CHAPTER 3. IBAÑEZ-MURTA AREA (NORTH)

3.1. Geology

3.1.1. Stratigraphy

The succession of this area comprises the Cretaceous (Aptian to Cenomanian stages) Divisadero Formation which is composed of large amount of acidic volcanic products and unconsolidated Quaternary sediments which cover the Divisadero Formation unconformably.

The Divisadero Formation overlies the Coyhaique Formation (Neocomian stage) unconformably at the type locality near Coyhaique. It is distributed widely in the eastern side of the area. General structural trend of these formations are N-S strike and gentle eastward dipping. The formation is distributed at the southern end of the survey area including the type locality. The lithology at the type locality is composed of tuffaceous sandstone and rhyolitic and dacitic tuffs, and these facies change to andesitic to the west. Andesitic activity in this area, however, is limited to small areas which will be mentioned later.

The geological map compiled data during the first phase survey shows that the Jurassic Ibañes Formation occurs below the Divisadero Formation in this area. However, the survey carried out in this phase revealed that the Divisadero Formation is distributed throughout the area and the Ibañes Formation was not found in the area. The geological map is shown in Fig.Ⅱ-3-1 and schematic columnar section is in Fig.Ⅱ-3-2.

As the sequence below the Quaternary System is limited to the Divisadero Formation, the geology of the area was shown in the geological map by lithology rather than formations. The schematic columnar sections are shown separately in eastern and western zones, because a large difference was recognized regarding the distribution pattern of intrusive rocks in the survey area with the boundary near the Blanco River flowing northward from the central part of this area. The description of these intrusive rocks will be discussed in section 3.2.2.

Due to the dense snow coverage at elevation above 1,500 m and at some parts of the southern slopes of the mountains during the survey, photogeological interpretation was extensively conducted for mapping. Because there is no vegetation above 1,000 m, aerial photographs were extremely effective for mapping. Photogeological interpretation was done with reference to the field topographical evidences confirmed geologically at the site.

The Divisadero Formation consists mainly of tuff, rhyolitic and andesitic lava. Therefore, it is divided into three major lithofacies groups, namely pyroclastic rocks (Kfdt), rhyolite lava (Kfdr) and andesite lava (Kfda). The pyroclastic rocks cover all distribution area of the Divisadero Formation and rhyolite lava occurs within the pyroclastic rocks. The rhyolite lava is divided into three major facies and lower facies occur in the western zone and their stratigraphic horizons change eastward to middle and upper. The andesite lava is divided into two major units and they are distributed in the western zone.

The followings are the description of three major lithofacies of the Divisadero Formation and the Quaternary Systems.

(1) Pyroclastic rocks (Kfdt)

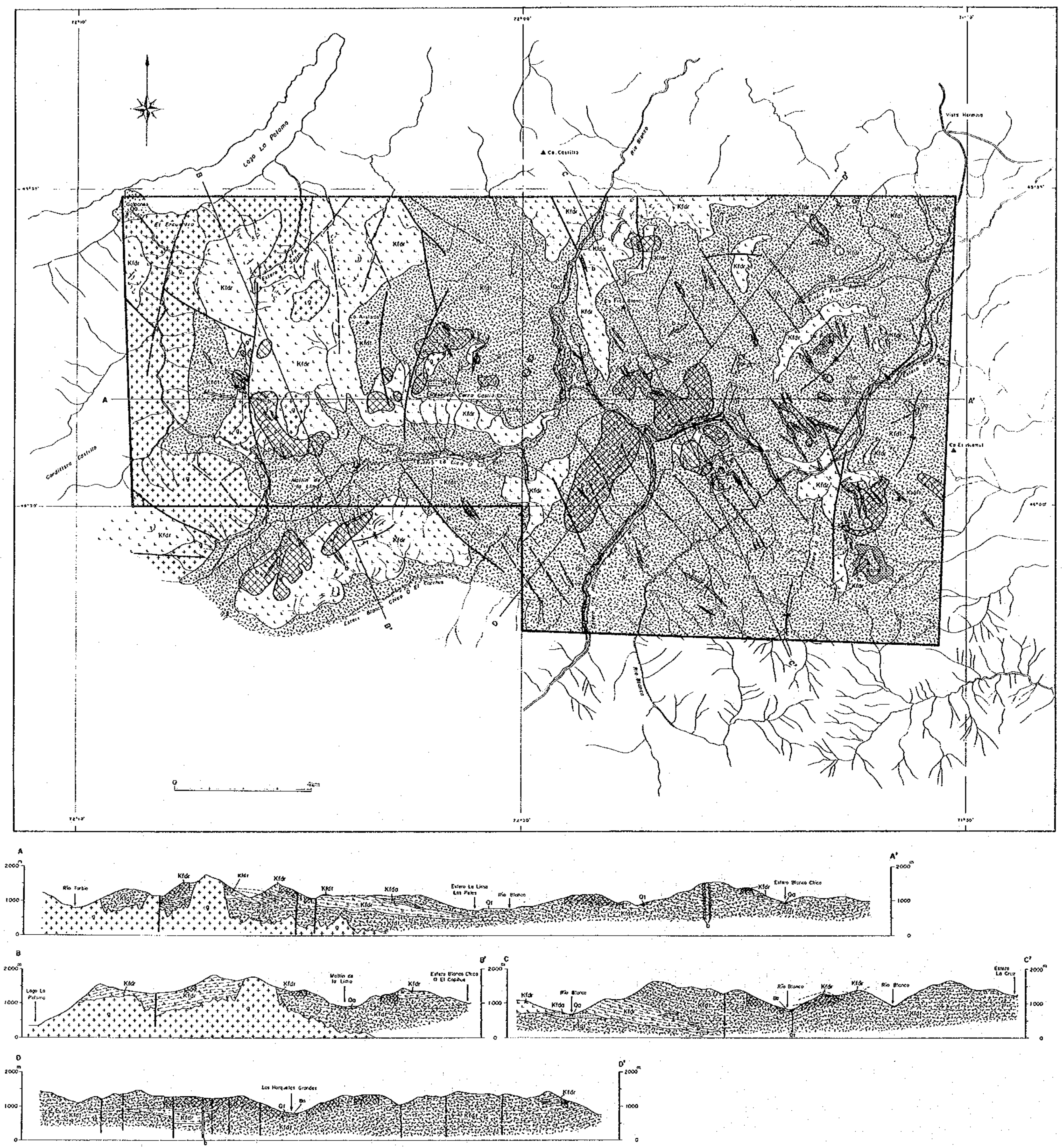
This is mainly distributed in the central to eastern part of this area. In the western zone, its distribution is limited, because of the wide distribution of rhyolite lavas and plutonic rocks, which will be mentioned later. The apparent thickness calculated from the exposed rocks including the rhyolite lava is estimated to be more than 2,500 m as shown in the cross sections of Fig.II-3-1.

This unit is subdivided lithologically into dacitic tuff breccia to lapilli tuff, fine tuff, welded tuff, sandy tuff and andesitic lapilli tuff to tuff, and the rock is made up of the alternation of these lithological units. Within these lithofacies, dacitic lapilli tuff is the most predominant followed by fine tuff. And moreover, thin layers of limestone, sandstone and mudstone are intercalated within these dacitic lapilli tuffs (These occurrences are recognized at the outcrops and are too small to express in the geological map).

The standard sequence of the pyroclastic rocks was recognized at the northeastern slopes in the western side of Pichi Blanco which is located in the northeastern edge of the area (Fig.II-3-3).

The major lithological features are described below.

- Dacitic lapilli tuff: It is generally pale gray to pale green and is either compact or brittle. It has massive appearance and bedding is developed every a few meters. It alternates with fine tuff. Outcrops at the



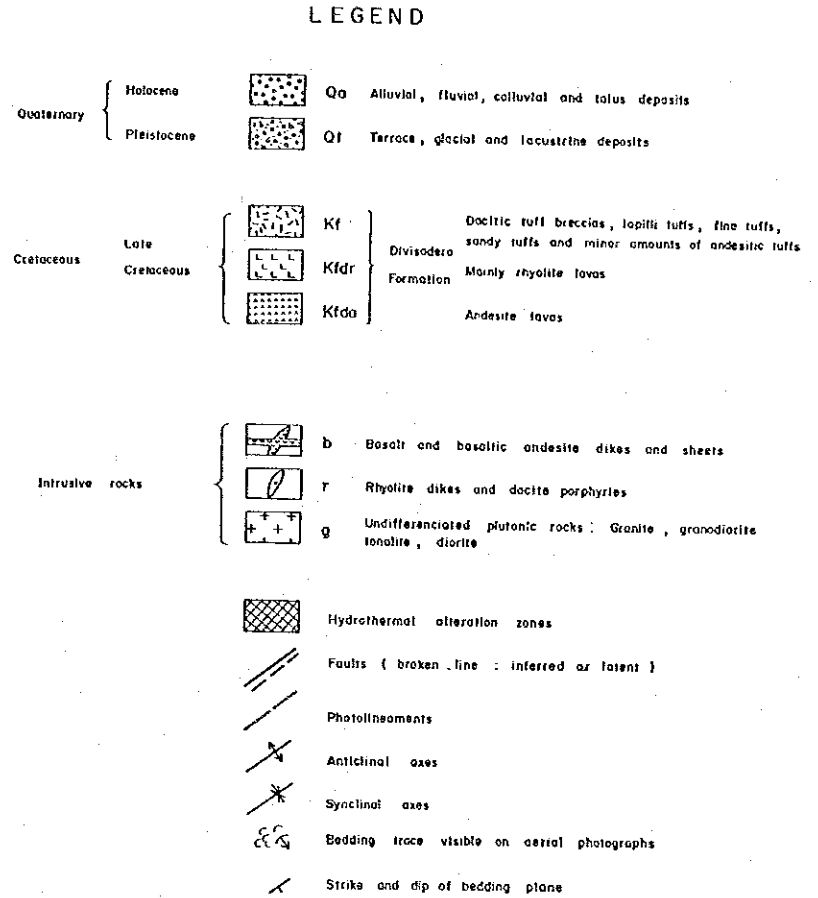


Fig. II-3-1 Geological Map of the Ibañez-Murta Area (North)

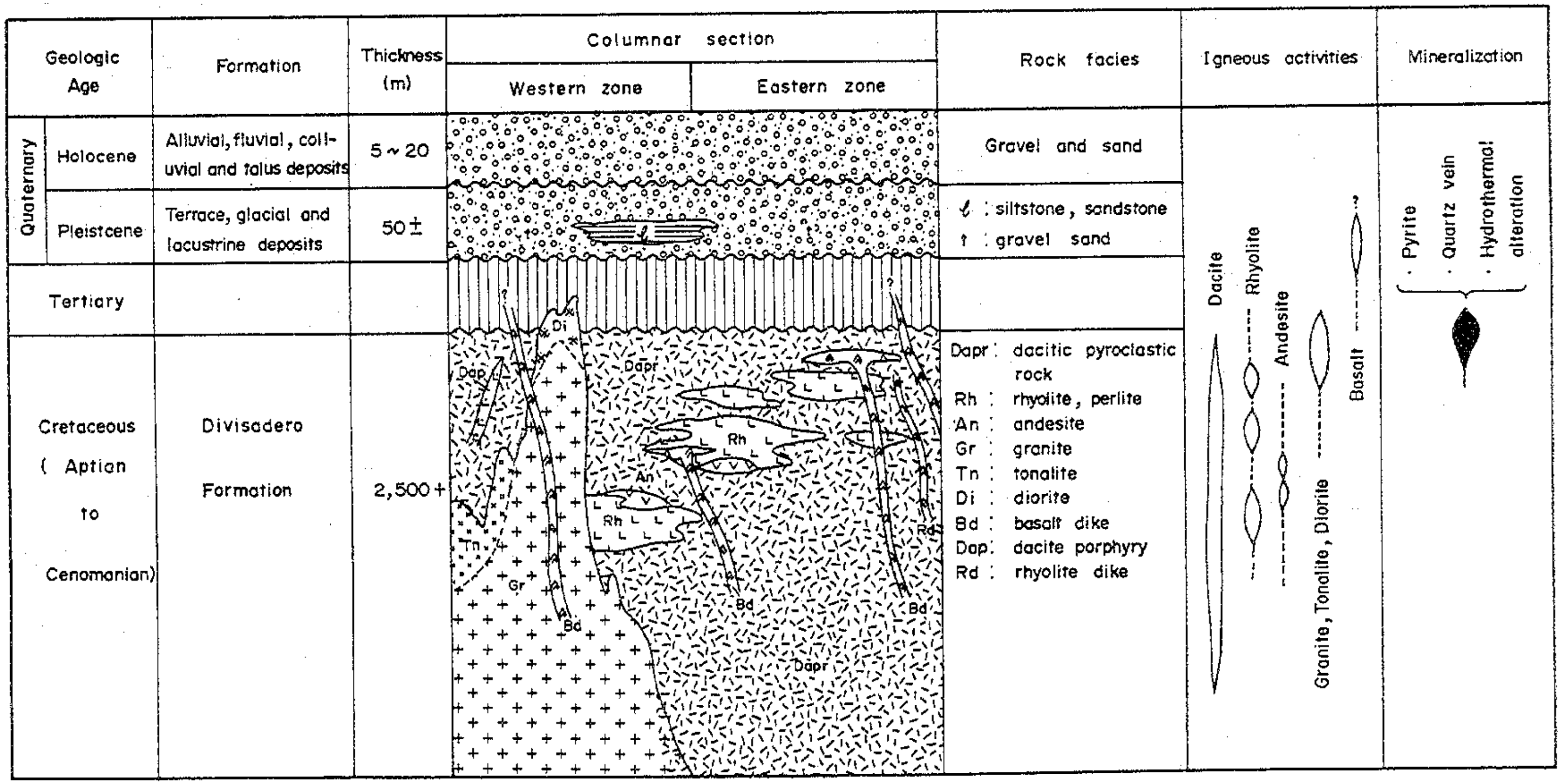


Fig. II -3-2 Schematic Columnar Section of the Ibañez-Murta Area (North) mountain side commonly form steep cliffs. The matrix consists of fine to medium-grained tuff and 1 to 2 mm diameter quartz grains are commonly recognized in them. The lapillis, 10 to 20 mm in diameter, are mainly composed of dacitic breccia and pumice fragments and occasionally contain andesitic breccias. Kaolin and calcite are recognized as matrix and rock fragments under microscope. These alteration minerals are considered to have formed by diagenesis and weathering.

- Fine tuff: It is generally gray to pale green and compact. The beddings are recognized every 10 to 30 cm intervals. The unit is usually 5 to 10 m thick and forms alternation with other rocks. Volcanic glass and sericites altered from feldspers and calcites are identified under microscope and chloritization is not strong.

- Andesitic lapilli tuff to tuff: It is generally reddish brown to reddish purple and slightly brittle. The lapilli tuff is usually massive but the tuff is medium to fine-grained and laminae are well developed. The groundmass of lapilli usually has pilotaxitic texture. These rocks are recognized in middle and upper part of the unit.

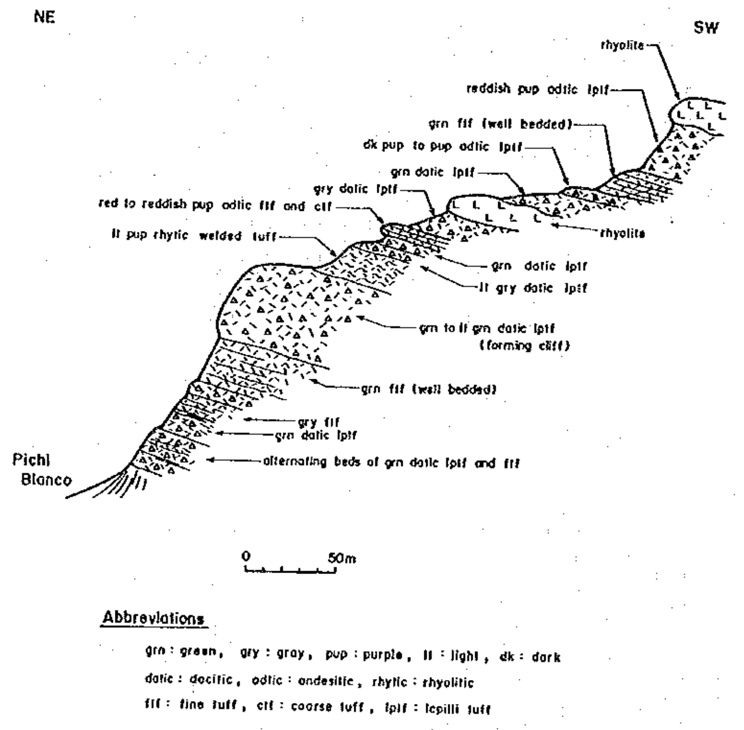


Fig. II -3-3 A Sketch of Stratigraphic Column
of the Divisadero Formation at Pichi Blanco

Limestone, sandstone and mudstone mentioned above are observed at the following locations.

(a) Limestone: The middle horizon of this unit near the Reserva Cerro Castillo in the central part of the area.
(b) Sandstone: The middle horizon of this unit near the national road in south central part of the area
(c) Mudstone: The lower horizon of this unit at mountain side slope of the right bank of the Turbio River in the western area.

Although very small in amount, the occurrence of sedimentary rocks such as limestone, sandstone and mudstone suggests the repeated local existence of some types of inland lake during deposition of the Divisadero Formation.

(2) Rhyolite Lava (Kfdr)

This lava occurs widely in the northwest, southwest, and north-central part of the area with good continuity. It occurs as small bodies in the east. The occurrence is largely grouped into three horizons stratigraphically, namely lower, middle, and upper. Geographically, these three occurrences are distributed from west to east in ascending order.

The maximum thickness of this lava is 850 m in lower, 700 m in middle and 300 m in upper horizons.

These lava bodies are homogeneous throughout the area, and hard and compact and white to cream. Flow structures are observed and these are useful for understanding the structural trend of these bodies. Observation under microscope revealed that the groundmass is glassy and accompanied by quartz and orthoclase. Phenocrysts are up to 1 mm of plagioclase and quartz. And kaolin and sericite are recognized as alteration minerals.

Small bodies of perlite were discovered at approximately 1 km east of Mt. Pico Negro in the eastern zone, and these are also included in this rock unit.

(3) Andesite Lava (Kfda)

The andesite lava is distributed mainly at the three locations in the central part of the area. Stratigraphically, it occurs in the middle part of the Divisadero Formation. It occurs in the pyroclastic rocks and also on and below the rhyolite lavas. The lava bodies are all small with maximum of 1 km length and 200 m thickness. The rock is dark green to dark purple, compact and aphanitic, but some trachyandesites with porphyritic textures are included. The major constituent of the Divisadero Formation is acidic lava and its pyroclastics, however, the presence of these andesitic rocks will show the temporary change from acidic to andesitic activity.

(4) Quaternary System (Qt and Qa)

The Quaternary System in this area is divided into Pleistocene Series consisting of fluvial terrace deposits, glacial deposits and lake deposits and Holocene Series which is alluvium. These two series are shown separately in the geological map.

The terrace deposits are distributed along the Blanco River with maximum width of 600 m and maximum thickness of 50 m. The glacial deposits are found near Pichi Blanco in the northeastern side of the area. The lake deposits consist of horizontally stratified silt stones and sandstones and are widely distributed at the right bank of the Lima River in the central part of the area.

The Holocene Series are mainly of Recent fluviatile sediments and are found along the major rivers in the area. However, at the upper reaches of the Blanco River and the lower reaches of the Turbio River in the area, the sediments hardly occur due to marked downward erosion. The valley bottom plain approximately 500 m wide exists at the uppermost part of the Lima River. This plain is judged topographically to be a relict river floor which was created by old the Lima River, resulting from river capture by the Turbio River. The deltaic sediment was discovered only at the river mouth of the Turbio River at the northwestern part of the area.

3.1.2. Intrusive rocks

Mafic or felsic dikes, and plutonic rocks mainly granitic, are distributed in the area. The dikes are concentrated in eastern zone of the area. Whereas, the plutonic rocks are distributed in the western zone and non in the eastern zone. The dikes are divided into basalt to basaltic andesite (b) which are most predominant and small amount of rhyolite or dacitic porphyry (r). The lithofacies of plutonic rocks (g) varies significantly and thus are left undifferentiated. The following is the description of lithology.

- Basalt to basaltic andesite dikes and sheets (b) : The dikes are usually 2 to 5 m wide and 200 to 500 m long (maximum 1,300 m). Parts of the dikes occur as sheets at four locations in the eastern zone. Their size is variable. And they are 800 m long and 70 m thick at Mt. Pico Negro in the northeastern part and 1,400 m long and 150 m thick at Mt. Bandera in the southeastern part. The rocks of these dikes and sheets are black to dark green, porphyritic and apparently not altered. Microscopic studies reveal that both groundmass and phenocrysts consist of augite and plagioclase and that mafic minerals are slightly chloritized. These dikes intruded through mineralized/altered zones, clearly mineralization. Major trend of intrusion is NW-SE.

- Rhyolite or dacite porphyry dikes (r) : Ten outcrops of these dikes have been formed, seven in western and three in eastern zone of the area. Generally the dikes are approximately 5 m wide and a rhyolite dike 30 m wide intruded in southwestern side of Mt. Pico Negro in the eastern zone. The length of this dike is less than 1,000 m. The lithology of rhyolite is similar to that of lava. Dacite porphyry is generally gray and compact. Large amount of chlorite and calcites are recognized as alteration minerals and these dikes are also judged to have intruded after the mineralization. Major trend of intrusion is NW-SE.

- Undifferentiated plutonic rocks (g) : The granitic rocks which intruded into all the rocks in the Divisadero Formation are widely distributed in western zone. Some isolated small bodies of approximately 1 km diameter are exposed in the area. And these bodies are considered to be connected underground. They are divided lithologically into granite, granodiorite, tonalite and diorite. Their contacts with the Divisadero Formation tend to be fine-grained with intermediate composition. Therefore, it is interpreted that the central part of the rock mass is coarse-grained granite and changes to granite and either tonalite or diorite complex at the marginal parts. The large trend of this rock mass extends N-S trend. The absolute age measured in a tonalite exposed at west end area is 94 Ma (Table 11 in Appendix).

3.1.3. Geologic structure

(1) Fold structures

Key beds such as sandstone and mudstone regionally traceable do not exist in the Divisadero Formation. Also usually relatively traceable fine tuff can be traced only within a few km here. However, some stratification was observed in lapilli tuff and also the clear alternation of these rocks and fine tuff. Rhyolite lava has flow structures especially at the outcrops located in steep cliffs.

The general geologic structure of this area is largely considered to be very gently dipping at 10 to 30° from the above field observation (Fig.II-3-1). This area is divided into the following four quadrants by structural characteristics.

1) Northwest quadrant

Pyroclastics generally have the N-S structural trend and is east dipping. In the west of Mt. Aislado, rhyolite lava on and near granites show dome structure. These trends were mainly identified by photogeological interpretation.

2) Southwest quadrant

Southeast dip and NE-SW strike are the general attitude of the units in this quadrant. There is a small syncline with the same trend.

3) Northeast quadrant

Structural trend of the pyroclastics is generally ENE-WNW and dips SSE. Anticline-syncline with 3 km wavelength was observed at the southeastern side of Mt. Pico Negro. Another change of the structure was observed near the Mineralization Group E (details will be discussed in section 3 2.) located at the northern part of Las Horquetas Grandes.

4) Southeast quadrant

Structural characteristics are similar to the northeast quadrant and they are almost horizontal except for some fold structures near the Mineralization Group H southeast of Las Horquesta Grandes.

The above structural trend reveals that the area at Las Horquestas Grandes and vicinity are the localities where structural undulations are developed.

(2) Faults

There is no significant fault which controls the major structure and only small faults occur in the western zone of the area. A group of faults found in the western zone is classified into N-S and NW-SE systems, and their sizes are small with maximum length of 6 km. The vertical displacements by fault at the surrounding formation are considered to be 100 to 300 m.

(3) Photolineaments

Photogeological interpretation provided many photolineaments in the area, although only a few faults indicating relative displacement between the blocks were recognized in this area. The distribution patterns and trends in the eastern and western zones have the following characteristics.

• Western zone : The photolineaments have variable trends, N-S, NE-SW and NW-SE, and no dominant trend was recognized. Density of photolineaments is low.

• Eastern zone : The distinct photolineaments trending NW-SE were found near mineralization zones, and they are distributed at 200 to 1,000 m intervals. The length of the photolineament is not very long with a maximum of 3 km. The zones with dense photolineaments extend in the NE-SW direction.

3.2. Mineralization

This area does not have any history of mining. As of December 1991, however, mining concessions have been established for the greater portion of the eastern part of the area, and active prospecting is in progress. Through the interpretation of Landsat TM image (simply called image, hereafter) prior to the field survey of the second phase, 12 of alteration zones (Nos. 4 to 15) were extracted within this area and they were revealed to be large. Since the tone of the alteration zones in the image resembled that of the alteration zone of the Laguna Verde Deposit, similar epithermal gold deposits were also expected to occur in this area. During the present survey, therefore, attention was paid to the extracted alteration zones and semi-detailed survey, including samplings with high density, were conducted aiming at evaluation of mineral potential of these zones.

As the result of the field survey, thirty-odd mineralization zones of various sizes were identified over the whole area, as shown in Fig.Ⅱ-3-1 and Fig.Ⅱ-3-4. For the convenience of explanation, these confirmed mineralization zones have been formed into eleven groups (A to K) on the basis of their distribution and mode of occurrence (hereafter, they will be called Mineralization Group A, etc.). Shown below is the number of analyzed samples collected from quartz veins and strongly silicified rocks in those eleven mineralization groups.

M.G.	Number of A.S.	M.G.	Number of A.S.
A	37	G	12
B	54	H	29
C	11	I	8
D	16	J	10
E	79	K	38
F	46	Total	340

M.G.: Mineralization Group
A.S.: Analyzed Samples

The dimensions and other characteristics of the above mineralization groups and the assay results are summarized in Tables 1, 2 and 3 in Appendix.

The host rocks of the above groups are pyroclastic rocks (Kfdt) and rhyolite lavas (Kfdr) mentioned in section 3.1. In part, the granite intruding these rocks also underwent mineralization. The host rocks are generally silicified and bleached; occurrence of veinlets and dissemination of pyrite and limonite are common; the surfaces of the host rocks are tinted reddish brown to yellowish brown. Presence or absence of quartz veins varies with the mineralization group. It is represented by the following two types.

(a) The mineralization group that shows stockworks or veins of white quartz with druses and pyrite are developed in the silicified host rock, and the veins are densely aligned parallel or en echelon at intervals of several to several tens of meters (Mineralization Groups E, F, G, H and K).

(b) The mineralization group composed mainly of pyrite dissemination, accompanied by veinlets of limonite; quartz occurs as veinlets only in very limited parts of the silicified host rock (Mineralization Groups A, B, C, D, I and J).

Mineralization groups of (a) type are located around Las Horquetas Grandes in the central part of the area. This indicates that formation of dominant quartz veins was concentrated in that part. The mode of occurrence and other features of the mineralization groups will be described below, putting emphasis on the (a) type groups. On the (b) type groups, just an outline will be given.

(1) Mineralization Group E

This group is located in the southern part of alteration zone "No. 12".

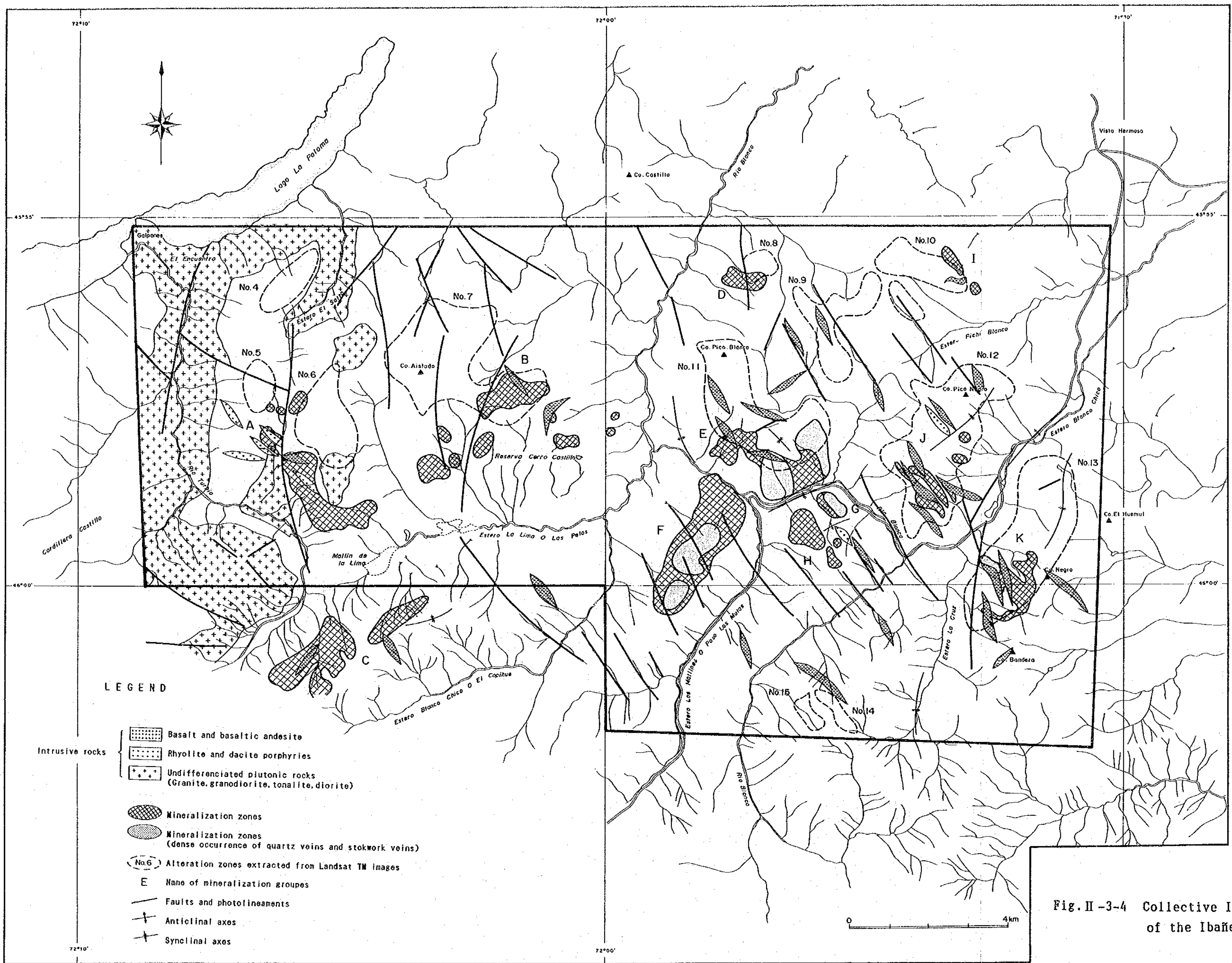


Fig. II-3-4 Collective Interpretation Map of the Ibañez-Murta Area (North)

The northern half of the extracted "alteration" zone consists of unaltered rocks. The mineralization zone is irregular in shape, and its confirmed area is about 4 km^2.

Dacitic lapilli tuff formed a strongly silicified zone in which 1 to 10 cm wide single veins or stockworks of quartz with druses are developed. The intervals of the quartz veins are indefinite, varying from several to several tens of meters. Strikes of the veins are divided into NW-SE and NE-SW system. Dips are steep in both cases. Between these single veins, stockwork veins are often found. Zones of concentrated quartz veins occur in the eastern part. In the central part of this mineralization group, the above zones occur with oval shape with long diameters about 1 km and short diameters about 500 m. They are elongated in the NNW-SSE direction. Alteration mineral other than quartz is a trace amount of sericite.

The assay results of the samples from the representative quartz veins is as follows, revealing the low content.

Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3SM849	20	0.8	10	68	16	<0.01
3SM855	<20	4.1	40	26	28	0.01
3TM866	<20	0.1	10	16	263	0.08
3YM862	<20	<0.1	40	<10	13	0.29

(2) Mineralization Group F

This group was not extracted from the image. It is located along the ridge of the mountainland extending NNE-SSW. It has an oval shape elongated in the same direction as above. The confirmed surface area is 1.0 x 3.5 km.

Dacitic lapilli tuff is the host rock of the entire group. This tuff is strongly silicified and bleached. In the strongly silicified rock accompanied by pyrite dissemination, white quartz occurs as 1 to 3 m wide stockworks or 3 to 10 cm wide single veins (30 cm in maximum width). The stockwork veins have an overwhelmingly extensive sphere of distribution. Pyrite is the only sulfide mineral recognizable with the unaided eyes in the quartz vein. The quartz stockworks have directions as zones. Stockwork veins are parallel with the single veins at intervals of several to several tens of meters. The general strike is NW-SE and the dip is nearly vertical. In the quartz veins wider than 10 cm, druses are often found. The zones of concentrated quartz veins take up about 50 % of the Mineralization Group F. They are developed in the central and southern parts, with an oval shape at both localities. A very small amount of sericite occurs as alteration mineral besides quartz. Silicificaiton is weak in the northeastern part of this mineralization group.

As indicated in the assay results of the representative quartz vein samples, the contents of precious and base metals are low.

Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3SM809	40	3.5	<10	11	<5	0.02
3SM811	60	2.7	<10	10	10	0.02
3SM816	160	0.5	10	16	5	0.10
3YM893	<20	1.1	<10	12	<5	0.04
3YM899	40	1.5	10	12	14	0.02

(3) Mineralization group G

This group was not extracted from the image. It is located on the north-facing slope in the south of the Mineralization Group E. It has an oval shape, elongated in the NW-SE direction. The confirmed surface area is 500 x 800 m.

The host rocks of this group are dacitic lapilli tuff and rhyolite lava. These rocks are bleached by extensive silicification, but the original rock textures are retained and pyrite dissemination is scarce. In some parts of the silicified rocks, white to gray quartz veins (maximum width 4 cm) are concentrated. The strike of the quartz veins is NW-SE and the dip is 60 to 70°SW. Occurrence of these quartz veins is limited to the northeastern part of this mineralization group.

The assay results of the samples from the representative quartz vein and silicified rock are given below, indicating a low content of analyzed metals.

Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3MM809	<20	0.5	12	12	<5	0.02
3SM8100	<20	0.1	<10	30	7	0.03

(4) Mineralization Group H

This group was not extracted from the image. It spreads over the mountainland having a NW-SE trending ridge in the south of the Mineralization Group E. It has an oval shape elongated in the same direction as the above. The confirmed surface area is 0.7 x 1.5 km. This group extends also in the

NW-SE direction.

The host rocks of this mineralization group are rhyolite lava and dacitic lapilli tuff, the former being dominant. These rocks are bleached by general silicification, but the textures and structures of the original rocks are retained, with the exception of a locally argillized zone. Dissemination of pyrite and film-like veinlets of limonite are commonly found in the host rocks. Due to oxidation the surfaces of the host rocks are tinted brown. Differing from the above mineralization groups, the major portion of the group H is marked with a large number of strongly silicified dikes and stockwork of quartz aligned either parallel or en echelon. Their characteristics are summarized as follows.

(a) Strongly silicified dikes are gray to dark gray, and always show protruding landforms. They are 0.5 to 2 m wide, 5 to 20 m long, presenting a remarkable pitch-and swell style. Brecciated zones, caused probably by hydrothermal explosion, occur within the dikes. Also, the dikes often comprise one to several centimeters wide stockwork veins of white to milky white chalcedonic quartz. Even in such cases, the dikes contain breccias with diameters of several centimeters order.
(b) The stockworks are composed of one to several centimeters wide white quartz veins, with a general width of 2 m. Where the strongly silicified dikes mentioned in (a) grade into stockwork of quartz, the overall width exceeds 3 m.
(c) The strongly silicified dikes and the stockwork zone strike generally NW-SE and dip 70° or more. However, strongly silicified dikes striking NE-SW and steeply dipping NW also exist locally.
(d) Trace amount of sericite is the only alteration mineral other than quartz.

The assay results of the representative samples taken from the stockwork quartz veins are as follows. Contents of all elements are low.

Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3MM847	<20	1.8	<10	<10	12	0.15
3MM850	<20	0.9	<10	<10	16	0.29
3MM851	<20	2.7	10	<10	8	0.40
3MM859	<20	0.8	<10	<10	<5	0.01
3MM865	<20	1.6	<10	10	<5	0.17

(5) Mineralization Group K

This group is situated roughly in the center of alteration zone "No. 13" which was extracted from the image. Other parts of the extracted "alteration" zone are composed of unaltered rocks. This group is located in the southeastern part of the area, somewhat apart from four other groups already mentioned. The group's shape is rather irregular, but macroscopically it extends in the NW-SE direction. A confirmed areal extent is about 1.7 km^2.

The host rocks are dacitic lapilli tuff and rhyolite lava, the former is overwhelmingly predominant. In the northwestern part of this group, there is a zone of quartz stockwork. The zone is oval in shape, about 500 m long and about 200 m wide, consisting of one to several centimeters wide veins of quartz. Quartz veins of 20 cm width are locally found but their extension is no more than 20 to 30 m. The zone of stockwork extends in the NW-SE direction. A very small amount of sericite was detected as alteration mineral other than quartz.

The assay results of the samples collected from quartz veinlets are given below. The content of precious and base metals is low, but a trace amount of gold is partly contained.

Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3SM836	40	2.9	<10	16	12	0.01
3SM839	40	5.3	10	21	35	2.10
3SM841	220	8.3	<10	33	17	2.04
3SM885	<20	<0.1	<10	10	32	0.01

(6) **Other mineralization groups (A, B, C, D, I, J)**

These groups are located in the western part (A, B, C), the northern part (D), the northeastern part (I) and the eastern part (J) of the area. Their relations with alteration zones extracted from the image are as follows.

- Group A: It is located in the south of the alteration zones "No. 5" and "No. 6".
- Group B: It is located in the east and south of the alteration zone "No. 7".
- Group C: It was not extracted from the image.
- Group D: It is located in the west of the alteration zone "No. 8".
- Group I: It corresponds to a part of the northern part of the alteration zone "No. 10".

- Group J: It roughly corresponds to the southern part of the alteration zone "No. 12".

Access to alteration zone "No. 4" is extremely difficult, so that the observation of actual condition of the alteration zone was hardly possible. Within the sphere of alteration zones "Nos. 9, 14, 15", unaltered (diagenetic alteration only) dacitic lapilli tuff and fine tuff are distributed, and no mineralization and alteration zones are present.

The host rocks of the above six mineralization groups are mostly pyroclastic rocks (Kfdt) and rhyolite lavas (Kfdr). In the Groups A and B, however, granite and diorite are argillized and pyritized, respectively. The dacitic lapilli tuff and the rhyolite lava in the mineralization groups are silicified (partly sericitized) and bleached, accompanied by dissemination and veinlets of pyrite and limonite. Some parts contain veinlets of quartz and zonal stockwork quartz veins, but the areas of their distribution are very narrow. The host rocks are reddish brown-yellowish brown due to oxidation.

The characteristics of the respective mineralization groups are as follows.

- Group A: Silicified dikes with pyrite dissemination and quartz stockwork occur in several places. They strike NW-SE with almost vertical dip.
- Group B: A very small amount of chalcopyrite-quartz dissemination was noted in a float of silicified rock in the central part of this group. Strongly silicified dikes (3 m wide), striking WNW-ESE and dipping 50°SSW, are also present.
- Group C: Strongly silicified dikes (3 m wide) with pyrite dissemination and quartz-limonite stockwork were found in several places. They strike NE-SW with almost vertical dip.
- Group D: As silicificaiton was not very strong, the original rock texture is retained. In the silicified rock, 0.5 to 1 cm wide parallel quartz veins are developed partially. They strike NE-SW and dip 58°NW.
- Group I: Only rhyolite lava is silicified, and it comprises pyrite dissemination. The original rock texture is recognizable. The surrounding pyroclastic rocks are free of alteration. Nearly vertical fractures striking NW-SE are developed within the silicified rock, but no quartz veins exist.
- Group J: This group extends in the NW-SE direction. Concentration of pyrite and stockwork are locally developed.

The following is the assay results of the representative strongly silicified rock and quartz veins collected from the respective mineralization groups. All analyzed elements are low.

M.G.	Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
A	3TM811	<20	0.6	870	10	18	1.46
B	3FM828	<20	0.2	50	34	49	0.02
C	3TM825	<20	0.9	280	8	49	1.20
D	3MM834	<20	0.5	10	73	117	0.70
I	3MM825	20	0.6	14	14	60	0.01
J	3SM822	<20	0.7	90	57	15	0.02

M.G.: Mineralization Group

3.3. Evaluation

(1) Regional setting of gold mineralization

The Andina Outer Zone (Zona Extraandina) in the Aysen Region is situated along the Chile-Argentine border. It extends clearly in the N-S direction with a scale of 10 to 20 km in width. This zone is a tectonic province characterized by the active acidic volcanism during the formative period of the Divisadero Formation. Within this tectonic province, gold ore deposits and alteration zones that might be attributable to volcanism were discovered, such as the Katterfeld Deposit, the Laguna Verde Deposit and the Lake Jeinimeni Alteration Zone, as described in the reports of the first and second phases.

The Ibañez-Murta Area(North) is also within this tectonic province, and through the geochemical exploration (panned concentrate) conducted by SERNAGEOMIN in 1991, Au anomalies were identified at three localities of this area. These anomalies were obtained from the vicinities of the Mineralization groups E, F and H which are mentioned in section 3.2.

(2) Characteristics and timing of mineralization

Mineralization Groups E, F, G and H occurring in the central part of the area (collectively called "Central Mineralization Groups", hereafter) have rhyolite lava and dacitic lapilli tuff as their host rocks. The sphere of silicification accompanied by pyrite dissemination attains about 10 km^2 in total area. The surface shape of the silicification zone is oval or circular. A large number of quartz stockwork and strongly silicified dikes are developed within the silicified host rocks. But, as mentioned in section 3.2., the assay results of samples revealed that these veins seldom contain such metals as Au and Ag, with only a very small exception. However, when the polished sections of quartz veins from the respective mineralization groups were examined under the microscope, very small amounts of chalcopyrite, occasionally arsenopyrite, were found in addition to pyrite.

For the purpose of supplementing the geological and mineralogical investigations of this area, geochemical exploration (panned concentrate) was carried out in the downstream parts of mineralization groups, and 45 samples were collected (refer to PLATE 20 and Table 5 in Appendix). The samples which showed relatively high content of Au are presented below. Sampling did not cover all the mineralization groups.

Sample No.	Indicative M.G.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	As(ppm)
3SP801	E	360	0.3	12	173	2315	<5
3MP804	D	60	0.6	37	430	3355	738
3PP802	K	340	0.3	7	88	250	98
3PP803	K	60	0.8	151	86	2184	<5
3VP801	K	160	0.8	10	24	398	6
3VP802	K	2.9ppm	1.9	14	32	175	<5
3VP803	J	1.5ppm	1.0	10	36	431	<5

M.G.: Mineralization Group

Overall assessment of the assay results, field occurrence and microscopic observation of polished sections, leads to the conclusion that Au mineralization, though weak, exists not only in the "Central Mineralization Groups" but also in other mineralization groups, and it is accompanied by very small amounts of Zn-As-Pb-Cu.

The mineralization groups of the area are extending, stratigraphically, from the middle part to the uppermost part of the Divisadero Formation. Thus, it is considered that the mineralization took place toward the end of the formative period of the Divisadero Formation. In the eastern part of the area, on the other hand, numerous dikes of basalt (or basaltic andesite) are found, extending in the NW-SE direction and cutting the mineralization groups. They are unaltered. The lithology of the dikes is closely similar to that of the plateau basalt which is sporadically distributed in the environment of this area and is called the Meseta Buenos Aires Formation, so the dikes and the basalt are regarded to have been active during roughly the same period.

The active times of the plateau basalt have been assigned to Pliocene and Paleocene to Middle Eocene by the K-Ar method (SKARMETA, 1978). Supposing the dikes of this area were active in the same period as the basalt, it can be interpreted that mineralization of this area terminated at the end of the Cretaceous period and did not extend over the Tertiary period.

(3) Comparison between mineralization groups and hydrothermal gold deposit models

Since the investigation of this area aimed at gold deposit exploration, the characteristics of the "Central Mineralization Groups" were compared with those of the vein type (a) and hot-spring-type (b) deposit, as in the case of the Cerro Aguja Alteration Zone (Table II-3-1).

Table II-3-1 Geological characteristics of Gold Deposits Associated with volcanic Activity

	Vein Type	Hot-Spring-Type (Round Mountain, etc.)	Central Mineralization Groups (this area)
Host Rock Alteration	Silicification (Qz)·Ad·Se + thin propylitic zone (Ch·Ab·Ep·Ca)	Silicification and acidic alteration (Qz·Al·Ka·P·D)·Ad·Cab Propylitic Zone (Ch·Ab·Ep·Ca) in the lower part	Silicification and intermediate alteration (Qz·Se)
Ore Deposit	Qz-Ad vein ; accompanied by Ka, Ca, Ch, Sm, Se, sulfide and sulfate minerals	Qz-Ad veinlets, stockwork veins, and dissemination ; accompanied by Ch, Sm, sulfide minerals and barite Rich in minor elements of Hg-As-Sb-Tl etc.	Qz veinlets, stockwork veinlets, and intensely silicified rock dike ; accompanied by a very small amount of sulfide minerals Dissemination ; pyrite-limonite etc.
Au/Ag Ratio	1 : 5 to 1 : 100	1 : 2 to 1 : 3.5	?
Formation Temperature (℃)	160 to 280	100 ~ 240	?
Formation Depth (m underground)	200 to 1,000	0 to 500	?

Abbreviations

Ch: Chlorite, Ab: Albite, Ep: Epidote, Ca: Calcite, Qz: Quartz, Ad: Adularia, Se: Sericite, Ka:Kaolinite, Sm: Smectite, Al: Alunite, P: Pyrophyllite, D: Diaspore, Cab: Carbonate minerals

Identification of types and depths of mineralization in this area, represented by the "Central Mineralization Groups", is one of the most important points of exploration. Although conclusive evidences are not available and it cannot be said with conviction, it does seem reasonable to consider that the Mesozoic mineralization of the "Central Mineralization Group" was of the hot-spring-type from the following characteristics.

a) A large-scale silicification zone of oval or circular shape exist.

b) Veinlets of chalcedonic quartz and pyrite are developed into stockwork form.

c) Strongly silicified dikes are partially brecciated, suggesting possible repetitions of brecciation due to hydrothermal explosion and silicification.

(4) Vertical positions and changes of mineralization groups

The "Central Mineralization Groups" comprise the zone in which stockwork and partly brecciated strongly silicified rock dikes are concentrated, as mentioned in (1), but they are devoid of acidic alteration zone composed of kaolinite and alunite or silica sinter. According to X-ray diffraction, a small amount of sericite as detected as alteration mineral besides quartz. By integrating these phenomena, it is considered that the level of the existing outcrops of the "Central Mineralization Groups" corresponds to the lower part of the "Stockwork veins" indicated in the schematic cross section of Fig.Ⅱ-1-4. The character of the alteration zone at that position in the model is not clear, but from the combination of detected alteration minerals the "Central Mineralization Groups" do not correspond to the upper part of the "Stockwork veins". The subsurface leached zone of silicificaiton, acidic alteration zone and silica sinter, that characterize the hot-spring-type gold deposit, would have been completely destroyed, eroded and transported away in the passage of time of 65 Ma or longer after the mineralization.

As for the vertical changes of mineralization groups, it is noted that the zones with concentrations of stockwork and strongly silicified dikes are accompanied by gently inclined folds, as shown in the geological profile of Fig.Ⅱ-3-1 (B-B′). The zones belong to an almost identical horizon. That is to say, the veinlets of quartz exposed between the position of the Blanco River and the mountain ridge show little changes in analytical values in spite of about 500 m vertical difference between the levels, and they comprise no concentrations of Au-Ag and base metals. In correlating the "Central Mineralization Groups" with the schematic cross section, the position of the present outcrops corresponds to the level of the "Stockwork veins" as mentioned before. Therefore, any prominent Au mineralization cannot be expected to occur in the lower part of the "Central Mineralization Groups".

Looking for the source of Au in the hydrothermal solution is not a simple problem but NELSON (1985, a talk at the symposium) pointed out that the zone comprising the Carlin-type gold deposit coincides with the distribution area of the basement black shale, and he ascribed the source of Au to that shale. In the Aysen Region, the Coyhaique Formation consisting chiefly of pelitic rocks is distributed beneath and around the Katterfeld Deposit, mentioned in (1). If Au could be dissolved much more by the circulation of hydrothermal solution through pelitic rocks, distribution of the Coyhaique Formation in this area and vicinities would be a requisite condition. But, from the state of regional distribution of the Coyhaique Formation, the possibility of its occurring beneath the Divisadero Formation of this area is very low, and in this respect also the Coyhaique Formation's contribution to Au mineralization may be small.

(5) Condition of fracture formation

As described in section 3.2., the extending direction of the zone of stockwork developed in the "Central Mineralization Groups" and the strike of the strongly silicified rock dikes are NW-SE for the most part. Though some of the dikes are aligned en echelon, they occur on the whole as groups of parallel veins. Since no echelon faults or low-angle reverse faults are found in the whole area, it is difficult to think this area has undergone wrench tectonics or thrust movement. If the NW-SE trending fractures were formed by the movement that produced normal faults, the maximum compression major stress axis (σ_1) would be vertical and the minimum compression (extension) major stress axis (σ_3) would be horizontal in the NE-SW direction. The major strike of the quartz veins of the Laguna Verde Deposit, which was reported in the First Phase, is also NW-SE, and this may suggest a possibility of regional occurrence of the fractures of NW-SE system.

CHAPTER 4. IBAÑEZ-MURTA AREA (SOUTH)

4.1. Photogeological Interpretation

4.1.1. Procedure of interpretation

(1) Data used

The areal extent of the work carried out is shown in Fig.Ⅱ-4-1. Aerial photographs used for this work are black and white prints at a scale of 1:68,000. They are published by the Instituto Geografico Militar de Chile. Total of 70 photographs were used for the interpretation.

Numbers of prints for each series are shown below.

Photo-number series	Numbers of prints	Photo-number series	Numbers of prints
3219 to 3223	4	2248 to 2252	5
3772 to 3775	4	0984 to 0992	9
2147 to 2150	4	0910 to 0917	8
2166 to 2150	6	0925 tc 0934	10
2227 to 2233	7	2457 to 2461	5

Total: 70 photographs

(2) Procedure of interpretation

Photogeological interpretation is generally completed through the procedure described below.

a) Preparation: Acquisition of materials, orientation of principal points of photographs and collection of the available geologic data and so on.
b) Interpretation and preparation of preliminary photogeological interpretation map.
c) Ground truth survey.
d) Re-interpretation referring to results of the ground truth survey and integrated examination.

The work was done with special emphasis on the following diagnostic interpretation criteria.

i) Photo-characteristics: tone and texture.
ii) Geomorphological features: drainage pattern and its density, rock resistance against erosion, relief energy, shape of ridge, existence and density of bedding, and direction and continuity of photolineaments.

ii) Superficial covers: vegetation and cultivation.

4.1.2. Results of interpretation

(1) Classification of photogeological units

Photogeological interpretation map is shown in PLATE 1. Seven units are defined in this area. Their photo-characteristics and geomorphological features are summarized in Table II-4-1.

a. Unit J

This unit is widely distributed in almost whole of the area, covering the part to the northern limit of Lake General Carrera and the surroundings of Puerto Ibañez and Cerro Castillo Village. The unit forms hilly mountains of low relief energy and relatively gentle ridges. The unit is characterized by the cuesta landforms that comprises obvious back slopes and front slopes with well bedded strata. The unit probably consists mainly of pyroclastic rocks.

b. Unit C

This unit is distributed mainly in the western part of the area, in the vicinity of Lake Lapparent and the Sin Nombre River and overlies the unit J. Tone of this unit is darker gray than that of the unit J. The ridges of this unit are very narrow forming very steep slopes. Although beddings are observed in this unit as expressed by light gray linear patterns within dark gray parts, the cuesta landforms are not recognized. The unit is probably made up of volcanic rocks.

c. Unit T_3

This unit is distributed to the northern limit of Lake General Carrera. Tone of the unit is rather light gray and texture is very smooth. The ridges of this unit are roundish and form gentle topography with low relief energy. This unit is probably composed of volcanic rocks.

d. Unit Q_1

This unit is distributed in the vicinity of Lake General Carrera and along the valley of the Ibañez River. The steep cliffs show a pair of stairs with roundish ridges on both sides of the Largo River to the west of Lake General Carrera, that consists mainly of terrace deposits. The unit distributed along the Ibañez River forms similar landforms to those of the Largo River and is assumed to also be composed of the terrace deposits. To the south of the Largo River, the unit forms hills with roundish ridges and probably consists of glacial deposits.

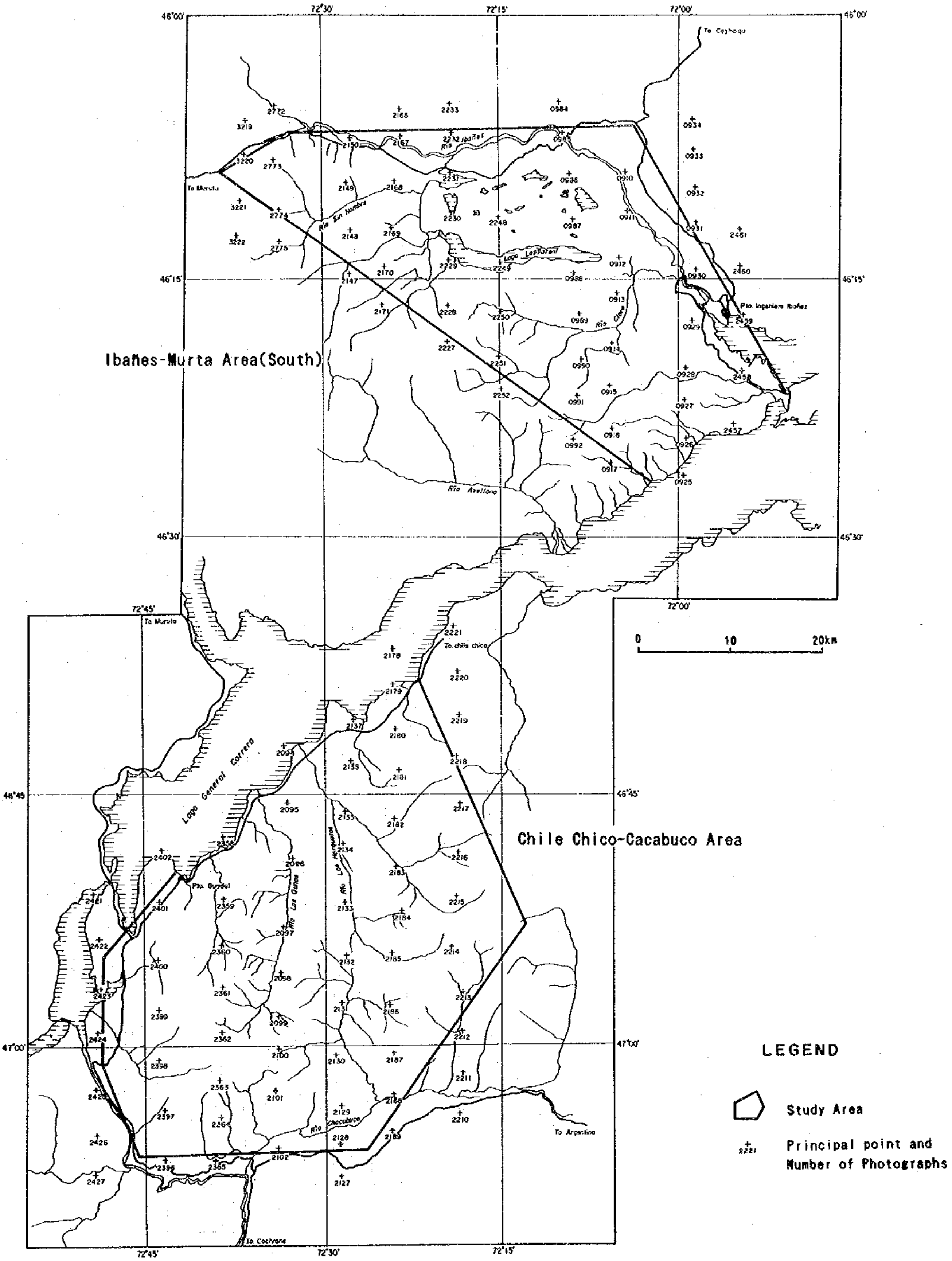
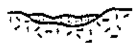
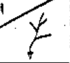
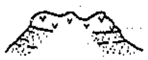


Fig. II -4-1 Map Showing Aerial Extension of Photogeological Interpretation of Aerial Photographs

Table II-4-1 Photogeological Interpretation Chart of the Ibañez-Murta Area (South)

Unit	Photo – Characteristics		Mophological – Expression					Cover	Conclosion	
	Tone	Texture	Drainage		Rock Properties			Vegetation	Probable Lithology	Existing Geological data
			Pattern	Density	Registance	Cros Section	Bedding			
Q_2	light gray	fine, smooth	meandering 	very low	very low		none	sparse	alluvium, fluviam	alluvium, fluviam
Q_1	light gray	fine, smooth	parallel 	low	low		none	sparse	terrace	alluvium, fluviam
T_3	light gray	fine	dendritic 	low	low medium		none	sparse	volcanic rocks	volcanic rocks
C	medium gray dark gray	coarse	dendritic 	medium	high		partly bedded	dense	volcanic rocks	volcanic rocks
J	medium gray	coarse, rough	angular 	medium	medium high		very well bedded	sparse	volcanic rocks sedimentary rocks	volcanic rocks
I_2	medium gray	coarse	dendritic 	low	high		massive	moderate	intrusive rocks	granitic rocks
I_1	dark gray	coarse	—	—	medium		massive	moderate	intrusive rocks	

e. Unit Q_2

The distribution of this unit is confined to valleys of main rivers such as the Ibañez River and plains. From this fact the unit obviously consists of the recent sediments.

f. Unit I_1

This unit is distributed on a small scale to the north of Lake General Carrera. Topography of the unit is extremely steep and protrudes from other units. These geomorphological features suggest that this unit is made up of small intrusive bodies.

g. Unit I_2

This unit is chiefly distributed in the northern part of the area. Rock resistance against erosion is relatively high and shape of ridges are similar to that of the Unit J. This unit is distinguished from the Unit J by existence of bedding. Rocks of the Unit J are well bedded, while this unit is mostly massive. This unit probably consists of intrusive rocks.

(2) Geologic structure

a. Photolineaments

Photolineaments are extracted mainly in the eastern and northern parts of the area and tend to occur densely in the Unit J as shown in PLATE 1. Density is higher in the vicinity of Puerto Ibañez and on the north of Lake Laparrent than in other parts. On the south of Lake Laparrent and in the western part of the area, density is low. Their directions are dominated by the N-S system in the eastern part and by the NE-SW system on the north of Lake Laparrent.

b. Fold

Beds of the Unit J macroscopically trend east to west and dip north, however, undulating folds with long wavelengths and low amplitudes are recognized in the units. Axes of the folds have the NE-SW to E-W strike. No folds are formed in the other units.

4.2. Geology

Geology of this area is composed of Late Jurassic and Cretaceous volcanic rocks, Quaternary fluviatile, glacial and lacustrine deposits, and intrusive rocks. The Jurassic System is correlated with the Ibañez Formation and the Cretaceous system with the Divisadero Formation. The geological map is shown in Fig.Ⅱ-4-2.

4.2.1. Stratigraphy

As shown in the schematic columnar section (Fig.Ⅱ-4-3), the stratigraphy of this area is made up of the Ibañez Formation, the Divisadero Formation and the Quaternary System, in ascending order.

(1) Ibañez Formation

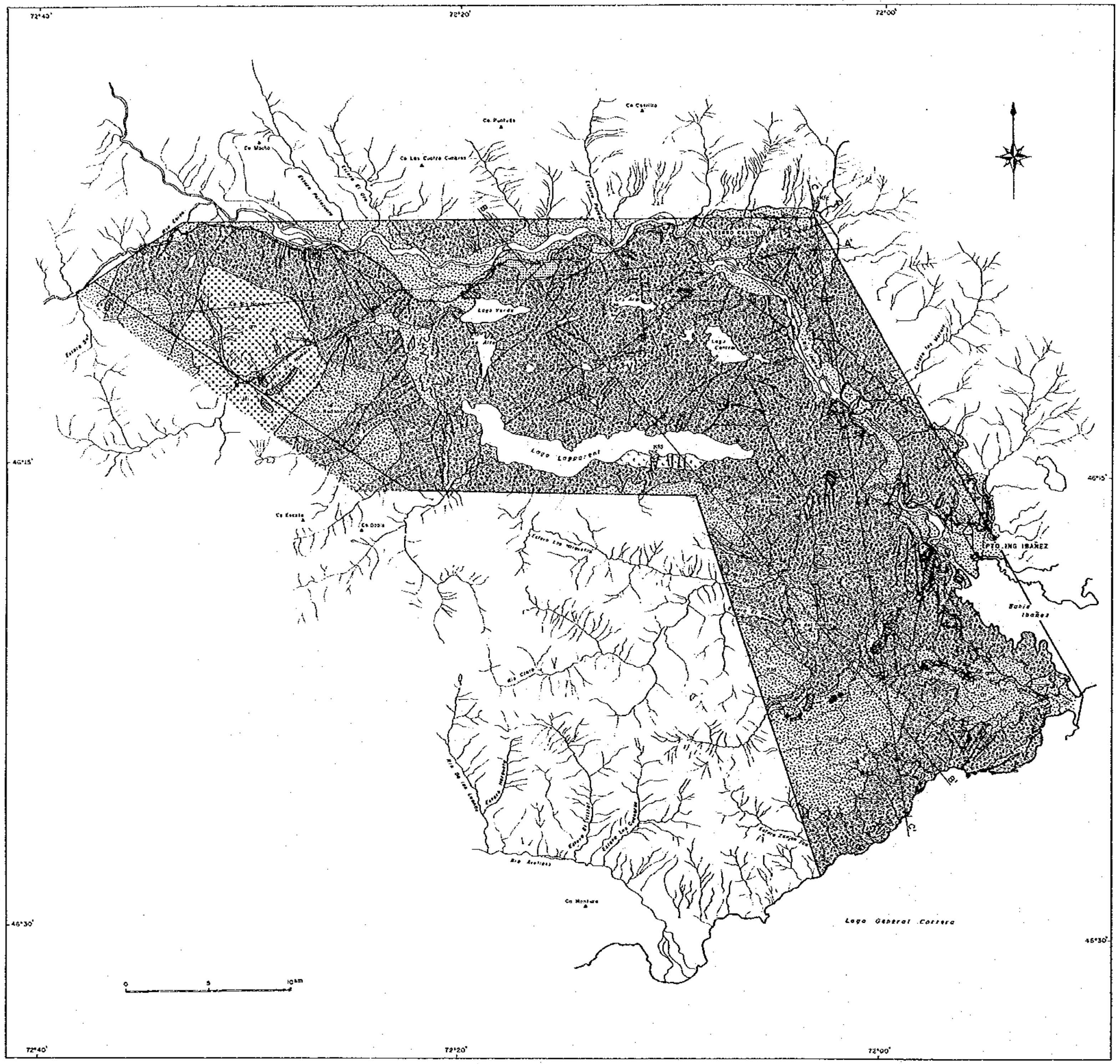
The Ibañez Formation is distributed almost throughout over the area. A zone extending from Puerto Ibañez to Peninsula Levican is the type locality. The total thickness of the formation is unknown as the lower limit is not confirmed, but a thick part (along the north shore of Lake General Carrera) is inferred to exceed 2,500 m. Dacitic pyroclastic rocks are predominant throughout the formation, but on the west side of the upper to middle horizons they are intercalated with lavas and pyroclastics of andesitic composition.

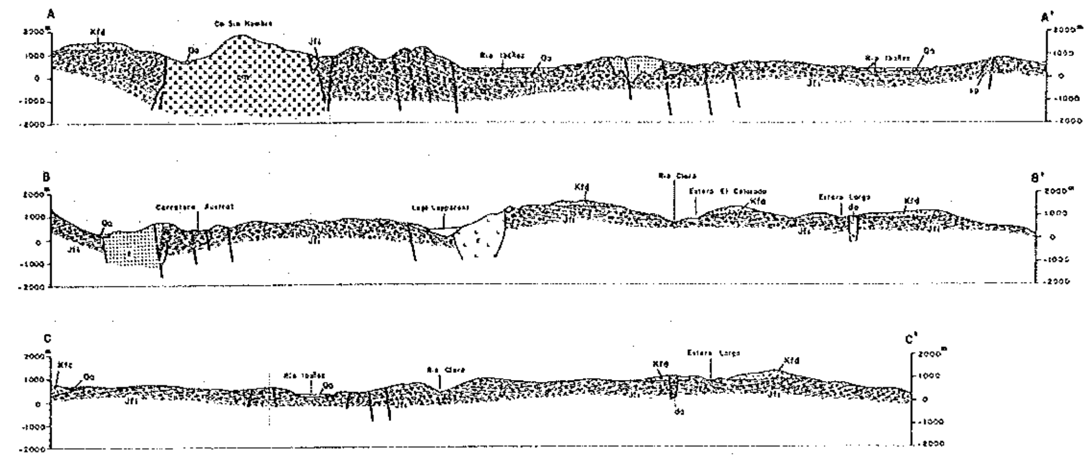
Dacitic pyroclastic rocks range from fine tuff to tuff breccia, though most abundant is lapilli tuff containing lapilli of 1 to 2 cm across. The pyroclastics are highly consolidated to such an extent as to rebound blows of a hammer, and their color is generally dark green. The hardness and the color are part of the criteria for discriminating these rocks from the bright green loose pyroclastics of the Divisadero Formation. The dacitic pyroclastics are characterized by graded bedding, as shown in Fig.Ⅱ-4-4, the grading unit being 50 to 200 cm thick.

These rocks comprise crystals of quartz and feldspar, red dacitic rock fragments and dark green patches (pumice?). The matrix consisting of dark-green compact volcanic ash is chloritized and carbonatized for the most part, epidotized in part. As the development of bedding is poor, the rocks appear generally massive, though the fine tuff is finely bedded.

The andesitic lavas and pyroclastics are distributed rather extensively in the central to western parts of this area. They occupy the upper horizons of the Ibañez Formation. Lava flows surpass the pyroclastics in quantity. The lava is dark green, hard, and has porphyritic or aphanitic texture. Most of lava bodies have undergone diagenetic metamorphism, resulting in the occurrence of great quantities of chlorite, epidote and carbonate minerals.

The formation's relation with the underlying strata is not known because there are no outcrops of the latter. For dating the eruptive period of the





L E G E N D

Quaternary	Holocene		Qa	Alluvial, fluvial, colluvial and talus deposits
	Pleistocene		Qt	Terrace and glacial deposits
Cretaceous	Aptian to Cenomanian		Kfd	Divisadero Formation : Dacite and andesit, and those pyroclastic rocks
	Neocomian		Kfc	Coyhaique Formation : Black shale and sandstone
Jurassic	Malm		Jfi	Ibanez Formation : Rhyolite, dacite and andesite, and those pyroclastic rocks
Intrusive rocks			r	Rhyolite
			da	Dacite
			m	Monzonite porphyry
			ba	Basaltic andesite
			sp	Syenite porphyry
			gd	Granodiorite
			qm	Quartz monzonite
			t	Tonalite
			gp	Granite porphyry

Fault and/or fracture

Ore vein

Hydrothermal alteration zones

Strike and dip of bedding plane

Fig. II-4-2 Geological Map of the Ibañez-Murta Area (South)

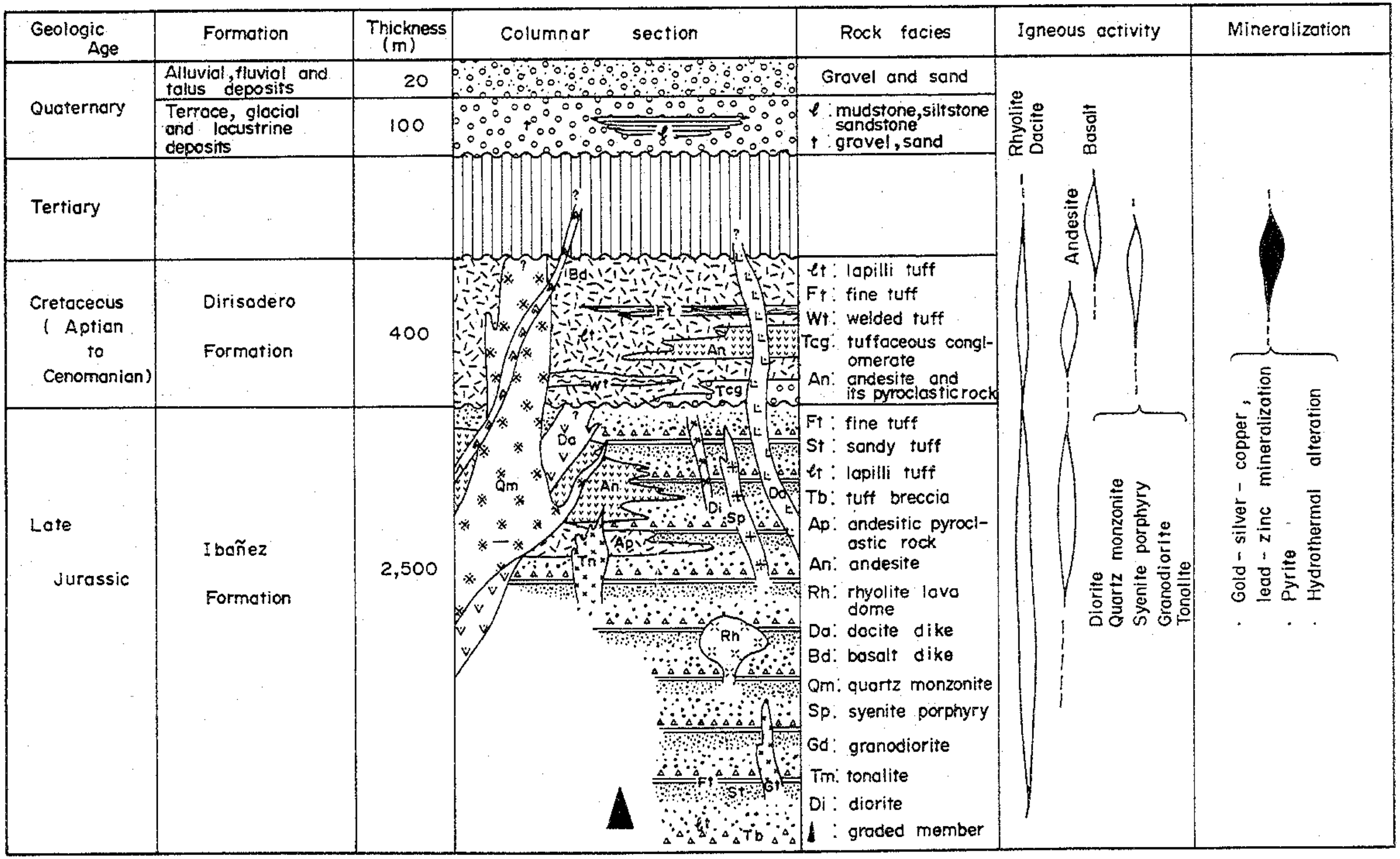


Fig. II -4-3 Schematic Columnar Section of the Ibañez-Murta Area (South) formation, the only clue available in the present investigation was the absolute age (93 Ma by the K-Ar method) of the tonalite intruding the formation, as will be mentioned later. RAMOS et al.,(1982), CHARRIER et al., (1978) and LEANZA (1967) have assigned the formation's eruptive period to Middle to Late Jurassic. Volcanic eruptions in this area must have occurred on land, since the Ibañez Formation has no intercalations of sedimentary rocks. On the Argentine side, a formation corresponding to the Ibañez Formation is known to be intercalated with shale that contains ammonite fossils. Accordingly, it is surmised that a marine area had spread over there.

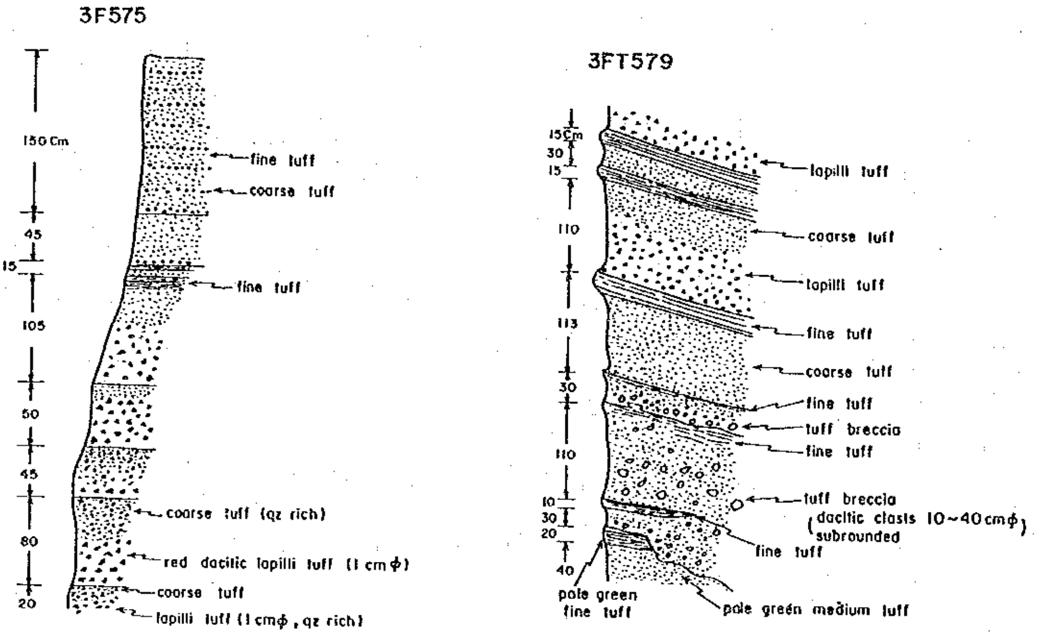


Fig. II-4-4 Sketches of Stratigraphic Columns of the Ibañez Formation at Localities of 3F575 and 3FT579

(2) Divisadero Formation

This formation is distributed in the highland (over 1,000 m above sea level) of the southwestern part and at the western end of the area. The formation at the western end is unidentified as it was covered with snow at the time of the survey, but it is treated as the Divisadero Formation on the basis of the similarity in photogeological and geomorphological features. The thickness of the Divisadero Formation is 200 to 400 m.

The formation is composed of pyroclastics and lavas of dacitic to andesitic composition, with dacitic pyroclastics being predominant.

Similarity of its lithofacies to the underlying Ibañez Formation makes it difficult to discriminate between the two formations, except for the different degrees of consolidation and the structural differences which are to be described later. Pyroclastics of the Divisadero Formation are lower in degree of consolidation and are more porous than those of the Ibañez Formation. The two formations differ in color also; the former has a characteristic bright green color, while the latter is tinted blackish green. The Ibañez Formation presents a gently undulating fold structure, whereas the Divisadero Formation has a nearly horizontal structure without any folds.

The lithofacies of the Divisadero Formation is dominated by lapilli tuff, associated with crystalline to lithic tuffs consisting of crystals of quartz and pink feldspar, lenses of pumice, and red dacitic rock fragments. Tuffaceous conglomerate of poor sorting and grading is developed near the basal part of the formation. The lower part of the formation is intercalated with welded tuff, and the middle part shows a predominance of andesitic lavas and their pyroclastics.

The relation with the underlying Ibañez Formation is clino-unconformity, partly parallel unconformity. Data for determining the formative period of the formation were not obtained in the present study, but according to the literature including Niemeyer et al.,(1984) and Baker et al.,(1981), the depositional period of the formation can be assigned to the Aptian to Cenomanian stages. The sedimentary environment of the formation was probably a land, as judged from the absence of marine deposits, though the existence of sandstone and conglomerate of volcanic origin suggests that part of the formation might have been deposited in ancient rivers or lakes. A lagoon deposit was reported from the vicinity of the type locality (Skarmeta and Charrier, 1976).

(3) Quaternary System

The Quaternary system of the area can be divided into the Pleistocene Series, consisting of fluviatile terrace, glacial and lacustrine deposits, and the Holocene Series composed of alluvium. The terrace deposit constitutes the greater portion of the Pleistocene Series, and is distributed in the drainage basins of major rivers such as the Largo and the Ibañez. There are three terrace plains. The relative height between the uppermost terrace plain and the present river bed is more than 100 m at maximum. Distribution of the glacial and lacustrine deposits is limited, the former occurring in the south of the Largo River and the latter along the Ibañez and the Sin Nombre Rivers.

The terrace and glacial deposits consist of sand and gravel, while the lacustrine deposit is composed of rhythmically alternating layers of silt and fine sand. All these deposits are unconsolidated. Most part of the alluvium is a deposit of the present river bed, occurring dominantly along the Ibañez River.

4.2.2. Intrusive rocks

The areal extent of the intrusive rocks of this area is large in the western part, becoming smaller in the central to eastern parts where their distribution is also scanty. The rocks occur as stocks and dikes. Their compositions are felsic in many cases though some are mafic. The lithofacies is much variable, ranging from quartz monzonite, granodiorite, tonalite, syenite porphyry, monzonite porphyry, tonalite porphyry, rhyolite, dacite, to basaltic andesite.

(1) Quartz monzonite

This rock, occurring as stock-like bodies, is widely distributed from the lower reaches of the Sin Nombre River to the Sin Nombre Mountain. It is greenish gray, coarse-grained and holocrystalline. Alteration is generally weak, its influence being no more than chloritization and epidotization of mafic minerals. The rock is penetrating the Divisadero Formation.

(2) Granodiorite

This rock occurs as a small stock along the road to Peninsula Levican, about 4 km south of Puerto Ibañez. As the rock suffered strong alteration, mafic minerals are completely chloritized and calcitized. The adjacent non-intrusive rock has undergone argillization.

(3) Tonalite

The rock showing the composition of tonalite comprises two types, one presents a hypidiomorphic-granular texture and the other a porphyritic texture. The former type occurs as a small stock penetrating the Ibañez Formation at about 2 km northeast of Lake Verde in the northern part of the area. It is a greenish gray, hard and fresh rock with the following chemical composition.

Sample No.	SiO_2	Al_2O_3	CaO	K_2O	Na_2O	FeO	Fe_2O_3	BaO	MgO	MnO	P_2O_5	TiO_2	LOI
3SR550	64.65	16.14	4.10	2.25	4.11		4.51	0.05	2.02	0.08	0.16	0.60	0.66

The absolute age determination by the K-Ar method obtained the value of 93 Ma. The age of the rock is Late Cretaceous.

The latter type of tonalite is found as a small stock intruding the Ibañez Formation along the Largo River. Mafic minerals are almost entirely chloritized.

(4) Syenite porphyry

Two bodies of syenite porphyry were confirmed. One of them occurs as a small stock at the northeastern end of the area. This is the host rock of the Fenix Mine which will be mentioned later. The rock is grayish white with a micrographic texture. It is affected by strong alteration and feldspar is almost entirely replaced by sericite and kaolin minerals. The other body is developed in a vein-form with a N-S trend in the lower reaches of the Claro River. It shows intense chloritization and carbonatization. Both bodies intruded into the Ibañez Formation.

(5) Monzonite porphyry

One body of monzonite porphyry was confirmed at 2 km south-southeast of the above-mentioned granodiorite stock. It is a small stock penetrating the Ibañez Formation. The rock underwent intense alteration, and almost all mafic minerals turned into chlorite and carbonate minerals, accompanied by numerous veinlets of limonite and calcite.

(6) Rhyolite

The intrusive facies of rhyolite is distributed with an E-W extension along the shore of Lake Lapparent. Its lithologic character resembles that of the rhyolite lava in the Ibañez Formation. This is probably a lava dome, judging from the fact that its distribution is discordant with the adjacent structure. The rock suffered intense alteration, as represented by silicification, sericitization, carbonatization, and kaolinitization.

(7) Dacite

More than ten dikes or small stocks of dacite are densely aligned in the NNE-SSW direction, and they pass through 3 km west of Puerto Ibañez. The length of the alignment, as far as confirmed, attains 13 km. Some of these rock bodies also penetrate the Divisadero Formation. The dacite is pale pink or brownish gray, and is marked with silicification, kaolinitization and sericitization. As will be mentioned later, the host rocks of the intrusion adjacent to the dacite generally show weak sericitization, and is accompanied by dissemination or stockwork of limonite and pyrite, so that the rock is considered to have been in close contact with mineralization and alteration.

(8) Basaltic andesite

Dikes of this type are distributed throughout the area. They occurs as 2 to 5 m wide platy dikes, cutting all of the above-mentioned intrusive rocks and alteration zones. Thus, being of a post-alteration intrusion, this is the youngest among the intrusive rocks of the area. The rock is dark green, coarse- to fine-grained, and locally presents dioritic, andesitic or basaltic facies. The extension of the dikes is multidirectional and no regularity is noticed.

4.2.3. Geologic structure

(1) Fold

The Ibañez Formation in the central to southern parts of the area shows a general strike of NE-SW trend and has a gentle northward plunge in a broad view, but in detail the structure is a gentle wavy fold with the fold axis in the same direction. Dip is also gentle, being 5 to 20°. At the eastern end of the area, the general strike bends southward and changes to NW-SE. Structure of the Ibañez Formation in the western part of the area is not clear.

The Divisadero Formation has a horizontal or nearly horizontal monoclinal structure, without any folds.

(2) Fault

Faults of the area can be divided roughly into two systems, namely, N20°W and N50°E. Faults of the former system are developed in the western, central and eastern parts; the distribution is the most dense in the eastern part. The N20°W system in the eastern part changes its direction to N20°W, N-S and N10°E, from north to south. Faults of the latter system, N50°E, are densely distributed north of Lake Lapparent in the middle of the area. They are less continuous than the faults of the N20°W system and are cut by the latter, indicating that they are older faults.

The N20°W system extends in parallel with the regional major structure, and is supposed to constitute part of the principal structure, while the N50°E system seems to be a local structure. Both systems are normal faults with steep dips (70 to 90°), but horizontal and vertical displacements are small. As both systems are cutting the Divisadero Formation as well as some of the intrusive rocks, the folding of this area must have been activated since the Cretaceous Period.

4.3. Mineralization

Vein-type ore deposits of copper, lead, zinc and molybdenum occur at several localities, and hydrothermal alteration zones are developed at about 20 localities in this area. The total number of the veins is to about 20, but those that have been worked or explored are the only five mentioned below. Existence of these deposits is an established fact, and no new discoveries have been made during the survey of this phase.

Cascara Mine (Au, Cu, Pb, Zn)
Co. Castillo Mine (Cu, Mo)
Vista Alegra Mine (Pb, Zn)
Long Mine (Pb, Zn)
Fenix Mine (Cu, Pb, Zn)

The first three mines were investigated previously and were described in the first phase report. The Fenix Mine has been investigated during this phase. The Long Mine is unconfirmed most probably due to the adit collapse (?). None of the mines is being worked currently.

Most of the hydrothermal alteration zones show weak silicification and weak argillization (chiefly kaolin minerals), and are accompanied almost always by disseminations or stockworks of limonite and hematite. Very small amounts of lead and zinc are recognized in some alteration zones, but many other zones are almost devoid of useful metals, and are accompanied only by dissemination or stockwork of pyrite and veinlets or stockwork of quartz. Locations of these zones are shown in PLATE 11, and their characteristics are given in Table 1 in Appendix.

Occurrences of the above-mentioned ore deposits and the zones of mineralization and alteration are concentrated in the eastern part of the area, as seen in PLATE 11. The deposits and alteration zones are described by deposit types below.

(1) Vein-type deposits

In this area, there are approximately 20 metalliferous veins extending from Mt. Castillo to the west of Puerto Ibañez. The characteristics of the veins by deposits are summarized in Table 1.

The vein fissures are roughly divided into the N30°W to N10°E systems (collectively called N-S system) and the N60°E to E-W systems (collectively E-W system). Their dip is steep, 70° to 90°, and the strike varies. The N-S system is relatively large in the number of veins and in the scale. The maximum strike extension of veins is 4,000 m for the Fenix Mine, followed by 150 m of the Cascara Mine. Other mines are several tens of meters long at most. The vein width also is the largest, 10 m, in the Fenix Mine, whereas the others are around 50 cm. At any rate, the workable high grade portion is no more than 60 cm, even for the Fenix.

Ore minerals are galena, sphalerite, pyrite, chalcopyrite and molybdenite, the first three being the principal constituents. Molybdenite is found only in the Cerro Castillo Mine. A vein located west of Lake Central consists only of pyrite and quartz. The gangue minerals are represented by quartz, rarely accompanied by calcite.

The host rocks are pyroclastic rocks, andesite and syenite porphyry of the Ibañez Formation. They underwent strong alterations such as silicification and chloritization within the vein, but outside or near the vein the alterations are very weak or almost nil.

Among the veins investigated during this phase, the Fenix Mine is most promising and will be described in the following.

Fenix Mine

Location: The Fenix Mine is situated at 660 m above sea level, about 5.5 km east-southeast of Cerro Castillo Village.

Geology: Lapilli tuff of the Ibañez Formation and syenite porphyry intruding it are distributed in the vicinity of the mine. Fissures of N70°E, N15°E and N20°W systems are intersecting each other; the first two systems are cutting the vein, but the fissures of the N20°W system extend parallel with the vein and are accompanied by fractures that are densely developed along the fissures (Fig.Ⅱ-4-5).

Mineralization: Veins occur in two systems, N20°W and N70°W, the former is the main veins and the latter is the branch veins. The main veins are aligned en echelon, with the local extension attaining to 4 km. As seen in the sketch (Fig.Ⅱ-4-7), a 10 m wide middle zone of the vein is composed of massive, milk-white, opaque or translucent quartz veins, and within this zone several veins consisting of galena, sphalerite,

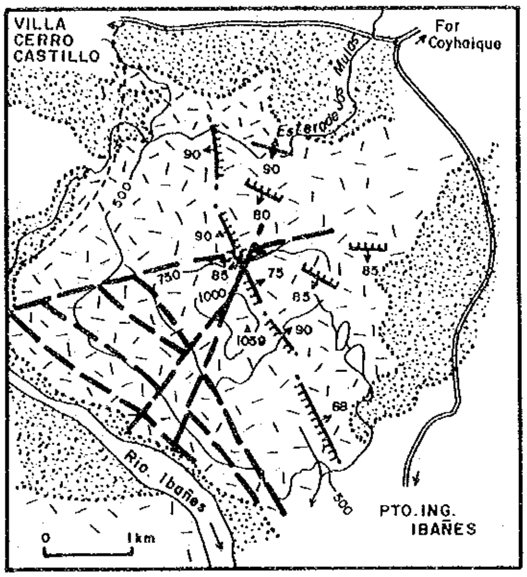


Fig. II-4-5 Distribution Map of Vein System of the Fenix Mine

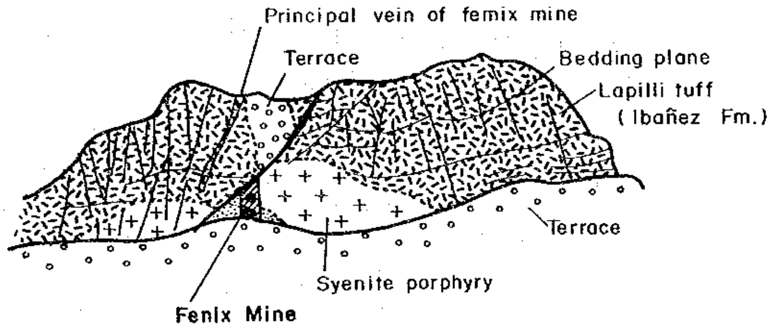


Fig. II-4-6 Geological Sketch of the Fenix Mine

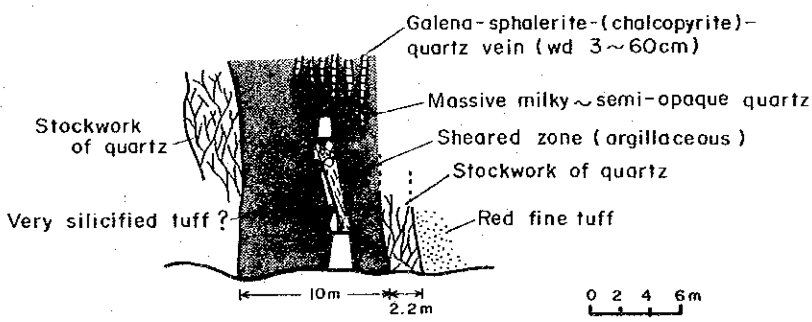


Fig. II-4-7 A Sketch of Vertical Section of the Principal Vein at the Fenix Mine chalcopyrite and porous quartz are developed; their width is 3 to 60 cm and they are either parallel or irregular. These lead-zinc-copper veins are variable in width and grade. There are two levels of drift dug into this zone. The above-mentioned ore minerals occur as disseminations within quartz. Galena and sphalerite are abundant, while chalcopyrite and pyrite are very small in amount. Along the outer zone of this metalliferous massive quartz zone, barren quartz stockwork veins are developed, and in contact with the host rock on the outside. The width of this stockwork of quartz veins is 2.2 m on the hanging wall side and +5 m on the foot wall side.

In the middle part of the vein, a 0.5 m wide shear zone with slickensides is developed, cutting the vein in a parallel direction. Numerous pieces of markedly silicified brecciated host rock (tuff?, 5 to 10 cm across) are found on the foot wall side of the massive quartz zone. The host rock (red fine tuff) of the quartz stockwork veins is intensely silicified, but on the outside of the veins the alteration is very weak, no more than a slight silicification.

Occurrences and properties of the minerals are listed below.

Sample No.	Vein Kind of sample	width	Au	Ag	Cu	Pb	Zn	S
3FM529	Main vein, sedimentary ore (lower level)	0.6	40	21.0	0.22%	0.16%	14.0%	11.7
3FM530	Main vein, (middle part)	0.6	0.4ppm	320.0	0.17%	0.16%	0.95%	2.8
3FM531	Main vein, sedimentary ore (upper level)		0.7ppm	114.0	670	1.10%	14.3%	19.1
3SM516	Main vein, (southern part)	1.0	<20	0.1	4	9	117	0
3SM517	Main vein, (southern part)	1.0	<20	0.1	1	11	107	0
3SM518	Main vein, (southern part)	1.0	<20	0.5	1	18	23	0
3FM524	Branch vein (northern part)	0.5	0.3ppm	36.0	81	912	153	0.1
3FM525	Branch vein (northern part)	2.3	0.5ppm	5.9	23	813	313	0.1
3FM527	Branch vein (northern part)	1.7	20	3.0	350	960	320	0.1
3SM514	Branch vein (middle part)	2.0	0.4ppm	3.7	9	223	222	1.1
3SM515	Branch vein (middle part)	0.4	<20	0.1	3	21	26	0

Two levels of drift are opened into this mine. The lower level is at 660 m above sea level, the upper level at 715 m, with a 55 m difference of elevation. Due to the collapse around 15 m from the adit, a total extension of the drifts is not known, but it must be very short, inferring from the amount of waste heaps (300 m^3 for the lower level, 90 m^3 for the upper level). While the total extension of the main veins attains 4,000 m as mentioned already, there are only these two drifts.

(2) Hydrothermal alteration zone

Alteration zones are found at about 20 localities in this area, as shown in PLATE 11. Their distribution is rather sporadic, except in the west of Puerto Ibañez. They are generally small in scale, with an average area of 500 m x 200 m. In most cases, alteration is medium-grade silicification and weak argillization. Principal products of alteration are quartz and kaolin minerals, with a small amount of sericite. Many of alteration zones contain dissemination or partly stockwork of pyrite, limonite, hematite and quartz. In alteration zones No.3 and No. 24, several streaks of galena, sphalerite and chalcopyrite are developed.

The alteration zones to the west of Puerto Ibañez are developed around dacite (intrusive rock), suggesting their close metallogenetic relation with the dacite. As mentioned before, the dacite is intruding the Divisadero Formation, so that the formative epoch of the alteration zones must have been after the deposition of the Divisadero Formation, that is, since the Cenomanian Stage. The reference ore grades of the respective alteration zones are presented in Table 1 in Appendix.

Described in the following are alteration zones No.3 and No.24 which have higher degree of alteration and are larger than the other alteration zones of the area.

1) Alteration zone No. 3

Alteration zones are developed to the north and south of Lake Verde. The northern one is tentatively called No. 3 and the southern one No. 4, but the two are considered to be continuous and treated as one zone. The zone, with a dimension of 2.7 x 0.6 km, extends in the north to south direction and narrows southward. The type of alteration is chiefly silicification, though a weak kaolinitization is also noticed. The host rocks are rhyolite, tuff and andesite of the Ibañez Formation.

The central part of the northern alteration zone yields sphalerite, galena and chalcopyrite, in veinlets (about 3 cm in width) and stockworks. The sphere of such metalliferous deposit is as wide as about 300 m, but the mineral contents are low, and the development of the deposit does not reach the south shore of Lake Verde.

Sample No.	Sampling locality	Au	Ag	Cu	Pb	Zn	S
3VM531H	North shore of Lake Verde	<20	7.3	8	0.11%	0.52%	0.29%
3VM531J	North shore of Lake Verde	<20	4.5	31	0.29%	0.18%	0.84%
3VM531L	North shore of Lake Verde	<20	1.1	6	212	41	0.11%
3VM531N	North shore of Lake Verde	<20	1.3	13	198	310	0.24%
3FM548	South shore of Lake Verde	<20	0.2	12	24	29	0.018%
3FM549	South shore of Lake Verde	<20	0.2	2	68	13	0.24%

Au is in ppb, other elements are in ppm.

2) Alteration zone No. 24

This zone is developed along the ridge in the southern middle reaches of the Largo River. As it is widely covered with the glacial deposit, its occurrence looks sporadic, but below the cover there is a possibility of the zone's further continuance. Presuming it is continuous, this alteration zone would be fairly large in scale, at least 2 km long and 0.5 km wide.

The central part of this alteration zone is argillized, mainly kaolin, but the marginal part has a silicified vein, several meters wide, and in this vein a large number of quartz veins (5 to 10 mm wide) are developed. Some of these veinlets of quartz are accompanied by a very small amount of galena dissemination. The principal alteration minerals are listed in Table 10 in Appendix. The data in Table 10 indicate that alteration zone No. 24 is characterized by acidic alteration. The assay results of the representative samples from this zone are as follows:

Sample No.	Sampling locality	Au	Ag	Cu	Pb	Zn	S
3TM554	Eastern argillized belt	<20	0.1	6	27	93	0.04%
3TM557	Western argillized belt	<20	1.3	6	321	121	0.06%
3TM558	Western silicified belt	<20	5.9	12	0.37%	123	1.385
3TM559	Western argillized belt	<20	1.2	4	89	161	0.02%
3TM560	Ditto	<20	0.6	4	102	154	0.01%
3TM561	Eastern silicified belt	120	2.5	62	0.35%	85	0.11%
3TM566		<20	0.4	74	169	72	0.07%

Au is in ppb, other elements are in ppm.

4.4. Geochemical Exploration

4.4.1. Sampling and assaying

Panning geochemistry was used because the major target was gold-silver. Total of 67 panned concentrate samples were collected and their localities are shown in PLATE 21. Samples were basically collected from immediately above the bedrock or clay bed where the heavy detrital minerals, especially gold grains are concentrated. About 20 of assay samples were concentrated by panning from about 8 kg of stream sediments. Samples were assayed for six elements, Au, Ag, Cu, Pb, Zn and As at SERNAGEOMIN Laboratory. The detection limits and analytical methods used are the same as those of Chapter 1.

4.4.2. Statistical data-processing

(1) Results of assaying

Assay results are listed in Table 5 in Appendix. Their characteristic features are summarized as follows:

The number of samples containing Au above the detection limit was 47 (30 %). Eleven of them contained Au in amounts in order of ppm. All samples contained Ag in amounts above the detection limit, but the all of them were less than 10 ppm with the exception of one sample. Cu and Pb assay results were also very low. That is, only two samples for Cu and nine samples for Pb were above 100 ppm. On the other hand, many Zn assays ranged between 200 and 300 ppm, but only 6 % of samples showed grades less than 100 ppm. Grades of As were generally low and only 6 % of samples were above the detection limit.

(2) Elemental statistics

Elemental statistic parameters are listed in TableII-4-2.

TableII-4-2 Elemental Statistics Parameters in Geochemistry of the Ibañez-Murta Area (South)

	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	As(ppm)
Mean	19.7	0.3	7.6	20.0	261.4	2.6
Max.	5600	34.1	186	1202	1053	88
Min.	5	0.1	1	1	46	2.5
m+σ	103.2	0.7	17.5	50.2	388.9	4.0
m+2σ	540.8	1.8	40.2	126.3	578.4	6.0

(3) Frequency distribution pattern

Frequency distribution histograms are shown in Fig.II-4-8. As shown,

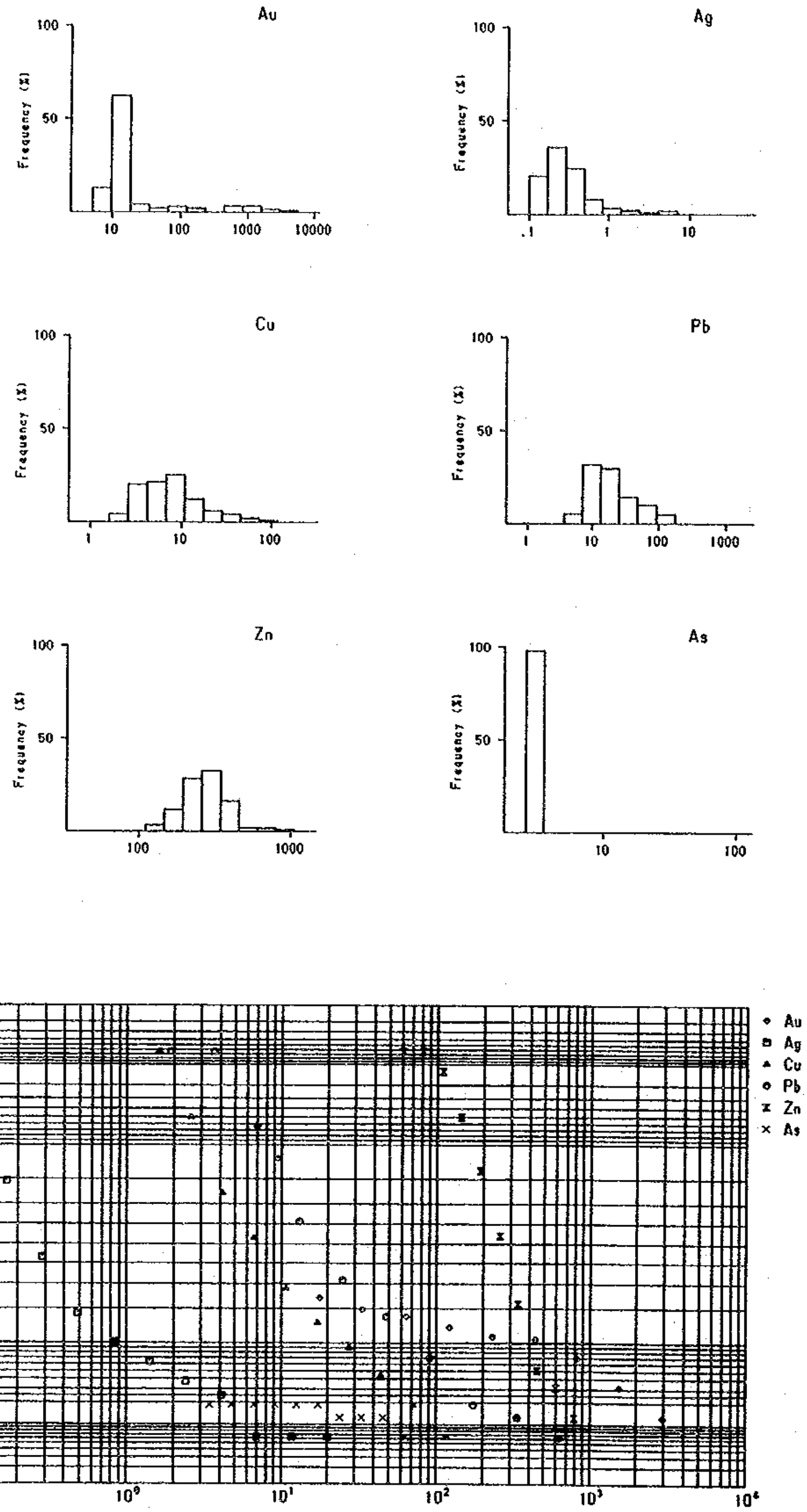


Fig. II -4-8 Histograms and Cumulative Frequency Curves Showing Frequency Distribution Patterns of Assays on Panned Concentrate Geochemical Samples Collected in the Ibañez-Murta Area (South) elements which are believed to follow a log-normal distribution are Ag, Cu, Pb and Zn. Frequency distribution of Au is grouped into two populations that their distribution centers are situated around the detection limit and 1000 ppb respectively. The most of As grades were below the detection limit.

(4) Correlation

Correlation coefficients are listed in Table II-4-3. Elements pairs showing coefficients higher than 0.5 are as follows:-

Cu-Zn: 0.606
Pb-Zn: 0.606
Cu-Ag: 0.585
Ag-Pb: 0.583
Au-Ag: 0.564

Table II-4-3 Correlation Coefficients between Elements Pairs in Geochemistry of the Ibañez-Murta Area (South)

	Au	Ag	Cu	Pb	Zn	As
Au	1.00000					
Ag	0.56470	1.00000				
Cu	0.36666	0.58572	1.00000			
Pb	0.36149	0.58380	0.60693	1.00000		
Zn	0.20243	0.38660	0.27638	0.60629	1.00000	
As	0.24684	0.31239	0.34960	0.21249	0.11692	1.00000

(5) Principal component analysis

Eigen vectors and eigen values are listed in Table II-4-4. Statistic meanings of each principal component are summarized as follows:-

First principal component

Every eigen vectors are positive numbers and in same level.

Second principal component

The eigen vectors of both Pb and Zn are positive numbers and similar values. Combinations of Au-As and Ag-Cu retain negative and similar eigen vectors respectively. Those combinations of metals match the general features of mineralization so that this principal component is believed to represent the mineralization of this area.

Third principal component

Absolute values of Au and As eigen vectors are large, but their signs are opposite each other.

Table II-4-4 Eigen Vectors and Eigen Values of Principal Component Analysis of the Ibañez-Murta Area (South)

	1	2	3	4	5	6
Au	0.37252	-0.30437	-0.65682	-0.39504	0.42057	-0.06522
Ag	0.48406	-0.09128	-0.24860	0.04658	-0.83096	0.05374
Cu	0.44881	-0.13009	0.11303	0.68120	0.24821	-0.49319
Pb	0.47797	0.34407	0.10680	0.16943	0.26581	0.73647
Zn	0.35226	0.61910	0.25042	-0.48064	0.00650	-0.44594
As	0.27009	-0.61680	0.64800	-0.34355	0.01789	0.09148
Eigen	3.00975	1.00587	0.77115	0.60706	0.34275	0.26342
Prop.	0.50162	0.16765	0.12853	0.10118	0.05713	0.04390
Cum. prop.	0.50162	0.66927	0.79780	0.89897	0.95610	1.00000

Those three principal components account for about 80% of total variance contributed by each eigen value.

Scores for the second principal components were calculated and listed in Table 7 in Appendix.

4.4.3. Geochemical anomalies and anomalous zones

(1) Threshold

Ag, Cu, Pb and Zn each make up one population each that follows a log-normal distribution so that $m+2\sigma$ values were selected for thresholds. Frequency distribution of Au is separated to two populations as mentioned above. On the basis of the idea that the higher population is the anomalous population, the lower limit of that sub-population was used for Au threshold. This cuts the whole Au population at the upper 1.5 %. As population is obviously discrete at the detection limit value and the threshold was fixed at that point. Thresholds used in this work are listed below.

Thresholds

Elements	Thresholds
Au	316 ppb
Ag	1.8 ppm
Cu	40 ppm
Pb	126 ppm
Zn	578 ppm
As	5 ppm

(2) Geochemically anomalous zones

Numbers of the geochemical anomalies are as shown below.

Numbers of Geochemical Anomalies

Elements	Numbers of Anomaly
Au	18
Ag	9
Cu	7
Pb	5
Zn	6
As	3

Those anomalies are plotted in PLATE 16. Distribution features of anomalies are described as below.

1) Au

Au anomalies are distributed a little densely in the northeastern area to Cerro Castillo Village and the northern and the western area of Puerto Ibañez. Anomalies around Puerto Ibañez occur as single anomalies in many cases.

2) Ag

Ag anomalies accompany the Au anomalies and three other dense anomalies were obtained in the west of Lake Laparrent.

3) Cu

Cu anomalies are in relatively dense distribution in the northern area to Cerro Castillo Village and the western part of the area.

4) Pb and Zn

Both anomalies occur in the same points in general. They are distributed densely in the western area of Puerto Ibañez.

5) As

Very few anomalies are diffused all over the area and it is hard to grasp the distribution pattern.

Sample points showing scores greater than 1.0 are distributed densely in the western area to Puerto Ibañez. Pb-Zn vein-type deposits are concentrated relatively densely in this area. Thus, Pb-Zn geochemical anomalies are believed to be derived from Pb-Zn mineralization. As to Au anomalies distributed to the north area of Puerto Ibañez, visible gold grains were observed in some samples (VP505 and VP513). They strongly suggest the existence of gold mineralization. Other anomalies are negligible.

4.5. Evaluation

(1) Geologic structure and mineralization

The Ibañez Formation of this area are gently folded with fold axes in the NE-SW direction and major fractures are developed with N20°W strike perpendicular to the fold axes. Principal vein-type ore deposits occur parallel to the fracture system. These deposits also are densely distributed in the eastern part where the fractures in the N20°W strike are well developed (Fig.II-4-9).

In view of above tectonic points, it is inferred that the N20°W tensional fractures were formed by the compressional stress in the NNW-SSE direction, resulting in the formation of the deposits along some of the fractures.

(2) Related igneous rocks and timing of mineralization

The ore deposits and hydrothermal alteration zones of this area are hosted by the Ibañez and Dividadero Formations, and are cut by basaltic dikes. It is reported the dikes intruded during the Pliocene (Skarmeta, 1978). On the other hand, small alteration zones are sporadically distributed to the west of Puerto Ibañez, occurring within and near the dacite dikes. The alteration appears to be closely associated with the intrusion of dikes because the dikes were also subjected to weak silicification or argillization. The alteration zones are believed to be formed after Middle Cretaceous, because the dikes intruded into the Divisadero Formation.

The above discussions suggest that the timing of mineralization was during the period between Late Cretaceous and Pliocene. However, the mineralization together with alteration presumably took place during the Late Cretaceous because it likely has a genetical relation to the acidic volcanism that resulted in the Divisadero Formation.

The other types of intrusive rocks are believed to have no relation to the mineralization because of their unaltered lithofacies.

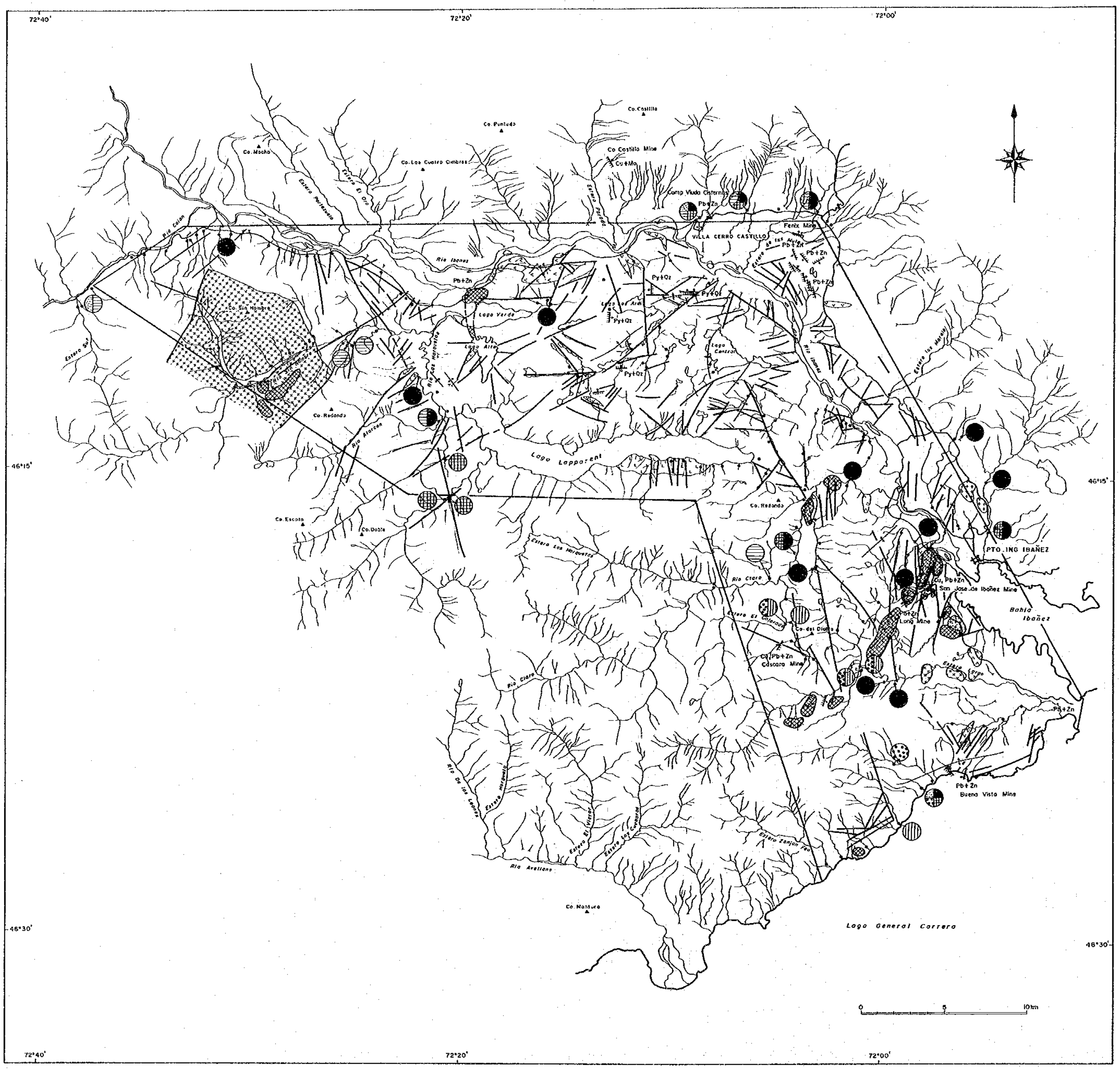


Fig. II-4-9 Collective Interpretation Map of the Ibañez-Murta Area (South)

CHAPTER 5. CHILE CHICO-CHACABUCO AREA

5.1. Photogeological Interpretation

5.1.1. Procedure of interpretation

(1) Data used

The areal extension of the interpretation is already shown in Fig.Ⅱ-4-1. Details of aerial photographs used for this area are the same as those in the Ibañez-Murta Area (South). Total of 57 photographs were used for the interpretation.

Numbers of prints for each series are shown below.

Photo-number series	Number of prints	Photo-number series	Number of prints
2421 to 2427	7	2128 to 2137	10
2396 to 2402	7	2178 to 2189	13
2358 to 2365	8	2210 to 2221	12

Total: 57 photographs

(2) Procedure of interpretation

Photogeological interpretation of this area was carried out with the same procedure and with the same diagnostic criteria as described in 4.1.1.

5.1.2. Results of interpretation

(1) Classification of photogeological units

Photogeological interpretation map is shown in PLATE 2. Eight units were discriminated in this area. Their photo-characteristics and geomorphological features are summarized in Table Ⅱ-5-1.

a. Unit M

This unit is broadly distributed in the northern, western, and southerr parts of the area and encloses the other units. Rock resistance is relatively high in some places of the western part and there the unit forms mountains with high relief energy. Other parts generally are represented by gently undulating hills. The unit shows densely striped texture and crenulation patterns that imply the bedding planes or schistosities. From these features the unit is believed to consist mainly of metamorphic rocks.

b. Unit J

Table II-5-1 Photogeological Interpretation Chart of the Chile Chico-Chacabuco Area

Unit	Photo – Characteristics		Mophological – Expression					Cover	Conclosion	
			Drainage		Rock Properties					
	Tone	Texture	Pattern	Density	Registance	Cros Section	Bedding	Vegetation	Probable Lithology	Existing Geological data
Q_2	light ~ light gray	fine . smooth	meandering	very low	very low		none	sparse	alluvium , fluviam	alluvium , fluviam
Q_1	light gray	fine	parallel, dendritic	low	low		none	sparse	terrace	alluvium , fluviam
T_2	light, light gray	fine	dendritic	high	low ~ medium		very well bedded	moderate	sedimentary rocks	sedimentary rocks
T_1	light gray medium gray	coarse	dendritic	medium	medium		very well bedded	moderate dense	sedimentary rocks	sedimentary rocks
C	light gray medium gray	coarse	dendritic	low	high		partly bedded	dense	volcanic rocks	volcanic rocks
J	gray	fine	dendritic	low	medium		bedded	moderate dense	volcanic rocks sedimentary rocks	volcanic rocks
M	medium gray dark gray	rough speckied	angular	medium	medium ~ high		well bedded	moderate	metamorphic rocks	metamorphic rocks
I	medium gray	rough	dendritic	low	medium		massive	moderate	intrusive rocks	intrusive rocks

This unit is continuously distributed in the eastern and southern part of the area. The unit appears to overlie the Unit M unconformably. Although the unit generally occupies the piedmont portions of low altitude, it is distributed in high altitude in the south. This unit generally shows high rock resistance and forms cliffs of thick sequence. Back slopes and front slopes are locally observed. These features suggest that the unit is composed of sedimentary rocks.

c. Unit C

This unit is confined to the eastern part of the area. Topography of this unit is very steep with high relief energy and shape of ridges is very narrow. Few bedding can be observed in this unit. The unit probably consists of massive volcanic rocks.

d. Unit T_1

This unit is distributed in the middle of the area and encloses the Unit T_2 which will be described later. Tone of the unit is light and beddings are distinctly observed. Alternating beds of high and low rock resistances show striped patterns on photographs. The unit is believed to consist of coarse-grained sedimentary rocks.

e. Unit T_2

This unit is distributed in the middle of this area and is elongated in the N-S direction. Although features of this unit are considerably similar to those of the Unit T_1, this unit is distinguished from the Unit T_1 by lighter tone and finer texture than those of the Unit T_1. From these factors it appears that this unit is composed of fine-grained sedimentary rocks.

f. Unit Q_1

This unit is distributed in the northern and southern parts of the area. It seems that the unit overlies the other units unconformably. Topography of this unit is homogeneously flat and the edges of the unit form cliffs. This type of landform indicates that the unit consists of terrace deposits.

g. Unit Q_2

This unit is distributed in valleys of main rivers, river-mouths, and piedmont portions. From its landform this unit is believed to consist of fluvial deposits of present rivers, talus, and fan deposits.

h. Unit I

Distribution of this unit is confined to the northern part of this area. The unit is sporadically distributed in the Unit M, however, it is distinguished from the Unit M by lighter tone and protruding topography. This landform suggests this unit to be intrusive rocks.

(2) Geologic structure

a. Photolineaments

Photolineaments are extracted densely in the western part of this area where the Unit M is distributed as shown in PLATE 2. Few are recognized in the middle and eastern part of the area. Their directions are dominated by the NE-SW.

b. Fold

Abundant beddings are recognized in the Units T_1 and T_2, forming back slopes and front slopes in several places. The back slope itself is a dip slope of sedimentary rocks. The back slopes strike the N-S direction and dip east along the Las Dunus River in the western side, while they dip west along the Las Horquetas River in the eastern side. Furthermore back slopes observed on photographs tend to change their strikes to the E-W direction toward the north and south. They dip south and north in the northern and southern parts respectively.

Based on these information a plunging synclinal structure was recognized around the ridge elongated in the N-S direction between the two rivers mentioned above. The axis of this structure trends in the N-S direction in the northern part and turns to the NNE-SSW in the southern part. The structure is characterized by asymmetric syncline since the eastern flank steeply dips west and the western flank gently dips east.

5.2. Geology

5.2.1. Stratigraphy

The basement of this area is composed of the Late Paleozoic complex of metamorphic rocks, mostly pelitic schist. Unconformably overlying the complex are volcanic and pyroclastic rocks of Jurassic Period (Middle to Late) and Cretaceous Period (Aptian to Cenomanian), sedimentary rocks of the Tertiary Period (Late Eocene to Early Pliocene), and unconsolidated Quaternary sediments.

The metamorphic complex (called basement metamorphics, hereafter) which constitutes the lowermost part of the stratigraphic sequence has not been given a geological name. The Jurassic System is composed of the Ibañez Formation and the Cretaceous System of the Divisadero Formation. The Tertiary sedimentary rocks are divided into the Guadal Formation in the lower part and the Galera Formation in the upper part. Fig.II-5-1 shows the geological map, and the schematic columnar section is given in Fig.II-5-2. Intrusive rocks will be described in 5.2.2.

(1) Basement metamorphics

The metamorphic rocks consistuting the basement of this area are widely distributed in the western to southern part and in the eastern part of the area. They are chiefly pelitic schist, with subordinate amounts of basic schist, calcareous schist and siliceous schist. All these rocks are crystalline schists of low metamorphic grade , but they have undergone intense deformation. In the pelitic schist, particularly, the axial plane cleavage (S_2 plane), which defies reproduction of the enveloping surface of folds (S_1 plane), is developed everywhere, along with the crenulation cleavage. On account of such mode of occurrence it is difficult to represent the overall aspects of stratigraphy and structure of the basement metamorphics with the result of sparse fieldwork. Nevertheless, helped by the presence of schistosity resembling the original rock's sedimentary structure a standard stratigraphic sequence has obtained, as indicated in Figure II-5-2. Since the basement metamorphics are considered to extend deeper underground, even with their marked deformation, their thickness can be estimated to exceed 2,000 m.

In recent years, the basement metamorphics have been modeled with the theory of plate tectonics, and are interpreted as an accretionary prism produced by the subduction of the rock mass from the west since the Carboniferous period, just like the case of the large-scale rock body of the Coastal Range (Mpodozis, C. and Ramos, V., 1989). The siliceous schist is excluded from the geological map, because it occurs as only several meters thick intercalations within the pelitic schist and its extension seldom exceeding several tens of meters. The lithofacies of each schist is described in the following.

1) Pelitic schist

The major portion of this rock is mica schist, composed of black to grayish black pelitic parts and white quartzose parts produced by segregation. These two parts alternate at several millimeter intervals. These alternating parts account for the schistosity of the mica schist. As the pelitic part is usually rich in alumina, minute pieces of muscovite make up the principal component, accompanied by small amounts of chlorite and graphite. The pelitic schist is poorly resistant to weathering erosion, due to the presence of schistosity, cleavage with minor folds and kink folds. Therefore, this rock does not make a steep terrain. Since the grade of metamorphism is low, biotite occurs only in a very small amount, but in Mineral indication No.1 at the northeastern end of the area, where contact metamorphism by intrusive rocks of latent existence caused polymetamorphism of the rock, the reddish brown pelitic part contains a large quantity of biotite. Also the white quartzose part was recrystallized and turned very hard and compact (locality 3MT712).

2) Basic schist and metabasite

These rocks, occurring as lenticular bodies within the pelitic schist, are distributed on a small scale in such areas as the neighborhood of Mallin Grande in the northeastern part, the south of Puerto Guadal in the northeastern part, the south of Puerto Guadal in the western part, and along the major streams of the Bertrand River. The rocks are classified into chlorite-epidote schist of low metamorphic grade with a chlorite schist facies, and metadiabase. Their original rocks are believed to be basic tuff and diabase, respectively; the former's structure can be defined because of the developed schistosity, whereas the latter, being massive, is generally indistinct in structure. As mentioned above, the pelitic schist is marked with minor folds and behaves as an incompetent rock to deformation, but the crystalline schist belonging to this rock group is devoid of such minor folds and so it can be regarded as competent to deformation. Accordingly, it is probable that the structures demonstrated by these rocks are reflecting, though partly, the structures of basement metamorphics. The maximum thickness of the basic schist and metabasite group is approximately 500 m.

3) Calcareous schist

This rock is distributed only at the spot 5 km northeast of Puerto Guadal. It occurs as lenticular layers forming three beds of varying thickness intercalated within the pelitic schist. The upper and middle beds are poor in continuity but the lower bed is traceable for about 2 km in the strike direction (southeast). A northwestward tracing is impossible due to the existence of Lake General Carrera. The lower bed is about 30 m thick on the whole, and it partially alternates with the pelitic schist in order of several centimeters thickness. The calcareous schist is generally gray to white. It shows schistosity where it alternates with the pelitic schist, but otherwise it is more or less massive. No minor folds are observed. Under the

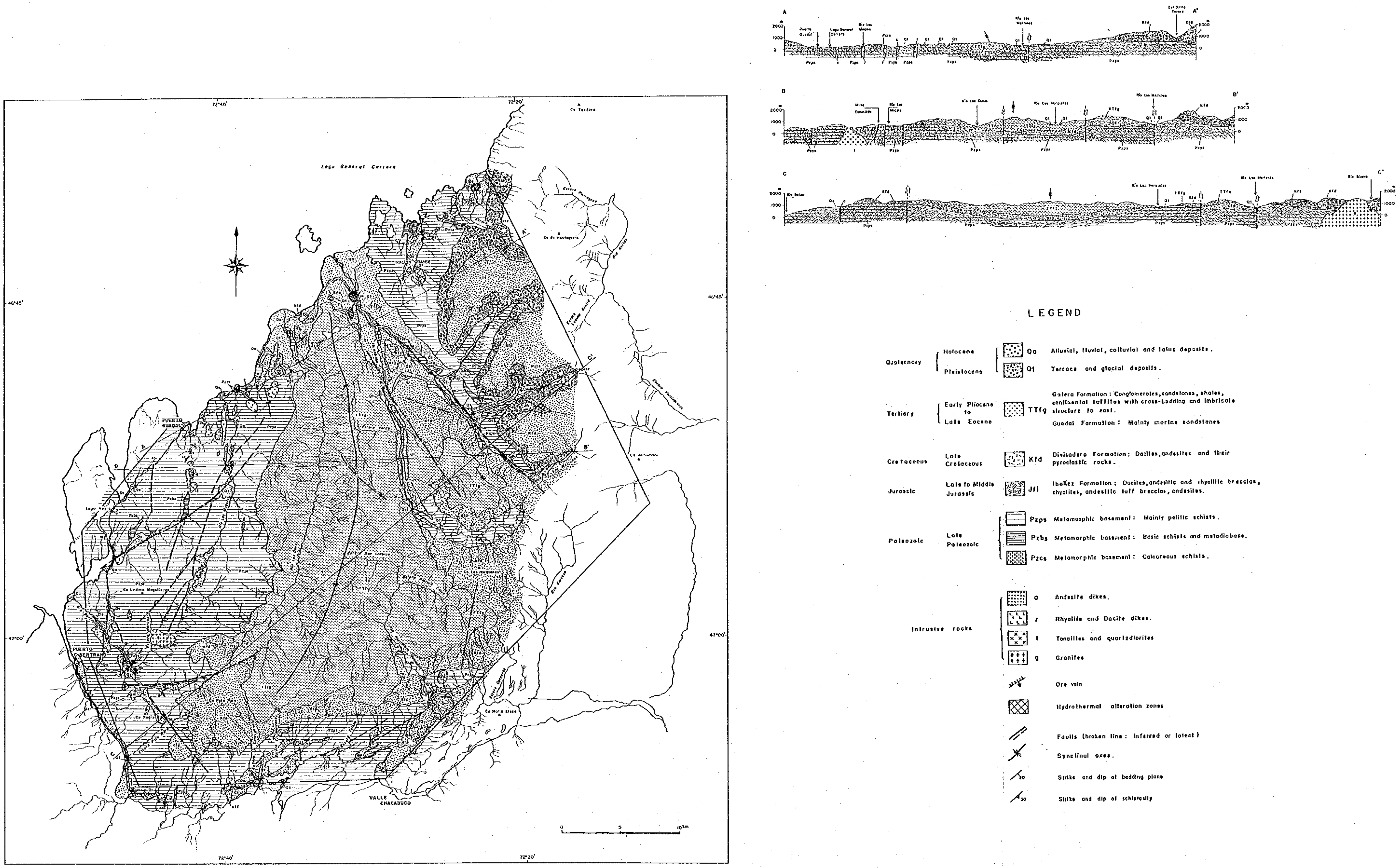


Fig. II-5-1 Geological Map of the Chile Chico-Chacabuco Area

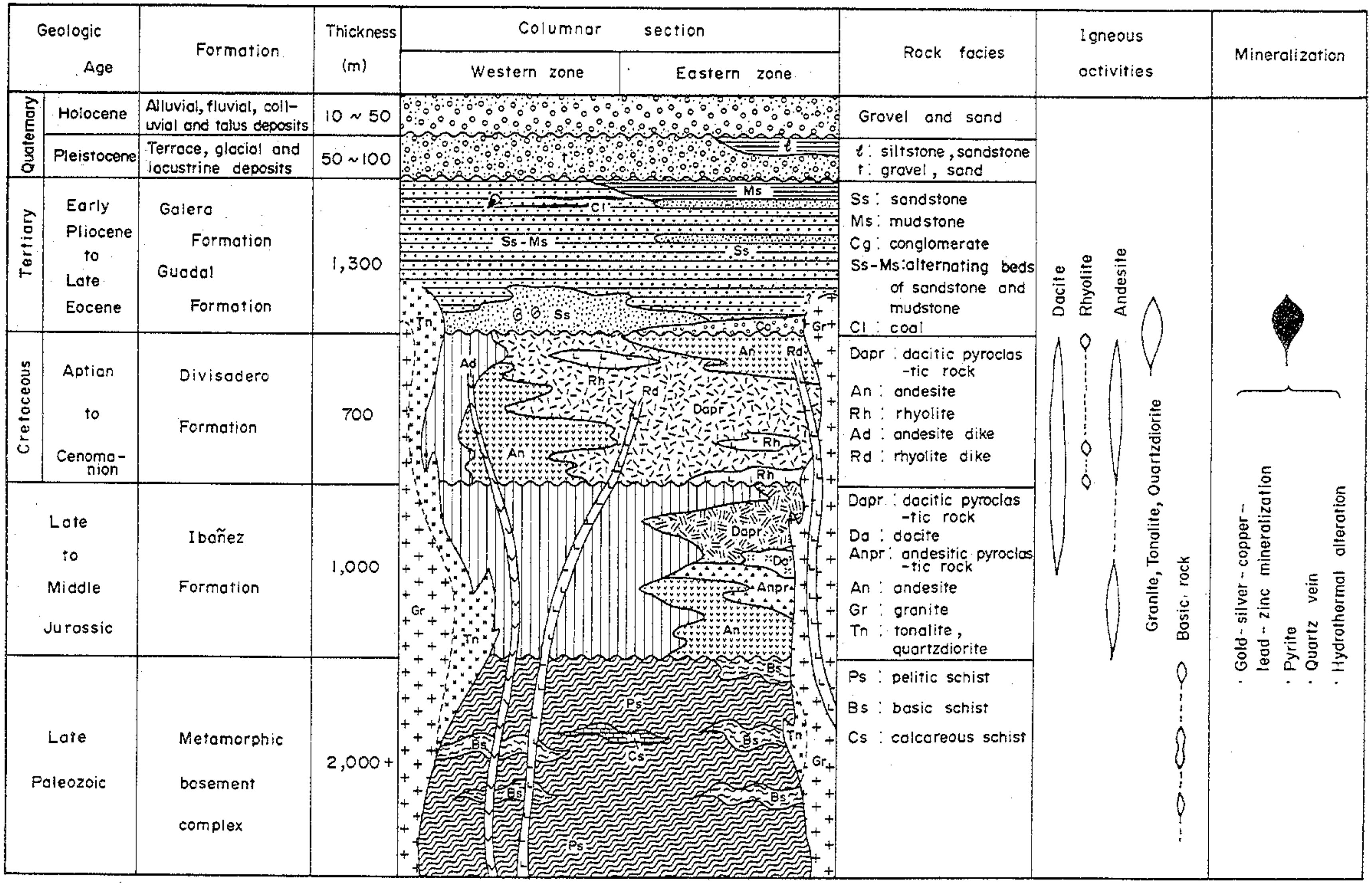


Fig. II-5-2 Schematic Columnar Section of the Chile Chico-Chacabuco Area microscope an abundance of recrystallized calcite is recognized besides a small amount of quartz. Veinlets of calcite cutting the texture of the rock are also noticed.

(2) Ibañez Formation

The Ibañez Formation is located in the northeast of the Los Maitenes River in the northeastern part of the area, where it overlies the basement metamorphics with unconformity. From the fact that the formation is not distributed in the southwest of a fault presumably existing on the above-mentioned river, the volcanic activity in that period might not have extended to the west of the northeastern part of the area.

As mentioned in Chapter 4 of the present volume, the stratigraphy of the Ibañez Formation at the type locality consists fundamentally of acidic volcanic and pyroclastic rocks in the lower part and intermediate ones in the upper part. In this area, however, the lower part of the formation is composed of andesitic rocks and the upper part is dacitic to rhyolitic rocks; the former is distributed by far extensively, while the latter's distribution is limited to the upper reaches of the Blanco River, a tributary of the Los Maitenes River.

The andesitic rocks have the following lithofacies:

(a) Dark green basaltic andesite lava (propylitic).
(b) Green or reddish purple lava of amygdaloidal texture.
(c) Reddish purple lapilli tuff.

Under the microscope the rocks of (a) have porphyritic texture, consisting of plagioclase and pyroxene for both the groundmass and phenocrysts. Alteration is remarkable, resulting in the occurrence of abundant chlorite and kaolinite, with subordinate amounts of calcite and epidote.

The dacitic or rhyolitic rocks have the following characteristics:

(d) Purple to reddish brown or gray lava of pauci-phenocryst texture.
(e) Gray, extremely hard and compact lapilli tuff or crystalline tuff (partly welded tuff).

The rock of (e) under the microscope shows cataclastic texture which suggests that brittle fracture has taken place. Quartz and plagioclase fragments are abundant, with less biotite and orthoclase. The matrix contains a large amount of sericite. The maximum thickness of the Ibañez Formation is estimated to be about 1,000 m.

(3) Divisadero Formation

Distribution of the Divisadero Formation is generally continuous, extending from northeastern part, through the eastern and southern parts, to the southwestern part of the area. In the area east of the Los Maitenes River, the formation unconformably overlies the Ibañez Formation, but to the west of the river it always overlies the basement metamorphics unconformably. In the Ibañez-Murta Area (North) mentioned in Chapter 3, the Divisadero Formation is composed chiefly of dacitic pyroclastic rocks, as thick as 2,500 m or more, but in the present area the formation locally varies in both lithology and structure, and contains a fair amount of andesitic rocks also. In the northeastern part, for instance, the lower part of the formation consists of dacitic volcanic rocks intercalated with rhyolite lava, and these rocks are covered by andesite lava of the upper part. In the southern part the formation is composed mostly of dacitic pyroclastics, but in the southwestern part andesite lava is widely distributed along the upper course of the Bertrand River.

The stratigraphic sequence of the formation's principal portion was observed continuously in the mountainland west of the Los Maitenes River in the northeastern part, where the following lithology, in ascending order, were identified.

- Light green to light grayish pink dacitic lapilli tuff or coarse tuff; quartz grains are abundant, lapillis are chloritized, welded structure is noticed in part. It is intercalated with pale green fine tuff. Bedding is developed in general. The thickness is +400 m.
- Light gray rhyolite lava; flow structure is developed, and the lava forms steep cliffs. The thickness is 50 to 70 m.
- Green dacitic lapilli tuff; somewhat massive, quartz abundant in matrix. The tuff is dacitic but contains andesitic lapilli as well. The thickness is approximately 250 m.
- Green basaltic andesite lava; the texture is partly porphyritic. The thickness is ±300 m.

On the other hand, the Divisadero Formation in the southern part consists mostly of pale green dacitic lapilli tuff and rhyolite lava, whereas in the southwestern part green andesite lava is widely distributed.

(4) Tertiary System (Guadal Formation and Galera Formation)

The Tertiary System occurs in the central part of this area. Its distribution extends about 35 km north to south with an average width about 15 km east to west. The regional distribution of the Tertiary System in the Aysen Region is mainly limited to the Andina Outer Zone (Zona Extraandina) near the Argentine border, but on the west side of the zone, namely the fore range (Precordillera), the Tertiary System occurs only in the present area with a wide distribution. As mentioned in 5.2.1, the Tertiary System in this area is divided into the Guadal Formation in the lower part and the Galera Formation in the upper part. However, the fieldwork did not go beyond local observation because the Tertiary System is a post-mineralization formation, and so it was excluded from the target for the exploration of ore deposits.

The lithofacies is represented by the alternation of gray, red and pale green medium-grained sandstone and black or reddish purple mudstone. The alternation is dominantly developed in the principal part of the distribution area. The lower part is locally composed of gray medium-grained sandstone, a certain horizon of which yields molluscan fossils in large quantities. Identified fossils are Cardium philippii, Chione patagonica and Turritella ambulacrum. These molluscas characterize the marine Tertiary Guadal Formation (Late Oligocene to Early Miocene). The upper part is reportedly intercalated with coal seams.

(5) Quaternary System

The Quaternary System of this area is divided into the Pleistocene Series, consisting of fluvial terrace deposit, glacial deposit and lacustrine deposit, and the Holocene Series composed of alluvial deposit. The two series are distinguished on the geological map.

The greater part of the Pleistocene Series is terrace deposit which is distributed along the courses of such major rivers as the Los Maitenes, Las Horquestas, Bertrand and Chacabuco. At least three terrace planes are recognized throughout the area, but they are treated collectively on the geological map. The relative height between the high-level terrace plane and the existing river bed exceeds 100 m at maximum. Glacial deposit and lacustrine deposit are meagerly distributed at the northeastern end of the area.

Among the alluvial deposit, the current river bed deposit is found in some places along the Chacabuco and Los Maitenes Rivers. But the downward erosion is very active, as seen in the Las Horquestas and las Dunas Rivers where the channels are quite narrow for a deposit to accumulate. On the other hand, the delta deposit is developed at the mouths of the Los Maitenes and las Dunas Rivers.

5.2.2. Intrusive rocks

In this area are distributed dikes and plutonic rocks of interdemiate to felsic compositions. Outcrops of these rocks are concentrated around Puerto Guadal in the northwestern part. The dikes are classified by rock types into andesite (a) and rhyolite or dacite (r), and the plutonic rocks into tonalite or quartz diorite (t) and granite(g).

- Andesite dike (a): It was recognized at eight localities, intruding the pelitic schist. The width is 50 to 100 m, and the maximum extension is approximately 1 km. In general, it is a green to dark green compact rock, and the mafic minerals are chloritized. The principal direction of intrusion is NNE-SSW.
- Rhyolite or dacite dike (r): This dike, also intruding the pelitic schist, is observed at 18 localities. The width is 50 to 300 m, with maximum extension about 3.5 km. It is generally cream-colored and porphyritic. The size of quartz phenocrysts is about 1 mm. Dikes of this type are concentrated in the east of Puerto Guadal, showing N-S to NNE-SSW directions of intrusion.
- Tonalite or quartz diorite (t): Tonalite also intrudes the pelitic schist and is observed at 14 localities. Outcrops are small in scale, with the maximum being 1 km x 1 km. Tonalite occurs as six bodies in the east and south of Puerto Guadal. The rock is holocrystalline and medium-grained. Mafic minerals are hornblende and biotite. Dating by the K-Ar method revealed the age of 115 Ma (Table 11 in Appendix).
  Quartz diorite is distributed to the west of the Las Dunas River and other places. The rock is generally dark green, holocrystalline and fine-grained. Mafic minerals are almost completely chloritized. Macroscopic direction of intrusion is N-S to NNE-SSW.
- Granite (g): Granite occurs as three bodies in the eastern and western parts. The body in the eastern part intrudes the Ibañez Formation. It is holocrystalline, medium- to coarse-grained, with potassium feldspar and biotite as the major constituents.

5.2.3. Geologic structure

(1) Fold

The basement metamorphics, widely distributed in the marginal parts of the present area, are composed mostly of pelitic schist. As mentioned in (1) of 5.2.1., the pelitic schist is marked with axial plane cleavage, and is intricately deformed to an incompetent formation, so that its original structure cannot be defined from the axial plane schistosity. Moreover, as the rock lacks traceable key beds such as those in psammitic rocks, fold structure is hardly discernible. Nevertheless, on the basis of the spatial disposition of S_1 plane of the pelitic schist (inclusive of the part alternating with calcareous schist) observed in various places of the area, and the basic schist that can be regarded as a competent formation, the following macroscopic structures were recognized. The dip is generally within a range of 30 to 50°.

- Northeastern part (in the vicinity of Mallin Grande); strike NE-SE, dip NW.
- Northeastern part (upper course of the Los Maitenes River); strike NW-SE, dip NE.
- Northwestern part (east of Puerto Guadal); strike N-S, dip E and W. An anticlinal structure of N-S trend is inferred.
- Northwestern part (south of Puerto Guadal); strike NNE-SSW, dip WNW.
- Southwestern part (in the vicinity of the Bertrand River); strike NE-SW, dip NW and NE. A synclinal structure striking NE-SW with 2 to 3 km wavelength is inferred.
- Southern part (in the vicinity of the Chacabuco River); strike NW-SE, dip SW.

The pelitic schist around the Chacabuco River in the southern part has suffered erosion by the glacier of about 10 km wide during the ice age, and a large number of roche moutonnée are observed in an ENE-WSW alignment which is not reflecting the structure of the pelitic schist.

The Ibañez Formation overlies the basement metamorphics with unconformity and has a structure entirely different from the latter; namely, the formation strikes generally NW-SE with a gentle NE dip (20 to 30°).

The Divisadero Formation in the northeastern part covers the Ibañez Formation and shows a nearly harmonious structure with the latter, but in other parts of the area it directly lies on the basement metamorphics and strike ENE-WSW or E-W on the whole and gently dips SSE or S together with somewhat horizontal portions.

The Tertiary System extends in a roughly N-S direction and forms a gently inclined synclinal structure that continues from the northern part (N-S trend) to the southern part (NNE-SSW trend). Where the structure plunges or occurs near the fault, both the strike and dip are fairly variable, but the system on the whole has an almost constant N-S strike which is especially distinct in the west limb. In the northern part, inclination of the east limb is slightly larger than the west limb. The synclinal axis runs always through the mountain ridge, indicating that the Tertiary system constitutes a typical synclinal ridge.

(2) Fault

In the northwestern part of this area, the faults of N-S, NNE-SSW and NE-SW systems occur mostly within the sphere of the pelitic schist's distribution. The basement metamorphics and some intrusive rocks are displaced by the faults of NE-SW system, but relative movements of other faults are not known. However, the faults of NNE-SSW system are almost concordant with the main direction of the intrusive rocks that are densely distributed in the neighborhood. On the other hand, the northeastern part has two faults of NW-SE system, one along the Los Maitenes River and the other in the west of the river, both with a considerable extension, the former as long as +20 km and the latter about 15 km. These faults are largely restricting the distribution of the Divisadero Formation and the Tertiary System, with the apparent vertical displacement of 500 m and 400 m, respectively, and in both cases the block on the northeast side was relatively uplifted. In the western and southern parts, there are the faults that displaced the Tertiary System, but they scarcely affected the geologic structure of the whole area.

5.3. Mineralization

Hitherto worked in this area are the Escondida Mine and the San Sebastian Mine. The ore deposit of the Escondida Mine comprises chalcopyrite as the major ore mineral, and quartz veins accompanied by galena and sphalerite. This mine was worked until 1981. The mine is excluded here, as it was described in the report of the first phase.

In the investigation of this phase, mineral indication was recognized at 13 localities. The location, properties and assay results are given in order of the locality number, as shown in Table 1 in Appendix. The San Sebastian

Mine is not numbered. Plate 12 indicates the localities of mineral occurrence. The types of ore deposit or mineralization are classified into vein, dissemination and stockwork vein. The principal ore minerals are limonite, pyrite, arsenopyrite, chalcopyrite, pyrrhotite, galena and sphalerite, but the silicification zone without any mineral veins shows only disseminations of pyrite and limonite in most cases.

The mode of occurrence and properties of the representative mineral indications (and ore deposits) in this area are given below.

(1) San Sebastian Mine

This mine is located at about 2 km south of Puerto Guadal, and belongs to the vein type. It was explored and exploited in the 1950s. The vein is reported to have a scope of about 300 m in strike direction and about 70 m in vertical extension. At present, approximately 50 m long drift (one level), prospecting gallery for branch veins (10 m or so) and a small heap of waste (5 m across, 2 m high) are only observed (Fig.II-5-3).

The vein occurs in the pelitic schist, filling the fissures of the rock. The major vein strikes generally N60°W and steeply dips NE. Principal sulfide minerals are sphalerite, galena and pyrite, accompanied by some chalcopyrite. The gangue mineral is quartz. The width of the observable vein is 5 to 10 cm, but it varies from place to place and is reported to have attained a maximum width of 90 cm at the time when the mine was active. Alteration of the host work is limited to the vein-side 20 cm which underwent silicificaiton. At a point about 50 m from the adit, there was a trench (10 m long, 1.5 m deep) dug in the direction perpendicular to the strike of the vein.

The grade of vein while being worked was comparatively high, recording Ag: 250g/t, Cu: 2.19%, Pb: 28% and Zn: 7.9%.

(2) Mineral Indication No. 1

The site is located near the Hernandes Bridge at the north-eastern end. The alteration zone has an extent of 100 x 300 m. There is no record of its prospecting or working.

The host rock of the alteration zone is the pelitic schist, one of the basement metamorphics. The schist turned into a polymetamorphic rock due to remarkable contact metamorphism. Thus, the felsic part has come to comprise recrystallized quartz of coarse grain size and dense texture, while in the

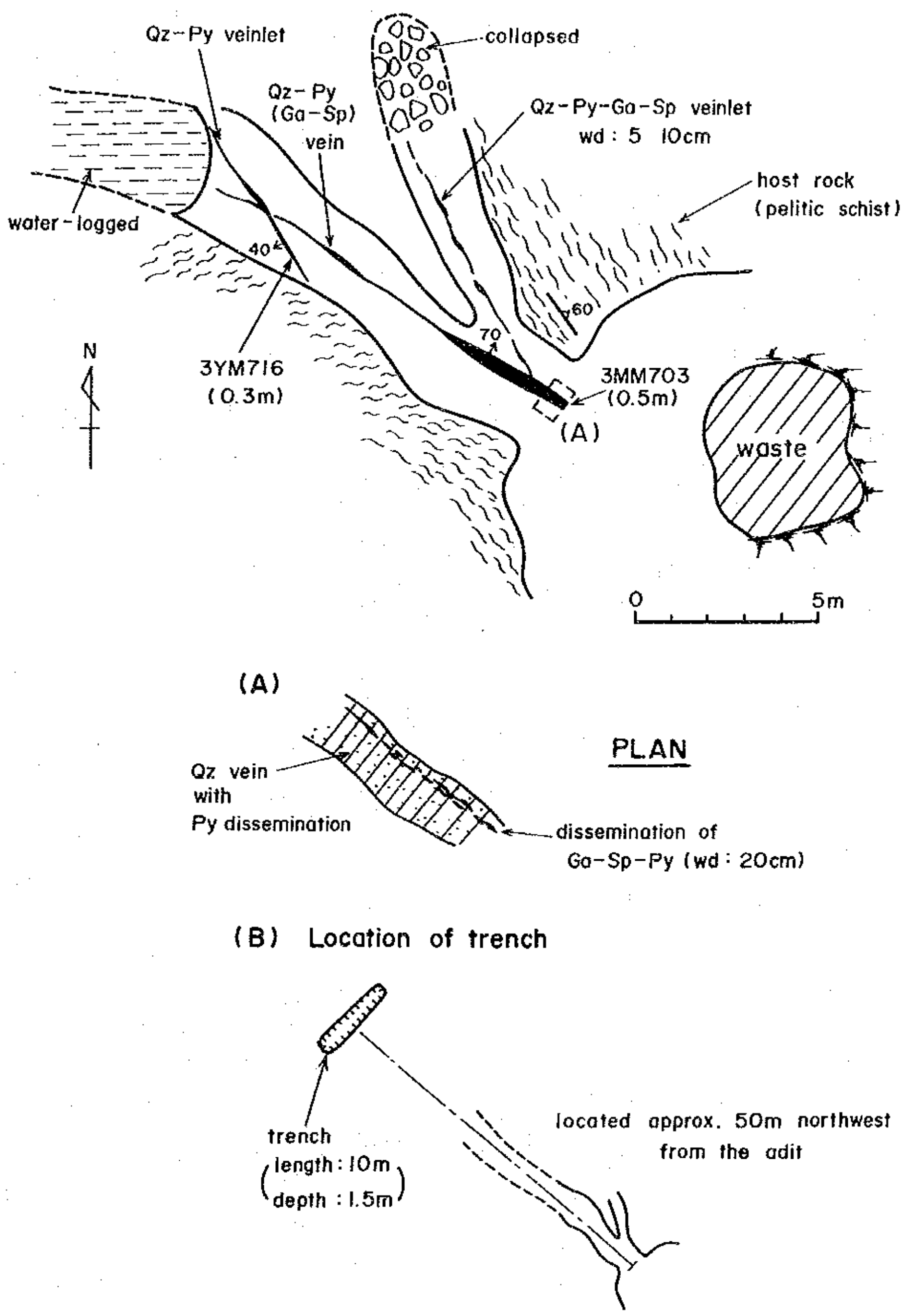


Fig. II-5-3 Plan Map of the San Sebastian Mine pelitic part a large quantity of biotite has been formed. These facts suggest the existence of a volcanic body at a shallow depth. Near the southern end of the alteration zone, a 6 to 10 cm wide vein of quartz and barite occurs, accompanied by chalcopyrite and pyrite (strike N81°E, dip 78°N). Veinlets of quartz and pyrite are often found, extending parallel to the quartz-barite vein. These veins are clearly cutting the schistosity of the host work. The alteration minerals of the vein-side metamorphic rock are quartz-chlorite-sericite. The analysis of the samples collected revealed the following result, low grade ore.

Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3MM712	80	2.6	1620	61	2675	3.24

(3) **Mineral Indication No. 3**

It is represented by two zones of alteration, one near the Maitenes Bridge over the Los Maitenes River, and the other to the south. The confirmed size on the surface is 300 x 600 m for both zones. However, the one near the Maitenes Bridge is surrounded by a thick terrace deposit, so that its actual dimension is presumed to be much larger. Although there are no records of prospecting or working of these alteration zones, two wells (30 m x 5 m and 50 m x 10 m in longer diameter x shorter diameter· depths not known) have been drilled into the delta deposit at about 100 m and 100 m downstream from the Maitenes Bridge, in pursuit of possible concentration of alluvial gold.

Dacitic lapilli tuff and tuff of the Divisadero Formation are the host rocks of the above-mentioned two zones of alteration. In the vicinity of the Maitenes Bridge, five or six streaks of parallel veinlets are noted. They are 2 to 5 cm wide (strike N36°W, dip 82°NE) and consist of pyrite, marcasite and quartz. Concentrations of pyrite in gravel form are found near the veinlets, but no other sulfide minerals can be observed with the unaided eye. On the other hand, no veins were recognized in the alteration zone south of the Maitenes Bridge. Both the alteration zones are markedly whitened due to silicification. Their surfaces are tinted brown with oxydized iron minerals.

The analytical result of the samples collected is laid out below, showing a low content of each element.

Sample No.	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3MM726	<20	7.7	7	55	13	55.0
3MM727	<20	0.2	2	18	14	0.14
3MM728	60	0.7	2	244	24	0.25

(4) Mineral Indication No. 4

This indication is located about 70 m downstream from the San Martin Bridge, and is represented by a single vein composed of quartz, silicified rocks and sulfide minerals (galena, sphalerite). It is reported that surface survey (sampling) was conducted in the 1980s, but there is no record of further prospecting.

An outcrop of the vein consisting of quartz, silicified rocks and sulfide minerals (general strike N9°W, dip 74°E) occurs on the left bank of the Las Dunas River. The silicified rhyolite lava of the Divisadero Formation is the host rock. The pelitic schist showing well-developed axial plane schistosity is exposed immediately under the rhyolite, and the boundary between the two rocks can be observed on the upstream side of the said bridge (Fig.II-5-4). The structures of the two rocks are not harmonious, and large quantities of fragments of the pelitic schist occur as xenoliths near the basal part of the rhyolite.

The vein fills the fissures of the above-mentioned two kinds of rocks. The width of the vein's outcrop is about 6 m but the hanging wall side vanishes into the river. The outcrop is traceable for about 20 m in the strike direction, and beyond that it goes under the thick terrace deposit. Veinlets or stockwork of galena, sphalerite and pyrite are developed within the 6 m wide vein of quartz and silicified rock. Bonanza, with a width of 5 to 30 cm, occurs along the foot wall and in the central part, but the width is very variable. Alteration in general is represented by silicification, and the gangues contains some quantity of sericite.

As shown in Fig.II-5-4, the grade of the collected samples including the host rock is not very high, as shown below. However, the grade of vein in the bonanza might exceed 15% in Pb and Zn.

Sample No.	Sampling width(m)	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	S(%)
3MM729a	2*	<20	2.1	82	1850	1275	0.18
3MM729b	1	<20	6.7	120	4875	7600	0.66
3MM729c	1	20	13.4	52	9325	2500	0.43

* Silicified host rock on the foot wall side.

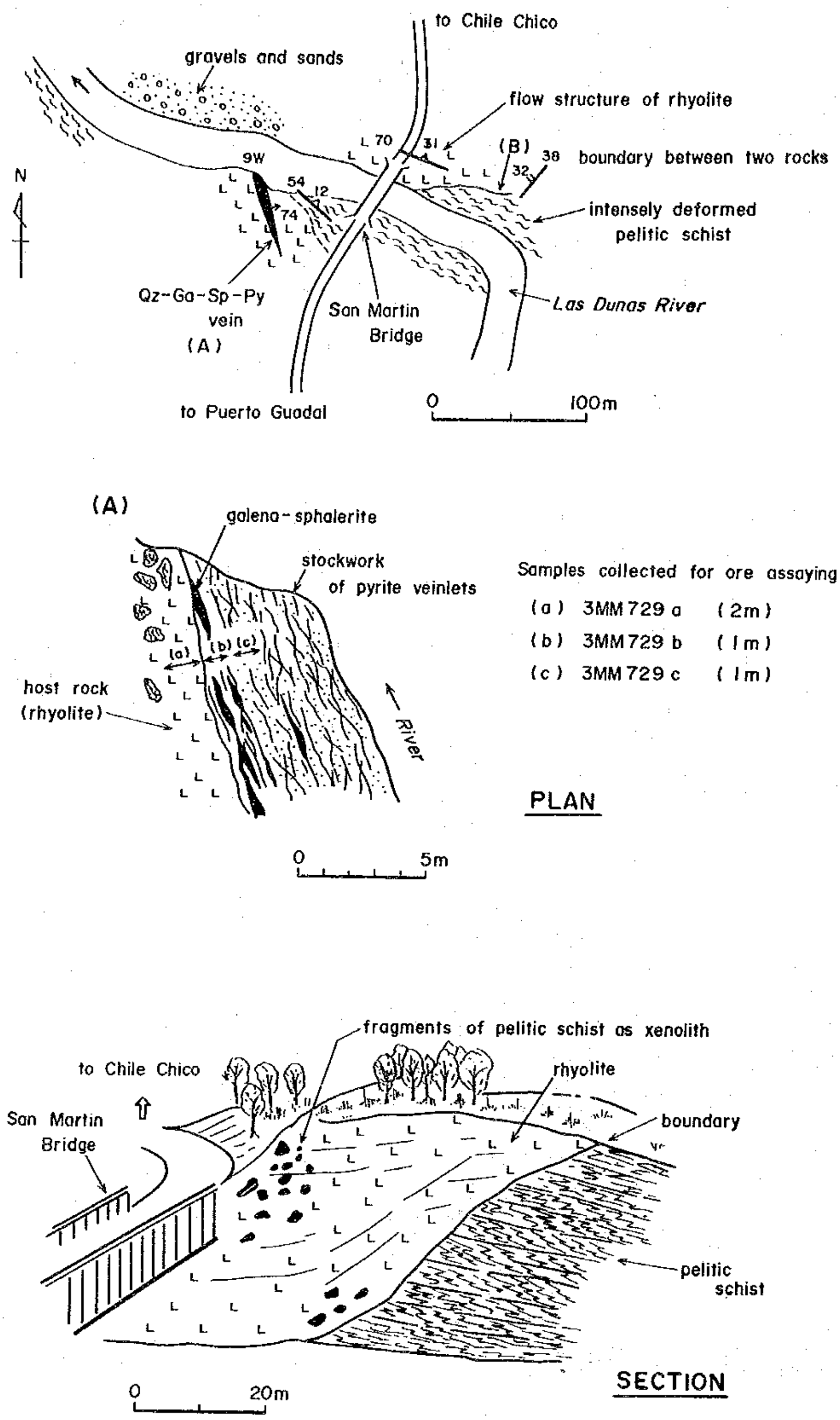


Fig. II-5-4 Geological Sketch of a Vein at Mineral Indication No.4 near the San Martin Bridge

5.4. Geochemical Exploration

5.4.1. Sampling and assaying

One hundred and sixty two stream sediment samples were collected and about 100 g of sample were submitted for the assaying after sieving through -30 mesh. The sample localities are shown in PLATE 22. Samples were pulverized to -200 mesh fraction by SERNAGEOMIN Laboratory and assayed by Chemex Labs.,Inc.,Canada. Six elements assayed are Au, Ag, Cu, Pb, Zn and As. The detection limits and analytical methods used are the same as those described in Chapter 2.

5.4.2. Statistical data-processing

(1) Results of assaying

The results of assaying are shown in Table 6 in Appendix. The characteristic features are summarized as follows.

The samples containing more Au than the detection limit are 18 %. And only one sample contains over 10 ppb (33 ppb) and others contain less than 10 ppb. Samples containing more Ag than the detection limit are merely 24 % and their maximum value, 0.25 ppm is extremely low.

Cu, Pb and Zn contents are generally very low and samples containing more than 100 ppm are zero for Cu and Pb and 66 for Zn.

As content is generally higher and many contain more than 10 ppm.

(2) Elemental statistics

Elemental statistical parameters are listed in Table II-5-2.

Table II-5-2 Elemental Statistics Parameters in Geochemistry of the Chile Chico-Chacabuco Area

	Au(ppb)	Ag(ppm)	Cu(ppm)	Pb(ppm)	Zn(ppm)	As(ppm)
Mean	0.66	0.03	9.1	9.6	91.8	10.2
Max.	33	0.25	57	87.0	431	418
Min.	0.5	0.03	1.5	5.0	26	1
m+σ	1.30	0.05	17.9	18.4	149.1	24.5
m+2σ	2.56	0.08	35.3	35.5	241.9	59.1

(3) Frequenc y distribution pattern

Frequency distribution diagram is shown in Fig.II-5-5. Elements Cu, Pb, Zn and As show a log-normal distribution. Au frequency distribution is separated into two groups divided at the detection limit. As to Ag distribution, a great peak is recognized in the area below detection limit, but there are also other four small sub-populations above the detection limit.

(4) Correlation

Correlation coefficients are listed in Table Ⅱ-5-3. Element pair Pb-Zn only shows coefficient greater than 0.5(r=0.607).

Table Ⅱ-5-3 Correlation Coefficients between Elements Pairs in Geochemistry of the Chile Chico-Chacabuco Area

	Au	Ag	Cu	Pb	Zn	As
Au	1.00000					
Ag	0.22157	1.00000				
Cu	0.11061	0.35755	1.00000			
Pb	0.10362	0.49134	0.47369	1.00000		
Zn	0.10205	0.22262	0.47983	0.60702	1.00000	
As	0.38745	0.40046	0.37453	0.37586	0.35556	1.00000

Table Ⅱ-5-4 Eigen Vectors and Eigen Values of Principal Component Analysis of the Chile Chico-Chacabuco Area

	1	2	3	4	5	6
Au	0.22454	-0.76569	0.31071	0.18860	-0.47800	-0.05198
Ag	0.40200	-0.15326	-0.79314	0.07871	-0.09508	0.41304
Cu	0.43370	0.23109	0.09755	-0.76455	-0.39444	-0.09415
Pb	0.48201	0.28097	-0.11619	0.45181	-0.04642	-0.68479
Zn	0.43373	0.35231	0.48616	0.33101	0.02249	0.58423
As	0.42357	-0.36575	0.12255	-0.24495	0.77732	-0.08702
Eigen	2.76077	1.11106	0.74287	0.56823	0.51054	0.30652
Prop.	0.46013	0.18518	0.12381	0.09470	0.08509	0.05109
Cum. prop.	0.46013	0.64531	0.76912	0.86382	0.94891	1.00000

(5) Principal component analysis

Eigen vector matrix and eigen values are shown in Table Ⅱ-5-4. Their statistical meaning is summarized as follows.

First principal component

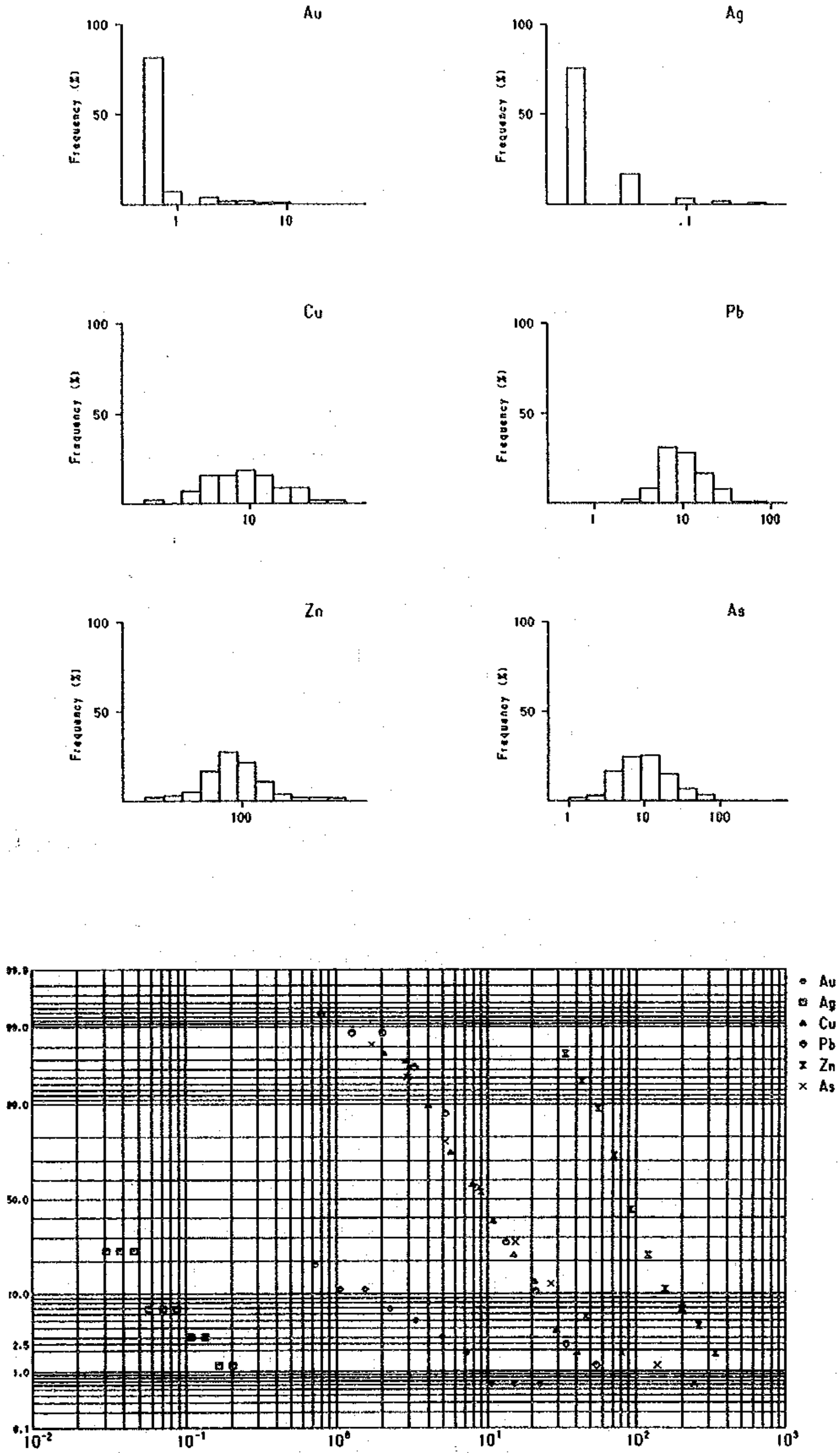


Fig.II-5-5 Histograms and Cumulative Frequency Curves Showing Frequency Distribution Patterns of Assays on Stream Sediment Geochemical Samples Collected in the Chile Chico-Chacabuco Area

All elements other than Au retain similar eigen vectors.

Second principal component

Element pairs Au-Ag, Pb-Zn and Cu-As retain similar eigen vectors respectively and the first two pairs show minus values and the rest is positive values. This feature resembles the geochemical aspects in this area and, therefore, this principal component is considered to represent the mineralization in this area.

Third principal component

Element pairs Au-Cu, Ag-As and Pb-Zn retain similar eigen vectors respectively. This does not match the general features of the mineralization.

Three principal components are counted to more than 80 % of total variance contributed by each eigen value.

Scores for second principal component representing the mineralization are listed in Table 7 in Appendix.

5.3.3. Geochemical anomalous zones

(1) Threshold

$M+2\sigma$ value was used as threshold for all elements other than Ag. As some populations are recognized in Ag frequency distribution pattern, Ag threshold was set at 2.5 % point on the cumulative frequency diagram (Fig.II-5-5). Thresholds used are as listed in the following table:-

Thresholds

Element	Threshold
Au	3 ppb
Ag	0.1 ppm
Cu	35 ppm
Pb	36 ppm
Zn	242 ppm
As	59 ppm

(2) Geochemically anomalous zones

The geochemical anomalies detected in this area are counted as shown in the following table.

Numbers of the Geochemical Anomalies

Element	Numbers of Anomalies
Au	11
Ag	11
Cu	4
Pb	4
Zn	8
As	4

Those anomalous points are plotted in PLATE 17. Major notable anomalous zones are as follows.

1) Au

Au anomalies are concentrated to the southern part of Puerto Guadal and the upper reaches of the Bertrand River.

2) Ag

The number of detected anomalies are relatively large, but their distribution is very sporadic. No specific anomalous zone is delineated.

3) Cu

Only four Cu anomalies were detected in the area and their distribution is sporadic.

4) Pb

Pb anomalies are very few and not concentrated.

5) Zn

Zn anomalies are concentrated to the southwestern part of Puerto Guadal.

6) As

As anomalies occur somewhat concentrated in the upper reaches of the Bertrand River overlapping Au anomalies.

Sample points showing scores greater than 1.0 are distributed in the southwestern part of Puerto Guadal. A few Cu-Pb-Zn vein deposits are known around this anomalous zone, and this zone overlaps the distribution of the intrusive rocks which are believed to be closely related to those mineralization. Therefore, these Pb-Zn anomalies are believed to indicate the existence of the mineralization. The anomalies of other elements are statistically anomalies, but not worthy.

5.5. Evaluation

(1) Results of the geological survey

The mineral potential of the following three types were pointed out in this area through the reconnaissance geological survey and geochemical exploration as well as the study of known deposits and prospects in the vicinity, which were conducted in the first phase. Additionally several possible alteration zones were extracted in this area from the interpretation of Landsat TM image of the second phase.

(a) Replacement Silva-type Pb-Zn deposits embedded in limestone beds of the basement metamorphics
(b) Vein-type Cu-Pb-Zn deposits represented by the Escondida Mine hosted by the basement metamorphics
(c) Epithermal gold deposits of Laguna Verde type is hosted by the Mesozoic strata

Both calcareous beds and granitic rocks resulting in contact metasomatism are indispensable for the mineralization of the type (a). The geological survey in this area revealed the occurrence of calcareous schist as alternating layers with pelitic schist at only one locality. The major layer of calcareous schist is about 30 m thick and is traceable for about 2 km. Felsic intrusive rocks such as tonalite are distributed in the vicinity of the calcareous schist. Despite these geological features no replacement of Pb-Zn was recognized. This lead to a conclusion that there is no mineral potential of the type (a) in this area.

Mining activity known in the northwestern part of this area is represented by two mines, namely the Escondida and San Sebastian Mines as described in section 5.3. These veins occur in the basement metamorphics, filling the fissures of the host rock. Dacitic and tonalitic intrusive bodies are distributed in the vicinity of those mines. This suggests that the vein-type mineralization took place in relation to activity of the intrusive rocks. Alteration of the host rocks near the veins is generally very weak silicification and it is limited to 20 cm from the veins. Through the field survey of this phase, quartz veins, segregation quartz with dissemination of pyrite, and dissemination zone of pyrite in basic schist were found in the western part of the area and are called the Mineral Indications No. 7, 8 and

9, respectively. However, all of them are small and show very low content of base metals. Therefore minable deposits cannot be expected in this part, in spite of the presence of minor mineralization zones. Additionally, mineral potential in the eastern part is also very low as shown in the Mineral Indication No. 1 where a small-scale silicified zone was found, accompanied by a very low grade veinlet.

With regard to deposits of the type (c), no gold mineralization zones were found in this area through the geological survey. Rocks of the Ibañez Formation are all unaltered, but several alteration zones of silicification and sericitization and a Pb-Zn vein are exposed in some parts of dacitic lapillic tuff and rhyolite lava of the Divisadero Formation distributed near Lake General Carrera. As described in section 5.3., a single Pb-Zn vein in the Mineral Indication No. 4 is 6 m wide including gangue rocks, while bonanza of the vein is much variable in width. Although the superficial part of the vein is hosted by silicified and sericitized rhyolite lava, the host rock is only 2 to 3 m thick and is underlain by broadly distributed pelitic schist. In other words, the vein is mainly embedded in pelitic schist, even though it was formed by a post-igneous action that accompanied the volcanic activity of the rhyolite lava. So far as pelitic schists in this area is concerned, it is believed that open and continuous fractures could not have developed in pelitic schists due to the following reasons:

- Minor folds and axial plane cleavages are well developed by intense deformation, but constant trend of their plunges and dips are not observed.
- A large amount of segregation quartz occur in complicated forms.

In fact, veins of known mines do not exceed 1 m in width and faults are sparsely distributed in pelitic schists. Taking these features into account, the veins are not likely to improve in the deeper zones. The vein itself is inferred to have been considerably eroded out because thick terrace deposits are distributed near the vein.

Other alteration zones are small and contain very small amount of useful metals, which indicate that only weak mineralization occurred in these zones.

(2) Evaluation of the alteration zones extracted from TM image

Eleven possible alteration zones were extracted in this area from Landsat TM image in the second phase. Seven of them exceed 1 km in length. Of these five and two zones are distributed in the eastern and southern parts of the area respectively (Fig.II-5-6). They usually show oval shape, but no specific elongation is recognized.

Results of ground truth on those alteration zones are summarized below.

a) Eastern part (upper reaches of the Blanco River)

Five alteration zones from TM image were located in the distribution areas of the Ibañez and Divisadero Formations, and granite. Both granite and rocks of the Ibañez Formation are unaltered as mentioned above. Therefore, zones extracted in those rocks do not exist. Even if alteration zones are present, they must be located in the Divisadero Formation area. These zones, however, could not be confirmed by the surface survey due to thick snow cover. Two Ag anomalies were detected by stream sediment geochemistry. No anomalies were found for other elements. These facts suggest that extracted alteration zones are without significant mineralization.

b) Southern part (tributaries of the Chacabuco River)

Two alteration zones are located in the Divisadero Formation area. They are situated in the uppermost reaches of the tributaries, where the vertical cliffs are formed on both sides of the valleys. Outcrops of these zones also could not be surveyed because of the snow cover. These zones are inferred to consists of silicified andesitic tuff, judging from the floats. The assay results of the silicified rocks indicate low content for all elements analyzed. Therefore, it is inferred that significant mineralizations will not be found in these zones.

(3) Appraisal of the results of photogeological interpretation

Geological data acquired through the surface survey generally agree with the results of the photogeological interpretation except for some details. The following points were verified by field evidences.

- Distribution and structure as well as lithofacies of the Tertiary System
- Distribution of crystalline schists
- Lineaments
- Calcareous schist exposed in crystalline schists
- Distribution of intrusive rocks

The major discrepancies between the interpretation and ground survey are the following points.

- Classification of units composed mainly of volcanic rocks: the boundary between the Ibañez and Divisadero Formations.
- Delineation of the areas consisting of lavas from pyroclastic rocks.
- Distribution and structure of units subjected to intense glaciation: Anomalous drainage patterns prevented accurate tracing of the basement unit. Additionally, bedding-like patterns and photolineaments parallel to the flowing direction of glacier does not reflect the actual structures.