PART II PARTICULARS

Chapter 1　Compilation of Previous Geological Data

1-1　Outline of Geology in Survey Area

Bolivia is composed of Precambrian, Paleozoic, Mesozoic, Tertiary and Quaternary formations, and igneous intrusions of Mesozoic and Tertiary ages.　Their distribution is shown in Fig. I-3-1 and Fig. II-1-1.

The geotectonic provinces are divided into eight sub-divisions, which from west to east, are called the Cordillera Occidental, Western Altiplano, Eastern Altiplano, Cordillera Oriental, Inter-Andes, Sub-Andes, Beni-Chaco Plain and Amazon Craton.

The survey area pertains to the Cordillera Occidental and Altiplano.

1) Cordillera Occidental

The Cordillera Occidental is extensively covered by Tertiary to recent volcanic rocks that effused along the uplifting axis in the N-S direction of the Mesozoic to Paleozoic basement rocks, where continental to netric sediments lie between the volcanic bodies.

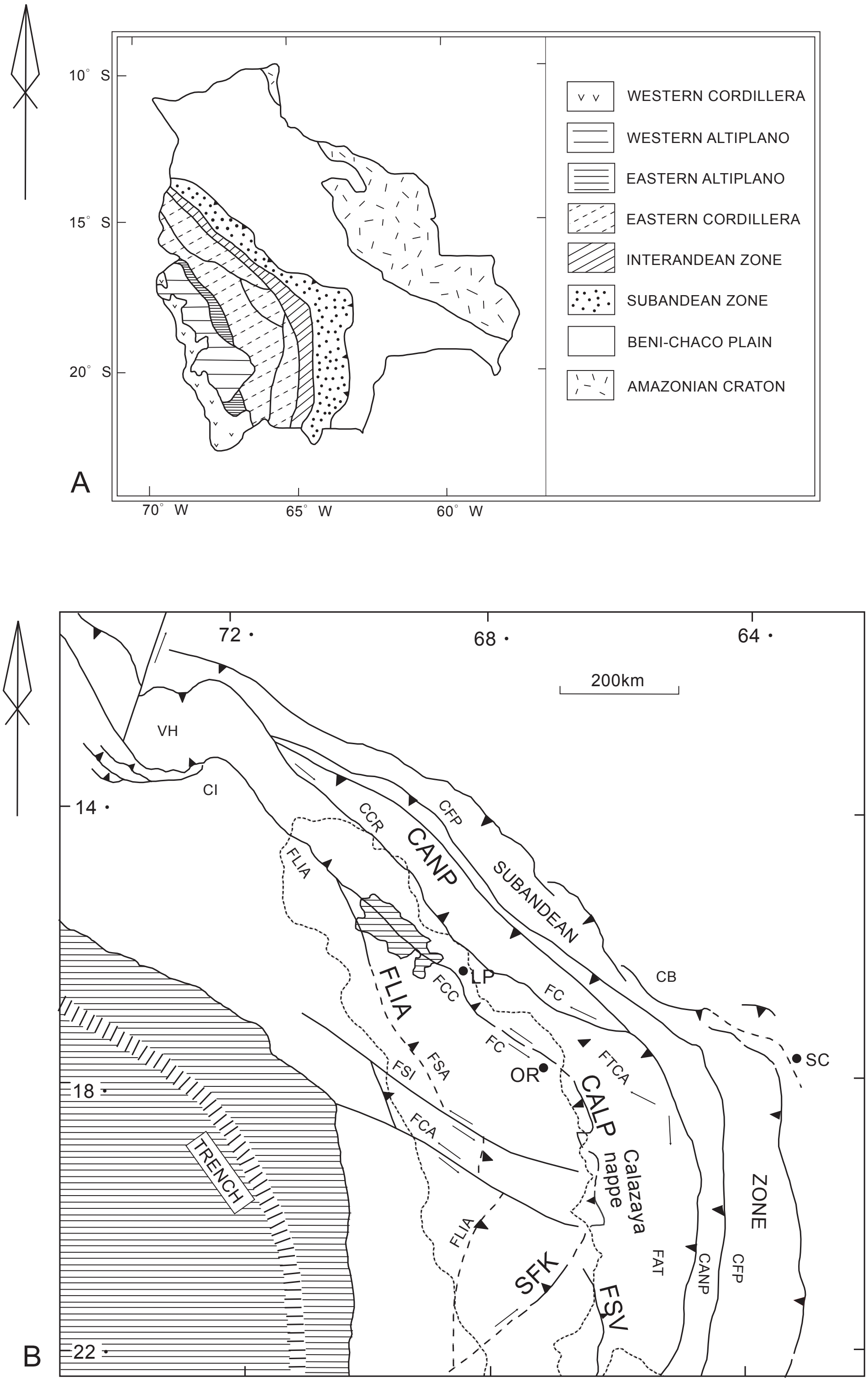
The Cordillera Occidental composed of a western eugeosyncline-volcanic arc an eastern miogeosyncline, developed in response to subduction (Andean orogeny) following cessation of the Hercynian orogeny. Shales and sandstones of the miogeosyncline were deposited in disconnected back arc basins during a period of extensional tectonism from late Jurassic through early Cretaceous time.　During this time, some period lava flows and volcaniclastic rocks were accumulating in the outboard eugeosyncline by late Cretaceous time.　Most of the area of the Cordillera Occidental was emergent; continental sediments were being deposited across the miogeosyncline and large granitoide plutons, that constitute the Coastal Batholith of Perú and Chile, were being embedded in the eugeosyncline.

2) Altiplano

The Altiplano has the Proterozoic to Paleozoic basement extensively covered by formations of vast volcanic product and continental sediments of the Cretaceous to the Recent age.

Since the beginning of the Andean orogeny, including the Altiplano have been predominantly a positive tectonic element along the continental margin.　Continental sedimentation, which began in the late Cretaceous, continued throughout most of the Cenozoic.

The continental sediments are composed of late Cretaceous continental molasse sediments (red bed) and Eocene to Oligocene foreland basin sediments (sandstone, and alternated beds of sandstone and mudstone)



Position of the Calazaya noppe within the Bolivian orocline (from Sempere et al.. 1991). Fine dottoed line:boundary of the present-day endreic Altiplano basin. FLIA=Intra-Andean Boundary Faultt. CANP=Main Andean Thrust. CALP=Main Altiplanic Thrust. SFK=Khenayani Fault System. FSV=San Vicente Fault. LP= La Paz. SC=Santa Crus. OR=Oruno.

CB=Chapare buttress. CCR=Cordillera Real Thrust. CFP=Main Frontal Thrust. CI=Cuzco indenter. FAT= Auiquilc-Tupiza fault. FC=Cochabamna Fault. FCA=Chita-Africa Fault. FCC=Coniri Thrust Front. FE= Eucaliptus fault. ESA=San Andres Fault. ESI=Sevaruyo-Incapuquio fault. FTCA=Toracari Fault-Arquc Thrust. VH=Vilcabamaba hinge.

Fig.II-1-1 Structural Geology of the Central Andes

A:Modefied from Baby et al.,1992b, with Western Cordellera volcanic arc added.
B:From Baby et al.,1992a. Additional structure names from Sempere et al.,1988.

In Pleistocene time most of the Altiplano was covered by large glacial lakes, the remnants are the present salars.

Igneous activity took place in the Miocene to Pliocene time. Andesitic effusive activity continued during the Miocene time in the southern part whilst, in the northern part, effusive activity of rhyolitic pyroclastic rocks continued from the Miocene to Pliocene time, which caused a huge amount of continental volcanic product to be deposited.

3) Cordillera Oriental

In the Cordillera Oriental, thick sedimentary rocks of the Paleozoic to Mesozoic age (miogeosyncline sediments) depositing on the Precambrian basement underwent the Caledonian (Ordovician), Hercynian (Devonian to Triassic) and Andean (Cretaceous to Cenozoic) orogenic movements, causing to form thrust faults with N-S axes and complicated fold structures.

Simultaneously with the end of the Hercynian movement (Permian to Triassic), the subject region became a tension field where peralkaline volcanic activity and intrusion of granitic plutonic rocks occurred.

Among them, plutonic rocks of granodiorite and adamellite occur mostly in the northern part of the Eastern Cordillera as batholith and lacolith. Meanwhile the intrusive rocks found in the middle and southern parts of the cordillera are hypabyssal and volcanic types except Karikari plutonic rock (granodiorite) near Potosí, and appear in stock and a volcanic neck.

Afterwards the plate subduction began causing calc-alkaline volcanic activity, which lasted from the Jurassic to the Cenozoic time.

At the time of the Andean orogenic movement (Tertiary), the Cordillera Oriental was uplifted by the E-W compressive stress causing the formation of fold and thrust fault zones. At the west side of the Cordillera, the andesitic volcanic activity, the ensuing intrusion of hypabyssal rocks and overthrust towards the Altiplano side took place.

1-2 Outline of Mineralization in the Survey Area

Ore deposits of metallic minerals concentrate in the area that embraces the Cordillera Occidental, Altiplano and Cordillera Oriental, where copper mineralization accompanying alkali basalt, sedimentary copper mineralization accompanying late Tertiary red sandstone beds, so-called 'Bolivian-type' polymetallic mineralization mainly of tin and silver, and epithermal mineralization mainly of gold and silver are known to be present. (Fig. I-3- 4, Fig. II-1-2)

From the Cordillera Oriental to the Altiplano, the Bolivian-type polymetallic vein deposits are found, while copper deposits accompanied by alkali basalt and red sandstone are present from the north to the south of the central Altiplano.

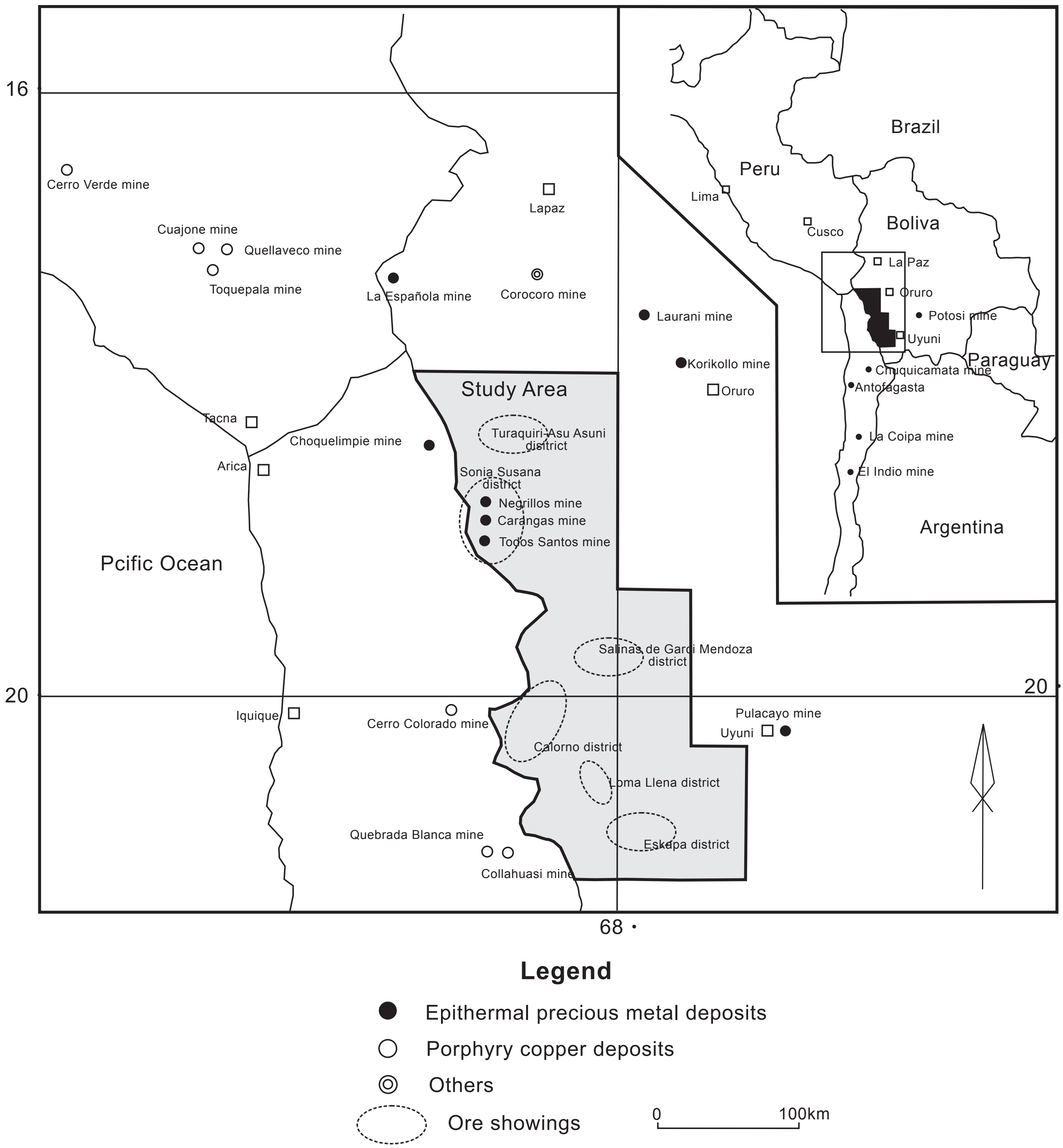


Fig.II-1-2 Location Map of the Ore deposits and Showings in the Adjacent Area

In the Cordillera Occidental, small-scale epithermal gold-silver veins embedded in Miocene dacitic volcanic rocks are known to exist, a part of which is accompanied by sulfide minerals such as copper, lead, zinc and bismuth.

Sediment-hosted copper mineralization accompanying alkali basalt and Paleogene red sandstone beds

The mineralization, known to be present from the north to the south of the central Altiplano, is relatively small in scale, a greater part of which has been worked out.

There are two types of ore deposit: one with native copper, cuprite, etc., occurring in veinlets or disseminated in late Oligocene alkali basalt, and the other with chalcopyrite, bornite, native copper, copper oxide minerals, etc. occurring bedded or disseminated in Paleogene red beds.

Typical of the later type is that of the Corocoro mine. For this reason, it is called 'Corocoro-type mineralization.'

Bolivian-type polymetallic vein deposit related with Neogene volcanic activity

This type of ore deposit is formed with small veins and veinlets related with igneous rocks intruding in medium to shallow depth, and contains part or all of such metals as tin, silver, gold, copper, lead, zinc, tungsten, bismuth and antimony.

Such deposits, related with andesitic to dacitic intrusive rock (stocks and dikes) and rarely related with volcanic rocks, are present in the Cordillera Oriental which is mainly underlain by Paleozoic sedimentary rocks and metasedimentary rocks (metamorphic rocks) , and also in the Altiplano underlain by continental sediments and volcanic rocks deposited.

Many of these ore deposits have good continuation in vertical and horizontal directions. In case of the Cerro Rico mine, the horizontal extension is 2 km, while the lowest level of the current operation is 900 m deep from the top of the mineralization portion. The bottom of the mineralization is still unknown.

In most of ore deposits, ore minerals are contained in respectively isolated veins, 10 cm to 2 m wide. Ore minerals are observable also in concentration zones of veins and veinlets.

Assemblage of minerals is complicated. More than 90% (in terms of weight percentage) of veins are composed of sulfide minerals such as pyrite, marcasite and magnetite, and are poor in non-sulfide gangue minerals, which characterize the mineralization of this type.

In hydrothermal alteration, a combination of quartz, sericite and pyrite is characteristic. In the upper and outer parts of an ore deposit, argillization advances and alteration portions containing alunite are existent.

While the formation time of the ore deposits is said to be Triassic, Oligocene and Miocene, most of the deposits are formed in middle to late Miocene time.

In view of the measurements of homogenization temperature of fluid inclusion and salt concentration, as well as the original stratigraphy inferred most of the Bolivian-type polymetallic vein deposits are presumably formed 0.5 km to 2.0 km under the surface.

Underlain by upper Tertiary or Quaternary rocks, the polymetallic vein deposits in the Altiplano have not yet been fully elucidated, but many of them are copper-rich Cu-Pb-Zn deposits, relatively poor in tin and tungsten.

The time of formation is believed to be the Miocene. It has been interpreted that these ore deposits form a part of the E-W belt-like arrangement of mineralization zones in the Cordillera Oriental.

A variety of ore deposit of this type is known, but they are roughly classified into two groups which follow:

<u>Ore deposits rich in silver and tin</u>

Mineralization of this type is often seen in the Cordillera Oriental. These have mineralogically complex combinations of silver, tin, lead, zinc, tungsten, bismuth, gold, etc.

Typical of such ore deposits are found at such mines as Cerro Rico de Potosí, Pulacayo and Huanuni. These are classified into two types: one rich in silver sulfate and the other in which the lower tin zones are exposed due to denudation (erosion) of the upper silver zones.

<u>Ore deposits rich in silver, gold and copper</u>

Mineralization of this type is seen in the Altiplano, the most typical of which is the Kori Kollo mine. The mine has silver, gold and some copper, apparently resembling auri-argentiferous iron sulfide deposits, but it is classified into the polymetallic deposit since it contains lead, zinc, antimony, tin, etc.

Epithermal gold-silver deposits related to Neogene volcanic activity

The volcanic-hosted epithermal precious-metal deposits are spatially and temporally related to eruptive centers-stratovlcanoes, calderas, and domes--within the volcanic complex. Included are both adularia-sericite and acid-sulphate types of deposits for which distinct sub-types can be distinguished and corresponding descriptive models constructed.

The dating indicates that most of the precious metal deposits were formed in the middle Miocene time (17~9 Ma) while some were formed in the Pliocene to Pleistocene time (5~1.2 Ma). It is considered that these ore deposits are still in the process of formation, accompanying the active thermal water systems and stratovolcanoes in the effusion stage.

The ore deposits in the survey area are high sulfidation deposits, which are considered to be formed with low-acidic thermal water of the magma origin ascending without mixing with meteoric water. These ore deposits are accompanied by strong argillization.

The mineralization is characterized by the development of pyrite and enargite veins and, in the peripheries; veins develop accompanied by base metals and silver.

One of the ore deposits of this category is the Laurani mine in the Department of La Paz.

Epithermal deposits related to hypabyssal activity in shallow zones

The quartz veins of La Española mine, formerly exploited in a minor scale, are said to be high sulfidation epithermal veins accompanied by alunite-kaoline, while the other mineralization is poor in base metal and tin contents, as compared with Bolivian-type polymetallic vein deposits.

Such mineralization accompanied by silicification is interpreted to be an epithermal precious metal deposit formed in relation to volcanic activity or shallowhypabyssal activity; therefore, occurrence of porphyry-type gold mineralization has been anticipated beneath the gold, silver and sulfide mineral dissemination portion, which is considered to be corresponding to the peripheries (in the upper part) of the porphyry-type gold mineralization.

Chapter 2 Satellite Image Analysis

2-1 Purpose of Analysis

In order to obtain the basic data for assessing mineral potential of the survey area, an analysis of satellite image has been conducted. Based on the spectrum data and texture data of satellite image, a distribution map of geological units and a lineament map were prepared to recognize the regional geological structure and to detect spectral anomalous area, which suggests the presence of, mineralized alteration zones.

2-2 Interpretation of Image and Analysis

As shown in Table II-2-1 seven scenes of Landsat TM data were used for the analysis.

Table II -2-1 List of LANDSAT TM data

Scene No.	Path	Row	Date
1	1	72	1987.05.30
2	2	72	1986.11.10
3	233	75	1986.05.30
4	1	73	1987.05.30
5	1	74	1986.10.02
6	233	73	1986.08.08
7	233	74	1989.07.23

Color synthetic images and ratioing images were prepared by the following procedure for the newly processed three scenes.

Based on the color synthetic image and the image showing anomaly area were made by ratioing analysis in seven scenes in total, geological units, geological structure and alteration are interpreted and mapped on a scale of 1:250,000 in every scene.

Fig. II-2-1 shows a mosaic of color synthetic images of seven LANDSAT TM scenes and a mosaic of images showing spectral anomaly area, which have been provided for interpretation.

2-3 Results of Interpretation and Analysis

Interpretation of geological units was conducted in reference to the existing geological map on a scale of 1:500,000. The geological units thus classified were numbered with serial numbers from the lower horizon with reference to the classification of the existing geological map. Summary of geological units obtained in seven scenes was shown in Fig. II-2-2, and correlation with the correspondent formation of the existing geological map is shown in Table II-2-2.

Fig. II-2-3 shows geological structure and Fig. II-2-4 shows a possible alteration zone,

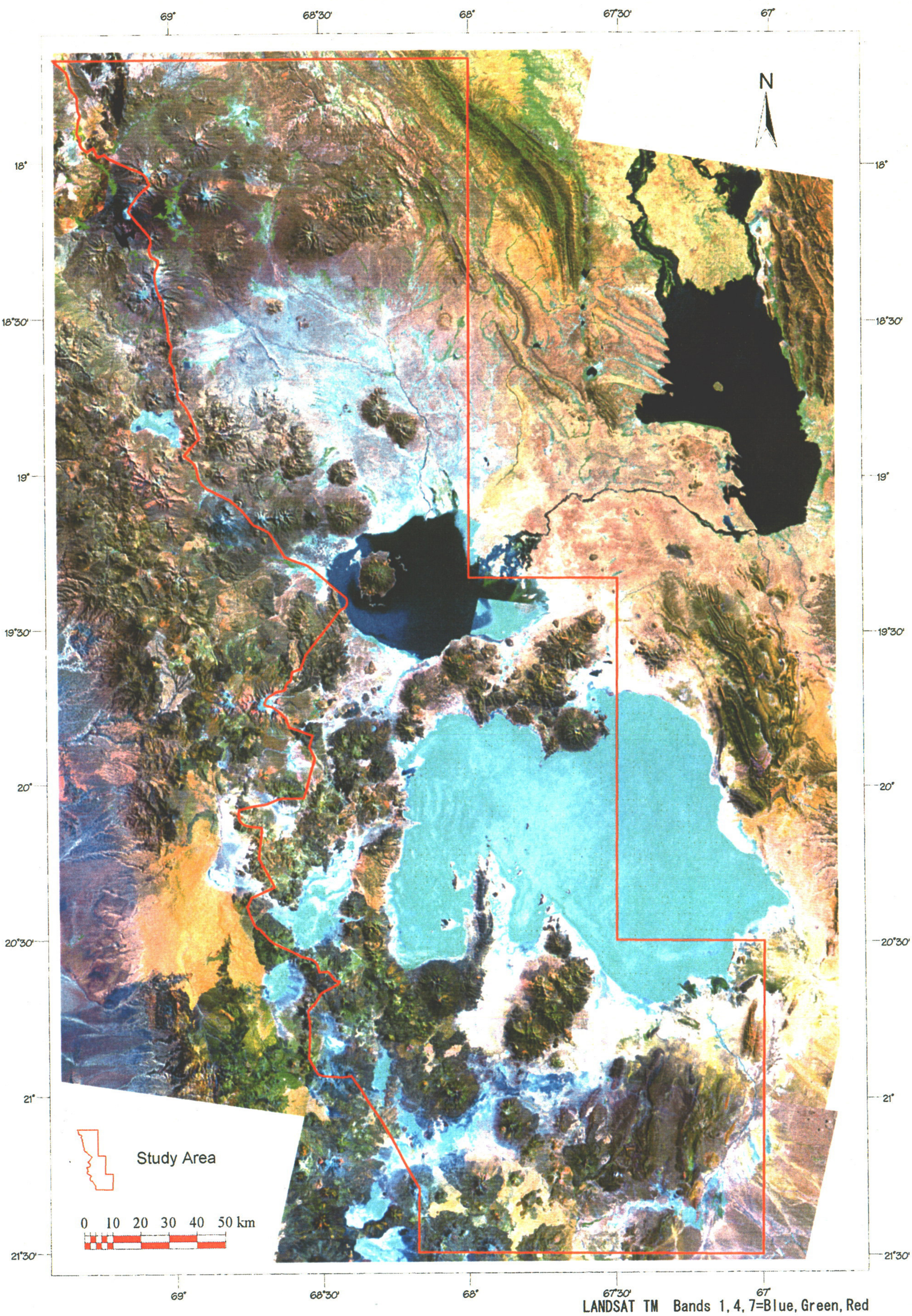


Fig.II-2-1 LANDSAT TM Color Composite Image

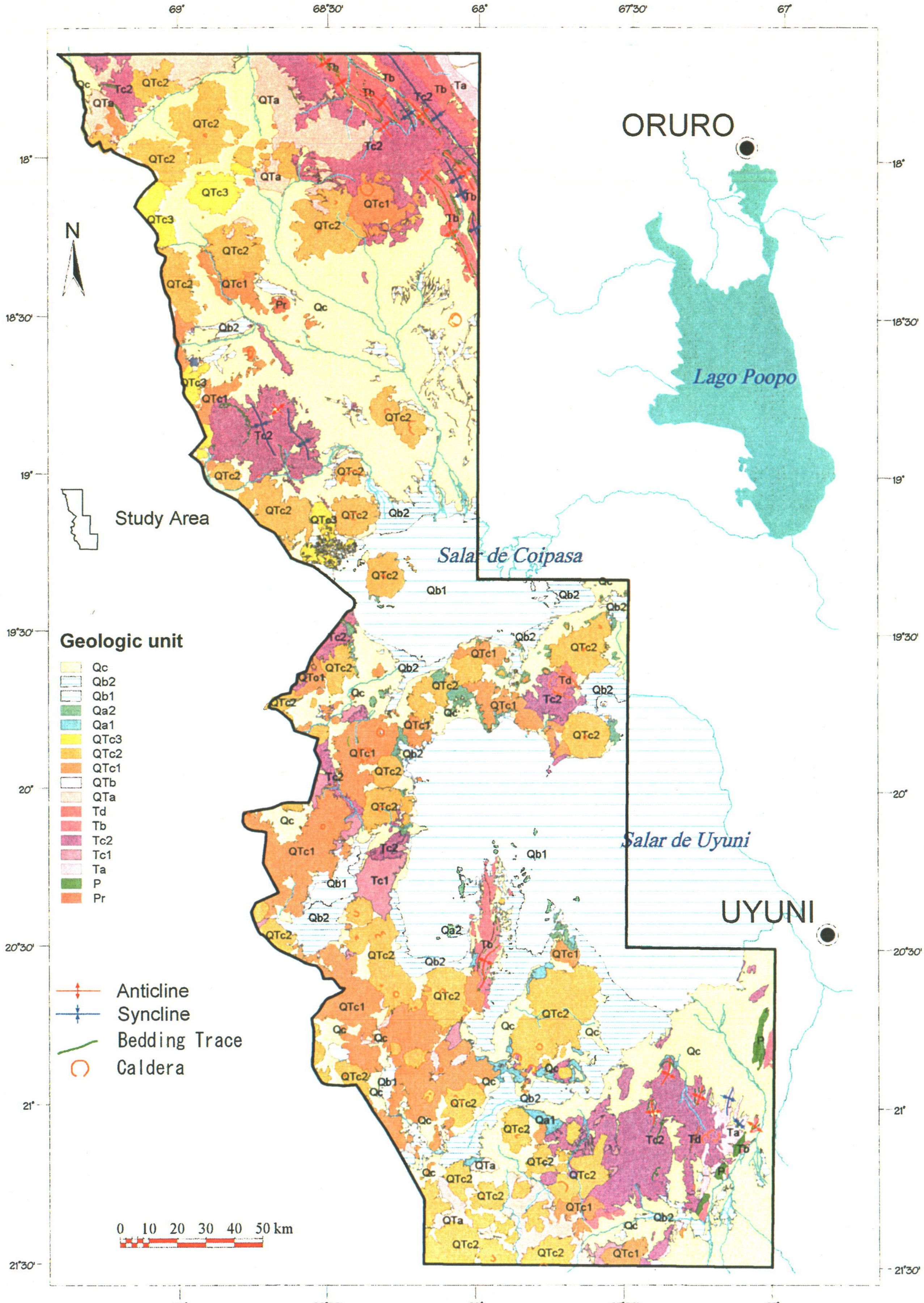


Fig. II-2-2 Geologic Interpretation Map of the LANDSAT TM Image

Table II-2-2 List of geologic unit

GEOLOGIC UNIT	COLOR on LANDSAT TM Color Composite Image	TEXTURE	DRAINAGE		ROCK RESISTANCE	BEDDING	LINEAMENT DENSITY	LITHOLOGY	GEOLOGICAL CORRELATION (U. S. Geological survey Bulletin, 1975)	
			PATTERN	DENSITY						
Qc	brownish gray, dark gray ~ light gray, pale brown	fine	dichotomic, dendritic	low - middle	low	-	rare	alluvium, talus deposit	Qsu	Surficial deposits (Holocene and Pleistocene)
Qb2	white, bluish white, dark ~ pale brown	fine	dichotomic	low	low	-	-	salt	Qs	Salt deposits (Holocene and Pleistocene)
Qb1	blue, light blue	fine	-	-	low	-	-			
Qa2	grayish brown, brownish gray	medium	parallel, dendritic	middle - high	high	poor bedded	-	limestone	Ql	Lacustrine deposits (Qa2 : Minchin Limestone) (Holocene and Pleistocene)
Qa1	yellowish gray	fine	parallel, dendritic	middle - high	low	poor bedded	-	lake deposite		
QTc3	dark bluish gray, dark green	coarse - medium	radial, sub-dendritic	low	high	-	low	andesite, dacite	QTsv	Stratovolcano deposits (Holocene to Miocene)
QTc2	dark brown ~ brown, dark gray	fine - medium	radial	low	high	-	low	andesite, dacite		
QTc1	dark gray ~ gray, brown	coarse - medium	sub-dendritic	middle - high	high	-	low	andesite, dacite		
QTb	brownish gray ~ light gray, yellowish gray	medium	pinnate	high	middle	-	-	conglomerate, sandstone, shale	QTs	Sedimentary rocks (Pleistocene and Pliocene)
Qta	pale brown, grayish brown	fine	parallel, dendritic, sub-dendritic	high	middle	-	-	ignimbrite	QTig	Ignimbrite (Perez tuff) (Pleistocene to Miocene)
Td	brownish gray, dark ~ light gray , reddish brown	medium	sub-dendritic	middle	high	-	-	dacite	Tl	Intrusive rocks (Pliocene to Oligocene)
Tc2	dark ~ pale brown, dark ~ light gray, grayish green	medium	parallel, dendritic, sub-dendritic, pinnate, radial	middle - high	high - middle	poor bedded - well bedded	low	volcanic rocks, pyrocrastic rocks	Tvnd Tig	Volcanic rocks, Pyroclastic rocks (Tc2 : Tagua Formation, Mauri Formation, Carangas Formation, Murmuntani Formation) (Tc1 : Quemez Formation) (Miocene and Oligocene)
Tc1	pale brown	fine	colinear, dendritic	high	middle	poor bedded	low	ignimbrite		
Tb	dark gray, brown, yellowish brown	medium	parallel, dendritic	high	middle	poor bedded - well bedded	low	conglomerate, sandstone, shale	Ts2	Sedimentary rocks (Pliocene to Oligocene)
Ta	dark brown ~ brown, brownish gray	fine	parallel, dendritic	low - middle	middle	bedded - well bedded	low	conglomerate, sandstone, shale	Ts1	Sedimentary rocks (Oligocene to Paleocene)
P	brawn, yellowish brown	medium	traillis	middle	high	bedded - well bedded	low	sandstone, shale	Pzs	Sedimentary rocks (Paleozoic)
Pr	light brawn ~ brown, dark gray	coarse - medium	sub-dendritic	middle	high	-	low	gneiss	QTig	Gneiss (Proterozoic)

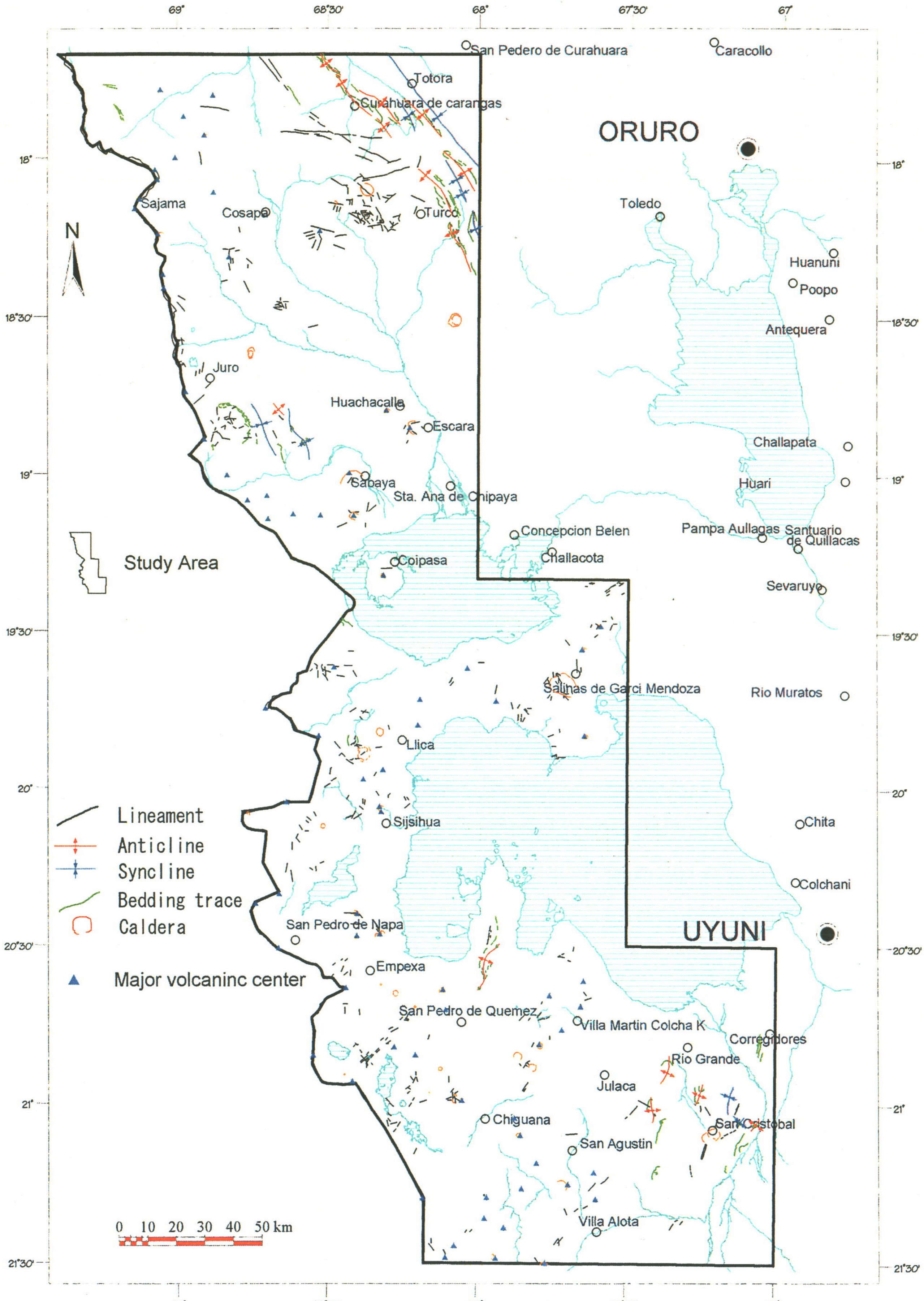


Fig. II-2-3 Extracted Lineament Map of the LANDSAT TM Image

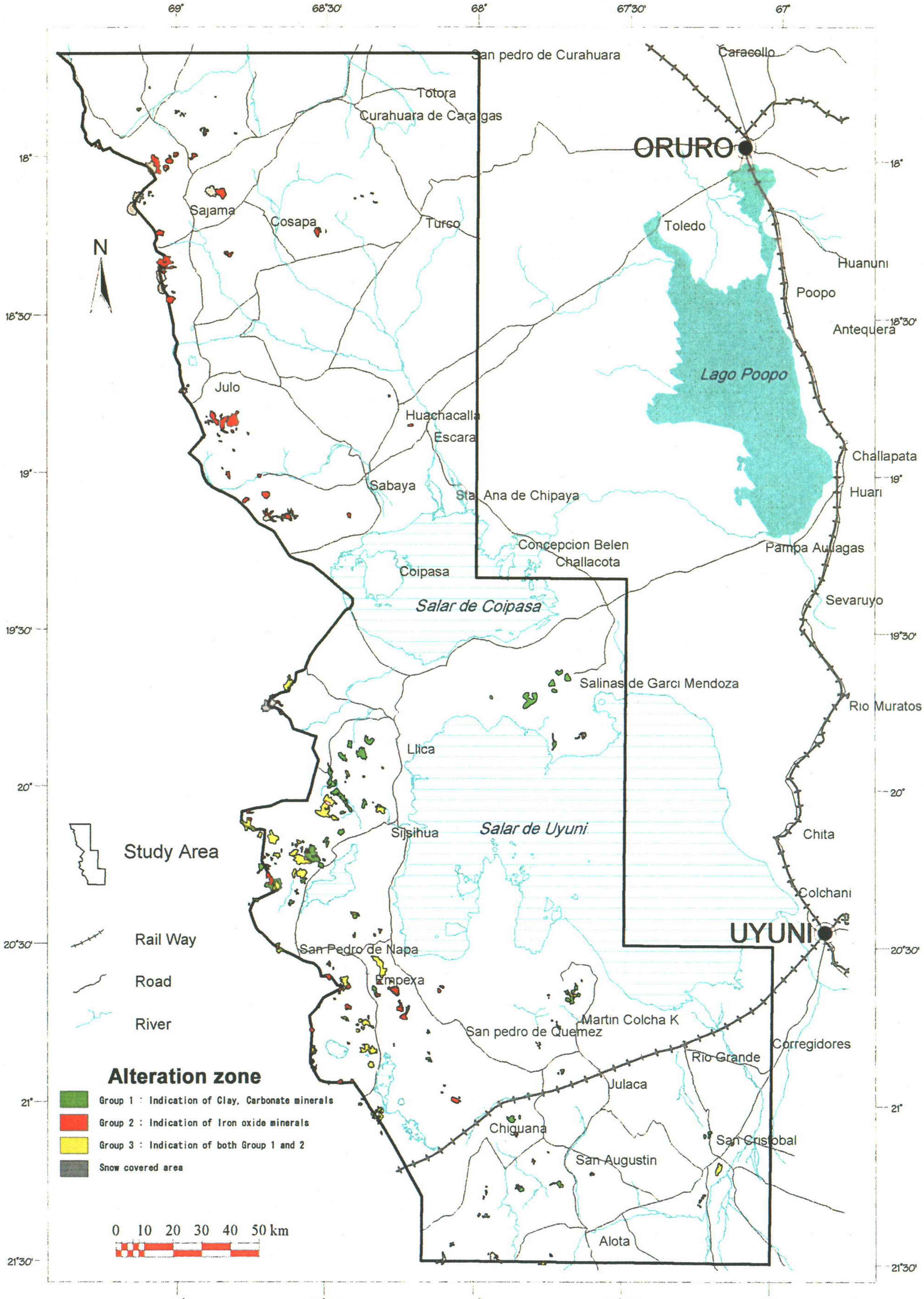


Fig.II-2-4 Extracted Alteration Map of LANDSAT TM Image detected from the spectral anomalies. In the study detecting an alteration zone, the spectral anomalies in alluvium and shadow area in the steep slope-facing southwest were excluded.

Spectral anomalies suggesting the presence of argillic carbonate alteration zone are shown as green parts. Spectral anomalies suggesting the presence of iron oxide alteration zone are shown as red parts. Spectral anomalies suggesting the presence of both argillic-carbonate alteration zone and iron oxide alteration zone are shown as yellow parts in Fig. II-2- 4.

2-4 Summary and Considerations

Result of analysis is summarized as follows:

(1) As the result of color synthetic image analysis, it was revealed that the lava and pyroclastics of Miocene to Holocene age related to mineralization are units of QTc1, QTc2 and QTc3 in this analysis. Among them, QTc2 and QTc3 clearly form stratovolcano, while the feature of stratovolcano is not clearly seen in QTc1 due to advanced erosion. In QTc3, explosion craters and lava flow are clearly recognized.

(2) Spectral anomalies suggesting the presence of alteration zones were recognized in the geologic units, Tc2, QTc1, QTc2 and QTc3. In units Tc2 and QTc1, the alteration zones were recognized in well-eroded volcanics and pyroclastics. On the other hand, alteration zones in QTc2 and QTc3 were recognized only in and around the crater of stratovolcano. Alteration zones in the unit QTc3 were excluded from prospective area as the unit is considered to be Holocene age that is too young for mineralization.

(3) Tectonic history of the area is reflected in the result of lineament analysis. Folding and thrust faulting were recognized in the formation of pre-Andes orogenesis such as units, P, Ta, Tb and Tc2. On the other hand, lineament is very few and short in units of the post Andes orogenesis. Relation between lineaments and alteration zones is not clear.

(4) Alteration zone located near the top of stratovolcano associated with exhalation sulphur deposits in the geologic unit QTc2 was excluded from the prospective area.

(5) Alteration zone near the top of the stratovolcano within geologic unit QTc2, which crosses the border of Chile, was also excluded from the prospective area.

(6) Independent small alteration zone of less than 2 km^2 was excluded from the prospective area.

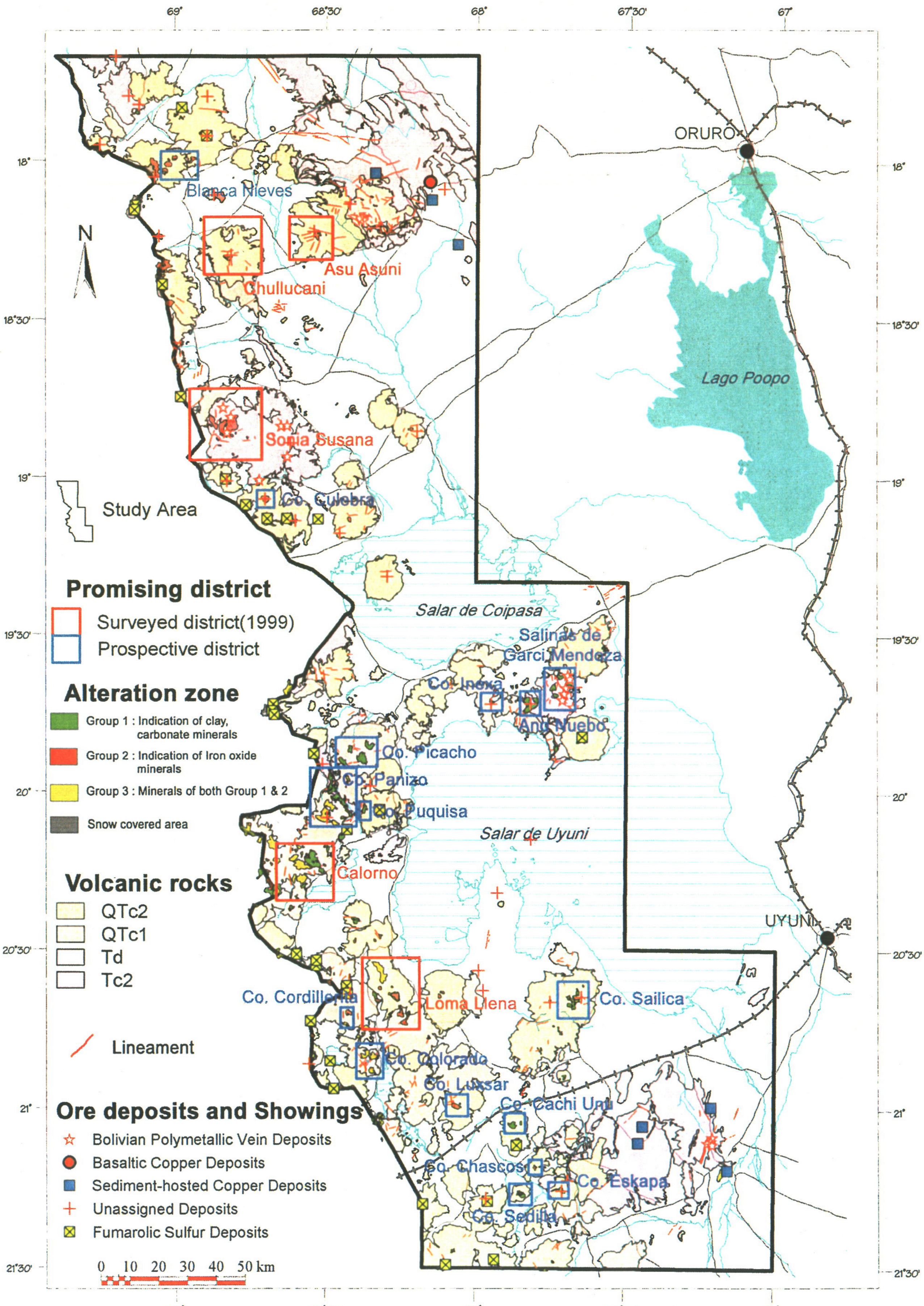


Fig. II-2-5 Integrated Map of Satellite Image Analysis

Summary of the analytical result is shown in Fig. II- 2- 5. In the figure, prospective alteration zones, Tertiary volcanics that related with alteration, lineament, known mineral deposits and showings and sedimentary sulfur deposits are illustrated.

The prospective alteration zones are classified into three categories according to the size, small for 2-10 km^2, medium for 10-20 km^2 and large for over 20 km^2. A brief explanation on the prospective areas is summarized in Table. II- 2- 3.

Table II -2-3 Summary of Prospective District

District	Location of alteration zone	Geologic unit of alteration zone	Indicated mineral	Scale of alteration zone (km^2)
Blanca Nieves	Slope	QTc2	Iron oxide	9
Chullcani	Top of the Mt.	QTc2	Iron oxide	3
Asu Asuni	Top of the Mt.	QTc2	Iron oxide	4
Sonia Susana	Centre of Dome Struct.	Tc2	Iron oxide	28
Cerro Culebra	Top of the Mt.	QTc2	Iron oxide	5
Salinas de Garci Mendoza, Año Nuevo,Iñexa	Top of the Mt.	Tc2	Clay, Carbonate	26
Cerro Picacho	Widely distr.	QTc1	Clay, Carbonate	22
Cerro Panizo Cerro Puquisa	Widely distr.	QTc1	Iron oxide, Clay, Carbonate	40
Calorno	Widely distr.	QTc1	Iron oxide, Clay, Carbonate	30
Loma Llena	Widely distr.	QTc1	Iron oxide, Clay, Carbonate	27
Cerro Cordillerita	Slope	QTc1	Iron oxide, Clay, Carbonate	4
Cerro Colorado	Top of the Mt.	QTc1	Iron oxide, Clay, Carbonate	12
Cerro Sailica	Top of the Mt.	QTc2	Iron oxide, Clay, Carbonate	10
Cerro Luxsar	Top of the Mt.	QTc2	Iron oxide, Clay, Carbonate	4
Cerro Cachi Unu	Top of the Mt	QTc2	Clay, Carbonate	4
Cerro Sedilla Cerro Chascos	Top of the Mt	QTc2	Iron oxide, Clay, Carbonate	4
Cerro Eskapa	Slope	QTc2	Clay, Carbonate	2