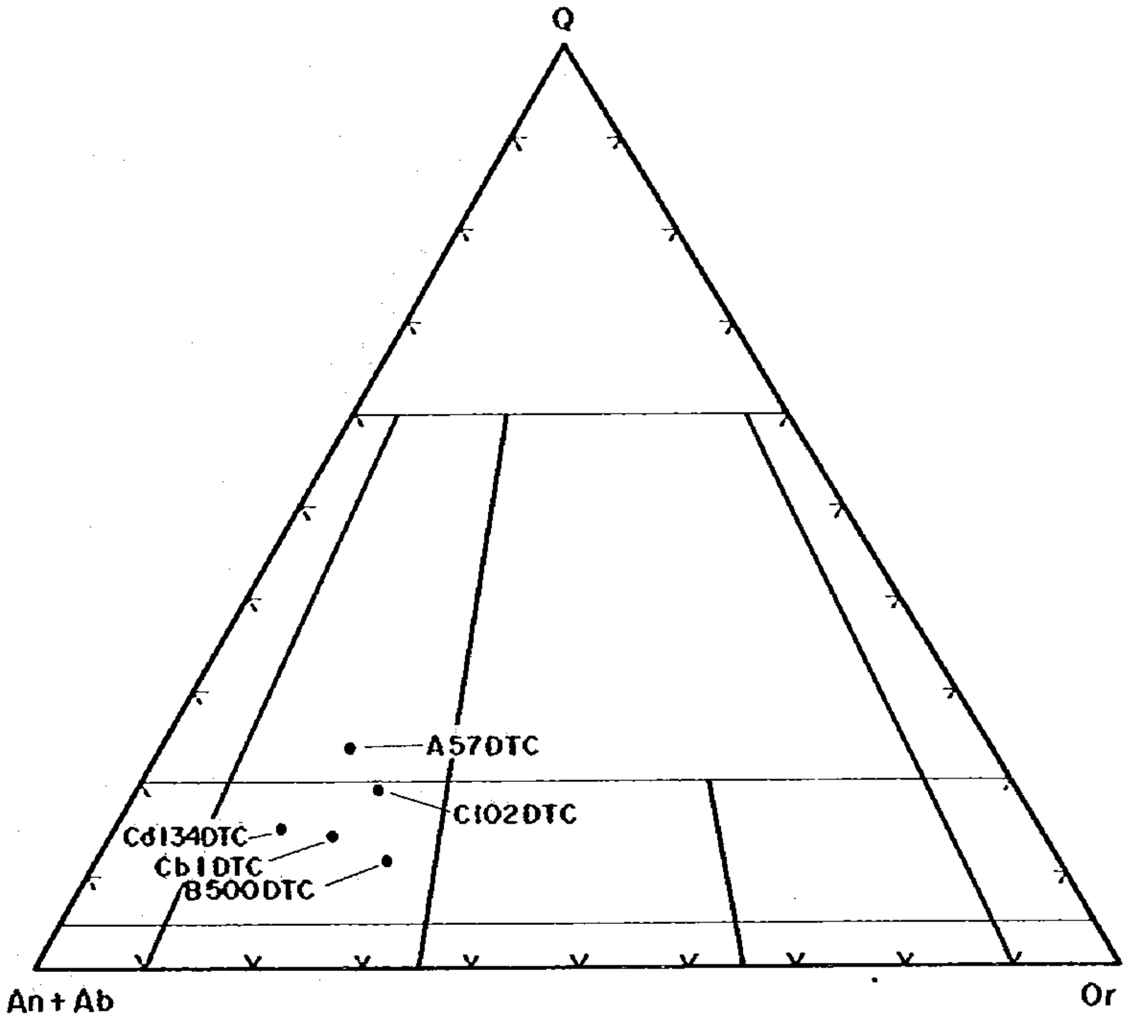


Fig.2-2-4 Normative Q-(An+Ab)-Or Diagram for the Dioritic Rocks in and around the EL TEJOCOTE Area.

Under the microscope, abundant phenocrysts of altered olivine, augite, brown common hornblende and plagioclase are observed in fine-grained holocrystalline groundmass composed of euhedral augite and lath-shaped pigioclase filling the interstices between the crystals of the former. The whole crystal of olivine is altered to calcite, serpentine and chlorite with only its outline having remained. It is considered that the rock belongs to Tba 1 among the activity of basaltic rocks in the district.

Andesite (Tian) is exposed near the ridge 0.8 kilometer to the northeast of El Cedral and on the mountain slope to the north of El Cobre. The occurrence of the former has not been made clear because of its poor exposure. The latter, however, has intruded into limestone and diorite as dyke (N35°W, 90°) with the extension of about 300 meters and 5 meters thickness. The rock is pale gray and compact in fresh part, and phenocrysts of long prismatic common hornblende are observed distinctly. Under the microscope, phenocrysts of plagioclase and pale green common hornblende are scattered in the groundmass composed of felted microlite aggregate of lath-shaped plagioclase and anhedral potash feldspar. It is observed that the phenocrysts of common hornblende are surrounded by microlite aggregate of augite(?), and a part of plagioclase has been replaced by calcite along the cleavage. The time of activity of the rock appears to be contemporaneous with andesite (Tan2) with the similar lithology distributed in the district, which is inferred to have been late Oligocene.

Geological Structure

The folding structures observed in the El Doctor Formation have the trends of folding axis such as NW-SE in the eastern part, NNW-SSE in the western part and NNE-SSW in the vicinity of El Cedral. Among these directions, that of NW-SE system is identical with the general trends of the whole district. It appears that the systems such as NNW-SSE and NNE-SSW are local structures developed from the major structure. The structural change of limestone is relatively notable in the surrounding area of Mesa de la Cebada, which is inferred to be due to the disturbance of structure caused by the intrusion of quartz diorite.

A fault which runs near El Salto with the trend of NE-SW is the sole and the greatest structure in the area. The southwestern extension of the fault continues for about 12 kilometers beyond the border of the area showing a character to cut transversely the Sierra Madre Oriental distributed in the region. Although it is difficult to estimate the throw of fault because of absence of key bed in the area, it has been estimated to be about 200 meters in the vicinity of El Cobre situated about 4 kilometers to the southwest of El Salto (JICA & MMAJ, 1981).

2-2-3 Ore Deposits

History of Mining and Outline of Ore Deposits

A record (Julis Guillermin, 1918) describes the production of iron before 1852 in the whole region of Encarnación including the EL TEJOCOTE area, and Encarnación was named to be a main iron producing center for Mexico City in the country at the time of around 1865, then the products was known as "Zimapán iron". At the remains of iron mill to be seen in Encarnación, the trace of machines which had been used in about 1911 such as those described in the following can be observed: a blast furnace (10 tons/day), three steel converters (125 kg capacity), three furnace (1 t capacity), two cupolas for small-scale smelting, one steam hammer, and two reduction rolls.

The El Cambio mine situated in the area seems to have been developed and operated during the period from 1850 to 1910. However, only the Santo Tomás mine (about 1.8 km to the south-southeast of Encarnación, outside of the area) was operating in 1911, the scale of mining of which had been being reduced at that time. Since those days, procurement of charcoal for smelting had been becoming more and more difficult. On top of it, difficulty of competition with imported iron from Europe and U.S.A. together with the economic disorder incurred by the Mexican Revolution (1910 ∿ 1917) led to the suspension of operation of iron mills, and all the mines were also closed.

In about 1966, Mr. Almando Martinez of Zimapán City reopened the Santo Tomás mine having leased the mining right from Mr. Patricio Honey, and the mines in the surrounding area such as Dulcas Nombres and San Francisco as well as the Las Delicias mine within the area were developed. The Aguila Roja mine (1.7 kilometers to the east-southeast of Encarnación, and outside of the area) was also developed in 1973. In almost all the mine, the operation seems to have been performed by open-cut mining by rock drill and in small underground drifts by hand-loading. In Aguila Roja, however, a kind of room and pillar method was adopted having used bulldozer and dump truck in underground because of its a little bigger scale of ore body [30 m (h) x 50 m (w) x 50 m (l)]. At present, the operation of all the mine except Aguila Roja has been suspended.

As mentioned above, contact metasomatism which has been accompanied by iron deposit (with or without copper) and copper deposit is observed in and around the area, and hydrothermal mineralization of vein type deposit (partly manto type) accompanied by small-scale lead and zinc mineralization is also found. The latters occur on the outside zone surrounding the dioritic intrusive rock, in contrast to the contact metasomatic deposits of iron and copper which have been emplaced at the contact of the intrusive rock with limestone (Table 2-2-3, Fig. 2-2-5, PL. 2-2-4).

Contact Metasomatic Deposit

The deposits occur in skarn zone found in various parts of contact between limestone and dioritic intrusive rock. Although the ore minerals of these deposits mainly consist of iron (magnetite) accompanied by copper (chalcopyrite and secondary malachite) in general, there found the deposits mostly composed of magnetite scarcely accompanied by copper minerals, and those on the contrary, as can be seen in the Santo Domingo mine and in other mineralized skarn, such as with very scarce amount of magnetite having dissemination of malachite in limonite which has been derived from sulfide minerals. Fig. 2-2-5 shows the distribution of these deposits in the area, and the ore deposits are described in the following.

(i) Las Delicias Mine (No. 20, Mine Lot No. 3085, 6.0 ha in area)

It is situated in the southeastern part of limestone projected into quartz diorite in a long and narrow zone in the form of roof pendant. The extent of mineralized zone is about 20 meters in

Table 2-2-3 Mines, Prospects and Ore Showings in the EL TEJOCOTE Area

Index ☆No.	Name of Mine	Type of Mineralization	Scale of Orebody (m)	Ore Minerals	Gangue Minerals	Workings
①	Prospect	Ht vein	1.2(w), +10(l)	lm, jr	ca, qz?	2 shafts
②	Prospect	Ht veinlets	0.3(w), +3 (l)	lm, jr	ca	2 pits
③	Outcrop	Ht veinlets(manto)	3.0(w), 15(l)	lm, jr	ca	–
④	(Floats)	Pm	?	mg, py	ga, ep	–
⑤	Outcrop	Pm	+1.0(w), 10(l)	mg, ml	ga, ca	–
⑥	(Floats)	Ht(?)	?	lm, jr	ca	–
⑦	(Floats)	Ht(?)	?	lm	–	–
⑧	Outcrop	Ht network	1.0(w), 2(l)	lm, jr	ca	–
⑨	Outcrop	Pm	1.5(w)	mg	ca, ga	–
⑩	(Floats)	Pm	?	mg	–	–
⑪	Outcrop	Pm	+3 (w), 10(l)	mg	ca	–
⑫	Prospect	Pm and Ht vein	0.3(w), +2(l)	lm, mg, ml	ca, ga	1 pit
⑬	Outcrop	Pm	+1 (w), 20(l)	mg, lm	ep, ga, ca	–
⑭	Nameless working	Pm	1.0(w), 18(l)	mg, ml	ga, ep, ca	3 pits
⑮	Nameless working	Pm	2.5(w)	mg	ga, ca	1 tunnel
⑯	Outcrop	Pm	2.0(w)	lm, ml	–	–
⑰	Prospect	Pm	1.5(w)	mg, cp, py, po, ml	ga, ca	2 pits
⑱	Las Delicias	Pm	1.6(w), 40(l)	mg, cp, py, po, ml	ga, ep, ca	2 pits, 1 tunnel
⑲	Outcrops	Pm	+1.6(w), 90(l)	lm	ga, ep, ca	–
⑳	Prospect	Pm	1.2(w), 20(l)	ml, lm	ga, ep, ca	1 shaft-tunnel
㉑	Santo Domingo 1	Pm	2.5(w)	lm	ga, ep, wo	1 shaft, 1pit
㉒	Santo Domingo 2	Ht vein	1.0(w)	lm	ca	1 shaft-tunnel
㉓	Outcrop	Pm	1.0(w)	py, lm	ep, ca	–
㉔	Outcrop	Pm	+1.0(w)	lm	ca	–
㉕	Prospect	Pm	1.5(w)	py, lm	ga, ep, ca	1 shaft, 1 tunnel
㉖	Outcrop	Ht vein	0.4~0.8(w)	ml, lm	ca	–
㉗	El Cambio	Pm	1.5(w), 40(l)	mg, cp, py, ml	ga, ep, ca	3 tunnels
㉘	"Piedra Iman"	Pm	5(w), 30(l)	mg, ml	ga, ep, ca	–
㉙	Nameless working	Ht ~ Pm	1.5(w)	mg, lm	ga, qz, ca	open pit
㉚	Nameless working	Ht cavity-filling	5(w), 8(l)	lm, jr	ca	1 tunnel
㉛	Prospect	Ht vein	3~4(w)	mg	–	1 pit
㉜	(Floats)	Pm	?	ba	ca, qz	–

Abbreviations: Ht, Hydrothermal; Pm, Pyrometasomatic; w, width, l; length; mg, magnetite; cp; chalcopyrite; py, pyrite; po; pyrrhotite; ml, malachite; lm, limonite; jr, jarosite; ba, barite; ga, garnet; ep, epidote; ca, calcite; qz, quartz.

☆ Index number corresponds number of mines on the Fig. 2-2-5

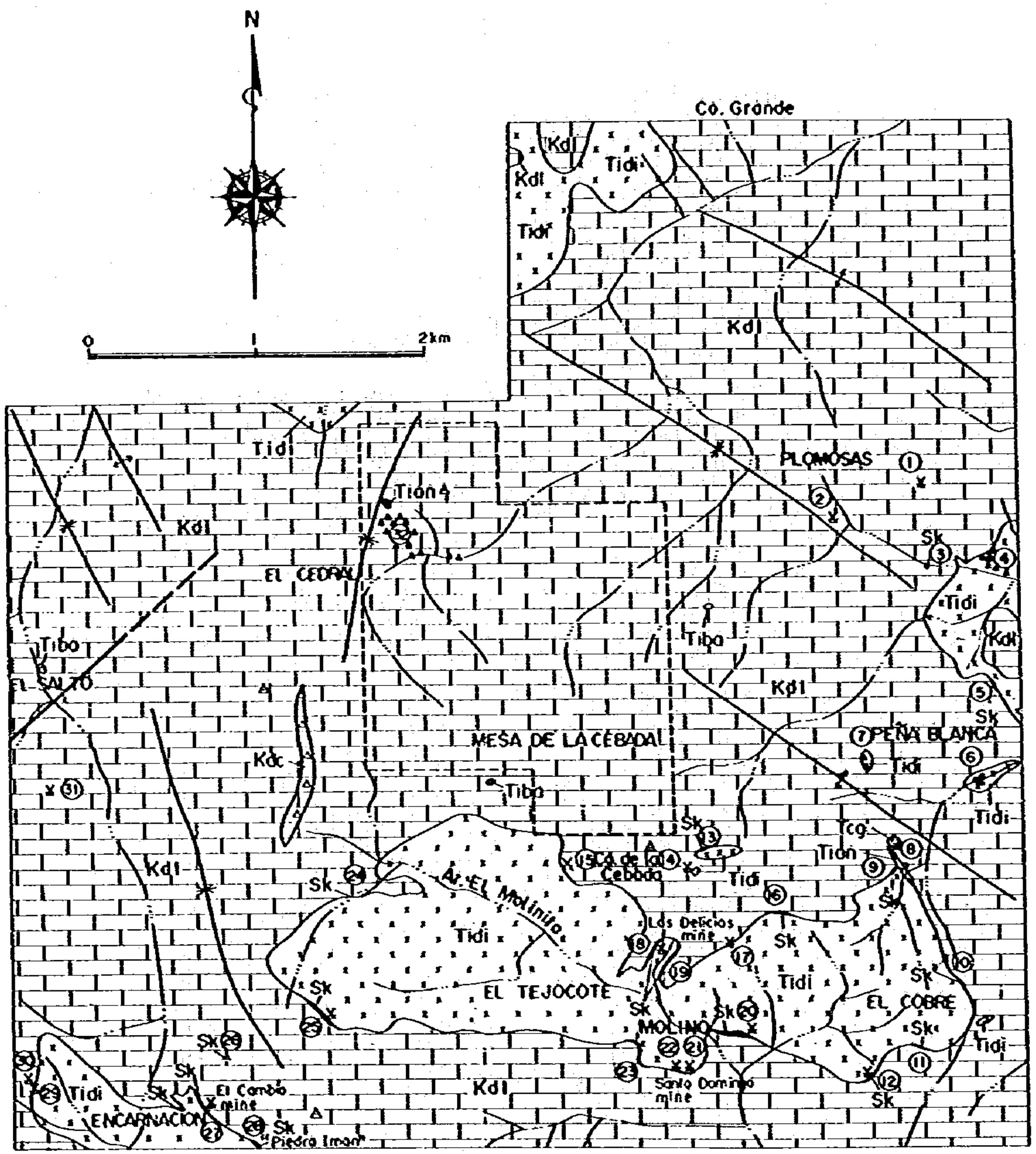
Table 2-2-4 Metal Contents of Ore Samples from the EL TEJOCOTE Area

Ser. No.	Sample No.	☆Index No. and Name of Mine	Au g/t	Ag g/t	Cu %	Pb %	Zn %	T.Fe %
1	A14M	① Prospect	—	65	—	1.8	3.73	—
2	A13M	② Prospect	—	23	—	0.74	39.2	—
3	A21M	④ Outcrop	—	9	0.06	0.01	0.03	—
4	A25M	③ (Floats)	—	44	0.68	0.01	0.26	—
5	A55M	⑤ Outcrop	—	—	1.3	—	—	—
6	A 6M	⑥ (Floats)	—	—	0.07	0.01	0.09	—
7	A31M	⑧ Outcrop	—	12	—	0.17	0.64	—
8	A10M	⑫ Prospect	—	—	0.14	0.01	—	—
9	C12MR*	⑬ Outcrop	0.02	2	0.042	0.002	0.11	—
10	A58M	⑭ Nameless mine	—	—	3.3	—	—	38
11	A15M	⑮ Prospect	—	16	1.4	—	—	—
12	C103MR*	⑱ Las Delicias	0.19	30	2.02	0.004	0.24	—
13	A19M	⑱ Las Delicias	0.26	20	1.4	—	—	44
14	A20M	⑱ Las Delicias	—	13	1.8	—	—	—
15	A40M	㉑ Santo Domingo 1	2.0	66	1.8	0.02	0.04	—
16	A39M	㉒ Santo Domingo 2	—	11	1.4	1.3	1.57	—
17	A38M	㉓ Outcrop	—	20	0.02	0.03	0.34	—
18	eA20M	㉔ Outcrop	—	0.5	0.029	0.003	—	—
19	A35M	㉕ Prospect	—	9.	0.38	0.01	0.04	—
20	eA7M	㉖ Outcrop	—	0.7	0.016	0.003	—	—
21	eA3M	㉗ El Cambio	—	45.4	0.192	0.003	—	—
22	eA6M	㉗ El Cambio	—	9.3	0.192	0.004	—	—
23	A62M	㉗ El Cambio	1.6	66	2.3	0.02	0.12	29
24	A63M	㉘ "Piedra Iman"	—	—	0.42	—	—	62
25	A43M	㉙ Nameless mine	—	50	0.01	0.44	—	—
26	A45M	㉛ Nameless mine	0.11	2	0.25	0.01	0.18	—
27	eA9M	㉜ (Floats)	—	0.7	0.003	0.011	—	—
28	eA12MR	㉜ (Floats)	—	7	0.01	0.02	0.15	62

(—: not analyzed)

* Samples were analyzed in the phase II (JICA and MMAJ 1981)

☆ Index number corresponds number of mine on the Fig 2-2-5



LEGEND

Tertiary	Tian	Andesite
	Tiba	Basalt
El Morro Fanglom.	Tcg	Conglomerate
	Sk	Skarn and ore showing
	Tidi	Diorite ~ granodiorite
Cretaceous — El Doctor Formation	Kdcl	Calcirudite and calcarenite
	Kdl	Massive to thick-bedded limestone
	▲▲	Ore floats

No.	Name of mine	Metals	No.	Name of mine	Metals
①	Prospect	Pb < Zn	⑰	Prospect	(Cu)
②	Prospect	Pb≪Zn	⑱	Los Delicias	Fe≫Cu
③	Outcrop	(Trace)	⑲	Outcrops	Fe≫Cu
④	(Floats)	Fe⋙Cu	⑳	Prospect	(Trace)
⑤	Outcrop	Fe≫Cu	㉑	Santo Domingo	Cu
⑥	(Floats)	(Trace)	㉒	Santo Domingo	Cu-Pb-Zn
⑦	(Floats)	(Trace)	㉓	Outcrop	(Trace)
⑧	Outcrop	(Trace)	㉔	Outcrop	(Trace)
⑨	Outcrop	Fe	㉕	Prospects	(Cu)
⑩	Outcrop	Fe	㉖	Outcrop	(Trace)
⑪	Outcrop	Fe	㉗	El Cambio	Fe≫Cu
⑫	Prospect	Fe⋙Cu	㉘	"Piedra Iman"	Fe⋙Cu
⑬	Outcrops	Fe	㉙	Prospect	(Pb-Zn)
⑭	Nameless mine	Fe≫Cu	㉚	Nameless mine	(Cu)
⑮	Prospect	Fe≫Cu	㉛	Prospect	(Ba)
⑯	Outcrop	Fe	㉜	(Floats)	Fe

Fig.2-2-5. Location Map of the Mines, Prospects and Ore Showings in the EL TEJOCOTE Area.

maximum width and about 100 meters in length, and another mineralized skarn (No. 19) with maximum width of about 18 meters and extension of more than 100 meters occurs to the southeast across the quartz diorite body (see Fig. 2-2-6).

Small tongue-shaped diorite put between limestone is slightly porphyritic, and has been markedly epidotized at the boundary with skarn and along the cracks. The ore deposit consists of two types, that is, ordinary skarn type deposit in which magnetite and sulfide minerals are contained in garnet-epidote skarn in width of 12 meters and vein type of magnetite with sulfide minerals, dipping gently or steeply (see Fig. 2-2-7). The latter is the magnetite vein disseminated with small amount of pyrite, pyrrhotite and chalcopyrite, and scarecely contains any gangue mineral. The steeply dipping veins fill the irregular fissures in limestone on the wall of open pit and are generally small on a scale. Some veins, however, are larger in underground, reaching more than 2 meters in width and more than 20 meters in extension. The gently dipping vein has apparent 1 to 2 meters thickness, and can be observed for about 45 meters along the intermittent outcrop, which seems to have been emplaced with a manto-form in the limestone. This manto-type deposit seems to have been formed by deposition of iron and copper from mineralizing solution which passed through limestone along fissure having encountered porous part or cavity, because it is connected with the steeply dipping vein in the lower part (Fig. 2-2-8). Among the samples taken from the ore stock, the magnetite ore showed the grades such as Total Fe 44% and Cu 1.4 ∿ 2.0%, and the skarn ore disseminated with chalcopyrite and pyrite showed Cu 1.8%. No notable assay value was obtained on the components of gold, silver, lead and zinc (Table 2-2-4). In the southern mineralized skarn zone across quartz diorite, the ore grade is lower than that of the old mine of Las Delicias, although small-scale concentration of pyrrhotite and malachite were observed.

The estimation of ore reserve in the vicinity of the Las Delicias mine, assuming the cut-off grade to be total Fe 55% and Cu 1%, resulted in to be 50,000 tons.

(ii) El Cambio Mine (No. 27, Mine Lot No. 916, 6.0 ha)

The mine is located at the place where irregular tongue-shaped quartz diorite projected into limestone. In this part, garnet-epidote skarn zone with 5 meters maximum width and about 300 meters extension is formed along the boundary between limestone and quartz diorite. The entrance of main adit is located at a little above the road, and further above a mark of the mine lot and an abandoned adit are found. Beside these, a prospecting pit (S64°E, 15 m in length) has been excavated at the place about 180 meters to the southeast of the entrance of main adit. A strong mineralization is recognized in the neighborhood of the mark of mine lot, and a little amount of malachite and magnetite is observed in skarn zone of 5 meters width near the road about 100 meters to the southwest of the entrance of main adit. In the main adit, the mineralized skarn can be observed at the point about 40 meters from the entrance, which continues to the heading (Fig. 2-2-9). The mineralized skarn has been formed in altered diorite intricately cut by small faults in the form of vein (less than 1 meter in width). Some old raises are found in the mineralized zone, to which no access is permitted at present.

The prospecting cross-cut about 180 meters to the southeast of the main adit grazes along a weakly mineralized garnet skarn at the entrance (4 meters along the northeastern wall), and pass through quartz diorite to the end of the cross-cut where a wollastonite-calcite vein (40 centimeters in width with strike and dip of N40°E and 85°SE) is exposed. The analysis of ore samples showed the following result, such as Cu 0.19% of the ore (eA3M) at the heading of cross-cut, Cu 2.3% and Ag 66 g/t of the remained ore (A62M) at the mark of mine lot, and Cu 0.19% and Ag 9.3 g/t of the mineralized skarn (eA6M) at about 100 meters to the southwest of the entrance of main adit, showing that the mineralization is smaller on a scale and lower in grade than that of the Las Delicias mine mentioned above.

(iii) Santo Domingo Mine (No. 21 and 22)

The mine is located on the southern side among the two mineralized zones exposed on both northern and southern sides of quartz diorite (the northern side is occupied by the Delicias mine). There found an old small-scale open pit (2 m in width, 7 m in length, 5 m in depth), an inclined shaft (-60°, more than 15 m in depth) and an adit in the area of Santo Domingo No. 21. Further about 80 meters to the west from there, a winze 5 meters deep is found, from the bottom of which a level extends to S15°W (Santo Domingo No. 22). In Santo Domingo No. 21, wollastonite-garnet-epidote skarn has formed on both sides of quartz diorite which intruded into limestone, and the dyke itself has been subjected to skarnization, and about 2 meters width of which has been left to be able to be seen at present (Fig. 2-2-10). The primary ore minerals are pyrite and chalcopyrite disseminated in

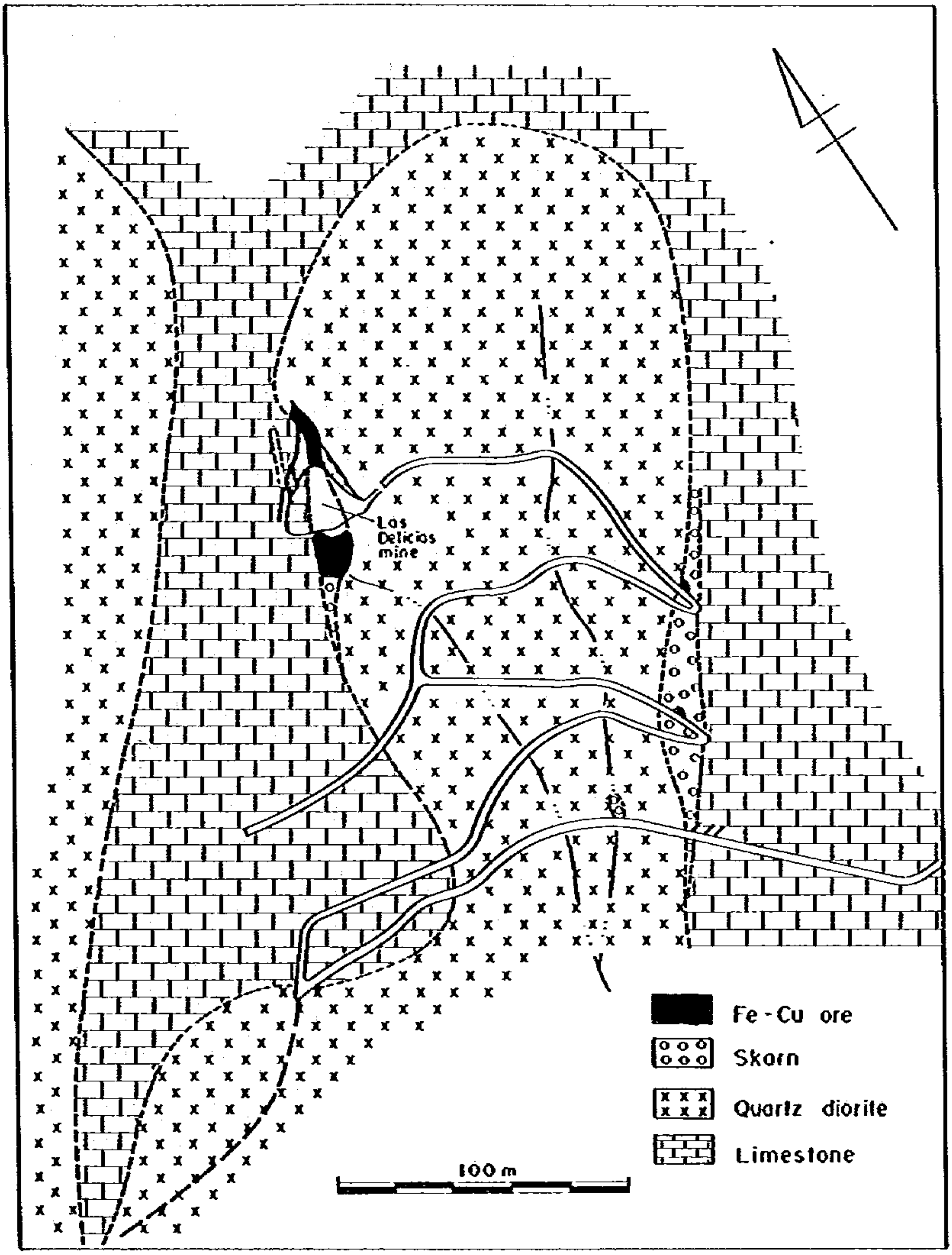


Fig. 2-2-6 Geological Sketch Map of the Las Delicias Mine Area.

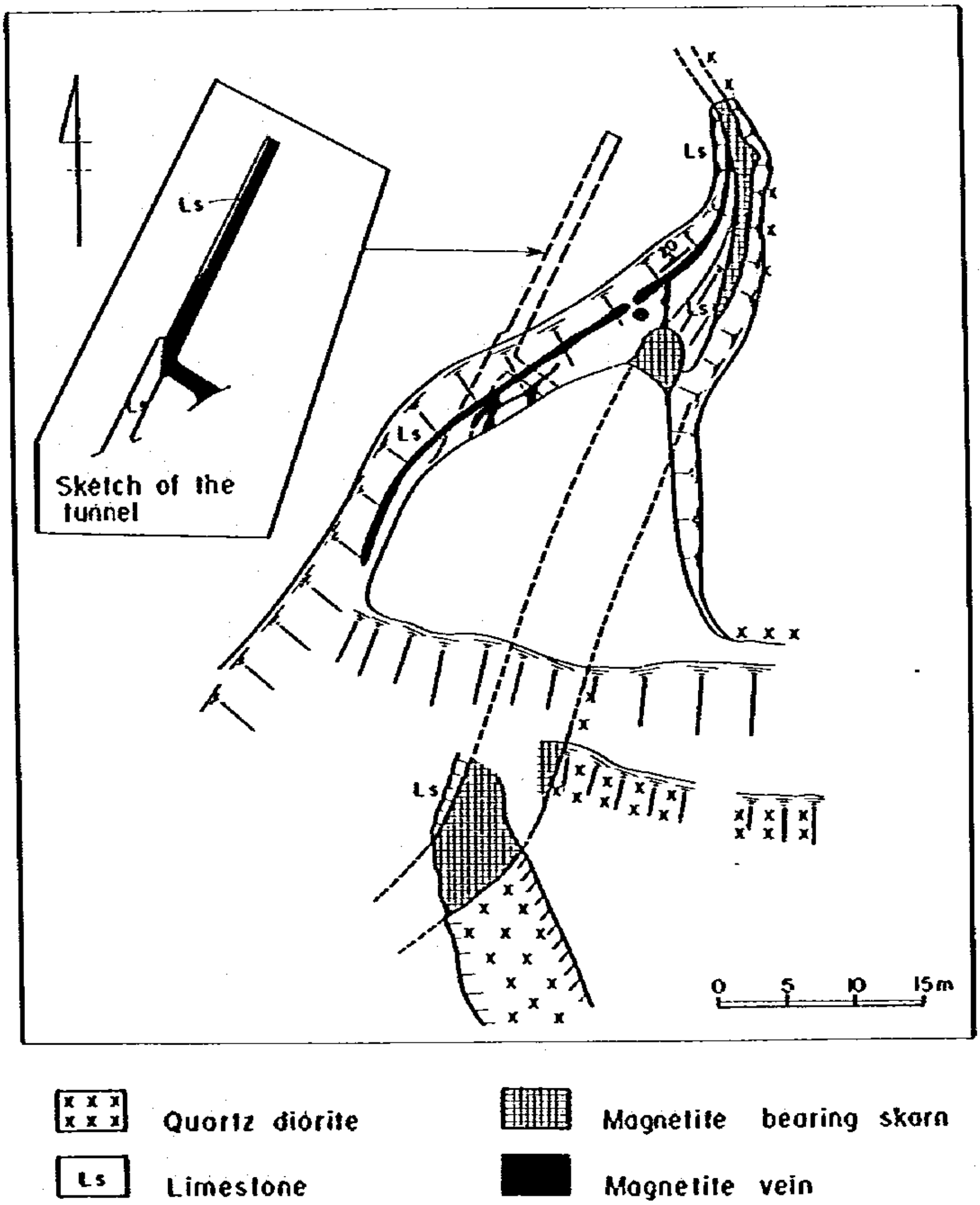


Fig. 2-2-7 Geological Sketch Map of the Las Delicias Mine.

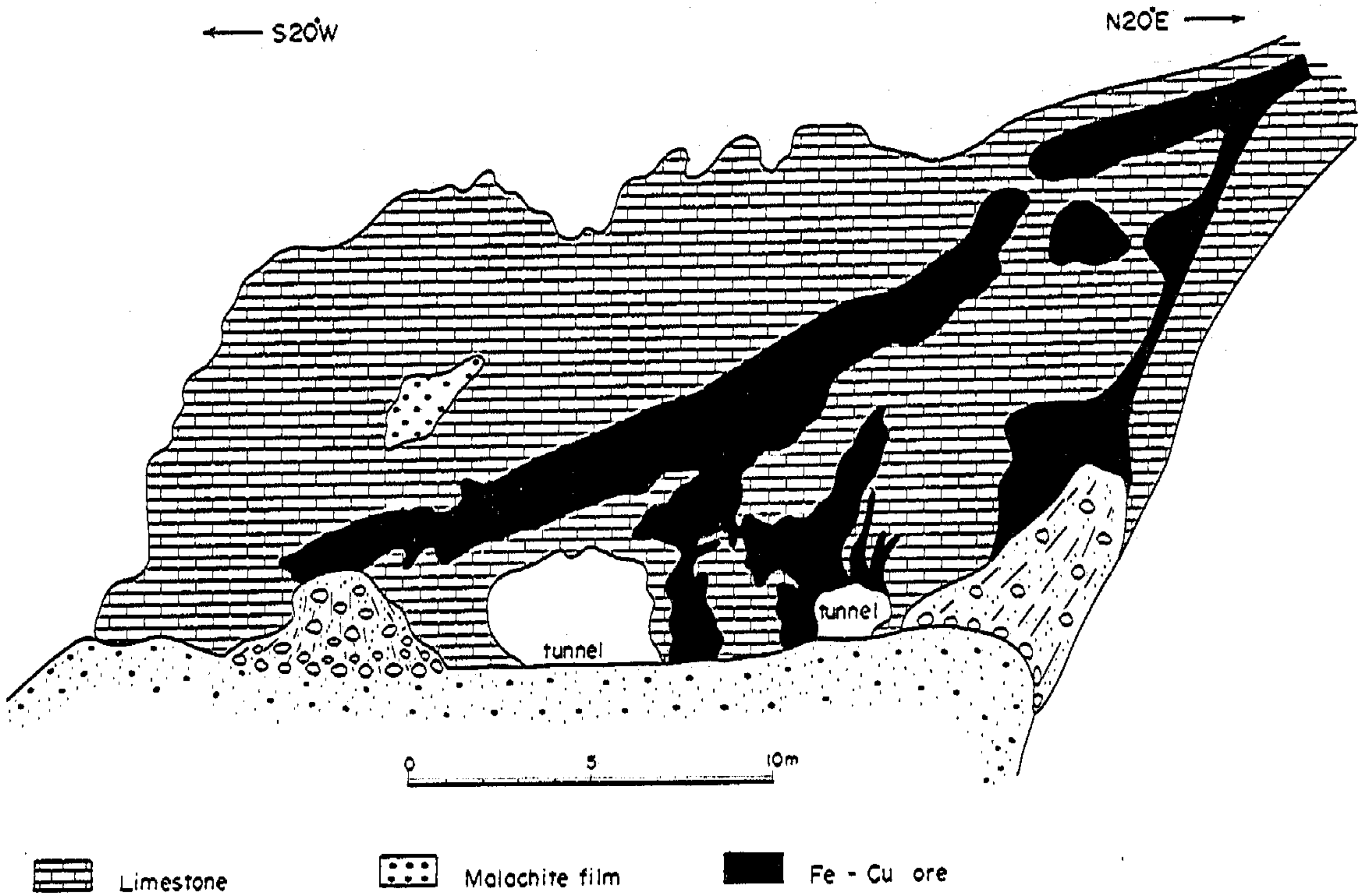


Fig. 2-2-8 Geological Sketch of the Main Face of the Las Delicias Mine.

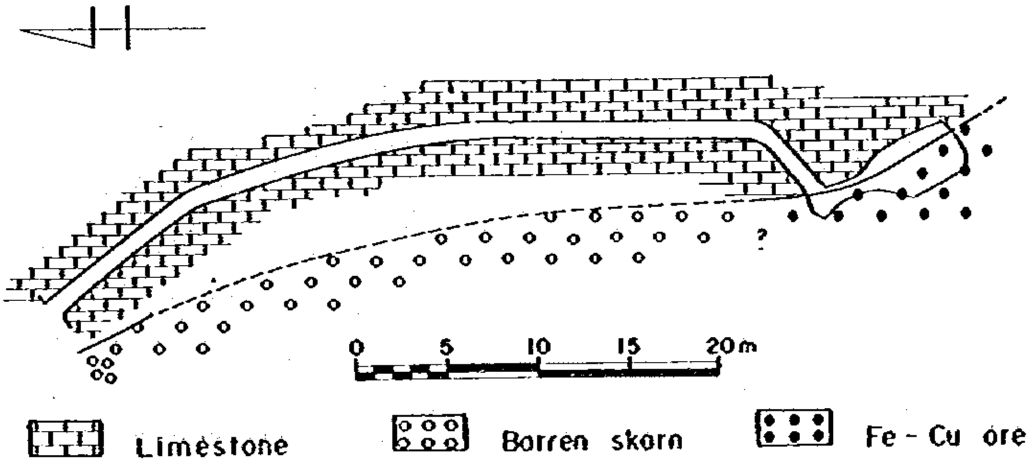


Fig. 2-2-9 Geological Sketch of the Main Adit of the El Cambio Mine.

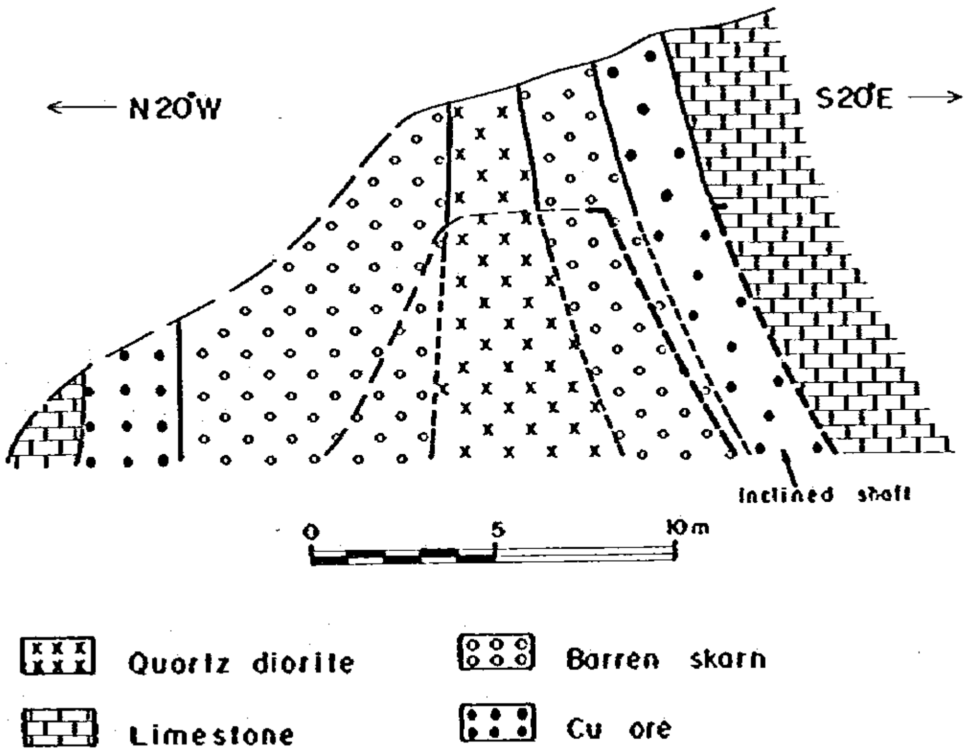


Fig. 2-2-10 Schematic Profile of the Santo Domingo Mine.

skarn and the secondary minerals to be observed are limonite, malachite, chrysocolla and azurite filling the cracks in skarn. The ore minerals are tend to be concentrated in a position close to limestone, and the copper minerals are found relatively concentrated in the range of about 2 meters from limestone in the south-southeastern side (on the side of the inclined shaft) and in the range of about 2.5 meters on the north-northwestern side. The result of analysis of the ore remained at the entrance of the inclined shaft (sample No. A40M) showed Cu 1.8% and Ag 66 g/t. The level was excavated through limestone, but its detail could not be made clear. At Santo Domingo No. 22, a limonitized ore vein of 1 meter width (N15°E, 90°) is found in limestone, and surrounding limestone is weakly silicified. The sample taken from the vein (the whole vein width, sample No. A39M) showed the grades of Cu 1.4%, Pb 1.3%, Zn 1.57% and Ag 11 g/t, showing the occurrence of lead and zinc beside copper. An epidote skarn zone (No. 23) of more than 10 meters thickness is found further 200 meters to the west from there, and limonite gossan can be seen on the surface.

The result of analysis of a representative sample taken from here (A38M) showed Cu 0.02%, Pb 0.03%, Zn 0.34% and Ag 20 g/t.

As described above, magnetite is absent in the mineralization of the Santo Domingo mine which is different from that of both mines of Las Delicias and El Cambio. Though on a small scale, it seems that it is pyrometasomatic copper mineralization of the later stage at the contact between the intrusive rock and limestone, and in a position further apart from the intrusive rock, vein type mineralization of copper, lead and zinc are observed. It is considred, therefore, that these show an excellent example of zonal arrangement of the mineralization in this area.

In addition to the above three mines, several unnamed small-scale old workings and prospecting are found in the area, and they are described in the order of the scale of mineralization.

On the northwestern side of a small stock of quartz diorite at the point 0.2 kilometers to the southeast of Cerro de la Cebada, several old workings of about 3 meters depth are found in an extent of approximately 20 m x 10 m (No. 14). In this part, occurrence of magnetite is similar to that of the Las Delicias mine. Magnetite is concentrated along the boundary between limestone and quartz diorite in a width of about 1 meter, and in addition, a vein of 1 meter thickness (N30°W, 90°) and lenses with thickness of 0.4 meters to 1 meter are found in limestone.

Skarn mineral consists mainly of epidote, and ore minerals are malachite as well as magnetite. A sample from the ore bank showed the grades such as Cu 3.3% and Total Fe 38%.

At the point of 0.5 kilometers to the west-southwest of Cerro de la Cebada, a prospecting cross-cut (No. 15) about 10 meters long has been excavated in limestone in the direction of N10°E. A skarn zone containing magnetite malachite and chrysocolla is observed on the western wall in the range from 4 meters to 6.5 meters from the entrance of the cross-cut. In addition, a quartz diorite dyke (20 centimeters width, N80°E, 90°) intruded into limestone at the 8 m point, and it is observed that limestone in the surroundings of quartz diorite is partly epidotized. A sample from the mineralized skarn (A15M) showed Cu 1.4%.

A collapsed mine working (No. 12) is found at the point 0.4 kilometers to the east of Cerro de la Ayuda, in which remained patches of magnetite (rarely contain malachite) are scattered. In this neighborhood, a pit which followed the limonitized ore vein (30 centimeters width, N45°W, 70°E) in limestone for about 2 meters is found. Although malachite is observed locally on the surface of the pit-wall, the sample taken from this part (A10M) showed low grade of Cu 0.14% and Pb 0.01%.

A very small-scale limonitized garnet skarn zone (about 3 meters width) occurs at the point 0.8 kilometers to the southeast of Cerro de la Cebada, in which some malachite dissemination is observed, and it was prospected (the trace of prospecting No. 17). An occurrence of epidote-garnet skarn zone of 40 meters maximum width with almost absence of mineralization is found at the point (topographical saddle) 0.7 kilometers to the east of Molino. An old prospecting level was extended from the bottom of a winze with the depth of about 4 meters excavated in limonitized zone (about 2 meters width) which is on the extension of the skarn zone above mentioned. No notable mineralization was observed.

A garnet-epidote skarn zone of 12 meters maximum width and about 200 meters extension is observed at the point 0.5 kilometer to the north of Cerro Cangandhó, which mineralization is generally weak. Dissemination of a small amount of pyrite (with chalcopyrite) is partly observed, and it was prospected by a shaft of 5 meters depth and an inclined shaft of 4 meters length (No. 25). A small amount of pyrite dissemination is observed in the waste of the former, and dark reddish brown limonite with pale yellowish-brown jarosite-filled vesicules is mixed in the remained ore of the latter. The result of analysis of the sample (A35M) showed the grades such as Cu 0.38%, Pb 0.01%, Zn 0.04% and Ag 9 g/t, indicating the content of a little amount of copper.

Beside the above old mine workings and old test pit, unexplored outcrops of malachite and magnetite are scattered everywhere near the contact between quartz diorite and limestone. The largest one among these is the outcrop (No. 28) called "Piedra Iman" by the local residents located 0.4 kilometers to the south-west of Cerro Cangandhó which is exposed in such scale as 5 meters thickness, about 30 meters extension on the strike side and about 20 meters length on the dip side. In the outcrop, magnetite ore containing small amount of malachite is concentrated on the limestone side to form a ore body, accompanied by garnet skarn zone (3 meters width) on the outside. The assay values of the representative sample of the ore are Cu 0.42% and Total Fe 62%.

Beside it, outcrops of malachite and magnetite are observed on the hillside (No. 5) of 0.9 kilometer to the east-northeast of Peña Blanca, along a mountain path 0.8 kilometer south-southeast of Peña Blanca (No. 9), the surrounding area of El Cobre (No. 10, 11) and along the road to the east of Cerro de la Cebada (No. 13, 16), but these are generally small in scale (Table 2-2-5).

Table 2-2-5 Metal Contents of Ore Samples from the Mines around the EL TEJOCOTE Area

Ser No.	Sample No.	Name of Mine	Au g/t	Ag g/t	Cu %	Pb %	Zn %	T.Fe %	Mn %
1	A46M	Corral Viejo	0.30	17	1.1	0.02	0.28	-	-
2	A49M	ditto	-	100	4.0	-	-	-	-
3	A66M	Nuevo Encino Prieto	6.7	130	0.32	8.5	5.78	18	1.30

In addition to these mineralized outcrops, there are some cases that many boulders of magnetite (with or without copper) or limonitized skarn are present to have been lumped together. For example, along the creek 1.2 kilometers to the southeast of Plomosas, abundant boulders of magnetite mass 1 meter in diameter or less than that are found which is estimated to be several tons in total, and boulders of pale green garnet-epidote skarn are scattered nearby. A part of the magnetite mass contains pyrite and chalcopyrite. The assay result of the sample (A25M) taken from such part showed the grades such as Cu 0.68%, Pb 0.01%, Zn 0.26% and Ag 44 g/t. Boulders of limonitized garnet skarn are found along the creek 0.8 kilometers to the east-southeast of Paña Blanca (No. 6), but no noticeable analytical value has been shown.

In the vicinity of El Cedral (No. 32), abundant boulders and pebbles of magnetite (about 10 tons) are found. The result of analysis of a representative sample (eA 12 MR) showed Cu 0.01%, Pb 0.02%, Zn 0.15%, Ag 7 g/t and Total Fe 62%.

Among these ore boulders, those found at No. 4 and No. 6 are considered to be close to the original source because they are positioned close to the contact between quartz diorite and limestone. On the contrary, although quartz diorite is found in vicinity of the ore boulders at No. 32, it is strongly possible that they have not been derived from the near 'in situ' source because of neither intrusive rocks nor skarnization in the limestone found close to their occurrence.

Hydrothermal Vein to Manto Type Ore deposits

As mentioned above, pyrometasomatic mineralizations represented mainly by magnetite with skarn minerals occur at the contact between quartz diorite and limestone, and hydrothermal vein to manto type ore deposits are found in the limestone outside of the skarn zones. These are observed in such places as the vicinity of Plomosas, old prospects to the southeast of Paña Blanca and west-northwest of Encarnación as small ore bodies on a scale containing lead, zinc and silver. These ore bodies consist mainly of limonite-hematite-jarosite aggregates.

In the vicinity of Plomosas, two shafts (No. 1), two old open pits including underground workings (No. 2) and outcrops (No. 3) are found. The shafts at No. 1 were sunk in limestone at a distance of 4 meters with each other. The southern one followed a reddish brown limonite vein of 1.2 meters width (N25°E, 84°E) for about 10 meters. A vein of 0.8 meter width (EW, 60°S) branched off from the major vein shows poor continuity. Limestone at the contact with the vein is weakly silicified, and silicified limestone breccias have partly remained in the vein. The channel sample from the major vein (A14M) showed the grades such as Pb 1.8%, Zn 3.73% and Ag 65 g/t. The detail of the inside of the northern shaft has not been made clear because of difficulty of access. The deposit which belongs to No. 2 occurs in the approximate extent of 5 m x 12 m in dark gray limestone in which abundant small fissures are present. In an old pit on the southeastern side, limonite stain is observed along the fissures (N35°W, 80°W and N10°E, 65°W) in limestone. A sample of limonite (A13M) taken from the waste showed the values such as Pb 0.74%, Zn 39.2% and Ag 23 g/t, showing that the ore is rich in zinc. It seems that zinc is contained in minerals such as smithsonite and calamine. In an old open pit (1.5 m x 4 m) and a level (less than 5 meters in length, N34°W) in the northwest, the detail of mineralization has not been observed because of all the mineralized part have been mined out.

No.3 is the outcrop of so-called manto type ore body having 3 meters thickness and 15 meters extension. Bottom of the outcrop (1 meter in thickness) and the part of southeastern end (3 meters in lateral extension) consist of reddish brown limonite and yellowish-brown jarosite, whereas the central part consists of irregular network veins (10 to 30 centimeters width) of limonite and jarosite. The mineralized zone gently dips less than 10° to the direction of extension.

The result of analysis of a sample (A21M) taken from the part dominant with limonite and jarosite showed the values such as Cu 0.06%, Pb 0.01%, Zn 0.03% and Ag 12 g/t, showing very low grade.

Along a path to the southeast of Peña Blanca, an outcrop of reddish-brown limonite having the extent of 2 m x 1 m is observed in recrystallized limestone (No. 8) as a form of pocket. The main mineralization seems to consist of network veins in limestone, and limonite stain and weak silicification are observed in the surrounding limestone. The result of analysis of the sample (A31M) showed Pb 0.17%, Zn 0.64% and Ag 12 g/t, showing a weak mineralization of lead and zinc.

An old open pit (No. 29) in the vicinity of the contact between limestone and quartz diorite and an old mine working (No. 30) in limestone about 30 meters apart from No. 29 are found to the west-northwest of Encarnación. No. 29 is an old pit on approximately 7 m (W) x 7 m (l) x 4 m (d) scale, in which skarnized diorite with garnet and an outcrop of magnetite having 1.5 meters width are observed, showing an aspect of contact metasomatism. The ore observed in the ore bank, however, consists mainly of fine-banded dissemination of jarosite and limonite in highly silicified limestone. The result of analysis of a representative sample (A43M) showed Cu 0.01%, Pb 0.44% and Ag 50 g/t. No. 30 consists of a trench and an old mine working (5 m x 8 m x 5 m) connected to the trench. It appears that a massive ore body of reddish-brown limonite and yellowish-brown jarosite had been emplaced. The average sample (6 m, A45M) of this part showed the grades such as Cu 0.25%, Pb 0.01%, Zn 0.18%, Ag 2 g/t and Au 0.11 g/t.

An old small test pit (No. 31) is found in limestone on the ridge 0.7 kilometer to the south of El Salto, and the remained ore of quartz and barite vein is observed scattering in it. In the surrounding area of it, a number of fissures occur in limestone in an extent of 50 meters in diameter, and it seems that quartz and barite veins would have filled those fissures. No mineralization accompanied by lead and zinc was observed.

There are other two mines outside of this area, in addition to the mines and showings in this area mentioned above, and the outline of these are described in the following.

(i) Corral Viejo Mine

The mine is situated at the contact of quartz diorite with limestone in the lower part of a small ridge 1.2 kilometers to the west of Encarnación. The main working to be observed is an old open pit having a dimension of 12 m (W) x 20 m (l) x 10 m (h), but a small-scale mine working is also found 100 meters to the north.

In the former, a limonitized skarn zone of 5 meters width which had been emplaced in contact with quartz diorite argillized to white clay, was mined, and, in addition, three lenses of garnet skarn vein less than 1 meter width are found in quartz diorite.

Skarnized quartz diorite containing relatively abundant malachite is found on a small scale to the extensions of the adjacent zones on both sides of the limonitized skarn zone. A vein-width channel sample (A46M) showed a grade such as Cu 1.1%, Pb 0.02%, Zn 0.28%, Au 0.30 g/t and Ag 17 g/t. A sample of the part containing abundant malachite (A49M) on the extension of the above, showed the grade such as Cu 4% and Ag 100 g/t. These results show that the main mineralization has been rich in copper and silver.

(ii) Nuervo Encino Prieto Mine

The mine is situated at the contact between limestone and quartz diorite in the lower part of a ridge about 5 kilometers to the north-northwest of Plomosas, and consists of an upper level (S44°W, more than 30 meters in length) and a lower drainage adit. The upper level was closed by locked iron railings, which prevented the access to the underground, and the details was not made clear. The investigation of the outcrop and the ore stock led to infer that the ore deposit consists mainly of lead and zinc ore minerals emplaced in garnet-epidote skarn accompanied by subordinate amount of silver, copper, iron and manganese. The ore found in the stock contains magnetite, pyrite, chalcopyrite, galena and sphalerite as primary minerals, and hematite, geothite, malachite, azurite, and psilomelane as secondary minerals. The result of analysis of an average sample from the ore stock (A66M) showed Cu 0.32%, Pb 8.5%, Zn 5.78%, Au 6.7 g/t, Ag 130 G/t, Total Fe 18% and Mn 1.3%.

2-2-4 Summary of the Survey Result

Geology of the EL TEJOCOTE area including the whole neighborhood of Encarnación is characterized by the predominant distribution of the thick-bedded to massive limestone (Kdl) member of the El Doctor Formation, and quartz diorite intruded into limestone in the form of stock in various sizes.

The ore deposits scattered in this area are generally divided into two types such as copper and iron ore deposit of contact metasomatic type emplaced in the skarn zone between limestone and quartz diorite, and silver, lead and zinc deposit of hydrothermal type emplaced in limestone in the outer surrounding part of the former.

The contact metasomatic deposit represented by such ore deposits as Las Delicias, Santo Domingo, El Cambio and Piedra Iman, are furthermore divided into three types, that is, (1) the irregular massive to lenticular and vein types consisting.mainly of magnetite accompanied by some amounts of iron sulfide and chalcopyrite emplaced in garnet-epidote (rarely wollastonite) skarn, (2) the lenticular type with dissemination of magnetite, pyrrhotite, pyrite and chalcopyrite in skarn zone, and (3) the type which contains galena and sphalerite in addition to those of the former type.

These deposits are subjected to oxidation on the surface. The size of skarn varies from several meters to about 20 meters in width, and the extension reaches up to several hundred meters. These skarn zones are intermittently arranged along the contact between intrusive rock and limestone. Therefore, the size of mineralized zone emplaced in the skarn is about 15 meters width in maximum and up to several tens meters in extension.

In terms the grade of ore, those consist mainly of magnetite show iron content of 44 to 66 percent of total iron, and iron sulfide dissemination-type skarn or those composed of limonite, jarosite and malachite, show the values such as Cu 1 ∿ 2%, Au 0.2 ∿ 0.3 g/t and Ag 20 ∿ 30 g/t containing subordinate amount of lead and zinc.

As an unusual example (Nuevo Encino Prieto mine), such values were shown as Au 6.7 g/t, Ag 130 g/t, Pb 8.5%, and Zn 5.78%. Beside these, there found the ore rich in zinc as the result of secondary enrichment.

On the other hand, the hydrothermal type deposits have been emplaced in limestone at a distance from the intrusive rocks, being mainly distributed in the surrounding area of Plomosas, to the southeast of Peña Blanca and to the west-northwest of Encarnación. These show the shapes such as irregular veins or gently dipping mantos having filled the fissures and cavities in limestone. The veins are accompanied by weak to moderate silicification in the hanging and foot walls, having the thickness of one to three meters and lateral extension of about 15 meters. Since the deposit has been completely oxidized, ore minerals consist mainly of limonite and jarosite and sometimes accompanied by small amount of malachite and magnetite. The ore grades are generally Ag 20 ∿ 65 g/t, Pb n%, Zn n ∿ n x 10% and Cu 0.n%.

The main purpose of this phase work composed of the detailed geological survey, IP electric survey and geochemical prospecting (soil samples on the IP survey lines), was to investigate the cause of the geochemical high Pb-Ag anomalies found in the creek flowing down northeastward from the Mesa de la Cebada by stream sediments samples of last year's work. The result of the geological survey of this phase reveals that ore deposits observed in this area, are rather small on a scale and also not so high grade.

The value for future exploration or the policy of exploration will be mentioned in the conclusion in Chapter 5 as the matter to be judged after the comprehensive evaluation of the results of geochemical prospecting described in Chapter 3 and geophysical survey in Chapter 4.

2-3 PROVIDENCIA Area

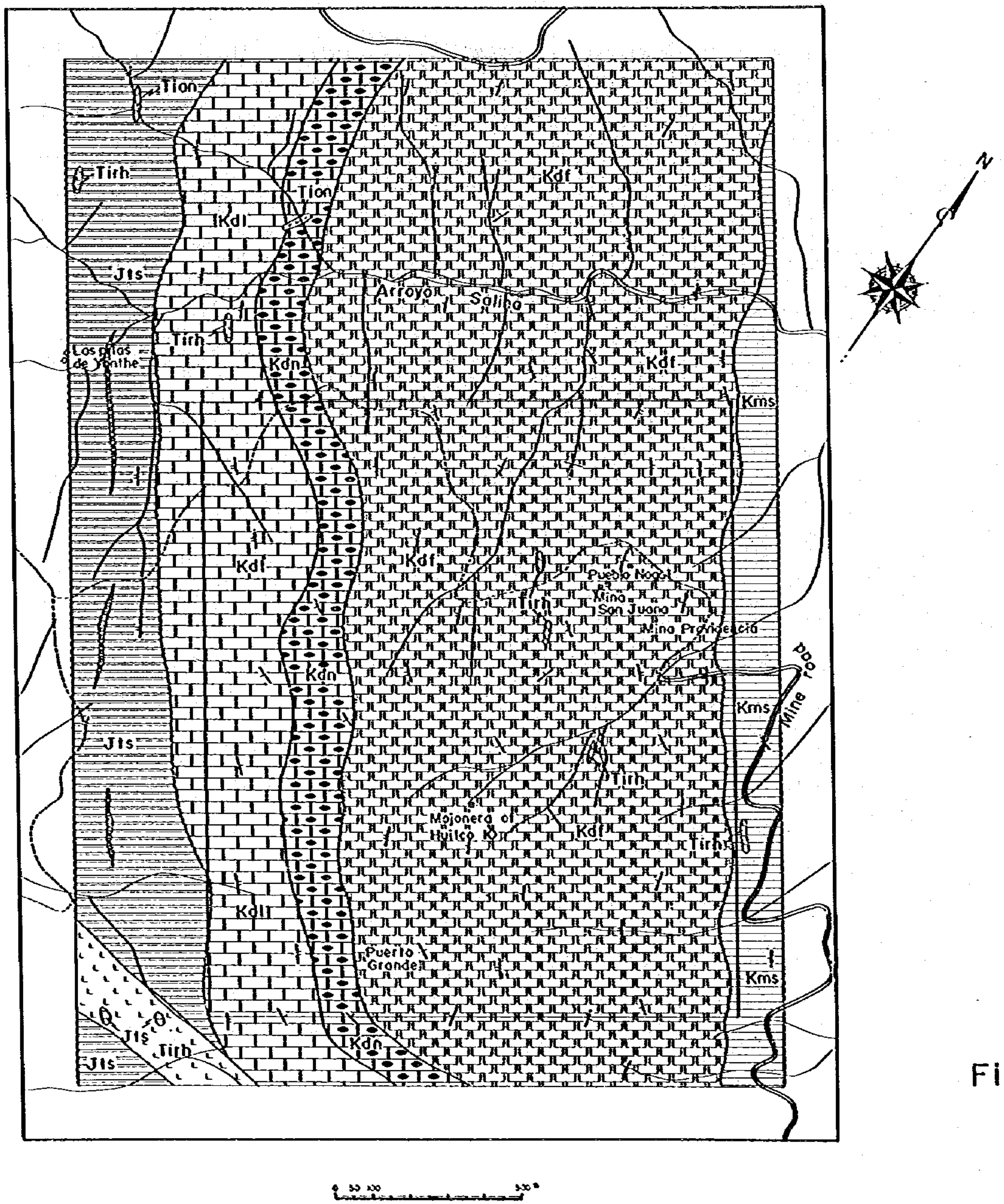
2-3-1 Location, Settlements, Topography and Vegetation

The PROVIDENCIA area occupies 6 square kilometers and is of rectangular shape having the base of 2 kilometers length with the direction of northeast to southwest, extending 3 kilometers from southeast to northwest. It is situated in the southern part of the district surveyed in the second year.

The topography of the area is notably characterized by the main peak of the Providencia mountain mass trending from south to north or northwest, and the foot of the mountain mass on both sides of east and west and northern side. The highest point of the main peak (Puerto Grande) is about 2,670 meters above sea level, and the lowest point of the foot of the mountains about 2,100 meters above sea level, the difference being 570 meters.

Although a well dissected landform is generally shown, the slope from the foot to ridge of the mountain is relatively steep. The drainage system consists of the Salina River (Arroyo Salina) which flows down east-northeastward cutting the Providencia mountain mass into halves, and branches of the Salina River which take their rises in the Providencia mountain mass. The main-stream of the Salina River has a considerable flow even in dry season, whereas other tributaries are dry river.

The vegetation of the area is represented by thin wood of conifers, and cactuses peculiar to Mexico as well as xerophite can be observed in the topographic lowland.



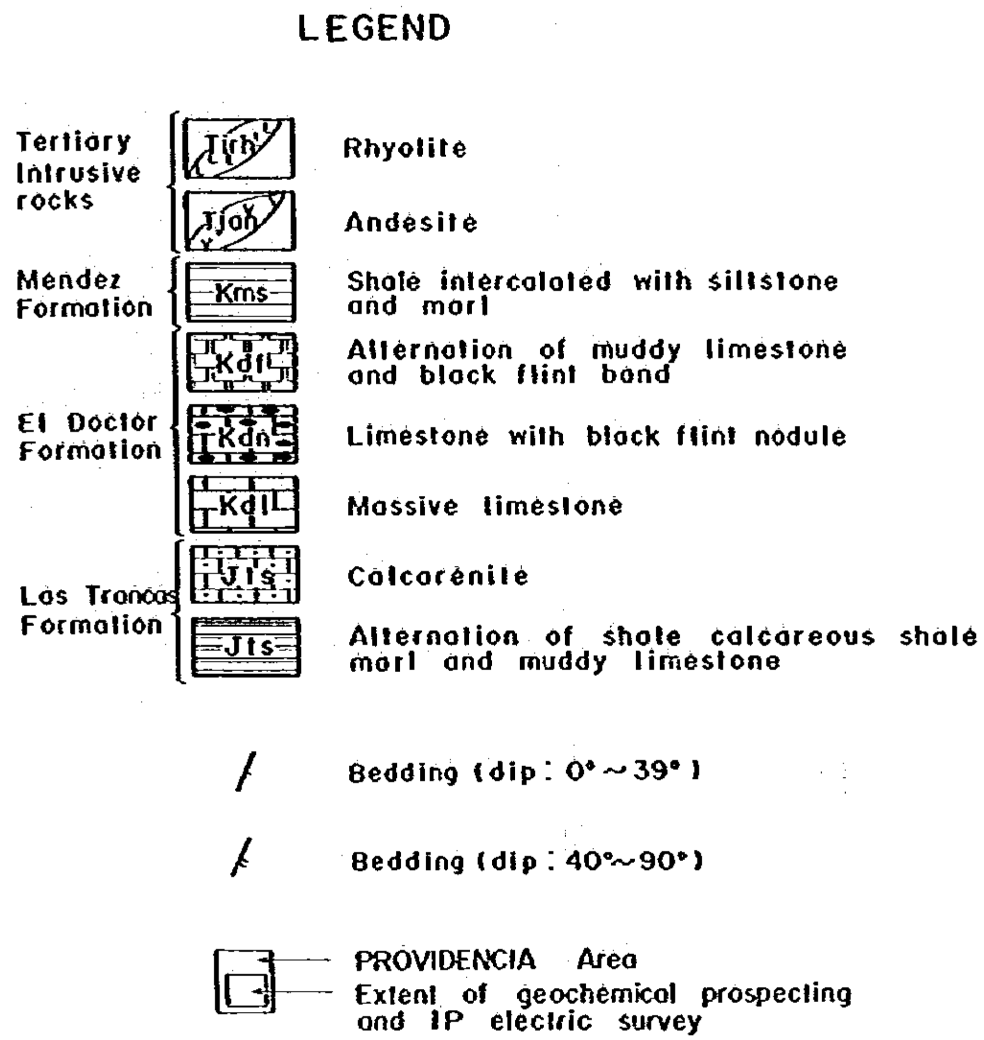


Fig.2-3-1 Geological Map of the PROVIDENCIA Area

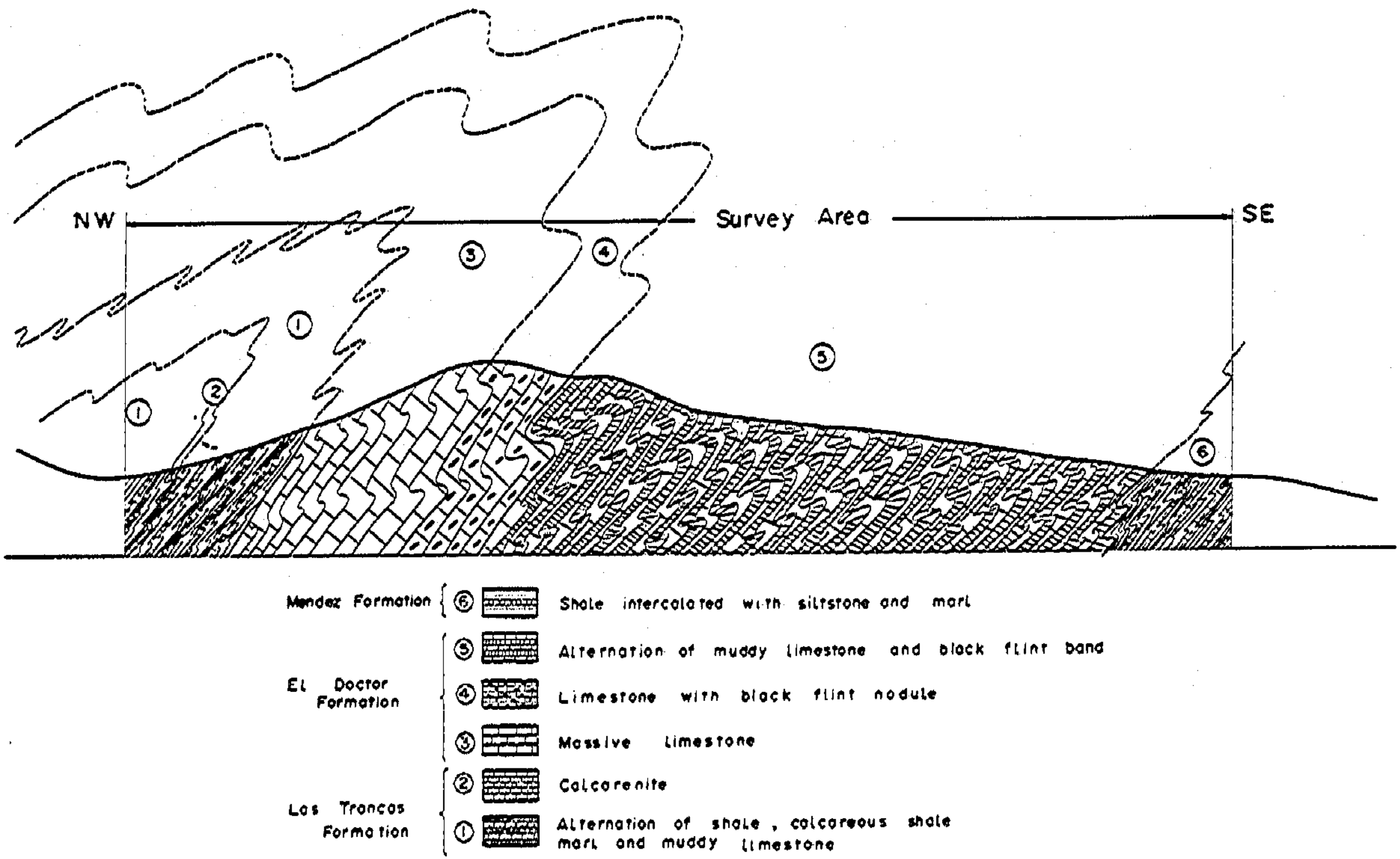


Fig. 2-3-2 Schematic Geological Profile of the PROVIDENCIA Area

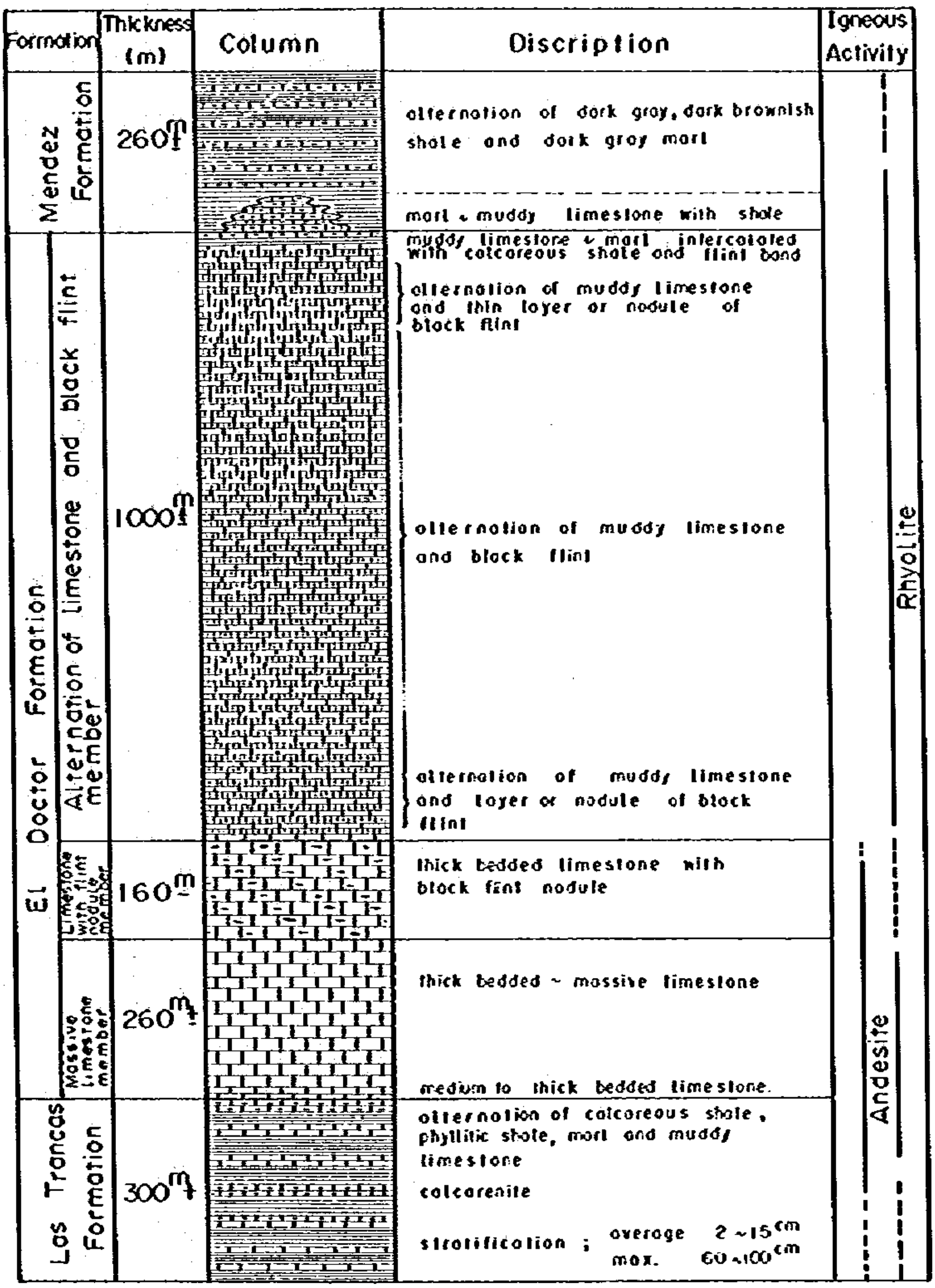


Fig. 2-3-3 Stratigraphic Column of the PROVIDENCIA Area

2-3-2 General Geology

The geology of the area is composed of pre-Tertiary pelitic to calcareous sedimentary rocks and Tertiary intrusive rocks intruded into the sedimentary rocks. The pre-Tertiary system consists of the Las Trancas Formation (Jts), the El Doctor Formation (Kdl, Kdn and Kdf members) and the Mendez Formation (Kms), and the Tertiary system is composed of andesitic rocks in the form of small-scale dykes (Tian) and rhyolitic rocks (Tirh) (See Fig. 2-3-1, 2-3-3, PL. 2-3-1, 2-3-2).

Because the area is positioned, from the standpoint of geological structure, in such place that has been put between a couple of the axes of large scale overfold-anticlinal and -synclinal structures, the pre-Tertiary formations distributed in zones from east to west with the trend of northwest - southeast show a reversal stratigraphic relation (See Fig. 2-3-2).

Las Trancas Formation (Jts)

It is distributed on a small scale in a narrow and long zone extending from northwest to southeast in the western part of the area. The formation exposed on the western outside of the area at the axial part of overfolded anticline which has an axial plane striking north-northwest and dipping west, consists of shale, marly shale, calcarenite and tuffaceous conglomerate, showing thickness of more than 700 meters. In this area, however, only about 300 meters of the upper part has been exposed. The lithology is represented by alternating beds of thin-bedded (1 cm ∿ 5 cm), partly phyllitic black shale and medium-bedded (5 cm ∿ 20 cm) dark gray calcareous shale to marl and local intercalation of medium to thick-bedded (20 cm ∿ 100 cm) calcarenite in the alternating bed. Among these, shale has been softened by weathering and marl or calcarenite has remained hard and compact on the surface, showing difference of resistivity between them against weathering erosion, which exhibit an uneven feature of the outcrop.

The general strike and dip of the formation are N15° ∿ 40°W and 40° ∿ 80°SW in the northern part and N45° ∿ 65°W and 40° ∿ 50°SW in the central part respectively. It conformably overlies the El Doctor Formation in appearance showing overturned stratigraphic relation, but the strike and dip at the southern end of the area are N30° ∿ 50°W and 50° ∿ 70°NE having returned to the normal stratigraphic relation. Apart from these major general strike and dip, minor fold structure derived from the major fold structure is found everywhere in the area, and repetition of small-scale anticline and syncline can be observed. The time of sedimentation has been identified, from the fossils sampled during the second year survey, to be from Tithonian of uppermost Jurassic to Neocomian of lowermost Cretaceous.

El Doctor Formation (Kdl, Kdn and Kdf members)

The formation has been divided into the following three members on the basis of lithology: dark gray to gray thick-bedded (30 cm to more than 100 cm) or massive limestone (Kdl) member, thick-bedded to massive limestone containing nodules or lenses of black flint (Kdn), and medium-bedded limestone (Kdf) member with rhythmical intercalation of thin layers of black flint and dark gray pelitic limestone. The boundaries between the three members are transitional. and the order of sedimentation in the area is, in ascending order, the Kdl member, the Kdn member and the Kdf member, which dominantly overlie the area. The Kdl and Kdn members cover the western side of the Providencia mountain mass and the Kdf member occupies the eastern side.

The general strike and dip of the formation are N35° ∿ 40°W and 50° ∿ 60°SW and are almost similar to those of the Las Trancas Formation underlying it. The repetition of minor fold structure found in the Las Trancas Formation is also observed in this formation, however the frequency of repetition is varied in each member. The Kdl member has a structure of repetition of gentle syncline and anticline with axial distance of more than 50 meters and the Kdn member a little less than 50 meters. In contrast to them, in the Kdf member, complicated repetition of syncline and anticline with shorter axial distance of 1 to 2 meters are often observed. It is considered that such difference has been caused by the lithology of each member having shown the difference of resistivity peculiar to each of them against the folding.

The Kdn member had been included in a bundle of the Kdf member in the second year survey. The reason was that no formation having the lithology corresponding to the Kdn member had been confirmed other than this area and that the boundary between the Kdn member and the Kdf member was transitional.

Although the thickness of the formation in the area has been roughly calculated on the geological map to be about 260 meters in the Kdl member, about 160 meters in the Kdn member and about 1,000 meters in the Kdf member, it is strongly possible that the true figures should be less than these when taking the minor folding into consideration.

The time of sedimentation of the formation corresponds to from middle Albian to late Turonian of Cretaceous as the result of fossil identification yielded from the formation in other area included in the surveyed area. The formation conformably overlies the underlying Las Trancas Formation, having been lacking in the strata belonging to from Aptian to early Albian.

Mendez Formation (Kms)

The main part of the formation is distributed on the eastern out side of the area, and its thickness has been estimated to be about 900 meters. The lowermost part, however, having the thickness of about 260 meters is distributed in the lowland at the foot of mountain at the eastern end of the area.

The formation in the area consists of thin-bedded (1 cm ∿ 3 cm) dark gray to dark brownish-gray shale and alternating beds of silt and medium-bedded (5 cm ∿ 30 cm) dark gray marl. The pelitic parts such as shale and silt are generally predominant. In the pelitic part, irregular small joints and fissures have been closely generated on the bedding plane, which make the rock readily exfoliate in platy small pieces. On the contrary, the marly part is hard and compact.

Marl is more or less dominant near the boundary with the underlying Kdf member of the El Doctor Formation. Such a part corresponds to the area of distribution of the Soyatal Formation called by Segerstrom (1962). Because of poor continuation to the strike sides of this part, it has been made in a bundle with the Mendez Formation.

The general strike and dip of the formation are N 5° ∿ 40°W and 40° ∿ 50°SW, and the repetition of small-scale folding found in this formation is observed more frequently than that of any other formations.

The time of sedimentation of the formation is from late Turonian to Campanian of Cretaceous, and the distribution of formation of the same rock facies is widely observed in the central part of Mexico.

The relation with the underlying El Doctor Formation is conformable in some part and unconformable partly, and it is conformable in this area.

Tertiary Intrusive Rocks

Tertiary intrusive rocks which intruded into the pre-Tertiary system in the area consist of andesitic rocks (Tian) and rhyolitic rocks (Tirh).

Andesitic rocks (Tian) are found as two rock bodies such as a sill-like small dyke having intruded into the Las Trancas Formation at the upstream of the Salina River which runs in the northwestern part of the area and a small dyke intruded into the Kdn member of the El Doctor Formation. These have a greenish gray tint and distinct porphyritic structure, and are hard and compact. Under the microscope, porphyritic structure that phenocryst of plagioclase and pyroxene are scattered in the groundmass conposed of plagioclase, quartz and calcite, and ophitic structure in groundmass, are observed. They generally undergo carbonitization and hydrothermal alteration, and pyroxene and plagioclase have been completely altered to chlorite (partly to calcite) to form irregularly shaped calcite in matrix. Quartz in the groundmass, however, is remained intact.

Rhyolitic rocks (Tirh) occur as rock bodies including a dyke of a moderate-scale exposed at the southern end of the area and six small-scale dykes distributed in the vicinity of the Providencia mine and in the northwestern part.

The moderate-scale dyke at the southern end of the area continues for about 5 kilometers in total extension running across the Providencia mountain mass including the southern end of the area and Cerro de Cardonal on the southeast of the area, having its rise in the San Clemente mountain mass to the east of the area. The rock contains characteristically quartz phenocrysts, and is grayish brown, hard and compact. Under the microscope, it is composed of phenocrysts consisting mainly of quartz and potash feldspar and small amount of plagioclase, and groundmass consisting of fine-grained quartz, plagioclase, potash feldspar and muscovite. Spherulitic texture is often observed in the groundmass. A part of the rock at the southern end of the area and in the vicinity of Cerro de Cardonal, however, has holocrystalline groundmass showing rock facies of granite porphyry. The sedimentary rocks at the contact with the dyke rock is slightly silicified by the intrusion of it, but other marked alteration can not be found.

The small-scale dykes in the vicinity of the mine in the east-central part of the area are weakly silicified and argillized, and are grayish brown. Under the microscope, fine-grained quartz produced by silicification and a small amount of potash feldspar and hematite, and quartz veinlets penetrating aboves, are observed. In many cases, the rocks of the Kdl member of the El Doctor Formation are found to have been oxidized and leached in the surrounding area of the dyke rock.

The time of intrustion of the rocks has been shown to be 25.5 ± 1.3 Ma by isotopic age determination by K-Ar method of the sample taken from the micrographic part in the vicinity of Cerro de Cardonal, indicating later Oligocene. In addition, K-Ar dating of San Clemente rhyolite showes 26.5 ± 1.3 Ma (MMAJ and JICA, 1980), which indicates that these are the products of approximately the same age. K-Ar absolute age and chemical composition of the two rock bodies are shown in Table 2-3-1.

Table 2-3-1 K-Ar Absolute Age Determination and Chemical Composition of Providencia and San Clemente Phyolites

K-Ar Age by Whole Rock

Area	Sample No.	K %	SCC $^{40}Ar^{R}/g \times 10^{-5}$	$^{40}Ar^{R}$	Age (Ma)
*SAN CLEMENTE	Cb 20 DTC	7.02 7.00	0.731 0.734	90.2 92.6	26.5±1.3
PROVIDENCIA	B 44 DTC	2.74 2.75 2.77	0.272 0.279	82.7 80.9	25.5±1.3

Chemical Composition

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	P_2O_5	Total (%)
*Cb 20 DTC	72.31	0.28	13.77	2.06	0.33	0.02	0.15	0.10	0.75	9.06	1.07	0.22	0.05	100.16
B 44 DTC	73.80	0.25	13.10	1.38	0.49	0.07	0.30	1.52	3.47	4.08	0.49	0.60	0.13	99.68

* Examined in PHASE I

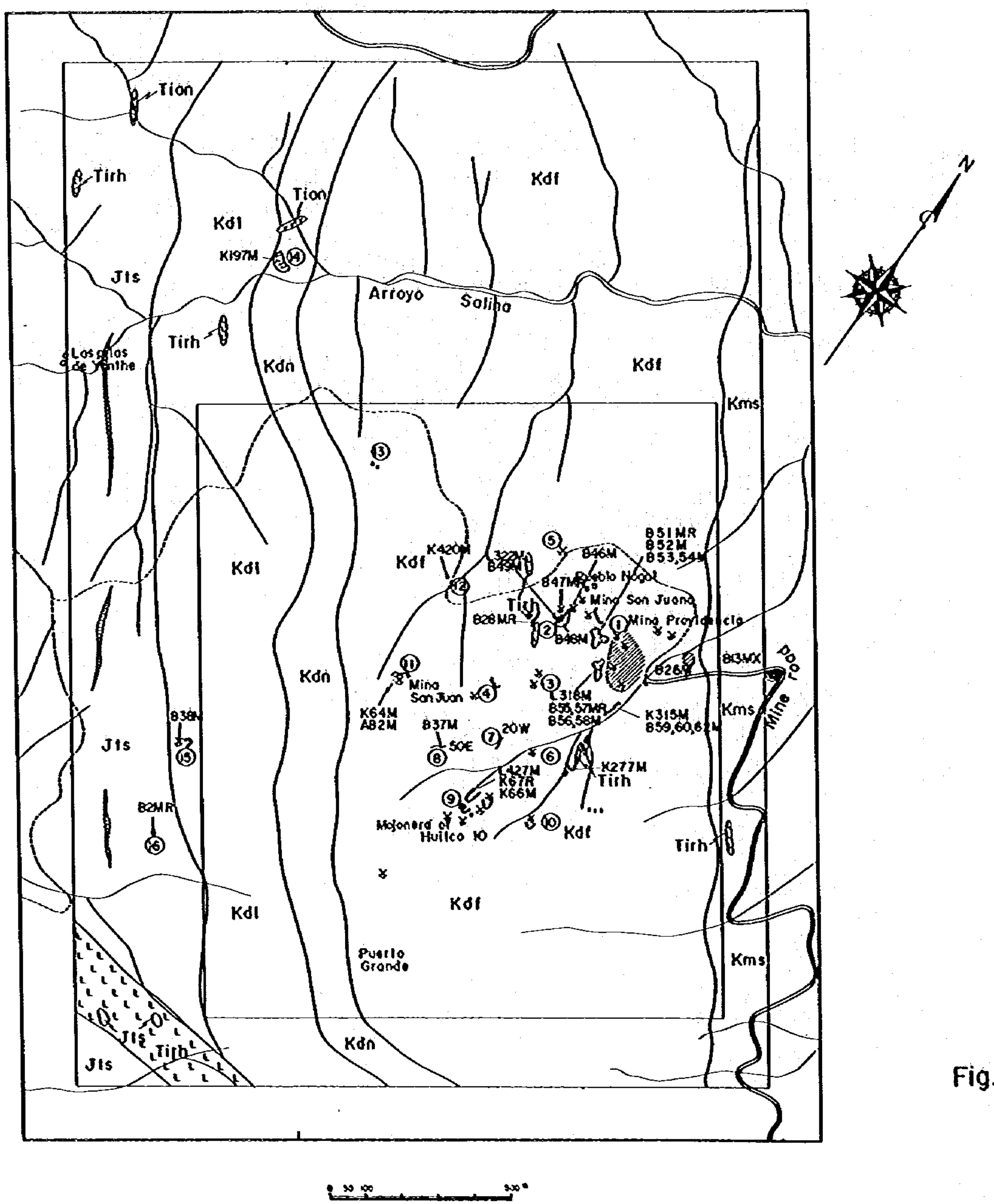
2-3-3 Ore Deposits

Old open pits and old tunnels are scattered within the extent of about 0.7 km x 1.0 km from the east-central part to the south-eastern part of the area. It is said that the Providencia mine, the San Juan mine and the San Juana mine were the major ones among those mine workings and that they were mined and prospected discontinuously. They are, however, left as they stand at present.

The Providencia mine is situated on the hill side to the west of the terminal of the mine road which leads to Yonthe, and there found four old open pits (maximum one is 100 m x 110 m x 5 m in size), five small shafts and waste dumps (140 m x 70 m x 2 m in maximum). The San Juana mine situated on the hill adjacent to the west of the Providencia mine consists of an old open pit and three small shafts, and some ore stock are found. The San Juan mine is located about 300 meters to the southwest of the San Juana mine, and consists of a small old open pit and a level connected to it. Beside these, there found a mark of mine lot (Mojonera Huilco 10) at the point about 500 meters to the south of the Providencia mine, and around these three old open pits (30 m x 40 m x 25 m in maximum), a shaft and two levels can be observed (PL. 2-3-4, Fig. 2-3-4).

Since the mark of mine lot shows the time of its establishment to have been in 1892, the time of activity of exploration and mining seems to have been during the period from 1890's to the beginning of 1900's.

The ore deposits were emplaced along the bedding planes or fissures in the black flint bearing limestone member (Kdf) of



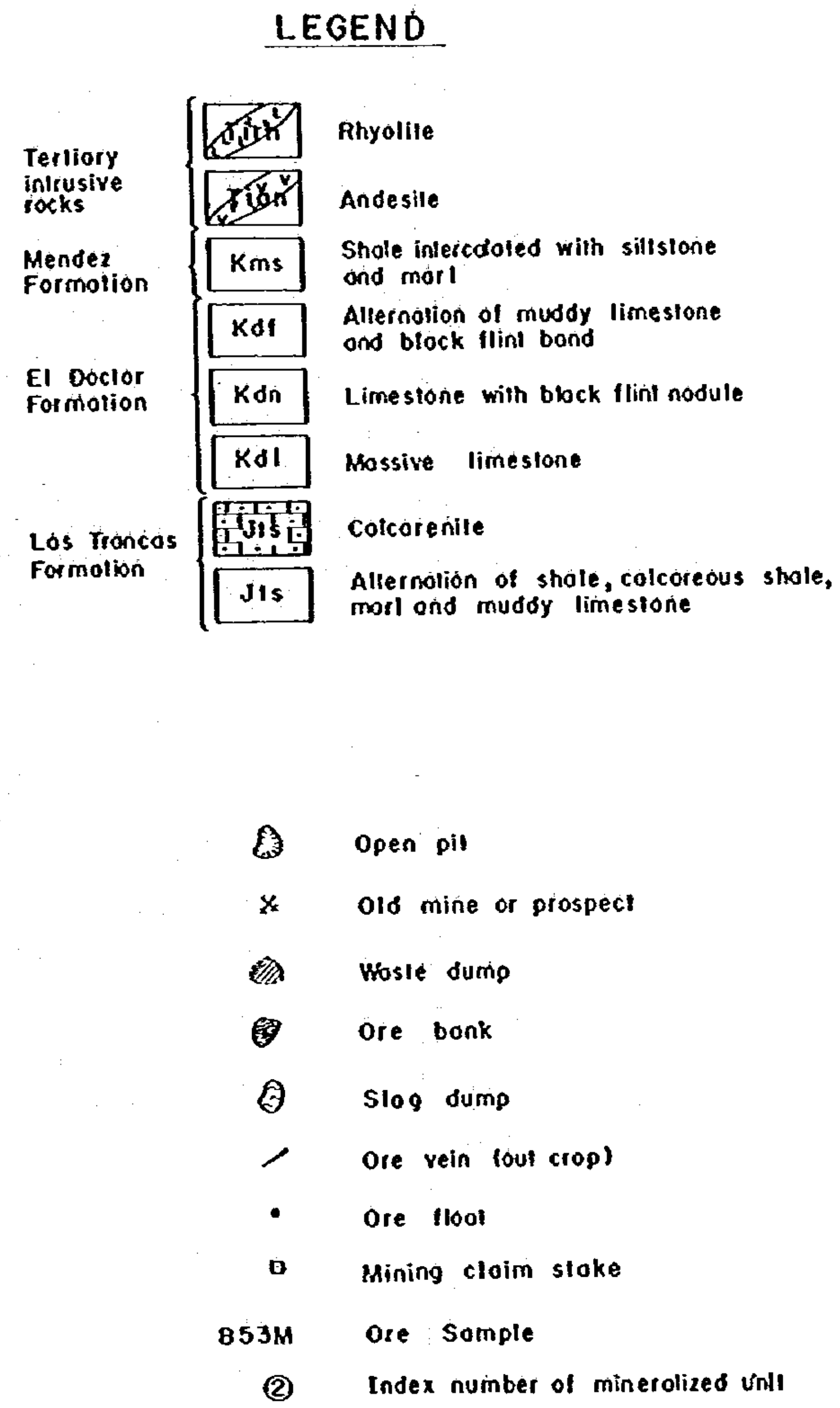
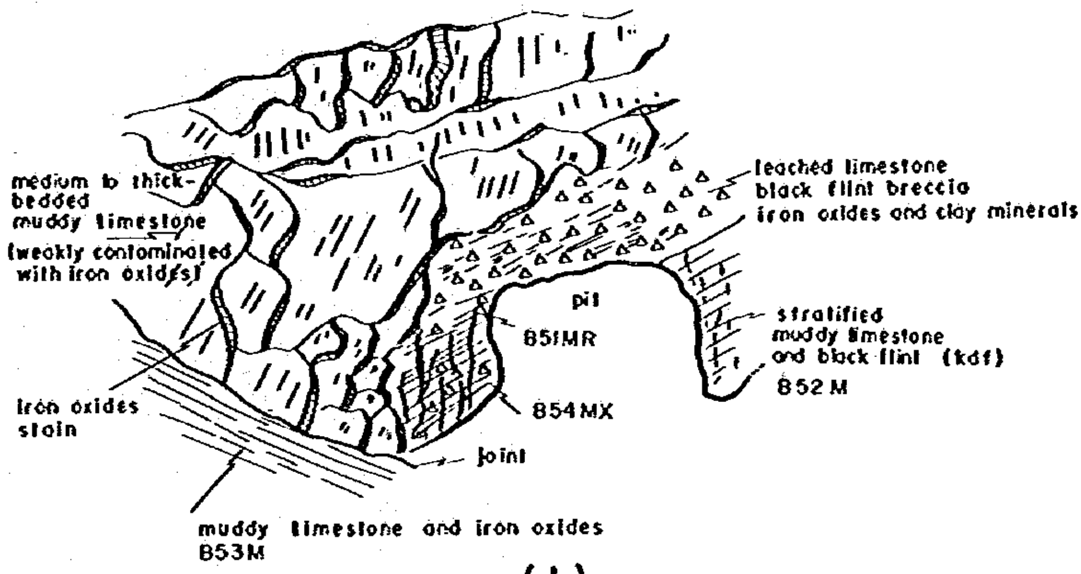
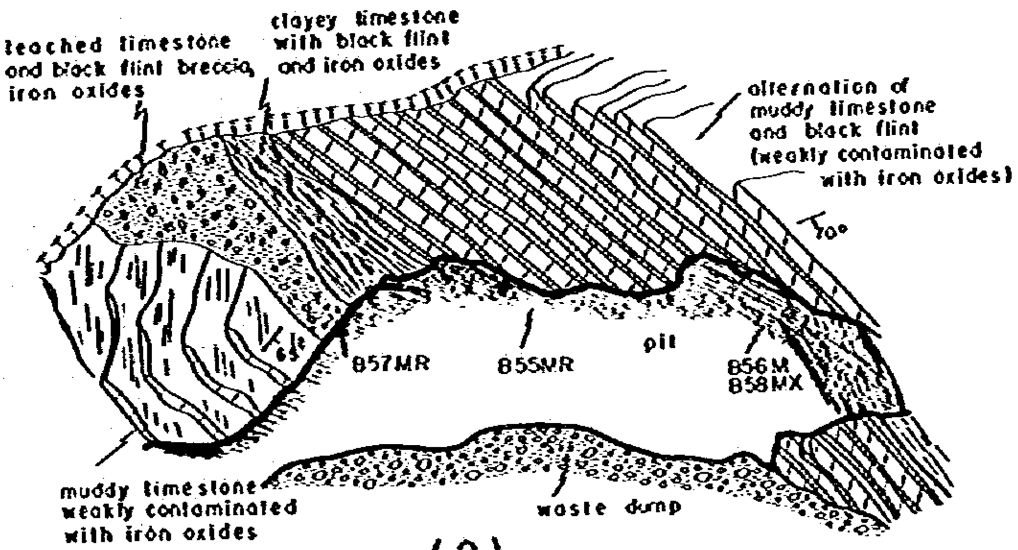


Fig. 2-3-4 Distribution Map of Mines, Prospects and Ore Showings in the PROVIDENCIA Area



(1)



(2)

Fig. 2-3-5 Skecth of the Providencia Mine in the PROVIDENCIA Area

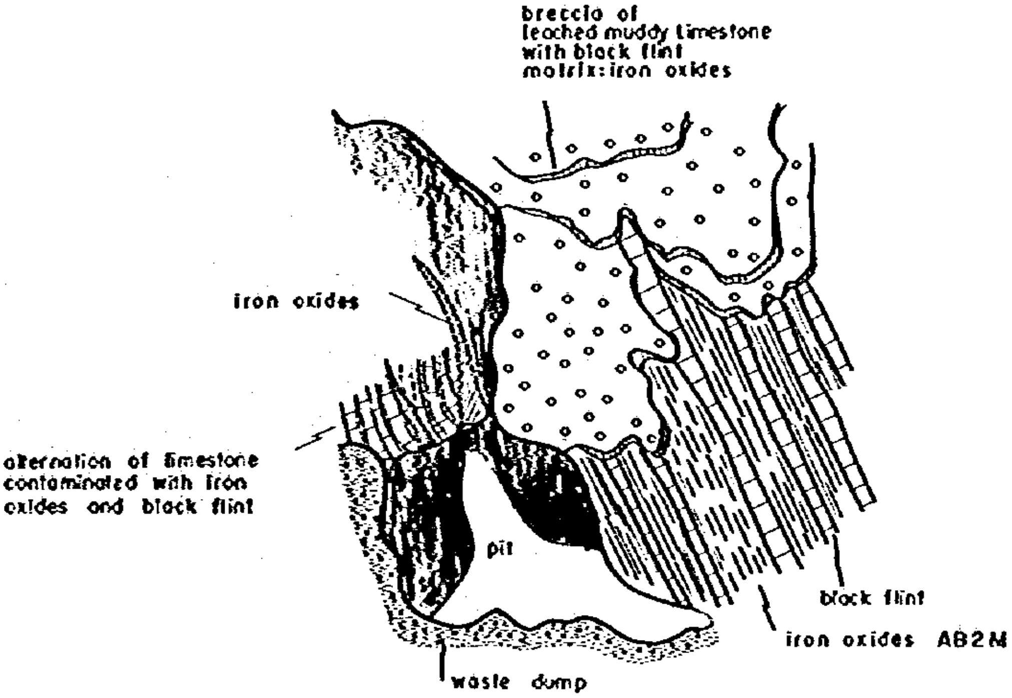


Fig. 2-3-6 Sketch of the San Juan Mine in the PROVIDENCIA Area

Table 2-3-2 List of Mines, Prospects and Ore Showings in the PROVIDENCIA Area

Index ☆№	Name of Mine	Type of Mineralization	Workings	Trend of Ore Showing	Principal Ore Minerals	Gangue Minerals	Alteration	Stratigraphic Unit of Country Rock	Reference Sample
①	Providencia	Ht massive and vein	4 open pits 70m×4m×5m 100m×110m×5m 70m×5m×5m 20m×20m×2m 6 shafts waste dump max 140m×70m×2m	N20°-35°W	hm, gt, jr, sm, hem	qz, ca, cl	oxidation carbonitization argillization	Kdf (leached limestone, brecciated limestone)	B13MX, B26M, B51MR, B52M, B53M, B54MX, B55MR, B56M, B57MR, B58MX, B59M, B60M, B62M, L315M*, L318M*
②	San Juana	Ht, vein	1 open pit 55m×5m×2.5m 4 shafts	N20°W ?	hm, gt, jr, sm, hem	qz, ca	oxidation carbonitization silicification	Kdf	B28M, B46M, B47M, B48MX, B49M, L322M*
③	Prospect	Ht	2 small adits	—	hm, gt	ca	oxidation carbonitization	Kdf	—
④	Prospect	Ht	1 small open pit 1 shaft	—	hm, gt, jr	ca	oxidation	Kdf	—
⑤	Prospect	Ht	1 adit	—	hm, jr	cl	oxidation argillization	Kdf	—
⑥	Prospect	Ht	2 small open pits 1 shaft	—	hm, jr	ca	oxidation	Kdf	K277M*
⑦	Outcrop	Ht, vein	1.0m×3m	N20°W	hm	—	oxidation	Kdf	—
⑧	Outcrop	Ht, vein	0.5m×4m	N50°E	hm, jr	—	oxidation	Kdf	B37M
⑨	Mojonera Huilco 10 and its surrounding	Ht, vein	3 open pits max:30m×40m×25m 1 shaft 2 adits	—	gn, hm, jr, gt	qz, ca	oxidation silicification carbonitization	Kdf	L427M*, K66M
⑩	Prospect	Ht, vein	1 open pit+adit	—	hm, jr	ca	oxidation	Kdf	—
⑪	San Juan	Ht, mant	1 open pit+adit	—	hm, jr	ca, cl	oxidation carbonitization argillization	Kdf (muddy limestone)	AB2M, K64M*
⑫	Floats	—	a small amount	—	hm, jr	—	—	—	K420M*
⑬	Floats	—	a small amount	—	hm, jr	—	—	—	B23M
⑭	Slag dump	—	30m×30m×1m	—	—	—	—	—	K197M*
⑮	Prospect	Ht, vein	1 open pit+adit 4m×3m×1m	N30°W	hm, jr	ca	oxidation carbonitization	Kdf	B38M
⑯	Floats	—	a small amount	—	hm, gt	—	—	—	B2MR

Abbreviations: Ht …… Hydrothermal, hm …… hematite, gt …… goethite, jr …… jarosite, sm …… smithsonite, hem …… hemimorphite, qz …… quartz, ca …… calcite, cl …… clay mineral

☆ Index number corresponds number of mines on the Fig 2-3-4

Table 2-3-3 Metal Contents of Ore Samples from the PROVIDENCIA Area

Name of Mine	No.	Sample No.	Coordinates E	Coordinates N	Type of Ore	Metal Contents Au g/t	Ag g/t	Cu %	Pb %	Zn %	T.Fe%
Providencia mine	1	B13MX	488410	2286625	iron oxides ore	–	25	0.01	0.63	35.8	–
	2	B26M	488175	2286500	iron oxides ore	–	2	0.01	4.9	0.22	–
	3	B51MR	487945	2286400	iron oxides gossan	–	–	–	0.74	10.4	–
	4	B52M	487945	2286400	iron oxides with limestone	0.01	42	0.01	0.26	1.26	29
	5	B53M	487945	2286400	iron oxides gossan	–	–	–	1.0	7.86	–
	6	B54MX	487945	2286400	iron oxides gossan	–	42	0.19	0.32	29.0	–
	7	B55MR	487985	2286305	iron oxides with limestone	–	–	–	1.1	8.20	–
	8	B56M	487985	2286305	iron oxides gossan	0.08	130	0.02	0.90	0.83	47
	9	B57MR	487985	2286305	iron oxides ore breccia	–	–	–	12	13.4	–
	10	B58MX	487985	2286305	iron oxides ore breccia	–	10	0.02	0.52	39.5	–
	11	B59M	488082	2286265	iron oxides gossan	–	–	–	1.7	22.7	–
	12	B60M	488082	2286265	iron oxides gossan	0.20	24	0.05	1.5	1.82	35
	13	B62M	488082	2286265	iron oxides ore	–	–	–	1.3	15.4	–
	14	*L315M	488085	2286270	iron oxides pool	0.01	80	0.023	1.81	10.1	–
	15	*L318M	487980	2286325	iron oxides pool	0.01	150	0.014	0.52	23.5	–
San Juana mine	16	B28MR	487750	2286325	iron oxides ore	–	10	<0.01	0.21	0.18	–
	17	B46M	487820	2286440	iron oxides ore	–	–	–	21	182	–
	18	B47MR	487800	2286410	iron oxides ore	0.08	14	0.02	6.2	20.5	30
	19	B48MX	487815	2286370	iron oxides ore	–	–	–	2.1	39.3	–
	20	B49M	487790	2286385	iron oxides ore	–	44	0.01	89	5.45	–
	21	*L322M	487800	2286410	iron oxides pool	0.24	200	0.10	7.03	0.15	–
San Juan mine	22	AB2M	487015	2285960	stratified iron oxides ore	–	8	0.09	5.3	2.03	–
	23	*K64M	487015	2285960	iron oxides ore	0.04	14	0.022	1.12	0.42	–
Mojonera Mulao 10 and its surrounding	24	B37M	487735	2285865	iron oxides ore	–	46	0.03	0.13	0.27	–
	25	*K66M	487905	2285760	galena-quartz veinlets	0.94	53	0.006	4.78	3.96	–
	26	*L427M	487900	2285795	veinlets of iron oxides	<0.01	120	0.011	0.71	3.20	–
	27	*K277M	488065	2286036	network of iron oxides	0.09	24	0.005	4.00	1.38	–
	28	*K420M	487485	2286300	iron oxides ore	0.02	14	0.009	0.02	0.035	–
Scattered old pit in the area	29	B23M	487125	2286440	iron oxides ore	–	2	0.01	0.29	0.13	–
	30	B36M	487135	2285455	iron oxides ore	–	1	<0.01	0.01	0.04	–
	31	B2MR	487225	2285195	iron oxides ore	–	2	<0.01	0.01	0.20	–
	32	*K197M	486583	2286700	slag	0.04	20	–	–	–	–

(–: not analyzed)

* Samples were analyzed in the phase I (JICA and MMAJ, 1981)

the El Doctor Formation showing irregular massive, manto and vein types.

The ore minerals consist mainly of iron oxides such as limonite, hematite and goethite associated with jarosite, smithsonite, calamine and cerussite. These ore minerals of lead and zinc, however, are complicately mixed in iron oxides and jarosite as tiny crystals, so that it is very hard to discern these minerals with the naked eye. The chemical analysis of the ore showed the silver content of 10 g/t to 200 g/t, but no significant correlation between the grade of silver and that of lead has not been recognized.

Thus no sulfide mineral can be found in general, since ore minerals observed on the surface consist of oxides and carbonates. Quartz veinlets accompanied with galena, however, has been exceptionally observed only at one place, the old mine working in the vicinity of Mojonera Huilco 10.

Calcite, quartz and kaoline are generally observed as gangue minerals. The types of ore deposits observed in the old pits of the Providencia mine are varied as shown in Fig. 2-3-5 (1), (2) and Fig. 2-3-6; such as the massive type having filled irregular cavities in limestone, the manto type having filled the leached parts of alternating beds of black flint and limestone, and the vein type having filled the fissures. The bearing of these deposits is generally consistent with strike and dip of the country rock having been arranged in approximate direction of N20° ∿ 35°W.

In the San Juana mine, an old open pit having a slightly inclined bottom, showing an L-shaped outline on the surface, and a vertical shaft, are found. It seems that a vein type or stockwork deposit was mined there. In the vicinity of Mojonera Huilco 10, an old pit in the shape of long ellipse in which a small-scale massive deposit would have occurred and an old pit which is surmised to have been excavated downward along the vein, are observed.

Several slightly silicified small dykes of rhyolite of 1 meter to 2 meters width are distributed in the vicinity of these mines with the trend of NW-SE.

In the neighboring area of old mine workings, calcareous rocks which form the country rock of ore deposit have undergone weak silicification, recrystallization and argillization, having been cut by quartz veinlets and calcite veinlets. The calcareous rocks at a little distance from the ore deposit, however, are remained fresh with recrystallization to be hardly observed.

Table 2-3-2 shows the types, country rocks and alterations of these ore deposits, and Table 2-2-3 summarizes the assay values of those ores. The assay values of representative ore-samples of the mines are as follows:

Table 2-3-4 Assay Values of Ore-Samples of the Mines

Location	Type of Ore body	Sample No.	Pb(%)	Zn(%)	Ag(g/t)	Cu(%)	Au(g/t)
San Juana mine, open pit	Irregular vein, oxides	B48MX	2.1	39.3	-	-	-
San Juana mine, shaft	Stocked ore, oxides	B49M	8.9	5.45	44	0.01	-
Providencia mine, open pit	Iron oxides-stained limestone	B54MX	0.32	29.0	42	0.19	-
Ditto	Brecciated limestone, oxides	B58MX	0.52	39.5	10	0.02	-

continued

Location	Type of Ore Body	Sample No.	Pb(%)	Zn(%)	Ag(g/t)	Cu(%)	Au(g/t)
Providencia mine road terminal	Stocked ore, oxides	B13MX	0.63	35.8	8	0.01	-
Mojonera Huilco 10, quartz vein	Quartz, sulfide ore	K66M	4.78	3.96	53	n.d.	0.94

As shown in the tables mentioned above, the main metallic components are zinc and lead accompanied with accessory amount of silver, whereas copper is contained only in negligible amount.

Among the 21 samples taken in the vicinity of the mine, 4 samples show more than 5 percent in lead content and 13 samples more than 7 percent in zinc content: particularly the samples which show approximate 40 percent of zinc were collected from different mine works indicating that this area is generally rich in zinc. This is also indicated by the ratio of Zn : Pb of the 28 samples which show 4.83 : 1. The maximum value of silver is 200 g/t and the average of the representative samples of ore is 40 to 50 g/t.

The occurrence of these ore deposits is limited within an extent of ellipse-shape having the extension of about 1,000 meters in the NNW-SSE direction and about 700 meters width in the ENE-WSW direction.

2-3-4 Summary of the Survey Result

Geology of the PROVIDENCIA area consists of dominant distribution of pelitic to calcareous sedimentary rocks of the pre-Tertiary such as Las Trancas Formation (Jts) and the El Doctor Formation (Kdl, Kdn and Kdf members) and limited distribution of small-scale dykes of Tertiary andesitic rocks and rhyolitic rocks. Among these, the Kdf member of the El Doctor Formation overlies the greater part of the area. It is mainly composed of medium-bedded limestone, which is characterized by the rock facies with rhythmical intercalation of thin beds of black flint.

While, among the Tertiary intrusive rocks, andesitic rocks (Tian) are observed in the northwestern part of the area as only two small-scale dykes, rhyolitic rocks occur as eight rock bodies in total to be observed including a large-scale dyke in the southern part of the area, two small dykes in the northwestern part and five small dykes in the vicinity of the mineralized zone. These are important in the point of view that they appear to have had a close relation to the mineralization of zinc, lead and silver in the area.

The rhyolitic rocks characteristically contain quartz phenocrysts and it is general that the groundmass consists of quartz, plagioclase and potash feldspar showing spherulitic texture, but hypabyssal facies is partly observed, the groundmass of it being holocrystalline.

The ore deposits consist of oxide ores having the forms of irregular massive, manto and vein, and are distributed in the east-central part to the southeastern part of the area within the extent of an ellipse with the major axis of about 1,000 meters length extending in the N-S direction and the minor axis 700 meters length. The main ore minerals are hematite, limonite, goethite, jarosite, smithsonite, calamine and cerrusite, and gangue minerals consist of quartz, calcite and kaoline.

The ore bodies are exposed on various scales. The exploration and mining works seem to have been carried out from 1890's to the beginning of 1900's, and the most of these were aimed at the superficial part of ore deposits, whereas the depth is remained untouched. The represintative ore contains about 40 percent of zinc, about 5 percent of lead and about 50 grams per ton of silver.

As to the future exploration of these ore deposits, the recommendation will be made in the clause of conclusion in Chapter 5 as a matter to be determined by comprehensive evaluation of the results of geochemical prospecting and geophysical survey (IP method) conducted in this year.