PART I General Remarks

PART 1 General Remarks

Chapter 1 Introduction

1-1 Background and Objective

In response to a request, the Japanese government dispatched a preliminary survey mission to the Republic of Chile and discussed this matter with the concerned organizations in that country. The Japanese side, the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ), and the Chilean side, Ministerio de Mineria, Agencia de Cooperacion Internacional (AGCI), Empresa Nacional de Mineria (ENAMI), entered into an agreement on August 14th, 1996. Based on this agreement, a three-year project entitled the Cooperative Mineral Resources Exploration in the Guanaca-Cholqui Area, was programmed to be conducted from 1996. This year is the first phase of the survey.

The objective of this project is to discover new ore deposits of copper and other useful minerals through the study of the geology, geological structure, mineralization, geochemistry, and geophysics of the area.

1-2 Coverage and Outline of the Survey

The Guanaca Area is located in about 800km north of Santiago and is located about 110 km northeast of Copiapó, region III (Fig. 1). The survey area is about 30km² and 5.5 km x 6.5 km. There is a private mine concession of about 2.5 km² which contains the La Guanaca mine in the survey area (Fig.2). This years survey consists of a geological survey, geochemical survey, and geophysical suvey. Details of the geological, geochemical , and geophysical survey and numbers of analyses are summarized in Table 1-1-1 and Table 1-1-2.

1-3 Members of the Survey Team

The members who participated in the project planing and negotiation, and field survey are as follows.

(1) Project planning and Negotiation

Japanese side

Masaaki Noguchi	Leader of the preliminary survey team,

Table 1-1-1 Survey specifications

Survey Method	Work Amount		
(1)Geological Survey & Geochemical exploration 1Guanaca Area	Survey Area	32	Km^2
	Survey Route	200	Km
(2)Geophysical Survey Guanaca Area (IP method)	Total Line Length	60	km
	Number of Lines	12	Lines
	Number of Measurement	1260	Times

Table 1-1-2 Laboratory work specifications

Laboratory studies	
1) Thin section	68samples
2) Polished section	8samples
3) X-ray diffraction analysis	92samples
4) Fluid inclusion filling temperature and ice melting tempreture	13samples
5) Chemical analysis	
a)Rock (8 elements : Au,Ag,As,Cu,Mo,Pb,Sb,Zn)	409samples
b)Ore Assay (32 elements : Au,Ag,Al,As,Ba,Be,Bi,Ca,Cd,Co,Cr,Cu,Fe,Hg,K,Mg,Mn,Mo,Na,Ni,P,Pb,Sb,Sc,Sr,Ti,Tl,U,V,W,Zn,S)	34samples
(8 elements : Au,Ag,As,Cu,Mo,Pb,Sb,Zn)	20samples
c)Bulk composition	
major elements	32samples
trace elements	10samples
REE	3samples
6) Dating (k-Ar method)	
a)bulk	9samples
b)sericite separation	3samples
7) Mode composition counting	16samples

	Executive Director, MMAJ
Kenichi Takahashi	Energy & Mining Development Study Division, JICA
Toshihiko Hayashi	Technical Cooperation Division, MMAJ
Takafumi Tsujimoto	Representative of Santiago Office, MMAJ

Chilean side

Benjamin Teplisky L.	Ministro de Minería, Ministerio de Minería
Enrique Soler G.	Director Ejecutivo, Agencia de Cooperacion Internacional (AGCI)
Claudio Agosini G.	Vicepresidente Ejecutivo, Empresa Nacional de Minería (ENAMI)
Iván Henríquez S.	Consultor Gerencia de Minería, ENAMI
Mario Serrano C.	Consultor Gerencia de Minería, ENAMI
Juan Tello Ortíz	Jefe Negocios Mineros, Gerencia Regional III Región, ENAMI
Roberto Orellana O.	Consultor Negocios Mineros, Gerencia Regional III Región, ENAMI

(2) Field work

Japanese side

Toshihiko Hayashi	MMAJ
Satoshi Yamaguchi	MMAJ
Hiroshi Shibasaki	MMAJ
Masaru Fuijita	Dowa Engineering Co.,Ltd.
Takeshi Yoshida	Dowa Engineering Co.,Ltd.
Masatoshi Maekawa	Dowa Engineering Co.,Ltd.

Chilean side

Pedro Pérez Fernandes	Geologist
José Cárdenaz Pérez	Geologist

1-4 Survey Period

Project planning and negotiation: August 9, 1996 to August 19, 1996

Field survey:

Geological and geochemical survey:	October 5, 1996	to	November 14, 1996
Geophysical survey	October 5, 1996	to	December 21, 1996

Chapter 2 Geography

2-1 Location and Access

The area is located in the third region, about 110 km northeast of Copiapó and covers an area of about 30km2. The area is located approximately 40 km south of the El Salvador Mine, and 30 km southwest of Potrerillos (Fig. 1-2-1). Access to the Survey area is by vehicle for approximately 110 km on paved road to the city of Diego de Almagro, after which a further 70 km and 1.5 hours drive on gravel road is required.

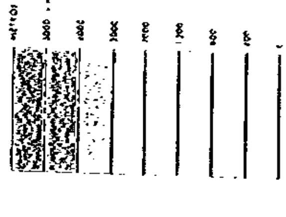
2-2 Topography

Northern Chile is characterized by four main longitudinal morphtectonic-physiographic provinces from the Pacific coast eastward: Coastal Cordillera, Longitudinal Valley, Precordillera, and the Andean Cordillera (Fig.1-2-2: after Sillitoe and Mckee, 1996). The survey area is located in the Precordillera region, and consists of a mountainous land of the Sierra Villanueva which is a small mountain range at the western end of the Cordillera Domeyko. Elevations in the survey area range from 2,200 m in the north to 3,600 m in the south. Geographical features within the survey area are divided into the mountains on the northwestern side and the mountains on the southeastern side by the wide valley elongate to the NE-SW (Fig.2). The northwestern mountain range trends in a similar direction. The southeast mountains are relatively steep, and a ridge (3,000 m to 3,600m above sea level) trends EW to NE. The La Guanaca mine and Rinconada de Villanueva (hereinafter referred to as "Rinconada") occur within a valley which trends NS (Fig.2). The Atacama gravels are distributed as a wide plane within the main NE-SW trending valley.

2-3 Climate and Vegetation

The survey area has a desert climate and as such, vegetation is very scarce. Precipitation increases progressively eastward with elevation and becomes sufficient to support a sparse, xerophytic flora. Hyperaridity affects the Coastal Cordillera, Longitudinal Valley, and western Precordillera, but annual precipitation attains 100 to 200 mm at the Collahuasi deposit on the eastern edge of the Precordillera (Sillitoe

Fig.1-2-1 Topographic map of the Guanaca area and surrounding



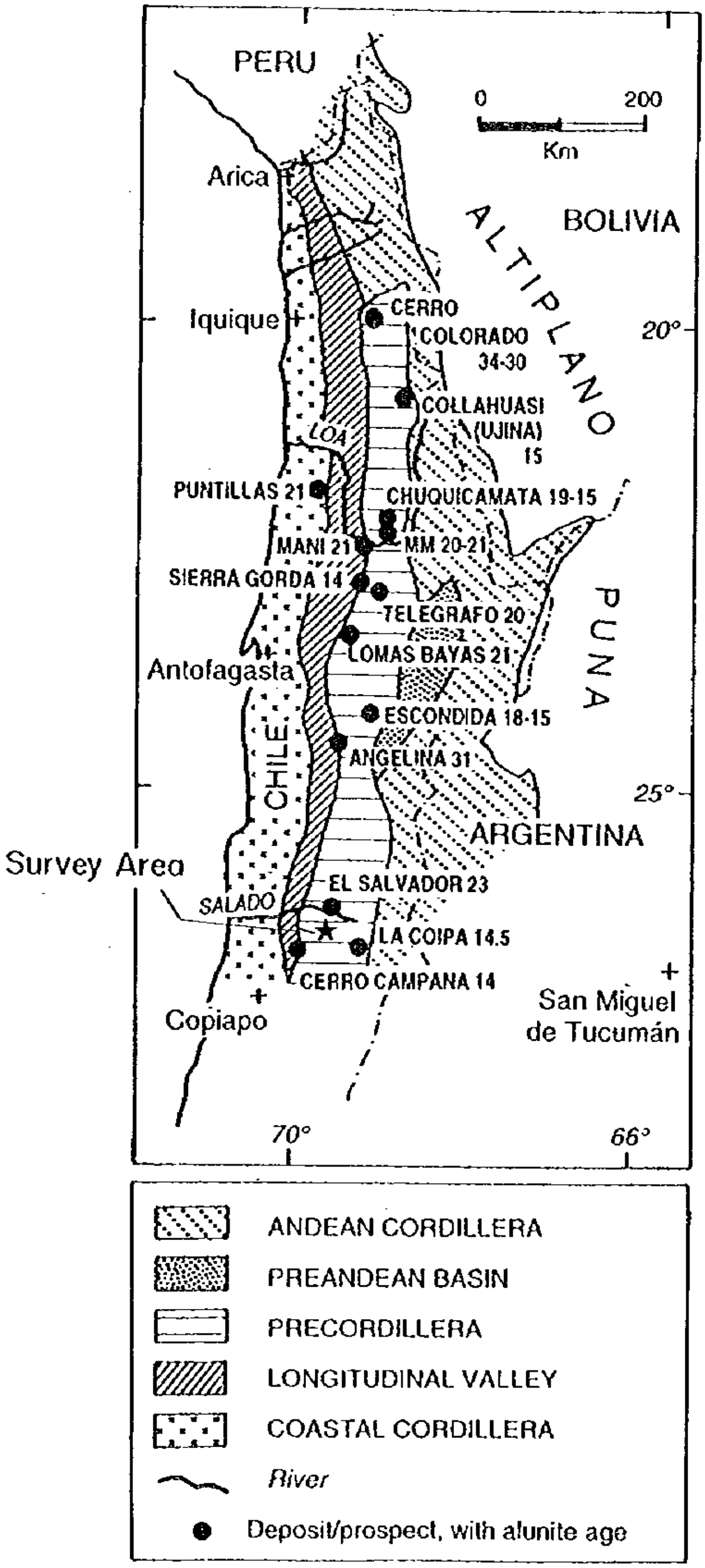


Fig.1-2-2　Porphyry copper deposits and prospects for which supergene alunite ages have been obtained in relation to the morphotectonic provinces of northern Chile (Sillitoe,1996)

and Mckee, 1996).

Chapter 3 Geology and economic geology in and around the Survey area.

3-1 Existing data

Existing data on the geology of the Survey area are summarized in Appendix1. The regional geological map which includes the Survey area has been published by Mercado (1978) at a scale of 1:250,000. Recently, SENAGEOMIN and CODELCO conducted geological surveys in the region from the El Salvador mine to the La Coipa mine (Cornejo et al., 1993).

3-2 General Geology

Fig. 1-3-1 outlines the geology around the survey area. The geology of this region is characterized by several zones which become progressively younger eastward. The geological zonal arrangement corresponds to the above mentioned geographical features (Fig. 1-2-2). The Coastal Cordillera consists mainly of igneous rocks of Jurassic age. The Atacama Fault marks the contact between the Longitudinal Valley and the Coastal Cordillera. The Longitudinal Valley is filled with Oligocene and younger sedimentary and volcanic material. The Precordillera roughly corresponds to the Domeyko mountains consisting of igneous and sedimentary rocks of Jurassic and Paleogene Tertiary age. In the Andean Cordillera zone, volcanics of Tertiary and Quaternary predominate. The Maricunga belt, a linear metallogenic unit where Micoene volcanic rocks are exposed, is located within this zone and is one of the most important provinces for epithermal precious metal deposits in Chile. The survey area is located on the western side of the Maricunga belt. Volcanic rocks distributed in the survey area are mainly Eocene in age, and are a little older than the rocks of the Maricunga belt.

3-3 Mineralization in and around the survey area

El Salvador porphyry copper type deposits occur to the north of the survey area within approximately 40 km. The Potrerillos mine is located about 30 km northeast of the survey area. The age of these porphyry copper deposits are_43~31Ma and 35Ma respectively. These porphyry copper deposits are located at the southern end of the late Eocene to early Oligocene belt which is the worlds principal principal copper repository. To the north of Copiapó and in the survey area this belt does not outcrop. In addition to the porphyry copper style mineralization, in and around the survey area occur

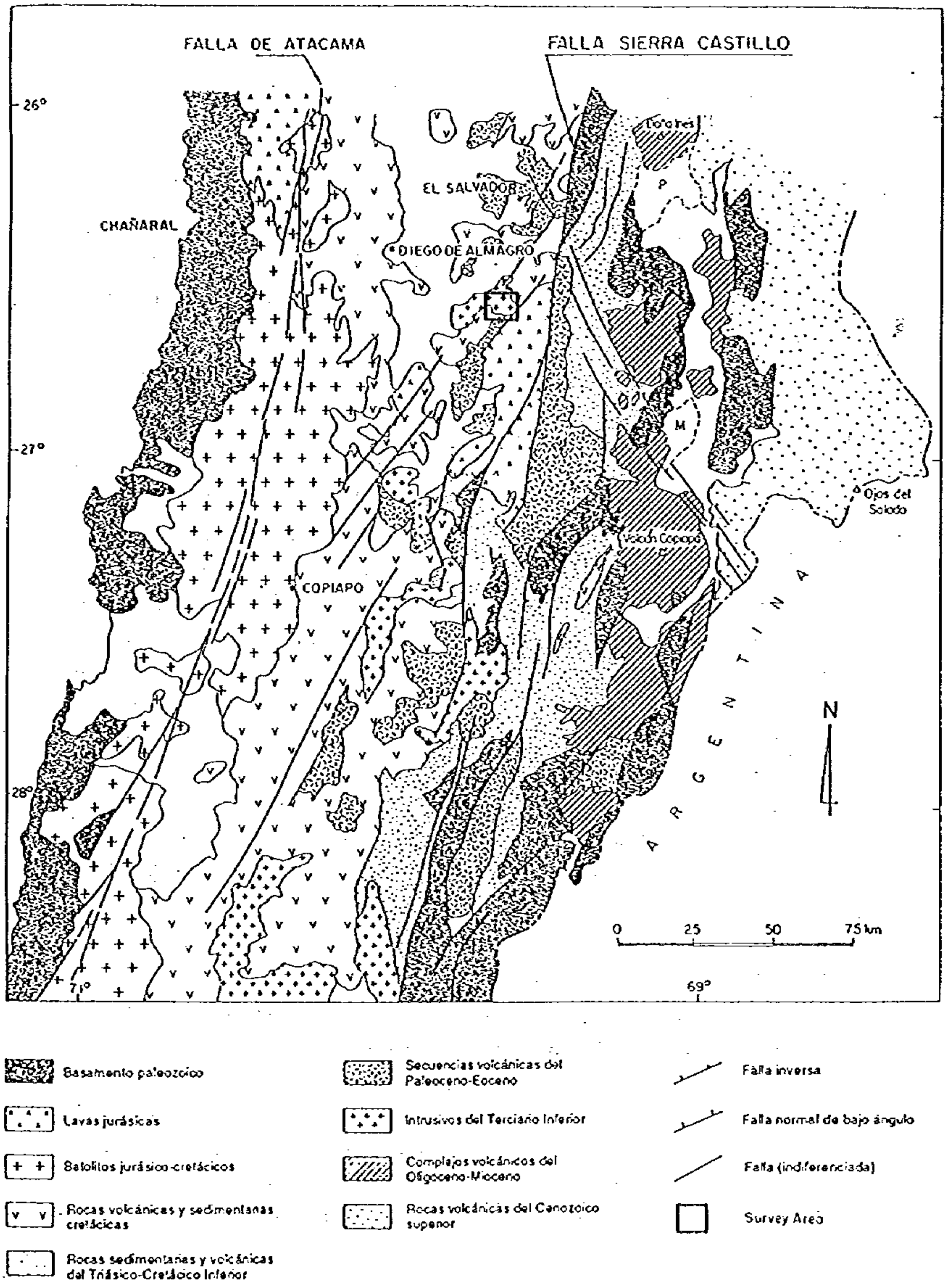


Fig.1-3-1 Schematic geological map of the Copiapó-El Salvador region (Cornejo et al., 1993)

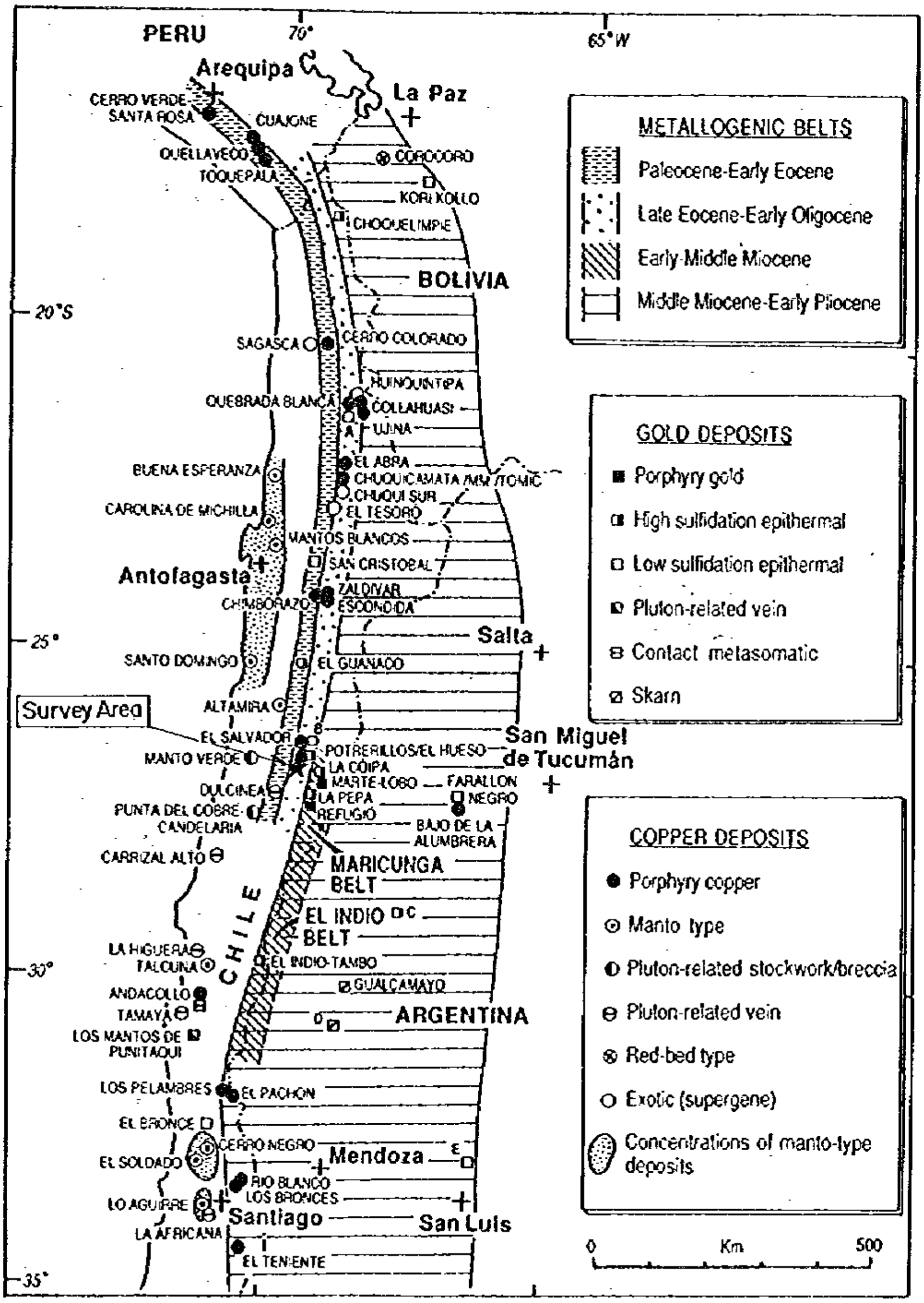


Fig.1-3-2 Location of the Survey area and metallogenic belts in the central Andes (Sillitoe, 1992)

numerous small workings which mined vein type oxide copper (Fig. 1-2-1). The La Guanaca mine is one of these, located in the center of the survey area, and was worked up until around 1995. The ore was sold to the ENAMI owned plant in El Salado. ENAMI funded the loan and technology guidance for the mine, and carried out pit surveys, drilling (non core, 5 holes, 573m), and a geophysical survey (CSAMT, 10 lines, line length: 400-500m) in 1994. Based on these results, it was estimated that ore reserves of oxide copper amounted to 6,850,000 t with 0.64 % T. Cu (Godoy and Gonzales, 1994). Located to the west of the survey area are the La Escondida and La Pimienta mines, and to the south the Enriqueta and Los Cuatro amigos mines (Fig. 1-2-1). Details of these mines are not known. To the south of the survey area, CODELCO drilled the alteration zone.

3-4 Exploration model

An exploration model based on the existing data is shown in Fig. 1-3-3. According to Godoy and Gonzalez (1994), stockwork style oxide copper has developed near surface, while the dissemination of chalcopyrite and pyrite developed in the deeper parts of the system (60m in depth). Stockwork oxide copper occurs in an intrusion breccia. The dissemination of chalcopyrite and pyrite developed in a porphyry. Silicifed and serictic alteration were developed in around the mine. On the other hand, the veins bearing oxide copper have developed at the Rinconada Prospect. Sericite alteration is also distributed in the Rinconada Prospect. From this data, we thought that a porphyry stock might be beneath the veins outcropping in the Rinconada Prospect, and that porphyry-style mineralization may have developed in the vicinity (Fig. 1-3-3). Based on the exploration model, we planed the first phase survey as follows.

- Delineation of the geology of the survey area, followed by identification of the igneous rocks that may have been responsible for the mineralization in the survey area.
  - Clarification of the distribution and characteristics of the alteration zone, followed by selection of target areas showing high potential for mineralization.
  - Delineate the distribution of geochemical anomalies, followed by selection of target areas showing high potential for mineralization.
  - Delineate the distribution of IP anomalies, followed by deduction of concealed mineralization.

Chapter 4 Survey Results

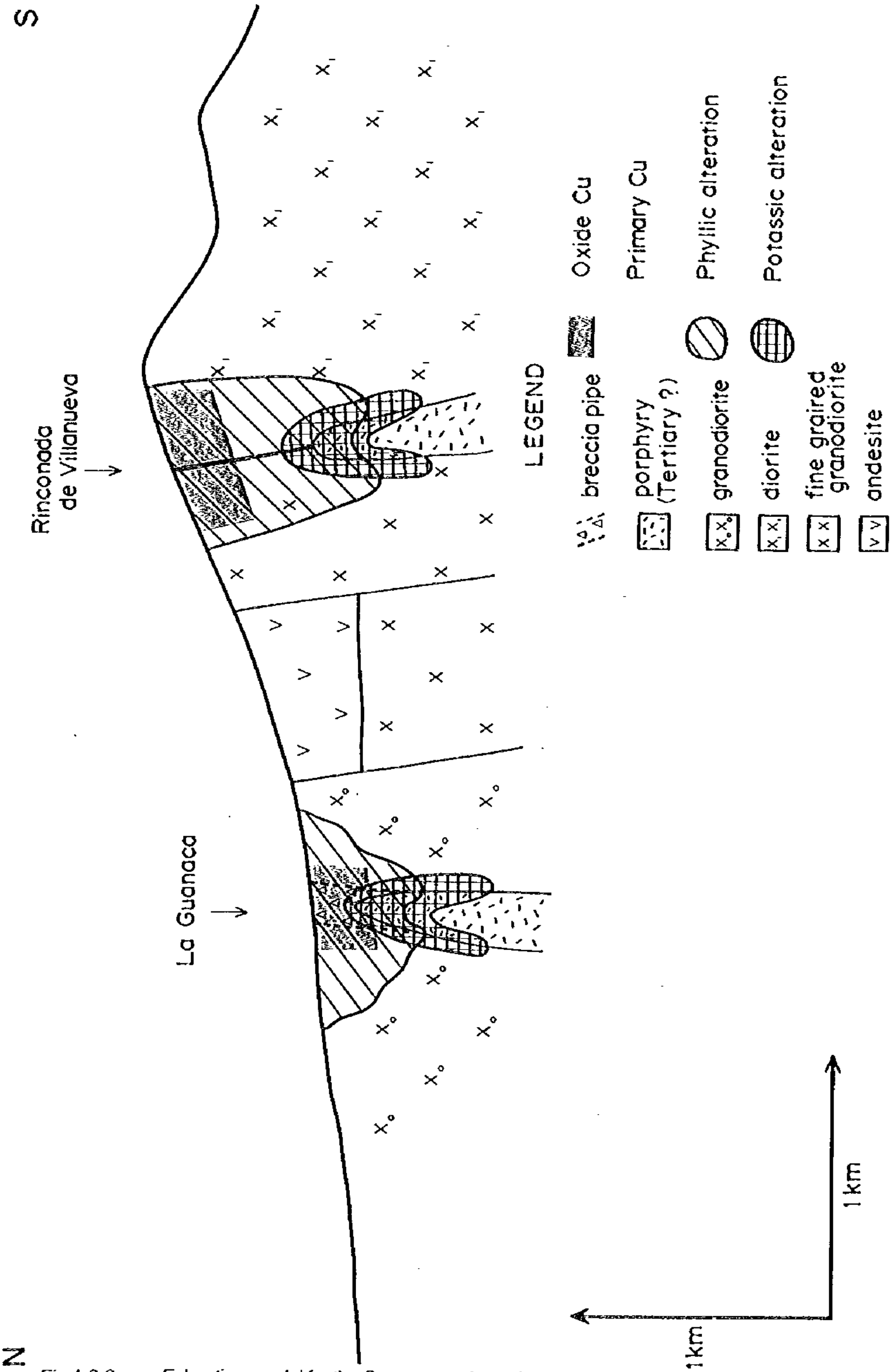
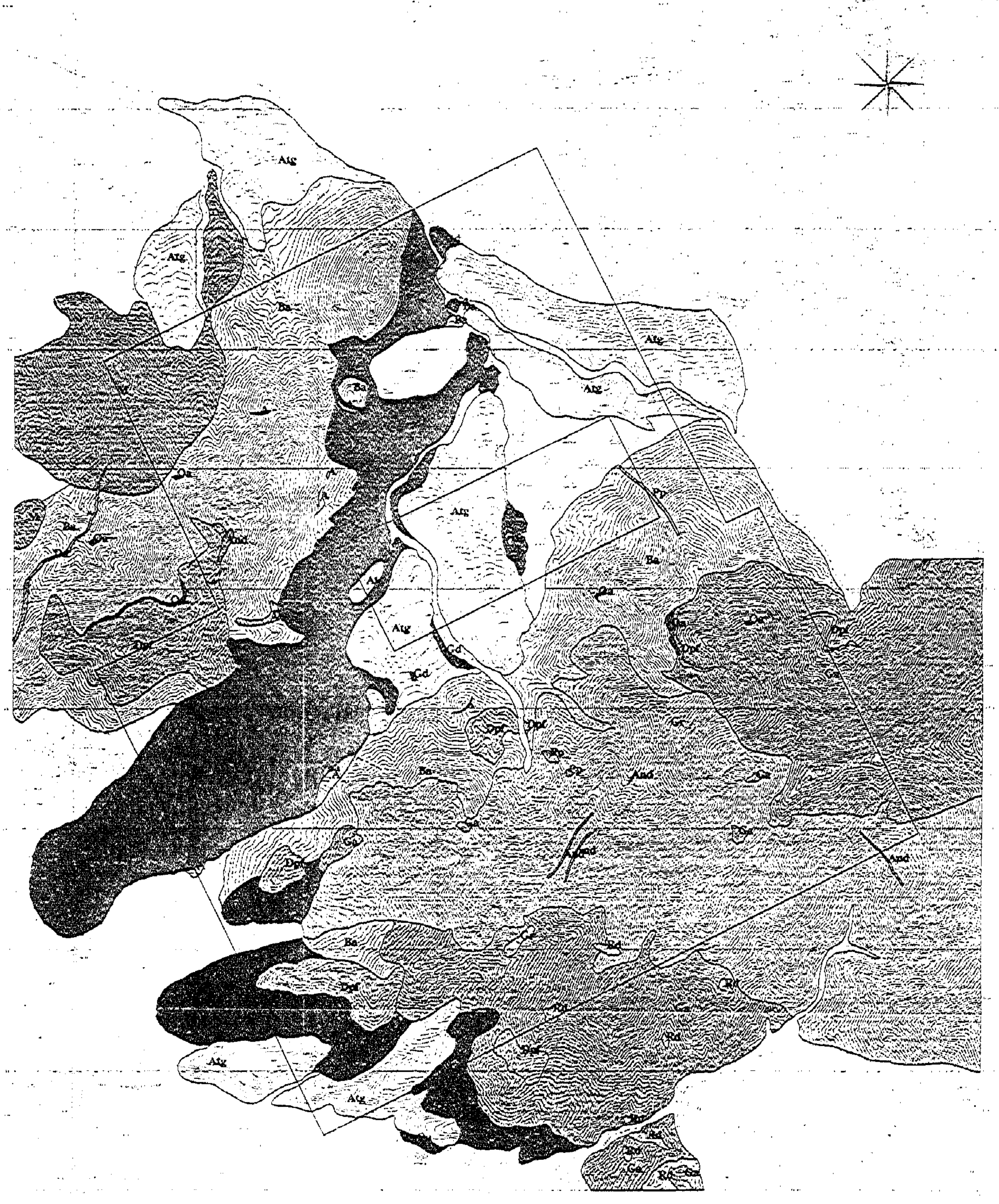


Fig.1-3-3 Exloration model for the Survey area based on existing data prior to this survey

Geological Map of GUANACA



Scale 1:32000
0 0.25 0.5 1 1.5 2 2.5 3km

Fig.1-4-1 Geological map of the Guanaca area

4-1 Results of the geological and geochemical survey

The geological map is shown in Fig. 1-4-1. The geology of the survey area consists of volcanic rocks of early Cretaceous to Paleogene age intruded by granitic rocks of Eocene age. These granitic rocks are divided into the following three bodies.

- Monzonite body that is distributed in the northwestern part of the survey area (M).
- Granodiorite body that is distributed in the central part of the survey area (Gd).
- Granite Monzonite body that is distributed in the south and southeastern part of the survey area (Gr).

In addition to the previously identified mineralization in the La Guanaca and Rinconada Prospects, several additional areas of mineralization were identified in the central and southern parts of the survey area.

The characteristics of the following three main prospects, the La Guanaca Prospect, the Rinconada Prospect, and the Central Prospect are shown in Table 1-4-1.

4-1-1 The La Guanaca Prospect

Two styles of mineralization have been identified in the surveyed areas.. One is a disseminated type chalcopyrite-pyrite mineralization occuring in a small porphyry stock, while the other is vein type copper mineralization occuring in the granodiorite. In addition, oxide copper mineralization occurs along joints of the granodiorite. This oxide copper mineralization may be supergene exotic copper mineralization. Sericite and K-silicate alteration are apparent in this prospect. Green biotite and K-feldspar are observed in the porphyry, however no epidote has been identified. The prospect is characterized by copper and molybdenum geochemical anomalies.

The disseminated type chalcopyrite-pyrite mineralization in the small porphyry stock is not typical of porphyry copper style mineralization as there are no stockworks or D-veins (Gustafson and Hunt,1975). However, the disseminated mineralization might be related to a porphyry copper style mineralization due to the existence of K-silicate alteration and the anomalous copper and molybdenum concentration in the rocks.

4-1-2 The Rinconada Prospect

Quartz vein type mineralization was observed in the Rinconada Prospect. Because chalcopyrite relicts are observed in the oxide copper within the quartz veins, the mineralization is not exotic but in situ copper mineralization. Quartz veins are hosted by the Aplitic granite. Sericite alteration is closely associated and developed along the veins, in addition to tourmaline and epidote, often observed within and around the veins. Epidote and chlorite alteration are apparent in the rocks within the prospect. Smectite is also observed in and around the veins and maybe a supergene product. The homogenization temperatures of the fluid inclusions from the quartz veins are approximately 200 ° C to 310 ° C. The salinity of the fluid inclusions from the quartz veins are in most cases rather low, around 1 wt. % NaCl equivalent, although some inclusions do occur which have relatively high salinities of 10 to 5 wt. % NaCl equivalent. In addition to the copper mineralization, gold, lead, and zinc mineralization has also been identified in the veins, which can explain the rock geochemical anomalies of copper, gold, lead, and zinc in this prospect.

4-1-3 The Central Prospect

Quartz vein type mineralization has been observed in the Central Prospect and as chalcopyrite relicts are observed in the oxide copper in the quartz veins, the mineralization is not exotic but in situ copper mineralization. Quartz veins are hosted by the Granodiorite and Llanta andesite with sericite alteration being developed along and around the veins. The homogenization temperatures of the fluid inclusions from the quartz veins are approximately 300° C to 340° C. The salinity of the fluid inclusions from the quartz veins are mainly rather high between 9 and 12 wt. % NaCl equivalent. Some inclusions have relatively low salinities of 3 wt. % NaCl equivalent. In addition to the copper mineralization, gold, lead, and zinc mineralization has also been identified in the veins, which can explain the rock geochemical anomalies of copper, gold, lead, and zinc in this prospect. These features are similar to those which characterize the Rinconada Prospect. In comparison however, the molybdenum contents of the rocks of the Central Prospect are a little higher than that of the Rinconada Prospect, while gold, silver, and lead concentrations of ore from the Rinconada Prospect are higher than those from the Central Prospect.

The above characteristics of the Rinconada and Central Prospects maybe interpreted as representing the peripheral parts of a porphyry copper style system. The Central prospect may be spatially closer to the center of a porphyry copper style system than the Rinconada Prospect based on the fluid inclusion temperatures and salinities, and the above mentioned geochemical features.

Table 1-4-1 Summary of Prospect characteristics

Prospect	La Guanaca			Central	Rinconada
type	disseminated	quartz vein	oxide Cu vein	quartz vein	quartz vein
host rock	Hb-Pl Porphyry(Hp)	Granodiorite3(Gd3)	Granodiorite3(Gd3)	Granodiorite3(Gd3) Llanta andesite(Ba)	Aplitic granite(Ag)
ore minerals primary	chalcopyrite bornite pyrite	chalcopyrite pyrite		chalcopyrite pyrite	chalcopyrite pyrite galena
secondary	geothite green Cu minerals* hematite	green Cu minerals* goethite	green Cu minerals* goethite	covellite green Cu minerals* geothite	chalcocite covellite green Cu minerals* cerussite mimetite
structure	within porphyry stock	N60° W~EW, 62° ~70° N	along joints of granodiorite	N64~85° W, N80° E 60° ~80° S	N10~40° E, N10~30° W 70~80° E, vertical
alteration	Potassic(K-feldspar, biotite), Phyllic(sercite)	Phyllic(sericite)	Supergene(smectite)	sericite, tourmaline propylitic(chlorite,epidote)	sericite, tourmaline propylitic(chlorite,epidote)
geochemical feature	high Cu, Mo			Cu,Mo,Au,Pb,Zn	Cu,Au,Ag,Pb,Zn
fluid inclusion	no data	no data	no data	300~340° C Av.300° C boiling 9~12wt%NaCl equiv.	200~310° C Av.270° C 0~10wt%NaCl equiv.
others	hydrothermal brecciation				
age of sericite	43.9±1.1Ma			no precise age	45.6±1.2Ma 46.0±1.2Ma
mineralization characteristics	upper portion of a porphyry Cu system?		supergene mineralization (exotic)	peripheral vein related to a porphyry Cu system or pluton related vein	peripheral vein related to a porphyry Cu system or pluton related vein

* : chrysocolla, chalcanthite, brochantite, malachite

4-2 Results of the geophysical survey

- Apparent resistivity reflects the geology of the Suvey area. Low apparent resistivity zone extends from center to northeastern part of the Survey area. This low apparent resistivity zone is correspond to the distribution of Atacama Gravel (Fig.2-4-7)
- The anomaly of the low apparent resistivity zone on line J near the Rinconada prospect may have potential for the mineralization. The anomaly is located in the higher resistivity zone that is expected from the geology (Fig.2-4-7).
- The IP anomaly on the line J seems likely to have the relationship to a mineralization. Because the location of the IP anomaly corresponds to the low resistivity zone on line J. However, it is difficult to discuss the relationship between the other IP anomalies and the potential of a mineralization, because the enough current was not transmitted.

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

The survey results are summarized as follows:

1) Three main prospects are recognized: the La Guanaca Prospect, Rinconada Prospect, and Central Prospect.
2) The characteristics of each of these prospects are interpreted in terms of the zonation of a porphyry copper style mineralized system. The La Guanaca prospect may be closest to the center of a porphyry copper style system, while the Rinconada and Central Prospects may represent the peripheral parts of the same of similar system.
3) If a vertical zoning of a porphyry copper style mineralization system can be supposed, it may be possible that the center of the system exists in the deeper part of the Rinconada Prospect. The IP anomaly at deeper levels near the Rinconada Prospect may reflect the center of the system and possoble mineralization.

5-2 Recommendations

Drilling surveys mentioned below are recommended for Phase II survey.

In order to check ore bodies, it is recommended to conduct drilling surveys at the following sites.

1) the Central prospect
2) the Rinconada prospect

3) the closer area of the La Guanaca prospect.

PART 2 SURVEY RESULTS

Chapter 1 Geological Survey

1-1 Objective

To understand the geology of the area, clarify the igneous rock types that may have been responsible for the mineralization, and to identify target areas showing high potential for mineralization.

1-2 Method

A geological survey was conducted using 1:5,000 and 1:10,000 scale maps produced from 1:40,000 air photographs. A detailed geological survey was carried out in the La Guanaca mine area and the Rinconada de Villanueva (herein after referred to as "Rinconada") Prospect, which are known areas of mineralization within the survey area. Typical rock and ore samples were collected for preparation of both thin and polished sections. Altered samples were analyzed by X-ray diffraction.

1-3 Results

1-3-1 Geology

The geology of the survey area is illustrated in Fig.1-4-1,Fig. 2-1-1 and Fig. 2-1-2. The schematic relationships of the rocks distributed in the Survey area, which are early Cretaceous to early Tertiary in age. The granitic bodies are divided into the following:

- A monzonite body located in northwestern part of the survey area (the Northwestern Monzonite body, M),
- A granodiorite body distributed in central part of the survey area (the Central Granodiorite body, Gd),
- A granite monzonite body occurred in south and southeastern part of the survey area (the South Granite Monzonite body, Gr).

The rocks distributed in the surveyed area have been divided into thirteen lithologic units as follows:

1) Andesitic lava and clastics (Ba)
2) Dacitic lapilli tuffwelded tuff (Dpf)
3) Andesitic lava and clastics (Ga)

Lithological Map of GUANACA

Scale 1:32000
0 0.25 0.5 1 1.5 2 2.5 3km

Fig.2-1-1 Lithological map of the Guanaca area.

Cross Section of GUANACA

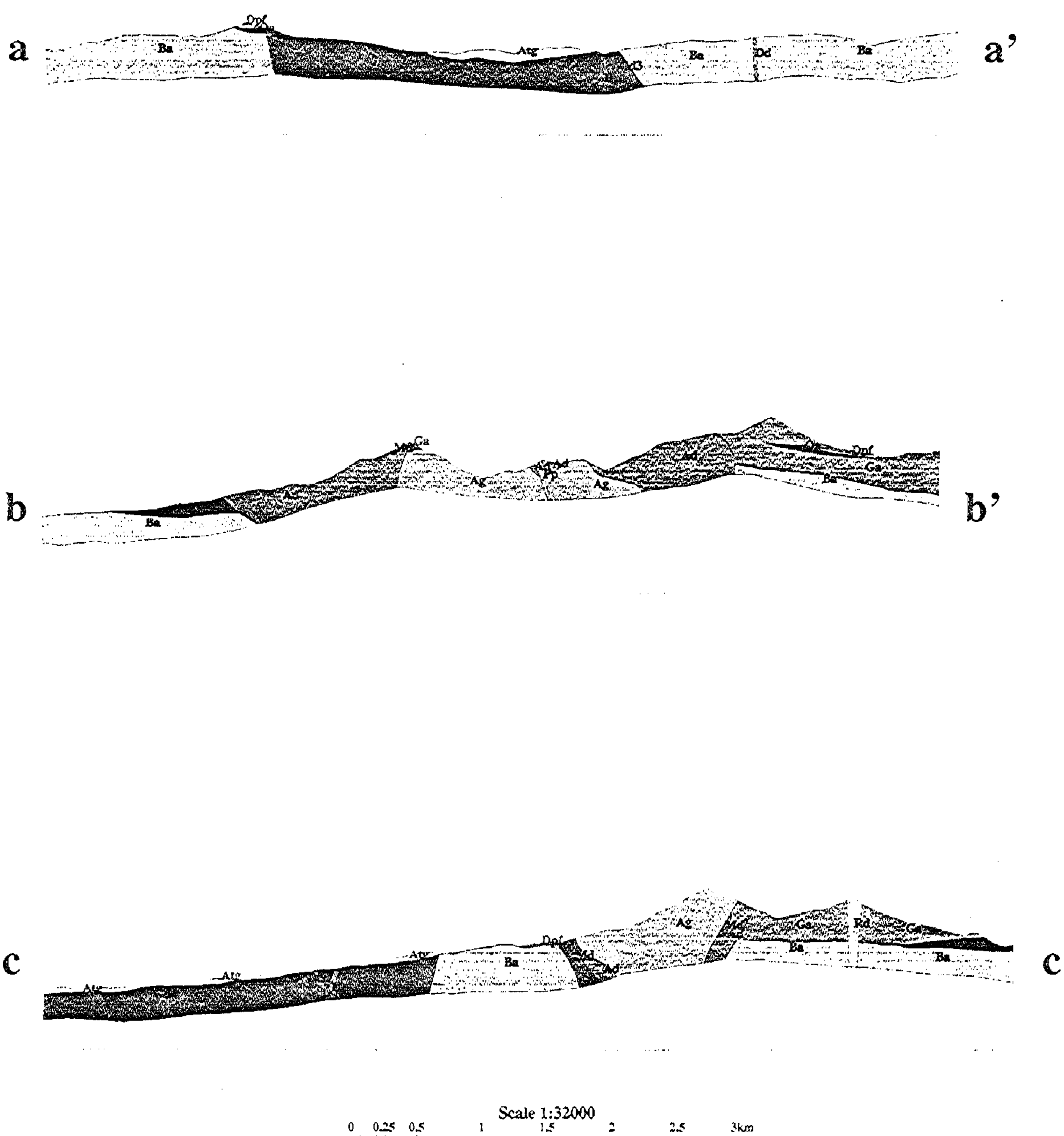


Fig.2-1-2 Lithological sections of the Guanaca area, section a-a', b-b', and c-c'.

PART II Survey Results

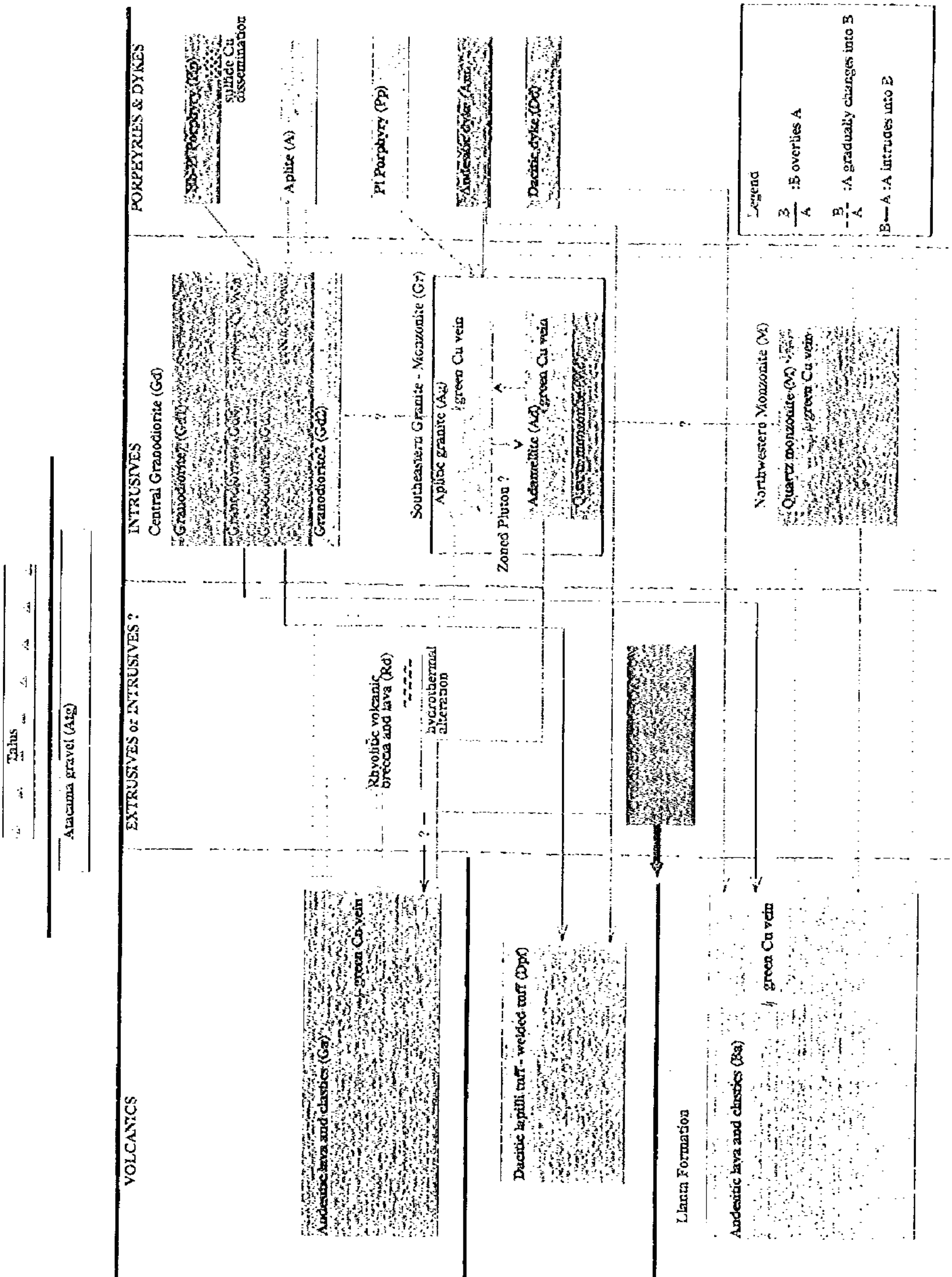


Fig 2-1-3 Stratigraphic relationships of rocks outcropping in the Guanaca area

4) Ocoitic andesite (Oa)

5) Rhyolitic volcanic breccia lava (Rd)

the northwestern monzonite body (M)

6) Quartz monzonite (M)

the South Granite Monzonite body (Gr)

7) Quartz monzonite (Md)

8) Adamellite (Ad)

9) Aplitic granite (Ag)

the Central Granodiorite body (Gd)

10) Granodiorite1 (Gd1)

11) Granodiorite2 (Gd2)

12) Granodiorite3 (Gd3)

13) Granodiorite4 (Gd4)

14) Dykes

- Hb-Pl porphyry dyke
- Aplite Pl porphyry dyke
- Andesitic dyke
- Dacitic dyke

1-3-2 Petrography

1) Andesitic lava and clastics (Ba)

Distribution: These rocks are distributed in the northwestern and central part of the Survey area and trend NE-SW. The black area in the satellite image (Fig. 3) corresponds to this group.

Occurrence and lithology: The black colored pyroxene-hornblende andesitic lavas and clasitc rocks compose the basement of the Survey area. The SiO_2 content of the bulk composition of these rocks are about 55 wt. % (Appendix 2, Fig.2-1-4). Volcanic breccias and tuff breccias are distributed around the 3001.5 m peak in northwestern part of the Survey area. Almost all rocks have been subject to contact metamorphism and at the contact with granitic rocks, the grain size of the andesite becomes larger and metamophic biotites occur. Chlorite-epidote-tourmaline-garnet veins are found in the contact zones. The andesite correlates with the Llanta Formation (KII) after Cornejo et al., (1993). According to Cornejo et al., (1993), the Llanta andesite is early Cretaceous in age and is extensively distributed around the Survey area. The type location is Llanta town, which is located 30 km NNW of the Survey area. To the south of the

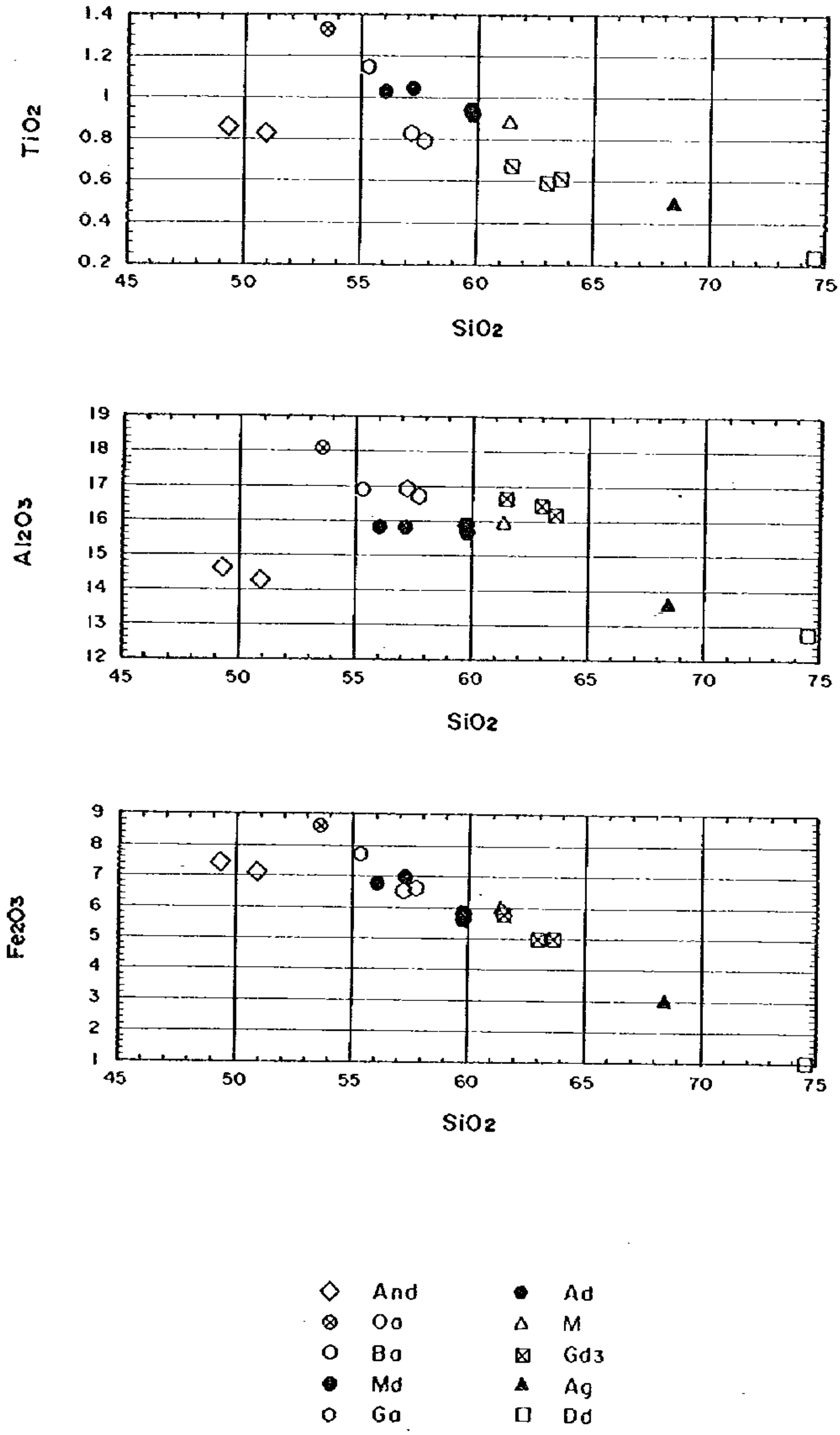


Fig.2-1-4 (1) Harker diagrams

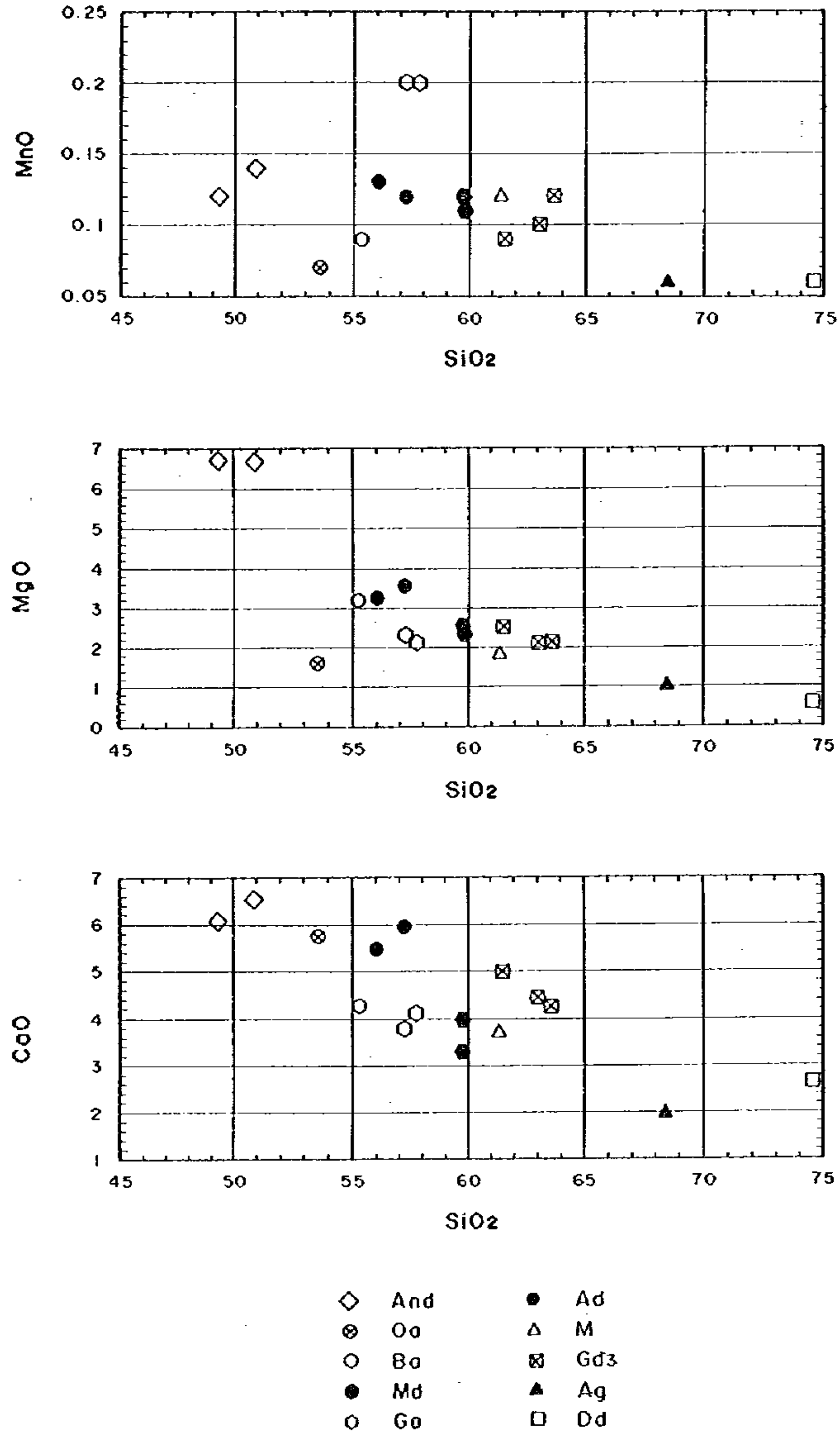


Fig 2-1-4 (2) Harker diagrams

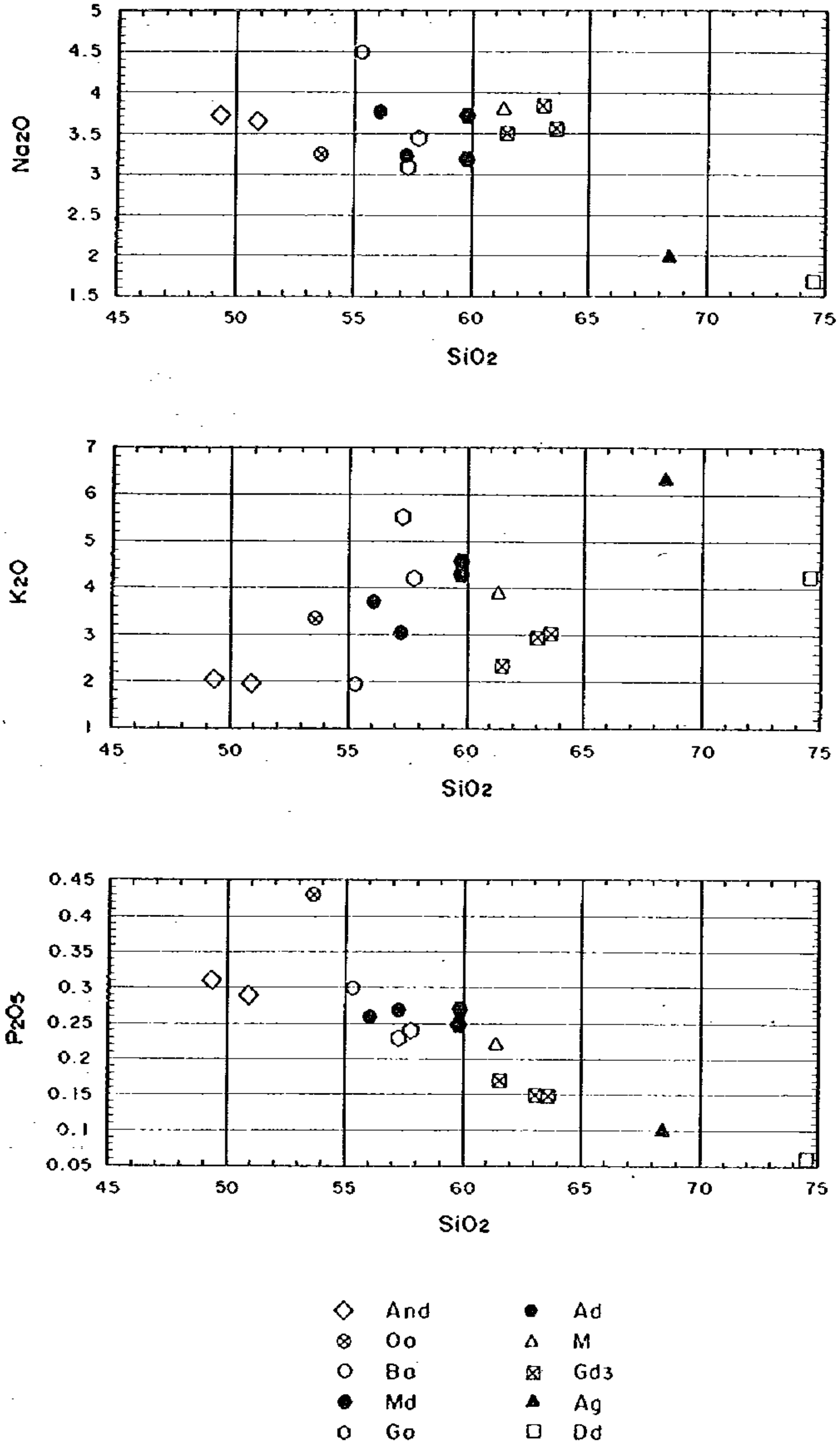


Fig.2-1-4 (3) Harker diagrams

Survey area, the Llanta Formation consists of sedimentary rocks such as conglomerate, however these sedimentary rocks are not distributed within the Survey area. Several small trenches were excavated and green copper mineralization was evident in narrow quartz veinlets.

2) Dacitic lapilli tuff (Dpf)

Distribution: These rocks are distributed on the western and southern ridge of the survey area.

Occurrence and lithology: The rocks are pyroclastic flow deposits. White to grayish in color. The lapilli tuff contains black to gray in colored andesites as lapillis. Breccia and lapilli are rounded to subrounded in a white to gray colored crystal rich (plagioclase) matrix. In some parts, the rock is welded (Fig.2-1-5). The rock is subjected to contact metamophism at or near contacts with granitic rocks. The rock has magentite and tourmaline clots in some parts. This rock correlates with the Cerro Vicuña Ignimbrite (Tiv) after Cornejo et al., (1993). According to Cornejo et al, (1993) the rock is Eocene in age. A K-Ar age determined during this survey is 42.6±2.1Ma and represents the age of alteration (see Table 2-3-2 and Chapter 3).

3) Andesitic lava and clastics (Ga)

Distribution: These rocks are distributed in the south and southeastern parts of the Survey area.

Occurrence and lithology: The rocks are greenish andesite lavas and andesitic clastics with a SiO_2 content of approximately 57 wt. %. (Appendix 2, Fig.2-1-4). The clastics consist of volcanic breccia, tuff breccia, and lapilli tuff and are extensively altered to chlorite and epidote. These rocks are considered to overlie the Llanta Andesite (Ba). At outcrop 137939, the volcanic breccia (Ga) is polymictic consisting of clasts of andesititc lava and lapilli tuff (Dpf), and overlies the Dacitic welded tuff (Dpf). Because of this relationships, the Ga andesite is considered to be younger and overlie the Dacitic lapilli tuff (Dpf.). This andesite correlates with the Cerro Vicuña daicitc dome and breccia complex (Tcdd) after Cornejo et al., (1993). According to Cornejo et al., (1993) these rocks are of Paleocene age. A K-Ar age determined during this study is 42.3±2.1Ma and represents the age of alteration (see Table 2-3-2 and Chapter 3).

4) Ocoitic andesite(Oa)

Distribution: This rock is distributed in the southern part of the Survey area, and to a much lesser degree in the eastern and western parts.

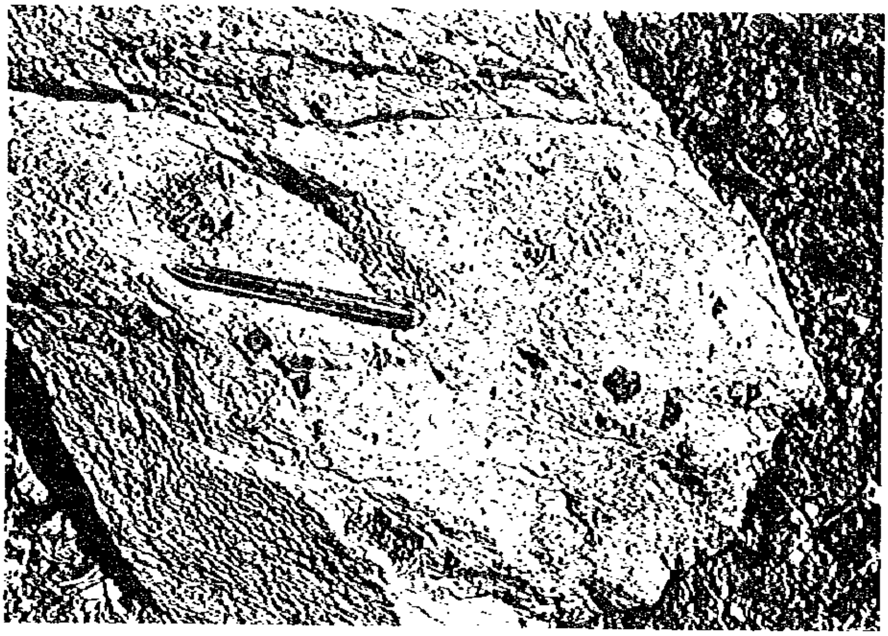


Fig.2-1-5 Photograph of lapilli tuff (Dpf)

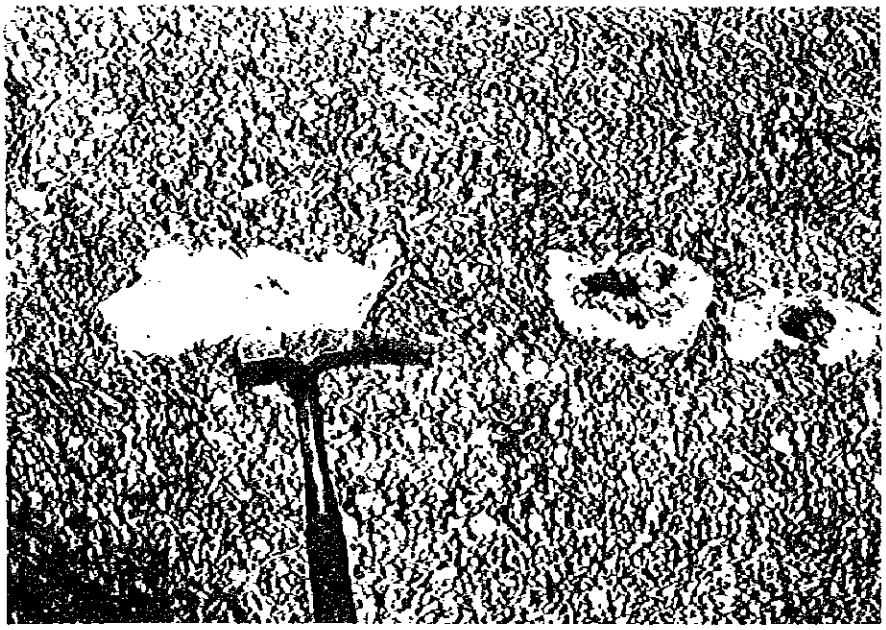


Fig 2-1-6 Photograph of Oooitic andesite (Oa).

Fig 2-1-7 Photograph shows the contact between the Ocolic andesite and the Green andesite (Ga)

Fig 2-1-8 Photograph shows the contact between the Ocolic andesite and the Green andesite (Ga) above. The point of the hammer marks the boundary between the Ocolic andesite (Oa) and the Green andesite (Ga) Plagioclase phenocrysts are parallel to the contact

Fig 2-1-9 Photograph of the ourcropping Rhyolitic volcanic breccia (Rd)

Occurrence and lithology: These rocks are characterized by very large plagioclase phenocrysts up to 30 mm in length and displaying a weak preferred orientation. These rocks are basaltic and alkaline in composition with SiO_2 contents of approximately 53 wt. % and Na_2O+K_2O contents of more than 6.0 wt % (Appendix 2, Fig.2-1-10). Around Quebrada Enriqueta, the rock is characterized by amygdaloidal cavities, some reaching 20cm in diameter, and filled with quartz and chlorite (Fig.2-1-6). Quartz veinlets with epidote haloes are observed in some places. There are some small trenchs where green copper minerals were dug. At outcrop 137917, the width of the quartz vein is 0.5cm, and strikes N75° E. The green copper minerals are chrysocolla and malacite. The contact between the Ocoitic andesite (Oc) and the Green andesite (Ga) is observed at Quebrada Enriqueta (Fig.2-1-7, Fig.2-1-8) is knife sharp, the plagioclase phenocrysts of the Ocoitic andesite are parallel to the contact. There is no flow foot breccia at the base of the Ocoitic andesite and might therefore have been emplaced in the Green andesite(Ga) like a sill body. According to Cornejo et al.,(1993), the Ocoitic andesite is a member of the Llanta Formation, however we consider that the Ocoitic andesite does not belong to the Llanta Formation based on the above mentioned reason.

5) Rhyolitic volcanic breccia and lava (Rd)

Distribution: This rock outcrops around Quebrada Enriqueta in the south of the Survey area.

Occurrence and lithology: This rock is a white rhyolitic volcanic breccia and lava. The volcanic breccia is composed of flow banded rhyolitic blocks. This rhyolitic breccia is thought to be an auto-brecciated lava due to its monolithologic character. It is thought that this rock intrudes the Andesite (Ga) judging from its dome like shape (Fig. 2-1-9). Bleaching and silicification due to hydrothermal activity is observed in this rock. Under the micoscope, very fine grained biotite aggregates are observed. In the south of the Quebrada Enriqueta, outside of the survey area, the rocks became white to yellowish brown in color due to the presence of illite/smectite interstratified clay minerals. Hydrothermal brecciation is also observed in this area. CODELCO previously carried out a drilling survey around this area.

6) Quartz monzonite(M)

Distribution : These rocks are distributed in and surrounding the northwestern part of the Survey area.

Occurrence and lithology : The monzonites are dark gray to greenish gray in color and have a medium grained, equigranular texture. The main mineral constituents are plagioclase, K-feldspar, quartz, hornblende, and biotite, plagioclase being most abundant. A little K-feldspar and quartz occupy irregular interspaces. Both minerals have a graphic growth texture. The modal analysis shows that this rock is a quartz monzodiorite to quartz monzonite according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). Plagioclase is partly altered to sericite, while hornblende and biotite are partly altered to chlorite, epidote, carbonate, and opaque minerals. The SiO_2 content of these rocks is approximately 61 wt. % and have high alkali (Na_2O + K_2O) contents around 7 wt. % (Appendix 2,Fig. 2-1-4). According to Cornejo et al. (1993), the K-Ar age of biotite from a monzonite sample collected in 8km away from the survey area is approximately 63±2 Ma and therefore of Paleocene age. This rock seems to be the oldest granitoid distributed around the Survey area.

7) Quartz monzonite (Md)

Distribution: These rocks are distributed in the southern part of the Survey area.

Occurrence and lithology : The monzonites are dark greenish-gray to dark gray in color. The rock is mafic and looks like a gabbro in the field, however the modal analysis indicates that this rock is monzodiorite to quartz monzonite according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). The mineral constituents are plagioclase, quartz, K-feldspar, orthopyroxene, hornblende, and very minor biotite. A little K-feldspar and quartz occur as intersititial minerals. Both display graphic and granophiric texture. Plagioclase is partly altered to sericite and epidote, while pyroxene is partly altered to chlorite and opaque minerals and hornblende to chlorite and epidote. The SiO_2 content of these rocks are approximately 56 to 57 wt. % (Appendix 2, Fig. 2-1-4) with rather high alikali contents (Na_2O + K_2O) of approximately 6 wt. %. These rocks grade into the Adamellite (Ad) mentioned below.

8) Adamellite(Ad)

Distribution: The rocks occur in the central and southern part of the Survey area.

Occurrence and lithology : The ademellite is dark greenish-gray to gray in color with a fine to medium grained texture. The modal analysis indicates that this rock is a quartz monzodiorite-quartz monzonite according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). The main mineral constituents are plagioclase, hornblende, biotite, quartz, and K-feldspar. A little K-feldspar and quartz occur as intersititial minerals. The SiO_2 content of this rocks are approximately 59 to 60 wt. % (Appendix 2, Fig. 2-1-4) and rather high alkali contents (Na_2O + K_2O) of approximately 7 wt. %. This rock may intrude and grade into the quartz monzonite (Md). The quartz monzonite (Md), the Adamellite (Ad), and the Aplitic granite (Ag) mentioned below grade into each other within a 50 m interval at the ridge south of Rinconada (the saddle between the 3174.5 m and 3167.5 m peaks; sample No. 96110418~96110422). Judging from the close spatial relationships, those 3 rock types are of similar age and may be genetically closely related.

9) Aplitic granite(Ag)

Distribution : These rocks are distributed between Rinconada and Cerro El Pimiento.

Occurrence and lithology : These aplitic granitic rocks are fine grained and white to light gray in color. The mafic minerals are almost entirely altered to chlorite and epidote. Rhyolitic dykes are found in some places, and in one case is observed to grade into the aplitic granite. Dykes of andesitic composition are also observed to be running parallel and hosted by the aplitic granite. Those andesite dykes are dark greenish gray in color and approximately 5m in width. The modal analysis indicates that these rocks are granites according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). The dominant mineral constituents are plagioclase, K-feldspar, and quartz. Mafic minerals have been completely replaced by epidote and opaque minerals. It is difficult to distinguish which minerals are primary. Some of plagioclase, which are a little bigger than the other minerals, are scattered. Except for the plagioclase, K-feldspar, plagioclase and quartz are almost the same size. These 3 minerals are anhedral to subhedral. Epidote often occurs as isolated grains. Some epidote is found as aggregates with chlorite and opaque minerals after mafic minerals. The SiO_2 content of these rocks are approximately 68 wt. % (Appendix 2, Fig. 2-1-4). The alkali contents are rather high ($Na_2O + K_2O \geqq 8$ wt%).

10) Granodiorite1 (Gd1)

Distribution: These rocks constitute the NE-SW trending ridge in the southeastern part of the Survey area.

Occurrence and lithology : This granodiorite has a medium to fine grained texture and is light greenish-gray to dark gray in color. Most of the mafic minerals are altered to chlorite. Tourmaline clots are found occasionally and in some occurences, tourmaline veinlets also occur. The tourmaline veinlets sometimes bear green copper minerals. The modal analysis shows that this rock is a granodiorite according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). The main mineral constituents are plagioclase, quartz, K-feldspar, hornblende, and biotite. K-feldspar and quartz occur as intersititial minerals. K-feldspar is less abundant than quartz. Almost all of the hornblende and biotite are altered to chlorite. A K-Ar age indicates the granodiorite has an age of 42.1 ±2.1 Ma (Table 2-3-2). This age may show a alteraiton age (see Chapter 3).

11) Granodiorite 2 (Gd2)

Distribution: These rocks are exposed in a restricted area within the Granodiorite (Gd3) mentioned below.

Occurrence and lithology : Fine grained mafic minerals are abundant and resembles a dioritic rock in the field. This rock appears to be a big cognate inclusion of the Granodiorite 3 (Gd3) as the Gd2 rock is very similar to the dioritic inclusion of the Granodiorite 3 (Gd3) and Granodiorite 4 (Gd4). The modal analysis shows that this rock is a granodiorite according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). The mineral constituents are plagioclase, quartz, K-feldspar, hornblende, biotite, and opaque minerals. The K-feldspar and quartz occur as intersititial minerals. These K-feldsapr have small plagioclase laths, euhedral hornblende and biotite poikiliticaly. Hornblende is most abundant among the mafic minerals, next in abundance is biotite, then the opaque minerals.

12) Granodiorite 3 (Gd3)

Distribution : This rock is distributed in the central part of the survey area.

Occurrence and lithology : The rock is characterized by a small abundance of mafic minerals. The modal analysis shows that this rock is a granodiorite according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). The mineral constituents are plagioclase, quartz, K-feldspar, hornblende, biotite, and opaque minerals. This rock is relatively fresh, with K-feldspar and quartz occurring interstitially. Two modes of occurrence of biotite are found. One occurs as isolated crystals while the other occurs as an overgrowth on hornblende. This rock is the host rock to the oxide copper vein of the La Guanaca prospect, and is also a host rock to the vein of the Central Prospect. The SiO_2 content of this rock is 6163 wt. % (Appendix 2, Fig.2-1-4).

13) Granodiorite 4 (Gd4)

Distribution : This rock is distributed in the northern part of the survey area and appears to be covered by the Atacama Gravels.

Occurrence and lithology : This rock is light gray in color and has a medium to coarse grained texture. In the south of Cerro Bonete, this rock intrudes the Llanta andesite (Ba). Pegmatitic dikes, which consist of quartz, K-feldspar, biotite, and tourmaline, are

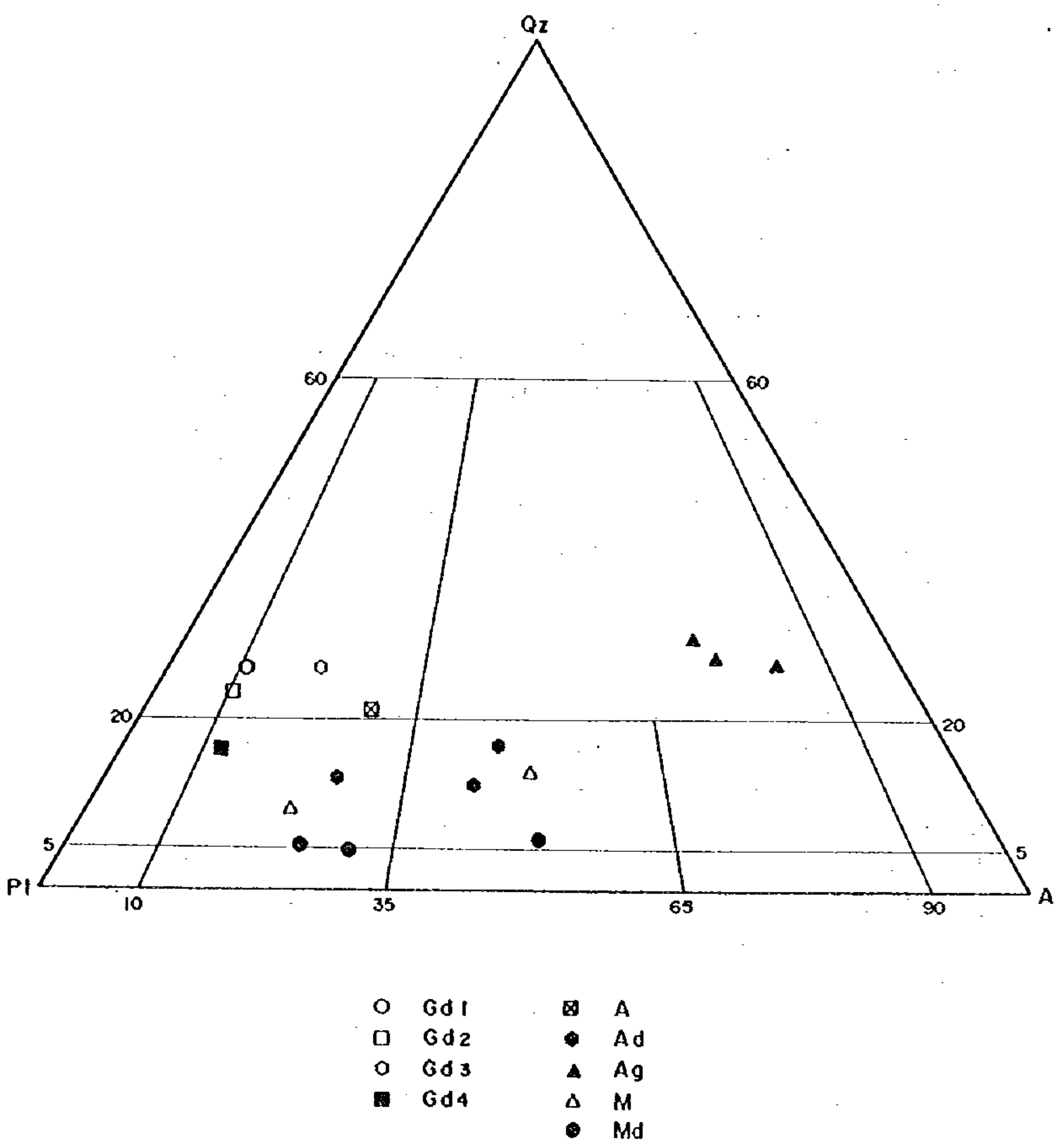


Fig 2-1-10 Modal composition of granitoid rocks.

scattered throughout this rock. The pegmatite dikes strike NW-SE and EW. The modal analysis of this rock indicates it is a granodiorite-quartz monzodiorite according to the IUGS nomenclature (Appendix 3, Fig. 2-1-10). The main mineral constituents are plagioclase, quartz, K-feldspar, biotite, hornblende, and opaque minerals. Mafic minerals only occur in small abundance while K-feldspar and quartz occur interstitially and as crystal clots. These small clots are characterized by small plagioclase laths, euhedral hornblende and poikilitic biotite. Some of the quartz occurs as micrographic and granophyric intergrowths with K-feldspar. These textures in K-feldspar and quartz are the same as that observed in the Granodiorite 2 (Gd2). Hornblende and biotite are subhedral, while the later is partly altered to chlorite. The SiO_2 content of this rock is 63 wt. % (Appendix 2, Fig. 2-1-4). Cornejo et al.(1993) reported that the K-Ar age of this rock are between 48±1.3 Ma and 47.8±1.3 Ma.

14) Dikes

In addition to the above rocks, some dikes are distributed in the survey area. The distribution of these rocks are restricted.

□ Hornblende- plagioclase porphyry (Hp)

This porphyry is located at the La Guanaca mine site. The porphyry occurs as a small stock in the Granodiorite 3 (Gd3) (Fig. 2-1-13). The diameter of the stock is only 30m. The porphyry is a host rock to mineralization of disseminated chalcopyrite and pyrite in the La Guanaca prospect. ENAMI (1995) showed that the porphyry also existed at a depth of 60m, it also outcrops at surface as shown in Fig.2-1-13. The rocks from underground are observed in the waste dump at the mine site. Those rocks from the waste dump have disseiminated chalcopyrite and pyrite. The rocks that outcrop at the surface have suffered weak supergene acid leaching. The sulfides have now changed to hematite and limonite. The rocks are strongly sericitized. Green colored biotite was also found in these rocks.

□ Aplite (A)

The aplite dikes intruding the Llanta andesite in the mountains of the northwestern part of the survey area are 5 to 15m in width, extend more than 2 km in length. Most of the aplite is a hundred to a few hundreds meters long and a few meters in width, white to pale-yellowish-brown in color. Fine grained. tourmaline clots are often found in this rock.

□ Plagioclase porphyry (Pp)

This rock intrudes the quartz monzonite (Md) and the adamellite (Ad) in the southern part of the survey area. This rock looks like the aplitic granite (Ag), except that plagioclase phenocrysts characterize this porphyry.

□ Andesite dike (Ad)

This rock is located in the southern part of the survey area. The dike intrudes the aplitic granite (Ag) and is dark greenish gray in color. Epidote and chlorite are widespread in this rock. The dike located on the southeastern slope of the 3624.3m peak (sample no. 271) is not an andesite but a basalt (Appendix 2, Fig. 2-1-4).

□ Dacitic dike (Dd)

This dike intrudes the Llanta andesite in the eastern part of the survey area.and is light gray in color. The dike is 10 to 20m in width, strikes N70W and dips 70N. Quartz phenocrysts of 1 to 5mm in diameter are observed. A thin green copper film with epidote are found at the contact between the Llanta andesite and the dike rock.

1-3-3 Relationships of the rocks

The relationships of the rocks are shown in Fig. 2-1-3. These rocks are mainly divided into two groups: volocanic rocks and intrusive rocks.

The volcanic rocks: The andesite (Ba) corresponds to the Llanta Formation, which forms the basement of the Survey area. According to Cornejo et al.(1993), the andesite is Lower Cretaceous in age. The Dacitic lapilli tuff/welded tuff (Dpf) overlies the Andesite (Ba). The relationship is concordant with that the breccia of the Andesite (Ba) and is seen as accidental fragments in the welded tuff (Dpf). The boundary between the Andesite (Ba) and the Dacitic lapilli tuff (Dpf) is nearly horizontal. The green colored andesite (Ga) overlies the Dacitic lapilli tuff (Dpf). The volcanic breccia of the Andesite (Ga) has a breccia of the lapilli tuff (Dpf). The Daicitc lapilli tuff (Dpf) and the Andesite (Ga) are thought to be Paleocene and/or Eocene in age.

Granitic rocks and dikes intrude the above volcanic rocks. There are three main granitic bodies in the Survey area as follows:

The Northwestern Monzonite (M), the Southeastern GraniteMonzonite (Gr), and the Central Granodiorite (Gd). The relationship of those three granitic bodies are unknown, because there is no contact between them. Judging that the Central Granodiorite (Gd) has no epidote alteration, the Central Granodiorite (Gd) could be the

Lithological Map of GUANACA

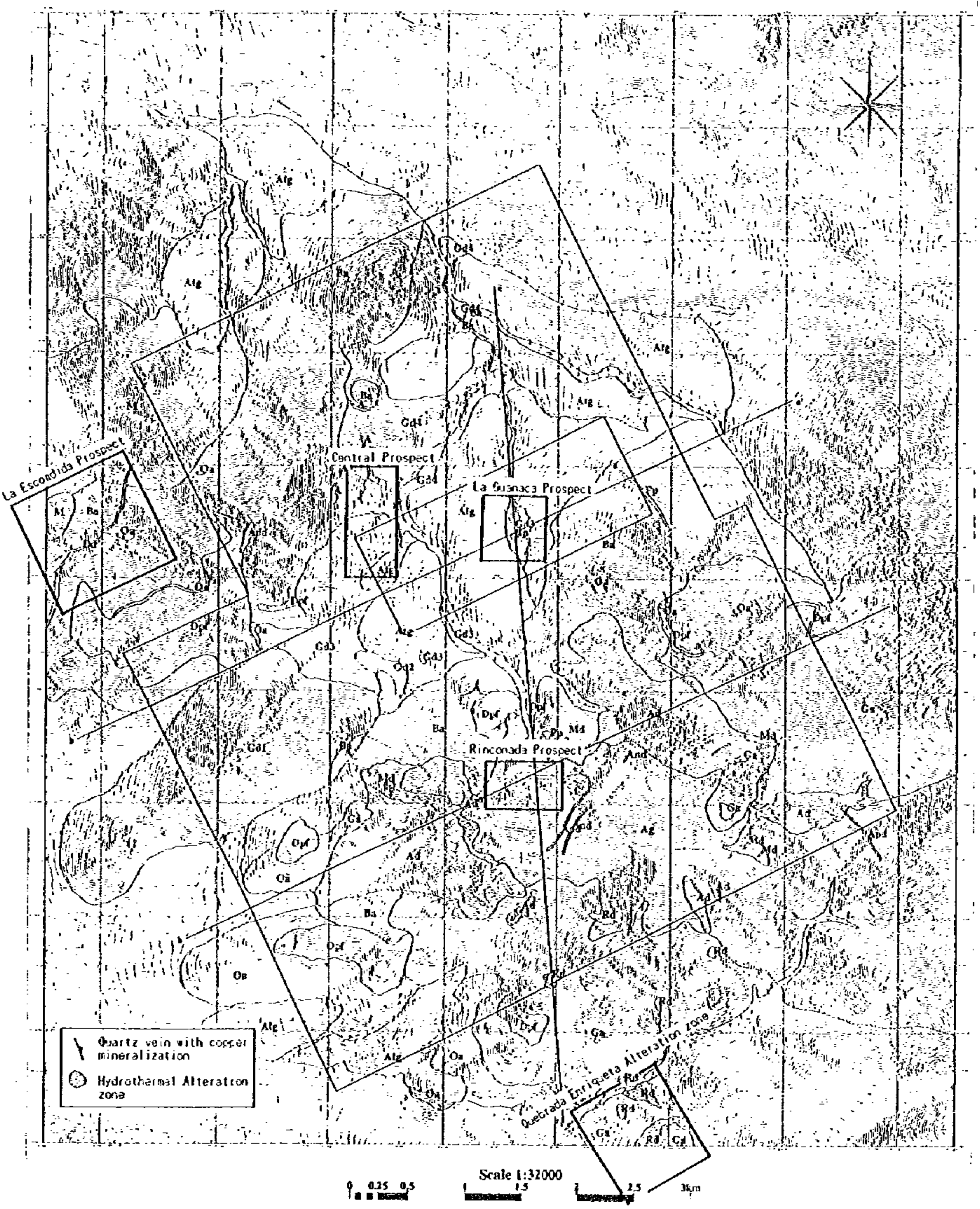


Fig 2-1-11 Distribution of the mineralization and prospects.

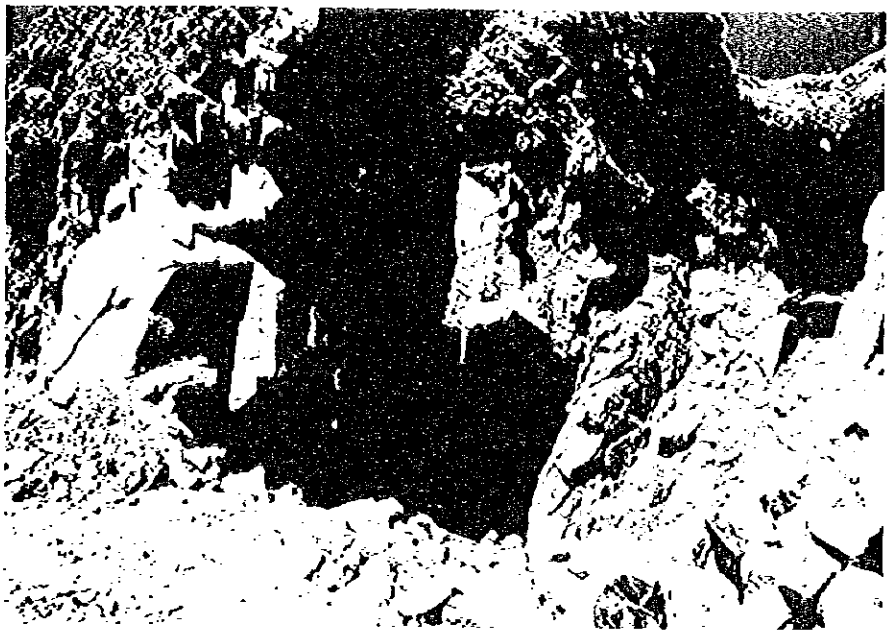
youngest granitic body. The relationships between the rocks that form the granitic bodies are as follows:
The Southeastern Granite-Monzonite (Gr) consists of the Monzodiorite (Md), the Adamellite (Ad), and the Aplitic Granite (Ag). Those rocks may have intrusive contacts with each other. As mentioned in the previous section, those three rocks have a narrow gradational zone (a few meters). Judging from the occurrence and field relationship of the three rock types, they may be closely related to each other in genesis and time.
The Central Granodiorite body consists of four Granodiorite rock types (Gd1 to Gd4). Gd1 grades into Gd3. The relationship between Gd3 and Gd4 is unknown, because there is no visible contact in the field. Judging from the topography, Gd4 may intrude into Gd3. Gd2 is thought to be a big cognate inclusion in Gd3.
The Ocoitic andesite (Oa) may intrude the above volcanic rocks as sheets. The Rhyolitic volcanic breccia (Rd) intrudes the Andesite (Ga).

1-3-4 Mineralization

Prior to this survey, it was already known that the La Guanaca and Rinconada prospects were mineralized to varying degrees (Fig.2). Besides these mineralization areas, mineralization is apparent in the central and southern parts of the survey area. The distribution of the mineralization and prospects are shown in Fig. 2-1-12.

1) La Guanaca Prospect

Fig.2-1-13 shows is a detailed geological map of the La Guanaca Prospect. The Granodiorite 3(Gd3) is exposed over most of this area. The Porphyry stock is exposed in the old pit site and intrudes the Granodiorite 3(Gd3) at the site (Fig.2-1-13). Two kinds of mineralization exist. One is disseminated type chalcopyrite-pyrite mineralization in a small porphyry stock . The other is a vein type copper mineralization in the granodiorite. In addition, oxide copper mineralization along joints of the granodiorite occurs. These rocks, originally from underground, are observed in the waste dump at the mine site. The rocks of the porphyry from the waste dump are characterized by disseminated chalcopyrite and pyrite. Where the porphyry cropps out at the surface it has suffered weak supergene acid leaching. The sulfides have now changed to hematite and limonite. Judging from the boxwork texture of the limonite, the limonite is derived from in situ oxidation of sulfide minerals. The rocks are strongly sericitized. The flakes of sericite are also big enough to be seen by the naked eye. Green colored biotite was also found in this rock. Based on these observations, both potassic and phyllic alteration have occured in this prospect. No



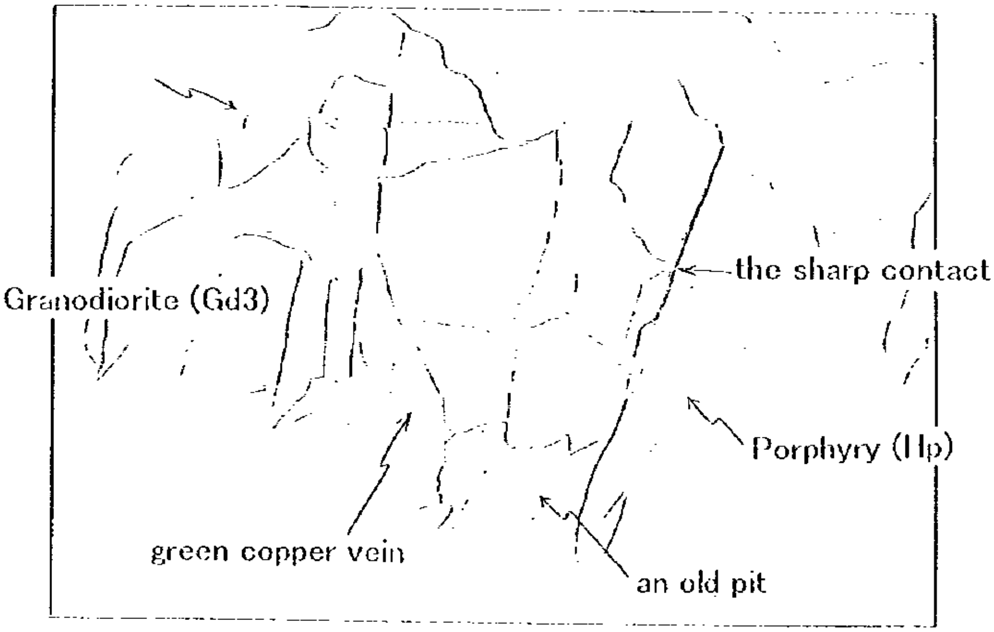


Fig 2-1-12 Photograph shows the contact between Hb-Pl porphyry (Hp) and Granodiorite3 (Gd3).

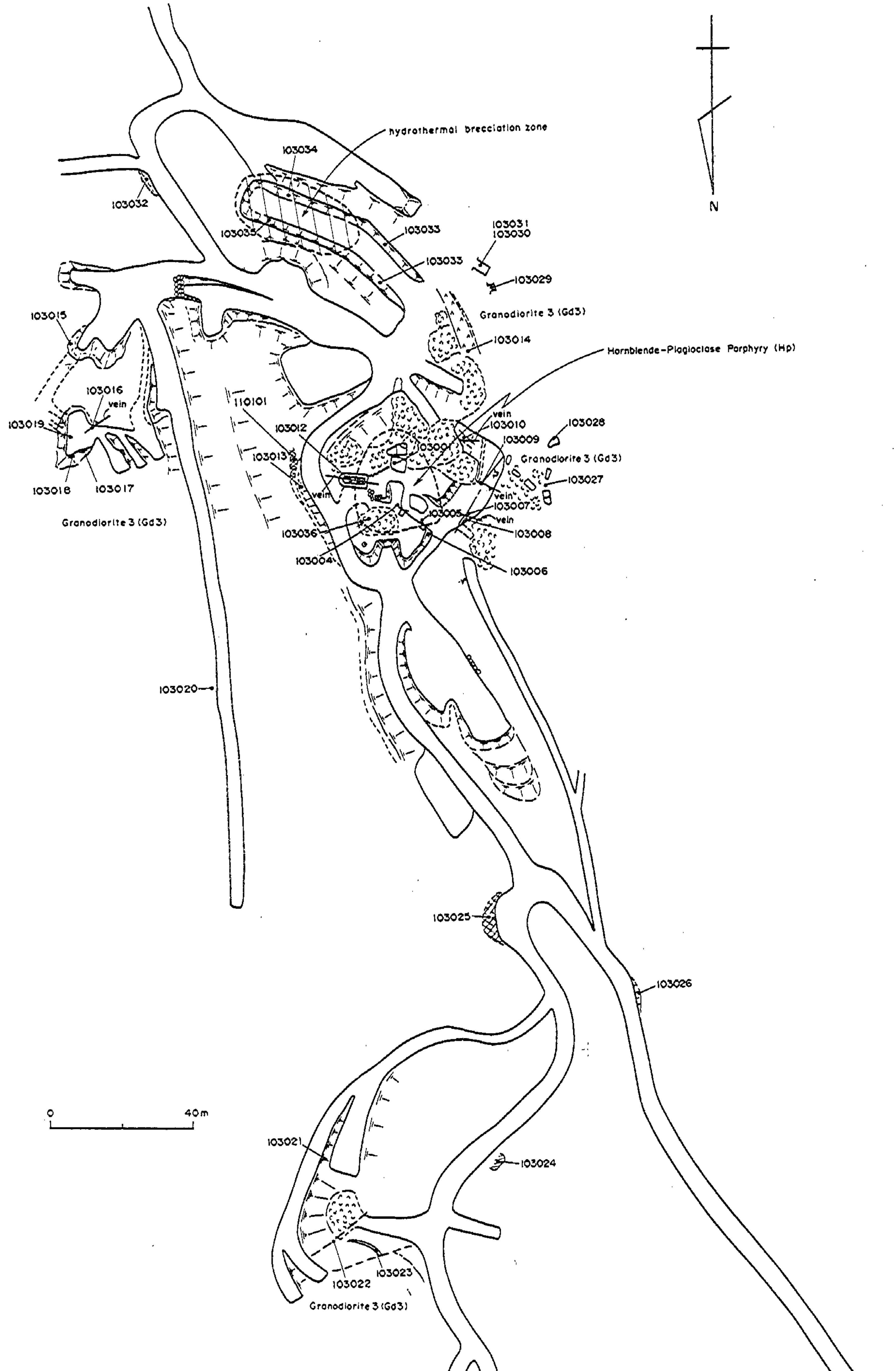


Fig.2-1-13 Detailed geological map based on tape and compass measurements of the La Guanaca Prospect

Fig.2-1-14 Chrysocolla vein in Granodiorite (Gd3) at the La Guanaca prospect.

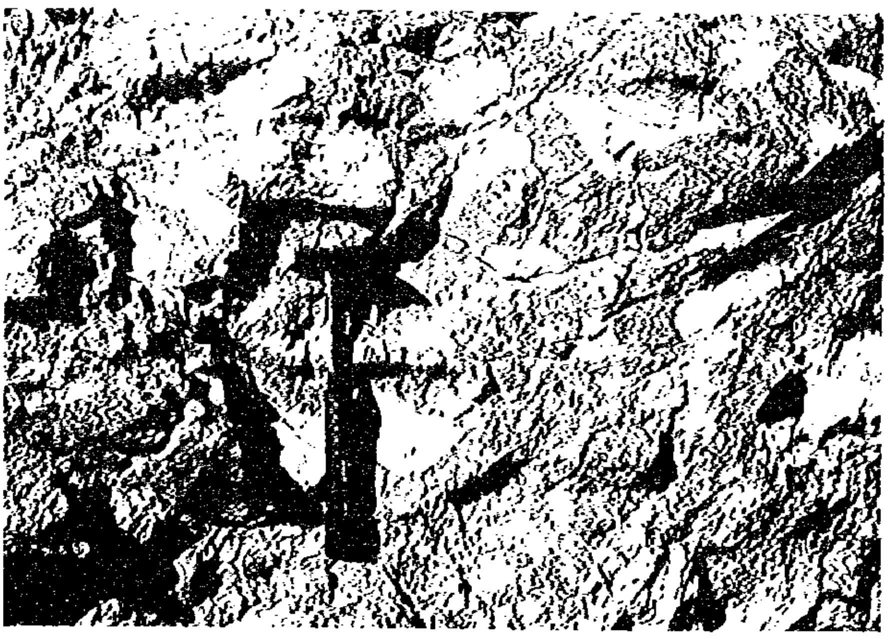


Fig 2-1-15 Photograph of the hydrothermal brecciation zone in the La Guanaca Prospect.

epidote however has been identified. The oxide copper mentioned above which occurs along the joint plane of the granodiorite (ie. Not associated with quartz veining) might be the product of supergene exotic copper mineralization. These copper veins have no alteration halo on either side of the mineralization as shown in Fig. 2-1-14. Some of the green copper veins have primary chalcopyrite relicts in the green copper minerals. The copper mineralization with the quartz veins may be in situ mineralization. Hydrothermal brecciation is observed at the trench site (see Fig 2-1-13). The matrix of the breccia is filled with sericite and limonite(Fig. 2-1-15), the flakes of sericite being big enough to be seen with the naked eye.

1) Rinconada Prospect

There are many small pits within this prospect (Fig. 2-1-16, Sheet 4). The green copper mineralization associated with quartz veins are observed in each pit. The host rock is the Aplitic granite (Ag). Most of the contacts between the quartz veins and the host rocks are not clear (Fig. 2-1-17, Fig.2-1-18). The width of the quartz veins range from a few centimeters to a few tens of centimeters. The veins strike N10° ~40° E, and N10° ~30° W, and dip 70 ° to vertical. The ore minerals are chrysocolla, malachite, brochantite, tenorite and chalcocite. Gangue minerals are quartz, sericite, chlorite, epidote and tourmaline. Coarse grained sericite is found in and around the vein. Skarn veins characterized by quartz, epidote, tourmaline, and garnet without the green copper mineralization are found around the veins. Epidote is a characteristic mineral in the Rinconada Prospect, commonly occurring in the veins as well as the host rocks. Epidote in the host aplitic granite is almost ubiquitous and represents a propylitic alteration product. Under the microscope, very small grains of chalcopyrite remain as part of the green copper mineralization. Chalcocite is also observed as part of the green copper mineralization. Galena is often found in association with the green copper minerals. Around the veins pale greenis-yellow colored smectite is found. This smectite is supposed to have been produced during the supergene stage.

3) Central prospect

Copper mineralization occurs with quartz veins (Fig. 2-1-19, Fig.2-1-20). About 7 veins are observed in the Central prospect. The host rocks are the Granodiorite 3 (Gd3) and Granodiorite 4 (Gd4), and in some cases partly hosted by the Llanta andesite. The width of the quartz veins range from a few centimeters to 6 centimeters. Rarely, some veins are a few tens of centimeters in width. The veins strike N80° E~N60° E, and, dip 60 ° S to vertical. The strikes are similar to that of the veins in the La Guanaca

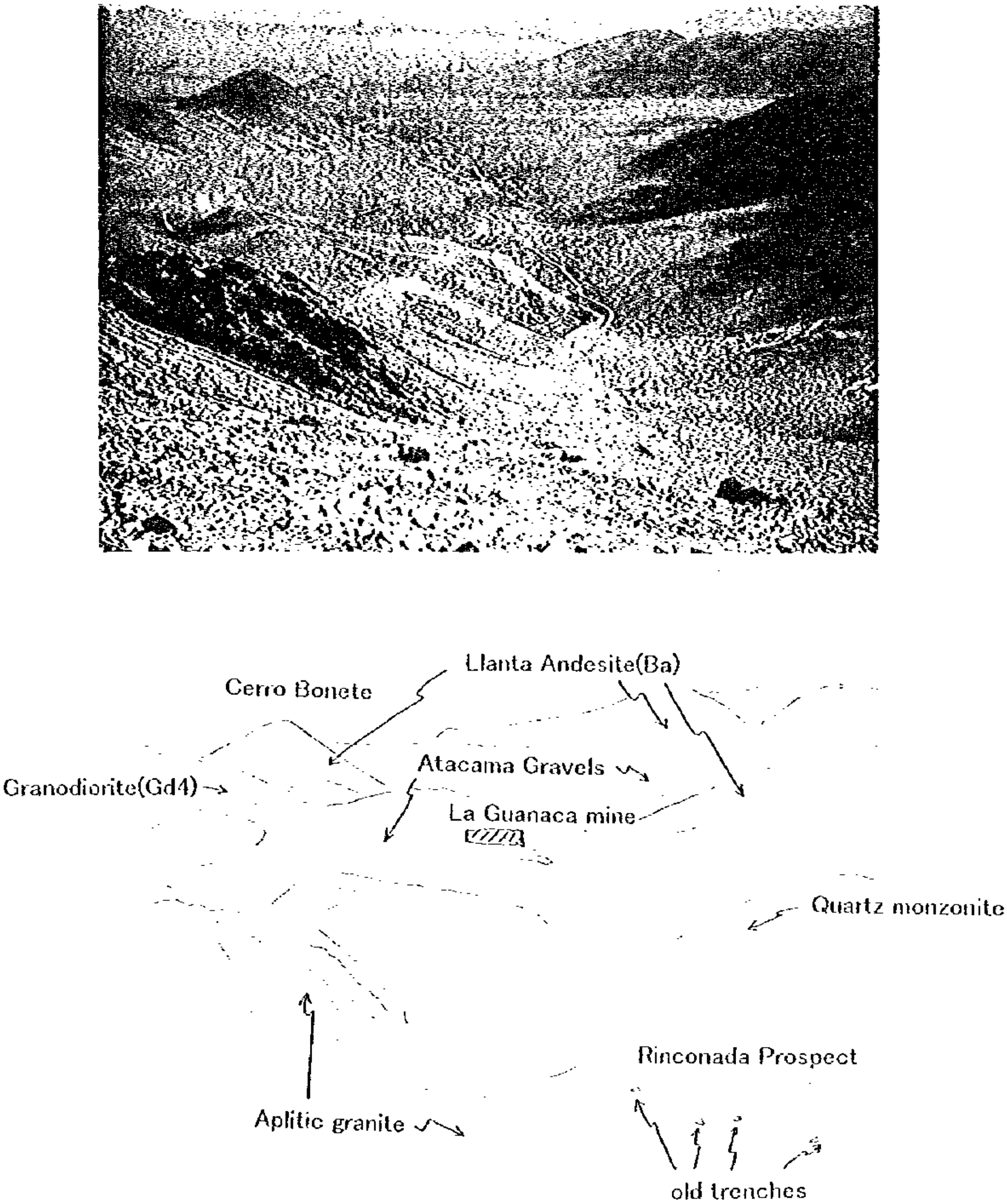


Fig 2-1-16 View of the Rinconada Prospect and outcropping geology

Fig 2-1-17 Quartz vein with green copper minieralization at the Rinconada Prospect

Fig 2-1-18 Quartz vein with green copper minieralization at the Rinconada Prospect

Fig 2-1-19 Quartz vein with green copper minieralization at the Central Prospect.

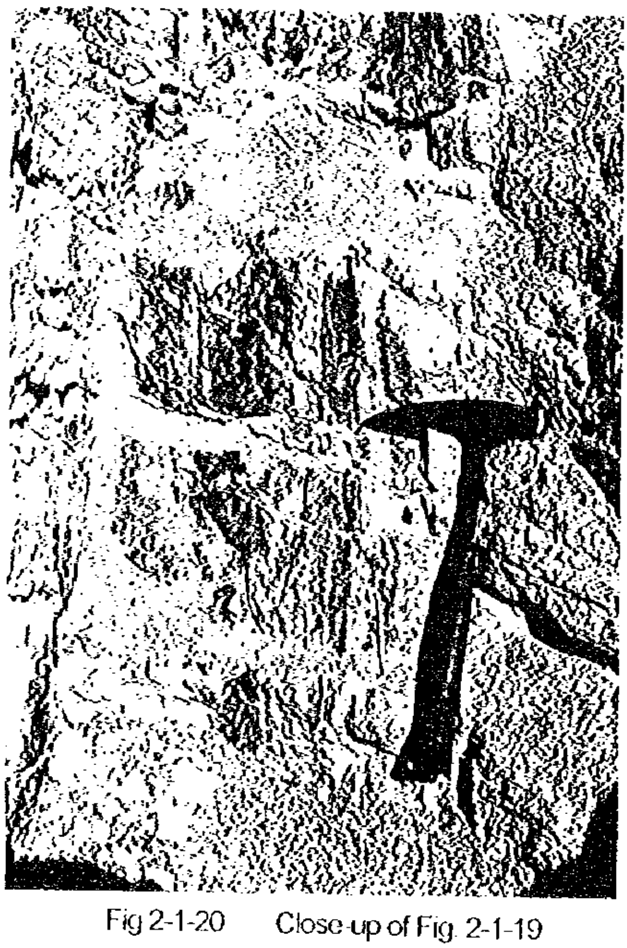


Fig 2-1-20 Close-up of Fig. 2-1-19

Prospect. The vein minerals are cuprite, tenorite, chrysocolla, malachite, and brochantite. Chalcopyrite and pyrite remained in the oxide copper minerals. This indicates that the copper mineralization in the Central Prospect is in situ mineralization and not exotic. Sericitic alteration extends along and around the veins. Tourmaline is also seen near the veins. The quartz veins are distributed near the contact between the Granodiortie and the Llanta andesite.

1) La Escondida Prospect

This prospect is outside the Survey area. Many old pits are distributed over an area of 500 m x 500 m. The biggest pit is located at outcrop No.96102818 and may have been the main pit of the La Escondida mine. The pit extends along a vein which strikes N80° W. The host rock is the Llanta andesite (Ba). The vein minerals are cuprite, tenorite, chrysocolla, malachite, and brochantite. The mineralization is the same as that of the Central prospect.

5) Qubrada Enriqueta alteration zone

This zone is also outside the Survey area. The host rock is a Rhyolitic volcanic breccia/lapilli tuff (Rd) and Andesitic volcanic breccia (Ga). Hydrothermal brecciation is observed where the matrix is only weakly silicified. Alteration is dominated by the minerals illite/smectite interlayered clay, and to a lesser extent illite. Kaolinite is observed in some places and may be a supergene product.