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JAPAN INTERNATIONAL [illegible] AGENCY

[illegible] JAPAN

# REPORT
# ON
# THE INVESTIGATION OF MINERAL POTENTIAL
# IN
# THE LONQUIMAY AREA AND REGIONS LOS LAGOS AND AYSEN, THE REPUBLIC OF CHILE
# AYSEN AREA

## PHASE III



FEBRUARY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

**PREFACE**

In response to the request of the Government of the Republic of Chile, the Japanese Government decided to conduct a Mineral Exploration Project in the Aysen Area and entrusted the survey to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

This is the third phase survey. The JICA and MMAJ sent a survey team headed by Mr. Yuya Furukawa to the Republic of Chile from 22 September, 1991 to 3 January, 1992.

The team exchanged views with the officials concerned of the Government of the Republic of Chile and conducted a field survey in the Aysen area. After the team returned to Japan, further studies were made and the present report is the result.

We hope that this report will serve for the development of this project and contribute to the promotion of friendly relations between our two countries.

We wish to express our deep appreciation to the officials concerned of the Government of the Republic of Chile for the close cooperation extended to the team.

February, 1992

Kensuke Yanagiya

Kensuke YANAGIYA
President,
Japan International Cooperation Agency

Gen-ichi FUKUHARA
President,
Metal Mining Agency of Japan

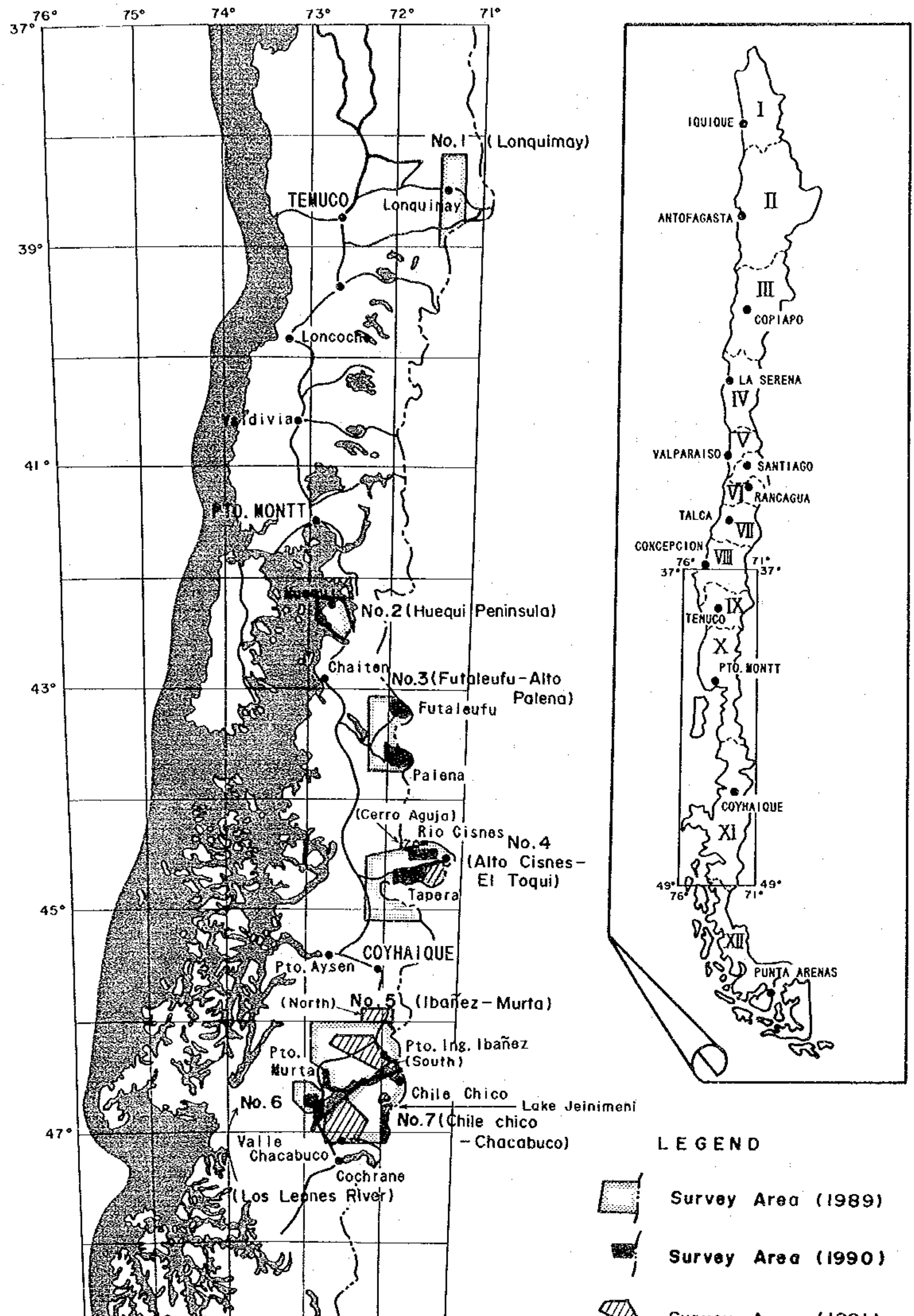


Figure I-1 Location Map of the Survey Areas

## SUMMARY


This is the third phase of the cooperative joint exploration project in the Aysen Region. On the basis of the conclusions of the Phase II, the investigation of this phase was planned with special emphasis on the epithermal gold-silver mineralization and lead-zinc replacement mineralization represented by the Laguna Verde Deposit and El Toqui or Silva Deposit respectively.

Taking geological setting and characteristics of mineralization of the selected areas into account, the following investigations were conducted.

1) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone): Geological survey and geochemical exploration
2) Alto Cisnes-El Toqui Area: Geological survey and geochemical exploration
3) Ibañez-Murta Area (North): Geological survey
4) Ibañez-Murta Area (South): Photogeological interpretation, geological survey, and geochemical exploration
5) Chile Chico-Chacabuco Area: Photogeological interpretation, geological survey, and geochemical exploration
6) Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone): Geological survey

This report summarizes the results of the third phase of the survey, and it will also form a portion of the final report which will be prepared with regard to the results obtained from the completed survey.

The field survey was carried out by two Chilean and five Japanese geologists during the period from September 22, 1991 to January 3, 1992. The subsequent interpretation of data obtained from the field and report preparation were done during in the period from January 4 to February 28, 1992.

### A. Results of the Phase III Survey

**(1) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)**

This area is underlain by the intermediate to felsic volcanic products of the Upper Jurassic Ibañez Formation, the Upper Cretaceous Divisadero Formation and granitic rocks that intruded in the two formations. The Cerro Aguja

Alteration Zone is widely exposed, hosted mainly by pyroclastic rocks of the Divisadero Formation. The zone is characterized by the acidic alteration with the dissemination of pyrite and minor amount of chalcopyrite as well as disseminations and stockworks of limonite and hematite. Assay results of altered rocks indicate extremely low contents of useful metalliferous elements. Only the arsenic content is relatively high (mean value: 123 ppm). The panned concentrate geochemistry yielded many As anomalies in the zone. The alteration zone is assumed to have genetical relation to hot-spring-type deposits based on the geological and geochemical features. Taking all factors into consideration, it is believed that no improvement of gold content can be anticipated in the deeper parts.

**(2) Alto Cisnes- El Toqui Area**

The geology of this area consists of the intermediate to felsic volcanic products of the Ibañez and Divisadero Formations and granitic stocks that intruded in these volcanic products. Although 14 alteration groups hosted by the rocks of the Ibañez and Divisadero Formations are confirmed in this area, only quartz veinlets or pyrite dissemination occur in these groups and contents of useful metalliferous elements are extremely low. Rocks of these groups are altered, but only weak silicification is recognized. Those factors indicate small prospectivity for promising subsurface mineralization with respect to the alteration zone. Furthermore, lead-zinc replacement deposits of El Toqui type, which are hosted by the Coyhaique Formation, hardly occur in this area due to the lack of this formation. No significant anomalies were obtained from geochemical exploration.

**(3) Ibañez-Murta Area (North)**

The geology of this area consists mainly of pyroclastic rocks of the Divisadero Formation and granitic rocks that intruded in the formation. More than 30 mineralization zones of various dimensions were confirmed in this area. Five mineralization groups are distributed in the middle of the area and called Mineralization Groups E, F, G, H, and K. They are hosted by rocks of the Divisadero Formation and are accompanied by intensive stockwork veins of quartz with dissemination of pyrite, limonite, and hematite. Rocks there are subjected to intense silicification and weak sericitization. Although Au grade ranging from 0.1 to 0.2 ppm were rarely obtained from assay of stockwork quartz, no concentration of other elements were detected. It is believed that the gold grade will not increase below these mineralization groups.

Only pyrite dissemination accompanied by quartz veinlets was found in the other mineralization groups where very low contents of gold, silver, and base metals were detected.

Those results lead to a conclusion that the prospectivity in this area is small with respect to gold and silver as well as base metals.

**(4) Ibañez-Murta Area (South)**

This area is widely underlain by dacitic pyroclastic rocks of the Ibañez Formation. These rocks host several vein Pb-Zn(-Cu-Mo) deposits and about 20 alteration zones of various dimensions. All of the vein type deposits are small in scale and are located in the eastern part of the area. Most of the alteration zones have areal extent of 500 x 200 m and have been affected by moderate silicification and weak argillization. Dissemination and stockwork of pyrite, limonite, and hematite commonly occur in these alteration zones, but few quartz veins and sulfide minerals are observed. Anomalous zones of Au-Pb-Zn and Au were recognized through panned concentrate geochemistry in the area. The former and the latter are distributed to the west and north of Puerto Ibañez, respectively. Neither deposits of Silva type nor of El Toqui type are anticipated to occur in the area.

Potential mineralization of this area is of Pb-Zn(-Cu) vein type and of epithermal Au-Ag type. The above Pb-Zn anomalous zone is a prospective area for the former type of mineralization. For the latter type two sub-areas can be proposed. One is the eastern part of this area toward the border with Argentine. The other is an area around the upper reaches of the Long River.

**(5) Chile Chico-Chacabuco Area**

The field survey revealed that the geology of this area is mainly composed of the Paleozoic basement metamorphics, the Ibañez and Divisadero Formations, and the Tertiary System. Several small Cu-Pb-Zn vein deposits are hosted by the basement metamorphics and occur in the northern part of the area. Although some alteration zones were recognized in the Divisadero Formation area, they were identified to be the faint silicification zones with sparse dissemination of pyrite and limonite. The Pb-Zn replacement mineralization of Silva type is not prospective in this area because very small amount of calcareous rocks is confirmed in the basement metamorphics.

**(6) Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)**

The survey revealed that the Alteration Group C is divided into several altered and unaltered zones. Although faint mineralizations of Au (1 to 2 g/t) and Pb accompanied by quartz veinlets are recognized in some parts, the veinlets are sparsely developed and their areal extent is small (200 x 200 m). The Alteration Group D is the silicification zone with dissemination of pyrite. Neither quartz veins nor significant contents of useful metalliferous elements were found in this group. It is believed that the Au mineralization is unlikely to improve below these alteration groups.

## B. Recommendations for Future Exploration

The following recommendations are made with regard to the six areas for future exploration based on the results of this survey.

(1) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

The prospectivity is small and the area does not warrant further exploration.

(2) Alto Cisnes-El Toqui Area

The necessity for further exploration work is small.

(3) Ibañez-Murta Area (North)

Further exploration work is concluded to be not feasible in this area.

(4) Ibañez-Murta Area (South)

Geological survey and geochemical exploration should be conducted in the following two areas because they are virgin areas and mineral potential for epithermal gold exists.

- Area enclosed by the road connecting Puerto Ibañez with Coyhaique and the Chile-Argentine border (east of the area surveyed in this phase)
- Area enclosed by the Avellano River and the upper reaches of the Long River (southwest of the area surveyed in this phase)

(5) Chile Chico-Chacabuco Area

The necessity for further exploration work is small.

(6) Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

The Lake Jeinimeni Alteration Zone itself does not warrant further exploration because the mineralization is faint and is not believed to improve underground.

The surrounding areas, however, are situated at the southern extension of the "Au-Ag belt" of the east of the Aysen Region. Furthermore, a plenty of alteration zones with geochemical anomalies of Au are aligned on the belt as described in the report of the second phase. Therefore, emphasis of future exploration is placed on the Au-Ag belt between Lake General Carrera and the Chacabuco River.

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# PART I
# OVERVIEW

## CHAPTER 1. INTRODUCTION

### 1.1. Background and Objective

The survey of this year is the third (final) phase of "The Investigation of Mineral Potential in the Lonquimay Area and Regions Los Lagos and Aysen, Republic of Chile ". This project started in the Fiscal 1989. Seven areas (Fig. I-1) were selected for preliminary investigation prior to the commencement of this project. The objective of this project is to evaluate the mineral potential of the areas through geoscientific study and to recommend promising areas for future exploration.

The first phase survey was carried out over the whole region and aims to clarify the regional features of geology and mineralization. It consisted of the following works.

(1) Photogeological interpretation of Landsat MSS (Multi-Spectral Scanner) images
(2) Compilation work of available relevant data
(3) Field survey of representative mines and mineral prospects

Geochemical exploration using panned concentrates and stream sediments was also carried out for acquiring the geochemical characteristics of the survey areas. This survey has revealed that further exploration in the Aysen Region should focus on epithermal vein type gold-silver concentration represented by the Laguna Verde Deposit and metasomatic type lead-zinc concentration such as the El Toqui and the Silva Deposits.

Based on the results of the first phase survey, geological and geochemical surveys were conducted in the following areas during the second phase. These areas were selected because the above two types of mineralization are expected.

(1) Futaleufu-Alto Palena Area
(2) Alto Cisnes-El Toqui Area (western part)
(3) Los Leones River Area

In addition to the surveys, interpretation of Landsat TM (Thematic

Mapper) images was also studied covering the area southward from the Futaleufu-Alto Palena Area in order to delineate hydrothermal alteration zones of Laguna Verde type. The second phase survey has disclosed that significant copper-lead-zinc mineralization does not exist in those areas despite sporadic distribution of mineral showings. However, numerous silicification zones similar to those of the Katterfeld Gold Deposit occur in the western part of the Alto Cisnes-El Toqui Area. Thus, the presence of gold mineralization is anticipated if the zones extends eastward.

Total of 170 alteration zones were extracted in the whole area through photogeological interpretation of Landsat TM images. The ground truth survey were done on 21 alteration zones among them. Gold mineralization containing ppm order of Au (maximum grade: 6.7 ppm Au) was found in three zones.

The following areas in which mineralization could be found were consequently selected for the third phase geological and geochemical surveys, considering the results of the first and second phase surveys mentioned above.

(1) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)
(2) Alto Cisnes-El Toqui Area
(3) Ibañez-Murta Area (North)
(4) Ibañez-Murta Area (South)
(5) Chile Chico-Chacabuco Area
(6) Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

Prior to the field surveys, photogeological interpretation using aerial photographs was carried out for the areas of (4) and (5) as a preliminary investigation.

## 1.2. Conclusions and Recommendations of the Second Phase Survey

### 1.2.1. Conclusions of the second phase survey

**(1) Satellite image interpretation**

This work was done using color composite images of bands 4-5-7 of the TM data of Landsat 5. Total of 170 alteration zones were extracted. Of these, sixteen zones to the south of the Laguna Verde Deposit were selected for the surface survey to verify.

The localities and shapes of the alteration zones extracted from the images differ slightly from the observation on the surface. But for practical purposes, about 90% of the localities by TM images largely coincide with the identification on surface. Total of 21 alteration zones are recognized in the area. Gold mineralization with maximum grade of 6.7 ppm Au was found in three zones. One of these three zones also carries 1.1% Pb.

There are other alteration zones (locality numbers 5-4 to 5-13) extracted from TM images. They are grouped at 65 km north of the Laguna Verde Deposit. They are large and lie on the N-S tectonic line which is considered to control the arrangement of mineralization and alteration zones. Considering this and the results in the south mentioned above, the existence of gold deposits of Laguna Verde type is expected in this area.

**(2) Photogeological interpretation of aerial photographs**

Photogeological interpretation and ground truth survey were conducted for the Alto Palena sub-area and the Alto Cisnes-El Toqui Area. Tectonic features, especially photolineaments agree well with those observed in the field. As to photogeological rock unit classification, many of the granitic rocks with tabular joints were confused with volcanic rocks. Topographical modification caused by glaciation sometimes prevented the correct interpretation of rock units. However, this photogeological work was very effective with regard to acquiring outline of general geologic settings, it was especially superior to the field survey for tracing faults.

**(3) Geological survey and geochemical exploration**

**a. Futaleufu-Alto Palena Area (Futaleufu sub-area)**

It is revealed by this survey that the geology of this area consists of the Upper Jurassic Ibañez Formation of andesitic volcanic products and the Upper Cretaceous Granitic intrusion. Many indications of gold and copper mineralization is found in the andesite of Ibañez Formation. These are believed to be caused by contact metasomatism related to the intrusion of granitic rocks. However, all of the indications are of low grade and small. Also the distribution of geochemical anomalies is sporadic, although several anomalies of Au, Pb, Zn and As are detected.

These results lead to the conclusion that the prospectivity is small and the area does not warrant further exploration.

**b. Futaleufu-Alto Palena Area (Alto Palena sub-area)**

Shale and andesitic volcanic rocks of the Coyhaique Formation host several veins and disseminated mineralization caused by contact metasomatism due to the intrusion of the granitic rocks. The mineralization zones are very small, although bonanzas are expected locally. On the other hand, dense distribution of geochemical anomalies of Pb, Zn and As is detected at several localities on the andesitic volcanic rocks of the Coyhaique Formation and the rocks of the Divisadero Formation at the eastern periphery of granitic intrusives. Although this geochemical feature might suggest the presence of lead-zinc vein type mineralization, large deposits of El Toqui type, namely calcareous rock replacement lead-zinc deposit, is not expected to occur in those geochemically anomalous zones because no calcareous rock crops out.

Further exploration work is concluded to be not feasible here.

c. Alto Cisnes-El Toqui Area

Geology of this area is composed mainly of the Late Jurassic Ibañez Formation and the Late Cretaceous granitic intrusion. Broad hydrothermal alteration zones accompanied by limonite-quartz stockworks are developed at the periphery of the granitic intrusive bodies. Major alteration type is silicification.

Ore assays on those alteration zones show low grade content. However, geochemical anomalies of Au, Pb and Zn overlap with the alteration zones. The mineralization of Laguna Verde type is expected for this area from the similarities of mineralization and alteration.

d. Los Leones River Area

Geology of this area consists of the Paleozoic metamorphic rocks, mainly muscovite schist and greenschist, and the intermediate to felsic intrusive rocks. Only faint copper-silver mineralization is developed in relation to the igneous activity of these intrusive rocks. Although Au, Pb and Zn geochemical anomalies were detected in the periphery of the intrusive bodies, these anomalies are extremely low level and do not suggest the existence of significant mineralization. Therefore, it is concluded that necessity for further exploration work is small.

e. Chile Chico-Chacabuco Area

TM image interpretation extracted 16 alteration zones and the surface survey located 21 zones. These 21 zones are grouped locality-wise into nine alteration groups, Group A to I.

Alteration Group C is ranked first regarding the prospectivity for gold mineralization. This is concluded from an ore assay of 6.7 ppm Au and 1.1% Pb on one sample, overlapping geochemical anomalies of Au, Ag, Pb, Zn and As, and the size of this alteration group. Alteration Groups D and I also have overlapping geochemical anomalies of Au, Ag, Pb and As. Rather intensive silicification and dense stockwork of limonite are observed. Considering those features of Groups D and I, they are assessed to be very important for gold exploration, second after the Group C. Whereas detailed survey might be nearly impossible due to its topographical conditions.

Other alteration groups are concluded to be less prospective from the results of ore assay and geochemistry, their small extension and low degrees of alteration.

### 1.2.2. Recommendations for the Phase III Exploration

The following works are recommended for the next stage based on the results of this survey.

(1) Geological and geochemical surveys for the alteration zones 5-4 to 5-13 extracted by interpretation of TM image this year.

(2) Detailed geological and geochemical surveys for the alteration zones A, B and C of the Alto Cisnes-El Toqui Area.

(3) Detailed geological and geochemical surveys for the Alteration Groups C and D of the Chile Chico-Chacabuco Area.

(4) Application of geophysical exploration using SIP technique for the important alteration zone selected by the works listed above.

Other than these areas, the zone between the Ibañez River and the Avellanos River in the Ibañez-Murta Area is remained to be untouched as recommended by the report of the first phase.

## 1.3. Outline of the Work in Phase III

### 1.3.1. Survey areas

Two types of work were selected and carried out as follows.

**(1) Photogeological interpretation of aerial photographs**

This work was carried out over two areas enclosed by the following coordinates.

a) Ibañez-Murta Area (South, Area: 1,216 $km^2$)

Northern Limit : 46°06′29″S
Southern Limit : 46°26′37″S
Eastern Limit : 71°51′24″W
Western Limit : 72°38′40″W

b) Chile Chico-Chacabuco Area (Area: 1,350 km²)
Northern Limit : 46°38′26″S
Southern Limit : 47°06′17″S
Eastern Limit : 72°11′08″W
Western Limit : 72°48′44″W

(2) Geological survey and geochemical exploration

The geological survey was carried out in six areas (Fig.I-1) and the geochemical exploration was conducted in four areas except for the Ibañez-Murta Area (North) and the Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone). Six areas are enclosed by the following coordinates.

a) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone, Area: 170 km²)
Northern Limit : 44°23′10″S
Southern Limit : 44°31′12″S
Eastern Limit : 71°33′10″W
Western Limit : 71°48′30″W

b) Alto Cisnes-El Toqui Area (Area: 580 km²)
Northern Limit : 44°31′37″S
Southern Limit : 44°48′23″S
Eastern Limit : 71°11′24″W
Western Limit : 71°32′03″W

c) Ibañez-Murta Area (North, Area: 270 km²)
Northern Limit : 45°54′39″S
Southern Limit : 46°02′10″S
Eastern Limit : 71°50′01″W
Western Limit : 72°08′58″W

d) Ibañez-Murta Area (South, Area: 980 km²)
Northern Limit : 46°06′29″S
Southern Limit : 46°26′37″S
Eastern Limit : 71°51′24″W
Western Limit : 72°38′40″W

e) Chile Chico-Chacabuco Area (Area: 1,350 km$^2$)

Coordinates are exactly the same as those of the area for photogeological interpretation.

f) Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone, Area: 17 km$^2$)

Northern Limit : 46°49′03″S

Southern Limit : 46°53′16″S

Eastern Limit : 71°59′07″W

Western Limit : 72°04′56″W

### 1.3.2. Objective of phase III survey

**(1) Photogeological interpretation of aerial photographs**

In order to conduct field survey efficiently, this interpretation was carried out for understanding the general geologic setting and geologic structure of the survey areas prior to the geological survey. Particular emphasis was placed upon extracting photolineaments.

**(2) Geological survey and geochemical exploration**

a) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

The work was planned to evaluate the mineral potential of the alteration zone which is developed in the northwestern part of this area.

b) Alto Cisnes-El Toqui Area

The area is situated to the east of the silicification zones which were recognized around the Buitrera River by the second phase survey. In this area, the eastern extension of the zones might be present and host-rock sequence of the El Toqui Deposit (the Coyhaique Formation) may be developed. Thus, the survey was carried out in order to define the gold and lead-zinc mineralizations in the silicification zones and the Coyhaique Formation respectively.

c) Ibañez-Murta Area (North)

The satellite image interpretation of the second phase has revealed that several large-scale hydrothermal alteration zones were concentrated in this area. The aim of the field survey is to evaluate the mineral potential of the epithermal gold deposits similar to the Laguna Verde Deposit.

d) Ibañez-Murta Area (South)

This area is widely underlain by the Ibañez, Coyhaique, and Divisadero

Formations which are the host-rock sequences of ore deposits. The satellite image interpretation also indicates the possible existence of hydrothermal alteration zones in the area. Thus, the objective of the survey is to evaluate the mineral potential within the distribution area of the Jurassic and Cretaceous Systems and to define the mineralization in the alteration zones.

e) Chile Chico-Chacabuco Area

Paleozoic metamorphic rocks, the Jurassic, Cretaceous, and Tertiary Systems are widely distributed in this area. All rock units except for the Tertiary System can be host-rock sequences of ore deposits. The aim of the field survey is to define the copper-lead-zinc and gold mineralizations in the Paleozoic and Mesozoic Systems respectively. Metasomatic lead-zinc deposits of Silva type and copper-lead-zinc vein type deposits are anticipated to occur in the Paleozoic System. On the other hand, epithermal gold deposits of Laguna Verde type might occur in the Mesozoic System since several hydrothermal alteration zones similar to that of the deposits were delineated by the image interpretation.

f) Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

Promising Au indications were obtained during the ground truth survey on Alteration Groups C and D which were extracted through the image interpretation of the second phase. Therefore, the survey was planned to pursue the potentiality of the gold mineralization and to confirm the areal extent of the mineralization zones if exist.

### 1.3.3. Survey methods

The survey methods employed differ from area to area as below.

#### (1) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

- Geological survey and geochemical exploration

Topographic maps at a scale of 1:25,000 enlarged from the 1:50,000 published maps were used in the field and route mapping was carried out at the former scale. The data were compiled into a geological map at a scale of 1:50,000. The panned concentrate geochemistry was employed.

#### (2) Alto Cisnes-El Toqui Area

- Geological survey geochemical exploration

Methods employed for route mapping and the compilation of geological map are the same as those of the Cerro Aguja Alteration Zone. The stream sediment geochemistry was carried out in this area.

(3) **Ibañez-Murta Area (North)**

- Geological survey

Methods employed for route mapping and the compilation of geological map are the same as those of the Alto Cisnes-El Toqui Area. Since several hydrothermal alteration zones are widely distributed in this area, the geological survey was conducted with special emphasis on the identification of alteration minerals and evaluation of mineral potential of those zones. The panned concentrate geochemistry was employed in some parts where few rocks crops out due to dense vegetation or snow covers.

(4) **Ibañez-Murta Area (South)**

- Photogeological interpretation

Black and white aerial photographs were used for the interpretation. The scale used was 1:68,000. Photogeological units were classified and geologic structures were recognized through stereoscopical interpretation. The photogeological interpretation map at a scale of 1:100,000 was prepared after this work.

- Geological survey and geochemical exploration

The 1:50,000 scale topographic maps were enlarged to 1:25,000 scale and were used in the field for route mapping. Results of the survey were compiled on a geological map at a scale of 1:100,000. The panned concentrate geochemistry was employed because gold concentration is expected in this area.

(5) **Chile Chico-Chacabuco Area**

- Photogeological interpretation

Methods employed for this work is same as those of the Ibañez-Murta Area (South).

- Geological survey and geochemical exploration

Methods employed for route mapping and the compilation of geological map are the same as those of the Ibañez-Murta Area (South). The stream sediment geochemistry was carried out where the copper-lead-zinc mineralization is expected in this area.

(6) **Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)**

- Geological survey

Methods employed for route mapping and the compilation of geological map are the same as those of the Alto Cisnes-El Toqui Area.

### 1.3.4. Amount of the work

The length of traverses and numbers of samples analyzed on each area are given in Table 1-1.

### 1.3.5. Organization of the survey team

The geological staff who participated in this project are as follows.

Japanese staff

| NAME | ROLE |
|---|---|
| Kousuke Takamoto (MMAJ[1]) | Planning and coordination |
| Yuya Furukawa (NED[2]) | Chief geologist of the project<br>Photogeological interpretation,<br>geological survey and geochemical exploration |
| Masataka Ochi ( 〃 ) | Photogeological interpretation,<br>geological survey and geochemical exploration |
| Susumu Takeda ( 〃 ) | Photogeological interpretation,<br>geological survey and geochemical exploration |
| Takashi Yoshie( 〃 ) | Geological survey and geochemical exploration |
| Kenji Sato ( 〃 ) | Geological survey and geochemical exploration |

Chilean staff

| NAME | ROLE |
|---|---|
| Carlos Portigliati Navarro<br>(SERNAGEOMIN[3]) | Chief geologist<br>Geological survey and geochemical exploration |
| Sonia Vogel Briceño<br>( 〃 ) | Geological survey and geochemical exploration |

1) Metal Mining Agency of Japan
2) Nikko Exploration & Development Co., Ltd.
3) Servicio Nacional de Geologia y Mineria, Chile

### 1.3.6. Duration of the work

The duration of the work are as listed below.

Photogeological interpretation of aerial photographs: 5 August - 5 September 1991

Geological survey and geochemical exploration: 22 September 1991 - 3 January 1992

Report preparation: 4 January - 28 February 1992

Table I-1 Numbers of Sampels Provided for Assaying and Laboratory Works

| Area | | Area ($km^2$) | Traverse length(km) | Panned concentrate (Au, Ag, Cu, Pb, Zn, As) | Stream sed. | Ore Assey (Au, Ag, Cu, Pb, Zn, S) | Whole rock analysis | Thin section | Polish section | X-ray diffraction | Dating (K-Ar) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 4 | Alto Cisnes-El Toqui Area | 580 | 256 | 0 | 150 | 49 | 3 | 13 | 0 | 8 | 3 |
| | Co. Aguja Alteration Zone | 170 | 84 | 67 | 0 | 27 | 0 | 4 | 4 | 5 | 0 |
| No. 5 | Ibañez-Murta Area (North) | 270 | 185.3 | 45 | 0 | 340 | 1 | 5 | 8 | 66 | 1 |
| | Ibañez-Murta Area (South) | 980 | 410 | 158 | 0 | 74 | 1 | 34 | 9 | 14 | 1 |
| No. 7 | Chile Chico-Chacabuco Area | 1,350 | 242 | 0 | 162 | 23 | 1 | 12 | 7 | 3 | 1 |
| | Lake Jeinimeni Alteration Zone | 17 | 21 | 0 | 0 | 73 | 0 | 0 | 0 | 8 | 0 |
| Total | | 3,367 | 1,198.3 | 270 | 312 | 586 | 6 | 68 | 28 | 104 | 6 |

## CHAPTER 2. GEOGRAPHY

### 2.1. Location and Access

#### 2.1.1 Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

This area lies in the northeastern part of the Coyhaique Prefecture of the XI Region and is located about 130 km north-northeast of Coyhaique city. The area is about 20 km as the crow flies from the north of Tapera Village. This village of about 500 habitants has a small aerodrome for small aircrafts. Distance from Coyhaique to Tapera is 190 km along the car-road. Only horse-roads are available to reach the area. It takes about four hours by car from Coyhaique to Tapera and nine more hours by horse from Tapera to the foot of Mt. Aguja. The alteration zone is developed around Mt. Aguja.

#### 2.1.2. Alto Cisnes-El Toqui Area

This area is situated in the northeastern part of the Coyhaique Prefecture of the XI Region and about 15 km west of Tapera. The area is of extremely thin population without any towns or villages. The area lies to the north-northeast of Coyhaique with direct distance of about 110 km. About four hours are needed to reach the western edge of the area by vehicle on road from Coyhaique. Only one passable road by car exists near the northern limit of the area, thus the movement within the area should be done mainly by horses or on foot.

#### 2.1.3. Ibañez-Murta Area (North)

This area lies in the southern part of the Coyhaique Prefecture of the XI Region and is located about 40 km south of Coyhaique. The area is easy of access from Coyhaique and it takes about one hour from that city to the area. The Austral main road runs longitudinally at the central part of the area and the horse-roads lie sparsely branching from the main road.

#### 2.1.4 Ibañez-Murta Area (South)

This area is located in the north to central part of the General Carrera Prefecture of the XI Region. The area lies between the Ibañez River and Lake General Carrera, and Lake Lapparent is in the central part. This lake is located 75 km south of Coyhaique and it takes about three hours by car and further three hours by horse from the city. The largest town, Puerto Ibañez of about 700 habitants, is located in the southeastern part of the area. The main road connects Coyhaique with this town. The Austral main road runs near the northern limit of the area to Murta Village. Horse-roads are well developed in the northern part of the area lying between the Ibañez River and

Lake Lapparent. However, the southern part is hard of access due to few horse-roads. Puerto Ibañez has a small aerodrome for small aircrafts and also regular ferryboat services are available for crossing Lake General Carrera.

### 2.1.5. Chile Chico-Chacabuco Area

This area extends over the General Carrera and Capitan Prat Prefectures of the XI Region. Puerto Guadal of about 500 to 600 habitants is the major town of this area and is located 320 km south-southwest of Coyhaique. About six hours are needed to reach the town by car from Coyhaique through the Austral main road. The town has a small aerodrome and small aircrafts for charter are available between Coyhaique and this town. Car-roads run along the northern, western and southern edges of the area. On the other hand, density of horse-roads is relatively high in the northern and western parts, but is extremely low in the eastern part.

### 2.1.6. Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

This area is situated near the Chile-Argentine border in the eastern part of the General Carrera Prefecture of the XI Region. The largest town is Chile Chico of about 2,000 habitants. To reach the town, ship ride on Lake General Carrera is necessary. The area is approximately 60 km south-southwest of Chile Chico. A road of 60 km long connects Chile Chico with Lake Jeinimeni. The alteration zones are developed to the north and south of the lake. It is about five hours trip from Coyhaique to Chile Chico by vehicle and ship. It takes further three hours by car to the area. The horse road network is very poor and the access to the alteration zones is very difficult.

## 2.2. Topography and Drainage Systems

### 2.2.1. Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

The ridge runs in the E-W direction at the northern limit (the Chile-Argentine border) of this area, forming the major watershed. The drainage system shows parallel pattern in the N-S trend perpendicular to the watershed. The summits of mountains are represented by 1,882 m (above sea level) of Mt. Aguja and 1,917 m of Mt. Huemules with the highest peak being 2,100 m of Mt. Steffen. This mountainous belt aligns in E-W direction and forms very steep slopes.

The major rivers are the Caceres River and its main tributary called the Magdalena River.

### 2.2.2. Alto Cisnes-El Toqui Area

The Cisnes River is the major river and flows from the east westward along the northern edge of this area. Whereas the main tributaries of this river such as the Buitrera, Winchester and Winchester Sur Rivers flow generally northward. The topography of this area is characterized by the gentle landform. Altitude of the terrains is between 600 to 2,000 m increasing from north southward.

### 2.2.3. Ibañez-Murta Area (North)

This area is situated within a mountainous belt called the Cordillera Castillo. The belt runs in the E-W direction and the summits of mountains range from 1,000 to 2,000 m. The area shows very steep topography and sparse plain. The drainage pattern is dendritic.

### 2.2.4. Ibañez-Murta Area (South)

Typical glacial landforms are developed in this area. The topography is characterized by straight rivers, broad U-shaped valleys, and extremely steep slopes. Waterfalls were formed in many localities preventing one from approaching the ridges. Ridges are usually gentle and mostly in the order of 1,500 m above sea level. Glaciers still remain in the western part of the area of more than 1,750 m in altitude. Altitude increases westward with the height peak being 1,842 m of Mt. Redondo. Longitudinal glacial lakes are developed all over the area making a beautiful landscape. The drainage pattern is trellis or dendritic. The major rivers such as the Ibañez, the Sin Nombre, and the Largo Rivers flow from west eastward.

### 2.2.5. Chile Chico-Chacabuco Area

The topography of this area shows the mountainous belt in the E-W direction, comprising Mt. Pato Raro, Mt. Las Horquetas, and Mt. Jeinimeni. The drainage system has the N-S direction, perpendicular to the belt. Altitude of the belt is between 1,000 to 2,000 m decreasing from east westward. The western part is dominantly gentle in topography. The drainage pattern is trellis in the central part representing the typical geomorphological features of alternating beds of sedimentary rocks. Glacial landforms such as U-shaped valleys, cirques, and hanging valleys are well developed in the eastern part.

### 2.2.6. Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

The topography of this area is characterized by the typical glacial landforms. The U-shaped valleys and glacial lakes (such as Lake Jeinimeni) are well developed throughout the area. The ridges show narrow jagged crests and slopes are considerably steep. The access to the summits is often difficult due to the above topography.

## CHAPTER 3. GENERAL GEOLOGY AND MINERALIZATION OF THE AYSEN REGION

The Region lies in the southern part of the Andes Orogenic Belt formed along the western margin of sub-stable landmass, west of the Guapore Craton.

The Region is underlain by Paleozoic metamorphic basement which is overlain by the Jurassic, Cretaceous, Tertiary and Quaternary Systems, and granitic rocks (Patagonia Batholith) intruded during the time from Jurassic to Tertiary. Distribution of the basement rocks is confined mainly to the western side of the area and they consist of greenschist, phyllite, quartz schist, mica schist, metasandstone, marl and calcareous schist. Metamorphic rocks other than greenschist are considered to be metasediments. Those rocks are intensely deformed. The Paleozoic basement is interpreted as an accretionary prism (Enricksen et al., 1990). The sedimentation period for the initial sedimentary rocks is still unknown, but those rocks are reported to be of Devonian to Carboniferous time by Skarmeta et al., (1984) in a part of the Precordillera of Aysen.

The Jurassic System is distributed to the east of the Patagonia Batholith elongated in the N-S direction, but it is distributed mainly in Argentine between lat. 39°S and 43°S. Rocks of the Jurassic System consist mainly of volcanic rocks and pyroclastic rocks ranging from intermediate to acidic in composition. However, they are made up of the flysh facies in the Lonquimay Area. Skarmeta et al.,(1984) reported that sedimentary rocks in this system are of Dogger to Malm Series.

The Cretaceous System also occurs to the east of the Patagonia Batholith, and divided into the Lower and Upper Cretaceous. The Lower Cretaceous is mainly distributed to the south of lat. 43°S and the Upper Cretaceous in the north. The Lower Cretaceous consists mainly of sedimentary rocks of marine origin, intermediate to acidic lavas and pyroclastic rocks in ascending order. The Upper Cretaceous consists mainly of volcanic rocks and continental sediments.

The Tertiary System is distributed mainly to the west of the Patagonia Batholith located north of lat. 43°S, but its distribution is discontinuous due to wide cover of the Quaternary System. Rocks of the lower part of the system are sedimentary rocks of marine origin. The upper part consists predominantly of continental sediments and volcanic rocks. This system occurs also to the east of the batholith in a small dimension. In these areas the lower part consists mainly of plateau basalts with small amount of marine sediments and the middle and upper part comprises continental sediments.

Extensive andesitic and basaltic volcanism took place during the end of Tertiary to early Quaternary mainly in the area of the Patagonia Batholith. A part of that volcanism is still active at present. The Quaternary alluvium is widely distributed in the plain (the Central Basin) located north of lat. 43°S, with the plain being enclosed by the Andes and the Coastal Ranges. The Quaternary is also characterized by abundant glacial deposits in this region.

Mesozoic to Early Cenozoic batholith (Andes Batholith) intruded along the western coast throughout the South America from Cape Horn to Colombia. A part of the batholith located south of lat. 39°S is called the Patagonia Batholith. The batholith consists of the backbone range of this region. It is distributed near the Chile-Argentine border from lat. 39°S to lat. 43°S, but crops out in the central part of the region from lat. 43°S southward. Period of intrusion of the batholith is estimated to be Middle Jurassic to Oligocene based on dating studies. Many rock types, granite to dunite are recognized in the batholith and chemical composition vary from basic on the west to acidic on the east (Skarmeta et al.,1984).

The extensive igneous activity caused by subduction of the oceanic plate took place in the western continental margin (Skarmeta et al., 1984). The activity is assumed to have begun in the Middle or Late Jurassic period. The plutonic intrusions intermittently occurred closely related to the activity along the western margin and the huge batholith was formed there until the Early Cenozoic. This igneous activity continued to the Cenozoic period and partly still active at present producing basaltic to andesitic volcanic materials.

Regional geologic structure is characterized by the N-S system for both fracture systems and fold structures. This direction is consistent for all sequences from Paleozoic to Recent. Fractures of this system are of young type, which were formed after the Middle Tertiary and are conspicuously developed in the Patagonia Batholith. Some of them extend over 100 to 150 km. Quaternary volcanism occurs along this fracture system with sporadic distribution of geothermal zones and hot springs.

Fold structures in Paleozoic sequences show composite folds accompanied by drag folds and their axes trend in the N-S direction. Fold structures developed in Mesozoic rocks are very gentle folds. Fold structures are not recognized in Cenozoic rocks. That is, the structural movements of Paleozoic and Mesozoic time are characterized by lateral movement, while those of Cenozoic are vertical movement.

Abundant mineralization of gold, silver, copper, lead, zinc, and molybdenum have already been recognized in this region and the adjacent area of Argentine. In Chilean region they are concentrated in the area from lat. 43°S southward. The distribution of ore deposits and mineral indications is mainly confined to the eastern marginal area of the Patagonia Batholith. Zonal arrangement of those mineralizations can be noticed from the eastern periphery of the batholith eastward as shown below (see Fig.I-2).

- Molybdenum belt
- Copper (-gold) belt
- Lead-zinc (-silver) belt

The remotest mineralization zone from the batholith is located about 100 km east of the batholith.

The molybdenum belt is situated in the periphery or in the vicinity of the batholith. Granitic rocks host the mineralization which occurs as stockwork veins. Mineral indications are relatively concentrated in the south of lat. 44°S, but are sparsely distributed as compared with other minerals.

Many ore deposits and mineral indications are found within the copper belt to the south of lat. 43°S. Their distribution is concentrated in Argentine between lat. 43°S and 44°S, but in Chile from lat. 43°S southward. Ore deposits of this belt are usually accompanied by a small amount of lead and zinc and in some cases by gold in the upper part of deposits. The copper deposits in this region are generally of small dimensions. Therefore, no deposit was exploited as copper mine so far in Chile.

The lead-zinc (-silver) belt is situated on the east of the copper belt and the mines are densely distributed in an area between lat. 45° and lat. 47°S. The production of lead and zinc from those mines attains 75 % of total volume in Chile. Many deposits belong to the vein type. Whereas also stratiform, replacement, massive, and lenticular types of deposits occur in calcareous rocks of Paleozoic or Mesozoic age. The lead ore in this belt contains rather high grade of silver with an average of about 100 g/t Ag. The representative lead and zinc ore deposits are the El Toqui and the Silva Deposits which are located in the Alto Cisnes-El Toqui Area and the Ibañez-Murta Area respectively. The former is a large scale ore deposit of stratiform replacement type and occurs in the calcareous rocks of the Lower Cretaceous Coyhaique Formation. The ore reserves of this mine are estimated to be 10 million tons at 4.5 % Pb and 12 % Zn. The Silva Deposit is also stratiform replacement deposit which occurs in the Paleozoic limestone beds. The ore reserves are 500,000 to 600,000 tons or more at 15 to 20 % Pb and Zn, and 40 to 60 g/t Ag.

The gold-silver belt apparently forms the easternmost zone of this arrangement from Coyhaique southward, however, this belt seems to extend obliquely and intersect the other belts as well as the batholith in the vicinity of Tapera Village. The continuity of this belt is not obvious between lat. 40°S and 43°S due to insufficient mineralization data. The gold-silver belt in the south from lat. 43°S seems to coincide with the central part of the Upper Cretaceous area. Therefore, it is considered that gold-silver mineralization probably occurred closely related to the Late Cretaceous volcanism.

Most of ore deposits in this zone are of vein type, however, the alluvial gold deposit derived from that of vein type was also discovered in the Lonquimay Area. The deposits in this belt are represented by gold bearing quartz veins accompanied by a very small amount of sulfide minerals. The occurrence of the veins are characterized by concentration of veinlets and broad acidic hydrothermal alteration zone. Host rocks of the deposits are Mesozoic volcanic and pyroclastic rocks that range in composition from acidic to intermediate. The representative ore deposits are the Katterfeld and the Laguna Verde Deposits which are located in the Alto Cisnes-El Toqui Area and the Chile Chico-Chacabuco Area respectively. Both deposits are newly discovered by recent exploration and now are in advanced exploration. Although the details of those deposits still are not open to others, they are believed to be considerably promising deposits from very active exploration. Few deposits of this type have been discovered in this belt, however, other indications similar to those deposits are anticipated to occur in this belt.

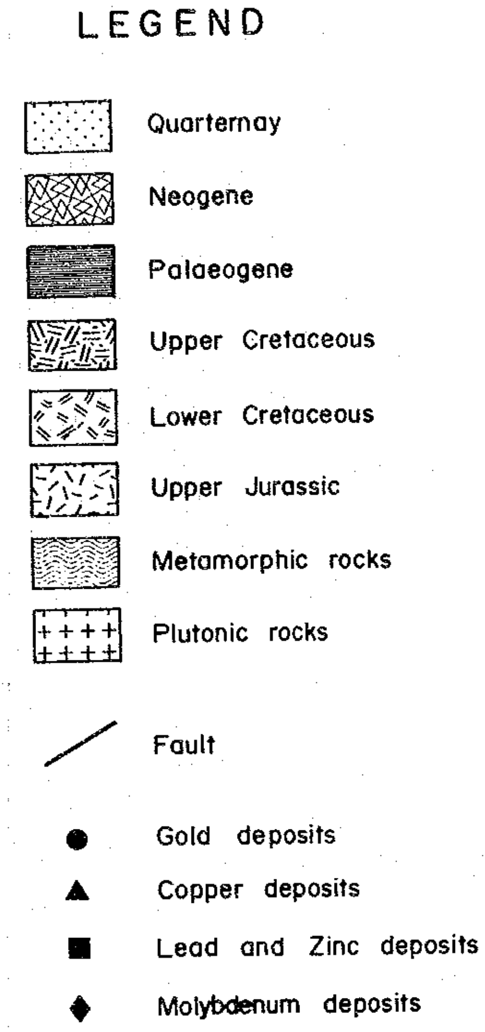




Fig. I -2 Distribution Map of Ore Deposits in the Southern Part of the Aysen Region

## CHAPTER 4. EVALUATION OF THE SURVEY RESULTS OF THE PHASE Ⅲ

### 4.1. General Features of Tectonics and Mineralization

#### 4.1.1. Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

Many investigation results have been reported on gold deposits associated with volcanic activity (BERGER and EIMON, 1982, TINGLEY and BERGER, 1985, IZAWA, 1985 etc.). General geological characteristics of gold deposits can be summarized as shown in Table Ⅱ-1-4 (Part Ⅱ, Chapter 1, 1.4.) based on the above results. The geological situation of the Cerro Aguja Alteration Zone will be described below in comparison with other known deposits.

The following surface geological features were recognized in the alteration zone:

- Only pyrite with a very small amount of chalcopyrite was found as a primary mineral. However, considerable arsenic concentration was obtained from assay results on altered rocks. The geochemical exploration resulted in the similar phenomenon.
- The central part of the alteration zone shows acidic alteration type with the mineral assemblage of quartz, alunite, pyrophyllite, and kaoline minerals, but sericite was detected at the periphery of the zone.
- Pyrite occurs as dissemination and stockwork. Neither stockwork nor veinlet of quartz was observed.
- Silica sinter, opalized rock and hydrothermal explosion breccia do not occur.

It is considered that the alteration zone is related to the hot-spring-type because of the characteristics mentioned above. The present alteration zone does not correspond to the superficial zone of the schematic cross section (Fig.Ⅱ-1-4, BERGER and EIMON, 1982) due to the absence of silica sinter, opalized rock and hydrothermal explosion breccia. The alteration zone might rather be situated between the "Silica sinter" zone and the "Stockwork veins" zone taking lack of stockwork veins into account. Arsenic contents are relatively high in the alteration zone as mentioned above. This also suggests that the alteration zone could be placed in a shallow zone of the cross section.

This alteration zone is inferred to have formed during the Late Cretaceous considering the ages of host rock and the basaltic dikes which cut the alteration zone. Hot-spring-type gold deposits were generally formed relatively in recent time, however, there is an exceptional case of the Early Cretaceous deposit such as the Pueblo Viejo Mine in Dominica. Therefore, it is not impossible to consider the formation time of the alteration zone as the Early Cretaceous.

### 4.1.2. Alto Cisnes-El Toqui Area

Hydrothermal alteration zones of various scales are well developed in this area, but mineralization zone was not confirmed. Alteration groups No.12 to 14 located in the northwestern part lie along a fault with N70°E strike. Dikes of quartz-monzonite porphyry often intruded in the vicinity of the groups and also were subjected to alteration. From these viewpoints, it is believed that the formation of those alteration groups are closely related to the fault and intrusion of the dikes. On the other hand, alteration groups and mineral indications (No.1 to No.11) are distributed around the large-scale granite stocks. The geochemical anomalies were also detected around the stocks. Therefore, those groups and indications are thought to have been affected by the granite stocks.

### 4.1.3. Ibañez-Murta Area (North)

Eleven alteration groups called Mineralization Group A to K are developed in this area. Five groups of E, F, G, H, and K are relatively concentrated in the central part and will be called the "Central Mineralization Group" hereafter, putting them together. This group is presumed to be of hot-spring-type in view of the following characteristics.

- Silicification zones are developed in the shapes of ellipse and circle Dimensions are; F: 4 x 1 km, E: 2 x 1.3 km, G: 0.9 x 0.4 km, H: 1.2 x 0.8 km etc.
- Dense distribution of stockwork veins of chalcedonic quartz and pyrite

The extensive silicification zones suggest that the Central Mineralization Group were formed under a shallow environment below the ground surface. It is inferred that brecciation by explosion, and the subsequent silicification and formation of quartz veinlets tock place due to the fact that dense distribution of quart-pyrite stockwork veins were found within the elliptical and circular silicificaiton zones. This brecciation zone is believed to correspond to the zone of hydrothermal explosion breccia which generally occurs in the hot-spring-type gold deposit. However, the main alteration mineral assemblage is quartz-sericite and no minerals showing acidic alteration such as kaolinite were detected. Neither silica sinter nor opalized rock crops out. In view of these geological characteristics, the Central Mineralization Group is presumably of hot-spring-type although the initial superficial parts have already been eroded out. The present level of outcrops of this group might correspond to the "Stockwork veins" zone of the section (Fig.Ⅱ-1-4). The "Stockwork vein" zone is under depositional environment of gold, but the gold contents in the Central Mineralization Group are extremely low. So far as this group is concerned, it can be solely attributed to very low contents of gold and silver in mineralizing solution.

#### 4.1.4. Ibañez-Murta Area (South)

The Ibañez Formation distributed in this area is gently folded with the 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. Those deposits also are densely distributed in the east where the fractures with N20°W strike are well developed. The deposits are believed to have been formed within some of the N20°W strike's tensional fractures which have resulted from the compressional stress in the NNW-SSE direction.

The ore deposits and hydrothermal alteration zones of this area occur in the rocks of the Ibañez and the Divisadero Formations, and are cut by the basalt dikes. It is reported that the dikes intruded during the Pliocene epoch (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 formation of this alteration is believed to be after Middle Cretaceous, judging from the fact that the dikes intruded into the Divisadero Formation.

Taking the above information into account, the mineralization took place at any time between Late Cretaceous and Pliocene in age. In other words, it is considered that the mineralization together with alteration occurred during the Late Cretaceous because it should have been closely related to the acidic volcanic activity resulting in the Divisadero Formation. The other types are thought to have no relation to the mineralization and the alteration because they have not been affected.

#### 4.1.5. Chile Chico-Chacabuco Area

Lead and zinc vein-type and dissemination-type mineralizations and mineral indications as well as alteration zones are sporadically distributed in this area. The vein system is not dominated by a specific direction and few faults were recognized in both the basement metamorphics and the Divisadero Formation. Therefore, it is difficult to discuss the relationships between the vein and fault systems. Nevertheless the lead and zinc mineralization is believed to have genetical close relation to felsic intrusive rocks such as rhyolite and tonalite, because the rocks intruded in the vicinity of the mineralization represented by the Escondida Mine. The mineralization and alteration are considered to have taken place after the Middle Cretaceous because the features similar to those in the Ibañez-Murta Area (South) were observed in the Divisadero Formation.

#### 4.1.6. Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

The alteration zones of this area are of epithermal type based on alteration mineral assemblage accompanied by local weak gold and lead mineralization. The mineral assemblage suggests that the present outcrop level is situated in a deeper zone than that of hot-spring-type deposits.

The alteration zones lie in the vicinity of dacite stocks, which indicates genetical close relationship between the zones and the stocks. Although the actual timing of the intrusion is unknown, it is believed that the intrusion was associated with the acidic volcanic activity resulting in the Divisadero Formation. Therefore, the stocks presumably intruded during Late Cretaceous together with the formation of the alteration zones.

The superficial parts of the alteration zones should have been eroded out because the zones have been formed in the Late Cretaceous, and it is difficult to point out the genetical process of the alteration zones. However, the zones might have been formed in deeper levels, considering the proximity to the dacite stocks. The Laguna Verde Deposits located about 60 km to the north of the area is also of epithermal type. It is reported that mineralization of the deposit vary from Au-Ag in the upper part to Pb-Zn in the lower part. Based on this condition the alteration zones of the area might be situated in deeper horizon than that of the deposit.

### 4.2. Relationships between Geochemical Anomalies and Mineralization

#### 4.2.1. Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

No mineralization but pyritization is found on the ground surface in the

Cerro Aguja Alteration Zone characterized by acidic alteration as described in section 4.1. This is supported by assay results of rock samples as shown below.

| | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | As(ppm) | S(%) |
|---|---|---|---|---|---|---|---|
| Inside of the A.Z. | 12.31 | 0.13 | 13.08 | 65.92 | 8.96 | 123.2 | 3.35 |
| Outside of the A.Z. | 21.54 | 0.22 | 21.15 | 28.31 | 52.50 | 14.38 | 0.93 |

(Figures of assay results are the mean value of 13 samples.
A.Z.: Alteration Zone)

The average grades of elements except for Pb, As and S are higher in the peripheries than inside of the alteration zone. On the other hand, the As and S values whithin the zone are about 10 and three times higher than the peripheries. In view of this fact, it appears that the surface of the alteration zone is rich in As and S and is poor in Au, Ag, Cu, and Zn. The Pb concentration might not have occurred in this zone because of the low content in the zone.

Anomalies of As are detected by panned concentrate geochemistry in all localities where the Cerro Aguja Alteration Zone has been dissected by the tributaries (Fig.II-1-5). Anomalies of other elements were obtained in the outside of the zone. Thus the assay results of rock samples are in excellent coincidence to those of geochemical exploration.

### 4.2.2. Alto Cisnes-El Toqui Area

No mineralization but only alteration zones are developed in this area. Six elements including Au, Ag and others for base metalliferous deposits were employed as the indicator elements in geochemical exploration. Anomalies of these elements amounted to 38 in total, among which 36 anomalies are located in the tributaries flowing from the outside of granite stocks. No anomalies was found in the tributaries through the stocks. This suggests that gold, silver, and base metalliferous mineralizations in this area may not have occurred in the granite stocks but in their vicinity.

### 4.2.3. Ibañez-Murta Area (South)

Mineral zoning is noticed in the southern part of the Aysen Region as mentioned in the Chapter 3 of the Part I. The Mo-Cu, Cu, Pb-Zn belts are aligned parallel from the western batholith eastward. Furthermore the Au-Ag belt is situated in the N-S direction near the Chile-Argentine border.

General distribution of geochemical anomalies is in good spatial accordance with those belts. This similar distribution pattern indicates that the results of panned concentrate geochemistry is consistent with the known mineralization. This area belongs to a cold district and has been subjected to intense glaciation. Therefore gold and other elements will be transported as particles of a solid and sulfide minerals respectively and are easy to be concentrated in the lower reaches of rather short tributaries of less than one km long. Some anomalies of Pb-Zn located to the west of Puerto Ibañez are believed to represent the Pb-Zn mineralization of the Cascara and Long Deposits.

#### 4.2.4. Chile Chico-Chacabuco Area

Systematic relationships between geochemical anomalies and mineralization could not be found in this area due to sparse distribution of ore deposits and mineralization zones.

### 4.3. Mineral Potential

#### 4.3.1. Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

The Cerro Aguja Alteration Zone extends widely and is characterized by acidic alteration. Rocks of the zone are intensely altered almost without any primary minerals. These suggest that the alteration zone has genetical relation to the hot-spring-type deposit. The zone will correspond to the shallow level of acidic environment just below the ground surface because it contains arsenic as minor elements. The Cerro Aguja Alteration Zone is in a favorable condition for gold deposition in view of the acidic environment of low temperature. In spite of these the gold contents are low in the zone, which consequently suggests low contents of gold in mineralizing solution. Therefore, grade of gold is not anticipated to improve in the deep underground of the alteration zone.

Lead, zinc, and copper contents will be increase in the deep underground, however, minable concentration is believed to be absent based on the general features of mineralization in the Aysen Region.

Many small alteration zones distributed around the Cerro Aguja Alteration Zone are made up of the marginal facies of the alteration which formed the main alteration zone. It hardly seems possible that the grade would improve below the surface of those small zones. The discussion above leads to a conclusion that the mineral potential of this area is small.

### 4.3.2. Alto Cisnes-El Toqui Area

Although 14 alteration groups were found in this area, only quartz veinlets or dissemination of pyrite occur in these groups and contents of the useful minerals are extremely low. Rocks of the groups are generally silicified, but the silicification is rather weak and primary minerals remain considerably in the rocks. Because of this, there is a small possibility that promising ore deposits exist below those alteration groups. So far as the Alteration Groups of No.12 to No.14 are concerned, they extend continuously and were formed with fault tectonic control of the N60°E strike. It is very difficult to pursue their extensions due to broad cover of the Quaternary System.

It hardly seems possible to detect the mineral indications through surface survey in the northern half of this area where the Quaternary System of post-mineralization age is extensively distributed. Furthermore, the stratiform replacement Pb-Zn deposits of the El Toqui type cannot be expected because of the lack of the Coyhaique Formation. Although some geochemical anomalies of Au are detected on the eastern slope of Mt. Los Matreros and there is a gold potential here, the mineralization, if exists, would be small because no alteration zones were found.

### 4.3.3. Ibañez-Murta Area (North)

The initial superficial part such as silica sinter has been eroded out in the Central Mineralization Group which has genetical relation to the hot-spring-type deposit. The present level of outcrops of this group might correspond to the "Stockwork veins" zone of the section (Fig.II-1-4), but gold contents of the group are very low. In other words, no deposition of gold took place despite the favorable condition for the deposition. Additionally no change in features of mineralization was found at the interval 500 m high. These suggest that few concentration of gold was within the mineralizing solution which formed the mineralization groups in this area. From this consideration there is a small possibility that the grade of gold will increase underground. Contents of lead and zinc probably increase in the deep underground, however, minable concentration of Pb-Zn deposit cannot be anticipated to exist based on the general features of mineralization of known mines.

Only the dissemination of pyrite accompanied by quartz veinlets was found in the other mineralization groups where few contents of gold, silver, and other base metals were detected. Outcrop levels of these groups are in the similar horizons to those of the Central Mineralization Group because the Divisadero Formation hosting all of the groups is regionally horizontal with gentle undulations. The principal alteration mineral is sericite in those groups, which indicate that the mineralization occurred in rather deep zone from the ground surface. Therefore, mineralization will not imrove in deeper underground.

On the basis of the above considerations, mineral potential of this area is believed to be low with respect to gold, silver as well as base metals.

#### 4.3.4. Ibañez-Murta Area (South)

The basement metamorphics and the Coyhaique Formation are not distributed in this area. Limestone beds accompany crystalline schists in some places of the basement metamorphics. Neither replacement Pb-Zn deposits of the Silva type nor of the El Toqui type are anticipated to occur from the above geological features.

Potential mineralization is Cu-Pb-Zn vein and epithermal Au-Ag types, but large deposits of both types cannot be expected based on the results of the surveys of this phase. Only single vein like the Cascara Deposit can be anticipated. The former mineralization might be found in the geochemical Pb-Zn anomalous zone located to the west of Puerto Ibañez. The latter type will be present in the upper reaches of the tributaries where the Au geochemical anomalies accompanied by gold grains were detected. The area extends as a belt from the road connecting Puerto Ibañez with Coyhaique to the Chile-Argentine border.

As stated in Chapter 3, the above areas lie on the N-S trending gold-silver belt where the Katterfeld and Laguna Verde Deposits are located. Although the areas have gold potential, large hot-spring-type gold deposits are not to likely occur due to the fact that no large alteration zones were observed and extracted through the field survey of this phase and TM image interpretation of the Second Phase respectively.

Some alteration zones were extracted from TM image in an area enclosed by the Avellano River and the upper reaches of the Long River. Only the area remains for further exploration since surface survey has not been conducted due to a hard access caused by thick snow cover.

#### 4.3.5. Chile Chico-Chacabuco Area

The calcareous schist was confirmed only at one locality despite the wide distribution of the basement metamorphics in this area. Therefore, Pb-Zn mineral potential of the Silva type is low. The Cu-Pb-Zn vein deposits hosted by either the basement metamorphics or the Ibañez and Divisadero Formations may occur in this area, but they must have small potentiality in view of the features of known mines and mineral indications.

There is no mineral potential in the middle of this area where the post-mineralization Tertiary marine sediments are widely distributed.

### 4.3.6. Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

The alteration zones of this area are of epithermal type based on alteration mineral assemblage and are accompanied by local weak gold lead mineralizations. The mineral assemblage suggests that the present level of outcrops is situated in a deeper horizon than that of hot-spring-type deposits.

It is difficult to estimate the strength of mineralization in deeper horizons. However, it can be stated that the present level of outcrops could have been under depositional environment of gold a: the formation time, but the present Au content is low. With all relevant factors considered, .he mineralization probably would not improve downward.

Therefore, mineral potential is believed to be low in this area.

# CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

## 5.1. Conclusions

### 5.1.1. Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

The Cerro Aguja Alteration Zone is developed in the western part of this area occupying an area of 5 km E-W and 4 km N-S, and is hosted by pyroclastic rocks of the Divisadero Formation. The alteration is acidic and is characterized by the dissemination of pyrite and a very small amount of chalcopyrite as well as disseminations and stockworks of limonite and hematite. Assay results of altered rocks show extremely low contents of useful metalliferous elements. Only the contents of arsenic are relatively high (mean value: 123 ppm). Anomalies of As are detected around the alteration zone by panned concentrate geochemical exploration.

The alteration zone is inferred to have genetical relation to hot-spring-type deposits based on features of host-rock alteration and minor elements. The present surface of the zone is believed to be situated between the ground surface and the "Stockwork veins" zone of the schematic section proposed by Berger and Eimon (1982). The alteration zone is in a favorable situation for gold deposition under the acidic environment, but no significant gold deposition was noticed. This suggests low contents of gold in mineralizing solution itself. From these viewpoints, no improvement of gold contents is anticipated below the present level of the alteration zone.

### 5.1.2. Alto Cisnes-El Toqui Area

Although 14 alteration groups hosted by the Ibañez and Divisadero Formations are distributed in this area, only quartz veinlets or dissemination of pyrite occur in these groups and contents of useful minerals are extremely low. Rocks are altered, but only weak silicification is recognized in these groups. In view of the above information, there is a small possibility that promising ore deposits occur within those alteration groups.

The stratiform replacement Pb-Zn deposits of El Toqui type hardly occur in this area due to the lack of the Coyhaique Formation. No significant anomalies were obtained through geochemical exploration.

### 5.1.3. Ibañez-Murta Area (North)

More than 30 mineralization zones of various dimensions are distributed in this area. Five mineralization groups called E, F, G, H, and K are hosted by lapilli tuff and rhyolite lava of the Divisadero Formation and are developed with intensive stockwork veins of quartz accompanied by dissemination of pyrite as well as stockwork and dissemination of limonite and hematite. Rocks of these groups are intensely silicified and weakly sericitized. Although grade of Au ranging from 0.1 to 0.2 ppm were rarely obtained from assaying on quartz of stockwork veins, no concentration of other elements were detected.

The present level of outcrops is believed to correspond to the "Stockwork veins" zone of the schematic section (Berger and Eimon, 1982), however, contents of gold are low. In other words, few concentration of gold was within the mineralizing solution because almost no gold mineralization was recognized despite the favorable condition for gold deposition. From this viewpoint there is a small possibility that the grade of gold will increase downward.

Only the dissemination of pyrite accompanied by quartz veinlets was found in the other mineralization groups where very few contents of gold, silver, and other base metals were detected. Therefore, mineralization will not improve further in the deep underground. On the basis of the above considerations, mineral potential of this area is believed to be low with respect to gold and silver as well as base metals.

### 5.1.4. Ibañez-Murta Area (South)

Some vein type Pb-Zn(-Cu-Mo) deposits occur and about 20 alteration zones of various dimensions are distributed in this area. The vein type deposits are mainly situated in the eastern part of the area in small scales. Most of the alteration zones have dimension of 500 x 200 m and rocks of the zones are silicified and weakly argillized. Disseminations and stockwork of pyrite, limonite, and hematite generally occur in these alteration zones, but few veins of quartz and sulfide minerals are observed. Anomalous zones of Au-Pb-Zn and Au were obtained through panned concentrate geochemistry. The former and the latter are distributed to the west and north of Puerto Ibañez, respectively.

Neither deposits of Silva type nor of El Toqui type are anticipated to occur in this area because of absence of the basement metamorphics and the Coyhaique Formation. Potential mineralizations are of Pb-Zn(-Cu) vein type and of epithermal Au-Ag type, but these deposits will be small because of the general features of mineralization of known mines. The former base metal mineralization might be found in the geochemical Pb-Zn anomalous zone located to the west of Puerto Ibañez. The latter epithermal gold concentration occur in two separated areas. One is an area enclosed by the road connecting Puerto Ibañez with Coyhaique and the Chile-Argentine border. The other is located in the upper reaches of the Long River. The above area near the Chile-Argentine border lies on the N-S trending gold-silver belt where the Katterfeld and Laguna Verde Deposits are located.

Some alteration zones were extracted from TM images in an area enclosed by the Avellano River and the upper reaches of the Long River. Only the area is prospective for epithermal gold mineralization. No surface survey was conducted in this phase due to thick snow cover.

### 5.1.5. Chile Chico-Chacabuco Area

Some vein type Cu-Pb-Zn deposits are situated in the northern part of this area. They are in small scales. Although several alteration zones are also distributed in the northeastern part of the area, rocks of the zones are weakly silicified together with dissemination or veinlets of pyrite and limonite. The Pb-Zn mineral potential of the Silva type is very small because the widely distributed basement metamorphics are interbedded with few calcareous schists. Cu-Pb-Zn veins hosted by the basement metamorphics, the Ibañez and Divisadero Formations are anticipated to occur in the vicinity of felsic intrusive rocks, but the mineral potential is low. Furthermore, there is no mineral potential in the middle of this area where the post-mineralization Tertiary marine sediments are widely distributed.

### 5.1.6. Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

The Alteration Group C extracted from TM image is divided into several parts with no alteration zones between the parts. Although quartz veinlets are exposed in some parts, accompanied by faint mineralization of Au (1 to 2 g/t) and Pb, the veinlets are sparsely developed in an area of 200 x 200 m. The Alteration Group D surveyed in the second phase is composed of the silicification zones with dissemination of pyrite. Neither quartz vein nor significant grades of useful metals were found in this group.

These alteration groups are of epithermal type based on alteration mineral assemblage. The present level of outcrops is believed to have been under depositional environment of gold when the formation time, because the groups were probably situated in the transitional zone from the acidic to intermediate zones. Despite the above condition the grade of gold is low in those groups. Therefore, the mineralization takes unlikely a turn for better downward.

## 5.2. Recommendations for Future Exploration

The following recommendations can be stated with regard to six areas for future exploration based on the results of this survey.

(1) Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

The prospectiveness is small and the area does not warrant further exploration.

(2) Alto Cisnes-El Toqui Area

The necessity for further exploration work is small.

(3) Ibañez-Murta Area (North)

Further exploration work is concluded to be not feasible in this area.

(4) Ibañez-Murta Area (South)

Geological survey and geochemical exploration should be conducted in two areas stated below because they remain unexplored and may have mineral potential of gold of epithermal type.

- Area enclosed by the road connecting Puerto Ibañez with Coyhaique and the Chile-Argentine border.
- Area enclosed by the Avellano River and the upper reaches of the Long River. This area is located to the west of the survey area of Third Phase.

(5) Chile Chico-Chacabuco Area

The necessity for further exploration work is small.

(6) Chile Chico-Chacabuco Area (Lake Jeinimeni Alteration Zone)

The Lake Jeinimeni Alteration Zone itself does not warrant further exploration because the mineralization is faint and is not believed to improve underground.

The surrounding areas, however, are situated at the southern extension of the "Au-Ag" belt mentioned before. Furthermore a plenty of alteration zones with geochemical anomalies of Au are aligned on the belt as described in the report of the Second Phase. Therefore, emphasis of future exploration is placed on the Au-Ag belt between Lake General Carrera and the Chacabuco River.

# PART Ⅱ
# DETAILED DISCUSSIONS

PART II

DETAILED DISCUSSIONS

# CHAPTER 1. ALTO CISNES-EL TOQUI AREA (CERRO AGUJA ALTERATION ZONE)

## 1.1. Geology

### 1.1.1. Stratigraphy

The geology of this area is composed of Jurassic (Middle to Upper) and Cretaceous (Aptian to Cenomanian) volcanic and pyroclastic rocks, and Quaternary sediments. Judging from the lithology and stratigraphy of the neighboring Alto Cisnes-El Toqui Area (described in Chapter 2), the Jurassic and Cretaceous Systems in this area are correlated to the Ibañez Formation and the Divisadero Formation, respectively. The geological map (Fig.II-1-1) and the schematic columnar section (Fig.II-1-2) are laid out. In the geological map, both the Ibañez and the Divisadero Formations are shown as rock facies. The intrusive rocks will be described in 1.1.2.

Photogeological interpretation played an extremely important role in the preparation of the geological map. This was particularly evident in the highland over 1500 m and parts of southern slope which were covered by snow during the survey.

**(1) Ibañez Formation**

This formation is distributed in the eastern to southern part of this area. It is distributed in zonal pattern near the Caceres River. The formation is composed mainly of dacitic lapilli tuff (Jfit). It is fine, gray, and partly silicified. Fine tuff is intercalated and bedding planes are observed. The thickness is over 1500 m, and the relation with the lower formation is not clear because of the lack of exposures at the lowermost part.

**(2) Divisadero Formation**

This formation occurs separately in the western, central and eastern to northern parts of this area. Of these parts, it is most widely distributed in the western part. Andesitic rocks (Kfda) and dacitic pyroclastic rocks (Kfdt) are major constituents of this formation. The former is mainly distributed in the western and central parts, and occurs in the lower part of the formation. In the western part, it is composed of greenish aphanitic lava, it is strongly chloritized and epidotized, and is very poor in lithological variation. Pyrite dissemination is partly observed. Other parts consist of alternation of the above andesitic lava and tuff breccia. There are regional variation in the lithology of the tuff breccia. In the western part, major constituent is fine tuff which is accompanied by small amounts of sandy tuff and lapilli tuff, and is overlying the above andesitic rocks. It was subjected to strong silicification, argillization and pyritization, and constitutes the main host rock in the Cerro Aguja Alteration Zone (described in section 1.2.). In other parts, lapilli tuff and tuff breccia are mainly developed. The thickness of the formation is estimated to be over 1000 m. The relation between this formation and the underlying Ibañez Formation is not clear. However, they are considered to be unconformable, judging from the distinct difference of their age and the geology of the neighboring areas.

(3) Quaternary

The Quaternary System in this area is divided into the Pleistocene Series composed of fluvial terrace deposits and glacial deposits, and the Holocene Series composed of alluvial, but they are summarized as one unit on the geological map. These deposits are distributed along the main rivers including the Caceres, the Neptuno, and the Magdalena Rivers. The terrace deposits generally have wide distribution, and at least two terrace surfaces are recognized. The height difference between higher terrace surface and the present river bed reaches 100 m. The Holocene Series (fluvial deposits and talus deposits) is developed along upper reaches of the Magdalena and other rivers.

### 1.1.2. Intrusive rocks

The felsic intrusive rocks occur widely in Mesozoic formations. They are divided into two rock types, namely granite-granodiorite-tonalite (g) and dacite porphyry (da). The former is considered to be a granitic complex composed of coarse granular granite as major constituent in association with intermediate rocks such as tonalite and microdiorite. The dacite porphyry is developed in the southern part on the west of the Cerro Aguja Alteration Zone, and occurs partially as a host rock of this alteration zone. Also it often becomes monzonite porphyry. Although the relation between the above two types is not clear, it is inferred that the granitic complex consists of plutonic rocks and the porphyry consists of intrusive rocks derived from the igneous complex. Small basalt dikes are found locally, and are free from mineralization and alteration.

### 1.1.3. Geologic structure

(1) Fold

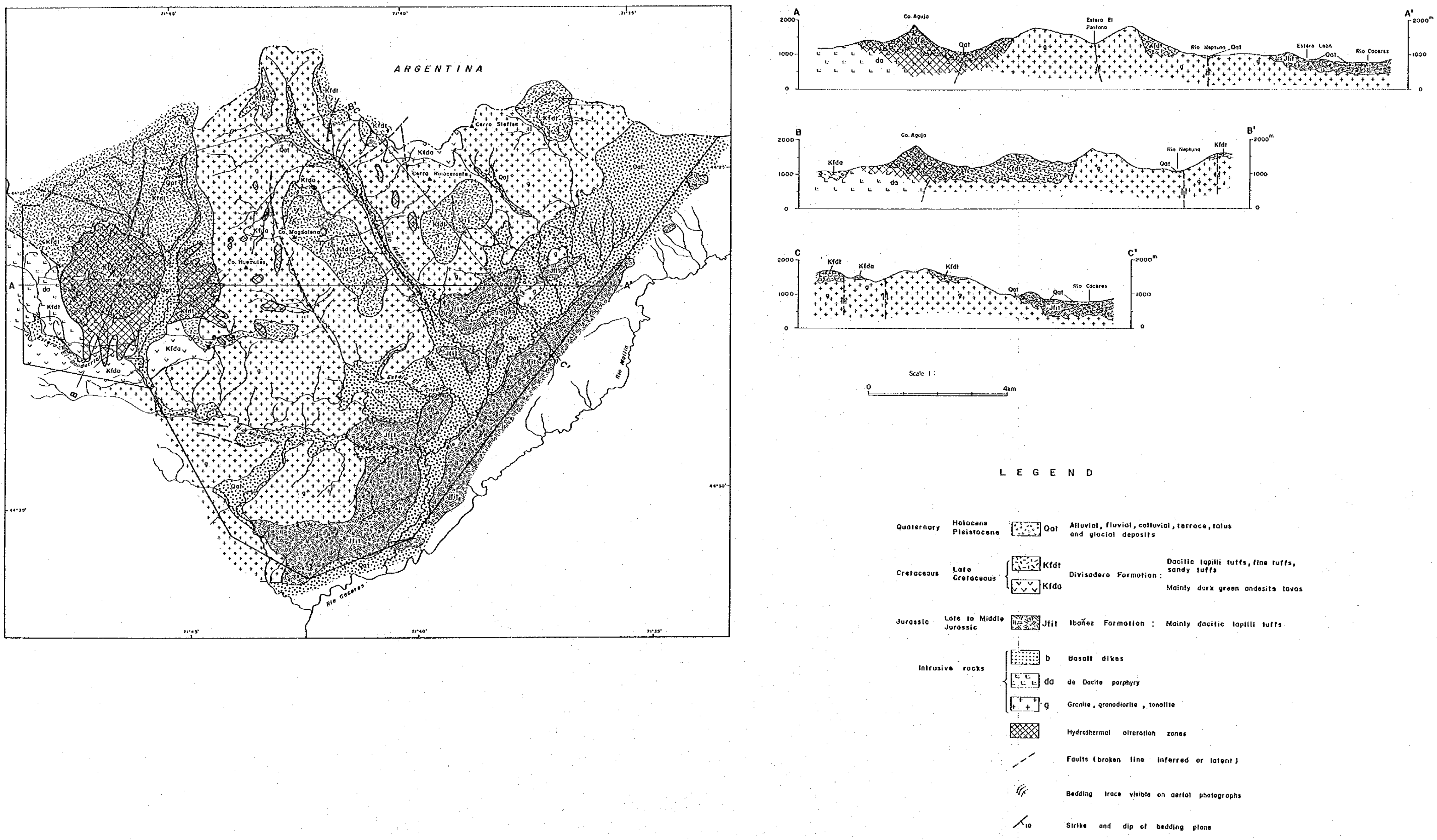



Fig. II-1-1 Geological Map of the Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

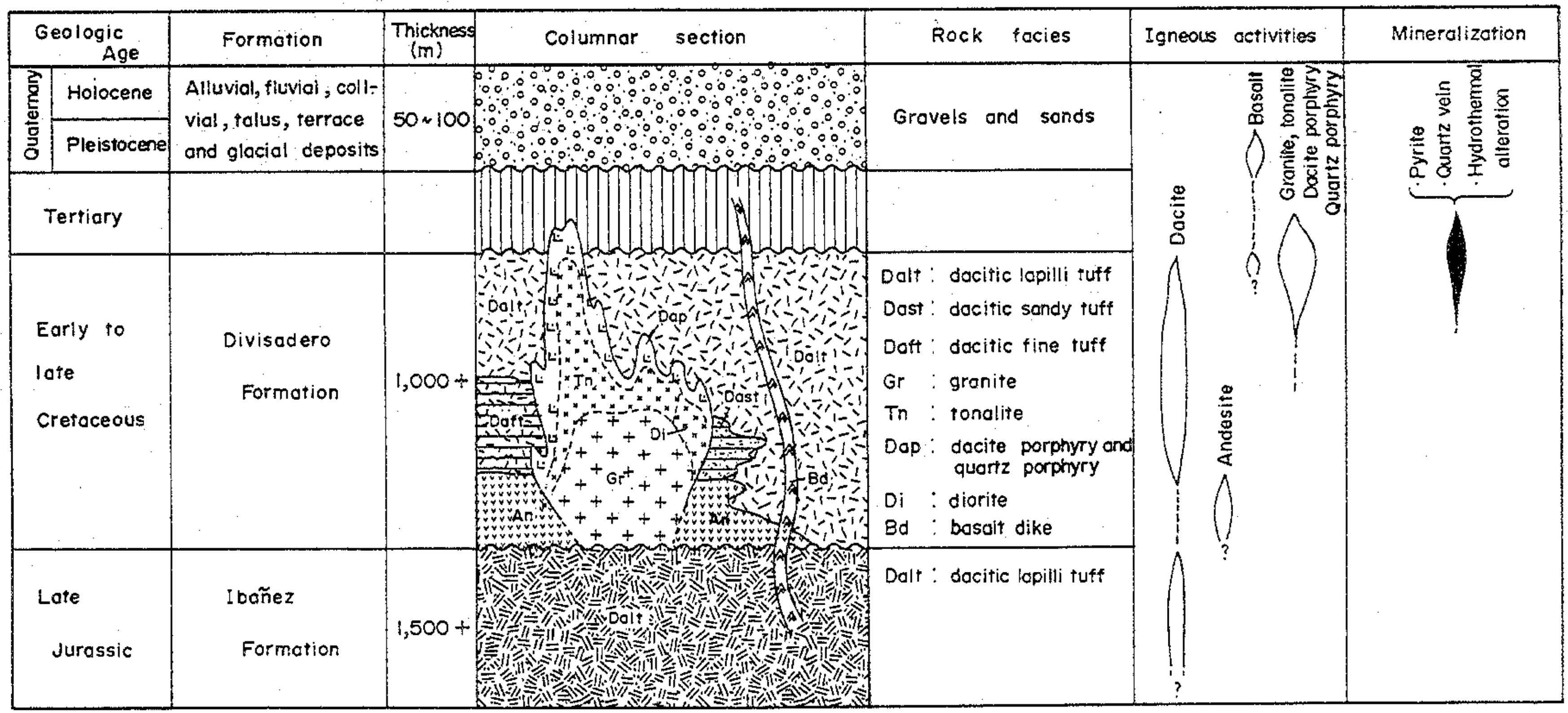



Fig. II-1-2 Schematic Columnar Section of the Alto Cisnes-El Toqui Area
(Cerro Aguja Alteration Zone )

About 60 % of this area is occupied by intrusive rocks, and Mesozoic formations are distributed locally. Furthermore, as most Mesozoic rocks are massive, it is not clear whether the whole area has obvious fold structure. Based on the bedding planes recognized in fine tuff and parts of sandy tuff, and those estimated from photogeological interpretation, macroscopic structure is considered to be as follows. The dip angle generally ranges from 10 to 30°.

- Eastern to southern Ibañez Formation : NE-SW strike, NW dip
- Western Divisadero Formation : E-W strike, N dip
- Central Divisadero Formation : NW-SE strike, NE dip
- Eastern Divisadero Formation : NW-SE strike, SW dip and E-W strike, S dip

(2) Fault

Nine faults extending from 2 to 10 km were recognized in this area. The faults of the NNW-SSE direction are relatively longer, and no other faults have systematic direction. The displacement is not distinct in the intrusive rocks, but the faults within the Divisadero Formation have vertical displacement ranging from 100 to 200 m.

### 1.2. Mineralization

There are no known ore deposits in this area, and the geophysical and drilling prospecting were never carried out in this area. However, a hydrothermal alteration zone is widely developed in the western part. As this zone is developed around Mt. Aguja (1882 m), this alteration zone is tentatively called the Cerro Aguja Alteration Zone. This zone is described below.

Cerro Aguja Alteration Zone

1) Locality

Mt. Aguja is situated at the upper reached Magdalena River, a tributary of the Caceres River, and it is nearly in the center of the alteration zone. The Chile-Argentine border is situated 2 km north from the north end of the alteration zone. Access to this area is inconvenient, passable only by horses. The traffic is stopped by snowfall in winter season.

2) Geology

The central part of the Cerro Aguja Alteration Zone is situated in the alternation of fine tuff and lapilli tuff of the Divisadero Formation. And the margin of this zone is in contact with andesite lava which underlie the formation. At the southern margin of this zone the Divisadero Formation is intruded by dacite porphyry, which is also altered. The granitic batholith is distributed widely from 2 km south of the dacite porphyry to the east margin of the alteration zone (Fig.II-1-1). Also, the alteration zone is intruded by some basaltic andesite dikes. The pyroclastic rocks developed in the center of the zone indicate E-W strike and gentle N dip (10 to 22°).

3) Mineralization

Sulfide minerals include pyrite and chalcopyrite. Pyrite is disseminated as fine grains in most of the alteration zone. A few amount of chalcopyrite is recognized microscopically as a relict mineral in disseminated limonite in the center of the alteration zone.

Oxide minerals including limonite and hematite occur abundantly as dissemination and stockwork throughout the whole alteration zone.

The assay results of altered rocks including large amounts of oxide minerals are as follows.

| | | Center of the A.Z. | Margin of the A.Z. |
|---|---|---|---|
| Number of Samples | | 13 | 13 |
| Au (ppb) | Max. | 40 | 160 |
| | Min. | <20 | <20 |
| | Mean | 12 | 22 |
| Ag (ppm) | Max. | 0.3 | 0.8 |
| | Min. | 0.1 | 0.1 |
| | Mean | 0.1 | 0.2 |
| Cu (ppm) | Max. | 40 | 180 |
| | Min. | 6 | 10 |
| | Mean | 13 | 21 |
| Pb (ppm) | Max. | 200 | 168 |
| | Min. | 6 | 3 |
| | Mean | 66 | 28 |
| Zn (ppm) | Max. | 44 | 348 |
| | Min. | <5 | <5 |
| | Mean | 9 | 53 |
| As (ppm) | Max. | 0.11% | 88 |
| | Min. | 9 | <5 |
| | Mean | 123 | 14 |
| S (%) | Max. | 12.50 | 6.04 |
| | Min. | 0.13 | 0.01 |
| | Mean | 3.35 | 0.93 |

A.Z.: Alteration Zone

It is seen in the above table that the contents of As and S are high in the central part. The other elements are generally very low, and they tend to be higher in the marginal parts than in the central part. It is evident that mineralization of Au, Ag, Cu, Pb and Zn is very weak.

4) Alteration

Alteration in the Cerro Aguja Alteration Zone is strong within a radius of 1.5 km of Mt. Aguja, and toward its outside the alteration becomes weak with irregular amoeba-like shape. Beside quartz, the primary minerals of the host rock are mostly replaced by secondary minerals in the strongly altered central part, and feldspar cannot be detected by the X-ray diffraction (Table 10 in Appendix). However, as the texture of original rock is preserved, it is possible to distinguish lapilli from fine tuff.

The alteration minerals in the central part are quartz, alunite, pyrophyllite and jarosite as major constituents, and minor kaolinite and very small amounts of chlorite as accessory minerals. Around the alteration zone, primary feldspar remains and quartz and sericite are detected as alteration minerals. Here the texture and structure of the host rock are completely preserved, and unaltered part gradually increases toward non-alteration zone. That is, in the central part of the Cerro Aguja Alteration Zone the alteration condition is acidic, and intermediate in the marginal area. The weak alteration in the marginal part of this zone extends for 5 km east of Mt. Aguja.

### 1.3. Geochemical Exploration

#### 1.3.1. Sampling and assaying

Panning geochemistry was used for gold-silver exploration. Total of 67 panned concentrates were collected and their localities are shown in PLATE 18. Samples were basically collected from immediately above the bedrock or clay bed where the heavy detrital minerals, especially gold grains are concentrated. About 20 g 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 limit and analysis methods used are shown in the following table.

Analytical Methods and Detection Limits

| Element | Digestion and Methods | Detection Limits | |
|---|---|---|---|
| | | Lower limit | Upper limit |
| Au | AAS-MIBK extraction | 20 ppb | 20 ppm |
| Ag | AAS | 0.1 ppm | 100 ppm |
| Cu | AAS | 1.0 ppm | 1.0 % |
| Pb | AAS | 1.0 ppm | 0.5 % |
| Zn | AAS | 1.0 ppm | 1.0 % |
| As | AAS | 5.0 ppm | 1.0 % |

AAS: Atomic Absorption Spectrometry
MIBK: Methyl Isobutyle Keton

### 1.3.2. Statistical data-processing

**(1) Results of assaying**

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

All elements other than Au and As existed in amounts greater than the detection limits in all samples analyzed. On the other hand, only 13% of Au and 10% of As samples analyzed contained the metals in amounts above the detection limit. The maximum and minimum values and the mean values are as shown in Table II-1-1. Most of the Au assay results does not exceed 100 ppb with the exception of 2 samples with Au content in the order of ppm. All Ag assay results were below 10 ppm. Cu and Pb contents were also generally low. Only one sample each contained over 100 ppm. On the other hand, many Zn assay results range in the order of 100 ppm with 12 % of samples containing less than 100 ppm. All As assays were below 60 ppm.

**(2) Elemental statistics**

Elemental statistic parameters are listed in Table II-1-1.

**Table II-1-1 Elemental Statistic Parameters in Geochemistry of the Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)**

| | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | As(ppm) |
|---|---|---|---|---|---|---|
| Mean | 13.8 | 0.3 | 12.6 | 20.8 | 143.4 | 3.1 |
| Max. | 4400 | 6.6 | 146 | 203 | 295 | 56 |
| Min. | 10 | 0.1 | 2 | 6 | 48 | 2.5 |
| M+$\sigma$ | 38.2 | 0.8 | 30.2 | 36.9 | 205.2 | 5.7 |
| M+2$\sigma$ | 105.9 | 2.0 | 72.6 | 65.4 | 293.5 | 10.9 |

**(3) Frequency distribution pattern**

Fig.Ⅱ-1-3 illustrates the frequency distribution histogram for each element. X-axis is expressed as logarithm scale. A group of elements Ag, Cu, Pb and Zn follow a log-normal distribution. Au frequency distribution pattern shows three separated populations in which the centers of the populations are situated around the detection limit, 80 ppb and 1000 ppb. Population of As obviously consists of two sub-populations situated in the areas below detection limit and 10 ppm or more.

(4) Correlation

Correlation coefficients matrix table is shown in Table Ⅱ-1-2. The elements pairs showing coefficients greater than 0.5 are Cu-Ag and Cu-Pb and they are as follows.

Cu-Ag: 0.66970
Cu-Pb: 0.60099

Table Ⅱ-1-2 Correlation Coefficients between Elements Pairs in Geochemistry of the Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

| | Au | Ag | Cu | Pb | Zn | As |
|---|---|---|---|---|---|---|
| Au | 1.00000 | | | | | |
| Ag | 0.25402 | 1.00000 | | | | |
| Cu | 0.08976 | 0.66970 | 1.00000 | | | |
| Pb | 0.14239 | 0.42642 | 0.60099 | 1.00000 | | |
| Zn | -0.06004 | 0.31841 | 0.08164 | 0.18705 | 1.00000 | |
| As | 0.12659 | -0.11580 | 0.27271 | 0.39956 | -0.13514 | 1.00000 |

Table Ⅱ-1-3 Eigen Vectors and Eigen Values of Principal Component Analysis of the Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Au | 0.20362 | 0.17166 | 0.87137 | 0.35798 | 0.03005 | 0.20182 |
| Ag | 0.51519 | -0.37041 | 0.21829 | -0.25631 | -0.22113 | -0.65965 |
| Cu | 0.56517 | 0.03756 | -0.11091 | -0.40625 | -0.29966 | 0.64190 |
| Pb | 0.53183 | 0.17363 | -0.22248 | 0.12875 | 0.78497 | -0.06893 |
| Zn | 0.19807 | -0.57440 | -0.25847 | 0.70697 | -0.18076 | 0.17760 |
| As | 0.22722 | 0.68690 | -0.25388 | 0.35317 | -0.45995 | -0.27531 |
| Eigen | 2.34661 | 1.32300 | 0.99678 | 0.77381 | 0.37871 | 0.18110 |
| Prop. | 0.39110 | 0.22050 | 0.16613 | 0.12897 | 0.06312 | 0.03018 |
| Cum. prop. | 0.39110 | 0.61160 | 0.77773 | 0.90670 | 0.96982 | 1.00000 |

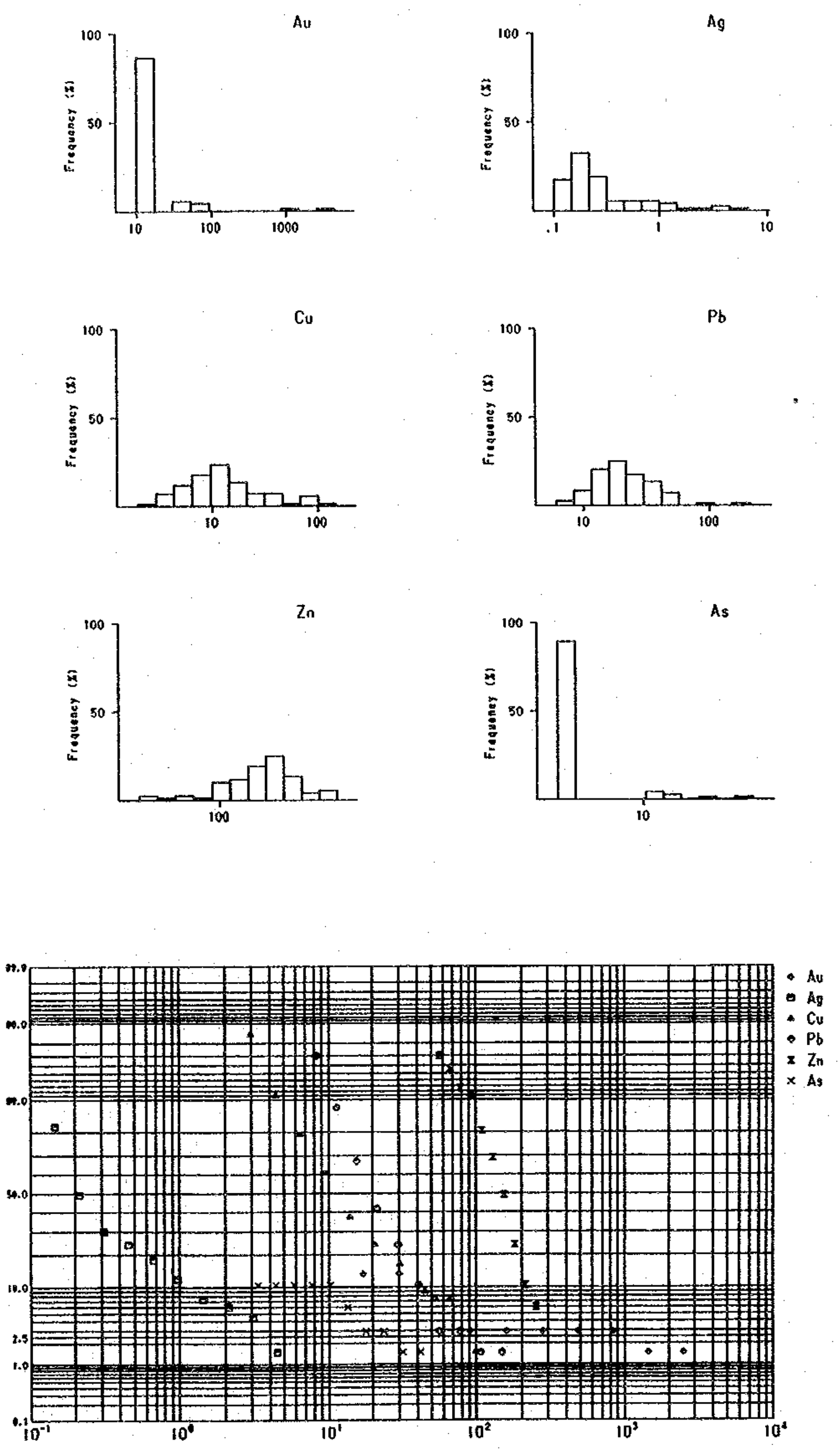



Fig. II-1-3 Histograms and Cumulative Frequency Curves Showing Frequency Distribution Patterns of Assays on Panned Concentrate Geochemical Samples Collected in the Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

(5) Principal component analysis

Principal components were analyzed in order to examine the interaction between various geochemical constituents and find the most efficient linear combination. The calculated eigen vectors and eigen values are shown in Table II-1-3. Principal components are interpreted with eigen vectors as follows.

First principal component

All the elements show the positive eigen vectors. By their values, the elements are grouped into two; Ag-Cu-Pb and Au-Zn-As. This combination pattern is not in accordance with the general mineralization features.

Second principal component

Eigen vector of As is a little high. Eigen vectors of Au-Pb and Ag-Zn range in the similar values respectively. This component is represented by As and is believed to express As mineralization which is related to no other elements.

Third principal component

Eigen vectors of Au is high and positive. Ag also has positive eigen vectors as well, but low. All other elements have negative eigen vectors. Au is the prime element in this component. This component may express the existence of Au mineralization. This component is characterized by low eigen value with less than 1.0 and low percentage of total variance contributed by each eigen value(17 %).

As discussed above, second principal component is believed to express the mineralization in this area. Therefore, the score values for this principal component were calculated for every sample. The calculated scores are listed in Table 7 in Appendix. All points except one showing scores greater than 1.0 are concentrated in the Cerro Aguja Alteration Zone (PLATE 14).

1.3.3. Geochemical anomalies and anomalous zones

(1) Threshold

Ag, Cu, Pb and Zn follow a log-normal distribution and $m+2\sigma$ values were used as threshold values because their frequency distribution patterns show unique populations for each element. The threshold values for Au and As were also $m+2\sigma$ although they do not show log-normal distribution. Thresholds used are listed in the following table.

Threshold

| Element | threshold |
|---|---|
| Au | 106 ppb |
| Ag | 2 ppm |
| Cu | 73 ppm |
| Pb | 65 ppm |
| Zn | 293 ppm |
| As | 11 ppm |

(2) Geochemical anomalous zones

The number of sampling points with geochemically anomalous values is as follows.

Numbers of Geochemically Anomalous Points

| Element | Number |
|---|---|
| Au | 2 |
| Ag | 4 |
| Cu | 4 |
| Pb | 2 |
| Zn | 1 |
| As | 7 |

The localities of their anomalies are shown in PLATE 14. Major features concerning their distributions are summarized as follows:-

1) Au

Two anomalies were detected in the middle reaches of the Leon Creek and the upper reaches of the Pantano Creek as much as several kilometers away from the Cerro Aguja Alteration Zone.

2) Ag

Ag anomalies occur several to some ten kilometers away from the Cerro Aguja Alteration Zone. They are single anomaly of Ag and the contents are very low.

3) Cu

Cu anomalies are sporadically distributed. Only one anomaly was obtained in the Cerro Aguja Alteration Zone. Cu assay results are very low.

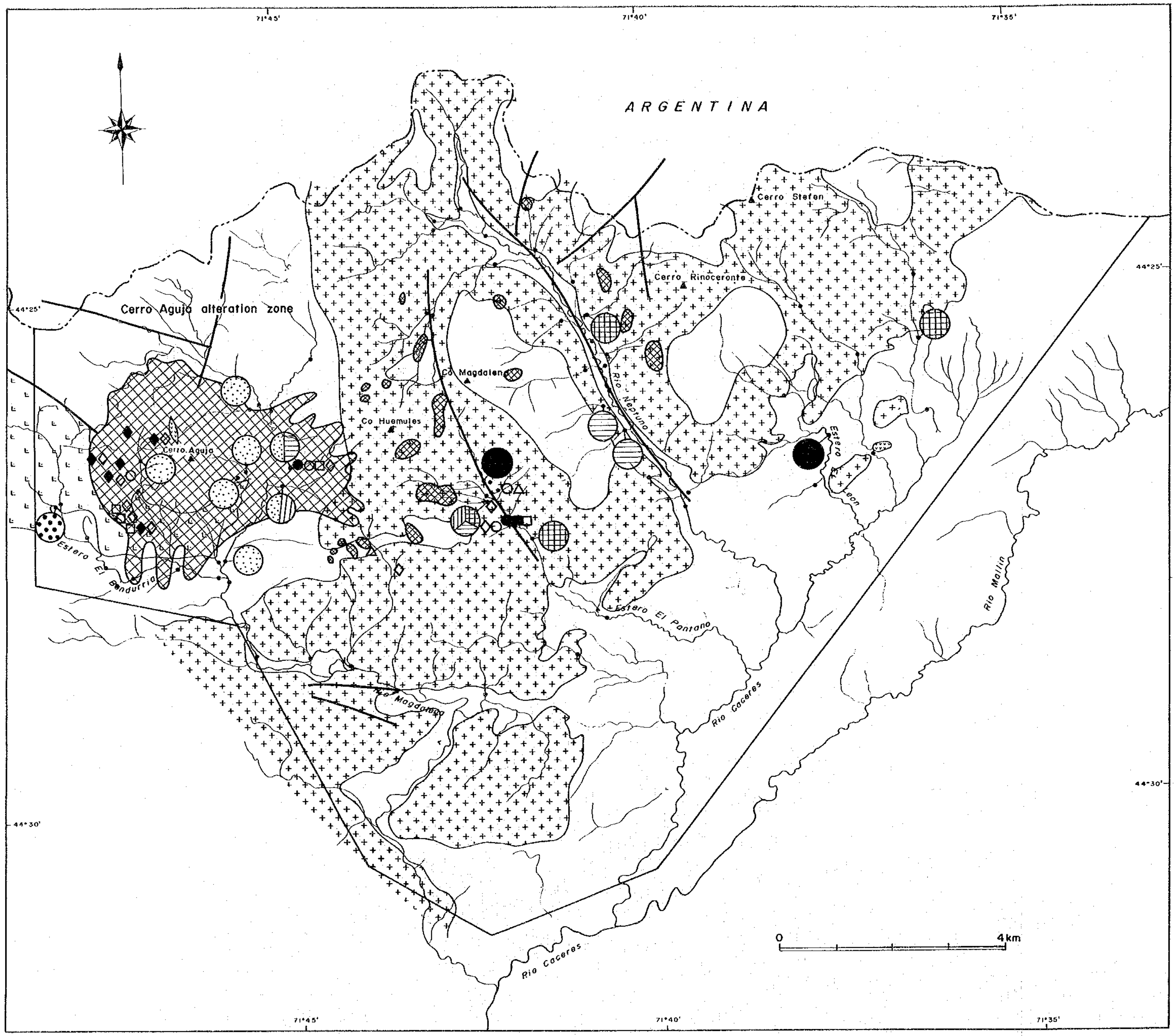
4) Pb and Zn

A few anomalies were recognized. Pb-Zn mineralization cannot be anticipated in the area.

5) As

Seven anomalies were obtained and all of them occur along the rivers which dissect the Cerro Aguja Alteration Zone. It is obvious from the assay results that As mineralization occurs in the Cerro Aguja Alteration Zone.

Based on the results of the geochemical exploration, it is concluded that As is the principal element in the mineralization of this area, but anomalies of other metals are not notable (Fig.Ⅱ-1-5).



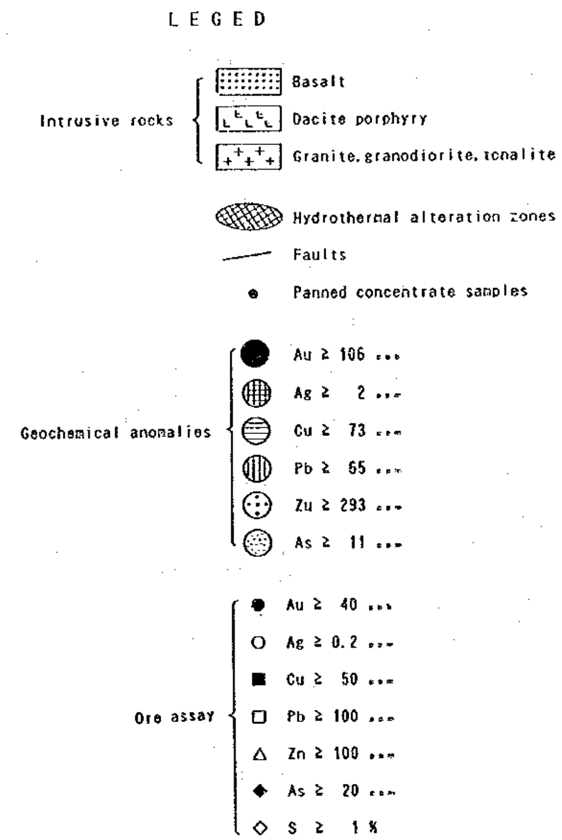




Fig. II-1-5 Collective Interpretation Map of the Alto Cisnes-El Toqui Area (Cerro Aguja Alteration Zone)

## 1.4. Evaluation

It is seen from the above that the alteration in this area is not associated with significant geochemical anomalies to warrant further studies. Also it is a fact that we do not have sufficient data for comparison with known type of mineralization. But it appears that if the alteration were to be associated with mineralization, the only type applicable here seems to be the hot-spring-type gold mineralization from the nature of the alteration ( Berger and Eimon, 1982). The characteristics of vein-type and the hot-spring-type are summarized in Table Ⅱ-1-4.

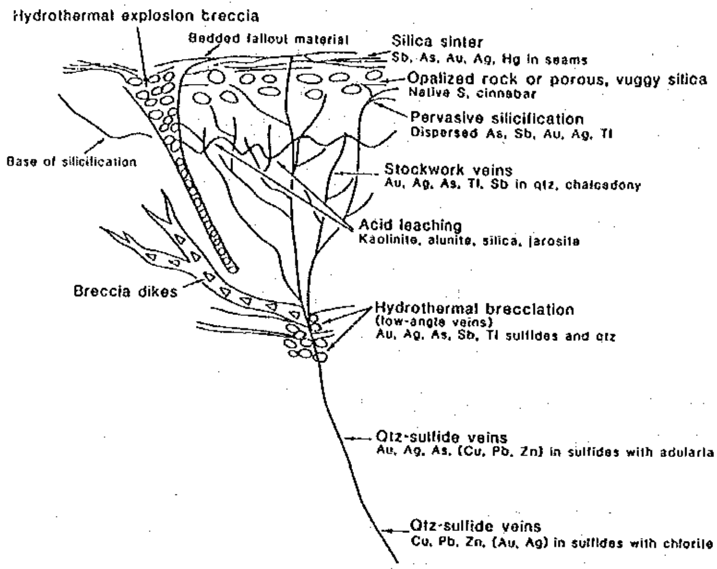
Table Ⅱ-1-4 Geological Characteristics of Gold Deposits Associated with Volcanic Activity

| | Vein Type | Hot-Spring-Type (Round Mountain, etc.) | Cerro Aguja Alteration Zone (this area) |
|---|---|---|---|
| Host Rock Alteration | Silicification (Qz)・Ad・Se within propylitic zone (Ch・Ab・Ep・Ca) | Silicification and acidic alteration (Qz・Al・Ka・P・D)・Ad・Cab<br>Propylitic Zone (Ch・Ab・Ep・・Ca) in the lower part | Silicification and asidic alteration (Qz・Al・Ka・P) |
| 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<br>Rich in minor elements of Hg-As-Sb-Tl etc. | Dissemination ; pyrite-limonite etc., containing a minor element of As |
| 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

Berger and Eimon (1982) also proposed a geological model of hot-spring-type gold deposit from the occurrence in the Round Mountain Deposit (Fig.Ⅱ-1-4).




(after Berger and Eimon, 1982)

**Fig. II-1-4 Schematic Cross Section Illustrating Geologic Features in a Hot-Spring-Type Gold Deposit**

When compared with the hot-spring-type gold deposits, the present alteration zone at the surface would correspond to the high grade zone (the "Stockwork veins" zone) of the above model proposed by Berger and Eimon. Since this does not contain significant gold, the lower horizons are expected also to be barren.

## CHAPTER 2. ALTO CISNES-EL TOQUI AREA

### 2.1. Geology

Geology of this area is composed of the Late Jurassic volcanics, the Middle Cretaceous volcanics, Quaternary plateau basalt, fluviatile-glacial-lacustrine deposits, and intrusive rocks. The Jurassic System is correlated with the Ibañez Formation, the Middle Cretaceous System with the Divisadero Formation and the Las Naciente del Rio Cisnes Formation, respectively. Geological map is presented in Fig.Ⅱ-2-1.

### 2.1.1. Stratigraphy

The stratigraphic sequence of the area consists of the Ibañez Formation, the Las Naciente del Rio Cisnes Formation and unconsolidated deposits in ascending order, as shown by the schematic columnar section in Fig.Ⅱ-2-2.

#### (1) Ibañez Formation

The Ibañez Formation is distributed in the valleys of major rivers (the Buitrera and Winchester Rivers) in the northern part of the area. The total thickness is not known as the lower limit of the formation is unconfirmed, but it is supposed to attain a maximum thickness of 7,000 m or more. Dacitic pyroclastic rocks are predominant in the lower and middle parts, whereas the upper part is dominated by andesitic lavas.

The dacitic pyroclastics range from fine tuff to tuff breccia, but the most dominant is lapilli tuff containing 1 to 2 cm size lapilli. The pyroclastics are generally dark green and hard, containing quartz and feldspar crystals, red dacitic rock fragments and green lenses of pumice. The matrix consists of dark green dense volcanic ash, and is mostly chloritized and carbonatized, partly epidotized.

As the development of bedding is poor the formation looks generally massive, though the fine tuff is finely bedded. The andesitic lava is dark green, hard and dense, showing an aphanitic texture. Almost all bodies of this rock are affected with diagenetic alteration, resulting in the formation of chlorite, epidote and carbonate minerals in large quantities.

The relation of the Ibañez Formation with the underlying strata is unknown since no outcrops of the latter are found. In the present investigation any data suggestive of the formation's eruptive period were not obtained, but it might be the Middle to Late Jurassic, as will be mentioned in

Chapter 4. 4.2. The formation of this area has no intercalations of marine facies. Therefore, it is inferred that volcanic eruption in the present area took place on land.

(2) Divisadero Formation

This formation is widely distributed extending from the area's central part to the national border on the south. The upper limit is unconfirmed, but even the confirmed part only is as thick as 9,000 m. In many cases the formation shows similar lithofacies to the underlying Ibañez Formation, making the discrimination between the two formations difficult. However, the two have been distinguished on the basis of their characteristics observed at the respective type localities (refer to Chapter 4). The characteristics are: the pyroclastic rocks distributed in the south of the middle reaches of the Buitrera River are relatively low in the degree of solidification; the landform changes drastically to a steep mountainous topography; welded tuff and alternating beds of siliceous shale and sandstone occur as intercalations. The lithofacies consists mainly of dacitic to andesitic pyroclastics and lavas, locally intercalated with alternation of siliceous sandstone and shale. The dacitic pyroclastics are widely distributed in the upper reaches of the Buitrera River, in the middle to upper reaches of the Winchester River, and in the upper reaches of the Los Perdidos River. These rocks are predominant in the lower and the upper parts of the formation. The major constituent is light green lapilli tuff which is composed of quartz and feldspar crystals, lenticular patches (pumice?) and red dacitic rock fragments. Along the middle reaches of the Winchester River, thin beds of welded tuff occur as intercalations.

The dacitic lava are alternating with the above-mentioned pyroclastics. The lava is dark gray, gray or greenish gray, and hard, with a porphyritic texture abundantly containing relatively large phenocrysts of quartz and feldspar. Thus, the lava in many cases presents a porphyritic aspect but in some cases the lithofacies is rhyolitic with flow structure and spherulitic texture. The whole rock analysis of the samples showing rhyolitic lithofacies has revealed 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3FR433 | 74.32 | 13.70 | 0.28 | 4.19 | 4.35 | 0.29 | 1.58 | 0.08 | 0.20 | 0.05 | 0.08 | 0.24 | 1.05 |

Unit: %

The andesitic facies is predominant in the upper part of the formation.

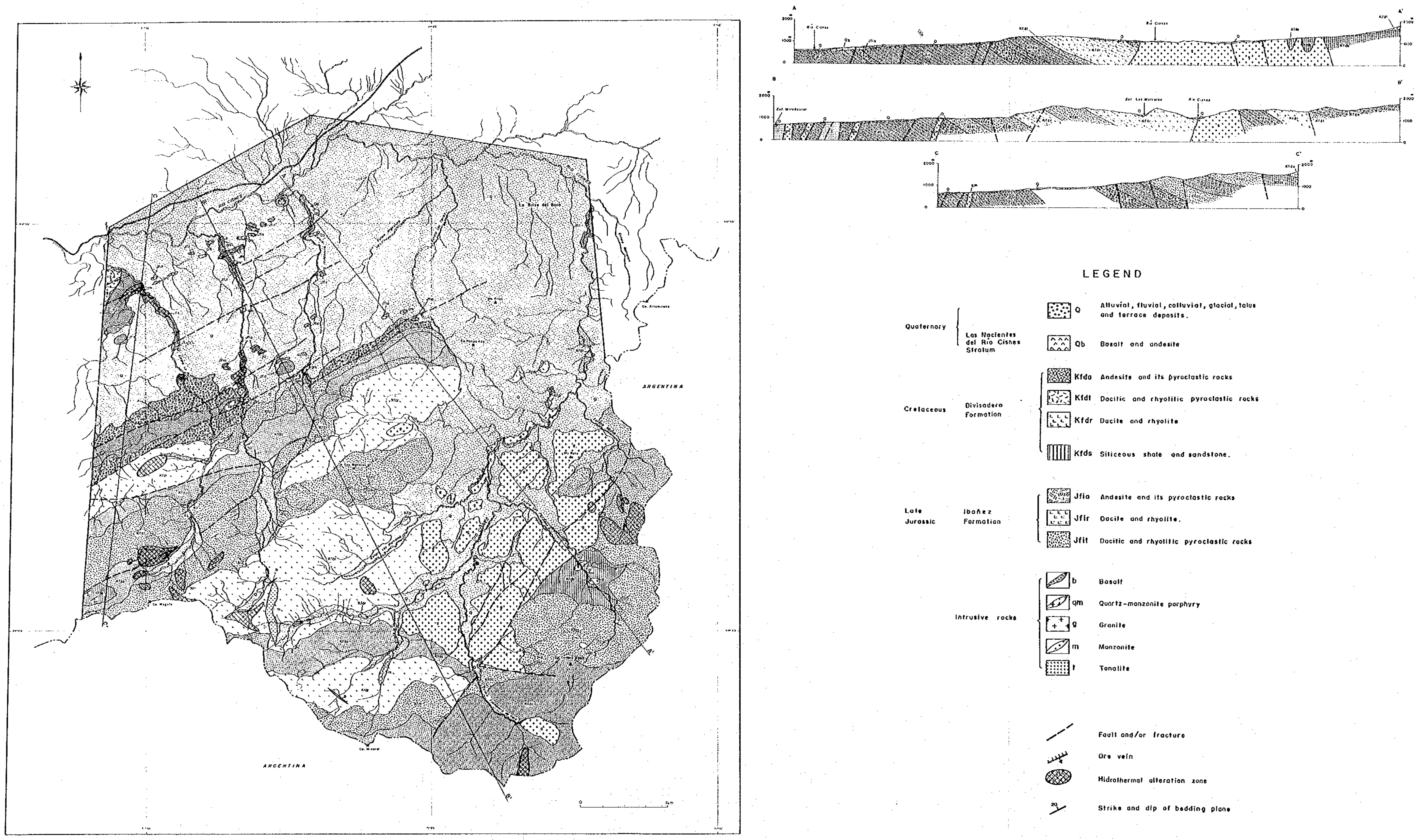



Fig.II-2-1 Geological Map of the Alto Cisnes-El Toqui Area

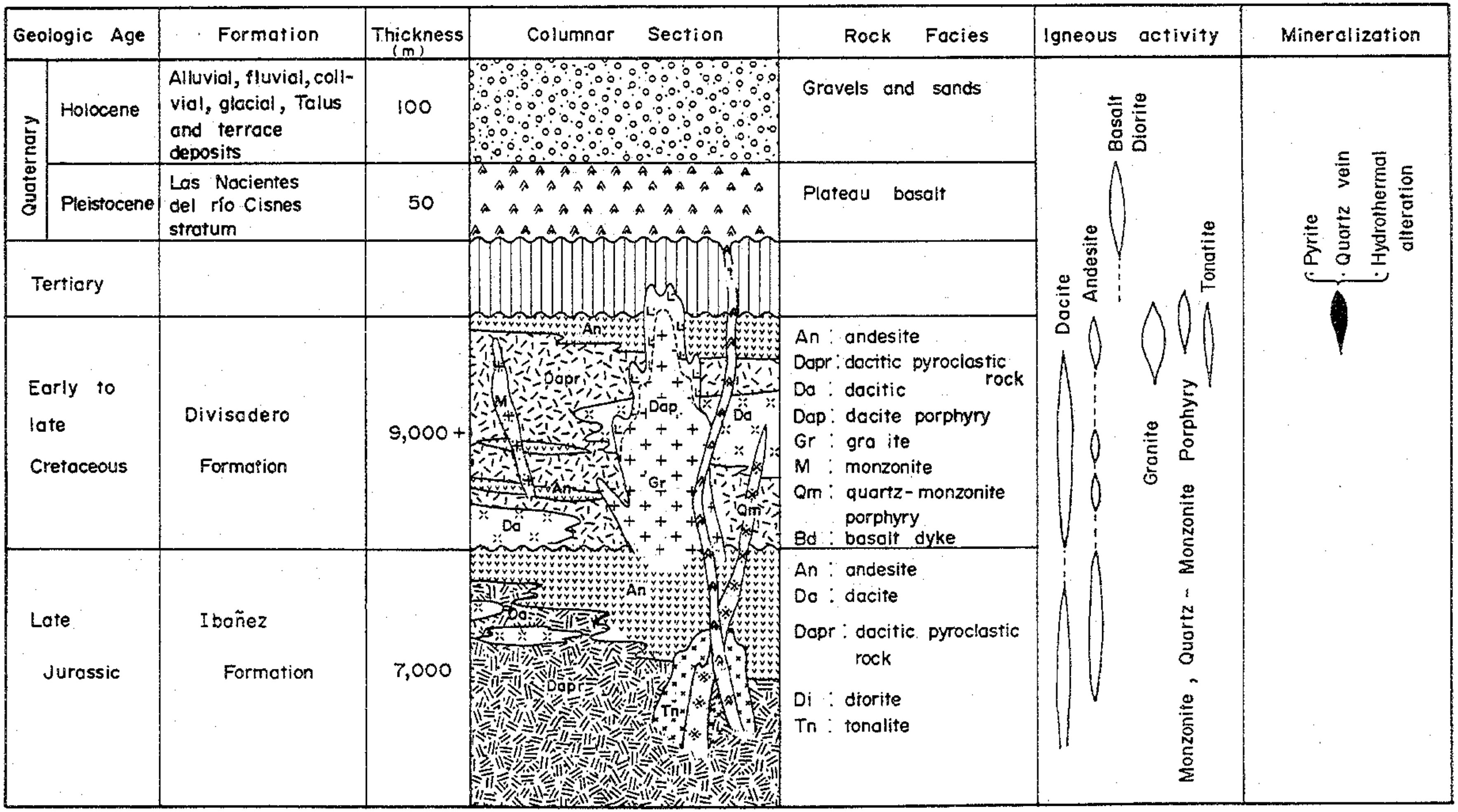



Fig. II-2-2 Schematic Columnar Section of the Alto Cisnes-El Toqui Area

The rock is dark green, dense and hard, shows an aphanitic texture, and is generally chloritized. Lava is the principal constituent, pyroclastics being of local occurrence. Alternating beds of sandstone and shale are distributed along the headstreams of the Pedregoso River and in the upper reaches of the Los Perdidos River, corresponding respectively to the upper and the middle horizons of the formation. This alternation consists of grayish white, hard, fine-grained sandstone and dark gray shale, both are remarkably siliceous. The thickness is +500 m.

The Divisadero Formation is in parallel unconformity with the underlying Ibañez Formation. In the present investigation, the absolute ages of the rhyolite lava and of the granite intruding the lava have been determined (K-Ar method) and obtained the values of 78 Ma and 124 Ma. These data suggest the depositional period of this formation to be Aptian to Cenomanian, which is not contradictory to the previous results.

The Divisadero Formation might have been laid down on land for the most part, because marine deposits are scarce. However, the presence of marine sandstone and shale implies that the sedimentary environment was partly marine during a certain period of time.

**(3) Las Naciente del Rio Cisnes Formation (plateau basalt)**

This rock body occurs in a small area of the lower reaches of the Winchester Sur River in the northern part of the area. Details are not known as most of it is covered by the Quaternary System, but it lies nearly horizontally upon the Ibañez Formation and forms a basaltic lava plateau. The thickness is around 50 m.

The lithofacies is black and somewhat brittle and porous, with chalcedony crystals filling the pores. Under the microscope a pilotaxitic texture is recognized. Lacking phenocrysts, it consists of abundant plagioclase and pyroxene, with a small amount of hornblende. Small amounts of chlorite, calcite and kaoline minerals occur as alteration minerals.

The rock body is correlated with the Las Naciente del Rio Cisnes Formation of SERNAGEOMIN (1983, 1984), and its eruptive period is assigned to Pliocene age.

**(4) Quaternary System**

The Quaternary System of this area can be divided into the Pleistocene series, consisting of fluvial terrace-glacial-lacustrine deposits, and the Holocene series of alluvium, though the two series are collectively expressed on the geological map. The greater part of the Pleistocene series is glacial deposit which is widely distributed in the northern to northeastern parts of the area. Pebbles constituting the glacial deposit are mainly round pebbles of granitic rock, rarely accompanied by pebbles of crystalline schist. From this fact it is inferred that the glacial movement in those days was from SW to NE, namely from the Chile side to the Argentine side.

The fluvial terrace deposit is represented by three terrace planes. The relative height between the uppermost terrace plane and the present river bed is over 100 m at maximum. Distribution of the lacustrine deposit is limited. The terrace and glacial deposits are composed of sand and gravel, while the lacustrine deposit consists of rhythmically alternating layers of silt and fine sand. The alluvium is the present river bed deposit for the most part, and is dominantly developed along the Cisnes River.

### 2.1.2. Intrusive rocks

Stocks and dikes of intrusive rocks are relatively abundant in this area. The rock body along the upper reaches of the Cisnes River is a large-scale stock with a plane area of 11 x 6 km, but many other bodies are less than 1 $km^2$ in plane area. The chemical composition is felsic in many cases. The lithofacies range from granite, tonalite, quartz-monzonite porphyry, monzonite porphyry and basaltic andesite.

#### (1) Granite

The granite occurs as large stocks along the upper reaches of the Cisnes River. The survey of this phase has confirmed five bodies, of which the largest is elongated NE-SW with an extension 11 km in longer diameter and 6 km in shorter diameter. The rock is greenish gray and hard, showing hypidiomorphic-granular texture. It abounds in quartz and feldspar crystals and, though weakly chloritized and weakly kaolinized, the rock is almost unaltered. The chemical composition is as follows.

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3TR402 | 70.30 | 14.51 | 0.16 | 3.56 | 5.09 | 0.58 | 2.01 | 0.08 | 0.59 | 0.09 | 0.19 | 0.48 | 0.91 |

Unit: %

The granite intrudes in the Divisadero Formation. The absolute age determination obtained the value 124 Ma. The age corresponds to Late

Cretaceous.

(2) Tonalite

The tonalite occurs as a small stock along the lower reaches of the Winchester River. The rock is grayish green, fine-grained and holocrystalline. It underwent weak alteration that accounts for the chloritized and epidotized mafic minerals. Details of the rock body are not known as the environment is covered with the Quaternary System.

(3) Quartz-monzonite porphyry

This rock is found as several dikes in the lower reaches of the Buitrera River and from the lower reaches of the Winchester River to the middle reaches of the Winchester Sur River. Details of its occurrence are not known because the environment is covered with the Quaternary System, but the rock had intruded along the N60°E faults as will be mentioned later. The pinkish gray lithofacies contains relatively large phenocrysts of quartz, potassium feldspar and hornblende. Most of mafic minerals have turned into chlorite and kaolin minerals.

(4) Monzonite porphyry

The monzonite porphyry occurs as three dike-like bodies intruding the Dividadero Formation along the headstreams of the Cisnes and Horqueta Rivers. Two of the bodies extend N-S, and one does E-W. The rock is brownish gray, hard and fresh.

(5) Basaltic andesite

Distribution of basaltic andesite is scarce. The rock occurs as 2 to 10 m wide platy dikes cutting the Divisadero Formation and alteration zones. It is of a post-alteration intrusion. The rock is dark green, coarse- to fine-grained, and the lithofacies varies from place to place, such as dioritic, andesitic or basaltic. Extension of the dikes is multi-directional, showing no regularity.

2.1.3. Geologic structure

(1) Fold

Both the Ibañes and Divisadero Formations present a monoclinal structure with a general strike of NE-SW and a southward dip. No folds are recognized. In the western part of the area, the dip of the two formations becomes rather steep, 20 to 60°. In the southeastern part the Divisadero Formation is reversely inclined in the southeast of the NE-SW fault and the dip becomes gentle, around 10°. This reverse inclination is probably due to faulting.

The structure of the plateau basalt is horizontal or almost horizontal.

(2) Fault

Several parallel faults trending N60°E are found in this area. They continue well and are traceable for 10-odd km. Faults whose dip was confirmed are few, but most of faults show a steep dip, 70 to 90°, and they are regarded as normal faults dipping NW in the northern part and S in the southern part of the area.

### 2.2. Mineralization

Although this area has no ore deposits or mineralization zones that have ever been worked or explored, the survey of this phase has confirmed 10-odd localities of hydrothermal alteration zones and several quartz veins along the lower and upper reaches of the Buitrera and Redondo Rivers, in the western part of the area. These occurrences have been divided into 14 groups and numbered No. 1, 2, and so on from east to west, to serve as the tentative names for alteration zones and mineral indications.

Their host rocks are the dacitic pyroclastic rocks of the Ibañez Formation or the dacitic to andesitic lavas and pyroclastics of the Divisadero Formation.

In many cases mineral indications present irregular massive forms, but Alteration Groups No. 12, No. 13 and No. 14 are elongate in the N60°E direction. The plane dimensions (of confirmed portions) are the largest in Alteration Group No.1, measuring 3.5 x 0.8 km, which is followed by Alteration Group No. 14 with of 1.5 km long and 1.8 km wide. Dimensions of others are around 1 $km^2$.

Alteration are silicification and argillization of low grade, and many alteration groups retain primary minerals that constituted the host rock. The principal alteration mineral is quartz. Besides quartz, small amounts of kaolin minerals were recognized in Alteration Groups Nos. 1, 12 and 13. Almost all groups show disseminations of fine-grained pyrite and limonite, and dissemination or stockwork of hematite. Veins or stockworks of quartz are developed in Groups Nos. 1, 2, 8, 12, 13 and 14. Locations of these groups are given in PLATE 9, and the characteristics of the alteration groups or mineral indications are summarized in Table 1 in appendix.

(1) Alteration Group No. 1 and mineral indication No. 2

Alteration Group No. 1 is located near the Chile-Argentine border in the upper reaches of the Redondo River, source of the Martin River. As shown in PLATE 9, this group is composed of the V-shaped main zone and the subordinate smaller zones around it. The plane dimensions are 3.5 x 0.8 km for the confirmed portions, as mentioned above, but the whole aspect is not known since the group extends further into the Argentine side. The subordinate zones have an area of about 0.5 x 0.5 km.

The host rocks are the pyroclastic rocks (mainly lapilli tuff) of the Divisadero Formation. The main alteration zone is yellowish brown or reddish brown, and so strongly silicified and argillized that the host rocks are hardly discernible in some places. The principal alteration mineral is quartz. Stockwork and dissemination of quartz are common, and stockwork or veinlets of quartz are locally developed. Quartz veins are 0.5 to 5 cm wide, consisting of translucent dense quartz, accompanied by no other metalliferous minerals than pyrite and limonite. This alteration zone comprises, on rare occasions, a single vein of quartz, about 5 cm wide, striking N30°W and dipping 90°.

The subordinate zones are zones of weak silicification and weak argillization, with pyrite dissemination. In a part of these zone, several streaks of 0.5 to 5 cm wide quartz vein are developed in parallel. The quartz vein bears no metalliferous minerals other than pyrite and limonite. The direction of the vein is N30°E/90°.

The ore assay results of the samples, mainly collected from the quartz veins in alteration group No. 1, are as follows, revealing the low grade of the elements.

| Sample No. | | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | S(%) |
|---|---|---|---|---|---|---|---|
| 3TM420 | Main zone stockwork quartz | <20 | 0.2 | 3 | 18 | 34 | <0.01 |
| 3TM421 | Ditto | <20 | 0.3 | 3 | 18 | 21 | <0.01 |
| 3TM422 | Ditto | <20 | 1.0 | 3 | 14 | 27 | 0.01 |
| 3TM423 | Ditto | <20 | 0.1 | 1 | 3 | 21 | <0.01 |
| 3TM424 | Ditto | <20 | 0.3 | 3 | 15 | 20 | <0.01 |
| 3TM425 | Ditto | <20 | 0.2 | 2 | 17 | 40 | <0.01 |
| 3TM427 | Ditto | <20 | 0.3 | 3 | 13 | 22 | <0.01 |
| 3TM428 | Ditto | <20 | 0.2 | 1 | 17 | 36 | <0.01 |
| 3TM429 | Ditto | <20 | 0.2 | 1 | 15 | 16 | 0.04 |
| 3TM430 | Ditto | <20 | 0.1 | <1 | 15 | 15 | 0.01 |
| 3TM414 | Subordinate zones | <20 | 0.2 | 3 | 11 | 17 | 0.01 |
| 3TM415 | Ditto | <20 | 0.2 | 2 | 13 | 15 | 0.01 |
| 3TM416 | Ditto | <20 | 0.5 | 2 | 15 | 9 | 0.01 |
| 3TM417 | Ditto | <20 | 0.1 | 3 | 12 | 30 | <0.01 |
| 3TM431 | Quartz vein | <20 | 0.4 | 4 | 28 | 38 | <0.01 |

Mineral Indication No.2 is the quartz vein developed in granite, and is located in the south branch of the Los Perdidos River. It is a 0.5 m wide single vein, striking E-W and dipping 50°S. It consists of translucent dense quartz, with a small amount of pyrite dissemination.

The vein grade is as follows.

| Sample No. | Vein width | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | S(%) |
|---|---|---|---|---|---|---|---|
| 3TM403 | 0.5 m | <20 | 0.1 | 2 | 13 | 64 | 0.01 |

**(2) Alteration Groups Nos. 3 to 5**

These groups are distributed in the upper reaches of the Tranquera de Vara River. They are silicified zones. Group No. 3 is widest in distribution, with an area of 1.5 x 0.3 km. The other two groups are 40 to 50 m wide. The host rock of each group is the andesite lava of the Divisadero Formation.

The Group No. 3 extends in N10°E strike and continues to the Argentine. The grade of the reference sample is as follows.

| Sample No. | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | S(%) |
|---|---|---|---|---|---|---|
| 3PM418a | <20 | 1.5 | 10 | 53 | 55 | 0.01 |

The grades of Groups Nos. 4 and 5 are given in Table 2 in Appendix.

**(3) Alteration Groups Nos. 6 and 7**

These are weakly silicified zones distributed in the upper reaches of the Cisnes River. The dimensions are 0.1 x 0.4 km for No. 6 and 0.8 x 0.5 km for No. 7. The host rock of the former is dacite porphyry which is probably a marginal facies of granite, and that of the latter is dacite lava of the Divisadero Formation. The Group No. 6 underwent only silicificaiton, while No. 7 is accompanied by disseminated pyrite.

| Sample No. | | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | S(%) |
|---|---|---|---|---|---|---|---|
| 3SM401 | Zone No. 6 | <20 | 0.1 | 8 | 16 | 17 | 0.18 |
| 3YM410 | Zone No. 7 | <20 | 0.3 | 2 | 10 | 40 | 0.01 |

**(4) Alteration Groups Nos. 8 to 11**

These Alteration Groups are concentrated at eight localities in the upper reaches of the adjacent two rivers, Buitrera and Winchester. They occur in irregular massive forms with plane dimensions around 1 km². Host rocks are dacitic pyroclastic rocks, dacite and andesite lava of the Divisadero Formation.

All the host rocks are decolorized to grayish white, and are accompanied by fine-grained pyrite disseminations. As the pyrite was oxidized into hematite and limonite, the outcrops are tinted reddish brown. Several-millimeters wide quartz veins are very rarely developed. No other minerals are found.

The ore assay results of the reference samples are as follows. Analytical values of all samples are given in Table 2 in Appendix.

| Sample No. | | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | S(%) |
|---|---|---|---|---|---|---|---|
| 3YM402 | Zone No. 8 | <20 | 0.2 | 4 | 18 | 12 | 0.11 |
| 3FM429 | Zone No. 9 | <20 | <0.1 | <10 | <10 | 8 | 0.04 |
| 3FM437 | Zone No. 10 | <20 | 0.1 | 22 | 25 | 58 | 4.20 |
| 3FM440 | Zone No. 11 | <20 | 0.1 | 22 | 31 | 167 | 4.48 |

(5) Alteration Groups Nos. 12 to 14

These groups are developed from the lower reaches of the Buitrera River to the lower reaches of the Winchester River adjacent on the east. They are elongated in the N60°E direction. The confirmed horizontal extension is 2 km in the longest, but the whole aspect is unknown as the neighborhood is covered with the Quaternary System. The Group No. 14 is the widest, attaining to about 1 km. Others are 200 to 300 m wide. Host rocks are quartz-monzonite porphyry and dacitic pyroclastic rocks of the Ibañez Formation.

In each of these alteration groups, stockwork or dissemination of pyrite, limonite and hematite are developed within the decolorized host rocks, and the outcrops are colored reddish brown, brown or yellowish brown. The portion of strong alteration presents quartz stockwork of several millimeters in width. This quartz vein is composed entirely of translucent massive quartz, without any other minerals. These mineralization and alteration are not spread uniformly within one zone, since their unaltered portions still remain in worm-hole forms at intervals of 10-odd meters. Quartz is the principal alteration mineral, but small amounts of sericite and kaolin minerals were detected in Groups Nos. 13 and 14 by X-ray diffraction.

The analysis of the representative samples gave the following result.

| Sample No. | | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | S(%) |
|---|---|---|---|---|---|---|---|
| 3VM450 | Zone No. 12 | <20 | 0.2 | <10 | 18 | 5 | 0.42 |
| 3VM454 | Zone No. 13 | <20 | 0.2 | <10 | <10 | 11 | 0.16 |
| 3FM401 | Zone No. 14 | 20 | 1.3 | 36 | 64 | 47 | 0.40 |

### 2.3. Geochemical Exploration

#### 2.3.1. Sampling and assaying

One hundred and fifty stream sediment samples were collected and approximately 100 g of sample were stored for the assaying after the sieving through -30 mesh. The locations of the samples are shown in PLATE 19. The samples were pulverized to -200 mesh fraction by SERNAGEOMIN Laboratory and assayed by Chemex Lab., Inc., Canada. Six elements for assaying are Au, Ag, Cu, Pb, Zn and As. The detection limits and analytical methods used are summarized in the following table.

Analytical Methods and Detection Limits

| Element | Digestion and Methods | Detection Limits | | | |
|---|---|---|---|---|---|
| | | Lower limit | | Upper limit | |
| Au | FA-NAA | 1 | ppb | 10,000 | ppb |
| Ag | ASS | 0.05 | ppm | 100 | ppm |
| Cu | ASS | 0.5 | ppm | 10,000 | ppm |
| Pb | ASS | 1 | ppm | 10,000 | ppm |
| Zn | ASS | 1 | ppm | 10,000 | ppm |
| As | ASS-hydrite/EDL | 0.5 | ppm | 10,000 | ppm |

FA : Fire Assay
NAA: Neutron Activation Analysis
ASS: Atomic Absorption Spectrometry
EDL: Eletrodeless Discharge Lamp

#### 2.3.2. Statistical data-processing

(1) Results of assaying

The results of assaying are shown in the Table 6 in Appendix. The characteristic features are summarized as follows: The samples containing Au more than detection limit are only 3 %. And just one sample shows 60 ppb (maximum value) and others show less than 10 ppb. Nineteen percent of samples contained more than detection level of Ag and their maximum value, 0.4 ppm is extremely low.

Cu, Pb and Zn contents also show low values and samples containing more than 100 ppm are zero in Cu, one in Pb and 12 in Zn.

(2) Elemental statistics

Basic statistical values are shown in Table Ⅱ-2-1.

Table Ⅱ-2-1 Elerental Statistics Parameters in Geochemistry of the Alto Cisnes-El Toqui Area

| | Au(ppb) | Ag(ppm) | Cu(ppm) | Pb(ppm) | Zn(ppm) | As(ppm) |
|---|---|---|---|---|---|---|
| Mean | 0.58 | 0.31 | 5.2 | 6.5 | 62.4 | 1.4 |
| Max. | 60 | 0.4 | 24 | 152 | 376 | 43.5 |
| Min. | 0.5 | 0.03 | 1.5 | 1 | 20 | 0.1 |
| M+σ | 1.06 | 0.05 | 8.7 | 13.8 | 92.3 | 4.7 |
| M+2σ | 1.9 | 0.08 | 14.6 | 29.3 | 136.4 | 15.6 |

(3) Frequency distribution pattern

Fig.Ⅱ-2-3 show the frequency distribution patterns of every element. Cu, Pb and Zn show log-normal distribution or similar patterns. Au and Ag have peaks below the detection levels.

(4) Correlation

Table Ⅱ-2-2 shows correlation coefficient between the elements pairs. Their absolute values more than 0.5 are listed as follows in descending orders; Pb-Zn; 0.78212, Cu-Zn; 0.66149, Cu-Pb; 0.64129 and Cu-As; 0.59783.

Table Ⅱ-2-2 Correlation Coefficients between Elements Pairs in Geochemistry of the Alto Cisnes-El Toqui Area

| | Au | Ag | Cu | Pb | Zn | As |
|---|---|---|---|---|---|---|
| Au | 1.00000 | | | | | |
| Ag | 0.16149 | 1.00000 | | | | |
| Cu | -0.07637 | 0.30683 | 1.00000 | | | |
| Pb | 0.09697 | 0.38808 | 0.64129 | 1.00000 | | |
| Zn | 0.01046 | 0.42681 | 0.66149 | 0.78212 | 1.00000 | |
| As | -0.05280 | 0.35571 | 0.59783 | 0.48089 | 0.30474 | 1.00000 |

(5) Principal component analysis

The principal component analysis was carried out in orcer to summarize the chemical meanings of assay for the understandings of the correlation between geological conditions and ore deposits and for the interpretation of assaying data. Their results are shown in Table Ⅱ-2-3. The followings are

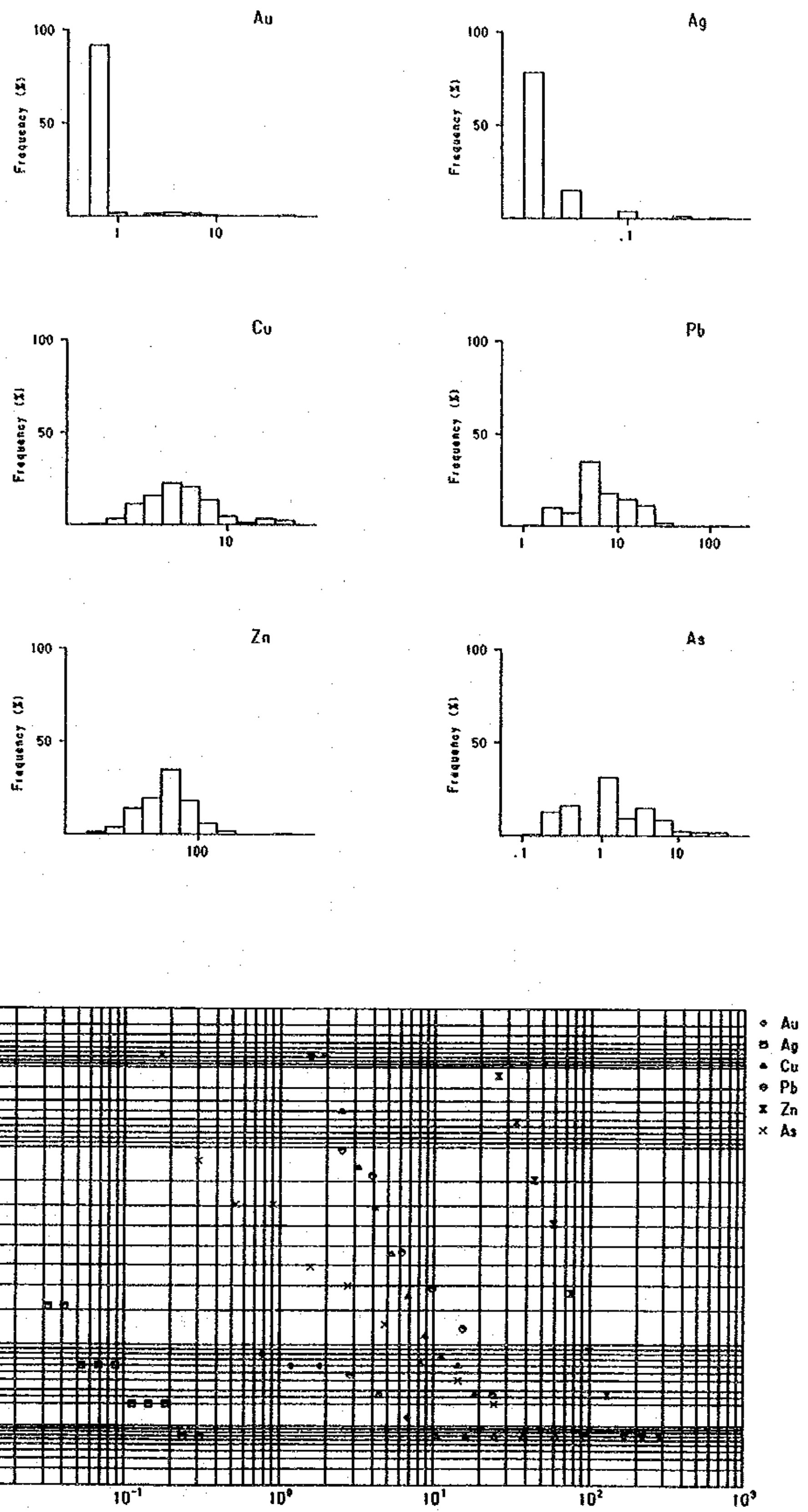



Fig. II-2-3 Histograms and Cumulative Frequency Curves Showing Frequency Distribution Patterns of Assays on Stream Sediment Geochemical Samples Collected in the Alto Cisnes-El Toqui Area the summaries of geochemical characters interpreted by the combination between eigen values and vectors.

Table II-2-3 Eigen Vectors and Eigen Values of Principal Component Analysis of the Alto Cisnes-El Toqui Area

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Au | 0.02537 | -0.88458 | -0.02007 | -0.44403 | -0.11837 | 0.07276 |
| Ag | 0.34396 | -0.35916 | 0.44934 | 0.71952 | -0.10762 | -0.14659 |
| Cu | 0.48596 | 0.22206 | -0.04292 | -0.26944 | -0.73355 | -0.31936 |
| Pb | 0.50269 | -0.05599 | -0.31162 | -0.09198 | 0.59858 | -0.52943 |
| Zn | 0.48531 | -0.01778 | -0.49877 | 0.20616 | -0.02953 | 0.68704 |
| As | 0.39581 | 0.18910 | 0.67080 | -0.40195 | 0.27773 | 0.34483 |
| Eigen | 3.02410 | 1.10237 | 0.75163 | 0.65941 | 0.30969 | 0.15280 |
| Prop. | 0.50402 | 0.18373 | 0.12527 | 0.10990 | 0.05161 | 0.02547 |
| Cum. prop. | 0.50402 | 0.68775 | 0.81302 | 0.92292 | 0.97453 | 1.00000 |

First principal component

Eigen vectors of all the elements other than Au are in similar positive numbers. Any notable statistical feature is not recognized.

Second principal component

Three pairs of elements, Au-Ag, Pb-Zn and Cu-As are in similar levels of eigen vectors. The former tow elements pairs carry minus eigen vectors and the latter has plus values. This component is believed to represent some aspects of the mineralization.

Third principal component

On the basis of the eigen vectors, Au-Cu, Ag-As and Pb-Zn are in similar values respectively.

Principal components up to the third component are accounted for more than 80% of total variance contributed by each eigen value.

Table 7 in Appendix shows the scores for the second principal component that represents the mineralization in the area. Two variables exceed 1.0 and their localities are plotted on PLATE 15.

2.3.3. Geochemical Anomalies and Anomalous Zones

(1) Threshold

Threshold for Ag was determined at the upper 2.5% point using the cumulative frequency distribution curve. For the other elements, $m+2\sigma$ was employed. Each threshold is listed in the following table.

Thresholds

| Element | Threshold |
|---|---|
| Au | 1.9 ppb |
| Ag | 0.1 ppm |
| Cu | 15 ppm |
| Pb | 29 ppm |
| Zn | 136 ppm |
| As | 15 ppm |

(2) Geochemically anomalous zones

Numbers of anomalies detected by this work are as follows:-

Numbers of Anomalies

| Element | Numbers of Anomalies |
|---|---|
| Au | 9 |
| Ag | 8 |
| Cu | 9 |
| Pb | 3 |
| Zn | 3 |
| As | 6 |

Localities are plotted in PLATE 15. Major features regarding their distributions are summarized as follows.

1) Au

All anomalies(6 points) lie on the eastern slope of Mt. Los Materos. Five of them are Au single anomalies, but one point carries also Ag, Cu, Pb and Zn anomalies.

2) Ag

Eight anomalies were obtained in this area. They are distributed sporadically , but three anomalies of them are concentrated in the upper reaches of the Mallin Creek. The Alteration Group No.1 lies a little up on this anomalous zone. All anomalies are of single Ag.

3) Cu

All anomalies (5 points) were obtained in the upper reaches of the Tranquera de Vara Creek. Three points of them carry also As anomalies, but the others are single anomalies. The Alteration Group No.3 is situated in the upper reaches of this anomalous zone.

4) Pb

Pb anomalies are few and in sporadic distribution.

5) Zn

Zn anomalies are few and in sporadic distribution as well as of Pb.

6) As

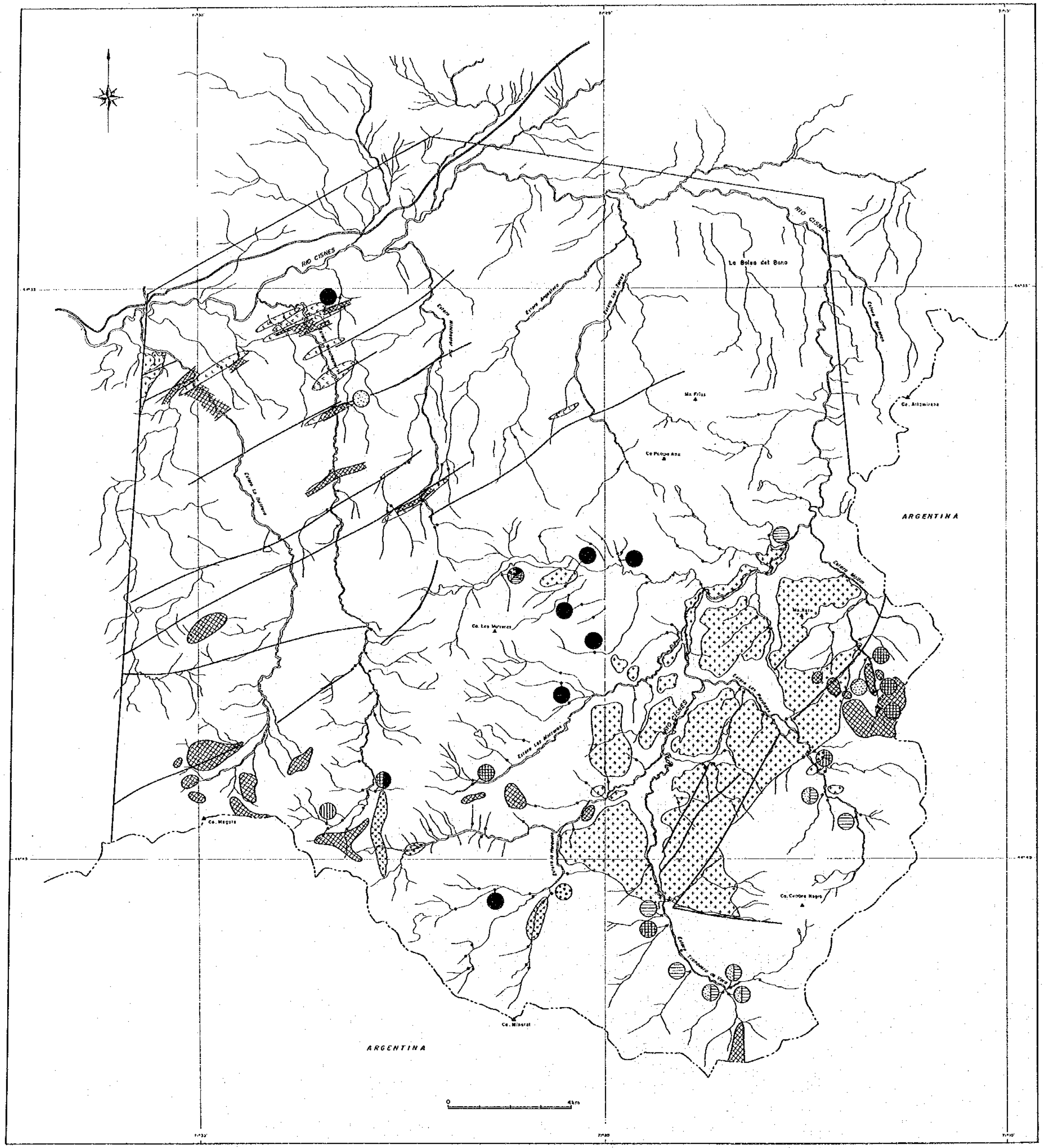
Small concentration of As-Cu anomalies was recognized in the upper reaches of the Tranquera de Vara Creek. The other anomalies are very sporadically distributed.

Only two scores for second principal component are greater than 1.0. This suggests that the geochemical anomalies in this area are in very low level.

## 2.4. Evaluation

· Related igneous rocks to mineralization

The Alteration Groups of No.12, 13 and 14 are distributed along faults of the N70°E strike in the northwestern part of the area as shown in Fig.Ⅱ-2-4. Additionally quartz-monzonite porphyry dikes intruded in the vicinity of all groups mentioned above. These dikes also are subjected to alteration and are thought to have intruded tectonically controlled by the faults. On the other hand, the other alteration groups (No. 1 to 11) are developed around the large granite stocks in the southern part of the area.




LEGEND

Intrusive rocks
- Quartz-monzonite porphyry
- Monzonite
- Tonalite
- Granite

Hydrothermal alteration zones

Faults

Stream sediment samples

Geochemical anomalies
- Au ≥ 1.9 ppb
- Ag ≥ 0.1 ppm
- Cu ≥ 15 ppm
- Pb ≥ 29 ppm
- Zu ≥ 136 ppm
- As ≥ 15 ppm

Fig. II -2-4 Collective Interpretation Map of the Alto Cisnes-El Toqui Area