4) Proyect Minero Rio Negro

Under the agreement between the Rio Negro province government and SEGEMAR, information systematization by GIS (Geographic Information System) is being executed on geology, mineral deposits, geophysical data, geochemical data and industrial raw materials. The fruits were published in the form of CD-ROM in 1998.

5) Chile-Argentine mining treaty

In order to improve an environment to promote mineral resource development around the border between Chile and Argentina, both governments agreed a mining treaty in December 1997. However, parliamentary approval in both countries was suspended because of a certain issue on the southern border. To solve this bottleneck, a new border treaty was signed and approved by the parliaments of both nations in June 1999, and finally ratified by the presidents of both nations in August 1999. Consequently, the mining treaty will now be tabled for parliamentary approval.

When the mining treaty is ratified, the mineral resources of Argentina can be exported from Chilean ports beyond the border, and the furtherance of Argentine mineral resources development can be expected in the area along the border with Chile.

Chapter 4 Synthetic interpretation on survey results

4-1 Existing data analysis

Much of the existing data on the survey areas was collected through the "Project finding in Argentine Republic" conducted by JICA/MMAJ from February 15 to March 12, 1999. Additional collection of existing data was conducted in this survey. The organizations from which the data was collected are SEGEMAR, Mining Direction (Direccion de Mineria) of provincial governments, CORMINE S.E.P., Minera Andacollo Gold S.A., and Minera el Desquite.

In SEGEMAR, information was collected from its head office in Buenos Aires, the General Roca branch in Rio Negro province, and the Comodoro Rivadavia branch in Chubut province. The General Roca branch covers Neuquen, Rio Negro and La Pampa provinces. The Comodoro Rivadavia branch covers Chubut, Santa Cruz and Tierra del Fuego provinces.

Among the Mining Direction of provincial governments, the Neuquen province has office in Zapala City. The Rio Negro province has branch office within SEGEMAR's General Roca branch. The Chubut province has branch office in Esquel City.

CORMINE S.E.P. is a public mining corporation established by Neuquen provincial

government. Its head office is located in Zapala City. Minera Andacollo Gold S.A. is a private company operating Andacollo gold mine in Neuquen province. Minera el Desquite is a private company exploring for gold at Joya del Sol deposits in Chubut province. A list of data collected from each organization is shown in Appendix-1.

Fig. II-1-1 shows the distribution of known deposits in the survey area based on existing data, distribution of classified magmatic arcs closely related to the mineralization, and distribution of alteration zones extracted from the LANDSAT TM image analysis. The data on the known deposits are mainly based on the reports of Zappettini (1998) and Zanettini et al. (1999). The distribution of the magmatic arcs in each period that are closely related to mineralization was arranged from the GIS data-set of Zappettini (1998). The LANDSAT TM image analysis was carried out in this survey.

According to Zappettini (1998), the following deposits are expected in the survey area; porphyry Cu-Au-Mo deposits, skarn deposits, high- and low-sulfidation epithermal Au deposits, auriferous polymetallic vein deposits, manto-type deposits and sedimentary Cu-U deposits. In consideration of the geological conditions based on the existing data analyses and the economic viability for mine development, ore deposit types with high priority to be surveyed are porphyry Cu-Au-Mo depoits, high- and low-sulfidation epithermal Au deposits and auriferous polymetallic vein deposits. All of them are closely related to activities of magmatic arcs. Therefore, eight districts were selected as high priority survey districts where known deposits of above mentioned three types are distributed and hydrothermal alteration zones were extracted by the satellite image analysis in periphery of the known deposits. Among them, six districts were surveyed by the ground truth survey based on the conditions of accessibility and consultation with SEGEMAR.

4-2 Satellite image analysis

The satellite image analysis was carried out as follows. False-color synthetic image (BGR = 1,4,5; scale: 1:250,000) and color-ratio composite image (BGR = 3/1, 4/5, 5/7; scale: 1:250,000) were prepared for 13 scenes from data of LANDAST No. 5 and No. 4 partly. The 13 scenes cover the survey area, and it is adjacent to the south side of the Eastern Andes area of lat. 28° S to 35° S, long. 67° W and westward, where the previous JICA/MMAJ project was conducted from 1997 to 1998. Then, photogeological interpretation, analyses of lineaments and extraction of alteration zones were executed.

The referential data for photogeological interpretation is as follows; Mapa Geológico de la Província del Mendoza (scale: 1:500,000), Mapa Geológico y de recursos minerales de la Província del Neuquen (scale: 1:500,000), Mapa Geológico de la Província del Rio Negro (scale: 1:750,000) and Mapa Geológico de la Província del Chubut (scale: 1:750,000). The results of

interpretation were generally consistent with the geological maps described above.

As to lineaments, there is development of N-S oriented lineaments with extension of 10 to 20 km that run throughout the area in parallel to the subduction zone on the present Peru-Chile Trench, i.e., the Nasca Plate. In addition, N-S oriented lineaments with extension of more than 100 km develop from lat. 41° S to 42° S. According to frequency and directions of the lineaments, the entire area can be divided into three domains; (1) from lat. 36° S to 40° S, (2) from lat. 40° S to 43° 30' S and (3) from lat. 43° 30' S to 45° S. Dominant lineaments are N-S oriented lineaments in domain (1), NW-SE and NNE-SSW oriented lineaments besides N-S oriented lineaments in domain (2) and multi-directional lineaments in domain (3). Many circular structures indicating the presence of intrusive rocks or calderas were extracted on Chos Malal and Zapala scenes where Tertiary magmatic arc is distributed.

On the other hand, 244 alteration zones were extracted as a result of the ratio mage analysis. These alteration zones are concentrated in six regions, which, as a whole, are aligned in almost N-S direction;

a) Northern region of Andacollo town
b) Western region of Zapala city
c) Western region of San Martin de Los Andes city
d) Region between Ñorquinco town and Esquel city
e) Southeastern region of Ñorquinco town
f) Region between Jose de San Martin town and Alto Rio Senguerr town

An interesting fact was that many of the alteration zones exist in lineament-concentrated zones in each domain. The alteration zones extracted from the satellite image analysis were confirmed in the field as the results of ground truth survey (Table II-4-1). It is indicated that the ratio image analysis is effective method to extract the alteration zones for the region with exposed rocks and sparse vegetation.

However, vegetation develops in the region from long. 71° W and westward. Particularly, the middle west to the southwest of Chubut province is forest land. Besides that high-altitude mountains are covered by fallen snow. In these regions, extraction of alteration zones is only applicable to limited exposed rocks on the mountains. Therefore, it has to be considered that all of actual alteration zones could not be extracted by the ratio image analysis.

4-3 Ground truth survey

In selecting of ground truth survey district of Phase-1, It is designed to understand the outline of whole geology of the survey area and to recognize the characteristics of typical mineral deposits as many as possible. Moreover, remote regions were excepted to conduct the survey for districts as many as possible in a short period, and consultation results with SEGEMAR was also considered.

Porphyry Cu-Au-Mo deposits, epithermal Au deposits, auriferous polymetallic vein deposits were thought to be important based on the results of existing data analysis. Interpretation was done for the field survey results and laboratory work results, these results were evaluated in comparison with a general metallogenic conceptual model.

As to alteration zones extracted from the satellite image analysis, locations to be surveyed were limited to those within a day's trip. Therefore, for places to which access was impossible, floats survey was conducted in downstream where the rivers run down from the mountains with alteration zones.

The ground truth survey was conducted for 31 districts in Phase-1 (Fig.II-3-1, Table II-3-1). Among them, 11 districts of Varvarco, Campana Mahuida, Palau Mahuida, Nireco, La Voluntad, El Bolson, Condorcanqui, Epuyen, Lago Cholila, Cerro Gonzalo, Arroyo Cascada were selected for follow-up survey in Phase-2 (Fig. II-4-2, Table II-4-2).

4-4 Control factors of mineralization

Various kinds of mineral deposits are expected in the survey areas, and the important deposits are porphyry Cu-Au deposits, epithermal Au deposits and auriferous polymetallic vein deposits, because of the economic viability for mine development.

Metallogeny and tectonic setting are inseparably related each other. Therefore, specific tectonic setting which control the objective mineralization should be primary extracted. For example, as to porphyry-type copper deposits and epithermal gold deposits, areas with intermediate to acidic igneous activity on land are selected, and, as to volcanogenic massive sulfide deposits, areas with submarine volcanic activity are selected (Sillitoe, 1980). In the cases of porphyry-type copper deposits and high-sulfidation epithermal gold deposits, areas with intermediate to acid igneous activity on land generating in a Chilean- or collision-type compressive stress field are selected. While, in the case of low-sulfidation epithermal gold deposits, restricting conditions due to a stress field are relatively small, but it is necessary to select areas with intermediate to acid volcanic activity on land such as an island arc, a back arc and a hot spot (Hedenquist, 1999). In the cases of regional scale and prospect scale with dimension narrowed, it is necessary to understand the evolution of tectonic development as

well as geological phenomena corresponding to the control factors of mineralization, in comparison with a conceptual metallogenic model of the target deposit type.

4-4-1 Supra-regional scale

Porphyry Cu deposits and epithermal Au deposits in the South American Andes are concentrated in the Cenozoic magmatic arc in the middle Andes area, commonly called the Andean Copper Belt (Sillitoe, 1992). If tectonic setting with the same conditions is recognized, the high probability for existence of deposits is expected.

The history of geological structure development in the South American Andes area is considered as follows; The South American continent had been located at the western border of the Gondowana land as a result of reunification the Rodinia Supercontinent, since its breakup in late Proterozoic. Particularly in the Pacific side, allochthonous terranes collided successively in the period between early Paleozoic and early Mesozoic. There was an active continental margin where igneous activities were generated accompanying these collisions. Events of the collisions from late Cambrian to Carboniferous are called the "Famatinia Event" and those from late Carboniferous to early Jurassic are called the "Gondowana Event". In the "Famatinia Event", there occurred collision and accretion of Cuyania (Precordillera) terrane and Chilenia terrane on the western margin of the Gondowana land, and accretionary prism and magmatic arc are formed on the western side of Cuyania terrene that located at the east to the Chilenia terrane across the oceanic basin. In the "Gondowana Event", the Patagonian terrane collided and accreted to the southern margin of the Gondowana land. After the Triassic, such collision events ceased. The Gondowana land broke up by the opening of Atlantic Ocean by "Mesozoic Event" in the Jurassic.

Plate subduction as the active continental margin from the Pacific side is presumed to begin in Paleozoic and was apparent in Cretaceous and became active as the "Andean Event" in Cenozoic. Subsequently, accretionary prisms and magmatic arcs were formed, and then Cordilleran type orogeny was generated. Subduction modes such as speeds, directions and angles were not uniform, and this diversity resulted in the generation of diversity in tectonics and igneous activity in the Andean zone. Major nonferrous metallic mineral resources in the Andean region were formed with close relation to igneous activity in these magmatic arcs.

The Southern Andes area is mainly located in Patagonia terrane, as the pre-accretion terranes. The south end part of Chilenia terrane in the north of the Neuquen province is also included in the survey area. These terranes have been influenced under the Cordilleran orogeny. Therefore, promising areas coincide with distribution of magmatic arcs related to the plate subduction from the Pacific side.

Intermediate to acidic igneous activity and mineralization related to them in magmatic

arcs, which are recognized in the survey areas, are roughly divided into the following five periods. Due to difference of tectonic settings, difference of characteristics of mineralization is observed. The five groups are (1) plutonic igneous activity of Carboniferous and subsequent volcanic activity of Choiyoi group of Permian to early Triassic, (2) volcanic rocks in the Lago la Plata formation of Jurassic and plutonic rocks of the same period, (3) volcanic rocks in the Divisadero formation of Cretaceous and plutonic rocks of the same period, (4) volcanic rocks of Paleogene and plutonic rocks of same period, and (5) volcanic rocks of Neogene and plutonic rocks of same period. It is obvious that fields of these igneous activities overlap in many places because the subduction zone was near the present Chilean Trench.

Igneous activity corresponding to (1) above is volcanic arcs that developed in the collision and accretion of the Patagonia terrane to the Gondowana land (Kay et al., 1989). In the south of South America, subduction began in the west side of the Chilenia Terrane, i.e., the Pacific side. The tectonics setting is extension tectonics that is considered to be of the Mariana-type (Ramos et al., 1986). Alcaparrosa (San Juan province: 267 ±4 Ma), San Jorge (Mendoza province: 270±4 Ma) and La Voluntad (Neuquen province: 281±4Ma) are known as porphyry Cu deposits considered to have been formed in this period (Sillitoe, 1976). In the survey areas, volcanic and plutonic rocks in this period are widely distributed in Cordillera del Viento in the north of Andacollo and in the zone extending from the area west of Zapala to the southeast between lat. 39° S and 41° S. In the survey area including La Voluntad, remarkable mineralization in this period, however, has not been found out.

Igneous activity corresponding to (2) and the early period of (3) above are characterized by highly-angled subduction of the oceanic plate from the Pacific side, as Mariana-type, in the "Mesozoic Events". In this period, manto-type deposits were generated in the volcanic arc formed on the northern part of Chilean shoreline (Sato, 1984). On the other hand, in Argentina as the back arc side, back-arc basins such as the Neuquen Basin and the Tarapaca Basin were formed. These formations continued from late Jurassic to early Cretaceous (Davidson and Mpodozia, 1996). Andesitic volcanic rocks in the Lago la Plata formation are widely distributed near lat. 42° S in the area. High-sulfidation epithermal gold deposit in Cerro Colorado of Chubut province is known in host rocks of the Lago la Plata formation (Perez and Sreda, 1989).

In the late period of (3), tectonic inversion from the Mariana-type to Chilean-type happened, and sedimentary basins disappeared and fold and thrust belts were formed in the back arc side (Ramos et al., 1996). In this period, porphyry Cu deposit of Campana Mahuida was formed in Neuquen province.

Igneous activity corresponding to group (4) resulted from Chilean-type subduction which became active from Paleocene to Miocene in particular. In Chile, large-scale mineral deposits were formed in this period, including porphyry Cu-Au deposits, and epithermal Au deposits

(Sillitoe, 1991 and 1992). Particularly, large-scale porphyry Cu deposits were formed in Chuquicamata, Escondida, El Salvador, El Abra, etc. by oblique subduction of the Nazca Plate from late Eocene to Oligocene, with intrusive rocks that are controlled by large-sized lateral faults, such as the Domeyko Fracture Zone. In the survey area, magmatic arcs in this period occurred overlapping accretionary prisms, back-arc basins and fore-arc areas of late Paleozoic, and the Cerro Caicayen deposit of Neuquen province is formed with intrusive rocks.

Igneous activity corresponding to group (5) is activity subsequent to that of (4). In the northwest part of Argentina, porphyry-type copper and gold deposits including Bajo de la Alumbrera of Catamarca province, El Pachon of San Juan province and Paramillos Sur of Mendoza province were generated.

In the survey areas as well, it is judged that the potentialoty of mineralization is higher in magmatic arcs of late Cretaceous and afterward, in which the Mariana-type subduction was inverted to the Chile-type.

4-4-2 Regional scale

In the survey areas, (1) Los Maitenes - El Salvaje is known as a porphyry Au deposit, (2) Cerro Caicayen, (3) Pino Andino, (4) Campana Mahuida, (5) La Voluntad, (6) Cerro Gonzalo and (7) Arroyo Luque are known as porphyry Cu deposits. In addition, (8) Cerro Riñon and (9) Cerro Colorado are known as high-sulfidation epithermal gold deposits. Deposits of (2), (3) and (4) are related to small-sized acid intrusive rocks of late Cretaceous and Paleogene, which intruded into sedimentary rocks in the Neuquen back-arc basin of Jurassic to early Cretaceous. They are arranged in the N-S direction between about lat. 37° 23' S and lat. 38° 12' S. This zone is considered as a fold and thrust belt and form a structural weak zone in the period of the tectonic inversion of Middle Cretaceous. Deposits of (6) and (7) exist in the distribution area of late Cretaceous batholith in the south of Esquel. Remarkable mineralization is not known in the distribution area of Neogene volcanic rocks in the survey areas. Therefore, it is judged that the potentiality of porphyry Cu and high-sulfidation Au deposits is higher in magmatic arcs of early Cretaceous to Paleogene in the survey area.

In the survey areas, low-sulfidation epithermal Au deposit is now known only in Joya del Sol of Chubut province. Besides this, neutral argillic alteration zones indicating low-sulfidation epithermal activity are known in Cushamen of Chubut province, but clear relation with tectonic setting and generation age are not known.

In the survey areas, the main auriferous polymetallic vein deposits are Andacollo (Erica and Sofia) of Neuquen province, Mina Maria of Rio Negro province, Huemules of Chubut province and Ferrocarrilera of Chubut province. Andacollo deposits hosted in the Choiyoi group have relation to Tertiary acidic intrusion. Mina Maria deposits are hosted in Paleogene

volcanic rocks and Ferrocarrilera deposits are hosted in Jurassic volcanic rocks. On the periphery of these three deposits, there are deposits of similar type. In particular, Andacollo (Erica, Sofia) and Huemules deposits are noteworthy because gold contents of these deposits are high.

Erosion after the volcanic activity is one of the important factors to know the preservation level of deposits. In porphyry Cu deposits, according to the conceptual model of Sillitoe (1995), litho cap is formed on the volcano top, high-sulfidation epithermal Au deposits are under the litho cap, and the main body of porphyry Cu deposits are formed about 2 km below the volcano top. The erosion level is determined by the balance among the uplift of magmatic arcs, glaciers, weathering and meteoric water. In the Chilean Andes, major porphyry Cu-Mo deposits develop between lat. 32° S and 34° S, and porphyry Cu-Au deposits and high-sulfidation epithermal Au deposits develop between lat. 26° 30' S and 31° S. It is considered that this difference is due to the larger depth of erosion in the southward (Sillitoe, 1991). In Cretaceous to Paleogene magmatic arcs of the survey area, acidic hydrothermal alteration zones were identified in Cerro Colorado, Varvarco and Butalon Norte. There is a possibility that kaolin clay deposits in Mina Gato and Estrella Gaucha are litho caps. In late Cretaceous to Paleogene magmatic arcs, potassic alteration zones are observed in shallow depth or on surface in Campana Mahuida, Cerro Caicayen and Cerro Gonzalo. On the other hand, acid alteration zones corresponding to high-sulfidation epithermal Au deposits or litho cap are not observed in these deposits, it can be interpreted that erosion reached the level of the deposit center. In Neogene magmatic arcs, volcanic topography is often preserved, and there is a high possibility that shallow parts of hydrothermal activity are also preserved. From this point of view, high- and low-sulfidation epithermal gold deposits are expected.

4-4-3 Prospect scale

Generally, porphyry Cu deposits and epithermal Au deposits often exist in the central part of volcanic activity, and occur in the core part of an andesitic stratovolcano or a dacitic dome complex (Sillitoe, 1991). Structural weak zones of circular structures and concentrated lineaments can be mentioned as activity fields of intrusive rocks with the mineralization. Fig. II-4-1 shows the distributions of circular structures, lineaments and known deposits.

Cerro Caicayen, Pino Andino, Campana Mahuida, and Cerro Gonzalo are known porphyry Cu deposits in the survey area. Cerro Caicayen deposits locate in the places where NNE-SSW and NW-SE oriented lineaments intersect. Campana Mahuida deposits locate in the places where NNE-SSW oriented lineaments develop. Pino Andino deposits locate in the places where NNW-SSE oriented lineaments develop. In Cerro Gonzalo, clear lineaments are not identified. Lieaments concentrated region is important as environments of intrusive

activities related to mineralization, although lineaments are not always related with mineralization.

On the other hand, many circular structures were extracted by satellite image analysis in Neogene magmatic arcs on the scenes of Malargue, Chos Malal and Zapala. On the Senguerr scene, several circular structures were extracted in Cretaceous magmatic arcs. However, any circular structures were not extracted in the porphyry Cu regions mentioned before. Extracted circular structures correspond to collapse calderas or slope collapse of Neogene volcanoes where erosion has not advanced so much.

In the relation between alteration zones and lineaments extracted from the satellite image analysis, ZA002 and ZA004 in Zapala scene, and SE002 to SE006 in Senguerr scene are located in or around the circular structures. And ZA006 to ZA033 in Zapala scene are located in lineaments concentrated region. Porphyry Cu-Au deposits and epithermal Au deposits are likely to be formed in alteration zones identified inside or near circular structures because it is the central part of volcanic activities. However, the preservation level of deposits may be deep because the erosion of volcano bodies have not been advanced so much,

Table II-4-1 shows the results of ground truth survey for alteration zones extracted from satellite image analysis. In the regions of Andacollo in Neuquen province, and Huemules and Joya del Sol in Chubut province, alteration zones were extracted with corresponding to the known deposits.

4-5 Selection of promising districts

4-5-1 Potential of mineralization

In this survey area, porphyry Cu-Au deposits, high- and low-sulfidation epithermal Au deposits and auriferous polymetallic vein deposits are expected. They were formed by igneous activities of magmatic arcs in the margin of the South American continent where the collision- and Cordillera-type orogeny occurred since Carboniferous. Therefore, these magmatic arcs are primarily selected as objectives of the survey. As mentioned above, In Mesozoic, subduction was Mariana-type in the period between Triassic and early Cretaceous, and there was an inversion to Chilean-type subduction in late Cretaceous.

In the survey area, the number of known porphyry Cu deposits is extremely smaller than that in the Copper Belt of the Central Andes in Chile and Peru. However, there are known porphyry Cu deposits in the survey area that are considered to be formed from late Cretaceous to Paleogene, including Campana Mahuida, Cerro Caicayen, and Cerro Gonzalo. The potential of the similar type deposits is expected to be high. In magmatic arcs of the same period, there are acid alteration zones with the possibility of litho cap such as Varvarco,

Estella Gaucha and Mina Gato. Cerro Colorado deposits are those of high-sulfidation epithermal Au, and there is potential of the similar type deposits and porphyry-Cu-Au deposits.

Low-sulfidation epithermal Au deposits are expected in magmatic arcs of each period regardless of the subduction types. The erosion level is one of the factors to define the potential of these deposits. In the survey area, auriferous quartz vein deposit is known in Joya del Sol district where Minera El Desquite S. A is conducting the exploration activities. It is considered that there is a high potential of the similar type deposits near the district. In addition, placer gold deposits in Rio Quillen, Rio Foyel, etc. are known in distribution areas of magmatic arcs of Permian to Paleogene. Gold deposits as sources of these placer gold are expected.

4-5-2 Selection of promising districts

Synthetical interepretation results are shown in Fig. II-4-2 and Table II-4-2. Based on the synthetical interpretation for the results of existing data analysis, satellite image analyses and ground truth survey, seven districts were selected as objectives of Phase-2 survey in second year (Fig. II-4-3). In these districts, porphyry Cu-Au deposits, high- and low-sulfidation epithermal gold deposits and auriferous polymetallic vein deposits are expected with high potential. As these deposits are closely related to magmatic arcs generated since Permian, the reasons for the selection of the districts are classified by magmatic arcs as follows. In the case that magmatic arcs overlap in the same district, they are individually described.

1) Permian to Triassic magmatic arcs

Tectonic settings at the time of formation of Choiyoi group of Permian to Triassic are considered to be Mariana-type. However, porphyry Cu deposits such as Alcaparossa deposit in San Juan province (263 ± 4 Ma) and San Jorge deposit in Mendoza province (270 ± 4 Ma) are known to the north of the survey area. There are also gold deposits in El Indio and Maricunga Belt in Chile, porphyry Cu deposits such as El Pachon in San Juan province and Paramillos Sur in Mendoza province that are related with Tertiary intrusive rocks into the Choiyoi group. Deposits of the similar type are expected in Choiyoi group distribution in the survey area.

a) Varvarco district

In this district, alteration zones of CM004 to CM007 were extracted by the satellite image analysis. Distribution of acid alteration zones and silicified rock ledges were identified in the field. The age of hydrothermal activity that formed the acid alteration zones is unknown, but

there is a possibility that the acid alteration zones correspond to the periphery of porphyry Cu deposit system. High-sulfidation epithermal Au deposits and porphyry Cu-Au deposits are expected. In addition, auriferous polymetallic vein deposits exist, precise comprehension on the condition of mineralization is necessary.

b) Nireco district

In this district, eighteen alteration zones of ZA020 to ZA037 were extracted by the satellite image analysis, in the distribution of Permian to Triassic igneous rocks. In addition, lineaments oriented NNW-SSE and NNE-SSW are concentrated in this district. Alteration zones of ZA027 to ZA029 were investigated by ground truth survey, and argillic alteration zones were identified. Although remarkable mineralization has not been confirmed, the potential of hydrothermal deposits can be expected from the presence of many alteration zones and concentrated lineaments. Porphyry Cu deposit is distributed in La Voluntad (281 ± 4 Ma), then the potential of the similar type deposits are expected.

c) Rio Quillen district

The ground truth survey was not executed for this district in Phase-1. Placer gold deposits are known all over the district. Gold deposits as sources of the placer gold are expected.

2) Late Cretaceous to Paleogene magmatic arcs

Magmatic arcs had been inverted to the Chilean-type since late Cretaceous. Particularly in Chile, large-sized porphyry Cu deposits were formed in Paleogene magmatic arcs. These magmatic arcs are the most noteworthy in Argentina.

a) Campana Mahuida district

Campana Mahuida and Pino Andino porphyry Cu deposits are known in this district, related with late Cretaceous acid to intermediate intrusives into fold belt in the western margin of the back-arc basin. Similar deposits are expected in the periphery.

b) Rio Foyel district

The ground truth survey was not executed for this district in Phase-1. Rio Foyel placer gold deposits are known in this district, and alteration zones are also extracted by the satellite image analysis. Gold deposits as sources of the placer gold are expected.

c) Epuyen district

Many alteration zones were extracted from the westward of El Bolson to the northward of Lago Cholila by the satellite image analysis. Placer gold deposit exists in the west of Epuyen.

The value of 0.24% Cu was obtained for brecciated silicified rock of float sample in Lago Cholila. Hence, the presence of porphyry Cu deposits and epithermal Au deposits are expected. On the other hand, in Condorcanqui deposits, the sulfur isotopic composition of chalcopyrite suggests the possibility of high-sulfidation epithermal Au deposits.

d) Cerro Gonzalo district

Arroyo Luque to Cerro Gonzalo porphyry Cu deposits are distributed in the granite batholith of late Cretaceous. Several characteristics of porphyry Cu system have been confirmed, such as hydrothermal breccia, small-sized secondary enrichment intersected by drilling and potassic alteration zones with chalcopyrite dissemination. Precise evaluation on the potential for the mineralization is desired.

3) Neogene magmatic arcs

a) Varvarco district

Neogene volcanic rocks are distributed from the northward to the westward of the varvaro district of Phase-1 survey, and circular structures have been extracted by the satellite image analysis. Alteration zones accompanied by mineralization are known in Cerro Blanco de Vaca Lauquen, Laguna Pajaritos, Arroyo Pajaritos, etc (CORMINE, 1996). Hence, hydrothermal deposits are expected.

b) Nireco district

Neogene volcanic rocks are distributed in and around Palau Mahuida. Erosion of volcanic rocks has not been advanced, and several paleovolcano bodies remain. Concentration of lineaments and 16 alteration zones were extracted by the satellite image analysis, in the places where these lineaments cross each other. In relating to these alteration zones, epithermal gold deposits are expected.

Chapter 5 Conclusions and proposals

5-1 Conclusions

In this survey area, porphyry Cu-Au deposits, high- and low-sulfidation epithermal Au deposits and auriferous polymetallic vein deposits are thought to be important from the metallogenesis viewpoint and economic viability for mine development.

In the whole Southern Andes including the survey area, igneous activities of the magmatic arcs were generated by the collision- and Cordillera-type orogeny since Carboniferous in the margin of the South American continent. Mineralization of above mentioned types are closely related with the activities of magmatic arcs of each period. Based on the evolution of tectonic setting, porphyry Cu-Au deposits are expected in upper Cretaceous to Paleogene magmatic arcs by the Chilean-type subduction rather than in Permian to lower Cretaceous magmatic arcs by the Mariana-type subduction. On the other hand, in Neogene magmatic arcs, high- and low-sulfidation epithermal Au deposits and auriferous polymetallic vein deposits are expected rather than porphyry Cu-Au deposits because the erosion has not been advanced.

In the LANDSAT TM image analyses, false color images and ratio images were used for photogeological interpretation, lineament analyses and extraction of alteration zones. The extracted alteration zones were confirmed in the field by the ground truth survey. The validity of ratio image analysis for exposed rock region was confirmed.

31 districts were selected for the ground truth survey of Phase-1 based on the results of existing data analysis and satellite image analysis. It is designed to understand the outline of whole geology of the survey area and to recognize the characteristics of many typical mineral deposits as much as possible. Moreover, remote regions were excepted to conduct the survey for many districts as much as possible in a short period, and consultation results with SEGEMAR was also considered.

Based on the survey results of Phase-1, 7 districts were selected for objectives of Phase-2 survey. These are Varvarco, Campana Mahuida, Nireco, Rio Quillen, Rio Foyel, Epuyen, Cerro Gonzalo districts.

In Varvarco district, Permian to Triassic magmatic arcs and Neogene magmatic arcs are distributed. In the former, high-sulfidation epithermal Au deposits and porphyry Cu-Au deposits are expected, while in the latter, high- and low- sulfidation epithermal gold deposits are expected. In Campana Mahuida district, upper Cretaceous to Paleogene magmatic arcs are distributed, and porphyry Cu-Au deposits are expected. In Nireco area, Permian to Triassic magmatic arcs and Neogene magmatic arcs are distributed, and porphyry Cu-Au deposits are expected in the former, while epithermal Au deposits are expected in the latter. In Rio Quillen district, Permian to Triassic magmatic arcs are distributed, and gold deposits are expected as sources of the placer gold. In Rio Foyel district, Paleogene magmatic arcs are distributed, and gold deposits are expected as sources of placer gold. In Epuyen district, upper Cretaceous to Paleogene magmatic arcs are distributed, and porphyry Cu-Au deposits and high-sulfidation epithermal Au deposits are expected. In Cerro Gonzalo area, upper Cretaceous to Paleogene magmatic arcs are distributed, and porphyry Cu-Au deposits are expected.

This survey is technical cooperation project through the governmental agreement. The purpose is evaluation of potential of non-ferrous metallic mineral resources in the survey area, and extraction of promising districts, and provision of the information for further exploration. Therefore, survey districts of Phase-2 survey were selected for the areas without mining properties and the areas where public sector has set up mining properties. Moreover, the areas with mining properties of private companies were also included in Phase-2 survey districts, for the promotion of mining investment by opening the report to public.

5-2 Proposals for Phase-2 survey

In the Phase-2 survey, the promising districts extracted by the Phse-1 survey should be followed-up in more detail. In addition, the ground truth survey for alteration zones that could not be approached by the time limit in the Phase-1 should also be executed in the Phase-2.

Meanwhile, the stream sediment samples collected by SEGEMAR in the past in Neuquen province should be geochemically re-analyzed, and these results can be utilized for extracting the promising area. Furthermore, SEGEMAR executed an airborne geophysical survey from lat. 37° 45' S to 39° 30' S, long. 70° 25' W to 71° W in the middle-west part of Neuquen province. The data from the magnetic and the radiometric surveys are desired to be interpreted geologically. This area includes Nireco districts and Campana Mahuida districts.

Optical Sensor (OPS) data of JERS-1 satellite which cover the area were, however, taken in the high gain mode and unavailable for extraction of alteration zones. Instead of OPS data, LANDSAT TM images are available for more detailed analysis of the alteration zones that were extracted from ratio images. This method should be applied to the area that cover the districts of the Phase-2 survey.

Fig. II-4-3 shows the objective districts of the Phase-2 survey. The following proposals are the tasks to be performed and the methods to be applied;

1) Varvarco district

This district includes the Varvarco district of Phase-1 survey. In this district, alteration zones of CM004 and CM005 were extracted by the satellite image analyses, and acid alteration zones and silicified rock ledges were confirmed in CM004 and acid alteration zones were confirmed in CM005. There is a possibility that these are corresponding to porphyry Cu litho cap. Besides, auriferous polymetallic vein deposits exist in this district. Therefore, it is necessary to identify the extension of the alteration zones and their characteristics, and to examine the possibilities of existence of high-sulfidation epithermal Au deposits and porphyry

Cu-Au deposits. As to the auriferous polymetallic vein deposits, the size and the nature of the deposits should be investigated. In addition, it is necessary to execute the ground truth survey for the hydrothermal alteration zones with mineralization, such as Cerro Blanco de Vaca Lauquen, Laguna Pajaritos, Arroyo Pajaritos, etc., distributed in the Neogene volcanic rocks near the Chilean border.

2) Campana Mahuida district

This district includes the Campana Mahuida district of Phase-1 survey. In this district porphyry Cu deposits; Campana Mahuida and Pino Andino exist. These deposits were fully surveyed by drilling in the past, but there are potentials of another unknown deposits similar to these. It is desired to extract anomalies by the results of geochemical analyses of stream sediments collected by SEGEMAR and to extract alteration zones by detailed analyses of satellite images. The geology and mineralization of this district should be investigated through the ground truth survey.

3) Nireco district

This district includes Palau Mahuida, Nireco and La Voluntad districts of Phase-1. In Palau Mahuida district, Neogene volcanoes are preserved. Together with numerous lineaments, a lot of alteration zones are extracted near the summits. These alteration zones are considered to indicate the shallow phenomenon of hydrothermal activities. It is necessary to investigate the characteristics of the alteration zones and to examine the possibility of the existence of epithermal Au deposits. In Nireco area as well, areas of concentrated lineaments and 18 alteration zones, though small in scale, were extracted by the satellite image analyses. The alteration zones are distributed in Permian granitic rocks and Permian to Triassic volcanic rocks. As alteration zones were extracted in La Voluntad district likewise, it is desired to conduct the ground truth survey to investigate the characteristics of the alteration zones and the condition of the mineralization. As yet, there are no descriptions of known deposits in the alteration zones of Palau Mahuida and Nireco.

4) Rio Quillen district

Though this district was not included in the Phase-1 survey, placer gold deposits are known in this district where Permian to Triassic granitic rocks and Paleogene volcanic rocks are distributed. Alteration zones were not extracted by the satellite image analyses, and there is a possibility that gold deposits have already been eroded. It is, however, desired to conduct the ground truth survey for evaluation of potentials on gold deposits, as sources of placer gold deposits.

5) Rio Foyel district

Though this district was not included in the Phase-1 survey, Rio Foyel placer gold deposit is known in the area where Paleogene volcanic rocks are distributed. The alteration zones were extracted by the satellite image analyses. It is desired to conduct the ground truth survey for evaluation of potentials on gold deposits, as sources of placer gold deposits.

6) Epuyen district

The district includes El Bolson, Condorcanqui, Epuyen, and Lago Cholila districts of Phase-1. In Lago Cholila district, alteration zones were extracted by the satellite image analyses, and value of 0.24% Cu was obtained for a float sample of brecciated silicified rock in the downstream. Hence, the existence of porphyry Cu deposits is expected. It is desired to investigate the characteristics of mineralization in the alteration zones by ground truth survey. In Condorcanqui district, the sulfur isotopic composition of chalcopyrite indicates the possibility of high-sulfidation epithermal Au deposits, in addition to the chalcopyrite deposit. Accordingly, investigation for the whole epithermal system is desired by ground truth survey. In Epuyen and El Bolson districts, alteration zones were extracted by the satellite image analysis, and placer gold deposits exist in Epuyen. It is desired to execute the ground truth survey for investigation of alteration and mineralization.

7) Cerro Gonzalo district

The district includes Cerro Gonzalo and Arroyo Cascada districts of Phase-1. In this district, Cerro Gonzalo porphyry Cu deposits, hosted in upper Cretaceous to Paleogene acidic intrusive rocks, are described by SEGEMAR. As the results of Phase-1 survey, presence of hydrothermal breccias with Cu oxide, small-scale secondary enrichment intersected by drilling, and potassic alteration zones with chalcopyrite dissemination were confirmed. It is desired to conduct the ground truth survey for investigation of alteration and mineralization in more detail.

In addition, the geochemical samples of about 1,000 stream sediments, rock and soil were taken by SEGEMAR in the past. These samples should be re-analyzed in order to detect the geochemical anomalies. In Arroyo Cascada district, the presence of gold mineralization was confirmed in quartz veins and silified rocks. It is necessary to investigate the size and the nature of the mineralization in more detail.