NO.

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

CONSOLIDATED REPORT

March 2002

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Republic of 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 surveys were implemented for the three years from FY1999 to FY2001 and completed as scheduled, under close collaboration with the officials concerned of the Government of the Republic of Bolivia and Servicio Nacional de Geología y Minería(SERGEOMIN).

This Consolidated Report summarized the overall results of the three-year survey.

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, 2002

Takao Kawakami
President
Japan International Cooperation Agency

Naohiro Tashiro
President
Metal Mining Agency of Japan

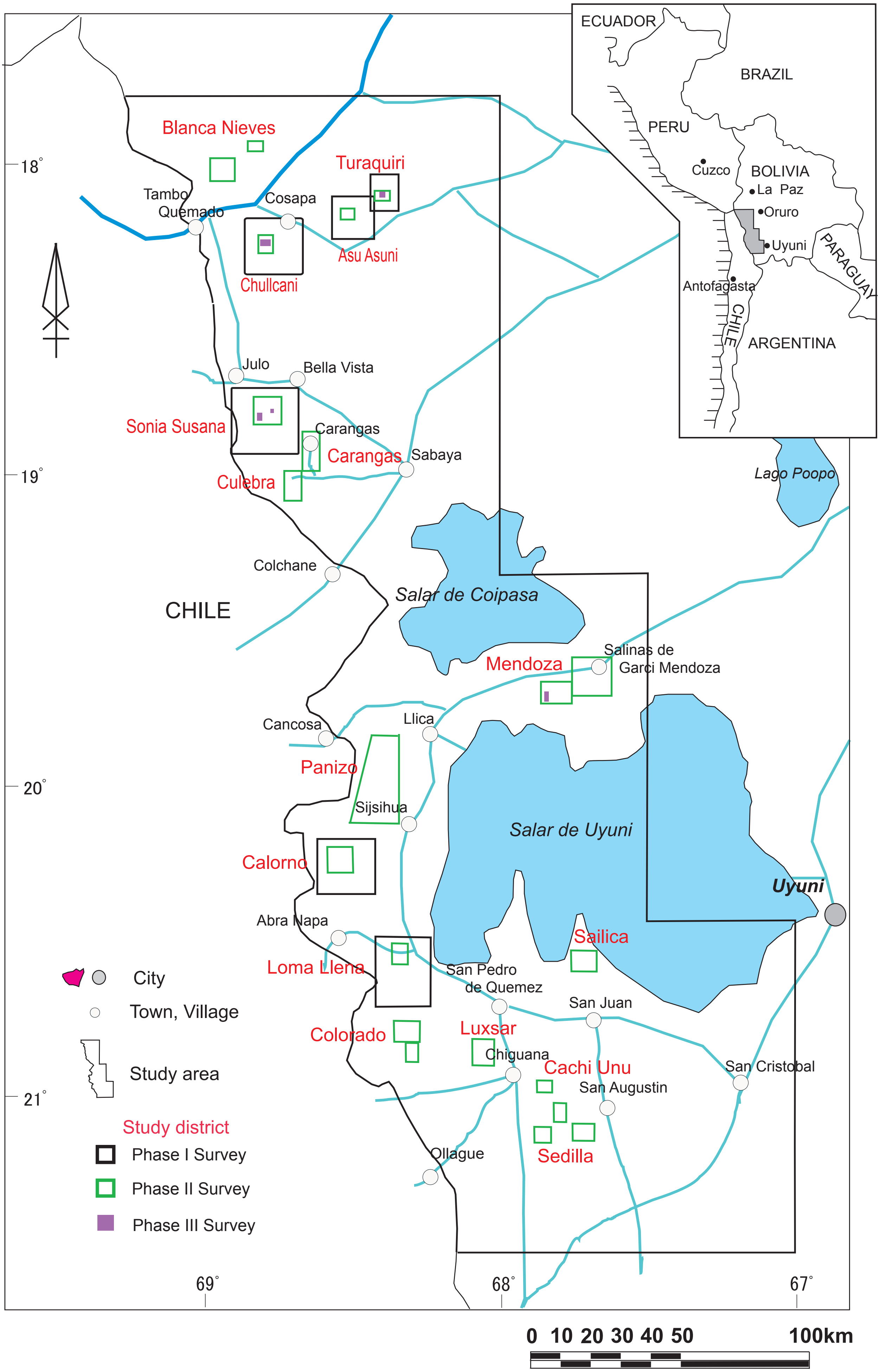

Fig. I-1 Location Map of the Survey Area

SUMMARY

This consolidated report summarized the overall results of the three-year survey from FY 1999 to FY2001 carried out in the Oruro-Uyuni region of the Republic of Bolivia, under the technical cooperation.

Survey findings, overall evaluation and exploration guidelines for the future are summarized in the following paragraphs.

Survey Findings

As the hydrothermal alteration zones exist widely in the Oruro-Uyuni region and also mineral showings exist, it is expected to host epithermal ore deposits at depth.

Considering the mineralization in the Altiplano and the Eastern Bolivian Andes, it was interpreted that the mineralization in the Western Bolivian Andes is similar to the Bolivian-type deposit and shows an epithermal type mineralization in the upper part, while it changes to a polymetallic mineralization in the lower part.

It is reported that the mineralized ages of Chilean porphyry type deposits have a tendency to become younger from west to east and the porphyry type deposits were expected.

Sixteen Districts were studied in three years.

After the surveys lots of matters about the mineralizations in the Oruro-Uyui region still remained unknown, nevertheless the following things became clear.

1) The satellite image analysis was proved to be useful for selection of alteration zones, as alteration zones selected by satellite image analysis in this survey well coincided with the results of the ground truth.

2) The area is underlain by volcanic rocks of early Miocene to Pleistocene, ther ages,however,showed irregular distributions.

3) Alteration minerals in the volcanic rocks showed a zonation of crystobalite zone, quartz zone, quartz-sericite zone from the outer part to the center part. Quartz-sericite zone in the volcanic rocks of Late Miocene or younger, is generally absent or small if exists, while quartz-sericite zone in the volcanic rocks of the Middle Miocene or older is widespread.

4) The vein materials showed a variation of clay, clay-silica, silica and quartz from the outer part to the center part. Manganese oxide is shown inside of clay in some place. In either case, quartz zone is acompanied by ore minerals such as gold, silver, copper, lead and zinc.

5) Results of the chemical analysis of samples from the La Deseada vein exposed from the top to the bottom, values of (gold), (copper), lead, arsenic and antimony are higher in the upper part of the mineralization, and those of gold, silver, copper, lead, zinc and antimony increase in the lower part of mineralization. Combination of these factors and vein character is a good indicator to consider the portion of a mineralized zone in the same area as Mendoza District.

6) Homogenization temperatures and salinities of fluid inclusions showed difference of ore solutions by each vein. Veins showing low temperatures like the La Deseada vein indicate the possibility of ore deposits underneath.

7) It is not cleared whether the quartz(calcedny)-barite vein changes to Bolivian-type? Polymetallic vein, as drilling survey was carried out only in the Chullcani. The reasen why no sulfide vein was confirmed in the ore showings in the older volcanic rocks, some part of mineralization in the Western Andes and Altiplano is considered to be different from the bolivian-type mineralization in the east.

8) Positive showing suggesting the existence of the porphyry type deposit could not be confirmed .

Conclusions of principal districts are as follow.

Turaquiri district

Many veins mainly of manganese dioxide are confirmed. It is suggested that veins beneath the manganese dioxide might change to Ag- Pb- Zn- Cu veins, but their size is insufficient for a bulk mining operation.

Chullcani district

It is interpreted that Volcano Chullcani is a single stratovolcano and subsequent erosion denuded the center part of the volcanic body exposing the tip of diorite. After drilling, dominant hydrothermal alteration zones were confirmed. However, significant mineralization was not intersected.

Possibilities remain for deposition of epithermal gold mineralization ore deposits in the southeastern part of the MJBO-2 drill hole related to intrusive activity in shallow parts. However, it is suggested that the gold mineralization was weak in general.

Sonia - Susana district

In Jankho Kkollu it is possible that the volcano was formed later than the time when the Carangas Formation was formed in Middle Miocene, instead of Upper Oligocene to Lower Miocene.

Many lead-zinc bearing barite-quartz veins are confirmed in areas south of the intrusive rock body. However, these are discontinuous and small in size. Therefore, ore deposits should not be expected to be large.

Positive signs suggesting existence of the porphyry type mineralization are not confirmed in the Santa Catalina Prospect.

Calorno district (Fig. I-4-2(5))

The hydrothermal alteration zones widespread in the district are considered to situate at the topmost (outermost) parts of the alteration zones.

Distribution of hydrothermal breccia is wide. High sulfidation type epithermal deposit or epithermal Au-Ag-Pb-Zn deposit related to volcanic activity are expected.

Although it is probable that the mineralization is weak or deep-seated, because geochemical anomaly is not remarkable.

Mendoza district

The existence of the similar ore deposit to La Deseada ore deposit is expected beneath the geochemical anomaly of Co. Mokho. Besides, as the alteration zone of Co. Mokho is continuously extended to La Deseada mine, the mineralization of two areas is probably connected.

Brecciated enargite ore collected from the Guadalupe mine suggest that existence of high sulfidation type epithermal mineralization. It is also inferred that two stages of mineralization have probably taken place.

A large number of lead-zinc-bearing veins are confirmed in propylitic rock in the Iranuta section of Chorka - Iranuta prospect. Although the mineralization of its area, believed to be epithermal Pb- Zn mineralization associated to hypabyssal activity caused by rhyolite intrusive rock in the north, are not expected large in scale.

In the Mt. Chorka, the size of mineralization may be small however a intrusive rock is inferred below the Mt. Chorka and hypabyssal intrusive activity related type and a high sulfidation epithermal type gold and silver mineralization is expected.

Panizo district

Large number of geochemical anomalies is confirmed in Panizo prospect of Panizo district. Epithermal type Au- Ag- Pb- Zn mineralization, or high sulfidation type Au- Ag- Cu mineralization is expected in the prospect. Possibilities of deposits expected at not so deep from the surface

Sailica district

There is a possibility of overlapping of high sulfidation type Au- Ag- Cu mineralization on epithermal Au- Ag- Pb- Zn deposit related to shallow volcanic activity.

Overall Evaluation

There are no strong reasons for further exploration can be suggested as the result of the project, although the three phase of the survey revealed detailed and information for the geology and mineralization of the area.

Exploration Guidelines for the Future

The recommendations for further explorations are summarized as follows, for in case of re-evaluating the potentiality of the Oruo - Uyuni Area and the adjacent Western Andes Region.

(1) Recommendations for exploration of epithermal type mineralization

The analysis of remote sensing data is a useful tool for selecting a hydrothermal alteration zone from a wide area. The potential mineralized zone should be selected by geochemical investigations. Further detailed geological investigations should be mentioned with the following viewpoints.

i) Existence of ore bringers (domes and intrusive rocks).

ii) Existence of hydrothermal fluid paths (mineralized solution).

iii) Repetitive supply of hydrothermal fluids (overlap of igneous activities).

The analytical study should be mentioned for the following viewpoints.

a) Dissection degree of volcano: distribution of igneous rock age, homogenization temperature of fluid inclusions, geochemical anomalies and alteration minerals, etc.)

b) Evaluation of the vertical position in mineralization: distribution of alteration minerals, geochemical anomalies and gangue minerals.

Those districts with high potential that are narrowed down in this detailed geological survey should preferably conduct geophysical exploration and drilling exploration to reveal the deep geological structures and mineralization.

(2) Recommendations for exploration of porphyry type mineralization

Th mineralized ages of Chilean porphyry copper deposits have a tendency to become younger from west to east. It shows the potentiality of this type mineralization in the volcanic region of the Western Bolivian Andes. But at the younger volcanoes, the porphyry type mineralization would be located quite deep underground if it exists.

Therefore it is desirable for a detailed investigation of volcanic stratigraphy (especially in dating the age of volcanic rocks) of the Western Andes Region as basic information for the explorations. It also should be important information for the exploration of the epithermal type mineralization mentioned above.

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PART I   GENERAL REMARKS

Chapter 1 Outline of the Survey

1-1 Survey Area and Purpose of the Survey

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.

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.

For effectively selecting a potential area for a mineral deposit in the short-term, a geological survey to reveal the geological setting and occurrence of mineral deposits will be carried out in the Oruro-Uyuni region, Republic of Bolivia.

1-2 Methods of the Survey

The survey was conducted for three years starting from the FY1999.The survey methods employed in the respective years are shown in Fig.I-1-1, while the work quantities by survey method are recorded in Table I-1-1. Extraction of areas that have potentialities of promising ore deposits were made as shown in Fig.I-1-2

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 4 districts (Turaquiri- Asu Asuni-chullcani, Sonia – Susana, Calorno District and Loma Llena Districts) with total area of 2,000 km^2 delimited within the survey area.

For Phase II, different scales of geological and geochemical surveys were carried out in the six districts of Phase I and ten new districts for Phase II for a total of 16 districts. Furthermore, chemical analysis was done for stream sediment samples taken by a counterpart organization of the Bolivia government.

Sub-detailed geological and geochemical surveys (scale of 1/10,000) were carried out in the districts of Turaquiri, Asu-Asuni and Chullcani, where alteration zones are rather smaller (survey area of 60 sq. km with total route length of 66 km).

Regional geological and geochemical surveys (scale of 1/25,000) were carried out in the districts of Sonia-Susana, Calorno and Loma Llena, where alteration zones are relatively larger (survey area of 330 sq. km with route length of 192 km).

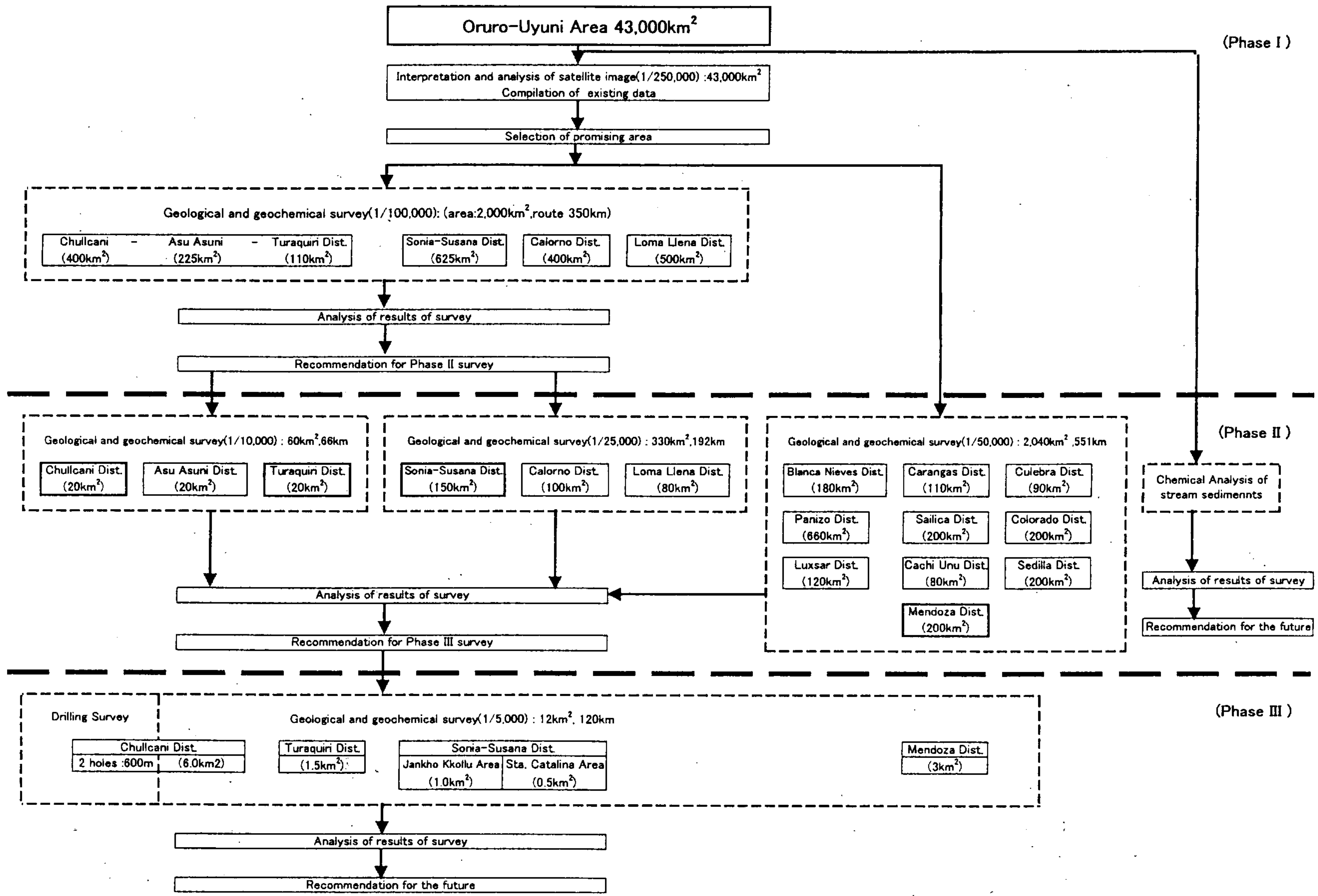

Fig.I-1-1 Flow Sheet of the Survey

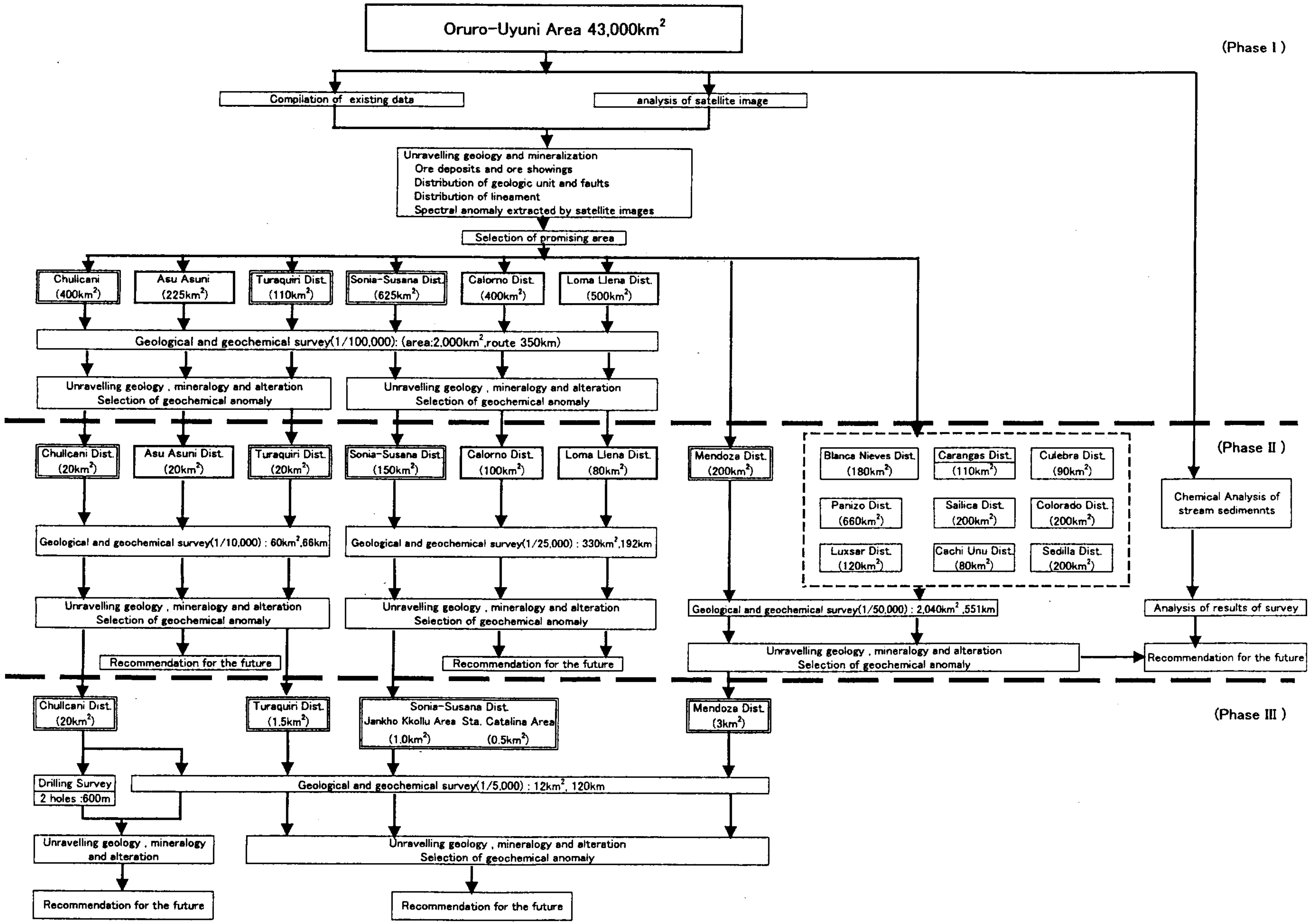

Fig.I-1-2 Flow Chart of Selection of the Promising Area

Also regional geological and geophysical surveys (scale of 1/50,000) were carried out for the districts of Blanca Nieves, Carangas, Culebra, Mendoza, Panizo, Sailica, Colorado, Luxsar, Cachi Unu, and Sedilla, which were not surveyed in Phase I (survey area of 2,040 sq. km and route length of 551 km).

For the Phase Ⅲ survey, geological surveys were conducted in four promising districts, which identified by the Phases I and Ⅱ surveys (Turaquiri, Chullcani, Sonia - Susana and Mendoza Districts). A drilling survey was also conducted in the Chullcani District (See Table I-1-1). Sampling and laboratory tests were conducted (Table I-1-2).

Ttable I-1-1 Methods and Contents of the Survey

	Phase I (1999)	Phase II (2000)	Phase III (2001)	Total (1999-2001)
Satellite Image Analysis	43,000km^2			
Geological Survey (1/100,000)	2,000km^2 350km			2,000km^2 350km
(1/50,000)		2,040km^2 551km		2,040km^2 551km
(1/25,000)		330km^2 192km		330km^2 192km
(1/10,000)		60km^2 66km		60km^2 66km
(1/5,000)			12km^2 120km	12km^2 120km
Drilling Survey			2 holes 600m	2 holes 600m
Laboratory Studies				
Chemical Analysis(rock)	800	2,600	710	4,110
〃 (ore)	30	150	10	190
〃 (stream sediments)	—	2,000	—	2,000
Thin Section	50	80	25	155
Polished Section	30	50	10	90
X-ray Diffract. Analysis	50	280	110	440
Fluid Inclusion	10	20	—	30
K-Ar Dating	10	28	—	38

1-3 Period of the Survey and Survey Team

Period of the survey for three years and members of the survey team are shown in Table I-2 , Table I-3.

Table I-1-2 Period of the Survey

	Period of Field Survey	Period of Analysis
Phase I	Feb.1 ,2000～Mar.7, 2000	Jan.17,2000～Mar.15,2000
Phase II	Nov.11,2000～Feb.9, 2001	Dec.1 ,2000～Mar.10.2001
Phase III	Jul.31,2001～Oct.20,2001	Aug.15,2001～Jan.15.2002

Table I-1-3(1) Members of the Survey Team (1)

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

Table I-1-3(2) Members of the Survey Team (2)

JAPAN	BOLIVIA SERGEOMIN
(Phase Ⅰ) HASHIMOTO Morio (Head) (Chief Geologist) NAKAMURA Kiyoshi (Geologist) KITA Barry (Geologist) KATSUNO Yutaka (Geologist) INOUE Toshio (Geologist) ISOGAI Koichi (Geologist) ADACHI Kazuhiro (Geologist)	(Phase Ⅰ) Fernando Murillo Salazar(Coordinator) (Chief Geologist) Ivar Alcocer Rodrigez (Geologist) Oscar Almendras Alarcon (Geologist) Manuel Menacho Leon (Geologist) Guido Quezada Cortez (Geologist) Yerco Santa Cruz Salvatierra (Geologist)
(Phase Ⅱ) HASHIMOTO Morio (Head) (Chief Geologist) TAKEBE Akimitsu (Geologist) ISOGAI Koichi (Geologist) KATSUNO Yutaka (Geologist) HIBI Fukuji (Geologist)	(Phase Ⅱ) Fernando Murillo Salazar(Coordinator) (Chief Geologist) Ivar Alcocer Rodrigez (Geologist) Oscar Almendras Alarcon (Geologist) Manuel Menacho Leon (Geologist) Guido Quezada Cortez (Geologist) Yerco Santa Cruz Salvatierra (Geologist)
(Phase Ⅲ) HASHIMOTO Morio (Head) (Chief Geologist) TAKEBE Akimitsu (Geologist) HIBI Fukuji (Geologist)	(Phase Ⅲ) Fernando Murillo Salazar(Coordinator) (Chief Geologist) Yerco Santa Cruz Salvatierra (Geologist) Girberto Borja Navarro (Geologist) Manuel Menacho Leon (Geologist) Guido Quezada Cortez (Geologist)

Chapter 2 Antecedents of the Survey

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.

At the Sailica District, GEOBOL (Servicio Geologico de Bolivia) has compiled geological map in 1965, furthermore in 1995 geological-geochemical survey and IP survey were carried out by the same public corporation with the German Aid.

At the Chinchilhuma prospect in the Panizo District, in 1995, geological-geochemical survey and IP survey have done by aid of CIDA (Canadian International Development Agency).

On the other hand at many areas, exploration and exploitation have done by individual companies , known activities were noted in the Phase II report, but the details are unpublished.

Chapter 3 General Geology

3-1 General Geology in 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)

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 neritic 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 mountaintops.

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

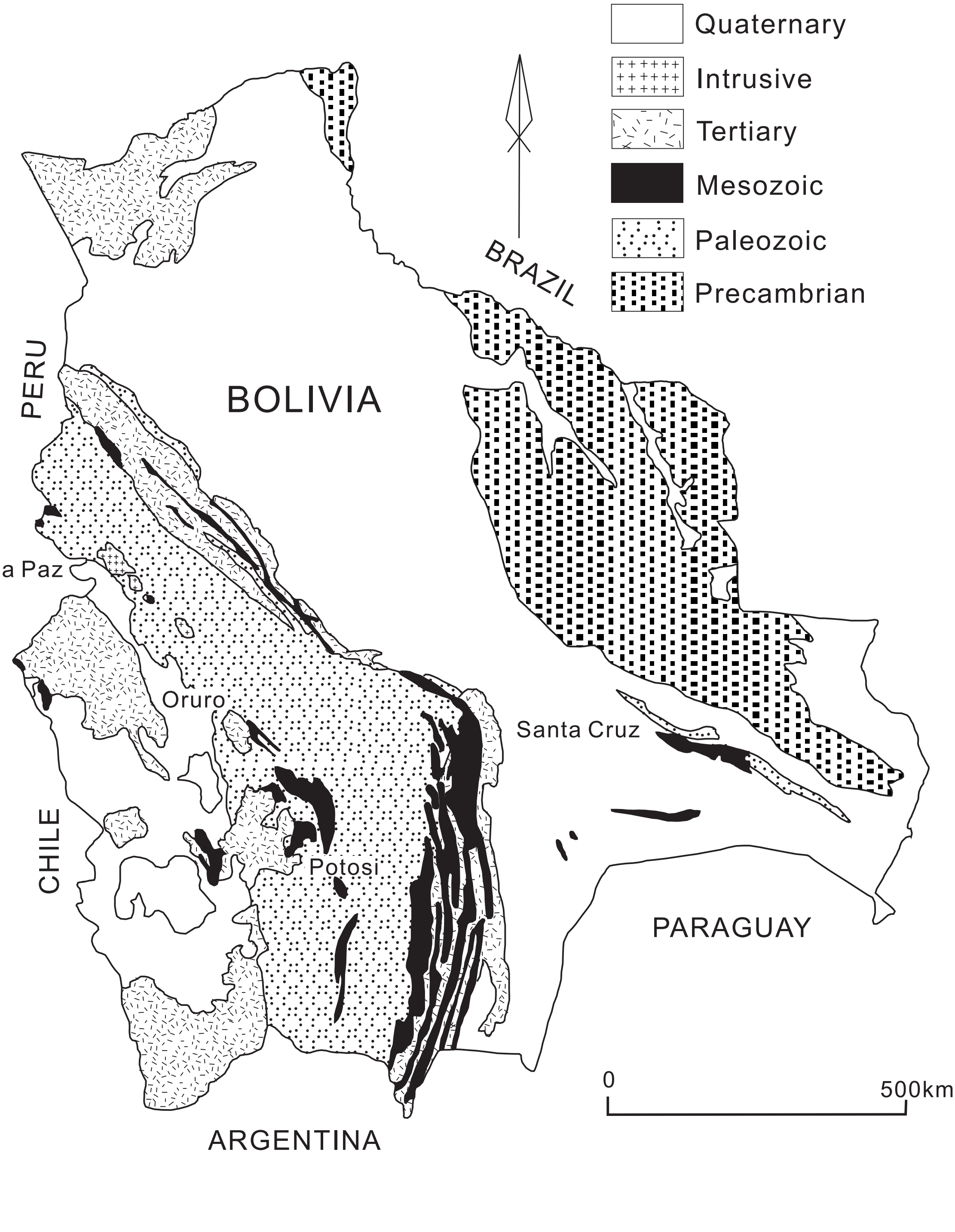

Fig.I-3-1 Geological Map of Bolivia

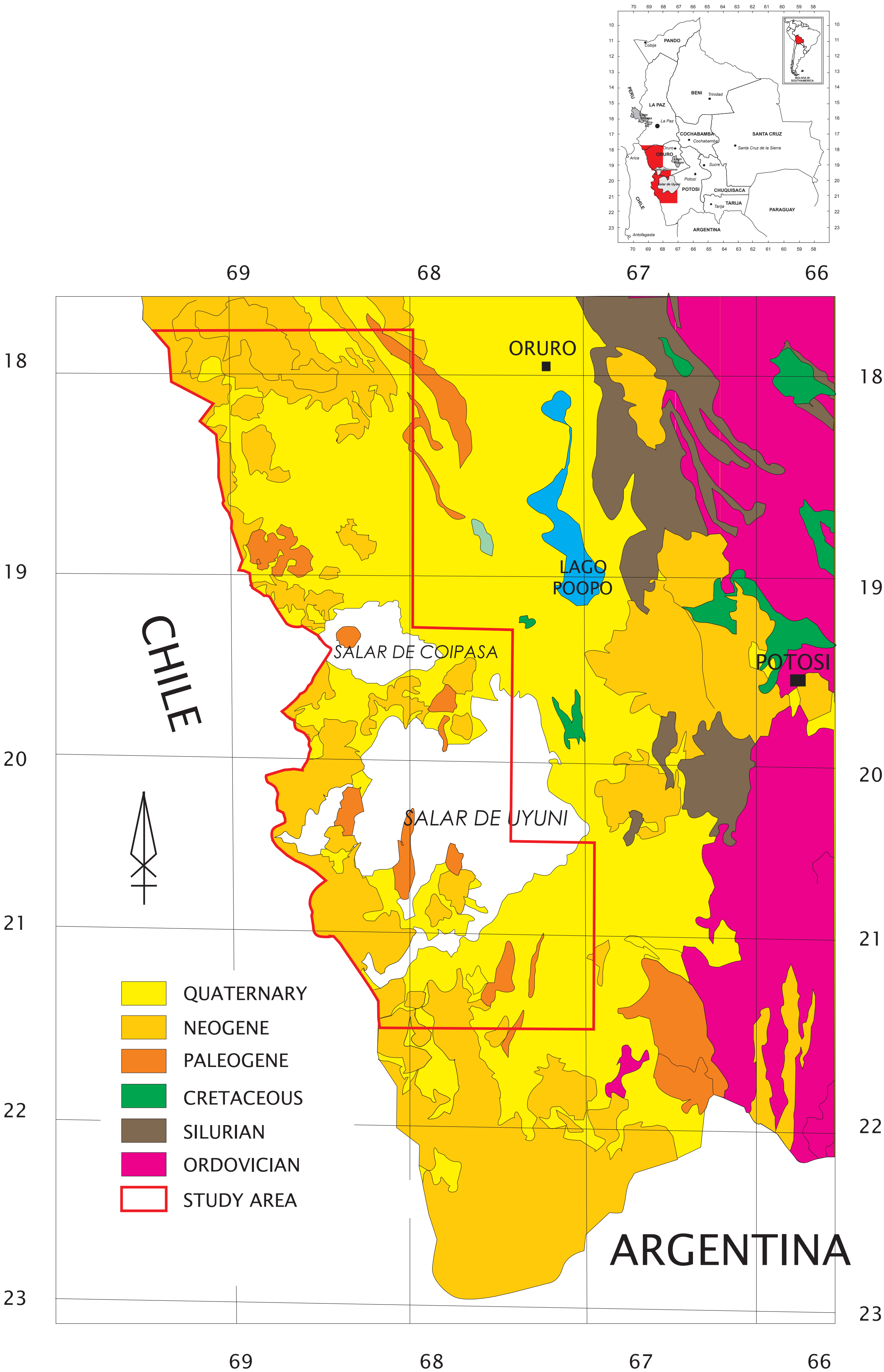

Fig. I-3-2 Schematic Geologic Map of the Area

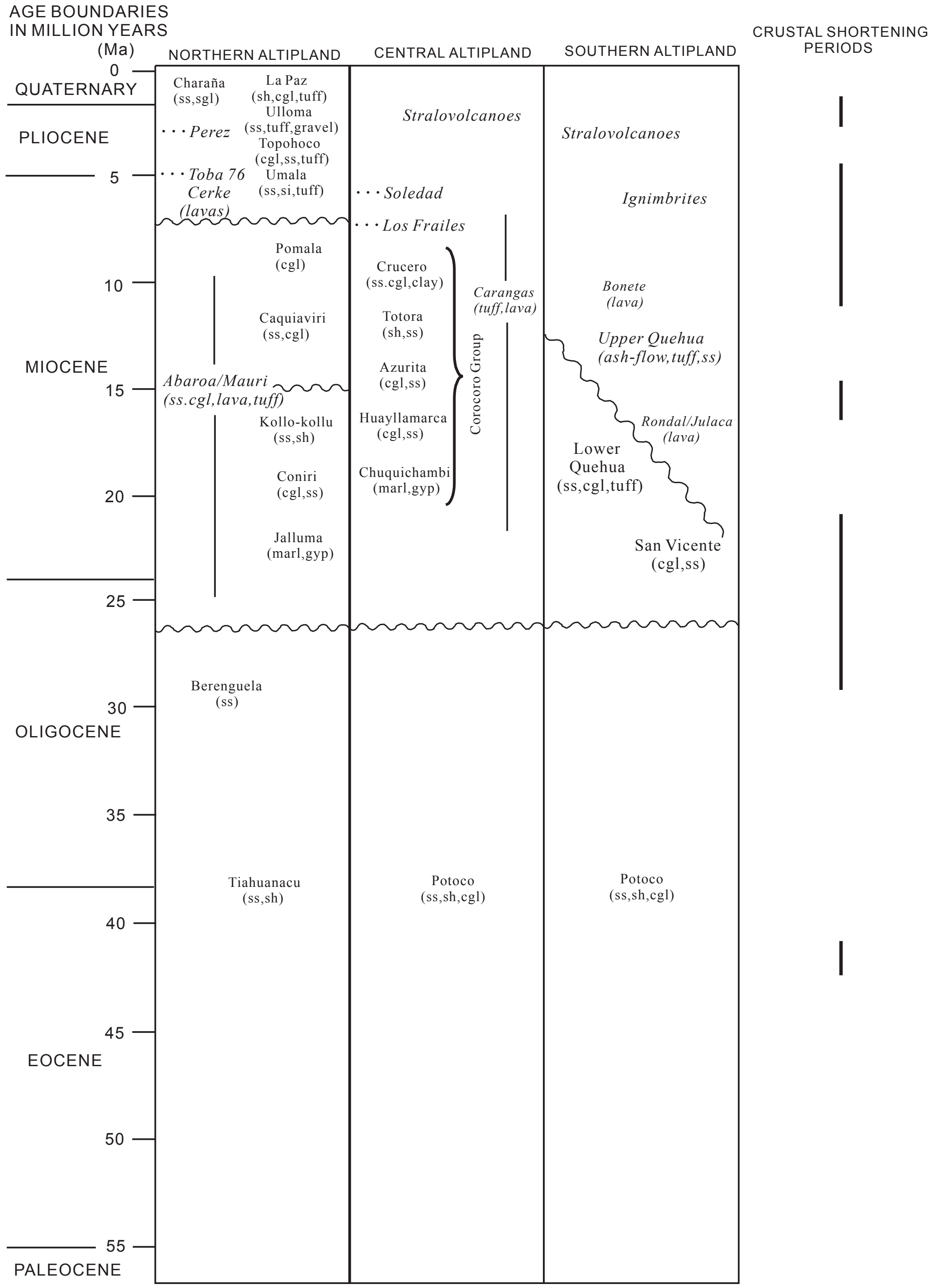

Fig.I-3-3 Schematic Geologic Column of the Survey Area

(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 folded mountains adjoining the eastern side of the Cordillera Oriental and the vast plain zones -- the Beni-Chaco Plain -- to the east.

The folded 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.

3-2 Characteristics of Mineralization in the 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.

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 .

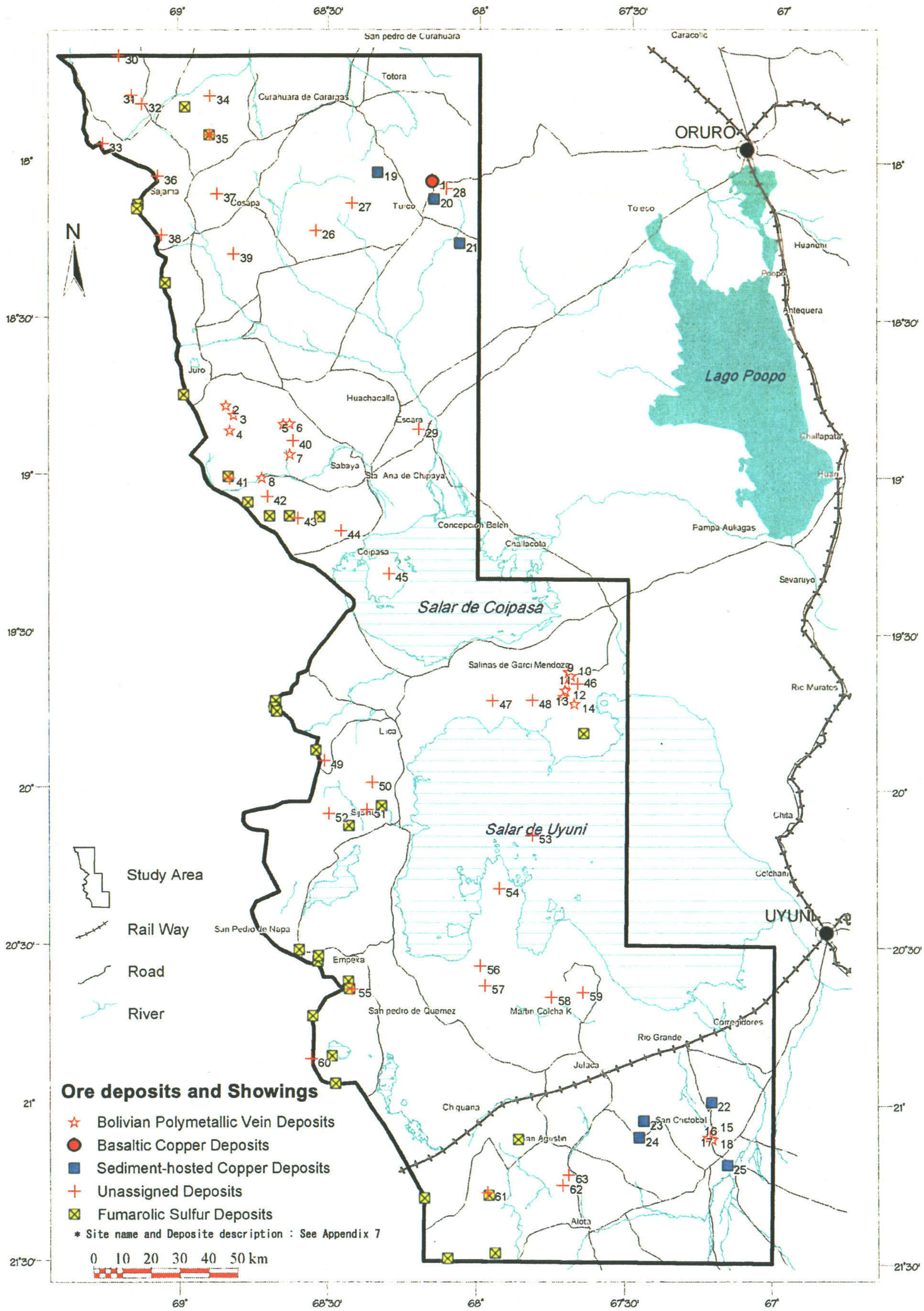

Fig. I-3-4 Ore Deposits and Showings in the Area

Chapter 4 Geographic Setting of the Survey Area

4-1 Location and Access

The study area covers three of the Bolivian departments; the most southern part of La Paz, the western part of Oruro and the northwest part of Potosí departments.

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.

4-2 Topography and Drainage System

The study area is located on 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 the extensive Puna - Altiplano plateau, which is after the Tibetan plateau that is the world highest and large plateau (700 x 200 km), is that it is covered by an extensive array of Neogene volcanic centers.

The second is a volcano chain that defines 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.), It developed 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, and runs into Salar de Coipasa.

The main rivers to drain into 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 the rainy season (December - March) making it difficult for transportation because of a lack of bridges.

4-3 Climate and Vegetation

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

The 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.

The dry season is in wintertime, and the maximum temperature rises to 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 it very cold during night. The humidity varies between 0 and 22% (Table I-2)

To describe the vegetation of the area, it is necessary to divide the Altiplano in two sections:

-Altiplano Central. - (18° - 20° 30' Lat. S) is distinguished by its cold and dry climate. As a result, large sand covers the pampas, which grows intermittently thola (lepidophyllum quadrangulare), yareta (azorella sp) and paja brava (stipa ichu). Some places cultivate quinua, potato, barley and other typical tubers.

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

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

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

As the hydrothermal alteration zones exist widely in the Oruro-Uyuni region and also mineral showings exist, it is expected to host epithermal ore deposits at depth.

Considering the mineralization in the Altiplano and the Eastern Bolivian Andes, it was interpreted that the mineralization in the Western Bolivian Andes is similar to the Bolivian-type deposit and shows an epithermal type mineralization in the upper part, while it changes to a polymetallic mineralization in the lower part.

It is reported that the mineralized ages of Chilean porphyry type deposits have a tendency to become younger from west to east and the porphyry type deposits were expected.

Sixteen Districts were studied in three years.

After the surveys lots of matters about the mineralizations in the Oruro-Uyui region still remained unknown, nevertheless the following things became clear.

1) The satellite image analysis was proved to be useful for selection of alteration zones, as alteration zones selected by satellite image analysis in this survey well coincided with the results of the ground truth.

2) The area is underlain by volcanic rocks of early Miocene to Pleistocene, ther ages,however,showed irregular distributions.

3) Alteration minerals in the volcanic rocks showed a zonation of crystobalite zone, quartz zone, quartz-sericite zone from the outer part to the center part. Quartz-sericite zone in the volcanic rocks of Late Miocene or younger, is generally absent or small if exists, while quartz-sericite zone in the volcanic rocks of the Middle Miocene or older is widespread.

4) The vein materials showed a variation of clay, clay-silica, silica and quartz from the outer part to the center part. Manganese oxide is shown inside of clay in some place. In either case, quartz zone is acompanied by ore minerals such as gold, silver, copper, lead and zinc.

5) Results of the chemical analysis of samples from the La Deseada vein exposed from the top to the bottom, values of (gold), (copper), lead, arsenic and antimony are higher in the upper part of the mineralization, and those of gold, silver, copper, lead, zinc and

antimony increase in the lower part of mineralization. Combination of these factors and vein character is a good indicator to consider the portion of a mineralized zone in the same area as Mendoza District.

6) Homogenization temperatures and salinities of fluid inclusions showed difference of ore solutions by each vein. Veins showing low temperatures like the La Deseada vein indicate the possibility of ore deposits underneath.

7) It is not cleared whether the quartz(calcedny)-barite vein changes to Bolivian-type? Polymetallic vein, as drilling survey was carried out only in the Chullcani. The reasen why no sulfide vein was confirmed in the ore showings in the older volcanic rocks, some part of mineralization in the Western Andes and Altiplano is considered to be different from the bolivian-type mineralization in the east.

8) Positive showing suggesting the existence of the porphyry type deposit could not be confirmed .

Conclusions of principal districts are as follow.

Turaquiri district

Many veins mainly of manganese dioxide are confirmed northwest of Turaquiri Deposit.

Most of them, however, are less than 10 cm in width and mineralizations of network and dissemination types are not confirmed.

The observation in the field suggests that veins beneath the manganese dioxide might change to Ag- Pb- Zn- Cu veins, but their size is insufficient for a bulk mining operation.

Chullcani district

It is interpreted that Volcano Chullcani is a single stratovolcano and subsequent erosion denuded the center part of the volcanic body exposing the tip of diorite. A quartz-sericite alteration zone shows that diorite intrusive rock is the center of hydrothermal activity. Two drill holes were carried out in the diorite intrusive rock and at the slope where is inferred to be a local center of hydrothermal activity. After drilling dominant hydrothermal alteration zones were confirmed. However, significant mineralization was not intersected.

Possibilities remain for deposition of epithermal gold mineralization ore deposits in the southeastern part of the MJBO-2 drill hole related to intrusive activity in shallow parts.

However, the facts that Volcano Chullcani is interpreted as a stratovolcano and the gold geochemical anomaly on the surface is not dominant in the deeper parts suggest possibilities that gold mineralization was weak in general.

Sonia - Susana district

In Jankho Kkollu it is possible that the volcano was formed later than the time when the Carangas Formation was formed in Middle Miocene, instead of Upper Oligocene to Lower Miocene.

Many lead-zinc bearing barite-quartz veins are confirmed in areas south of the intrusive rock body. A limonite vein was confirmed north of the intrusive rock body.

The mineralization of this area is estimated to be epithermal Ag- Pb- Zn- Cu deposits related to a hypabyssal rock intrusion activity in a shallow place. However, ore veins in the south part are discontinuous and small in size. The veins in the north part are also very small. Therefore, ore deposits should not be expected to be large.

Geochemical anomaly of molybdenum shows that the porphyry type mineralization is expected for the Santa Catalina Prospect in the Sonia- Susana District. However, positive signs suggesting its existence are not confirmed.

Calorno district (Fig. I-4-2(5))

The hydrothermal alteration zones widespread in the district are considered to situate at the topmost (outermost) parts of the alteration zones.

At the place where gossan, mainly of geothite, occurs along the Rio Agua Milagro, low sulfidation type epithermal ore deposit is considerable nearby.

At some place in the northern part of the survey area, it is interpreted that a hydrothermal alteration zone was formed from strong acid solution of magma origin, high sulfidation type epithermal deposit or epithermal Au-Ag-Pb-Zn deposit related to volcanic activity are expected.

Although large deposits are expected because of the existence of wide area of hydrothermal breccia, it is probable that the mineralization is weak or deep-seated, because geochemical anomaly is not remarkable

Mendoza district

The presence of epithermal Au- Ag- Pb- Zn deposit related to shallow volcanic activity is presumed in Co. Kancha. The result of K-Ar dating of the alteration minerals suggests that the hydrothermal alteration took place at least twice in the area. The mineralization, however, is probably weak or deep-seated, as the geochemical anomalies are weak and scattered.

The ore deposit of the La Deseada mine is an epithermal Au- Ag- Pb- Zn deposit related to shallow volcanic activity.

The existence of the similar ore deposit to La Deseada ore deposit is expected beneath the geochemical anomaly of Co. Mokho. Besides, as the alteration zone of Co. Mokho is continuously extended to La Deseada mine, the mineralization of two areas is probably connected.

Enargite collected from the waste dump at the portal of the Guadalupe mine suggest that there is a high sulfidation type epithermal mineralization. As the ore of enargite and pyrite is brecciated, two stages of mineralization have probably taken place.

A large number of lead-zinc-bearing veins are confirmed in propylitic rock in the Iranuta section. The mineralization in the Iranuta section is believed to be epithermal Pb- Zn mineralization associated to hypabyssal activity caused by rhyolite intrusive rock in the north and that the mineralization is different from Mt. Chorka.

Veins at Iranuta are believed to be exposed relatively deeper parts as epithermal ore deposit and large-scale ore deposits are not expected.

At the upper part of the northern slope of Mt. Chorka where acidic alteration zones are spotted, a high sulfidation type Au-Cu mineralization is expected.

Considering strong hydrothermal activity, intrusive rock are estimated below the Mt. Chorka.

Epithermal gold and silver deposits related to hypabyssal intrusive activity in shallow places are expected. The size of mineralization, however, may be small because Mt. Chorka is interpreted as a single stratovolcano.

Panizo district

In Panizo prospect of Panizo district, the mineralization of northern and southwestern parts of the area is expected an epithermal type Au- Ag- Pb- Zn mineralization, and in the central part high sulfidation type Au- Ag- Cu mineralization is expected.

In the southwestern part, mineralization of high sulfidation type epithermal deposit could be overlapped.

As the K-Ar dating of the alteration mineral showed late of Middle Miocene, erosion has been considerably advanced. As the geochemical anomalies are rather intense, if exists , its level is not so deep from the surface,.

Sailica district

The mineralization of Plasmar mine correspond to epithermal Au- Ag- Pb- Zn deposit related to shallow volcanic activity, based on the previous data and result of geochemical survey. And there is a possibility of overlapping of high sulfidation type Au- Ag- Cu mineraliztion. As there is an extensive alteration zone and remarkable geochemical anomalies, the possibility of existence of ore deposits in underground seems to be high.

5-2 Recommendations for the future

There are no strong reasons for further exploration can be suggested as the result of the project, although the third phase of the survey revealed detailed and information for the geology and mineralization of the area.

However, the recommendations for further explorations are summarized as follows, for in case of re-evaluating the potentiality of the Oruo - Uyuni Area and the adjacent Western Andes Region.

(1) Recommendations for exploration of epithermal type mineralization

The analysis of remote sensing data is a useful tool for selecting a hydrothermal alteration zone from a wide area. The potential mineralized zone should be selected by geochemical investigations. Further detailed geological investigations should be mentioned with the following viewpoints.

i) Existence of ore bringers (domes and intrusive rocks).

ii) Existence of hydrothermal fluid paths (mineralized solution).

iii) Repetitive supply of hydrothermal fluids (overlap of igneous activities).

The analytical study should be mentioned for the following viewpoints.

a) Dissection degree of volcano: distribution of igneous rock age, homogenization temperature of fluid inclusions, geochemical anomalies and alteration minerals, etc.)

b) Evaluation of the vertical position in mineralization: distribution of alteration minerals, geochemical anomalies and gangue minerals.

Those districts with high potential that are narrowed down in this detailed geological survey should preferably conduct geophysical exploration and drilling exploration to reveal the deep geological structures and mineralization.

(2) Recommendations for exploration of porphyry type mineralization

Th mineralized ages of Chilean porphyry copper deposits have a tendency to become younger from west to east. It shows the potentiality of this type mineralization in the volcanic region of the Western Bolivian Andes. But at the younger volcanoes, the porphyry type mineralization would be located quite deep underground if it exists.

Therefore it is desirable for a detailed investigation of volcanic stratigraphy (especially in dating the age of volcanic rocks) of the Western Andes Region as basic information for the explorations. It also should be important information for the exploration of the epithermal type mineralization mentioned above.