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

PHASE I

JUNE 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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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).

The JICA and MMAJ sent a survey team headed by Mr. Yuya Furukawa to the Republic of Chile from 20 December 1989. to 28 March, 1989.

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.

June 1990

Kensuke Yanagiya

Kensuke YANAGIYA
President,
Japan International Cooperation Agency

Gen-ichi FUKUHARA
President,
Metal Mining Agency of Japan

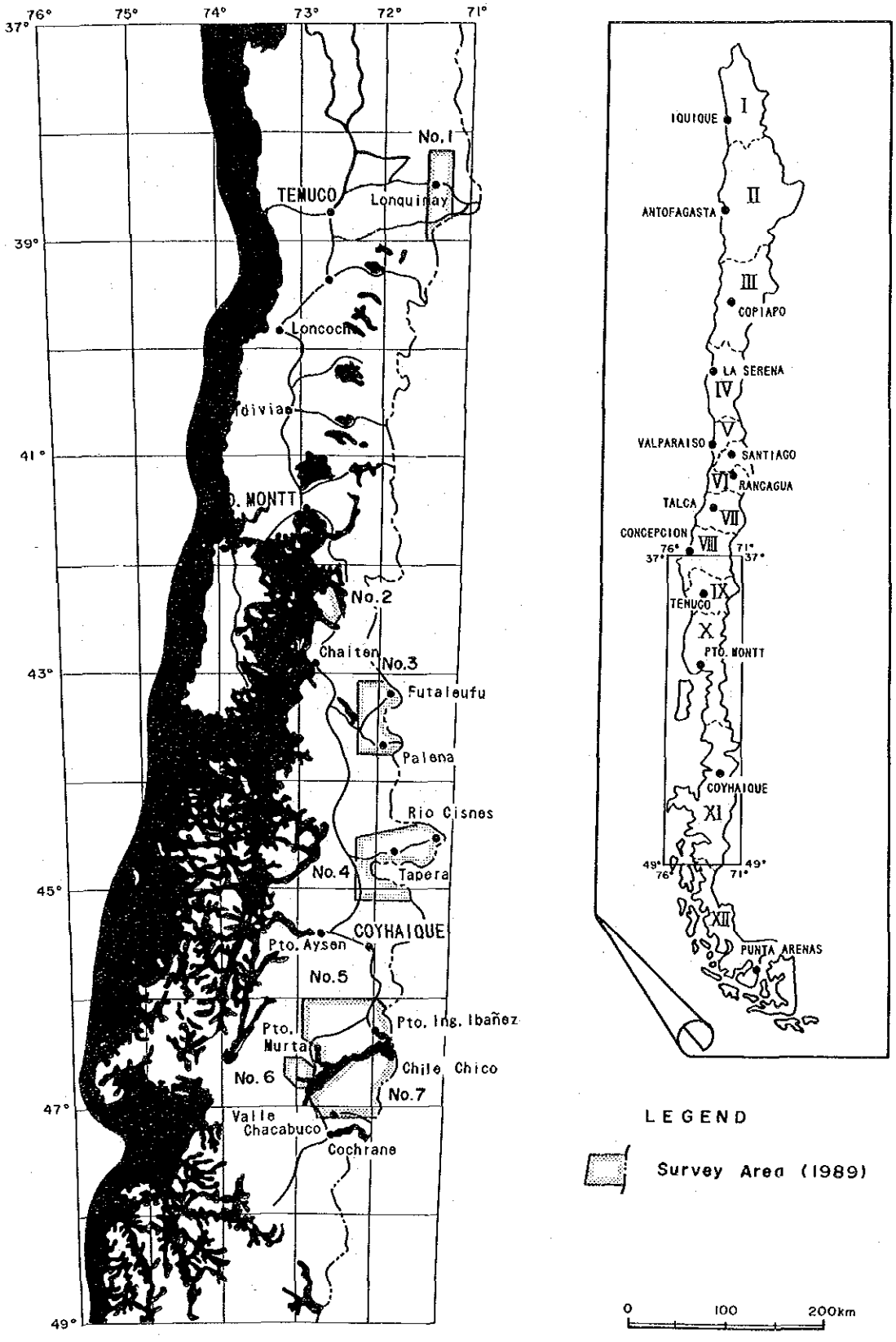
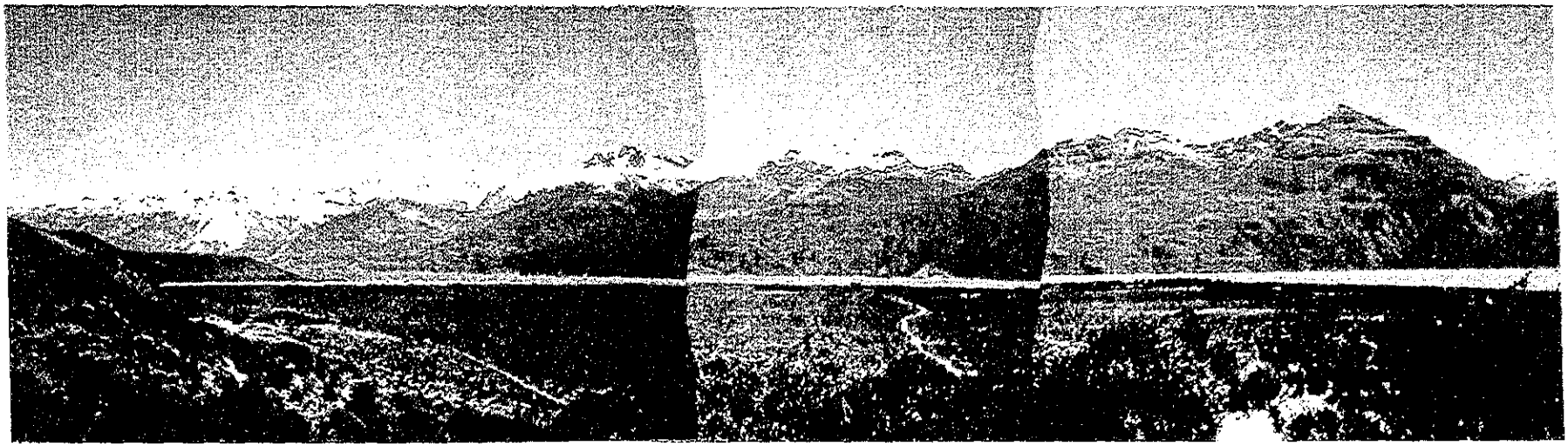


Fig. I-1-1 Location Map of Surveyed Area



A distant view of Area No. 5 from the southeyn coast of the Lake General Carrera

Vegetations on the upriver area of the Traiguanca river in the northern part Area No. 5

SUMMARY

This investigation is called officially "The Investigation of Mineral Potential in the Lonquimay Area and Regions Los Lagos and Aysen, the Republic of Chile". This report embodies the results of first phase investigation of that. The aim of this investigation is to evaluate potentials of undiscovered ore deposit in Aysen region, Chile, through investigations for geologic settings and size of known deposits.

The surveyed areas lie on mountainous area at 500 to 2,500m of elevation extending along the border line with Argentina. Seven areas were selected for survey from large region ranging between 38°S and 47°S in latitude. Four counties, the Ⅸ region to the Ⅹ region, cover them.

Climate is of cold climate zone except for that of Area No 1(Lonquimay area). Much rain and cold summer (about 20°C in daytime) are characteristic weather caused by affections of westerlies. Vegetations grow only at elevation below 1,500m. Forest trees are mainly coniferous trees. Road networks are developed well in north of Puerto Montt city. Whereas, southern district of it is left developed still insufficiently. Only a main road has connected to the southern edge of the survey area recently. The region is of very few population. For example, even Coyhaique city, political and economical center of the region, has 35,000 population. All other towns are of 500 to 2,000 in populations.

The survey of this year consists of three works: Landsat image analysis, compilation of existing data and field work.

Landsat image analysis used 17 scenes covering about 405,000 km^2 for photogeological interpretation.

This work focused on study regarding geology and geologic structure. Twelve geologic units were recognized. Unit of granitic rocks lies on central zone broadly elongating from north to south to constitute batholith. Units distributed on both side of it correspond to volcanic rocks and sedimentary rocks.

On western side of distribution zone of Patagonia Batholith, unit of Paleozoic rocks is distributed broadly, while eastern side is underlain by units of volcanic rocks and sedimentary rocks of post-Paleozoic age.

Total of 1,212 lineaments were extracted with three prevailing systems of their directions: N5°E-N5°W, N5°E-N15°E and N15°W-N25°W. System of N5°E-N5°W predominates in batholith zone and extends very continuously. Quarternary volcanos arrange along lineaments of this system. Lineaments of other two systems occur densely in the distribution area of Paleozoic unit and Mesozoic unit on eastern side of the batholith. They tend to be short lineament. In the zone many deposits are distributed densely, the system of N15°E-N25°W is predominated.

Geology and mineralization are summarized as follows by compilation work of existing data. Geology of the region was evoluted on the Andes orogenic belt developed on western margin of the Brazilian shield. Geological units after Paleozoic time overlie on basement of Paleozoic unit and granitic rocks of the Patagonia Batholith intrude into this region. This activity was trigered in Jurassic time and continued until Early Tertiary time. Jurassic units consist of mainly intermediate or accidic volcanic rocks. Cretaceous units are composed of sedimentary rocks of marine origin and intermediate volcanic rocks. Tertiary and Quarternery units consist of mainly intermediate volcanic rocks and intercalate either marine sediments or continental sediments.

Paleozoic units show complicated geologic structure such as structure caused by block movement and composite fold. Fold structures are developed in Mesozoic units as well, but they are of simple and gentle structure. Cenozoic units consist of nearly flat beds.

Deposits of many ore metals, gold, silver, copper, lead, zinc and molybdenium, are distributed in this region. Distribution of those deposits are concentrated on the eastern margin of the Patagonia Batholith showing regional metal zoning with arranging eastward from the eastern edge of the Patagonia Batholith : molybdenium zone, copper(-gold) zone, lead-zinc(-silver) zone.

Molybdenium deposits are narrow veins and occur in edge of the batholith. They are of small scale, but are accompanied with gold in some cases. Copper(-gold) deposits are mostly vein deposit and small as well. Lead-zinc(-silver) deposit are mainly vein deposit, but calcareous rock replacement deposits of this metal assemble also occur in Paleozoic and Mesozoic units. Replacement deposits in Mesozoic unit are represented by the El Toqui deposit in ore

reserve of 20 million tonnes class. Limestone replacement deposits in Paleozoic unit are represented by the Silva and Rosillo deposits. Those ore reserves range between 500 thousand and 600 thousand tonnes. Most of gold(-silver) deposits are vein. Katterfeld and Laguna Verde deposits consist of swarm of gold bearing quartz veins with epithermal(hot spring type?) features.

Field work consists of geological survey and geochemical survey, and the results of them are summarized as follows:-

Area No1: Lonquimay Area

Gold and copper mineralization occur in this area. Gold deposits are vein or network vein and placer deposit. Both mineralizations are of small scale. Geochemically anomalies of Au and Ag were obtained in the zone between Maravilla Mountain and the Bio Bio river.

Area No 2: Huequi Peninsula Area

Although the existence of ultramafic rock was identified, neither distribution area nor size are known. Geochemical anomalies of Au was obtained in western part of the area by stream sediment geochemistry.

Area No 3: Futaleufu-Alto Palena Area

Favorable rock unit of Mesozoic units are distributed in this area. Some geochemical anomalies were detected as well. Consequentry, further exploration may encounter new discovery of deposits.

Area No 4: Alto Cisnes-El Toqui Area

Mesozoic calcareous rock hosted deposits, the El Toqui and the Cerro Estatuas, occur in this area. This Mesozoic units lie eastern part of the area. Gold vein deposit represented by the Katterfeld deposit also occur in the area. Those deposits are large and rich so that mineralizations of those styles are targetted.

Area No 5: Ibañez-Murta Area

Many deposits are distributed in this area, but most of them are very small. The area lying in northern part of the area, between the Avellanos river and the Ibañez river, is left unexplored due to access problem, while geologic setting is favorable for hosting deposit and a gold mineralization is known. Lead-zinc deposit of the Silva and the El Toqui type and gold deposit of the Katterfeld type are expected in this unexplored area.

Area No 6: Los Leones Area

Geochemical anomalies of Au and As were obtained in the area of the Leones river and the Canar river.

Area No 7: Chile Chico-Chacabuco Area

About 20 deposits are known. Among them, gold deposit of Laguna Verde type and lead deposit of La Poza type are noted. Geochemical anomalies of Au, Ag and As were obtained in the area of the Aviles river associated with gossaneous hydrothermal alteration zone. Therefore, this anomalous zone is noted as well.

The following surveys are recommended:-

(1) Extraction of alteration zones by using TM images from the area ranging between Area No 3 and Area No 7 and follow-up ground survey.
(2) Aerialphotograph interpretation on distribution area of Mesozoic units and verification survey including geochemical survey to test the existence of mineralization in Area No 3 and 4.
(3) Geological survey and geochemical survey in northern part of Area No 3 to follow up Geochemical anomalies of Au and Ag.
(4) Geological survey and geochemical survey in northern part of Area No 6 to follow up Geochemical anomalies of Au and Ag.
(5) Detailed geological survey for La Poza deposit and La Paulina deposit in Area No 7.

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PART I: OVERVIEW

PART I
OVERVIEW

CHAPTER 1. Introduction

1.1 Background and Objective

This investigation project is called officially "The Investigation of Mineral Potential in the Lonquimay area and Regions Los Lagos and Aysen, Republic of Chile". The aim of this project is to estimate the potential of undiscovered deposits through the investigation of the general geologic settings and the known deposits in the Aysen region, Chile. This report embodies the results of the first phase investigation.

The region has been left to be undeveloped so far. Many deposits are known throughout the region, while only several small mines of the base-metal were constructed in the surrounding area of the Lake General Carrera. Recent construction or improvement of the road network in the region, however, led exploration works to the region. Some Companies of western countries have put extensive exploration activities in these ten years to have highlighted the potentials of mineral resources in the region. Japanese government made decision to conduct the mineral exploration as the cooperative project based on circumstances mentioned above.

Detailed information regarding the geology and mineralization was not available, although significant results were established by extensive explorations of the Western companies. Consequently, the work of the first phase was begun by obtaining elemental data about geology and mineralization and then preliminary ground survey followed. Work of this year was emphasized on deliniating exploration target for the second phase.

1.2. Areal Extent and Work Operation of the First Phase Survey

1.2.1 Survey Areas

There are seven areas for the investigation with being scattered between

38° S and 47° S in latitude as shown in Figure I-1-1. The areas are mainly located on the Andes mountains that runs along the border line with the Republic of Argentine.

Areas of those investigated areas are shown in Table I-1-1.

Table I-1-1 Areas of Surveyed Areas

Surney area	Areas (km^2)	Survey area	Area (km^2)
No 1 Lonquimay area	1,490	No 5 Ibañez-Murta area	4,690
No 2 Huequi Peninsula area	730	No 6 Los Leones area	740
		No 7 Chile Chico-Chacabuco area	4,240
No 3 Futaleufu-Alto Palena area	2,310		
No 4 Alto Cisnes-El Toqui area	3,720		

1.2.2. Work of the First Phase

The works of this year are categorized into three kinds of works; that is, Landsat MSS image analysis, compilation works for the all geological materials concerning the geology and the mineralization in the survey areas, and field surveys.

The Landsat MSS image analysis and the compilation works were conducted prior to the field surveys in order to contribute to make the plans for the field surveys. The Landsat image analysis was completed in Tokyo and the compilation work was done in Santiago respectively.

The subjects emphasized on the works are as follows:-

a. Landsat MSS Image Analysis

The aim of this work is to reveal the geologic structures and then explain the spatial relationships between the geologic structures and the mineralizations by the photogeological interpretation on the 17 scenes of the

Landsat MSS image.

b. Compilation Work

Aim of this work is to understand geological relationships between geology and characteristics of the mineralizations, with collecting and analyzing the materials regarding the geology, the mineral prospects/mine, the geophysical exploration, the geochemical exploration and so on. In addition to that, the past mining activities and the conditions of the exploration and mining titles were searched.

c. Field Surveys

The field surveys consisted of two parts; geological survey which was mainly site inspection on the mineral prospects and mines, and geochemical exploration. The deposits for the site inspections were selected by the two preliminary works mentioned above.

The site inspections emphasized study of the geological environment and characteristics of the mineralization. Efforts were made to understand any particular geologic feature which could be applicable for further exploration. The localities of the site inspections were not restricted to them selected from the preliminary works, but localities were exchanged anytime depending on the informations that were obtained from the local people.

The known geochemical anomalous zones were followed by sampling of stream sediment and heavy detrial minerals(pan concentrate), which were completed with use of the topographic maps at the scale of 1:50,000.

Details of the each work are mentioned in the each section.

1.2.3. Amount of the Works

Amount of the samples taken for analyses are listed on Table 1-1-2.

1.2.4. Duration of the Works

Duration of the each work is as follows:-

Table I-1-2 Amount of Samples for Analyses

Area	Classification of samples							
	Geochemical Analyses		Ore Assaying	Thin Section	Polished Section	X-Ray Diffraction	Dating	Whole Rock Analysis
	Stream Sediment	Pan Concentrate						
Area No 1 Lonquimay	70	54	23	1	1	2	1	1
Area No 2 Huequi Peninsula	29	29	2	5	0	0	1	3
Area No 3 Futaleufu-Alto Palena	106	105	20	5	13	5	1	13
Area No 4 Alto Cisnes El Toque	46	46	26	9	9	18	3	6
Area No 5 Ibañez-Murta	66	62	135	31	28	49	2	9
Area No 6 Los Leones	15	15	2	4	0	0	2	3
Area No 7 Chile Chico-Chacabuco	60	60	54	13	16	26	0	1
TOTAL	392	371	262	68	67	100	11	36

* Landsat image analysis: From 11 December,1989 to 8 January,1990
* Data compilation: From 21 December,1989 to 9 January, 1990
* Geological survey and geochemical exploration: From 14 January,1990 to 6 March,1990
* Compilation of results of field survey: From 7 March,1990 to 28 March,1990

1.3 Organization of the Survey Team

Prior to field survey, a mission visited Santiago to conclude the Scope of Work. Following persons discussed about contracting the agreement. The discussion continued from 17 October to 28 October,1989.

【CHILEAN SIDE】

Maria Teresa Cañas Pinochet	Director of SERNAGEOMIN †
Dr. Jose Corvalán Diaz	Deputy Director of SERNGEOMIN
Carlos Portigliati Navarro	Chief Geologist of Economic Geology Division of SERNAGEOMIN

【JAPANESE SIDE】

Kyoichi Koyama	Metal Mining Agency of Japan
Tohru Motooka	Ministry of Foreign Affairs
Hiroyasu Kainuma	Japan International Cooperation Agency
Hideya Metsugi	Metal Mining Agency of Japan

†:Servicio Nacional de Geologia y Mineria Chile

Geologists who took part in this project are as follows

【JAPANESE GEOLOGICAL STAFF】

Yoshio Kawabata(MMAJ)	Planning and coordinating
Hideya Metsugi (MMAJ)	Planning and coordinating
Nobuyuki Kawamura(MMAJ)	Planning and coordinating
Yuya Furukawa (NED)	Chief geologist of the project
	Compilation work
	Geological survey and geochemical exploration
Susumu Takeda (NED)	Satelite imaginary analysis
	Geological survey and geochemical exploration

Kazuyasu Sugawara(NED)	Geological survey and geochemical exploration
Takashi Yoshie(NED)	Compilation work
	Geological survey and geochemical exploration

MMAJ: Metal Mining Agency Japan
NED: Nikko Exploration and Development

【CHILEAN GEOLOGICAL STAFF】

Carlos Portigliati Navarro	Coordinator, Chief geologist
Orland Rivera	Geological survey, Geochemical exploration
Sonia Vogel	X-ray analysis
Lucia Cuitiño	Microscopy

CHAPTER 2 Geography

2.1 Location and Access

Area No 1: The Lonquimay Area

The Lonquimay, the largest town in the area, lies approximately on the eastern rim of the central part of the IX Region or about 600km south of Santiago. The shotest trip from Santiago is to fly to Victoria by airplane and then reach to the area by vehicle.

The Lonquimay town is a center of the timber industry and therefore the road network is well developed.

Area No 2: The Huequi Peninsula Area

The area is located in approximately 100km south-southwest of Puerto Montt, the capital city of the X Region. The only one road lies through the base of the peninsula from Puerto Montt. The main survey area is in the apex of the peninsula and any commercial transportation system is not available to reach there. A voyage from Puerto Montt with hireling a vessel is the only way to the area. It is about eight hours trip.

Development of the road network is very poor. Only some short roads run around the small village in the apex of the peninsula.

Area No 3: Futaleufu-Alto Palena Area

The area is located in the south eastern part of the X Region. The area has two relatively large town: Futaleufu and Palena. Direct distances to towns from Puerto Montt are about 200km and 300km respectively. Both towns have commercial airport and commercial regular airflight by small aircraft from Chaiten where is situated in about 170km south of Puerto Montt. An irregular commercial air flight from Puerto Montt is available as well. Although the area is also accessible by vehicle from Puerto Montt, it takes at least two days because the road is disconnected in three places between Puert Montt and Chaiten. In the disconnected parts, vehicles can be transported by the regular car-ferry vessels.

The main roads which lie through the both towns to the Argentine are on a good condition. Other ones diverging from main roads, however, do not develop well.

Area No 4: Alto Cisnes-El Toqui Area

The area is located in the northern part of the XI Region. The survey area is composed of two subareas, the Alto Cisnes subarea of the north and the El Toqui subarea of the south where are divided by the Lago Fontana of Argentina. The Alto Cisnes subarea is in about 100km north in direct distance and the El Toqui subarea in 60km north from Coyhaique, the capital city of the XI Region.

The main road traversing through the Alto Cisnes subarea to Argentina is kept on good condition. The El Toqui subarea has good conditioned roads as well because large mines, for instance the El Toqui mine and the Katterfeld mine, are in operation.

Area No 5: Ibañez-Murta Area

Area No 6: Río Los Leones Area

Area No 7: Chile Chico-Chacabuco Area

These areas surround a great lake, the Lake General Carrera where is located in about 170km south in direct distance from Coyhaique. There is no road surrounding completely the lake so that it is fairly hard to move within the group of areas other than the travel along the main roads.

There are two roads connecting to the Lake General Carrera from Coyhaique. One runs through the Puerto Murta lying on the north western

coast of the lake, to the south of the area No 7. Another one terminates in the Puerto Ibañez, a small town on the north eastern coast. Ship is the unique traffic to the zone between Puerto Murta and Puerto Ibañez because there is not any road other than the horse roads.

The area No 6 and the southern part of the area No 7 are accessible through the road mentioned above that lies through Puerto Murta. Traffic is very incovenient to reach the northern part of the area No 7. There are two ways to reach the zone. One way terminates in the Puerto Guadal and other one does to the Fechinal. For travelling to Fechinal, a regular car-ferry between Puerto Ibañez and Chile Chico can be used. Whereas, the zone between Puerto Guadal and Fechinal is not accessible by any commercial traffic, otherwise the way crossing the lake by a small boat is the only route to reach there.

2.2 Topography and Drainage System

Most of the survey area is in the mountainous region at the altitude of 1,000 to 2,500m extending along the Andes mountains nearby the border line with Argentine. The topography in the region is characterized by the steep mountains. Especially the development of glacier and glacial lake is prominent except for in the area No 1 and No 2. Glacial lakes are arranging north to south with the orientation of E-W or NEE-SWW. Whereas fjords are developed in the Pacific coast region which together with the rugged topography prevented from the constructions of the road network in the Aysen region.

Drainage system is characterized by a feature of rivers running into Glacial lakes. It usually shows dendric pattern. The rivers derived from the Andes Mountains run toward east, but their channel directions are turned off by hard granitic rocks which occupy large areas.

2.3. Climate and Vegetation

The area No 1 (Lonquimay area) belongs to the temperate zone characterized by a moderate climate. Other areas belong to cold climate zone and is characterized by much raining throughout the year and is affected by westerlies.

Part of the mountains at elevation of more than 1,500m has generally no vegetations. Mainly coniferous forests are developed at the elevation below that. Lowlands are covered by grass and used as pastoral area.

Chapter 3 Existing Geological Data

3.1. Outlines of the Previous Works

Work covering throughout the areas is the Geological Map of Chile at scale of 1:1,000,000(SERNAGEOMIN,1982). This geological map was made by compilation of several geological surveys. Those maps are of several scales ranging between 1:50,000 and 1:1,000,000. Major previous works are as follows:-

Area No 1

Many geological and geochemical surveys were conducted in this area. SERNAGEOMIN is carrying out geological compilation work at scale of 1:250,000 including verification survey since several years ago. For the area lying in central part of this area, JICA-MMAJ conducted geological survey, geochemical survey, geophysical survey and drilling exploration in 1978 and 1979. Their works were concentrated on the area of 600km^2 surrounding the Galletue mineralized zone.

Area No 2

Very few works were conducted for this area. Geological map covering whole the area is only Geological Map of Chile(1:1,000,000) mentioned above. Gechemical survey was conducted in the northern edge of the peninsula on a small scale. Aero magnetic survey was done on marine area by ENAP in 1962. Its coverage area on land is very limited to just northern edge of the penissula.

Area No 3

The work of Thiele et al(1978) covers whole the area. Scale of the map is 1:500,000. A preliminary geochemical survey and ground magnetic survey cover a small area surrounding Futaleufu town.

Area No 4

The following works cover whole the area : CORFO(1982), SERNAGEOMIN(1983) and SERNAGEOMIN(1984). Former two maps are at 1:250,000 and the last map is at scale of 1:500,000. Those works were completed by using Landsat images. Very few geochemical works were completed in this area. Only SERNAGEOMIN(1984?) conducted geochemical survey just along the main road lying out of the area. Some mines are in operation at the moment, such as the El Toqui mine. They are exploring

their areas by themselves, but those data are not available.

Area No 5

Geological surveys covering whole the area are SERNAGEOMIN(1982) at scale of 1:250,000 and SERNAGEOMIN(1984) at scale of 1:500,000. As to the local geology, MMAJ(1978 and 1979) surveyed the surrounding area of the Lake General Carrera at scale of 1:100,000. They also completed survey at scale of 1:10,000 on the Silva mine area and the Pelado mine area including geophysical survey(IP method) and trenching work.

Previous surveys are concentrated on the mining center distributed in surrounding area of the Lake General Carrera. Whereas, only few surveys were put on the area between the Avellanos river and Ibañez river.

Geolchemical survey was conducted by only SERNAGEOMIN along main load around 1984.

Area No 6

Geological survey covering whole the area is the same work as that in Area No 5. Nearly no other geological works have been done.

Geocheical survey was conducted by only SERNAGEOMIN along main load lying from Area No 5 around 1984.

Area No 7

This area lies next in south of Aera No 5. Works completed in this area are of same kind and same amount as those in Area No 5.

Gold mineralization was discovered in the Laguna Verde deposit lying southern part of the area. This new discovery activated the exploration works of companies.

3.2. General Geology of the Aysen Region

The area lies the Andes orogenic belt formed along the western margin of sub-stable landmass, western part of the Brazilian shield.

The area is underlain by the basement of Paleozoic metamporphic complex, Jurassic system, Cretaceous system, Tertiary system, Quarternary system and granitic rocks(Patagonia Batholith) intruded

during the time from Jurassic to Tertiary time. Basement rocks of north of latitude 47°S are distributed mainly on western side of the area and they consist of metamorphic rocks such as greenschist, phyllite, quartz schist, mica schist, metasandstone, marl and calcareous schist. Metamorphic rocks other than greenchist are considered to be metasediments. Those rocks are very deformed. Geologic time of sedimentary rocks is reported to be of Devonian to Carboniferous time in Aisen foreland mountains (Precordillera de Aisen) by Skarmeta et al.,(1984).

Jurassic system is distributed on east of the Patagonia Batholith elongating with N-S direction. Rocks of Jurassic system consist of mainly intermediate or accidic volcanic rocks and pyroclastic rocks. Skarmeta et al.(1984) reported that those sedimentary rocks are of Dogger to Malm series.

Cretaceous system underlies east of the Patagonia Batholith. Lower Cretaceous unit consists of mainly sedimentary rocks of marine origin, intermediate to accidic volcanic rocks and pyroclastic rocks in ascending order. Upper Cretaceous unit consists of mainly volcanic rocks and continental sediments.

Tertiary system lies on both side of the Patagonia Batholith. Rocks of Tertiary unit are sedimentary rocks of marine origin, continental sediments and volcanic rocks.

Extensive volcanism of andesite and basalt took place mainly in the area of the Patagonia Batholith distributing during end of Tertiary to early Quarternary. A part of that still continues to the present.

Batholith of Mesozoic to Cenozoic (Andes Batholith) intruded along western coast line throughout the South America from Cape Horn to Colombia. A part of the Batholith on south of 39°S of latitude are called the Patagonia Batholith which is distributed in the investigated area. Granitic intrusions of stock-shaped are distribued in especially the eastern marginal zone of the Batholith. Period of intrusion is estimated to be Middle Jurassic to Oligocene based on many dating studies. Many rock types, granite to dunite are recognized in the Batholith and chemical composition show basic on the west and accidic on the east(Skarmeta et al.,1984).

The basement rocks of Pre-Mesozoic age are deformerd extensively and contains tholeiitic metabasite. It is assumed from those that the basement is a mélange formed in the subduction zone(Skarmeta et al.,1984). Extensive volcanism caused by subduction was still maintained also during Mesozoic time in the western margin of the continent(Skarmeta et al.,1984). This activity is assumed to have begun in middle or late Jurassic period. This igneous activity continued even in Cenozoic period and is partly still active at the present.

Regional geologic strucure is prevailed by N-S system for either fracture systems or fold structures. Those direction is constant since Paleozoic time to Recent. Fold structure formed during Paleozoic time show fold composite folds accompanied with drag folds and their axis trend N-S direction. Fold structures developed in Mesozoic rock are very gentle folds. No fold structures are not recognized in Cenozoic rocks. That is, the structural movements of Paleozoic and Mesozoic time are characterized by lateral movement, while them of Cenozoic are vertical movement.

3.3. Geologic Settings

Area No 1

Geology of the area is characterized by extensive volcanic activities of post-Miocene time. This activities is still maintained to the date.

This area lies on the eastern margin of the Patagonia Batholith. In central part of the area, stocks of granitic rocks related to the Patagonia Batholith are distributed.

Southern extention of the Porphyry Copper belt lies through this area (Sillitoe,1981).

Area No 2

This area lies on western margin of the Patagonia Batholith and also on extention of Paleozoic unit elongating with N-S direction on western side of Chile. A part of Paleozoic unit is intruded by ultramafic rocks.

Area No 3

This area lies on eastern margin of the Patagonia Batholith and most of the area is underlain by granitic rocks.

Mesozoic units which consist of Jurassic unit and Cretaceous unit are intruded by granitic rocks. This area is in western rim of distribution area

of Mesozoic unit.

Area No 4

Geology extends to this area from Area No 4 so that this area is in similar geological setting to that of Area No 3. This area lies on center of a Mesozoic sedimentary basin which was called Magallanes geosyncline by Ruiz(1965) so that Mesozoic units are thick. This basin is said to be in shallow and warm marine circumstance.

Area No 5

The Patagonia Batholith is shifting to west in south of the region. It is distributed in western edge of the area. Paleozoic unit and Mesozoic unit are intruded by many stocks of granitic rocks throughout the area. Those granitic rocks are closely related to the batholith. Paleozoic unit consists of metamorphic rocks extended from Area No 2. Limestone beds interbeded into this metamorphic rocks are favorable rock unit for lead-zinc deposits in this area.

Area No 6

Distribution area of the Patagonia Batholith lies about half of the area. No units after Paleozoic time are distributed except for the intussive rocks.

Area No 7

This area is just adjacent to Area No 5 in south. Geologic settings are very similar to them of Area No 5.

3.4. Mining History of the Surveyed Area

Mining activities of Chile, known as a mining country, were restricted in northern half of the country so far. Whereas, recently Aysen region has been highlighted by increase of lead-zinc production and new discoveries of large gold deposits. This region was left developed insufficiently due to mainly physical problems such as severe climate and bad access conditions, though potentials of mineral resources were appreciated.

Zinc yielded from this region takes 75% of total zinc production in Chile instead of bad physical conditions. Twenty mines were and some of them are in operation in this region, according to CORFO(1982 and 1983). Alluvial moning is excluded from this figure. Among them, two mines are in operation(the El Toqui mine and the Rosillo mine) and four mines are being explored (the Cerro Estatuas, the Katterfeld, the Santa Teresa and the Laguna Verde). Only the

Laguna Verde deposit is a new discovery. Other three deposits are explored in order to obtain further ore reserves after completion of mining of old deposits mined in past.

Oldest mine is the Silva mine of lead-zinc. This mine was discovered in 1936 and its production was continued for 52 years until it was closed at completion of mining in 1988.

Generalized mining history of the major mines are as follows:-

1930s : First discovery of the Silva mine (1936)
1940s : Commencement of the production in the Silva mine
1950s : Commencement of the production in the Rosillo mine, La Chivas mine and "old vein" deposit of the Katterfeld mine
1960s : Productions of those mines continued
1970s : Metallgesellshaht, a German company, conducted extensive exploration works for the Cerro Estatuas deposit. Lac minerals, Canadian company, discovered large gold deposit in Katterfeldmine
1980s : Commencement of production of the La Poza mine(1980)
Production of La Poza mine was suspended(1982)
Commencement of production of the El Toqui mine (vein deposit) and the Cerro Estatuas mine(1983)
Commencement of production of stratiform deposit of the El Toqui mine (1984)
Las Chivas mine was closed out (1986)
Production of the santa Teresa mine was suspended(1987?)
Large gold deposit was discovered in Laguna Verde deposit(1987)
The Silva mine was closed out(1988)

Mining activities in Aysen region seems to have been activated mostly during the years between later 1970s and early 1980s. Production amounts of the XI Region was reported as follows:-

Gold : 0.4kg(from alluvial mining)
Silver : 918.5kg (292kg from lead concentrate and 626.5kg from zinc concentrate)
Lead : 223 t
Zinc : 1,516 t
(after the mining statistic of SERNAGEOMIN)

Chapter 4 Discussions of Results of Survey

4.1. Characteristics of Geologic Structure and Mineralization, and Controls on Mineralization

Fracture systems in the Aysen region are generally classified into NNE-SSW system and NW-SE system. Fractures of the former system tend to extend continuously along the Patagonia Batholith. Distribution of them are mainly in central zone of the batholith. Quarternary volcanos and hot springs arrange along fractures of this system. No mineralization is recognized along this structure. Consequentry, this structure is believed to be of post-mineralization.

On the other hand, fractures of the NW-SE system are distributed densely on the distribution area of Paleozoic and Mesozoic units lying in south of Coyhaique city. "Island-shaped landmass" underlies the area on side of Argentine(Miyashiro et al,1978). Elongation of this landmass is of NW-SE direction and it extends beneath the area where fracture of NW-SE system occur densely. Therefore, those fractures are understood to be reflected the structure of basement. Deposits of Area No 5 to 7 occur in the fracture zone and it appears that the mineralizations in those areas are controled by those fractures. Vein systems of some deposits, for instance Laguna Verde, Cerro Mayo and Las Chivas, show NW-SE system and ore-bonanzas of the El Toqui deposit is said to be controled by those fracture systems.

Mineralization in the region is represented by polymetallic mineralization of gold, silver, copper, lead, zinc and molybdenium. Many of deposits are distributed on eastern margin of the Patagonia Batholith showing regional zoning of metal associations. That is, they are arranging in order of molybdenium zone, copper(gold) zone, lead-zinc(silver) zone and gold-silver zone toward outside from eastern edge of the batholith. The most outside deposit lies about 100km east from the batholith.

Molybdenium zone lies in edge of the batholith or just nearby it. Generally deposits are narrow vein depopsit occuring in granitic rocks. Deposits of the copper(gold) zone are concentrated on area in south of 43°S in latitude. Most of deposits are vein dposit and of small scale. Some deposits contains gold. Deposits of lead-zinc(silver) zone are concentrated in area ranging between 45° and 47° in latitude.

Seventy five percentages of total lead-zinc production in Chile are yieled from this zone so far. Many of deposits are vein deposit. stratiform, massive and lense-shaped deposits which replaced limestone of Paleozoic and Mesozoic age occur as well. Lead ore derived from the deposits in this zone contains relatively high amount of silver, averaging 100g/t Ag. Messozoic calecareous rock replacement deposits are represented by the El Toqui deposit which has ore reserve of 20 million tonnes class. Paleozoic limestone replacement deposits are represented by the Silva deposit and the Rosillo deposit. Their ore reserves range between 500 thausand and 600 thousand tonnes.

Gold-silver zone lies on outermost part of them. Most deposits are vein deposit. Deposits belonging to this zone are represented by Katterfeld deposit and Laguna Verde deposit. Both deposits have a feature of gold bearing epithermal(possibly hot spring type?) quartz vein swarm. Country rocks are accidic or intermediate volcanic rocks and pyroclastic rocks of Mesozoic age. Both are recent discoveries and exploration works are still ongoing so that detailed features have not been revealed completely. Judging from extensiveness of exploration activities, however, they seem to be very promissing deposits. Increase of discovery of this type of deposit is expected to be brought by further explorations.

4.2. Geochemical Characteristics of the Surveyed Areas

Each investigated area have particular geochemical features as hollows:-

Area No 1

Geochemical elements are grouped into two associations by principal component analysis : Cu-Pb-Zn association and Au-As association. This implies the mineralization in the area can be divided into two styles having above metal associations. Gold and arsenic association shows more higher anomalies and therfore is believed to represent the geoochemical characteristics in this area.

Area No 2

Higher eigen vectors were brought to Cu, Pd, Co, Fe, Mn, Ni and Cr by principal component analysis. This suggests the existence of ultramafic rocks. Geochemical features of this area is characterized by elements of Au, Cr, Ni, Co and Pd on the basis of anomalous values of elements. Gold and other elements listed above seem to be classified into different associations.

Area No 3

Principal component analysis grouped elements into Pb-Zn association and Mo association. Geochemical anomalies are characterized by Au, Ag, Pb and As. Three styles of mineralization are assumed to exist in the area ; they are of Au-Ag, Pb-Zn and Mo.

Area No 4

Elements are grouped into Cu-Pb-Zn association and Mo association. Geochemical anomalies are characterized by Pb and Mo.

Areas No 5 to 7

Elements are grouped into Pb-Zn association and Cu association. Geochemical anomalies are characterized by Au, Pb, Mo and As. The mineralization of these areas are considered to be of three styles ; Cu-Au-As, Pb and Mo.

4.3. Potentials of Ore Deposit

Characteristics of deposits and geochemistry lead to following conclusions regarding the potentials of ore depodit in Aysen region.

Area No 1

Gold deposit is expected in the area judging from the features of known prospects and geochemistry. Deposit would be vein deposit with character of hypothermal systems.

Area No 2

Gold deposit and orthomagmatic deposit associated with ultramafic rocks are expected, but this assumption is not very concrete idea due to deficiency of sufficient geological informations.

Area No 3 and 4

Eastern part of this area is overlain by Ibañez Formation and Coyhaique Formation. Lead anomalies were obtained as well. Therefore, mineralization of the El Toqui style is expected. Gossaneous hydrothermal alteration zone is found in west of Futaleufu town. Geochemical gold anomalies also occur around this zone as well and then gold deposit simmilar to the Katterfeld deposit is expected.

Area No 5

Central part to eastern part of the area are highlighted for potentials of large gold deposit of the Laguna Verde type. Whereas higher potentials of

mineralization of the Silva deposit style is considered to be in western part of this area.

Area No 6

This area is adjacent to the Patagonia Batholith and is overlain by broad distribution of metamorphic rocks so that hypothermal gold deposit accompanied with copper is expected.

Area No 7

In the distribution area of Ibañez Formation lying in eastern part of this area, many gossaneous hydrothermal alteration zones are developed. They are associated with gold geochemical anomalies. This leads very positively to an expectation that mineralization of the Laguna Verde deposit style occur in the area. Whereas, the distribution area of Paleozoic unit in western part of the area is expected for mineralization of the Silva deposit style.

Chapter 5 Conclusions and Recommendations

5.1. Conclusions

Area No 1: Lonquimay area

Mineralization of this area is characterized by gold and copper. Two styles of gold mineralizations are found in this area; that is, vein or network vein deposit and placer gold deposit. The former occurs in intrusive rocks or Cretaceous rocks. Some veins show grade of several grammes per tonne to some ten grammes per tonne of gold in a part of them, while their sizes are very small. The latter is placer deposit accumulated in glacier sediments of the Bio Bio river. This deposit is locally being mined on a small scale, but scale of deposit is very small. Further exploration works seem to obtain no more large ore reserves of the both styles of deposits.

Mineralization zone of the Prphry copper type, according to existing data, are found in the southern coast area of the Lake Galletue. Very disappointing results for this zone were obtained by exploration works includig geochemistry and drilling which led to a conclusion that no more further work strike significant intersection(JICA-MMAJ,1979).

Gold and silver stream sediment geochemical anomalies were found a little densely in the area between the Maravilla mountain and the Bio Bio river lying northern part of the Area No 1.

Area No 2: Huequi Peninsula area

The survey of this year identified the existence of ultramafic rock intruded by granitic rock in the base of the Comau mountain situated in northern part of the peninsula. Distribution and size of ultramafic rockbody are not identified. Gold anomalies were found by stream sediment geochemistry in the western part of the area.

Area No 3: Futaleufu-Alto Palena area

This investigation identified indications of copper mineraliztion occuring in intermediate to accic volcanic rocks. Whereas, no promissing deposit was found. However, it is believed that further exploration work may get new discovery of promissing deposit of gold, silver, lead and zinc in the distribution area of Jurassic system. This expectation stands on the following evidence:-

This area lies on the eastern margin of the Patasgonia Batholith, and is overlain by Jurassic volcanic rocks and calcareous rocks of marine origin(Ibañez Formation, Coyhaique Formation and Divisadero Formation) which are closely related to the mineralizations of the Aysen region. Furthermore, gold and silver geochemical anomalies were obtained in northwest of Futaleifu town. In the vicinity of Palena town, dense distribution of lead geochemical anomalies were found. Those are considered to lead to the above expectation.

Area No 4: Alto Cisnes-El Toqui area

This area lies the eastern margin of the Patagonia Batholith and eastern part of the area is overlain by Mesozoic units. Large lead-zinc deposits, represented by the El Toqui and Cerro Estatuas, are considered to be formed by replacement of calcareous beds of Mesozoic units. Vein deposit of gold also occurs which is represented by the Katterfeld deposit. In Katterfeld deposit, parallel veins are distributed and the mineralized zone is one kilometers wide. This zone is associated with gossaneous hydrothermal alteration zone of some kilometers width.

Those deposits are predominant in both scale and ore grade so that they would be targeted for exploration of undiscovered deposit.

Area No 5: Ibañez-Murta area

Paleozoic metamorphic rocks and Mesozoic units lie on this area. Although more than 70 mines and prospects occur in those rocks, many of them are small.

Sufficient exploration works have not been conducted in the area between the Avellanos river and the Ibañez river due to access problem. This area is underlain by Paleozoic unit and Mesozoic unit, and intruded by many stocks of granitic rocks. Moreover, a gold prospect occurs in the down river of the Avellanos river. Those leads to a expectation that lead-zinc deposit of the Silva style and the El Toqui style, or gold deposit of Katterfeld style are still remaind to be undiscovered.

No geochemical anomalies were obtained throughout the area No 5.

Area No 6: Los Leones River area

This area is underlain by the Patagonia Batholith on western part and Paleozoic unit on eastern part of the area. Gold and arsenic geochemical anomalies were obtained densely in the basins of the Leones river and the Cañar river. Whereas, no interesting deposit was found.

Area No 7: Chile Chico-Chacabuco area

Geology of this area consists of Paleozoic metamorphic rocks, Mesozoic unit, Cenozoic unit, and stocks and dykes derived from the Patagonia Batholith. About 20 deposits are known. Among them, gold mineralization of Laguna Verde style and lead mineralization of La Pozs style are noted.

Laguna Verde deposit is an epithermal vein deposit which may be classified into hot spring type. Numerous quartz veins occur in Ibañez Formation. This deposit is associated with broad hydrothermal alteration zone with assemblage of silicification and kaolinitization.

La Poza deposit is possibly sub-marine volcanogenetic deposit. It is expected to have potential for the discovery of further ore.

Geochemical anomalies of gold, silver and arsenic were obtained densely and hydrothermal alteration zone associated with gossan was found in upriver area of anomalies. Therefore, this anomalous zone is worth noting.

5.2. Recommendations

5.2.1. Selected Subjects for Further Explorations

The following lines are recommended for further explorations on the basis of the conclusions defined above.

Area No 1: Lonquimay area

Gold mineralization should be targeted. Minable placer deposits lie this area, while the source of gold grains has not been identified. In order to find the source deposit, the work must forward to lead a line after integrated analises of all geochemical data including them obtained by SERNAGEOMIN. It is also advisable to analyze geochemically anomalous zone lying around the Maravilla mountain.

Area No 2: Huequi Peninsula area

It is recommended to get basical geological informations at first. Existence of ultramafic rock has been identified by this survey so that its distribution area and size will have to be defined. Aeromagnetic survey is believed to be the most suitable method for that purpose. Therefore, it is recommended that delineation of survey area by aeromagnetic survey will be followed by geological and geochemical survey.

Gold grain of about one millimeter in diameter was found in a geochemical anomalous point of gold. This anomalous zone is worth being followed up so that it is recommended to follow up ultrmafic rock and geochemical anomaliy of gold.

Area No 3: Futaleufu-Alto Palena area

To get undiscovered mineralization of the El Toqui style, horizon of ore-bearing beds will have to be chased by using aerialphotograph interpretation at the first and then ground surveys including geochemical survey will test the mineralization.

Geochemical anomalies of gold are found a little densely in north of Futaleufu town. This anomalous zone will have to be re-surveyed more detailedly.

Gold mineralization of the Katterfeld style is associated with broad hydrothermal alteration zone so that it is advisable to extract the similar alteration zone by using Landsat TM image.

Area No 4: Alto Cisnes-El Toqui area

Lead-zinc mineralization of the El Toqui style is expected in eastern part of the area. This kind of mineralization must be targeted and followed up by the same procedure as that of Area No 3.

Area No: 5 Ibañez-Murta area

Geological survey and geochemical exploration are advisable for the area between the Ibañez river and Avellanos river.

Area No 6: Los Leones area

Following up the geochemical anomalous zone of gold and silver is recommended.

Area No 7: Chile Chico-Chacabuco area

Mineralization of the Laguna Verde is associated with broad hydrothermal alteration. Landsat TM image analysis is suitable for discovering this type of mineralization.

La Poza and La Paulina deposits may be a volcanogenetic syngenetic deposit. Minable ores are expected to be still remained to be undiscovered. Therfore, detailed geological survey at scale of 1:5,000 is advisable.

Another advisable target is geochemically anomalous zone of gold and silver lying the basin of the Avilles river.

5.2.2. Recommendations for the Second Phase

The following investigations are especially recommended for the second phase.

(1) Landsat TM image analysis and geological survey for alteration zone extracted by TM image in the regional zone between eastern edge of the Patagonia Batholith and the border line with Argentine ranging from Area No 3 to Area No 7.

(2) Photogeology by using aerialphotographs to follow up ore horizons and test survey including geochemistry for mineralization in distribution area of Mesozoic unit of Area No 3 and No 4.

(3) Geological and geochemical survey to follow up geochemically anomalous zone of gold and silver in nortern part of Area No 3.

(4) Geological and geochemical survey to follow up geochemically anomalous zone of gold and silver in Area No 6.

(5) Detailed geological survey for La Poza deposit and La Paulina deposit in Area No 7.

PART Ⅱ: DETAILED DISCUSSIONS

PART Ⅱ
DETAILED DISCUSSIONS

CHAPTER 1 Satellite Image Interpretation

1.1. Data

The image data used for this analysis are 17 CCT (Computer Compatible Tape) scene which was acquired by Multispectral Scanner (MSS) on Landsat 5. The images which are as clear as possible without cloud or snow are selected. The data were obtained through EOSAT (Earth Observation Satellite Company. c/o EROS Data Center, Sioux Falls, South Dakota 57198, USA). The data are listed in Table Ⅱ-1-1 and the areai coverage of images is shown in Fig.Ⅱ-1-1.

Table Ⅱ-1-1 Landsat Images Used for Interpretation

EXPO-DATA	SCENE ID	PATH ROW	SCEN-CENTER-POINT	CLOUD %
86, 03, 19	85074813500 X0	231 090	43°11′ 70°38′	10
85, 01, 27	85033213545 X0	231 091	44°37′ 71°10′	20
84, 12, 26	85030013550 X0	231 092	46°02′ 71°39′	10
84, 12, 26	85030013553 X0	231 093	47°27′ 72°12′	10
87, 02, 09	85107513491 X0	232 086	37°28′ 70°25′	0
86, 03, 26	85075513545 X0	232 087	38°54′ 70°48′	0
86, 03, 26	85075513552 X0	232 088	40°19′ 71°15′	0
85, 03, 07	85037114001 X0	232 089	41°46′ 71°44′	0
86, 04, 27	85078713552 X0	232 090	43°11′ 72°13′	0
85, 03, 07	85037114010 X0	232 091	44°37′ 72°42′	10
87, 02, 09	85107513514 X0	232 092	46°01′ 73°18′	20
87, 02, 09	85107513520 X0	232 093	47°26′ 73°50′	10
85, 02, 26	85036214051 X0	233 086	37°28′ 71°55′	0
85, 02, 26	85036214054 X0	233 087	38°54′ 72°21′	0
85, 02, 26	85036214060 X0	233 088	40°19′ 72°48′	10
85, 02, 10	85034614063 X0	233 089	41°45′ 73°16′	10
85, 02, 10	85034614065 X0	233 090	43°10′ 73°45′	10

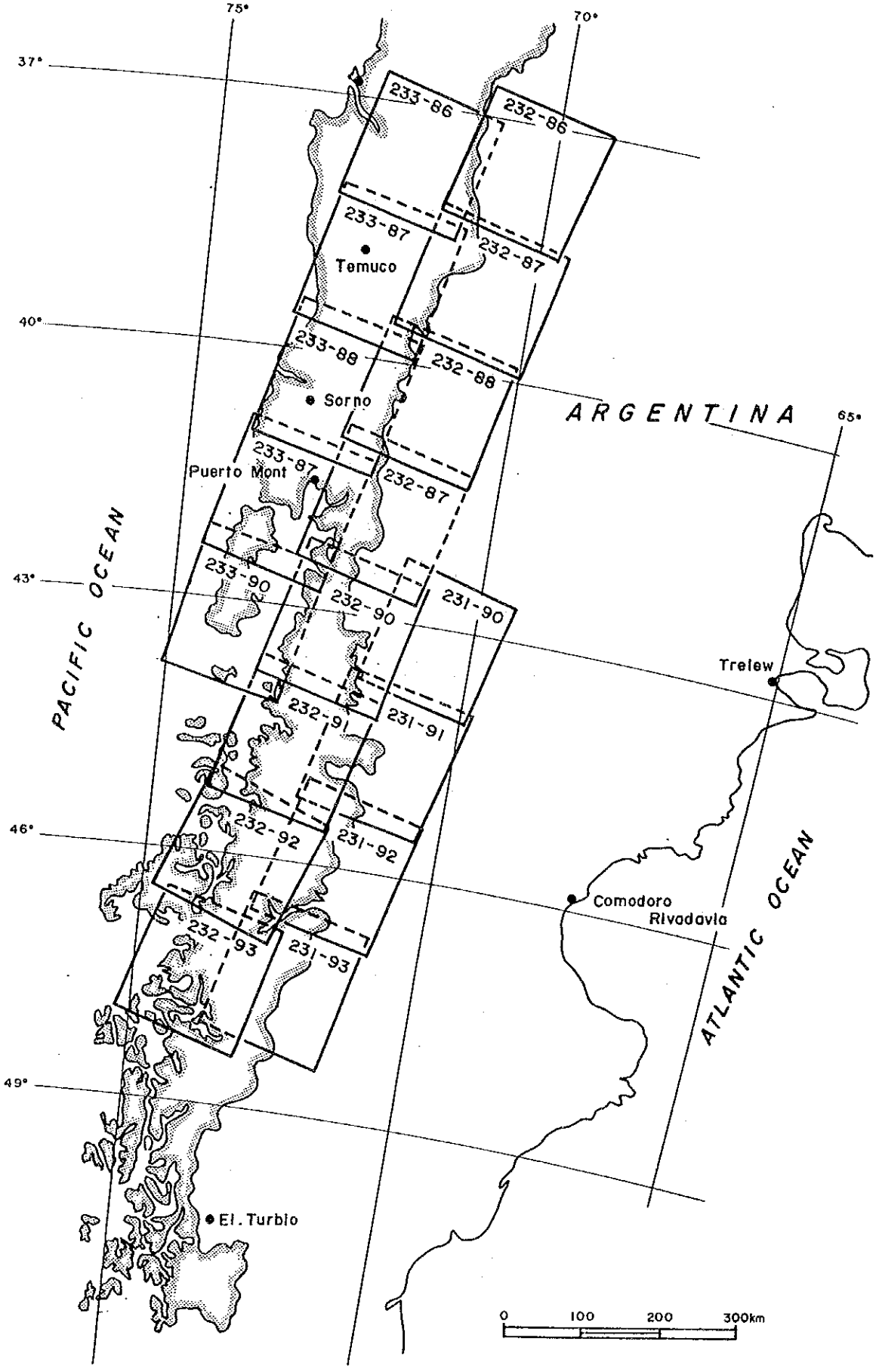


Fig. II-1-1 Location Map of Landsat

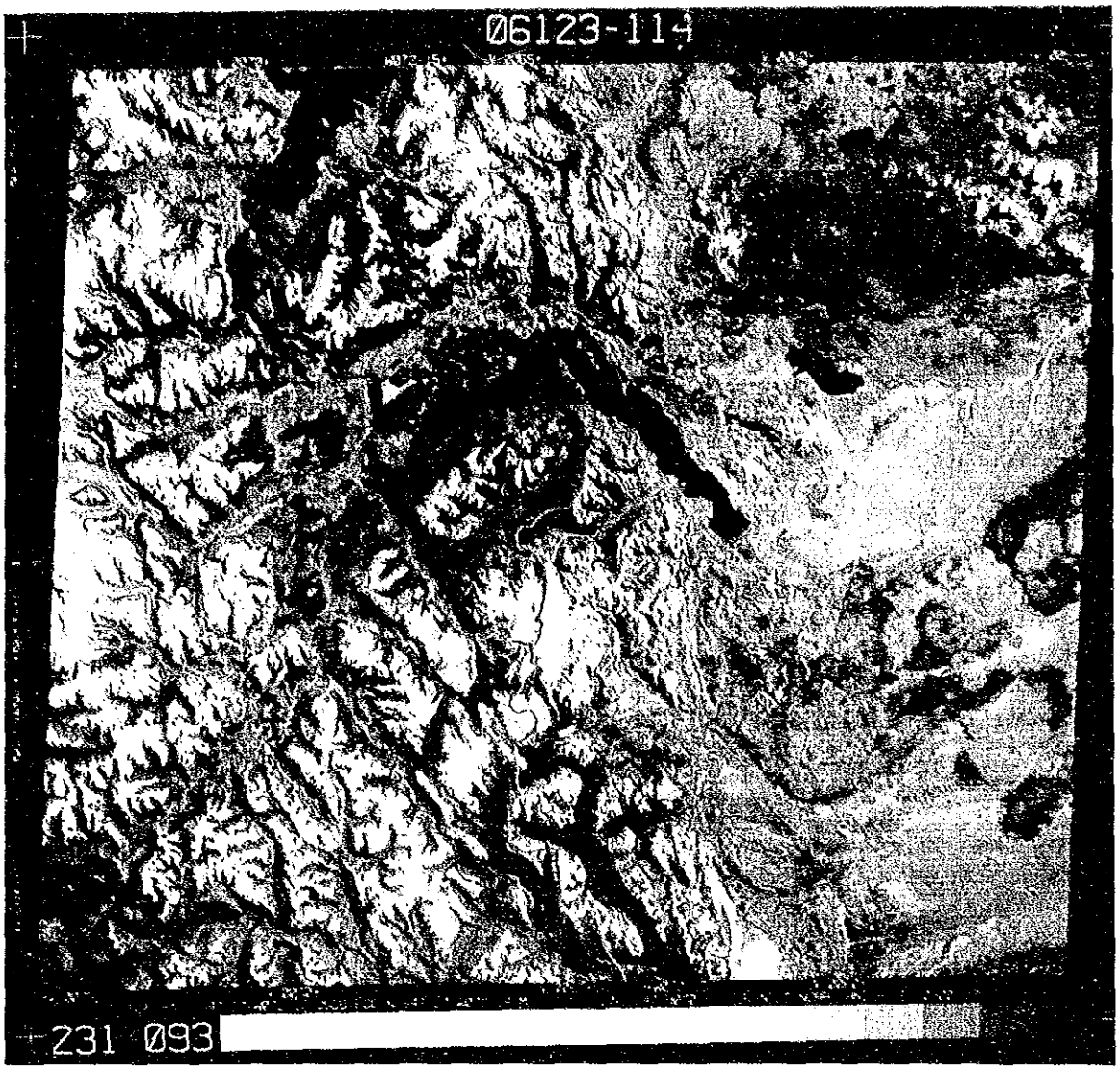


Photo. 1 False Colour Image of Landsat MSS (Band 4:blue 5:green 7:red)

Landsat 5 was launched on 18 March, 1984 and is on a sun synchrous orbit at a height of approximately 700km. Its cycle is 16 days (Fig.Ⅱ-1-2) and carries Thematic Mapper(TM) as well.

TM data, compared to those of MSS, have higher resolution, larger number of bands, wider range of wavelength and generally higher quality. For example, the normal resolution is 80m for MSS while that for TM is 30m, therefore, greater detail can be read from the TM images than from the MSS. Also MSS contains four band data while TM has seven bands with greater spectral information (TableⅡ-1-2).

Table Ⅱ-1-2 Comparison of Wave Length Range of Each Band

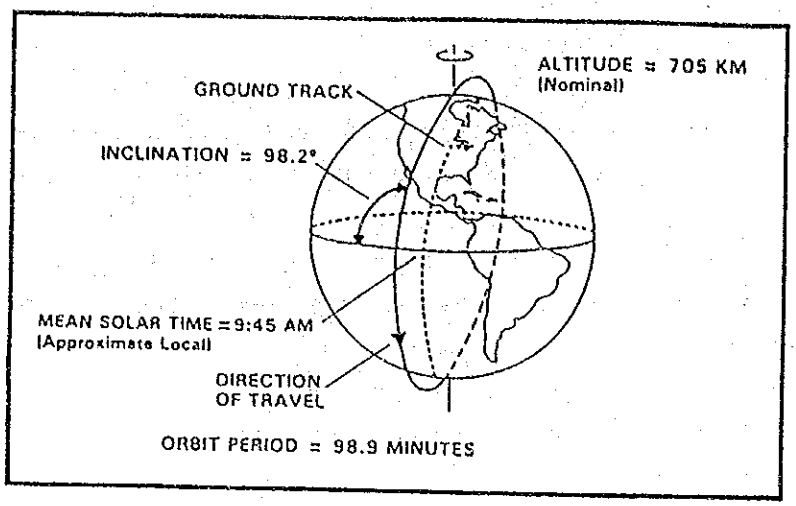
MSS		TM	
Band	Wavelength	Band	Wavelength
4	0.5-0.6μm	1	0.45-0.52μm
5	0.6-0.7	2	0.52-0.60
6	0.7-0.8	3	0.63-0.69
7	0.8-1.1	4	0.76-0.90
		5	1.55-1.75
		7	2.08-2.36
		6	10.6-12.5

In the investigated area of this year, the MSS data are obtained easily compared to the TM data because the TM data take much time to process those digital data. This study employed the MSS data by the reasons which the aim of this analysis is mainly to read the geologic structure, but detailed interpretation was not required, but short term was required to complete interpretation.

1.2. Method of Analysis

For the analysis, much attention was focused on photogeological characteristics such as tone and texture as well as on drainage patterns, drainage density, rock resistance, existence of bedding and other tographic features. Then geologic units (lithology) were delineated, lineaments, annular (ring) structures, foldings and other structural features were read and interpreted.

The lineaments are topografic features which suggest fractured zones and the main basis for the interpretation are as follows:-



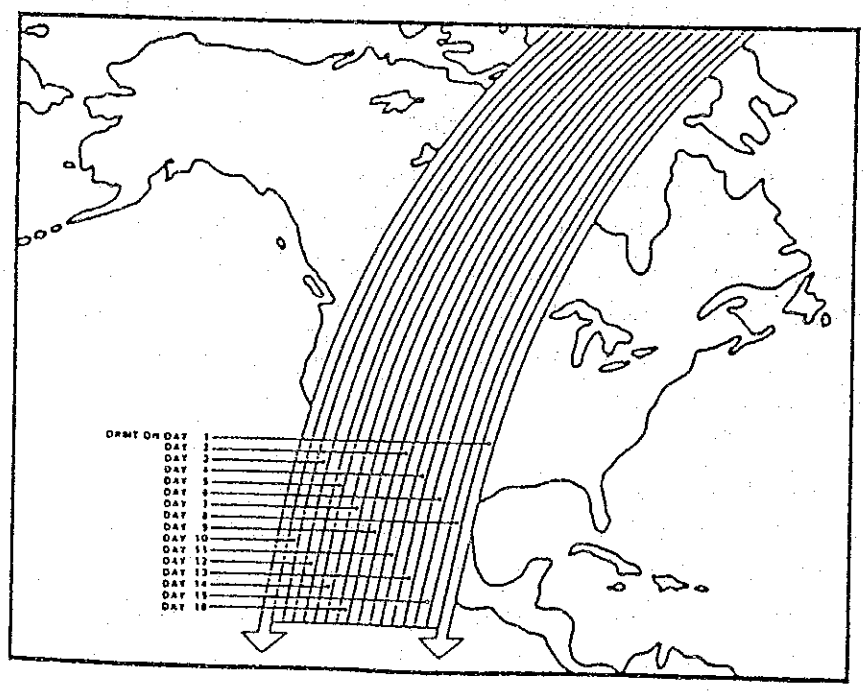


Fig. Ⅱ-1-2 Orbit and Ground Coverage Pattern of Landsat 5