REPORT
ON
THE MINERAL EXPLORATION
IN THE [illegible] AREA
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MARCH 2000

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

REPORT
ON
THE MINERAL EXPLORATION
IN THE ORURO–UYUNI AREA
OF
THE REPUBLIC OF BOLIVIA

(PHASE I)

MARCH 2000

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

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

The JICA and MMAJ sent to the Republic of Bolivia a survey team headed by Mr. HASHIMOTO Morio from February 1 to March 7, 2000.

The team exchanged views with the officials concerned of the Government of the Republic of Bolivia and conducted a field survey in the Oruro-Uyuni area. After the team returned to Japan, further studies were made and the present report has been prepared.

We hope that this report will serve for the development of the 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 Bolivia for their close cooperation extended to the team.

March, 2000

Kimio Fujita
President
Japan International Cooperation Agency

Naohiro Tashiro
President
Metal Mining Agency of Japan

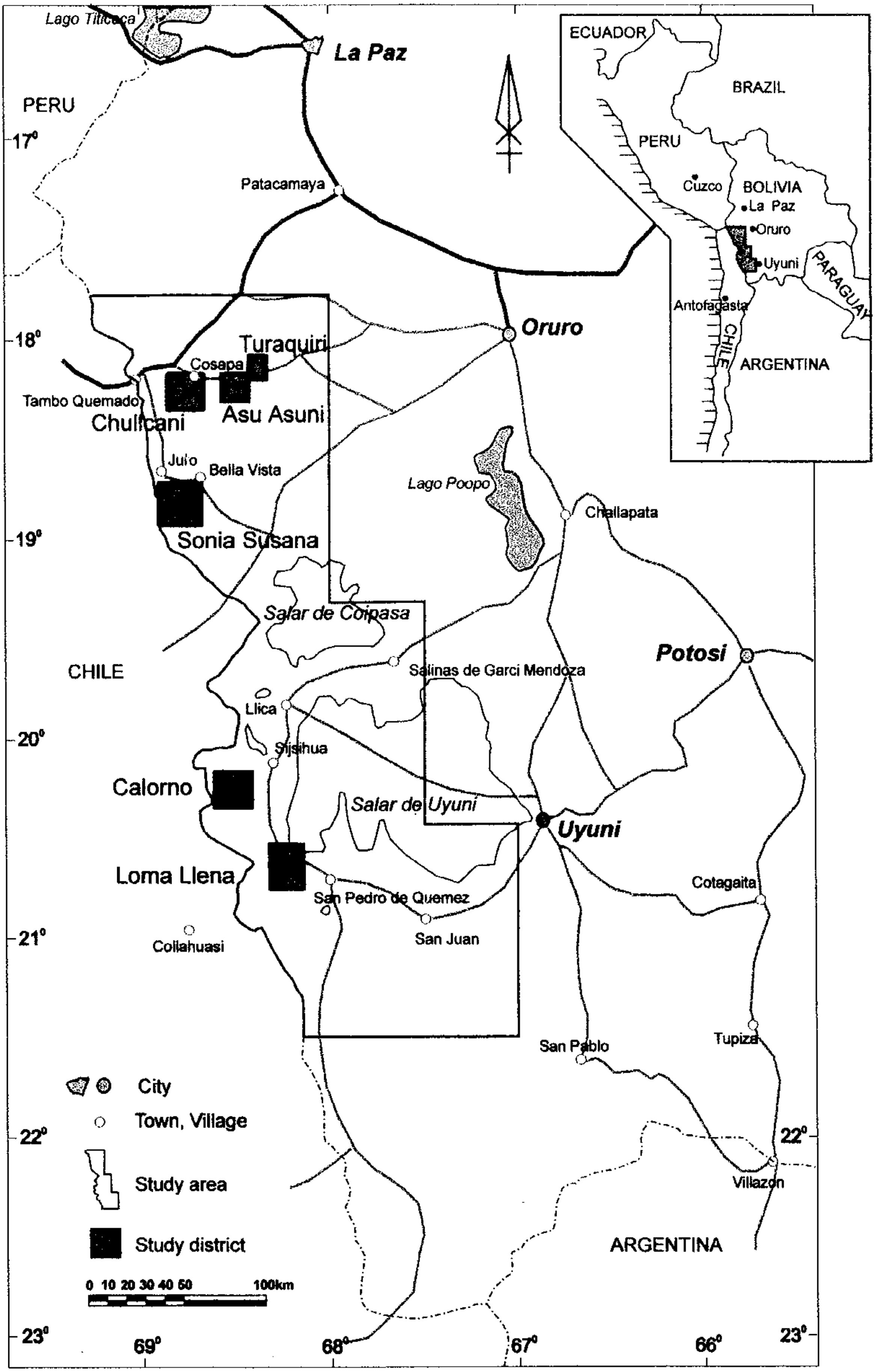

Fig. I-1 Location Map of the Survey Area

SUMMARY

This report sums up the survey in Phase I (FY1999, the first fiscal year of the survey) implemented in the Oruro-Uyuni region of the Republic of Bolivia, under the Technical Cooperation for Mineral Exploration.

The survey findings, overall evaluation and exploration guidelines for Phase II are summarized in the following paragraphs:

Survey Findings

[1] Turaquiri - Asu Asuni - Chulcani Districts

Turaquiri District : There are epithermal, lead-bearing quartz-barite veins along with small-sized silicification-argillization zones. The dating of host rocks indicates 5.5 Ma, which corresponds to the close of the late Miocene time.

Asu Asuni District : Although medium-sized silicification and argillization zones spread and pyrite dissemination was ascertained, no marked geochemical anomalies were found.

Chulcani District : Medium-sized silicification and argillization zones extend, and geochemical anomalies of gold are present. The dating of host rocks indicated 6.1 Ma, which corresponds to the late Miocene time.

[2] Sonia - Susana District

Silicification, argillization and propylitization zones are widespread, and geochemical anomalies are present. Besides, indications of mineralization have been ascertained, which are a gold-bearing quartz vein (3.0 g/t Au; 24 g/t Ag), lead-bearing barite vein (4.2% Pb; 1.0% Zn) and zinc-bearing quartz vein (1.2% Zn). The dating of old rocks in the district indicated 17.7 Ma, which corresponds to the early Miocene time, while the north and west parts of the district are underlain by new rocks of 1.7 Ma and 1.5 Ma, respectively, which corresponds to the late Pliocene and Pleistocene time.

COMINCO conducted a drilling survey of 10 boreholes, with the total extension of 2,000 m.

[3] Calorno District

Silicification and argillization zones are widespread, in which a goethite zone extends over 800 m. Although no marked geochemical anomalies are existent, small anomalous portions are spotted in the central part. The dating of wall rocks indicated 11.7 Ma and 9.0 Ma, which correspond to the middle to late Miocene time, older than the so far accepted Quaternary volcanic rocks.

[4] Loma Llena District

Silicification and argillization zones are widespread but no marked geochemical anomalies were found, except pyrite dissemination and pyrite veinlets were ascertained in the northern part. The dating in the district indicated 6.2 Ma, 4.1 Ma and 3.8 Ma, which range from the late Miocene to early Pliocene time.

Overall Evaluation

The survey revealed that the hydrothermal alteration zones widespread in the Oruro-Uyuni region are likely to host epithermal ore deposits at depth.

The promising areas selected on the basis of the Phase-I geological survey and geochemical sample assay are from north to south: Turaquiri district, Chulcani district and Calorno district. The Sonia - Susana district could be promising, depending on the drilling results in the existing data.

Exploration Guidelines for Phase II

For Phase II, it is recommended to conduct secondary geological and geochemical surveys in the districts investigated in Phase I, in order to obtain more detailed information.

As regards the districts not investigated in Phase I, where the presence of alteration zones is inferred, such as the districts of Blanca Nieves, Cerro Picacho and Cerro Panizo, and also other areas where medium to minor-scale alteration zones exist, it is desirable to conduct geological and geochemical surveys at a preliminary level.

Selection of promising areas where alteration zones are too small to be fully ascertained by satellite interpretation should desirably be made by a geochemical survey of stream sediments.

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PART I GENERAL REMARKS

Chapter 1 Introduction

1.1 Background and Purpose of Survey

To comply with the request of the Government of Bolivia, the subject mineral resources survey in the Oruro-Uyuni region of the Republic of Bolivia is undertaken by the Government of Japan, in conformity to the Scope of Work agreed to between the two governments on 10 December 1999.

The survey is intended to clarify the geologic conditions and occurrence of ore deposits in the Oruro-Uyuni region, thereby discovering new deposits. It is also aimed to transfer the relevant technology to the host nation's organizations concerned throughout the survey period.

1-2 Outline of Phase I Survey

1-2-1 Survey Area

The Oruro-Uyuni region is situated approximately between 150 km and 560 km south of La Paz, the capital city. (Fig. I-1) The western half of the region is constituted by mountainous zones, alt. 4,000 m to 5,000 m, whereas the eastern half consists mainly of moderately inclined plateaus and saline lakes of altitudes up to 4,000 m above sea level.

1-2-2 Purpose of Survey

The Phase-I survey comprises satellite image analysis, collection and study of existing mineral resources data, both covering the whole survey area of 43,000 km^2, as well as geological and geochemical surveys covering an area of 2,000 km^2 delimited within the survey area. Purposes of the respective surveys are summarized as follows:

1) Collection, sorting and analysis of existing data, for outlining the ore deposits, ore showings and occurrences in the survey area, which serves to extract promising zones and acquire knowledge necessary for overall analysis of findings of the satellite image analysis, and geological and geochemical surveys.

2) Photogeologic interpretation of satellite images covering the whole survey area, aimed to clarify the regional geologic structure and lithofacies, and also interpretation from a spectral analysis image of alteration zones accompanying mineralization, which serves to extract promising zones.

3) Geological and geochemical surveys, aimed to clarify the relationship of geology and geologic structure with mineralization in the area; and, extraction of promising zones, for which characteristics of alteration zones and distribution of geochemical anomalies are considered.

1-2-3 Method of survey

1) Analysis of existing data

The existing data concerning geology and ore deposits were collected at the Servicio Nacional de Geología y Minería - SERGEOMIN

2) Satellite image analysis

From the LANDSAT TM data, a false color image on a 1:250 000 scale was prepared, for which an optimum combination of the bands for the geologic interpretation of the subject area was selected. From the image, geologic units and geologic structure were interpreted. Based on the interpretation, a geologic unit map and a lineament analysis map, both on a scale of 1:250 000, were drawn. Besides, spectral analysis by the ratioing process was conducted to prepare a 1:250 000-scale image most appropriate for the extraction of alteration zones. A map showing the alteration zones extracted from the spectral analysis image was prepared at a scale of 1:250 000. Results of the interpretation were converted to digital data compatible with the ARC-View. The data processing and analysis work were implemented in Japan.

3) Geological and geochemical surveys

Geological and geochemical surveys were conducted in the survey areas which were selected from the promising zones extracted by the satellite image interpretation and analysis of existing data. The selected districts are the Turaquiri - Asu Asuni – Chulcani, Sonia - Susana, Calorno and Loma Llena, which altogether covers an area of 2,000 km^2 and has a total route extension of 350 km.

A mobile camp was set up at villages of the respective districts.

Route maps for the geological and geochemical surveys were prepared by enlarging a 1:50 000-scale topographic map. The GPS was utilized for positioning. Outcrops of special importance were sketched on 1:100 to 1:200 scales and photographed in color. The survey findings were incorporated into a 1:100 000-scale geologic map.

Simultaneously with the geological survey, sampling of various types at the quantities indicated in Table I-1-1 was conducted and laboratory tests were carried out.

Table I -1-1 List of Laboratory Test

CONTENT	Items and amount of Laboratory tests	
Geological & Geochemical surveys	①Chemical Analysis (rock)	800
	②Chemical Analysis (ore)	30
	③Thin Section	50
	④Polished Section	30
	⑤X-ray analysis	50
	⑥Measurement of F.I(Temp.& Salinity)	10
	⑦Dating (K-Ar method)	10

Elements of chemical analysis : 11 (Au,Ag,Cu,Pb,Zn,As,Sb,Hg,Mo,Ba,Sn)

1-2-4 Survey Team

The names of the members of the Japanese survey team and their counterparts in Bolivia are as follows:

Japan		Bolivia Republic	
Name	Entity	Name	Entity
TUJIMOTO Takashi (Head)	MMAJ	Rene Renjel Dominquez (Vice Minister)	
UMETSU Kei (Coordinator)	JICA	Marcelo Claure Zapata (Presitent)	SERGEOMIN
HARADA Takeshi (Geologist)	MMAJ	Carlos Riera Kilibarda	SERGEOMIN

Japan		Bolivia Republic	
Name	Entity	Name	Entity
HASHIMOTO Morio (Head/General) (Chief Geologist)	MINDECO	Fernando Murillo Salazar (Coordinator) (Chief Geologist)	SERGEOMIN
NAKAMURA Kiyoshi (Geologist) (Coordinator)	〃	Ivar Alcocer Rodrigez (Geologist)	〃
KITA Barry (Geologist)	〃	Oscar Almendras Alarcon (Geologist)	〃
KATSUNO Yutaka (Geologist)	〃	Manuel Menacho Leon (Geologist)	〃
INOUE Toshio (Geologist)	〃	Guido Quezada Cortez (Geologist)	〃
ISOGAI Kouichi (Geologist)	〃	Yerco Santa Cruz Salvatierra (Geologist)	〃
ADACHI Kazuhiro (Geologist)	〃		

* Mitsui Mineral Development Engineering Co., Ltd.

1-2-5 Period of Survey

Period of the survey is shown in Table I-2

Table I-1-2 Period of the Survey

	2000			
	JAN	FEB	MAR	APR
Preparation	17 — 31			
Field surv.		1 —	— 7	
Lab. work		15 —	— 15	
Reporting			8 — 24	

Chapter 2 Geographic setting of Survey Area

2-1 Location and Access

The study area covers three of the Bolivian departments; the most southern part of La Paz (2%), the western part of Oruro(34%) and the northwest part of Potosí (64%) departments. (The figures in brackets mean the percentage of the total study area in each department.)

The area corresponds to the Bolivian Andes, embracing the Cordillera Occidental and part of the Altiplano.

There are two ways of access to the area from La Paz; by car or train, or combining both of them, however the trip by car is the most convenient. Regarding the points to get into the field area, there are the following alternatives: (fig I-1)

To the northern point (1 day trip/one way)

La Paz → (101km) Patacamaya → (205km) Cosapa → (90km) Bella Vista

To the central and southern points (2 days trip/one way)

La paz → (228km) Oruro → (319km) Uyuni → (120km) San Juan → (50km) San Pedro de Quemez

The train actually runs only from Oruro city to Uyuni where it splits: one branch to Villazón (Argentina), and the other to Ollague (Chile). However to use this way is very restrictive due to the small number of trains running, and the combination with car transportation at Uyuni or another intermediate points is very difficult.

The road between La Paz - Oruro down to Challapata is the only paved part, after that all the roads are unpaved, is why during rain season is hard to drive.

During the dry season it is possible to drive onto the Salar de Uyuni, which is very flat and easy to cross from north to south or east to west.

2-2 Topography and Drainage System

The geographic and physiographic setting of the Andes is formed by Holocene volcanic centers, and the widest part of the orogenic belt and its greatest average elevations are found in the

Central Andes, in the region of the Bolivian orocline, the mountain chain of the Andes form, the spine of South America, linking countries creating a common geology, ecology and economic heritage bred of this link.

The study area is located on the two physiographic provinces, in the westernmost part of Bolivia, which are: first, the Altiplano or a flat plain at an elevation of about 3,700 m above the sea level, with longitudinal and transversal elevations covering an area of about 100,000 km^2. The most prominent geographic feature of an extensive Puna - Altiplano plateau, which is after the Tibetan plateau, the world highest and large plateau (700 x 200 km), covered by an extensive array of Neogene volcanic centers.

The second is a volcanos chain, defining the natural border with Perú and Chile with altitudes of higher than 6,000 m.a.s.l. (Sajama, 6,542 m; Parinacota, 6,132 m; Payachatas, 5,982 m; Tunupa, 5,000 m.), developed along 620 km from north (Perú) to south (Argentina) running in the NW - SE direction.

The drainage of the area belongs to the central basins or lacustrine, which covers almost all the Altiplano and is formed by: Lago Titicaca, Lago Poopó, Salar de Coipasa, Salar de Uyuni and Río Desaguadero.

Lago Poopó is located in the Oruro department (Prov. Poopó, Sancari and Abaroa) at 3,868 m. Its main rivers are: Pazña, Challapata, Conde, Sevaruyo, and Kimpara.

The Lakajahuira River is the only drainage between Poopó and Salar de Coipasa, Ríos Lauca and Sabaya run into Salar de Coipasa.

The main rivers to drain into the Salar de Uyuni are Río Grande or Quetena in the south and Río Chica Chica in the east. Among them, almost all the rivers are very small and intermittent, having water only during rain season (December - March) making it difficult for transportation because of a lack of bridges.

2-3 Climate and Vegetation

Bolivia is in the south latitude (10° - 23°) so the climate should be tropical to subtropical however due to the altitude in the study area over 3,600 m is dry and cold. During nighttime, temperature is below zero almost all throughout year.

Rainy season corresponds to summer (December to March) and the annual precipitation is about 400 mm (Table 1).

In some parts of the area due to the intensive cold, rain is converted to snow or ice. The maximum temperature of this season is about 22°C, and the minimum temperature is -5°C approximately.

The dry season belongs to wintertime, and the maximum temperature rises 18°C and the minimum is -22°C, even the temperature makes it the best time for fieldwork. In winter, winds are very strong from the west and temperature difference between day and night are 30°C making very cold during night and the humidity varies between 0 and 22% (Table I-2)

Table Ⅰ-2 Temperature and Humidity in Oruro City

	Ene.	Feb.	Mar.	Abr.	May.	Jun.	Jul.	Ago.	Sep.	Oct.	Nov.	Dic.	Anual
Temp.Ambiente °C	11.5	11.0	10.5	9.2	5.8	3.4	2.7	4.9	7.2	9.4	10.9	11.7	8.2
Temp. Maxima Media	18.3	18.5	17.8	17.9	16.3	14.3	14.1	16.5	17.6	18.7	19.6	19.5	17.40
Temp. Minima Media	4.7	3.5	3.2	0.5	-4.7	-7.4	-8.7	-6.6	-3.2	0.2	2.3	3.9	-1.0
Precipitation mm.	87.1	48.8	64.3	25.4	8.2	3.7	5.8	5.6	22.7	26.5	27	39.5	364.6
Humedad Relativa	61	53	59	54	52	44	43	41	42	41	43	45	48
Direction y vel. Nudos	E-7	E-6	E-6	S-5	S-3	S-2	NW-4	S-4	S-5	S-6	S-7	E-5	S-5

Station : Oruro, Province : Ilocodo, Departament : Oruro

Period : 1995－1999 Latitud Sur : 17°58' , Longitud Oeste : 67°04' , Altitud : 3,702 m

To describe the vegetation of the area, it is necessary to divide the Altiplano in two sectors:
-Altiplano Central. - (18° - 20° 30' Lat. S) is distinguished by its cold and dry climate, as a result a large sand covers the pampas in which grows intermittently, thola (lepidophyllum quadrangulare), yareta (azorella sp) and paja brava (stipa ichu). Among this in some places cultivate quinua, potato, barley and other typical tubers.

Around the slopes of the volcanic cones grow small trees and bushes: Keñua, Kiswara and Thola.

-Altiplano Sur.- (20°30"- 22°51"Lat. S) is a dessert and sandy zone, where lives parihuanas or flamencos (phoenicopterus chilensis). Around the western edge of Salar de Uyuni (Llica - Salinas de Garci Mendoza) are developed big areas of quinua crops.

Chapter 3 Existing Geological Information of Survey Area

3-1 Outline of Previous Surveys

Up to now, the Cordillera Occidental has not many regional geology studies, because even though Bolivia is a mining country, there was more emphasis on the eastern Andes (Cordillera Oriental) for its high tin content and other polymetallic ore deposits.

The most detailed study was carried out during the period of 1990-1992 by the Geological Surveys of U.S.A. and Bolivia (U.S. Geological Survey Bulletin, No. 1975).

They focused the study on the two physiografic provinces in the westernmost part of Bolivia, the Altiplano and the Cordillera Occidental, attached to the Perú and Chile border. The result of the cooperative venture between the U.S. Geological Survey (USGS) the U.S. Bureau of Mines (USBM) and the Servicio Geológico de Bolivia (GEOBOL) started as a preliminary search of the existing published and unpublished literature, and was followed by field parties that visited selected sites.

The final report of the mentioned survey has been condensed and published in the Bulletin No.1975 [Geology and Mineral Resources of Altiplano and Cordillera Occidental, Bolivia]. According to the report, extraction of alteration zones by satellite image interpretation and geological survey was executed. The findings of the past gravity survey and airborne magnetic survey for the purpose of oil exploration are summarized in the report.

The gravity survey and airborne magnetic survey were undertaken by the YPBF - Yacimientos Petrolíferos Fiscales Bolivianos, with a view to inferring boundaries of rock facies by the difference in density and magnetism, and also to estimate the depths of basement rocks mainly underlain by thick sedimentary rocks of the Altiplano.

In 1997 geological projects started on the border regions between Argentina, Bolivia, Chile and Perú, the so called Multinational Andean Program, for five years which major focus was the regional mapping on the border areas and interpretation of geoscience data. The purposes of the programs are scientific guidance and technical support to obtain from which and between the participating countries.

3-2 General Geology of the Surrounding Areas

Bolivia is roughly divided into five geotectonic provinces which, from west to east, are called the Cordillera Occidental, the Altiplano, the Cordillera Oriental, the Sub-Andes - Beni-Chaco Plain, and the Brazilian Shield.

The survey area pertains to the Cordillera Occidental and the Altiplano. (Figs. I-3-1 and I-3-2)

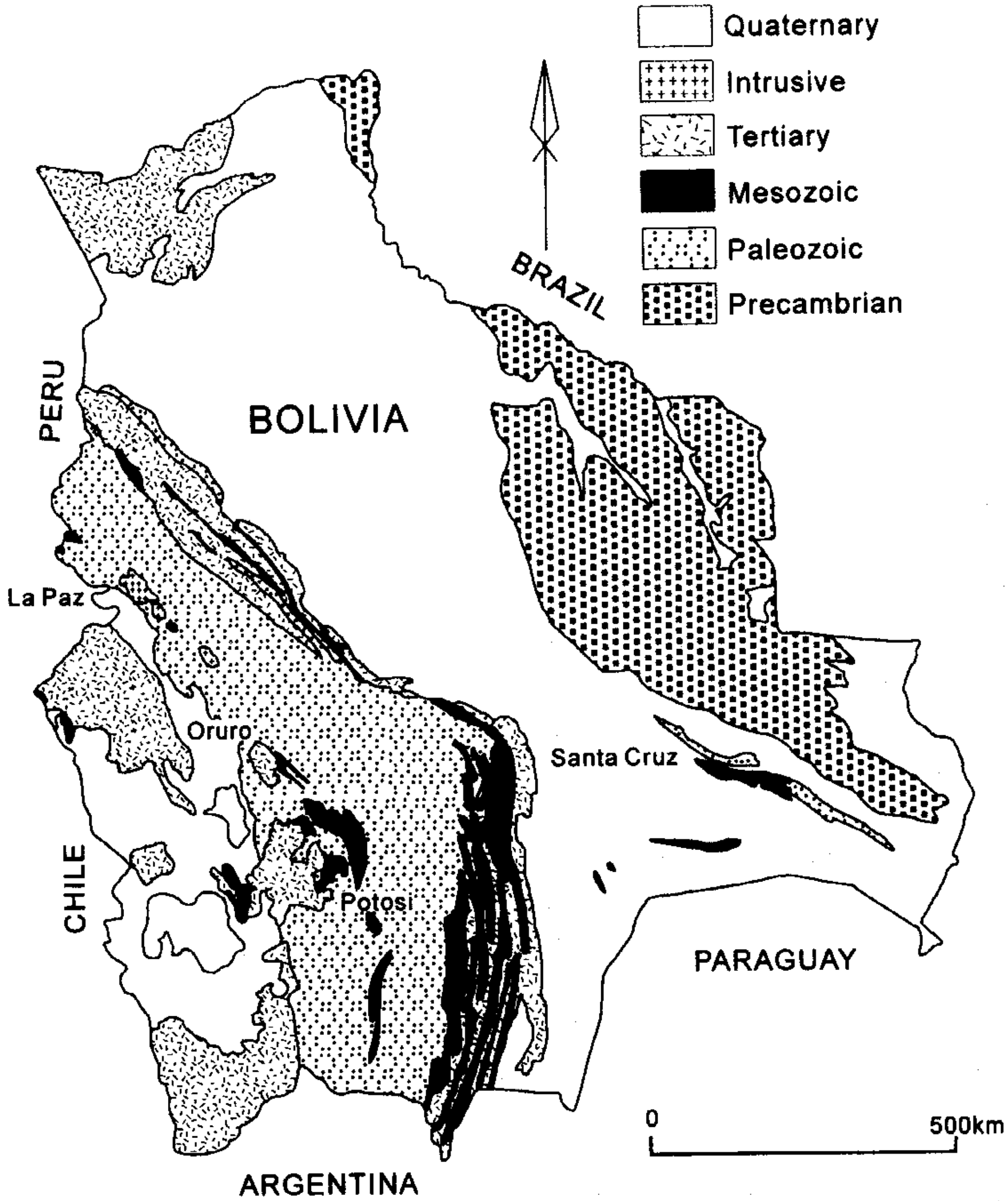


Fig. I -3-1 Geological Map of Bolivia

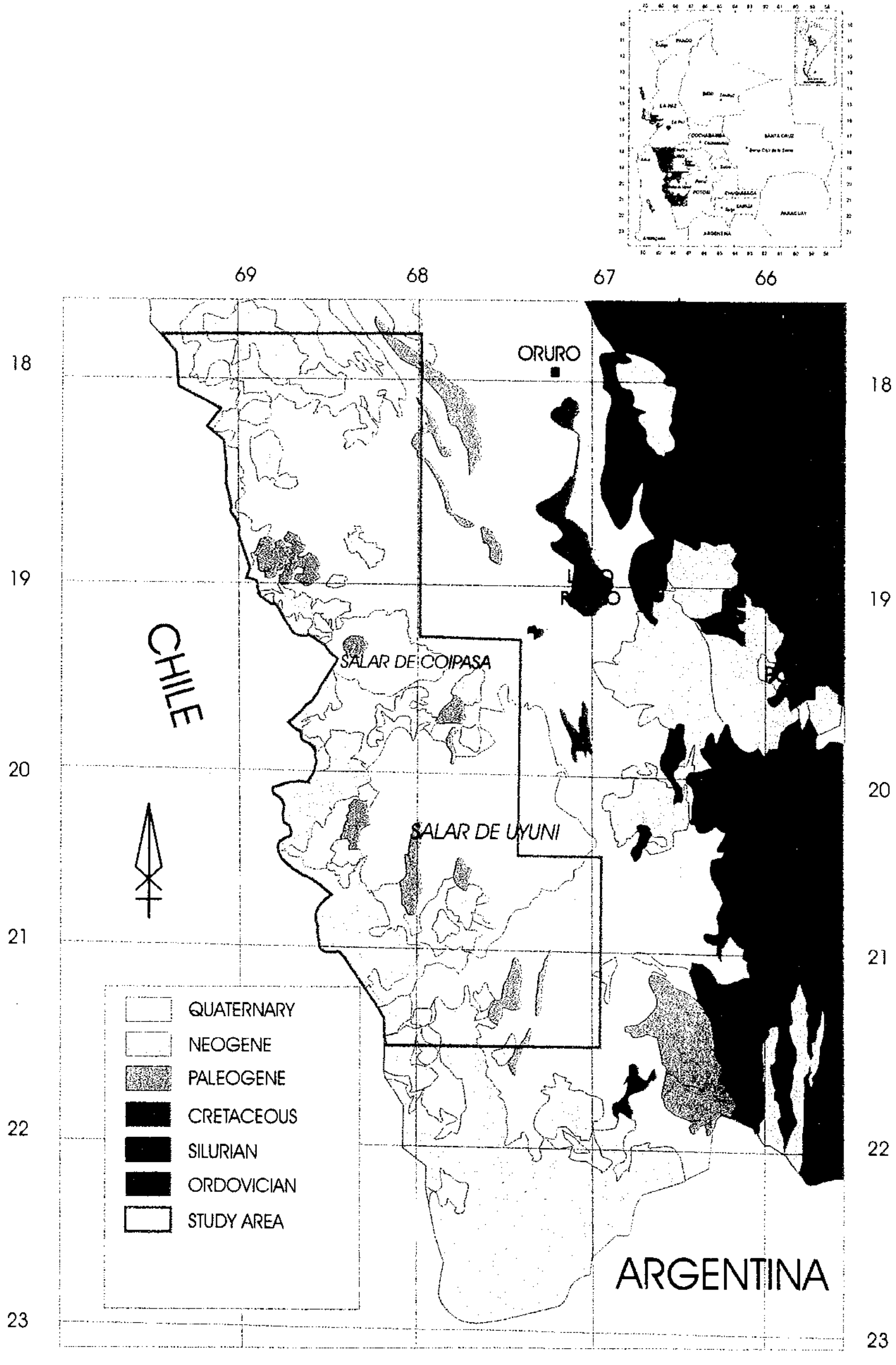


Fig. I -3-2 Schematic Geologic Map of the Area

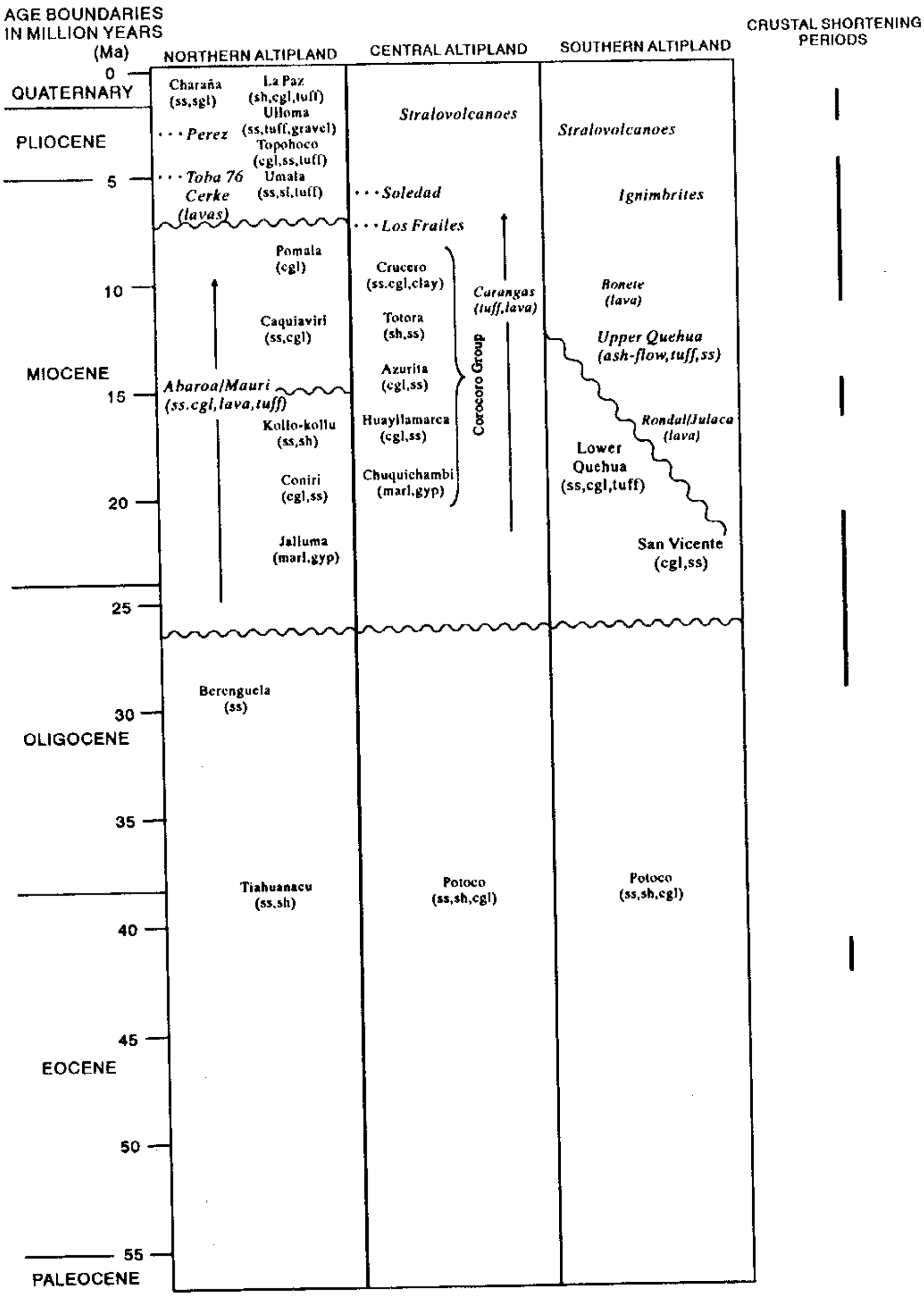


Fig I-3-3 Schematic Geologic Column of the Survey Area

Cordillera Occidental

The Cordillera Occidental is extensively covered by Tertiary to Recent volcanic rocks that effused along the N-S uplifting axis of the Mesozoic to Paleozoic basement rocks, where continental to netric sediments lie between the volcanic bodies.

The volcanic rocks that constitute mountains are chiefly late Miocene to Pliocene andesite and rhyolite lava, while Quaternary dacite is also present in the vicinity of the mountain tops.

The large-scale and widespread volcanic activity, characteristic of the Cordillera Occidental, was brought about by the subduction of the Nazca Plate under the South American Continental Plate. Accompanying the volcanic activity, numerous stratovolcanoes were formed.

Altiplano

The Altiplano has the Proterozoic to Paleozoic basement extensively covered by formations of vast volcanic product and continental sediments of the Cretaceous to the Recent age.

The continental sediments are composed of late Cretaceous continental molasse sediments (red bed) and Eocene to Oligocene foreland basin sediments (sandstone, and alternated beds of sandstone and mudstone).

Igneous activity took place in the Miocene to Pliocene time. Andesitic effusive activity continued during the Miocene time in the southern part whilst, in the northern part, effusive activity of rhyolitic pyroclastic rocks continued from the Miocene to Pliocene time, which caused a huge amount of continental volcanic product to be deposited.

A schematic geologic column of the survey area is exhibited in Fig. I-3-3.

Cordillera Oriental

The Cordillera Oriental is underlain by abyssal to terrigenous sediments of the Paleozoic age and marine to continental shelf carbonate rocks of the Mesozoic age.

These are composed of thick sedimentary rocks of the Paleozoic to Mesozoic age (miogeosyncline sediments) deposited on the Precambrian basement, where thrust faults with N-S axes and complicated fold structures were formed by the Caledonian (Ordovician), Hercynian (Devonian to Triassic) and Andean (Cretaceous to Cenozoic) orogenic movements.

Simultaneously with the close of the Hercynian movement (Permian to Triassic), the subject region became a tension field where peralkaline volcanic activity and intrusion of granitic plutonic rocks occurred.

Afterwards, the plate subduction began, causing calc-alkaline volcanic activity which lasted from the Jurassic to the Cenozoic time.

At the time of the Andean orogenic movement (Tertiary), the Cordillera Oriental was uplifted by the E-W compressive stress, causing to form the fold zones and thrust fault zones. At the western side of the Cordillera, the andesitic volcanic activity, the ensuing intrusion of hypabyssal rocks and overthrust towards the Altiplano side took place.

Sub-Andes - Beni-Chaco Plain

The region consists of the fold mountains adjoining the eastern side of the Cordillera Oriental and the vast plain zones -- the Beni-Chaco Plain -- to the east.

The fold mountains are composed of Paleozoic and Neogene rocks. In the eastern plain zones, these formations are extensively underlain by Quaternary lake sediments and talus sediments.

Brazilian Shield

An extension of the Brazilian Shield stretches toward the eastern Bolivia to form a tropical rain forest zone covering an area of 22,000 km^2.

The region is underlain by Proterozoic to Cretaceous rocks, mostly Proterozoic altered rocks such as gneiss, biotite schist and quartz schist.

These altered rocks underwent laterization in the Tertiary or later time, covered by Quaternary alluvium.

3-3 Characteristics of Mineralization in Survey Area

Ore deposits of metallic minerals concentrate in the area that embraces the Cordillera Occidental, Altiplano and Cordillera Oriental, where copper mineralization accompanying alkali basalt, sedimentary copper mineralization accompanying late Tertiary red sandstone beds, so-called 'Bolivian-type' polymetallic mineralization mainly of tin and silver, and epithermal mineralization mainly of gold and silver are known to be present.

In the Cordillera Occidental, small-scale epithermal gold-silver veins embedded in Miocene dacitic volcanic rocks are known to exist, a part of which is accompanied by sulfide minerals such as copper, lead, zinc and bismuth.

Also present in the area are hydrothermal alteration zones, mainly argillized and widespread in dacitic volcanic rocks. Silicification and pyrite dissemination are observed partly in the alteration zones. Under these hydrothermal alteration zones, occurrence of porphyry-type gold-copper deposits is expected.

From the Cordillera Oriental to the Altiplano, the Bolivian-type polymetallic vein deposits are found, while copper deposits accompanied by alkali basalt and red sandstone are present from the north to the south of the central Altiplano.

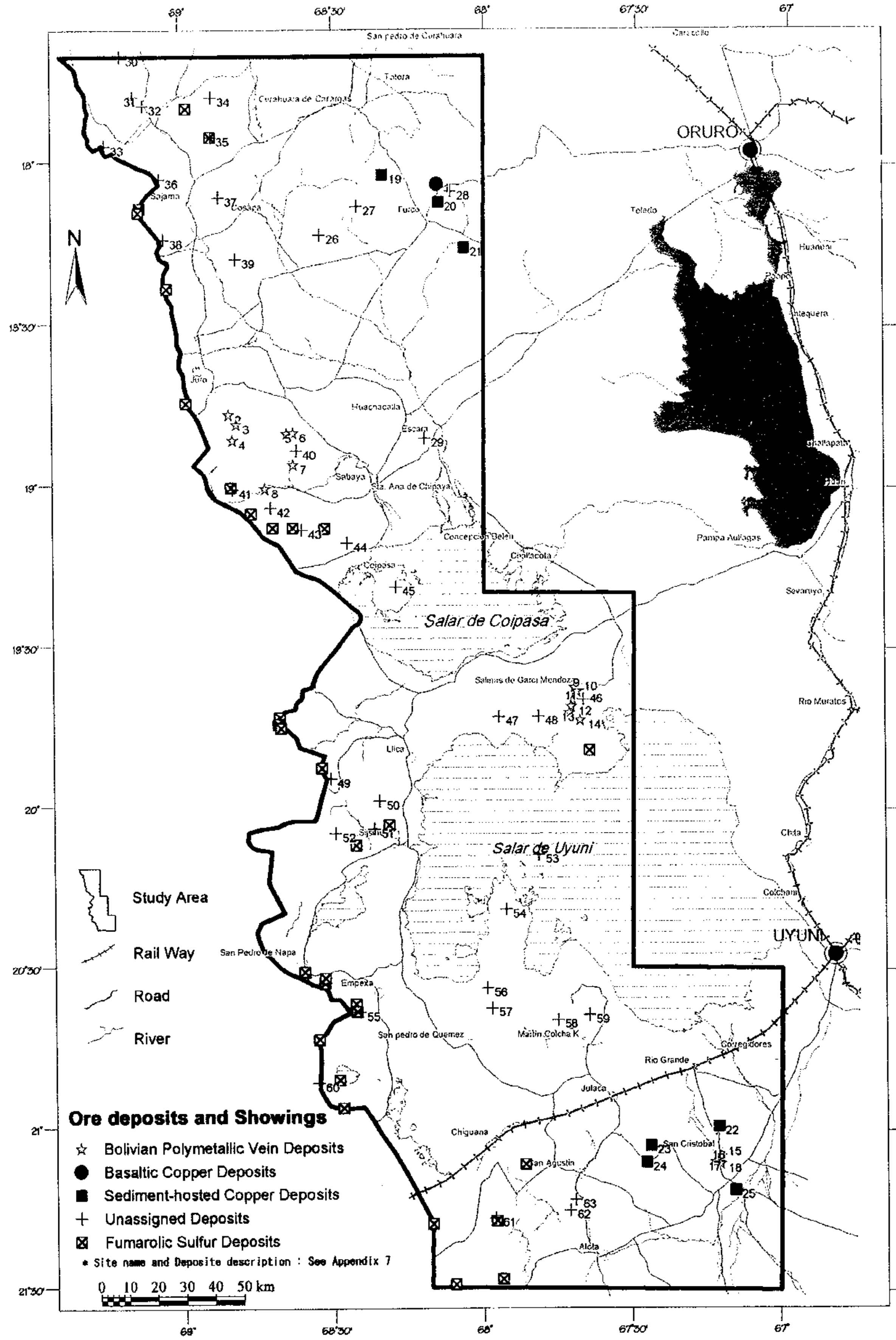


Fig. I-3-4 Ore deposits and showings in the area

The Bolivian-type polymetallic vein deposits, underlain by the upper Tertiary to Quaternary, have not yet been fully elucidated, but many of them are lead-zinc deposits with relatively low tin-tungsten contents and high copper content. A variety of Bolivian-type polymetallic vein deposits are known; they are roughly divided into those rich in silver and tin and those rich in silver, gold and copper.

Ore deposits rich in silver and tin are often seen in the Cordillera Oriental. These have mineralogically complex combinations of silver, tin, lead, zinc, tungsten, bismuth, gold, etc.

Typical of such ore deposits are found at such mines as Cerro Rico de Potos*, Pulacayo and Huanuni, which are classified into two types: one rich in silver sulfate minerals and the other in which the lower tin zones become exposed as a result of denudation of the upper silver zones.

Ore deposits rich in silver, gold and copper are seen in the Altiplano, the most typical of which is the Kori Kollo mine currently under operation. The deposit has silver, gold and some copper, apparently resembling auri-argentiferous iron sulfide deposits, but it is classified into the polymetallic deposit as it contains lead, zinc, antimony, tin, etc.

The mines and ore showings existent in the survey area are shown in Fig. I-3-4 and Appendix 7.

3-4 Brief Mining History of Survey Area

Considering that the mining industry in Bolivia was developed mainly in the Cordillera Oriental, at the so called "Tin Belt" only a few mines were operated in the Cordillera Occidental, the mines were principally of native sulphur and non metallic elements (boron, calcium, sodium).

At the Turaquiri silver-lead mine which was exploited during the colonial times, there still remain stone-built old stopes and ruins of ore processing yards.

The Carangas mine and the Negrillos mine have silver-lead deposits exploited during the colonial and post-colonial periods till the 1950's. Some 1.5 million tons of ore are estimated to have been mined. In the 1980's, exploitation was carried out by COMSUR.

In the Salinas de Garci Mendoza district, there are a number of polymetallic vein-type deposits containing silver and base metals at the Maria Luisa, San Miguel, Margarita, Guadalupe and La Descada mines. These mines are not operating currently. From the remains of the old operation and quantity of waste left there, the old operation was presumably not so large in scale. The COMIBOL operated these mines until some 20 years ago. It is estimated that San Miguel and Margarita produced several thousand tons of ore, while several hundred thousand tons were mined from Maria Luisa.

The San Cristbal district has eight polymetallic vein-type deposits, which have been intermittently operated since the discoveries in the early 17th century. The largest Toldos mine is currently worked by open pit combined with underground mining. Silver is recovered by cyanidation heap leaching. At present, Andean Silver Co. plans a large-scale redevelopment of all the ore deposits by open pit.

The Eskapa mine has vein-type copper deposits, which was discovered and exploited in the colonial times. From 1968 to 1971, small-scale operation was undertaken by a nearby mining cooperative.

In the Sonia - Susana district, COMINCO has executed geochemical, electrical and drilling surveys (10 boreholes; total extension 2,000 m). Remains of small-scale exploration sites are left in various locations of the district.

The Kori Kollo mine at the County of La Joya near the survey area is the only gold mine in Bolivia. The mine has massive auriferous deposits whose ore reserves is 65 million tons grading Au 2.3 g/t and Ag 15 g/t. The annual gold production reaches 320,000 oz. The approximate grade of crude ore is 2.4 g/t.

The Laurani mine has an epithermal precious metal deposit of quartz-alunite. In the colonial times, silver and copper were exploited while, later on, gold, silver and some copper were mined. In recent years, exploration has been undertaken by BHP and others. Small ore bodies (2 million tons grading Au 2.5 g/t, Ag 220 g/t and Cu 1.0%) have reportedly been seized.

Chapter 4 Comprehensive analysis

4-1 Relationship of Geology and Geologic Structure with Mineralization

4-1-1 Geology

The survey area is extensively covered by volcanic rocks centering around the Cordillera Occidental, except crystalline schist and gneiss exposed in inliers to the southeast of the Chulcani district and continental sediments of Tertiary or a later age observed in some parts of the Altiplano.

The volcanic rocks generally form stratovolcanoes; alteration -- mainly argillization -- zones are widespread in the volcanic rocks. The known ore deposits are embedded in these alteration zones, presumably formed by the hydrothermal process.

4-1-2 Geologic structure

Excepting the San Cristbal deposit(trending NE-SW) and the Eskapa district(trending N-S), mineralization is observed in fractures with the E-W trend; the trends are E-W at Turaquiri, E-W(N70° W) at Carangas and E-W(N80° E ~ N75° W) at Salinas de Garci Mendoza. The fractures with the E-W trend might have fulfilled an essential function.

4-1-3 Expected types of ore deposits

The following types of ore deposit are expected to be present in the survey area:

[1] Copper deposits accompanying alkali basalt

[2] Bedded copper deposits embedded in Paleogene red sedimentary rocks

(The Corocoro-type deposits)

[3] Epithermal deposits

[4] Bolivian-type polymetallic vein deposits

[5] Porphyry-type copper-gold deposits

Of these types, veinlet-type and disseminated copper deposits accompanying late Oligocene alkali basalt and the Corocoro-type deposits are not large enough in scale to be exploration targets.

Bolivian-type polymetallic vein deposits have a general tendency that sulfide mineral veins in the lower part change into barite-quartz or barite-chalcedony veins in the upper part, which is considered attributable to porphyry-type mineralization shifting to epithermal mineralization.

Therefore, the presence of these veins may suggest emplacement of Bolivian-type polymetallic vein deposits in the lower part and of porphyry-type deposits in the deeper part.

Figs. II-1-5 and II-1-6 indicate schematic models of hydrothermal ore deposits including the Bolivian-type polymetallic vein deposits and porphyry copper-gold deposits accompanied by epithermal alteration, respectively.

Propylitization zones are seen outside of somewhat deep parts of the mineralization zones. When these alteration zones coexist with argillization zones, degree of erosion, and presence, intensity and location of mineralization are inferable.

At known ore deposits, dacitic to rhyolitic domes or intrusive rocks are present, which concern mineralization. In some cases, diatremes and breccia pipes (hydrothermal breccia) also concern mineralization.

4-1-4 Turaquiri - Asu Asuni - Chulcani district

1) Turaquiri district (Fig. I-4-1(1))

The Turaquiri ore deposit is interpreted as an epithermal barite - quartz vein-type deposit accompanied by base metals that fill fractures with the E-W trend, formed with development of a caldera or accompanied by precious metal mineralization.

The homogenization temperatures of fluid inclusions in quartz taken from the veins are as low as 168°C to 227°C, whereas the salt concentration is 3.1 to 17.9 wt % which is as high as those of tin-tungsten veins of Bolivian-type deposits.

Reasons for the high salt concentration in contrast to the low homogenization temperature of Turaquiri deposit remain to be further studied.

The alteration is mostly propylitization although some wall rock silicification and argillization is observed.

Since the past exploitation was confined only to vein portions, there is a likelihood that network-like or disseminated ore deposits of low grade, large ore reserves -- like the San Cristbal and Toldos mines -- are left unexploited. Intensive mineralization can be anticipated especially at the peripheral zone where two veins cross each other in depths.

Bolivian-type mineralization is likely to be present in deep barite-quartz veins; besides, presence of parallel veins concordant with the Turaquiri deposit can be anticipated in an area including the ore showings in the south, in view of the presence of alteration zones and fractures.

2) Asu Asuni district (Fig. I-4-1(2))

While fractures trending E-W develop also in the Asu Asuni district, no indication of dominant mineralization has been seized by the geochemical analysis, in spite of the presence of already propylitized andesite. Mineralization might have taken place in deep portions or may be weak.

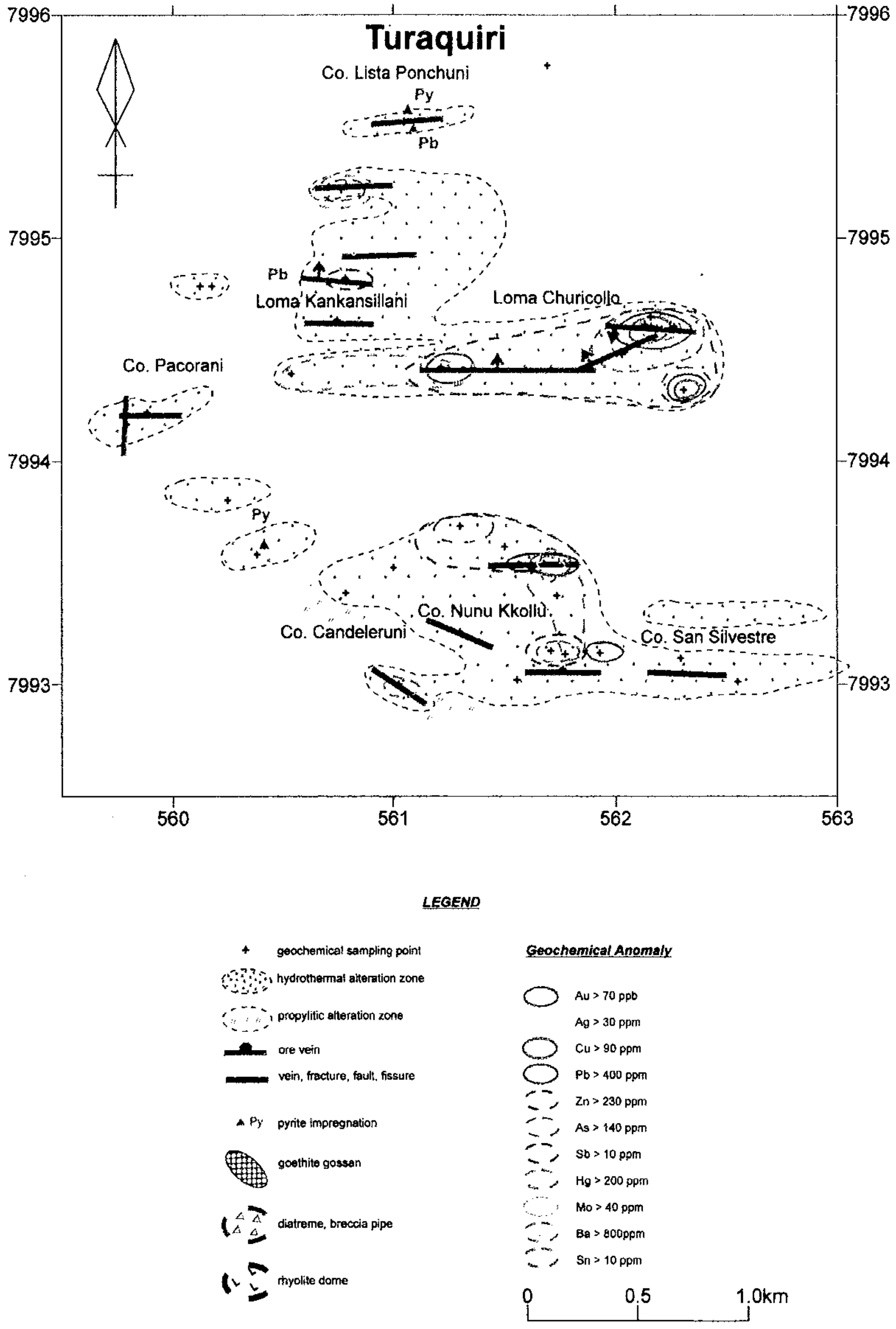


Fig. I -4-1 (1) Integrated Interpretation Map of the Turaquiri District

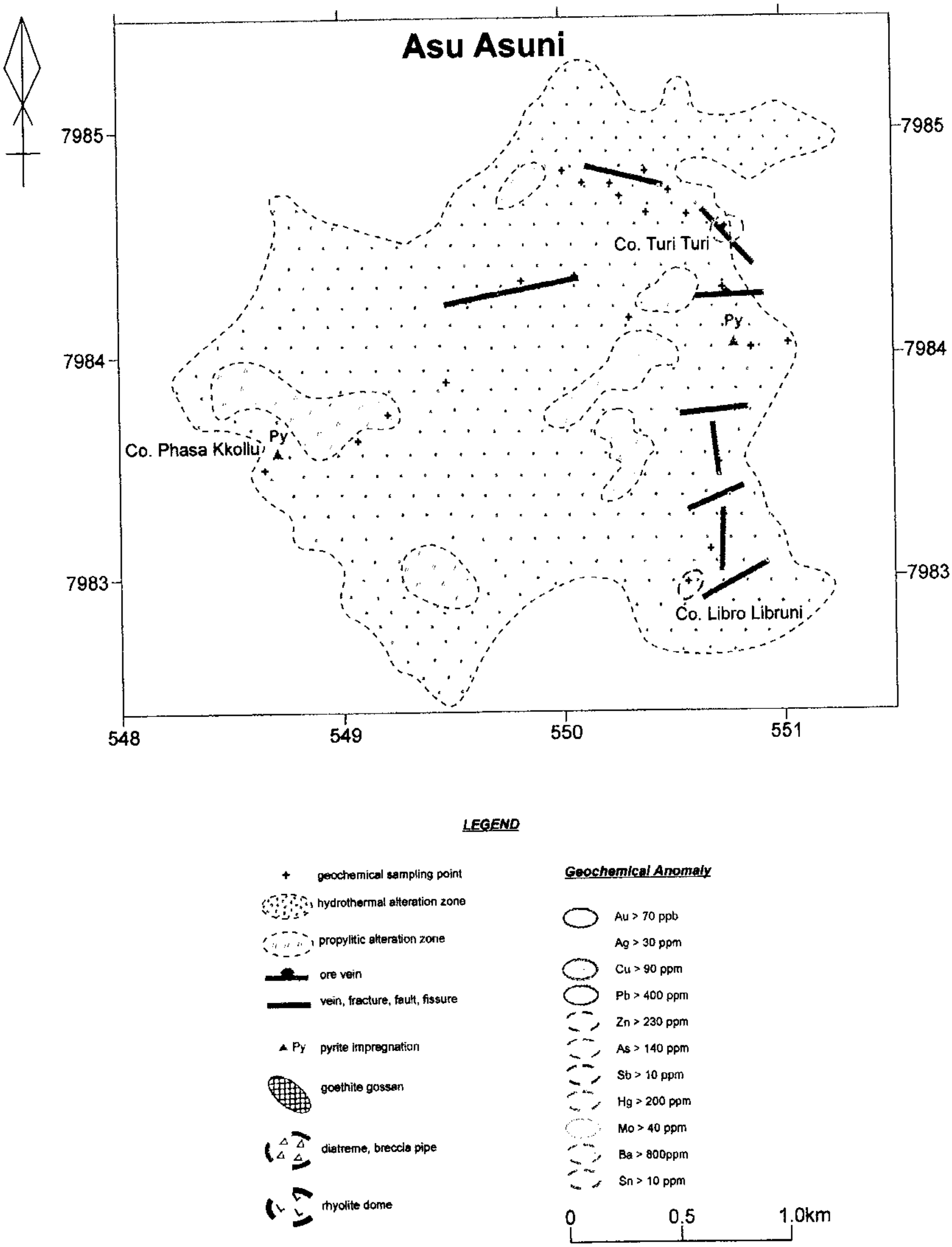


Fig. I -4-1 (2) Integrated Interpretation Map of the Asu Asuni District

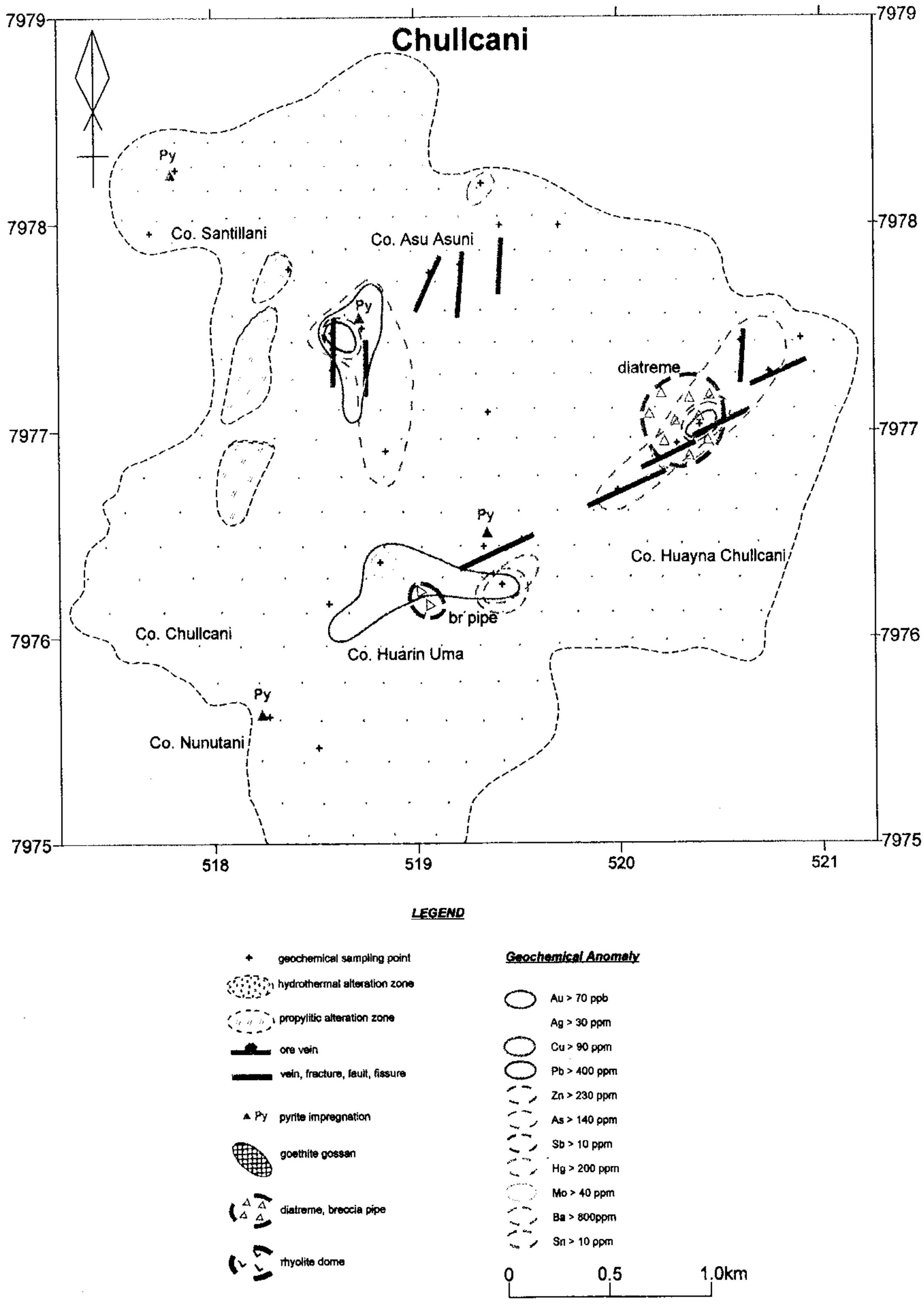


Fig. I -4-1 (3) Integrated Interpretation Map of the Chullcani District

3) Chulcani district (Fig. I-4-1(3))

The geochemical survey in the Chulcani district ascertained two types of mineralization -- accompanied and unaccompanied by gold. At geochemical anomaly portions, lead, mercury and arsenic anomalies overlap weak zinc anomalies. The mineralization unaccompanied by gold is considered to be related to diatremes, where copper, arsenic and mercury anomalies overlap weak lead and zinc anomalies.

In depths of these anomalous zones, occurrence of epithermal precious metal deposits or epithermal polymetallic deposits can be anticipated.

4-1-5 Sonia - Susana district (Fig. I-4-1(4))

At Santa Catalina Loma, anomalies of gold, copper, lead and zinc overlap. Presence of epithermal polymetallic deposits similar to those at the Carangas district are expectable.

The Cerro Entre Campanini is inferred to be a rhyolite dome. Geochemical anomalies of gold, tin, antimony and arsenic overlap in the southeastern part, where Bolivian-type polymetallic deposits related to the rhyolite dome are likely to occur.

At the Cerro Llica Khaua, gold veins accompanied by copper have been seized; although geochemical anomalies were not detected, occurrence of epithermal gold-silver(-copper) deposits in the lower part can be anticipated.

According to the counterpart, a drilling survey (10 boreholes totalling 2,000 m) in the district carried out by a concessionaire ascertained that propylitization is continued at all the boreholes, resulting in finding no marked ore showings but lead-bearing barite veinlets in some parts. The center of mineralization is possibly located at some other part or at a deeper level.

4-1-6 Calorno district (Fig. I-4-1(5))

The hydrothermal alteration zones widespread in the district are considered to be situated at the topmost (outermost) parts of the alteration zones, because non-altered rocks are left on top of many mountains while the presence of propylite is not known.

Although there is no sizable geochemical anomaly, anomalous portions of mercury, barium, arsenic and antimony exist in the alteration zones of the Cerro Huaylla to the Cerro Irun Laque. Pyrophyllite, a somewhat high-temperature, acidic mineral, has been confirmed though only at one spot. It is interpreted that a hydrothermal alteration zone was formed from strong acid solution, which suggests possible occurrence of high-sulfidization epithermal deposits in depths.

Gossans, mainly of geothite, that occur along the Rio Agua Milagro show arsenic and antimony anomalies at the uppermost part of the upper reaches; it is conceivable that thermal water effused from around the uppermost part and flowed down. As the district appears to be a little

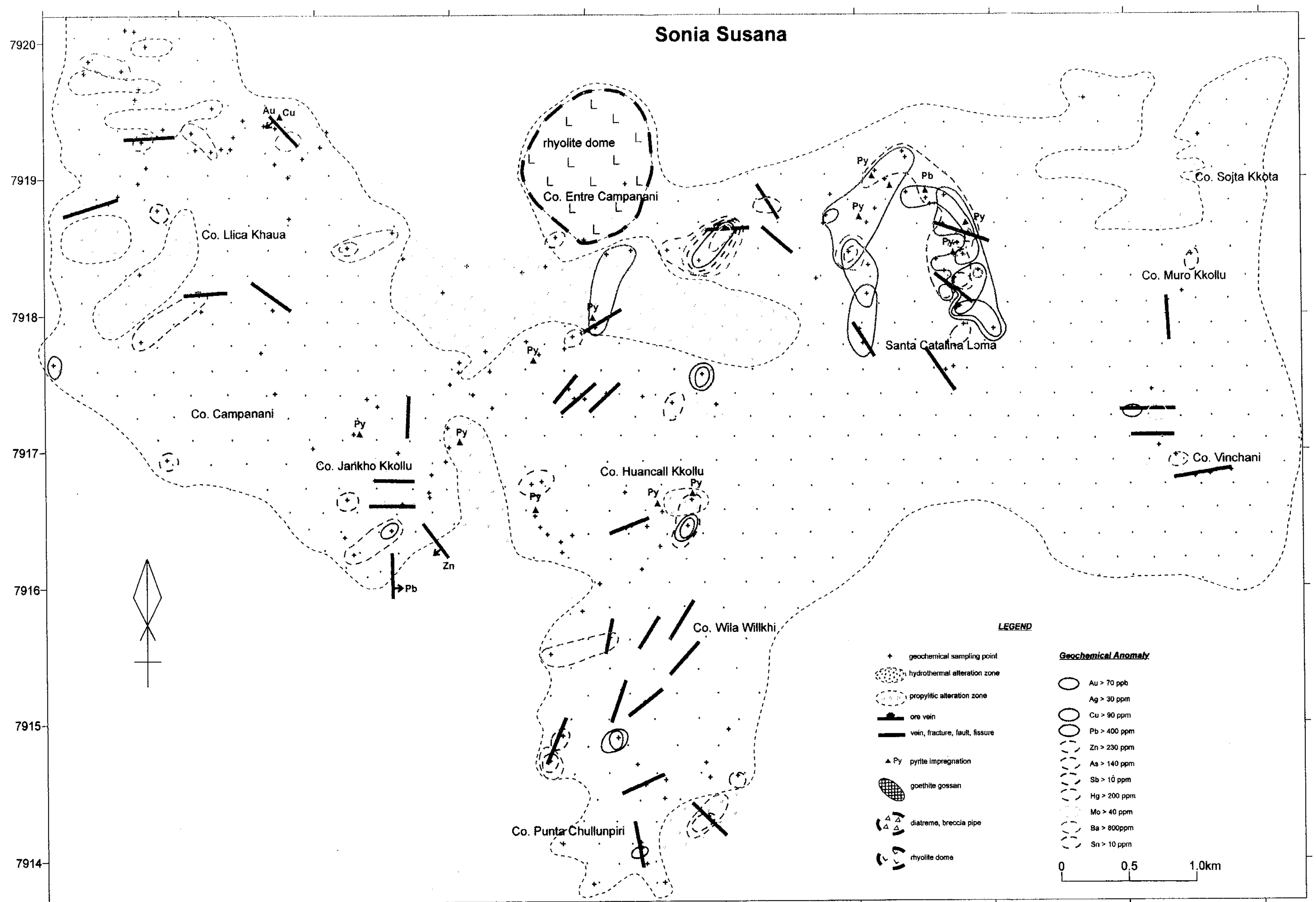


Fig. I -4-1 (4) Integrated Interpretation Map of the Sonia-Susana District

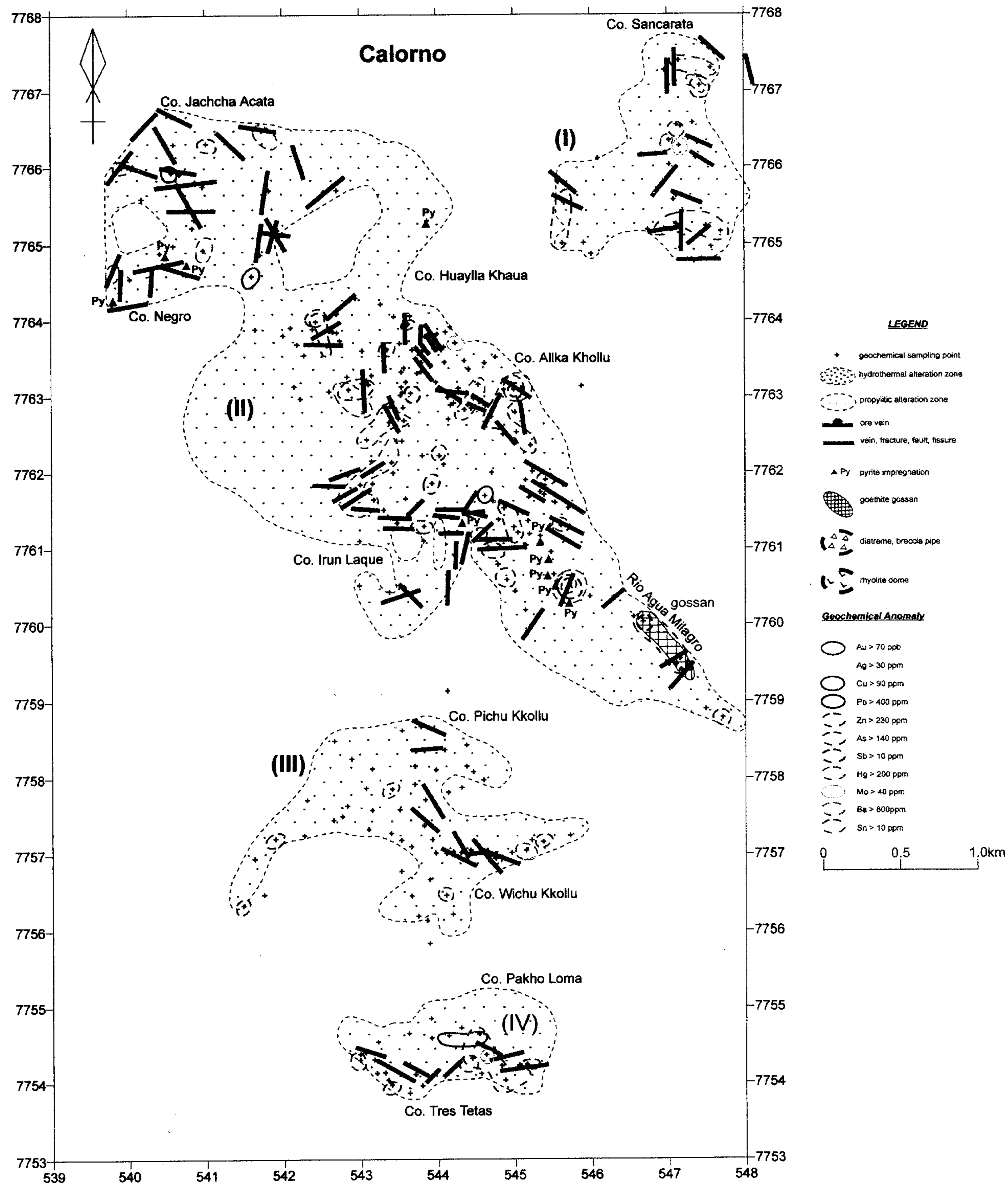


Fig. I -4-1 (5) Integrated Interpretation Map of the Calorno District

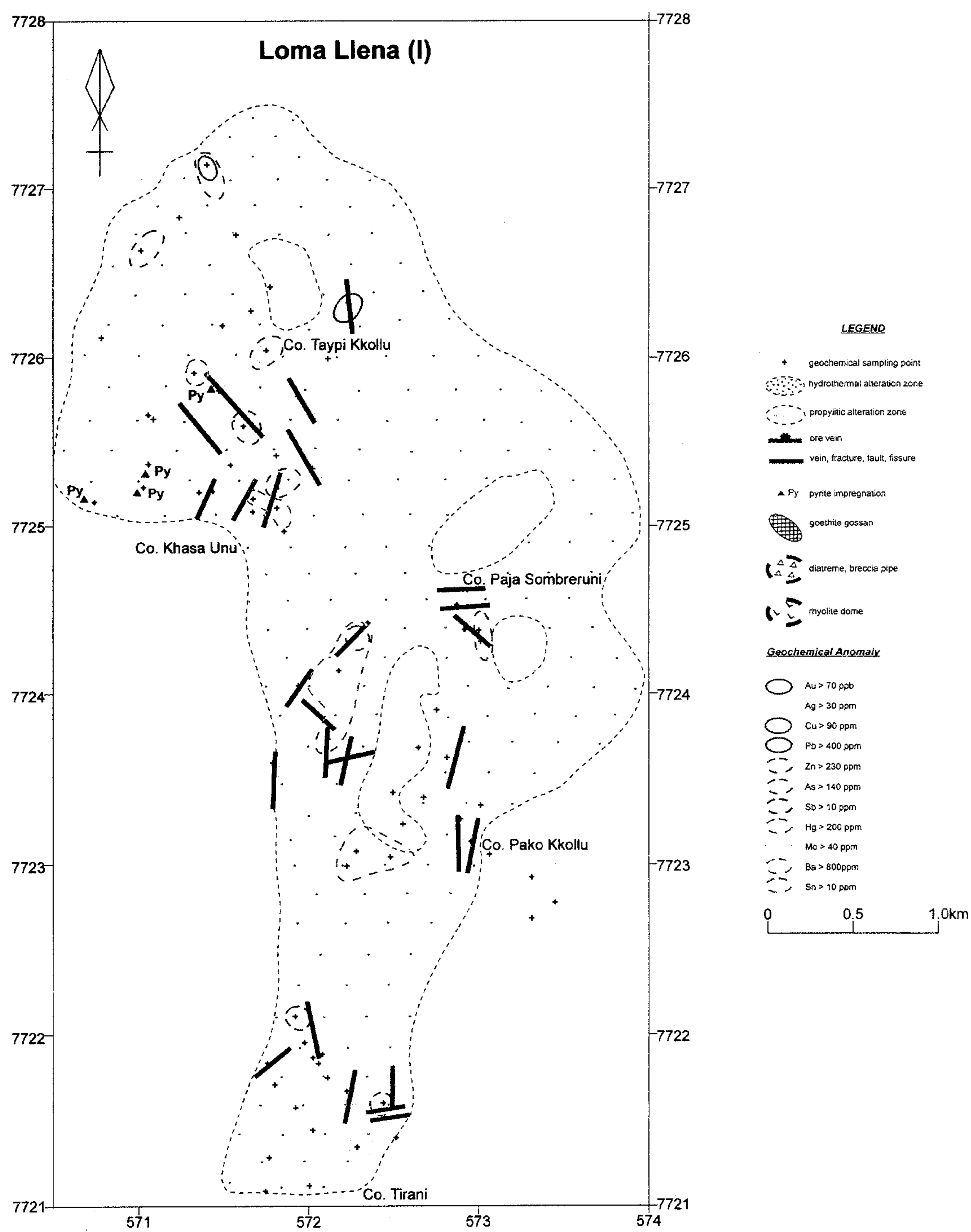


Fig. I -4-1 (6) Integrated Interpretation Map of the Loma Llena District (I)

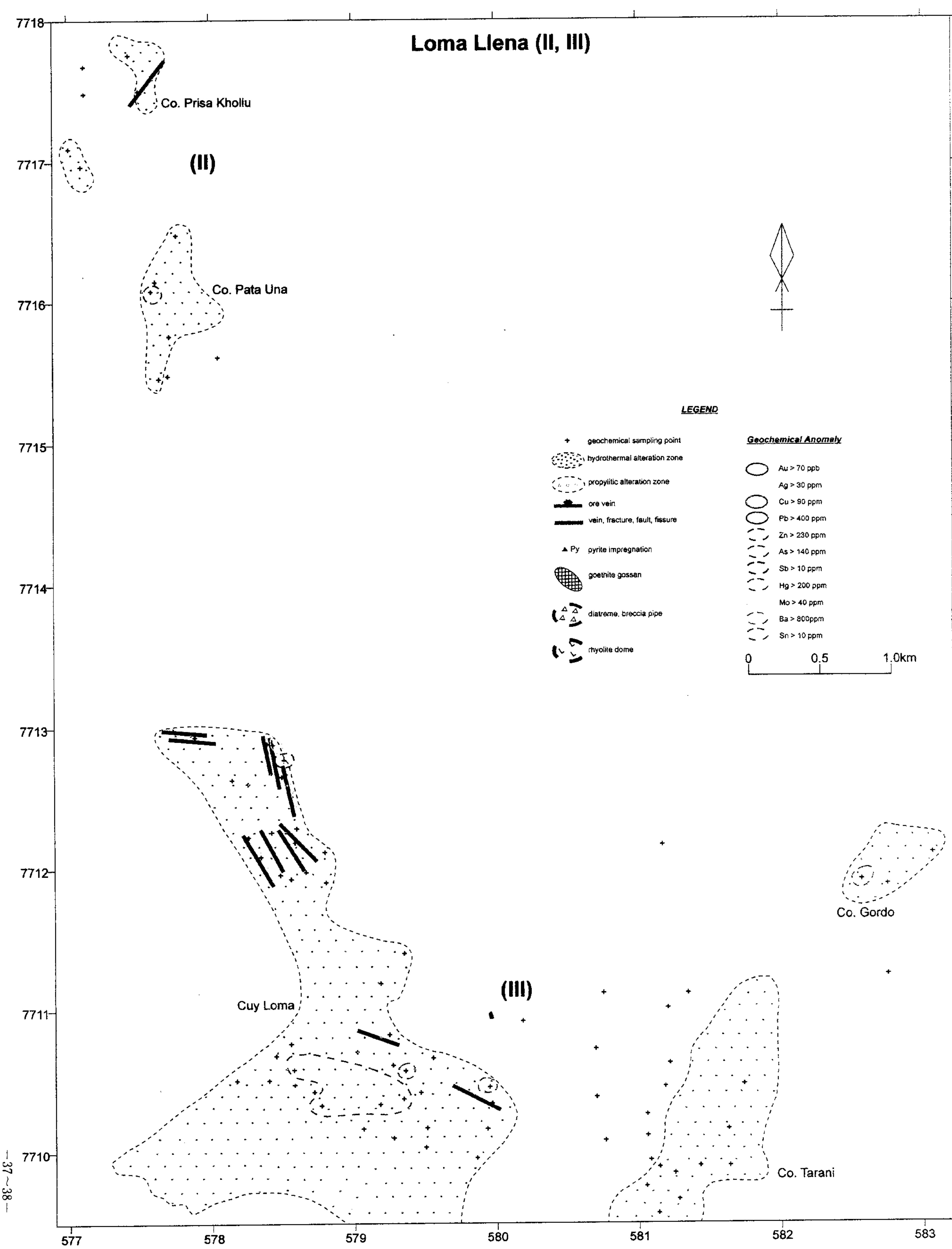


Fig. I -4-1 (7) Integrated Interpretation Map of the Loma Llena District (II)(III)

away from the center of a volcanic body, occurrence of low-sulfidization epithermal ore deposits is possible.

4-1-7 Loma Llena district (Figs. I-4-1(6) and (7))

Since non-altered rocks are left on top of mountains and presence of propylite is unknown, hydrothermal alteration zones in the district are presumably situated at the topmost (outermost) parts of the alteration zones. Geochemical anomaly is not dominant; mineralization, if any, is likely to be weak or to occur in depths.

4-2 Potentialities of Occurrence of Ore Deposits

In the Cordillera Occidental, there are numerous volcanoes, which have fumaroles near their peaks of an altitude of 6,000 m or so, containing sulfur so abundantly that fumarolic sulfur is still being deposited. It is conceived that, in some volcanic bodies, high-sulfidization hydrothermal ore deposits and Bolivian-type polymetallic vein deposits are possibly formed in the central parts. In case of young volcanoes, however, it is highly likely that mineralization is present in such depths that exploration and development are hard to carry out, since ore deposits are still in the process of formation or erosion has not advanced sufficiently. In view of the fact that the epithermal gold deposits at the Hishikari mine in Japan is considered to have been formed about a million years ago, it seems reasonable to exclude volcanoes younger than a million years from the exploration target list.

If there is a volcanic body older than one million years that has extensive hydrothermal zones, geochemical anomalies and dominant fractures preferably trending E-W and andesitic, rhyolitic and especially dacitic domes, the district is considered to have excellent potentialities and highly promising.

Outside of the Phase I survey area, presence of alteration zones was inferred from the satellite image interpretation at the Blanca Nieves, Cerro Picacho and Cerro Panizo districts. (Fig. I-4-2)

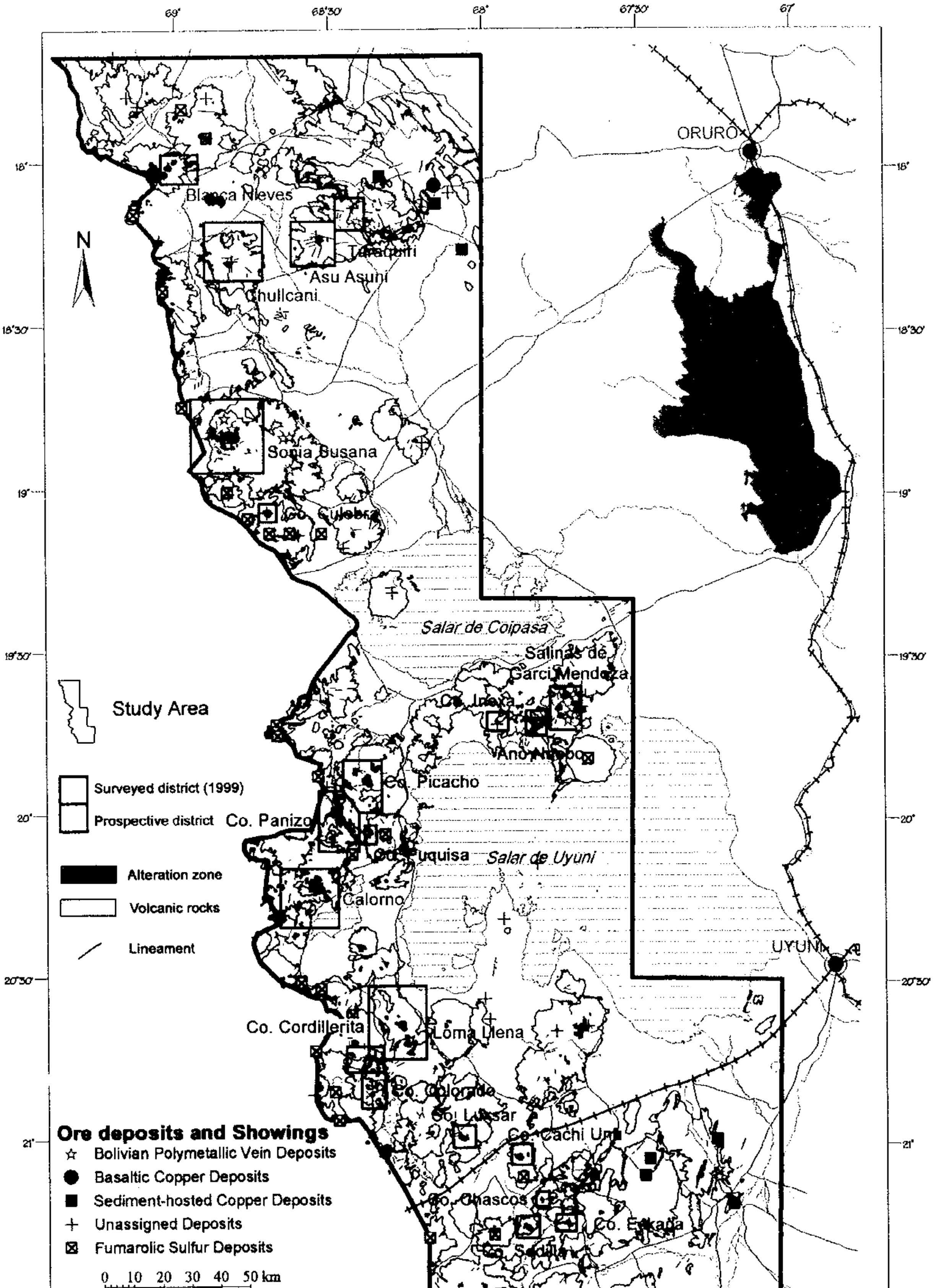


Fig. I-4-2 Integrated Interpretation Map of the area

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

The geological and geochemical surveys were carried out in six districts, which are Turaquiri, Asu Asuni, Chulcani, Sonia - Susana, Calorno and Loma Llena, that were selected as promising districts as the result of the analysis of existing data and satellite image interpretation implemented in Phase I.

The survey findings are summarized as follows:

Turaquiri - Asu Asuni - Chulcani Districts

The Turaquiri deposit is considered to be an epithermal vein-type ore deposit accompanied by base and precious metals, which was formed in relation with the Pliocene resurgent caldera activity. The deposit had been exploited since the Colonial times. The exploitation targeted only the vein portions, consequently, there is the possibility that stockwork or disseminated ore deposits with low-grade, large ore reserves are left unexploited.

The occurrence of ore deposits of the mentioned types is especially likely at the deep portion where the south vein is intersected by the north vein, as bonanzas are apt to be formed in this portion.

From the distribution of alteration zones and fractures, the occurrence of parallel veins concordant with the Turaquiri deposit can be anticipated in the district including the south ore showings.

Despite the fact that the Asu Asuni districts are underlain by already propylitized andesite, no dominant geochemical anomaly was found. Mineralization, if any, is presumed to be weak or occur at depth. The district is considered to be of low priority for exploration.

In the Chulcani district, the geochemical survey found gold anomaly zones at two locations. From the presence of breccia pipes and a diatreme, possible occurrence of epithermal deposits of precious metals or epithermal polymetallic deposits is expected at depth. The district is considered to be of the highest priority.

Sonia – Susana District

Geochemical anomalies of gold, copper, lead and zinc overlap in Santa Catalina Loma; presence of epithermal polymetallic deposits similar to those at the Carangas district to the east is expected.

The Cerro Entre Campanani is considered to be a rhyolite dome, and is further southeast of geochemical anomalies of gold, tin, antimony and arsenic overlap. The occurrence of Bolivian-type polymetallic ore deposits can be anticipated.

In the Cerro Llica Khaua, gold veins accompanied by copper has been ascertained. Although geochemical anomalies are not found in the surrounding areas, epithermal gold-silver-copper ore deposits can be anticipated in the lower part.

However according to the information furnished by the counterpart of the survey, COMINCO-Bolivia has carried out exploration including a drilling survey of 10 boreholes but no marked ore showings were encountered. It will be necessary to obtain relevant information for further study.

Calorno District

The dating of andesite samples taken at two spots in the district indicated the middle to late Miocene time, older than the so far accepted Pliocene to Pleistocene time. Accordingly, the alteration zones widespread in the wall rocks are also inferred to have been formed in the Miocene time.

In view of the fact that non-altered rocks are left on the mountain tops and the presence of propylite is unknown, hydrothermal alteration zones in the district appear to be situated at the topmost (outermost) parts of the alteration zones.

From the Cerro Huaylla to the Cerro Irun Laque, geochemical anomalies are not concentrated but those of mercury, barium, arsenic and antimony are spotted. High-sulfidation epithermal deposits or Bolivian-type polymetallic deposits possibly occur at depths.

Underneath the gossans in the southeast, there is a possibility of the occurrence of low-sulfidation epithermal deposits.

Loma Llena District

Since non-altered rocks are left on the mountain tops and the presence of propylite is unknown, the hydrothermal alteration zones in the district are presumably situated at the topmost (outermost) parts of the alteration zones.

A geochemical anomaly is not dominant; mineralization, if any, is likely to be weak or to occur at depths. Priority of the district is considered to be low.

On the basis of the Phase-I survey findings, the promising districts have been selected, which are (in the order of priority): [1] Chukani, [2] Turaquiri, [3] Calorno, and [4] Sonia - Susana.

5-2 Recommendations for the Phase II

The Phase-I survey revealed that the Oruro-Uyuni region is extensively underlain by hydrothermal alteration zones and the occurrence of epithermal ore deposits can be expected at depth of the zones.

For Phase II, it is recommended that a secondary geological survey should be conducted in the districts investigated in Phase I, in order to obtain further details.

Chukani District

secondary geological and geochemical surveys should be conducted in the district, with the principal aims of ascertaining continuity and extension of gold anomaly zones, and zoning of altered minerals.

Turaquiri District

With a view to ascertaining the westward continuity of the known veins and presence and size of the parallel veins, it is desirable to carry out semi-detailed geological and geochemical surveys.

Sonia - Susana District

In the district, geochemical anomaly portions were ascertained. In order to further clarify the characteristics of the mineralization and zoning of the alteration zones, it is desirable to conduct semi-detailed geological and geochemical surveys. Simultaneously, it will be necessary to obtain information on past drilling and electric survey findings, as far as practicable, for further study.

Calorno District

In this district, it is desirable to conduct semi-detailed geological and geochemical surveys with the principal aim of ascertaining occurrence of hydrothermal breccia, presence of volcanic domes and zoning of the alteration zones from the Cerro Huaylla to the Cerro Irun Laque.

For the Asu Asuni and Loma Llena districts, complimentary geological and geochemical surveys will be needed.

Concerning the other districts where alteration zones were selected by image interpretation but a field survey was not implemented during Phase I, it is desirable to conduct geological and geochemical surveys at a preliminary level.

Blanca Nieves District

The district adjoins the Chilean border northwest of the Chukani district and is situated northeast of the Choquelimpie mine, Chile. The satellite image analysis indicates alteration zones of iron oxide.

Cerro Picacho District

The district is situated to the north of the Cerro Panizo district and referred to below. The satellite image analysis indicates extensive alteration -- mainly argillization -- zones. On the slope of the Cerro Chinchiluma in the south, presence of a Bolivian-type polymetallic vein deposit of gold, silver, copper, lead, zinc and tin has been reported.

Cerro Panizo District

The district is situated to the north of the Calorno district. The satellite image analysis indicates extensive iron oxide and argillization zones.

In addition to the mentioned districts, alteration zones are present in the Cerro Clebra, Iñexa, Año Nuevo, Cerro Puquisa, Cerro Cordillerita, Cerro Colorado, Cerro Sairica, Cerro Luxar, Cerro Cachi Unu, Cerro Chascos, Cerro Zedilla and Cerro Eskapa districts, where preliminary geological and geochemical surveys will be necessary.

To evaluate other minor-scale alteration zones and unconfirmed ore showings, it is recommended to conduct a geochemical survey of stream sediments covering the entire area of the survey.

PART II PARTICULARS

Chapter 1 Compilation of Previous Geological Data

1-1 Outline of Geology in Survey Area

Bolivia is composed of Precambrian, Paleozoic, Mesozoic, Tertiary and Quaternary formations, and igneous intrusions of Mesozoic and Tertiary ages. Their distribution is shown in Fig. I-3-1 and Fig. II-1-1.

The geotectonic provinces are divided into eight sub-divisions, which from west to east, are called the Cordillera Occidental, Western Altiplano, Eastern Altiplano, Cordillera Oriental, Inter-Andes, Sub-Andes, Beni-Chaco Plain and Amazon Craton. (Fig. II-1-2)

The survey area pertains to the Cordillera Occidental and Altiplano.

1) Cordillera Occidental

The Cordillera Occidental is extensively covered by Tertiary to recent volcanic rocks that effused along the uplifting axis in the N-S direction of the Mesozoic to Paleozoic basement rocks, where continental to netric sediments lie between the volcanic bodies.

The Cordillera Occidental composed of a western eugeosyncline-volcanic arc an eastern miogeosyncline, developed in response to subduction (Andean orogeny) following cessation of the Hercynian orogeny. Shales and sandstones of the miogeosyncline were deposited in disconnected back arc basins during a period of extensional tectonism from late Jurassic through early Cretaceous time. During this time, some period lava flows and volcaniclastic rocks were accumulating in the outboard eugeosyncline by late Cretaceous time. Most of the area of the Cordillera Occidental was emergent; continental sediments were being deposited across the miogeosyncline and large granitoide plutons, that constitute the Coastal Batholith of Perú and Chile, were being embedded in the eugeosyncline.

2) Altiplano

The Altiplano has the Proterozoic to Paleozoic basement extensively covered by formations of vast volcanic product and continental sediments of the Cretaceous to the Recent age.

Since the beginning of the Andean orogeny, including the Altiplano have been predominantly a positive tectonic element along the continental margin. Continental sedimentation, which began in the late Cretaceous, continued throughout most of the Cenozoic.

The continental sediments are composed of late Cretaceous continental molasse sediments (red bed) and Eocene to Oligocene foreland basin sediments (sandstone, and alternated beds of sandstone and mudstone)

In Pleistocene time most of the Altiplano was covered by large glacial lakes, the remnants are the present salars.

Igneous activity took place in the Miocene to Pliocene time. Andesitic effusive activity continued during the Miocene time in the southern part whilst, in the northern part, effusive activity of rhyolitic pyroclastic rocks continued from the Miocene to Pliocene time, which caused a huge amount of continental volcanic product to be deposited.

3) Cordillera Oriental

In the Cordillera Oriental, thick sedimentary rocks of the Paleozoic to Mesozoic age (miogeosyncline sediments) depositing on the Precambrian basement underwent the Caledonian (Ordovician), Hercynian (Devonian to Triassic) and Andean (Cretaceous to Cenozoic) orogenic movements, causing to form thrust faults with N-S axes and complicated fold structures.

Simultaneously with the end of the Hercynian movement (Permian to Triassic), the subject region became a tension field where peralkaline volcanic activity and intrusion of granitic plutonic rocks occurred.

Among them, plutonic rocks of granodiorite and adamellite occur mostly in the northern part of the Eastern Cordillera as batholith and lacolith. Meanwhile the intrusive rocks found in the middle and southern parts of the cordillera are hypabyssal and volcanic types except Karikari plutonic rock (granodiorite) near Potosí, and appear in stock and a volcanic neck.

Afterwards the plate subduction began causing calc-alkaline volcanic activity, which lasted from the Jurassic to the Cenozoic time.

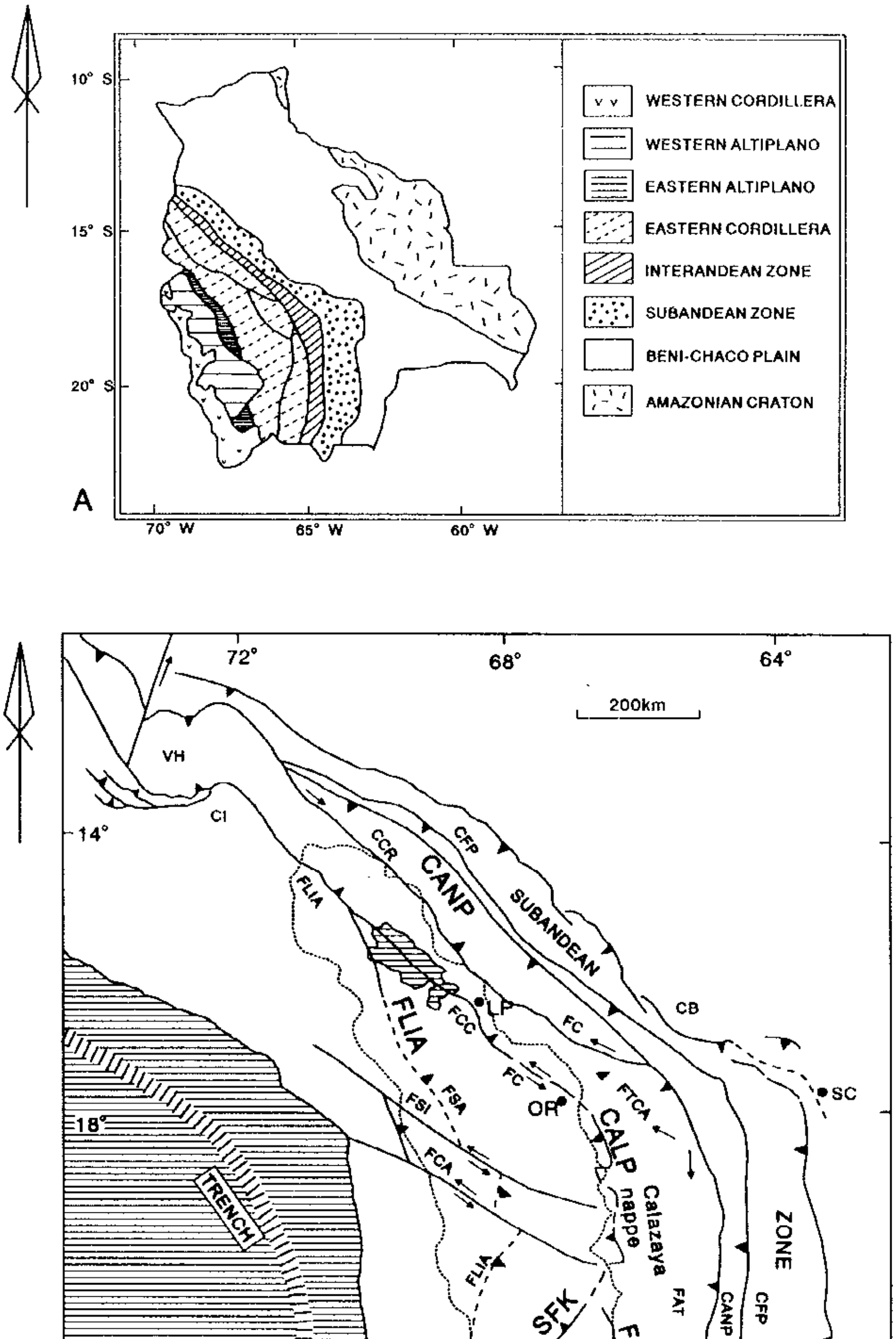
At the time of the Andean orogenic movement (Tertiary), the Cordillera Oriental was uplifted by the E-W compressive stress causing the formation of fold and thrust fault zones. At the west side of the Cordillera, the andesitic volcanic activity, the ensuing intrusion of hypabyssal rocks and overthrust towards the Altiplano side took place.

1-1-1 Sedimentation

To describe the sedimentary rocks, refer to Altiplano, because it is characterized as a series of intramontane foreland basins that received sediments from convergent fold and thrust belts. Its evolution involves the eastward underthrusting of a wedge of the Cordillera Occidental and its Proterozoic basement, forming the Bolivian orocline and westward thrusting of the Paleozoic miogeoclinal rocks of the Cordillera Oriental.

The Altiplano can be separated into structural domains by Coipasa strip (elongate block bounded W-NW trending faults).

The Ulloma domain, north of the Coipasa strip is a basin (N-NW trending) along a SW



Position of the Calazaya noppe within the Bolivian orocline (from Sempere et al., 1991). Fine dottoed line:boundary of the present-day endreic Altiplano basin. FLIA=Intra-Andean Boundary Faultt. CANP=Main Andean Thrust. CALP=Main Altiplanic Thrust. SFK=Khenayani Fault System. FSV=San Vicente Fault. LP= La Paz. SC=Santa Crus. OR=Oruno.

CB=Chapare buttress. CCR=Cordillera Real Thrust. CFP=Main Frontal Thrust. CI=Cuzco indenter. FAT= Auiquile-Tupiza fault. FC=Cochabamna Fault. FCA=Chita-Africa Fault. FCC=Coniri Thrust Front. FE= Eucaliptus fault. ESA=San Andres Fault. ESI=Sevaruyo-Incapuquio fault. FTCA=Toracari Fault-Arque Thrust. VH=Vilcabamaba hinge.

Fig. II-1-1 Structural Geology of the Central Andes

A:Modefied from Baby et al.,1992b, with Western Cordellera volcanic arc added.
B:From Baby et al.,1992a. Additional structure names from Sempere et al.,1988.

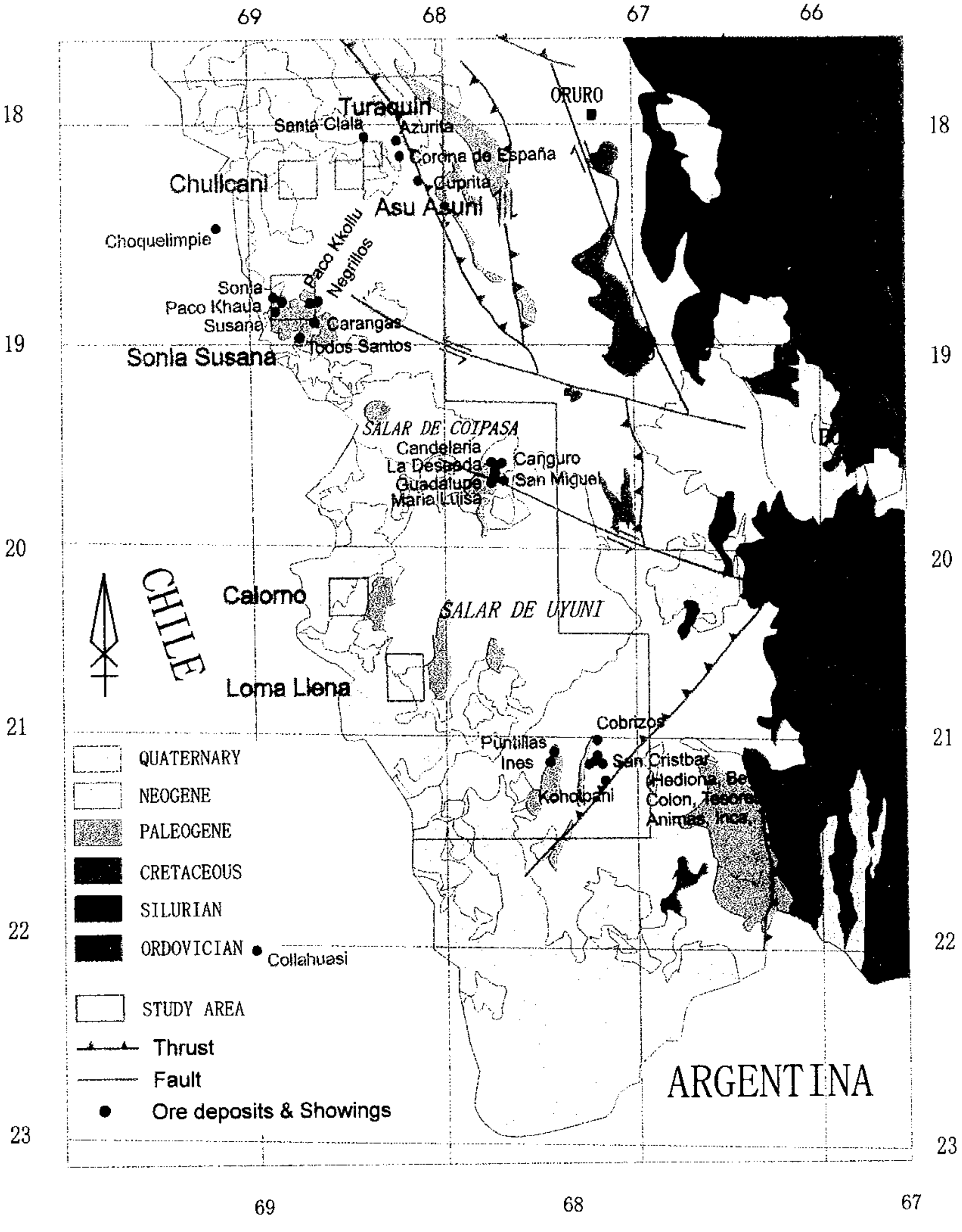


Fig. II-1-2 Integrated Interpretation Map of Previous Information of the Area

vergence fold.

The Uyuni domain to the south (N-NE trending fold) contains upper Ordovician and younger rocks. To the east, the Uyuni domain is bounded by fault systems that place Ordovician sedimentary rocks of the Cordillera Oriental over the Cenozoic rocks of the Altiplano. Two large outliers of Ordovician rocks in the southern part of the Lipez basin are similar to those found in the Cordillera Oriental.

During the Tertiary as much as 15,000 m of continental sedimentary rocks were deposited in rapidly subsiding base on the Altiplano, deposition began in the Paleocene and Eocene, and in the Oligocene and Miocene, coincident with the deformation in the region. These rocks overlie unconformable on a basement of folded Paleozoic sedimentary rocks that is locally covered by thin marine to continental sedimentary rocks of Cretaceous age.

The thickest Tertiary rocks are apparently in the northern and central Altiplano, another thick section is the Serrania de Huallamarca west of Oruro, coarse sandstone and conglomerates of the Coniri Fm. were deposited unconformable on Tiahuanacu beds in a foreland basin. Younger sedimentary rocks as sandstone, shale and conglomerate (Kori-Kollo Fm), and volcanic flows and tuffs of the Mauri Formation continued to fill the subsiding basin until Pliocene.

Fluvial and lacustrine sand, silt, clay, and local gravel (Charaña, Ulloma and Umala Fms.) are interbedded with regional tuff units (Perez Fm.).

To the south in the central and southern parts of the Altiplano, the basal units consist of a series of dark-red to purplish-red sandstone, siltstone, shale and conglomerates (Potoco Fm.) overlying conformably a Cretaceous section.

Following the sedimentary cycle, volcanic activity began in the late Oligocene to early Miocene depositing volcanic and volcaniclastic rocks (Quehua Fm.) from large eruptive centers, especially in the southern Altiplano.

During the Pliocene; most eruptive activity had shifted westward; where it presently is restricted to the Cordillera Occidental.

The Quaternary is characterized by mountain ice caps above 4,300 meters altitude, with glaciation probably dating back to the Pliocene, and contemporary flooding of the whole Altiplano in a lake or series of lakes of pluvial origin. Erosional and depositional terraces mark several high shorelines of the lakes, and the lacustrine sediments buried the topography of the Altiplano

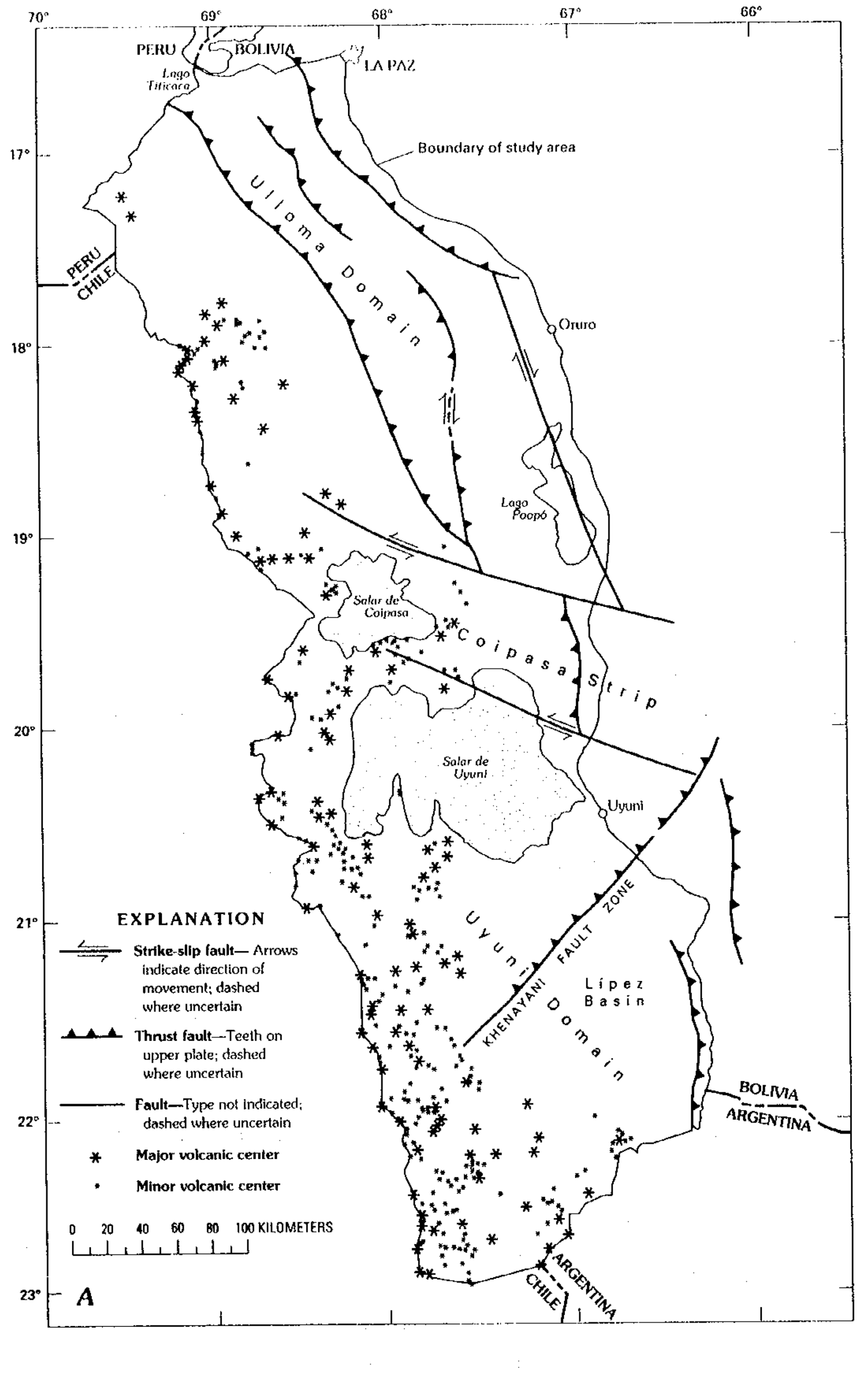


Fig. II-1-3 Schematic Tectonic Map of the Area resulting in the characteristic, present day flat surface.

The Holocene was marked by sharp climatic drying of the Andes, resulting in the formation of salt lakes (salares), saline and alkaline lakes on the southern Altiplano..

There are over 200 such lakes, which have resources of evaporitic salts (halite, gypsum, sylvite, sodium carbonate, sodium sulfate) and brines (containing Li, B, KMg, NaCl, sodium carbonate and sodium sulfate), borates, hectorite, diatomite and clays.

The outstanding resource is the Salar de Uyuni, the largest salt lake in the world (10,582 km^2). The largest lithium resource in the world (5.5 Mt at 423 g/l average concentrated in the Rio Grande estuary with grades of 900-4,000 g/l), together with large resources of potassium (110 Mt at 8.7 g/l) and boron (3.2 Mt at 247 g/l). Current exploitation of the salt lakes is restricted to halite (about 10,000 tonnes per year) and borates.

1-1-2 Volcanism

Volcanic activity on the Altiplano and in the Cordillera Occidental of Bolivia began in the late Oligocene to early Miocene time, broadly coincident with the beginning of the Incaic phase of the Andean orogeny and has continued with few interruptions to the present. Earliest activity, in the Oligocene and Miocene, resulted in the development of large eruptive complexes and concomitant intrusive activity in the southern Altiplano and along both margins of the Altiplano. Beginning in late Miocene time and continuing throughout the Pliocene, large volumes of ignimbrite were erupted from caldera-shield complexes, mostly in the southern Altiplano.

Stratovolcanoes of the modern Andean arc, which form most of the Cordillera Occidental, began to build as early late Miocene time (ca. 7 Ma) concurrent with the late stages of ignimbrite activity. Although there are no reports of historic eruptive activity, seven of the stratovolcanoes contain active fumaroles and more than a dozen show preserved vent structure, lava flows, and domes.

Alkaline volcanic activity was initiated in the Late Oligocene (21-28 Ma) in the Western Cordillera and Western Altiplano, coincident with the first major period of deformation. At the same time, granitoid plutons were intruded in the southern part of the Cordillera Real (Illimani, Quimsa Chata, Santa Vera Cruz) with related tin-tungsten-silver-lead-zinc-polymetallic mineralization (20-28 Ma).

Similar deposits to the south as far as Potosí, such as Colquiri and Chicote Grande, are hosted by Paleozoic sediments and related to buried plutons of this age.

The main period of magmatism was the Middle Miocene (12-17 Ma) with an eastward "breakout" of magmatism in an unusually broad arc across the Western Cordillera, Altiplano and Eastern Cordillera, generally forming small extrusive (domes) and intrusive (stocks, sills) bodies.

Further magmatism occurred across this wide arc during the Late Miocene (5-10 Ma) during the second main period of crustal shortening. This was characterized by stratovolcanoes, ash-flow calderas, and major ignimbrite shields such as Los Frailes and Morococala in the Eastern Cordillera.

The long live periods of felsic magmatism were coeval with the compressive periods.

The highly evolved silicic volcanic rocks of the Los Frailes massif contain several volcanogenic uranium deposits and occurrences of rhyolite-hosted tin mineralization.

Quaternary volcanism is restricted to the Western Cordillera and southern Altiplano. Fumarolic sulfur deposits occur within the highest parts of Late Miocene to Quaternary stratovolcanoes, associated with advanced argillic alteration, silicification and alunite. Large zones of alteration and sulfur mineralization have commonly been exposed by glaciation or sector cone collapse. There are many sulfur mines in these deposits, the largest of which is the Susana Mine with 40 Mt of 48-54% sulphur or 280 Mt 18-35% sulphur ore.

1-1-3 Tectonics

Bolivia is a part of the continental South American Plate that is spreading westward at a rate of about 30 mm per year away from the Mid Atlantic Ridge. It over-rides the oceanic Nazca Plate which is spreading eastward at 60 mm per year from the East Pacific Rise (Fig.II-1-4).

The Precambrian shield of the South American craton crops out in eastern Bolivia, while western Bolivia lies on the Paleozoic to Recent cordilleran (oceanic-continental) plate margin of South America which forms the Andes mountain chain. The Nazca Plate dips eastward and is being subducted beneath the South American Plate. The plate-boundary zone is obliquely convergent.

The Benioff Zone is segmented into shallow dipping (5° to 15°) and more steeply dipping (20° to 30°) zones.

Active volcanism only occurs above the steep sections, forming three volcanic zones along the margin of South American Continent. The Western Cordillera of Bolivia is situated within the Central Volcanic Zone (CVZ, 16°S to 28°S).

The Bolivian Andes is underlain by unusually thick continental crust, which is up to 70 km thick beneath the Altiplano.

Earthquake seismology indicates that the subducted Nazca Plate reaches depths of up to 600 km beneath the Sub-Andean Zone, with a seismic gap between 300 and 550 km depth. Seismic activity in Bolivia is low and there have been no major earthquakes.

The first major deformation in the Andean Cycle in Bolivia occurred during the Late Oligocene to Early Miocene (19-27 Ma) when the orogenic front sediments jumped from west of Bolivia to the Eastern Cordillera and the Bolivian Andes started to develop as a mountain belt .

The formation of the mountain belt is the result of compression to the rigid Precambrian basement of the Altiplano. Major crustal shortening by thrusting occurred in the Eastern Cordillera, and deformation of the Sub-Andean Zone also began.

Since the Late Oligocene, the Altiplano has functioned as an intermountane foreland basin with deposition of thick continental sediments, and also in the Western and Eastern Cordilleras it has formed smaller basins.

The external foreland basin moved east to the Sub-Andean - Llanura (Beni-Chaco) Basin.

The second major period of thrusting occurred between 5-11 Ma. Thrusting is mainly eastward verging toward the foreland, with an important westward verging overturned thrust in the eastern side of the Eastern Cordillera.

Extensive erosional surface developed in the Eastern Cordillera after each phase of shortening and uplift, those are so called the Middle Miocene Chayanta Surface, and the Late Miocene to Quaternary San Juan del Oro Surface.

There was a marine transgression in the central and southern Sub-Andean basin during the Chasiquense (Late Miocene).

The Andean orogeny is considered that are the results mainly of large amounts of crustal shortening caused by thrusting, with consequent crustal thickening causing uplift. Magmatic crustal additions are considered to be volumetrically less important.

The shortening may have been caused by low angle subduction (present dip 30°, estimated Miocene dip 20°) of young oceanic crust.

The start of deformation in the Late Oligocene coincides to with a major change in the convergence of direction of Nazca and South American Plates to orthogonal E-W and high rate.

The Central Andean orocline developed during the main phases of crustal shortening as a result of differential advance of the thrust front controlled by the presence or absence of decollements; the orocline developed in the Santa Cruz area where the Lower Ordovician black shale basin was widest distributed.

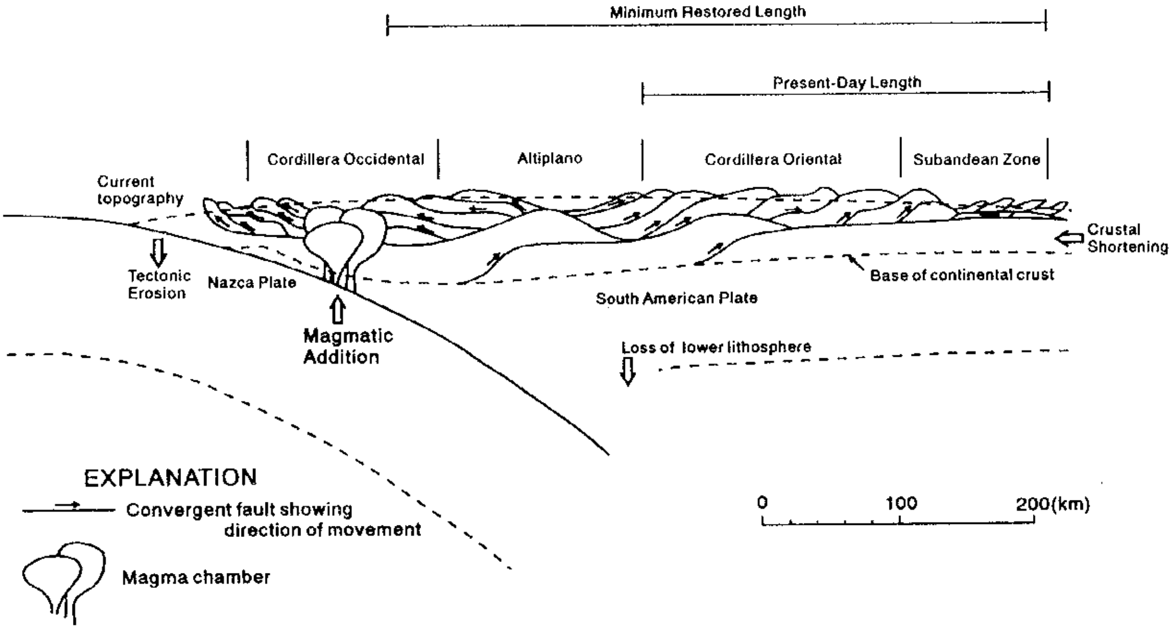


Fig II-1-4 Crustal section of the structure and growth of the Central Andes (Sheffels,1990)

1-2 Outline of Mineralization in Survey Area

Ore deposits of metallic minerals concentrate in the area that embraces the Cordillera Occidental, Altiplano and Cordillera Oriental, where copper mineralization accompanying alkali basalt, sedimentary copper mineralization accompanying late Tertiary red sandstone beds, so-called 'Bolivian-type' polymetallic mineralization mainly of tin and silver, and epithermal mineralization mainly of gold and silver are known to be present. (Fig. II-1-5)

From the Cordillera Oriental to the Altiplano, the Bolivian-type polymetallic vein deposits are found, while copper deposits accompanied by alkali basalt and red sandstone are present from the north to the south of the central Altiplano.

In the Cordillera Occidental, small-scale epithermal gold-silver veins embedded in Miocene dacitic volcanic rocks are known to exist, a part of which is accompanied by sulfide minerals such as copper, lead, zinc and bismuth.

Sediment-hosted copper mineralization accompanying alkali basalt and Paleogene red sandstone beds

The mineralization, known to be present from the north to the south of the central Altiplano, is relatively small in scale, a greater part of which has been worked out.

There are two types of ore deposit: one with native copper, cuprite, etc., occurring in veinlets or disseminated in late Oligocene alkali basalt, and the other with chalcopyrite, bornite, native copper, copper oxide minerals, etc. occurring bedded or disseminated in Paleogene red beds.

Typical of the later type is that of the Corocoro mine. (For this reason, it is called 'Corocoro-type mineralization.') The Corocoro deposit is 15 m wide and 4 km in extension. The cumulative total of run-of-mine ore since 1952 reached 7 million t (approx. 500,000 t of metal content). The ore contained 15 g/t of silver on average.

The Corocoro-type ore deposit is composed of native copper, cuprite and chalcocite occurring in continental red sandstone and conglomerates formed in the reducing circumstance, constituted with a strata-bound bedded mineralization portion and the inferior dissemination portion.

As regards the mineralization process, there are two hypotheses. One explains that mineralizing solution from a low-temperature epithermal ore deposit sinks into permeable beds to form an ore deposit (epigenesis), whereas the other interprets that low-temperature copper mineralizing solution sinks into permeable beds like ground water, and precipitates in dissemination to generate an ore deposit, as seen in the case of sedimentary uranium deposits.

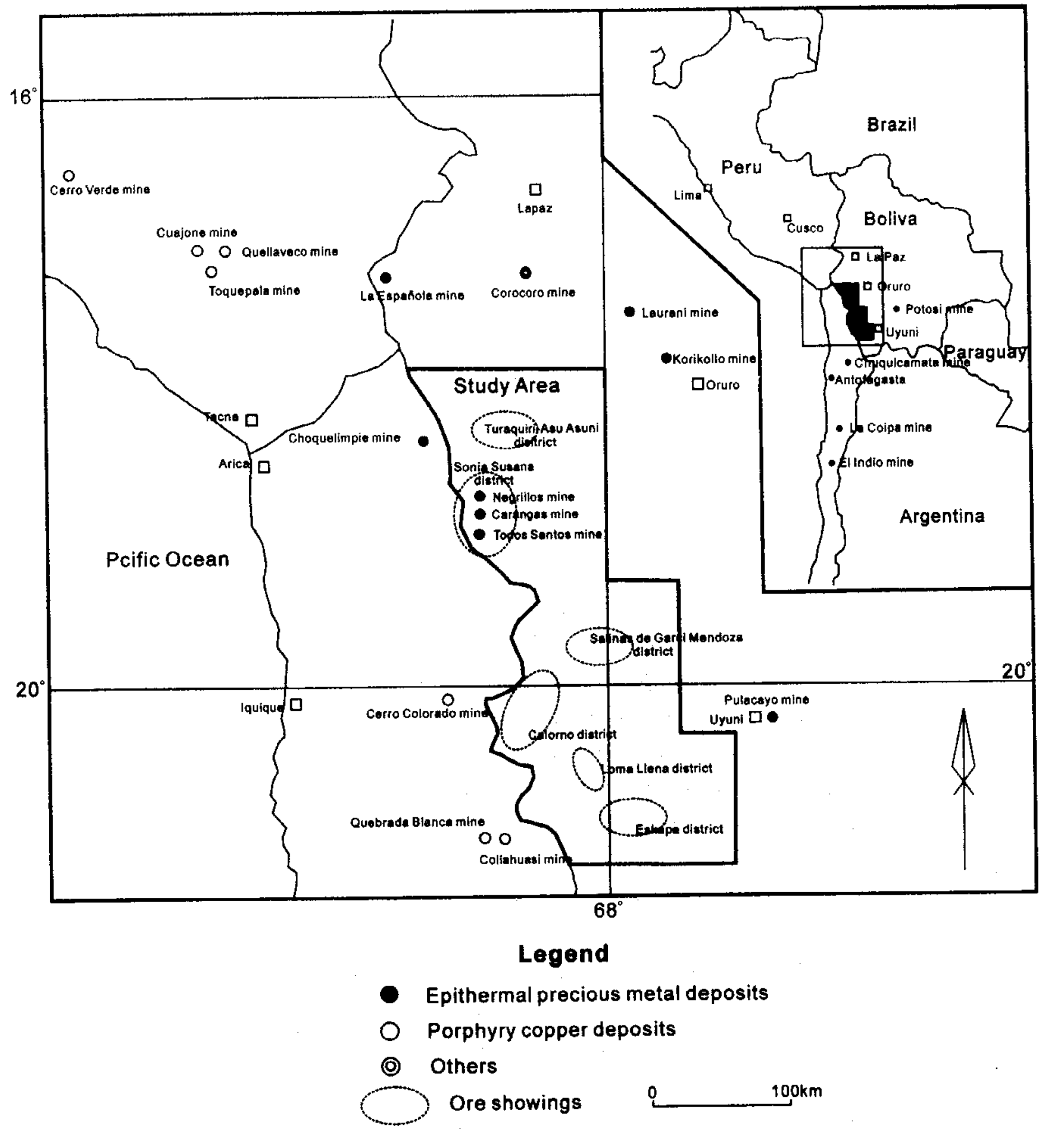


Fig. II -1-5 Location Map of the Ore Deposits and Showings in the Adjacent Area

Bolivian-type polymetallic vein deposit related with Neogene volcanic activity

This type of ore deposit is formed with small veins and veinlets related with igneous rocks intruding in medium to shallow depth, and contains part or all of such metals as tin, silver, gold, copper, lead, zinc, tungsten, bismuth and antimony.

Such deposits, related with andesitic to dacitic intrusives (stocks and dikes) and rarely related with volcanic rocks, are present in the Cordillera Oriental which is mainly underlain by Paleozoic sedimentary rocks and metasedimentary rocks (metamorphic rocks), and also in the Altiplano underlain by continental sediments and volcanic rocks deposited.

Many of these ore deposits have good continuation in vertical and horizontal directions. In case of the Cerro Rico mine, the horizontal extension is 2 km, while the lowest level of the current operation is 900 m deep from the top of the mineralization portion. The bottom of the mineralization is still unknown.

In most of ore deposits, ore minerals are contained in respectively isolated veins, 10 cm to 2 m wide. Ore minerals are observable also in concentration zones of veins and veinlets.

Assemblage of minerals is complicated. More than 90% (in terms of weight percentage) of veins are composed of sulfide minerals such as pyrite, marcasite and magnetite, and are poor in non-sulfide gangue minerals, which characterize the mineralization of this type.

In hydrothermal alteration, a combination of quartz, sericite and pyrite is characteristic. In the upper and outer parts of an ore deposit, argillization advances and alteration portions containing alunite are existent.

While the formation time of the ore deposits is said to be Triassic, Oligocene and Miocene, most of the deposits are formed in middle to late Miocene time.

In view of the measurements of homogenization temperature of fluid inclusion and salt concentration, as well as the original stratigraphy inferred, most of the Bolivian-type polymetallic vein deposits were presumably formed 0.5 km to 2.0 km under the surface. (Fig. II-1-5)

Underlain by upper Tertiary or Quaternary rocks, the polymetallic vein deposits in the Altiplano have not yet been fully elucidated, but many of them are copper-rich Cu-Pb-Zn deposits, relatively poor in tin and tungsten.

The time of formation is believed to be the Miocene. It has been interpreted that these ore deposits form a part of the E-W belt-like arrangement of mineralization zones in the Cordillera Oriental.

A variety of ore deposit of this type are known, but they are roughly classified into two groups which follow:

Ore deposits rich in silver and tin

Mineralization of this type is often seen in the Cordillera Oriental. These have mineralogically complex combinations of silver, tin, lead, zinc, tungsten, bismuth, gold, etc.

Typical of such ore deposits are found at such mines as Cerro Rico de Potosí, Pulacayo and Huanuni. These are classified into two types: one rich in silver sulfate and the other in which the lower tin zones are exposed due to denudation (erosion) of the upper silver zones.

Ore deposits rich in silver, gold and copper

Mineralization of this type is seen in the Altiplano, the most typical of which is the Kori Kollo mine. The mine has silver, gold and some copper, apparently resembling auri-argentiferous iron sulfide deposits, but it is classified into the polymetallic deposit since it contains lead, zinc, antimony, tin, etc.

Kori Kollo mine

The Kori Kollo mine is located on a hill, alt. 3,700-3,900 m, in the La Joya area, 4.5 km northwest of the city of Oruro.

In 1977, the Empresa Unificada (EMUSA) acquired the concessions to conduct exploration from 1980 to 1988, which resulted in the discovery of a low-grade, large-scale gold deposit with confirmed ore reserves of 10 million t of oxide ore averaging 1.65 g/t Au and 25 g/t Ag, and 53 million t of sulfide ore averaging 2.3 g/t Au, 13.8 g/t Ag. An open-pit operation was commenced in 1993.

Currently, the operation is undertaken by the Inti Raymi Co., 88% owned by Battle Mountain Gold, Inc., USA and 12% by EMUSA. The annual gold production is 320,000 oz. (The gold grade of crude ore is approximately 2.4 g/t.) Kori Kollo mine is the only gold mine in Bolivia at present.

The ore deposit exists in an intruding Miocene dacite dome, controlled by Silurian shale (the Catavi Formation) and the tectonic line is in the direction of N25° W, in which three ore bodies, Kori Kollo, Llallagua and Palca-- from south to north -- have been found.

The principal portion of mineralization is constituted with fine veins of auriferous pyrite striking N10° - 20° E and dipping 75° -85° NW and peripheral pyrite dissemination zones. The vein widths are several millimeters to 1 m. A concentration zone of veins, 200 m wide, is observed at the central part of the deposit.

Ore minerals in the veins are pyrite, arsenopyrite, marcasite, chalcopyrite, galena, sphalerite, tetrahedrite, stibnite, realgar, electrum, etc., while a small amount of quartz is contained in the wall rock.

Epithermal gold-silver deposits related with Neogene volcanic activity

The volcanic-hosted epithermal precious-metal deposits are spatially and temporally related to eruptive centers-stratovlcanoes, calderas, and domes--within the volcanic complex. Included are both adularia-sericite and acid-sulphate types of deposits for which distinct sub-types can be distinguished and corresponding descriptive models constructed.

The dating indicates that most of the precious metal deposits were formed in the middle Miocene time (17~9 Ma) while some were formed in the Pliocene to Pleistocene time (5~1.2 Ma). It is considered that these ore deposits are still in the process of formation, accompanying the active thermal water systems and stratovolcanoes in the effusion stage.

The ore deposits in the survey area are high-sulfidation deposits, which are considered to be formed with low-acidic thermal water of the magma origin ascending without mixing with meteoric water. These ore deposits are accompanied by strong argillization.

The mineralization is characterized by the development of pyrite and enargite veins and, in the peripheries; veins develop accompanied by base metals and silver.

One of the ore deposits of this category is the Laurani mine in the Department of La Paz.

Laurani mine

The mine is located on a mountain with an altitude of about 4,100 m, and 90 km northwest of the city of Oruro. During the colonial period, the objects of exploitation were silver and copper.

The deposit is composed of veins in a dacitic to andesitic complex rock body (dome, lava and pyroclastic rocks) of the late Miocene age (8.4 Ma), which intrudes into the Paleozoic (Silurian quartzite, shale and sandstone) and Cretaceous red continental sediments (shale, red sandstone and conglomerate).

In the dacitic intrusive rocks, fractures are developed with three trends of N60° ~70° E; N4° ~20° E; and, N20° ~40° W, which control the mineralization. The principal vein, maximum several meters wide and 2 km long, is formed in the fractures trending N60° ~70° E.

Ore minerals are auriferous pyrite, enargite, tetrahedrite, galena, sphalerite, marcasite, various silver sulfate minerals, stannite, etc. Gangue such as barite, quartz and alunite are observed.

From the central part toward the peripheries of the wall rock, thermal water alteration is observed that varies from quartz-alunite zones to intensive argillization zones, and to propylite zones.

As the subject ore deposit possesses the characters of both the polymetallic deposit and the epithermal vein, the exploitation at the initial stage targeted silver and copper, which later shifted to gold and silver.

Drilling surveys were conducted by BHP and other foreign-affiliated firms, which have reportedly seized a small-scale gold-silver mineralization portion with ore reserves of 2 million t, averaging 2.5 g/t Au, 220 g/t Ag and 1.0% Cu.

Epithermal deposits related with subvolcanic activity in shallow zones

The quartz veins of La Española mine, formerly exploited in a minor scale, are said to be high-sulfidation epithermal veins accompanied by alunite-kaoline, while the other mineralization is poor in base metal and tin contents, as compared with Bolivian-type polymetallic vein deposits.

Such mineralization accompanied by silicification is interpreted to be an epithermal precious metal deposit formed in relation to volcanic activity or shallow subvolcanic activity; therefore, occurrence of porphyry-type gold mineralization has been anticipated beneath the gold, silver and sulfide mineral dissemination portion, which is considered to be corresponding to the peripheries (in the upper part) of the porphyry-type gold mineralization.

In pyrite dissemination areas accompanied by silicification-sericitization zones in La Española area, drilling survey of seven boreholes was carried out by ASARCO in search of porphyry-type gold-copper mineralization.

La Española mine

The mine pertains to the Department of La Paz, located within the Andes Mountains at an approximate altitude of. 4,300 m, 187 km west of the city of La Paz, 40 km WNW of the Santiago de Machaca village and 5 to 6 km east of the Chilean border. The ore deposit is embedded in early to middle Miocene volcanic rocks and volcanic pyroclastic rocks (the Avaloa Group), and the peripheries are underlain by new volcanic rocks of late Miocene age.

Some dacites intrude into these volcanic rocks, forming volcanic rock domes and lava flows. The period of main dacitic magma activity is inferred to be 11 Ma (middle Miocene) from dating.

Mineralization exists in two dome-like dacitic intrusive rock bodies (the San Geronimo and Santa Rosa rock bodies), which underwent strong argillization and partial silicification. In the peripheries of the altered rock bodies, propylitization is observed.

Intensively silicified fracture zones are present in the argillized rock bodies, where quartz-sphalerite-galena-enargite-pyrite veins and low-grade auriferous pyrite-disseminated ores are observed.

1-3 Particulars of Geology and Ore Deposits by District

Numerous ore deposits and ore showings are known to exist in the Cordillera Occidental and Altiplano, the major examples of which are described in the following paragraphs.

1-3-1 Turaquiri district

The Turaquiri is located in the northern part of the Western Cordillera, near the border with the Altiplano.

In the area of the mining property, the stratigraphic column consists from a volcaniclastic sequence in the base, overlaid by rhyolitic ash flow tuffs of the Mauri Fm, and at the top strongly welded intracaldera Turaquiri tuffs, and andesitic-dacitic lava flows and breccia.

The mineralization of the prospect is of epithermal and polymetallic vein-type. This mineralization shows an association of base metal and precious metal minerals. The ore is composed of galena, sphalerite, arsenopyrite, tetrahedrite and chalcopyrite, with gangue of quartz, jasperoid quartz, barite, calcite, pyrite, hematite and manganese oxides. The hydrothermal alteration is zoned, with the silicification developed close to the veins, surrounded by haloes of intermediate argillization (montmorillonite and sericite) and propilitization.

This deposit is so similar to the adularia-sericite epithermal type. Its origin seems to be related to the resurgent stage of the Turaquri caldera

1-3-2 Asu Asuni district

Asu Asuni is located close to westward of Turaquiri in the Sajama province of Oruro.

Asu Asuni hill consists of a stratovolcano of Pliocene age (4.1 Ma), and is developed over a Precambrian basement, with altitudes over 5.088 m.a.s.l. The hill is moderately eroded and shows a large hidrothermal alteration in the crater.

Porphyritic lava flows of andesitic-basaltic and andesitic composition and volcaniclastic rocks are interbedded in thin layers.

All of these rocks are partially covered by glaciar, colluvial, and alluvial deposits.

Dissemination of pyrite and iron oxides are widely observed on the surface and veinlets are restricted in silicified, argillized and propylitized rocks.

Pyrite is mainly associated with quartz, alunite and jarossite. There are just three small manual labor mines with very small dumps of altered rock.

The Asu Asuni altered zone covers over 7.5 km^2, and the most important part is the Churi Loma Sector with 0.7 km^2. The main alterations are: silicification with diverse intensity, surrounded by advanced argillic zones (alunite, jarossite, pyrophyllite, pyrite and quartz), moderate argillic and choritized zones.

Asu Asuni is a high sulfidation epithermal deposit.

1-3-3 Chulcani district

Chulkani is located in Sajama Province of Oruro, at an average altitude between 4,000 and

5,032 m.a.s.l.

This area is part of the Cenozoic Volcanic Central Zone of the Andes. The volcanic rocks in the area had been developed since Upper Miocene to Pleistocene. These rocks comprise rhyolitic tuff and andesitic lava flows. The andesitic lava flows constitute prominent volcanic cones and usually with different erosional states. It seems to be controlled these volcanic centers by the regional lineaments (NW, NE).

Chullcani and Choquelimpie (Chile) aligned on the NE regional lineament.

The area is located in the eroded central part of the Chullcani volcano, it is mainly composed of andesitic breccias and lava flows (*Lavas Chullcani).* A younger andesitic lava flow (*Lava Santillani)* outcrops toward the NW. In the NE part, there is a basaltic andesitic plug (Paco Khuchu), which is the last volcanic event of the area.

A joint system (N41° to 60°E) is developed in the area

Chullcani lava is altered more than 7 km. Four types of alteration had defined in the area: silicification, advanced argillization, intermedium argillization and propyllitization. Silicification consists of calcedonic and microcrystalline quartz with disseminated pyrite.

Mineralization is mainly sulfides as pyrite and chalcopyrite; those are disseminated in the rock and/or found in quartz veins.

Chullcani is a high sulfidation epithermal deposit.

1-3-4 Sonia - Susana district

Sonia - Susana is near the Bolivia-Chile border, about 279 km SW of Oruro City.

The area is covered with an eroded strato-volcano complex.

On the northeastern mountainside between the Negrillos and Framani villages, there are thick alternated beds of tuff and lava flow (the Carangas Group) northeast of the Virulko village which strike NW and dips 40° -50° NE.

These alternated beds are faults (whose directions are unknown) adjacent to the stratovolcanic sediments on the southwest side (Negrillos Group). At these faults, thermal springs are seen gushing out.

From the dating of pyroclastic rocks, the effusion time of these volvanic rocks is inferred to be 5.3 Ma, or the end of the late Miocene age.

Propylitic alteration is widespread, and argillization and silicification may be locally distributed.

The argillization is thought to be an overprint on regional propylitic alteration.

A few quartz – pyrite veinlets were observed in some outcrops. All of the quartz seems to be epithermal vein quartz, however there are not any visible sulfide minerals other than pyrite.

Pyrite is common in the brecciated zone, as veinlets and fracture coating. The andesite contacted with breccia zone is also strongly fractured and contains sparse fine-grained pyrite. In some other areas the altered rocks contain disseminated pyrite and hematite.

Low-level anomalies of gold, silver, lead, zinc are detected in the altered rocks, and possible occurrence of epithermal precious metal deposits or perhaps, polymetallic vein-type deposits is anticipated.

1-3-5 Carangas District

The Todos Santos district is about 20 km east of the Bolivia-Chile border and about 240 km west of Oruro.

The district includes three inactive mining areas, Todos Santos, Carangas, and Negrillos, and several known prospects.

The mineralization of the area has characteristics of silver-rich polymetallic veins and disseminations in volcanic rocks.

Host rocks of the mineral deposits of the Todos Santos district are a sequence of interlayer andesitic lava flows and breccias, silicic pyroclastic rocks, lava domes, and related (?) shallow intrusions referred to the Carangas Formation .

Todos Santos

The Todos Santos deposits consist mainly of small veins and disseminated fault zone that cut across tuffs and breccias near the eastern margin of the rhyolite dome. The rhyolite was interpreted as a stock and more recently as a dome.

The rhyolite dome intruded into a fault zone and this also controls the mineralization.

The host rocks of the mineralization are tuffs and breccias strongly argillized.

The ore minerals consist of disseminated pyrite, yellow sphalerite and a dark-gray metallic mineral (tetrahedrite?).

Compañía Minera del Sur (COMSUR) has estimated ore reserves at 1 Mt at 0.7 g/t of gold and 70 g/t of silver by drilling.

Carangas

Deposits near the village of Carangas are exposed on two low hills and consist of small silver-rich polymetallic veins as thick as 12 cm and dissemination. Both occur in pyroclastic rocks of the Carangas Formation near small rhyolitic intrusions and breccias. The deposits were apparently mined in Spanish colonial times.

The dacitic lithic tuff of Carangas Formation is argillized and contains propylitic andesite breccia and quartz, feldspar and biotite crystal fragments.

Two zones of intense alteration, trending about N. 70° W., occur in the tuff. The lower altered zone is strongly fractured and locally stained intensely with iron and manganese oxides.

The upper altered zone is similar but no silicification is observed.

The Carangas silver-lead mine was exploited during the colonial and postcolonial periods till the 1950's or so.

Silicification, argillization and pyritization are the most marked of the alteration. Two alteration zones striking 70° N are observed on the Espiritu Santo hills.

It is reported that samples taken from oxidized veins included in silicified tuff contain 700g/t Ag, 0.6% Pb and 2% Zn, while tuff in the wall rock contains 50 g/t Ag and 0.5% Pb.

The ore minerals are fine grained, containing tetrahedrite, sphalerite, proustite, pyrargyrite, native silver, pyrite and galena, accompanied by some chalcopyrite.

The gangue minerals are chalcedonic or opaline quartz, barite, magnesite, siderite, etc.

The ore deposits in the ore indication area of Carangas are considered to be typical examples of the epithermal precious metal vein-type deposit accompanied by the Neogene volcanic activity in the Mid-Andean volcanic arc.

Negrillos

Mineral occurrences near the town of Negrillos consist of silver-bearing veins, veinlets and breccia fillings in andesitic lava flows and volcanic breccia. These volcanic rocks may be a part of the Carangas Formation, or they might be related to younger stratovolcanoes. Two adits and numerous small prospects, many of those apparently date back from Spanish colonial times.

The wall rock of the veinlets is intensely argillized and contains sporadically disseminated pyrite.

According the USGS 1975; this deposit contains Au= 0.008 to 0.10 ppm, Ag= 300 to 1,000 ppm, Pb= >20,000 ppm; Zn= 5,000 - 10,000 ppm, and Cu= 7,000 ppm.

1-3-6 Salinas de Garci Mendoza district

The Salinas de Garci Mendoza district is located in the Intersalar Range, between Salar de Uyuni and Salar de Coipasa about 260 km SSW of Oruro.

The district is situated along approximately EW and NW trending fracture zones and dikes. Both areas consist mainly of volcanic rocks of Miocene to Quaternary. In the district, an older sequence of andesitic lava flows and breccias, tuffs, and volcaniclastic sedimentary rocks are intruded and overlain by several small to medium bodies of intrusive-extrusive rhyolite and coarsely porphyritic dacite. The thickness of the older volcanic sequence is about 700 m. It is overlain by roughly an equal thickness of andesitic and basaltic lava flows from younger stratovolcanoes of late Miocene to Quaternary age, whose imposing cone dominates the surrounding landscape, as Cerro Tunupa in the south of the district.

The dating of lava flow of these stratovolcanoes indicates 4.5±0.3 Ma at the Mt. Coracora north of Salinas de Garci Mendoza and 1.8±0.2 Ma on the north slope of the Cerro Tunupa, both being Pliocene.

In general, the district presents intense hydrothermal alteration ranging from silicification, passing to argillic alteration (different grades) ending in highly propilitized rocks.

Pervasive, argillic and silicic alteration are in the intrusive centers at Mokho, Chufusa and Chorka.

Thick, brecciated silica caps with hematite, overlying kaolinized areas, on the tops of Mokho and Chorka represent the upper parts of hydrothermal systems. The variety of intrusive rocks related to pervasive alterations, such as the swarms of silicified radial dykes and silicified minor intrusives, indicate a high potential for disseminated and vein type gold bearing polymetallic mineralization.

In the Maria Luisa, Margarita, Guadalupe and La Deseada mines, it shows a mineralized, structures accompanied by dykes and veins of radial distribution to the Mokho resurgent intrusive center. mineralogy and general characteristics of the geologic environment of the district are similar to the Bolivian polymetallic vein deposits and that means epithermal to mesothermal mineralization.

The status of mines and prospects in the district are as follow:

Cangura (Cerro Kancha): Area of vuggy silica rock.

La Deseada: Inactive mine; in situ reserves of 2.5 million tonnes, 0.4 g/t Au; 280 g/t Ag; dump reserves of 30.000 t, 0.4 g/t Au, 400 g/t Ag; underground working about 30 m.

María Luisa: Inactive mine; COMIBOL property; drilling reported but reserves not available; extensive underground working (500-1,000 m?)

The ore deposit is situated in the mountain, alt. 3,900 m above sea level, 10 km southwest of the village of Salinas de Garci Mendoza.

The deposit is composed of quartz veins located at a silicified fault zone in Miocene dacite (the Santo Domingo vein), whose average width is about 2 m (between 1 m and 6 m) and extension reaches 2 km.

On the surface, the veins strike N75° W while, underground they strike E-W and dip vertically or at high angles northward.

All veins contain some 2% to 3% of pyrite on average and 1% of metallic minerals including sphalerite and a small quantity of chalcopyrite, and black to silver-black minerals such as galena, freibergite, stephanite, and copper minerals.

Metallic minerals are fine-grained (rarely exceeding 2 mm), occurring in dissemination or in lumps, 1 cm to 5 cm in diameter.

The most abundant gangue minerals are quartz, which is white to dark grey-colored, have massive to equigranular texture and cavities of 10 wt. % or more.

There are small-scale secondary veins which are 20 cm to 60 cm wide, striking N40° W and dipping 60° northward, and contain 10% to 40% of metallic minerals.

From the samples taken from underground veins, 82~1,400 ppm Ag, 0.1~0.85 ppm Au, 1,100~59,000 ppm Pb, 5,800~10,000 ppm Zn and 360~1,400 ppm Cu were detected.

The mine, operated by COMIBOL until some 20 years ago, has presumably produced several hundred thousand tons of ores.

San Miguel mine : (Operation suspended; drilling results unfavorable; tunnels 300 m)

Two silicified fracture zones, 8 m and 12 m wide, respectively, lie over an extension of 150 m from the mine portal.

Quartz veins, 25 cm wide, are observed in these fracture zones, which strike N50° -60° W and dip vertically. Pyroclastic rocks between the quartz veins underwent alteration such as propylitization, argillization, silicification and sericitization.

Although dissemination of iron and manganese are generally seen in the silicified zones, no metallic minerals are observable nor detected as anomalies of silver, gold, lead and zinc.

Margarita mine : Operation suspended; drilling results unfavorable; tunnels 700-800m

This mine pertains to the same mineralization zone as the San Miguel mine, the both mines being connected underground by a vertical shaft.

The mineralization portion is not continuous; the most continuous part is approximately 50-70 m in extension but intensively fractured.

Galena and sphalerite account for 20-30% on average (between 3% and 90%) of the continuous part while pyrite, also generally existent, accounts for several percent.

Gangue minerals are mostly quartz, the most common is massive or plate-like shapes and colorless, white- or red-colored (due to the contained laterite).

The host rocks (Tagua Group) of the San Miguel and Margarita mines are mostly propylitized and intensively argillized near the veins, but the argillization is confined to a range of 1-2 m outside of the veins.

Silicification is limited only to the fractured zones, in which quartz veins controlled by parallel fissures are existent, as well as those accompanied by galena (about 3%) and sphalerite (1%).

In these quartz veins, 14-20 ppm Ag, 0.05-2.1 ppm Au, 5%-9% Pb and 3,300-5,000 ppm Zn are detected; however, no marked anomalies of silver, gold, lead and zinc have been taken in the wall rock within 1 m from the veins.

The ore deposit was operated by COMIBOL until some 20 years ago and is presumed to have produced several thousand tons of ore.

1-3-7 Calorno district

The district is located within the Cordillera Occidental, alt. about 4,500 m above sea level, some 38 km southwest of the city of Oruro, and west of the saline lake of Empexa.

This is a fairly new prospect, so it there was no study up to now. Morphologically is located in the western sector of the central volcanic zone (CVZ) and belongs to the volcanic chain of the Lipez. The volcanism had evolved from the upper Miocene to the Pleistocene covering the pre-Paleocene rocks, as ignimbritic flat lands, and dacitic/andesitic stratovolcanoes with some vent rocks.

Remarkable hydrothermal alteration is observed in the district.

It is possible that, in the lower part of the alteration zones, Oligocene to Miocene volcanic rocks and supergene to hypabyssal rocks occur similarly to the Carangas area, and these rocks are partially exposed due to erosion.

1-3-8 San Cristóbal district

The San Cristobal district is located to southwest of Uyuni (408 km from La Paz) at the western edge of the great plain in the southern Altiplano.

It includes eight known polymetallic vein deposits that have been worked intermittently since the discovery of silver, in the early 17th century. At the present time, only the Toldos deposit is under mining activity.

The volcanic Complex consists of volcanic breccias, ash-flows and lavas intruded by andesitic and dacitic stocks and domes.

Having epithermal polymetallic mineralization embedded in Miocene volcanic complex, about 20 km in diameter, the ore deposit is composed of veinlets of quartz, barite, sphalerite and galena, as well as portions disseminated by pyrite-argentiferous minerals (argentiferous galena).

Toldos mine, the largest of the district, has a low-grade ore deposit exploited by open pit combined with underground mining. Silver is recovered by cyanide heap leaching.

In the Toldos ore deposit, dacitic porphyry intrudes into a large andesitic porphyry rock body; the K-Ar dating of altered dacitic porphyry and fresh or non-altered dacitic porphyry are 8.5 ± 0.3 Ma and 8.0 ± 0.1 Ma, respectively, both being late Miocene.

The ore deposit is constituted with a series of almost vertical veins trending NE, and exploited over an extension of 300 m at several different levels.

These veins have an average width less than 30 cm, occasionally exceeding 1 m, and contain mainly hematite, barite and siderite, as well as small quantities of quartz and magnetite depending on the location.

The main ore minerals are native silver and argentite while minor quantities of chalcopyrite, pyrite, arsenopyrite, pirargyrite and polybasite are observed.

At the Toldos mine, open-pit mining targets stockwork auriferous pyrite veins and veinlets developing in argillized dacitic porphyry that lie between the veins exploited in the past.

Andean Silver Co., a subsidiary of Apex Silver Mines, USA, is working out a large-scale redevelopment program of all seven mines in the area, including the Toldos mine, by open pit. The exploitation is aimed not only at the silver-bearing pyrite veins but also the pyrite-dissemination portions that contain some silver, as well as galena, sphalerite, tetrahedrite existent in the stockwork veins.

For the development project, a drilling survey extending 142 km in total has been carried out so far, which determined confirmed and probable ore reserves of 120 million t, grading 1.78 oz/st Ag, 0.5% Pb and 1.5% Zn. The company announced that the mine has one of the world's largest silver ore reserves.

The start of operation is scheduled for 2001.

1-3-9 Eskapa district

The district is situated on the mountainside of the volcano Eskapa, alt. 4,200 m above sea level, at the southern tip of the saline lake of Uyuni, 125 km southwest of the city of Uyuni.

The Mt. Eskapa, alt. 5,145 m and Mt. Khala Katin, both being late Tertiary stratovolcanoes, lie to the north of the caldera Pastos Grande. These volcanoes are composed of Miocene to Pleistocene ignimbrite and pyroclastic rocks of the Upper Quchua Group.

The Eskapa mine is a small-scale vein-type copper deposit lying on the north slope of the volcano Eskapa, alt. 4,300-4,250 m. Discovered and exploited during the colonial times, the mine was reopened and operated on a minor scale from 1968 to 1971 by a local mining cooperative.

The ore deposit is embedded in lava or a dome of dacitic to rhyolitic porphyry. The mining was done at an irregularly fractured brecciation zone striking N10° W.

The ore minerals are mainly tenorite and chrysocolla, and some malachite.

As to the gangue minerals, white to light green-colored, brittle calcite is partially present, filling large cavities of breccia and massive stones.

In copper-rich veins, silver (30 ppm) and a small quantity of lead (3,000 ppm) are detected.

In the eroded central part of the slope of the Eskapa volcanic body, mainly white to brown-colored argillization is widespread (more than 12 km^2)

Past surveys were conducted on a fracture zone trending NW of an alteration zone, where iron oxide is conspicuously spotted and plate-like barite crystals are seen partially filling cavities between breccia.

Samples collected by a geologist who investigated the alteration zone in 1917 are said to contain 5.5 oz/st Au and 30.5 oz/st Ag, but it is not known where the samples were taken.

A Canadian prospecting company, Samex, carried out exploration in the southern part of this district.

1-3-10 Ore deposits in Chile

Several ore showings of precious metals and hydrothermal alteration zones in the Republic of Chile were also studied for reference. These are embedded in Neogene volcanic rocks.

Descriptions are limited only to the three mines so far well studied, of which genetic relationship between the Neogene volcanic activity and precious metal mineralization is well known, as well as the porphyry copper-type Collahuasi mine.

Choquelimpie mine(Au, Ag)

This gold-silver mine in the First Department of the Republic of Chile. located within the Andes Mountains, alt. 4,860 m, 10 km west of the Bolivian border which is 115 km east of Arica.

It is recorded that silver was mined in the 17th century. In 1988, the mine operation by open pit at a rate of 5,500 tpd and by heap leaching was started by Cia Contratual Minera Vilacollo, a joint venture of Shell Chile, Westfield Minera and Citibank.

The volcanic activity in the area, continuing from the late Miocene to the Recent time, took place at the intersection of the main lineament trending N60° E and faults trending N35° E.

The Choquelimpie deposit is of precious metal mineralization accompanied by marked hydrothermal alteration seen in the central portion of an eroded calc-alkalic stratovolcano (late Tertiary to Quaternary?) having a structure, which looks like a caldera.

The stratovolcano that bears the ore deposit is composed of dacite, andesite lave, breccia, etc.; dome-like dacite of late Miocene (6.60$\pm$0.20 Ma) intrudes into it.

Most of the mineralization portion exploited in the past were silver-rich narrow veins, whereas the current operation is concentrated on the hydrothermal breccia bodies trending N60° E which extend over 2 km.

The mineralization in the hydrothermal breccia occurred after intrusion of feldspar porphyry, cutting and altering the porphyry. The feldspar porphyry is considered to have played an important part in controlling the field of occurrence of the mineralization.

In the hydrothermal breccia bodies, three groups of clearly different combinations of minerals are observed: a) auri-argentiferous pyrite group, which is the most important of all from the economic point of view; b) arsenic minerals group whose silver content is not high but gold content is remarkably high; and c) lead-zinc-copper-arsenic-antimony group which contains spotted gold. This is considered to be attributable to the mineralization repeated along the fissure systems that controlled the field (position) of the hydrothermal activity.

In the breccia and the neighboring rocks, native gold, native silver, electrum, argentite, etc. are observed, while veins containing lead, zinc, gold and silver, which cut the breccia bodies of the mineralization at the later (last) stage, are also present.

The gangue minerals such as sericite, calcite, chlorite, hematite, barite, quartz, chalcedony, kaolinite, dickite and alunite are observed.

In the peripheries of the mineralization zone, a propylitization zone is present, changing inwardly into a sericite-pyrite zone.

Silicification accompanied by lead, zinc, pyrite, kaolinite and barite is overprinted on the sericite-pyrite zone near the breccia bodies.

The homogenization temperatures of the fluid inclusions taken from around the breccia bodies are within a range of 213 to 305℃, while values under 5 wt % of salt concentration in terms of NaCl are obtained; therefore, the mineralization is considered to have occurred at a depth of at least 300 m under the paleo-ground water table.

Although the Choquelimpie mine has been interpreted to be an epithermal ore deposit embedded in volcanic rocks, accompanied by silver, gold, lead and zinc, and rich in acidic sulfate minerals, it has both characteristics of high-sulfidation epithermal gold-silver deposit and polymetallic-type deposits. Therefore, the mine is considered to be somewhat different from the Maricunga mine and El Indio mine in central Chile, which are accompanied by gold, silver, copper and arsenic.

La Coipa (Ag, Au)

The La Coipa district is located 130 km NE of Copiapó, at an average elevation of 4,100 m. In the district precious-metal indications in pyroclastic rocks and underlying black Jurassic (?) siltstones were discovered recently.

Mineralization is related to advanced argillic alteration, with alunite, pyrophyllite, some sericite and native sulphur, and traces of zunyite. Several silicified hydrothermal breccias contain the highest metal contents.

Reconnaissance of rock-chip sampling yielded an average of 13.3 g/ton Ag and 2.1 g/ton Au in the mineralized structure (with maximum of 44 g/ton Ag and 8.8 g/t Au).

Rock geochemical survey indicate clear silver anomalies (including a value of more than 800 ppm), together with anomalous As (up to 107,000 ppm), Sb (up to 650 ppm), Cu (Up to 2500 ppm), Pb (up to 13,200 ppm) and Zn (up to 540 ppm) values. Geochemical values seem to be vertically zoned.

On the top of the alteration zone, vuggy, banded and brecciated siliceous sinters, containing native S and Hg minerals (cinnabar and metacinnabar), are present.

El Indio (Au, Ag, Cu)

The El Indio district is a part of a 200-km long, elongate belt of alteration zones, oriented approximately N-S and located near the Chile-Argentina frontier. The belt includes more than 20 alteration zones, some of them known to contain precious-metal mineralization.

The El Indio deposits is a part of an extensive alteration zone (about 145 km) hosted by a Late Jurassic–Cretaceous andesitic sequence and Late Oligocene–Middle Miocene sequence composed of rhyolitic, dacitic, andesitic, and basaltic rocks.

Hydrothermal alteration patterns usually present an internal strong silicification (sometimes including argillization on fractures), with argillic minerals in an intermediate position (both zones accompanied by anhydrite, gypsum, alunite, native sulphur and jarosite). The external haloes are prophylitized. Siliceous sinters are described.

The El Indio deposits are a group of 90–100 veins in an area of 5 km^2.

The El Indio mine exploits a vein complex occupying a 400 x 100 m, area delimited by a N–S fault and characterised by mineralized tension fractures, which contains mainly enargite and pyrite, with minor chalcopyrite, tetrahedrite-tennantite, sphalerite and galena at depth. Native gold is associated with quartz veinlets cutting sulphides. Average grades are 8–10 g/ton Au, 140–160 g/ton Ag and 8–14% Cu. Published reserves are 3,290,000 metric tons of 12.3 g/ton Au, 141 g/ton Ag and 3.98% Cu, plus 70,200 metric tons of direct-shipping ore (277 g/ton Au, 116 g/ton Ag and 2.2% Cu).

K-Ar dating shows Middle to Late Miocene age for the alteration-mineralization in the El Indio district.

In the northern part of the neighboring Chile, there are many porphyry copper-type (molybdenum and gold) ore deposits accompanied by hypabyssal rocks that intrude into Mesozoic to Tertiary sedimentary rocks and igneous rocks (geosynclinal sediments), most of which are only dozens of kilometers away from the Bolivian border.

These ore deposits are formed in relation with felsitic to intermediate, intrusive rocks. Their formation time is considered to be 60 Ma to 5 Ma (late Paleocene to early Pliocene). These are accompanied by extensive alteration zones such as argillization and leaching-type hydrothermal alteration.

Located dozens of kilometers away from the border southeast of the survey area is the Collahuasi mine, which started operation in 1998.

Collahuasi mine (Cu)

The mine in the First Department of the Republic of Chile is located within the Andes range, alt. 4,400 m, 15 km east of the Bolivian border, 10 km west of the Quebrada Blanca mine and 180 km southeast of the port of Iquique.

The location falls on the northern end of the porphyry copper-type mineralization zone, which runs north and south in northern Chile.

The basement rocks of the area are constituted with Permian to Triassic, andesitic to rhyolitic volcanic rocks (Collahuasi Group), pyroclastic sediments and granitic abyssal rocks.

The basement rocks form an uplift zone, 30 km to 40 km wide and 200 km long, extending north to south, was heaved up by Oligocene to Miocene fault activity. To the south of the uplift zone, El Abra and Chuquicamata mines are situated.

Accompanying the uplifting activity, many faults with the trends of NNW-SSE, NE-SE and N-S are formed. Controlled by these fault systems, various types of hydrothermal and volcanic activity took place, causing major ore deposits to be formed in the zone.

Afterwards, most of the area was thickly covered by Miocene to Holocene thick volcanic rocks. The subject ore deposits are formed around the two late Eocene to early Oligocene porphyry stocks that intrude into Permian to Triassic, andesitic to dacitic volcanic rock beds. The three ore deposits -- Ujina, Rosario and Huinquintipa -- have been confirmed.

The Ujina and Rosario deposits are typical porphyry copper deposits, which have secondary enrichment zones and large sulfide zones underneath, in which gold, silver and copper-bearing vein-type mineralization is seen overlapping.

The ore minerals are chiefly pyrite, chalcopyrite and bornite; also observable are some molybdenite, tetrahedrite and enargite.

There is an alteration zoning, which, from the central part outward, changes from potassium alteration zone (potassium feldspar-orthoclase-biotite) to quartz-sericitization zones, and to propylitization zones. The alteration is overlapped by leaching and argillization that accompany the vein-type mineralization of a later time.

The Ujina deposit has minable ore reserves totaling 150 Mt, of which sulfide ore amounts to 124 Mt, grading 1.76% Cu at a cutoff grade of 1%, while oxide and mixed ores are 26 Mt, grading 1.2% Cu at cutoff grades of 0.3% and 0.4%, respectively.

The open-pit mining operation was commenced in July, 1998 at a rate of 60,000 tpd of sulfide ore.

The Rosario deposit is located 5 km west of the Ujina deposit. It has minable ore reserves totaling 439 Mt, of which sulfide ore amounts to 423 t, grading 1.12% Cu at a cutoff grade of 1%, and oxide and mixed ores is 16 million t, grading 1.33% Cu at cutoff grades of 0.3% and 0.4%, respectively.

The Huinquintipa deposit, located 4 km west of the Rosario deposit, is a secondary ore deposit mainly of copper oxide ores.

1-4 Summary and Considerations

The ore deposits confirmed in the survey area and its surroundings are classified into copper deposits accompanying alkali basalt, bedded copper deposits embedded in red sandstone (the Corocoro-type deposits), Bolivian-type polymetallic vein deposits, epithermal deposits and porphyry copper deposits.

Copper deposits accompanying alkali basalt and the bedded copper deposits in sedimentary rocks in Bolivia are not large enough in scale for immediate exploration targets.

Most of the Bolivian-type polymetallic vein deposits existing from the Cordillera Oriental to Altiplano were formed in the Miocene time but some were formed in the Tertiary or earlier. In areas of the Cordillera Occidental and Altiplano where Miocene or lower rocks are present, ore deposits are possibly concealed by the upper rocks.

It is known that, in the Cordillera Occidental and Altiplano, hydrothermal alteration is widespread in Tertiary rocks.

In hydrothermal ore deposits, generally, a variety of mineralization such as high-sulfidation hydrothermal deposits, low-sulfidation hydrothermal deposits, porphyry-type gold deposits, hydrothermal sediments, etc. are known. Most of the Bolivian-type polymetallic vein deposits are also considered to be ore deposits of epithermal origin formed near the surface, accompanied by similar hydrothermal alteration zones. Therefore, the epithermal alteration existing in volcanic rock areas are likely to be one of these types of mineralization, and ore deposits possibly occur underneath.

As seen from the schematic drawing on the occurrence of a Bolivian-type polymetallic vein deposit and schematic model of a porphyry copper-gold deposit accompanied by hydrothermal alteration (Figs. II-1-6 and -7), a porphyry copper deposit could possibly occur beneath the Bolivian-type polymetallic vein deposit.

It is also conceivable that a porphyry gold deposit is, at its lower part, related with or shifting to a porphyry copper deposit.

High-sulfidation epithermal vein-type deposits are accompanied by hydrothermal alteration characteristic of marked argillization containing alunite, kaolin and pyrophylite. Alunite and