PART I OVERVIEW

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CHAPTER 1 INTRODUCTION

1-1 Background and Objectives

In response to the request by the Government of the Republic of Chile to conduct mineral exploration, the Japanese Government dispatched a mission to discuss the details of the project in December 1999. And as a result of the consultations with Corporacción Nacional del Cobre de Chile (CODELCO), an agreement was reached for cooperative exploration of the Region I area and the "Scope of Work (SW)" was signed by the representative of both Governments. The objective of this project is to assess the mineral potential of the area through analysis of existing data, analysis of satellite images, geological survey, geochemical exploration, geophysical exploration, and drilling during the three year period of fiscal 1999 to 2001.

This is the first year of this project.

1-2 Outline of the Area, Objectives, and Work during the First Year

The survey area is located in the northern part of Chile (Fig. 1-1). Also the areas surveyed by various methods are laid out in Figures 2-1-7, 2-2-1, 2-3-2.

The objective of the work carried out during the first year is to select efficiently the promising areas from the extensive survey area. And to transfer technology to the counterpart organization of the Republic of Chile.

The work carried out during the first year comprises; analysis of existing information and data, analysis of satellite images, geological survey, and geochemical survey. The total amount of work done is shown in Table 1-1.

Regarding analysis of existing data, information related to geology, ore deposits and past exploration were compiled, and thereby basis for interpreting the results of the analysis of satellite images, the geological survey and the geochemical prospecting were acquired. And also, alteration zoning and the geologic structure were clarified from GEOSCAN, and thereby promising areas for occurrence of ore deposits were selected.

Photogeologic interpretation of satellite images was carried out, and the general geologic structure of the survey area was clarified, and the promising areas thus were selected.

As for geological survey and geochemical survey; ground truth to verify geologic structure, mineralization and alteration was carried out in some parts of the above promising areas. And samples for laboratory work were collected. The number of samples is shown in Table 1-1.

1-3 Members of the Survey Team

(1) Mission for Scope of Work Consultation

1) Japanese side

Kenji Sawada (Team leader, Deputy Director General, Mineral Resource Survey Department, MMAJ)

Yukifumi Yamaguchi (Planning Division, Mining and Industrial Development Study Department, JICA)

Takashi Kamiki (Technical Cooperation Division, Mineral Resource Survey Department, MMAJ)

Tazuko Ichinohe (Assistant Representative of Chile Office, JICA)

Takahisa Yamamoto (Representative of Santiago Office, MMAJ)

Yoshiaki Igarashi (Deputy Representative of Santiago Office, MMAJ)

2) Chilean side

Sergio Jimenez M. (Minister of Mining)

Ivan Valenzuela R. (Vice President, Exploration and Mining Association, CODELCO)

Francisco Camus I. (Exploration Vice President, CODELCO)

Jorge Skarmeta M. (Exploration Manager, CODELCO)

Enrique A. Tidy (Senior Research Geologist, CODELCO)

Gerardo Behn R. (Geophysicist, CODELCO)

Karsten Berg H. (Senior Geologist, CODELCO)

(2) Field supervisor

Takeshi Harada (Technical Cooperation Division, Mineral Resource Survey Department, MMAJ)

(3) Survey Team

1) Japanese side (Nikko Exploration & Development Co., Ltd.)

Masaaki Sugawara (Team leader, Chief Geologist,)

Table 1-1 Amount of Work

Survey Method	Amount	
Analysis of Existing Data Geoscan	Areal extent	2,550 km^2
Analysis of Satellite Images Landsat TM	Areal extent	34,000 km^2
Geological Survey	Areal extent	600 km^2
	Length of traverse	100 km
	Laboratory work	
	Thin sections	30 sections
	Polished sections	20 sections
	X-ray diffraction	20 samples
	Ore assay (Au, Ag, Cu, Mo, Pb, Zn, S)	20 samples
	Fluid inclusion analysis	
	Homogenization temperature	5 samples
	Salinity	5 samples
	K-Ar age determination	
	Whole rock / Mineral	5 samples
Geochemical Prospecting	Geochemistry of rock (Au, Ag, As, Sb, Hg, Cu, Mo, Pb, Zn)	100 samples

Koji Hamano (Senior Geologist)
Makoto Miyoshi (Senior Geologist)
Yasunori Ito (Geologist)

2) Chilean side (CODELCO)
Enrique A. Tidy (Senior Research Geologist)
Karsten Berg H. (Senior Geologist)

1-4 Duration

Scope of Work consultation: 5 December 1999 to 13 December 1999
Field supervising: 13 March 2000 to 24 March 2000
Analysis of existing information and data: 21 January 2000 to 10 March 2000
Analysis of satellite images: 21 January 2000 to 20 March 2000
Geological and geochemical survey: 12 March 2000 to 24 March 2000
Laboratory work and report preparation: 21 January 2000 to 26 March 2000

CHAPTER 2 GEOGRAPHY OF THE SURVEY AREA

2-1 Location and Access

The survey area is located in the eastern part of Region I with about 400km in the N-S direction and about 100km in the E-W. The area is 34,000 km^2 bounded by the following meridians and latitudes (Fig. 1).

	Lat. S	Long. W		Lat. S	Long. W
①	18° 16′	70° 02′	②	17° 30′	69° 28′
③	21° 15′	69° 28′	④	21° 15′	68° 12′

The area is bordered on the north by Peru, and on the east by Bolivia.

Major cities in the vicinity are Arica and Iquique. The population is about 170 thousand in the former, and about 150 thousand in the latter.

It is three-hour flight from the Santiago international airport to Iquique, and also four-hours to Arica.

There is a Pan-American highway along the west boundary of the survey area. There are several roads from the highway to the east, and those are mostly unpaved. A road system is not developed in the area, and the access to inland areas is difficult, particularly to the eastern part. Iquique or Arica to the eastern part is more than several hours by car.

2-2 Topography and Drainage

The northern and central parts of Chile comprise three parallel geologic zones; the Andes to the east, the Coastal Range to the west and the Central Valley between the two mountain ranges. The western part of the survey area belongs to the Central Valley to the Pre-andes zone with gentle relief of relatively low elevation (1,000-3,000m). The eastern part of the survey area belongs to the Pre-andes zone to the Andes Range with steep relief of high elevation (3,000-5,000m).

The drainage of the area flows from the east to the west, and is usually dry, but a flood rarely rises. In the Central Valley underflow of water occurs, and the drainage becomes extinct.

2-3 Climate and Vegetation

The survey area belongs to the desert climatic zone and also to the alpine climatic zone, and is constantly exposed to strong winds. The relatively cold season is June to September and relatively mild warm season is January to March. During December to March thunderstorms occur often. At Arica, the average annual temperature is 18.7℃, and during December to March the maximum temperature is 28℃ and minimum temperature is 16.8℃.

The vegetation of the area is very scarce owing to paucity of precipitation.

CHAPTER 3 OUTLINE OF GEOLOGY AND MINERALIZATION OF THE SURVEY AREA

A geological map of the survey area is shown in Figure 1-3-1, and a stratigraphy in Table 1-3-1.

The geology of the survey area is comprised of Paleozoic, Carboniferous~Triassic System, Jurassic System, Cretaceous System, Upper Cretaceous~ Paleogene System, Paleogene System, Neogene System and Quaternary System.

Pre-tertiary system is intermittently distributed in the northern part (north of about 18° 48′ S), central part (between about 19° 27′ S～20° 16′ S) and southern part (south of about 20° 29′ S) of the survey area.

Southern Pre-tertiary system consists of Paleozoic sedimentary rocks-volcanic rocks-metamorphic rocks, Carboniferous~Triassic volcanic rocks, Jurassic volcanic rocks-sedimentary rocks, Cretaceous volcanic rocks, Cretaceous~Paleogene volcanic rocks and Pleozoic plutonic rocks, and is intruded by Cretaceous~Paleogene intrusive rocks (plutonic rocks, hypabyssal rocks).

Pre-tertiary system of the central part consists of Paleozoic sedimentary rocks, Jurassic sedimentary rocks, Cretaceous volcanic rocks, Cretaceous~Paleogene volcanic rocks, and is intruded by Cretaceous~Paleogene intrusive rocks (plutonic rocks, hypabyssal rocks).

Northern Pre-tertiary system consists of Paleozoic metamorphic rocks, Jurassic sedimentary rocks, Cretaceous volcanic rocks and Cretaceous~Paleogene volcanic rocks, and is intruded by Cretaceous~Paleogene intrusive rocks (plutonic rocks, hypabyssal rocks).

Tertiary System consists of Oligocene~Miocene sedimentary rocks distributed in the southern part of the survey area, Miocene volcanic product in the southeasternmost part and Miocene~Pliocene volcanic product in the northern and central~southern part. The latter has ignimbrite, and is distributed in areas with relatively gentle relief around the Paleozoic~Mesozoic area.

In the eastern part of the survey area, Pliocene~Pleistocene volcanic product is distributed throughout the zone north of the central part, along the Bolivia border etc.

Quaternary sand and gravel are distributed widely in the western part of the survey area.

There is a N-S trending zone with development of faults south of the central part of the survey area. This fault group consists of continuous faults of N-S system and those of NE-SW system derived from the former faults. The faults of N-S system include the West Fault which is estimated to be controlling the distribution of the porphyry copper deposits. On the other hand large faults of NNW-SSE~NW-SE system are predominant in the northern part. NNW-SSE~N-S trending faults developed in the north may be located in the northern extension of the N-S fault group of the central part.

Many prospects of base metals Cu, Pb, Zn, etc., and precious metals Au, Ag occur in Paleozoic~Mesozoic areas and its periphery, and large scale deposits and prospects of porphyry copper type exist in those prospects. Prominent mineralization of porphyry copper type are as follows;

Southern part : Collahuasi-Ujina deposits, Quebrada Blanca deposit, Olga prospect, Copaquire prospect
Central part : Cerro Colorado deposit, Mocha prospect, Queen Elizabeth prospect, La Planada prospect
Northern part : Tignamar prospect

Regarding the above mineralization of porphyry copper type, Cerro Colorado deposit and Mocha prospect are considered to be the product of Paleogene to Early Eocene mineralization, and are correlated to the porphyry copper zone in Peru. Others are considered to have formed by mineralization between Late Eocene and Early Oligocene.

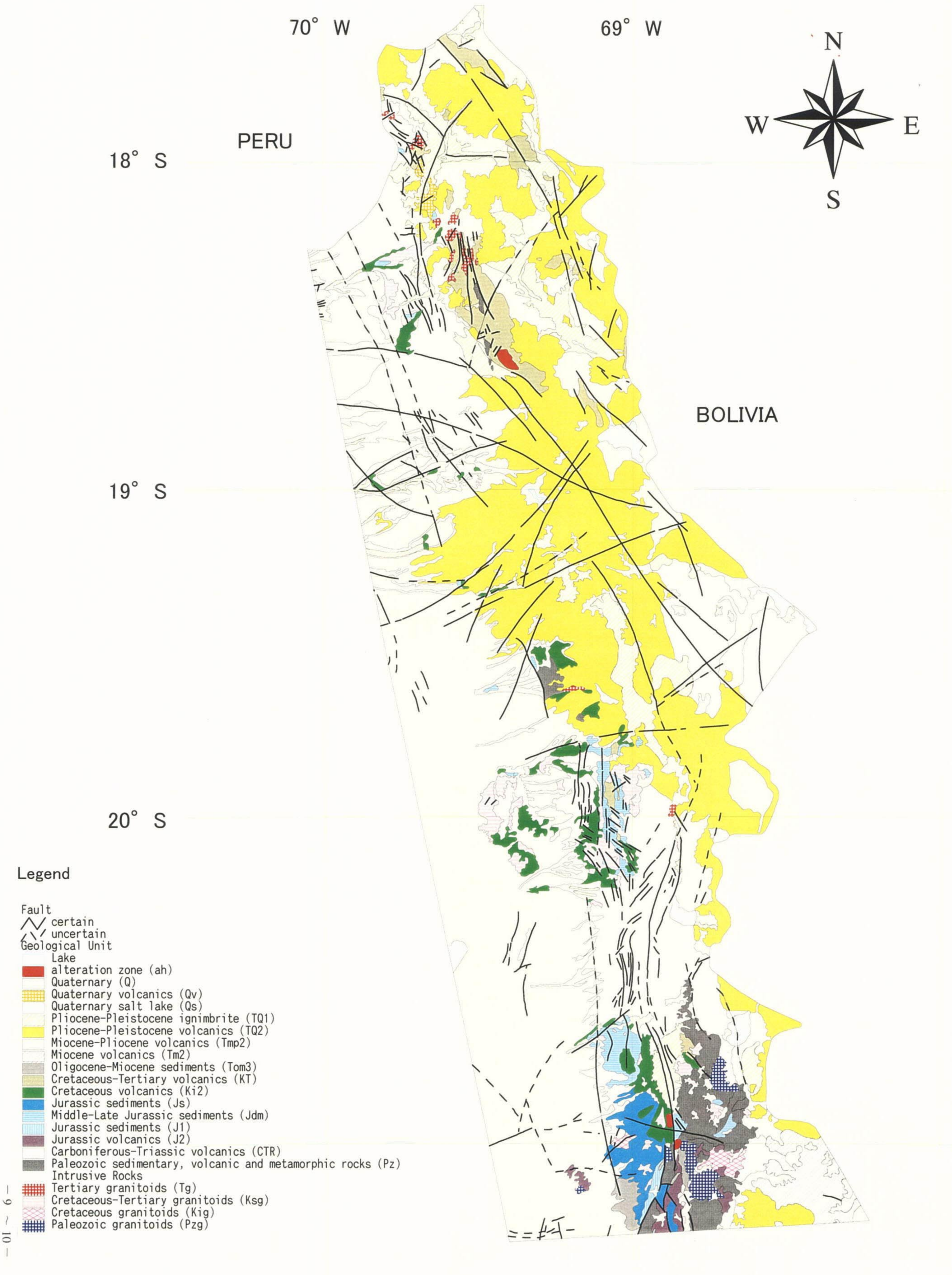

Fig. 1-3-1 Geological Map of the Study Area

Table 1-3-1 Stratigraphy of the Study Area

Period	Epoch	Formation (example)	Strata: Symbols: 1:1,000,000 Geologic Map	1:250,000 Geologic Map*1	1:50,000 Geologic Map*2	Photogeologic Interpretation Map 1:250,000 TM	Photogeologic Interpretation Map 1:50,000 GEOSCAN	Strata: Lithology	Intrusive Rocks: Symbols: 1:1,000,000 Geologic Map	1:250,000 Geologic Map *1	1:50,000 Geologic Map *2	Photogeologic Interpretation Map 1:250,000 TM	Photogeologic Interpretation Map 1:50,000 GEOSCAN		Intrusive Rocks: Lithology	Mineralization
QUATERNARY			Q, Qv	Qal, Qpd, Qcs, Qip(i), Qip(s)	Qp	Qd, Qa, Qd_1, Qa1, Ts2, Ts3	Qal ,Qtl, Qd, Qs	Fluvial, Lacustrine, Glacial, Aeolian, Alluvial, Colluvial, Mudflow, Talus								
QUATERNARY - TERTIARY	Pleistocene - Pliocene	Huaylas	TQ_1	Tsu, Tsh, TPv, Tpvi, TPiv	TQi(Qp)	TQ_1, Tvs_2	Ti_4, Ti_{4w}	Dacitic Ignimbrite, Tuff, Intercalation of continental sediments								
		Cola de Zorro	TQ_2	TMv, TMvi		Tv_1, Tv_2, Tv_3	Tv, Tvc, Tvb_2, Tvb_1, Tva	Andesitic - basaltic flow, pyroclastic rock					(d) dyke			
TERTIARY	Pliocene - Miocene	Altos de Picas	Tmp_2	Tt	TQt	Tvs, Ts_1	Tt, Ti_1, Ti_2, Ti_3	Rhyolitic - basaltic flow, pyroclastic rock, Ignimbrite, Intercalation of continental sediments								
	Miocene	Trapa - Trapa	Tm_2	Tpd		Tv_1		Rhyolitic -dacitic tuff, andesitic - dacitic flow, pyroclastic rock	Tg	KTi		Ti		Tg	Plutonic/Hypabysal rocks	Epithermal
	Miocene - Oligocene	San Pedro	Tom_2	Tmc (OLLAGÜE)		Ts_1, Ts		Conglomerate, Breccia, Sandstone, Shale, Siltstone (continental facies)								
	Paleocene									Tgrd, Tdc, Tmc			(d) dyke	Tgd	Quartz diorite	Porphyry Copper
EARLY TERTIARY - LATE CRETACEOUS		Las Chilcas	KT	Kiv		K, Kv	K_2	Andesitic - rhyolitic flow, pyroclastic rock, Dacitic - rhyolitic Ignimbrite, Intercalation of shale/limestone/sandstone/ conglomerate (continental)	Ksg	KTpgr, Ksg, Kgd	Kg	Kg		Kg /Kp	Plutonic/Hypabyssal rocks	
EARLY CRETACEOUS		Bandurria, Lo Prado	Ki_2	Kce, Ka	Kce, KTpb	Kv	K_1	Andesitic - rhyolitic / trachytic flow, pyroclastic rock, Ignimbrite, Intercalation of sediments	Kig							
LATE JURASSIC		Rio Damas	Js	Jsc, Jqc		Js_2	Js_2 /Jkv	Conglomerate, Sandstone, Shale, Limestone, Andesitic flow, breccia (continental;Js_2) /Basalt lava doleritic dikes, trachyte with tuffs and chert (Late Jurassic to Early Cretaceous ; Jkv)								
LATE - MIDDLE JURASSIC	Malm - Dogger	El Profeta	Jdm	Jqm		Jv, Js_1, Js_2	Js_1 /Js_1s	Sandstone, Calcareous sandstone, Limestone, Marl, Shale, Conglomerate, Chert								
JURASSIC			J_1	Jm		Js_1										
		La Negra	J_2	JKv		Jv	Jv	Andesitic flow/tuff, Rhyolitic/dacitic/trachytic flow, Dacitic tuff with intercalation of sediments								
JURASSIC - TRIASSIC									TR-jg						Triassic - Jurassic, Granitoid	
TRIASSIC - CARBONIFEROUS		Porfido cuarcifera	CTR	-	-	-	-	Tuff, Breccia flow and mainly rhyolitic to dacitic ignimbrites intercalated with pyroclastics and hypabyssal rocks	Pzg	Pg, Pzgrd, Pzgr, Pzsg			(d) dyke		Plutonic/Hypabyssal rocks : Paleozoic	
PALEOZOIC		Aguada de la Perdiz	Pz	Pzc(s), Pzc(m), Pzc(l), Pzim	-	P	Pz Pzv	Southern part : Micaceous schist, Metacherts, Serpentinite (metamorphosed) (Permian) Central part : Quartzitic/feldspathic sandstone, Shale, Conglomerate, Chert, Limestone (Silurian-Ordovician) Northern part : Micaceous schist, Amphibole gneiss, Sedimentary and volcanic rocks. (mylonitization in part)				Pg		Pzg	Diorite, Granite, Granodiorite,	

*1 : COLLACAGUE, OLLAGÜE, QUILLAGUE (GEOSCAN AREA)

*2 : QUIPISCA, MAMIÑA (GEOSCAN AREA)

CHAPTER 4 INTEGRATED ANALYSIS OF SURVEY RESULTS

4 - 1 Geologic Structure, Mineralization Characteristics, and Structural Control

4-1-1 Types of mineralization

The mineralization of the study area was classified into the following types in accordance with the existing materials (Table 2-1-1).

Porphyry-type Cu, ② porphyry-type Cu-Mo, ③ porphyry-type Cu-Au, ④ vein-type Mo, ⑤ irregular-type Cu, ⑥ vein-type Cu, ⑦ shape-unknown-type Cu, ⑧ vein-type Au, ⑨ shape-unknown-type Au, ⑩ bedded-type Cu, ⑪ vein-type Ag-Pb-Zn, ⑫ shape-unknown-type Ag-Pb-(Zn), ⑬ vein-shape-unknown-type Ag, ⑭ vein-type Sb, ⑮ vein-type Mn, ⑯ irregular-type Mn, ⑰ shape-unknown-type Mn, ⑱ vein-type Fe, ⑲ irregular-type Fe, ⑳ shape-unknown-type Fe.

Of the above, ④ is believed to be strongly related to porphyry copper type mineralization, and ⑤ to ⑨ types are considered to have the possibility of some relation to porphyry copper mineralization, but types ⑩ to ⑳ are relatively far from the porphyry copper mineralization. Therefore, types ④ to ⑨ will be called prospect with possibly close relation to porphyry copper mineralization.

4-1-2 Age of igneous activities and types of mineralization

In the study area, the N-S ~ NNW-SSE igneous arc moved eastward with time. The igneous arcs of Jurassic-Early Cretaceous, Paleocene-early Eocene, and late Eocene-early Oligocene are inferred to have been parallel, but the igneous arc was oblique to the above during Miocene-Quaternary, and the overlap increases northward from the south (Fig. 2-1-5).

Many of the ore deposits and prospects occur in the porphyry copper belts of Paleocene-early Eocene and late Eocene-early Oligocene. But in the northern part, the deposits and prospects occur also to the east of the porphyry copper belt. The central axis of the Miocene-Quaternary igneous arc is near the late Eocene-early Oligocene porphyry copper belt. And therefore, there are many mineralized zones related to the Miocene-Quaternary igneous activity in the northern part, and some of them are believed to overlap the porphyry copper mineralized zone.

In the northern part, many of the porphyry mineralization and possibly related prospects occur in Paleocene-early Eocene porphyry copper belt and the Ag-Pb-Zn hydrothermal belt occur to the east of this belt.

On the hand, in the central and southern parts, the porphyry copper mineralization and possibly related prospects all occur in two porphyry copper belts. These belts and the Miocene-Quaternary igneous arc overlap significantly in the central part, but in a small scale in the south. In the central part, mineralized zones formed by the Miocene-Quaternary igneous activity possibly overlap the porphyry copper mineralized zone in the late Eocene-early Oligocene porphyry copper belt. The porphyry copper mineralized zones and possibly related prospects occur in the porphyry copper belt, and they tend to occur more on the western side as we go north.

4-1-3 Intrusive rocks and ore deposits - mineral prospects

In the northern part, among all prospects, only a limited number occur near intrusive rocks (plutonic, hypabyssal rocks), they are particularly rare near Tertiary granitic rocks (Fig. 1-4-1). Porphyry copper mineralized zones and possibly related prospects occur near Cretaceous-Tertiary intrusive bodies with the exception of those at Tignamar and near 19° S.

In the central part, all mineral prospects, with the exception of Ag-Pb-Zn veins in the north, occur in and near Cretaceous-Tertiary intrusive rocks (plutonic and hypabyssal rocks).

In the southern part, all mineral prospects, with the exception of those in the west and north, occur in and near Cretaceous-Tertiary intrusive rocks (plutonic and hypabyssal rocks). Porphyry copper mineralized zones and vein Mo prospects are relatively concentrated near the intrusive bodies. The mineral prospects possibly related to porphyry copper mineralization (Cu veins, irregular Cu, Cu mineralization of unknown shape) occur in the vicinity of the porphyry mineralization. Ag-Pb-Zn prospects also occur among the above.

4-1-4 Stratigraphy and ore deposits - mineral prospects

Ore-bearing horizons were inferred from interpretation of geological maps and TM images (Fig. 2-2-1, 2-2-3).

In the northern part, porphyry copper mineralized zones and possibly closely related prospects in or near the porphyry copper belt occur, with the exception of Tignamar, in Cretaceous-Tertiary intrusive rocks or in Cretaceous volcanic rocks. Other mineral prospects are in Cretaceous-Tertiary volcanic rocks and younger formations.

In the central part, the porphyry copper mineralization occurs in Cretaceous volcanic rocks or in Cretaceous-Tertiary intrusive rocks, and mineral prospects with the possiblity of porphyry copper-type minerlization occur in Middle to Late Jurassic sedimentary rocks, in Cretaceous volcanic rocks, in Cretaceous-Tertiary intrusive bodies, or in formations younger than Tertiary.

In the southern part, the porphyry copper-type mineralization occurs in Paleozoic sedimentary and volcanic rocks, in Cretaceous volcanic rocks, or in Cretaceous-Tertiary intrusive bodies, and mineral prospects with the possibility of porphyry copper-type mineralization occur, aside from the above, in Jurassic volcanic and sedimentary rocks, Cretaceous granitic rocks, in Oligocene-Miocene sedimentary rocks, or in formation younger than Miocene.

4-1-5 Faults and ore deposits - mineral prospects

Faults and ore deposits-mineral prospects are very closely related on geological maps, and the mineralized zones generally occur within about 8km of the faults (Fig. 2-1-1). The mineral prospects located far from faults are observed only in the western zone of the central part and the southeastern zone of the southern part.

The strike of the faults with ore deposits and mineral prospects in the vicinity is very diverse.

4-1-6 Lineaments and ore deposits - mineral prospects

Lineaments extracted from TM image interpretation and the occurrence of ore deposits-mineral prospects are very closely related. These mineralized zones are generally within about 4km of the lineaments and are distributed where lineaments are developed (Fig. 1-4-2). Exceptional mineral prospects which occur more than 9km from lineaments are found in the northern zone of the northern part, northern zone of the southern and central parts and in the western zone of the southern part.

The strike of the lineaments with ore deposits and mineral prospects in the vicinity is very diverse.

Lineament groups consisting of obliquely intersecting lineaments tend to be distributed in areas where ore deposits or mineral prospects are concentrated. However, as in the southeastern zone of the central part, the occurrence of these lineament groups is not necessarily accompanied by mineral prospects.

Porphyry copper mineralized zones occur either in the periphery (lineament concentration 50~159m/km^2) of lineament concentrated zones (Cerro Colorado, Collahuasi etc.,) or near the center of relatively high lineament concentration (lineament concentration 150~300m/km^2) (Quebrada Blanca, Copaquire, etc.,) (Fig. 1-4-2).

4-1-7 Alteration zones and ore deposits - mineral prospects

The relation between ore deposits-prospects and alteration zones extracted by TM image and GEOSCAN interpretation is described below.

In the northern part, ore deposits and prospects are associated with parts of groups of alteration zones aligned in the NNW-SSE direction. But mineral prospects also occur in areas where alteration zones are not extracted such as the eastern and western parts. Many of the porphyry copper-type mineralized zones and possibly closely related prospects occur in the above western part of the survey area.

In the central part, many prospects occur in the alteration zones and vicinity with the exception of the northern and southeastern zones.

In the southern part, mineral prospects occur in alteration zones and vicinity with the exception of the western zone.

The location of the large porphyry copper deposits discovered recently does not necessarily coincide with alteration zones, but they are within 4km of the altered zones. In TM images, color anomalies do not have sharp boundaries and thus the extracted alteration zones may have been mapped smaller than their actual size. Also as the access is generally not good in this area, it is anticipated that there is a high possibility of undiscovered mineral prospects near the known ore deposits. Therefore, it was assumed that hydrothermal activity occurred within a range of 4km from alteration zones and ore deposits-prospects. It is seen from Figure 1-4-3 that the area of hydrothermal activity is aligned in the NNW-SSE direction. But there are E-W system hydrothermal zones intersecting the NNW-SSE direction in the northern, central, and southern parts of the area. Known porphyry copper mineralized zones are distributed within this E-W system. CODELCO proposed that the igneous intrusive bodies related to mineralization originated form a large-scale magma chamber elongated in the E-W direction. This is based on geomagnetic anomalies transecting Central Andes, the existence of E-W alignment of volcanoes, and the distribution of porphyry copper deposits. The existence of the above E-W system of hydrothermal activity is in agreement with this line of thinking.

The distribution of hydrothermal activity mostly agrees with that of the development of lineation in the central and southern parts, but the correspondence is relatively poor in the northern part and the hydrothermal activity can be correlated better with the distribution of Miocene-Quaternary volcanoes.

4 - 2 Mineral Potential of the Survey Area

Many hydrothermal alteration zones, fractured zones, and mineral prospects are widely distributed in the survey area and they are very closely interrelated. Therefore, the mineral potential of the area, as a whole, is considered to be high.

Porphyry copper mineralization occurs in several localities in the northern, central, and southern parts of the area. And very large porphyry copper deposits were discovered relatively recently in the central and southern parts and they are presently being mined. Alteration zones extracted from image interpretation and existing data indicate that many mineral prospects with possibility of porphyry copper mineralization occur in the porphyry copper belt already reported. These alteration zones and mineral prospect and their vicinity are considered to have high potential for porphyry copper deposits.

The conditions for occurrence of cordillera-type porphyry copper deposits are inferred to be as follows.

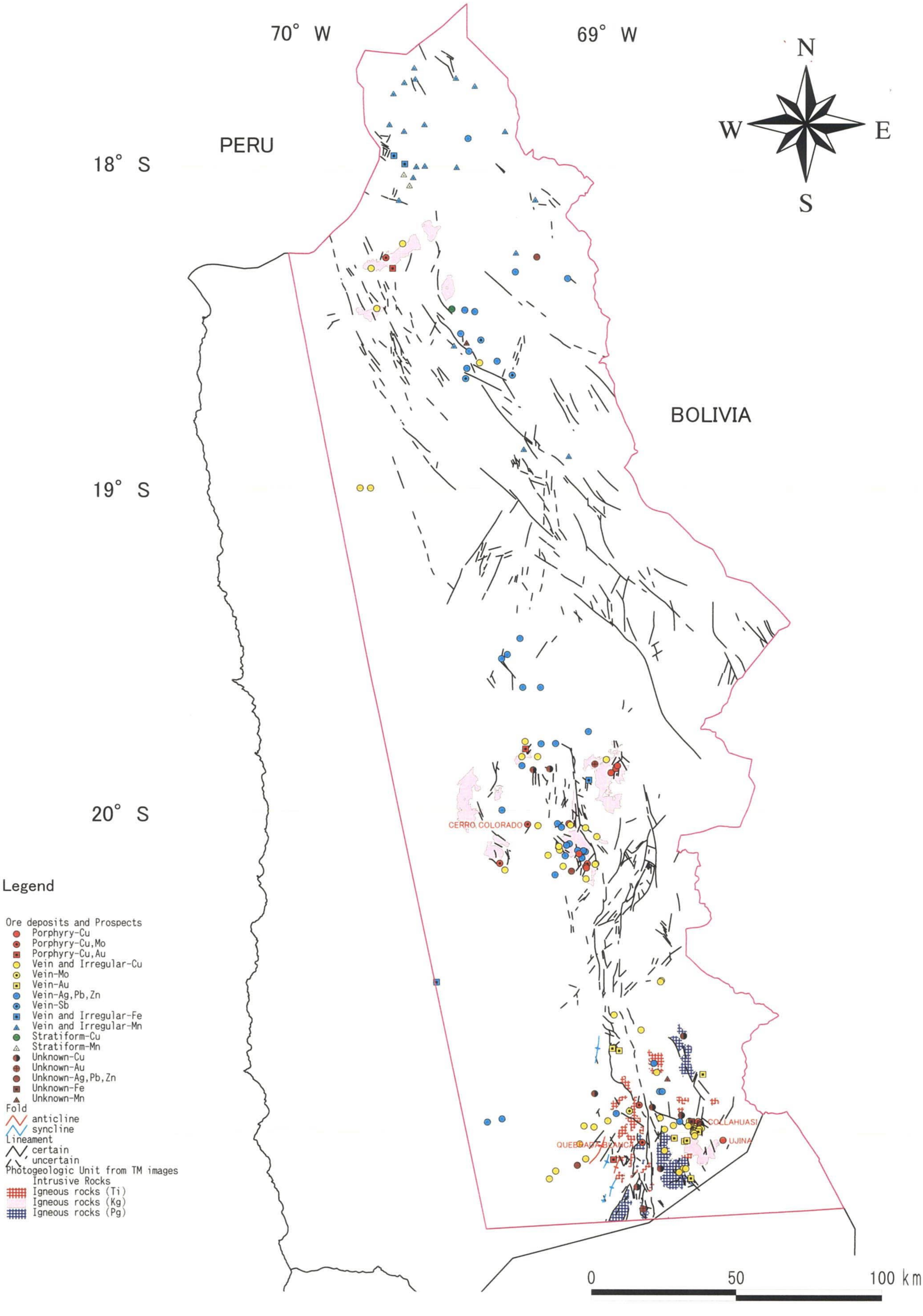

Fig. 1-4-1 Relationship among Granitoids from TM images, Ore Deposits and Prospects in the Study Area

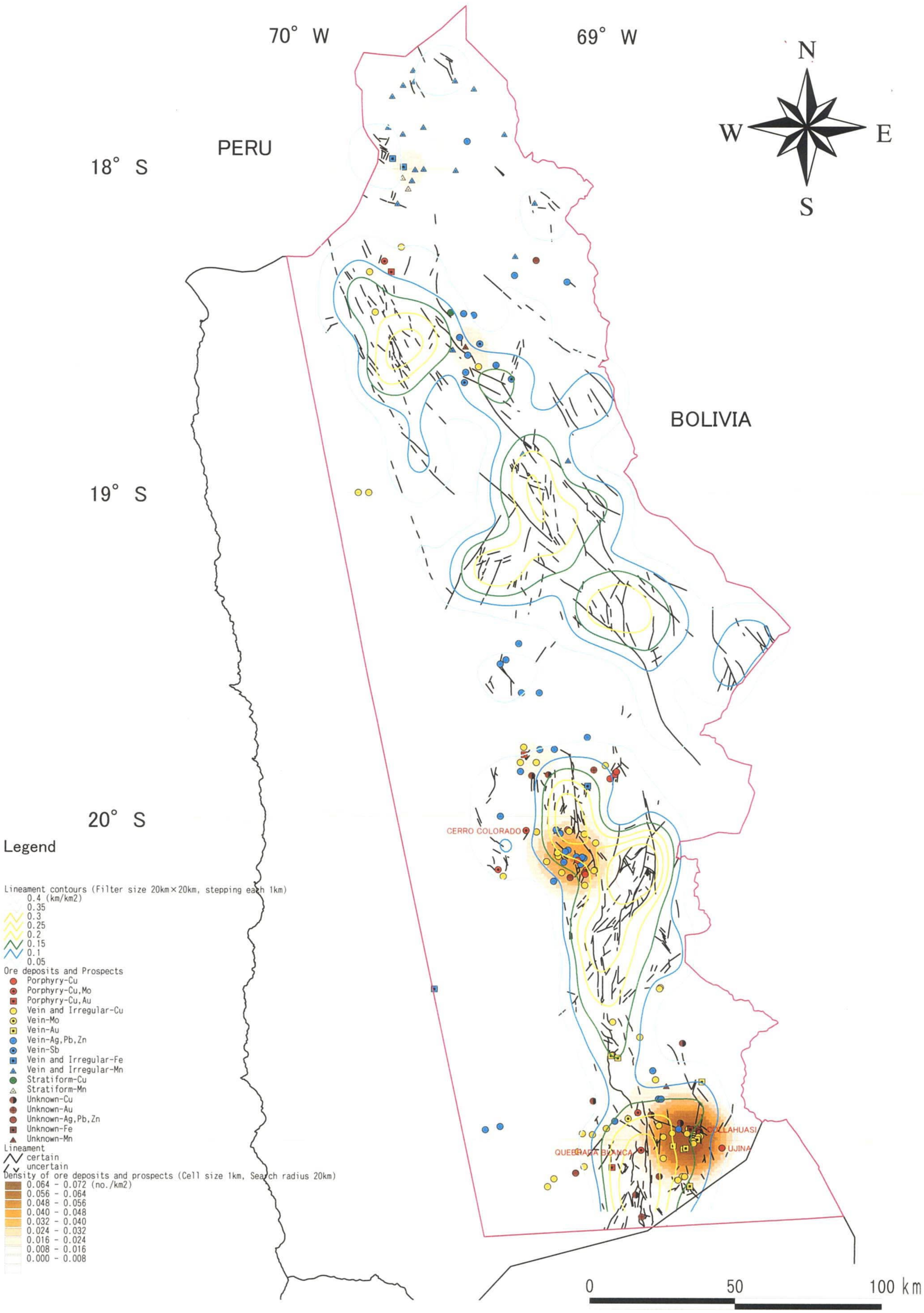

Fig. 1-4-2 Relationship between Density of Ore Deposits & Prospects and Lineaments in the Study Area

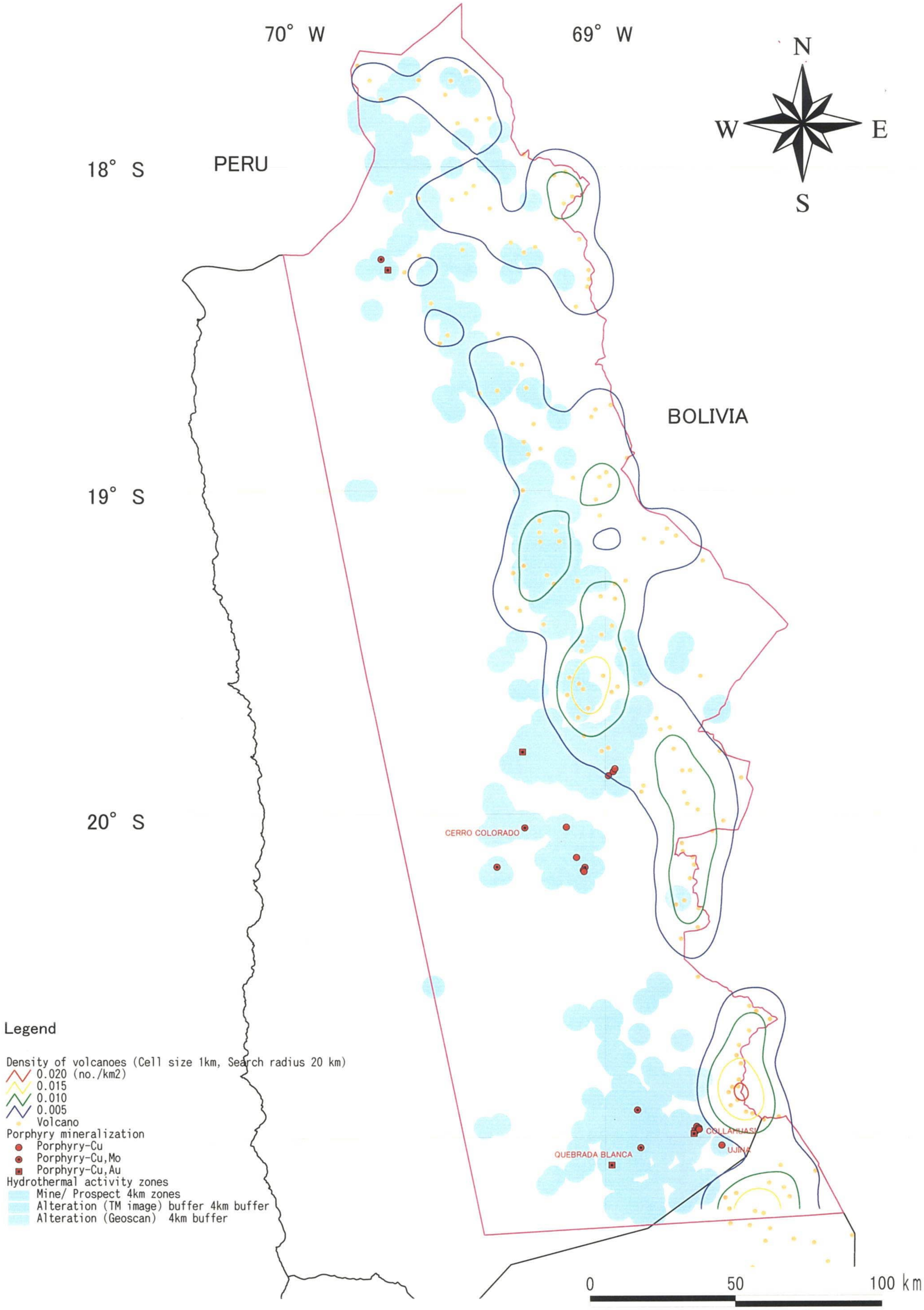

Fig. 1-4-3 Hydrothermal Activity Zones of the Study Area

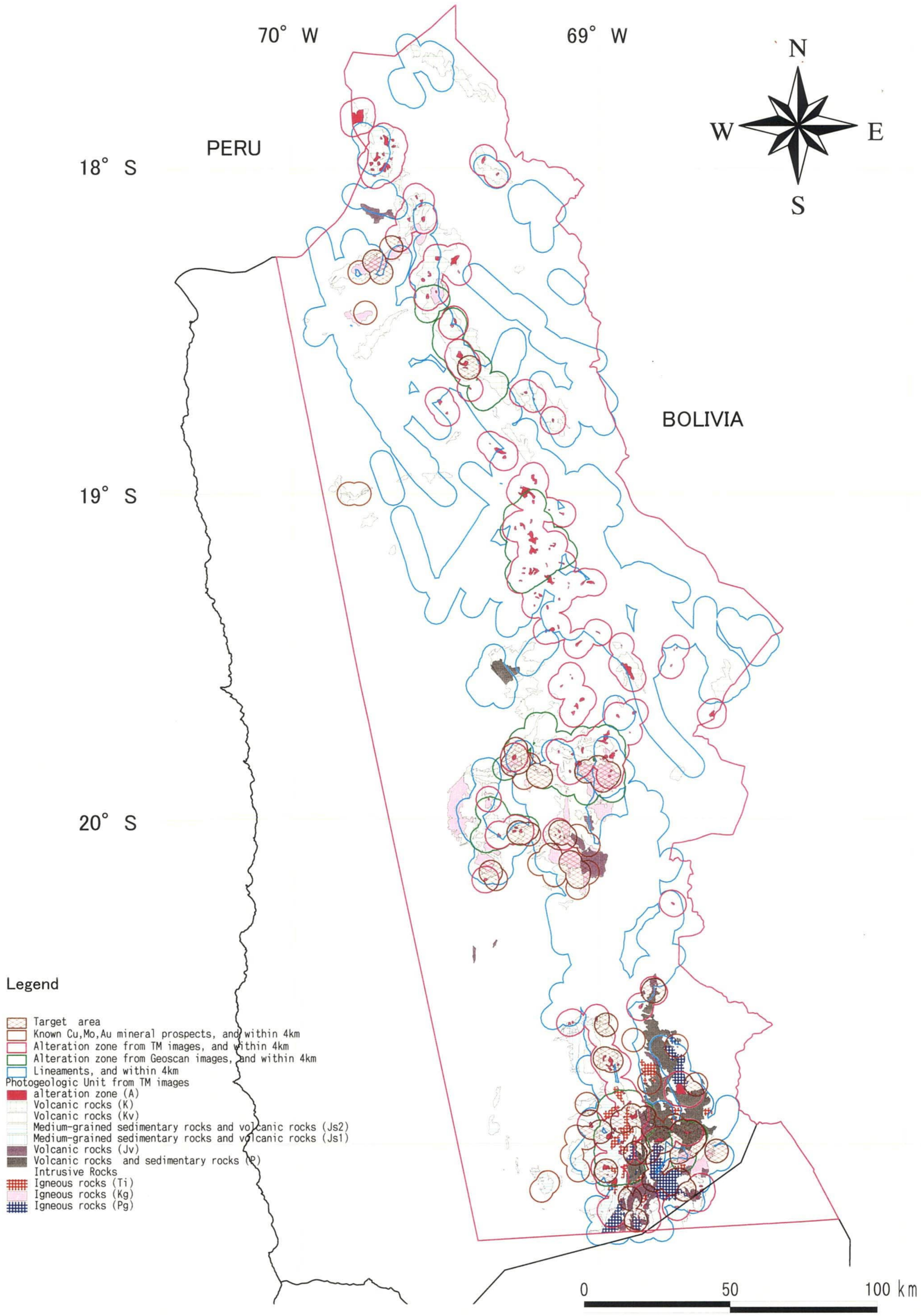

Fig. 1-4-4 Integrated Interpretation Map

These deposits are associated with Paleocene-Oligocene intrusive rocks and thus the ore horizon is Oligocene or earlier.

It is inferred that the intrusive bodies associated with mineralization rose through deep fractures and that fractured zones developed which became the conduits for hydrothermal activity after the formation of the deposits. Thus fractured zones are formed around porphyry copper deposits.

Zonal distribution of Cu-Mo→Cu-FeS_2→FeS_2→Pb-Zn-Ag→Mn / Ag-Au is formed from the center of the deposit outward, and vein or replacement-type Cu, Pb-Zn-Ag, Mn, or Ag-Au deposits or showings occur around the deposits.

Alteration zones are formed around the deposits at the time of ore genesis. Mineralization becomes hydrothermal at the later stages, and acidic alteration zones or high sulfidation-type Au mineralized zones are formed in the upper part of the deposits.

On the basis of the above considerations and of structural and mineralization characteristics of the area and of structural control mentioned in 4-1, localities corresponding to one or more of the following conditions were selected as having potential for porphyry copper deposits (Fig. 1-4-4).

1. Porphyry copper-type mineral prospects and vicinity within 4km range.

2. Mineral prospects in early Oligocene and older formations (Mo veins, irregular Cu, Cu veins, unknown-shaped Cu, Au veins, unknown-shaped Au) and alteration zones in the same formations (acidic alteration and sericitized zones extracted by GEOSCAN image analysis, and alteration zones extracted by TM image analysis) and within 4km of the above.

Within the porphyry copper belt, there are localities where lineaments are extracted but alteration zones are not because of the cover by later geologic units. Some of these lineaments could be extension of fractures associated with porphyry copper mineralization and subsequently re-activated. Thus the existence of blind porphyry copper deposits in the vicinity is a possibility. Therefore, such localities could be targets of exploration if the geologic formations overlying the ore deposits are thin. The exploration potential would rise if the thickness of such formations and the existence of ore deposits could be inferred by geophysical exploration.

Also it is noted that Miocene-Quaternary igneous activity occurred extensively in the central and northern part of the survey area. The known mineral prospects and alteration zones and their vicinity are believed to have high potential for epithermal deposits (mainly Au-Ag-Pb-Zn veins) associated with the above igneous activity.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5 - 1 Conclusions

Analysis of existing data including GEOSCAN image analysis, satellite image analysis, and geological survey and geochemical survey were carried out in Region I during the first year survey and the following conclusions were reached.

1. Many alteration zones were extracted in Paleogene and older formation and vicinity and in Miocene-Quaternary volcanic rocks by TM image analysis. These alteration zones are aligned in the NW-SE~NNW-SSE direction in the northern part, and in N-S~NNW-SSE direction in the central to the southern parts of the survey area. The above direction of alteration zone alignment is harmonious with the prominent direction of the lineaments developed in the alteration zones.

2. Analysis of images of visible near infrared-short-wave infrared region, short-wave infrared region, and thermal infrared region was carried out and the following results were obtained. Detailed geologic structure was clarified; alteration zones consisting of sericite, kaolin, alunite, and silica were extracted at Tignamar, Palca, Queen Elizabeth, Cerro Colorado, Copaquiri, and Collahuasi areas; and sericitized zone was extracted at Mocha area.

3. Mineralization of the known deposits and mineral prospects of the survey area was classified from the analysis of existing data on geology and ore deposits. And porphyry copper-type mineralized zones and possibly closely related prospects (Mo veins, irregular Cu, Cu veins, unknown-shaped Cu, Au veins, unknown-shaped Au) were selected.

4. Many mineral prospects closely related to porphyry copper-type mineralized zones are distributed in Paleocene-early Eocene porphyry copper belt in the northern part, and in Paleocene-early Eocene and late Eocene-early Oligocene porphyry copper belts in the central to southern parts of the survey area. Epithermal mineralized zones related to Miocene-Quaternary igneous activity occur in the northern to central parts of the area and some of it is believed to overlap with the porphyry copper mineralized zones.

5. Porphyry copper mineralized zones and possibly closely related prospects occur in and

near Cretaceous-Tertiary intrusive bodies (plutonic and hypabyssal rocks).

6. Porphyry copper mineralized zones occur; in the northern and central parts in Cretaceous-Tertiary intrusive bodies or in Cretaceous volcanic rocks, and in the southern part in Paleozoic sedimentary and volcanic rocks, Cretaceous volcanic rocks, Paleozoic granitic rocks, or in Cretaceous-Tertiary intrusive bodies.

7. Faults on geological maps and fractures expressed as lineaments extracted from TM images are fractures which are generally closely related to the occurrence of ore deposits and prospects. The direction of the lineaments near the deposits and prospects is diverse. The porphyry copper mineralized zones occur either in the peripheries of the zones where lineaments are developed (Cerro Colorado, Collahuassi, etc.,) or near the center of lineament concentration (Quebrada Blanca, Copaquire, etc.).

8. In the central and southern parts many mineral prospects including porphyry copper mineralized zones occur in the alteration zones or vicinity, while in the northern part many of them occur in localities where alteration zones have not been extracted.

9. Assuming that hydrothermal activity related to mineralization is effective within a range of 4km from the alteration zones and ore deposits and prospects, hydrothermal zones are generally elongated in the NNW-SSE direction, but existence of those elongated in the E-W direction intersecting the major NNW-SSE direction is inferred. The known porphyry copper mineralized zones occur in this E-W hydrothermal system. The hydrothermal zones coincide with lineament concentration in the central and southern parts, but the correlation between the two is relatively poor in the northern part, with better coincidence with the distribution of Miocene-Quaternary volcanoes.

10. The following localities were selected as promising for porphyry copper occurrence.
Porphyry copper-type mineral prospects and within 4km range.
Mineral prospects possibly related to porphyry copper mineralization in Oligocene and older formations (Mo veins, irregular Cu, Cu veins, unknown-shaped Cu, Au veins, unknown-shaped Au) and alteration zones (acidic alteration zones and sericitized zones extracted by GEOSCAN image analysis and alteration zones extracted by TM image analysis), and within 4km of the above.

5 - 2 Recommendations for the second year survey

1. It is recommended that verification survey be carried out in localities selected as promising for porphyry copper occurrence and were not surveyed during the first year.

2. Geomagnetic anomalies at right angles to the axis of Central Andes are probably closely related porphyry copper-type mineralized zones. The existing airborne geomagnetic maps are not sufficiently precise for extracting promising zones. Therefore, it is recommended that high precision airborne geomagnetic survey be carried out and the details of the above trans-Central Andes geomagnetic anomalies be clarified. This will result in more focused targeting of the promising localities and in selection of promising localities for blind buried deposits in areas where alteration zones were not detected because of coverage by younger formations.

3. It is recommended that gravity survey be carried out in localities extracted as promising for porphyry copper occurrence by the above high precision airborne geomagnetic survey so that the thickness of the formations overlying mineralized zones can be inferred.

4. It is recommended that geological reconnaissance be carried out in localities considered to be promising from the results of image analysis and high precision airborne geomagnetic survey.