



**REPORT  
ON  
REGIONAL SURVEY  
FOR  
MINERAL RESOURCES  
IN  
THE NORTHWEST AREA  
THE ARGENTINE REPUBLIC**

**PHASE I**

**MARCH 2002**

JICA LIBRARY  
  
J1169192(0)

**JAPAN INTERNATIONAL COOPERATION AGENCY  
METAL MINING AGENCY OF JAPAN**

  
CR(2)  
02-958

**REPORT  
ON  
REGIONAL SURVEY  
FOR  
MINERAL RESOURCES  
IN  
THE NORTHWEST AREA  
THE ARGENTINE REPUBLIC**

**PHASE I**

**MARCH 2002**

**JAPAN INTERNATIONAL COOPERATION AGENCY  
METAL MINING AGENCY OF JAPAN**



1169192【0】

## PREFACE

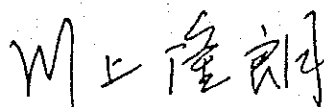
In responding to the request of the Government of the Argentine Republic, the Government of Japan decided to conduct a regional survey for mineral resources in the Northwest area, Argentine republic, and entrusted the survey to the Japan International Cooperation Agency (JICA). JICA, considering the technical nature of geology and mineral resources, entrusted the survey to the Metal Mining Agency of Japan (MMAJ).

JICA and MMAJ agreed on the Scope of Work (S/W) with the Servicio Geologico Minero Argentino, Subsecretaria de Minería, Secretaria de Energía y Minería, Ministerio de Infraestructura y Vivienda of the Government of the Argentine Republic after discussing the survey program, on July 12, 2001. The survey will be carried out within a period of two years commencing from 2001.

MMAJ dispatched a survey team consisting of four members to Argentina from September 20 to November 17, 2001. The survey in Argentina was carried out successfully with close cooperation of the Argentine government authorities. This report summarizes the results of the survey carried out in the first year, and it constitutes a part of the final report which will be submitted after completion of the survey of second year.

We would like to express our sincere appreciation to the officials concerned of the Argentine government, and we also grateful to the officials concerned of the Ministry of Foreign Affairs of Japan, the Ministry of Economy, Trade and Industry of Japan, and the Japanese Embassy in Argentina for their helpful supports to conduct the survey.

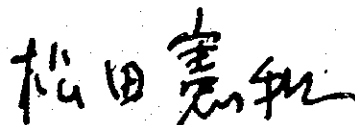
March, 2002



Takao Kawakami

President

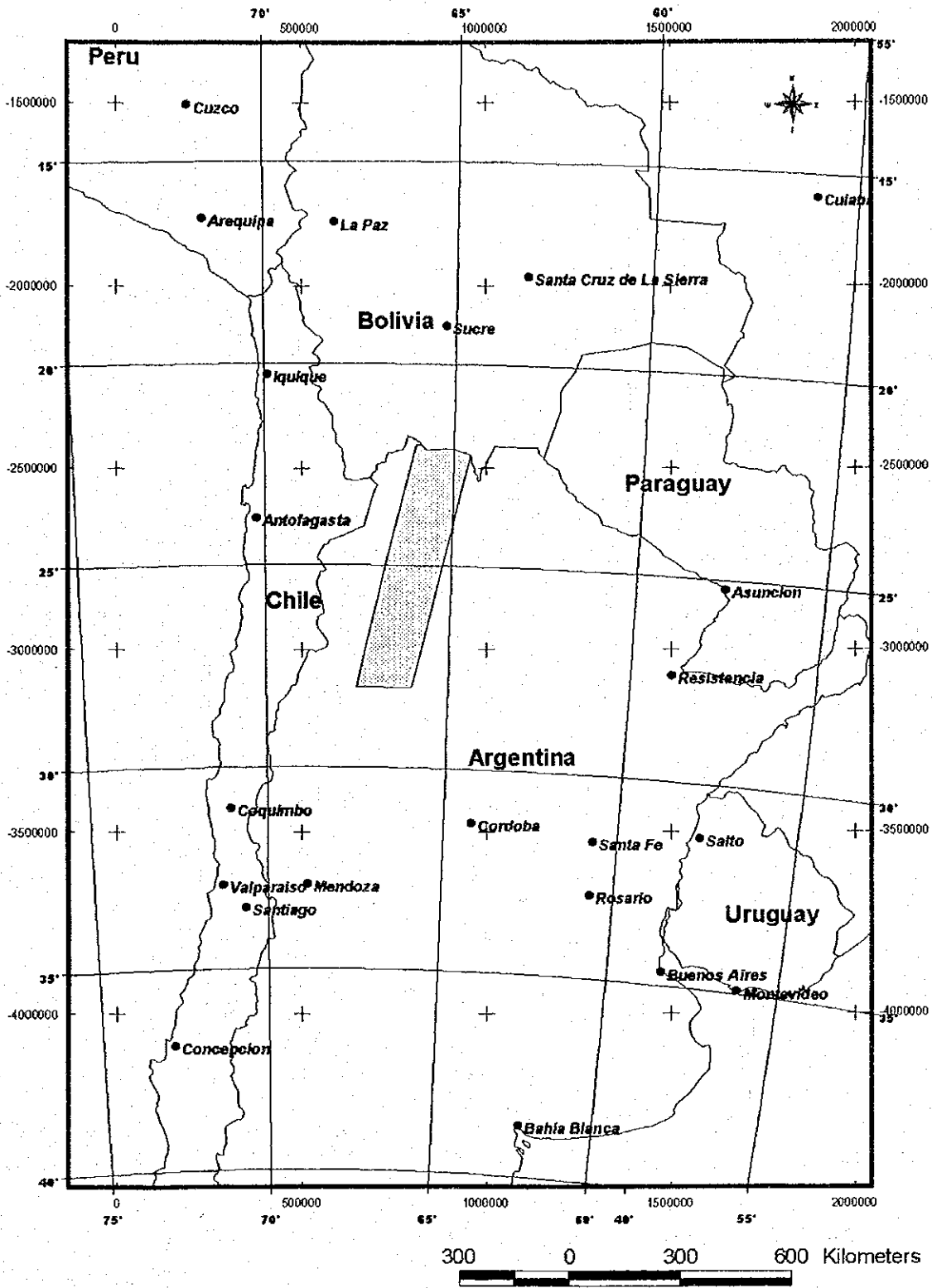
Japan International Cooperation Agency



Norikazu Matsuda

President

Metal Mining Agency of Japan



Location map of the North West Area, the Argentine Republic.

## Summary

This survey is conducted, under the scope of work in the agreement dated July 12, 2001, between the Japanese government and the Argentine government, over a time span of two years for the investigation of nonferrous metallic mineral resources in the Northwestern area of the Argentine republic. The objective is to assess mineral resources potential and to select promising areas over the entire survey area.

In this year, the first year of this project, the analysis of existing data, satellite images, airborne geophysics data, stream sediments, and ground truth were implemented. In the existing data analysis, collected information were summarized in order to concentrate on potential area for minerals. In the satellite image analysis, ASTER images were used to discriminate alteration zones and to classify the alteration minerals. For airborne geophysical analysis, magnetic and radiometric data provided by the Argentine side were processed to find relations between regional geology and mineral deposits. In geochemical analysis, stream sediment samples collected by Argentine side in the past were analyzed.

In consideration of the possibility of future mining development, this survey focused on porphyry copper and copper/gold deposits, epithermal gold/silver deposits, SEDEX-type lead/zinc deposit and volcanogenic massive sulfide deposits. The analysis shows that the SEDEX/sulfide deposits and volcanogenic massive sulfide deposits are mainly controlled by the distribution of Ordovician sediments in passive margin or magmatic arc in the north of survey area. Meanwhile, porphyry copper and copper/gold deposits, and the epithermal gold/silver deposits are restricted to the area of Tertiary volcanic rocks, which extending in the NW-SE direction from the Chilean border like arm shapes, and restricted also to the area of intrusive rocks between the arm extensions. Finally, 24 areas were selected as a promising area, then ground truth was conducted in 40 mineral showings and alteration zones outlined from the satellite images.

Consequently, it was found that the litho-geochemical exploration with using mudstone was especially effective in order to the discriminate ore horizon associated with the SEDEX-type lead/zinc deposits. Further, it was verified that the potential for the SEDEX-type lead/zinc deposit is high in the north-south trending zone from the Mina Aguilar deposit to the Pumahuasi deposit, meanwhile the potential for the volcanogenic massive sulfide deposits is particularly high in the area that volcanic rocks are distributed in Ordovician sediments in the western part of survey area. Detailed survey will be recommended to these areas in the future.

It was further shown that porphyry copper and copper/gold deposits develop in Farallon Negro area in a volcanic arm with relatively advanced erosion and in Inca Viejo area located in margin of intrusive rocks between arms, and in the west of Tucuman located in an arm's extension. On the other hand, the alteration zone related to the epithermal gold/silver deposit have a tendency to distribute in eroded area, such as Agua Caliente caldera. These mineral showings and alteration zones were

surveyed in detail in the latter half of the 1990s. However, in the second year of the project, more detailed surveys will be needed for the southeast extension of the volcanic rock arm for porphyry copper and copper/gold deposits, and to survey the alteration zones in and around the caldera for the epithermal gold/silver deposit.

In the analysis of ASTER images, the known porphyry copper and copper/gold deposits, and their related alteration zones were well discriminated and effectiveness of ASTER was verified. However, some mis-identification of alteration zone was observed in the analysis, improvements will be necessary as an issue in the future.

# CONTENTS

Preface	
Location map of the survey area	
Summary	
Contents	
List of figures and tables	

## PART I: GENERAL DISCUSSIONS

### Chapter 1 Introduction

1-1 Circumstance of the survey	1
1-2 Outline of the survey	2
1-2-1 Objectives of the survey	2
1-2-2 Survey area	2
1-2-3 Survey methods	2
1-2-4 Survey team	3
1-2-5 Period and amount of the survey	3

### Chapter 2 Geography of the survey area-

2-1 Location and accessibility	5
2-2 Topography and drainage system	5
2-3 Climate and vegetation	5

### Chapter 3 General geology and recent mining activities

3-1 General geology	8
3-1-1 Outline of geology in Argentina and locations of the survey area	8
3-1-2 Geology and mineral deposits in the survey area	17
3-2 Mining activity	28
3-2-1 Mining policies	28
3-2-2 Mining production	28
3-2-3 Mining legislation system	28
3-2-4 Recent trends of exploration and development	29



## **Chapter 4 Interpretation on survey results**

4-1 Analysis of the existing data .....	33
4-2 Data analysis of airborne geophysics .....	33
4-3 Stream sediments geochemistry .....	39
4-4 Satellite image analysis .....	40
4-5 Ground truth .....	40
4-6 Structure and Control factors of mineralization .....	44
4-7 Potentiality of existing mineral deposits and selection of promising areas .....	44

## **Chapter 5 Conclusion and recommendation**

5-1 Conclusions .....	47
5-2 Recommendation for Phase-2 survey .....	49

## **PART II: DETAILED DISCUSSIONS**

### **Chapter 1 Existing data analysis**

1-1 Collecting existing data .....	53
1-2 Data base .....	53
1-3 Distribution of deposits and known mineral showings .....	53
1-4 Compilation and analysis of existing data .....	53

### **Chapter 2 Data analysis of airborne geophysics**

2-1 Summary of the survey .....	55
2-2 Data type and analysis method .....	55
2-2-2 Analysis method .....	55
2-2-1 Data type .....	55
2-2-3 Others .....	55
2-3 Results of data analysis .....	57
2-3-1 Characteristics of each analyzed image .....	57
2-4 Guides to selection of high-potential areas by analysis of the airborne geophysical survey .....	61

2-5 Summary .....	62
-------------------	----

**Chapter 3 Stream sediments geochemistry**

3-1 Circumstances .....	81
3-2 Samples .....	81
3-3 Analysis .....	81
3-4 Evaluation .....	81

**Chapter 4 Satellite image analysis**

4-1 Data processing of the LANDSAT TM image .....	87
4-1-1 Satellite data and processing .....	87
4-2 Analysis and interpretation of LANDSAT TM images .....	89
4-3 Data processing of the ASTER image .....	89
4-3-1 Outline of analysis .....	89
4-3-2 Data used .....	91
4-3-3 Band registration .....	92
4-3-4 Pseudo reflectance conversion .....	95
4-3-5 Removing vegetation effects .....	106
4-3-6 Processing of false color images and the band ratioing composites .....	107
4-3-7 Identification of alteration minerals .....	110
4-3-8 SiO <sub>2</sub> content map .....	121
4-3-9 DEM(Digital Elevation Model) .....	128
4-3-10 Task for the future .....	131
4-4 Review of analysis result .....	133
4-4-1 Interpretation and analysis .....	133
4-4-2 Result of interpretation .....	155
4-5 Discussion .....	193
4-6 Summary .....	194

**Chapter 5 Ground truth**

5-1 Selection of survey zones .....	197
5-1-1 Selection of potential zones based on analysis of the existing data on geology and ore deposits .....	197
5-1-2 Extraction of highly potential zones based on the analysis of satellite images .....	197

5-1-3 Selection of high-potential zones based on the analysis of aerial physical exploration data .....	197
5-2 Survey results for each district .....	203
5-2-1 La Gateada mineral showings (Zone 1) .....	203
5-2-2 La Bélgica mineral showings (Zone 2) .....	205
5-2-3 La Pumahuasi mineral showings (Zone 2) .....	208
5-2-4 Sol de Mayo mineral showings (Zone 2) .....	210
5-2-5 Santa Rosa mineral showings (Zone 3) .....	213
5-2-6 La Ciénaga mineral showings (Zone 5) .....	215
5-2-7 Pan de Azúcar mineral showing (Zone-7) .....	217
5-2-8 Tupiza mineral showings (Zone 7) .....	222
5-2-9 Rachaite mineral showings (Zone 9) .....	224
5-2-10 La Candelaria mineral showings .....	228
5-2-11 Rumicruz-La Pricima mineral showings (Zone 11) .....	230
5-2-12 El Aguilar mine (Zone 15) .....	233
5-2-13 Rio Grande mineral showings (Zone 15) .....	249
5-2-14 La Colorada mineral showings (Zone 18) .....	251
5-2-15 Limeca mineral showings (Zone 18) .....	256
5-2-16 Tusca mineral showings (Zone 22) .....	257
5-2-17 Coiruro mineral showings (Zone 24) .....	258
5-2-18 Incachule mineral showings (Zone 16) .....	260
5-2-19 Organullo mineral showings (Zone 27) .....	265
5-2-20 El Acay mineral showings (Zone 27) .....	269
5-2-21 Pancho Arias mineral showings (Zone 28) .....	271
5-2-22 Centenario mineral showings .....	275
5-2-23 Vicuna Muerta mineral showings (Zone 31) .....	280
5-2-24 Inca Viejo Mineral showings (Zone 31) .....	284
5-2-25 Diablillos mineral showings (Zone 31) .....	286
5-2-26 Condor Yacu mineral showings (Zone 31) .....	290
5-2-27 Brealito mineral showings (Zone 34) .....	291
5-2-28 Laguna Grande mineral showings .....	294
5-2-29 Laguna del Salitre mineral showings (Zone 39) .....	298
5-2-30 Laguna Blanca mineral showings .....	301
5-2-31 Vaca Vizcana mineral showings (Zone 42) .....	305
5-2-32 El Alisar mineral showings (Zone 46) .....	310
5-2-33 El Pago mineral showings .....	318

5-2-34 Alto de la Blenda (Laboreo, Nudo, Esperanza) ore deposit .....	321
5-2-35 AguaTapada mineral showings (Zone 43) .....	325
5-2-36 Bajo de la Alumbreira ore deposit (Zone 43) .....	330
5-2-37 Bajo de la Durazno mineral showings (Zone 43) .....	336
5-2-38 Agua Rica (Zone 43) .....	337
5-2-39 Capillitas mineral showings (Zone 43) .....	344
5-2-40 Capillitas NE alteration zone .....	348
5-3 Preliminary study for presumption of a mineralized horizon by litho geochemistry (discriminant analysis) .....	350
5-3-1 Purpose .....	350
5-3-2 Development of the discriminant functions .....	351
5-3-3 Results of discriminant analysis .....	351
5-3-4 Presumption of ore horizon .....	351
5-3-5 Conclusion and suggestions .....	355
5-4 Lito geochemical characteristics of siltstones and volcanic rocks .....	355
5-5 Sulfur isotopic ratios of SEDEX-type lead and zinc deposits and vein-type polymetallic deposits. ....	354

## **Chapter 6 Discussion**

6-1 Geology, mineralization and structural control of mineralization .....	363
6-2 Potential of the existence of deposits and selection of promising area .....	367

## **PART III: CONCLUSION AND RECOMMENDATION**

<b>Chapter 1 Conclusions</b> .....	375
<b>Chapter 2 Recommendation for Phase-2 survey</b> .....	378

References  
Appendixes

## Figures

### Part-I

Fig.I-3-1-1-1	Accretionary terrane in the southern region of South America (taken from Zappettini, 1998) .....	10
Fig.I-3-1-1-2	Major segments of Southern Central Andes related to the Nazca Plate segmentation (taken from Ramos, 2000). .....	14
Fig.I-3-1-1-3	Topographic units in Argentina (taken from Ramos, 1999b). .....	16
Fig.I-3-1-2-1	Geological map of the survey area (compiled from mapa geologico de la provincia de “Jujuy”, “Salta”, .....	18
	“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). .....	19
Fig.I-3-1-2-3	Distribution of mineral deposits in the survey area (taken from Zappettini, 1998). .....	20
Fig.I-3-2-1-1	Idealised trends in mining sector reform in the 1990s and mineral activities in some selected successful countries (taken from Naito and Remy, 2001). .....	31
Fig.I-4-1-1	Location of mineral occurrences and deposits, and cluster of them listed on the Appendix. ....	34
Fig.I-4-5-1	Selected promising zones and survey points. ....	41
Fig.I-4-7-1	Flow chart for the selection of potential zones and recommended areas for the 2 <sup>nd</sup> year’s survey. ....	46

### Part-II

Fig.II-1-3-1	Location of Mineralized zones in the Project area .....	54
Fig.II-2-2-1-1	Location of the airborne geophysical survey .....	56
Fig.II-2-2-1-2	Total Magnetic Intensity image (TMI) .....	63
Fig.II-2-2-1-3	Total Mangnetic Intensity(Reduced to the Pole:RTP) .....	64
Fig.II-2-2-1-4	First vertical derivative image of RTP .....	65
Fig.II-2-2-1-5	First horizontal derivative image of RTP .....	66
Fig.II-2-2-1-6	Second horizontal derivative image of RTP .....	67
Fig.II-2-2-1-7	Upward continuation (500m) of RTP .....	68
Fig.II-2-2-1-8	Total count(TC) image .....	69
Fig.II-2-2-1-9	Radiometric image(K) .....	70
Fig.II-2-2-1-10	Radiometric image(T) .....	71
Fig.II-2-2-1-11	Radiometric image(U) .....	72
Fig.II-2-2-1-12	Color composite image of K,T,U(RGB=KTU) .....	73

Fig.II-2-2-1-13 Ratio K/T image .....	74
Fig.II-2-2-1-14 Ratio K/(K+T+U)image .....	75
Fig.II-2-2-1-15 Digital terrain model image(DEM) .....	76
Fig.II-2-2-1-16 Geological map .....	77
Fig.II-2-2-1-17 Tectonic line, mineral occurrences, alteration zone .....	78
Fig.II-2-2-1-18 Airborne geophysical map from Chernicoff,C.J., Zappettine, E.O. 2000 .....	79
Fig.II-2-2-1-19 Gravity model image .....	80
Fig.II-3-3-4-1 Geochemical anomaly map (Cu). .....	83
Fig.II-3-3-4-2 Geochemical anomaly map (Pb). .....	84
Fig.II-3-3-4-3 Geochemical anomaly map (Zn). .....	85
Fig.II-3-3-4-4 Geochemical anomaly map (Ag). .....	86
Fig.II-4-1-1-1 Image analysis area of Landsat TM .....	88
Fig.II-4-3-2-1 Index map of ASTER image over the survey area .....	91
Fig.II-4-3-3-1 A processing step for band to band registration .....	94
Fig.II-4-3-4-1 Dispersion diagrams of DN between Data012~017 .....	98
Fig.II-4-3-4-2 Dispersion diagrams of DN, Data102 .....	99
Fig.II-4-3-4-3 Distribution of surface materials selected by high correlation value .....	101
Fig.II-4-3-4-4 An example of "Pampa" area selected by high correlation pixels of ASTER bands(El Salvador, Chile) .....	102
Fig.II-4-3-7-1 Spectral pattern of mixed phase of Goethite - Sericite .....	111
Fig.II-4-3-7-2 Spectral pattern of alteration minerals and ferro-oxide minerals in acidic alteration zone .....	112
Fig.II-4-3-7-3 Spectral pattern of alteration minerals and ferro-oxide minerals in intermediate-alkali alteration zone .....	113
Fig.II-4-3-7-4 An example of spectral pattern mixing of two minerals .....	114
Fig.II-4-3-7-5 An example of mineral identification .....	116
Fig.II-4-3-7-6 Mineral identification(top: BGR=247, middle: ratio image, bottom: RGB=Aln,Kao,Ser) .....	119
Fig.II-4-3-7-7 Mineral identification(top: RGB=Aln,Goe,Ser, middle: RGB=Aln+Kao,Ser,Chl, bottom: RGB=Goe,Hem,Qtz) .....	120
Fig.II-4-3-8-1 Comparison with SiO <sub>2</sub> map and geology .....	127
Fig.II-4-3-9-1 Index map of ASTER image area for DEM .....	129
Fig.II-4-3-9-2 False color image(BGR=147) and ASTER DEM image(Scene 012-016) .....	130
Fig.II-4-4-1-1 BGR=147 (False color image) .....	135
Fig.II-4-4-1-2a BGR=4/5,4/6,4/7 (Ratio image-1) .....	137
Fig.II-4-4-1-2b BGR=4/5, 4/6, 4/7 (Ratio image-2) .....	139

## Figures

### Part-I

Fig.I-3-1-1-1	Accretionary terrane in the southern region of South America (taken from Zappettini, 1998)	10
Fig.I-3-1-1-2	Major segments of Southern Central Andes related to the Nazca Plate segmentation (taken from Ramos, 2000).	14
Fig.I-3-1-1-3	Topographic units in Argentina (taken from Ramos, 1999b).	16
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").	18
Fig.I-3-1-2-2	Geological structure map of the survey area (compiled from JICA and MMAJ,1998 and Riller et al., 2001).	19
Fig.I-3-1-2-3	Distribution of mineral deposits in the survey area (taken from Zappettini, 1998).	20
Fig.I-3-2-1-1	Idealised trends in mining sector reform in the 1990s and mineral activities in some selected successful countries (taken from Naito and Remy, 2001).	31
Fig.I-4-1-1	Location of mineral occurrences and deposits, and cluster of them listed on the Appendix.	34
Fig.I-4-5-1	Selected promising zones and survey points.	41
Fig.I-4-7-1	Flow chart for the selection of potential zones and recommended areas for the 2 <sup>nd</sup> year's survey.	46

### Part-II

Fig.II-1-3-1	Location of Mineralized zones in the Project area	54
Fig.II-2-2-1-1	Location of the airborne geophysical survey	56
Fig.II-2-2-1-2	Total Magnetic Intensity image (TMI)	63
Fig.II-2-2-1-3	Total Magnetic Intensity(Reduced to the Pole:RTP)	64
Fig.II-2-2-1-4	First vertical derivative image of RTP	65
Fig.II-2-2-1-5	First horizontal derivative image of RTP	66
Fig.II-2-2-1-6	Second horizontal derivative image of RTP	67
Fig.II-2-2-1-7	Upward continuation (500m) of RTP	68
Fig.II-2-2-1-8	Total count(TC) image	69
Fig.II-2-2-1-9	Radiometric image(K)	70
Fig.II-2-2-1-10	Radiometric image(T)	71
Fig.II-2-2-1-11	Radiometric image(U)	72
Fig.II-2-2-1-12	Color composite image of K,T,U(=KTU)	73

Fig.II-2-2-1-13 Ratio K/T image .....	74
Fig.II-2-2-1-14 Ratio K/(K+T+U)image .....	75
Fig.II-2-2-1-15 Digital terrain model image(DEM) .....	76
Fig.II-2-2-1-16 Geological map .....	77
Fig.II-2-2-1-17 Tectonic line, mineral occurrences, alteration zone .....	78
Fig.II-2-2-1-18 Airborne geophysical map from Chernicoff, C.J., Zappettine, E.O. 2000 .....	79
Fig.II-2-2-1-19 Gravity model image .....	80
Fig.II-3-3-4-1 Geochemical anomaly map (Cu). .....	83
Fig.II-3-3-4-2 Geochemical anomaly map (Pb). .....	84
Fig.II-3-3-4-3 Geochemical anomaly map (Zn). .....	85
Fig.II-3-3-4-4 Geochemical anomaly map (Ag). .....	86
Fig.II-4-1-1-1 Image analysis area of Landsat TM .....	88
Fig.II-4-3-2-1 Index map of ASTER image over the survey area .....	91
Fig.II-4-3-3-1 A processing step for band to band registration .....	94
Fig.II-4-3-4-1 Dispersion diagrams of DN between Data012~017 .....	98
Fig.II-4-3-4-2 Dispersion diagrams of DN, Data102 .....	99
Fig.II-4-3-4-3 Distribution of surface materials selected by high correlation value .....	101
Fig.II-4-3-4-4 An example of "Pampa" area selected by high correlation pixels of ASTER bands(El Salvador, Chile) .....	102
Fig.II-4-3-7-1 Spectral pattern of mixed phase of Goethite - Sericite .....	111
Fig.II-4-3-7-2 Spectral pattern of alteration minerals and ferro-oxide minerals in acidic alteration zone .....	112
Fig.II-4-3-7-3 Spectral pattern of alteration minerals and ferro-oxide minerals in intermediate-alkali alteration zone .....	113
Fig.II-4-3-7-4 An example of spectral pattern mixing of two minerals .....	114
Fig.II-4-3-7-5 An example of mineral identification .....	116
Fig.II-4-3-7-6 Mineral identification(top: BGR=247, middle: ratio image, bottom: RGB=Aln,Kao,Ser) .....	119
Fig.II-4-3-7-7 Mineral identification(top: RGB=Aln,Goe,Ser, middle: RGB=Aln+Kao,Ser,Chl, bottom: RGB=Goe,Hem,Qtz) .....	120
Fig.II-4-3-8-1 Comparison with SiO <sub>2</sub> map and geology .....	127
Fig.II-4-3-9-1 Index map of ASTER image area for DEM .....	129
Fig.II-4-3-9-2 False color image(BGR=147) and ASTER DEM image(Scene 012-016) .....	130
Fig.II-4-4-1-1 BGR=147 (False color image) .....	135
Fig.II-4-4-1-2a BGR=4/5,4/6,4/7 (Ratio image-1) .....	137
Fig.II-4-4-1-2b BGR=4/5, 4/6, 4/7 (Ratio image-2) .....	139



Fig.II-4-4-1-3	BGR= Ser, Kao, Aln (mineral identification)	141
Fig.II-4-4-1-4	BGR= Ser, Goe, Aln (mineral identification)	143
Fig.II-4-4-1-5	BGR= Chl, Ser, Aln+Kao (mineral identification)	145
Fig.II-4-4-1-6	BGR= Qtz, Hem, Geo (mineral identification)	147
Fig.II-4-4-1-7	Alteration zone outlined by ASTER and Landsat TM	149
Fig.II-4-4-1-8	SiO <sub>2</sub> contents	151
Fig.II-4-4-1-9	Landsat TM false color image (BGR=145)	153
Fig.II-4-4-4-1	False color image of scene 012(BGR=147)	156
Fig.II-4-4-4-2	False color image of scene 013(BGR=147)	158
Fig.II-4-4-4-3	False color image of scene 014(BGR=147)	160
Fig.II-4-4-4-4	False color image of scene 015(BGR=147)	162
Fig.II-4-4-4-5	False color image of scene 016(BGR=147)	165
Fig.II-4-4-4-6	False color image of scene 017(BGR=147)	167
Fig.II-4-4-4-7	False color image of scene 101(BGR=147)	169
Fig.II-4-4-4-8	False color image of scene 102(BGR=147)	171
Fig.II-4-4-4-9	False color image of scene 103(BGR=147)	174
Fig.II-4-4-4-10	False color image of scene 201(BGR=147)	176
Fig.II-4-4-4-11	False color image of scene 202(BGR=147)	179
Fig.II-4-4-4-12	False color image of scene 203(BGR=147)	182
Fig.II-4-4-4-13	False color image of scene 6200(BGR=147)	185
Fig.II-4-4-4-14	False color image of scene 6201 (BGR=147)	187
Fig.II-4-4-4-15	False color image of scene 6601(BGR=147)	190
Fig.II-5-1-2-1	Alteration zone, Neogene Volcanics and promising area	199
Fig.II-5-1-3-1	Promissing area outlined by airborne geophysical data (radiometric K/T image)	200
Fig.II-5-1-3-2	Promissing area outlined by airborne geophysical data (radiometric K/(K+T+U) image)	201
Fig.II-5-1-3-3	RTP image and Neogene Volcanics (Galan cardera area)	202
Fig.II-5-1-3-4	RTP image and Neogene Volcanics (Vicuna Muerta area)	202
Fig.II-5-2-1-1	La Gateada mineral occurrence	204
Fig.II-5-2-2-1	La Belgica mineral occurrence	206
Fig.II-5-2-3-1	Pumahuasi mineral occurrence	209
Fig.II-5-2-4-1	Sol de Mayo mineral occurrence	211
Fig.II-5-2-5-1	Santa Rosa mineral occurrence	214
Fig.II-5-2-6-1	La Cienaga mineral occurrence	216
Fig.II-5-2-7-1	Pan de Azucar mineral occurrence	218
Fig.II-5-2-7-2	ASTER image around the Pan de Azucar mineral occurrence	219

Fig.II-5-2-8-1	Tupiza mineral occurrence	223
Fig.II-5-2-9-1	Simplified geological sketch, occurrence of hydrothermal alteration zones and old adit.	226
Fig.II-5-2-9-2	ASTER image around Rachite. (a) False color image, (b) Ratio image, (c) Iso-grain model image.	227
Fig.II-5-2-10-1	La Candelaria mineral occurrence	229
Fig.II-5-2-11-1	La Puricima-Rumicruz mineral occurrence	231
Fig.II-5-2-12-1	Geological map of the Aguilar mine area (provided by Mineral Aguilar S. A.)	234
Fig.II-5-2-12-2	El Aguilar mine	235
Fig.II-5-2-12-3	Relation between drill hole #3070 and SEDEX mineralized zone	238
Fig.II-5-2-12-4(1)	Geochemical variation diagrams of drill holes #3070 and a lower part of #3244	239
Fig.II-5-2-12-4(2)	Geochemical variation diagrams of drill holes #3070 and a lower part of #3244	240
Fig.II-5-2-12-5	Histograms of 29 elements for drill holes #3070 and a lower part of #3244	241
Fig.II-5-2-12-6	Variation diagrams of discriminant values for drill holes #3070 and a lower part of #3244	243
Fig.II-5-2-12-7	El Aguilar deposit (ASTER BGR=147)	244
Fig.II-5-2-13-1	SEDEX ore zone observed in the Rio Grande	250
Fig.II-5-2-14-1	La Corolada deposit	254
Fig.II-5-2-14-2	Drill core sample and photomicrograph of the sample	255
Fig.II-5-2-14-3	Cu-Pb-Zn diagram of typical SEDEX deposits (Goodfellow et al., 1993) and La Colorada deposit	255
	( Pacific Rim internal report)	
Fig.II-5-2-16-1	Tusca mineral occurrence	258
Fig.II-5-2-17-1	Coiruro mineral occurrence	260
Fig.II-5-2-18-1	Incachule mineral occurrence	263
Fig.II-5-2-18-2	Birds-eye view of Incachule and Organullo mineral occurrence	264
Fig.II-5-2-19-2	Organullo mineral showing and Incachule mineral showing (ASTER BGR=147)	268
Fig.II-5-2-20-1	El Acay mineral occurrence	270
Fig.II-5-2-21-1	Pancho Arias mineral occurrence	273
Fig.II-5-2-21-2	ASTER image around the Pancho Arias mineral occurrence	274
Fig.II-5-2-22-1	Centenario mineral occurrence	276
Fig.II-5-2-22-2	ASTER image around the Centenario alteration zone	277
Fig.II-5-2-22-3	Birds-eye view of the Centenario alteration zone	278
Fig.II-5-2-22-4	Birds-eye view of Vicuna Muerta and Inca Viejo mineral occurrence	279

Fig.II-5-2-23-1 Vicuna Muerta mineral occurrence .....	281
Fig.II-5-2-23-2 ASTER image around the Centenario, Inca Viejo, Diablillos, Condor Yacu mineral occurrence .....	282
Fig.II-5-2-24-1 Inca Viejo mineral occurrence .....	285
Fig.II-5-2-25-1 Diablillos and Condor Yacu mineral occurrence .....	288
Fig.II-5-2-25-2 Birds-eye view of Diablillos and Condor Yacu mineral occurrence .....	289
Fig.II-5-2-27-1 Brealito mineral occurrence .....	292
Fig.II-5-2-27-2 Landsat TM image around the Brealito mineral occurrence .....	293
Fig.II-5-2-28-1 Laguna Grande alteration zone (perspective view) .....	295
Fig.II-5-2-28-2 ASTER image around the Laguna Grande alteration zone .....	296
Fig.II-5-2-28-3 Birds-eye view of Laguna Grande alteration zone and Laguna del Salitre mineral occurrence .....	297
Fig.II-5-2-29-1 Laguna Salitre mineral occurrence .....	300
Fig.II-5-2-30-1 Laguna Blanca alteration zone .....	302
Fig.II-5-2-30-2 ASTER image around the Laguna Blanca alteration zone .....	303
Fig.II-5-2-30-3 Bird-eye view around Laguna Blanca alteration zone .....	304
Fig.II-5-2-31-1 Simplified geological map around the Vaca Viscana mineral occurrence .....	308
Fig.II-5-2-31-2 Vaca Vizcana mineral showing(Landsat TM BGR=145) .....	309
Fig.II-5-2-32-1 (a) Geological map of around the Alizar mineral occurrence (taken from Martinez y Chipulina, 1996) .....	315
Fig.II-5-2-32-1 (b) Schematic cross section of the El Alisar mineral occurrence (taken from Martinez y Chipulina, 1996) .....	315
Fig.II-5-2-32-2 Discrimination diagrams for volcanic rocks .....	316
Fig.II-5-2-32-3 El Alisar mineral showing(Landsat TM BGR=145) .....	317
Fig.II-5-2-33-1 Distribution of rock types and alterations, El Pago sector .....	319
Fig.II-5-2-33-2 Distribution of alteration zones extracted by ASTER data .....	320
Fig.II-5-2-34-1 Simplified geological map around the Zone-43 .....	322
Fig.II-5-2-34-2 Alto de la Blenda (Laboreo, Nudo, Esperanza) deposit, Bajo de la Alumbreira deposit, Bajo El Durazno mineral showing (ASTER BGR=123) .....	323
Fig.II-5-2-35-1 Agua Tapada mineral occurrence .....	326
Fig.II-5-2-35-2 ASTER image around the Bajo de la Alumbreira deposit, Agua Tapada and Bajo El Durazno mineral occurrences .....	327
Fig.II-5-2-35-3 Agua Tapada occurrence, Bajo de la Alumbreira deposit, Bajo El Durazno occurrence, Agua Rica deposit Capillitas deposit, Capillitas NE alteration zone .....	328

Fig.II-5-2-35-4	Bajo de la Alumbreira deposit, Bajo El Durazno occurrence, Agua Rica deposit Capillitas deposit, Capillitas NE alteration zone .....	329
Fig.II-5-2-36-1	Geology of the Bajo de la Alumbreira mine (taken from Angera, 1999) .....	332
Fig.II-5-2-36-2	Geological cross section of the Bajo de la Alumbreira (taken from Angera, 1999) .....	332
Fig.II-5-2-36-3	Hydrothermal alteration zones of the Bajo de la Alumbreira mine (taken from Angera, 1999) .....	333
Fig.II-5-2-38-1	Simplified geological map of Agua Rica district (taken from BHP-Billiton and Northern .....	341
	Orion internal report)	
Fig.II-5-2-38-2	Hydrothermal alteration in Agua Rica district (taken from Roco y Koukharsky, 1999) .....	342
Fig.II-5-2-38-3	Agua Rica deposit(ASTER BGR=123) .....	343
Fig.II-5-2-39-1(a)	Major lithologic units and location of the veins in Capillitas mine (taken from Marquez-Zavalía, 1999) .....	346
Fig.II-5-2-39-1(b)	Schematic profiles. A: from Nueva Esperanza vein to Isabel vein. B: from Nueva vein to Santa Luisa vein. (taken from Marquez-Zavalía, 1999) .....	346
Fig.II-5-2-39-2	Capillitas deposit and Capillitas NE alteration zone(ASTER BGR=123) .....	347
Fig.II-5-2-40-1	Capillitas NE alteration zone.(a)Distant view,(b),Closed view,(c)Outcrop of the fault zone .....	349
Fig.II-5-3-1	Distribution of the Ordovician rock samples discriminated to 3 groups .....	357
Fig.II-5-4-1-1	Chemical comparison slate in the survey area with the Shimanto accretionary prism (Fujinaga and Kato, 2001) .....	358
Fig.II-5-4-1-2	Chemical comparison slate in the survey area with the Shimanto accretionary prism (Fujinaga and Kato, 2001) .....	359
Fig.II-6-1-1	Environment of formation of SEDEX deposits. ....	367
Fig.II-6-1-2	Distribution of the Ordovician systems, Precambrian Puncoviscana Formation, SEDEX type deposits and volcanogenic massive sulfide deposits. ....	368
Fig.II-6-1-3	Distribution of Neogene volcanics, porphyry and epithermal type deposits and major faults. ....	369
Fig.II-6-1-4	Total magnetic intensity (reduced to the pole) and distribution of porphyry and epithermal type deposits. ....	370
Fig.II-6-1-5	Spatial relationship of major linements, and porphyry type deposits and epithermal type deposits in the central Chile and northeastern Argentina. ....	371
Fig.II-6-1-6	Genetic models of SEDEX and MVT representing the mixing of basal metalliferous fluids with ambient anoxic waters at the sea floor (taken from Goodfellow et al, 1993). ....	367

Fig.II-6-1-7	General model of a zoned magmatic hydrothermal system and spatial relationship of porphyry and epithermal system (taken from Tosdal and Richards,2001), .....	372
Fig.II-6-1-8	Idealized model of caldera structure and mineralization (taken from Sillitoe, 1984) .....	372
Fig.II-6-2-1	Selected promising area and recommended area for the survey of next year (SEDEX and VMS type deposits), .....	373
Fig.II-6-2-2	Selected promising area and recommended area for the survey of next year (porphyry and epithermal type deposits), .....	374

## Tables

### Part-I

Table I-2-3-1	Climate table of Salta and La Quiaca.	7
Table I-3-1-2-1	Simplified stratigraphy of the survey area.	21
Table I-3-1-2-2	Deposit type and mineral deposits in the survey area.	22
Table I-3-2-2-1	Investment of mining development in the Argentine Republic.	31
Table I-3-2-4-1	Recent mineral exploration around the survey area.	32
Table I-4-1-1	List of mineralized zones in the survey area.	35
Table I-4-5-1	Record of the ground truth.	42
Table I-4-5-2	Outline of survey results.	43

### Part-II

Table II-3-3-1	List of elements and detection limits.	82
Table II-4-1-1	Path/Row, data acquisition, sun azimuth and sun elevation of the Landsat TM image	87
Table II-4-3-1	Acquisition data of ASTER image	92
Table II-4-3-2	Data012 Pixel location error between band4 and band5(before registration)	94
Table II-4-3-3	Data012 Pixel location error between band4 and band5(after registration)	94
Table II-4-3-4	Regression coefficients of band to band registration based on band 1 to 3	104
Table II-4-3-5	Regression coefficients of band to band registration based on band 1 to 3 for neighbor bands	104
Table II-4-3-6	Regression coefficients for band to band registration based on band1	105
Table II-4-3-7	Regression coefficients for band to band registration based on METI(2001)	105
Table II-4-3-8	Result on the most fitted pseudo-reflectance of pixel(top three score)	115
Table II-4-3-9	Emissivity value of TIR	125
Table II-5-2-12-1	Characteristics of the Ordovician formations in the Aguilar range	245
Table II-5-2-12-2	Chemical analysis results of drill core samples	246
Table II-5-2-12-3	Result of discriminant analysis for 77 core samples collected from the holes drilled intersecting the SEDEX ore zone	247
Table II-5-2-12-4	Discriminant function coefficients	248

## Appendix

Table A-1	List of samples and laboratory test .....	1
Table A-2	Result of the laboratory test (microscopic observation of rock and ore samples) .....	10
Table A-3	Result of the laboratory test (X-ray diffraction) .....	12
Table A-4	Result of the laboratory test (geochemical analysis ) .....	15
Table A-5	Result of the laboratory test (sulphur and oxygen isotope) .....	21
Table A-6	Result of the laboratory test (fluid inclusion) .....	22
Table A-7	Result of the laboratory test (K-Ar dating) .....	22
Table A-8	List of mineral occurrence in the survey area .....	23
Table A-9	List of collected printed data .....	36
Figure A-1	Location map of sample .....	47