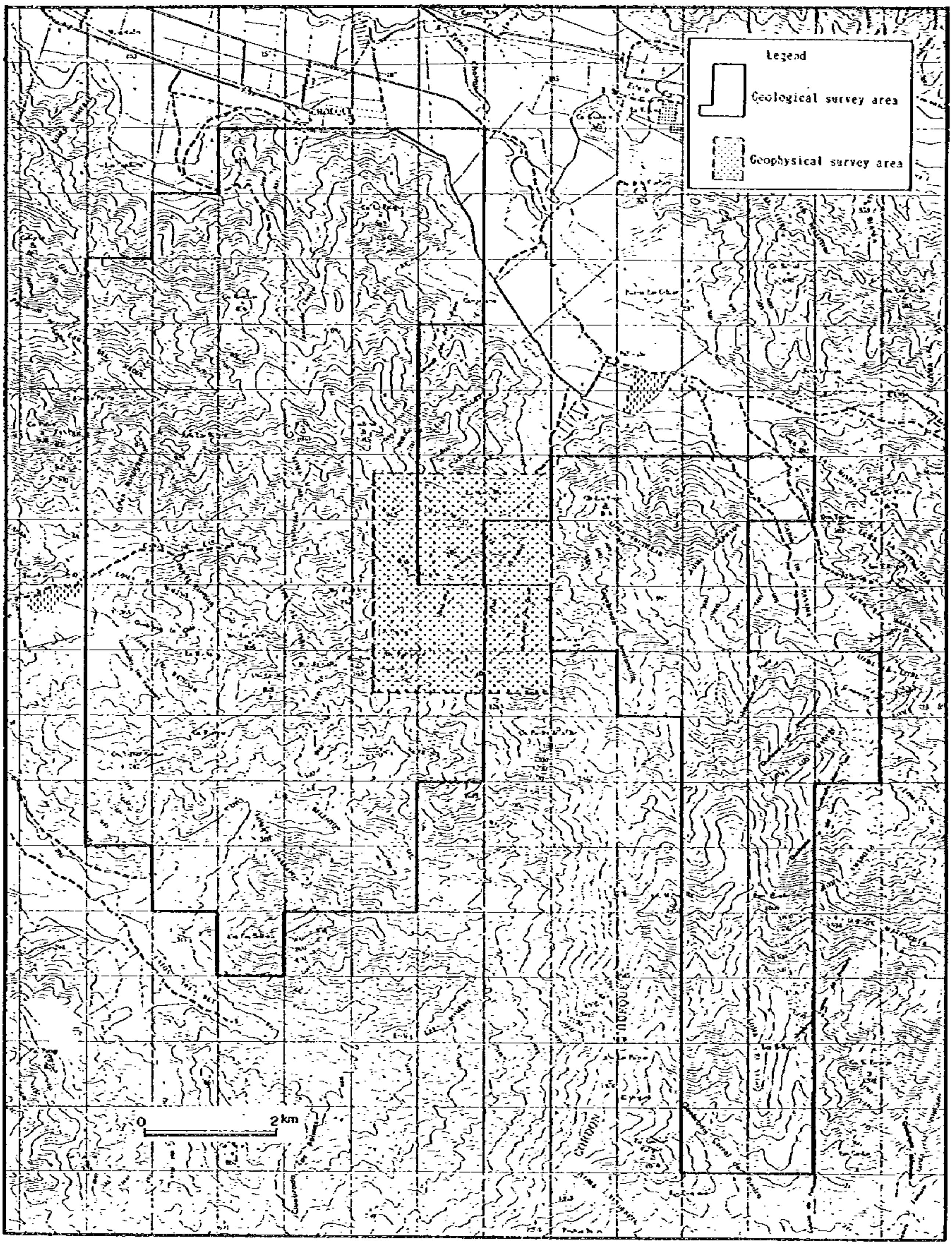
CHOLQUI AREA



Locality Map of Survey Area - 2 (Geological and Geophysical Survey)

ABSTRUCT

This Project was carried out to make sure of the relation between the geologicalcircustance and mineralization, especially to identify the ore horizon and its distribution, at Cholqui area in the Republic of Chile.
For this object, geological, geochemical and geophysical survey(IP and TEMmethod) were carried out in1996 at this area.
The abstruct of the survey resilts are followings

1. Result of Geological Survey
The area is underlain, from the bottom, by the Jurassic Lower Horqueta Member (mainly marine andesite lava), the Upper Horqueta Member(mainly continental andesite lava, its pyroclastics intercalated by thin sandstone and shale), Cretaceous Lo Prado Formation(marine dacite to andesite lavas, their pyroclastics, sandstone andshale), and intrusive rocks(quartzdiorite, granodiorite, andesiteetc.
The Ocoita, which is presumably associated with copper mineralization, is characteristic andesite with very much large plagioclase phenocrysts, shows the absolute age of Middle Cretaceous, and is probably intrusive judging from its occurrence and petro-chemical composision.
The geological trends strike roughly north to south, and dip to east, showing a monoclinic structure. NW-SE faults are dominant in the area.

More than 30 mineral occurrences have been confirmed in the area, and all of them are of copper mineralization. Mosy of them are in the Upper Horqueta Member. but the others are in the Lo Prado Formation. The relation between these mineral occurrences and fault system are not clear.
Only Las Guias Mine has been operated in a small-scale, and the others have been only prospected by very small-scale size trenching.
The constituent minerals of Las Guias Mine are bornite, chalcocite, chalcopyrite, pyrite, malachite, crysocolla etc.. These minerals are embracedin the Ocoita, as net work~dissemination, therefore the occurrence shows primary replacement mineralization under low temperature condition.
The mineralization in the Lo Prado Formation is mainly chalcopyrite-pyrite quarz veinlet ~dissemination with weak silicification and argillization, and it indicates that mineralization is basically different from thatof malachite-crysocolla, azurite etc. mineralization in the Upper Horqueta Member.

Judging from field evidences and laboratory works of absolute age determination of igneous rocks, filling temperature and salinity of fluid inclusion, δO, δS isotopic ratio etc., ore genesis and forming proces are as follows

① Intrusie of Ocoita associated to mineral occurrenes intimately ……Middle Cretaceos

② Primary replacement mineralization of bornite-chalcocite forming ore shoots of Las Guias Mine……since Paleogene

③ Primary hydrothermal mineralization of chalcopyrite-pyrite quartz veinlet ……since Paleogene

④ Mineralization of malachite, crysocolla, azurite etc. ……since Paleogene

2. Result of Geochemical Survey

Rock and soil geochemical survey were carried out in the area, and result of them are concluded as follows.

① Cu-anomaly zones in rock are almost concordant with the mineral occurrences in the area, and reflect them, espetially in the Ocoita. These evidences show that Ocoita should have available rock-property for mineralization.

② Also high marked zones for the pricipal component analysis are well concord ant with mineral occurrences, reflecting locations of mineralized zones.

3. Result of Geophysical Survey

Seven anomalies have been extracted by IP and TEM method in the area as follows

① Anomaly A: south part of Las Guias Mine

② Anomaly B: about 500m west from Las Guias Mine

③ Anomaly C: about 800m northwest from Las Guias Mine

④ Anomaly D: about 1,100m west from Las Guias Mine

⑤ Anomaly E: around Angelita Mine

⑥ Anomaly F: about 2,000m northwest from Cerro Chaquilla

⑦ Anomaly G: about 1,700m north from Las Guias Mine

4. Recommendations for the Second Years Program

Based on the all survey results in this year, followings are recommended for the next year

① The principal characteristics of the geology, geochemistry, mineralization etc. have been almost interpreted. Therefore, the future exploration program should be planned after interpretation of the drilling survey result as follows.

② If more geophysical survey is planned in this area, it should be limited in the Ocoita distribution area by the means of the geological and geochemical survey results.

③ Geophysical anomaly zone E is situated around Angelita Mine accompanying many green copper mineralizations and some chalcopyrite-pyrite quartz veinlet, also it has a possibility with bornite-chalcocite ore deposits. Therefore anomaly E should be confirmed by drilling.

The same type another mineral occurrences in the survey area confirmed should be re-estimated based on the result of that drilling.

④ A drilling program for the geophysical anomaly zone D is also recommended to know its cause.

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PART 1 SURVEY RESULT

Chapter 1 Outline of the Survey

1-1 Background and Object of the Survey

Some survey programs of Cooperative Mineral Resources Development Project by Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ) have been conducted in the northern Chile, eastern part of Conception, central Chile, Antofagasta, Cero Negro, and Velagua Progreso areas in Chile since 1975. The results of the surveys have significantly contributed to increase data for mineral resources exploration and to grade-up exploration techniques in Chile, in addition to new discovery of the Cero Negro deposit, an economically feasible ore deposit. The achievement of the projects has been highly appraised by the Chilean relevant organizations, and has significantly contributed for creation of the close relation between Chile and Japan.

Based on the above mentions process, the Chilean government proposed to conduct the exploration project in the Cholqui area, to the west of Santiago. Many mineral occurrences and old workings, mainly of copper, have been known in the area, and many private prospectors have been active since Spanish colony age. Recently, the area is noticed as a potential area for Manto-type copper ores by many exploration organizations including overseas agencies. Only some geological surveys and small-scale geophysical surveys, however, have been conducted in the known ore area by Empresa Nacional de Minera (ENAMI) during 1991 and 1992, and any systematic exploration program has never been conducted.

It was judged that discovery of new ore deposits by systematic exploration programs in the area would significantly contribute to the Chilean economical development. Accordingly, Japanese government decided to conduct a new Co-operative Mineral Resources Development Project in the area, three-years program from 1996.

1-2 Method and Content of the Survey

Table 1-1-1 shows contents and works of each survey item including laboratory tests. Object and outline of each survey category is as follows.

(1) Geological survey

Principal object of the geological survey is to make clear relation between geological structure and mineralization, especially ore-hosting stratigraphic horizon and its distribution. The survey is performed making 1:10,000 scale route maps, and a same-scale geological map and profiles are produced based on the route maps. Some laboratory tests are performed to support the interpretation of the result of the geological survey. Integrated interpretation regarding characteristics of mineralization and alteration is done based on the results of those works.

(2) Geochemical survey

Principal object of the geochemical survey is to support estimation of potential zones for minerals based on geochemistry of rocks and soil. Geochemical characteristics are analyzes based on the results of the rock and soil geochemical surveys, and interpreted together with the geological and laboratory survey results.

(3) Geophysical survey

Principal object of the geophysical survey is to extract geophysical anomaly zones relating mineralization in the area. The induces polarization method (IP method) is applied to fined resistivity and IP anomalies, transient electromagnetic method (TEM) is for extracting resistivity anomalies closely relating mineralization based on analyzed resistivity structures.

In addition to the field survey, typical rock and mineral specimens are measured their resistivity and IP effect in laboratory to assist interpretation of the field survey results.

1-3 Survey Period and Team Members

Table 1-1-2 and 1-1-3 show the survey period and survey team members.

Table 1-1-1 List of specification of survey

1. Geological survey
1) Detailed geological survey   Area: $93km^2$, Route length: 220km
2) Laboratory works
Thin section number of samples: 40
Polished section number of samples: 20
X-ray diffraction number of samples: 100
Chemical analysis
Rock Samples(Au, Ag, As, Sb, Hg, Cd, Co, Cu, Fe, Pb, Mn, Mo, Ni, V, Zn): 400
Soil samples(Au, Ag, As, Sb, Hg, Cd, Co, Cu, Fe, Pb, Mn, Mo, Ni, V, Zn): 150
Ore samples(Au, Ag, Cu, Mo, Pb, Zn, S): 20
Whole rock samples(SiO2, TiO2, Al2O3, FeO, Fe2O3, MnO, MgO, CaO, Na2O, K2O, P2O5, LOI, Ba, Rb, Sr, Zr, Nb, Y): 20
Fluid Inclusion microthermometry and Salinity samples: 10
EPMA analysis ore samples: 10
Stable Isotope(δ O)analysis samples: 3
Stable Isotope(δ S)analysis samples: 6
Age dating(K-Ar method) samples: 6
2. Geophysical survey
1) IP survey   20 line-km, 1,800 points
2) TEM survey   20 line-km, 190 points
3) Laboratory works   Measurement of resistivity and chargability of rock samples: 40

Table 1-1-2 Period of Survy

Geological and Geochemical survey	5 October 1996 to 9 Dicember 1996
Geophysical survey	5 October 1996 to 21 Dicember 1996
Analyisis and Reporting	22 October 1996 to 28 Febrary 1997

Table 1-1-3 Members of Survey

Planning and Managing	Field surveiors
Japan side	Mr. Toshiya, Itoh, geologist
Mr. Masaharu Noguchi	DOWA Engineering Co., Ltd. (DEC)
Metal Mining Agency of Japan(MMAJ)	Mr. Ko Aizawa, Geologist, DEC.
Mr. Kenichi Takahashi	Mr. Junichi, Ishikawa, Geologist, DEC.
Japan International Cooporation Agency	Mr. Kazuhiko Kinoshita, Geophysist, DEC
Mr. Toshihiko Hayashi MMAJ	Mr. Yoshihiko Ogawa, Geophysist, DEC.
Mr. Takafumi Tsujimoto MMAJ	Mr. Hidehiko Watanabe, Geophysist, DEC
Chile side	Mr. Patricio Trujillo Ramizes
Mr. Ivan Heriquez	Empresa National de Mineria
Empresa National de Mineria	Mr. Oscar Arce Torres
Mr. Mario Serrano	Empresa National de Mineria
Empresa National de Mineria	

Chapter 2 Geography of the Survey Area

2-1 Location and Access

The location map of the area is in the top of the report. The survey area is situated in the central part of Chile, approximately 60 kilometers southwest of Santiago, the capital prefecture of the country. The area is in Cholqui, Paliocabe, and Tantehue Villages in Melipilla County, La Region Metropolotana. The access to the area from Santiago can be done taking highway No.76 through Melipilla City. It takes about two hours by car. Highway No.76 from Santiago to Paliocabe is paved, but rest of the route is of steep and hair-pin bend. Melipilla City is the capital of the county, and there is no problem about procurement of common goods except special survey equipment and after communication ways.

2-2 Topography and Drainage System

The survey area is situated in the coastal mountain range in the country. Surrounding areas of the survey area are occupied by flat planes and deeply and widely cut valleys, and utilized for farming and stock breeding. The elevation of the flat land there is about 180 meters above the sea level, but its height increases toward the mountainous area. The mountainous area shows young rug topographic features. Cerro Watancilla, 1,910 meters above sea level, stands out in the eastern survey area, and a high ridge above 1,000 meters extends north to south around there. In the eastern survey area, a high ridge exceeding 900 meters high extends north to south centering Lidres, 1,085 meters high, and some ridges exceeding the same level extends toward west from the north-west extending ridge. It is very hard to perform surveys in those high mountain areas because of rocky and steep slopes.

An apparent caldera landscape, about 10 kilometers in diameter, is recognized in the southwestern area, however, the result of the geological survey has revealed that it is not caldera, simply has been formed by erosion.

The drainage system in the area shows a dendritic pattern stretching north to south around Rivers Quebrada Las Guias and Cajon de Panama in the eastern and central areas, and stretching east to west around Rivers Quebrada El Cajon, Cajon de Las Casas, and Quebrada del Rey in the eastern area. These systems have almost no water flow and stream sediment due to the climate condition in the area.

2-3 Climate and Vegetation

The area is situated in the mild Mediterranean climate area, and the climate is clearly separated in dry and wet seasons. The average temperature is 14 degrees through a year, seven degrees in winter from May to September, and 17 degrees in summer from October to April. The average precipitation is 265 millimeters through a year, 56 millimeters in the wet season from May to August, and several millimeters in the dry season from September to April.

Large-scale farming for vegetable and fruits as well as stock farming are prosperous in flat land areas, and the area plays a very important role for the country as the biggest food supplier. Large-scale poultry farming and hog raising are especially popular in the area, and it is difficult to enter into those farming areas for surveys due to problem of quarantine for animals.

The mountainous area is almost completely covered by thorny shrubs, tall trees, and grasses. The area, however, adjoins a national park, and cutting in the area is strictly prohibited. Cutting survey lines to efficiently perform various surveys is hopeful, however survey lines have been set without cutting.

Chapter 3 Outline of Geology

3-1 Outline of Past Surveys

Very small-scale copper deposits such as Las Guias, Angelita, and Mona Blanca are known in the area. Other than those, many copper mineral occurrences exist in the area. Very shallow pit prospecting, up to several meters deep, has been commonly performed for the occurrences in the past since Spanish colonial age, however details of that is not clear.

As mentioned above, some small-scale prospecting works have been performed by private prospectors in the area, however, no systematic exploration work has been conducted, and no many geological data for the area exists. However, a concept that the occurrences in the area are of the Manto type, is widely recognized, and many domestic and foreign mining sectors are interested in exploration activity in the area.

Relatively systematically written survey reports for the area are as follows.

* 1981: Geologia del area de Choloqui-Cajón de Acuelo-Villa Alhue, Region Melipilla, Memoria de Titulo Universidad de Chile, Facultad de ciencias fisicas y matematicas, Departamento de Geologia. Cario Naci P.

The report describes the fundamental stratigraphy, petrography, geological structure, and mineral occurrences based on the aero-photographic study for the area, 40 × 40 kilometers, south of Rio Maipu, 52 days geological survey for the area, laboratory works including microscopic study for 70 rock thin-sections. It contains a geological map, 1:10,000 in scale.

* 1992: Diagnostico geologico minero minas: Angelita, Rinconada, Bello Horizonte, Area Paliocabe. Region Metropolitana, M. Areva, ENAMI. Gerencia Quinta Region.

The report follows the above mentioned report regarding geology, petrology, and geological structure, but describes details of the result of the underground adit survey and ore reserve estimation.

* Fragmental reports for the mineral occurrences by ENAMI

These reports simply describe mineral occurrences in the area.

Other than above mentioned activities, in 1980, 1991, and 1995, JICA has conducted some short-period survey programs for the mineral occurrences situating north of the survey area this time to appraise potential for exploration activity.

3-2 Geological Setting and Outline of Geology

The survey area is situated in the coastal mountains of Andean Cordillera, which is extending north to south in the Pacific Coast side of the South American continent. The Andes is geologically and geographically divided into following three zones from the Pacific side.

* Cordillera de la Costa ··· coastal mountain range
* Cordillera de los Andes
* Precordillera

The Andes, in a broad sense, is distributed stretching north to south about 9,500 kilometers in the western rim of the continent, and it varies from 300 to 700 kilometers in width. The Andes is geologically a folded mountains, and has been formed during the geologically young stage orogenic movement in early Cenozoic.

The history of the geologic structure of the Andes is summarized as follows.
(1) The Pre-Andes subsidence occurred in the eastern side of the present Andes during Late Cambrian to Middle Devonian time. Thick sediments reaching 10 kilometers deposited there, and the area uplifted over the surface in Middle Permian time.
(2) Following the events, the Andes subsidence zone was formed in the western side of the uplifted zone accompanying with significant volcanic activity in Late Triassic time. This geosynclinal zone was intruded by The Andes Batholith mainly consisting of granodiorite during Cretaceous to Paleogene time, and then uplifted over the surface by abrupt upheaval movement since Pliocene time.
(3) The coastal mountains has been formed by host-graven movement, having undergone two stages orogenic movements during Paleozoic time on Precambrian to Paleozoic formations.
(4) Calc-alkali volcanic activity has took place in the whole area of the Andes during Pliocene to Quaternary time.

Principal non-ferrous metal ore deposits in Chile mainly consisting of porphyry copper deposits are closely associated with the granodiorite bodies in the coastal mountains intruded in Cretaceous to Paleogene time.

Recent plate-tectonic theory clearly explains how the geological divisions in the Andes has been formed, by collision of two plates, subduction, accretion terrain, magmatic activity, strike fault etc. According to the theory, the coastal mountain is in the added bodies. The petrochemical characters of a series of the andesitic bodies in the region accords with that of typical continental rim areas and island-arc areas, supporting the theory.

The survey area is principally underlain by Jurassic to Cretaceous andesitic rocks.

Table 1-1-1 shows the geological columnar section of the area.

(1) Lower part of the Horqueta Formation: mainly composed of Middle Jurassic andesite lavas and pyroclastic rocks, accompanied with thin beds of sandstones. Marine sediments.

(2) Upper part of the Horqueta Formation: mainly composed of Late Jurassic andesite lavas and pyroclastic rocks, accompanied with thin beds of sandstones and mudstones. Continental sediments.

(3) Lo Prado Formation: mainly composed of Early Cretaceous andesite lavas and pyroclastic rocks, and dacite lavas and pyroclastic rocks, accompanied with thin beds of fine-grained sandstones, shales, and limestones. Marine sediments.

(4) Alluvial Formation: composed of stream and debris sediments. No mark in the geological map.

(5) Intrusive rocks: consisting of granodiorite, andesite, dacite, quartz porphyry, and porphyrite, intruding into above mentioned formations.

These formations except alluvial and intrusive rocks have undergone strong propylitization. The geological structure of the area is very simple, generally stretching north to south, dipping 30 degrees to the east. NW-SE trending faults are dominant in the area.

The absolute ages for various intrusive rocks are as follows: 139.20 ± 1.47 Ma (Jurassic to Cretaceous) for the small-scale quartz diorite bodies in the southwestern area, corresponding to Tantehue Granite in the existing geological map, 90.23 ± 1.47 Ma (middle Cretaceous) for the granodiorite body in the southeastern area, corresponding to Alhue Granite in the existing geological map, 69.76 ± 1.53 Ma and 46.98 ± 1.08 Ma (late Cretaceous to Paleogene) for various andesite dikes, and 99.36 ± 2.13 Ma and 95.39 ± 2.08 Ma (middle Cretaceous) for the Ocoita, seemingly associated the mineralization. The Ocoita in the area is of intrusive judging from its occurrence and petrochemical character.

3-3 History of Mining

The mining history in the area is not well known as mentioned in Part 1 Outline of the Survey.

In the past, the large-scale Narthue copper smelter was constructed by France at the side of Rio Maipu for the ores from small mines of Suello, Espino, Socavon Venas etc. locating nearby Cerro Yerbas Buenus, about 15 kilometers northeast of the survey area. But it was stopped its operation in 1917. Infrastructure for mining operation for the small mines such as road, railway, tunnel, was fully arranged, and the smelter once had about 30,000 employers. The smelter treated oxide ores such as malachite, not handled sulfide ores such as chalcocite and bornite.

Nearby the surrey area, about 30 kilometers southeast, Las Animas and El Manzanas Mines are operating for vein type gold, silver, copper, lead, and zinc ores, and selling their concentrates to the Alhue smelter. It is said that the grade of ores is 1.30 g/t for Au, 1,300 to 4,00 g/t for Ag, 20 to 30 % for Zn, 8 to 10 % for Pb, 1.3 to 2.0 % for Cu, 32 % for SiO2. Other than that, a small-scale gold mine is operating to the south of the survey area for gold-bearing quartz veins associated with granodiorite intrusive activity.

No highly economical large-scale ore deposits have been discovered in and around the survey area yet, however, this area is noticed as a potential area for Manto-type copper deposits and gold-bearing quartz veins. Recently, many domestic and foreign mining sectors are interested in to start their exploration activities there.

Chapter 4 Integrated Interpretation of Results

4-1 Characteristics of Mineralization and Concept of Genesis

4-1-1 Characteristics of Mineralization

Mineralization occurred in the area is summarized as follows.

(1) Sixty-five percent of the total 30 mineral occurrences confirmed in the area this time is concentrated in the Upper Horqueta Member, however, no phenomenon to indicate the direct genetic relation between the Ocoita and mineralization in the geology and geochemistry in the area has been found. Also, it does not appear that the distribution of the mineral occurrences is controlled by some tectonic elements such as fault.

(2) Principal mineral occurrences and associated alteration are as follows.

* Net-work or disseminated mineral occurrences of secondary minerals mainly composed of malachite: This type of mineral occurrences occupy most of occurrences found in the area except the bornite-chalcocite occurrence in the Las Guias Mine. The mineralization has been abruptly ceased in the edges to the both sides and depth, and no phenomenon to transform to barren quartz veins or alteration zones is seen. No alteration except regional diagenesis has been occurred in the spots.

* Net-work or disseminated mineral occurrences mainly composed of bornite and chalcocite in the Las Guias Mine: No alteration mineral except regional diagenesis minerals is seen in the spot.

* Very small-scale chalcopyrite-pyrite quartz veins in the andesites: Some impregnation of secondary copper minerals is seen in this primary mineral occurrences. The occurrences are associated with minor-amounts of alteration minerals such as sericite and kaolin.

* Net-work or disseminated mineral occurrences of chalcopyrite and pyrite in the Lo Prado Formation: The mineralization are accompanied by silicification and argillization.

* The result of X-ray analysis for samples taken by regular pattern method from the Las Guias Mine area has revealed that no alteration mineral exists in the samples except diagenesis minerals.

* Common constituent minerals appeared in the occurrences are bornite, chalcocite, chalcopyrite, hematite, malachite, chrysocolla, azurite, atacamite, etc. Under the microscope, it appears that bornite, chalcocite, and chalcopyrite replaced parts of host rocks, and a little alteration minerals are seen nearby the edges of the ore minerals.

* Close paragenesis of bornite-chalcocite-digenite, colloform structure, and exsolution structure of djurleite from chalcocite indicate mineralization under low temperature.

(3) Summary of the liquid inclusion test result is summarized as follow.

* Homogenization temperature of the chalcopyrite-pyrite bearing quartz is 200 to 265 degree, that of the barren quartz is about 170 degree, and that of the barren quartz and calcite vein of secondary genesis is about 130 degree. No homogenization temperature of the mineralized parts of the bornite and chalcocite in the Las Guias Mine is obtained.

* It is supposed that three kinds of solutions, having higher than 10%, 10 to 5%, and lower than 5% of the salt density existed. No homogenized temperature of the bornite and chalcocite in the Las Guias Mine is obtained.

Judging from the above mentioned results, the hydrothermal activity in the area occurred several times with different temperature and salt density.

(4) Stable isotope elements, δ O and δ S, have been measured to investigate origin and behavior of ore solution relating to the mineralization and to assume ore-forming mechanism. The results are as follows.

* δ O shows high values of 13.4 to 16.3% to SMOW. It suggests that the primary solution reacted to the sedimentary and metamorphosed rocks during transposing process in the ground.

* δ S shows high values of 18.8 to 19.4% CDT. It suggests that sulfuric acid ion originated from the marine water was trapped in the deep ground, reduced by some heat source, transferred to other places, transformed to hydrogen sulfide during the

process, and finally homogenized to the stable isotopic ratio. During a series of the process, it is resumed that copper ions were solved in the solution, and bornite and chalcocite minerals were deposited under the low temperature condition, controlled by the suitable geological structure.

4-1-2 Concept of Ore Genesis

Based on above mentioned survey results, following ore-forming process is idealized. Fig. 1-1-1 shows a schematic diagram of ore-forming process for bornite-chalcocite ores in the Ocoita.

(1) Intrusion of the Ocoita -- Middle Cretaceous

The rock has undergone all mineralization.

(2) Primary replacement mineralization of bornite and chalcocite forming ore shoots of the Las Guias Deposit -- since Paleogene

The ore shoots exist in the Ocoita, being discordant to the surrounding sedimentary rock formations, and extend to the andesite dikes in the area. The geochemical copper content in the Ocoita is abnormally high compared with all other rocks in the area. From the microscopic observation results, it is judged that the copper minerals are of primary mineralization, replaced host rocks. It is presumed that the minerals were deposited under the low temperature condition, based on the mineral assemblage and traces of weak alteration around the ore minerals. Also, the phenomena suggest that the mineralization could be closely related with the physical character of the Ocoita, porous and heterogeneous. This type of mineralization forms relatively large-scale high grade ore deposits.

(3) Primary mineralization of chalcopyrite-pyrite quartz vein -- since Paleogene

The veins exist in the underground of the Las Guias and Angelita Mines, and in the Lo Prado Formation. Judging from its occurrences, the mineralization is of presumably after the above mentioned bornite-chalcocite mineralization stage. These two mineralization are probably brought under the different physical and chemical conditions, judging from the different mineral assemblages. The geochemical survey result has revealed that the Au-Sb-Pb content in the Lo Prado Formation tends to higher than that in the Horqueta Formation, and it supports the above mentioned presumption. This type of mineralization is significantly small-scale, and no economical ore has been found yet.

(4) Secondary copper mineralization mainly of malachite

This mineralization is overlapped previously mentioned all other mineral occurrences, being in the last stage. The occurrences of this type mineralization are controlled by cracks and druses in the bornite-chalcocite ore shoots and host rocks in

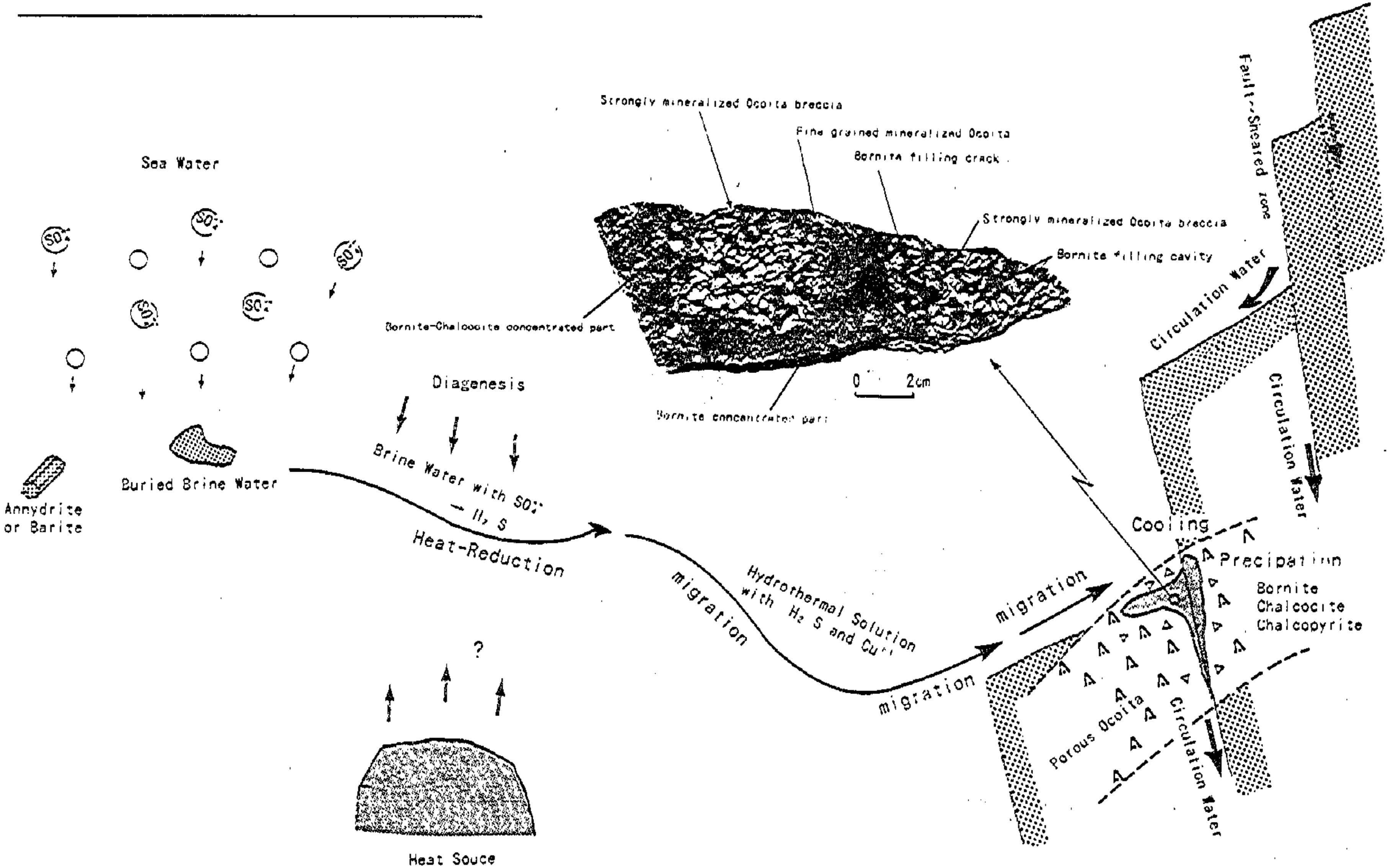


Fig. 1-1-1 Schematic conception map of mineralization

the Las Guias Mine, and by spaces of cracks and banded structures in the chalcopyrite-pyrite quartz veins. These occurrences clearly show later stage one than other stages such as vein forming. It is quite possible that the mineralization was brought from existing primary ores through oxidation and transfer process. This type of the mineral occurrences are small-scale, and no economical one has been found yet.

4-2 Geochemical Survey

Geochemical surveys for rock and soil have been performed to extract potential zones for minerals in the ground. Four hundred and ten rock samples and 152 soil samples have been collected, and following 15 elements have been chemically assayed; Au, Ag, As, Sb, Hg, Cd, Co, Cu, Fe, Pb, Mn, Mo, Ni, V, and Zn.

Some investigations to know relations between geochemical concentration of each element and mineralized zones, between copper anomalies and content of other elements, correlation of copper content in each formation and andesitic rocks, and principal component analysis have been performed to achieve the above mentioned object. The results of the investigation have revealed following points.

* Cu anomaly zones for rocks are coincident with the distribution of the mineral occurrences, and well reflect mineralized zones. No relation between other elements than copper and mineral occurrences has been recognized.

* High content zones for As, Ag, and Sb are coincident to a part of Cu anomalies, however, generally no clear correlation is recognized between Cu anomalies and high content zones of other elements.

* Cu anomalies in the soil are smaller-scale than those in the rocks, and sit in the anomalies in the rocks. Accordingly, anomalies in the rocks can represent anomalies in the soil.

* Cu is concentrated in the andesitic rocks in the Horqueta Formation, especially in the Ocoita, appearing the Ocoita itself shows big Cu anomalies in some places. It might be caused by high porosity of the rock compared with others, allowing seepage of mineral solution.

* High marked zones for the principal component analysis are well coincident to mineral occurrences, reflecting locations of mineralized zones. .

Based on the above mentioned results, the relation between extracted anomaly zones or high marked zones and mineralized zones has been investigated. The result is summarized as follows.

* Cu anomalies, A-1 to A-19, cover about 80% of the all mineral occurrences. It can be

said that the Cu anomaly map is a good petrochemical analysis map for copper prospecting.

* High marked zones in rock and soil cover about 80% of the all mineral occurrences, and its distribution map is a good copper geochemical analysis map for prospecting.

The point having Cu anomalies and high marked zones duplicative for rock and soil in the area indicates the location of the Las Guias Mine.

Accordingly, the whole area, which contains many surface mineral occurrences and the Ocoita showing high content of Cu, is itself an anomaly zone, and is a natural contamination zone. It could be, therefore, very difficult to utilize such geochemical survey methods for prospecting of buried mineral deposits. But, if there are some mineral occurrences like as same type and scale mineralization above mentioned, they should be recognized by the geochemical survey exploration method.

4-3 Geophysical Survey

The Induced Polarization method (IP method) and Transient Electro-Magnetic method (TEM method) have been utilized in the survey. The measured survey lines and points are 20 kilometers and 1,800 points for IP method, and 20 kilometers and 190 points for TEM method. The results for both surveys are summarize as follows.

* The laboratory test result has revealed that the average resistivity and polarizability for principal constituent rocks in the area are 4,390 ohm-meter and 0 mV/V for andesitic rocks and secondary copper bearing andesitic rocks, 4,100 ohm-meter and 0mV/V for the Ocoita, and 54 ohm-meter and 45 mV/V for the bornite-chalcocite ores. There are clear differences between barren rocks and bornite-chalcocite bearing rocks for both, resistivity and polarizability. It is judged that if suitable scale of bornite-chalcocite ore is in the andesitic rock in the shallow subsurface, it is possible to detect such ore by the geophysical methods.

* The result of the IP survey has revealed that the shallow subsurface resistivity structure is of three layers. The resistivity for the first and second layers is low, 300 to 600 ohm-meter, and that for the third layer is medium, 1,500 ohm-meter. The depth of the boundary between the second and third layers is about 100 meters. The background of the polarizability shows 2 to 4 mV/V, and anomalies showing 10 to 20 mV/V have been detected in many spots. Some of them are accompanied with low resistivity anomalies.

* The result of the TEM survey has revealed that the resistivity structure in the deep ground is of two layers, the upper low resistivity layer showing lower than 1,000 ohm-

meter and the lower medium resistivity layer showing higher than 1,000 ohm-meter. The depth of the boundary between two layers is about 100 meters, and it is coincident to the boundary shown by the IP survey result. Some low resistivity zones have been detected in several places extending further deep ground.

* From the investigation of the resistivity structure and polarizability, seven anomalies, A to G, have been extracted. The outline of the anomalies and the interpretation for them are as follows.

① Anomaly zone A situated in the south of the Las Guias Mine area:

A low resistivity zone showing 100 ohm-meters with high polarizability of 20 mV/V extends to the depth of about 100 meters. But the low resistivity zone disappears at the depth of 300 meters. The anomaly is situated in the shallow part of the Ocoita, which is the host rock of the Las Guias Deposit. It is, therefore, possible that the anomaly indicates the same type of ore as the bornite-chalcocite ore in the Las Guias.

② Anomaly zone B situated at El Remota, about 500 meters to the west of the Las Guias Mine:

A medium resistivity showing 1,000 ohm-meter with high polarizability of 10 mV/V extends to the depth of 150 meters. The low resistivity zone disappears at the depth of 300 meters. The anomaly zone is situated in the shallow part of the Ocoita, which is the host rock of the Las Guias Deposit. It is possible that the anomaly indicates the same type of mineral occurrence as the bornite-chalcocite ore in the Las Guias.

③ Anomaly zone C situated at El Remota, about 800 meters to the west of the Las Guias Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V extends to the depth of 200 meters. The low resistivity zone possibly extends to the depth of 300 meters. It is possible that the anomaly zone indicates the same type of mineral occurrence as the bornite-chalcocite ore in the Las Guias or an aquifer associated with a fault stretching NW to SE.

④ Anomaly zone D along a stream on the west side of El Remota Hill, about 1,100 meters west of the Las Guias Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V extends to the depth of 150 meters. It is possible that the low resistivity zone extends to the depth of 300 meters. The anomaly zone has been detected only in the survey line "2", however, it is a large-scale anomaly zone. No mineral occurrence or alteration zone is seen in the vicinity area corresponding to such large-scale of anomaly. The anomaly zone is situated along a gentle stream, and a dike exists on the west of the anomaly. It is possible that the anomaly is caused by the topographic feature and sheared zones controlled by the dike nearby the anomaly.

⑤ Anomaly zone E in the Angelita Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V, partly 30 mV/V, extends to the depth of 200 meters. It is possible that a part of the anomaly extends to the depth of 300 meters. Many prospecting pits exist around there, but they are of small-scale. Mineral occurrences around there are mainly composed of secondary copper minerals such as malachite, and any primary mineral such as bornite is not seen there. The mineral occurrence is not accompanied by any alteration zone, an disappears at the depth of several meters. Faults stretching north to west and NW to SE around the anomaly. Chalcopyrite-pyrite quartz veinlets are seen in the underground of the mine. Judging from the above mentioned facts, it is possible that the anomaly represents an aquifer associated with sheared zones controlled by faults. Besides, considering the existence of chalcopyrite-pyrite quartz vein in the area, there is still some possibility that the anomaly was cause by a presumed large-scale mineralized zone in the depth.

⑥ Anomaly zone F situated about 2,000 meters northwest of Chaquilla:

A medium resistivity zone showing 1,500 ohm-meter with high polarizability of 30 mV/V extends to the depth of 150 meters. It is possible that the low resistivity zone extends to the depth of 300 meters. The geological setting and character of the mineralization are same those of Anomaly zone F, but no chalcopyrite-pyrite quartz vein is seen there. It is ,therefore, that the anomaly reflects an aquifer associated with a fault.

⑦ Anomaly zone G situated about 1,700 meters north of the Las Guias Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V extends to the depth of 200 meters. It is possible that a part of the anomaly zone extends further depth of 300 meters. The anomaly zone is situated along a valley, and there are a Ocoita dike and fault stretching north to south. It is possible that the anomaly zone reflects a bornite-chalcocite mineral occurrence or an aquifer controlled by a faults or sheared zone.

The above mentioned anomaly zones indicate a potential for buried ores, however, its scale might be small judging from its low polarizability values, lower than about 60% of the value for the ore (45 mV/V). It is also possible that the anomalies reflect some aquifer controlled by the space in the rocks etc.

4-4 Potential for Ore Deposit

The potential for ore deposits in the area is summarized as follows.

(1) Many mineral occurrences mainly consisting of malachite have been confirmed by the geological survey program in the Horqueta Formation. All of those are of small-scale, specially to the downward. If those occurrences are accompanied with ore shoots of bornite and chalcocite, those would be of nearly same-scale as that of the Las Guias Deposit.

(2) As the results of the integral interpretation for the mineralization in the area, it is judged that some potential for ore shoots of bornite-chalcocite exists in brecciated parts of the Ocoita.

(3) The hydrothermal veins in the Lo Prado Formation are of smaller-scale than those in the Horqueta Formation, and its associated alteration is also weak. Judging from these facts, the potential for large-scale ores is low .

(4) The geochemical anomalies found in the area cover the all mineral occurrences found by the geological survey, and it is estimated that the geochemical survey result well reflects the location of mineral occurrences. An anomaly situated in the Lower Horqueta Member is not associated with a mineral occurrence. The sampling density there is low, however it is judged that the anomaly reflects the same grade of geochemical character as that in the Upper Horqueta Member. It is judged that the potential for ores in the anomaly zone in the Lower Horqueta Member is low.

(5) Some potential for sulfide ores is, in various degrees, in the seven anomaly zones detected by the geophysical survey.

Chapter 5 Conolusions and Recommendations for Second Year

5-1 Conclusions

5-1-1 Geological Survey

The area is underlain by the Jurassic Horqueta Formation and Cretaceous Lo Prado Formation. The Horqueta Formation is divided into the Upper and Lower Members. The Lower Member is mainly composed of marine andesite lavas and andesitic pyroclastic rocks intercalated by dacite lavas, and the Upper Member consists mainly of continental andesite lavas, partly Ocoita, and andesitic pyroclastic rocks, intercalated by thin beds of sandstone and shale. The Lo Prado Formation is mainly composed of marine dacite to andesite lavas and andesitic pyroclastic rocks, accompanied by beds of sandstone, shale, and limestone. Intrusive bodies of granodiorite, quartz diorite, andesite, and dacite exist in the above mentioned formations. The formations trend approximately north to south, and dip around 30 degrees to the east, showing a simple monoclinic structure. The NW to SE fault system is dominant in the area.

The K-Ar dating for the intrusive rocks has revealed its intrusion stage. Those are as follows; Tantehue quartz diorite - Jurassic to Cretaceous; Alhue granodiorite - middle Cretaceous; andesite dikes - late Cretaceous to Paleogene; Ocoita - middle Cretaceous, at least two stages. Judging from its occurrences and petrochemical character, the Ocoita, closely associated with mineralization, is probably intrusive rock having two intrusion stages.

About 30 mineral occurrences have been confirmed in the area, and almost all of them are of copper. About 65 % of them are in the andesitic rocks of the Upper Horqueta Member, and the rest are in the Lo Prado Formation. No mineral occurrence is seen in the Lower Horqueta Member. Among these occurrences, only the Las Guias and Mona Blanca Mines have operated in the past. It has been confirmed by trench prospecting that the scale of the occurrences is quite small, several thousand tons, except the Las Guias Deposit. The ore shoots of the Las Guias are arrayed in a line stretching NW to SE, and dip 70 degrees to the north. Judging from the size of the mined areas, the shoots are less than 30 x 20 x 6 meters in scale. Three shoots existed in the mine, and they appear not controlled by any fault.

The mineral occurrences in the Horqueta Formation are of net-work or disseminated ores mainly composed of malachite, and those in the Lo Prado Formation are of chalcopyrite-pyrite quartz vein or disseminated ore. Only the ore shoots of the Las Guias Deposit are of bornite-chalcocite net-work or disseminated ore, discordant to the formation and accompanied by net-work or dissemination of secondary stage copper minerals. All mineral occurrences other than the chalcopyrite-pyrite quartz veins do not show any transition to barren quartz veins or alteration zones to the depth. The mineralization in the Horqueta Formation has are not been accompanied by associated alteration except propylitization due to regional diagenesis. The mineralization in the Lo Prado Formation is accompanied by weak silicification, sericitization, and kaolinization.

The filling temperature of the liquid inclusions and salt density of the chalcopyrite-pyrite quartz veins, quartz veins cutting the bornite-chalcocite mineral occurrences, and barren quartz-calcite veins in the andesite have been measured.

The temperatures for each type are 200 to 265 degrees, 170 degrees, and 130 degrees respectively, and it indicates that all types of hydrothermal activities have different temperatures and activities. The measured salt densities are classified into four populations, less than 0.3 %, more than 0.3 to less than 5.0 %, more than 5.0 to less than 10.0 %, and more than 10.0%. respectively. The salt densities are not correlated with the filling temperatures. The salt densities obtained from one specimen are also clearly separated into four populations, showing a range of more than seven per cent. It is, therefore, supposed that different hydrothermal activities having different salt densities have been active in the past.

As the results of above mentioned measurements, it is concluded that the mineral occurrences in the area have been formed by several different hydrothermal activities having different temperatures and salt densities. No data indicating the filling temperature and salt density in the bornite-chalcocite mineralization in the Las Guias Deposit has obtained.

The constituent minerals of the deposit are bornite, chalcocite, digenite, chalcopyrite, pyrite, magnetite, malachite, chrysocolla, azurite, and atacamite. These minerals have replaced part of the host rocks, and a little alteration minerals have been locally formed. The close paragenesis of bornite-chalcocite-digenite, colloform structure, and exsolution structure of djurleite from chalcocite indicate the mineralization under the low temperature.

The stable isotope study has been performed to infer the mineralization mechanism through the origin and behavior of the ore solution. The δ O shows high values of 13.4 % to 16.3 % to SMOW, and it suggests that the primary ore solution reacted with sedimentary rocks or metamorphic rocks during its transfer process. The δ S shows 18.8 % to 19.4 % to CDT, and it suggests that sulfuric acid ions originated from the sea-water were enclosed in the deep underground, reduced by some heat source, transferred, and finally transformed to hydrogen sulfide through the process and the stable isotopic ratio was homogenized. Through a series of the process, it is presumed that Cu ions were solved in the solution, then the copper minerals such as bornite and chalcocite were deposited under the suitable low temperature conditions controlled by some geological structure.

Judging from the results of the above mentioned studies and field survey, the possible ore-forming stages are presumed as follows.

① Intrusion of the Ocoita -- Middle Cretaceous

The rock has undergone all mineralization.

② Primary replacement mineralization of bornite and chalcocite forming ore shoots of the Las Guias Deposit -- since Paleogene

The ore shoots exist in the brecciated heterogeneous Ocoita, being discordant to the surrounding sedimentary rock formations, and extend to the andesite dikes in the area. The geochemical copper content in the Ocoita is abnormally high compared with all other rocks in the area. This suggests that the mineralization could be closely related with the porous and heterogeneous physical character of the Ocoita. This type of mineralization forms relatively large-scale high grade ore deposits.

③ Primary mineralization of chalcopyrite-pyrite quartz vein -- since Paleogene

The veins exist in the underground of the Las Guias and Angelita Mines, and in the Lo Prado Formation. Judging from its occurrences, the mineralization is presumably occurred after the above mentioned bornite-chalcocite mineralization stage. These two mineralization are probably brought under the different physical and chemical conditions, judging from the different mineral assemblages. The geochemical survey result has revealed that the Au-Sb-Pb content in the Lo Prado Formation tends to higher than that in the Horqueta Formation, and it supports the above mentioned presumption. This type of mineralization is significantly small-scale, and no economical ore has been found yet.

④ Secondary copper mineralization mainly of malachite

This mineralization is overlapped previously mentioned all other mineral occurrences, being in the last stage. The occurrences of this type mineralization are controlled by cracks and druses in the bornite-chalcocite ore shoots and host rocks in the Las Guias Mine, and by spaces of cracks and banded structures in the chalcopyrite-pyrite quartz veins. These occurrences clearly show later stage one than other stages such as vein forming. It is quite possible that the mineralization was brought from existing primary ores through oxidation and transfer process. This type of the mineral occurrences are small-scale, and no economical ore has been found yet.

5-1-2 Geochemical Survey

Four hundred and ten rock samples and 152 soil samples have been analyzed to estimate potential for buried copper ores. Analyzed 15 elements for both categories are as follows; As, Ag, Au, Sb, Hg, Cd, Co, Cu, Fe, Pb, Mn, Mo, Ni, V, and Zn.

Some investigations to know relations between geochemical concentration of each element and mineralized zones, between copper anomalies and content of other elements, correlation of copper content in each formation and andesitic rocks, and principal component analysis have been performed to achieve the above mentioned object. The results of the investigation have revealed following points.

* Cu anomaly zones in the rocks are well coincident to the distribution of the mineral occurrences, and well reflect ore minerals. No relation between other elements than

copper and mineral occurrences has been recognized.

* High content zones for As, Ag, and Sb are coincident to a part of Cu anomalies, however, generally no clear correlation is recognized between Cu anomalies and high content zones of other elements.

* Cu anomalies in the soil are smaller-scale than those in the rocks, and sit in the anomalies in the rocks. Accordingly, anomalies in the rocks can represent anomalies in the soil.

* Cu is concentrated in the andesitic rocks in the Horqueta Formation, especially in the Ocoita, appearing the Ocoita itself shows big Cu anomalies in some places. It might be caused by its high porosity compared with other rocks, allowing seepage of mineral solution.

* High marked zones for the principal component analysis are well coincident to mineral occurrences, reflecting locations of mineralized zones.

Based on the above mentioned results, the relation between extracted anomaly zones or high marked zones and mineralized zones has been investigated. The result is summarized as follows.

① Cu anomaly

Cu anomaly zones, A-1 to A-19, cover about 80% of the all mineral occurrences in the area. It can be said that the copper anomaly map itself is a good petrochemical prospecting map for copper in the area. Among these anomalies, some anomalies appeared in barren areas will be described in the following.

* Anomalies A-2 and A-3 are situated adjacent to Anomaly A-1, and can be a part of A-1.

* Anomalies A-5 and A-6 might represent one anomaly. The anomalies are of large-scale, and situated in the Lower Horqueta Member. Because the relation between the geology and mineralization in the area is not clear, these anomalies will be investigated together with other studies.

* Anomaly A-13 can be a part of Anomaly A-14 situated on the southwest of the anomaly.

* Anomalies A-12, A-16, and A-18 are not reliable because of a few numbers of samples.

② High marked zones for rock geochemistry

Twenty-six high marked zones have been detected in the rock geochemistry. Among them, R-1, R-4, R-5, R-9, R-12, R-14, and R-16 show relatively large-scale distribution, and cover about 80% of the total mineral occurrences. It well reflects those mineral occurrences, and it can be said that the rock geochemical anomaly map is a good prospecting map for copper in the area. Accordingly, the anomalies appeared in barren areas will be described in the following.

* High marked zone R-2 is duplicated on an Au anomaly zone in the rock. In spite of no detail geologic setting data is available, it can be a good target for prospecting.

* High marked zone R-3 can be a part of R-4 situated on the southwest of the anomaly.

* High marked zone R-5 is of large-scale and situated in the Lower Horqueta Member. No relation between the anomaly and the geological setting, therefore, it will be investigated together with other studies.

* High marked zones R-21 and R-22 are not reliable because of a few numbers of samples.

③ High marked zones for soil geochemistry

Five high marked zones have been detected in the soil geochemistry. Among them, S-2 covers about 75% of the total mineral occurrences, and well reflects those mineral occurrences. It can be said that the soil geochemistry map is a good prospecting map for copper in the area. Accordingly, the anomalies appeared in barren area will be described in the following.

* High marked zone S-1 is of large-scale and situated in the Lower Horqueta. No detail geological setting is known, therefore, it will be investigated together with other studies.

* High marked zones S-4 and S-5 are not reliable because of a few numbers of samples.

④ Integrated interpretation

Some duplicative anomaly zones extracted from the above mentioned various categories have been extracted to select favorable prospecting targets. The appraisal for those targets is as follows.

* Anomaly zones G-1, G-2, G-3 can be unified to one. The anomaly zone is coincident to a high Au zone, and worth further prospecting. It is possible that the presumed mineral occurrence by the anomaly is associated with a dacite dome.

* Anomaly zone G-4 reflects the mineral occurrences in the Las Guias Mine, but the location of the anomaly is out of the mineral right area.

* Anomaly zone G-5 reflects a small-scale gold occurrence, but it is worth further prospecting.

* Anomaly zones G-6 and G-7 are not reliable because of a few numbers of samples.

In conclusion, the whole area, which contains many surface mineral occurrences and the Ocoita showing high content of Cu, forms itself an anomaly zone, and is a natural contamination zone. It could be, therefore, very difficult to utilize such geochemical survey methods for prospecting of buried mineral deposits. But , if there are some mineral occurrences like as same type and scale mineralization above mentioned, they should be recognized by the geochemical survey exploration method.

5-1-3 Geophysical survey

The Induced Polarization method (IP method) and Transient Electro-Magnetic method (TEM method) have been utilized in the survey. The measured survey lines and points are 20 kilometers and 1,800 points for IP method, and 20 kilometers and 190 points for TEM method. The results for both surveys are summarize as follows.

* The laboratory test result has revealed that the average resistivity and polarizability for principal constituent rocks in the area are 4,390 ohm-meter and 0 mV/V for andesitic rocks and secondary copper bearing andesitic rocks, 4,100 ohm-meter and 0 mV/V for Ocoita, 51 ohm-meter and 45 mV/V for Ocoita accompanied by bornite-chalcocite net-work or dissemination. There are clear differences between barren rocks and bornite-chalcocite bearing rocks for both, resistivity and polarizability.

It is judged that if suitable scale of bornite-chalcocite ore is in the andesitic rock in the shallow subsurface, it is possible to detect such ore by the geophysical methods.

* The result of the IP survey has revealed that the shallow subsurface resistivity structure is of three layers. The resistivity for the first and second layers is low, 300 to 600 ohm-meter, and that for the third layer is medium, 1,500 ohm-meter. The depth of the boundary between the second and third layers is about 100 meters. The background of the polarizability shows 2 to 4 mV/V, and anomalies showing 10 to 20 mV/V have been detected in many spots. Some of them are accompanied with low resistivity anomalies.

* The result of the TEM survey has revealed that the resistivity structure in the deep ground is of two layers, the upper low resistivity layer showing lower than 1,000 ohm-meter and the lower medium resistivity layer showing higher than 1,000 ohm-meter. The depth of the boundary between two layers is about 100 meters, and it is coincident to the boundary shown by the IP survey result. Some low resistivity zones have been detected in several places extending further deep ground.

* From the investigation of the resistivity structure and polarizability, seven anomalies, A to G, have been extracted. The outline of the anomalies and the interpretation for them are as follows.

① Anomaly zone A situated in the south of the Las Guias Mine area:

A low resistivity zone showing 100 ohm-meters with high polarizability of 20 mV/V extends to the depth of about 100 meters. But the low resistivity zone disappears at the depth of 300 meters. The anomaly is situated in the shallow part of the Ocoita, which is the host rock of the Las Guias Deposit. It is, therefore, possible that the anomaly indicates the same type of ore as the bornite-chalcocite ore in the Las Guias.

② Anomaly zone B situated at El Remota, about 500 meters to the west of the Las Guias Mine:

A medium resistivity showing 1,000 ohm-meter with high polarizability of 10 mV/V extends to the depth of 150 meters. The low resistivity zone disappears at the depth of 300 meters. The anomaly zone is situated in the shallow part of the Ocoita, which is the host rock of the Las Guias Deposit. It is possible that the anomaly indicates the same type of mineral occurrence as the bornite-chalcocite ore in the Las Guias.

③ Anomaly zone C situated at El Remota, about 800 meters to the west of the Las Guias Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V extends to the depth of 200 meters. The low resistivity zone possibly extends to the depth of 300 meters. It is possible that the anomaly zone indicates the same type of mineral occurrence as the bornite-chalcocite ore in the Las Guias or an aquifer associated with a fault stretching NW to SE.

④ Anomaly zone D along a stream on the west side of El Remota Hill, about 1,100 meters west of the Las Guias Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V extends to the depth of 150 meters. It is possible that the low resistivity zone extends to the depth of 300 meters. The anomaly zone has been detected only in the survey line "2", however, it is a large-scale anomaly zone. No mineral occurrence or alteration zone is seen in the vicinity area corresponding to such large-scale of anomaly. The anomaly zone is situated along a gentle stream, and a dike exists on the west of the anomaly. It is possible that the anomaly is caused by the topographic feature and sheared zones controlled by the dike nearby the anomaly.

⑤ Anomaly zone E in the Angelita Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V, partly 30 mV/V, extends to the depth of 200 meters. It is possible that a part of the anomaly extends to the depth of 300 meters. Many prospecting pits exist around there, but they are of small-scale. Mineral occurrences around there are mainly composed of secondary copper minerals such as malachite, and any primary mineral such as bornite is not seen there. Faults stretching north to west and NW to SE around the anomaly. Chalcopyrite-pyrite quartz veinlets are seen in the underground of the mine. Judging from the above mentioned facts, there are two possibilities that the anomaly reflects expanded chalcopyrite-pyrite quartz veins in the depth or an aquifer associated with sheared zones controlled by faults.

⑥ Anomaly zone F situated about 2,000 meters northwest of Chaquilla:

A medium resistivity zone showing 1,500 ohm-meter with high polarizability of 30 mV/V extends to the depth of 150 meters. It is possible that the low resistivity zone extends to the depth of 300 meters. The geological setting and character of the mineralization are same those of Anomaly zone F, but no chalcopyrite-pyrite quartz vein is seen there. It is possible that the anomaly reflects some sulfide ores judging from its higher polarizability than that of Anomaly F. Besides there is still some possibility that the anomaly reflects an aquifer associated with a fault or sheared zone.

⑦ Anomaly zone G situated about 1,700 meters north of the Las Guias Mine:

A low resistivity zone showing 300 ohm-meter with high polarizability of 15 mV/V extends to the depth of 200 meters. It is possible that a part of the anomaly zone extends further depth of 300 meters. The anomaly zone is situated along a valley, and there are a Ocoita dike and fault stretching north to south. It is possible that the anomaly zone reflects a bornite-chalcocite mineral occurrence or an aquifer controlled by a faults or sheared zone.

The above mentioned anomaly zones indicate a potential for buried sulfide ores, however, its scale might be small judging from its low polarizability values, lower than about 60% of the value for the ore (45 mV/V). It is also possible that the anomalies reflect some aquifer controlled by the space in the rocks etc.

5-2 Recommendations for the Second Year's Program

Based on the all survey results in this year, followings are recommended for the next year.

(1) The principal characteristics of the geology ,geochemistry, mineralization etc. have been almost interpreted. Therefore, the future exploration program should be planned after interpretation of the drilling survey result as follows.

(2) If more geophysical survey is planned in this year, it should be limited in the Ocoita distribution area by the means of the geological and geochemical survey results.

(3) Geophysical anomaly zone E is situated around Angelita Mine accompanying many green copper mineral occurrences and some chalcopyrite-pyrite quartz veinlet, also it has possibility with bornite-chalcopyrite ore deposits. Therefore anomaly E

should be confirmed by drilling. The same type another mineral occurrences in the survey area should be re-estimated based on the result of drilling.

(4) A drilling program for the geophysical anomaly D is also recommended to confirm the cause.

PART 2 DETAILED SURVEY RESULTS

Chapter 1 Geological Survey

1-1 Outline of Geology

Table 2-1-1 shows the stratigraphic succession of the survey, and Fig. 2-1-1,Fig.2-1-2 shows the geological map and profiles.

The area is situated in the coastal mountains stretching north to south. Existence of Manto-type ores has been already known in the mountains. Some small-scale occurrences have been confirmed in the survey area, and many operating and past worked mines exist to the south of the area. Accordingly, this area is noticed as a mineral district in the middle coastal mountains, and recently many domestic and foreign mining sectors are interested in this area.

The coastal mountains have undergone three organic movements since Paleozoic time as well as Cordillera de Los Andes. It is interpreted that the preset topographic feature has been formed by the Andes Orogenic Movement during Cretaceous to Paleogene. During the Andes Orogeny, the Andes Batholith mainly consisting of granodiorite intruded in the area, being accompanied by porphyry copper mineralization. A part of this batholith is exposed in the survey area.

The survey area is underlain by the Lower and Upper Horqueta Members of Jurassic, Lo Prado Formation of Cretaceous, from western side to eastern side, granitic intrusive bodies, and dacite and andesite dikes.

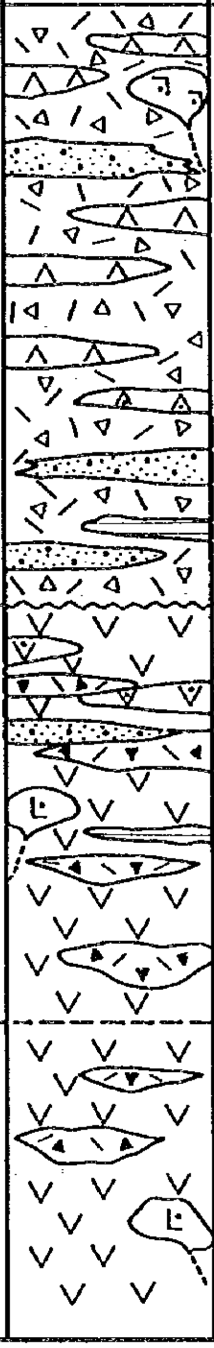
The Lower Horqueta Member is mainly composed of marine andesite lava, and the Upper Horqueta Formation mainly consists of continental red andesite lava accompanied by red sandstone thin beds. The Lo Prado Formation is composed of marine dacite to andesite lava partially being interbedded by sandstone thin beds. This composition reflects the change of a series of igneous activity in various sedimentary environments.

The formations generally strike north to south, and dip 20 to 30 degrees to the east. This monoclinic simple structure is accordant with the geological structure of the Coastal mountains.

Faults stretching northwest to southeast domain in the area, but no big dislocation is recognized.

Mineralization happened in the area is mainly of copper, so-called Manto-type. The Las Guias Deposit is principally composed of oxide minerals such as bornite and malachite, but other very small-scale occurrences are mainly composed of malachite. The survey result this time has revealed that 20 mineral occurrences out of total 30 occurrences confirmed by the survey are situated in the Upper Horqueta Member, and

Table 2-1-1 Geological Column of Cholqui area

Geologic Time		Formation		Geology	Thickness	Description	Intrusive rocks
Mesozoic	Cretaceous	Lo Prado			1500m+	Dacitic ~ Andesitic Pyroclastic rocks (Tuff, Lapilli tuff, Tuff breccio) Dacite (Lava dome) Sandstone Andesite lava and sill (so called Ocoita) Andesite lava (massive and brecciated) Shale	Andesite Dacite Granite and Diorite
	Jurassic	Horqueta	Upper		1500m+	Red coloured Andesite lava (massive and brecciated) Andesite lava and sill (so called Ocoita) Sandstone Dacite (Lava dome) Shale Andesitic Pyroclastic rocks (Tuff, Lapilli tuff, Tuff breccia)	
			Lower			Dark green ~ gray coloured Andesite lava (massive and rarely brecciated) Andesitic Pyroclastic rocks (Tuff, Lapilli Tuff, Tuff breccia) Dacite (Lava dome)	

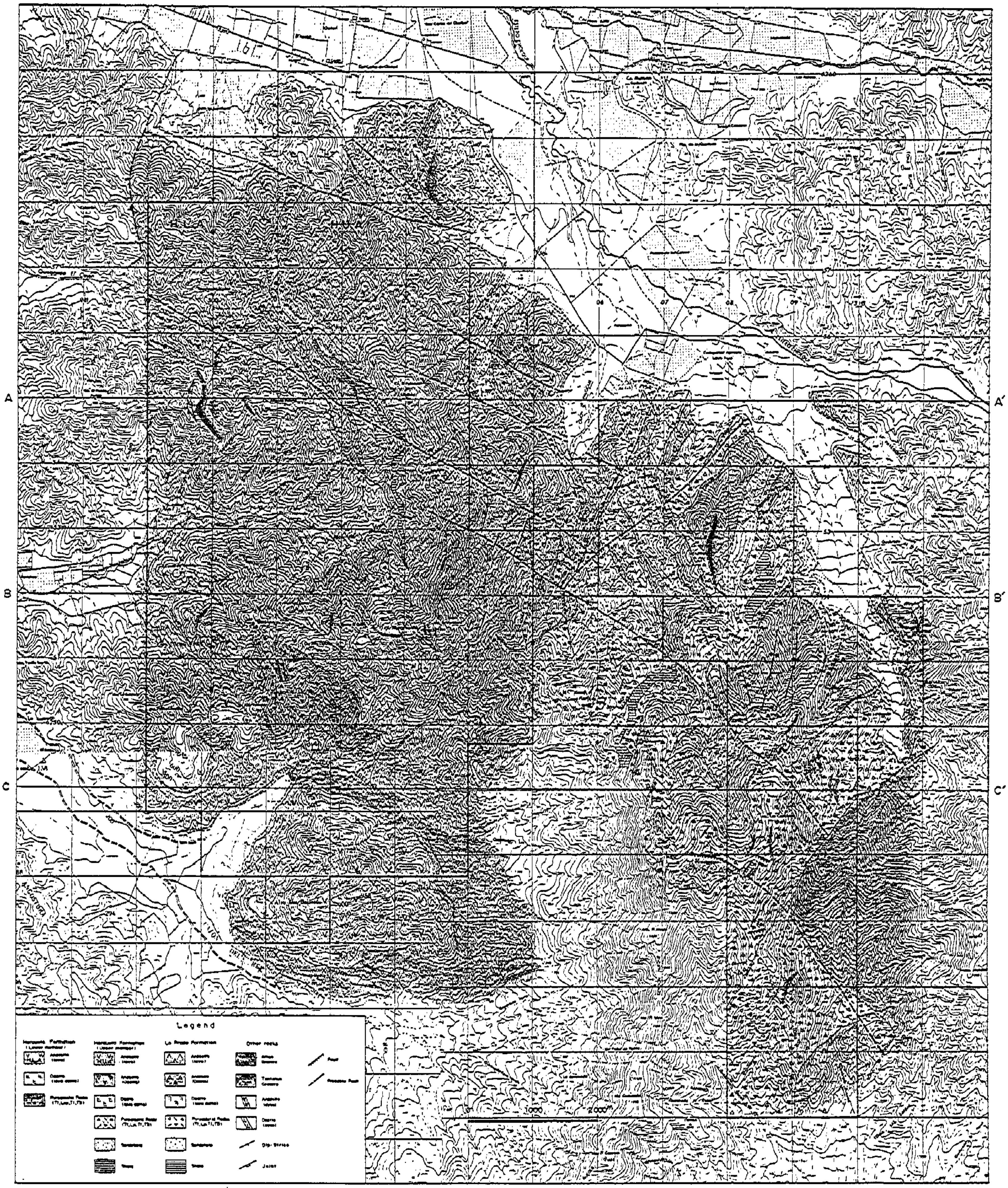


Fig. 2-1-1 Geological map of Cholqui area

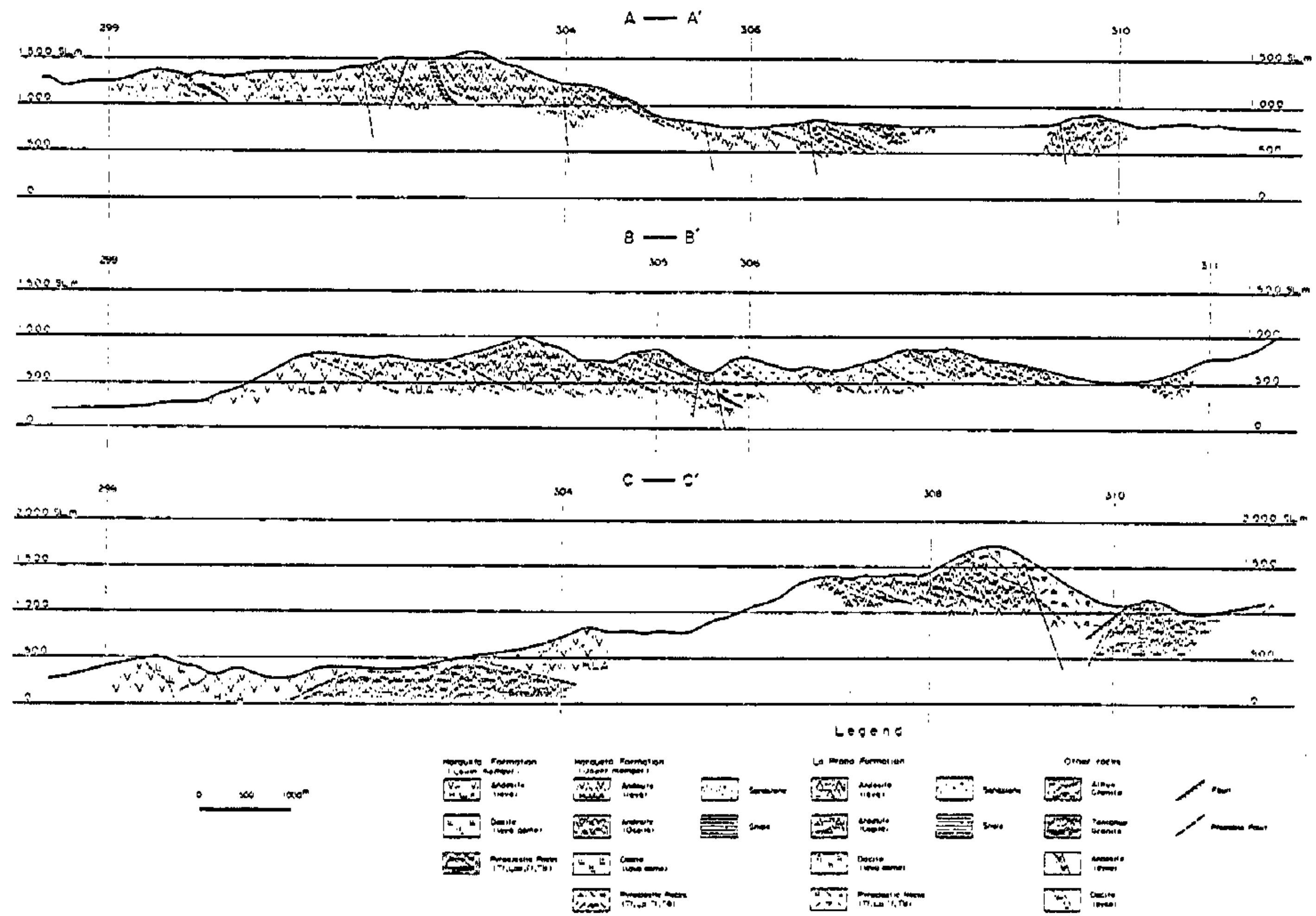


Fig. 2-1-2 Geological section map of Cholqui area

the rest are in the Lo Prado Formation. It clearly shows that some selective favorableness exists in the mineralization.

The detailed description of the formations and intrusive rocks is as follows.

1-2 Description of Geology

(1) Horqueta Formation (+1,600 meters in thickness)

The formation is divided into two members, the Upper and Lower Members. According to the geological map, 1:50,000 in scale, however, the formation is not divided into two members, and presents only one unit formation mainly comprising of andesite and andesitic pyroclastic rocks locally interbedded by thin beds of marine and continental sandstone, shale, and tuffaceous sandstone.

a. Lower Horqueta Member

The Lower Horqueta Member is mainly composed of andesite lava accompanied with andesitic pyroclastic rocks, volcanic breccia, and tuff breccia, and locally being interbedded by thin beds of mudstone and medium-grained sandstone. Dacite lava domes also exist in the member.

It is supposed that the andesite lava are of shallow water eruption due to the co-existence of medium-grained sandstone. The lava are dark gray to black or dark green in color, and hard and massive. They very scarcely show autobrecciated or water-cooled brecciated structure. The dominant phenocryst mineral is plagioclase, but amphibole is scarcely recognized. The rocks around the granite body in the southern area have undergone epidotization and chrolitization.

The main constituent rocks of the member are judged as hypersthene-augite andesite or augite andesite under the microscope. The former shows clear porphyritic texture, and phenocrysts are mainly composed plagioclase followed by augite, then a small-amount of hypersthene and iron minerals. The groundmass shows hyalopilitic texture, generally similar appearance to the andesite of Japan. The grade of alteration is weak. The latter is scarce of phenocryst, consisting of some amount of plagioclase and small-amount of augite and iron minerals. The grade of alteration is slightly high. Some texture suggests that incomplete mixture of magma has occurred in the rocks. The alteration minerals are chlorite sericite, epidote, calcite, quartz, oxide iron, etc.

The andesitic tuff, lapilli-tuff, and tuff breccia show dark green, and consist of several kinds of andesite and a small-amount of mudstone. The sorting of the pyroclastic rocks is poor, and the boundary with lava flows is generally unclear. Some fragments of plagioclase and amphibole exist in the groundmass and tuffaceous parts of the rocks. Andesite fragments in the rocks are same rocks of the member, containing large-amounts of white plagioclase, and the groundmass shows reddish brown.

The dacite lava are comprised of white to gray non-phenocryst rocks. It is judged that the lava are intrusive domes from their occurrences.

b. Upper Horqueta Member

The member is mainly comprised of andesite lava accompanied with andesitic pyroclastic rocks and interbedded with thin beds of continental red sandstone and mudstone. The andesite is generally accompanied with oxide iron minerals, and shows characteristic brown to reddish brown, suggesting continental origin. An characteristic andesite body called Ocoita is distributed around the Las Guias mine in the relatively upper parts of the member. The andesite body shows a lava form and sill or sheet, but relation between those two different forms is not clear. Dacite lava domes also exist in the member.

The andesite lava are mainly composed of significantly autobrecciated brown to reddish brown andesite, and partly dark brown to dark gray massive. It is sometimes very difficult to distinguish the significantly autobrecciated andesite lava from the andesitic lapilli tuff or tuff breccia by naked eye. The andesite generally contains milky white or rarely transparent plagioclase phenocrysts.

Under the microscope, the rock is identified as hypersthene-bearing augite andesite. The rocks generally show reddish rusty color due to oxidation in a high temperature during the eruption, and the containing colored minerals have been decomposed and altered reflecting an environment of continental eruption. The rocks commonly show the porphyritic texture, and contain a large-amount of plagioclase and a minor-amount of hypersthene phenocrysts. The groundmass shows the hyalopilitic texture, suggesting high grade alteration. There are some rocks belonging to hypersthene-augite bearing hornblende dacite among the rocks named andesite in field by naked eye.

As previously mentioned, the continental volcanic and pyroclastic rocks show the characteristic porphyritic texture, containing quartz, plagioclase, hypersthene, augite, hornblende, iron minerals, etc. The augite has been completely changed to opacite due to oxidation under the high temperature, the iron minerals in the groundmass have been oxidized, accordingly the rocks generally show reddish rusty color and fine-grained, hypohyaline, hyalopilitic to intersertal texture. The grade of alteration is relatively high, and the alteration minerals are chlorite, sericite, calcite, quartz, and iron oxides.

The tuffs show brown to reddish brown, consisting of lapilli tuff or tuff breccia containing fragments of andesitic tuff and andesite. Under the microscope, the tuffaceous part is identified as andesitic coarse-grained tuff, consisting well sorted andesitic coarse-grained volcanic ash and shows reddish rusty color due to the oxidation in high temperature in the air. The grade of alteration is high, but the texture of tuffs remains.

The lapilli tuff is augite-amphibole andesitic, consisting of various size of andesite fragments, smaller than 8 millimeters in diameter. Hornblende is particularly common in the rock. The fragments are sub-angular to rounded. The rock shows generally reddish brown due to oxidation in high-temperature, and a part of hornblende crystals has been completely changed to opacite. The grade of alteration, however, is not high, existing chlorite, calcite, quartz, and iron oxides as alteration minerals.

The so-called Ocoita shows generally dark greenish gray, and a characteristic face containing large euhedral plagioclase phenocrysts. The rock bodies are generally concordant to the surrounding strata, apparently lava flows, however they show intrusive occurrences in some places. Under the microscope, it is determined as basalt to mafic andesite (basaltic andesite), containing large-amounts of plagioclase, and small-amounts of olivine and/or augite. The groundmass is composed of plagioclase showing scarce zoning structure, hornblende, iron minerals, and glassy material, in some occasions a small to minor-amount of olivine, and rarely quartz. The alteration minerals are chlorite, sericite, calcite, quartz, clay minerals, oxide iron, and opaque minerals. The grade of alteration is relatively high. Serpentine occurs in some occasion. A part of Ocoita located nearby the ore deposits has undergone mineralization comprising of network, impregnation, and filling amygdale, containing bornite, chalcocite, and small-amounts of hematite (specularite). It is judged that the Ocoita is a typical high-alumina volcanic rock locating in isolated islands or of active continental rims due to its petrographic texture, rock forming mineral assemblage, and higher-content of Ba, Sr, and Nb than those in the common andesite.

Fig 2-1-3 shows the triangle diagram of Na2O;K2O-MgO;FeO-Fe2O3, based on the results of the whole rock analysis for the Ocoita and andesite of the Horqueta Formation.

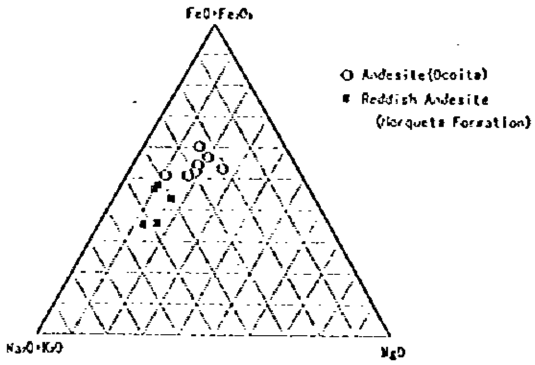


Fig. 2-1-3 $Na_2O+K_2O \cdot MgO \cdot FeO+Fe_2O_3$ diagram

From the diagram, it is supposed that the magmatic differentiation of the andesites of the Horqueta Formation is more progressed than that of the Ocoita. The Ocoita shows partly lava occurrence or intrusive occurrence, and apparently sits conformably in the upper most of the Horqueta Formation. If the Ocoita was produced by lava eruption, the Ocoita and andesite should be different products produced by same volcanic eruption. But this hypothesis is contradictory to the magmatic differentiation theory, due to the different petrochemical constituent of both rocks. In addition to that, the Ocoita shows late Cretaceous in age by the dating test, and there is difference between the Ocoita and Jurassic Horqueta Formation. The Ocoita, definitely, does not belong to the Lo Prado Formation, judging from different rock faces, petrographical character, and occurrence. It is, accordingly, judged that the Ocoita and andesites in the Horqueta Formation were originated from different magmas having different stages of progress, and the Ocoita is the intrusive rock of middle Cretaceous. Due to its alteration, it is hard to strictly say, but the rock might belong to the high alumina basalt of the olivine tholeiite series. (according to Dr. Aoki's private correspondence)

The interbedded thin beds of sandstone in the andesitic rocks are medium to fine grained, reddish brown, partly tuffaceous, and with poor bedding. Under the microscope, the rock is composed of fine-grained quartz and plagioclase fragments, and shows reddish rusty color due to hematite filling opening of crystals. The grade of compression is slightly progressed.

The shale shows brownish gray, having bedding of 5 to 30 centimeters thick.

(2) Lo Prado Formation (1,500 meters in thickness)

The type locality of the formation is Lo Prado, western part of Santiago City. The formation is mainly composed of dacitic to andesitic tuff, lapilli tuff, and tuff breccia, and intercalated by andesitic to dacitic lava, and beds of sandstone, limestone, and shale.

The tuffaceous rocks generally show greenish to brownish gray, and consist of lapilli tuff derived dacite, andesitic lapilli tuff, and fine-grained tuff. The bedding, several centimeters to meters thick, is clear in some cases, but sorting is generally poor.

Under the microscope, the dacitic lapilli tuff is composed of fragments of dacite, andesite, tuff, and volcanic ash, smaller than 8 millimeters in diameter. The fragments are mainly sub-angular, but in some cases angular or rounded. The matrix is composed of quartz, plagioclase, biotite, and minor-amounts of iron minerals, in some cases containing large-amounts of glassy material. The grade of alteration is low, and sericite, chlorite, epidote, and quartz have been produced.

Under the microscope, the andesitic lapilli tuff is composed of large-amounts of small fragments of andesite, smaller than 12 millimeters in diameter, and volcanic ash, in some cases accompanied with dacite fragments. The fragments are sub-angular. The matrix is mainly composed of plagioclase and grassy material, in some cases accompanied with some iron minerals. The grade of alteration is high, and chlorite, calcite, epidote, montmorillonite, and quartz have been produces.

The fine-grained tuff shows gray to greenish gray, and largely consists of glassy material containing minor amounts of plagioclase. Quartz and iron hydroide have been produces by silicification after the deposition.

The andesite lava show dark gray, but yellowish gray or greenish gray in the northeastern area due to alteration. The lava are mainly massive, but in some cases, show the autobrecciated texture, or intercalate some beds of sedimentary rocks. The phenocrysts mainly consist of plagioclase, but commonly do not show clear porphyritic texture. Under the microscope, the rock is determined as hypersthene-augite andesite. The phenocrysts are plagioclase, augite, hypersthene, and iron minerals in order of amount. The euhedral to subhedral plagioclase, smaller than 5 millimeters in diameter, domains in the phenocryst. In some cases, collective phenocrysts of plagioclase, augite, hypersthene, and iron minerals are recognized. The groundmass is composed of a large-amount of plagioclase, and medium amounts of augite, hypersthene, iron minerals, and glass. A large amount of silicate minerals are contained in the groundmass in some cases. The texture of the rocks is porphyritic, fluidal glass, or cryptocrystalline felsic textures. The grade of alteration is high, and chlorite and sericite have been produced.

The Ocoita shows similar occurrence and visible characteristics to that of the Upper Horqueta Member. Under the microscope, it is determined as olivine bearing andesite. The phenocryst is composed of large-amounts of plagioclase, and small-amounts of olivine and iron minerals. Large euhedral plagioclase crystals, smaller than 17 millimeters in diameter, occupies about 25 per cent of the total amount of phenocrysts. The grade of alteration is high, and Chlorite sericite, epidote, montmorillonite, quartz, and pyrite have been produced.

The dacite lava show gray to white, and non-porphyritic texture. It is judged that the lava are of lave domes from their occurrences.

The sandstone is mainly of medium-grained, showing bedding of more than 10 centimeters to several meters in thickness. The rock is composed of fine-grained andesite and silicified andesite, locally calcitic parts. The opening between sand-grains is, in some cases, filled by calcite and plagioclase crystals.

(3) Intrusive Rocks

Granodiorite intrusive bodies exists in the southwestern and southeastern survey areas. Andesite, dacite, and quartz porphyry dikes has intruded in the whole area. Most of the intrusive dikes trend north to south, but northwest to southeast in some bodies. Some of them are more than 1 kilometer in length and several hundred meters in width, but most of them are small-scale, less than 500 meters in length, several tens centimeters to several tens meters in width. It is presumed that these dikes intruded after Cretaceous time, judging from the fact all dikes cut the Lo Prado Formation.

The Tantehue Granodiorite, according to existing data, belongs to the Jurassic Tantehue Granite. The rock is visually dark gray fresh holocrystalline, and plagioclase and colored minerals are recognized. Under the microscope, the rock is determined as biotite-augite quartz diorite. The phenocrysts are composed of large-amounts of quartz and plagioclase, medium-amounts of biotite, hornblende, and iron minerals, small-amounts of cummingtonite and augite, and rarely sphene and apatite. A part of plagioclase phenocrysts show euhedral crystals, but most of the crystals are of semihedral to anhedral. The rocks show medium-grained equigranular texture. The rock faces are quite fresh, however, minor-amounts of chlorite, sericite, and montmorillonite have been produced in the rock as secondary minerals. The age of the rock shows 139.20 ± 3.0 Ma according to the K-Ar age determination test in the survey, and it accords to the boundary time between Late Jurassic and Cretaceous.

The Alhue Granodiorite has intruded in the southwestern and southeastern areas, and belongs to the Cretaceous Alhue Granite according to some existing data. The rock is leucocratic medium to fine grained holocrystalline rock, and containing some fragments of the xenolith of the Tantehue Granodiorite (being mentioned in the later part of the report) in some parts of the southwestern area. Under the microscope, the rock is determined as augite-biotite granodiorite or biotite-hornblende granodiorite. The phenocrysts are composed of quartz, plagioclase, potassium feldspars, biotite, and hornblende, accompanied by small-amounts of iron minerals and minor amounts of sphene and apatite. Most of the plagioclase, sphene, and apatite are subhedral to anhedral, but partly euhedral, showing a medium grained, smaller than 5 millimeters in diameter, equigranular texture. The feldspar and parts of colored minerals have undergone alteration, and chlorite and sericite have been produced. The rocks also have given thermal affect to the surrounding andesite of the Lower Horqueta Member, and chlorite, garnet, and other alteration minerals have been produced there. The date of the intrusion of the rocks has been determined as 90.23 ± 1.47 Ma by the K-Ar age determination test in the survey. The age corresponds to Middle Cretaceous time.

The dikes are of andesite, dacite, and quartz porphyry, and most of them are very small-scale. The results of the microscopic observation are as follows.

The pyroxene andesite has phenocrysts of large-amounts of plagioclase and small-amounts of pyroxene and iron minerals, and its groundmass is composed of large-amounts of plagioclase and volcanic ash, and small-amounts of quartz and iron minerals. The grade of alteration is high, and its alteration minerals are chlorite, iron hydroxide, sericite, calcite, clay minerals, and quartz. The rock shows an intersertal texture.

The augite andesite (augite porphyrite) is commonly non-phenocryst, but in some cases contains small-amounts of plagioclase and augite phenocrysts. The groundmass is composed of large-amounts of plagioclase and volcanic ash, medium amounts of augite and iron minerals. The grade of alteration is high, and alteration minerals are chlorite, epidote, calcite, clay minerals, and sericite. The rock shows an intersertal texture.

The non-phenocryst andesite (porphyrite) has phenocrysts of large-amounts of plagioclase, medium-amounts of augite, iron minerals, and volcanic glass, showing a coarse-grained hypocrystalline and intersertal texture. The grade of alteration is high, and its alteration minerals are chlorite, epidote, quartz, leucoxene, clay minerals, and calcite. The result of the age determination test in the survey, as mentioned later, has revealed that the rock intruded in Late Cretaceous time.

The olivine-augite andesite has phenocrysts of medium-amounts of plagioclase and augite, small-amounts of olivine and iron minerals. The groundmass is composed of large-amounts of plagioclase, medium-amounts of augite, iron minerals, and volcanic ash. The grade of alteration is high, and its alteration minerals are chlorite, epidote, augite, hornblende (?), quartz, clay minerals, and iron oxides. The result of the age determination test in the survey has revealed that the rock intruded in Late Cretaceous time.

The hornblende dacite has phenocrysts of medium-amounts of plagioclase, and small-amounts of hornblende and iron minerals. The groundmass consists of large amounts of volcanic ash. The rock has undergone strong silicification, and shows bluish rusty color. The grade of alteration is high, and its alteration minerals are chlorite, sericite, montmorillonite, quartz, and iron oxides. Quartz and montmorillonite have occurred along clacks in the rock. The rock shows a porphyritic texture. The biotite-quartz porphyry has phenocrysts of large-amounts of plagioclase, medium-amounts of quartz, and small-amounts of biotite and iron minerals. The groundmass consists of large-amounts of quartz, medium-amounts of potash feldspar and plagioclase, and small-amounts of iron minerals. The grade of alteration is high, and the alteration minerals are chlorite, iron hydroxide, calcite, sericite, and clay minerals. The rock shows fine-grained holocrystalline and felsic textures.

The olivine-augite andesite and aphyric andesite are common among all dikes, and easily can be seen on the surface and in the underground of the Las Guias and Angelita Mines. The result of the age determination test in the survey has revealed that these dikes intruded in Cre-ltaceous and Paleogene times.

1-3 Geological Structure

(1) Depositional and Folding Structures

The sandstone, mudstone, and fine-grained tuff show clear bedding, several centimeters to several meters in thickness. The red sandstone of the Upper Horqueta Member and the lapilli tuff of the Lo Prado Formation, in some cases, show bedding. The bedding strikes NNW-SSE, NNE-SSW, or N-S, and generally dips 10 degrees, not greater than 35 degrees, to the east, except nearby faults or dikes. The geological structure is of monoclinic. A part of the upper Lo Prado Formation, nearby Quebra Tio Torre, shows a weak folding structure in andesite lava.

(2) Fault Structure

WNW-ESE and NW-SE fissure systems domain in the survey area, and they have good continuity. They can be easily traced on aero-photographs. Conjugate faults with the dominant faults extend NNE-SSW or NE-SW. Other fracture zones and faults stretching E-W and NE-SW are seen in the field, but their continuity is poor. It is presumed that the faults have occurred in the time of the intrusion of the Alhue Granodiorite or after that activity, because the dominant faults stretching WNW-ESE and NW-SE cut the upper parts of the Lo Prado Formation, and parts of the faults control the distribution of the Alhue granodiorite. Other than those faults accompanied by large-scale sheared zones, small fissures stretching N-S, NW-SE, and E-W are seen in the underground or surface pits in the Las Guias and Angelita Mines. No primary ore minerals such as pyrite and chalcopyrite can be seen in those fissures as well as alteration minerals, therefore it is judged that they are not directory related with mineralization. But, some stain of copper oxides exists in the fissures.

1.4 Determination of Absolute Age of Igneous Rock

The absolute ages of six igneous rocks have been determined by the K-Ar method to study the relation between the igneous activity and mineralization. Table A- show the basic measuring data, and Table 2-1 shows the results.

The samples Nos.1, 2, and 4 show stable data within error range, but Nos.3, 5, and 6 show fluctuated data, in some cases out of error range. Nos.3, 5, and 6 are from the Ocoita and granodiorite, and the fluctuation of the data presumably indicate uneveness of the constituent minerals of these rocks. Some differences in error range, air-fraction, rock face, etc. exist among all samples, however Table 2-1 shows simple arithmetic average figures of measured values.

Table 2-1-2 Result of age determination of igneous rocks

NO	Samp-No	Rock name	K-Ar age	Geologic age
1	C-15	Olivine augite andesite (dike)	46.98 ±1.04	Paleogene
2	C-16	Aphyric andesite(dike)	69.76 ±1.53	Later Cretaceous
3	C-17	Olivineaugite andesite(Ocoita)	99.36 ±2.15	Middle Cretaceous
4	A-50	Olivine basalt(Ocoita)	95.39 ±2.08	Middle Cretaceous
5	C-121	Biotie hornblendeqoartz diorite	139.20±3.00	Jurassic-Cretacous
6	D-45	Biotite Hornblende granodiorite	90.23 ±1.47	Middle Cretaceous

These intrusive rocks cut up to the Cretaceous Lo Prado Formation.

The Ocoita shows almost conformable to the underling and overlying formations, appearing occurrence of lava. In some places, it shows various rock faces such as intrusive or brecciated lava, but the relation between those different faces is not clear. Two interpretations for the occurrence, lava and intrusive body, have existed for many years.

The result of age determination test in this study has indicated Middle Cretaceous for two samples of the Ocoita.

The Ocoita is situated around the contact zone between Jurassic continental andesites and Cretaceous marine dacitic rocks, appearing a lava flow or sheet. It is very difficult to say which category the Ocoita should belong to, only from the result of the age determination.

However, it is more reasonable to say that the Ocoita is of intrusive, because small bodies of Ocoita exist in the andesite of the Jurassic Horqueta Formation, and based on an integrated interpretation of petrochemical content of the rock and magmatic differentiation theory.

The Ocoita is associated with bornite-chalcocite and chalcopyrite-pyrite mineralization in the Las Guias Mine, and the mineralization expands to the andesite dikes. Accordingly, it is concluded that the mineralization occurred in Paleogene time, after the intrusion of the Ocoita and andesite dikes.

1-5 Ore Deposit

1-5-1 Outline of ore deposit

The survey area is situated in the middle of the coastal mountains, one of the major mineral district in Chile, and many domestic and foreign mining sectors are interested in the area for future exploration activity.

Many mineral occurrences, old adits, and operating mines exist in the area. Fig. 2-1-4 shows the distribution of the 30 mineral occurrences confirmed by the survey, together with rock boundaries, the distribution of the Ocoita, and location of faults.

Among these mineral occurrences, about 20 of them are in the andesites of the Upper Horqueta Member, and the others are in the Lo Prado Formation. No mineral occurrence exists in the Lower Horqueta Member.

The mineral occurrences in the area are classified into following three categories; net-work or disseminated copper ores mainly consisting of malachite accompanied with small-amounts of azurite, chrysocolla, and atacamite; net-work or disseminated ores composed of bornite and chalcocite; and chalcopyrite-pyrite quartz veins. The mineral occurrences mainly consisting of malachite are in the Upper Horqueta Member, that of bornite and chalcocite is only in the ore shoots of the Las Guias Deposit, and the chalcopyrite-pyrite quartz veins are in the Lo Prado Formation. A little alteration minerals are locally seen nearby the mineral occurrences, but generally not in the host rocks.

The X-ray analysis has revealed that the appearance intensity of chlorite and albite are 12 and 73 for the Ocoita (39 samples), 14 and 77 for other rocks in the Horqueta Formation (43 samples), 14 and 69 for the rocks around the Las Guias Mine (40 samples), respectively. It can be said that no difference in the alteration grade for mineralized and non-mineralized rocks.

The constituent minerals are mainly consisting of bornite, chalcocite, digenite, malachite, accompanied with minor amounts of azurite, chrysocolla, atacamite, pyrite, chalcopyrite, magnetite, and hematite. The gangue minerals of the chalcopyrite-pyrite

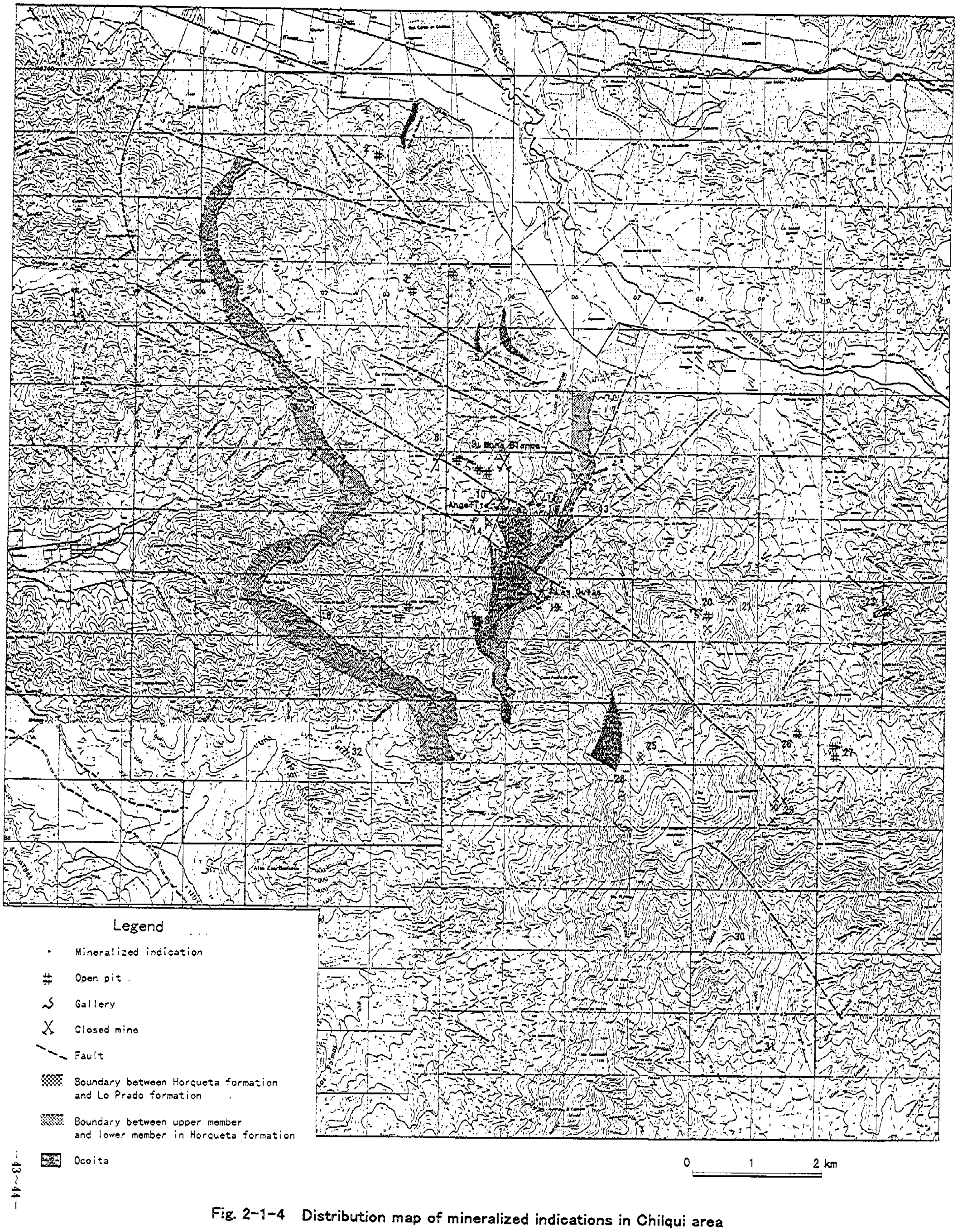


Fig. 2-1-4 Distribution map of mineralized indications in Chilqui area

quartz veins are quartz, calcite, and minor amounts of clay minerals. No gangue mineral is accompanied with other mineral occurrences.

1-5-2 Description of mineral occurrence

Fig. 2-1-4 shows the location of the known mineral occurrences. Also Fig.2-1-15~Fig.2-1-17 show various maps of geochemical data of mineral occurrences. Only the Las Guias and Mona Blanca Mines have been operated, and mined out ores from the underground, but no record for the mined-out amounts is available. Underground prospecting has been done in the Angelita Mine, but no economical ores has been found. Most of the other mineral occurrences situated in the Upper Horqueta Member have been prospected by small-scale open pits, however, the mineral occurrences disappear at the bottom of the pits. The ore deposits of the Las Guias and Angelita Mines, other malachite occurrences, and mineral occurrences in the Lo Prado are described in the followings. No hematite gossan is seen in the mineral occurrences in the Horqueta Formation, reflecting their mineral constituent, but very common those in the Lo Prado Formation.

(1) Las Guias Mine

The mine is situate at the upstream area of the Las Guias Valley in the central part of the survey area, about 710 meters above the sea level.

The ore are in the Ocoita, andesite, andesitic pyroclastic rocks, and andesite dikes in the Upper Horqueta Member. Judging from the alignment of the old pits, the ore deposit extends NW-SE, and dips 70 degrees to the north, oblique to the bedding of the host rocks.

The lower adit is at the level of 707 meters, the transportation adit is at 722 meters, and the upper adit is at 738 meters above the sea level. Several small old prospecting adits are scattered there. Two or three old mined zones are in the upper and transportation adits. Only minor amounts of malachite stains in the andesite and chalcopyrite-pyrite quartz veinlets are seen in the lower adit.

Three ore shoots exist in the underground, judging from the open spaces in the adits, and their maximum size is 30 meters in lateral, 20 meters in vertical, and 6 meters in width. x 6 meters. The malachite occurrence disappears at the depth of 90 meters from the surface. The minable ores have been completely mined out, and it is impossible to see the direct relation between the ore and host rock, and occurrence of the ore.

Small faults and slid faces stretching N-S, NE-SE, and E-W are seen around the

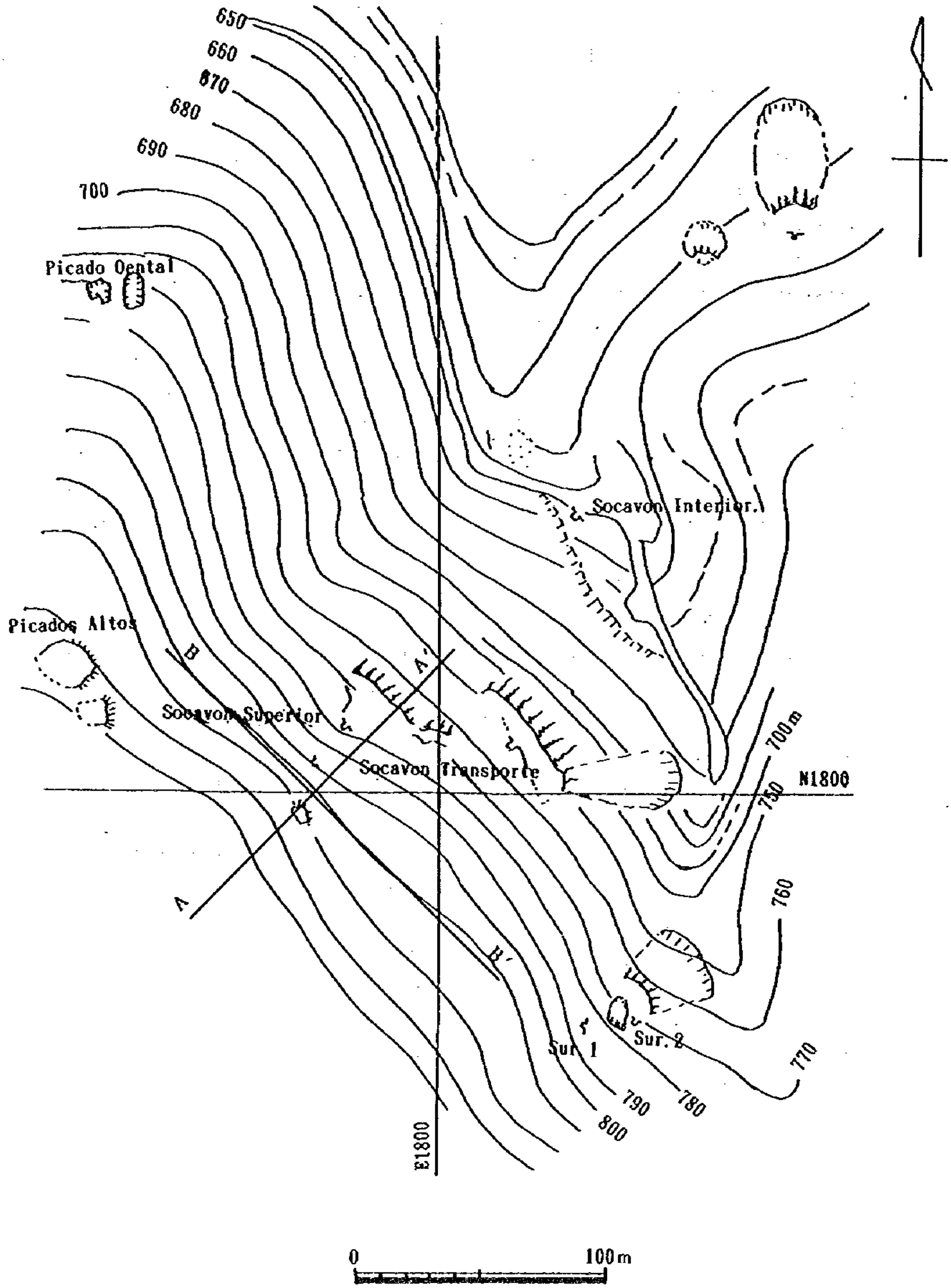


Fig. 2-1-5 Pit-location map of Las Guias mine

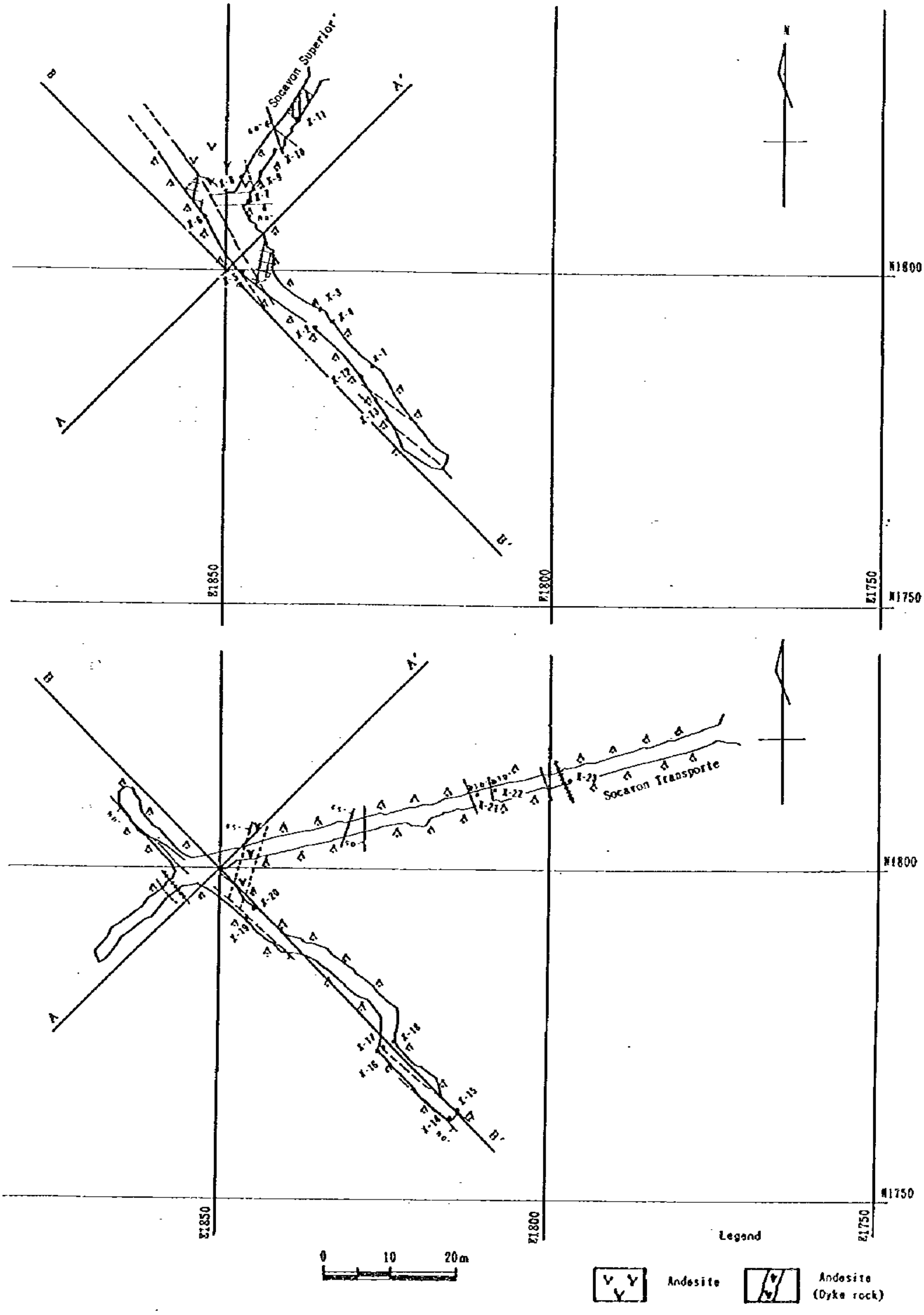


Fig. 2-1-6 Under grand geological map of Las Guias Mine

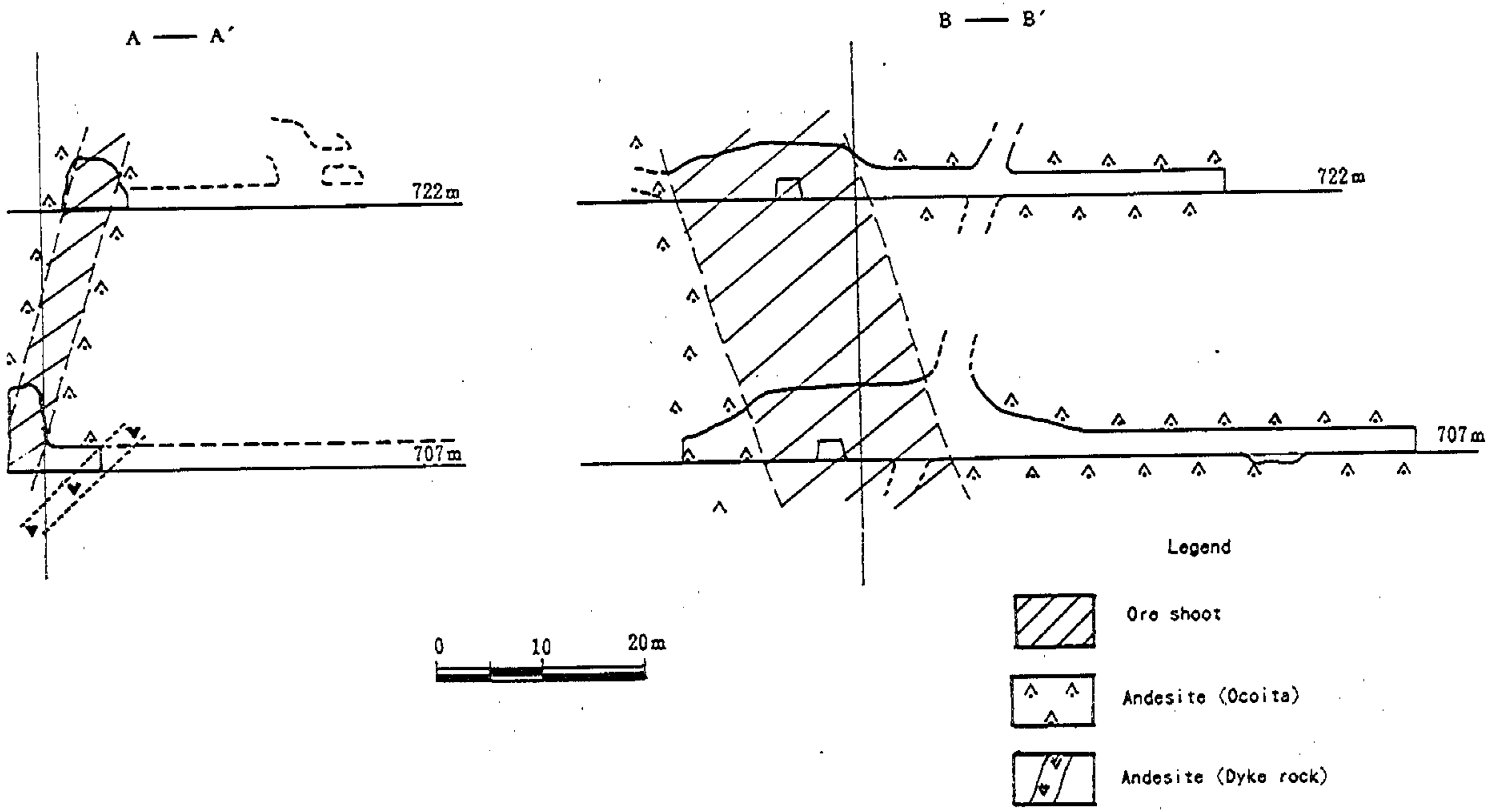


Fig. 2-1-7 Geological section of Las Guias Mine

mine and in the adits, but no mineral occurrence accompanies with them. A small fault having same trend as that of the deposit is seen in the upper adit, and the X-ray analysis has revealed that a clay sample taken from the fault contains minor amounts of kaolin accompanied with silicified mineral. No mineral occurrence, however, is seen in the fault, and the fault is not associated with mineralization.

The mineral occurrences are divided into two categories, sulfide ore mainly consisting of bornite-chalcocite-chalcopyrite, and oxide ore mainly consisting of malachite.

The bornite-chalcocite ore shows mainly net-work, veinlet, or disseminated ore in the Ocoita, and in some places the mineralization extends to the andesite dikes. The disseminated bornite shows euhedral crystals, appearing phenocrysts. The ore shoots are composed of these bornite crystals. The Ocoita, host rock for the minerals, show an heterogeneous brecciated texture, and the breccia shows a coarse and porous porphyritic texture, filed by fine and compact matrix material in its spaces in between breccias. The ore minerals have been produced in the brecciated parts, and it indicate that the mineralization has been controlled by some physical conditions such as existence of air-babbles and open spaces in the rocks. The malachite mineralization has overlapped on the primary ores, and made rich ore shoots in the deposit.

The constituent ore minerals are principally bornite and chalcocite, accompanied by digenite, djurleite, chalcopyrite, pyrite, hematite, magnetite, sphalerite, malachite, chrysocolla, azurite, and atacamite. Under the microscope, it shows a relatively simple texture. These minerals primarily replaced the host rocks, and filled open spaces in the rocks. A little alteration minerals are locally seen.

Under the microscope, the bornite and chalcocite show close paragenesis in the form of fine crystals of smaller than 2 millimeters in diameter, and exsolution minerals of digenite and djurleite are commonly seen. The hematite crystals are smaller than 1 millimeter in diameter, fills spaces between the copper minerals, and partly transformed from magnetite. Minor amounts of chalcopyrite crystals are smaller than 2 millimeters in diameter, and show a close paragenesis with the other copper minerals. Minor amounts of pyrite shows the colloform texture in its fine crystals of 2 millimeters in diameter.

The close paragenesis of bornite-chalcocite-digenite, colloform texture in pyrite, and exsolution texture of djurleite from chalcocite indicate that the mineralization occurred under the low temperature. Local and weak alteration occurred just around the ore minerals is not accompanied by kaolin and sericite, and it suggests that the ore solution was weak acidic.

The malachite mineral occurrences are of net-work or disseminated in the cracks or disseminated in the druses and open spaces in the Ocoita and andesite. The malachite shows euhedral crystals in the cracks and open spaces, and in some places shows euhedral crystals on the surface of other early crystallized minerals. These net-works or veinlets of the malachite cut the bornite-chalcocite ores and ore shoots, and it clearly indicates that the malachite mineralization is of later stage.

The malachite veinlets are not accompanied by alteration minerals, and abruptly disappear to the depth. No transition to barren quartz or alteration zone appears there.

Under the microscope, the ore minerals penetrate into the cracks and open spaces in the rocks, and are precipitated there. It appears of secondary occurrence, but in some places it appears of primary occurrence.

Total 40 rock specimens have been taken around the mine in spacing of 50 meters N-S and E-W, and tested by the X-ray analysis. The alteration minerals are mainly consisting of chlorite and albite, and sericite and kaolin are not identified. It has been confirmed by the microscopic study that the alteration is of regional diagenesis, which is common in the andesitic rocks in the area. It has been also confirmed that the alteration occurred in the host rocks around the ores in the underground adits is same kind alteration as that of the surface. Sericite and kaolin are seen in the underground, but they are not accompanied by any ore mineral, and no association with mineralization is recognized.

Judging from the above mentioned phenomena, at least, most of the mineral occurrences composed of malachite have not been derived from hydrothermal ore solution sitting in the depth. It is rather supposed that the mineralization has been controlled by physical conditions of the rocks such as cracks and open spaces, and the minerals have been precipitated through the seepage water from the surface.

The chalcopyrite-pyrite quartz veinlets, 1 to 5 centimeters in width, exists in the lower adit. The malachite films stain along the cracks in the chalcopyrite-pyrite quartz veinlets. The X-ray analysis has revealed that the veins are accompanied with minor amounts of kaolin and sericite. Judging from the ore mineral assemblage of the veins, alteration minerals, and occurrence of minerals, the veins are of common hydrothermal, different from the previously mentioned other mineral occurrences in stage and character. Fig. 2-1-11 shows its occurrence.

(2) Angelita Mine

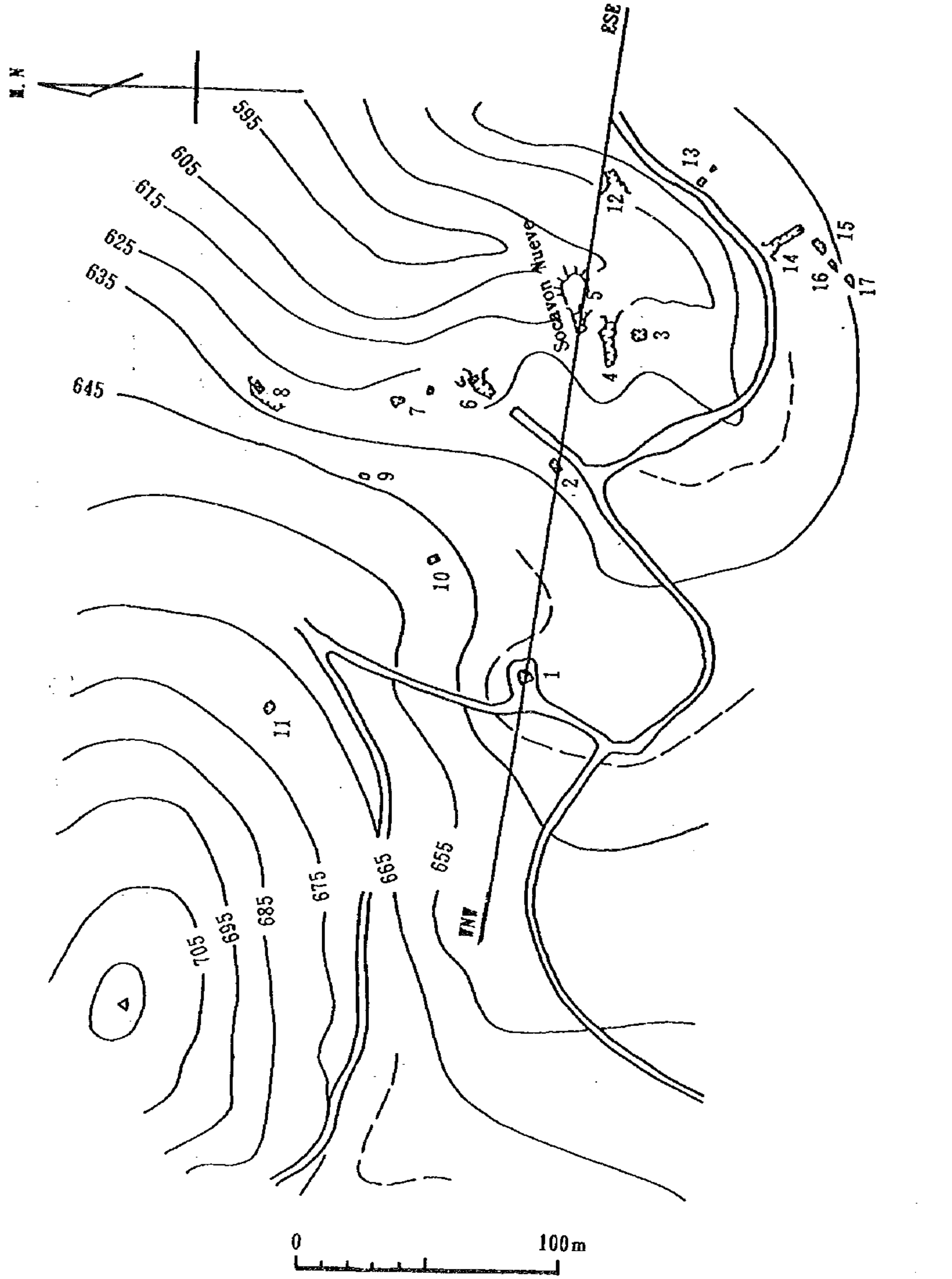


Fig. 2-1-8 Pit-Location map of Angelita mine

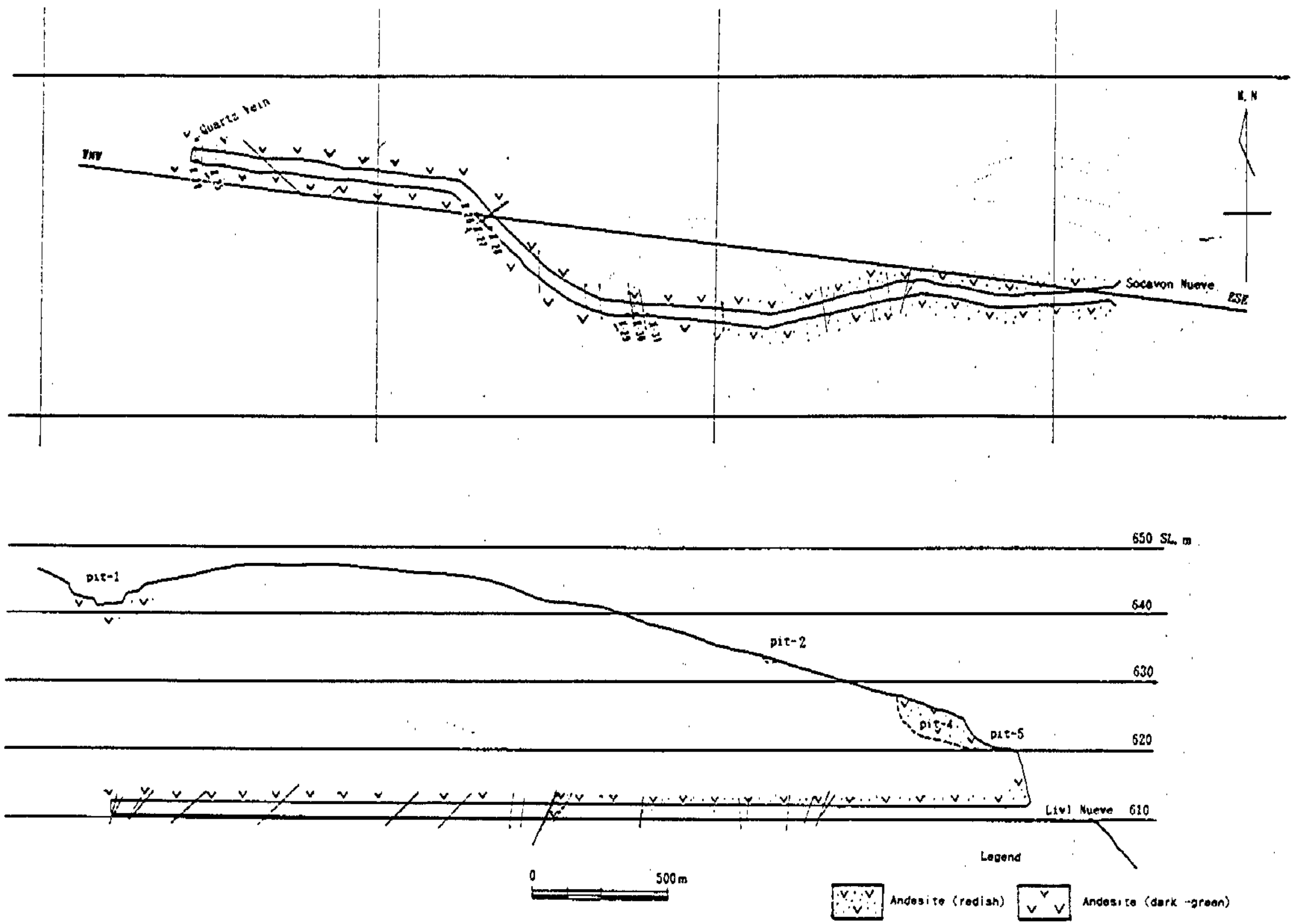


Fig. 2-1-9 Under grand geological and section map of Angelita Mine

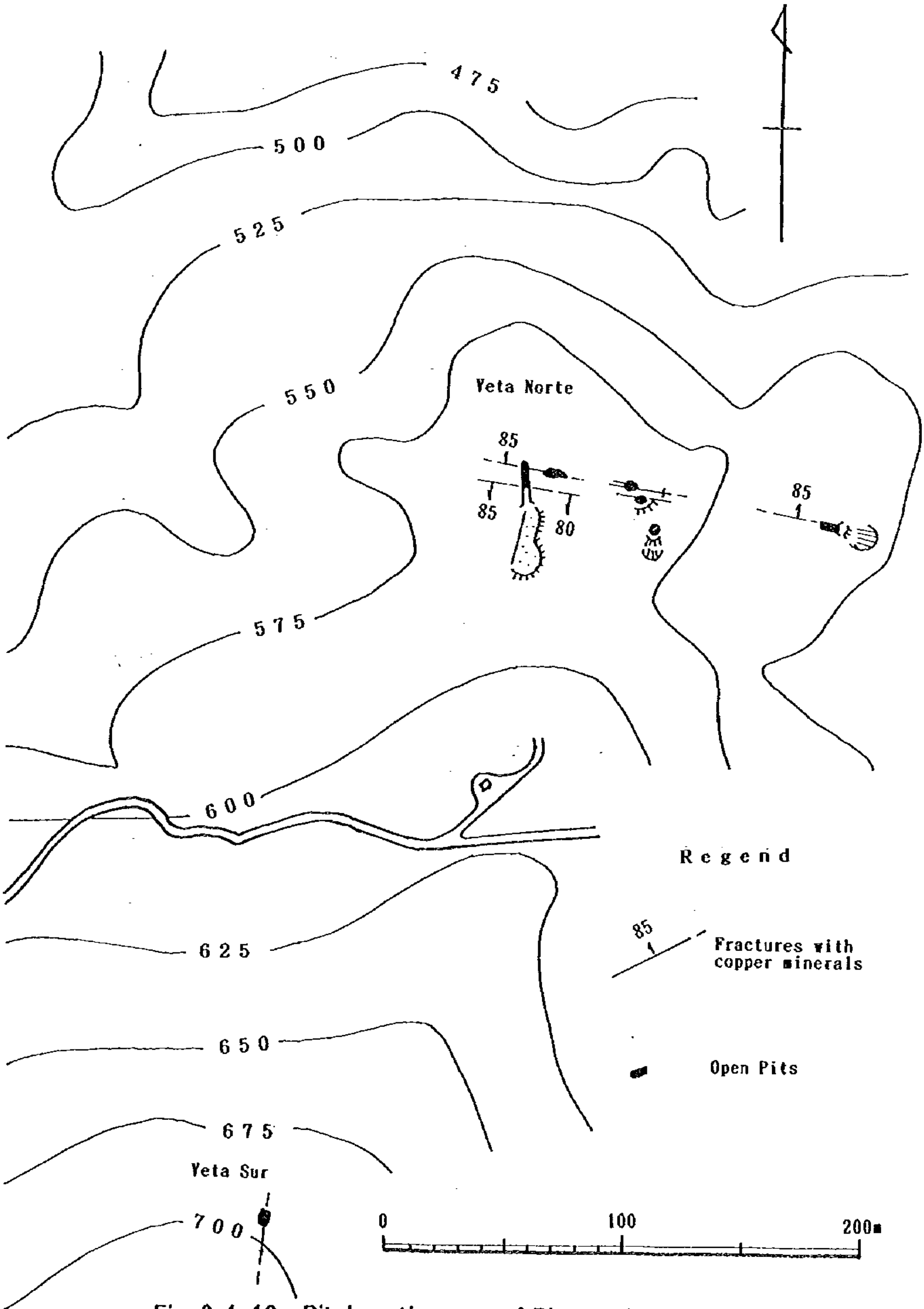


Fig. 2-1-10 Pit-Location map of Rinconada mine

The Angelita Mine is situated about 2 kilometers northwest of the Las Guias Mine, at about 610 meters above the sea level. Fig. 2-1-8 shows the location of the mine.

The host rocks of the deposit are the Ocoita, andesite, and andesitic pyroclastic rocks of the Upper Horqueta Member, and andesite dikes. Many small-scale pits are distributed on the surface, and an adit, about 150 meters in length, exists about 30 meters below the pit area. But no mined out open space is seen in the adit. The twelve pits on the surface are 5 meters in diameter and 2 meters in depth in size, and no ore mineral is seen the bottoms of the pits. It is said that the ores are very small in size. No clear alignment is seen in the distribution of the pits. Small faults stretching N-S are dominant on the surface and in the underground. Other small faults and slid faces tend to stretch NW-SE and NE-SW. All those faults are not associated with any mineral occurrences.

Minor amounts of malachite veinlets are locally seen along small-scale faults and cracks in the andesite in the underground.

The principal ore mineral is malachite, and its occurrence, constituent minerals, appearance under the microscope are just same as those of the Las Guias deposit. But in case of the Angelita Mine, minor amount of sphalerite is accompanied in some places.

The X-ray analysis for specimens taken from the adit has revealed that only regional diagenesis minerals exist in the specimens just same as in case of the Las Guias Mine, and no other common alteration mineral accompanied with mineralization such as kaolin and sericite is recognized in there.

Judging from the above mentioned investigation result, the character of the malachite mineralization in the Angelita Deposit is just same as that of the Las Guias Deposit.

Very thin chalcopyrite-pyrite quartz veins, 5 centimeters in width, are seen at the end of the adit. The veins have same appearance as those of the Las Guias Deposit, accompanied with malachite stains along cracks. It seems that the character of the vein is also same as that of the Las Guias Deposit.

(3) Other Mineral Occurrences in the Upper Horqueta Member

Most of the other mineral occurrences in the Upper Horqueta Member than previously described are small-scale, only being done several meters depth of prospecting pits. The host rocks are the Ocoita, andesite, and andesitic pyroclastic rocks. It is estimated that the maximum ore reserve is several thousand tone of ore, judging from the size of the pits and the geological state of the bottoms of the pits. The

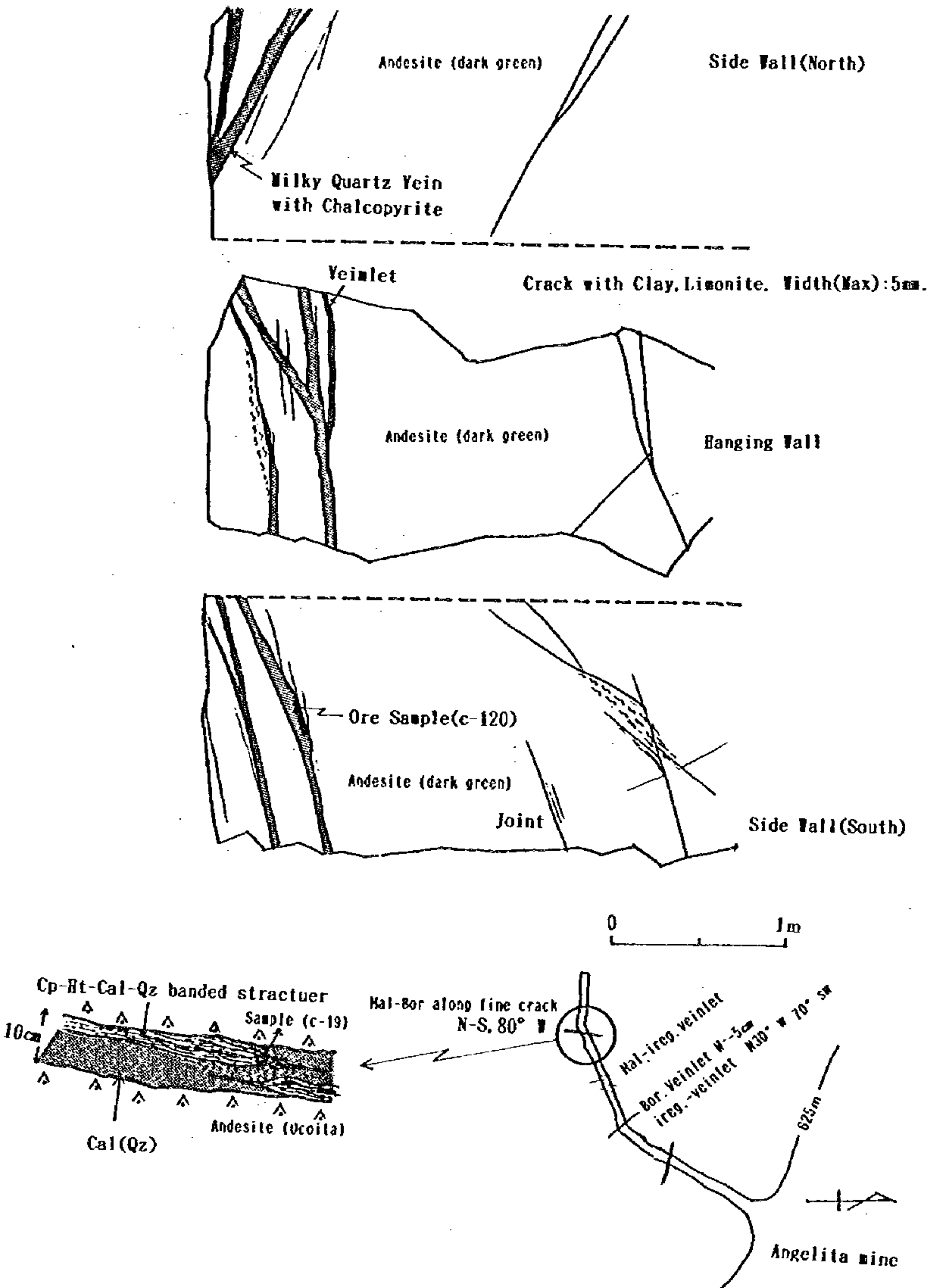


Fig. 2-1-11 Sketch of Chalcopyrite-Quartz vein

mineralization is of very local.

It appears that the distribution of the many pits around there does not have any pattern controlled by some elements such as fault. The principal ore mineral is malachite, and its occurrence, constituent minerals, and appearance under the microscope are similar to those of the Las Guias and Angelita Deposits. It seems that the character of the mineralization is also same as that of those mines.

(4) Mineral Occurrences in the Lo Prado Formation

About half of the mineral occurrences in the Lo Prado Formation have been performed small-scale pit prospecting before. The other half, however, dot not have any trace of prospecting activity. The mineralization in the Lo Prado Formation is relatively weak compared with that in the Upper Horqueta Member. The mineralization occurred in the all rocks of the formation.

The distribution of the mineral occurrences is not controlled by any fault or other tectonic lines, as can be seen in Fig. 2-1-4.

The alignment of the occurrences is approximately N-S for two series, Nos.20, 31, 25, and 28, and Nos. 23, 26, 27, 29, and 30, and approximately E-W for a series of Nos.20, 21, 22, and 23. No fault exists along these lines, and no relation to the different host rocks is recognized, therefore it seems that the distribution is accidental.

The mineral occurrences are of chalcopyrite-pyrite quartz veinlets, net-woks, and disseminated. Minor or trace amounts of malachite exists there. It indicates that the mineralization is completely different from that of the malachite. Hematite gossan is common on the surface in mineralized area.

The constituent minerals of the occurrences are chalcopyrite and pyrite, accompanied with minor amounts of sphalerite, bornite, magnetite, and hematite, and its gangue minerals are quartz and calcite accompanied with minor amounts of clay minerals.

Under the microscope, banded texture of quartz is commonly seen, and euhedral to subhedral crystals of chalcopyrite and pyrite exist there. The pyrite crystals fill spaces between pyrite crystals, and the both frequently show colloform texture.

Weak silicification occurred in the host rocks around the mineral occurrences.

Magnetite-epidote-quartz veins associated with the diorite intrusion in the southern area are very common, therefore it is possible that the ore veins in the area have undergone thermal metamorphism from the dioritic intrusive rocks.

1-5-3 Liquid Inclusion

The homogenized temperature and salt density of the liquid inclusions in the 11 specimens taken from the survey area have been measured to investigate physicochemical conditions of the mineralization. A-10 shows the measurement result, and Fig. 2-1-12 shows a statistical data of the homogenized temperature and salt density.

Almost all of liquid inclusions are of boiled vapor-liquid phase, and its volume ratio is low. Liquid inclusions of the quartz and calcite specimens showing close paragenesis and co-precipitation with bornite-chalcocite are not taken. Accordingly, no data is obtained for the homogenized temperature and salt density indicating the bornite-chalcocite mineralization of the ore shoots in the Las Guias Deposit.

(1) Homogenized temperature of liquid inclusion

The homogenized temperature is summarized from Fig. 2-1-12 as follows.

* The difference between the maximum and minimum values of the homogenized temperature for each specimen is around 60 degrees, and the measuring result shows stable values.

* The homogenized temperature of specimens C-110 and C-19 is 264 degrees and 245 degrees respectively, showing highest values in the specimens. C-110 is from the epidote quartz vein in the Ocoita situated about 3 kilometers northwest of the granodiorite body in the southeastern part of the survey area. Judging from the location of the specimen and its mineral assemblage, it is supposed that the specimen shows the high value compared with other ones, due to an existing ore vein has undergone hydrothermal alteration associated with the granodiorite intrusion.

* The average homogenized temperature of the specimens C-47, A-17, and A-54 is 200 degrees. Only A-54 is from the barren quartz vein in the red andesite of the Upper Horqueta Member in Cerro Rico, central survey area. The other specimens are from the pyrite quartz vein in the Las Guias and Angelita Mines. It is judged that the homogenized temperature of the specimens C-47 and A-17 represent the genetic temperature of the popular chalcopyrite-pyrite quartz veins.

* The homogenized temperature of the specimens B-61, B-62, and C-120 is around 170 degrees. The specimens are from the bornite-chalcocite ore and barren quartz vein cutting the oxide ore in the Las Guias and Angelita Mines. The temperature could represent the genetic temperature of the common barren quartz veins in the area. It is assumed that the quartz vein activity is of the later stage judging from their occurrence.

* The homogenized temperature of the specimens B-63, C-62, and B-59 is around 130 degrees. The specimens are from the irregular quartz vein and calcite vein in the

andesite and sandy tuff. The temperature is generally low, and its values are scattered. It is assumed that the temperature could reflect the genetic temperature of the secondarily segregated quartz and calcite veins judging from the above mentioned data and occurrence.

(2) Salt density of liquid inclusion

The salt density of the specimens is summarized from Fig. 2-1-12 as follows.

* The salt density of the specimens A-54, B-61, and B-59 is around 10%, that of C-62 is around 6%, that of C-120 and C-19 is 2% to 3%, and that of B-62 is around 0.2%. These specimens are classified into different populations.

* The salt density of the specimen C-47 is around 9% and 2%, that of A-17 is around 15% and 3%, that of B-63 is around 20% and 10%, and that of C-110 is around 17% and 6%. The each specimen is clearly divided into the high density and low density populations.

* A statistical analysis for the all data indicates that the salt density for the all specimens is classified into following four populations; less than 0.23% (T-1), 0.23% to less than 5.0% (T-2), 5.0% to 10.0% (T-3), and more than 10.0% (T-4). It indicates that several solutions having different salt densities existed there.

The correlation between the homogenized temperature and salt density for the all data is not good. The salt density of T-1 is stable showing no correlation with the homogenized temperature, and that of T-2 tends to show a positive correlation with the temperature. T-3 tends to show low salt density in low temperature and high salt density in high temperature. T-4 does not show any correlation between them.

In a vein, the salt density is very various in some cases, and the correlation between the homogenized temperature is not always good. It can be interpreted that several solutions having different temperature and salt density have been active for the ore genesis.

Based on the above mentioned various test results, it is possible to propose following two series of genesis; (a) crystallization of ore minerals from several ore solutions having different salt density, and (b) crystallization of ore minerals due to changes of physical and chemical conditions by boiling of a ore solution. The salt density in a specimen is, however, clearly separated into two populations, and the difference of the salt density between the different populations in the four specimens is more than 7% showing no existence of intermediate value between them. It suggests that the ore minerals have not crystallized from one kind of ore solution due to boiling, but crystallized from more than two different kinds of ore solutions having different

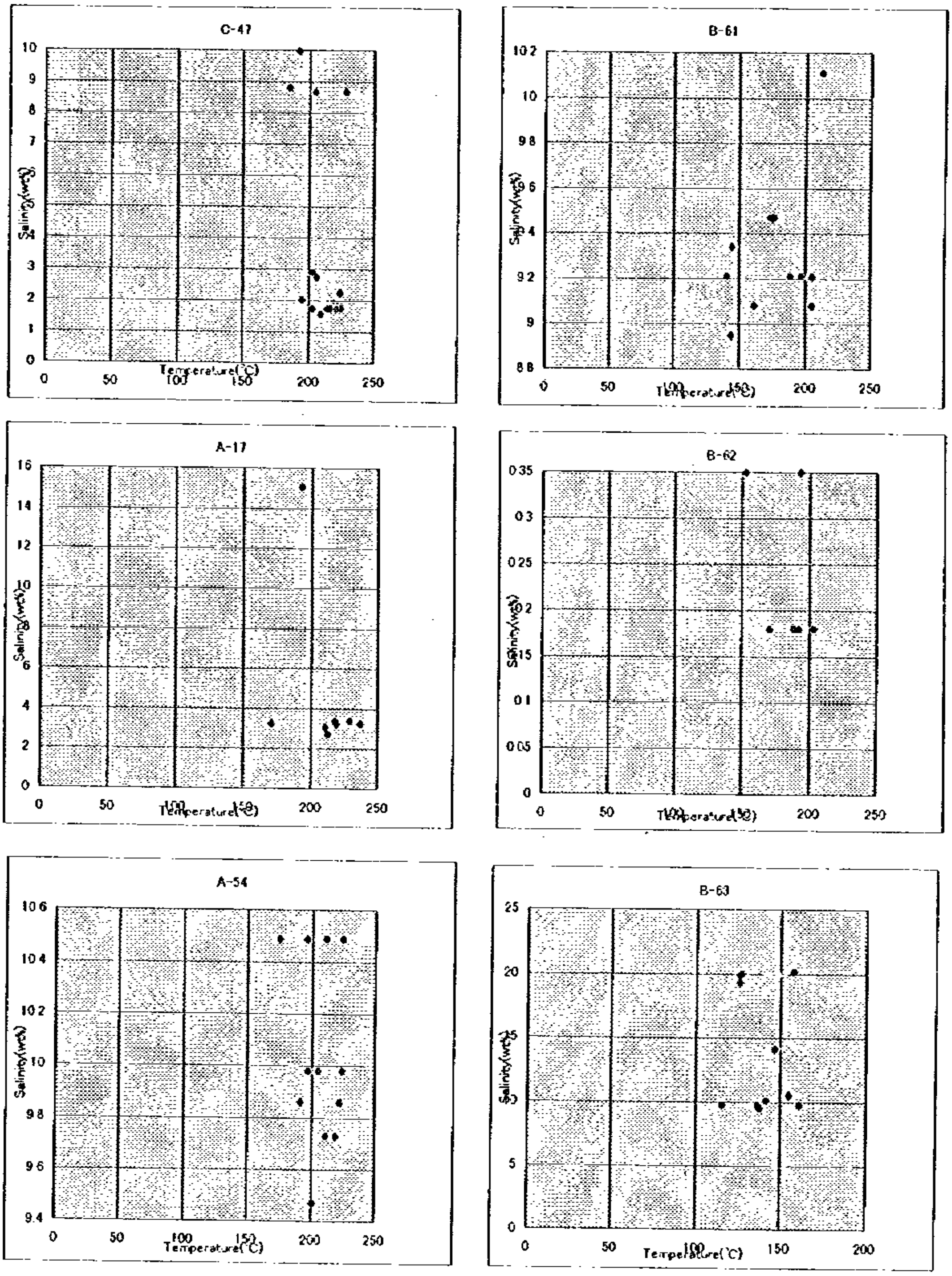


Fig. 2-1-12 Filling temperature and salinity of fluid inclusion 1/2

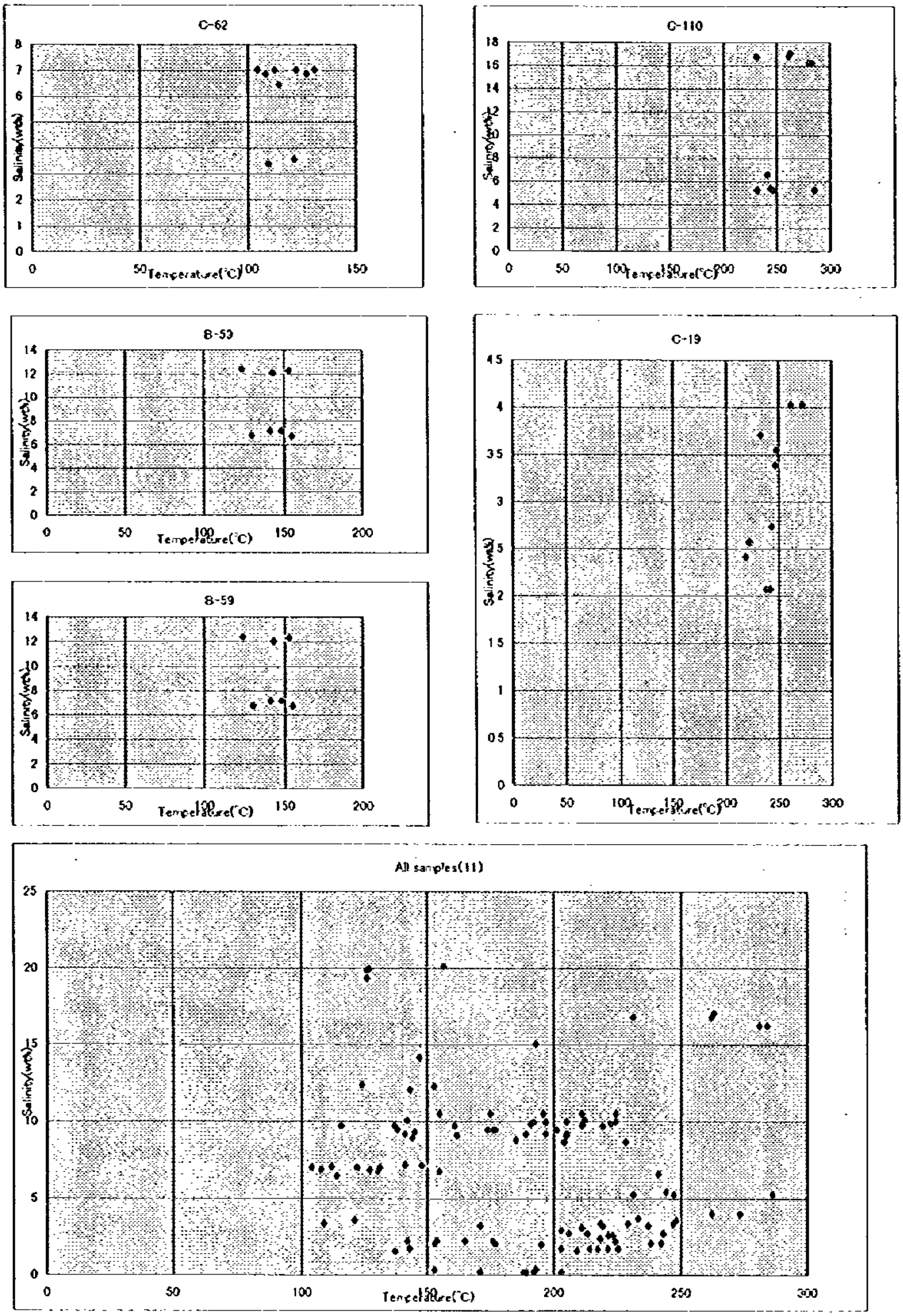


Fig. 2-1-12 Filling temperature and salinity of fluid inclusion 2/2