REPORT
ON
THE GEOLOGICAL SURVEY
IN THE SOUTH AREA
OF
THE REPUBLIC OF PERU

PHASE Ⅰ

February 2001

THE JAPAN INTERNATIONAL COOPERATION AGENCY
THE METAL MINING AGENCY OF JAPAN

PREFACE

In response to the request of the Government of the Republic of Peru, the Japanese Government determined to conduct a series of survey related to exploration of ore deposits including analyses of the existing geologic information and the satellite images, for the purpose of examining the potentialities of mineral resources in the southern areas of the Republic, and entrusted the survey to the Japan International Cooperation Agency (JICA). In view of the geological and mineralogical nature of the intended survey, the JICA commissioned the Metal Mining Agency of Japan (MMAJ) to implement the survey.

The survey was commenced in FY2000 (Phase I). In Phase I, the MMAJ sent a specialist to Peru for the period from February 4 to 18, 2001, for the analyses of existing geologic information and satellite images. The work was completed as scheduled, in close collaboration with the Peruvian government agencies concerned, especially the INGEMMET of the Ministry of Energy and Mines.

This Report consolidates the results of surveys in Phase I, which will form an integral part of the final report to be elaborated when all the survey is completed.

We should like to take this opportunity to express our sincere gratitude to the Peruvian government agencies and persons concerned for their valuable cooperation. We are also thankful to the Japanese Ministry of Foreign Affairs, the Ministry of Economy, Trade and Industry, the Embassy of Japan in Peru and persons concerned who have rendered assistance and support for the survey.

February, 2001

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THE GEOLOGICAL SURVEY
IN THE SOUTH AREAS OF THE REPUBLIC OF PERU
(PHASE I)

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Summary

This Report consolidates the results of the regional survey of mineral resources in Phase I (FY2000, the first fiscal year of the survey) implemented in southern areas of the Republic of Peru, under the Technical Cooperation for the Mineral Exploration. The subject survey was aimed to effectively extract interesting areas from the extensive survey area in a short period of time, by means of satellite image analysis, analysis of the existing geologic information and integrated analysis of survey findings of the subject area.

The Phase-I survey covers an approximate area of 45,000 km^2, which extends over 18 quadrangles of the 1:100 000-scale topographic map published by the Instituto Geográfico Nacional of the Republic of Peru. Topographically, the subject area spreads over the Cordillera Occidental, the Inter-Andean valley zones including the Titicaca basin, and the Cordillera Oriental, although a large part of the area pertains to the highlands, alt. 4,500m or more, of the Cordillera Occidental.

Conducted for the survey were analysis of the JERS-1 SAR images and the LANDSAT TM images, as well as analysis of the existing geologic information. Simultaneously with the survey, transfer of technology concerning satellite image analysis to the host nation's organization, the Instituto Geológico, Minero y Metalúrgico (INGEMMET) of the Peru's Ministry of Energy and Mines was put into practice. Results of the satellite image analysis and the analysis of existing information were integrated and analyzed, for evaluation of potentialities for occurrence of ore deposits in the entire survey area so that areas of interest might be extracted.

The survey findings are summarized as follows.

(1) Satellite image analysis

1. The R21 anomalies(the iron-oxide index) were extracted mainly from Tertiary intrusive rocks distributed in the northwestern and northern parts of the survey area and also from the surrounding sedimentary rocks of the Silurian to Devonian, Carboniferous, and Carboniferous to Permian times.

2. The lineament density is not necessarily high in the Tertiary intrusive rocks, but tends to be high in the sedimentary rocks surrounding the intrusive bodies.

3. Of the lineaments in the survey area, those with the NW-SE trend are generally dominant, which is considered to reflect the presence of thrust faults formed in relation with the Andean fold structures.

4. No remarkable differences by the geologic time were discerned in the directional tendency of lineaments. The only exception is that, in the Quadrangle 29-s in the northwest of the subject area, a change in the directional tendency is observed. The change suggests that lineaments trending NNW-SSE and NE-SW developed up to the Jurassic to Cretaceous time, while those trending NW-SE, parallel with the Andes, developed from the Paleogene onward.

(2) Analysis of existing geologic information

In the survey area, Paleozoic to Quaternary sedimentary rocks lie extending toward NNW-SSE. Permian and Neogene intrusive rocks lie intruding into the sedimentary rocks. In terms of the Peru's metallogenic provinces, the area extends over the central polymetallic belt, the tin belt and the marginal polymetallic belt.

The known mineralization in the area are divisible into the vein-type Au deposits in Paleozoic rocks, the Sn-W-Cu deposits relating to Permian granites, the Ag-Pb-Cu-Zn vein and skarn deposits in Triassic to Cretaceous rocks, and the Sn-W-Cu-Pb-Zn vein deposits related to Miocene granites. Besides, the Au placer deposits lie from the Cordillera Oriental to the Amazon plain, while presence of uranium mineralization related to Miocene to Pliocene pyroclastic rocks is also known.

The mineralization in the survey area can be summarized as follows:

Vein-type Au deposits in Paleozoic rocks :

- Santo Domingo, Manco Capac, Candelaria, Benditani
- Gavilán de Oro, Untuca, Ana Maria, Carabarcuna
- La Rinconada

Sn-W-Cu deposits accompanying Permian granites :

- Condoriquiña, Sarita

Ag-Pb-Cu-Zn vein and skarn deposits in the Triassic to Cretaceous rocks :

- Cerro del Inca Azur, Casa de Plata, Atura, Santa Ana

Sn-W-Cu-Pb-Zn vein deposits related to Miocene granites :

- San Rafael, Palca XI

Au placer deposits in the area spreading from the Cordillera Oriental to the

Amazon plain :

- San Antonio de Poto, (the Madre de Dios, Huaypetuhe and Caichive rivers)

Uranium mineralization related to Miocene to Pliocene pyroclastic rocks :

- The Macusani area

(3) Integrated analysis and recommendations

The integrated analysis was conducted based on the findings of the satellite image analysis and the analysis of existing geologic information, which resulted in extraction of the five areas of interest indicated below. The extraction of interesting areas were made under the following criteria: (i) anomalies in the iron-oxide index, (ii) lineament density, (iii) distribution of Pliocene to Miocene and Permian granites, and (iv) distribution of the known mineral indications.

1. Calhuahuacho area
2. Livitaca area
3. Macusani area
4. Usicayos area
5. Vilque area

In order to verify the geology and mineralization in these areas, geological reconnaissance survey should desirably be implemented.

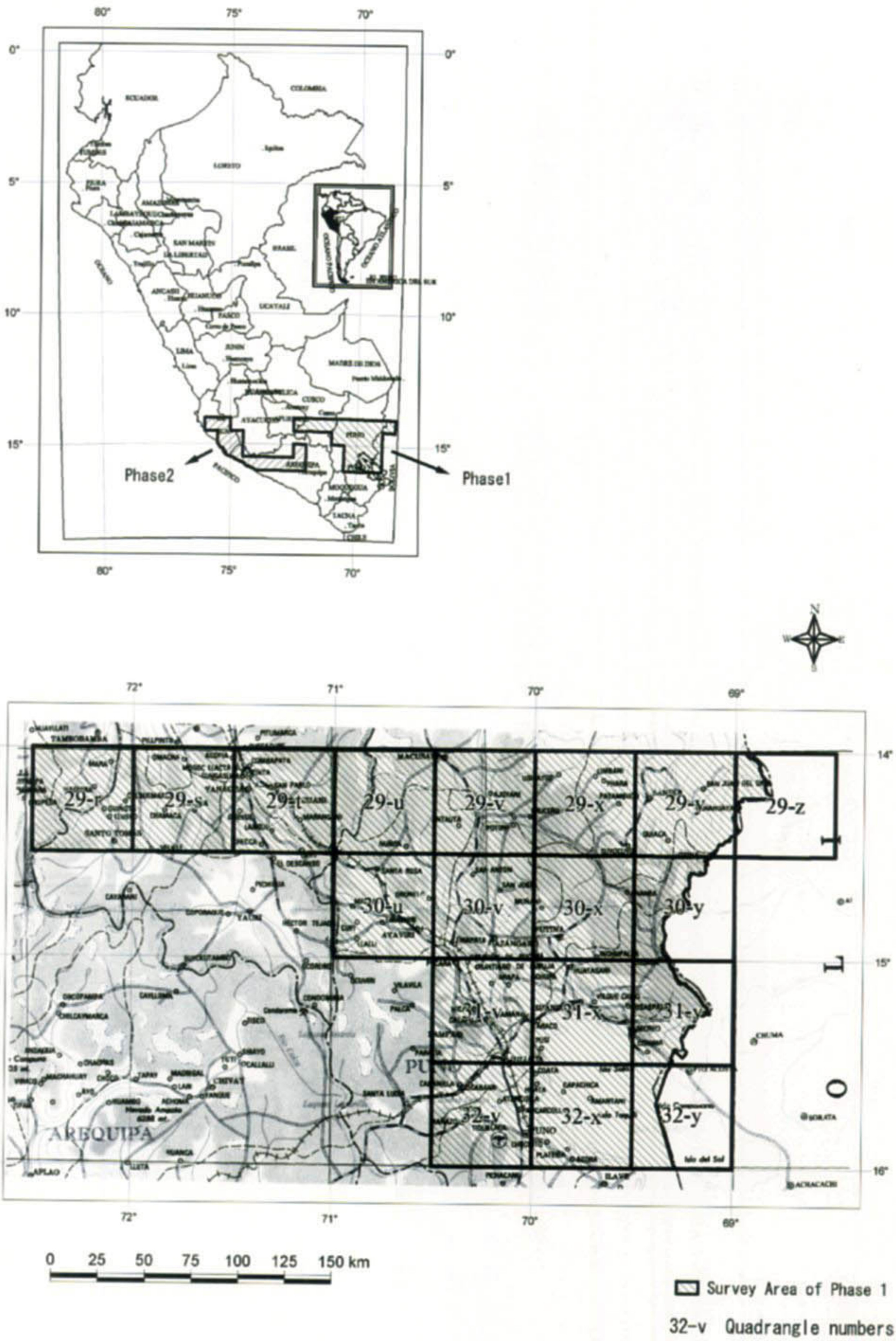

Fig.1 Location Map of the Survey Area

PART I

GENERALITIES

Chapter 1 Outline of Survey

1-1 Antecedents and Purpose of Survey

The mining is one of the critical basic industries of Peru. The nation's export of metallic mineral products in 1999 reached 3 billion dollars, which accounts for 49.2% of her total export value. The national terrotory of Peru is 1,285,220 km^2 in area. The topography, geologic units and metallogenic provinces all extend from the Pacific side to the east, in parallel belts trending NNW-SSE.

The metallogenic provinces can be roughly classified into the vein-type and porphyry copper-type metallogenic provinces on the Pacific-side slopes of the Cordillera Occidental, the vein-type Au-Zn-Pb provinces in the volcanic rock zones in the Cordillera Occidental, the vein-, dissemination-, skarn- and manto-type Ag-Cu-Pb-Zn provinces in the sedimentary rock zones in the Cordillera Occidental, and the vein-, dissemination- and skarn-type Au-Ag-Cu-Pb-Zn-Sn-W provinces in the Cordillera Oriental.

The survey area, situated between lat. 14° and 16° S and east of long. 72° 32'W, topographically consists of the Cordillera Occidental that forms the plateau-like configuration called Altiplano, and the Cordillera Oriental that forms the foothill zones in the uppermost part of the Amazon headwaters. In view of the relationship with the mentioned metallogenic provinces, occurrence of Ag-Cu-Pb-Zn ore deposits can be expected mainly in the Cordillera Occidental whereas, in the Cordillera Oriental, occurrence of Au-Sn-W deposits is expectable.

The Peruvian government requested the Japanese government to execute collaborative survey aimed to investigate potentialities for occurrence of ore deposits, thereby helping promote mining investments in the subject area. In response to the request, the Japanese government sent a mission to Peru for the period from October 14 to 21, 2000, for consultation on the survey plan, and the Scope of Work was signed on October 18, 2000.

The subject survey is intended to effectively and speedily extract interesting areas where occurrence of ore deposits is anticipated, by integrating the findings of the satellite image analysis and the analysis of existing geologic information to be conducted in compliance with the Scope of Work. Simultaneously, it is intended to transfer the technology concerning the methods of survey and analysis to the INGEMMET - Instituto Geológico Minero y Metalúrgico, the Peruvian counterpart for the survey.

1-2 Scope of Phase-I Survey and Outline of Survey Work

The survey area as agreed upon in the Scope of Work is an area covered by the 30 sheets of the 1:100 000-scale topographic map. In Phase I, the analyses of the JERS-1 SAR and LANDSAT TM images and of existing geologic information were conducted of the eastern part of the survey area, between Lat.14° S and 16 ° S, and east of long. 72° 30' W, which extends over the 18 quadrangles. (Fig.1)

The survey was implemented in the following procedures.

Data processing and interpretation of satellite images were carried out mainly in Japan after the JERS-1 SAR and LANDSAT TM data and the 1:100 000 topographic map were obtained, while the analysis of existing geologic information was carried out in Japan and Peru after the geological information and mines-mineral indications data were made available in Peru. During the survey in Peru, a part of the image interpretation and analysis work were practiced jointly with the INGEMMET engieneers at their office in Lima, with a view to transferring the image analysis technology.

The geologic interpretation map, lineament map, spectral anomaly distribution map, list of the known mineral indications, integrated analysis map, etc. were prepared based upon the analyses of satellite images and existing information.

1-3 Organization of Missions

Organization of the missions for the prior consultation and the survey are shown in Tables 1 and 2.

Table 1 Mission for previous agreement and negotiation

Peruvian side		Japanese side	
Ing. Juan Mendoza Marsano	INGEMMET	Mr. Shigeru Yokoyama	MMAJ
Ing. Hugo Rivera Mantilla	INGEMMET	Mr. Kenzo Hagio	METI
Ing. Oscar Palacios Moncayo	INGEMMET	Mr. Masashi Kasai	JICA
Ing. José León Aparicio	INGEMMET	Mr. Noboru Fuji	MMAJ
Ing. Manuel Paz Maidana	INGEMMET	Ms. Yuri Torizava	MMAJ
Ing. Yorry Carrasco Pinares	INGEMMET	Mr. Satoshi Shiokava	MMAJ

INGEMMET: Instituto Geológico Minero y Metalúrgico
JICA: Japan International Cooperation Agency
METI: Ministry of Economy, Trade and Industry
MMAJ: Metal Mining Agency of Japan

Table 2 Mission for the field survey

Peruvian side		Japanese side	
Ing. Julio Sanchez Miliano	INGEMMET	Mr. Kiyoshi Nakamura	MINDECO
Ing. Enzzo Viaccava	INGEMMET		

MINDECO: Mitsui Mineral Development Engineering Co., Ltd.

1-4 Period and Quantities of Survey

The period for survey is shown in Table 3, and quantities of the survey work are indicated in Table 4.

Table 3 Study period

	2000						2001					
	November			December			January			February		
Planning and Preparation			11/29									
Satelite Image Analysis												
・Image Processing												
・Image Interpretation												
・Digitizing												
Existing Data Analysis												
・Travel										2/4	2/18	
・Satelite Image and Existing Data Analysis												
Analizing and Report Writing												2/28

Table 4 Quantity of the study

Survey items	Quantities
Satelite Image Analysis	Survey area : 45,000 km^2
Existing Data Analysis	Survey area : 45,000 km^2

Satellite data used	
JERS-1 SAR	25 scenes
LANDSAT TM	6 scenes

Chapter 2 Geography of the Survey Area

2-1 Location and Transportation

The survey area, situated east-southeast of Lima, extends over about 400 km between long. 75° 30' W and the Bolivian border and about 200 km between lat.14° 00' S and 16° 00' S. The area extends over the three Departments - Puno, Cuzco and Apurimac. The major cities in the area are Juliaca in the south and Puno at the southernmost edge. The survey area is accessible from Lima by air up to the city of Cuzco or Puno, and overland from there. The flight from Lima to Cuzco and Puno respectively takes about an hour and an hour and half, while it takes about two hours by car from Cuzco to the northern end of the area.

2-2 Topography and Drainage Pattern

The topography of the survey area is divided, from west to east, into the Cordillera Occidental, the inter-Andean valley zone and the Cordillera Oriental.

The western part of the survey area is situated east of the Cordillera Occidental, where the Altiplano, peneplains at an altitude of about 4,500m, spreads out. The inter-Andean valley zone extendingin a narrow strip from the Titicaca basin northeastward divides the Cordilleras Occidental and Oriental. The northeastern part of the survey area is included in the Cordillera Oriental, where lies the so-called foothill zone ranging in altitude from 1,000m to 2,000m.

The northwest to north-central part of the survey area is situated in the uppermost headwaters of the Amazonian system, where rivers such as the Santo Tomás, a branch of the Apurimac River, generally runs from south to north. In the area from the central to the eastern part of the survey area, small dainage patterns such as the Azángaro River flowing into Lake Titicaca are dominant, which generally run from northwest to southeast. The Cordillera Oriental in the eastern part of the survey area is situated at the headwaters of the Inambari River, a branch of the Manú River of the Amazon system, where rivers generally flow from south-southwest to north-northeast.

2-3 Climate and Vegetation

The climate in the subject area, belonging to the cold highland climate type, is rather monotonous all the year round but has the rainy season from November to March and the dry season from April to October. The annual precipitation is around 900 mm and the annual average atmospheric temperature is around 10 °C, although the diurnal range of temperature is so wide especially in the dry season when the maximum temperature occasionally exceeds 20°C while the minimum temperature goes below minus 10℃.

Chapter 3 Existing Geologic Information of the Survey Area

3-1 Outline of Existing Geologic Information

In the survey area, precious metals, copper, etc. had been mined since the Pre-Inca times. During the Colonial period, mineral prospecting was conducted vigorously, if not systematically, in search of precious metals; and, huge amounts of gold and silver were produced.

Modern geological survey was commenced in the 1950's by the INGEMMET. The national geologic map at a scale of 1:1 000 000 of the whole of Peru was compiled by the INGEMMET in 1973. The geological mapping survey was implemented from 1973 to 1996, whereby the geologic maps at a scale of 1:100 000 of the 18 quadrangles which cover the survey area were completed. Besides, surveys of local geology and ore deposits have been undertaken by the INGEMMET, the Banco Minero del Perú, the Universidad Nacional San Antonio Abad del Cuzco, and also by private mining companies.

In the seven quadrangles (29-u, 29-v, 29-x, 29-y, 29-z, 30-x and 30-y) in the northeast of the survey area, geochemical prospecting of stream sand(10 elements: Au, Ag, Cu, Pb, Zn, Sn, Mo, W, As and Sb) has been carried out, in parallel with the mapping survey.

In the Bolivian border zone in the east of the survey area, the five-year Multinational Andean Project has been underway, in which government and private concerns of Canada, Argentine, Bolivia, Chile and Peru have participated. Under the Project, geological and mapping survey of metallogenic provinces have been conducted. The survey findings of the Project have been utilized for elaboration of the 1:100 000-scale geologic map.

For general geological and petrological studies on the survey area, publications such as a comprehensive research on southern Peru by O. Palacios et al(1978) are available, in addition to the INGEMMET's geologic maps as referred to above.

Regarding the general geology, ore deposits and metallogenic provinces in the survey area, a number of researches and studies have been elaborated by various authors, such as Bellido, E. et al.(1972) on the general conditions for metallogenic provinces in Peru; Chacon, N. et al.(1995) on the metallogenic provinces - guidelines for prospecting of metallic ore deposits; Clark, A. et al.(1990) on the topographic conditions and secondary enrichment of porphyry copper deposits; Fornari, M. et al.(1991) on gold occurrence in Lower Paleozoic of the Cordillera Ocriental; Ponzoni, H. et al.(1989) on the metallogenic provinces throughout Peru; Rivera, H.(1986) on the geology and ore deposits in the

Cordillera Oriental; Steinmuller, K.(1999) on the metallogenic provinces, models for genesis, prospecting and ambience; etc.

3-2 Outline of Geology (Figs. 2 and 3)

The survey area is underlain by Paleozoic to Quaternary sedimentary rocks extending in the NW-SE direction. Permian, Triassic and Neogene intrusive rocks lies intruding into the sedimentary rocks. The northeastern part of the survey area is underlain by Paleozoic rocks, while sedimentary rocks of younger ages lie southeastward.

The geotectonic history of the subject area is summarized in the following paragraphs.

(1) Paleozoic Era

After the termination of the Brasilida orogenic movement at around 600 M.a., the Late Precambrian topography was eroded to form peneplains in Peru from the Cambrian period onward. In the peneplains, pyroclastic rocks and continental volcanic rocks deposited in the tension field.

At the dawn of the Hercynian orogenic movement, mountain ranges were formed to undergo the subsequent erosion.

(2) Permian to Jurassic igneous activity

From the Late Permian to Early Jurassic time, alkalic basalt, shoshonite, peralkalic volcanic rocks were generated in the tension field in southeastern Peru. [Kontak et al., 1985]

From the Permian to the Jurassic time(240-190 M.a.), extensive intrusive rocks of granodiorite and monzonite(the Coasa Pluton, the Limbani Pluton, the Aricona Pluton, and the Limacpampa Pluton of the Carabaya Batholith), as well as the peralkalic intrusive rock body of the Middle Jurassic(189-170 M.a.) Allincapac complex were formed in close relationship with volcanic rocks.

(3) Andean orogenic period

The Andean orogenic period is characterized by the marine sedimentation that began in the Upper Triassic and continued on into the Upper Cretaceous, followed by folding, igneous activity and continental sedimentation, which have continued till today.

(4) Tertiary Period

In the Paleocene time, sedimentation of continental red beds continued with increasing upheavals, to form the Puno Group in the southeast and the Huayabamba Group in the eastern basin. In the Late Paleocene, a stock was formed in the Arequipa -Toquepala area after formation of the coastal batholith. [Beckinsale et al., 1985]

In the Inca Age(the Eocene), an orogenic movement took place accompanied by folding, which reached its peak toward the end of the Eocene time.

In the south and the basin areas, sedimentation of continental red bed continued. (The Moquegua Group, the Puno Group and Hayabamba Group)

After the Inca Age, continental volcanism occurred between the Late Eocene and the Early Miocene, which is known as the Tacna Group in the Departments of Arequipa, Moquegua and Tacna. These interfinger with the upper formation of the Moquegua Group's red beds.

In the Middle Miocene(17-14 M.a.), the volcanism caused uplifting, fault and erosion all over the eastern Andes area, affected by the orogenesis in the Quechua-I Age. Volcanic rocks were formed over the surface of the eastern Andes continuously into the Late Miocene time, which are composed mainly of pyroclastic rocks, dacitic rocks and rhyolitic rocks (the Huaylillas Formation and the Maure Group).

In the eastern Andes, a monzonite granite stock was formed from the Oligocene to the Miocene time; also formed were the pyroclastic rocks dated as 10-4 M.a. (the Quenamari Group).

From the Middle to Late Pliocene, volcanic activity took place in the south, whereby pyroclastic rocks of the Senca Group(3.5-2.5 M.a.) deposited. The presence of lacustrine sediments(the Capillune Formation) indicates that the volcanism ceased afterward but was reactivated to cause effusion of lavas of andesitic to dacitic composition and pyroclastic rocks, thereby forming a group of volcanic cones (the Barroso Group).

(5) Quaternary Period

The Andes continued to briskly uplift during the Pleistocene. At the altitudes of the Cordilleras Occidental and Oriental, glaciers were extensively formed, while moraine and fluvio-glacial deposits were formed in valleys at the heights, whereby the river flow at the lowlands carried huge amounts of gravels, sand and clay which deposited over the peneplains downstream. In the south, volcanic activity related to the volcanic cones continued and formed the lava flow and pyroclastic rocks of the Barroso Group.

3-3 Outline of Ore Deposits

In the central Andes, the metallogenic provinces can be arranged in parallel with the Pacific coastline. Heuschmidt(1995) classified the metallogenic provinces into the copper belt, central polymetallic belt, tin belt and marginal polymetallic belt, from the Pacific coast toward the interior of the South American Continent. (Fig. 4) In the southeastern central part of the survey area, the tin belt extends toward Bolivia, while the marginal polymetallic belt lies on the northeast of the tin belt and the central polymetallic belt on the southwest.

The mineralization in the survey area is roughly divisible into the vein-type Au ore deposits in Paleozoic rocks, Sn-W-Cu deposits related with Permian granites, Ag-Pb-Cu-Zn vein or skarn deposits in Jurassic to Cretaceous rocks and Sn-W-Cu-Pb-Zn vein-type deposits related to Miocene granites. Besides, Au placer deposits are distributed in the Cordillera Oriental to the Amazon plain, while the presence of uranium mineralization related to Miocene to Pliocene pyroclastic rocks is also known.

As regards operating mines, the vein-type San Rafael tin mine (vein-type; Fig. 5 - No. 148) is well known, as well as the Palca XI (W; vein-type; ibid. No.300) and La Rinconada(Au; vein-type; ibid., No.238). As for suspended mines and mineral indications, there are Quenamari mine (polymetallic; vein-type; ibid. No.118), Casa de Plata(Pb-Ag; vein-type; ibid., No.144), Cerro de Inca No.28 (Pb-Ag; manto-type; ibid., No.131), Esperanza de Potoni (Pb-Ag; vein-type; ibid., No.108), Marcia (polymetallic; vein-type; ibid., No. 279), Nicaragua(Pb-Ag; vein-type; ibid., No.184), Nilda (Pb-Zn; vein-type; ibid., No. 261), Sarita (Cu-Ag-Mo-W-Sn; vein-type; ibid., No.187), Tres Marias I and II(Cu-Ag; vein-type; ibid., No.114), etc. All these ore deposits lie in the tin mineralization zone that starts in the north central portion of the survey area and extends southeastward to Bolivia.

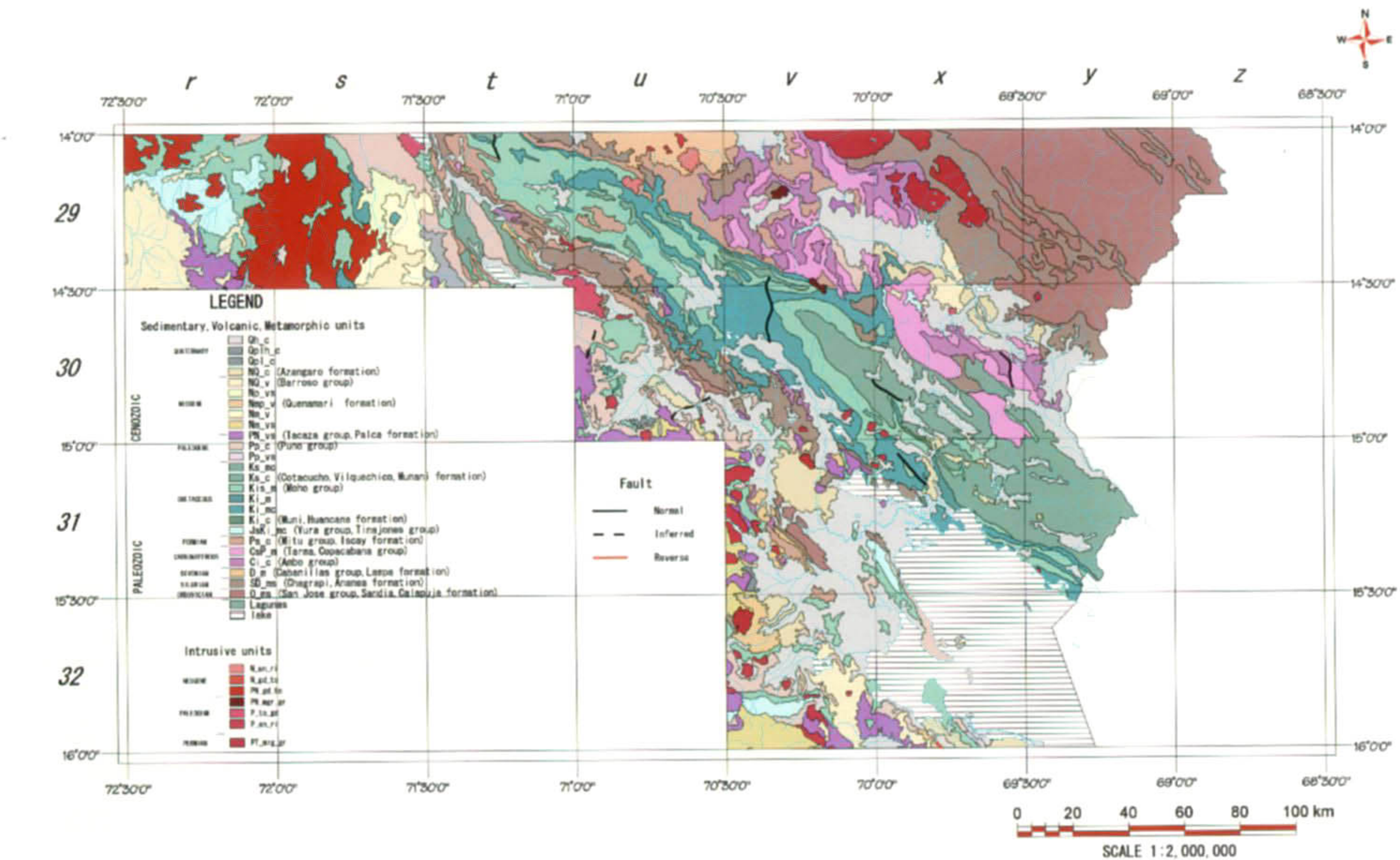

Fig.2 Geology of the survey area

	Geological Age		Formation Name	Lithology	Intrusive rocks (Age)	Remarks	Mineralization
CENOZOIC	Quarternary		Quarternary Formation	Sand、Gravel			
	Paleogene—Neogene		Azangaro Formation	Sandstone、Siltstone	Cenozoic intrusive rocks		Au (Placer)
			Barroso Group	Lava、Welded tuff			U (Network-Vein)
			Quenamari Formation	Welded tuff			Sn-W-Cu-Pb-Zn (Vein)
			Senca Formation	Tuff			
			Palca Group	Welded tuff			
			Tacaza Formation	Sandstone、Conglomerate			
	Paleogene		Puno Group	Shale、Conglomerate			
MESOZOIC	Cretaceous	Upper	Moho Group	Sandstone、Conglomerate			Ag-Pb-Zn-Cu (Vein)
			Munani Formation	Sandstone、Conglomerate			
			Vilquechico Formation	Shale、Siltstone、Limestone			
			Cotacuchos Formation	Sandstone、Conglomerate			
		Lower	Huancane Formation	Sandstone			
			Muni Formation	Mudstone			
	Cretaceous to Jurassic		Yura Group	Sandstone、Shale、Limestone			
	Triassic	Upper			Coasa Pluton (238Ma)	Intrudes into the Tarma,Copacabana Formation	Sn-W-Cu-Mo (Vein、Skarn、Greisen)
		Middle			Huisaroque Pluton (236Ma)	Intrudes into the Chagrapi Formation	
					Limbani Pluton (230Ma)	Causes contact metamorphism to the Ananea Formation	
PALEOZOIC	Permian	Upper	Iscay Group	Lava、Tuff	Utccuccacca Granite (? Ma)	Causes contact metamorphism to the Sandia Formation	
			Mitu Group	Sandstone	Aricoma Pluton (234Ma)	Intrudes into the Ambo Formation	
		Lower	Copacabana Group	Limestone	San Judas Tadeo Pluton (270Ma)	Intrudes into the Cabanillas Group	
	Carboniferous	Upper	Tarma Group	Sandstone、Limestone			
		Lower	Ambo Group	Sandstone			
	Silurian to Devonian		Lampa Formation	Sandstone			
			Chagrapi Formation	Siltstone、Shale			
			Cabanillas Group	Sandstone、Quartzite			
			Ananea Formation	Siltstone、Shale			
	Ordovician	Upper	Calapuja Formation	Shale、Sandstone			Au(Vein、Manto)
			Sandia Formation	Slate、Quartzite			
		Lower	San Jose Group	Slate、Quartzite			

Fig.3　Schematic geologic column

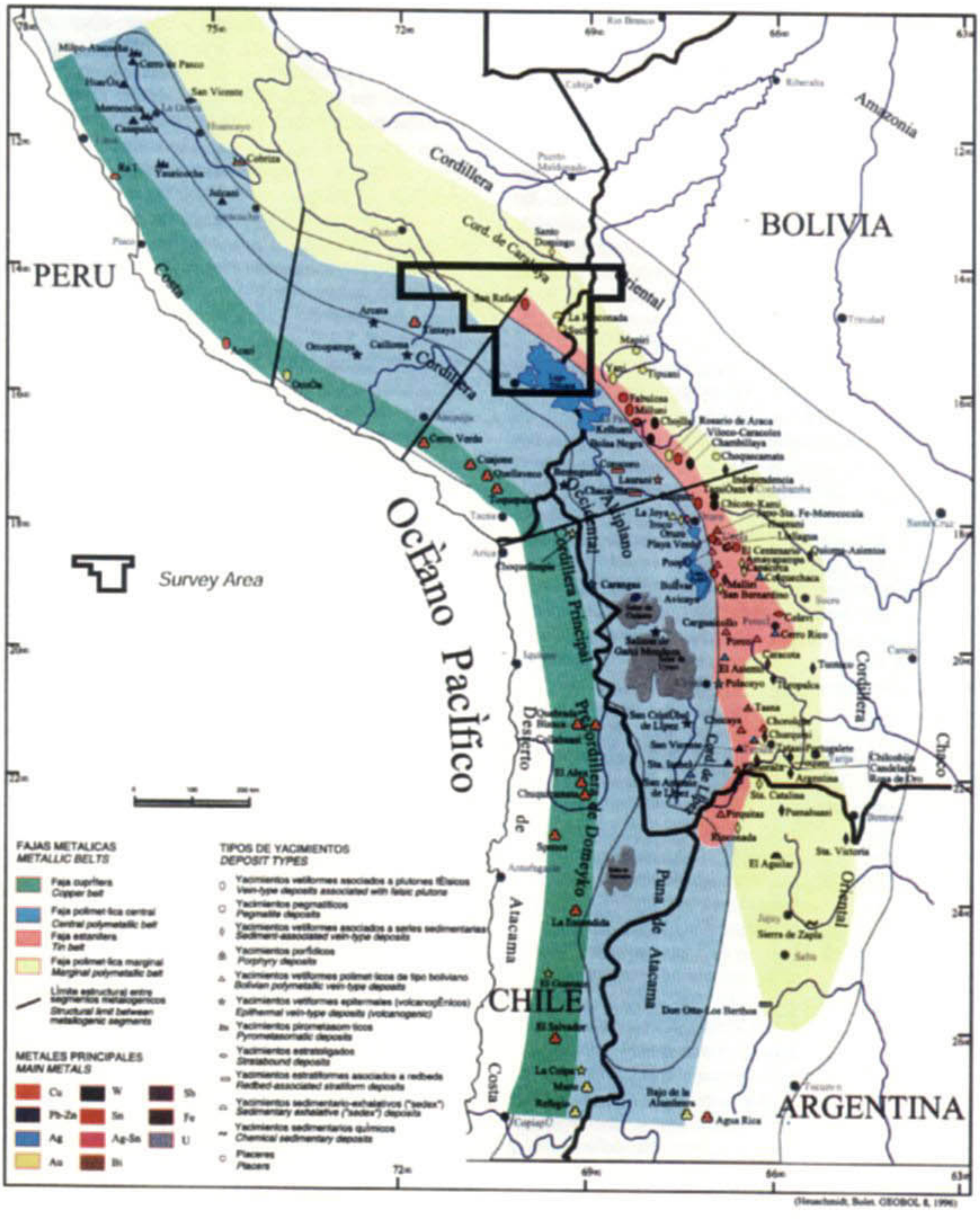

Fig.4 Metallogenic province in central part of the Andean range

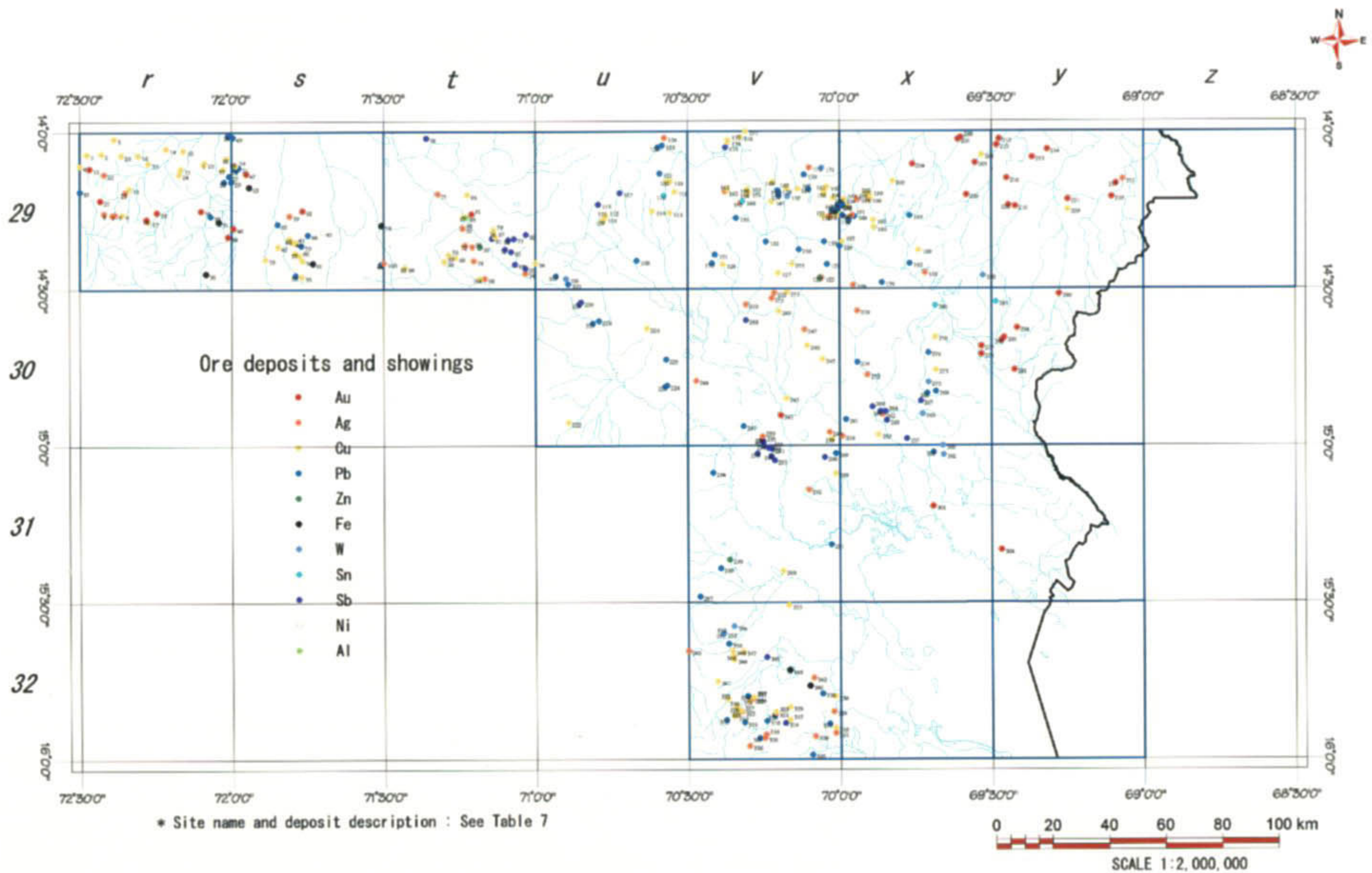

Fig.5 Location map of ore deposits and mineral indications

PART II

PARTICULARS

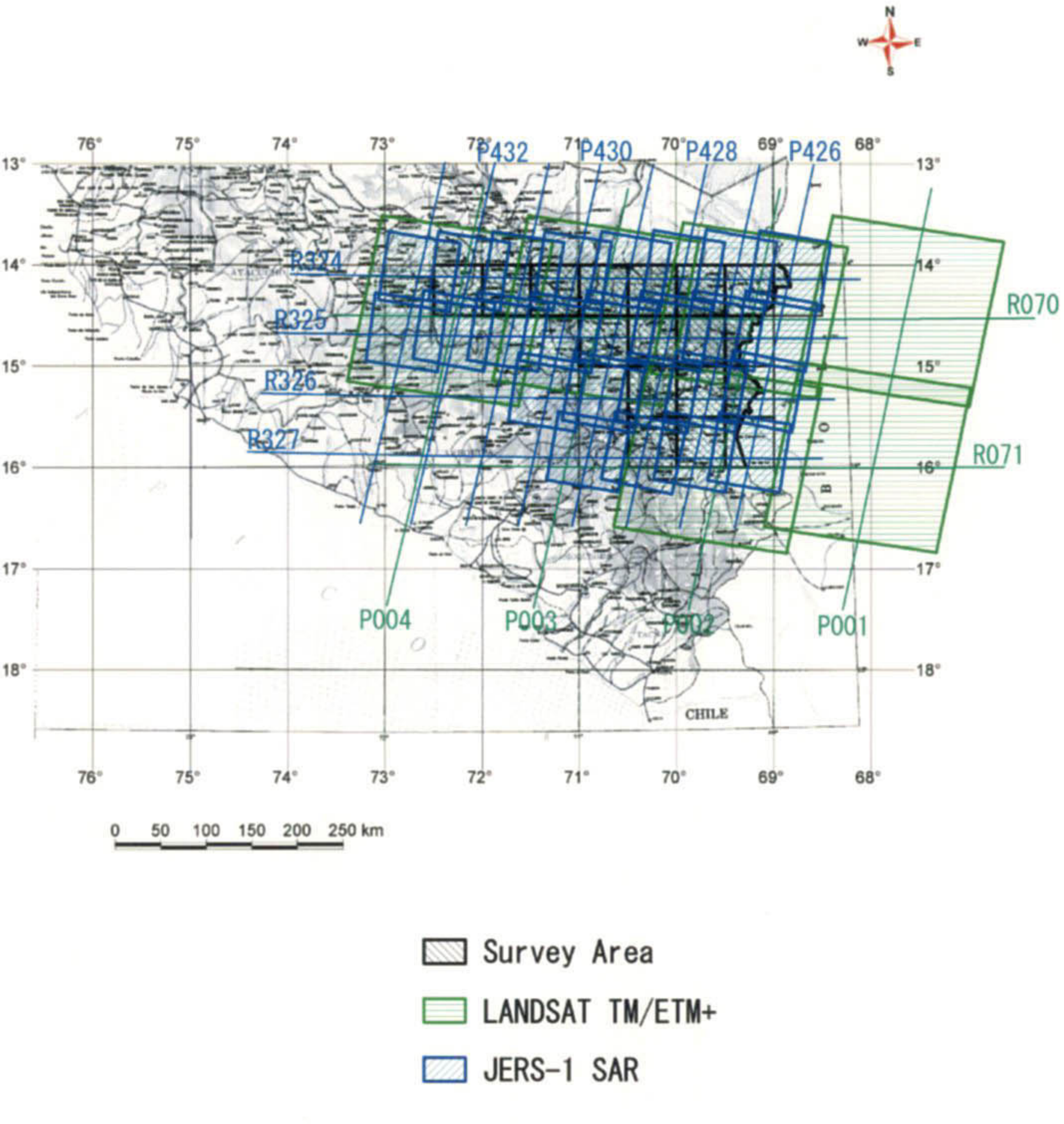

Fig.6 Coverage of satellite data used

Table 5 Satellite data used

JERS-1 SAR DATA

	Path	Row	Date	Level
1	426	324	1995/10/31	2.1
2	426	325	1994/07/04	2.1
3	426	326	1994/07/04	2.1
4	426	327	1994/07/04	2.1
5	427	324	1992/07/31	2.1
6	427	325	1994/05/22	2.1
7	427	326	1996/01/28	2.1
8	427	327	1994/05/22	2.1
9	428	324	1992/08/01	2.1
10	428	325	1996/06/09	2.1
11	428	326	1996/06/09	2.1
12	428	327	1994/07/06	2.1
13	429	324	1996/12/03	2.1
14	429	325	1994/05/24	2.1
15	429	326	1996/12/03	2.1
16	429	327	1994/05/24	2.1
17	430	324	1992/08/03	2.1
18	430	325	1996/12/04	2.1
19	430	326	1992/08/03	2.1
20	431	324	1994/04/12	2.1
21	431	325	1996/12/05	2.1
22	432	324	1997/07/14	2.1
23	432	325	1997/07/14	2.1
24	433	324	1997/01/20	2.1
25	433	325	1997/01/20	2.1

LANDSAT DATA

	Path	Row	Date	Sensor
1	001	070	2000/07/28	ETM+
2	001	071	2000/05/25	ETM+
3	002	070	1990/09/21	TM
4	002	071	2000/09/05	ETM+
5	003	070	2000/06/24	ETM+
6	004	070	2000/08/02	ETM+

Chapter I Satellite Image Analysis

1-1 Purpose of Image Analysis

Through the interpretation of the JERS-1 SAR and LANDSAT TM images, the geologic interpretation maps and lineament maps were prepared with the aim of grasping the regional geologic structure, thereby providing basic data necessary for the evaluation of potentialities for occurrence of mineral resources in the survey area. The prepared interpretation maps correspond to the 18 Quadrangles numbered 29-r, 29-s, 29-t, 29-u, 29-v, 29-x, 29-y, 29-z, 30-u, 30-v, 30-x, 30-y, 31-v, 31-x, 31-y, 32-v, 32-x, and 32-y of the 1:100 000-scale topographic maps elaborated by the Instituto Geográfico Nacional (IGN). Each side of a quadrangle is equivalent to 30 minutes of the latitude and longitude.

1-2 Image Processing

1-2-1 Data Used

Data used for the analysis are 25 scenes of the JERS-1 SAR data and 6 scenes of the LANDSAT TM data as indicated in Fig. 6 and Table 5.

1-2-2 Procedures for Processing of JERS-1 SAR Images

Respective images of the 18 quadrangles were processed for the interpretation, in the following procedures:

1. Data loading: All the JERS-1 SAR data included in the EXABITE tapes provided by ERSDAC were loaded down on the hard disk(HD) connected to an engineering work station(EWS).

2. File conversion: The transferred image data files were converted to the standard image database format of PCI/EASI-PACE, an image processing software developed by PCI of Canada.

3. Bit number conversion: The 16-bit image data were converted into the 8-bit image data.

4. Histogram normalization: Simultaneously with the bit number conversion, histograms of digital numbers were normalized.

5. Image rotation: Images were rotated clockwise by 90 degrees.

6. Correction of antenna pattern: In order to re-correct the characteristics of antenna pattern of JERS-1 SAR data -- an average DN gradually decreases from

the far range to the near range -- an average of the azimuth direction of each scene was calculated so that each pixel value might be divided by the average.

7. Assignment of coordinates: The UTM coordinates of the four corners of each scene were read from the header information and assigned.

8. Preparation of image database for mosaicking: The PCI image database file was prepared, which has the UTM coordinate system for making mosaic images.

9. Pasting of center image: The scene nearest to the center of the survey area was pasted to the database file for making mosaic images. The pasting position was determined by the positional information in the header file.

10. Image mosaicking: Image mosaicking was done in order starting from the images adjoining the central image. Several dozens of tie-points were fixed at an overlap of images and geometric correction was applied so that the residual error might be reduced to 1 pixel or less. Simultaneously, the brightness was adjusted so that difference in the DN value between two images might be reduced.

11. Speckle noise reduction: An Enhanced Lee Filter (5 x 5) was employed to reduce speckle noises.

12. File conversion: After converting the PCIDSK file to an image file of the TIFF format, the image data was imported to the data format(.rvc) of the TNTmips, an integrated GIS software of the Microimages, Inc. of USA.

13. Projection on the maps: With the projection function of the TNTmips, the imported image data were projected on the maps, for which confluences, towns and other landmarks were utilized as the ground control points for georeferencing. The scanned images of the 1:100 000-scale topographic maps published by the IGN were utilized as the reference. The method of projection on a map was based on the UTM(zone=19) while the 1956 Venezuela was used for the earth ellipsoid model.

14. Extraction of sub-scene images of respective quadrangles: Based on the map projection data, 18 sub-scene images corresponding to the respective quadrangles in the survey area were prepared.

15. Annotation: The respective sub-scene images were annotated with the UTM coordinates, scale bars, titles of quadrangles, etc.

16. Conversion of file format: The format of image files was converted from the .rvc to the TIFF format so as to fit to the output device used.

17. Resampling of image resolution: Resolution of each sub-scene image was adjusted to output at 300 dpi and at a 1:200 000-scale. Consequently, the spatial resolution of images was resampled to about 16.9 m per pixel.

18. Hard copy output: Two sets of the 18 sub-scene images, totalling 36 images, were output at a 1:200 000-scale by a digital photo-printer(Lightjet 5000). The prepared JERS-1 SAR mosaic images are exhibited in Fig.7, while a part of the same sub-scene images are exhibited in Figs. 12-1(Quad. 29-r) and 13-1(Quad. 29-s).

1-2-3 Procedures for Processing of LANDSAT TM color composite images

The respective images of the 18 quadrangles were processed for the interpretation, in the following procedures:

1. Data loading and file conversion: The LANDSAT TM data recorded in a CD purchased from the RESTECwere loaded down on the hard disk(HD) connected to an engineering work station(EWS). The image data files were then converted to the format of PCIDSK and 6 PCIDSK for each scene to be used were prepared. The transferred data are those of Bands 1, 2, 3, 4, 5 and 7, while the thermal ultra-red band(Band 6) is excepted.

2. Assignment of coordinates: The UTM coordinates of the four corners of each scene were red from the header information and assigned.

3. Preparation of image database for mosaicking: The PCIDSK that has the UTM coordinate system for making mosaic image was prepared.

4. Pasting of center image: The scene nearest to the center of the survey area was pasted to the database file for making mosaic images. The pasting position was determined by the positional information in the header file.

5. Image mosaicking: Image mosaicking was done in order starting from the images adjoining the central image. Several dozens of tie-points were fixed at an overlap of images and geometric correction was applied so that the residual error might be reduced to 1 pixel or less. Simultaneously, the brightness was adjusted at each band so that difference in DN value between two images might be reduced.

6. Enhancement of contrast: Histogram equalized stretching was applied to each of the mosaicked images of bands 1, 4 and 5 to enhance the contrast.

7. Enhancement of edges: The edges of images were enhanced by the Laplacian

filter processing.

8. Conversion of file format: The PCIDSK file format was converted to the TIFF format which, in turn, was converted to the .rvc format.

9. Projection on the maps: With the projection function of the TNTmips, the imported image data were projected on the maps, for which confluences, towns and other landmarks were utilized as the ground control points for georeferencing. The scanned images of the 1:100 000-scale topographic maps published by the IGN were utilized as the reference. The projection on a map was based on the UTM (zone=19) while the 1956 Venezuela was used for the earth ellipsoid model.

10. Extraction of sub-scene images of respective quadrangles: Based on the data projected on the maps, 18 sub-scene images corresponding to the respective quadrangles in the survey area were prepared, when the Bands 1, 4 and 5 were assigned blue, green and red colors, respectively.

11. Annotation: The respective sub-scene images were annotated with the UTM coordinates, scale bars, titles of quadrangles, etc.

12. Conversion of file format: The format of image files was converted from the .rvc to the TIFF format so as to fit to the output device used.

13. Resampling of image resolution: Resolution of each sub-scene image was adjusted to output at 300 dpi and at a 1:200 000-scale. Consequently, the spatial resolution of images was resampled to about 16.9 m per pixel.

14. Hard copy output: Two sets of the 18 sub-scene images, totalling 36 images, were output at a 1:200 000-scale by a digital photo-printer (Lightjet 5000). The prepared LANDSAT TM mosaic images are exhibited in Fig. 8, while a part of the same sub-scene images are exhibited in Figs. 12-2(Quad. 29-r) and 13-2(Quad. 29-s).

1-2-4 Procedures for Preparation of LANDSAT TM ratioing images

Ratioing images of the 18 quadrangles were prepared in the following procedures:

1. Preparation of masks: The masks corresponding to vegetation, water body + shadow + blank, and to cloud + snow + alluvium were prepared. The thresholds of the respective masks are as follows:

- Vegetation: NDVI > 0.1

NDVI(Normalized Differential Vegetation Index)
NDVI = (Band4 - Band3) / (Band4 + Band 3)

- Water body, shadow and blank: Band5 < 42
- Cloud, snow and alluvium: Band 1 < 120

2. Ratioing: With the pixels not covered by the mentioned masks, Band(2-1)/(2+1) for the purpose of extracting iron oxide zones (hereafter called 'R21'), and Band(5-7)/(5+7) for the purpose of extracting argillization zones (hereafter called 'R57') were calculated, which were exported to 32-bit real data.

3. Extraction of anomalies: From the ratioing results of the mentioned two types of anomalies, statistical values were calculated, as follows:

Ratioing type	Mean	Standard Deviation	1σ(*1)	2σ (*2)
R21	-0.563138	0.308633	-0.254505	0.054128
R57	-0.200122	0.646497	0.446375	1.092872

(*1) '1σ'= Mean + Standard Deviation
(*2) '2σ'= Mean + 2 × Standard Deviation

For the R21, '1σ' and '2σ' were used as the thresholds to extract anomaly areas.

R21 anomaly area : Result of R21 > 1σ (= -0.25)
R21 high-anomaly area : Result of R21 > 2σ (=0.05)

For the R57, '1σ' and '1.5σ' (=0.7696235) were used as the thresholds to extract anomaly areas, because '2σ' exceeds the maximum value(=1).

R57 anomaly area : Result of R57 > 1σ (=0.44)
R57 high-anomaly area : Result of R57 > 1.5σ (=0.76)

4. Image composition: The extracted anomaly areas were shown in a composite image, laid over the LANDSAT TM band-5 image, in red color for high-anomaly areas and in yellow color for anomaly areas.

5. Extraction of sub-scene images of respective quadrangles: Based on the data projected on the maps, 18 sub-scene images corresponding to the respective quadrangles in the survey area were prepared.

6. Annotation: The respective sub-scene images were annotated with the UTM coordinates, scale bars, titles of quadrangles, etc.

7. Conversion of file format: The format of image files was converted from the .rvc to the TIFF format, so as to fit to the output device used.

8. Resampling of image resolution: Resolution of each sub-scene image was adjusted to output at 300 dpi and at a 1:200 000-scale. Consequently, the spatial resolution of images was resampled to about 16.9 m per pixel.

9. Hard copy output: Two sets of the 18 sub-scene images, totalling 36 images, were output at a 1:200 000-scale by a digital photo-printer (Lightjet 5000).

1-2-5 Results of Ratioing

(1) R21(the iron-oxide index)

In the survey area, anomalies of 2σ or more were only slightly extracted from the northern edge of the Quad. 29-u. These anomalies are spotted in Tertiary intrusive rocks(t), the surrounding Tertiary volcanic products(N) and in the overlying Cretaceous(K2).

Anomalies of 1σ or more were extracted mainly from (i) the Quad. 29-r and 29-s in the northwest of the survey area, (ii) the zone extending from the north-central to the southeast up to the north shore of Lake Titicaca, and from (iii) the Quad. 29-u and 29-r in the north of the survey area. The anomalies in (ii) and (iii) have a tendency of trending NW-SE. The anomalies in (i) tend to be distributed in the unit t, widespread from the 29-r to the 29-s and its surroundings, while those in (ii) tend to be distribured in the Silurian-Devonian(SD), the Carboniferous(C) and the surrounding Quaternary(Q), presumably strata-bound. The anomalies in (iii) tend to be distributed in small bodies of the unit t and the surrounding sedimentary rocks (the SD, C, CP, etc.)

From these distribution tendencies, it is inferred that the anomalies in (i) and (iii) are likely to indicate presence of thermal alteration zones related with igneous activity, whereas those in (ii) are likely to reflect the lithofacies of sedimentary rocks.

(2) R57(the clay-minerals index)

Few anomalies of 1.5σ ore more were extracted in the survey area. Those of 1.0σ or more are distributed chiefly in the Quad. 32-v, 32-x, and 32-y in the south of the area. Most of the anomalies were extracted in the Quaternary(Q). Presumably, clay minerals that are weathering products were extracted as anomalies.

1-3 Geological Interpretation of Images

1-3-1 Interpretation Procedure

The output images of the 1:200 000-scale SAR images and TM color composite images prepared were used for the interpretation work. The results of interpretation were digitized and converted to the GIS data convertible with the ArchInfo, a GIS software produced by the ESRI of the USA.

1. Geologic units: Based on differences in surface textures and topographic characteristics, the survey area was divided into a number of the geologic units.

Correlation of photogeologic characteristics of the respective geologic units and the existing geologic maps was tabulated. For the division of the geologic units, reference was made to the National Geologic Map at a scale of 1:2 000 000 (INGEMMET, 1995) and the existing 1:100 000-scale geologic maps of the respective quadrangles.

2. Interpretation of lineament and geologic structure: The geologic structural factors such as fault, lineament and folding structure were delineated, for which micro-topographyc features were considered.

3. Digitizing: Scanned data of hand-written geologic interpretation maps and the lineament maps were loaded on a computer as raster data which, in turn, were converted to vector data. Figures such as polygons and lines included in the vector data were manually retouched on the monitor screen and the attributes such as names of the geologic units and structures were added to the respective figures. The TNTmips was employed for the series of processing.

4. Preparation of GIS data set: Geographic data such as drainage patterns, lakes, roads, villages and national borders in the Arc/Info "Coverage" format provided by the INGEMMET were converted to a vector object of the .rvc file, overlaid on the interpretation results, annotated with legends, scale, quadrangle numbers, names, etc., and then output by a color plotter at a 1:200 000-scale. Two types of output maps -- the geologic interpretation map and the lineament map -- were prepared. From the respective vector data of the geologic boundaries, faults, geologic structures and lineaments included in the .rvc file, the files in the Arc/Info Coverage format were prepared as the final products.

1-3-2 Division of Geologic Units

For the image interpretation, the "501 Cuadrángulos Geológicos Digitales de la Carta Nacional 1960-1999," (INGEMMET, 1999) and the "MAPA Geológico del Perú - 1:2 000 000," (INGEMMET, 1995) were referred to. The list of the geologic units is exhibited in Table 6, in which correlation with those in the above mentioned data(INGEMMET, 1999 and 1995) is demonstrated under the title of "Geological Correlation." In Table 6, the correlation with the INGEMMET, 1999 is limited to main formations only.

For the interpretation, the survey area is divided into the following 16 geologic units. (Fig.10)

- The geologic unit Q represents the Quaternary System.

- The units N, P, NQ1 and NQ2 represent the Paleogene to the Quaternary(Pleistocene).

- The units K1 and K2 represent the Cretaceous.

- The unit J represents the Jurassic.

- The units C and CP represent the Carboniferous to Permian.

- The unit SD represents the Silurian to Devonian.

- The units O1 and O2 represent the Ordovician.

- The units t, k and pm represent the intrusive rocks.

Quaternary System(Q) lies extensively on the northwest of Lake Titicaca and along rivers and lakes.

From southwest to northeast in the interpretation area, the units lie generally in order of Cretaceous(K1 and K2), Carboniferous to Permian(C and CP), Silurian to Devonian(SD) and Ordovician(O1 and O2). However, the zone extending west-northwestward from Lake Titicaca, on the whole, forms an anticline or elevation of the geologic structure; the west-northwestern part of the fold axis is underlain by Silurian to Devonian(SD) while the east-southeastern part by lower Ordovician(O1). In the southwest of the zone extending west-northwestward from Lake Titicaca within the interpretation area, there lie Paleogene to Quaternary(NQ1.NQ2, N and P), mainly covering Cretaceous(K1 and K2). Jurassic to lower Cretaceous(J) is underlain by Paleogene to Quaternary at the west end(Quad. 28-u) and the southwest end(Quad. 32-v), lying underneath Cretaceous. None of Jurassic to lower Cretaceous rocks(J) lie east of the mentioned zone.

Features of the respective geologic units appearing on the images are described in the following paragraphs.

(1) Unit Q

The unit is widespread northwest of Lake Titicaca and also lies along rivers and lakes. Composed of stream sediments, alluvium and lacustrine sediments, the unit appears light brown and has smooth and flat texture. In the mountainous terrain, the unit is composed of talus deposits and glacial deposits such as moraine, and is light brown-colored and fine to medium-textured. Moraine is widespread in the northeast of the Quad. 30-x and in the Quad. 30-y, .

(2) Unit NQ2

The unit is relatively widespread along the rivers northwest of Lake Titicaca, mainly in the Quad. 30-u, 31-v and 32-v. The unit on the whole is brown to light brown, low in the drainage density and medium to fine-textured, excepting the Quad.30-u where the texture is coarse. The unit corresponds to the Azángaro Formation composed of Pliocene to Pleistocene gravels.

(3) Unit NQ1

The unit lies rather extensively in the Quad. 29-r, 29-s, 32-v and 32-x. It is dark brown to brown or bluish gray-colored, fine to medium-textured, low to medium in the drainage density, and relatively high in the erosion resistance. On the whole, the unit lies almost horizontally, and no remarkable structure is discernible. It corresponds to the Barroso Group composed of Pliocene to Pleistocene volcanic products.

(4) Unit N

The unit, widespread in the north of the Quad. 29-u, along the rivers in the Quad. 30-x, etc., is dark brown to brown and fine to medium-textured. The drainage density is low to medium, while the erosion resistance is at a medium level. On the whole, the unit lies almost horizontally, having no remarkable structures. The unit corresponds to the groups such as Mouse, Sillapaca, Palca, Tacna, etc., composed of Neogene volcanic products.

(5) Unit P

The unit, lying along river basins on the northwest of Lake Titicaca and to its west, is light brown and fine to medium-textured. Pinnated and sub-parallel drainage patterns are densely observed in places. Bedding traces, often folded, are dominant along the rivers in the northwest of Lake Titicaca while, at the west side, no dominant bedding traces are discernible. The unit corresponds to the Puno Group composed of Paleogene sedimentary rocks, unconformably overlying the K1 and inferior units.

(6) Unit K2

The unit is observable in many of the quadrangles except the northeastern and southern parts of the interpretation area. It is dark brown to brown, fine-to medium-textured, having low to medium drainage density and low to medium erosion resistance. Bedding traces are conspicuous in many parts of the northeast, which form a number of short-frequency folds, accompanied by the K1. The unit corresponds to late Cretaceous sedimentary rocks, such as the Arenisca Muriani, Vilque Chico, Arenisca Cotacucho and the Moho Formations.

(7) Unit K1

The unit is observable in many of the quadrangles except the northeast of the interpretation area. It is brown to grayish brown and medium to coarse-textured, having medium to high drainage density and medium to high erosion resistance. Bedding traces are conspicuous in many parts of the northeast, accompanied by the K2, forming a number of short-frequency folds. The unit corresponds to early Cretaceous sedimentary rocks, such as the Huancané, Muni, Capachica, Ayavacas, Sipin and Angostura Formations.

(8) Unit J

Presence of the unit is confined only to the Quad. 29-r and 32-v. It is dark brown to brown and fine to medium-textured, having medium drainage density and medium erosion resistance. Bedding traces in small quantities are observed in some parts. The unit corresponds to Jurassic to early Cretaceous sedimentary rocks, such as the Yura Group in the Quad. 29-r and the Lagunilla Group in the Quad. 32-v.

(9) Unit CP

The unit is widespread chiefly in the Quad. 29-t, 29-u, 29-v, 29-x, 30-x and 30-y. It is light brown to brown and fine to medium-textured, having low to medium drainage density and low to medium erosion resistance. Only a few bedding traces are observable. The unit is accompanied by the unit C, and a number of short-frequency folds are formed. It corresponds to the Iscay Group, composed of Carboniferous to Permian volcanic products.

(10) Unit C

The unit are widespread mainly in the Quad. 29-u, 29-v, 29-x, 30-x and 30-y. It is light brown to brown and fine to medium-textured, having low drainage density and low to medium erosion resistance. A few bedding traces are observed. The unit is accompanied by the unit CP, forming many short-frequency folds. It corresponds to early Carboniferous sedimentary rocks such as the Ambo Group.

(11) Unit SD

The unit has been confirmed in many quandrangles except the western part of the interpretation area. It is light brown to brown and medium to coarse-textured. The drainage density is at a medium level; many rectangular drainage patterns are observable. The erosion resistance is medium to high, forming the steep topography. Only a few bedding traces are observed. A number of fold structures are discernible all over the unit. An anticlinal axis is formed in the Quad. 29-t and 29-u. In the northeast, short-frequency folds develop in the Quad. 29-x, 29-y and 29-z. The unit corresponds to Devonian sedimentary rocks, such as Ananea Formation, Lampa Formation, and Cabanillas Group.

(12) Unit O2

The unit, as confirmed in the Quad. 29-x, 29-y, 29-z and 30-y, is light brown to brown and medium-textured, having low to medium drainage density and the characteristically trellis-like drainage patterns. The erosion resistance is medium to high, whereby steep configuration is formed. The unit corresponds to Ordovician sedimentary rocks such as the Sandla Group.

(13) Unit O1

The unit corresponds to the lowermost of all the units confirmed within the interpretation area. The unit has been confirmed mainly in the Quad. 29-x and 29-y in the northeast of the area and in the Quad. 30-u and 31-v in the river basins on the northwest of Lake Titicaca. It is light brown to brown and medium-textured, having low to medium drainage density and characterized by rectangular, trellis-like drainage patterns. The erosion resistance is medium to high, causing to form the steep landform. Bedding traces are rarely observed. Short-frequency folds are formed in the Quad. 29-x and 29-y. The unit corresponds to early Ordovician sedimentary rocks, such as the San José Group and the Calapuja Formation.

(14) Unit t

The unit, widespread in the Quad. 29-r and 29-s, is dark brown to brown and medium to coarse-textured, having high drainage density. The erosion resistance ranges from low to high depending on localities. The unit corresponds to Tertiary intrusive rocks.

(15) Unit k

The unit, lying in a small scale in the southwest of the Quad. 30-u, is dark brown to brown and fine to medium-textured. The drainage density is at low to medium levels while the erosion resistance is at a medium level. The unit corresponds to Cretaceous intrusive rocks.

(16) Unit pm

The unit is relatively widespread from the northeast of the Quad. 29-v to the

Quad. 29-x. It is brown-colored and medium to coarse-textured, having medium drainage density and medium to high erosion resistance. The unit corresponds to Permian intrusive rocks.

Results of the interpretation of the respective quadrangles are described in the following paragraphs.

(1) Quad. 29-r [Figs. 12-1,12-2, 12-3 and 12-4]

The Jurassic to lower Cretaceous(J) and the upper Cretaceous(K2) extend from the center to the northeast of the quadrangle. Bedding traces are discernible in both units in small quantities, which strike E-W in the northeast while NNW in the center. In some parts, the Units J and K2 lie in contact with each other by faults striking WNW. Tertiary intrusive rocks(the unit t) intrude into these rocks, which are widespread especially in the northwestern and southeastern parts. In the south, the Paleogene overlies the unitsJ and K2 while, in the southwest, the Pliocene and the Pleistocene(NQ1) are widespread overlying these units. The NQ1 is observed mainly at slightly elevated places along rivers, lying nearly horizontally.

Anomalies in the iron oxide index were extracted mainly from around the unit t body in the southeast of the quadrangle and also from the NQ1.

The quadrangle has hilly topography, the difference in elevation between the valley and the ridge portions reaching 2,000m. Accordingly, the SAR images are affected by the foreshortening so strongly that the hilltops shift about 1.5 km eastward from the right positions. Manual correction was applied to the SAR images utilizing the topographic features as references, prior to the image analysis.

(2) Quad. 29-s [Figs. 13-1, 13-2, 13-3 and 13-4]

Tertiary intrusive rocks(t) are widespread in the west of the quadrangle, in which upper Cretaceous rocks are spotted. The lower Cretaceous(K1) and the upper Cretaceous(K2) lie along the eastern edge of the unit t, on the east of which lies the Paleogene (P). Farther east, or at the northeast end of the quadrangle, lies the K2. The P and the K2 form an open synclinal structure extending north-northeastward. In the east of the area underlain by the P, bedding traces were confirmed, as well as the WSW dips. These rocks are underlain by the Pliocene to Pleistocene(NQ1) in the northeast of the quadrangle.

Anomalies in the iron oxide index were extracted chiefly from around the unit t body near the center of the quadrangle. No anomalies in the clay minerals index were extracted.

As the quadrangle has undulating landform, the SAR images are affected by foreshortening; therefore, the images had to be manually corrected to the right positions based on the topographic features as references, prior to the image analysis.

(3) Quad. 29-t

The quadrangle, on the whole, consists of two synclinal structures extending from WNW to NNW and an anticinal structure intercalated between the former. The synclinal structure on the northwest side has the upper Cretaceous(K2) overlying its axis and the lower Cretaceous(K1), the Carboniferous to Permian(CP) and the Silurian to Devonian(SD) lying toward the both flanks. In the areas underlain by the K2 and K1, short-frequency folds remarkably develop; the INGEMMET (1999) indicates that overturned folds are dominant. The SD which lies on the southwest side corresponds to the axis of the NW trending anticlinal structure. On the southwest side of the anticlinal structure, the NNW trending synclinal structure lies, and the Paleogen(P) lies on its axis while the units K2, K1 and P extend toward the both flanks. In the unit P, bedding traces are so remarkable that the synclinal structure can be confirmed. To its southwest, the unit P lies bounded by faults.

(4) Quad. 29-u

The quadrangle, on the whole, consists of a WNW trending synclinal structure and an anticlinal structure southwest of the syncline. Such structure continues on from the Quad. 29-t. On the axis of the syncline which traverses near the center of the quadrangle, lie the lower Cretaceous(K1) and the upper Cretaceous(K2), where short-frequency folds predominate. The INGEMMET(1999) indicates that there develop overturned folds. A relatively large number of bedding traces are observed in the K2, which allows these structures to be partially confirmed. On the southwest side, there is a WNW trending anticlinal structure. Its axis is underlain by the Silurian to Devonian(SD) while its flanks by the Carboniferous to Permian(CP). The northeastern flank of the synclinal structure is underlain, approximately in northeasterly order, by the lower Carboniferous (C), the CP and the CD. Many of relatively short-frequency folds are observable also in the areas underlain by the C and CP. The northern part of the quadrangle is underlain by the Neogene(N), which lies almost horizontally.

(5) Quad. 29-v

The lower Carboniferous(C) and the Carboniferous to Permian(CP) are widespread in the quadrangle, where relatively short-frequency folds prevail. Though many of the folds strike NW, those striking NE are also frequently observable. The INGEMMET (1999) indicates that some overturned folds are also present. While bedding traces are scarce in the areas underlain by the C and CP, some are confirmable in places. The southwestern part of the quadrangle is underlain by the lower Cretaceous(K1) and the upper Cretaceous(K2), where many short-frequency folds are formed. A relatively large number of bedding traces are observable there, allowing the structure to be partially confirmed. The northeastern part of the quadrangle is underlain by Permian intrusive rocks(pm).

(6) Quad. 29-x

The quadrangle is largely underlain, from the northeast to the southwest, by the younger geologic units trending NW, which in ascending order are mainly the lower Ordovician(O1), the upper Ordovician(O2), the Silurian to Devonian(SD), the lower Carboniferous(C), and the Carboniferous to Permian(CP). In these units, many short-frequency folds are observed; the INGEMMET(1999) states that there are also overturned folds. The O1 and O2, and also the O2 and SD lie in contact with each other by NW trending faults, which are inferred to be thrust faults. The SD and the inferior units have high erosion resistance, forming relatively steep configuration. Permian intrusive rocks(the unit pm) intrude into the C and the inferior units. The Quaternary(Q) lies along the rivers in the northeast of the quadrangle, which is surrounded by the Neogene(N). No predominant fold structures are observed in these rocks.

(7) Quad. 29-y

The southeast edge of the quadrangle pertains to the Bolivian territory. Most of the formations included in the quadrangle strike northeast. The northeastern part is underlain by the upper Ordovician(O2), the central part by the lower Ordovician(O1) and the southwestern part by the O2 and the Silurian to Devonian(SD), The northeastern and central parts are covered by vegetation. The INGEMMET(1999) indicates that these formations have numerous short-frequency folds, some of which are overturned folds. Though no remarkable bedding traces are observed, the folding structure can be confirmed with the distribution of formations. These formations have high erosion resistance, forming relatively steep landforms. Many rectangular or trellis-like drainage patterns are observed.

(8) Quad. 29-z

The quadrangle is covered with vegetation, a most part of which is occupied by the Bolivian territory except the northeast portion.

The upper Ordovician(O2) and the Silurian to Devonian(SD) lie in the quadrangle. The INGEMMET(1999) states that a great deal of short-frequency folds have been observed in these formations. No remarkable bedding traces are observable; the area underlain by the SD corresponds to the synclinal axis, with which the fold structure can be confirmed.

(9) Quad. 30-u

The Santa Ròsa River runs southeastward in the central part of the quadrangle, and the Quaternary(Q) lies extensively around its basin, where the Paleogene(P) and the Neogene(N) are spotted, while, in the north of the basin, also lie the Pliocene to Pleistocene(NQ2). The southern and western parts of the quadrangle are underlain by the lower Cretaceous(K1) which, in turn, is covered by the Paleogene(P) and the Neogene(N). Though the INGEMMET(1999) indicates presence of folds in the K1, they are small in size and unclear in the images. Many bedding traces are observed in some parts of the P, which are confirmed to strike NNW and dip westward. The northeast side of the Santa Rosa basin is almost underlain, in northeasterly order, by the lower Ordovician(O1), the Silurian to Devonian(SD), the lower Cretaceous(K1) and the upper Cretaceous(K2), all striking NNW.

(10) Quad. 30-v

The quadrangle is underlain, in northeasterly order, by the Silurian to Devonian(SD), the lower Carboniferous(C), the lower Cretaceous(K1) and the upper Cretaceous (K2), striking NW. The K1 and the K2 lie extensively from the central to southeastern part of the quadrangle, where short-frequency folds, as well as overturned folds, are observed according to the INGEMMET(1999). In the K1 and the K2, many bedding traces are observable, whereby the fold structure can be partially confirmed. The river basin in the southwestern part is underlain by the Paleogene(P).

(11) Quad. 30-x

From SW to NE in the quadrangle, formations striking NW lie approximately in the order of the lower Cretaceous(K1) and the upper Cretaceous(K2), the lower Carboniferous(C) and the Carboniferous to Permian(CP), and the Silurian to Devonian(SD). In the central part, the K2 and the CP lie in contact with each other by faults trending WNW to NNW. Numerous bedding traces are observed in the K1 and the K2 in the southwestern part, where short-frequency folds develop, according to the INGEMMET(1999). A synclinal structure plunging southeastward is formed in the southeast of the areas underlain by the C and the CP while, in the northwest, the Quaternary(Q) -- mainly moraine -- spreads over the river basin, as well as the Neogene(N).

(12) Quad. 30-y

The eastern half of the quadrangle is occupied by the Bolivian territory. Nearly a half of the Peruvian side is underlain by the Quaternary(Q) -- mainly moraine. From southwest to northeast, the area is generally underlain by the formations striking NW, in the order of the upper Cretaceous(K2), the lower Carboniferous(C) and the Carboniferous to Permian(CP), the Silurian to Devonian(SD) and the upper Ordovician(O2). The SD and the O2 lie in fault contact in some places. The INGEMMET(1999) reports that a large number of short-frequency folds are observed in these formations. The SD and the O2 have relatively high erosion resistance, forming steep configuration, and is characterized by the trellis-like drainage patterns.

(13) Quad. 31-v

The central part of the quadrangle is extensively covered by the Quaternary(Q) and also by the Pliocene to Pleistocene(NQ2). The western part consists mainly of the lower Ordovician(O1), the Silurian to Devonian(SD), the lower Carboniferous(C), the Carboniferous to Permian(CP), the lower Cretaceous(K1) and the upper Cretaceous(K2). On its south, a synclinal structure plunging SW is observed and the CP lies on the axis. Tertiary intrusive rocks intrude into these rocks, which are further covered by the Neogene(N) at the western edge. In the O1 lying here, numerous bedding traces are observed. The northeast of the quadrangle is mostly underlain, from the southeast to the northwest, by the NW trending SD, K1 and K2, which in turn are covered by the Neogene(N) and the Paleogene(P). In the southwest side, as well, the K1 lies bounded by some faults. The southeastern part of the quadrangle corresponds to its extension, where the K1 lies in contact with the SD on the northeast.

(14) Quad. 31-x

Lake Titicaca is situated in the south of the quadrangle. The Quaternary(Q) lies in the northwest of the lake. On the southwest, the Silurian to Devonian(SD) and the Paleogene(P) lie trending nearly NE and, farther southwest, lie the lower Cretaceous(K1) and the upper Cretaceous(K2). The K1 and the K2 are widespread trending nearly WNW at the northeast side of Lake Titicaca, while the SD lies near the boundary with the area underlain by the Quaternary. In other words, the SD underlies Lake Titicaca and its northwest neighborhood, whilst the northeast and southwest sides of the SD zone is underlain by the K1 and the K2. The INGEMMET(1999) indicates that folds are generally dominant in the areas underlain by theK1 and the K2, especially in the K1 and the K2 lying along the northeastern periphery of the Quaternary. Here, bedding traces are also remarkable; a part of the fold structure is confirmable on the images. A great deal of faults trending NW to NWN are also observed, many of which are inferred to be thrust faults.

(15) Quad. 31-y

The eastern half of the quadrangle is the Bolivian territory. The Peruvian side is underlain by the lower Cretaceous(K1) and the upper Cretaceous(K2) generally striking WNW. Bedding traces are relatively numerous in the south, where the repetition of the K1 and K2 is observable. The central to northern part is extensively underlain by the K2. Though no remarkable structures were observable as bedding traces are not clear, the INGEMMET(1999) reports that many short-frequency folds have been observed.

(16) Quad. 32-v

The central to northeastern part of the quadrangle is extensively covered by the Quaternary(Q) and the Pliocene to Pleistocene(NQ1 and NQ2). The western part is mainly underlain by the Silurian to Devonian(SD), the lower Cretaceous(K1) and the Paleogene(P). These units generally strike E-W, and the younger units overlie from the north to the south. On the south, however, the K1 thrusts the P with thrust faults trending E-W and dipping S and, in turn, the K1 is thrust by the Jurassic to lower Cretaceous(J). The bedding traces are unclear but many short-frequency folds are discerned according to the INGEMMET(1999). The farther south area is underlain by the NQ1. No remarkable structures are recognized. The NQ1 lies also in the southeast, almost horizontally.

(17) Quad. 32-x

Lake Titicaca occupies a large part of the quadrangle and the remaining area is mostly underlain by the Quaternary(Q). The main geologic units lying in the quadrangle are the lower Cretaceous(K1) and the Paleogene(P). Bedding traces are remarkable in some parts of the P, which generally strike NNW. In the southern part, these units are underlain by the Neogene(N) and the Pliocene to Pleistocene(NQ1). The NQ1 lies almost horizontally.

(18) Quad. 32-y

The central to eastern half of the quadrangle is the Bolivian territory while a greater part of the quadrangle is occupied by Lake Titicaca. As regards the distribution of geologic units, the lower Cretaceous(K1) and upper Cretaceous(K2) overlie the northern side of the Lake, the Silurian to Devonian(SD) overlies the islands, and the southern side is slightly underlain by the Quaternary(Q) and the Pliocene to Pleistocene(NQ2).

1-3-3 Interpretation of Geologic Structure [Fig.11]

WNW to NW trending faults develop from the central to northeastern part of the interpretation area, which is underlain by the Cretaceous(K1 and K2), the Carboniferous to Permian(C and CP), the Silurian to Devonian(SD) and the Ordovician(O1 and O2). Accompanying the folds, numerous thrust faults and lineaments trending WNW are discerned. The thrust faults generally dip NE. NE to NNE trending lineaments are relatively numerous in the area. Short-frequency folds are predominant in the areas underlain by the K1 and K2 extending from the north of Lake Titicaca toward the north-northwest. The INGEMMET(1999) indicates that a large number of overturned folds are also present. The lineament density is relatively high at around the areas underlain by the K1 and K2 extending from the north of Lake Titicaca toward NNW, whereas it is low in the areas underlain by the SD, O1 and O2 in the northeastern part of the interpretation area.

Compared with the area, the northwestern and the southwestern parts, situated west of the zone extending from Lake Titicaca toward WNW and underlain by the Jurassic to Lower Cretaceous(J), have somewhat different geologic structures. The lineament density is medium to low in these areas where E-W or ESE trending structures are frequently discerned.

The units K2 and J lying at the northwest edge(west of the Quad. 29-r) have a fold structure trending E-W.

The SD, K1 and J at the southern edge(the western part of the Quad. 32-v) extends east to west, while the folds and thrust faults also strike east to west. The thrust faults have south dips.

The Paleogene and subsequent units have extensive distributions, mainly from the zone extending from Lake Titicaca toward WNW, to the southwest side. In the Quad. 29-t, the Paleogene(P) lying in the zone forms folds conformably with the K1 and K2 while, to the west of the zone, no remarkable fold structures are recognized in the Paleogene and subsequent units.

The lineaments frequently discerned in the areas underlain by the Paleogene and subsequent units trend NE to NNE and ENE in the Quad. 29-r and 29-s in the west; NNE and ENE to EW in the Quad. 30-u; and, WNW to ESE in the Quad. 31-v, 32-v and 32-x in the southwest; on the whole, lineaments trending E-W are dominant.

As explained above, the distribution of geologic units and the geologic structures, on the whole, are somewhat different between the two areas bounded by the zone extending from Lake Titicaca toward WNW, which corresponds to the anticlinal axis or elevation of a geologic structure.

The northeast zone -- including the mentioned zone -- lacks the unit J, while short-frequency folds and thrust faults trending WNW develop in the unit P and underlying units. A large number of overturned folds are also present in the K1, K2 and underlying units. In the vicinity of the areas underlain by the K1 and K2 extending WNW along the northeastern edge of this zone, lineaments, folds and thrust faults prevail, indicating that the zone underwent more intense deformation than the other zones.

In the Quad. 29-r and 32-v southwest of the above zone, the unit J deposits, the K1 and the underlying units form the E-W trending structures, the P has long-frequency folds discernible, and no remarkable geologic structures are discernible in the Pliocene to Pleistocene(NQ1).

A great deal of lineaments trending S-N tend to be recognized in the Quad. 30-x, 30-y, the northeast of 31-x and 31-y in the eastern part of the subject area, and also in the Quad 32-v in the southwestern part.

The results of lineament analysis of the respective quadrangles are summarized as follows.

(1) Quad. 29-r [Figs. 12-1, 12-2 and 12-6]

The lineament density is somewhat low in the areas underlain by Tertiary intrusive rocks(the unit t), and medium in the other areas. NW trending lineaments are relatively numerous. The Jurassic to Lower Cretaceous(J) and the Upper Cretaceous(K2) lie in fault contact, in some parts. Linements trending NW are observed rather frequently in the areas underlain by the Pliocene to Pleistocene (NQ1). Besides, NNW trending lineaments are observable in the areas underlain by the J, K2 and NQ1 while, in the areas underlain by the unit t, the Paleogene(P) and the NQ1, ENE trending lineaments are discerned.

(2) Quad. 29-s [Figs. 13-1, 13-2, 13-6]

The lineament density is somewhat low in the areas underlain by Tertiary intrusive rocks(t), while that in the other areas is medium to low. In the quadrangle, lineaments trending ENE, S-N and NNW are rather frequently observed. The lineaments are also observable in the Pliocene to Pleistocene(NQ1).

(3) Quad. 29-t

The lineament density is low in the NQ1 but medium in the other units. In the quadrangle, lineaments trending WNW to NNW are dominant and in good continuity. These are concordant with the fold structures in the area, many of which are inferred to be thrust faults formed with the fold structures. Besides, lineaments trending ENE to NE are rather frequently observed.

(4) Quad. 29-u

The lineament density is relatively high in the areas underlain by the Lower Cretaceous(K1) and the Upper Cretaceous(K2) which corresponds to the WNW trending synclinal axis traversing near the center of the Quadrangle. However, the lineament density is low at the northeast side of the synclinal structure. Lineaments trending northwest to north-northwestward are predominant and in good continuity in the quadrangle. The lineaments are concordant with the fold structures in the area, many of which are inferred to be thrust faults formed with the fold structures. Besides, relatively numerous lineaments trending ENE to NE are discerned.

(5) Quad. 29-v

In general, the lineament density is at a medium level but relatively low in the northern side. In the quadrangle, lineaments trending WNW to NNW prevail, which are in good continuity. These are concordant with the fold structures in the area, many of which are inferred to be thrust faults formed with the fold structures. Besides, a relatively large number of lineaments trending ENE to NE are discerned.

(6) Quad. 29-x

The lineament density is generally low. Many NW to NNW trending lineaments are observed in good continuity. These lineaments are concordant with the fold structure in the area, many of which are inferred to be thrust faults formed with the fold structure. In the northeastern part, presence of thrust faults with the same trends is inferable, which divide the formations into belt-like blocks.

(7) Quad. 29-y

Generally, the lineament density is low. Many lineaments trending NW are observed in good continuity. These are concordant with the fold structure in the area, many of which are inferred to be thrust faults formed with the fold structure. Besides, lineaments trending NE and E-W are observed rather frequently.

(8) Quad. 29-z

In general, the lineament density is low. A great deal of NW trending lineaments are observed in good continuity. These are concordant with the fold structures in the area, many of which are inferred to be thrust faults formed with the fold structures. Besides, lineaments trending NE and E-W are observed rather frequently.

(9) Quad. 30-u

In general, the lineament density is relatively low. Especially, to the southwest of the Santa Rosa River, the lineament density is even lower. From the river zone northeastward, lineaments trending NNE are relatively dominant and in good continuity, followed by those trending ENE to E-W. The trends are not concordant with those of the fold structures in the area. Lineaments trending NW, concordant with the fold structures, are discernible but very few.

Relatively dominant lineaments trending mainly north-northeast and east-northeast to east-west are observed in the Pliocene to Pleistocene(NQ2) overlying the Santa Rosa basin.

(10) Quad. 30-v

The lineament density is low in the southwestern part underlain by the Silurian to Devonian(SD), while the central to northeastern part underlain by the lower Cretaceous(K1) and the upper Cretaceous(K2) has medium to relatively high lineament density. In the areas underlain by the K1 and K2, NW trending lineaments are frequently observed in good continuity. These are concordant with the fold structures in the area, many of which are inferred to be thrust faults formed with the fold structures. Lineament trending NE to NNE are observed, as well.

(11) Quad. 30-x

The lineament density is medium to relatively high in the areas underlain by the lower Carboniferous(C) and the Carboniferous to Permian(CP), while the northeastern areas underlain by the Silurian to Devonian have low lineament density. Generally, NW trending lineaments are dominant. These lineaments are concordant with the fold structures in the area, many of which are inferred to be thrust faults formed with the fold structure. NNE trending lineaments are also frequently discerned. Both of the lineaments are discernible in the Neogene(N) in the northeastern part of the quadrangle, where those trending NNE is somewhat dominant.

(12) Quad. 30-y

The lineament density in the quadrangle is at a medium level. NW trending lineaments are generally dominant. These are concordant with the fold structures in the area, many of which are inferably related with thrust faults formed with the fold structures. NW trending lineaments are observable, as well. A small number of lineaments trending S-N are observable in the areas underlain by the Quaternary(Q).

(13) Quad. 31-v

Lineaments are scarcely discernible in areas underlain by the Quaternary(Q) in the quadrangle. In the areas underlain by the Neogene(N) to Paleogene(P), however, only a few of them are discernible, while the areas underlain by the inferior units has medium lineament density. In general, lineaments trending NW to NNW are predominant, followed by those trending ENE which are discernible in the western part. The areas underlain by the Pliocene to Pleistocene(NQ1) also has a relatively large number of lineaments trending WNW.

(14) Quad. 31-x

While the lineament density is nil in the area spreading northwest of Lake Titicaca underlain by the Quaternary(Q), that is at a medium level in the northeastern area underlain by the lower Cretaceous(K1) and the upper Cretaceous(K2), and is low in the southeastern area underlain by the K1 and K2. In general, lineaments trending WNW are dominant. In the northeastern part, a large number of lineaments trending S-N are discerned.

(15) Quad. 31-y

The lineament density is relatively high. WNW trending lineaments are predominant. These are concordant with the folding structures in the area, many of which are inferrably related with thrust faults formed with the fold structures. A large number of lineaments trending S-N are discerned, as well.

(16) Quad. 32-v

Few lineaments are discernible in the areas underlain by the Quaternary(Q), while the areas underlain by other units has medium lineament density. The dominant trend slightly varies depending on areas and units in which the lineaments are distributed.

Lineaments trending ENE and S-N are dominant in the areas mainly underlain by the Silurian-Devonian(SD), the Jurassic to lower Cretaceous(J), the lower Cretaceous (K1) and the Paleogene(P). In the areas underlain by the Neogene(N) and the Pliocene to Pleistocene(NQ1 and NQ2), dominant are those trending E-W and NNW.

(17) Quad. 32-x

Few lineaments are discernible in the areas underlain by the Quaternary(Q) while the areas underlain by other units have medium lineament density. The dominant trend varies slightly depending on areas and units. NNW trending lineaments in good continuity are dominant in the northwestern to the southern parts of the quadrangle underlain by the Neogene(N) and the Pliocene to Pleistocene(NQ1), the NNE to S-N trends predominate, and WNW trending lineaments in good continuity are also observable.

(18) Quad. 32-y

The central to eastern half of the quadrangle is the Bolivian territory and the even larger part is occupied by Lake Titicaca so that the quadrangle has a limited land portion. Therefore, lineaments are only slightly discernible in the northern part underlain by Lower Cretaceous(K1) and the Upper Cretaceous(K2).

1-4 Analysis of GIS Data

1-4-1 Methods of Analysis

In order to clarify differences in the lineament density by areas and also in the lineament direction by geologic units with the aid of the GIS data set prepared on the basis of the interpretation results, the following analyses were made:

1. Lineament density analysis
2. Lineament direction analysis

The analysis methods are described in the following paragraphs.

1. Analysis of Lineament density

1) The lineament data prepared of the respective quadrangles were integrated into the MOSS(Map Overlay and Statistical System) format file, one of the GIS standard format by the USGS.

2) By obtaining a cumulative extension of all faults and lineaments included in a 5km x 5km grid, the lineament density (m/km^2) of the grid were calculated, which was standardized with the assumed maximum value of 1. For computation of the density, an analysis tool developed by MINDECO was employed.

3) The computation results output in the CSV format was converted to vector point data of the TNTimps .rvc file.

4) From the vector, the TIN (Triangular Irregular Network) data were prepared.

5) A 3-dimentional model optimum for the TIN was prepared, which was output as 16-bit raster data.

6) From the raster data, contour maps of lineament density were drawn, and statistical values were calculated from the original CVS format data. Lineament density anomaly areas were extracted where density values are higher than '2σ' (=Mean + 2 $\times$ Standard Deviation).

2. Analysis of Lineament direction

1) Lineaments included in a same geologic unit were extracted from the geologic interpretation maps overlaid with the lineament maps, to prepare lineament maps of the respective geologic unit.

2) Rose diagrams (RD) were prepared from the directional data of each lineament, for which the Directional Analysis of the TNTmips was employed.

3) Similarly, rose diagrams were prepared of lineaments of the respective quadrangles.

4) In order to clarify the directional tendencies of lineaments by geologic times, lineaments were extracted from areas where Ordovician to Permian, Jurassic to Cretaceous and Paleogene to Quaternary rocks are respectively distributed.

5) RDs of the respective quadrangles were prepared in the same manner as the RD of lineaments in the entire area.

1-4-2 Results of Analysis

(1) Analysis of lineament density [Fig. 14]

Analysis of the distribution of lineament density in the whole survey area indicates that high density zones tend to extend with the NW-SE and NE-SW trends, which reflect the trends of dominant lineaments. Although there is no substantial difference by area, the lineament density tends to be low in the Inter-Andean valley zone extending from around Lake Titicaca northwestward and in the Cordillera Oriental in the northeastern part of the survey area.

Detailed analysis of the lineament density in respective quadrangles suggests that differences in the lineament density come out of the area and the underlying geologic unit. The main tendencies may be summarized as follows: In the Quad. 29-r and 29-s in the northeastern part of the area, the lineament density tend to be high at around the areas underlain by the unit t (Tertiary intrusive rocks). [Figs.12-5~6 and
13-5~6]; in the Quad. 29-t, 29-u and 29-v in the northern part, the density tends to be high in the unit CP(Carboniferous to Permian volcanic products); and, in the Quad. 31-y in the eastern part, the density tends to be high in the unit K2(upper Cretaceous sedimentary rocks).

(2) Analysis of lineament trend [Figs. 15-1 ~ 15-4]

The dominant trend of lineaments throughout the survey area is NW-SE, concordant with that of the Andes, which is followed by N-S and NE-SW.

A prominent feature has been discerned in the tendency by area. In the Quad. 29-s in the northeast, lineaments trending NE-SW are dominant, followed by those trending N-S. Those trending N-S are dominant in the Quad. 30-u in the central part of the area.

No marked differences are discernible in the tendency of lineament trend by geologic time. The only exception is found in the Quad. 29-s in the northwestern part of the survey area, where the NNW-SSE, NE-SW and NW-SE trends develop almost uniformly in the Jurassic to Cretaceous whereas, in the Paleogene to Quaternary, the NW-SE tends to be remarkably dominant. The analysis indicates that the tendencies in the lineament trends in the quadrangle in all the geologic units were determined by the directional tendencies of the Paleogene to the Quaternary.

1-5 Considerations

The results of the Phase-I satellite image analysis may be summarized as follows:

1. The anomalies in the iron-oxide index were extracted mainly from Tertiary intrusive rocks overlying the northwestern part of the survey area(Quad. 29-r [Fig.12-3] and Quad. 29-s [Fig.13-3] and from the surrounding areas, and also from within the small rock body of the same intrusive rocks overlying the

northern part(Quad. 29-u and 20-v) and the surrounding sedimentary rocks of the Silurian to Devonian, the Carboniferous and the Carboniferous to Permian.

2. The lineament density in Tertiary intrusive rocks is not necessarily high but it tends to be high in the sedimentary rocks around the intrusive bodies.

3. In the survey area, lineaments trending NW-SE are generally dominant, which is considered to reflect the presence of thrust faults formed in relation with the fold structures in the Andean range.

4. No noticeable differences were recognizable in the tendency of lineament trends by geologic time. The only exception is the Quad. 29-s in the northwest of the survey area, where a change in the tendency of directional distribution was discerned, which suggests that the NNW-SSE trend developed up to the Jurassic to Cretaceous time, and from the Paleogene time onward, the NW-SE trend parallel to the Andes developed.

From the analysis, the following interpretation is feasible:

It is interpreted that, due to the intrusion of Tertiary granites (granodiorite, tonalite, etc., as indicated in the existing geologic information), fractures were apt to develop in the sedimentary rocks lying in the surroundings of bodies. Some of the high lineament density zones are likely to reflect that the development of fractures was related with the intrusion of granite bodies.

The fractures developing around the intrusive rocks could have served as passages for hydrothermal circulation, whose heat source was the intrusive rocks in themselves or later igneous activity. Should such hydrothermal circulation have taken place, it could have concentrated iron-oxide minerals near the surface. Some of the anomalies in the iron-oxide index caught by the ratioing processing possibly indicate the presence of such iron-oxide zones.

There is a possibility that valuable metals deposited in the mentioned geologic conditions, which is considered important for the exploration of ore deposits. In other words, high potentialities for occurrence of ore deposits can be expected in areas located in the vicinity of Tertiary rocks, where the lineament density is high and anomalies in the iron-oxide index are extracted.

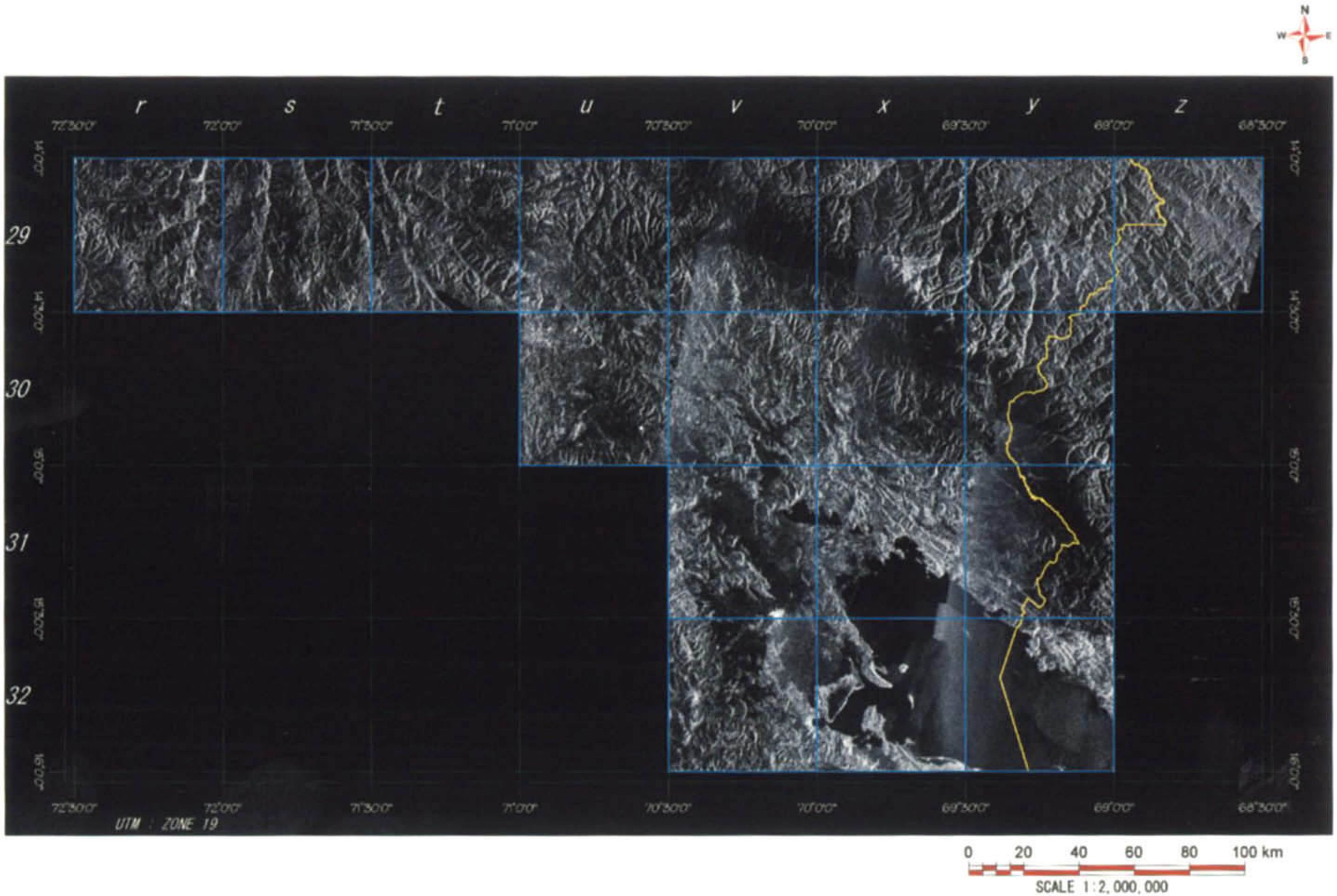

Fig.7 JERS-1 SAR mosaic image

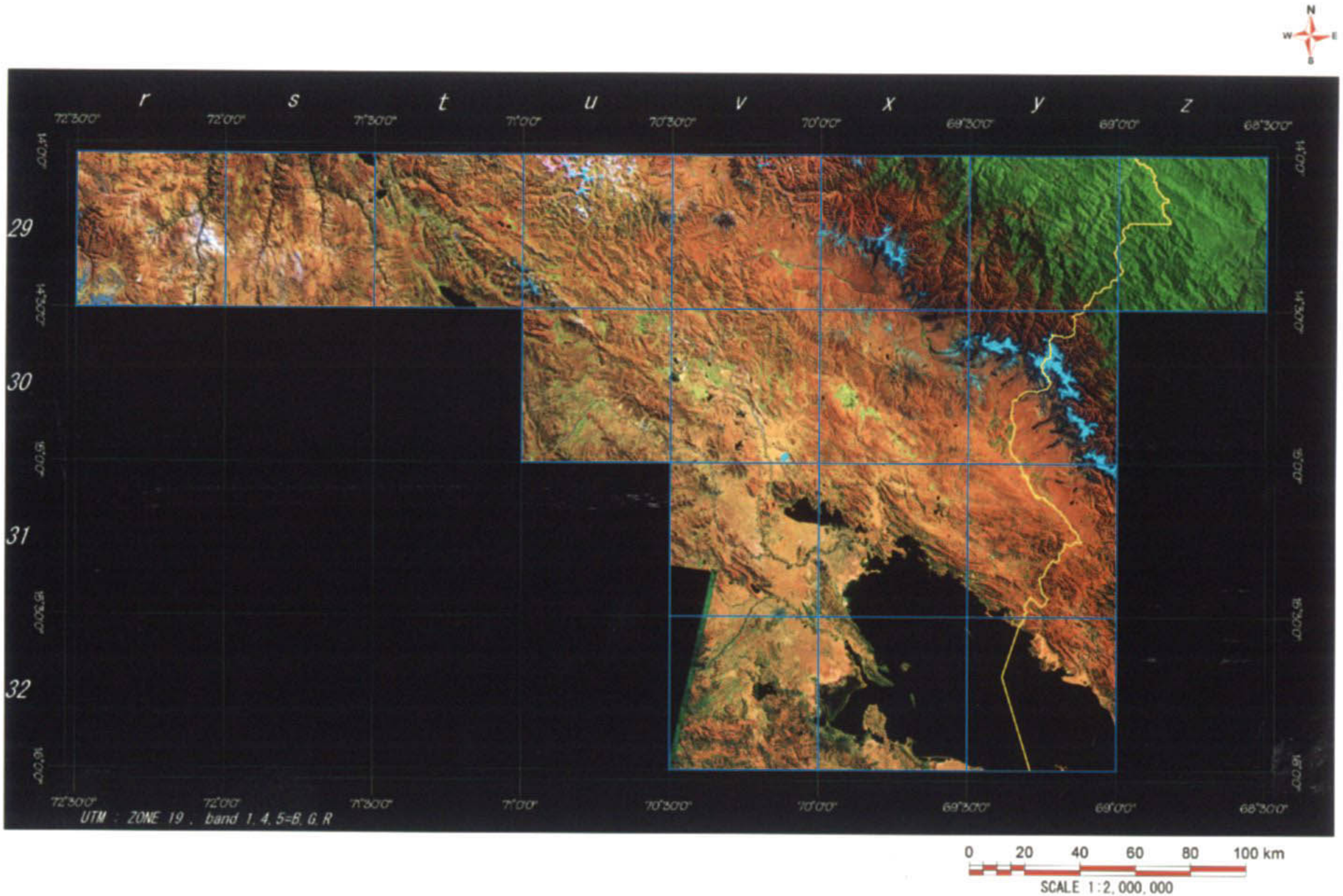

Fig.8 LANDSAT TM mosaic image

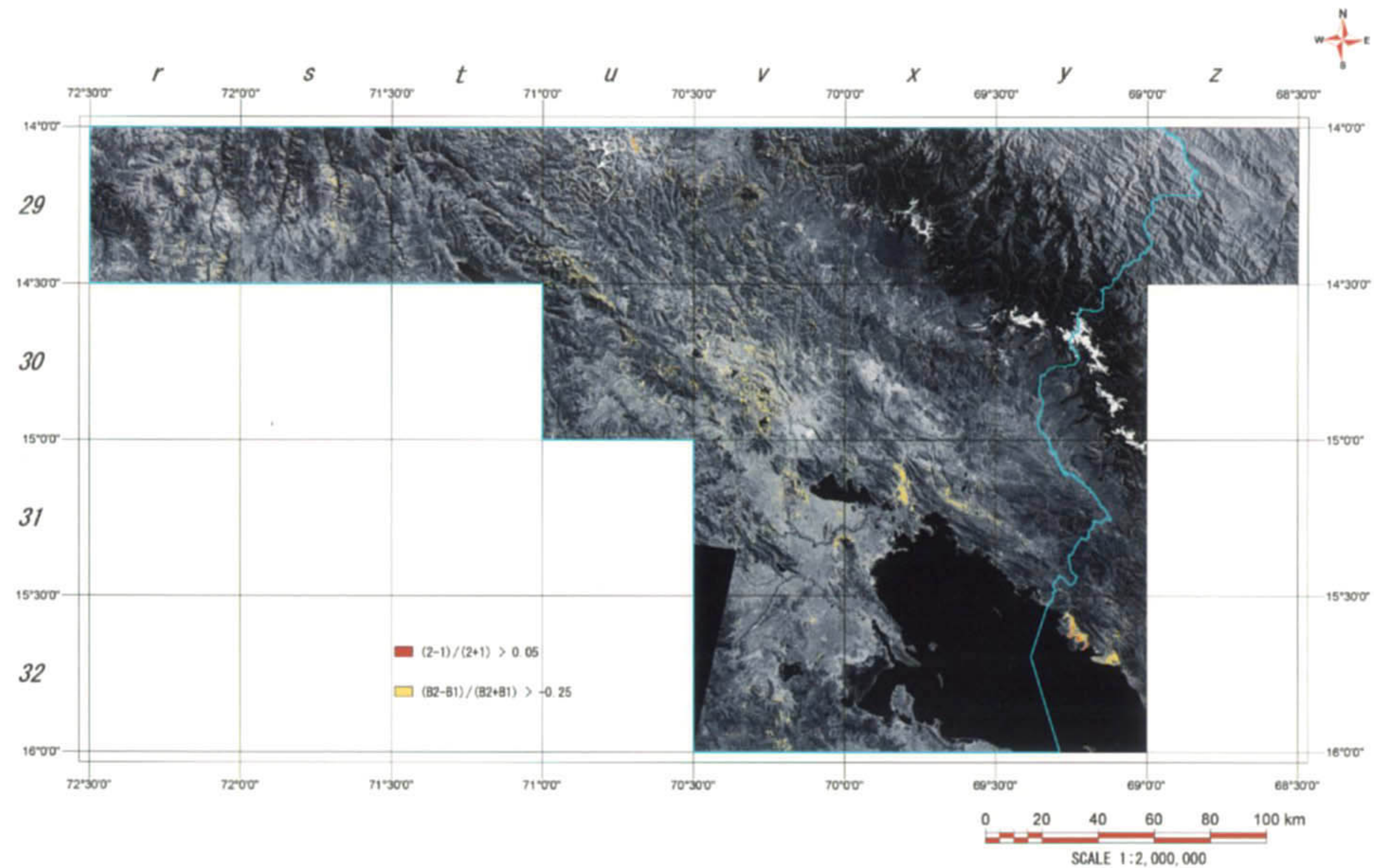

Fig.9-1 LANDSAT TM ratio anomaly map 1 (Index of iron oxide minerals)

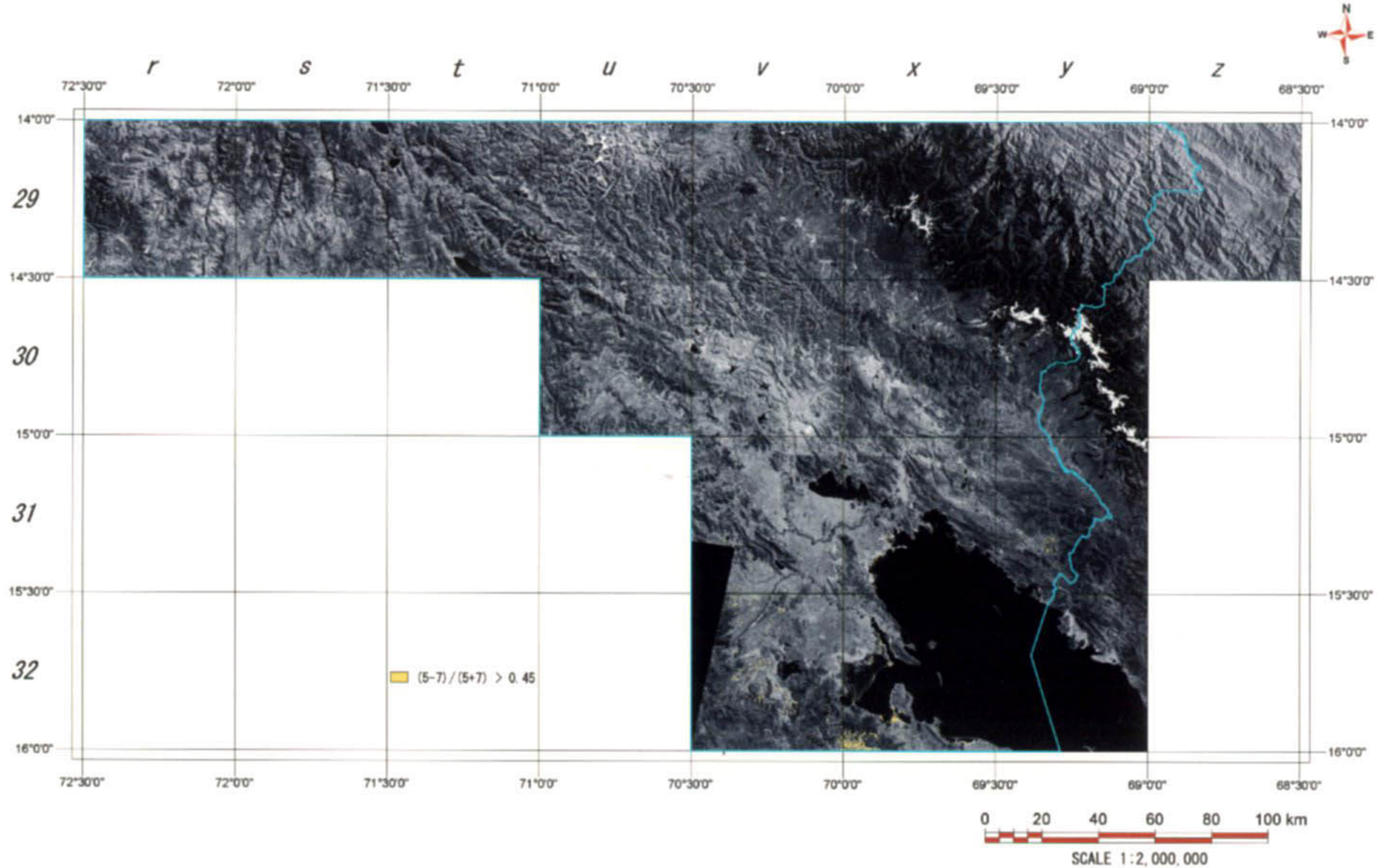

Fig.9-2 LANDSAT TM ratio anomaly map 2 (Index of clay minerals)

Table 6 List of geologic units

GEOLOGIC UNIT	COLOR	TEXTURE	DRAINAGE PATTERN	DRAINAGE DENSITY	ROCK RESISTANCE	BEDDING	LINEAMENT DENSITY	LITHOLOGY	GEOLOGICAL CORRELATION 1	GEOLOGICAL CORRELATION 2
Q	pale brown	fine	sub-dendritic	low	low	-	low	sedimentary rocks (Quaternary)	Qh,Qpl	
NQ2	brown ～ pale brown	fine - coarse	sub-dendritic, pinnate	low	low	-	low - middle	pebble (Pliocene to Pleistocene)	NQ	Azangaro formation
NQ1	dark brown ～ brown, blue gray	fine - medium	sub-parallel	low - middle	middle - high	-	low	volcanic rocks (Pliocene to Pleistocene)		Barroso group
N	pale brown ～ brown, brownish gray	fine - medium	sub-dendritic	middle	low - middle	poor bedded	low	volcanic rocks (Neogene)	Nvs	Mouse group, Sillapaca group, Palca group, Tacaza group
P	pale brown	fine - medium	sub-dendritic, pinnate, sub-parallel	low - high	middle	bedded - well bedded	middle	sedimentary rocks (Paleogene)	P	Puno group
K2	dark brown ～ brown	fine - medium	sub-dendritic	low - middle	low - middle	poor bedded - well bedded	low - middle	sedimentary rocks (Upper Cretaceous)	Ks	Arenisca Muriani formation, Vilquechico formation, Arenisca Cotacucho formation, Moho formation
K1	brown ～ grayish brown	medium - coarse	sub-dendritic	middle	middle - high	poor bedded - bedded	low - middle	sedimentary rocks (Lower Cretaceous)	Ki	Huancane formation, Muni formation, Capachica formation, Ayavacas formation, Sipin formation, Angostura formation
J	dark brown ～ brown	fine - medium	sub-dendritic	middle	middle	poor bedded	low	sedimentary rocks (Jurassic to Lower Cretaceous)	Js	Yura group, Lagunillas group
CP	pale brown ～ brown	fine - medium	sub-dendritic	low - middle	low - middle	poor bedded	low - middle	volcanic rocks (Carboniferous to Permian)	Ps/CP	Iscay group
C	pale brown ～ brown	fine	sub-dendritic	low	low - middle	poor bedded	low	sedimentary rocks (Lower Carboniferous)		Ambo group
SD	pale brown ～ brown, gray ～ brownish gray	medium - coarse	sub-dendritic, Rectangular	middle	middle - high	poor bedded	low - middle	sedimentary rocks (Silurian to Devonian)	Pi	Ananea formation, Lampa formation, Cabanillas group
O2	pale brown ～ brown	medium	Rectangular trellis	low - middle	middle - high	poor bedded	low	sedimentary rocks (Upper Ordovician)		Sandia formation
O1	pale brown ～ brown	medium	sub-dendritic, Rectangular, trellis	low - middle	middle - high	poor bedded	low	sedimentary rocks (Lower Ordovician)		San Jose group, Calapuja formation
t	dark brown ～ brown	medium - coarse	sub-dendritic	middle - high	low - high	-	low	intrusive rocks (Cretaceous)	C	
k	pale brown ～ brown	fine - medium	sub-dendritic	low - middle	middle	-	-	intrusive rocks (Cretaceous)		
pm	brown	medium - coarse	sub-dendritic	middle	middle - high	-	low	intrusive rocks (Permian)		

*GEOLOGICAL CORRELATION 1:「501 Cuadrangulos Geologicos Digitales de la Varta Nacional 1960-1999」
2:「MAP GEOLOGICO DEL PERU 1:2,000,001」

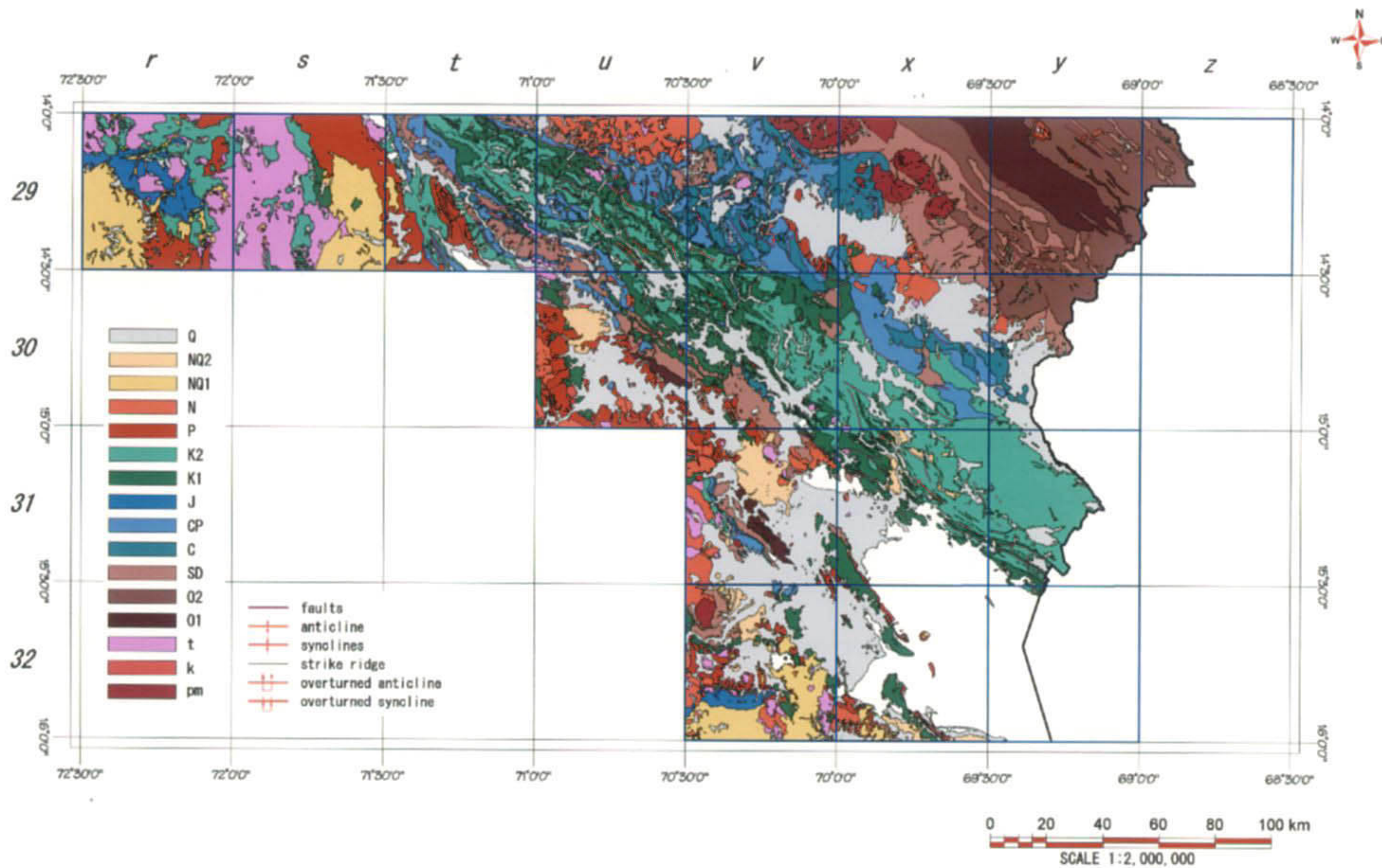

Fig.10 Geologic interpretation map

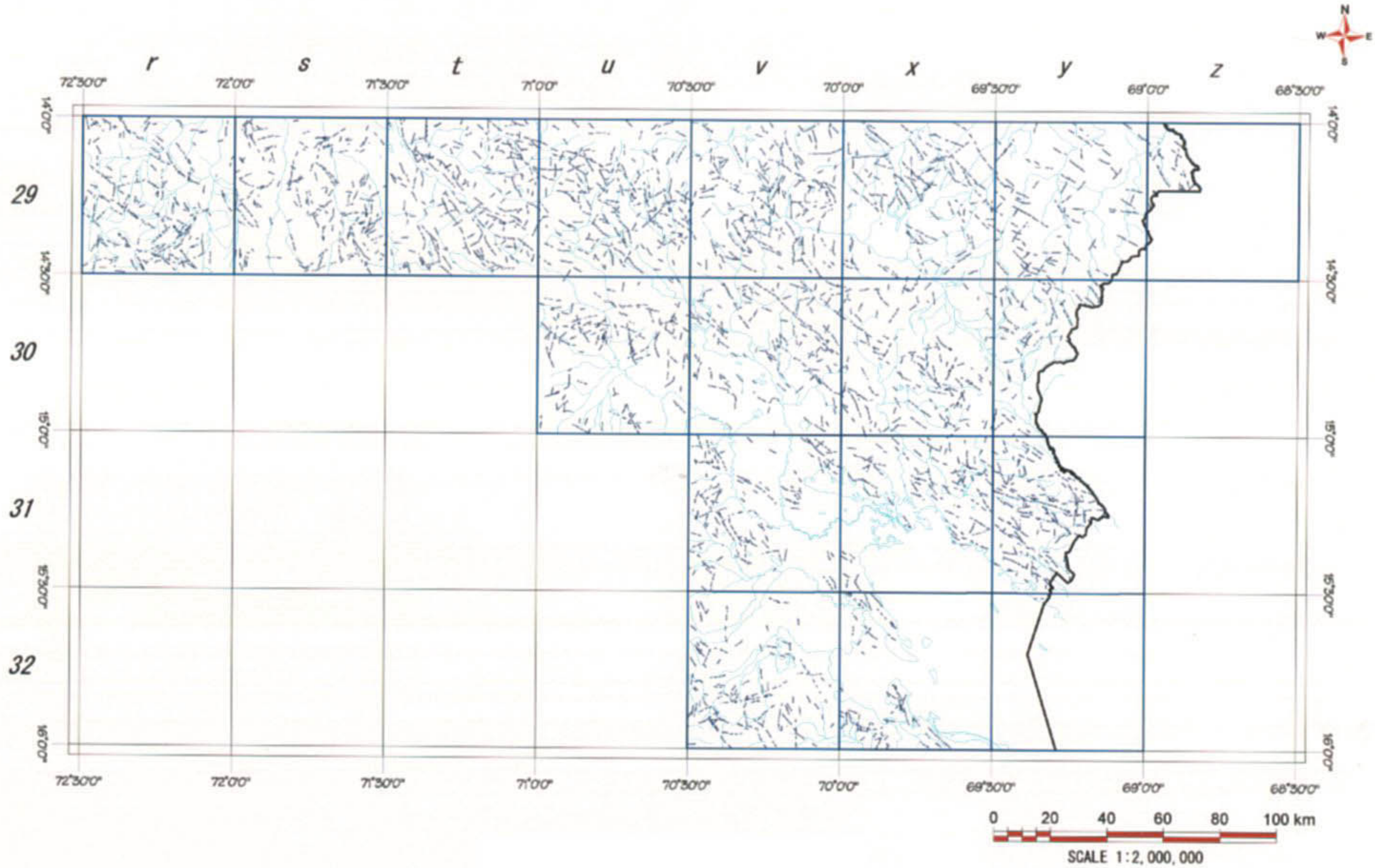

Fig.11 Lineament map

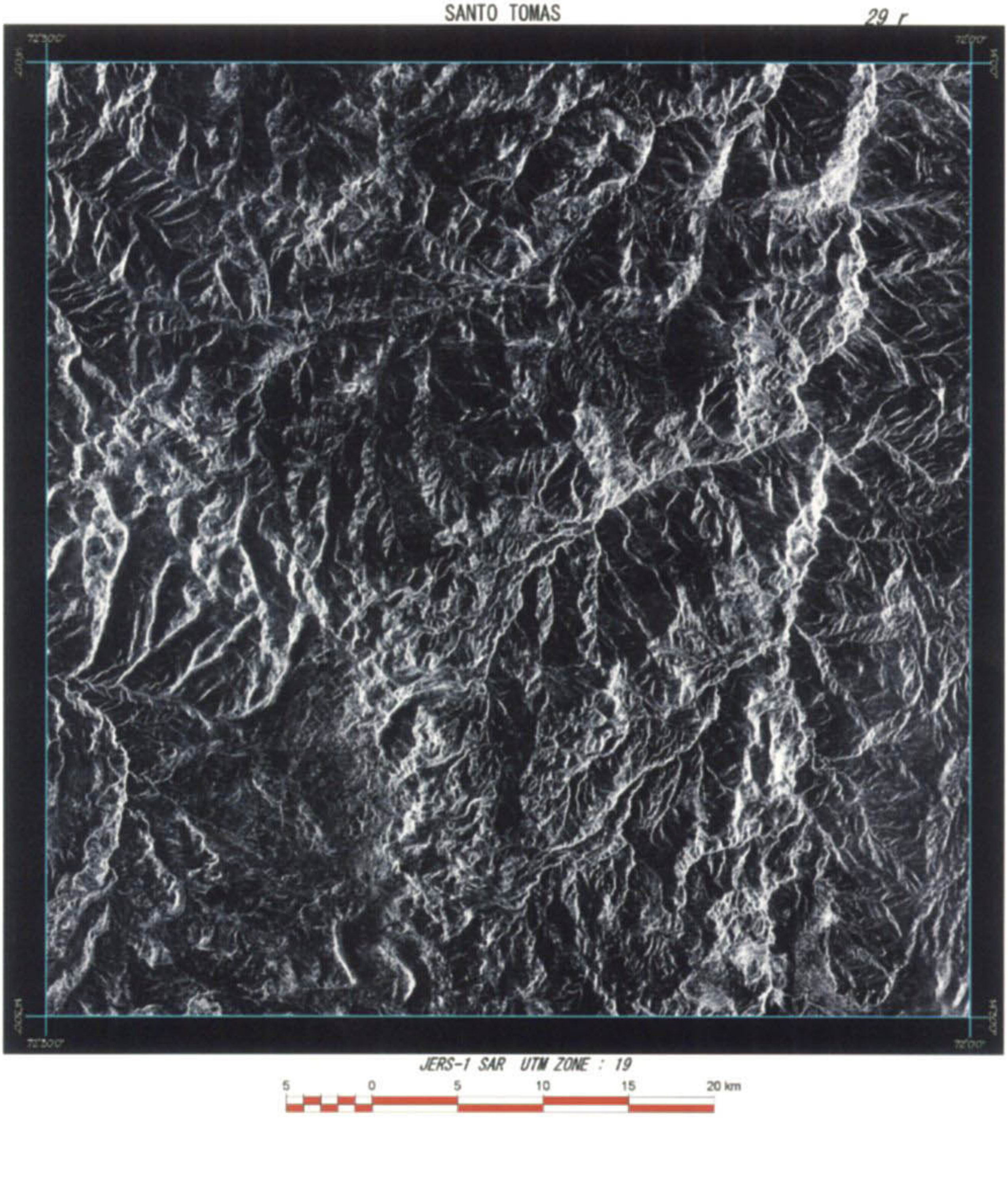

Fig.12-1 Santo Tomas quadrangle (29-r) JERS-1 SAR image

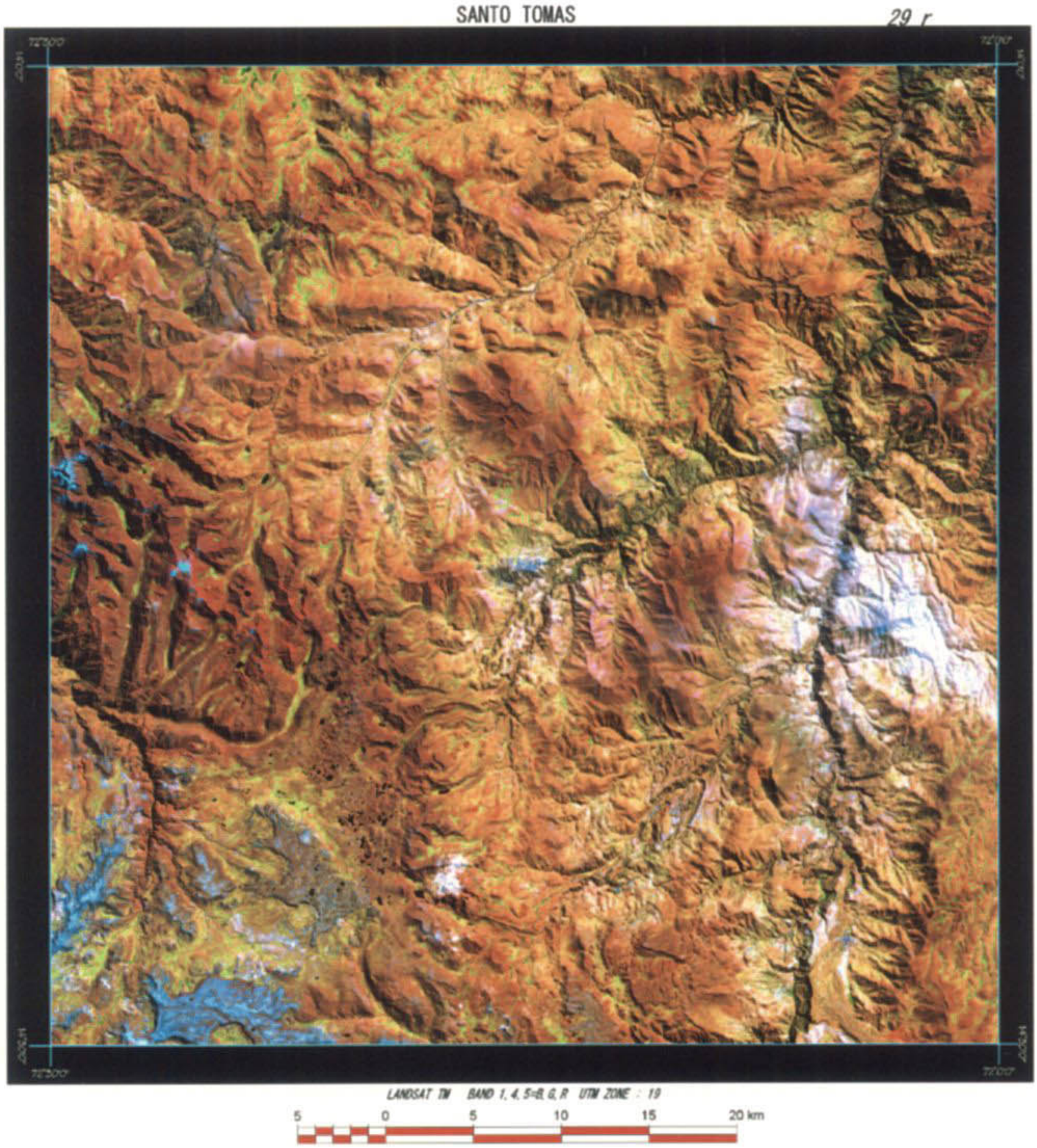

Fig.12-2 Santo Tomas quadrangle (29-r) LANDSAT TM image

Fig.12-3 Santo Tomas quadrangle (29-r) LANDSAT TM ratio anomaly map
(Index of iron oxide minerals)

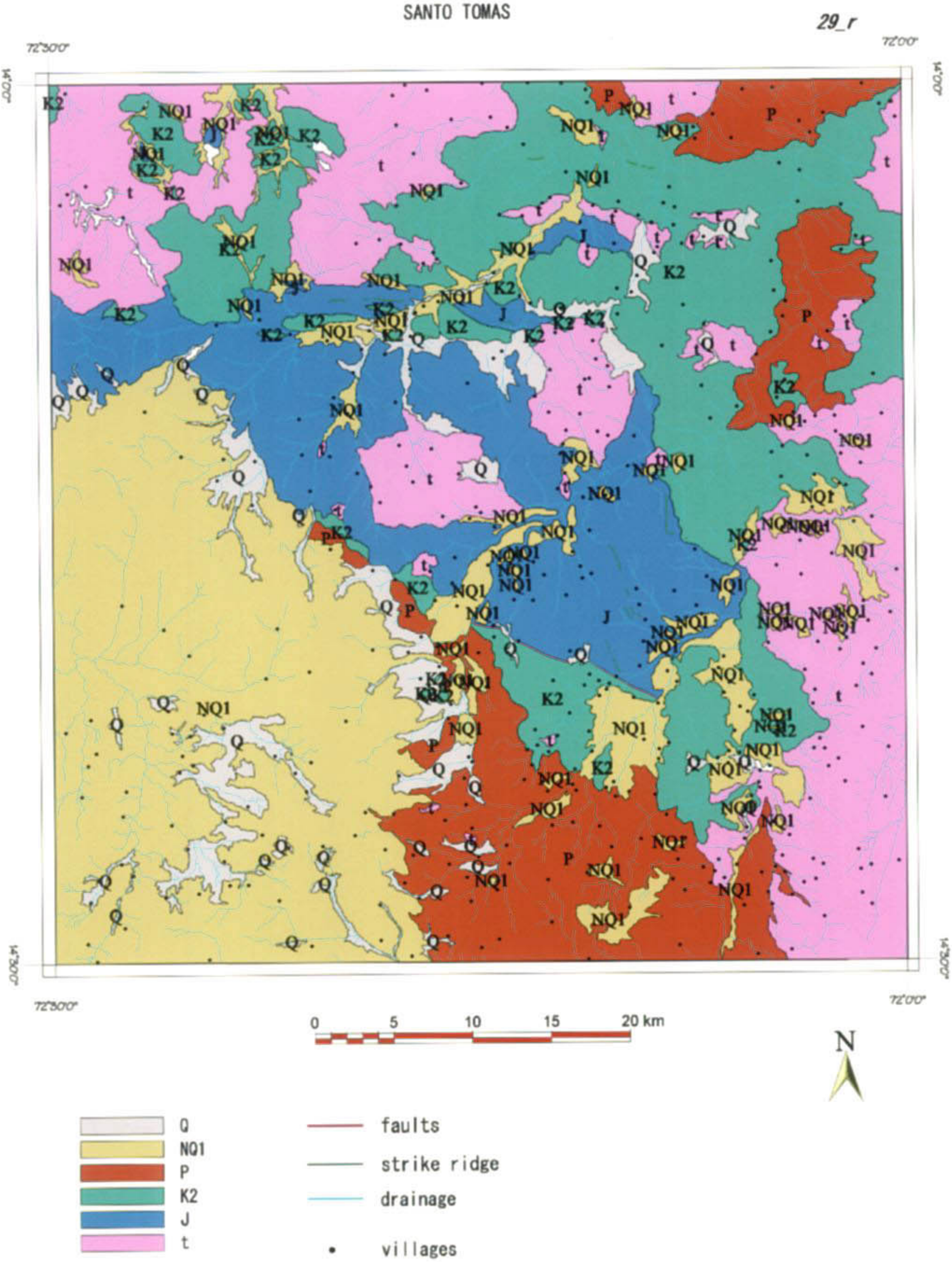

Fig.12-4 Santo Tomas quadrangle (29-r) Geologic interpretation map

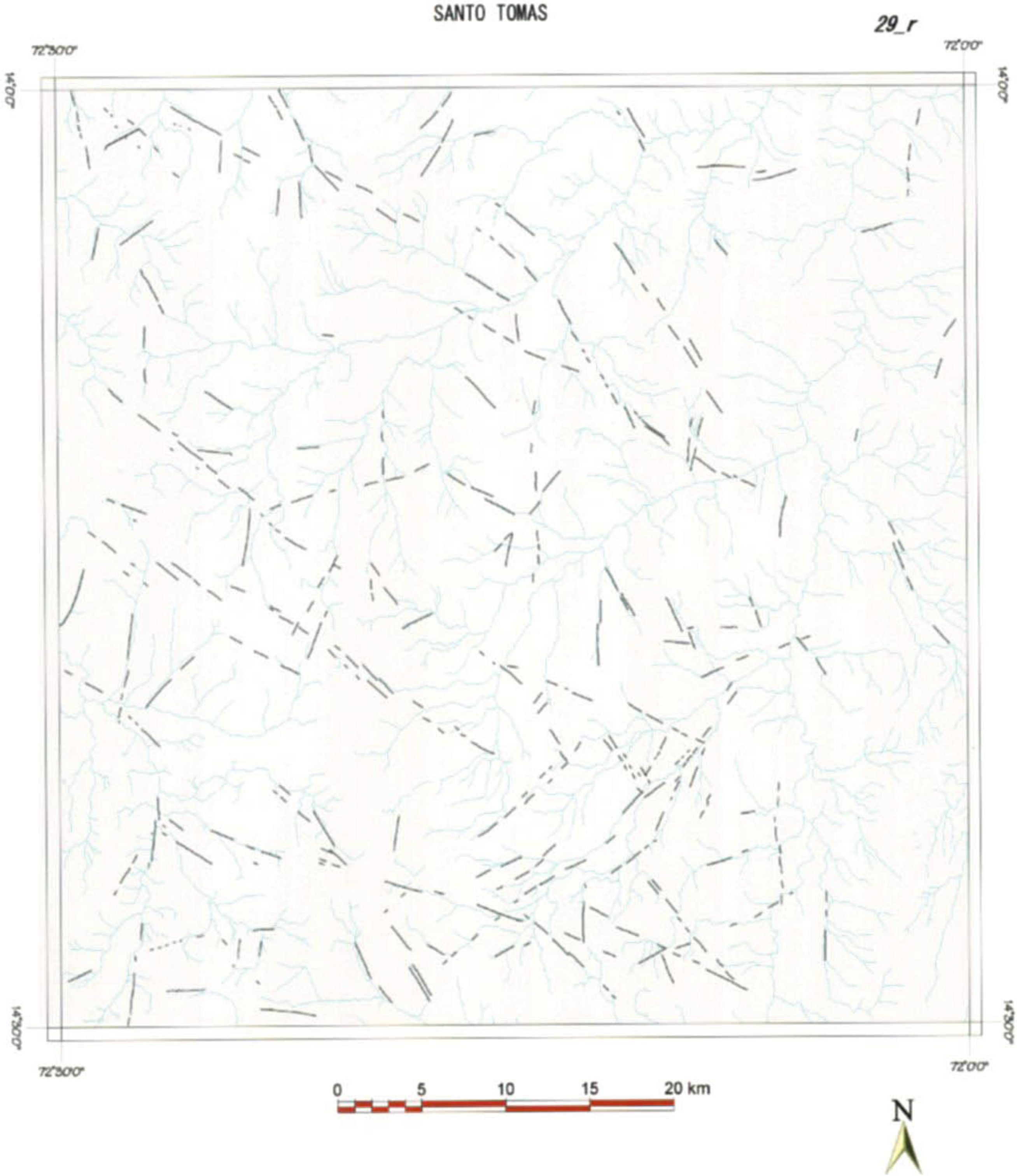

Fig.12-5 Santo Tomas quadrangle (29-r) Lineament map

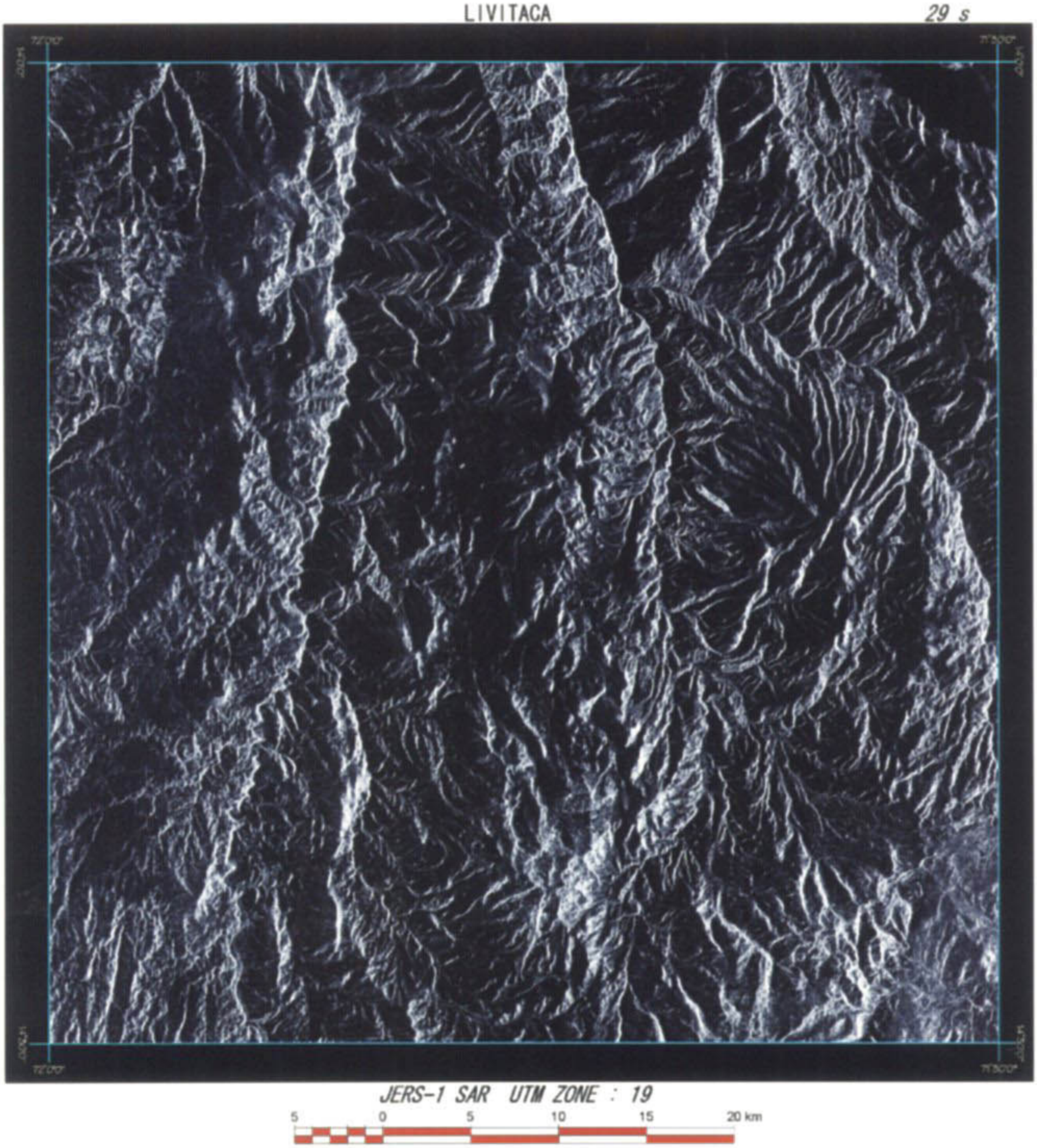

Fig.13-1 Livitaca quadrangle(29-s)JERS-1 SAR image

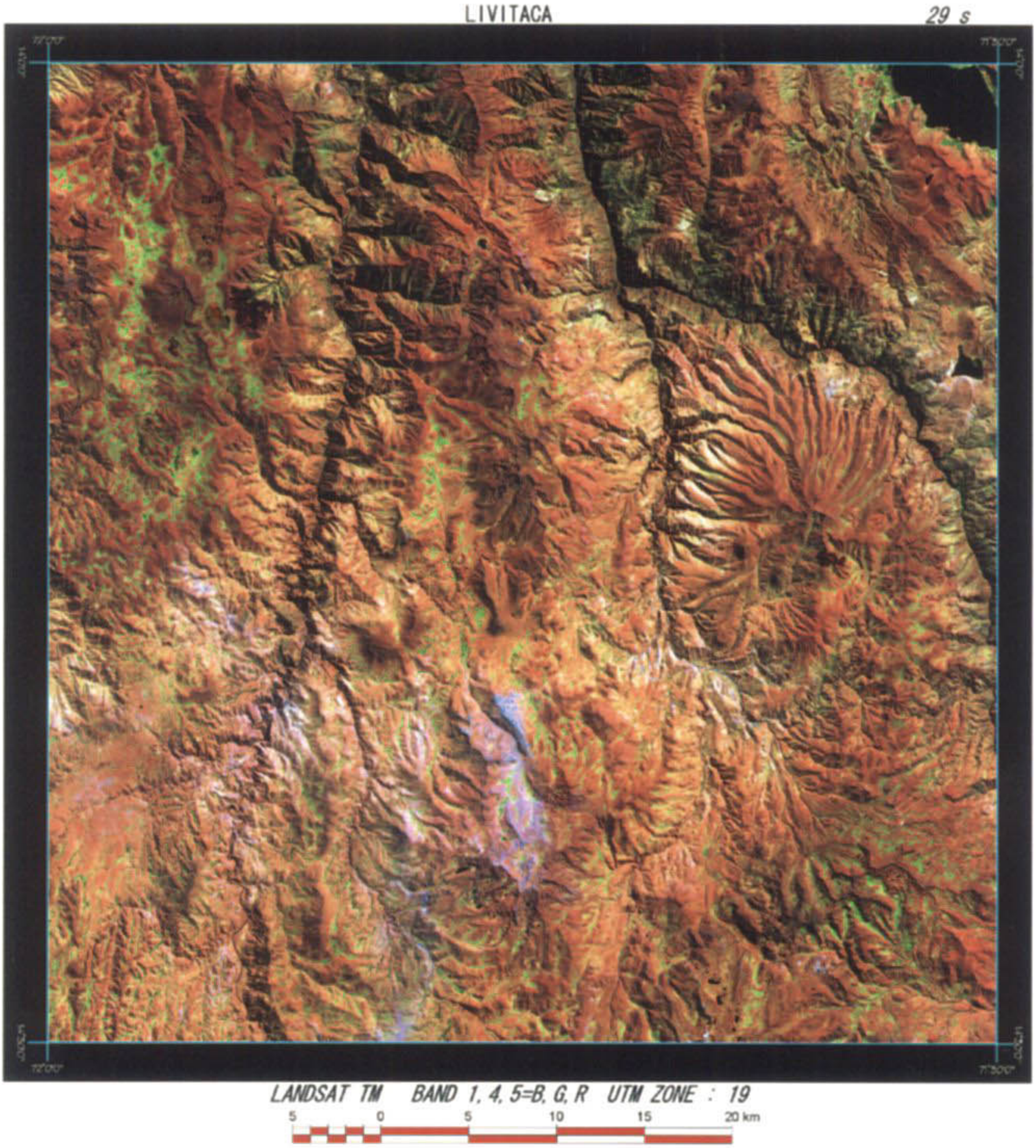

Fig.13-2 Livitaca quadrangle (29-s) LANDSAT TM image

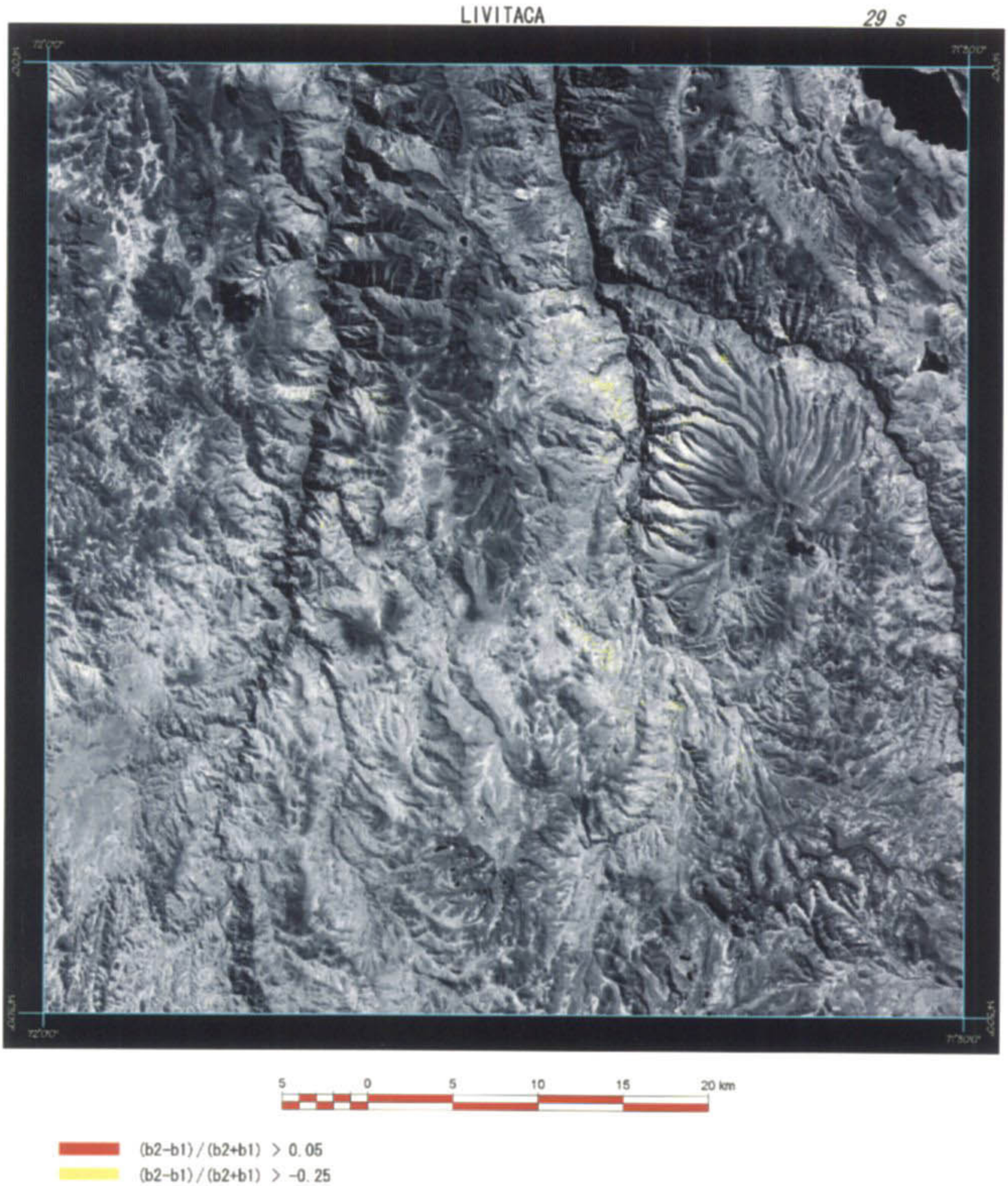

Fig.13-3 Livitaca quadrangle (29-s) LANDSAT TM ratio anomaly map
(Index of iron oxide minerals)

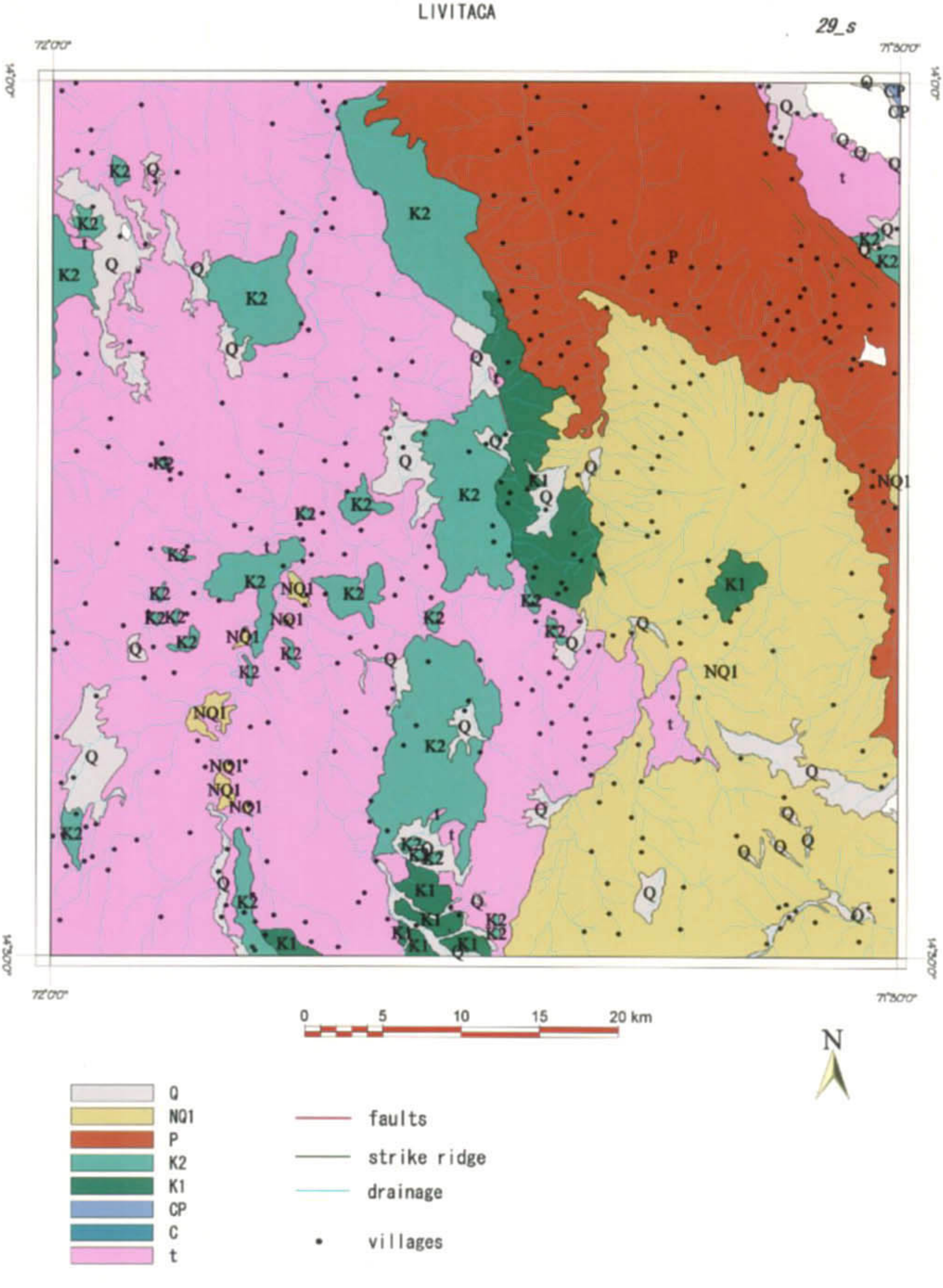

Fig.13-4 Livitaca quadrangle (29-s) Geologic interpretation map

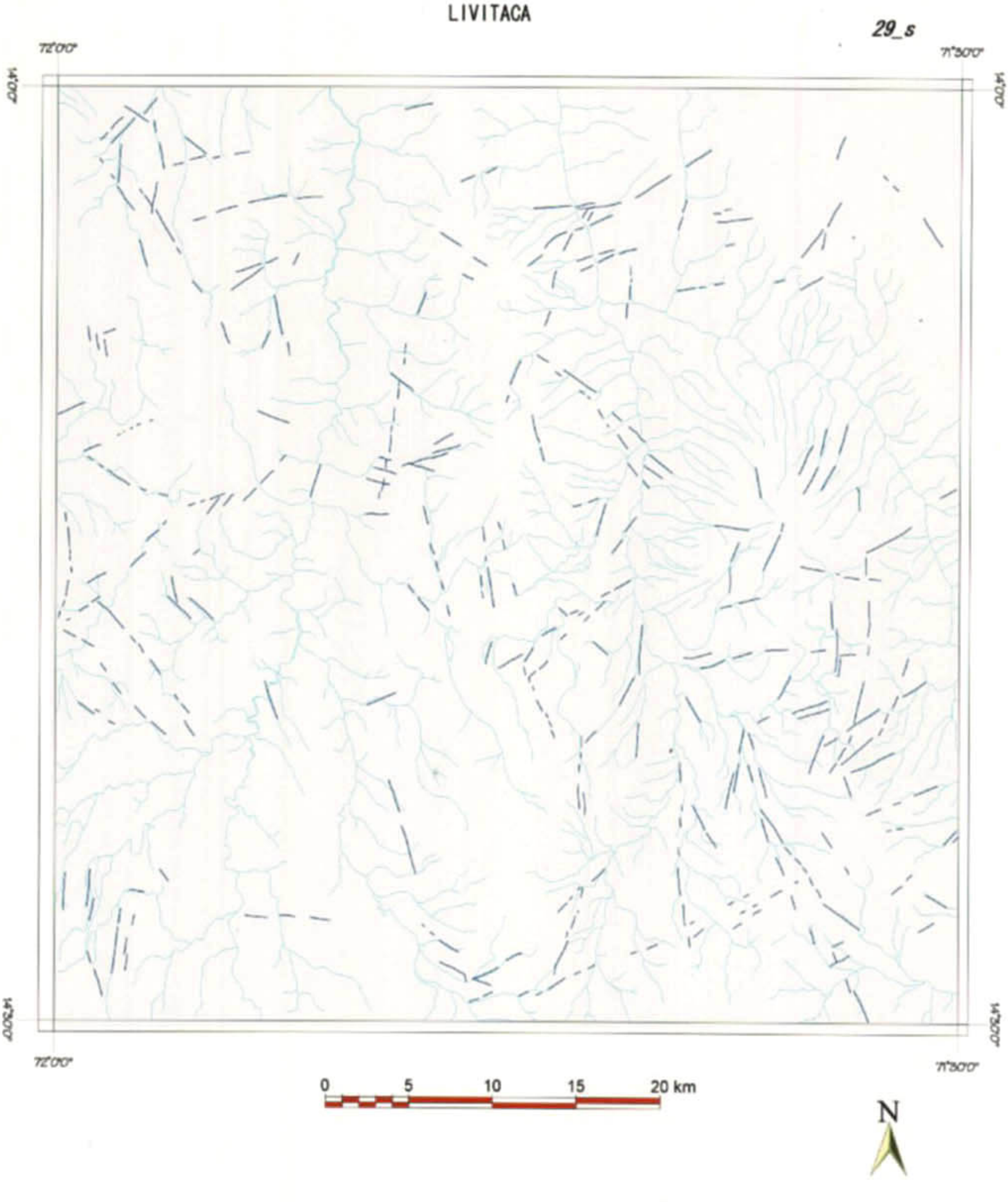

Fig.13-5 Livitaca quadrangle (29-s) Lineament map

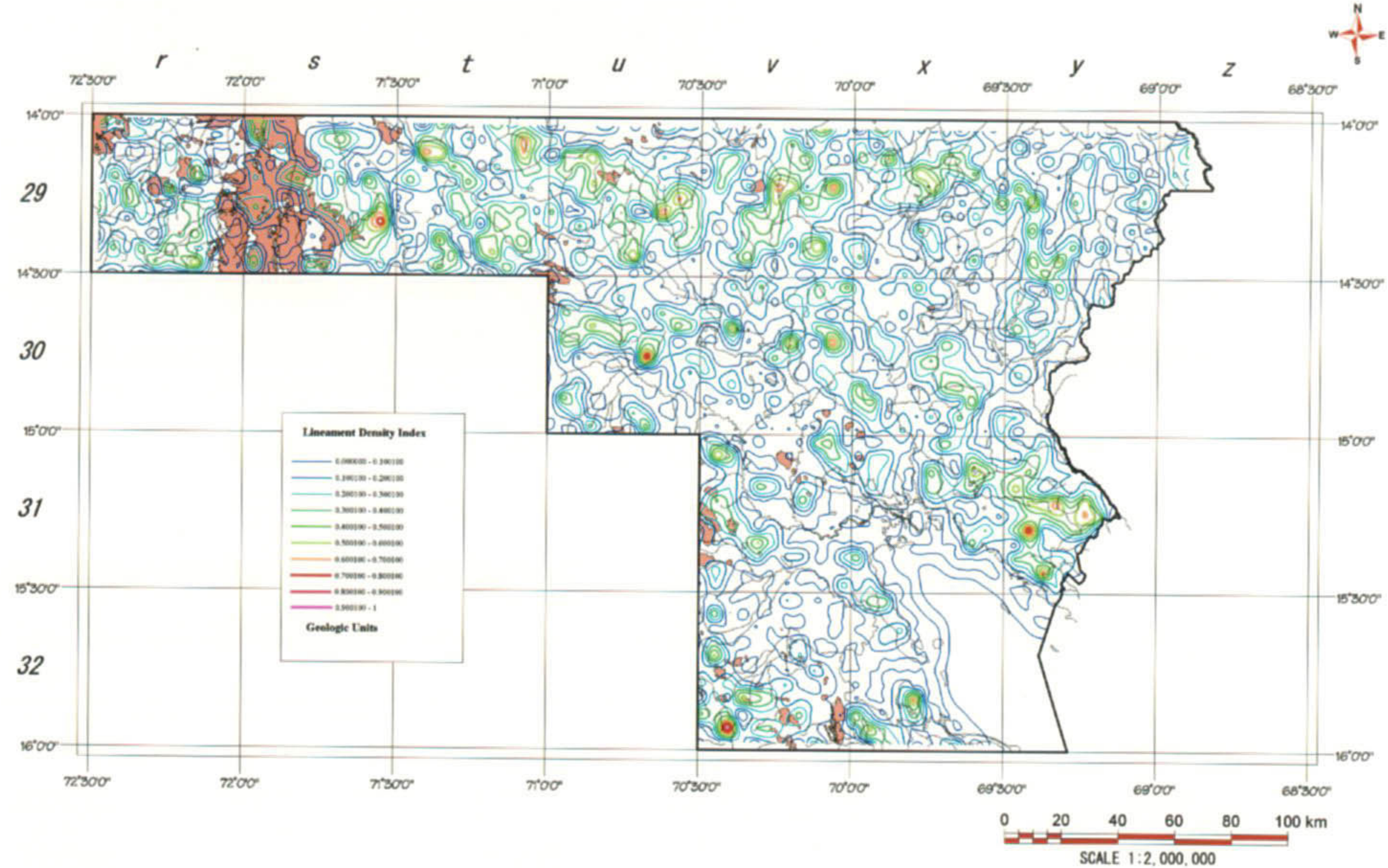

Fig.14 Lineament density map

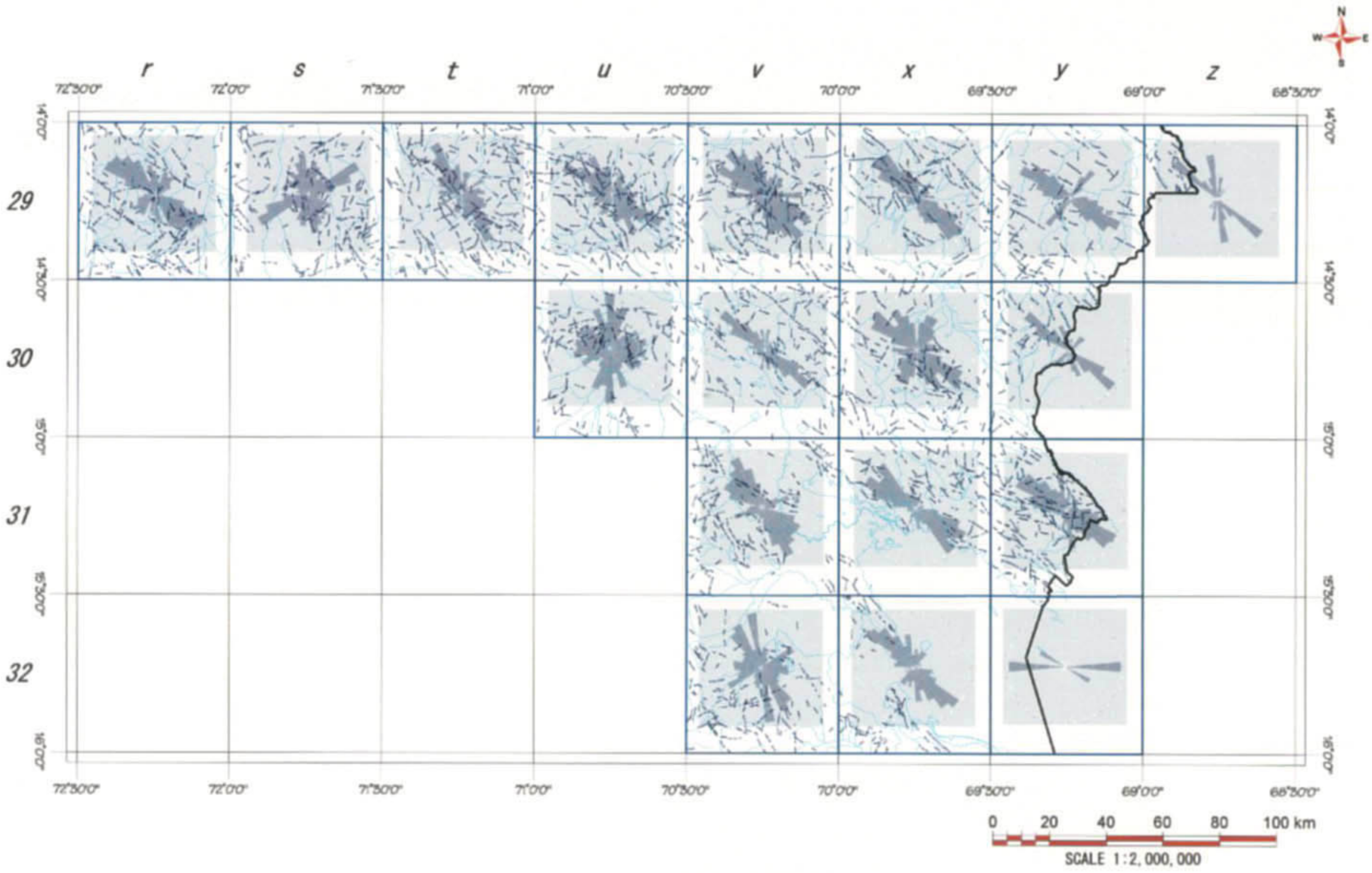

Fig.15-1 Lineament rose diagram

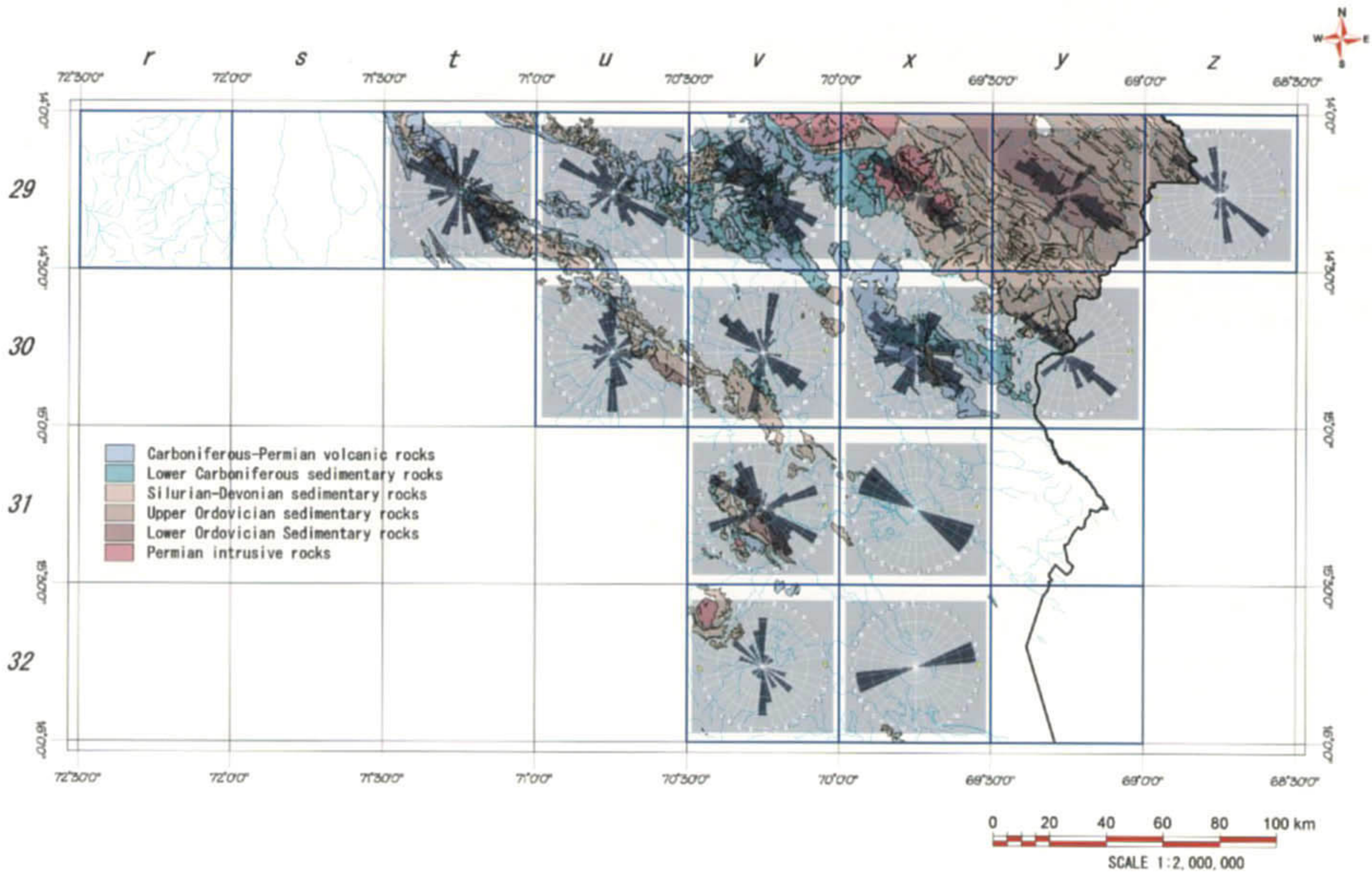

Fig.15-2　Lineament rose diagram of the Ordovician to Permian units

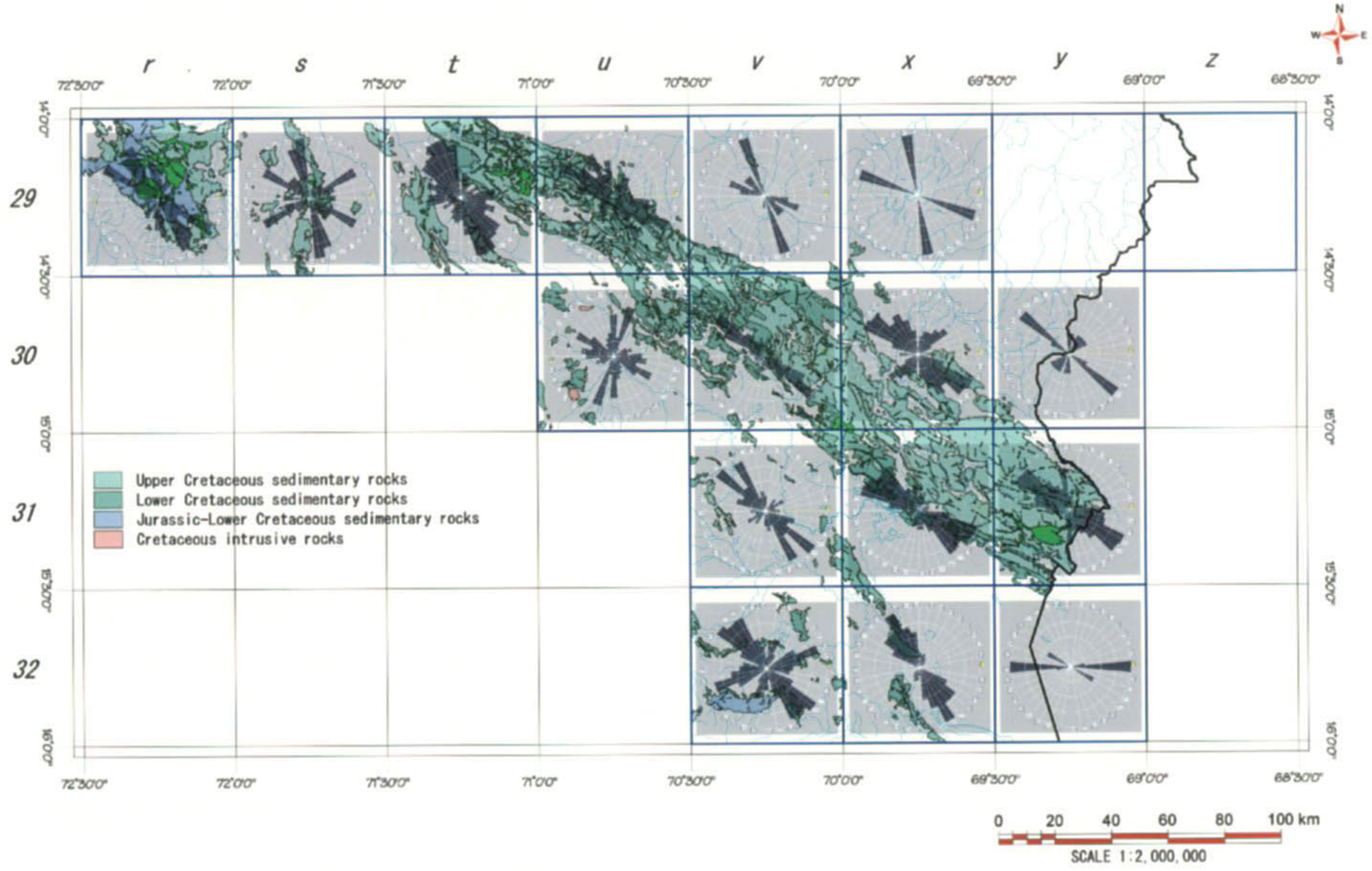

Fig.15-3 Lineament rose diagram of the Jurassic to Cretaceous units

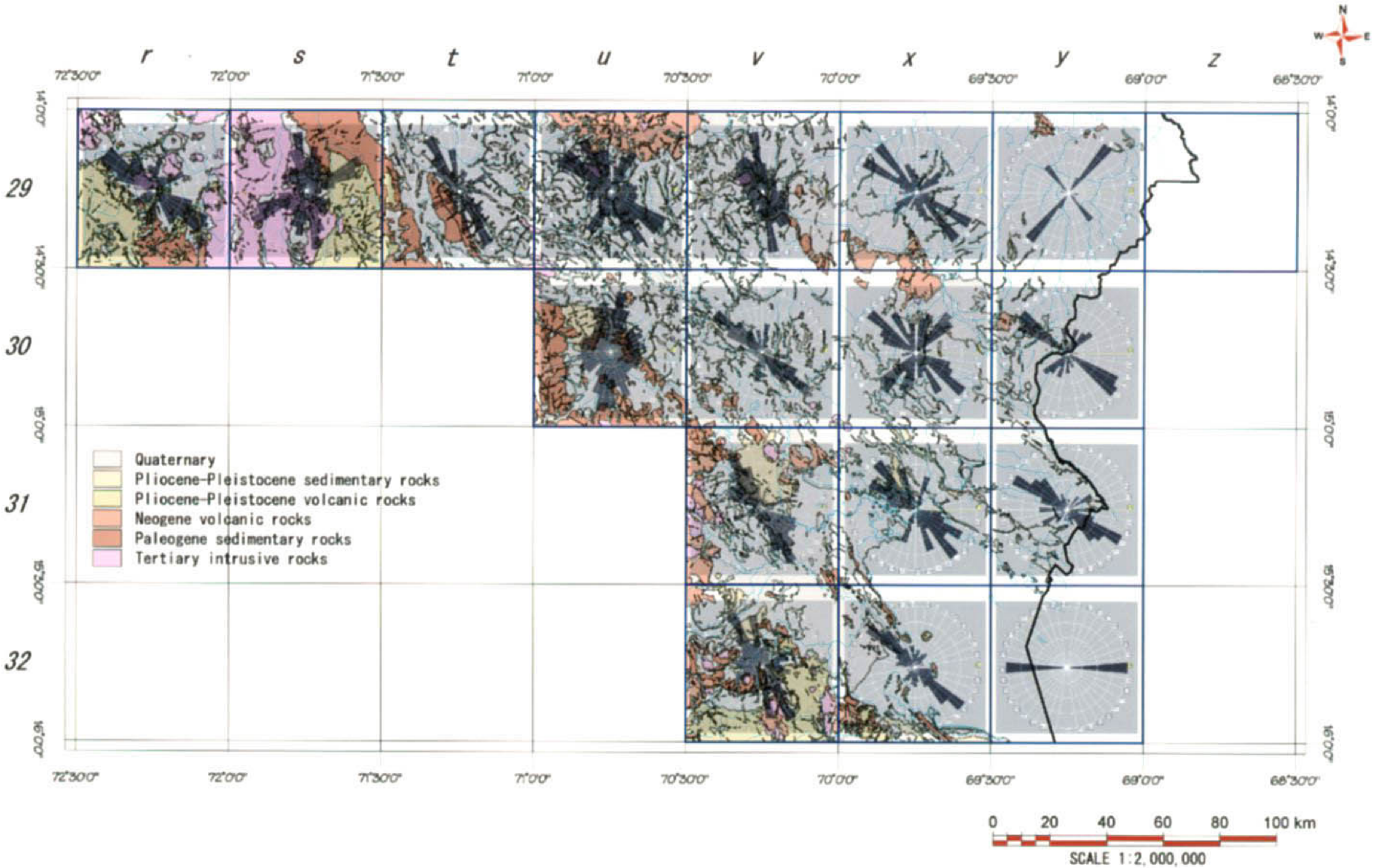

Fig.15-4 Lineament rose diagram of the Paleogene to Quaternary units

Chapter 2 Analysis of Existing Geologic Information

2-1 Purpose of Analysis

It was intended to grasp an outline and conditions of occurrence of the ore deposits and mineral indications in the survey area by collecting , sorting and analyzing the existing geologic information.

2-2 Geology

The survey area is underlain by Paleozoic to the Quaternary sedimentary rocks extending northwest and southwestward. Intruding into these rocks, lie Permian, Triassic and Neogene intrusive rocks. The Northeastern part of the area is underlain by the Paleogene, while sedimentary rocks of younger ages increasingly prevails southwestward.

Chronological descriptions on the sedimentary and intrusive rocks are given in the following paragraphs.

2-2-1 Paleozoic Unit

(1) Lower Ordovician System

1) San José Group

The Group is made up mainly of a thick sequence of muddy slate and some quartzite, and is divided into two formations called the Iparo Formation and the Purumpata Formation. The upper formation is more fine-grained. Time classification by the graptolite facies is possible. The Group lies in the Cordillera Oriental.

(2) Upper Ordovician System

1) Sandia Formation

The Formation is composed of an intensively folded sequence of quartzite and slaty phyllite. In the lower layers, numerous milky-white quartz veinlets and veins ranging in width from 5cm to 10 cm are present. A trace amount of disseminated native gold is obseervable. The Formation lies in the Cordillera Oriental.

2) Calapuja Formation

The Formation, located in the quadrangle of Juliaca, strikes NW and is composed mainly of sandy shale intercalating sandstone layers that intensively fluctuates in thickness. In its upper layer, the sandy shale beds are alternated with siliceous sandstone beds ranging in thickness from 50m to 100m. The Formation lies in the Altiplano.

(3) Silurian to Devonian System

1) Ananea Formation

The Formation lies in the area that forms a western branch of the high peaks of the Cordillera Oriental, and is composed of supergene, metamorphic schist.

Generally, the Formation is made up mainly of slaty, argillaceous siltstone, slaty siltstone,10 cm to 80 cm thick, and siliceous sandstone, 20 cm to 40 cm thick, and is dark gray, bluish gray and black-colored. The Formation lies in the Cordillera Oriental.

The Formation includes the following fossils.

- Heterophrentis sp. (The upper Silurian to lower Devonian)

2) Cabanillas Group

Dominant in the Group is gray shale beds intercalating thin layers of yellow-greenish gray siliceous sandstone and light brown argillaceous quartzite. Locally, it includes limestone nodules with iron content. The Group lies in the Altiplano.

3) Chagrapi Formation

It is composed of black shale lying mainly in the basal bed and a thin bed of micaceous siltstone that intercalates thin, lutaceous sandstone layers with well developed laminas. Extra fine-grained limonite nodules are universally yielded. The Formation lies in the Altiplano.

The Formation includes the following fossils:

- Clarkeia antisiensis
- Harrignotia acutiplicata
- Armosina
- Heterothella Freitana
- Pleurothyrella sp
- Orbiculoides cf. Baini

- Aushelospirefer cf. Antarticus
- Chonetes Falklandicus
- Metacryphacus convexus
- Conularia cf. Apicana

4) Lampa Formation

The Formation consists of silty, siliceous sandstone layers ranging in thickness from 10 cm to 70 cm. Fine parallel bedding of siltstone and mud are observed, as well as cross bedding in places. The Formation lies in the Altiplano.

The observed fossil facies are as follows:

- Scaphiocoelia sp.
- Crytonella sp.
- Australocoelia tourteloni

(4) Lower Carboniferous System

1) Ambo Group (Mississippi Sub-period)

The first Formation consists of a conglomerate layer ranging in thickness from 2 cm to 4 cm, which include subangular pebble of 0.5 cm to 1 cm in size. The Formation is cross bedding with the cross bedding sandstone ranging in thickness from 1m to 2m.

The second Formation consists of a layer of 0.5m to 1m in thickness of medium-grained, massive sandstone ranging in size from 0.5m to 1m, which intercalate thin beds of black shale.

The third Formation consists of a black and violet-tinged shale layer rich in mica (sericite and muscovite).

The fourth Formation consists largely of gray-colored, medium-grained sandstone layers ranging in thickness from 10 cm to 15 cm, which intercalate black shale.

The Formation is characterized by the following fossils:

- Calamites sp.
- Rhacopteris sp.
- R. ovata
- Rhynchonellacea ind.
- Hemiple Thorhynchus cf. Hallani

(5) Upper Carboniferous System

1) Tarma Group

The Group is made up mainly of a medium- to coarse-grained feldspartic sandstone layer ranging in thickness from 10m to 15m, intercalating a thin layer of white to green limestone. Alternated beds of gray and red limestone and siliceous sandstone continue upward.

(6) Lower Permian System

1) Copacabana Group

The Group is composed of cream and dark gray limestone, largely silicified and dolomitized. Dolomitic limestone, gray, argillaceous to silty mudstone and grayish violet and reddish grey-colored shale are intercalated.

(7) Upper Permian System

1) Mitu Group

The Group is made up mainly of graywacke, siliceous conglomerate, and fine- or medium-grained arkosic sandstone.

2) Iscay Group

The Group consists of volcanic rocks, and is divisible into two layers: the lower layer composed of lava flow and the upper layer composed of tuff.

2-2-2 Mesozoic Unit

(1) Cretaceous to Jurassic System

1) Yura Group

The Group is composed of marine sedimentary rocks and, in the survey area, is divisible into the underlying Chuquibambilla Formation and the overlying Soraya Formation.

The Chuquibambilla Formation is dominated by dark brown, fine- to coarse-grained sandstones. The Formation is lenticular, as thick as 50 m, and all the layers are intensely folded. The upper siliceous layer is made up of black and light gray limestone, on top of which sandstones are intercalated.

The Soraya Formation is greenish white to pink-colored, made up of medium- to coarse-grained siliceous sandstones including limestones and coarse-grained quartz. These layers are massive and compact, ranging in thickness from 0.3 to 5 m. Black shale and gray sandstones, 10 cm thick, are intercalated.

(2) Lower Cretaceous System

1) Muni Formation

The Formation is composed of silty mudstone intercalating mudstones and dark red-colored arkosic sandstones. The Formation is a cross bedding layer, 40 cm thick, lying in the Lake Titicaca area.

2) Huancané Formation

The Formation consists of arkosic sandstone and includes white to yellowish white and dark red, coarse-grained quartz. It is observed in beds ranging in thickness from 30cm to 60cm, in which thick layers of sandstone very close to conglomerate, and gray, reddish or greenish silty mudstone are intercalated.

(3) Middle Cretaceous System

1) Moho Group

The Group consists of sandstone, red shale, silty mudstone and limestone. In the survey area, the Group is divided into the following three formations.

2) Cotacuchos Formation

The Formation is subdivided into three layers. The lower layer consists of medium- and coarse-grained quartzose and granitic sandstone and conglomerate. The middle layer consists of granitic sandstone alone. The upper layer consists of medium- to fine-grained sandstone.

3) Vilquechico Formation

The Formation is sub-divided into three layers. The lower layer consists of red and green shale with well developed lamina, alternating in cycles of 2 to 5 cm in thickness with very fine-grained sandstones. The middle layer consists of green shale, siltstone and dolomitized limestone. The upper layer, 1 to 2 m thick, consists of medium- to coarse-grained sandstone.

4)Muñani Formation

The Formation is also sub-divided into three beds. The lower bed, 2 to 4 m thick, is made up of conglomerate consisting of coarse-grained sandstone, milky white quartz and limestone. The middle layer consists of pink and reddish-colored, medium-grained sandstones alternated in cycles of 0.5 to 1 m in thickness. The medium-grained sandstones alternate with extra-fine-grained sandstones and red shale. The upper bed, 20 to 30 cm thick, consists of medium-grained sandstone.

2-2-3 Cenozoic Unit

(1) Paleogene System

1) Puno Group

The lower Formation of the Group consists of alternation of shale layers and miscellaneous-colored, medium-grained sandstones, intercalating fine to medium-grained conglomerates at places. The middle formation consists of light gray to brown arkosic sandstones ranging in thickness from 2 to 8 m, intercalating reddish shale and conglomerate. The upper formation consists of thick layers of brown and light gray-colored conglomerate. (The Oligocene)

(2) Paleogene to Neogene System

1) Tacaza volcanic rocks

In the lower bed, coarse-grained conglomerates consisting of subangular quartzite and limestone pebbles are observed. In the middle bed, gray, green and red-colored, medium to coarse-grained sandstones are alternated with thin layers of reddish violet tuffaceous mudstone. The upper bed is composed of thick layers of conglomerate whose matrix is again tuffaceous. (The Oligocene to Miocene)

2) Palca Group

The lower bed of the Group consists of yellowish brown to grayish brown-colored, strongly welded ignimbrite, while the middle bed is composed of grayish pink hyaloclastic(unwelded) and the upper bed consists of layered ignimbrite, 10 cm in maximum thickness, including clastic grains diminishing in size. (The lower to middle Miocene)

3) Senca volcanic rocks (The western Andes)

The rocks are made up of rhyolitic and rhyo-dacitic tuff, intercalating lentform, conglomeratic tuff beds. Quartz crystals, feldspar, biotite and glass fragments are also observable. (The middle Pliocene)

4) Quenamari Formation (The eastern Andes)

In the survey area, the Formation is divisible into two members. The Chacacuniza Member includes quartz, plagioclase, sanidine, biotite and glass and rock fragments. The matrix is cryptcristalline. Latitic tuff of rhyolitic chemical composition overlies. In the Yupamayo Member, white or grayish white ignimbrite layers, 3 m thick, are alternated with thick layers of ignimbrite of rhyolitic latite. (The Miocene and Pliocene)

5) Barroso Group

The volcanic rocks consisting mainly of andesitic, trachytic and trachy-andesitic lavas and pyroclastic rocks are collectively called the Barroso Group. In the survey area, the Group is called Mendivil Formation, which can be sub-divided into the two; the Mayama volcanic rocks correspond to the volcano Chila while the Vilcanari volcanic rocks to the volcano Barroso.

The Malmaya volcanic rocks are made up of andesitic, dacitic, trachy-andesitic and rhyo-dacitic lavas, above which breccias are alternated with tuffaceous conglomerates, making the hardness markedly variable.

The Vilcarani volcanic rocks are made up of a sequence of pyroclastics -- ignimbrite, agglomerate and ash -- and andesitic and dacitic lavas. (The Pliocene and Pleistocene)

6) Azángaro Formation (Lake Titicaca)

The Formation consists of fine-grained sandstones and siltstones, which are beige to red-colored, varying in thickness from 30 to 40cm and to 1 m at a maximum. Siltstone and carbonaceous black shale are intercalated. (The Pliocene to Pleistocene)

(3) Quaternary System

Quaternary sediments fill out the valleys, basins and plains. Moraine, glacial sediments and alluvium lie in the survey area.

2-2-3 Intrusive Rocks

Intrusive rocks exposed in the survey area are assigned to the Permian to Pliocene. They can be classified by the geologic ages and chemical compositions, as follows.

1) Coasa Pluton

The plutonic body is exposed in the Quadrangles of Macusani(NE) and Limbani (NW), in the survey area, characterized by the steep, conspicuous landform that forms a part of the eastern Andes.

The intrusive body consists of porphyritic granites. These are irregularly grained light-colored rocks composed of orthoclase megaphenocrist with remarkable twins and biotite altered to chlorite, including apatite and zircon. Chemical analysis indicates that the $K2O:Na2O$ ratio is approximately 1 : 2, while CaO is low in the ratio.

The Pluton intrudes into the Ambo Group's sandstone and the Ananea Formation's slate, to cause contact metamorphism to the wall rocks. In case of the Ambo Group, it has caused a large quantity of pyrite to be impregnated in the tuff. Skarns are formed in the carbonate rock formations of the Tarma Group and the Copacabana Group, which have been under exploitation at several localities.

The K-Ar dating and Rb-Sr dating have indicated ±238 M.a.; the intrusion is inferred to be Triassic in age.

2) Limbani Pluton

The plutonic body is exposed in the central part of the Quad. Limbani and extends toward the Andes. The body grades from equigranular granodiorite into fine- to medium-grained, equigranular monzonite. The main minerals are plagioclase, quartz and feldspar, while biotite, muscovite, chlorite, sericite, amphibole and limonite are the accessory minerals.

In the survey area, the pluton intrudes into the Ananea Group, to cause the contact metamorphism to schist. The contact metamorphism caused high-density joints trending NW-SE and NE-SW and a network-like fissure zone to be formed. The pluton is dated as 230 M.a.±10 M.a. by the U-Pb dating; the intrusion is inferred to be Upper Triassic in age.

3) Aricona Pluton

The plutonic body is exposed in the central left portion of the Quad. Limbani, in the neighborhood of other bodies, and concordantly extends towards the Andes. The rock facies grade from granodiorite into monzonite.

The texture of the pluton resembles that of the Coasa body. The Aricona granites contain biotite as the only mafic mineral but primary muscovite is unobservable.

The intrusive body is characterized by ilmenite and its oxides. The main minerals are plagioclase, quartz and feldspar, accompanied by the accessory minerals such as biotite, amphibole, clay minerals, sericite, opaque minerals, chlorite, epidote and zircon.

The Pluton intrudes into the Ambo Group and the Ananea Formation. The K-Ar dating of the intrusive body indicates 212 to 217 M.a. (Kontak, D. et al., 1985), whilst Dalmayrac, B. et al.(1980) dated the body as ±234 M.A. The intrusion is inferred to be Upper Permian in age.

4) Utccuccacca granites

The rocks are exposed in the northwestern part of the Quad. Rinconada, inferably formed by a regional fault system trending NW-SE.

The major minerals are orthoclase, microcline, quartz, plagioclase, muscovite and biotite. Orthoclase and plagioclase are slightly deformed. Intrusion of the body caused the contact metamorphic zone of andalusite facies to grow. The contact metamorphism declines as the distance from the granites increases.

The granite body intrudes into the Sandia Formation, where a vast sandstone block lies surrounded by the intrusive body. The intrusion further traverses a fault, from which the intrusion is inferred to be Upper Perminan in age.

5) San Judas Tadeo body

Intrusion of the body can be seen in the northwest of the Cabanillas village in the Quad. Puno. The intrusive body is also visible at Mt. Camallata, composed of light gray, medium-grained monzonite. Under the microscope, weakly deformed, irregularly shaped quartz(25%), orthoclase(25%) and those containing partly sericitized plagioclase are observed. As the mafic mineral, biotite partly altered to chlorite and epidote are observable.

The monzonite intrudes into quartzite and shale of the Cabanillas Group. At the contact zone, hornfels is observed. The K-Ar dating indicates 270 M.a.; the intrusion is inferred to be Lower Permian in age.

(2) Mesozoic intrusive rocks

1) Huisaroque intrusive body

The intrusive body, composed of tonalite, is exposed in the north of Juliaca. The body is basic and has phenocrysts, 8 mm in a maximum size. Biotite is platy, 2 mm thick. Red-colored granite containing xenolith, 20 cm in a maximum size, of platy or elliptic, gray-colored and medium grained diorite is observed.

In the periphery of the intrusive body, narrow contact metamorphic zones are observed.

The body intrude into the Chagrapi Formation. The K-Ar dating of samples taken from Mt. Huisaroque indicates ± 236 M.a.; the intrusion is inferred to be Middle Triassic in age.

(3) Cenozoic intrusive rocks

A number of intrusive bodies that constitute the Apurimac batholith lie in the quadrangles of Santo Tomás and Livitaca. These are enormous bodies of granodiorite, tonalite and diorite.

The diorite exposed at the eastern end of the Quad. Santo Tomás and at the western end of the Quad. Livitaca is fine- to medium-grained, porphyritic or granular-textured, containing 30% to 60% of mafic minerals. The major minerals are plagioclase and a trace amount of quartz, accompanied by bluish green amphibole and reddish brown mica.

The tonalite in the survey area is light-colored and medium-grained, whose main minerals are euhedral and twin plagioclase and quartz. The tonalite body is cut by countless dikes of different composition, such as aplite, pegmatite and hypabissal rocks.

Macroscopically, the granodiorite has the same characterics as those of the tonalite. Distribution of the granodiorite is seen in the Quad. Juliaca, which forms a series of plutons.

2-3 Ore Deposits

In the central Andes, the metallogenic provinces can be arranged in parallel with the Pacific coastline. Heuschmidt(1995) classified the metallogenic provinces, from the Pacific coast toward the interior of the South American Continent, into the copper belt, the central polymetallic belt, the tin belt and the marginal polymetallic belt. [Fig.5] In the subject survey area, the tin belt extends from the central part southeastward to Bolivia, the marginal polymetallic belt lies on the northeast of the tin belt, while the central polymetallic belt on the southeast of the tin belt. Fig.5 exhibits the location map of ore deposits and mineral indications, which are listed in Table 7.

Following are the descriptions on the mineralization in the survey area classified by wall rocks.

2-3-1 Paleozoic Ore Deposits

(1) Vein-type and stratiform Au deposits in Lower Paleozoic formations

Gold ore deposits occur in weakly metamorphosed lower Paleozoic formations. Gold bearing quartz veins in Ordovician tuffs, stratiform gold-bearing quartz lenses embedded in Silurian and Devonian tuffs such as the Ana Maria deposit, and stratiform ore deposits of gold-bearing, massive sulfides such as La Rinconada deposit are known. [Fornari et al., 1988] Syngenetic ore deposits of both types were also formed by the Early Hercynian orogenesis.

The vein-type ore deposits, averaging 1.2 m in width, are composed of quartz, gold, stibnite, pyrite and small amounts of galena and arsenopyrite. Gold is present in sulfides. A lentform quartz body is 20 cm in maximum thickness and several meters long, composed of chlorite, epidote, arsenopyrite, magnetite, pyrite, galena and chalcopyrite, averaging Au 10-25 g/t. A stratiform deposit of massive sulfides is 1 to 2m thick. Marked mineralization is observed in black schist which contains chlorite, and magnetite, pyrite and arsenopyrite are included. The average gold content is 2 g/t or less. In the periphery of dominant mineralization, network-like mineralization of quartz, chlorite, and sulfide is locally observed. The dominant mineralization has high contents of As, Sb, Ag and also Pb, Zn, Cu, Sn and W though in small quantities. [Ibid.]

The primary gold concentration (massive sulfide deposits) was caused by the submarine hydrothermal process related to early Paleozoic igneous activity [Ibid.] Afterward, gold was moved by deformation and metamorphism during the early Hercynian period to be concentrated in convenient tectonic lines such as veins and lenses, and in rocks.

(2) Sn-W-Cu ore deposits related to Permian to Jurassic granite intrusion

Sn-W-Cu-Mo vein deposits, greisens and skarns lie in the Carabaya batholith complex in the Cordillera Oriental, which constitute the plutons of Coasa, Limbani, Aricona and Limacpampa. The most important examples of this category are the mines in Condorquiña and Sarita. The former has a series of greisens including cassiterite, wolframite, sphalerite and arsenopyrite associated with the Limacpampa granite body, as well as chlorite-quartz veins. The Sarita mine, where the Aricona granite body lies [Clark et al., 1990], consists of a large number of greisens disseminated with chalcopyrite accompanied by scheelite, cassiterite and molybdenite [Candiotti & Guerrero, 1988]. The Sn-W-Cu-Mo deposits associated with the Carabaya batholith are placed in the Permian to Jurassic. [Lancelot et al., 1978 and Clark et al., 1990] A study on the lead isotope has revealed that the metallic elements of these deposits are of the continental origin. [Kontak et al., 1990]

2-3-2 Mesozoic Ore Deposits

Mesozoic ore deposits are characterized by the vein and stratiform structures. It has been interpreted that stratiform ore deposits were formed by the hydrothermal process, in the light of the fact that vein deposits related with Cretaceous to Cenozoic intrusive rocks are associated with skarn deposits.

However, detailed surveys of the genesis of ore deposits indicate that syngenetic ore deposits act an important part for the genesis of metallic ore deposits. Two processes are conceivable for the genesis of ore deposits. One is the mineralization related to the development of volcanic sedimentary rocks within the Andes basin(Upper Triassic to Upper Cretaceous formations), whereas the other is related to the coastal batholiths and (Upper Cretaceous) stocks in the Cordillera Oriental.

(1) Ag-Pb-Cu-Zn veins associated with Upper Cretaceous intrusive rocks

Clark et al.(1990) refer to the Ag-Pb-Cu-Zn veins in the Crucero basin situated between the Precordillera and the Cordillera of Carabaya.

Of these veins, important are the Cerro del Inca Azul, Casa de Plata and Santa Ana. The vein deposits lie in the rocks of the Tarma and Copacabana Groups(Upper Carboniferous to Lower Permian) and in the Upper Cretaceous granodiorite stocks.

The veins are dominated by quartz and include carbonate rocks, pyrite, chalcopyrite, galena, sphalerite and acanthite.

Brecciation, silicification and chloritization are observed in the wall rocks in which ore deposits are emplaced.

The study on the lead isotope indicates that a part of lead originates from mantos.

2-3-3 Cenozoic Ore Deposits

For the genesis of metallic ore deposits in this geologic age, two factors are conceivable. One is the formation of batholiths whilst the other is the intrusion of semi-volcanic stocks resulting from the surface volcanism.

(1) Sn-W-Cu-Zn-Pb ore deposits related with Oligocene to Miocene granite stocks

A number of the Sn-W-Cu-Zn-Pb ore deposits lie between the Precordillera and the Cordillera of Carabaya.

The most important of them are the San Rafael mine and the Palca XI mine. [Clark et al., 1983 and 1990; Fornari et al., 1990]

The ore deposits consist of polymetallic veins, which show vestiges of repeated sedimentation. The veins strike NW-SE and lie associated with monzonite stocks intruding into Lower Paleozoic slate, phyllite and tuff.

These ore deposits were formed in 25 to 23 M.a.(the Upper Oligocene) and are related with subvolcanic intrusive rocks. The San Rafael ore deposit contains Sn 5.2% to 6.5%. Its ore minerals are mainly cassiterite and chalcopyrite while the gangue minerals are quartz, chlorite and calcite.

The Palca XI ore deposit is composed mainly of wolframite and scheelite, averaging WO3 1.3%. From a study on the fluid inclusion [Palma, 1981], ore deposits of this category were inferably formed at a depth of 1,000 m below the paleosurface and in the temperature ranging from 390℃ to 220℃.

The mentioned study on lead isotope indicates that these metals are inferred to be of continental origin.

(2) Uranium ore deposits related to Miocene to Pliocene pyroclastic rocks

In the Macusani area, many uranium ore deposits are present in thick beds of rhyolitic pyroclastic rocks of the Quenamari Formation. The mineralization forms a network-like ore deposits consisting of pitchblende-pyrite veinlets, in the vicinity of pyroclastic flow. The pyroclastic rocks have high contents of Sn, W, Be, F, Li, P and B, besides uranium. Most of the mineralization containing uranium are dated as 8 to 6 M.a. [Clark et al., 1990] The mineralization is inferred to be related with hydrothermal activity caused by intrusion of felsitic rocks, because the uranium mineralization is observed in the vicinity of rhyolitic stocks that have very close geochemical similarity to volcanic rocks.

(3) Gold placer deposits in Cordillera Oriental

Important ore deposits of this category are those lying in the southeast of the Cordillera Oriental, which can be classified into three types by topographic locations. Two of the types are placer deposits located in heights of the

Cordillera Oriental and those in the Amazon plain. [Fornari et al., 1988] In case of these two types, gold is present mostly in glacial deposits and fluvio-glacial deposits formed in the Pleistocene time. The representative of this type is San Antonio de Poto. The third type is gold included in Holocene stream sediments, as represented by those lying in the Madre de Dios basins, the Huaypetuhe River and the Caichive River. Placer deposits on heights and lowlands of the Cordillera Oriental are inferred to have their origin in Lower Paleozoic gold-bearing veins and mantos, whereas the auriferous materials included in the placer deposits in the Amazon plains resulted from the repeated movements of glaciers and fluvio-glacial deposits. [Fornari et al., 1988]

2-3-4 Respective Ore Deposits

A table showing data on the mines and ore deposits in the survey area is attached at the back of this Report.

Though a large number of mineral indications and vestiges of old mines are known to exist in the survey area, currently operating mines are relatively few. The San Rafael mine (500 tpd; tin; vein-type), the Palca XI mine(300 tpd; tungsten; vein-type) and La Rinconanda(minor scale; gold; manto-type) are currently under operation by underground mining.

Descriptions on major ore deposits located within the survey area are given in the following paragraphs, in order from the northwest to the southeast.

(1) Esperanza de Potoni ore deposit [Quad. 29-u: Nuñoa; Fig. 5 - No.108]

Located at the District of Azangaro, Department of Puno, an altitude of 4,400m, and 32 km from Crucero, the Esperanza is a vein-type lead-silver ore deposit embedded in the Copacabana Formation. The vein lies near the axis of an anticlinal structure, horizontally extending over 100m (of which 25m is the high-grade portion), striking N30° ~60° and vertically dipping. Ore minerals are cerussite and subordinate quantities of galena and malachite. The deposit was worked in a small scale of 25 tpm but the operation has been suspended. The high grade portion averages Pb 20% and Au 6 oz/s.t.

(2) Tres Marias I and II deposits [Quad. 29-u: Nuñoa; Fig. 5 - No.114]

Located at Dist. Melgar, Dept. Puno, alt. 4,600m, and 27 km from Macusani, the ore deposits is a copper and silver ore deposit embedded in gray sandstones as the host rock. The lenticular beds are arranged in parallel, striking N24° and dipping 70° SE. The ore minerals are chalcopyrite while the gangue minerals are quartz, pyrite and iron hydroxide. Underground mining(4 tpm; Cu 21% and Ag 7.5 oz.s.t) was carried out but later suspended.

(3) Quenamari ore deposit [Quad. 29-u: Nuñoa; Fig. 5 - No.118]

Located at Dist. Carabaya, Dept. Puno, alt. 4,500 m, and 35km from Macusai, the Quenamari is a copper-lead-zinc-silver ore deposit consisting of 4 veins. Silicified monzonite stocks and fissures are dominant. The vein strikes NW-SE, averaging 0.60 m in width. The ore minerals are chalcopyrite and covelline. Exploration was conducted in the past and is currently underway.

(4) Cerro Inca No.28 ore deposit(Quad. 29-v: Macusani; Fig. 5 - No.131)

Located at Dist. Azangaro, Dept. Puno, alt. 4,200 m, and 24 km from Crucero, the Cerro Inca No.28 is a stratiform ore deposit of lead and silver consisting of 4 mantos, with an irregularly lenticular ore body. Ores are embedded in alternated beds of limestone and shale. The vein strikes N15° W and dips 25° SW. The ore minerals are galena and cerussite, while the gangue minerals are quartz and pyrite.

Underground operation was carried out at an unknown rate but, at present the operation is suspended. Ores in the stockyard indictates Pb 38.8% and Ag 0.8 oz/s.t.

(5) San Rafael ore deposit (Quad. 29-v: Macusani; Fig. 5 - No.148)

Located at Dist. Azangaro, Dept. Puno, alt. 4,800 m, and 44 km from San José, the San Rafael is a fissure filling, hydrothermal-type -- partly metasomatic -- tin-copper ore deposit. It is associated with the igneous rocks called the San Rafael monzonite, which intrudes into the Ambo Formation consisting of sandstone, shale and slate, extending over an area of 5 km x 7.5 km.

The ore deposit consists of quartz-tourmaline veinlets in a vein averaging 5 m in width. The ore minerals are cassiterite, chalcopyrite and subordinate quantities of galena, sphalerite, tetrahedrite, whilst the gangue minerals are quartz, calcite, pyrite and fluorite. Chloritization and weak kaolinization are observed inside and outside of the vein whereas slate is slightly silicified.

The San Rafael is the largest mine in the subject area; 500 tpd underground operation is carried out.

(6) Santa Ana ore deposit (Quad. 29-v: Macusani; Fig. 5 - No.136)

The ore deposit is located at Dist. Carabaya, Dept. Puno, alt. 4,500 m, and 127 km from Crucero. A granodiorite body intrudes into sandstones striking N85° E and dipping 30° SE. Copper mineralization is observed in open fissure systems in the intrusive body. In the wall rocks, silicification and some pyritization and kaolinitization are observed. The vein averages 0.80 m in width. The ore minerals are chalcopyrite while gangue minerals are quartz, disseminated pyrite and barite.

In the past, underground mining was carried out with galleries at 3 levels but the operation has been suspended. The ore grades Cu 0.7%, and the ore reserves is considered small in scale.

(7) Casa de Plata ore deposit (Quad. 29-v: Macusani; Fig. 5 - No.144)

Located in Dist. Carabaya, Dept. Puno, alt. 4,800 m, and 25 km from Crucero, the Casa de Plata is a vein-type lead-silver ore deposit. The vein strikes N30° W and dips 75° NE and SW, averaging 0.50 m in width. The ore mineral is argentiferous galena, while the gangue minerals are barite, calcite, pyrite and quartz.

The ore reserves are 11,000 t, grading Pb 13.8% and Ag 8.6 oz/s.t. The ore deposit was extensively worked in the past and underground operation was carried out at an approximate rate of 10 tpm but later suspended. The stopes are now submerged and collapsed.

(8) Nicaragua ore deposit (Quad. 29-x: Limbani; Fig. 5 - No.184)

Located at Dist. Azangaro, Dept. Puno, alt. 4,400 m, and 38 km from Rosario, the Nicaragua is a lead-silver ore deposit, composed of veins and lentform ore bodies, whose host rocks are limestone and conglomerate of the Copacabana Formation. The ore minerals are cerussite and subordinate quantities of galena and sphalerite, while the gangue minerals are quartz, pyrite, calcite and barite.

The mining operation has been suspended though 20-tpm operation was carried out in the past. The ore reserves are small but grade Pb 20-25% and Ag 1.2-1.6 oz/s.t.

(9) Sarita ore deposit (Quad. 29-x: Limbani; Fig. 5 - No.187)

The Sarita ore deposit is located at Dist. Carabaya, Dept. Puno, alt. 4,700 m, and 22 km from Crucero via Limbani. The Aricona granite body and andesite dikes intrude into the Ambo Group. The ore deposit is a greisen-type, emplaced in fissures or andesite dikes, bearing copper, silver, molybdenum, tungsten and tin. The ore body has an irregular platy shape, ranging in thickness from 6 m to 12 m. The ore minerals are chalcopyrite, bornite, malachite, chrysocolla, minor quantities of molybdenite and tungsten-tin minerals. Chalcopyrite fills grain gaps, cavities and cleavages.

Currently, operation is suspended while past operation turned out 157,000 t. grading Cu 3.0% and Ag 0.96 oz/s.t. The ore reserves are 2 million tons.

(10) Nilda ore deposit (Quad. 29-x: Putina; Fig. 5 - No.261)

Located in Dist. Azangaro, Dept. Puno, alt. 4,800 m, and 37 km from Crucero, the Nilda is a lead-zinc ore deposit emplaced in the structural breccia zone averaging 4.35 m in width, whose host rocks are limestones in the Ayavacas Formation intercalating shale, sandstones and conglomerates. The deposits is a disseminated-type, 150 m long and 25 m wide. The ore minerals are cerussite, argentiferous galena and sphalerite.

Currently, the ore deposit is at a stage of trenching survey. The inferred ore reserves are 12,000 t, averaging Ag 0.6 oz/s.t., Pb 8.5% and Zn 11.6%.

(11) Marcia ore deposit (Quad. 29-x: Putina; Fig.5 - No. 279)

Located at Dist. Azangaro, Dept. Puno, alt. 4,400 m, and 45 km from Crucero, the Marcia is a vein-type lead-silver-zinc ore deposit. The vein strikes N67° W and dips 60° NE, averaging 0.65 m in width. the ore minerals are argentiferous galena, sphalerite while the gangue minerals are quartz and iron oxide.

Currently, mining operation is suspended. Ores in the stockyard averages Ag 0.7 oz/s.t., Zn 10% and Pb 9.9%.

(12) San Antonio de Poto ore deposit (Quad. 29-x:Putina; Fig. 5 - No.277)

Located in Dist. Sandia, Dept. Puno, alt. 4,600 m, and 65 km from Putina, the San Antonio de Poto is a gold deposit, classified as the glacial sedimentary deposit, in conglomerates consisting mainly of pebble left after the retreat of glaciers. Gold is yielded in forms of threads, rarely nuggets or very fine-grained dissemination.

From 1962 to 71, run-of-mine ores totalling 3 million tons, averaging Au 0.26 g/t was mined by dredging operation. Operation has been suspended since then.

(13) La Rinconada ore reserves (Quad. 29-y: Rinconada; Fig. 5 - No.283)

Located in Dist. Sandia, Dept. Puno, alt. 5,000 m, and 15 km from Ananea, La Rinconada is a vein-type gold deposit in black slate of the Ananea Formation, which fills the manto structure. Gold is yielded in massive quartz, accompanied by microcrystals of arsenopyrite and pyrite.

The ore deposit is under small-scale exploitation. The ore reserves are unknown.

(14) Condorquiña ore deposit (Quad. 29-y: Rinconada; Fog. 5 - No.285)

Located at Dist. Sandia, Dept. Puno, alt. 5,000 m, and 17 km from Ananea, the Condorquiña is a vein-type tin-tungsten-copper-molybdenum ore deposit associated with the Limacpampa granite body in the Carabaya batholith complex. The ore deposit consists of a series of greisens including cassiterite, molybdenite, sphalerite and arsenopyrite, and also a chlorite-quartz vein. Dating of the mineralization indicates a Permian to Jurassic age.

(15) Palca XI ore deposit (Quad. 31-x: Huancané; Fig. 5 - No.300)

Located at Dist Huancané, Dept. Puno, alt. 4,600 m, and 45 km from Putina, the Palca XI is a vein-type tungsten ore deposit. The vein is of a platy structure, strikes N20° W and dips 50° NE, and lies near and in parallel with a reverse fault. The ore minerals are ferberite and scheelite, while the gangue minerals are quartz, kaolin, specularite, pyrite, magnetite and carbonate minerals.

The ore deposit is currently exploited by the cut and fill method at the rate of 7,900 tpm of crude ore. The ore reserves are 200,000 t, grading WO3 1.10%.

2-4 Considerations

The survey area is underlain by Paleozoic to Quaternary sedimentary rocks extending from NNW to SSE. Permian and Neogene intrusive rocks intrude into these rocks. In terms of the Peru's metallogenic provinces, the area extends over the central polymetallic belt, the tin belt and the marginal polymetallic belt.

The known mineralization in the area are divisible into the vein-type Au deposits in Paleozoic rocks, the Sn-W-Cu deposits related with Permian granites, the Ag-Pb-Cu-Zn vein- and skarn-type deposits in Triassic to Cretaceous rocks, and the Sn-W-Cu-Pb-Zn vein deposits related with Miocene granites. Besides, the Au placer deposits are distributed from the Cordillera Oriental to the Amazon plain, and the presence of uranium mineralization related with Miocene to Pliocene pyroclastic rocks is also known.

The mineralization in the survey area can be summarized as follows:

TheVein-type Au deposits in Paleozoic rocks :

- Santo Domingo, Manco Capac, Candelaria and Benditani
- Gavilán de Oro, Untuca, Ana María and Carabarcuna
- La Rinconada

The Sn-W-Cu deposits related with Permian granites :

- Condoriquiña and Sarita

The Ag-Pb-Cu-Zn vein and skarn deposits in the Triassic to Cretaceous rocks :

- Cerro del Inca Azur, Casa de Plata, Atura and Santa Ana

The Sn-W-Cu-Pb-Zn vein deposits related to Miocene granites :

- San Rafael and Palca XI

The Au placer deposits in the area spreading from the Cordillera Oriental to the Amazon plain :

- San Antonio de Poto, (the Madre de Dios, Huaypetuhe and Caichive rivers)

The Uranium mineralization related to Miocene to Pliocene pyroclastic rocks :

- The Macusani area

Table 7 List of ore deposits and mineral indications (1)

No.	NAME	QUAD-RANGLE	LATITUDE	LONGITUDE	EASTING	NORTHING	ELEMENT	WALL ROCK
1	CRISTO DE LOS ANDES	29-r	14-06-06S	072-05-29W	166161.7	8438834	CU	CUARCITAS INTERESTRATIFICADAS CON LUTITAS Y ARENISCAS MARGOSAS
2	AZULCACA	29-r	14-04-08S	072-25-40W	129745.8	8441960	CU AG AU	CALIZA, CUARCITA
3	FOCOMARCA	29-r	14-01-16S	072-23-10W	134175.7	8447318	CU AG AU	CALIZA
4	COCHASAYHUAS	29-r	14-06-24S	072-30-00W	121998.7	8437660	CU AG AU PB	CUARCITA, LUTITAS PIZARROZAS
5	LA SORPRESA	29-r	14-04-12S	072-28-33W	124551.8	8441761	CU AG	CALIZA
6	CRISTO DE LOS ANDES №1	29-r	14-15-40S	072-21-30W	137561.0	8420777	CU PB AG	CALIZAS.
7	PALAO №11	29-r	14-15-50S	072-23-30W	133963.6	8420417	AG PB	CALIZAS.
8	PALAO №12	29-r	14-15-30S	072-25-10W	130954.3	8420988	AG PB	CALIZAS.
9	PALAO №13	29-r	14-15-40S	072-23-00W	134860.0	8420738	AG PB	CALIZAS.
10	JUANITA №1 AL №4	29-r	14-03-30S	072-09-30W	158862.0	8443537	CU	CALIZAS.
11	AMERICO DARIO	29-r	14-07-00S	072-10-00W	158048.3	8437064	CU AG	CALIZAS.
12	UNION CERROPATAS	29-r	14-06-55S	072-28-05W	125466.5	8436758	AU AG	
13	SANTO CRISTO	29-r	14-10-45S	072-20-10W	139831.1	8429688	CU AU	
14	CHALCOBAMBA	29-r	14-03-10S	072-12-55W	152697.1	8444069	CU	CALIZAS
15	FERROBAMBA	29-r	14-05-54S	072-16-24W	146490.6	8438937	CU	CALIZAS
16	SULFOBAMBA	29-r	14-04-21S	072-18-24W	142847.0	8441748	CU	
17	CRISTO REY	29-r	14-17-00S	072-16-24W	146777.9	8418447	CU AU	
18	ESPERANZA	29-r	14-16-34S	072-16-45W	146136.2	8419238	AU	
19	OSCOLLO	29-r	14-15-18S	072-14-42W	149793.8	8421628	AU	ALUVIALES
20	CHARCAS	29-r	14-04-24S	072-21-44W	136841.6	8441570	CU AG AU	CALIZAS
21	HUANZO	29-r	14-13-00S	072-25-54W	129566.7	8425584	AU AG	
22	SAN ANTONIO	29-r	14-07-59S	072-25-08W	130810.3	8434866	AG AU CU PB ZN	
23	TAYA	29-r	14-11-31S	072-21-02W	138290.6	8428450	AG AU	
24	MALLMANLLA	29-r	14-08-00S	072-10-20W	157472.1	8435211	CU	INTRUSIVAS, SEDIMENTARIAS
25	CRISTO DE LOS ANDES 1	29-r	14-05-51S	072-05-18W	166486.3	8439300	CU	ARENISCAS, LUTITAS
26	PODEROSA I	29-r	14-00-39S	072-00-40W	174710.2	8449005	PB AG	
27	CERRO PUYANI	29-r	14-08-20S	072-00-30W	175191.7	8434829	PB AG	
28	SAN SEBASTIANO	29-r	14-09-25S	072-01-29W	173446.7	8432807	PB ZN CU	
29	20 DE ENERO	29-r	14-09-25S	072-00-03W	176027.7	8432840	PB ZN CU AG	
30	IMPERIAL	29-r	14-27-00S	072-05-00W	167544.8	8400271	FE	GRANODIORITA, CALIZA
31	CERRO DE PASCO	29-r	14-17-08S	072-02-30W	171801.7	8418541	FE	GRANODIORITA, CALIZA
32	DOLORES JATUN PUYANI	29-r	14-11-17S	072-30-00W	122133.5	8428644	PB AG	CALIZAS
33	SANTA JUDITH	29-r	14-16-01S	072-04-06W	168894.0	8420564	PB AG	CALIZA
34	CARMEN ALTO 1	29-r	14-19-55S	072-00-43W	175077.5	8413446	AU CU	DIORITA
35	PODEROSA	29-r	14-00-39S	072-00-40W	174710.2	8449005	PB	SEDIMENTARIA
36	JARMAHUACHO	29-r	14-05-00S	072-01-00W	174211.6	8440969	CU	INTRUSIVAS, SEDIMENTARIAS
37	HUINCHOS	29-r	14-07-03S	072-01-40W	173059.7	8437170	CU AU	
38	LA GRAN PIRAMIDE	29-r	14-15-00S	072-06-00W	165449.4	8422396	AU	
39	CALIZA AZUL	29-s	14-15-58S	071-48-34W	844307.4	8420479	AG PB	SEDIMENTARIAS
40	QUIMBALETE	29-s	14-20-22S	071-48-34W	844195.6	8412357	CU	CALIZAS
41	PROVIDENCIA D	29-s	14-20-55S	071-47-26W	846221.3	8411314	CU AG	CALIZAS
42	SILVIA I	29-s	14-21-49S	071-50-51W	840049.9	8409737	CU AU	VOLCANICAS
43	AUREA	29-s	14-21-00S	071-48-00W	845199.3	8411174	CU AG	SEDIMENTARIA, INTRUSIVO
44	URIEL PRIMERO	29-s	14-25-16S	071-30-33W	876487.1	8402841	PB AG ZN CU	INTRUSIVAS
45	SAN MARTIN	29-s	14-19-00S	071-42-00W	856050.5	8414714	NI CU	CALCAREO FERRUGINOSO
46	EMPERATRIZ	29-s	14-18-16S	071-59-36W	824392.0	8416499	AU	CALIZA, CUARCITA, LUTITA
47	CARMEN ALTO NUEVO	29-s	14-07-55S	071-56-66W	829140.8	8435542	AU	
48	SAN MARCELO	29-s	14-06-36S	071-59-27W	824939.2	8438027	PB ZN AG	
49	CARMELITANA	29-s	14-00-58S	071-59-43W	824591.9	8448429	PB ZN AG	
50	LUCIUS	29-s	14-21-39S	071-46-16W	848302.1	8409931	PB CU ZN	
51	PODEROSA	29-s	14-06-46S	071-58-36W	826466.4	8437699	PB AG	SEDIMENTARIAS
52	MARCELO	29-s	14-07-07S	071-59-03W	825647.6	8437064	PB AG	CALIZA

Table 7 List of ore deposits and mineral indications (2)

No.	NAME	QUAD-RANGLE	LATITUDE	LONGITUDE	EASTING	NORTHING	ELEMENT	WALL ROCK
53	BRILLANTE AZUL	29-s	14-27-21S	071-47-23W	846146.2	8399437	PB ZN CU	
54	IRIS	29-s	14-06-20S	071-59-10W	825455.9	8438512	CU	DIORITA, CALIZA
55	VELASCO 1	29-s	14-27-35S	071-46-10W	848327.9	8398976	CU	DIORITA, CALIZA
56	TORO SENTADO	29-s	14-24-30S	071-46-03W	848617.9	8404664	CU PB	DIORITA, CALIZA
57	MONTE ROJO	29-s	14-23-06S	071-47-25W	846195.6	8407283	CU	CALIZA, DIORITA
58	SAN MARTIN No 37 AL 64	29-s	14-17-50S	071-30-27W	876874.4	8416563	FE	CALIZAS
59	EXALTACION	29-s	14-24-15S	071-53-20W	835521.7	8405307	CU	SEDIMENTARIAS
60	MONTE ROJO #2	29-s	14-23-35S	071-46-40W	847532.3	8406372	CU	INTRUSIVAS
61	HURANIO	29-s	14-25-00S	071-44-00W	852293.8	8403689	FE CU	SEDIMENTARIAS, INTRUSIVAS
62	LIVITACA	29-s	14-15-00S	071-46-00W	848952.9	8422199	AU FE	SEDIMENTARIAS
63	SAN MARTIN	29-s	14-10-30S	071-56-30W	830159.4	8430760	FE	SEDIMENTARIAS, INTRUSIVAS
64	LOMAS DE ORO	29-s	14-19-34S	071-44-56W	850755.9	8413743	PB AG ZN CU	
65	CUMBRE ROJA	29-s	14-17-30S	071-50-54W	840068.8	8417706	PB AG ZN CU	
66	LAS FLORES No3	29-t	14-24-47S	071-18-00W	899086.3	8403380	CU AG	ARENISCAS ARCOSICAS
67	CARMEN	29-t	14-16-09S	071-14-10W	906245.9	8419212	CU AG	SEDIMENTARIO (LUTITA Y ARENISCA).
68	WILLY	29-t	14-23-56S	071-15-50W	903012.3	8404887	CU AG	SEDIMENTARIO (ARENISCAS ARKOSICAS)
69	ROCIO DEL CARME	29-t	14-24-43S	071-18-00W	899088.3	8403503	CU AG	SEDIMENTARIO-ARENISCA ARCOSICA.
70	CLARA LUZ	29-t	14-23-24S	071-17-11W	900597.4	8405911	CU AG	ARENISCA
71	CAYMA	29-t	14-11-52S	071-19-20W	897065.9	8427271	AG CU	ARENISCAS Y LUTITAS
72	ELIANA	29-t	14-21-37S	071-13-55W	906532.4	8409109	AG CU	SEDIMENTARIO- ARENISCAS Y LUTITAS.
73	GIOVANA	29-t	14-24-33S	071-12-12W	909533.9	8403641	AG CU	ARENISCAS GRISES Y LUTITAS MARRONES
74	MARIA DORA	29-t	14-27-00S	071-02-00W	927818.1	8398805	AG CU AU	PIZARRAS Y ARENISCAS CUARCITICAS.
75	PORVENIR	29-t	14-22-25S	071-06-04W	920641.4	8407397	SB	PIZARRAS Y ARENISCAS CUARZOSAS
76	POTOSI No1	29-t	14-20-00S	071-08-15W	916785.4	8411926	AG SB	PIZARRAS, LUTITAS Y ARENISCAS.
77	ESPERANZA AURORA No	29-t	14-20-24S	071-04-17W	923916.1	8411067	SB	PIZARRAS Y LUTITAS
78	FE Y ESPERANZA	29-t	14-01-13S	071-21-36W	893287.0	8447002	SB PB AG	PIZARRAS AMARILLAS Y NEGRAS.
79	JESUS NAZARENO No6	29-t	14-18-43S	071-08-20W	916674.9	8414299	CU AG PB	CALIZAS
80	REBUSCADA No1	29-t	14-22-52S	071-04-51W	922818.1	8406528	SB PB CU	PIZARRAS PRINCIPALMENTE, CON ALGO DE CUARCITAS,ARENISCAS Y LUTITAS.
81	MODESTIA	29-t	14-20-21S	071-08-37W	916114.3	8411291	SB	PIZARRAS, CUARCITAS Y ARENISCAS.
82	AUGUSTA V	29-t	14-19-36S	071-01-57W	928143.5	8412473	SB CU	PIZARRAS Y CUARCITAS
83	FRANCISCA No1	29-t	14-25-52S	071-25-51W	884927.4	8401603	CU AG	ARENISCAS
84	FRANCISCA No2	29-t	14-25-50S	071-25-50W	884958.0	8401664	CU AG	ARENISCAS
85	FRANCISCA No3	29-t	14-25-15S	071-04-02W	924213.3	8402101	SB	PIZARRAS
86	SAN JUAN DE HERCCA	29-t	14-21-54S	071-12-30W	909073.9	8408544	AG CU	ARENISCAS
87	SANTA ROSA	29-t	14-18-23S	071-14-26W	905699.1	8415096	AG CU	ARENISCAS
88	LEILA	29-t	14-18-20S	071-14-26W	905700.6	8415188	AG CU	ARENISCAS
89	MACUSANI	29-t	14-16-18S	071-13-44W	907022.2	8418923	AL	
90	SACSAYHUAMAN	29-t	14-20-35S	071-05-25W	921869.3	8410763	SB	CUARCITA, ESQUISTOS, ARENISCA
91	GILDA	29-t	14-15-39S	071-12-40W	908962.9	8420092	AU CU	LUTITA, ARENISCA
92	AMPARO LUCIA	29-t	14-15-39S	071-12-40W	908962.9	8420092	AU	ARENISCA
93	LAURA JESUS	29-t	14-15-39S	071-12-40W	908962.9	8420092	AU CU	ARENISCA
94	VILCANOTA	29-t	14-25-00S	071-00-00W	931482.7	8402437	CU ZN PB AG	SEDIMENTARIAS
95	SAN RAMON	29-t	14-26-00S	071-02-00W	927850.1	8400652	SB CU	
96	PATANZA	29-t	14-12-00S	071-13-30W	907571.5	8426857	CU	
97	MARIA DE FATIMA	29-t	14-20-00S	071-08-00W	917235.5	8411919	CU AU	PIZARRAS, CUARCITAS Y ARENISCAS
98	CHANCHAN	29-t	14-28-00S	071-10-00W	913387.7	8397203	AG CU SB AU	
99	U.E.A. ANDEREAL	29-t	14-22-00S	071-11-00W	911771.7	8408315	ZN PB	
100	REMIGIA N§ 1	29-t	14-25-00S	071-30-00W	877483.9	8403318	AG PB ZN	INTRUSIVAS-DACITAS Y LUTITAS PORFIRITICAS
101	URIEL PRIMERO	29-t	14-25-00S	071-30-00W	877483.9	8403318	AG PB ZN AU	INTRUSIVAS
102	MALENA SEGUNDA	29-t	14-25-00S	071-30-00W	877483.9	8403318	AG PB ZN	INTRUSIVAS-DACITAS Y LUTITAS PORFIRITICAS
103	ANDEREAL N§3	29-t	14-22-00S	071-11-00W	911771.7	8408315	CU AU	
104	COBRE INCA	29-t	14-28-00S	071-11-00W	911587.6	8397233	CU AU	PIZARRAS, CUARCITAS Y ARENISCAS

Table 7 List of ore deposits and mineral indications (3)

No.	NAME	QUAD-RANGLE	LATITUDE	LONGITUDE	EASTING	NORTHING	ELEMENT	WALL ROCK
105	OFELIA II, MINA	29-u	14-29-00S	070-53-33W	296021	8397957	PB AG ZN	ESQUISTOS PIZARROSOS
106	REYNA DE LOS ANGELES, MINA	29-u	14-28-00S	070-54-00W	295197	8399794	W	
107	OFELIA I, MINA	29-u	14-27-32S	070-56-00W	291596	8400625	PB AG ZN	ESQUISTOS PIZARROSOS
108	ESPERANZA DE POTONI , MINA	29-u	14-24-36S	070-40-00W	320309	8406260	PB AG	ARENISCA
109	OSINOCCA DEL INCA No34, MINA	29-u	14-16-58S	070-46-40W	308219	8420247	CU AG	
110	OSINOCCA DEL INCA No35, MINA	29-u	14-16-35S	070-46-29W	308543	8420956	CU AG	GRANITO
111	CHIHUISCALLANI DEL INCA, MINA	29-u	14-16-10S	070-46-15W	308957	8421728	CU AG	PIZARRAS
112	SANTA ELENA No 100, MINA	29-u	14-16-06S	070-46-06W	309226	8421853	CU AG	PIZARRAS
113	CARABAYA, MINA	29-u	14-15-30S	070-33-30W	331879	8423121	CU PB ZN	SEDIMENTARIAS, METAMORFICAS
114	TRES MARIAS, MINA	29-u	14-15-12S	070-36-54W	325760	8423633	CU AG	METACUARCITAS, CUARCITAS, PIZARRAS
115	VIRGEN DEL CARMEN No 6, MINA	29-u	14-13-54S	070-47-36W	306496	8425889	SB	DACITA
116	SAN RAFAEL II, MINA	29-u	14-12-10S	070-34-40W	329739	8429254	SN CU	FILITAS, CUARCITAS
117	CINCO HERMANITOS, MINA	29-u	14-11-42S	070-43-21W	314112	8430004	SB	RIOLITA
118	QUENAMARI, MINA	29-u	14-11-30S	070-32-30W	333629	8430509	CU SN	PIZARRAS, ARENISCAS, CALIZAS
119	MINSUR LLOCCESA II, MINA	29-u	14-09-30S	070-33-20W	332105	8434187	CU SB	SEDIMENTARIAS
120	MINSUR LLOCCESA I, MINA	29-u	14-09-30S	070-34-00W	330905	8434179	CU SN	SEDIMENTARIAS
121	CORANI, MINA	29-u	14-08-00S	070-35-30W	328188	8436926	PB ZN AG	TUFOS RIOLITICOS
122	MERCEDES, MINA	29-u	14-03-00S	070-35-53W	327435	8446141	PB ZN AG	ARENISCAS
123	LOLA, MINA	29-u	14-02-40S	070-35-00W	329021	8446767	PB AG ZN	ARENISCAS
124	FIDEL, MINA	29-u	14-01-12S	070-34-36W	329723	8449476	AG SB	ADAMELITA
125	CECILIA, MINA	29-v	14-27-54S	070-03-33W	385843	8400564	AG PB ZN	
126	CECILIA 7, MINA	29-v	14-27-54S	070-03-51W	385304	8400561	ZN PB AG	LUTITAS PIZARROSAS, ARENISCAS, CUARCITAS, CALIZAS
127	TRES AVENTUREROS, MINA	29-v	14-26-58S	070-12-05W	370504	8402209	CU PB AG	ARENISCAS, CALIZAS
128	SAN ANTONIO, MINA	29-v	14-25-18S	070-23-02W	350810	8405171	CU AG	ARENISCAS
129	SAN ANTONIO No9, MINA	29-v	14-25-18S	070-02-28W	387768	8405366	PB AG ZN	ARENISCAS, CALIZAS
130	LEONOR, MINA	29-v	14-25-09S	070-25-09W	347005	8405424	PB AG ZN	CALIZAS
131	CERRO DEL INCA No 28	29-v	14-23-30S	070-24-36W	347975	8408473	PB AG	CALIZAS
132	PICHICAPA, MINA	29-v	14-21-00S	070-14-30W	366102	8413187	PB ZN AG	ARENISCAS
133	GENCHURUNI, MINA	29-v	14-21-00S	070-03-00W	386773	8413289	PB AG CU	ANDESITAS, CALIZAS, ARENISCAS
134	DON ARTURO, MINA	29-v	14-17-04S	069-58-11W	395400	8420578	PB AG CU	ARENISCAS, LUTITAS, CALIZAS, DIORITA
135	ROSA DE BUENA ESPERANZA No4, MINA	29-v	14-16-30S	070-20-24W	355449	8421424	PB AG	CALIZA, ARENISCA
136	SANTA ANA 1, MINA	29-v	14-16-15S	070-02-05W	388382	8422054	CU AG	DIORITA
137	CERRO BLINDADO, MINA	29-v	14-16-13S	070-03-12W	386374	8422106	CU AG	CALIZAS, LUTITAS, PIZARRAS
138	CERRO DEL INCA No27, MINA	29-v	14-16-12S	070-02-00W	388531	8422146	AG PB	ARENISCAS, PIZARRAS
139	ALI BABA, MINA	29-v	14-16-00S	070-01-00W	390328	8422523	CU AG	CUARCITAS
140	SORPRESA, MINA	29-v	14-16-00S	070-01-00W	390328	8422523	PB AG	ARENISCA
141	SANTA ANA DOS, MINA	29-v	14-15-54S	070-00-00W	392125	8422715	CU AG	ARENISCAS
142	COLQUIHUASI, MINA	29-v	14-15-12S	070-00-42W	390861	8424000	PB AG	ARENISCAS
143	EL ESPAÑOL, MINA	29-v	14-15-01S	070-01-30W	389421	8424332	PB AG	ARENISCAS
144	CASA DE PLATA, MINA	29-v	14-14-18S	069-59-27W	393101	8425669	PB AG	ARENISCA
145	NO SEAS ENVIDIOSO,MINA	29-v	14-13-35S	070-19-30W	357036	8426811	AG PB ZN SN	CUARCITAS
146	LUCILA DEL INCA No 3, MINA	29-v	14-13-28S	069-59-30W	393005	8427205	PB AG	ARENISCAS
147	QUENAMARI, PROSPECTO	29-v	14-13-24S	070-13-20W	368126	8427210	CU AG	LUTITA
148	SAN RAFAEL, MINA	29-v	14-13-20S	070-19-06W	357753	8427276	SN CU	CUARCITAS
149	SAN LUIS 1, MINA	29-v	14-12-59S	069-59-10W	393601	8428099	CU PB AG	ARENISCAS
150	SAN MARTIN, MINA	29-v	14-12-45S	070-01-15W	389852	8428513	CU AG	PIZARRAS Y ARENISCAS
151	LA REYNA, MINA	29-v	14-12-45S	070-01-15W	389852	8428513	CU AG	ARENISCAS, PIZARRAS
152	PRECOS, MINA	29-v	14-12-24S	070-10-14W	373692	8429082	W AU	TONALITA
153	SAN JUAN BAUTISTA No11 , MINA	29-v	14-12-15S	070-11-57W	370603	8429343	PB AG	ARENISCAS
154	UNION , MINAS	29-v	14-11-57S	070-18-09W	359448	8429836	CU AG PB SN	
155	NAZARETH No29, MINAS	29-v	14-11-57S	070-18-09W	359448	8429836	CU AG SN	PIZARRAS, MONZONITA
156	SAN JUAN No 100, CONCESION	29-v	14-11-54S	070-03-03W	386608	8430065	CU PB AG	ARENISCA

Table 7 List of ore deposits and mineral indications (4)

No.	NAME	QUAD-RANGLE	LATITUDE	LONGITUDE	EASTING	NORTHING	ELEMENT	WALL ROCK
157	EL CONDOR, MINA	29-v	14-11-50S	070-18-00W	359716	8430053	CU AG	GRANITO
158	SAN JUAN BAUTISTA, MINA	29-v	14-11-42S	070-12-00W	370507	8430357	PB AG	ARENISCAS
159	NAZARETH, MINA	29-v	14-11-42S	070-18-00W	359715	8430299	CU AG	PIZARRAS
160	NAZARETH 17, MINA	29-v	14-11-30S	070-22-35W	351468	8430620	AG PB ZN	PIZARRAS, ESQUISTOS, CUARCITAS
161	SAN FROILAN №1, MINA	29-v	14-11-20S	070-03-06W	386513	8431110	CU AG	ANDESITA
162	SAN JUAN BAUTISTA № 1, MINA	29-v	14-11-18S	070-12-09W	370234	8431093	PB AG	ARENISCA
163	ROSARIO DE ANTAUTA, MINA	29-v	14-11-10S	070-22-05W	352364	8431240	CU ZN PB AG	PIZARRAS, ESQUISTOS, CUARCITAS
164	CONDE DE MONTECRISTO, MINA	29-v	14-11-02S	070-06-09W	381024	8431637	PB AG	ARENISCAS, PIZARRAS
165	IRMA DEL INCA № 19, MINA	29-v	14-11-00S	070-08-12W	377336	8431681	CU AG	ARENISCAS
166	NAZARETH 27, MINA	29-v	14-11-00S	070-18-10W	358408	8431588	CU AG AU	PIZARRAS
167	VIRGEN DE CHAPI, MINA	29-v	14-10-53S	070-10-18W	373558	8431878	CU AG PB	ARENISCAS
168	ROMMEL II, CONCESION	29-v	14-10-36S	070-02-30W	387586	8432466	CU PB AG	ARENISCA
169	SILVIA PRIMERA, MINA	29-v	14-09-39S	070-13-12W	368329	8434125	CU AG	CUARCITAS, CALIZAS
170	VOLVEREMOS, MINA	29-v	14-08-18S	070-07-02W	379411	8436669	PB AG	ARENISCAS
171	MINERA LOS CORAJE, MINA	29-v	14-07-00S	070-03-30W	385757	8439065	W CU	GRANITO, GRANODIORITA
172	CHICASCO № 4, MINA	29-v	14-06-54S	070-06-00W	381258	8439259	AG CU	ARENISCAS
173	LA FABULOSA; MINA	29-v	14-03-03S	070-22-30W	351527	8446201	SB	PIZARRA
174	UNION S.A., MINA	29-v	14-02-00S	070-22-00W	352416	8448142	CU AG	METAMORFICAS, SEDIMENTARIAS, VOLCANICAS
175	VIRGEN DE ASUNTA № 2, MINA	29-v	14-01-42S	070-22-00W	352412	8448695	CU AG	ARENISCAS
176	SUSUYA, MINA	29-v	14-01-06S	070-19-36W	356726	8449826	CU AG AU	GRANITO
177	MIGUEL ANGEL №1, MINA	29-v	14-00-00S	070-18-32W	358635	8451865	CU AG	ANDESITAS
178	PRINCESA, MINA	29-x	14-29-17S	069-57-18W	397082	8398063	AG PB MN	ARENISCAS
179	JAIME, MINA	29-x	14-28-48S	069-51-39W	407227	8398994	PB CU AG	CALIZA
180	PUNO 27, MINA	29-x	14-27-30S	069-31-44W	442997	8401499	W SB	IGNEAS, METAMORFICAS
181	SANTA ROSA DE PATAMBUCO, MINA	29-x	14-26-58S	069-43-09W	422485	8402426	AG PB CU	PIZARRAS
182	DIONICIA I, MINA	29-x	14-25-12S	069-46-09W	417085	8405666	PB CU	ARENISCA, PIZARRA
183	JUAN-PEPE-MANUEL, MINA	29-x	14-22-39S	069-44-24W	420214	8410377	CU AG AU	PIZARRA
184	NICARAGUA, MINA	29-x	14-21-55S	070-00-00W	392173	8411623	PB	CALIZAS
185	CERRO VERDE, MINA	29-x	14-21-00S	069-59-30W	393064	8413317	CU	ANDESITAS
186	ROSARIO DE CRUCERO X, MINA	29-x	14-18-18S	069-53-15W	404279	8418340	CU AG	GRANODIORITA
187	SARITA №1, MINA	29-x	14-16-54S	069-53-18W	404179	8420921	CU AG	VOLCANICAS Y SEDIMENTARIAS
188	DOÑA ELVIRA, MINA	29-x	14-16-12S	069-57-06W	397342	8422184	PB AG CU	ARENISCA
189	MILAGRO DE CANCHARANI, MINA	29-x	14-16-06S	069-46-09W	417029	8422441	PB ZN CU	GRANODIORITA
190	CERRO DEL INCA AZUL, MINA	29-x	14-16-00S	069-59-24W	393205	8422535	PB ZN AG	ARENISCAS
191	MAYCITA I, MINA	29-x	14-16-00S	069-57-30W	396621	8422550	AG CU PB	CALIZAS, ANDESITAS, ARENISCAS
192	PILCO DEL INCA, MINA	29-x	14-14-18S	069-58-32W	394750	8425676	CU AG	DACITA
193	REY DEL PLOMO, MINA	29-x	14-14-06S	070-00-21W	391481	8426031	PB AG	CALIZAS, LUTITAS, PIZARRAS
194	BOTARICA, MINA	29-x	14-14-00S	069-59-24W	393189	8426223	PB	ARENISCAS
195	INCA №2, MINA	29-x	14-13-00S	069-56-30W	398397	8428088	AG PB	CALIZAS, ARENISCAS, PIZARRAS
196	JERUSALEN 12, MINA	29-x	14-12-57S	069-54-12W	402533	8428196	AG CU	GRANODIORITA
197	CERRO DEL INCA №25, MINA	29-x	14-12-57S	069-54-12W	402533	8428196	CU	PIZARRAS
198	CERRO DEL INCA №26, MINA	29-x	14-12-57S	069-54-12W	402533	8428196	CU AG	PIZARRAS
199	CERRO DEL INCA №35, MINA	29-x	14-12-30S	069-54-01W	402859	8429027	CU	PIZARRAS
200	ZONA AURIFERA DE PACOPACUNI	29-x	14-12-05S	069-35-00W	437057	8429904	AU	PIZARRA
201	CERRO DEL INCA №1, MINA	29-x	14-12-00S	069-54-43W	401597	8429944	CU	ARENISCAS
202	TUTUNCHI, MINA	29-x	14-11-57S	069-54-12W	402525	8430040	CU	ARENISCAS
203	SAN JOSE, PROSPECTO	29-x	14-09-30S	069-49-30W	410963	8434588	CU AG	PIZARRAS
204	SALVADOR DE CARCEL PUNCO, MINA	29-x	14-06-18S	069-45-36W	417959	8440510	AU	PIZARRAS Y LUTITAS
205	SEÑOR DE CCAPAZO №1, MINA	29-x	14-06-00S	069-33-15W	440178	8441125	AU	PIZARRAS
206	CORDOVA A, MINA	29-x	14-04-29S	069-31-58W	442481	8443926	CU AU	TONALITA
207	ALPACATO, BANCO	29-x	14-01-35S	069-36-42W	433949	8449252	AU	MATERIAL ALUVIAL
208	SANTA MARIA, BANCO	29-x	14-01-12S	069-36-06W	435027	8449961	AU	MATERIAL ALUVIAL

Table 7 List of ore deposits and mineral indications (5)

No.	NAME	QUAD-RANGLE	LATITUDE	LONGITUDE	EASTING	NORTHING	ELEMENT	WALL ROCK
209	ANTONIO 1, MINA	29-y	14-15-00S	069-15-00W	473031	8424592	CU AG	GRANODIORITA
210	FLOR DE JESUS, MINA	29-y	14-14-19S	069-25-19W	454479	8425825	AU	CONGLOMERADO
211	SALVADOR, MINA	29-y	14-09-12S	069-04-06W	492625	8435296	AG CU	GRANODIORITA
212	LUCKY STRIKE, MINA	29-y	14-01-30S	069-28-30W	448707	8449439	AU	MATERIAL ALUVIAL
213	EL REBELDE, MINA	29-y	14-05-00S	069-22-00W	460445	8424575	AU	CONGLOMERADO
214	DELFI MARINA, MINA	29-y	14-03-30S	069-19-00W	465810	8445781	AU	CONGLOMERADO
215	SAN MIGUEL I, MINA	29-y	14-02-40S	069-29-00W	447812	8447287	AU	PIZARRAS
216	ESTRELLA DEL SUR, MINA	29-y	14-09-00S	069-27-00W	451433	8435619	AU	CONGLOMERADO
217	BUEN SUCESO, MINA	29-y	14-10-00S	069-05-30W	490108	8433821	AU	CONGLOMERADO
218	CERRO DEL INCA No3, MINA	29-y	14-16-00S	070-01-00W	390328	8422523	PB AG	ARENISCA
219	SERPIENTE DE ORO, MINA	29-y	14-12-30S	069-06-20W	488611	8429212	AU	CONGLOMERADO
220	MONTEBELLO, PROSPECTO	29-y	14-14-08S	069-26-40W	452051	8426158	AU	
221	NUEVO HORIZONTE, MINA	29-y	14-13-00S	069-15-00W	473027	8428278	AU	DACITAS, ANDESITAS, GRANODIORITAS
222	PUCASAYA; MINA	30-u	14-55-30S	070-53-30W	296521	8349084	CU AG	ARENISCAS, CUARCITAS
223	NAPOLEON BONAPARTE III, MINA	30-u	14-48-41S	070-34-25W	330652	8361921	PB AG	CALIZAS
224	SANTA ROSA DE QUIVES A, MINA	30-u	14-48-30S	070-34-00W	331397	8362264	PB AG	ARCILLAS
225	SANTA TERESA DE JESUS No1, MINA	30-u	14-43-30S	070-34-15W	330884	8371481	PB	CALIZAS, ARENISCAS
226	SANTA MARTHA No1, MINA	30-u	14-37-30S	070-38-00W	324074	8382498	CU AG	ARENISCAS
227	OFELIA No1 Y No2; DENUNCIO	30-u	14-36-34S	070-48-39W	304937	8384074	PB ZN	
228	RAYA BLANCA, MINA	30-u	14-36-05S	070-47-30W	306995	8384981	PB AG	PIZARRAS
229	CHOLINA TULA, MINA	30-u	14-32-50S	070-51-21W	300032	8390920	SB W	PIZARRAS
230	CHOLINA DE VIZCACHANI, MINA	30-u	14-32-30S	070-51-00W	300655	8391540	SB W	PIZARRAS
231	ANTONITO, MINA	30-v	15-00-39S	070-13-24W	368480	8340112	SB	PIZARRAS
232	DEFENSA No2, MINA	30-v	15-00-27S	070-14-03W	367314	8340474	SB	PIZARRAS,LUTITAS
233	GERMANIA, MINA	30-v	15-00-21S	070-13-42W	367940	8340662	SB	PIZARRAS,LUTITAS
234	SANTA ROSA DE CHAIPICOCHA, MINA	30-v	15-00-00S	070-15-00W	365606	8341295	SB CU AG PB	PIZARRAS
235	SEÑOR DE LOS MILAGROS DEL SANTUARIO, MINA	30-v	14-59-18S	070-15-03W	365509	8342585	SB	PIZARRAS
236	SAN ANTONIO No 2, MINA	30-v	14-59-06S	070-15-15W	365149	8342951	SB	PIZARRAS, LUTITAS
237	CHAPI 4, MINA	30-v	14-58-54S	070-15-18W	365057	8343320	SB	PIZARRAS
238	MACAYA II, MINA	30-v	14-58-40S	070-01-30W	389788	8343877	CU AG AU	ARENISCAS
239	VICTORIA I, MINA	30-v	14-58-15S	070-15-15W	365140	8344519	AG PB CU	ARENISCAS
240	SURUPANA No2, MINA	30-v	14-57-27S	070-02-00W	388882	8346116	AG PB CU	ARENISCA, CUARCITAS
241	LILIANA MAURILIA No 3, MINA	30-v	14-56-15S	070-18-57W	358486	8348168	PB SB AG	PIZARRAS
242	BENDITANI, PROSPECTO	30-v	14-54-14S	070-11-37W	371613	8351960	AU	
243	SAN RAFAEL, MINA	30-v	14-50-55S	070-10-28W	373642	8358086	CU	ARENISCA
244	TITIÑAHUI B, MINA	30-v	14-47-36S	070-28-18W	341619	8364013	AG PB	ARENISCAS, CALIZAS
245	JUAN FRANCISCO, MINA	30-v	14-43-30S	070-03-18W	386430	8371824	CU	ARENISCAS
246	ASUNTA, MINA	30-v	14-40-54S	070-06-21W	380934	8376591	CU PB	ARENISCAS
247	SURUPANA, MINA	30-v	14-37-48S	070-06-55W	379889	8382302	AG CU	ARENISCA, DIQUE ANDESITICO
248	REVANCHA, MINA	30-v	14-36-00S	070-18-30W	359076	8385509	SB PB	GRANODIORITA, BRECHA VOLCANICA
249	NAZARETH No27, PROSPECTO	30-v	14-34-18S	070-12-00W	370730	8388708	CU AG AU	CALIZA
250	LOS TRES AVENTUREROS, DENUNCIO	30-v	14-33-00S	070-18-30W	359044	8391041	AG PB	CALIZA, ANDESITA
251	ROSA TINGACHA-DOS, MINA	30-v	14-31-50S	070-13-24W	368191	8393243	AG PB CU	DIORITA
252	CANUNI, MINA	30-v	14-30-48S	070-12-55W	369049	8395152	AG PB ZN SB	CUARCITAS
253	JUAN JOSE, MINA	30-v	14-30-42S	070-10-21W	373658	8395361	CU PB ZN AG AU	RIOLITA
254	FORTALEZA, MINA	30-v	14-30-42S	070-10-21W	373658	8395361	CU PB ZN AG AU	RIOLITA
255	SAN ANTONIO No 2, MINA	30-v	14-25-15S	070-09-21W	375404	8405418	CU AG	PIZARRAS
256	POMASI DEL INCA, MINA	30-v	14-22-30S	070-08-00W	377804	8410500	PB AG	CALIZAS
257	LUIS CARLOS, MINA	30-x	14-58-42S	069-46-42W	416313	8343924	SB PB ZN	PIZARRAS
258	CARCOUTA, MINA	30-x	14-58-12S	069-59-30W	393369	8344754	AG PB SB	ARENISCAS Y LUTITAS
259	4 DE JULIO, MINA	30-x	14-57-54S	069-52-18W	406271	8345361	CU	ARENISCAS
260	CONCEPCION DOS, MINA	30-x	14-55-13S	069-50-40W	409171	8350319	SB AU	ANDESITAS PORFIRITICAS, CALIZAS

Table 7 List of ore deposits and mineral indications (6)

No.	NAME	QUAD-RANGLE	LATITUDE	LONGITUDE	EASTING	NORTHING	ELEMENT	WALL ROCK
261	NILDA, MINA	30-x	14-54-58S	069-58-45W	394687	8350721	PB ZN AG	CALIZAS
262	LA SUERTE RM UNO, MINA	30-x	14-54-00S	069-51-30W	407677	8352557	AG PB ZN	CALIZAS
263	REGINA, MINA	30-x	14-53-57S	069-43-36W	421840	8352699	W	
264	SUMA ARUMA, MINA	30-x	14-53-30S	069-51-00W	408570	8353482	SB	
265	NATTY, MINA	30-x	14-53-30S	069-52-00W	406777	8353475	SB	
266	SAN ISIDRO, MINA	30-x	14-52-36S	069-53-33W	403991	8355123	SB	PIZARRAS
267	SAN PEDRO, MINA	30-x	14-51-30S	069-44-00W	421108	8357213	SB AG	PIZARRAS, CALIZAS
268	CECILIA 9, MINA	30-x	14-50-00S	069-42-42W	423430	8359986	PB AG	CALIZA
269	CECILIA 5, MINA	30-x	14-49-39S	069-40-58W	426536	8360641	PB ZN AG	ARENISCAS, CUARCITAS
270	QUIETA NEGRA, MINA	30-x	14-47-50S	069-42-30W	423776	8363982	W ZN PB AG	CALIZAS, ANDESITAS
271	CONCEPCION DOS, MINA	30-x	14-47-50S	069-42-30W	423776	8363982	SB	CALIZAS, ANDESITAS
272	MATIAS I, MINA	30-x	14-46-30S	069-54-30W	402242	8366362	AG PB ZN	PIZARRAS, ARENISCAS, LUTITAS
273	RECUPERADA DOS, MINA	30-x	14-45-30S	069-41-00W	426453	8368291	CU AG	PIZARRA, ESQUISTOS
274	SANTA ANITA, MINA	30-x	14-44-00S	069-56-30W	398635	8370956	PB ZN	ARENISCAS, CUARCITAS
275	VIZCACHANI, MINA	30-x	14-42-30S	069-32-00W	442585	8373865	AU	
276	ALEJANDRITO 2,MINA	30-x	14-42-15S	069-42-30W	423743	8374274	PB AG ZN	ARENISCAS
277	SAN ANTONIO DE POTO, MINA	30-x	14-41-00S	069-32-00W	442578	8376631	AU	CONGLOMERADO
278	SEÑOR DE LOS MILAGROS №1, MINA	30-x	14-39-12S	069-41-06W	426239	8379905	CU PB AG ZN	CUARCITAS
279	MARCIA, MINA	30-x	14-34-12S	069-56-30W	398560	8389023	AG PB ZN	CONGLOMERADO
280	ANCOCCALA, MINA	30-x	14-33-12S	069-41-06W	426205	8390966	SN AU	PIZARRAS, ARENISCAS, CUARCITAS EN FRAGMENTOS DENTRO DE MATERIAL DETRITICO
281	TRAPICHE №3, MINA	30-y	14-45-30S	069-25-30W	454258	8368360	AU	PIZARRAS
282	ANA MARIA, MINA	30-y	14-39-50S	069-27-55W	449901	8378797	AU	PIZARRAS
283	LA RINCONADA, MINA	30-y	14-39-24S	069-27-30W	450648	8379598	AU	ARENISCAS CUARZOSAS, ESQUISTOS NEGROS ARENOSOS
284	MARIBEL DE ORO, MINA	30-y	14-37-30S	069-25-00W	455128	8383109	AU	LUTITAS
285	CONDORIQUIÑA, MINA	30-y	14-32-30S	069-29-10W	447629	8392311	SN	PIZARRAS, CUARCITAS
286	SUCHES, MINA	30-y	14-31-00S	069-15-99W	471298	8395115	AU	PIZARRAS
287	SEÑOR DE LOS MILAGROS, PROSPECTO	31-v	15-28-51S	070-27-39W	343291	8287957	PB AG	PIZARRAS, CUARCITAS
288	TONALITA NAHUIRA, PROSPECTO	31-v	15-24-00S	070-11-12W	372657	8297081	CU AU	
289	EL COFRE, MINA	31-v	15-23-30S	070-23-30W	350649	8297872	PB AG ZN	ANDESITAS, BRECHAS
290	ELBA, MINA	31-v	15-21-49S	070-21-45W	353760	8300996	ZN	
291	AHI NOMAS, MINA	31-v	15-18-57S	070-01-42W	389605	8306479	PB ZN CU AG	CALIZAS
292	LA MINERA, MINA	31-v	15-08-30S	070-06-04W	381694	8325708	AG CU	ANDESITA
293	URANO, MINA	31-v	15-05-18S	070-00-45W	391189	8331654	CU AG	CUARCITAS, ARENISCAS
294	CARMEN, MINA	31-v	15-05-12S	070-25-00W	347746	8331598	PB AG CU	ARENISCAS
295	PALOMA AZUL, MINA	31-v	15-02-50S	070-12-50W	369519	8336092	SB AG PB	CALIZAS, ARENISCAS, PIZARRAS
296	SANTA SOFIA, MINA	31-v	15-02-15S	070-02-57W	387221	8337258	SB PB	PIZARRAS
297	ELSSA Y LA URVIOLA, MINA	31-v	15-02-00S	070-13-30W	368315	8337622	SB	PIZARRAS, DACITAS
298	SAN MARTIN DE ANTAÑA, MINA	31-v	15-01-33S	070-16-12W	363472	8338424	SB	ESQUISTOS PIZARROSOS
299	SALOMON, MINA	31-v	15-01-30S	070-00-48W	391067	8338659	PB AG	ARENISCAS
300	PALCA 11, MINA	31-x	15-00-00S	069-39-38W	428981	8341548	W	CUARCITAS
301	EL DORADO №1, MINA	31-x	15-11-38S	069-41-33W	425614	8320091	AU	MATERIAL ALUVIAL
302	SARA ISABEL, MINA	31-x	15-01-45S	069-39-30W	429230	8338323	W AG AU	SEDIMENTARIAS, INTRUSIVAS
303	SANTA CRUZ DE HUANCANE №2, MINA	31-x	15-01-15S	069-41-30W	425643	8339234	PB AG	PIZARRAS, LUTITAS
304	ANANEA, PROYECTO	31-y	15-20-00S	069-28-05W	449757	8304731	AU	
305	PROGRESO III, MINA	32-v	15-59-12S	070-05-36W	383009	8232232	PB AG	ARENISCAS, CUARCITAS
306	URANO UNO, MINA	32-v	15-57-30S	070-18-00W	360872	8235240	AG PB CU	CALIZAS, ARENISCAS, SIENITA
307	PEDRO NOLASCO, PROSPECTO	32-v	15-56-00S	070-16-00W	364423	8238027	PB CU	
308	CHUPICA, PROSPECTO	32-v	15-56-00S	070-15-00W	366207	8238038	AG PB ZN	CALIZA
309	ARENALES, MINA	32-v	15-55-38S	070-05-02W	383985	8238814	AG	ANDESITA
310	ENRIQUE Y JESSICA; MINA	32-v	15-55-18S	070-14-45W	366646	8239332	AG PB ZN	ARENISCAS
311	POMPERIA, DEPOSITO	32-v	15-55-00S	070-01-00W	391175	8240018	AG PB	LUTITAS
312	RICARDO, PROSPECTO	32-v	15-54-00S	070-01-00W	391166	8241861	CU PB AG	

Table 7 List of ore deposits and mineral indications (7)

No.	NAME	QUAD-RANGLE	LATITUDE	LONGITUDE	EASTING	NORTHING	ELEMENT	WALL ROCK
313	PUNO, AREA	32-v	15-53-14S	070-02-10W	389078	8243265	PB AG ZN	VOLCANICAS
314	TALISMAN, MINA	32-v	15-53-06S	070-10-54W	373492	8243428	SB PB AG	DACITA
315	SANTA MESTRES, MINA	32-v	15-53-00S	070-19-00W	359036	8243526	PB AG ZN	ARENISCAS, LUTITAS
316	SAN FRANCISCO №2, MINA	32-v	15-52-42S	070-14-36W	366885	8244127	PB AG	
317	ADELANTE ENA №2, MINA	32-v	15-52-30S	070-10-00W	375092	8244543	CU AG	ARENISCA , RIOLITA
318	LA UNION, MINA	32-v	15-52-30S	070-22-30W	352783	8244408	PB AG ZN	ROCAS VOLCANICAS
319	LUZ DE ORO, MINA	32-v	15-51-50S	070-20-52W	355691	8245656	CU AU	ARENISCA
320	SANTA BARBARA, MINA	32-v	15-51-40S	070-13-00W	369729	8246050	PB AG AU	CALIZAS
321	LA VIRGEN DE LA CANDELARIA, MINA	32-v	15-51-12S	070-12-51W	369992	8246912	AG PB	ANDESITA
322	ALADINO, MINA	32-v	15-51-10S	070-20-12W	356873	8246893	CU AU AG	ARENISCA
323	CONCEBIDA, MINA	32-v	15-51-00S	070-12-48W	370079	8247281	CU AU AG	ARCOSAS
324	CERRO DEL INCA №17, MINA	32-v	15-50-56S	070-01-20W	390544	8247513	AG	ANDESITA
325	SANTA MESTRES, MINA	32-v	15-50-54S	070-19-27W	358208	8247394	AG PB ZN	ARENISCA
326	LULITA, MINA	32-v	15-50-54S	070-19-27W	358208	8247394	CU AG AU	PIZARRA
327	ALADINO SEIS, MINA	32-v	15-50-48S	070-19-39W	357850	8247576	CU AG	ARENISCA
328	BOLSA DE MERCURIO, MINA	32-v	15-50-12S	070-20-33W	356236	8248672	CU HG	ARENISCAS
329	CRISTOBAL CINNABAR, PROSPECTO	32-v	15-50-03S	070-10-00W	375067	8249061	CU HG	
330	SANTIAGUITO, MINA	32-v	15-50-00S	070-20-30W	356323	8249041	CU AG AU	DIORITAS, FANGOLITOS, CONGLOMERADOS
331	LOS ROSALES №4, MINA	32-v	15-48-52S	070-17-52W	361011	8251161	CU AG AU	ARENISCAS
332	SAN MARTIN, MINA	32-v	15-48-33S	070-17-42W	361305	8251746	CU AU	ARENISCAS
333	SANTA ROSA DE MORGADO, MINA	32-v	15-48-33S	070-22-15W	353182	8251695	CU AG	CALIZA
334	SAN MARTIN ERES TU, MINA	32-v	15-48-27S	070-17-15W	362107	8251936	AG PB ZN	ARENISCA
335	LOS ROSALES, MINA	32-v	15-48-12S	070-17-12W	362194	8252397	CU AG AU	ARENISCAS
336	SANTIAGUITO, MINA	32-v	15-48-12S	070-17-12W	362194	8252397	CU AG AU	ARCOSAS, LUTITAS
337	INMACULADA, MINA	32-v	15-48-05S	070-17-10W	362252	8252613	CU AU AG	ARCOSA, LUTITAS
338	LA VIRGEN DE LA CANDELARIA, MINA	32-v	15-47-54S	070-18-20W	360167	8252938	PB AG	ANDESITA
339	SILVIA PRIMERA, MINA	32-v	15-47-28S	070-03-33W	386556	8253885	PB CU AG	ARENISCAS, ANDESITA
340	COMPENSACION, PROSPECTO	32-v	15-46-00S	070-06-00W	382167	8256567	FE	CALIZAS
341	SAN MARTINCITO I, MINA	32-v	15-45-06S	070-24-12W	349658	8258034	CU AU	ARENISCAS
342	HUASCAR DOS, MINA	32-v	15-44-30S	070-05-16W	383463	8259340	AG PB	CALIZAS, ARENISCAS, ROCAS VOLCANICAS
343	UMAYO, PROSPECTO	32-v	15-43-00S	070-10-00W	374995	8262060	FE	ARENISCAS
344	PUCACANCHA, MINA	32-v	15-41-00S	070-20-58W	355384	8265632	CU AG	CALIZAS
345	PALOMA BLANCA, MINA	32-v	15-40-30S	070-14-30W	366931	8266624	SB AG PB	PIZARRAS, LUTITAS, ARENISCAS
346	CANCHARANI, MINA	32-v	15-40-18S	070-21-06W	355138	8266921	CU AG	ARENISCAS, CUARCITAS
347	SANTA ANA № 6, MINA	32-v	15-39-24S	070-19-09W	358611	8268602	CU AG	CALIZAS
348	MINSUR 31, MINA	32-v	15-39-21S	070-21-17W	354799	8268671	CU PB	CALIZAS, LUTITAS
349	MINA CINCO, DENUNCIO	32-v, 32-u	15-39-15S	070-30-00W	339224	8268750	AG PB ZN CU AU	ANDESITA, RIOLITA, INTRUSIVOS
350	TIO JUANITO, MINA	32-v	15-37-54S	070-22-00W	353501	8271336	PB AG	LUTITAS
351	ROSA CARELA I, MINA	32-v	15-36-02S	070-23-09W	351424	8274765	W	ARENISCAS, PIZARRAS, CUARCITAS
352	TUNGSTENO, MINA	32-v	15-36-00S	070-23-00W	351692	8274828	W	ARENISCA, LUTITA
353	SAN JUDAS TADEO, MINA	32-v	15-35-54S	070-22-59W	351720	8275013	W	ARENISCAS, PIZARRAS, CUARCITAS
354	MILAGRO DE SAN JUDAS TADEO №1, MINA	32-v	15-34-35S	070-20-57W	355339	8277464	W MO	ARENISCAS, CUARCITAS
355	SANTA ELENA DE COBREMANI, MINA	32-v	15-30-33S	070-10-06W	374690	8285015	CU AG	ANDESITAS
356	CERRO AZOGUINE, PROSPECTO	32-x	15-48-00S	070-01-00W	391113	8252924	CU HG	SEDIMENTARIAS, VOLCANICAS

Chapter 3 Integrated Analysis

The results of the satellite image analysis and the analysis of the existing geologic information were integrated with the aid of the GIS, so that the integrated analysis map might be drawn. Interesting areas for exploration of metallic mineral resources were extracted from the integrated analysis map. The map indicates the results of the analysis as itemized below. [Fig.16]

[1] Locations of the known ore deposits and mineral indications
[2] Distribution of the igneous rocks related with ore deposits and the wall rocks in which the ore deposits are emplaced
[3] Lineaments
[4] Distribution of lineament density
[5] R21 Anomalies (the iron-oxide index)

Based on the integrated analysis, areas of interest were extracted from the entire survey area. For extracting the areas, the following factors were employed as the selection criteria:

[1] High concentration areas of the R21 anomalies extracted by the satellite image analysis.
[2] High density areas of lineaments.
[3] Areas where Miocene to Pliocene and Permian granites are distributed, which are considered to be related with the mineralization.
[4] Areas where the known mineral indications are distributed.

As the result, the following five areas have been extracted, in order from the northeast to southwest:

[1] Calhuahuacho area
[2] Livitaca area
[3] Macusani area
[4] Usicayos area
[5] Vilque area

The Table below outlines the extracted areas

Areas of Interest

Name of area	Center Coordinates	R21 (the iron-oxide index)	Lineament density	Intrusive rocks (age、lithology)	Known indications in the vicinity	Geologic features (age、formation name)
[1] Calhua-huacho	14°15'S 72°10'W	High	High	Miocene Granodiorite	Ferobanba (Cu、srtatiform) etc.	Cretaceous Yura Group Puente Piedra Formation Moho Group
[2] Livitaca	14°15'S 71°40'W	High	Medium high	Pliocene Quartz porphyry Trachyte Andesite	Katanga (Cu、Skarn) etc.	Cretaceous Muni Formation Huancane Formation Moho Group
[3] Macusani	14°15'S 70°20'W	High	At the North-Medium high At the South-High	Pliocene Quartz porphyry Trachyte Andesite	San Rafael (Sn、Cu、Vein) and many other Cu、Pb、Zn、Sn、Sb deposits	Carboniferous Ambo Group Permian Mitu Group
[4] Usicayos	14°10'S 70°10'W	High	Medium high	Permian Monzonite Granite	Sarita (Cu、Ag、Mo、W、Sn dissemi-nation) and many other Ag、Cu、Pb、Zn、Sn deposits	Carboniferous Ambo Group Tarma Group Copacabana Group
[5] Vilque	15°50'S 70°15'W	Middle	At the Northwest - High	Miocene Andesite Rhyolite	San Martin (Cu、Au) etc. and many other Cu-Ag-Au or Cu-Pb-Zn deposits	Cretaceous Moho Group Pliocene Barroso Group

[1] Calhuahuacho area

In the vicinity of the northern edge of the area, skarn- and hydrothermal-type strata-bound Cu(-Fe) deposits, such as the Ferrobamba, Chalcobamba and Cristo de los Andes deposits, are distributed. Indications of gold placers are also distributed in the eastern and western peripheries of the area.

It has been confirmed that the copper deposits are formed at the contacts between Jurassic to Cretaceous limestone and Quaternary granodiorite, diorite and monzonite, accompanied by hydrothermal alteration zones though small in scale. [Mitsui Mining & Smelting Co., 1997]

In the surroundings of Tertiary intrusive rocks lying in the north-central and southern parts of the area, the R21 anomalies (in the iron-oxide index) are spotted, which possibly indicate the presence of hydrothermal alteration zones. The lineament density is also high in the area. From these facts, the area is considered to have conditions likely to cause hydrothermal activity. It is inferred, therefore, that the area has high potentialities for occurrence of skarn-hydrothermal deposits similar to the known ore deposits.

[2] Livitaca area

There are skarn-type Fe(-Cu) deposits such as the Livitava and San Martin deposits in this area; and, in the southwestern neighborhood, lie Cu-Pb-Zn deposits (of unknown types) such as the Lomas de Oro deposit.

Similar to the Calhuahuacho area, this area has the tendency that the R21 anomalies concentrate around Tertiary intrusive rock, where the lineament density is also high. The area is therefore considered to have high potentialities for occurrence of skarn- or vein-type deposits of copper, lead, zinc, etc.

[3] Macusani area

Vein-type Sn-Cu deposits as represented by the San Rafael deposits are emplaced in Tertiary intrusive rocks in the area. Besides, many manto-type lead deposits such as the Cerro del Inca No.28 and Cu-Pb-Zn-Ag deposits such as the Quenamari deposit are emplaced in sedimentary rocks surrounding the intrusive rocks. The Quenamari's veins trends NW-SE.

In the area, the R21 anomalies tend to concentrate to some extent around Quaternary intrusive rocks in the northwest and central-northeast parts and around Permian intrusive rocks lying in the south-central part. The lineament density is especially high in the southern part and the NW-SE trend is dominant.

The R21 anomalies around Tertiary intrusive rocks are likely to indicate the presence of mineralization-alteration zones, which is considered to provide guidelines for exploration.

[4] Usicayos area

The area lies adjacent to the northeast side of the preceding Macusani area and is elongated in the NW-SE direction. Cu-Ag-Mo-W-Sn dissemination-type (or stockwork-type) deposits such as the Sarita deposit, and a large number of Cu-Pb-Zn and Cu-Ag deposits and indications (of unknown types) are distributed in the area.

The R21 anomalies concentrate in Carboniferous to Permian rocks in the northwest, whereas ore deposits and indications are distributed mainly from the center toward the southeast; and, no correlation is found between them. In the existing literature, however, the Permian intrusive rocks lying in the north and southeast of the area are regarded as correlative igneous rocks, and the lineament density is somewhat high in these areas. Therefore, the Usicayos area has been extracted as one of the areas of interest.

[5] Vilque area

In this area, Cu-Ag(-Au) and/or Cu-Pb-Zn deposits and indications are distributed in Tertiary intrusive rocks and in the surrounding zones, but their types are not specified in the existing geologic information.

Likewise, the R21 anomalies tend to concentrate in and around Tertiary intrusive rocks, while the lineament density is somewhat high in the northwest of the area. Although type of ore deposits is unknown, the R21 anomalies extracted from around the Tertiary intrusive rocks are likely to suggest mineralization-alteration. The area is considered to require investigations.

After examining the existing regional geochemical prospecting data, field investigation shall desirably be performed in order that the geology and mineralization in these areas may be verified.

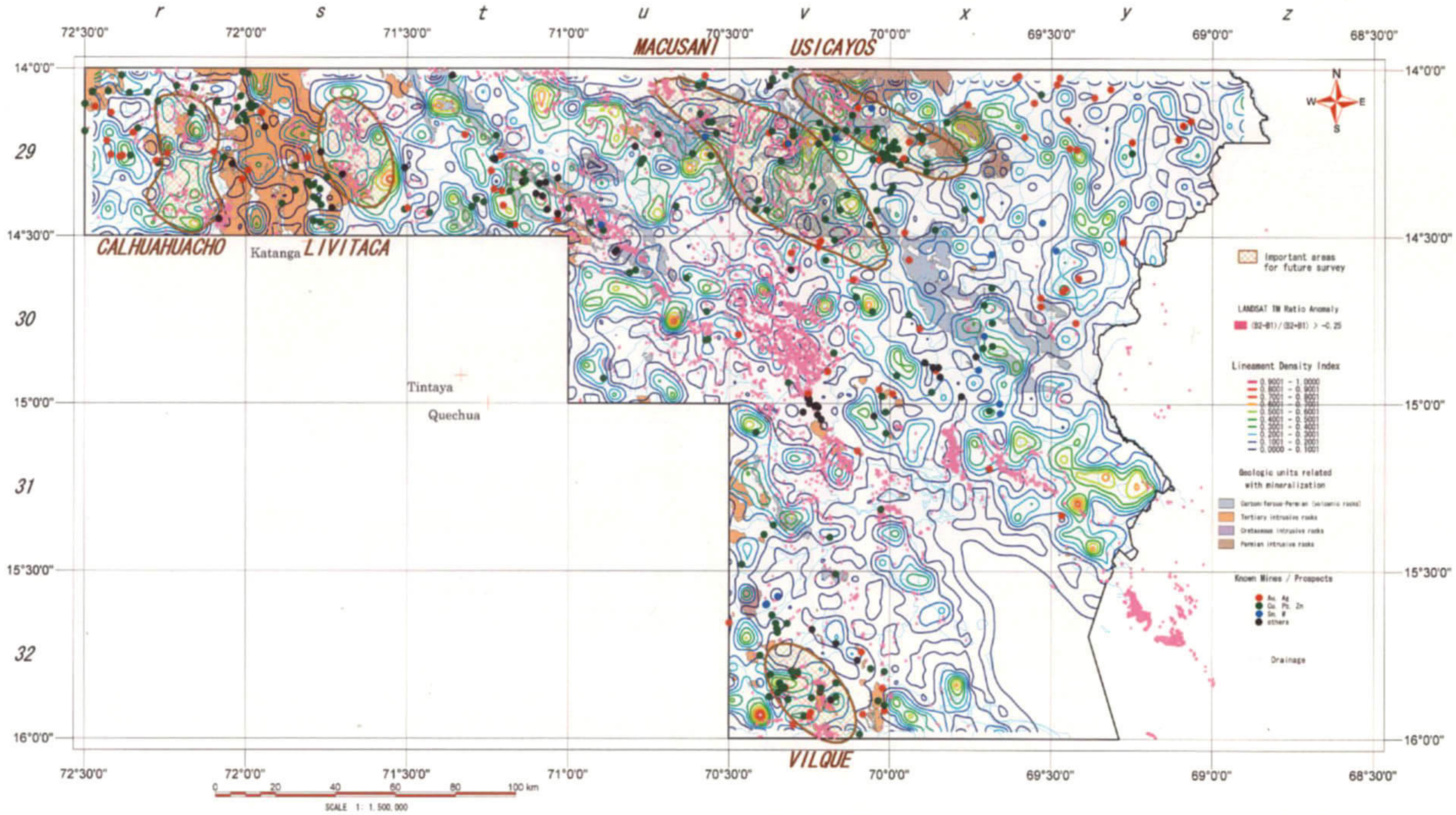

Fig.16 Integrated analysis map