PART I: GENERAL DISCUSSIONS

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Chapter 1 Introduction

1-1 Circumstances of execution of the survey

Technical cooperation by the Japanese Government in the field of nonferrous mineral resources in the Argentine Republic was started in 1977. The main object of these surveys was to assess potentials of mineral resources in mining concession areas held by organizations related to the Argentine Government and to discover mineral deposits. The Argentine Government started a reform of mining policies in the early 1990s. Laws related to mining (the Mining Investment Law, the Mining Reorganization Law and Federal Mining agreement Law) were revised in 1993, and allotment of the roles of the public sector and private sector was clearly shown. At the same time, policies for promotion of foreign investment were set out. The role of the government was allotted to improvement and provision of basic information. Accompanying this, the regarding assistance of Japanese Government, priority was given to basic surveys to promote mining investment, and, therefore, regional geological survey program have been carried out since 1997.

The following are the projects carried out in the Argentine Republic so far.

Name of the area	Scheme	Period (Japanese fiscal year*)
Northern area	Geological Survey	1977-1980
Famatina area	Regional Development Planning	1980
Patagonia area	Geological Survey	1981-1983
Alto de la Blenda area	Geological Survey	1986-1989
Farallon Negro area	Regional Development Planning	1990-1991
Western area	Geological Survey	1992-1994
Eastern Andes area	Regional Geological Survey	1997-1998
Southern Andes area	Regional Geological Survey	1999-2000

* from April to next March

Under such situation, Secretaria de Energia y Minera, Ministerio de Infraestructura y Vivienda highly appreciated the results of the project carried out so far and requested to the Japanese government to execute a geological survey in the northwestern area of the country which has high potentialities for the existence of copper, gold and lead/zinc deposits by Official Letter F No. 408 on November 7, 2000. Considering the high potential of mineral resources in the country and the importance of contribution to resource policies of the country, the Japanese Government determined to execute a regional geological survey over two years, from the 2001 fiscal year.

1-2 Outline of the survey

1-2-1 Objectives of the survey

The objectives of the survey is to efficiently extract promising areas with potential for the presence of deposits from the wide area by carrying out analysis of the existing data (including analysis of data of airborne magnetic surveys and radioactive exploration, and interpretation of results of geochemical exploration), analysis of satellite images, and ground truth, and then by comprehensively analyzing the obtained results. It is also aimed at promoting technical transfer to organizations of the counterpart country.

1-2-2 Survey area

The survey area covers 100,000 km^2 located in the northwestern part of the Argentine Republic and surrounded by places at Long. 64.5°W. Lat. 22°S., Long. 66°W. Lat. 22°S., Long. 67.5°W. Lat. 28°S., and Long. 66°W. Lat. 28°S. Administrative districts covered by the survey extend over Jujuy, Salta, Tucuman and Catamarca provinces.

1-2-3 Method of the survey

1) Analysis of the existing data

A database was made after collecting publications by organizations related to Government of the Argentine Republic and state governments such as SEGEMAR, research paper and internal materials of mining companies. Then, analysis was carried out targeting to porphry copper and copper/gold deposits, epithermal gold deposits, SEDEX lead/zinc deposits and volcanogenic massive sulfide deposits, as deposit types which are thought to be having high economic values in the survey area.

2) Analysis of airborne magnetics and radioactive exploration

There was provision of digital data obtained by the SEGEMAR in 1998. A total magnetic map (reduced to pole) and a vertical derivative analysis map etc. were prepared from magnetic data, and Th, U and K map etc. were prepared from radiometric data. Then, geological interpretation was implemented.

3) Analysis of satellite images

Analysis of satellite images was carried out by the use of the ASTER image whose data service was started in 2001. After the selection of 15 scenes which could be analyzed at that time, alteration zones and lineaments were extracted from false color images and color-ratio composites, and by the iso-grain model method. For the area not covered by the ASTER image, analysis was made with results of analysis of the LANDSAT TM image (JICA and MMAJ, 1998).

4) Interpretation of stream sediment geochemistry

Geochemical analysis of stream sediments for 5000 samples with 48 elements and interpretation were also implemented. Samples were previously taken by Argentine side and provided to this project.

5) Ground truth

Based on analyses by the above-mentioned four methods, 28 zones of a cluster of deposits and places of mineral showings were extracted. Among representative places of mineral showings and alteration zones of them, considering records of investigations carried out so far and accessibility, 36 mineral showings and 4 alteration zones inferred by satellite image analysis were selected as ground truth zones. The survey was carried out in these representative places of mineral showings and alteration zones. The object of the survey was to grasp the geological structure, alteration and mineralization. Samples for laboratory tests were also collected and used for analysis.

1-2-4 Survey team

(1) Japanese side

Leader	Ken Nakayama	Japan Mining Engineering Center
	Ikuhiro Hayashi	Japan Mining Engineering Center
	Takashi Ooka	Japan Mining Engineering Center
	Ryu-ta Ookubo	Japan Mining Engineering Center

(2) Argentine side

Leader	Jorge Guillou	Servicio Geologico Minero Argentino, Salta
	Osvaldo Gonzalez	Servicio Geologico Minero Argentino, Tucuman
	Eulogio Ramallo	Servicio Geologico Minero Argentino, Salta
	Raul Seggiaro	Servicio Geologico Minero Argentino, Salta
	Raul Becchio	Servicio Geologico Minero Argentino, Salta

(3) Project supervisor

	NoboruFujii	Metal Mining Agency of Japan

1-2-5 Period and amount of the survey

1) Period of the survey

From August 21, 2001, to March 15, 2002 (In this period, ground truth was carried out from September 20, 2001, to November 17, 2001.)

2) Quantity of the survey

Existing data analysis: 12 days

Ground truth: 36 days

Data analysis of airborne magnetics and radioactive exploration: 67,000 km^2

Analysis of stream sediments: 5,000 samples

Analysis of satellite images: 15 scenes of the ASTER image

Chapter 2 Geography

2-1 Location and accessibility

This survey area is located in the northwestern part of the Argentine Republic and coveres over four administrative provinces. The capital of province such as Jujuy and Salta exists in the area. Regular flights from Buenos Aires are operated. Although out of the area, there are the capital of province such as Tucuman, Catamaruca and La Rioja where regular flights are also operated; therefore, access to the survey area is good. On the eastern side of the area, paved national and provincial roads are well developed, including National Road 9, and transportation from the north to south direction is convenient. In Puna region to the western side, the main road is National Road 40 running north and south. It is not paved, but the condition of maintenance is not bad. The road network is limited in the east to west direction. Bolivia is reached through La Quiaca, a town at the northernmost end. On the other hand, Antofagasta in Chile is reached through San Antonio de los Cobres.

2-2 Topography and drainage system

The topography of the survey area reflects its geology well. According to Ramos (1999), the northern part of the area is divided into four topographical zones; Puna, Cordillera Oriental, Sieras Subandinas and Sierras Pampeanas westward from the east. Puna is highlands about 3,500 m above sea level, located in the extension of Altiplano, Bolivia. Because of an inland basin, development of the drainage system is poor, and there are many salt lakes. Cordillera Oriental is also a mountainous district 4,000 to 5,000 m above sea level, extending south and north direction from Bolivia, and the south-to-north tending drainage system develops. Access is poor, and the population is also very sparse. Sierras Pampeanas comprises an alluvial basin and a mountainous district 1,500 to 5,000 m above sea level, and a south-to-north tending system develops.

2-3 Climate and vegetation

Climate and vegetation in the survey area are controlled largely by topography. Puna, the northern part of Sierras Pampeanas and Cordillera Oriental 3,500 to 5,000 m above sea level have an inland dry climate and little vegetation. In La Quiaca located on the border with Bolivia, the average daily difference in temperature is as high as 19℃, annual precipitation is 322 mm and average humidity is 50%. Particularly in the winter season from May to September, average monthly precipitation is 1.2 mm, which is an extremely small amount (Table I-2-3-1). On the other hand, in the eastern border part of Cordillera Oriental covering Jujuy, Salta and Tucuman cities, a jungle zone around 2,000 m above sea level develops, and it is humid. Salta is relatively humid, the average annual precipitation is approximately 670 mm and average humidity reaches 70% (Table I-2-3-1). The best period for field surveys is the early summer, i.e., October and November.

Table I-2-3-1 Climate table of Salta and La Quiaca

(A) Salta

Latitude 24°51'S, longitude 65°29'W, elevation 1,226 m

Month	Mean sta. press. (mbar)	Temperature (°C) daily mean	daily range	extreme max.	extreme min.	Mean vapor press. (mbar)	Precipitation(mm) mean	max.in 24 h	Relat. humid. (%)	Number of days with precip. (>1mm)	thunder-storm	fog	Mean cloud-iness (tenths)	Mean daily sun-shine	Wind preval. direct.	mean speed	Clear days	Cloudy days
Jan.	875.7	21.4	12.7	38.4	6.1	18.9	176	95	78	14	7	1	5.6	6.3	NE	1.4	0.3	15.2
Feb.	876.3	20.5	11.6	39.3	7.7	18.9	149	115	82	13	4	< 1	5.8	5.3	NE	1.1	0.9	14.8
Mar.	877	19.2	11.7	34.7	2.6	17.7	94	75	80	12	3	2	5.4	4.4	NE	0.8	1.2	17
Apr.	878.1	16.5	13	33.6	-1.2	14.1	25	55	75	6	< 1	3	5.3	4.8	NE	1.1	3	13.9
May	878.3	13.5	15.1	33.9	-4.6	11.5	6	35	74	3	< 1	2	4.5	5.1	N	1.1	6.1	11.6
June	878.2	11.1	16.6	33.1	-9.5	9.8	3	15	74	1	0	2	4.1	4.6	N	1.1	7.4	9.7
July	878.6	10.6	18.3	35	-9.9	8.4	2	5	66	1	0	1	3.2	6	N	1.4	9.3	8.1
Aug.	878.5	12.4	19.4	36.3	-6.6	8.3	4	5	58	1	< 1	< 1	3	7	NE	1.4	12	7.4
Sept.	877.7	15.9	17.7	38	-3.6	9.6	5	15	53	3	< 1	< 1	3.5	5.9	NE	1.4	6.4	8.8
Oct.	876.6	18.4	15.6	38.8	-2.2	12.3	25	45	58	6	1	< 1	4.5	5.3	NE	1.7	5.1	10.2
Nov.	875.7	20.7	14.4	39	1.8	14.8	61	45	61	8	4	< 1	4.4	5.9	NE	1.7	2.1	11
Dec.	875.4	21.5	13.7	39.5	3.9	17.2	121	95	67	12	6	< 1	4.5	6	NE	1.7	1.1	10.6
Annual	877.1	16.8	15	39.5	-9.9	13.4	671	115	69	80	26	12	4.5	5.6	NE	1.3	54.9	138.3

(B) La Quiaca

Latitude 22°06'S, longitude 65°36'W, elevation 3,459 m

Month	Mean sta. press. (mbar)	Temperature(°C) daily mean	daily range	extreme max.	extreme min.	Mean vapor press. (mbar)	Precipitation (mm) mean	max.in 24 h	Relat. humid. (%)	Number of days with precip. (>1mm)	thunder storm	fog	Mean cloud-iness (tenths)	Mean daily sun-shine	Wind preval. direct.	mean speed	Clear days	Cloudy days	Mean evap. (mm)
Jan.	672.2	12.4	14.3	27.1	-1.2	8.9	89	45	62	15	10	0	5.7	8.6	NE	3.6	0.7	16.7	184
Feb.	672.3	12.4	14.4	27	-1.2	9.2	77	35	64	12	9	< 1	5.4	8.5	NE	3.3	0.3	13.2	158
Mar.	672.5	12.2	15.9	27.8	-3.1	8.2			58	8	7	< 1	4.2	9.3	NE	3.1	3.2	8	182
Apr.	672.8	10.3	19.4	25.8	-8.7	5.6	5	35	45	2	2	< 1	3	9.7	NE	2.8	8.7	4.2	150
May	672.8	6.6	21.7	25	-12.7	3.5	1	5	36	< 1	< 1	< 1	2	9.8	S	2.8	15.2	2.9	121
June	672.8	3.9	23.3	22	-15.8	2.8	2	25	35	< 1	0	< 1	1.9	9.4	S	3.3	16.7	2.5	102
July	672.7	4	23.5	21.1	-15.2	2.9	1	5	36	< 1	< 1	< 1	1.6	9.6	S	3.1	16.4	1.7	99
Aug.	672.4	6.4	23.4	22.8	-14.6	3.2	0	15	38	< 1	< 1	< 1	2	9.8	S	3.6	15.5	2.1	132
Sept.	671.9	9.2	21.7	25.8	-12.2	4.4	2	5	38	1	1	< 1	2.6	9.6	S	4.2	9.9	3.5	177
Oct.	671.5	11.1	20.2	27.4	-10.7	5.8	9	25	44	2	3	0	3.4	10	NE	4.4	6.5	5.8	212
Nov.	671.2	12.3	18.1	28.4	-4.7	7.3	31	25	51	6	9	< 1	4.3	10.1	NE	4.4	2.2	6.1	208
Dec.	671.6	12.6	15.8	28.3	-1.2	8.4	63	25	57	12	12	< 1	5.2	9.4	NE	4.2	0.5	12.5	196
Annual	672.3	9.5	19.1	28.4	-15.8	5.9	322	45	50	59	54	2	3.4	9.5	NE	3.6	95.8	79.2	1,921

Chapter 3 General geology and recent mining activities

3-1 General geology

3-1-1 Outline of geology in Argentina and locations of the survey area

3-1-1-1 Tectonic classification in Argentina

It was shown in the paper written by Ramos et al. (in 1986) and the paper written by Ramos (in 1988) that the land of Argentina was formed in the tectonic stratigraphical way by collisions and additions of allochthonous terranes which originally had been independent (Fig. I-3-1-1-1). The land of Argentina is roughly divided into five parts; Rio de la Plata Craton, Pampia Terrane, Cuyania Terrane, Chilenia Terrane and Patagonia Terrane.

Rio de la Plata Craton is further subdivided into several small terranes, which were added around 2300 to 1900 Ma. It is considered that these small terranes were fused and concreted by Trans-Amazonic (or Tandillia) orogenic movements by the lower Proterozoic.

Pampia Terrane is basically composed of carbonate rock basements accompanied by crystalline schist and gneiss. These were a metamorphosed sequence that had been accumulated in the stable marginal sea in the period around 1000 to 900 Ma and collided with and added to Rio de la Plata Craton in about 750 Ma (the upper Proterozoic). Calc-alkali magmatic arcs prior to the suture with Rio la Plata Craton are distributed as tonalite and orthogneiss in Cordoba Province. Suture lines are shown by ophiolite or basic-ultrabasic rock zones and, probably, the largest one corresponds to the addition of Famatina in the lower Paleozoic.

In the northwestern border side of Pampia Terrane, Arequipa - Antofalla Terrane is added and forms the basement of Puna (a plateau 3,500 - 4,000 m above sea level, which extends over Puna de Atacama, Bolivia, Chile and Argentina). The present locational relationship was formed in the upper Proterozoic. Arequipa in the north side was formed in the lower to middle Proterozoic, and Antofalla in the south side was formed the upper Proterozoic to the early Paleozoic; they stretch from the north-west end to Chile, Bolivia and Peru. Arequipa-Antofalla Terrane separated from Pamia Terrane in the lower Paleozoic through the lifting process, and a marginal sea was formed between them. After that, these terranes collided again by Ocloyic orogenic movements and re-constructed suture lines. The volcanic rock belt in the western part of Puna is considered to represent magmatic arcs before the suture.

Cuyania Terrane is also called Cuyania-Precordillera Terrane; it is composed of metamorphic rocks of high- to low-metamorphic grades that were metamorphosed from 900 to 1100 Ma, and of sedimentary rocks in the early Paleozoic. It is considered from the sedimentary sequence and the age of metamorphosis of the basement that these have their origin in Grenville Zone in the east part of Laurentia. Suture lines that seem to show the addition of Cuyania and Precordillera in the Proterozoic appear on the west slope of the Pie de Palo mountains. It is deemed that Cuyania Terrane was added to Pampia Terrane around the end of the Ordovician.

One of characteristics of the basement of Chilenia Terrane is that it was covered with magmatic activities and metamorphism in the upper Paleozoic. There are evidences of deformation and metamorphism from 500 to 415 Ma in some part of the basement, which are covered with Silurian deposits. Chilenia Terrane was added to Cuyania Terrane in the upper Devonian. Those suture lines are shown by many fragmentary ophiolite rocks. Plutonic rocks and andesitic volcanic rocks forming Cordillera Frontal represent magmatic arcs prior to the suture.

Patagonia Terrane is composed of two terranes, Somuncura and Deseado. These collided in the period of Famatina orogenic movements in the lower Paleozoic, before which magmatic arcs related to subduction of Deseado crustal block had been formed. Patagonia Terrane was added to the Argentine main body in the upper Paleozoic. Activities of plutonic rocks of the Somun Cura group of the Permian System correspond to magmatic arcs prior to the suture.

3-1-1-2 History of tectogenesis in Argentina

According to Ramos (1999a), the following roughly seven orogenic movements cycles are recognized in Argentina.

Cycle	Age (Ma)	Mountains
* Andes	45 - 0	Andes
* Patagonia	98 - 75	Fueguina
* Gondowana	290 - 250	Ventania and Cordillera Frontal
* Famatina	465 - 385	Precordillera and Pampeanas western mountains
* Pampia	600 - 520	Pampeanas eastern mountains
* Grenville	1,100 - 1,050	Proto-Pie de Palo
* Tandillia	2,000 - 1,800	Tandillia

There were two ages in the Mesozoic when numerous lifted sedimentary basins were formed by tensile movements over a very wide area. These are called the Gondowana tensile cycle (from the Triassic to the Jurassic) and the Patagonia tensile cycle (in the Cretaceous).

*** Precambrian (Tandillia cycle - Grenville cycle - Pampia cycle)**

The oldest rocks in Argentina correspond to the Tandillia cycle in the lower Proterozoic and are exposed in the middle-southern part of Buenos Aires Province and on the Martin Garcia Island scatteringly. The main types of composing rocks are granite to tonalitic gneiss, migmatite and amphibolite, accompanied by crystalline schist, marble and acid to basic dykes. A distinctive feature

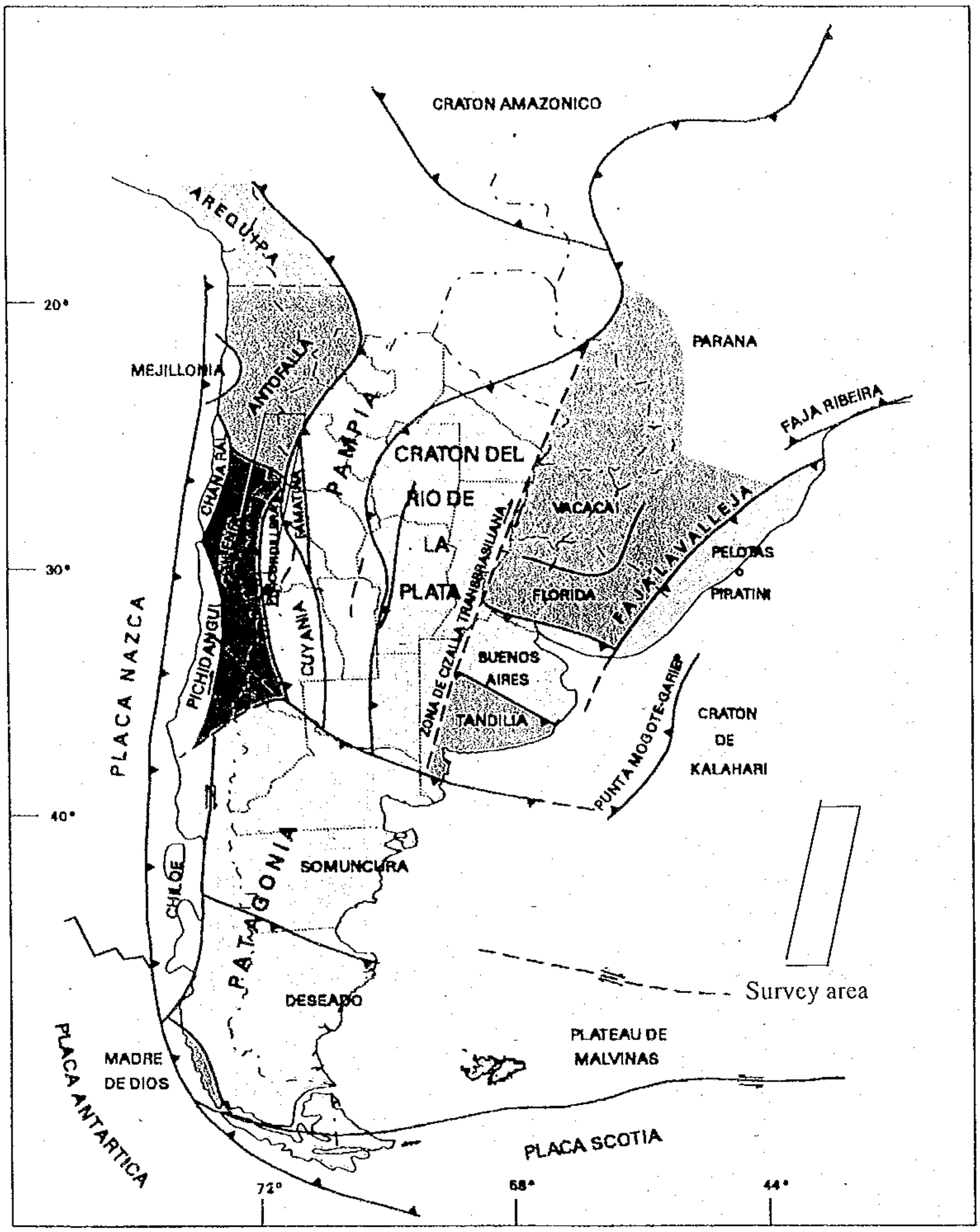


Fig. I-3-1-1-1 Accretionary terranes in the southern region of South America
(taken from Zappettini, 1998)

is development of a mylonite zone that has been highly deformed and is considered to have been formed when Tandilia Terrane collided with Buenos Aires Terrane.

It is deemed that the Grenville cycle is a cycle that formed the basement of Cuyania Terrne, and is confirmed as metamorphic basement rocks of the Pie de Palo mountains at the west end of Pampeanas mountains in San Juan Province. This basement is composed of the young crust formed by addition of island arcs in the period between 1,050 Ma and 950 Ma.

It is considered that the Pampia cycle is related to the collision of Pampia Terrane with Rio de la Plata Terrane in the upper Proterozoic. It is made up of sedimentary rocks that received diverse deformation and metamorphism, metamorphic rocks, granite rocks and volcanic rocks. Judging from granite rocks concerning subduction, the age of this cycle corresponds to the period from the upper Proterozoic to the early Cambrian. These rocks compose the basements of Puna Zone, Cordillera Oriental Zone and Sierras Pampeanas Zone. Representative rocks in the survey area are turbidite metasediments in the Santa Victoria mountains (Cordillera Oriental) and Puncoviscana layer distributed in Puna and corresponding layers. Metasediments and gneiss of the same age are also distributed in the southern part and the eastern part of Farallon Negro Region. Puncoviscana layer received folding from the lower Proterozoic to the early Cambrian; it was slightly metamorphosed and intruded by granite rocks of Cañani and La Quesera. Angular unconformity is observed between Puncoviscana layer and Cambrian sedimentary rocks above it; this is called the Tilcaric deformation event.

*** Paleozoic (Famatina cycle - Gondowana cycle)**

The Famatina cycle corresponds to a cycle that influenced the north and middle parts of Argentina from the middle Ordovician to the middle Devonian. It is composed of two crustal deformation events, Ocloyic orogenic movements of the middle to lower Ordovician and Chanic orogenic movements of the lower to middle Devonian.

In the northwestern region in Argentina, Arequipa-Antofalla Terrane collided with the Gondowana Continent in the early Cambrian but was cut off again by lifting in the period from the upper Cambrian to the lower Ordovician. On this lifted sedimentary basin, siliceous sandstone of Meson Formations of the middle to upper Cambrian and pelite of Santa Victoria group of the lower to middle Ordovician accumulated. In the upper part of Santa Victoria group in Cordillera Oriental, there is an insertion of volcanic rocks and volcanic pyroclastic rocks of the Arenig-Llanvirn series of 476 to 467 Ma, which were generated by bimodal magmatic activities of dacite and basalt. Near surface intrusive rock is also seen. These magmatic activities are recognized as the Eastern La Puna Effusion Zone (Faja Eruptiva Oriental). After these activities, the sedimentary basin was closed over in the middle to upper Ordovician, and Arequipa Antofalla Terrane and Pampia Terrane were combined again. Together with the combination, the clastic rock sequence and the igneous rocks and the volcaniclastic material sequence were deformed hard by orogenic movements with west-facing vergence, which are called Ocloyic deformation movements.

In the Precordillera - Pampeanas mountains, rocks of the Famatina cycle, are distributed in Precordillera and the Pampeanas western mountains. They now compose Cuyania Terrane. It is said that Cuyania Terrane was separated from the Laurentian Continent in the lower Cambrian and collided with Pampia Terrane around the period between 460 and 470 Ma. In Pampeanas western mountains, granite rocks and volcanic rocks related to subduction are recognized in the period between 510 and 470 Ma, and ceased in about 465 Ma. After that, Ocloyic deformation movements, which brought about intrusion activities of granite and severe deformation actions at the time of collision, started. The collision and combination of Chilenia in and after the early Devonian caused both development of foreland sedimentary basins and deformation and uplift of the basement of Precordillera. Episodes of deformation actions that took place in the Devonian are grouped as Chanic movements, which are a cause of unconformity between sediments of the Devonian system and the lime system.

The Gondowana cycle represents orogenic movements of the Andes type that developed widely along the western edge of the Gondowana Continent in the Permian. Magmatic activities are distinctive, and large-scale episodes of volcanic rocks and plutonic rocks are contained. As volcanic rocks of this cycle, those of Choiyoi group are representative. The base of Choiyoi group begins with a basic sequence related to tholeiitic magmatic arcs, the middle part has andesite and dacite, and rhyolitic volcanic rocks and volcaniclastic material are seen widely in the top. The rhyolite sequence in the top indicates that there were important tensile events after deformation actions of the Gondowana cycle. Rocks ranging from rhyolite to dacite of Choiyoi group are related to near surface intrusive rocks with similar composition, which are composed of syenitic to monzonitic granite. Granite rocks of the late orogenic period from the Permian to the Triassic spread from the south of Catamarca Province to the western part of La Rioja Province, from which part to Cordillera Frontal in San Juan and Mendoza Provinces these rocks are widely observed. In Neuquén Province, these granite rocks are distributed in the Viento mountains and Cerro Granito.

***Mesozoic (Gondowana tensional cycle - Patagonia tensional cycle - Patagonia cycle)**

In the age of the Gondowana tensional cycle (from the Triassic to the Jurassic), a wide region of the basement of the Andes and adjoining areas was put in remarkable tensional condition. Several lifted sedimentary basins appeared in the Las Malvinas plateau, the San Julian basin, the Cuyo basin, Neuquen basin and Patagonia. These lifted systems began as Triassic terrestrial sedimentary basins, and many of them became marine sedimentary basins successively in the Jurassic.

In the age of the Patagonia tensional cycle (the Cretaceous), accompanying the development of the subduction zone of the Mariana type, the back arc area was controlled by the wide tensional process along magmatic arcs. This tensional system is related to opening of the South Pacific following the Gondowana lifting system. The Patagonian lifting system developed several lifted sedimentary basins extending north and south in the middle northern part of Argentina. Several lifted sub-sedimentary basins represented by Salta group belong to this cycle. In the eastern part of Puna and in Cordillera Oriental, these tensile events are related to intrusion of granite rocks and small-scale intrusion of carbonatite in the plate.

Rocks associated with the Patagonia orogenic movement cycle (in the upper Cretaceous) are observed in the Fueguina mountains in Patagonia and in the insular region in the southern side of the Fuego Island. In these places, turbidite received deformation actions, and the ophiolite composite rock that was split accompanying them is seen.

*** Cenozoic (Andes cycle)**

The Andes cycle is an orogenic movement cycle that took place along the Andes and has continued from the late Mesozoic to the present time. This cycle is characterized by 1) fault movements accompanying uplift, folding structure and diagonal subduction of the Andes, 2) volcanic and intrusive rocks widely distributed and 3) many hydrothermal deposits. This cycle is roughly divided into two subcycles, that of the Paleogene and that of the Neogene. Both cycles are controlled by change in relative convergence speed between the Nasca plate and the South American plate.

The Paleogene subcycle is represented by volcanic rocks of the Eocene to the early Pliocene distributed west of the Arizaro salt lake in Puna, Salta Province. In connection with this, sedimentary basins subsided around Arizaro, and several thick sedimentary basins between mountains developed. In relation to this subcycle, what is known in the southern part of Mendoza Province and the western part of Neuquén Provincein is a series of several sediments at the time of orogenic movements of the Eocene, several volcanos and a center of intrusive rocks. Magmatic arcs of this subcycle are distributed on the Chilean side, enter into the Argentine side from the place around the northwestern part of Neuquén Province, and reach the middle western part of Chubuto Province through Baliroche in Rio Negro. Although andesite is dominant in the volcanic rock sequence, basalt is dominant in Mendoza and Santa Cruz Provinces. In the period of the Paleogene subcycle, the plate convergence speed of the South American plate and the Nasca plate was relatively slow, and constituents of diagonal subduction were contained. In Chile, this resulted in sideslips of the Domeyko fault system extending south and north, and, along them, there is distribution of many deposits of porphyry copper, copper and gold and epithermal deposits. On the other hand, on the Argentine side, numerous lineaments extending northwest and southeast

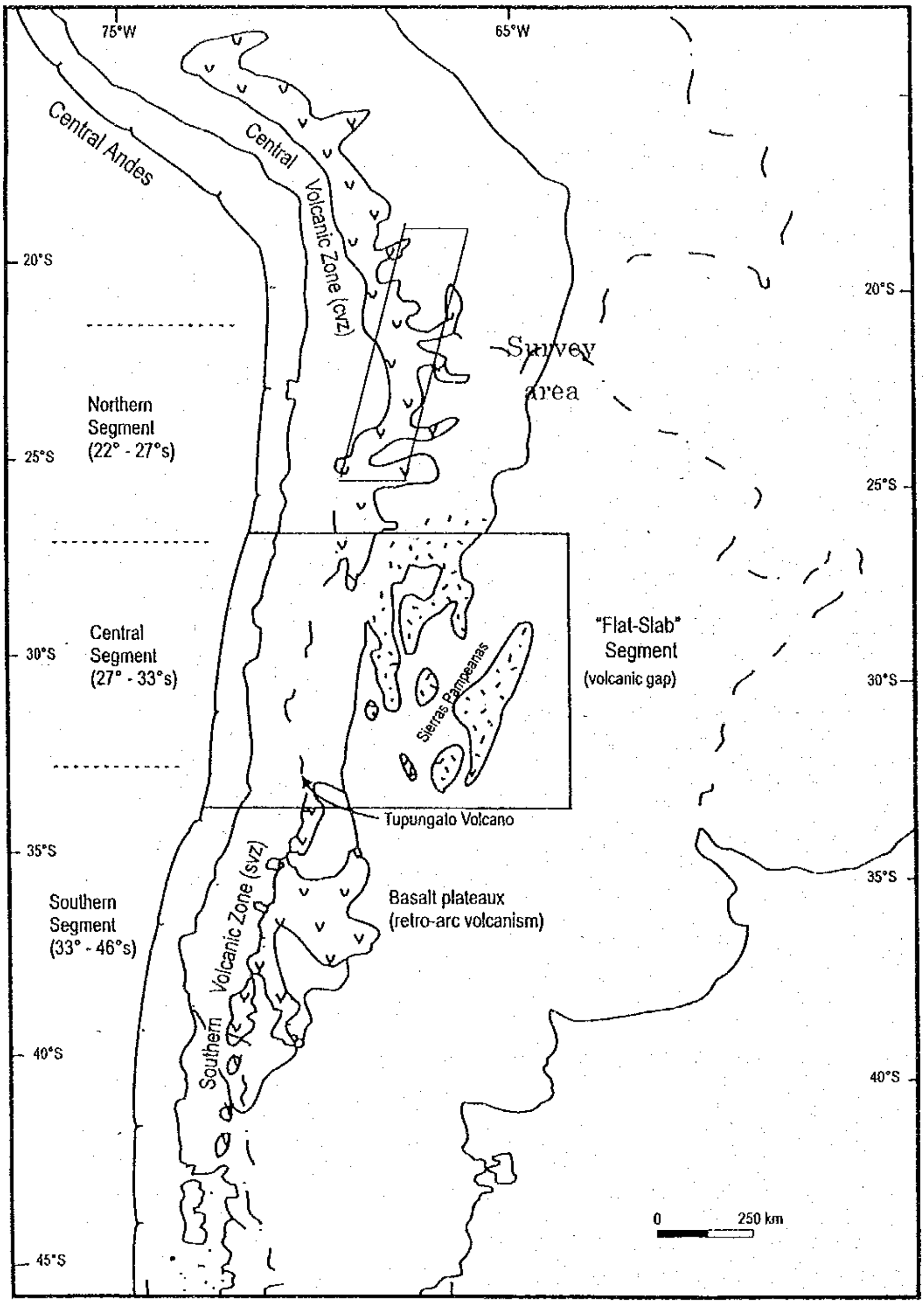


Fig. I-3-1-1-2 Major segments of Southern Central Andes related to the Nazca Plate segmentation (taken from Ramos, 2000).

developed. Among them, El Toro - Olacapato Lineament became a factor that let granite rocks such as those in El Acay intrude.

The Neogene subcycle has continued since the Miocene up to now, and shows orogenic movements and magmatic activities, whose forms differ according to latitude (Fig. I-3-1-1-2).

The northern area (at 22° to 27° S Lat.) almost corresponds to the range of Puna. Volcanic activities started around 26 Ma in the Andes on the Chilean side. After that, the accompanying dip of subduction of the Nasca plate became gentle, and magmatic arcs expanded east to the Argentine side from 17 to 12 Ma. This expansion occurred along selective structural corridors (corredores preferenciales), along which lineaments controlling stratovolcanos, volcanic domes, calderas, volcanic cone, subvolcanic rock and others were determined. Stratovolcanos are composed of andesite to dacite lava and volcaniclastic flow, while volcanic domes are made up of dacitic to rhyodacitic rocks. The expansion of magmatic arcs was accompanied by movement of the landslip front and formation of foreland sedimentary basins following it. This movement continued toward Puna, Cordillera Oriental and the Subandinas mountains from the lower Miocene to the Quaternary. In Cordillera Oriental and the Subandinas mountains, both of which are at 24° to 25° S Lat., the basement received deformation actions by inversion tectonics of Cretaceous normal faults that had formed the Salta group. On and after 12 Ma, the accompanying dip of the subduction plate became steep again, and the main magmatic activities moved to the west and flowed out to the ground surface as large-scale ignimbrite flow. Magmatic arcs in this latitude zone have been located on the Chilean side since the lower Pliocene up to now.

The central area (at 27° to 33° S Lat.) includes the highest part of the Andes in La Rioja, San Juan and Mendoza Provinces. It is characterized by a lack of volcanic activities from the late Miocene to the present time. This is related to the fact that the dip of subduction in this area became gentle in and after 18 Ma, and the crust came to have a thick formation. In this area, there were no volcanic activities in the Oligocene, but the volcanic activities restarted on the Chilean side from 26 Ma. Volcanic activities expanded to the Argentine side in Cordillera Principal around 15 to 16 Ma, then further expanded to Precordillera and reached the Pampeanas mountains in the middle to upper Miocene. At the same time, the orogenic front characterized by fold and thrust also moved to the east. These magmatic activities associated with subduction ceased later in the east places than in the west places; they ceased in Cordillera Principal and Precordillera in the period 6 Ma, and in the Pampeanas mountains in the period between 4.9 and 1.9 Ma.

In the southern area (at 33° to 46° S Lat.), the subduction speed of the plate increased in the Miocene, and a compression place was formed. This compression place is remarkable in places north of 36° S Lat., insignificant at 36° to 40° S Lat., and is not recognized in the area south of this latitude zone. Magmatic arcs of the upper Cenozoic show two different characteristics; andesite to dacite is dominant at 33° to 37° S Lat., and basalt is dominant at 37° to 46° S Lat. The dip of

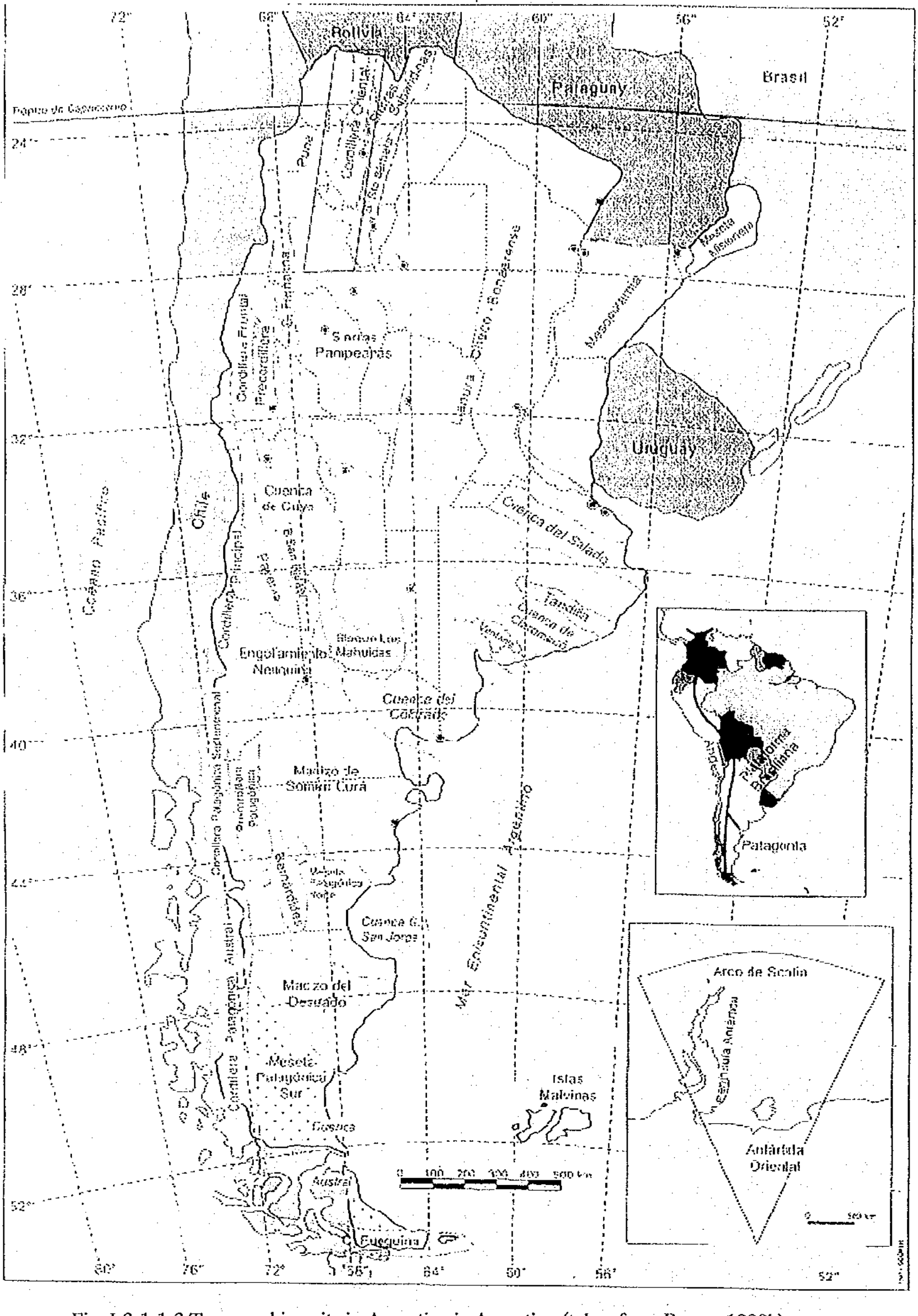


Fig. I-3-1-1-3 Topographic units in Argentina in Argentina (taken from Ramos,1999b) subduction in this area is about 30 degrees, while the dip in places around 35° to 36° S Lat. is about 40 degrees. North of 36° S Lat., Neogene foreland sedimentary basins have developed well, and thick sediment during orogenic movements are distributed.

3-1-1-3 Location of the survey area

Seeing the terrane division, the most part of the area covered by this survey is included in Pampia Terrane, and a part of the northwest area is included in Arequipa-Antofalla Terrane (Fig. I-3-1-1-1). According to geographical structure division, a part of the northwest to west area belongs to the Puna area, the north to middle part belongs to the Cordillera Oriental area, the south part to Pampeanas mountains area, the northeast part to the Subandinas mountains area and the east part to the area of the Santa Barbara system.

According to three latitude zones divided according to the dip of plate subduction in the Neogene subcycle, almost the whole survey area is included in the northern part, and only part of the southern side belongs to the central area (Fig. I-3-1-1-2). In the Andes on the Chilean side west of this survey area, Paleogene magmatic arcs are distributed, and many large-scale porphyry copper deposits (such as El Abra, Chuquicamata, Zaldivar, Escondida and El Salvador) exist, while porphyry gold deposits (represented by Maricunga Belt) exist in the Miocene magmatic arcs.

3-1-2 Geology and mineral deposits in the survey area

3-1-2-1 Geology of the survey area

Table I-3-1-2-1 shows the outline of geological stratigraphy of this survey area. The stratigraphy is shown by dividing the survey area into Puna area, Cordillera Oriental area and Pampeanas Mountains area. The schematic diagram of geology in this survey area is shown in Fig. I-3-1-2-1 and Fig. I-3-1-2-2. Although the survey area includes Subandinas Mountains area and Santa Barbara System area, these areas are not put in the stratigraphy table because they are part of the northeast to east part and do not have important places of ore indications. The summary of geology in the survey area is explained below, based on Table I-3-1-2-1.

What forms the basement of the survey area is sedimentary rocks and metamorphic rocks of the late Proterozoic to the early Cambrian, and is Puncoviscana multiple seam and corresponding layers that are distributed in the Cordillera Oriental mountains (the Santa Victoria mountains), the Cachi mountains, the Quilmes mountains and the Aconquija mountains. The distribution is relatively wide in Cordillera Oriental area and the Pampeanas mountains and little in Puna area. The kinds of composing rocks include non-metamorphic to weak-metamorphic sedimentary rocks, gneiss (tonalite and granite), crystalline schist, migmatite, marble, felsite and metamorphic basic rock.

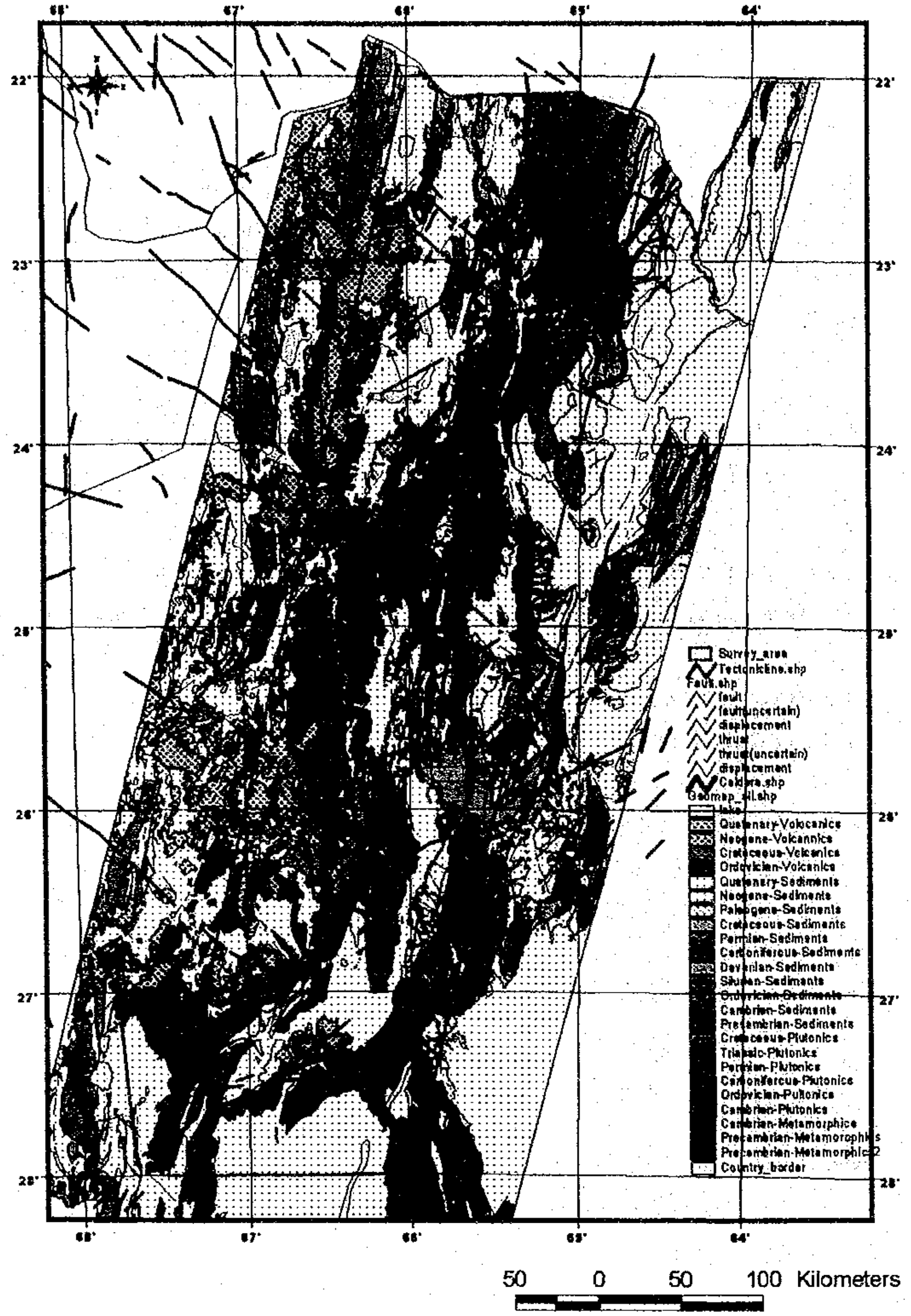


Fig. I-3-1-2-1 Geological map of the survey area (compiled from mapa geologico de la provincia de "Jujuy", "Salta", "Tucuman"and "Catamarca)

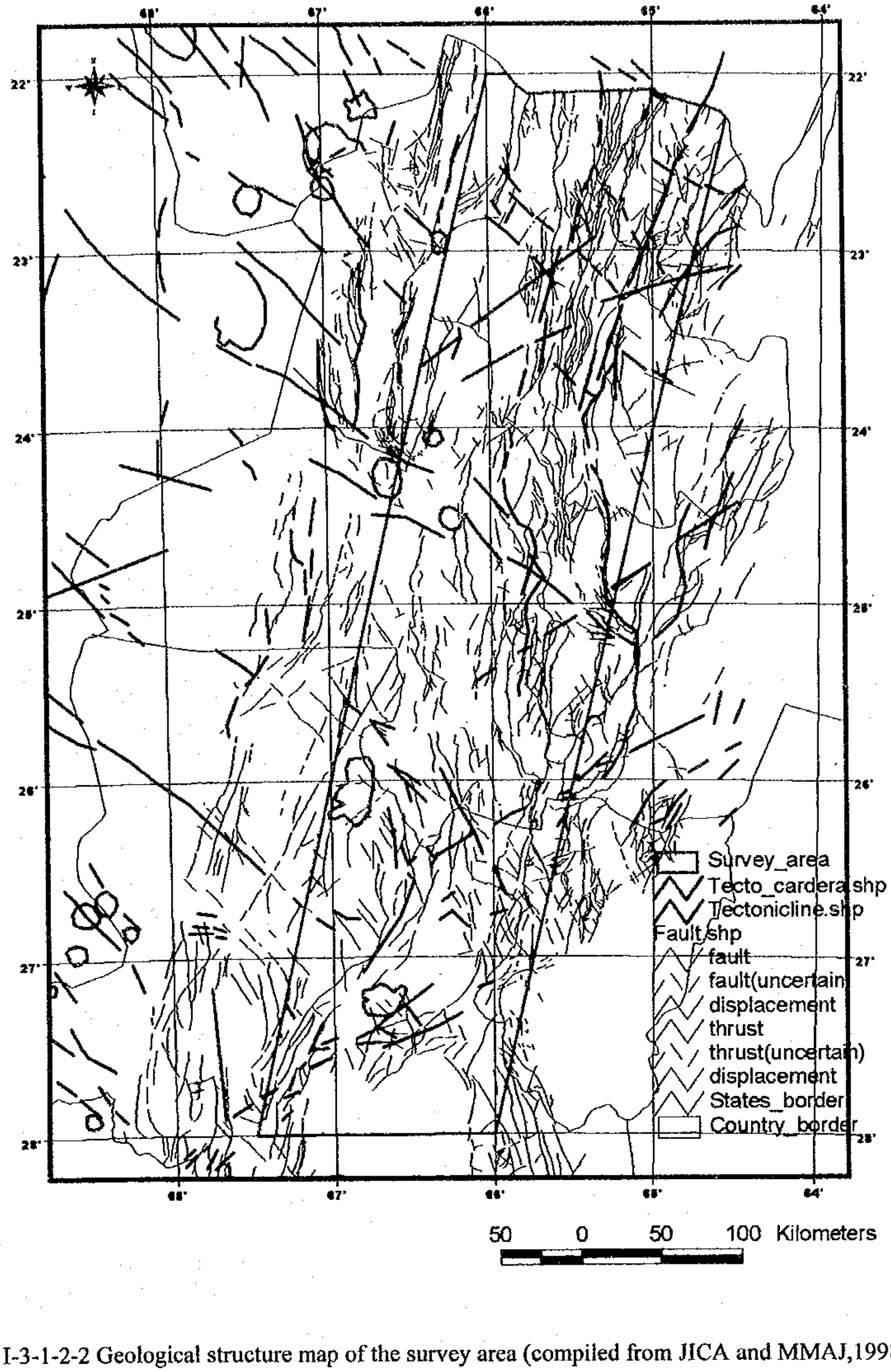


Fig. I-3-1-2-2 Geological structure map of the survey area (compiled from JICA and MMAJ,1998 and Riller et al., 2001)

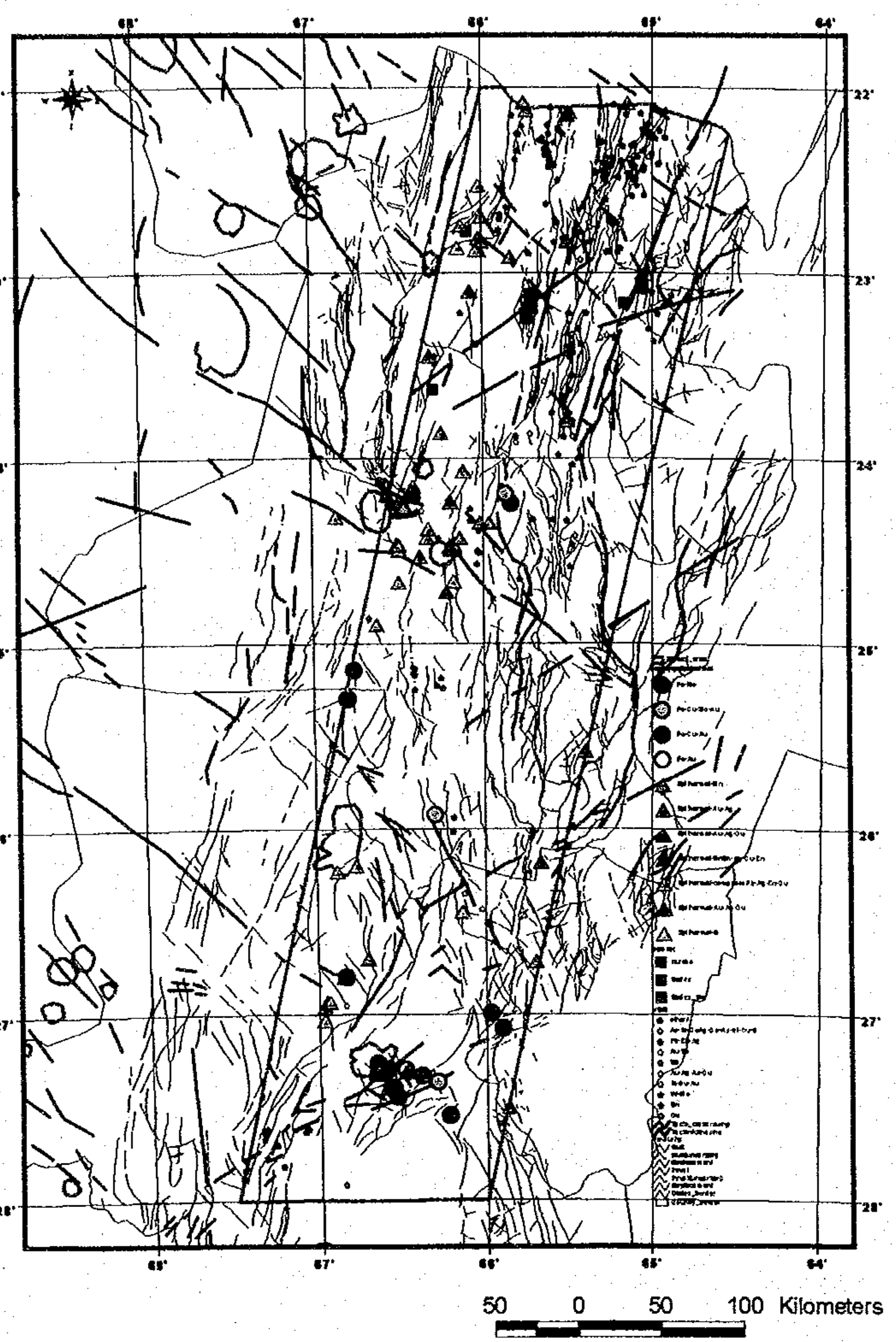


Fig. I-3-1-2-3 Distribution map of mineral showings and deposits (taken from Zappettini, 1998)

Table3-1-2-1 Simplified stratigraphy of the survey area.

	Puna Region: Stratigraphy	Puna Region: Intrusive	Cordillera Oriental Region: Stratigraphy	Cordillera Oriental Region: Intrusive	Sierras Pampeanas Region: Stratigraphy	Sierras Pampeanas Region: Intrusive	Tectonic Cycles
Quaternary	Modern detrital accumulation, evaporite of salar, modern volcanic center(basalt)		Modern detrital accumulation, modern volcanic center(basalt)	Tuzgle effusive complex (dacite, rhyodacite, andesite porphyry, rhyodacitic tuff)	Modern detrital accumulation, evaporite deposits, monogenetic center (andesite, basalt)		
Neogene: Pliocene	Fm.Rumibola (andesite, basalt); Ignimbrite, dacitic · andesitic lava		Fm.Uquia, Fm.Maimara; Travertine limestone; Fm.Rumibola (andesite,basalt)				Neogene subcycle
Neogene: Miocene	Clastic and volcaniclastic sequences: Gr.Pastos Grandes, Fm.Puertas de San Pedro, Fm.Cara Cara, Fm.Tiomayo, Fm.Moreta; Volcanic complex (dacitic-rhyolitic ignimbrite, andesitic · dacitic lava, tuff, breccia)	Fm.Inca Viejo (Rhyolitic · dacitic porphyry)	Clastic and volcaniclastic sequences: Gr.Oran, Gr.Payogastilla, Fm.Pisungo, Fm.Luracatao		Clastic sequence: Gr.Pastos Grandes, Gr.Santa Maria, Gr.Aconquija, etc. (indifferentiated continental sediments with marine intercalations); Volcanic associations (dacitic - rhyolitic ignimbrite, andesitic-basaltic stratovolcano, andesitic · dacitic stratovolcano)	Hypabyssal intrusives (dacitic porphyry, andesitic porphyry, monzonite, etc.)	Andes cycle
Paleogene: Oligocene			Fm.Rio Grande (continental conglomeratic arenite,siltstone)	Fm.Acay (granite, monzonite)			Paleogene subcycle
Paleogene: Eocene			Fm.Casa Grande (continental arenite,marly siltstone,claystone)				
Paleogene: Paleocene	Gr.Salta (continental conglomerate, pelite, arenite, limestone), Subgr.Santa Barbara, Subgr.Balbuena, Subgr.Pirgua		Gr.Salta (continental conglomerate, pelite, arenite, limestone), Subgr.Santa Barbara, Subgr.Balbuena, Subgr.Pirgua				
Cretaceous		Fm.Aguilar (granitoids) and equivalents		Fm.Hornillos (syenite, monzonite, pulaskite, alkali- lamprophyre, tinguaite); Fm.Aguilar (granitoids) and equivalents		Papachacra Granite (monzogranite)	Patagonia cycle; Patagonia extentional cycle; Gondowana extentional cycle
Jurassic		Permian dioritic · granitic stock complex	Gr.Mandiyuti (arenite, pelite, diamictite)				Gondowana cycle
I	Postordovician · precretaceous clastic sequences		Gr.Machareti (arenite, pelite, diamictite)			Granite of Los Ratones, Sauce Guacho, Las Juntas, etc.	
Silurian	Fm.Salar del Rincon (fluvial conglomerate, marine arenite)		Fm.Pescado, Fm.Cerro Piedras, Fm.Porongal, Fm.Baritu; Fm.Lipeon (marine diamictite,lutite), Fm.Mecoyita (marine diamictite,arenite,lutite)			Indifferentiated batholith body and plutons (granite, granodiorite with gneissic foliation, granite and granodiorite porphyry, monzogranite, rhyodacite porphyry, mylonite, etc.	Chanic movement; Famatina cycle; Ocloyic movement
Ordovician	Fm.Tolillar (metagreywacke, metavolcanite), Fm.Falda Cienaga (lutite, pyroclastic, greywacke, lava)	Magmatic sequences (Faja Eruptiva) (plutonic, volcanic, subvolcanic rocks)	Gr.Santa Victoria (marine arenite,quartzite,pelite) and equivalents	Magmatic sequences (Faja Eruptiva) (plutonic, volcanic, subvolcanic rocks)	Gr.Cachinan, Fm.El Portezuelo, Fm.Famabalasto, Fm.Loma Corral (metamorphic); Sedimentary and metasedimentary rock with lava, intrusive, piroclastic and volcaniclastic rock	Norite, granodiorite, gabbro, amphibolite, serpentinite, etc.	
Cambrian			Gr.Meson (marine quartzite, pelite)	Fm.Cachi, Fm.Canani, Fm.Tipayoc, Fm.Quesera (granitoids)			Tilcaric movement
Precambrian	Fm.Pachamama, Centenario igneous-metamorphic complex, Rio Blanco complex, Fm.Antofallita		Fm.Puncoviscana (greywacke, pelite, schist, slate, shale, phyllite), Fm.La Paya, Tolombon complex, Fm.Tienditas, Fm.Sancha, Fm.Medina		Fm.Puncoviscana (greywacke, pelite, schist, slate, shale, phyllite), Fm.Suncho (greywacke, pelite, conglomerate), Suncho gneiss, Piscoyacu gneiss, Tolombon complex, Fm.Medina		Pampia cycle

Table I-3-1-2-2 Deposit type and main deposits in the survey area

Deposit type	Province	Zone	Name of mine	Elements	Type	Age	Lithology
Precambrian vein	SALTA	Z-12	Esperanza (Esther)	Cu-Pb-Zn-Ag-U-Co	Polymetalic vein	Precambrian, Cambrian	Schists, slates and quartzites
	JUJUY	Z-23	9 de julio	Pb-Ag-Zn	Polymetalic vein	Precambrian	Schists, slates, greywackes, phyllites
	JUJUY	Z-24	Coiruro	Sb-Au	Epithermal	Precambrian	Schists, slates and greywackes, rhyolitic dikes
	JUJUY	Z-24	Chorrillos	Cu-Ag-Sb-Pb	Vein and brecciated vein	Precambrian	Schists, slates, limestones, phyllites
	SALTA	Z-34	Brealito	Cu	Unknown	Precambrian, Cretaceous	Metasediments, Porphyritic body
Ordovician SEDEX (VMS)	JUJUY	Z-15	Esperanza	Pb-Ag-Zn	SEDEX	Ordovician	Shale
	JUJUY	Z-15	El Aguilar	Pb-Ag-Zn	SEDEX	Ordovician-Cretaceous	Quartzites, granite
	SALTA	Z-18	La Colorada	Cu-Pb-Zn- Fe	SEDEX? (VMS)	Ordovician	Quartzitic sandstones, greywackes, shales and granites
Ordovician polymetalic vein	JUJUY	Z-01	La Gatcada	Pb	Vein	Ordovician	Sandstones, shales
	JUJUY	Z-02	Pumahuasi	Pb-Zn	Vein	Ordovician	Sandstones and shales
	JUJUY	Z-02	Sol de Mayo	Pb-Zn	Vein	Ordovician	Sandstones and shales
	JUJUY	Z-02	La Bélgica	Pb-Zn	Vein	Ordovician	Sandstones and shales
	SALTA	Z-03	La Niquelina	Ni-Pb-Zn-(Co-As-Cu-U)	Polymetalic vein	Cambrian, Ordovician	Quartzite, shale and sandstone
	SALTA	Z-05	La Ciénaga	Pb-Cu-Ag-Zn-Barite	Polymetalic vein	Ordovician	Shales and sandstones
	SALTA	Z-05	Vizcachani	Pb-Ba-Ag-Cu	Polymetalic vein	Ordovician	Shales and sandstones
	JUJUY	Z-11	La Purisima (Rumicruz)	Cu-Pb-Barite	Polymetallic vein	Ordovician	Sandstones, shales and siltstones
Miocene porphyry Cu-Au-Mo	SALTA	Z-27	Organullo	Au	Porphyry Au	Tertiary	Dacitic and andesitic flows. Dioritic stock
	SALTA	Z-28	Pancho Arias	Mo-Cu-Au	Porphyry Mo-Cu	Precambrian, Miocene	Leptometamorphic rocks, Dacitic porphyry dikes swarm and intrusive and hydrothermal breccias
	SALTA	Z-31	Inca Viejo	Au-(Cu-Mo)	Porphyry Au	Tertiary (Miocene)	Monzonitic and dacitic porphyries, intrusive and collapse tourmaline-bearing breccias
	SALTA	Z-31	Diablillos	Au-Cu	Porphyry Au-Cu	Miocene	Granitic intrusive, intrusive breccia
	CATAMARCA	Z-43	Bajo de la Alumbrera	Cu, Au	Porphyry Cu-Au	Upper Miocene	Andesitic breccia, Andesitic tuff, Andesitic dikes and sills, Quartz andesitic stock and dikes
	CATAMARCA	Z-43	Bajo de Agua Tapada	Cu-Au	Porphyry Cu-Au	Upper Miocene	Dacitic porphyry stock, andesitic breccia, qz-andesite
	CATAMARCA	Z-43	Agua Rica	Cu, Mo, Au	Porphyry Cu	Upper Miocene	Syenodiorite, porphyries
	CATAMARCA	Z-43	Filo Colorado	Cu, Au, Mo	Porphyry Cu	Ordovician, Upper Miocene	Granite, Dolerite and Dacites
	TUCUMAN	Z-46	El Alisar	Cu-Au	Porphyry Cu-Au	Miocene	Andesitic porphyry, andesites and intrusive and hidrotemal breccias
	TUCUMAN		El Pago	Cu-Au-Pb-Zn	Porphyry Cu-Au	Precambrian upper, miocene?	Gneiss/Migmatite
Miocene epithermal vein	SALTA	Z-26	Incachule	Sb	Epithermal vein	Tertiary (Miocene)	Dacite
	SALTA	Z-31	Diablillos	Au-Cu	High sulfidation epithermal	Miocene	Granitic intrusive, intrusive breccia
	CATAMARCA	Z-43	Agua Tapada	Au-Ag	Low sulfidation epithermal	Upper Miocene	Andesitic breccias and Quartz andesites
	CATAMARCA	Z-43	Farallón Negro (Alto de la Blenda)	Au, Ag, Mn	Low sulfidation epithermal	Upper Miocene	Andesitic breccias and Monzonite
	CATAMARCA	Z-43	Mina Capillitas	Cu-Au-Pb-Zn-Ag	Disseminated, veinlets, filling, massive, chimney and vein (High sulfidation)	Upper Miocene	Volcanic breccia/Rhyolite/Tuff
	CATAMARCA	Z-43	Agua Rica	Cu, Mo, Pb, Zn, Ag, Au	High sulfidation epithermal	Upper Miocene	Igneous breccia, hydrothermal breccias
Miocene polymetalic vein	JUJUY	Z-07	Pan de Azúcar-Potosí-España	Pb-Ag-Zn-Sb	Epithermal polymetallic	Middle Miocene	Dacites and andesites
	JUJUY	Z-09	Rachaite	Pb-Zn-Ag-Mn	Epithermal polymetallic	Mioceno superior	Dacites, andesites, tuffs, breccias
	SALTA	Z-26	Concordia	Pb-Ag-Zn	Epithermal polymetallic	Cretaceous, Miocene-Pliocene	Conglomerates, dacites and dacitic breccias
	SALTA	Z-26	La Poma	Pb-Ag-Zn	Epithermal polymetallic	Tertiary	Dacites and dacitic tuffs
	SALTA	Z-27	Organullo	Au-Bi-Cu-Pb-Zn	Epithermal polymetallic	Tertiary, Precambria	Slates and schists
	SALTA	Z-27	El Acay	Fe-Cu-Pb-Zn	Skarn and vein	Cretaceous, Oligocene	Garnetiferous skarn, limestone, calcareous sandstone, marl, granite
	CATAMARCA	Z-39	Languna del Salitre	Pb, Zn, Ag, Au	Epithermal polymetallic	Miocene	Monzodiorite
Cretaceous Stratabound Cu	SALTA	Z-38	Vallecito	Cu	Impregnation, disseminated (stratabound)	Ordovician (Cretaceous)	Migmatites, granites (conglomerates, sandstones)
	SALTA	Z-39	Margarita, Zorriquín	Cu	Stratabound Cu	Cretaceous	Sandstones and conglomerates
	SALTA		Custodio, San Martín, Salamanca	Cu	Stratabound Cu	Cretaceous	Conglomerates and arcosic sandstones
	SALTA		Doña Inés	Cu-Fe	Stratabound, impregnation, vein	Cretaceous	Conglomerates and sandstones
	SALTA		Elba, María, León	Cu-Pb	Stratabound Cu	Cretaceous	Calcareous sandstone, oolitic limestone, sandy limestone
Alluvial placer Au	SALTA	Z-04	Pueblo de Minas	Au	Alluvial gold	Pleistocene, Holocene	Alluvial-colluvial deposits
	SALTA	Z-04	Santa Cruz	Au	Alluvial gold	Pleistocene, Holocene	Aluvial plane deposit
	SALTA	Z-04	Pucará	Au	Alluvial gold	Pleistocene, Holocene	Aluvial plane deposit
	SALTA	Z-04	Santa Rosita, Pucará, Cerros Bravos	Au	Alluvial gold	Pleistocene, Holocene	Alluvial plain deposits
	SALTA	Z-04	Cerros Bravos	Au	Alluvial gold	Pleistocene-Holocene	Aluvial plane deposit

In the early Cambrian, these basement rocks received intrusion of granite rocks represented by trondheimite distributed west of Cachi. These granite rocks are called Cachi, Canani, Tipayoc, and Quesera multiple seams and are mainly distributed in Cordillera Oriental area. The kinds of composing rocks include trondheimite, granite, tonalite and granodiorite.

Dip unconformity is observed between strata of the Precambrian system and the Cambrian system, and is associated with Tilcaric deformation movements in the Pampia cycle. The Cambrian system in Cordillera Oriental area includes marine siliceous sandstone, shale and slate, which are collectively called Meson group. Meson group covers the upper part of the plutonic rock body of Canani multiple seam in unconformity. In Pampeanas Mountains area, gneiss, slate and crystalline schist of the same age are distributed in the Penon, the Laguna Blanca and the Altohuasi mountains located in the southwest end of the survey area.

Strata of the lower Ordovician are composed of marine shale, slate and siliceous sandstone, which are represented by Santa Victoria group in Cordillera Oriental area and cover the upper part of Meson group partially in conformity (Fig. I-3-1-2-1). Santa Victoria group has many vein-type lead/zinc deposits including El Aguilar Deposit, which is a SEDEX-type zinc and lead deposit. In the upper part (Acoite Formation) of Santa Victoria group, volcanic to semi-plutonic rocks called Faja Eruptiva (Oriental) exist and intrude widely. These rocks are volcanic rocks and volcaniclastic rocks of the Arenig-Llanvirn series generated by bimodal magmatic activities of dacite to rhyolite and basalt, and are accompanied by near surface intrusive rocks with similar composition. These sedimentary rocks and volcanic/volcaniclastic rocks received compressed deformation by Ocloyic deformation movements of the Famatina cycle and were subjected to fold/fault movements. As a result, primitive Puna uplifted and formed unconformity with the Silurian sediments, its upper strata.

The range of distribution of Silurian to Jurassic strata is limited, and shallow-marine to terrestrial sedimentary strata are distributed only locally in the eastern part of the Cordillera Oriental mountains and in the Subandinas mountains. These strata do not have a relationship with deposits.

The eastern part of Puna and Cordillera Oriental area adjoining it received intrusion of granite rocks related to the Patagonia tensile cycle from the end of the Jurassic to the lower Cretaceous. Representative of these rocks are Aguilar granite rocks distributed along the Aguilar mountains, which are composed of biotite tourmaline granite, monzonitic granite, granite-porphyry, muscovitic granite and hornblende granite. Aguilar granite rocks exerted contact metamorphism upon the SEDEX deposit of El Aguilar Mine.

Lifted sedimentary basins extending south and north created by the Patagonia tensile cycle were formed in various places, such as Cordillera Oriental area and the southern part of Salta City, from the lower Cretaceous to the Eocene. In these terrestrial sedimentary basins, conglomerate, mudstone, sandstone and limestone sedimented.

In the age of the Andes cycle, local foreland sedimentary basins accompanying the Andes orogenic movements were formed in various places, and the formation continues still while the center of sediment is being moved to the east.

In the Oligocene, there was formation of several northwest-southeast lineaments in the area ranging from Chile to Argentina, such as El Toro-Olacapato Lineament, which is related to diagonal subduction of the plate from the Andes cycle to the Paleogene subcycle. Acay granite rocks (granite and monzonite) intruding the top of Mount Acay (5716 m) are located in this El Toro-Olacapato Lineament.

In the Miocene, the accompanying dip of the subducting plate became gentle, and magmatic arcs expanded to inland of Argentina and formed a sequence of volcanic rocks - volcaniclastic rocks - intrusive rocks mainly composed of andesite, dacite and rhyolite. These arcs did not expand uniformly but in a beltlike form extending northwest and southeast, and four belts of this kind are observed in the survey area (Fig. I-3-1-2-1). The southernmost one of these four belts includes Farallon Negro Volcanic Complex and has many porphyry copper/gold deposits and epithermal deposits. In other belts, the existence of similar deposits has been confirmed.

From the upper Miocene to the Quaternary, scaling down on the Chilean side, the main magmatic arcs locally formed andesite, basaltic lava, dacite and rhyolitic ignimbrite. The cause of this is considered to be calc-alkali magmatic activities inside the plate that are related to the fact that the plate subduction angle became deep again.

3-1-2-2 Mineral deposits in the survey area

The distribution of the main known places of ore indications in the survey area is shown in Fig. I-3-1-2-3. The main ones of these known places of ore indications are shown in Table I-3-1-2-2. In the survey area, various types of nonferrous metal deposits and places of these ore indications are known, including porphyry copper/gold deposits, epithermal gold/silver deposits, mesothermal gold deposits, SEDEX lead/zinc deposits, volcanic massive sulfide deposits, polymetallic vein deposits, skarn deposits, pegmatite deposits, and sedimentary copper/uranium deposits. The number of these deposits and places is five hundred or more. Those which are important from an economic point of view are porphyry copper/gold deposits, epithermal gold/silver deposits, SEDEX lead/zinc deposits and polymetallic vein deposits. Porphyry copper/gold deposits and epithermal gold deposits were formed by Neogene magmatic activities, while SEDEX lead/zinc deposits are syngenetic deposits held by Santa Victoria group of the Ordovician system. Although polymetallic vein deposits were formed in each age, there were more formations in the Precambrian, the Ordovician and the Neogene. The main deposit types are outlined below.

*** Vein deposits with wall rock of the Precambrian group**

Places belonging to this type include Esperanza (in the Esther area, Pb-Ag-Zn-U) in Zone 12, 9 de Julio (Pb-Ag-Zn) in Zone 23, Pueblo Viejo (Au) in Zone 19, Coiruro (Sb-Au) and Chorrillos (Cu-Ag-Sb-Pb) in Zone 24 and Brealito (Cu) in Zone 34. These places are considered to have vein deposits with various origins, and all are held in rocks of the Precambrian system. There is the possibility that the age of deposit generation is much more recent.

*** Ordovician SEDEX lead/zinc deposits (or VMS deposits)**

Deposits of this type are El Aguilar and Esperanza in Zone 15 and La Colorada in Zone 18 only. It is said that these are massive sulfide deposits existing in the Ordovician system. El Aguilar and Esperanza are SEDEX deposits and produce lead, zinc and silver at present. Although La Colorada is classified as SEDEX in many materials, it is considered from materials and drilling core samples collected this time that it is classified as a volcanic massive sulfide deposit.

*** Polymetallic vein deposits with Ordovician wall rock**

More deposits of this type exist in the northern part of the survey area than in other parts, and there are many deposits of this type including La Gateada (Pb-Ag-Zn) in Zone 1, Pumahuasi, La Belgica, Sol de Mayo (Pb-Zn) in Zone 2, La Niquelina (Ni-Pb-Zn) in Zone 3, Vizcachani (Pb-Ba-Ag-Cu) and La Cienaga (Pb-Cu-Ag-Zn-Ba) in Zone 5 and Rumicruz (La Purisima, Cu-Pb-Ba) in Zone 11. Among these vein deposits, there are many mines where small-scale mining was carried out. Because of the small scale, however, it is considered to be difficult to execute development targeting base metal such as copper, lead and zinc at present. There is the possibility that these vein deposits are relevant to SEDEX deposits, and they may become important as a guide to investigation of the SEDEX type.

*** Miocene Porphyry (Cu-Au-Mo) deposits**

Deposits of this type are distributed in the southern part and the middle part of the survey area and include Organullo (Au-Bi-Cu-Pb-Zn) in Zone 27, Pancho Arias (Cu- Mo) in Zone 28, Inca Viejo (Cu-Mo) and Diablillos (Au-Cu) in Zone 31, Bajo de la Alumbrera, Bajo de Agua Tapada (Cu-Au), Agua Rica (Cu-Mo-Au) and Filo Colorado (Cu-Au-Mo) in Zone 43, El Alisal (Cu-Au) in Zone 46, and El Pago (Cu-Au-Pb-Zn in Zone 47. In Bajo de la Alumbrera, open-pit mining is being carried out now, and copper concentrates of 215,000 tons were produced in 1999. These porphyry deposits are distributed along Miocene magmatic arcs stretching out from the Chilean side together with the next Miocene epithermal deposits. In the survey area, four such magmatic arcs extend northwest and southeast on the whole in a beltlike form.

*** Miocene epithermal deposits and polymetallic vein deposits**

Accompanying Miocene porphyry deposits, epithermal deposits are distributed mainly in the southern part and the middle part of the survey area. Many polymetallic vein deposits exist and are distributed in all of the southern part, the middle part and the northern part. Representative epithermal deposits include Incachule (epithermal Sb) in Zone 26, Diablillos (gold and silver of the high sulfidation system) in Zone 31, Agua Tapada (gold and silver of the low sulfide system), Farellon Negro (Alto de la Blenda, low-sulfidation system gold and silver Mn), Agua Rica (gold and silver of the high sulfidation system) and Capillitas (Cu-Au-Pb-Zn-Ag of the high sulfide system) in Zone 43. As representative polymetallic vein deposits, many deposits are widely distributed, including Pan de Azucar-Potosi-España (Pb-Ag-Zn-Sb) in Zone 7, Rachaite (Pb-Zn-Ag-Mn) in Zone 9, Concordia (Pb-Ag-Zn) and La Poma (Pb-Ag-Zn) in Zone 26, Organullo (Au-Cu-Bi-Pb-Zn) and El Acay (skarn, dike, slate, Cu-Pb-Zn) in Zone 27, Laguna del Salitre (Pb-Zn-Cu) in Zone 39.

*** Cretaceous sedimentary copper deposits**

Deposits of this type exist in Salta group from the Cretaceous system to the Paleogene system in the middle part of the survey area. They include Vallecito in Zone 38, Margarita (Zorrinquin) in Zone 39, and Custodio (San Martin, Salamanca), Dona Ines and Elba (Maria, Leon) of which have not been zoned at this time. The importance of these deposits seems to be low.

*** Quaternary placer gold deposits**

Many deposits of this type are distributed along the Santa Cruz river in Zone 4 in the northern part of the survey area. There are a lot of deposits with past production records, such as Santa Cruz, Pucara, Santa Rosita, Pueblo de Minas and Cerros Bravos. Although the economic importance of placer gold seems to be low, vein gold deposits as a supplying source may be significant.

*** Quarternary evaporate deposits**

Deposits of this type are evaporation deposits and exist in salt lake sediments of this age. Although they are not included in minerals covered by this survey, many mines producing boron/rock salt now exist in Zones 21, 29 and 30. Outside the survey area, Salar del Hombre Muerto, a lithium mine, exists west of the middle part of the survey area.

Regarding the summary of the geology of and deposits in Andes Region stated above, although there is a lot of general literature, the materials listed below were mainly referred to.

- Zappettini, E.O. (Ed.), Mapa metalogenético de la República Argentina, Version Preliminar (CD-ROM): SEGEMAR, 1998.

- Zappettini, E.O., 1999, Evolución geotectónica y metalogénesis de Argentina: Recursos Minerales de la Republica Argentina Vol.1 (Ed. E.O.Zappettini), SEGEMAR, Anales 35, pp.51-73.
- Ramos, V.A., 1999a, Ciclos orogénicos y evolución tectonica: Recursos Minerales de la Republica Argentina Vol.1 (Ed. E.O.Sappettini), SEGEMAR, Anales 35, pp.29-49.
- Ramos V.A., 1999b, Las provincias geológicas del territorio Argentino: Geología Argentina (Ed. R.Caminos), SEGEMAR, Anales no,29, pp.41-96.
- Ramos, V.A., 2000, The southern central Andes: Tectonic evolution of South America (Ed. Cordani,U.G., Milani,E.J., Thomaz,F.A., Campos,D.A), pp561-604, Rio de Janeiro,2000.

For regional geology, provincial geological maps and 1/250,000 geological maps of Jujuy, Salta, Tucman and Catamarca Provinces were also referred to.

- Mapa Geológico de la Provincia de Catamarca, 1:500,000, SEGEMAR,1995.
- Mapa Geológico de la Provincia de Tucuman, 1:500,000, SEGEMAR,1994.
- Mapa Geológico de la Provincia de Salta, 1:500,000, SEGEMAR,1998.
- Mapa Geológico de la Provincia de Jujuy, 1:500,000, SEGEMAR,1996.
- Hoja Geológica 2566-I, San Antonio de los Cobres, Dirección Nacional del Servicio Geológico,1996.
- Hoja Geológica 2766-II, San Miguel de Tucumán, Dirección Nacional del Servicio Geológico,1999.
- Hoja Geológica 2366-II y 2166-IV, La Quiaca, Dirección Nacional del Servicio Geológico,1999.
- Hoja Geológica 2566-III, Cachi, Dirección Nacional del Servicio Geológico,1998.

3-2 Mining activity

3-2-1 Mining policies

With support from the World Bank, the Argentine Republic launched a radical economic reform program in the beginning of the 1990s. As a result of this mining policy reform, a legislation system meeting the international standard was completed and an environment for mining investment was improved. The object is to complete the legal system necessary for mining development and to create a competitive market for the reduction of private investment risk and for advantageous investment. In the analysis by the MMAJ and the World Bank (2001), the Argentine Republic was classified as a country developing reform (Fig. 1-3-2-1). Countries completing the reform are Chile, Peru, Mexico and Indonesia. In these countries, mining production has increased by leaps and bounds.

3-2-2 Mining production

The effect of the mining policy reform was truly shown in mining production activities, and there was remarkable increase in the amount of investments, amount of production and amount of exports in the mining sector after 1993 (See Table 3-2-1). In particular, the increase in the amount of production and the amount of export was largely attributed to the start of production at three international-scale mines; Bajo de la Alumbrera, Cerro Vanguardia and Salar del Hombre Muerto.

3-2-3 Mining legislation system

As mentioned above, the Government of the Argentine Republic carried out improvement and completion of the legislation system to promote mining investment in the 1990s. At present, there are the following laws related to mining:

・Mining Code: enacted in 1886, revised in 1997

・Mining Investment Law No. 24,196: established in 1993

Stable tax system, exemption from property tax, exemption/reduction of the import tax and placing the highest limit of royalties at 3%.

・Mining Reorganization Law No. 24,224: established in 1993

Preparation of geological maps, establishment of COGEMIN, and expansion of mining and exploitation areas.

・Federal Mining Agreement Law No. 24,228: established in 1993

Association of mining producer for each province, open bids of large scale exploration projects, auction of mines, and promotion of update of mining registration.

・Mining Updating Law No. 24,498: established in 1995

Exploration in exclusive areas, and deletion of mines with nullified license from registration.

・Environmental Protection for Mining Industry Law No. 24,585: established in 1995

· Promotion of environmentally sustainable production, and promotion of environmental protection mechanism

Although the details of these laws related to mining are omitted, importance is attached to promotion and guarantee of mining investment from inside and outside of the country, based on the following basic concepts.

- Ownership of minerals shall belong to the state or province to which land where minerals are produced.
- The state or province shall grant the private sector the right to execute prospecting, development and/or mining.
- The mining right shall be an independent right that is separate and different from land ownership.
- Mine development shall be put into the private sector, including foreign capital.

That is to say, tax incentives are employed for the following purposes: neutrality of foreign capital, legal guarantee of mining rights obtained, leadership of the private sector regarding the development of natural resources, opening of state mining concession, expansion of exploration and mining areas, and reduction of environmental protection and prospecting costs and business and operation costs.

3-2-4 Recent trends of exploration and development

In the 1990s, South America was a region where mining investment expanded most widely. The background was, of course, the high potential of mineral resources in South America, but improvement of the environment for mining investment realized by the mining policy reform of countries holding resources contributed largely to this. Although being behind Chile, which established the Mining Law in 1983, Argentina established three laws - the Mining Investment Law, the Mining Reorganization Law and the Federal Mining Agreement Law - in 1993, which allowed an environment for private investment to become in place. As a result, the amount of this country's prospecting investment increased by leaps and bounds, from 70 million dollars in 1992 to 790 million dollars in 1997. This led to the development of large-scale mines, such as Bajo de la Alumbrera Mine (in Catamarca Province; porphyry type copper/gold deposits), Cerro Vanguardia Mine (in Santa Cruz Province; epithermal gold deposits), and Salar de Hombre Muerto Mine (in Catamarca Province; lithium deposits in salt lake). In particular, from 1996 to 1998, foreign capital rushed to the country, which brought about a prospecting boom. In and after 1999, however, due to saturation of prospecting, the worsened world economy and sluggish metal market conditions, foreign prospecting companies have tended to pull out. In such a situation, the three mines mentioned above were developed after the mining policy reform and continue production satisfactorily.

Deposits whose development is frozen due to sluggish metal market conditions and for financial reasons are El Pachon (in San Juan Province; porphyry type copper/molybdenum deposits; Cambior (50%) and Campania Minara San Jose (50%)), Agua Rica (in Catamarca Province; porphyry type copper deposits; BHP Biliton (70%) and Northern Orion (30%)), San Jorge (in Mendoza Province; porphyry type copper/gold deposits; Northern Orion (100%)), Del Carmen (in San Juan Province; epithermal gold and silver deposits; Barrick and Homestake), Manantial Espejo (in Santa Cruz Province; epithermal gold and silver deposits; Silver Black Hawk (80%) and Barrick (20%)), and Pirquitas (in Jujuy Province; polymetallic vein type silver, zinc and tin deposits; Sunshine Argentina (100%)).

Deposits that can be mentioned as those in preparation for development now are Veladero (in San Juan Province; epithermal gold and silver deposits; Barrick (40%) and Argentina Gold (60%)), Pascua-Lama (in San Juan Province; epithermal gold and silver deposits; Barrick (100%)) and Esquel (in Chubt Province; epithermal gold and silver deposits; Brancote (74%) and others (26%)).

Similarly, in places surrounding the survey area, exploration activities were carried out from 1996 to 1998, but most of them are slowed down now. Table 1-3-3-2 shows the exploration during the above-mentioned period. The main target of exploration was porphyry type copper and copper/gold deposits and epithermal gold deposits.

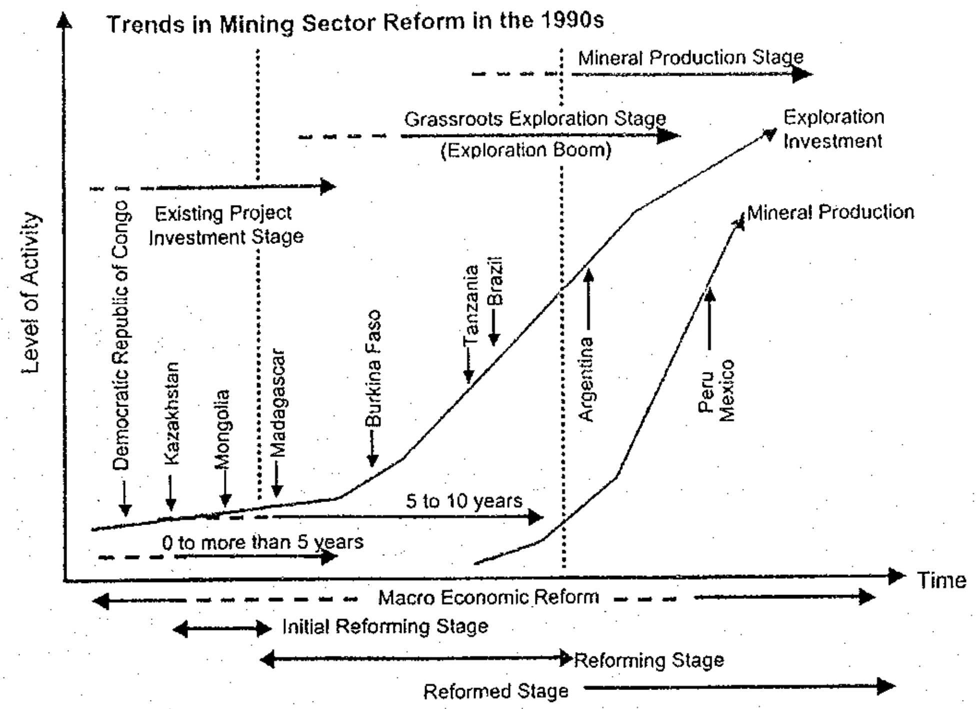


Fig. I-3-2-1-1 Idealized trends in mining sector reform in the 1990s and mining activities in some selected successful countries (taken from Naito and Remy (2001)

Table I-3-2-2-1 Investment of mining development in Argentine Republic (MMUS$)

year	1993	1994	1995	1996	1997	1998	1999
Mining Investment	-	23	101	708	658	249	156
Mining Production	481	468	513	543	665	1151	1329
Export of Mineral Products	16	24	30	36	113	565	791

(Source: Secretaria de Energia y Mineria)

Table I-3-2-4-1 Recent exploration around the survey area

Name of Project	Province	Company	Deposit type	Duration	Methodology	Status
Agua Caliente	Jujuy	MIM Argentina Exploration S. A.	Epithermal (Au, Ag)	1998	GS, GC, DR	abandon
Centenario North	Salta	Aranlee Resources (USA)	Epithermal (Au, Ag)	1999	GC, GP, TR, DR	abandon
Centenario South	Salta	Lapacha Mineral SRL	Porphyry (Cu, Au)	2001	GS, GC, DR	?
Cerro Gordo	Salta	Mansfield Minera S. A. and RTZ	Epithermal (Au, Ag)	1997	GC, TR, DR	?
Cerro Juncal	Salta	Mansfield Minera S. A.	Epithermal (Au, Ag)	1999		
Cerro Samenta	Salta	Mansfield Minera S. A.	Porphyry (Cu, Au)	1996-2001		abandon
Chincillas	Jujuy	Aranlee Resources (USA)	Porphyry (Cu, Au)	1996-1997	GA, GC, TR, DR	abandon
Condor Yacu	Salta	Cardero Resource Corp. (USA)	Epithermal (Au, Ag)	2001	DR	under exploration
Diablillos	Salta	Pacific Rim (Canada) and Barrick Exploration Argentina (Canada	Epithermal (Au, Ag)	1989-2001	GS, GC, GP, TR, DR	start development from 2002 ?
El Acay	Salta	Aranlee Resources (USA), RTZ	Epithermal (Au, Ag)	1996-1997		abandon
El Alisar	Tucuman		Porphyry (Cu, Au)		GC	?
El Oculto	Jujuy	Aranlee Resources (USA)	Epithermal (Au, Ag)	1996	Dr	abandon
Inca Viejo	Salta	High American Gold	Porphyry (Cu, Au)	1997-1999	DR	?
La Colorada	Salta	Pacific Rim (Canada)	VMSD	1993-1998	GS, GC, GP, TR, DR	abandon
Mina Concordia	Salta	Mansfield Minera S. A. and RTZ	Epithermal (Au, Ag)	1995-1998	GS, GC, GP, TR, DR	?
Organullo	Salta	Triton Mining (Canada)	Epithermal (Au, Ag)			
Pancho Arias	Salta	Aranlee Resources (USA)	Porphyry (Cu, Mo)	1995		abandon
Socompa	Salta	RTZ	Porphyry (Cu, Au)	1997-1998		abandon
TacaTaca Bajo	Salta	Corrientes Resources and RTZ	Porphyry (Cu, Au)			
TacaTaca Sur	Salta	Mansfield Minera S. A. and Teck Corporation	Epithermal (Au, Ag) ?	1998	?	abandon

GS:Geological survey
GC:Geochemical exploration
GP:Geophysical exploration
TR:Trenching
DR:Drilling

Chapter 4 Interpretation on survey results

4-1 Analysis of the existing data

In order to concentrate on mineral potential area, information about geology, explorations, concessions etc., were collected and summarized from publications of organizations related to Government of the Argentine Republic and state governments, such as the Bureau of Geology and Mineral Resources (SEGEMAR), academy publications and internal materials of mining companies.

A new database of mineral deposit and mineral showings(total 512 point) was created in this analysis from compiling existing database of SSM, SEGEMAR y IGRM, (1999), database of Zappettini, (1999, CD-ROM) and geological maps published in Argentine etc., with cooperation of SEGEMAR experts. Using with GIS, distribution of mineral occurrences or mineral showings were visualized to compare geology and geological structure. Finally mineral deposits and mineral showings were grouped as 44 mineral potential area.

Through the database compilation, the following results especially regarding to distribution of minerals were summarized.

-Potential area of known porphyry copper deposit

Zone-43: Miocene porphyry copper and gold deposit in Andalgala, Catamarca states(Bajo de la Alumbrera, Agua Rica etc.)

-Potential area of porphyry copper and copper/gold deposits, epithermal gold deposits

Zone-07, Zone-09, Zone-24, Zone-26, Zone-27, Zone-28, Zone-39, Zone-42, Zone-43, Zone-46: Tertiary volcanic area in north side of survey area.

-Potential area of SEDEX lead/zinc deposits and volcanic massive sulfide

Zone-15:SEDEXtype(El Aguilar, Esperanza), Zone-01, Zone-02, Zone-08, Zone-10, Zone-11, Zone-12, Zone-15, Zone-17, Zone-22, Zone-03, Zone-05, Zone-18.

4-2 Data analysis of airborne geophysics

In order to select highly potential area for mineral deposits and regional geological structures, airborne geophysical data (magnetics and radioactivity) provided by SEGEMAR are processed. The area spreads over Jujuy, Salta and Catamarca States, covering the west part of the survey area. The area of the north part is approximately 23,000 km^2 and that of the south part is about 44,000 km^2.

Air-borne geophysical data includes magnetic data(Total magnetic intensity (MI), Reduce to the pole (RTP)), radiometric data(Potassium (K), Thorium (T), Uranium (U)), and digital topographical data(DEM). Processing type are First vertical derivative(1VD), Second vertical derivative(2VD), First horizontal derivative for RTP, and ratio of K/T, K/(K + T + U) and Color composite image(RGB=KTU) for radiometric data.

Characteristics of the whole survey area were compared from the viewpoint of regional scale

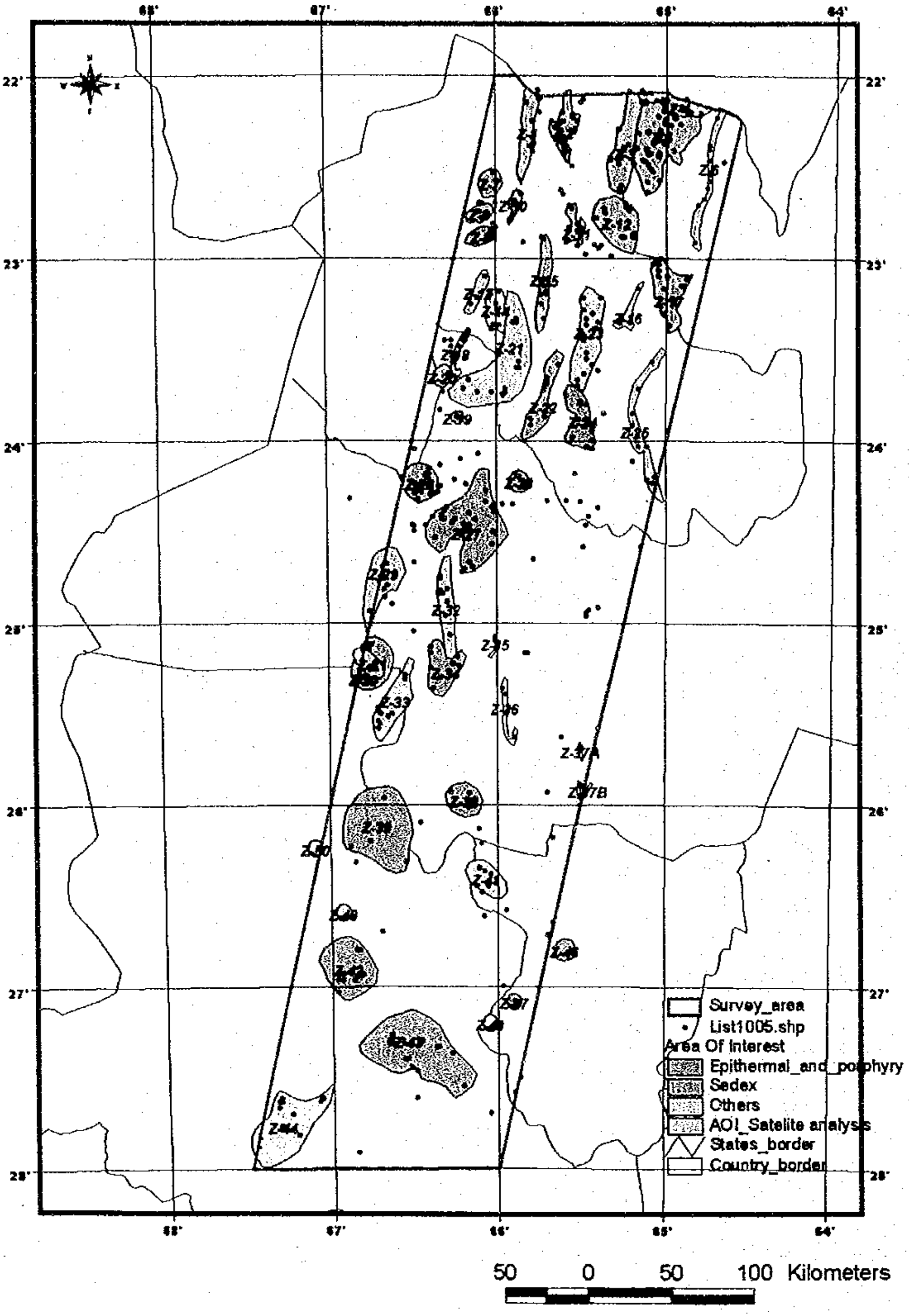


Fig. I-4-1-1 Location of mineral showings and deposits, and cluster of them listed on the Appendix

Table I-4-1-1 List of mineralized zones in the survey area

Zone No.	Province	Element / Material	Type	Age of Host Rock	Location and Access	Topography and Vegetation	Geology	Mineralization	Geological structure	Aero-magnetic anomaly	Alteration extracted by ASTER image	Area (km^2)	Number of mineral occurrences	Mineral occurrence surveyed	Evaluation
Zone-01	JUJUY	Cu (-Pb)	Vein	Ordovician	It covers Cordon de Escaya and a northern part of Sierra Cochinoca and is located about 10km to the northern end of the zone from La Quiaca and about 20km to the southern end from Abra Pampa. Two Roads crossing the zone exist northern and central parts of the zone.	Mountains with altitudes of 3,500-4,500m and a few scattered shrubs.	Dacitic porphyry, sandstone and shale of the Ordovician Cochinoca-Escaya Complex	It includes three occurrences of Cu and one occurrence of Pb vein type mineralization hosted by the Cochinoca-Escaya Complex.	N-S trending faults and volcanics distributions	A low magnetic anomalous area exists trending N-S with a weak to medium grade and is associated with a small magnetic semi-circular structure with 5km in a diameter to the west.	A small alteration zone with an area of $1km^2$ is extracted along the western fault in the north area.	400	5	La Caseada	
Zone-02	JUJUY	Pb-Zn (-Ag-Cu)	Vein	Ordovician	It occupies a wide area including the Pumahuasi mining district to the south of La Quiaca.	Hilly regions with altitudes of 3,500-4,000m and a few vegetation.	Sandstone and shale of the Ordovician Acoite Formation	It includes 19 occurrences composed mainly of Pb-Zn vein type mineralization hosted by the Acoite Formation.	N-S trending faults and folding axes	A weak high magnetic anomalous area exists trending N-S.	-	340	24	La Belgica La Pumahuasi Sol de Mayo	
Zone-03	SALTA	Barite-Pb (-Cu-Zn)	Vein	Ordovician, Cambrian	It covers the main part of Sierra Santa Victoria located about 40km to the east of La Quiaca.	Mountains with altitudes of 4,000-5,000m and a few vegetation.	Cambrian Mesón Group and Ordovician Santa Rosita Formation	Ten in a total of 17 occurrences are barite and/or Pb vein type mineralizations, and the other 7 occurrences are Cu-associated vein type mineralizations. Most of the mineralizations are hosted by shale and sandstone of the Santa Rosita Formation. Only La Niquelina mineralization is unique. It contains Ni and hosted by the Upper Cambrian Chalhualmayoc and the Santa Rosita formations.	-	-	-	1000	16	Santa Rosa	
Zone-04	SALTA	Au	Placer	Pleistocene - Holocene	It is located about 60km to the east of La Quiaca and covers the Santa Cruz river and its tributaries. The northern side of the zone is limited by the border	Mountains with altitudes of 2,000-4,000m and woody vegetation.	-	Placer gold in the alluvial plain deposits	-	-	-	350	11		Out of the survey target
Zone-05	SALTA	Barite-Pb (-Cu-Zn)	Vein	Precambrian, Ordovician, Silurian	It covers an eastern wide foot area of Sierra Santa Victoria. Santa Victoria town is located within the zone.	Mountains with altitudes of 2,000-4,500m and woody vegetation.	Precambrian Puncoviscana Formation, Cambrian Mesón Group and Ordovician Santa Rosita Formation	The 26 occurrences in a total of 30 occurrences are mainly of Pb-barite vein type mineralization hosted by shale and sandstone of the Ordovician Santa Rosita Formation. Nine in the 26 occurrences contain Cu, and Churquipampa, El Quinsillal and Río Blanco	Faults and folding axes show NNW-SSE to NNE-SSW trends.	-	-	1100	30	La Cienaga	
Zone-06	SALTA	P_2O_5	Stratiform	Ordovician, Silurian	It is located about 30km to the east of Santa Victoria town and covers a narrow area with a width of about 10km and a length of about 80km, trending NNE-SSW.	Mountains with altitudes of 1,000-2,000m and woody vegetation.	Ordovician Labrado and Centinela formations, and Silurian Lipeón Formation	Stratiform biocoenose phosphates beds intercalated with quartzite, sandstone and lutite of the Ordovician Labrado and Centinela formations, and stratiform oolitic iron beds in siltstone and greywacke of the overlying Silurian Lipeón	Approximate N-S trending structure (strike of bedding)	-	-	450	10		Out of the survey target
Zone-07	JUJUY	Pb-Ag-Zn (-Sb)	Vein	Middle Miocene	It is an area including Pan de Azucar mine located about 40km to Abra Pampa.	Hills with altitudes of 3,700-4,200m and a few vegetation.	Middle Miocene Laguna de Pozuelos Volcanic Complex	It includes occurrences of Pb-Ag-Zn (-Sb) veins hosted by dacite and andesite of Middle Miocene Laguna de Pozuelos Volcanic Complex. A mineralized zone of Pan de Azucar-Potosi-Espana has a reserve of 59,000t with 4.62%Pb, 6.58%Zn, 0.224kg/tAg and 0.88%Sb.	NE-SW trending fault zone and NNW-SSE trending faults	A small area exists with a striped pattern of high and low magnetic anomalies.	The small alteration zone extracted by TM is observed as similar location and size in the southern part.	200	1	Pan de Azucar	
Zone-08	JUJUY	Pb-Zn-(Cu-Ag-Au-Sb)	Vein	Ordovician	It is located about 30km from Abra Pampa. Road condition is not good within the zone.	Mountains with altitudes of 3,500-4,500m and scattered shrubs.	Lutite and sandstone of the Ordovician Acoite Formation, and sandstone, shale and rhyodacitic porphyry of the Ordovician Cochinoca-Escaya	It includes two occurrences composed mainly Pb-Zn mineralization and some Sb and Au.	NE-SW and N-S trending faults and NE-SW trending volcanics distributions	The zone is located in a low magnetic anomalous area with a medium grade.	No alteration zone is extracted.	110	3	Tupiza	
Zone-09	JUJUY	Sb(-Au) / Pb-Zn-Ag	Vein and Dissemination	Neogene tertiary	It is an area to the south of Rachaite village located about 50km to the WSW of Abra Pampa.	Mountains with altitudes of 3,500-5,000m and a few vegetation.	Neogene Tertiary (Miocene)	It includes two occurrences of Sb(-Au) vein type mineralization in the eastern part and one occurrence of Pb-Zn-Ag stockwork and vein type mineralization in the western part. All of them are hosted by dacite, andesite and tuff of Neogene	A large fault trending E-W to NE-SW in the north and a semi-circular structure with about 15km of the major axis and about 5km of minor axis in the southwestern part of the zone.	An area with a striped pattern of intense high and low magnetic anomalies exists trending E-W.	Some alteration zones with a total area of $3km^2$ are extracted in the semi-circular structure in the southwestern part.	150	4	Rachaite	
Zone-10	JUJUY	Barite-Pb (-Cu)	Vein	Ordovician	It is located at southern part of the Sierra Cochinoca and includes Cochinoca village of about 20km from Abra Pampa.	Mountains with altitudes of 3,500-4,500m and scattered shrubs.	Ordovician Acoite Formation and Cochinoca-Escaya Complex	Four in a total of 5 occurrences are barite and/or Pb mineralization of vein type. Only Barcosconie occurrence is composed of Cu	Faults, folding axes and distribution of volcanics, all trend approximately N-S.	A low magnetic anomalous area exists with a weak grade.	No alteration zone is extracted.	100	5		
Zone-11	JUJUY	Barite-Pb (-Cu-Zn-Ag)	Vein and Dissemination	Ordovician	It is located about 15km from Abra Pampa. Road condition is not good within the zone.	Mountains with altitudes of 3,700-4,100m and scattered shrubs.	Ordovician Santa Victoria Group surrounded by post-Cretaceous formations	Five in a total of eight occurrences are mineralization mainly of Cu vein type, other two are Pb-barite veintype mineralization. Four occurrences in the Rumicruz district are characterized by Ni association.	Either faults or folding axes trend approximately N-S.	A set of high and low magnetic anomalies with a weak grade exists trending NE-SW in the southern half of the zone.	-	130	8	La Pricima - Rumicruz	
Zone-12	JUJUY	Pb-Zn-Cu (-Ag-Barite)	Vein	(Precamb.~) Ordovician	It is a wide area centered by Iruya, the capital town of the department. Iruya is located about 40km to the ENE of Tres Cruces.	Mountains with altitudes of 3,000-4,500m.	Precambrian Puncoviscana Formation, Cambrian Mesón Group, Ordovician Santa Rosita Formation and Cretaceous Balbuena Sub-group	Seven in a total of 13 occurrences are vein type mineralizations composed mainly of Cu, and the other six occurrences are barite and/or Pb-Zn mineralization. La Esperanza occurrence in the six is characterized by U-association.	NNW-SSE to NE-SSW trending faults and folding axes	-	-	450	13		
Zone-13	JUJUY	Cu-Sn	Vein and Pegmatite	Ordovician, Tertiary	It is located about 70km to the southwest of Abra Pampa and covers Cerros de Pelomoy trending NNE-SSW.	Mountains with altitudes of 3,500-4,300m.	Ordovician Acoite and Chiqueros formations, Tertiary rhyolite dykes and Neogene tertiary welded tuff in the western part	It includes three vein type occurrences. Two occurrences are Cu mineralizations hosted by the Ordovician Chiqueros Formation, and the one is a Sn-Pb mineralization hosted by rhyolite dyke intruding the Ordovician	NNE-SSW trending faults in the east and NNW-SSE trading faults in the north of the zone	The zone is covered by low magnetic anomalies with an intense to medium magnitude.	Some alteration zones with a total area of $10km^2$ located along the fault trending NNW-SSE are extracted in an area covered by the Ordovician.	150	3		Out of the survey target

Zone No.	Province	Element / Material	Type	Age of Host Rock	Location and Access	Topography and Vegetation	Geology	Mineralization	Geological structure	Aero-magnetic anomaly	Alteration extracted by ASTER Image	Area (km^2)	Number of mineral occurrences	Mineral occurrence surveyed	Evaluation
Zone-14	JUJUY	W	Greisen	Jurassic - Cretaceous	It is located about 70km to the SSW of Abra Pampa and covers mountains of Cerro Norado and Cerro Alfar, trending N-S.	Mountains with altitudes of 3,500-4,500m.	Jurassic to Cretaceous Tusaquillas Batholith (granodiorite)	All five occurrences included in the zone are W-greisen mineralizations hosted by granodiorite of the Jurassic to Cretaceous Tusaquillas Batholith.		The zone is covered by low magnetic anomalies with a weak to medium magnitude.	Topical about 10 alteration zones with areas of approximately $10km^2$ are extracted in the area covered by granodiorite of the Tusaquillas Batholith.	300	5		Out of the survey target
Zone-15	JUJUY	Pb-Ag-Zn (-Au-Barite)	Vein and SEDEX	Ordovician	It covers Sierra del Aguilar including Aguilar mine. There is a good road to the mine from Tres Cruces in the eastern flank of the range, but no road crossing the range.	Mountains with altitudes of 4,000-5,000m and a few vegetation.	Ordovician Santa Rosita Formation (Lampazar Formation, Aguilar Formation and Padrioc Formation)	Four in a total of seven occurrences are SEDEX Pb-Zn-Ag stratiform mineralizations interbedded in the Lampazar, Aguilar or Padrioc formations, and other two occurrences are Pb simple veins hosted by sandstone, siltstone and shale of the Acoite Formation.	Faults and folding axes trend mainly N-S. Other NW-SE trending fault cut them diagonally in the central part of the zone.	The zone is located in a low magnetic anomalous area with a weak to medium grade.	Two small alteration zones with a total area of $3km^2$ are extracted in an area covered by the Ordovician Santa Victoria Group and an area to the southeast of El Aguilar mine.	300	7	La Candelaria Rio Grande El Aguilar	
Zone-16	JUJUY	Barite-Pb (-Zn-Ag)	Vein(?)	Precambrian - Cambrian	It is located about 20km to the east of Humahuaca and covers the Cianzo river and its tributaries.	Mountains with altitudes of 3,000-4,200m.	Precambrian Puncoviscana Formation, Cambrian Mesón Group and Ordovician Santa Victoria Group	It includes three occurrences of barite vein with some Pb and an occurrence of Pb-Ag-Zn vein, hosted by the Precambrian Puncoviscana Formation and	An intersection of N-S and NE-SW trending faults			150	5		
Zone-17	JUJUY	Barite-Pb (-Cu-Zn)	Vein(?)	Ordovician	It covers a wide area of Sierra de Zenta with its eastern foot. It is about 20km to the western flank of the range to the nearest town of Humahuaca.	Mountains with altitudes of 1,000-5,000m and thick vegetation in its eastern foot.	Precambrian Puncoviscana Formation, Cambrian Mesón Group, Ordovician Santa Victoria Group (Santa Rosita and Acoite formations), Ordovician Centinela Formation and Silurian Lipeón	Ten in a total of 11 occurrences are composed of barite and/or Pb vein type mineralizations maily hosted by shale and sandstone of the Ordovician Santa Victoria Formation.	Faults show N-S, NE-SW and NW-SE trends.			600	13		
Zone-18	SALTA	Pb-Zn-Cu	SEDEX or VMS	Ordovician, Tertiary	It covers the northern part of Sierra del Cobre and is located about 70km to the north of San Antonio de los Cobres.	Hilly mountains with altitudes of 3,500-4,200m and a few vegetation.	Ordovician Santa Victoria Group (Chiquero and Falda Cienaga formations) and Neogene Tertiary welded tuff in the western part.	The zone includes La Colorada of SEDEX (massive sulphide) and covered by the Ordovician Santa Victoria Group. It also includes Pb vein and Cu vein. La Colorada of SEDEX has an indicated reserve of 12 Mt with 33-50%Fe, 20-30%S, 0.5%Cu, 0.9-3%Zn, 0.1-3%Pb, 7-10g/tAg and 0.7g/tAu.	Approximately N-S trending faults	The zone is located in a weak to medium magnetic anomalous area, and a relatively high magnetic anomalies with a weak grade exists trending NW-SE in the central part.	No alteration zone is extracted.	500	3	La Colorada Linseca	
Zone-19	SALTA	Au	Placer	Pleistocene - Holocene	It is located about 40km to the north of San Antonio de los Cobres town and covers a small area including Pueblo Viejo occurrence of placer gold.	Hilly mountains with altitudes of 3,500-4,000m.	Precambrian Puncoviscana Formation	Placer gold with detrital sediments near Au-vein hosted by the Precambrian Puncoviscana Formation		The zone is covered by high magnetic anomalies with a medium magnitude.	No alteration zone is extracted.	100	2		Out of the survey target
Zone-20	JUJUY	REE-Th	Carbonatite	Ordovician, Cretaceous	It is located about 80km to the north of San Antonio de los Cobres town and covers mountains formed of Cerro Curamayo, Filo Honduras, Cerro Volcan and Cerro Cobres.	Hilly mountains with altitudes of 3,500-4,500m.	Ordovician Acoite and Chiqueros formations, Late Ordovician Cobres Granodiorite and carbonatite dykes	It includes eight occurrences of REE-Th carbonatite dike intruding the Late Ordovician granodiorite hosted by the Acoite and Chiqueros formations	N-S trending granodiorite elongation	The zone corresponds to a magnetic anomalous area with a weak to medium magnitude. A relatively high magnetic anomalies with a weak magnitude exists trending NW-SE in the central part.	No alteration zone is extracted.	150	9		Out of the survey target
Zone-21	JUJUY	Borates	Evaporite	Pleistocene - Holocene	It covers a wide area including Laguna de Guayatayoc and Salinas Grandes located about 60km to the SSW of Abra Pampa and about 70km to the north of San Antonio de los Cobres.	Large lakes with an altitude of approximately 3,400m.	Pleistocene to Recent fine sediments	It includes 13 evaporitic deposits of borates and salt in the Salinas Grandes salt lake.		The zone nearly corresponds to a wide high magnetic anomalous area with an intense to medium magnitude.	No alteration zone is extracted.	1400	13		Out of the survey target
Zone-22	JUJUY	Barite	Vein(?)	Precambrian and Ordovician	It is a small area trending NNE-SSW and located to the east of the Salinas Grandes.	Small mountain ranges with 3,800-4,200m and a few vegetation.	Precambrian Puncoviscana Formation and Ordovician Acoite Formation	All of 9 occurrences in the zone are composed of barite simple vein hosted by sandstone and shale of the Acoite Formation and slate, phyllite and schist of the Puncoviscana	NNW-SSE to NNE-SSW trending faults and folding axes		Two alteration zones with areas of $5km^2$ are extracted in the area covered by the Precambrian Puncoviscana Formation.	550	10	Tusca	
Zone-23	JUJUY	Cu, Pb-Ag-Zn, Ba	Vein	Precambrian (-Ordovician)	It is located about 20km to the southwest of Humahuaca town and covers the Sierra Alta range trending N-S.	Mountains with altitudes of 4,000-5,200m.	Precambrian Puncoviscana Formation, Cambrian Mesón Group and Ordovician Acoite Formation	It includes seven occurrences of Cu vein, four occurrences of Pb-Ag-Zn vein and two occurrences of barite vein, hosted mainly by the Precambrian Puncoviscana Formation and Cambrian Mesón	NNW-SSE to NNE-SSW trending faults and folding axes		No alteration zone is extracted.	900	15		
Zone-24	JUJUY	Cu-Pb-Zn-Ag-Sb-Au	Vein	Precambrian	It covers the western mountains of Quebrada de Humahuaca, including Volcan village about 40km to the NNW of San Salvador de Jujuy.	Mountains with altitudes of 1,500-4,500m and woody vegetation in the lower part.	Precambrian Puncoviscana Formation, Cambrian Mesón Group and rhyolitic dykes	It includes seven ocurrences of vein type mineralization hosted by schists, slate and some rhyolite dyke of the Precambrian Puncoviscana Formation. The occurrences are base-metals mineralization such as Cu and also includes Sb-Au vein type mineralization.	NNW-SSE trending faults		No alteration zone is extracted.	600	9	Coiruro	
Zone-25	JUJUY	P_2O_5	Mantiform	Ordovician, Silurian	It is located about 30km to the northwest of Lib. Grl. San Martin city and covers an arc-shaped area in the western slope of the Serrania de Calilegua and Cerros de Ovejeria.	Mountains with altitudes of 1,000-3,000m and jungle adjacent to Calilegua National Park.	Ordovician Labrado and Centinela formations, and Silurian Lipeón Formation	Stratiform biocoenose phosphates beds interbedded with quartzose sandstone and lutite of the Ordovician Centinela and Labrado formations, and stratiform oolitic iron beds in ferruginous micaceous sandstone of the overlying Silurian Lipeóns Formation.	NNW-SSE to NNE-SSW trnding faults and folding axes		No alteration zone is extracted.	500	11		Out of the survey target
Zone-26	SALTA	Sb, Pb-Ag-Zn	Vein	Ordovician, Cretaceous, Tertiary	It covers an area about 10km to the west of San Antonio de los Cobres.	Mountains with altitudes of 3,700-5,000m and a few vegetation.	Precambrian Puncoviscana Formation, Ordovician Oire Effusive Complex, Cretaceous Pirgua Sub-group, Tertiary Punta del Viento Formation (dacite), and Miocene Agua Caliente Formation (dacite) and Rumibola Formation (andesite)	It includes 17 occurrences of vein type mineralizations and two occurrences of placer gold. The vein type mineralizations are composed of 13 Pb-Ag-Zn occurrences and four Sb occurrences, and hosted by the Ordovician granodiorite, the Cretaceous conglomerate and the Tertiary dacitic and andesitic rocks.	Tertiary volcanic area in the zone is located on an extension line of NW-SE trending fault zone in the Paleozoic area to the west of the zone.	A set of high and low magnetic anomalies with a intense magnitude exists trending E-W.	Some alteration zones with a total area of $10km^2$ are extracted in an area covered by the Tertiary volcanics and the Precambrian Puncoviscana Formation.	440	25		

Zone No.	Province	Element / Material	Type	Age of Host Rock	Location and Access	Topography and Vegetation	Geology	Mineralization	Geological structure	Aero-magnetic anomaly	Alteration extracted by ASTER image	Area (km²)	Number of mineral occurrences	Mineral occurrence surveyed	Evaluation
Zone-27	SALTA	Cu-Pb-Zn (Au, Ag, Bi)	Vein and Dissemination	Precambrian, Cretaceous, Tertiary	It covers a wide area about 10km to the southeast of S.A. de los Cobres. National rutes #40 and #51 from S.A. de los Cobres are crossing the zone.	Mountains with altitudes of 3,000-5,000m and a few vegetation.	Precambrian Puncoviscana Formation, Cretaceous Yacoraite Formation, Oligocene Acay Granite, Oligocene to Miocene Rio Grande Formation, Miocene to Pliocene Payogastilla Group and Pliocene Rumibola Formation (andesites)	10 in a total of 22 occurrences are vein type mineralizations of Cu hosted by the Precambrian Puncoviscana Formation, nine occurrences are mineralizations of base metals such as Cu-Pb-Zn hosted mainly by the Tertiary volcanics, and the other three occurrences are mineralizations composed of Au. One of the Au mineralization is the Organullo occurrence of porphyry Au hosted by the Tertiary dacitic and andesitic	N-S trending faults	In the eastern central, a high magnetic anomalous zone with a intense to medium magnitude exists trending E-W, and in the eastern north, a low magnetic anomalous zone with a intense to medium magnitude exists and in the eastern south, a set of high and low magnetic anomalies exists with a weak magnitude. In the western side, a striped pattern of intense high and low magnetic anomalie is located trending NE-SW.	Some alteration zones in the area covered by the Precambrian Puncoviscana Formation in the eastern part and some in the area covered by the Tertiary volcanics are arranged trending NNE-SSW, extracted with a total area of 15km².	1400	22	El Acay Organullo Incachule	
Zone-28	SALTA	Mo-Cu-Au	Dissemination and Porphyry	Precambrian, Miocene	It covers an area about 30km to the southeast of S.A. de los Cobres and about 60km to the northwest of Salta. The zone is cut by National Rute #51 in the southern part and surrounded by a rough way. It is accessible.	Mountains with altitudes of 3,000-4,400m and a few vegetation.	Precambrian Puncoviscana Formation (Metamorphic rocks), Miocene dacite porphyry and Tastil Granites	It includes the Pancho Arias occurrence of porphyry Mo-Cu-Au hosted by the Precambrian leptometamorphic rocks, and the Miocene dacitic porphyry dikes and hydrothermal breccias.			Some alteration zones with a total area of approximately 3km² are extracted in the area covered by leptometamorphic rocks of the Precambrian Puncoviscana Formation.	190	2	Pancho Arias	
Zone-29	SALTA	Borates	Fossil Evaporite and Evaporite	Miocene, Pleistocene - Holocene	It covers an area including Salar de la Laguna located about 50km to the SSW of San Antonio de los Cobres.	Salt lakes with an altitude of approximately 4,000m.	Miocene and Pleistocene to Recent fine sediments	It includes four evaporite and five fossil evaporite deposits of borates in the Sijes salt lake.		the zone is covered by weak low magnetic anomalies.	No alteration zone is extracted.	500	9		Out of the survey target
Zone-30	SALTA	Borates	Evaporite	Pleistocene - Holocene	It covers an area including Laguna Ratones located about 100km to the SSW of San Antonio de los Cobres.	Salt lakes with an altitude of approximately 4,000m.	Pleistocene to Recent fine sediments	It includes eight evaporite deposits of borates in the Salar de Diablillos salt lake located on the southern extension of the Sijes salt lake.		the zone is covered by weak low magnetic anomalies.		190	8		Out of the survey target
Zone-31	SALTA	Au-Cu (-Mo)	Dissemination and Vein	Ordovician, Tertiary	It covers an area about 50km to the west of Cachi town, about 100km to the NNE of Antofagasta de la Sierra town and also about 100km to the SSW of S.A. de los Cobres. It is not accessible for one day trip from these towns.	Hilly area with altitudes of 4,000-5,000m and a few vegetation.	Precambrian Rio Blanco Complex (sillimanite schist), Ordovician Oire Effusive Complex, and Miocene monzonite porphyry, dacite porphyry and granitic intrusives	It includes two occurrences of porphyry Au-Cu mineralization hosted by the Miocene intrusives and breccias, and a occurrence of base-metal vein type mineralization hosted by the Ordovician Oire Eruptive Complex.	N-S and NW-SE trending faults	No remarkable magnetic anomaly exists except for a weak low magnetic anomaly in the central part.	Relatively large alteration zones with a total area of 10km² are extracted around the area covered by the Tertiary volcanics (Inca Viejo), some with a total area of 3km² are extracted in the area covered by the Precambrian Rio Blanco Complex and the intruding Tertiary granitic rocks (Diablillos) and some alteration zones with the maximum area of 7km² are extracted in the area covered by the Precambrian Rio Blanco Complex and Quaternary sediments between Inca Viejo and Diablillos.	600	4	Vicuna Muerta Inca Viejo Diablillos Condor Yacu	
Zone-32	SALTA	Mica	Pegmatite	Precambrian	It is located about 20km to the NW of Cachi town and covers an area including the Sierra de Cachi trending N-S.	Mountains with altitudes of 5,000-6,380m.	Precambrian Pachamama Igneo Metamorphic Complex	It includes six occurrences of sillimanite vein or nodule hosted by the Precambrian Pachamama Igneo-Metamorphic Complex and four occurrences of Be-mina pegmatite hosted by the Precambrian Rio Blanco Metamorphic Complex.	NW-SE and NNE-SSW trending faults	A set of weak high and low magnetic anomalies exists E-W trending.	A very small alteration zone is extracted in the south end of the zone.	900	10		Out of the survey target
Zone-33	SALTA	Nb-Ta-Li-Bi-Be	Pegmatite	Precambrian - Lower Cambrian	It is located about 50km to the SW of Cachi town and covers an area including the upper tributaries of the Rio Blanco, trending NE-SW.	Mountains with altitudes of 3,200-4,600m.	Precambrian Puncoviscana Formation (La Paya Formation) and Late Cambrian Cachi Trondhjemite Plutons	All nine occurrences included in the zone are Nb-Ta-Li-Bi-Be pegmatites hosted by the Precambrian Puncoviscana Formation (La Paya Formation) and the intruding Precambrian to Late cambrian Cachi Trondhiemite	NW-SE trending faults and NNW-SSE trending intrusive body elongation	The northern half of the zone is covered by low magnetic anomalies and southern half is covered by high magnetic anomalies with weak to medium grade.	No alteration zone is extracted.	600	10		Out of the survey target
Zone-34	SALTA	Pb-Ag, Cu	Vein and Stratabound	Precambrian, Cretaceous	It covers an area SW adjacent to Cachi town.	Mountains with altitudes of 2,100-4,600m and a few vegetation.	Precambrian La Paya Formation (Puncoviscana Formation), Cambrian Cachi Granite, Cretaceous Pirgua Sub-group and Cretaceous porphyry body	Six in a total of eight occurrences are Pb simple vein type mineralizations with some Ag, mainly hosted by the Precambrian slates, schist and phyllite, one is Brealito occurrence of Cu, and the other is El Monte occurrence of stratabound Cu in the Cretaceous	NNW-SSE to N-S trending faults	The zone is mostly covered by weak high magnetic anomalies, associated with weak low magnetic anomalies in the south.	No alteration zone is extracted.	370	8	Brealito	
Zone-35	SALTA	U-V	Strata-bound	Cretaceous	It is located about 20km to the east of Cachi town and occupies the eastern slope of Cerro Tintin.	A hill with an altitude of 3,763m	Cretaceous Yacoraite Formation	It includes only stratabound and tabular U-V deposit interbedded by micaceous calcareous sandstone, oolitic limestone and sandy limestone of the Cretaceous Yacoraite Formation.			No alteration zone is extracted.	60	1		Out of the survey target
Zone-36	SALTA	U-V	Strata-bound	Cretaceous	It is located about 40km to the SE of Cachi town and occupies the Sierra Colorada.	Hills with altitudes of 2,500-3,500m	Cretaceous Yacoraite Formation	It includes four stratabound and tabular U-V deposit interbedded by micaceous calcareous sandstone, oolitic limestone and sandy limestone of the Cretaceous Yacoraite Formation.			No alteration zone is extracted.	200	4		Out of the survey target
Zone-37	SALTA	U-V	Strata-bound	Cretaceous	It is located about 40km to the SW of Guachipas town and includes Cerro El Penon and Cerro Quitilipi.	Hills with altitudes of 1,500-2,500m.	Cretaceous Yacoraite Formation	It includes two stratabound and tabular U-V deposit interbedded by micaceous calcareous sandstone, oolitic limestone and sandy limestone of the Cretaceous Yacoraite Formation.			No alteration zone is extracted.	125	2		Out of the survey target
Zone-38	SALTA	Cu	Vein and Stratabound	Precambrian, Ordovician, Cretaceous	It covers an area about 30km to the south of Angastaco village. There is no accessible road from the village in the zone.	Mountains with altitudes of 3,500-5,000m	Precambrian Tolombón Metamorphic Complex, Precambrian Puncoviscana Formation, Ordovician Oire Effusive Complex, Cretaceous Pirgua Sub-group, and Neogene Tertiary welded tuff and Payogastilla Group	It includes two occurrences of Cu vein type mineralizations hosted by the Precambrian Tolombón Metamorphic Complex and Puncoviscana Formation, and the other one is Vallecito occurrence of stratabound Cu in the Cretaceous Pirgua Subgroup.	Mainly NNW-SSE to NW-SE and E-W trending faults	Weak magnetic anomalies exist, low in the north and high in the south.	No alteration zone is extracted.	300	3		

Zone No.	Province	Element / Material	Type	Age of Host Rock	Location and Access	Topography and Vegetation	Geology	Mineralization	Geological structure	Aero-magnetic anomaly	Alteration extracted by ASTER image	Area (km^2)	Number of mineral occurrences	Mineral occurrence surveyed	Evaluation
Zone-39	CATAMARCA / SALTA	Cu	Vein and Stratabound	Cretaceous, Tertiary	It covers a wide area about 40km to the east of Antofagasta de la Sierra town and about 70km to the northwest of Santa Maria town. There is few accessible road from the towns in the zone.	Mountains with altitudes of 4,000-5,000m	Cretaceous Pirgua Sub-group, Miocene monzodioriteand volcanic rocks, Miocene to Pliocene Payogastilla Group and Pliocene to Pleistocene volcanic rocks	It includes two occurrences of stratabound Cu mineralization in the Cretaceous Pirgua Subgroup and the Miocene to Pliocene Payogastilla Group, and the other one is Languna del Salitre occurrence of Pb-Zn vein hosted by the Miocene Monzodiorite.	NW-SE, NE-SW and N-S trending faults, a large circular structure with about 40km of the major axis and about 25km of minor axis to the northwest of the zone, and a very small circular structure with about 3km in a diameter between faults trending NW-SE in the southern part.	The zone is located in a wide high and low magnetic anomalous area with an intense magnitude. The southeast part of the zone is high and the northwest part is low. In the northwest part, a part of a magnetic circular structure exists corresponding to the western arc of the large circular structure, and in the central part, a striped pattern of high and low magnetic anomalies	An alteration zone with an area of 1km^2 and some small and sporadical alteration zones are extracted in the southwest and along the eastern margin of the large circular structure in the west. All of the zones are not correspond to the zones extracted by TM.	1500	3	Laguna del Salitre	
Zone-40	TUCUMAN / CATAMARCA / SALTA	Micatile	Pegmatite	Upper Precambrian, Lower Carboniferous	It is located about 30km to the NNW of Santa Maria town and occupies an N-S trending area including Cerro Quilmes, Cerro Vicuna Horco and Cerro Tres Rios.	Mountains with altitudes of 3,500-5,500m	Late Precambrian Piscoyacú Gneiss and Tolombón Metamorphic Complex	It includes eight occurrences of mica pegmatite deposits hosted by the Precambrian Tolombón Metamorphic Complex and the Upper Precambrian Piscoyacu Gneiss.	NNW-SSE and NW-SE trending faults	The northern part is covered by high magnetic anomalies with medium to intense magnitude and the central to southern part is covered by weak magnetic anomalies.	No alteration zone is extracted.	900	9		Out of the survey target
Zone-41	TUCUMAN	Cu-Pb-Zn-Au	Dissemination	Upper Precambrian	It is located about 40km to the NNW of Santa Maria town and occupies an NW-SE trending area including the Cerro Negro de los Halcones.	Mountains with altitudes of 2,000-4,000m.	Precambrian Piscoyacu Gneiss and Carboniferous Granite Stocks	It includes two occurrences of Cu-Pb-Zn-Au disseminations hosted by gneiss and migmatite of the Upper Precambrian Piscoyacu Gneiss, and one .	NNW-SSE and E-W trending faults Las Canas occurrence is located on an extension line of NNW-SSE trending fault zone.	No remarkable magnetic anomaly exists in the zone.	No alteration zone is extracted.	350	2		
Zone-42	CATAMARCA	Au	Vein	Upper Cambrian - Ordovician - Silurian , Upper Miocene	It covers an area about 70km to the north of Belen city. National Rute #43 for Antofagasta de la Sierra from Belen is passing through the north and east sides of the zone but there is no road within the zone.	Mountains with altitudes of 2,500-4,500m and a few vegetation.	Upper Cambrian to Lower Ordovician Cachinda Group (metasediments), Upper Ordovician to Silurian Chango Real Granites and Granitic Gneiss, Miocene andesitic porphyry intrusives and dykes, and Upper Miocene La Hoyada Formation (andesite)	Eight in a total of 19 occurrences of various types are occurences mainly of polymetallic mineralizations hosted by the Upper Cambrian to Lower Ordovician. Four are occurrences of Pb-Ag-Cu vein type mineralization hosted by the Upper Miocene La Hoyada Formation, and the others includes Vaca Vizcana occurrence of porphyry Cu hosted by the Chango Real Granodiorite and the intruding andesitic porphyry dikes of the	NW-SE and N-S trending fault and a circular structure with about 15km in a diameter.	A wide striped pattern of high and low magnetic anomalies exists to the west of the zone. The striped pattern of magnetic anomalies extends to the north of the area, with a medium grade.	Some tiny alteration zones elongated in a E-W trend are extracted in the area covered by the Tertiary volcanics within the circular structure in the northeast.	350	14	Vaca Vizcana	
Zone-43	CATAMARCA	Cu-Mo-Pb-Zn-Ag-Au	Dissemination and/or Vein	Ordovician, Upper Miocene	It covers a wide area including the Fumabuasi mining district to the south of La Quiaca. There are pavement roads for main occurrences.	Mountains with altitudes of 1,000-4,700m and a few vegetation.	Upper Miocene Farallón Negro Volcanic Complex and Canudo Breccia	It includes 28 occurrences composed mainly of porphyry Cu such as Bajo de la Alumbrera mine and Agua Rica and epithermal low sulfidation Au such as Alto de la Blenda mine.	In the central part, The large fault trending NNW-SSE, along which metamorphic rocks are located, in the southern batholith of granite , a large fault trending NE-SW to E-W, and in the western Agua de Dionisio district, a circular structure with about 15km in a diameter.	A striped pattern of high and low magnetic anomalies with a intense magnitude exists trending NE-SW in the western Agua de Dionisio area. In the pattern, a magnetic circular structure is located with 7km of the minor axis and 15km of the major axis. In the central north of the eastern part, A striped pattern of high and low magnetic anomalies with a intense magnitude exists trending NE-SW.	Relatively large alteration zones with the maximum area of 10km^2 are mostly extracted around the known ore deposits in the area covered by the Tertiary volcanics.	1200	26	Alto de la Blenda (Laboreo, Nudo, Esperanza) Agua Tapada Bajo de la Alumbrera Bajo El Durazno Capillitas	
Zone-44	CATAMARCA	W	Vein	Upper Precambrian, Upper Ordovician, Silurian			Late Precambrian, Late Ordovician and Silurian metamorphic rocks and granite	It includes 13 occurrences of Sn or W vein type mineralizations mainly hosted by the Chango Real Granite and the intruded schist of the Upper Precambrian Famabalasto	NNW-SSE to NNE-SSW trending faults		No alteration zone is extracted.	1200	13		Out of the survey target
Zone-46	TUCUMAN	Cu - Au	Dissemination	Ordovician, Miocene	It covers an area about 10km to the northeast of Tafi del Valle and about 30km to the west of San Miguel de Tucuman. There is no accessible road to the zone.	Mountains with altitudes of 1,500-3,000m and a thick vegetation	Ordovician Mala Mala Granodiorite and Miocene Volcanic Complex	It covers El Alisal occurrence of porphyry Cu-Au hosted by the Ordovician Mala Mala granodiorite and the intruding Miocene andesitic rocks.	NW-SE trending faults.		No alteration zone is extracted.	60	1	El Alisar	
Zone-47	TUCUMAN	Cu-Au-Pb-Zn	Dissemination	Upper Precambrian	It includes El Pago occurrence about 50km to the south of Tafi del Valle town and about 70km to the WSW of San Miguel de Tucuman. There is no accessible road from the main roads.	Mountains with altitudes of 2,000-3,500m and a thick vegetation.	Gneiss and migmatite of the Upper Precambrian Piscoyacu Gneiss, and the intruding porphyry and lamprophyre	It is reported that pyrite, chalcopyrite, sphalerite and galena are disseminated in the basement rocks and the intruding porphyry and lamprophyre, and alterations such as sericitic, argillic, silicic, potasic and propylitic occur.	ENE-WSW trending faults		Some alteration zones are extracted with a total area of about 1km^2.	30	1		

for these magnetic and radioactive data. As a result, in the magnetic data analysis, the area with distribution of Tertiary volcanic rocks is clearly shown as an area with short wavelength in the magnetic data. In the survey area, epithermal deposits and porphyry-type deposits are consistent with the area with distribution of these volcanic rocks well. In some of zones where exposure of the intrusive rock body is small in the surface layer, distribution of magnetic structure of a long-wavelength is also recognized, which is considered to indicate the presence of the intrusive rock body in the deep part.

By radioactive data, the distribution of volcanic rocks in particular could be clearly shown, and, therefore, it seems possible to use this data for presumption of rock types. We calculated the ratio of potassium to potassium plus thorium plus uranium in order to assume the presence of epithermal deposits, etc. The results show that places where this ratio is high correspond to the area with deposits distribution from the viewpoint of the wide area. On the other hand, from the viewpoint of the local area, there is a tendency that deposits concentrate near places with a high ratio of potassium to thorium.

As a future subject, it is necessary to minutely compare geology, tectonics, radiometric data, etc. of specified areas extracted as highly potential areas in order to specify areas with deposits distribution from the more minute point of view. Besides this, improvement of data and quality is mentioned as our request. As vegetation is thin in most of the range of this airborne geophysical exploration, distribution of Tertiary volcanic rocks can be grasped easily on the satellite image. However, vegetation is thick in the zone where airborne geophysical data has not been obtained, which is located on the east side of the survey area. The importance of employing the airborne geophysical data is higher in this side. As grid-like noise is recognized on the data (particularly, linear structure in the direction of south to north has more noise component), it is necessary to improve the quality of data.

4-3 Stream sediments geochemistry

In this fiscal year, the 48 elements analysis were made for the stream sediment samples of about 5000 that had collected by SEGEMAR in the past geological survey.

The analysis results show the distributions of copper, lead, zinc and silver in Northwest area. A copper anomaly corresponds to the distribution of known porphyry copper deposits, especially the high anomaly value is seen around Agua Rica mineral showings. Lead anomaly is mainly distributing over known SEDEX deposits, and partly seen around porphyry copper deposits. Zinc anomaly also distributes the SEDEX deposits. Silver anomaly is seen in the wide area in the southern part of surveyed area. The distribution corresponds well to the distribution of Ordovician granites in Southern part of the area.

4-4 Satellite image analysis

This analysis targeting the dry area with bare rocks aimed at identification of alteration minerals in the alteration zone accompanying deposits by the use of actual data obtained by the ASTER, which enables satellite data to be effectively used for exploration of metal deposits.

Prior to the analysis, the following pre-processing was carried out:

- Registration between bands to correct divergence of pixels that occurs inside and among telescopes.
- Pseudo reflection conversion using the pseudo reflection conversion factor (the Ministry of Economy and Industry, 2001).
- Removal of reflectance spectra of plants using the SAVI (soil adjust vegetation index).

For identification and semi-quantitative analysis of alteration minerals, the iso-grain model, for which consideration was given to reflection and absorption among mineral particles, was used. In this analysis, nine kinds of minerals observed widely were selected. A database of spectral reflection where these minerals were mixed was prepared by the use of the iso-grain model, and mineral identification and semi-quantitative analysis of minerals on the ground surface were carried out. Mineral mapping was then executed.

In addition, a DEM was prepared from data of the stereoscopic image of five successive scenes without clouds. Spatial resolution of the prepared DEM was determined to be 30 m. At the same time, orthorectified images at a spatial resolution of 30 m were prepared for each of VNIR and SWIR data, and a satellite birds-eye view was also prepared.

Furthermore, atmospheric correction and separation of temperature and emissivity were carried out for data of thermal bands, which are one of the characteristics of the ASTER. Mapping of SiO2 contents was carried out by the use of the conversion expression proposed in the METI (2000).

In the discrimination of alteration zones by the use of the visible and short-wavelength infrared ranges of the ASTER and the iso-grained model, more alteration zones could be discriminated by far than with the existing analysis with the LANDSAT TM used. As a result of the field verification, it was found that almost all of the known deposits and places of mineral showing had been covered. The future objective is to identify alteration zones accompanied by mineral showing and those without mineral showing, and to verify alteration zones that have not been confirmed

4-5 Ground truth

Based on above four kinds of survey method, 24 survey zone were selected as potential area of mineral deposits, and then 36 mineral showings and 4 alteration zone were selected among the area from view point of exploration history and accessibility to the point and carry out field survey. Major proposes of the survey were to make the features of geological structure, alteration,

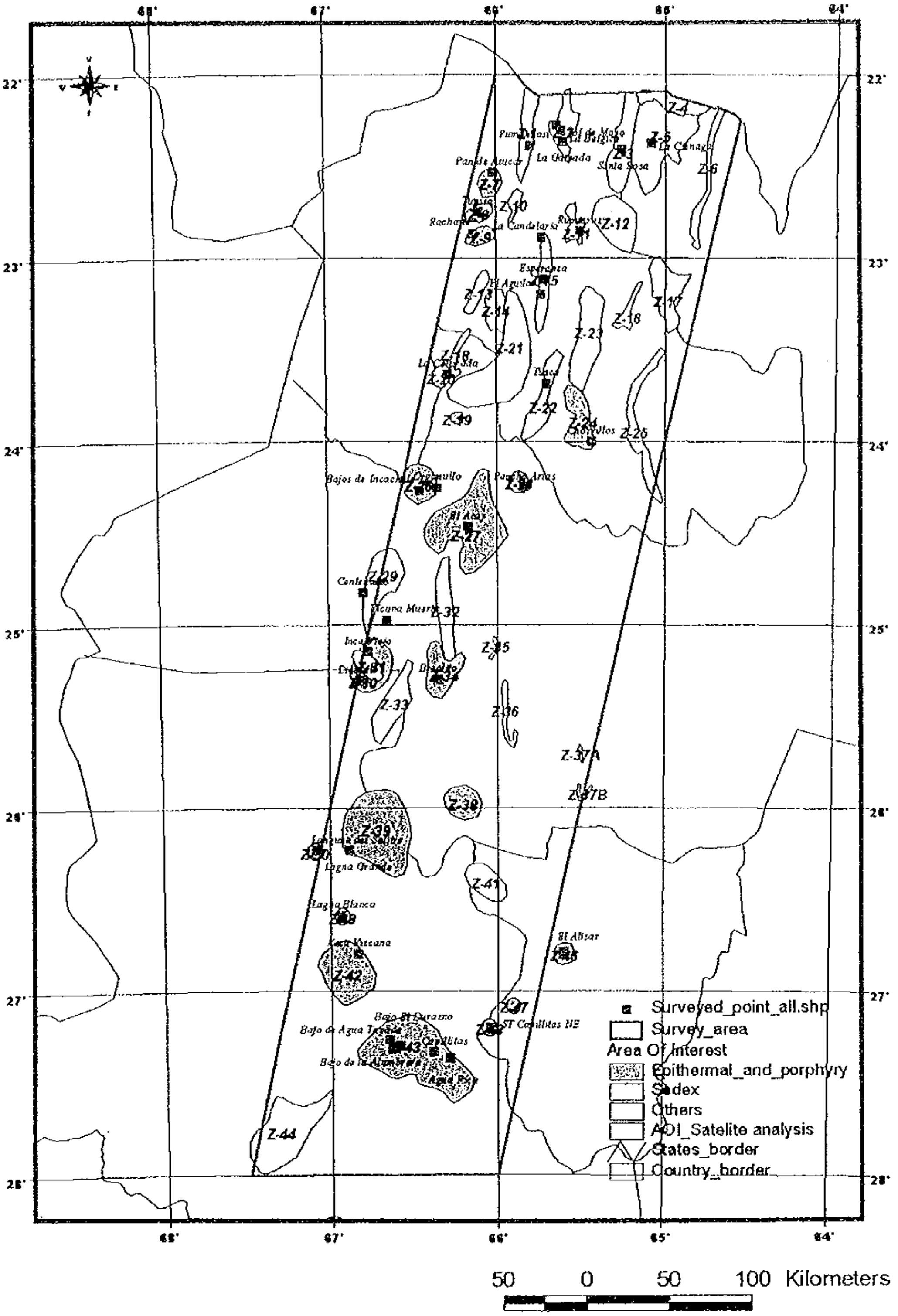


Fig.I-4-5-1 Selected promising zones and survey points.

Table I-4-5-1 Record of ground truth

Date	October																									November						
Mineral showings	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7
Farallon Negro		■																															
Agua Tapada		■																															
Bajo de la Alumbrera			■																														
Bajo El Durazuno			■																														
Agua Rica				■																													
Capillitas					■																												
Capillitas NE					■																												
Vaca Vizcana						■																											
Lagna Blanca						■																											
Lagna del Salitre							■																										
Lagna Grande							■																										
El Alisar											■																						
Brealito															■																		
El Acay															■																		
Incachule																■																	
Organullo																■																	
Vicuna Mueruta																	■																
Inca Viejo																	■																
Diablillos																		■															
Condor Yacu																		■															
Ceatenario																			■														
Pancho Arias																				■													
Mina El Aguilar																								■									
Esperanza																								■									
Rio Grande																									■								
Belgica																										■							
Pumahuasi																										■							
Sol del Mayo																										■							
La Cienaga																											■						
Santa Rosa																											■						
La Geteada																												■					
Pan de Azucar																													■				
Tupiza																													■				
La Pricima																														■			
Rumicruz																														■			
La Candelaria																														■			
Rachaite																															■		
La Colorada																																■	
Limeca																																■	
Tusca																																	■
Coiruro																																	■

Table I-4-5-2 Outline of survey results

No.	Mineral occurrences surveyed	Zone No.	Element / Material	Type	Alteration extracted by ASTER image	Survey results	Project status	Activity status	Holding of mining right	Evaluation
1	La Gateada	Zone-01	Pb	Vein	-	A quartz vein with Cu-Pb-Zn was observed.	AP	ABD	-	×
2	La Belgica	Zone-02	Pb-Zn	Vein	-	Some barite vein with Pb were observed.	AP	ABD	-	×
3	La Pumahuasi	Zone-02	Pb-Zn	Vein	-	Barite with Pb was observed in waste dumps.	AP	ABD	-	×
4	Sol de Mayo	Zone-02	Pb-Zn	Vein	-	Barite with Pb was observed in a stock pile.	AP	ABD	-	×
5	Santa Rosa	Zone-03	Barite	Vein	-	Barite with Pb was observed in a stock pile.	AP	ABD	-	×
6	La Cienaga	Zone-05	Pb -Cu-Barite	Vein	-	Some barite vein with malachite was observed at the entrance of a gallery and Pb-Zn-Cu ore were found in a stock pile.	AP	ABD	-	×
7	Pan de Azucar	Zone-07	Pb-Ag-Zn -Sb	Vein	O		AP	ABD	-	
8	Tupiza	Zone-08	Pb-Ag-Zn-Cu	Vein	-		AP	ABD	-	×
9	Rachaite	Zone-09	Pb-Zn-Ag-Mn	Vein and Dissemination	O		BS	NOA	?	O
10	La Candelaria	Zone-15	Pb	Vein	×	Some small barite veins with Pb were observed.	AP	ABD	-	×
11	La Pricima - Rumicruz	Zone-11	Cu-Pb-Barite-Ni-Co-Zn-Ag-Au	Vein	×		AP	ABD	-	×
12	El Aguilar	Zone-15	Pb-Ag-Zn	SEDEX	×	Active mine of SEDEX	PR	ACT	Compania Minera Aguilar S. A	O
13	Rio Grande	Zone-15		SEDEX	×	Some massive pyrrhotite beds were found.	BS	HLD	Compania Minera Aguilar S. A	O
14	La Colorada	Zone-18	Cu-Pb-Zn-Fe	SEDEX or VMS	×	Thick massive sulphide ore with a high Fe-S content was found in the drill cores which were collected by a private	RD	ABD	-	O
15	Lineca	Zone-18			×	The existence of SEDEX horizon is reported.	BS	ABD		O
16	Tusca	Zone-22	Barite	Vein	O?	Barite veins have been mined out on the surface.	AP	ABD	-	×
17	Coiruro	Zone-24	Sb-Au	Vein	-	Old adits and pits are found on the steep slope.	AP	ABD	-	×
18	Incachule	Out of			O		RD	HLD?		O
19	Organullo	Zone-27	Cu-Pb-Bi / Cu-Au	Vein and Dissemination	O	In the Organullo north, drillings were carried out for porphyry Cu by a private company.	RD	HLD?		O
20	El Acay	Zone-27	Fe-Cu-Pb-Zn	Vein and Dissemination	-		BS	HLD?		O
21	Pancho Arias	Zone-28	Mo-Cu-Au	Dissemination and Porphyry	O	It has been drilled for porphyry Cu by a private company.	RD	HLD?		O
22	Centenario	Alteration	-	-	O		RD	HLD?		O
23	Vicuna Muerta	Zone-31	-	-	O	The topography shows an interesting circular	BS			×
24	Inca Viejo	Zone-31	Au-(Cu-Mo)	Dissemination and Vein	O	It has been drilled for porphyry Cu by a private company.	RD	HLD?		O
25	Diablillos	Zone-31	Au-Cu		O	It has been drilled for porphyry Cu by private companies	FS	HLD	Pacific Rim	O
26	Condor Yacu	Zone-31	Au-Cu		O	Explorations including drillings are being carried out by a private company	RD	HLD		O
27	Brealito	Zone-34	Cu		×		RD	?		×
28	Laguna Grande	Alteration	-	-	O		-	-		×
29	Laguna del Salitre	Zone-39	Pb-Zn	Vein and Stratabound	×		AP	-		×
30	Laguna Blanca	Alteration	-	-	O		-	-		×
31	Vaca Vizcana	Zone-42	Cu-Au	Porphyry Cu	-		AP	-		×
32	El Alisar	Zone-46	Cu-Au	Porphyry Cu	-	Porphyry Cu-Au hosted by the Ordovician Mala Mala granodiorite and the intruding Miocene andesitic rocks.	BS	HLD		O
33	El Pago	Zone-47	Cu-Au-Pb-Zn	Dissemination	O		BS	HLD		O
34	Alto de la Blenda (Laboreo, Nudo, Esperanza)	Zone-43	Au-Ag-Mn	Epithermal, low sulfidation	O		PR	ACT	YMAD	O
35	Agua Tapada	Zone-43	Au		O		RD?	HLD?		
36	Bajo de la Alumbrera	Zone-43	Cu-Au	Porphyry Cu-Au	O		PR	ACT	YMAD	O
37	Bajo El Durazno	Zone-43	Cu-Au	Porphyry Cu-Au	O		RD?	HLD?		
38	Agua Rica	Zone-43	Cu-Mo-Pb-Zn-Ag-Au	Porphyry Cu	O		FS	ACT	BHP	O
39	Capillitas	Zone-43	Cu-Au-Pb-Zn-Ag	Vein and Dissemination	O		AP	HLD		×
40	Capillitas NE Alteration	Alteration	-	-	O		-	-		×

mineralization clear and to collect samples for geochemical analysis. Fig.I-4-5-1 shows the location of field survey conducted and Table I-4-5-1 and Table I-4-5-2 shows the survey schedule and summary of result respectively.

4-6 Structure and Control factors of mineralization

As described in Chapter 3, the geology of northwestern Argentina is characterized by Cordillera type orogeny caused by the accretion and collision of micro continents to the Gondowana continent at its southwestern periphery in the times of the upper Precambrian to the lower Palezoic, and also by the easterly oceanic plate subduction from the upper Paleozoic to the present.

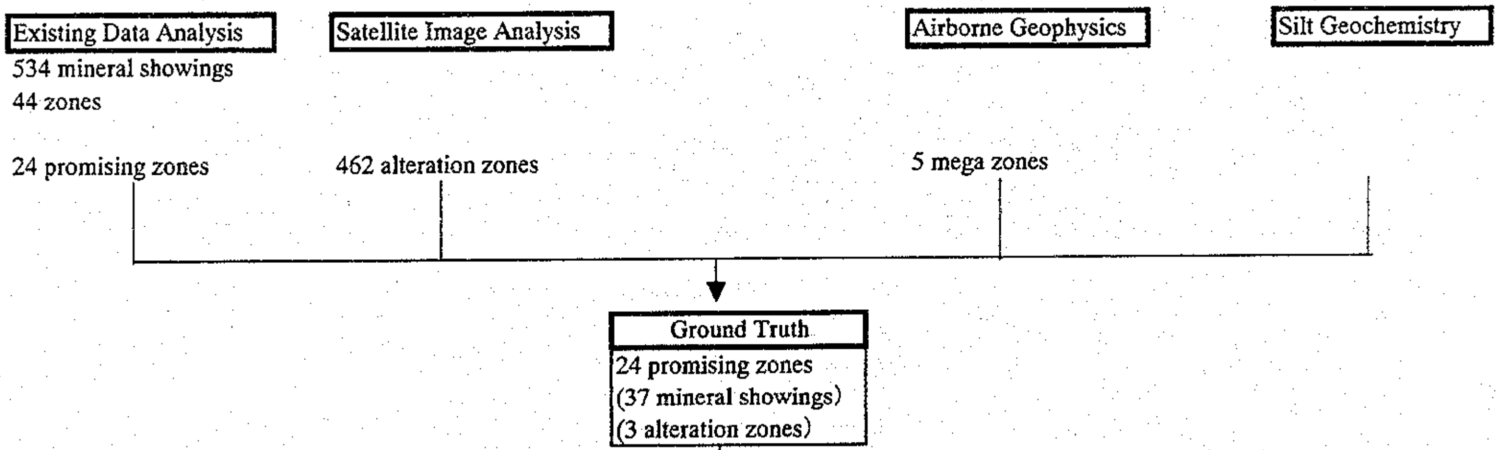
From Precambrian to Quaternary mineralization is closely related with geological development of the area. Above all, in the Ordovician system, there is high potentiality of existing SEDEX type lead and zinc deposits and volcanogenic massive sulfide deposits and in the Neogene system there is high potentiality of existing porphyry type copper and copper/gold deposits and epithermal gold deposits.

The El Aguilar deposit classified as SEDEX type lead and zinc deposits occurres in the lower Ordovician Acoite formation which is passive margin deposits to the east of the north of the survey area. The La Colorada deposit classified as volcanogenic massive sulfide deposit occurred in the Ordovician magmatic arc to the west of the north of the survey area.

The porphyry type copper and copper/gold deposits and the epithermal gold and silver deposit are limited to the areas of four Neogene volcanic rock extending like an armed shape in a SE direction from the Chilean border, in the neighborhood of intrusive rocks between the arms, and on the arm extensions. The porphyry type copper and copper/gold deposits develop around Farallon Negro, which is one of the volcanic rock arm of relatively advanced erosion, in the neighborhood of Inca Viejo, which is on the periphery of intrusive rock area between the arms, and to the west of Tucuman, which is the arm's extension. On the other hand, the alteration zones related to the epithermal gold and silver deposit tend to exist at a less eroded area, such as those near the Agua Caliente caldera.

4-7 Potentiality of existing mineral deposits and selection of promising areas

As described above, a new deposit is expected to be discovered for the SEDEX type lead/zinc deposit, a stratabound type deposit, in the Acoite formation extending from El Aguilar to Pumahuasi among all the Ordovician system, and for the volcanogenic massive sulfide deposit in the magmatic arc. As there is a high potential of porphyry type copper and copper/gold deposits throughout this area, detailed surveys have already been conducted. There is a possibility that the same deposit is carried in the extension of the volcanic rock arm. While detailed surveys have already been carried out on the epithermal gold and silver deposit, detailed surveys are desired at the hydrothermally altered zones around the calderas of less eroded area, such as Garan, Agua Calienie, Coranzuli, etc. In particular, since the area around the Coranzuli caldera overlaps the tin zone, which continues from the Bolivian side, this area is expected simultaneously to carry polymetallic deposits.



Deposits type	Potential zones	→ Recommended area for the 2nd year's survey
SEDEX	Zone-2	Pumahuasi
	Zone-3 and 5	Santa Victoria
	Zone-15	El Aguilar
VMSD	Zone-18	La Colorada
Porphyry Cu, Cu/Au	Zone-28	Pancho Arias
	Zone-30	
	Zone-31	
	Zone-43	
	Zone-46 and 47	El Alizar-El Pago
Epithermal Au/Ag	Zone-7 and 9	Pan de Azucar-Rachaite
	Zone-30	
	Zone-31	
	Zone-39	Galan
	Zone-43	

Fig. I-4-7-1 Flow chart for the selection of the potential zones and recommended area for the 2nd year's survey

Chapter 5 Conclusion and recommendation

5-1 Conclusion

In this fiscal year, the first year of the two-year survey, 40 points consisting of mineral showings and alteration zones were selected and the ground truth was carried out for those points, based on analysis of the existing data, analysis of airborne magnetics and radiometric data, analysis of satellite images, and analysis and interpretation of geochemical data of stream sediments. In the stage of analysis of the existing data, the target was concentrated to SEDEX type lead/zinc deposits, porphyry type copper and copper/gold deposits, and epithermal gold deposits as deposit types with high economic values. Comprehensive examination was made with the above mentioned four analyses together with results of ground truth and laboratory tests. As a result, the following conclusions were reached.

1) SEDEX type lead/zinc deposits and volcanogenic massive sulfide deposits

For exploration of SEDEX type lead/zinc deposits, there are only a few clues because deposits of this type generally have a weak alteration halo differently from other hydrothermal deposits. With drilling cores which intersected El Aguilar deposits provided by Compania Minera Aguilar S.A. for this survey, it was attempted to delineate ore horizons, hanging wall and footwall by the statistical analysis of the geochemical data. As a result, it was found that there was a difference in chemical composition between them, and methodology such as lithogeochemical exploration would be an effective method.

According to the interpretation of sedimentary basins by Sureda (1999), it is inferred that a zone with a possibility of hydrothermal activities is a zone from El Aguilar to Pumahuasi, which corresponds to the central part of a sedimentary basin of the secondary to tertiary order (the area with distribution of Lower Ordovician Santa Victoria Group). In the vicinity of El Aguilar deposits (Zone 15), including Rio Grande located in this zone, an ore horizon inferred from lithogeochemistry extends north and south direction. Therefore, this area is considered to be a zone with the highest possibility of the existence of deposits. In the Ordovician system on the east side, the upper part of the Santa Victoria Group are distributed and SEDEX type lead/zinc deposits are expected in the deeper level.

The sulfur isotopic ratio of lead in vein-type lead, zinc and barite deposits in the area with distribution of the Ordovician system represent -3 to 4‰, while that of lead in El Aguilar deposits is as heavy as 15 to 25‰. Therefore, the origin of sulfur of these deposits is considered to be different.

La Colorada deposits distributed on the west side of the area in the Ordovician system were regarded as volcanogenic massive sulfide deposits because the deposits were accompanied by volcanic rocks in the vicinity, because filling texture with sulfide minerals in the space of brecciated volcanic rock is observed and because the content of copper is higher than those of lead and zinc compared with typical SEDEX deposits. Although the control factor of this deposit are not clear, if it was formed accompanying volcanic activity, it is expected that similar deposits exist in the whole magmatic arc of the Ordovician on the west side in the north part of the survey area.

2) Porphyry type copper and copper/gold deposits

Miocene to Pliocene magmatic arcs developed near the border between Chile and Argentina. In this area, four volcanic rocks extend like an arm in the SE direction from these north south trending main magmatic arc. We tentatively called them No.1 to No.4 arms for convenience. Distribution of porphyry type copper and copper/gold deposits and epithermal gold deposits are restricted in these four arms. Therefore, these four zones can be fundamentally mentioned as highly potential zones. Particularly, Arm No. 4 has some porphyry type deposits and alteration zones such as Bajo de la Alumbrera, Bajo de la Agua Tapada, and Filo Colorado. Although distribution of volcanic rocks is very small near Inca Viejo halfway between Arms No. 2 and No. 3, it is assumed from the results of airborne magnetics that the potentiality of intrusive rocks exists in the shallow part of the vicinity. In addition, mineralized zones including Inca Viejo, Diablillos, Condor Yacu and Centenario are known. Therefore, even though the distribution of volcanic rocks is very small, these zones can be regarded as those with high potential for the presence of porphyry type copper and copper/gold deposits and epithermal gold deposits.

In the SE tending extension of each arm, small-scale intrusive rocks are scattered, which are not expressed on a small scale geological map. Porphyry type copper and copper/gold mineralizations are observed inside and outside those rocks. This mineralization corresponds to Agua Rica deposits of Arm No. 4, El Alisal and El Pago of Arm No.3 and Panco Arias alteration zone of Arm No. 2. These have been also extracted as alteration zones in the analysis of the satellite image.

Regarding porphyry type copper and copper/gold deposits, the potential for the existence of deposits is thought to be high, as mentioned above. Substantially minute investigations have been already carried out, and room for exploration is considered to exist in the SE tending extension of each arm.

In three north arms of the four, there are resurgent calderas accompanied by ignimbrite, and erosion of volcanic body has not advanced so much yet. Therefore, if porphyry type copper and copper/gold deposits are formed in these volcanic arms, those deposits exist in the deeper level and cannot be the object of exploration.

It is considered that epithermal gold deposits are at the favorable level of erosion. In particular, Rachaite and Incachule alteration zones are obviously inside the caldera wall and can be regarded as products of the volcano-hydrothermal system. A similar presumption can be applied to alteration zone on the east side of Galan caldera extracted from the analysis of the satellite image.

3) Analysis of the ASTER image

The following method was employed this time for the first time: First, the false image, the color-ratio composite and the semi-grain model image were prepared from the ASTER image. Alterations were then extracted and checked with the known deposits and alteration zones. Alterations could be extracted with almost no omission, and the effectiveness of this analysis was verified.

5-2 Recommendation for Phase-2 survey

This year, the potential of the whole survey area was assessed by the analyses of the existing data, satellite images, data of airborne geophysics and radiometric exploration, and data of geochemistry of stream sediments and by the ground truth. For the second year survey, we would like to recommend regarding zones that are thought to have high potential for the existence of deposits but have been surveyed insufficiently, and future surveys of which are expected to lead to the discovery of deposits, among potential zones extracted in the evaluation of the whole survey area.

1) SEDEX type lead/zinc deposits and volcanogenic massive sulfide deposits

In the survey area, El Aguilar Mine is only the operating mine as SEDEX type lead/zinc deposits. For the exploration of deposits of this type, clues for exploration of which are a few, what is desired is a methodology that enables:

a) First of all, grasping precisely the characteristics of El Aguilar deposits (including Esperanza deposits) and factor which control the mineralization, and

b) Deductively applying exploration elements lead by the above-mentioned grasping and general exploration elements of the main SEDEX type lead/zinc deposits in the world to surrounding similar geological environment. There is a similarity that the representative SEDEX type lead/zinc deposits in the world are formed in small-scale sedimentary basins with anoxic environments in large-scale sedimentary basins such as passive margin (for example, Sangster and Macintyre, 1983; Lydon, 1995). Sureda (1999) inferred that El Aguilar deposits were formed in Padrioc Basin of the third order spreading north and south from El Aguilar to Pumahuasi. From the viewpoint of the regional area, it is desirable to re-analyze (re-examine) sedimentary basins in terms of positioning of El Aguilar deposits in the Ordovician system, based on the existing sedimentological data.

The ore horizon of the El Aguilar deposits is generally considered, from mega-fossils, as Acoite formation of the Lower Ordovician. Tracing of horizons hosting deposits is important as well as the above-mentioned analysis of sedimentary basins. It is desired to clarify the stratigraphy by using Lower Paleozoic microfossils with high resolution (conodont and radiolaria).

The lithogeochemical exploration method with argillaceous rocks used is an effective methodology for SEDEX type lead/zinc deposits with a few clues for exploration. It is desirable that this method should be employed in surveys of surrounding places, and, at the same time, additional tests should be made around the said deposits so as to heighten the accuracy of this method.

Concretely, in addition to stratigraphical division with microfossils, it is necessary to clarify horizons hosting deposits by using lithogeochemistry in **Zone 15 (El Aguilar area)** including Rio Grande It is also necessary to extract, by the similar method, horizons hosting deposits in the east-to-west route **(Zones 2, 3 and 5) (Pumahuasi and Santa Victoria area)** connecting Pumahuasi, Santa Rosa and La Cienaga mineral showings.

In La Colorada deposits, massive sulfide deposits were identified by drilling of Pacific Rim Co., Ltd. It is indispensable to grasp the characteristics of this deposit by using drill core. Similarly to El Aguilar, lithogeochemical exploration is required for extraction of horizons hosting deposits. In the case of volcanogenic massive sulfide deposits, it is expected that a hydrothermal alteration zone exists in the hanging wall and footwall, and confirmation of its existence is necessary. Because development of calc-alkali volcanic rocks is observed, the said deposits are different in tectonic setting from El Aguilar deposits, but the environment of the generation is almost unknown. Therefore, it is desired to make examinations with the existing data from the viewpoint of volcanic activity and generation of massive sulfide deposits, based on an understanding of the characteristics of La Colorada Deposits

Concretely, it is desirable to carry out investigation in **Zone-18 (La Colorada area)** including La Colorada deposit and Limeca mineral showing where similar type of mineralization to those of La Colorada have been discovered.

As for porphyry type copper and copper/gold deposits and epithermal gold deposits, known places of mineral showings and alteration zones in and around the survey area were surveyed in detail by foreign exploration companies in the latter half of 1990s, as shown in Table I-3-2-4-1.

It is hard to say that porphyry type copper and copper/gold deposits have been fully investigated in small-scale stock of the Neogene in the basement rocks located in the extension of volcanic rock arms away from the main body of volcanic rock. Concretely, areas to be investigated are **Zone-28 (Pancho Arias area), Zone-46 (El Alisar-El Pago area)**. El Pago was not extracted as a potential zone in the analysis of the existing data carried out this time. Latter have been extracted by analysis of the satellite images as alteration zones. It is desirable to grasp the characteristics and the extension of alteration halo.

Regarding epithermal gold deposits, many mineral showings are found in the arms of volcanic rocks. It has been clarified from the analysis of satellite images and the ground truth carried out this time that there is development of argillized alteration zones accompanied by base metal on the wall of annular structure or resurgent calderas such as Rachaite, Incachule and Pan de Azucar. These zones show the shallow part of the hydrothermal system, and it is expected that epithermal gold deposits exist in the deeper level.

Concretely speaking, the target is the zone around Pozuelos depression starting from Cornazuli caldera where Rachaite alteration zone is located in the north part of the survey area to the vicinity of Pozuelos depression (**Pan de Azucar-Rachaite area**) where Pan de Azucar deposits exist, and the zone surrounding Galan caldera (**Galan area**) in the south part of the survey area. For the whole area of the former, including Zones-7 and-9, it is desirable to investigate both the existing alteration zones and alteration zones extracted from satellite images, regarding characteristics of alteration, distribution and the presence or absence of mineralization. Particularly, as this area is located at the south end of the Bolivian tin belt, and mineralization of tin in Pan de Azucar deposit is known, the potential for vein type polymetallic deposits is considered high. On the other hand, from the analysis of satellite images, alterations were extracted in the caldela wall and on its southeast side around Zone-39 and Galan caldela in the latter zone. However, this zone has not been sufficiently surveyed yet. It is desirable to investigate the characteristics and the distribution of alteration, and the presence or absence of mineralization.