REPUBLIC OF PERU
REPORT ON MINERAL EXPLORATION
IN
COTAHUASI AREA

PHASE I

GEOLOGICAL SURVEY
GEOCHEMICAL PROSPECTING

FEBRUARY 1986

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

At the request of the Government of the Republic of Peru, the Japanese Government planned and carried out a geological survey concerning mineral exploration to examine the possibility of the existence of mineral resources in the Cotahuasi area located in the southern part of Peru. The Japan International Cooperation Agency was entrusted with the execution of the general plan. The Japan International Cooperation Agency in turn entrusted the execution of this survey to the Metal Mining Agency of Japan since this survey was essentially a professional survey of geology and mineral resources.

The Metal Mining Agency of Japan organized a survey team consisting of six members in 1985, the first year of the survey project, and despatched the team to Peru during the period from September 30, 1985 to December 27, 1985.

The on-site survey was conducted as scheduled with the cooperation of the Peru Government, particularly the Instituto Geologico Minero y Metalurgico (INGEMMET) of the Ministerio de Energía y Minas of Peru.

This report describes the survey results in the first year and will form part of the final report.

Lastly, we would like to express our heartfelt gratitude to the members concerned of the Government of the Republic of Peru, the Ministry of Foreign Affairs of Japan, the Ministry of International Trade and Industry of Japan and the Embassy of Japan in Peru, and to all those who extended their kind cooperation to us in executing the above-mentioned survey.

February, 1986

Keisuke Arita

Keisuke Arita
President,
Japan International Cooperation Agency

Masayuki Nishiie

Masayuki Nishiie
President,
Metal Mining Agency of Japan

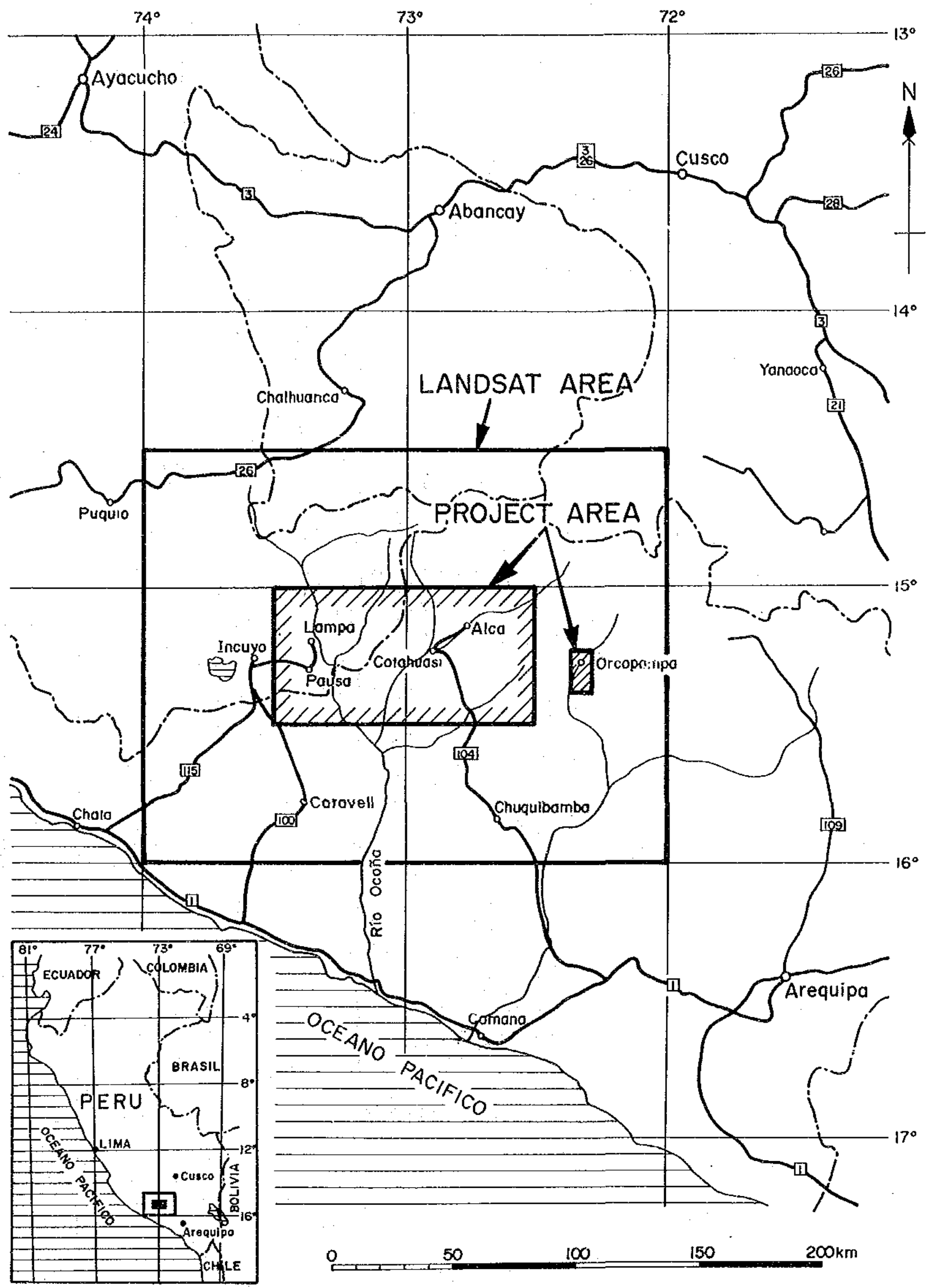

Fig.G-1 Location Map of the Project Area

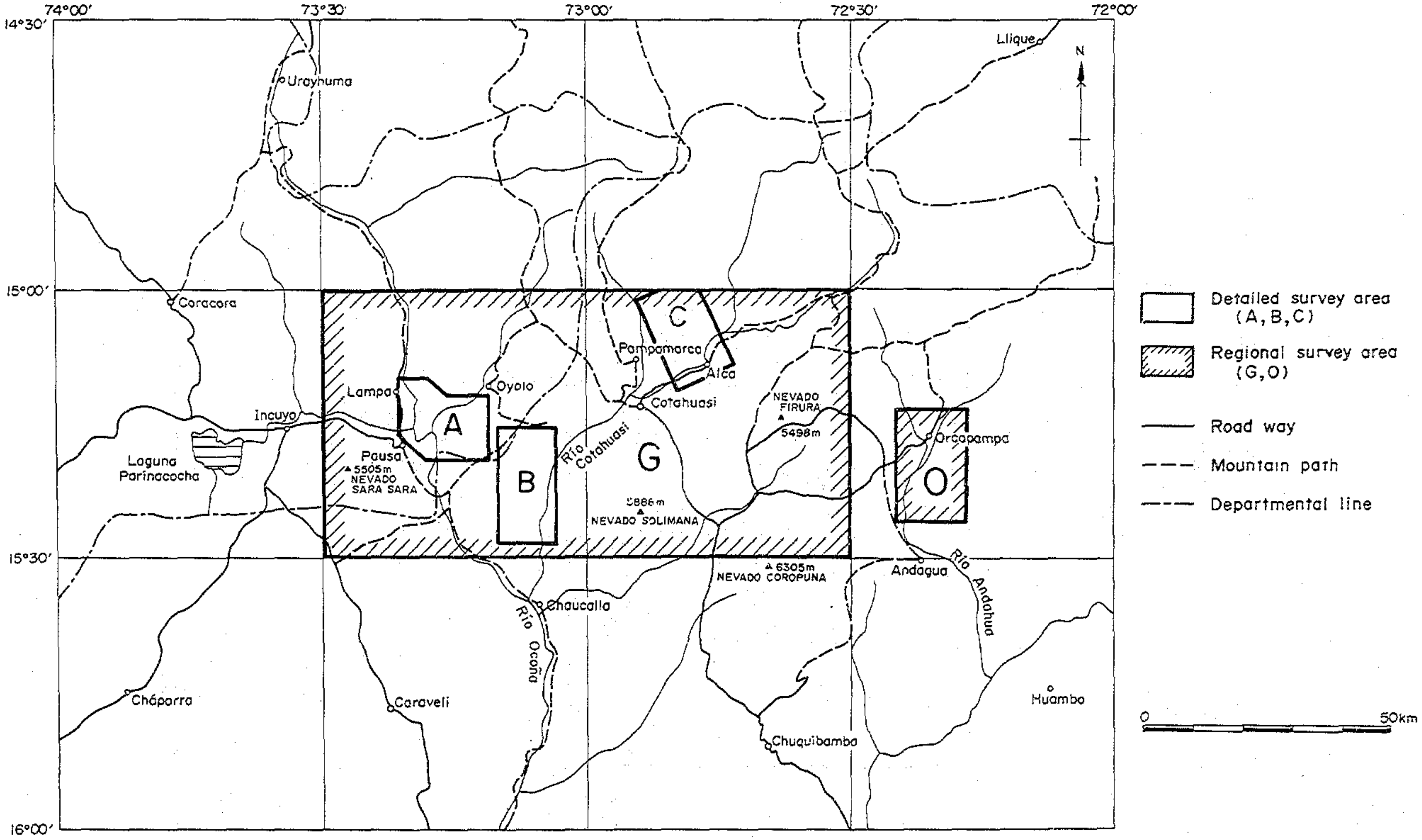

Fig.G-2 Location Map of the Survey Area

ABSTRACT

Arcata Mine and Orcopampa Mine are known to exist to the east of the Kotahuasi District of the Republic of Peru and gold-silver vein type deposits belonging to the Nazca-Ocoña zone are also known to occur to the south of the district. The present survey was planned to explore the possibility of occurrence of similar mineral deposits in the survey area.

The first-year survey conducted in the survey area consists of LANDSAT image analysis in the field, geological survey and geochemical prospecting. A geochemical prospecting was also carried out in the vicinity of Orcopampa Mine for the purpose of model survey for an ore deposit. The survey was aimed at identifying those areas having great possibility of occurrence of mineral deposits through synthetic analysis of the geology, geological structure, mineralized and alteration zones and geochemical characteristics of the survey area.

The survey area is located in the highlands of 4,000 to 5,000 m above sea level on the southwest slopes of the Andes and great valleys ranging from 1,000 to 2,500 m in specific height are found in the area. Those valleys belong to the Ocoña drainage system which flows into the Pacific. Volcanos of the Quaternary rise about 6,000 m above sea level over the highlands.

The geology of the survey area consists of Precambrian basement composed of gneissosed granite and diorite, thick Jurassic and Cretaceous formations composed of clastic and calcareous rocks, and widespread Tertiary and Quaternary formations composed mainly of volcanic rocks and intrusive rocks.

Intrusive rocks occur as batholiths of diorite and numerous stocks and dikes of diorite and andesite. These are partly accompanied by skarns and alteration zones.

The strata formed before the middle stage of the Neogene period are generally folded heavily and turned into blocks. However, folds are not observable in the strata of the middle and upper parts of the Neogene system and faults in the strata are very small.

A large number of alteration zones are observable in the survey area, but those alteration zones overlapping geochemically anomalous zones are distributed only in the strata formed before the middle stage of the Neogene period.

The mineralized zones in the survey area are mostly those of gold-silver bearing veins formed in quartz veins and oxidized zones along fracture zones and joints. In some parts of the survey area there can be observed small-scale contact metasomatic mineralization of gold, silver, lead and zinc in skarns.

Following are zones of great possibility of occurrence of mineral deposits in the survey area which are selected on the basis of the results of the present survey.

(1) Mina Pararapa composed primarily of gold-silver bearing quartz veins;

(2) Alteration zone of Tanisca overlapping a geochemically anomalous zone of gold;

(3) Mina de Luicho composed of gold bearing quartz veins and oxidized zones; and

(4) Alteration zone of Pirca overlapping geochemically anomalous zones of zinc and silver.

In the Chururo Pampa area to the southwest of the survey area is located Cruz Vuelta Mine where gold bearing quartz and clay veins are currently being prospected and mined and latent mineralized zones are expected to be found in neighbouring stretches of the flatland.

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CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

1-1 Purpose of the Survey

The first-year programme of the cooperative mineral exploration project in the Cotahuasi area in the Republic of Peru consisted of a geological survey, geochemical prospecting and analysis of LANDSAT images. These investigative activities were aimed at determining the occurrence of mineral deposits by shedding light on the geological conditions of the area investigated. The top-priority task of the survey was the selection of promising areas through a comprehensive study of the relationship between the geological structure and mineralization and of the geochemical characteristics.

1-2 Contents of the Survey

Contents of the first-year survey are shown in Table 1-1 and quantities of laboratory tests conducted are shown in Table 1-2.

Table 1-1 Outline of the Survey

Investigation	Quantity of Investigation	
Geological survey and geochemical prospecting		
(1) Regional survey area	Area investigated;	5,200 km^2
	Distance explored;	1,493 km
	No. of geochemical prospecting samples taken	1,309
(2) Detailed survey area	Area investigated	800 km^2
	Distance explored;	643 km
	No. of geochemical prospecting samples taken	815
(3) Orcopampa area	No. of geochemical prospecting samples taken	50
(4) All areas	No. of geochronological samples taken	5
(5) LANDSAT image analysis	Area covered by photo-geological reading	30,000 km^2

Table 1-2 Quantity of Laboratory Works

Items of Analysis and Composition	Quantity
Thin section of rock	50
Polished section of ore	22
X-ray diffraction	25
Chemical analysis Rock; SiO_2, TiO_2, FeO, Fe_2O_3, MnO, MgO, CaO, K_2O, BaO, Na_2O, Al_2O_3, P_2O_5, LOI	20 (260 constituents)
Minerals; Au, Ag, Cu, Pb, Zn	24 (120 constituents)
Radiometric (K-Ar dating) dating	5
Geochemical prospecting samples analyzed Stream sediments; Au, Ag, Cu, Pb, Zn, As	2,174 (13,044 constituents)

1-3 Schedule of the Survey

The survey was carried out in accordance with the following time schedule. Details of the schedule are illustrated in Table 1-3.

Planning and preparations; Sept. 25 to Oct. 19, 1985
Field survey activities; Sept. 30 to Dec. 27, 1985
Laboratory work and analysis of data; Dec. 28, 1985 to Feb. 28, 1986

Table 1-3 Schedule of Survey

Item	Sep. 1985	Oct. 1985	Nov. 1985	Dec. 1985	Jan. 1986	Feb. 1986
(1) Planning and preparation	5 — 29 - - -	- - - 19				
(2) Field survey	30 ———	———	———	——— 27		
Mobilization: 1st group	30 ———	——— 4				
Mobilization: 2nd group		7 ——— 14				
Mobilization: 3rd group		21 ——— 25				
Geological survey and geochemical prospecting		15 ———	———	——— 19		
LANDSAT image analysis						
Analysis of geochemical		31 ———	———	——— 19		
Withdrawal				20 ——— 27		
(3) Laboratory work			29 ———	———	———	——— 28
· Analysis of geochemical prospecting samples			29 ———	——— 19 ———	———	
· Radiometric dating					9 ———	——— 10
· Various laboratory tests					10 ———	——— 10
· Data analysis and chart preparation					8 ———	——— 23
· Tracing and drafting					16 ———	——— 25
· Preparation of draft report, translation into English and editting					11 - - - 24 ———; 25 ———	——— 9; ——— 25
· Printing and binding						26

Scale in No. Days: 50, 100, 150

1-4 Organization of the Survey Team

Listed below are those persons who were on the Japanese and Peruvian negotiating teams and those on the field survey teams of the two countries.

(1) Negotiating team

Japanese side

Makoto Ishida, leader	Metal Mining Agency of Japan
Yoshikazu Taketomi	Ministry of International Trade and Industry; Agency of Natural Resources and Energy
Sumihiro Fure	Metal Mining Agency of Japan; Lima Office
Tadaaki Ezawa	Metal Mining Agency of Japan
Takashi Kamiki	ditto

Peruvian side

Juan Zegarra W., leader	Instituto Geologico Minero y Metalurgico
Gregorio Flores N.	ditto
Erick Soriano B.	ditto

(2) Field survey team

Japanese side

Hiroshi Miyajima,	leader	Sumiko Consultants Co., Ltd.
Kiyoharu Nakashima,	member	ditto
Masatsugu Sakai,	ditto	ditto
Seiji Tsuchida,	ditto	ditto
Jiro Natori,	ditto	ditto
Hisaaki Nagao,	ditto	ditto

Peruvian side

Cesar Vilca Neira,	co-leader	Instituto Geologico Minero y Metalurgico
Hector Zarate Olazagal,	member	ditto
Walter Rodriguez Olaete,	ditto	ditto
Carlos Jimenez Velasco,	ditto	ditto
Emilio Rojas Rivera,	ditto	ditto

The field survey was carried out by five to six groups, each consisting in principle of one Japanese geologist, one Peruvian geologist, a few assistants and some horses.

CHAPTER 2 GENERAL CONDITIONS

CHAPTER 2 GENERAL CONDITIONS

2-1 General Situation of the Republic of Peru

The Republic of Peru (hereinafter referred to Peru) abuts the Pacific Ocean and lies between the Equator and lat. 18°20'S and covers an area of 1,285,215 km^2 (nearly 3.4 times as large as Japan). With Lima as its capital, this South American country has a population of 18,710,000 (estimate of 1983), of which Natives account for 47% (Bolivia is another South American country with a high Native population), mestizos about 40% and whites 12%. The official language is Spanish which is spoken throughout the country. Kechua is widely spoken among the Natives and in some areas the Peruvian-Bolivian borders Aimala is spoken.

Peru's Gross National Product for 1982 amounted to US$22.03 billion for a per capital GNP of US$1,260. The domestic production of primary energy totaled 11,080,000 tons in oil equivalent as compared with the consumption of 7,660,000 tons. The country abounds in mineral resources and is the world's second largest producer of silver (1,458 tons in 1981), fourth largest in zinc (about 500,000 tons in 1981), fifth largest in lead (187,000 tons in 1981) and seventh largest in copper (336,000 tons in 1983). It is also flessed with crude oil and natural gas.

According to the 1983 statistics, Peru's exports and imports amounted to US$3,015 million and US$2,688 million, respectively, showing a trade surplus of US$327 million. The nation's official external debt amounted to US$11,484 million as of the end of 1982. According to trade statistics published by the Asahi Shimbunsha in 1986, Peru's exports of zinc, silver, copper and other minerals to Japan and her imports of automobiles, steel products, machinery and other manufactured goods from Japan totaled US$407.26 million and US$160.11 million, respectively, in 1984.

Galloping inflation brought about a serious economic dislocation in Peru before 1984. After coming to power, the present Peruvian regime has implemented a series of measures aimed at the stabilization of the national economy, such as the fixing of the exchange rate of Soles against the US dollar and price control. The present bank exchange rate of Soles against the US dollar stands at 17,300 Soles to US$1.00 and the official rate at 14,000 Soles to US$1.00. The Peruvian Government has announced its intention to freeze the exchange rates and oil price until the end of the first six-month period of 1986.

2-2 Location of the Survey Area and Access

The survey areas are located in the southern part of the Republic of Peru.

The area covered by the LANDSAT image analysis spans the departments of Arequipa, Ayacucho, Apurimac and Puno and forms a rectangle of about 30,000 km^2 enclosed by the lines connecting lat. 14°30'S and 16°00'S and long. 72°00'W and 74°00'W (Fig. 1).

The area covered by the geological survey and geochemical prospecting is situated substantially in the middle of the area covered by the LANDSAT image analysis. The regional survey area is located near the borders between the departments of Arequipa and Ayacucho and covers an area of about 6,000 km^2 enclosed by the lines connecting lat. 15°00'S and lat. 15°30'S and long. 72°30'W and 73°30'W, less an area of about 800 km^2 which corresponds to the detailed survey area. Detailed survey areas comprise three areas, A, B and C, each of them defined further in the following table.

Area A		Area B		Area C	
South lat.	West long.	South lat.	West long.	South lat.	West long.
15°09'	73°11'	15°14'	73°03'	15°00'	72°47'
15°09'	73°16'	15°14'	73°03'	15°00'	72°47'
15°07'	73°18'	15°14'	73°03'	15°00'	72°47'
15°07'	73°21'	15°29'	73°03'	15°11'	72°50'
15°13'	73°21'			15°08'	72°43'
15°17'	73°18'				
15°17'	73°11'				
Area approx. 250 km^2		Area approx. 340 km^2		Area approx. 210 km^2	

The Orcopampa area, located to the east of the regional survey area, is approximately 550 km^2 in area enclosed by the lines connecting lat. 15°11'S and 15°25'S and long. 72°17'W and 72°25'W.

The principal communities in the survey area which are served by a road passable in vehicles are Cotahuasi and Pausa, both located almost in the center of the area. The access road to the two communities starts in Arequipa, Peru's second largest city, but there is no roadway connecting the communities directly (Fig. 3).

Cotahuasi can be reached by following the National Highway 1 from Arequipa to Tambillo and then taking Departmental Road 103 running northwestward and passing Pta Colorado, Aplao and Chuquibamba. The distance between Arequipa and Cotahuasi is about 410 km and can be covered in eight to ten hours by car. That section of the access road running from Arequipa to Pta Colorado (nearly

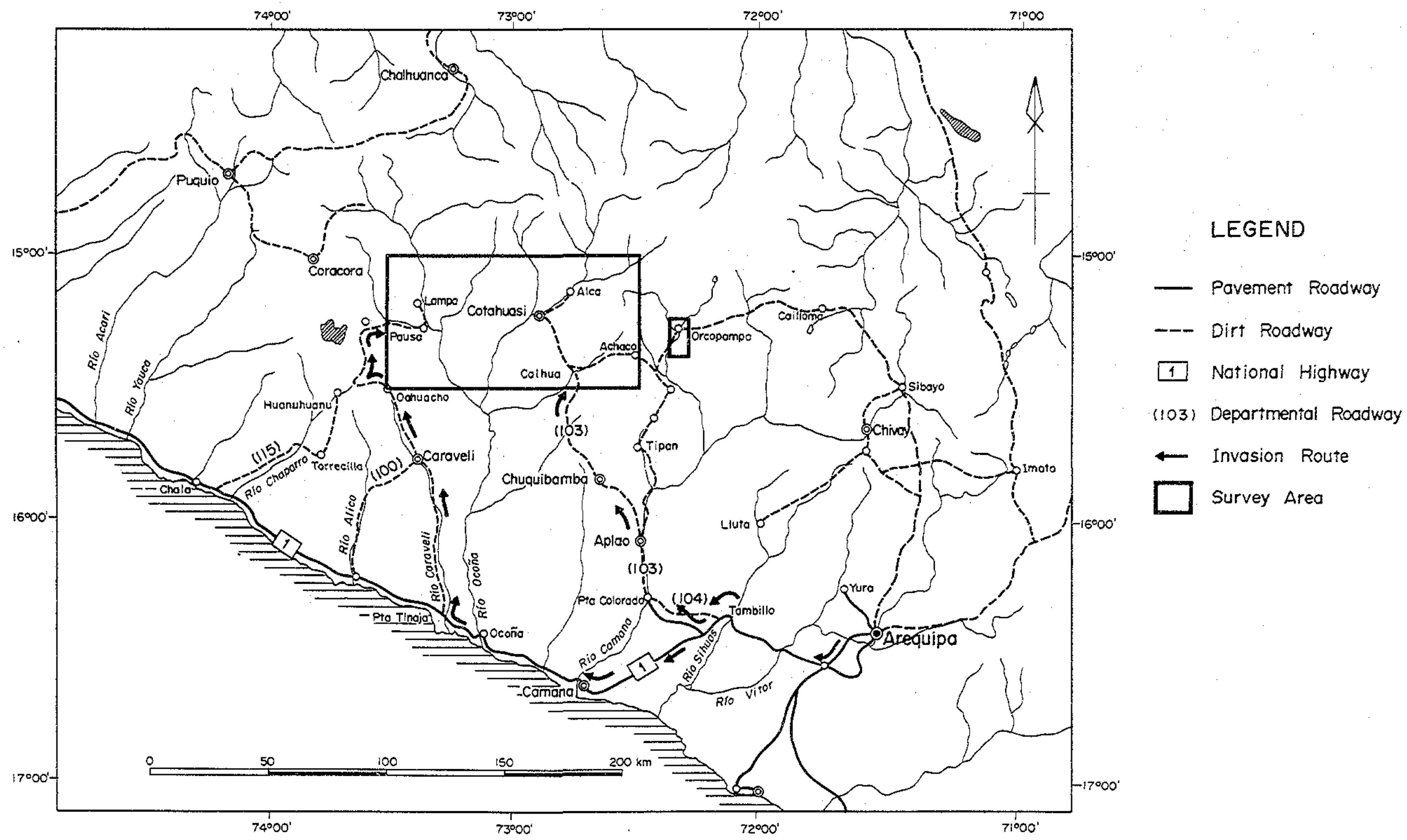


Fig. 2-1 Accesibility Map to the Survey Area

180 km) is paved, but the remaining section (about 230 km) leading to Cotahuasi is a gravel road.

Pausa can be reached by following the National Highway 1 along the coastline from Arequipa to Pta Tinaja, then proceeding northward to Caraveli and from there taking the Departmental Road 100. The distance between Arequipa and Pausa is about 490 km and can be covered in 10 to 12 hours by car. The Arequipa-Pta Tinaja section of about 280 km in length is paved and the remaining section of about 210 km leading to Pausa is a gravel road. The roadway condition between Arequipa and Pausa is worse than those of the Arequipa-Cotahuasi route.

Pausa can also be reached by following the National Highway 100 from Atica and then taking the Departmental Road 115 from Chala, but this route takes much longer time.

The roads passable by vehicle in the survey area, with the exception of the above-mentioned access roads from Arequipa, include a gravel road of about 20 km connecting Alca and Cotahuasi, a second gravel road of about 15 km running from Pausa to Lampa along a river and another gravel road running about 8 km to the south. There are no other roadways and horses provide the only means of transportation of men and goods.

2-3 Topography

The survey area is located in the southwest of the Altiplano, a plateau 4,000 to 5,000 m above sea level, in the Andes. The Altiplano is deeply incised by two Grand Cannyon-shaped valleys of relative height ranging from 1,000 to 2,500 m which are believed to have been formed by dissection after the middle stage of the Tertiary. These are the rivers of Rio Maran and Rio Cotahuasi which meet together into the Rio Ocona which pours in the south into the Pacific.

Rising above the Altiplano are Quaternary volcanos 5,500 to 6,300 m above sea level which range from WNW to ESE. These include Nevado Sara Sara (5,505 m), Nevado Solimana (6,093 m), Nevado Firura (5,498 m) and Nevado Coropuna (6,377 m). In the ESE direction other Quaternary volcanos of comparable height including Nevado Anpato (6,288 m), stretch into outside the survey area.

The Altiplano generally consists of gently sloping hills and stretches of flatland among them. Marshlands or extensive grasslands called "pampa" and marshes or lagoons called "laguna" are formed in the basins.

The valleys shaped like the Grand Cannyon are mostly sloped at a greater angle than 40° and they often form precipitous (sloped at 60° to 70°) or nearly perpendicular cliffs. There are intermittent stretches of alluvial flatland of limited area along major rivers. The breast of the steep slopes are dotted with gently sloping flatlands of limited area.

2-4 Climate and Vegetation

The region extending from the southwestern end of the survey area to the Pacific Coast belongs to the arid zone of the South American Pacific Coasts which is characterized by the desert type climate which permits of almost no vegetation. On the other hand, the Altiplano district including the survey area belongs to the semiarid climate and is generally called a zone of grass-covered cold highlands and basins.

In the survey area, the difference between the lowest and highest elevation is approximately 5,200 m, the lowest being the vicinity (1,150 m) of the southern bed of Rio Cotahuasi and Rio Maran and the highest being Nevado Coropuna (6,377 m). As a result, the climate and vegetation of the survey area vary widely with elevation.

In the areas along the Rio Cotahuasi and Rio Maran which are at a lower elevation than 2,300 m, the temperature is higher and papayas, bananas, grapes, pacays and other fruits are raised and a variety of trees and plants grow.

The areas lying between 2,300 and 3,500 m in height have a mild semiarid climate and maize, wheat, other cereals and broad beans are raised there, but fruits are almost non-existent. In the hill district several species of cactus and shrubs grow rather densely. Most of the communities, including Cotahuasi and Pausa where a base camp was set up, are concentrated in this mild semiarid climate zone.

The climate of the mountain district ranging in elevation between approximately 3,500 m and 5,000 m is a cool to cold semiarid climate. The midslopes of the mountains of up to about 4,000 m in height are dotted with a growth of several species of cactus and shrubs, but in the Altiplano district ranging in elevation from 4,000 to 5,000 m the growth of cactus and shrubs is very limited and a greater part of this district forms a desert except a wide variety of moss growing in the pampas and scatterings of low shrubs.

The mountains of 5,000 m or greater height are crowned with perpetual snow and in this mountain district the weather is extremely cold and no vegetation is found.

In the Altiplano district, rainfall is generally small and the dry season lasts from April to September and the wet season from October to March. In the survey area, the wet season sets in earlier in its eastern part and rainfall starts in October, but in the western part the wet season tends to begin half a month to a month later. During the wet season, snow falls in the mountains of 4,000 m or more in height and rain falls in the lower mountains.

2-5 Previous Geological Works

The reports on major previous surveys on geology and mineral deposits in and around the survey areas include the following:

(1) Mario J.A.F., (1975);
Geologia de la Mina Orcopampa y Alrededores, Arequipa, Boletin de la Sociedad Geologica del Peru Tomo 46 P.9-24

(2) Julio C.V., (1975);
Geologica de los Cuadranglos de Huambo y Orcopampa, Ministerio de Energia y Minas Direccion General de Mineria Servicio de Geologia y Mineria.

(3) Victor P.G., (1983);
Geologia de los Cuadranglos de Pausa y Caraveli, INGEMMET Bol. No.37 Serie A., Lima

(4) Carlos G.R., David D.M., (1983);
Estratigrafia y Tectonica Terciaria del Area Coracora--Pacapausa, INGEMMET Bol. Sociedad Geologica del Peru No.71, 1983

(5) Onuma N. (1985);
Collected Paper on Geochemical Investigation of the Central Andes Volcanic Zone, Southern Peru, 1980-1981, Overseas Scientific Research (Nos. 504112 and 56043012)

In addition, a geological map on a 1/50,000 scale of the Cotahuasi area (unpublished) is available at INGEMMET.

The report of (1) above deals with the mineralization and alteration of the Orcopampa mine. The report of (2) contains a 1/100,000 scale geological map of the Humbo and Orcopampa areas and detailed descriptions of their geology and geological structure. The report of (3) contains a 1/100,000 scale geological map and profiles of the Pausa and Caraveli areas and the attached text. The report of (4) compiles the results of a study of the stratigraphy and geological structure of the Tertiary system of the northern and western part of the Pausa area. The report of (5) provides a detailed treatment of the age determination of the Tertiary and Quaternary volcanic rocks in the southern part of Peru including the survey area, and of their chemical composition and the behaviors of their radioactive elements.

These reports were used as basic data for the reading of the LANDSAT images and the planning of the field surveys.

2-6 Outline of Geology and Mineral Deposits of the Survey Area

Basement of the survey area and vicinity consists of a composite body composed primarily of Precambrian gneisses and diorites and these rocks are distributed in the southern part of the survey area.

The Jurassic system which covers the Precambrian rocks discordantly is composed mainly of green or brown andesitic volcanic rocks in the lower part and a part of the bottom of the system exhibits a schistosed structure. The middle part of the Jurassic system is composed of layers of grey to black limestones which is in turn overlain by dark grey to greyish green shales. The upper part of the Jurassic system is mainly composed of quartzites.

The Cretaceous system is composed of a thick bed of light grey to grey siliceous sandstone overlain by a formation consisting principally of shales with sandstones which is in turn overlain by a layer of grey to dark grey limestones with fossils. The Jurassic and Cretaceous systems are highly folded and faulted and are discordantly overlain by the Tertiary system.

The Tertiary system of the survey area consists of sedimentary rocks, principally sandstones and conglomerates, which are overlain by andesitic and dacitic volcanic rocks with noticeable facies changes. The volcanic rocks are in turn overlain by rhyolitic pyroclastic rocks. Localized folds are observed in the sedimentary rocks and andesitic volcanic rocks which form the lower part of the Tertiary system.

The Quaternary system of the survey area includes Nevado Solimana and other volcanos of greater height than 5,000 m. Its lowermost formation is composed of andesitic volcanic rocks which are widespread in the Altiplano district. This formation is overlain by moraines which are in turn overlain by basaltic to andesitic volcanic rocks formed by local extrusion. The alluvial formation consists generally of tuffaceous sedimentary rocks which are distributed along the major rivers, in gentle slopes and basins of the Altiplano.

Major intrusive rocks in the survey area include the Cretaceous granitic intrusive rocks corresponding to the Coast batholith and the Tertiary microdioritic and andesitic intrusive rocks. These intrusive rocks are in stocks or batholiths and have a distribution in the southern to the central part of the survey area.

The intrusive rocks in the Coast batholith are arranged in WNW-ESE direction but the direction in which the Tertiary intrusive rocks are arranged is not known since they are overlain by Quaternary formations. Generally, however, the Tertiary intrusive rocks tend to be arranged in NW-SE and NE-SW directions.

The strata formed before the middle Miocene (before the activities of the dacitic volcanic rocks of the Alpabamba Formation) are in blocks as a result of their intense deformation by folds and faults. On the other hand, folds and faults are not observed in the strata formed after the Miocene (after the activities of the andesitic volcanic rocks of the Tacaza Formation) with the exception of small faults. The pre-middle Miocene strata manifest an anticline and syncline with the fold axis in NW-SE or WNW-ESE directions. The faults in NW-SE direction are conspicuous and are crossed by E-W, NE-SW and N-S faults.

Distribution of alteration and mineralized zones is small in scale in the areas underlain mainly by sedimentary rocks of Pre-Tertiary age because of the abundance of limestones and silic sandstones. In the areas distributed by the post-Cretaceous volcanic rocks, on the contrary, relatively large altered and mineralized zones with brown contamination are often found. In the detailed survey areas, major alteration zones are located around Oyolo in the northeastern part of Area A and around Mina Lucho in the southwestern part of the same area, around Tanizca in the western part of Area B and around Mina Picha in the northwestern part of the same area, and around Mina Pararapa in the northern central part of Area C. In the regional survey area, major alteration zones are found in the south of Sara Sara located in the southwestern part of the area, around Pirca and in the south of Maran.

Among these alteration zones, the Tanisca zone is the largest in the whole survey area and continues about 10 km north to south with a width of 1 to 3 km. This alteration zone is an argillaceous alteration zone within the andesitic volcanic rocks (Tacaza Formation) and partly contains weakly silicified zones. Oxidized clay veins and thin quartz veins bearing gold are found among the sandstones (Yura Formation) distributed in the lower part of the aforesaid alteration zone, and these veins were prospected on a small scale for gold in the past.

The alteration zone of Mina Pararapa is a brown alteration zone where altered porphyritic andesite dikes intruding in NNW-SSE direction and surrounding andesitic volcanic rocks (Tacaza Formation) are contaminated with ferrous oxide. In this alteration zone gold-silver-bearing quartz veins occur in N20°W strike and

80°NE dip, and this vein-type ore deposit was prospected through tunnels until very recently. This deposit is locally graded high with Au 40 g/t but shows variation of gold contents and an average grade of Au is 4.61 g/t within 200 m long vein strike (according to the available mine data). The vein-type deposit is traceable over a length of about 1.3 km with a width of 0.5 to 1.5 m. In addition, parallel veins are likely to exist. The alteration zone containing the gold-silver-bearing quartz veins measures approximately 2.5 km long in NNW-SSE direction and about 1 km wide.

In addition, alteration zones of Mina Lucho and the south of Moran manifest mineralization of gold, but the size of the mineralized zones is thought to be rather limited.

The alteration zone of Mina Picha is found in the vicinity of the contact between Cretaceous limestone beds (Arcurquina Formation) and an intruded diorite body and contact metasomatic deposits containing small massive lenticular copper, lead and zinc ores are found in skarns.

The other alteration zones are mostly argillaceous zones contaminated by limonite and manifest a poor state of mineralization. Of the alteration zones outside the preliminary survey area as read out from LANDSAT images, those located in the southwest of Nevado Coropuna to the southeast, near Nasama to the northwest and in the northeast of Nevado Firuna to the northeast are relatively large and these alteration zones are presumed to be mainly argillaceous alteration zones.

CHAPTER 3 ANALYSIS OF LANDSAT IMAGES

CHAPTER 3 ANALYSIS OF LANDSAT IMAGES

Photogeological interpretation of LANDSAT images covering a wide area of 30,000 km^2 including the survey area was performed in the field. The results of this work were utilized as a guideline for the surface geological exploration and for the purpose of processing and compilation of the data regarding the result of the survey.

3-1 Method of Analysis

(1) Data Used

From the Multi Spectral Scanner (MSS) data the most appropriate MMS data corresponding to the extent of the survey area were selected and the following materials were prepared.

- o four false color images (4, 5 and 7 bands), scale 1/250,000
- o four black and white images (7 band), scale 1/250,000
- o four CCT (Computer Compartible Tape)

The entire survey area is covered by four LANDSAT images.

The existing geological data used for the purpose of the photogeological interpretation include the following:

- o Mapa Geologico del Cuadranglo de Pausa 1/100,000 (INGEMMET)
- o Mapa Geologico del Cuadranglo de Caraveli 1/100,000 (INGEMMET)
- o Mapa Geologico del Cuadranglo de Cotahuasi 1/100,000 (Inside data of INGEMMET)

(2) *Photogeological Interpretation*

The interpretation work was performed on the four false color images and four black and white images. Before the interpretation, a set of interpretation factors corresponding to the various geological units used in the existing data were selected. These factors were applied to the entire survey area to provide a geological classification. The LANDSAT images were interpreted to determine strikes and dips of strata, linear structures, fold structures and so on.

The results of the photogeological interpretation were compiled on a 1/250,000 scale drainage map prepared from a topographic map on the same scale and a reduced map to a 1/250,000 scale from the existing maps on a 1/100,000 scale.

The drainage map with the interpretation results was provided for use in the geological survey.

3-2 Results of Analysis

The results of the analysis of the LANDSAT images are shown in full in PL.1 and Fig. 3-2.

3-2-1 Geological Classification

Interpretation factors for the geological classification which could be identified from the false color images are mainly color tones, ground surfaces, drainage systems and topographical features. Based on the characteristics of these factors, the geology of the survey area was classified broadly into 12 groups. The characteristics of the interpretation factors for the various geological units and the estimated rock types are given in Table 3-1.

For the survey area it was difficult to provide a geological classification for the pre-Tertiary Groups, but the geology of the area underlain by post-Cretaceous rocks could be classified with relative clearness. The intrusive rocks could not be classified by the method because of their lack of distinct characteristics.

3-2-2 Lineament

Lineaments of the survey area are characterized by a wide difference in direction and density between the northern and the southern half of the area.

In the distribution areas of mainly pre-Quaternary formations in the southern half of the survey area, densely aggregated NW-SE linearments are observable conspicuously and E-W lineaments of good continuity are also found.

On the other hand, in the distribution areas of Quaternary formations in the northern half of the survey area, lineaments manifest a relatively poor development and their directions are NE-SW and partly N-S.

The lineaments in the survey area are mostly 5 to 10 km in length and some of E-W lineaments in the southwestern part of the area are as long as 20 km.

3-2-3 Circular Structure

In the survey area, circular and semicircular structures, mostly 2 to 5 km in diameter, are well developed and some of them have a diameter of 10 km. Many of the circular and semicircular structures are arranged in NW-SE and NE-SW directions. The NW-SE structures are also observable most conspicuously in the zone extending from the neighborhood of Nasama in the northwestern part of the survey area to Potrero in the south. In the southwest of this zone the NW-SE structures are also distributed in the zone extending from Marchante to

Reparticion in the southeast. The NE-SW structures have a conspicuous distribution in the zone extending from Ocaque in the northeastern part of the survey area to Cotahuasi in the middle. The direction of the arrangement of the circular and semicircular structures is in substantial agreement with that of the lineaments. Besides, some circular and semicircular structures are found in the southeast and north-northwest of the survey area.

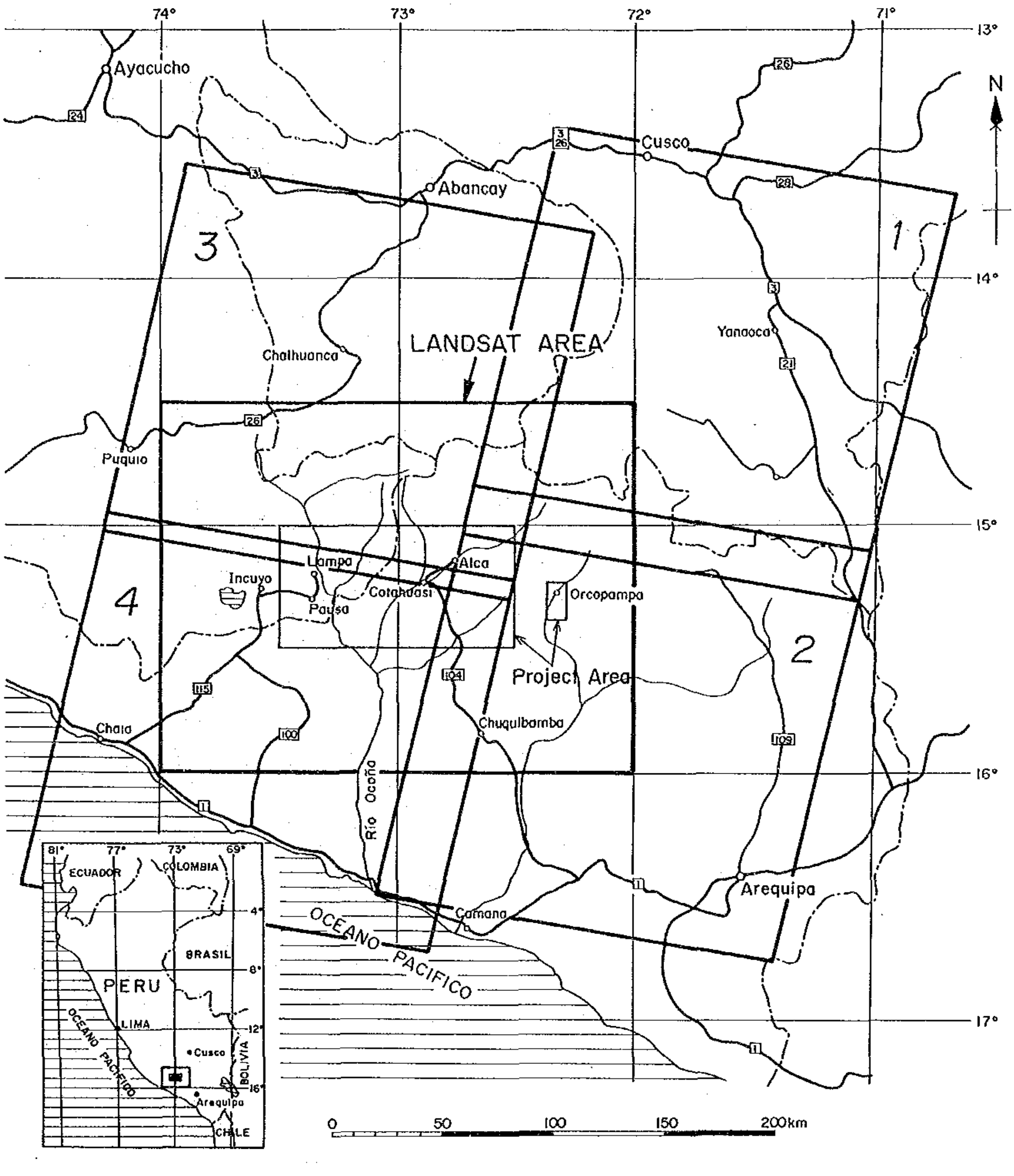
3-2-4 Alteration Zones

Slightly greenish white zones observable on the false color images correspond to the alteration zones contaminated by limonite. Of these zones, the major ones are found near Nasama in the northwest, in the south of Nevado Sara Sara, Tanisca, in the southwest of Nevado Coropuna and in the northeast of Nevado Firura. The alteration zone of Tanisca manifest a mineralization of gold.

The mineral deposits in the area covered by the LANDSAT image analysis include complex ore deposits of Orcopampa and Arcala in the east and many deposits belonging to the gold deposit zone of Nazca. In the middle, south and the southwest. The distribution pattern of these deposits does not show any correspondence to the direction and arrangement of the lineaments and circular and semicircular structures. Some of the deposits, however, tend to occur in proximity to lineaments and circular structures.

3-2-5 Other Interpretation Factors

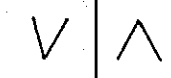
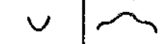
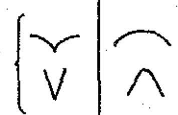
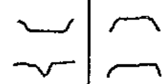
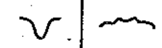
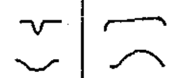
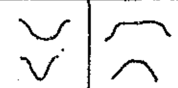
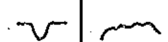
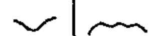
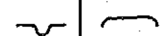
The strikes and dips of strata, and anticlinal structures are observable in the Tertiary formations in the western and southern parts of the survey area. In the zone of volcanic rocks of the Tertiary and Quaternary systems of the northern half of the survey area, the boundary between pyroclastic rocks and lava flows can often be defined clearly. For geological classifications only those lava flows considered to be the latest of the Quaternary were classified under Qr-2.

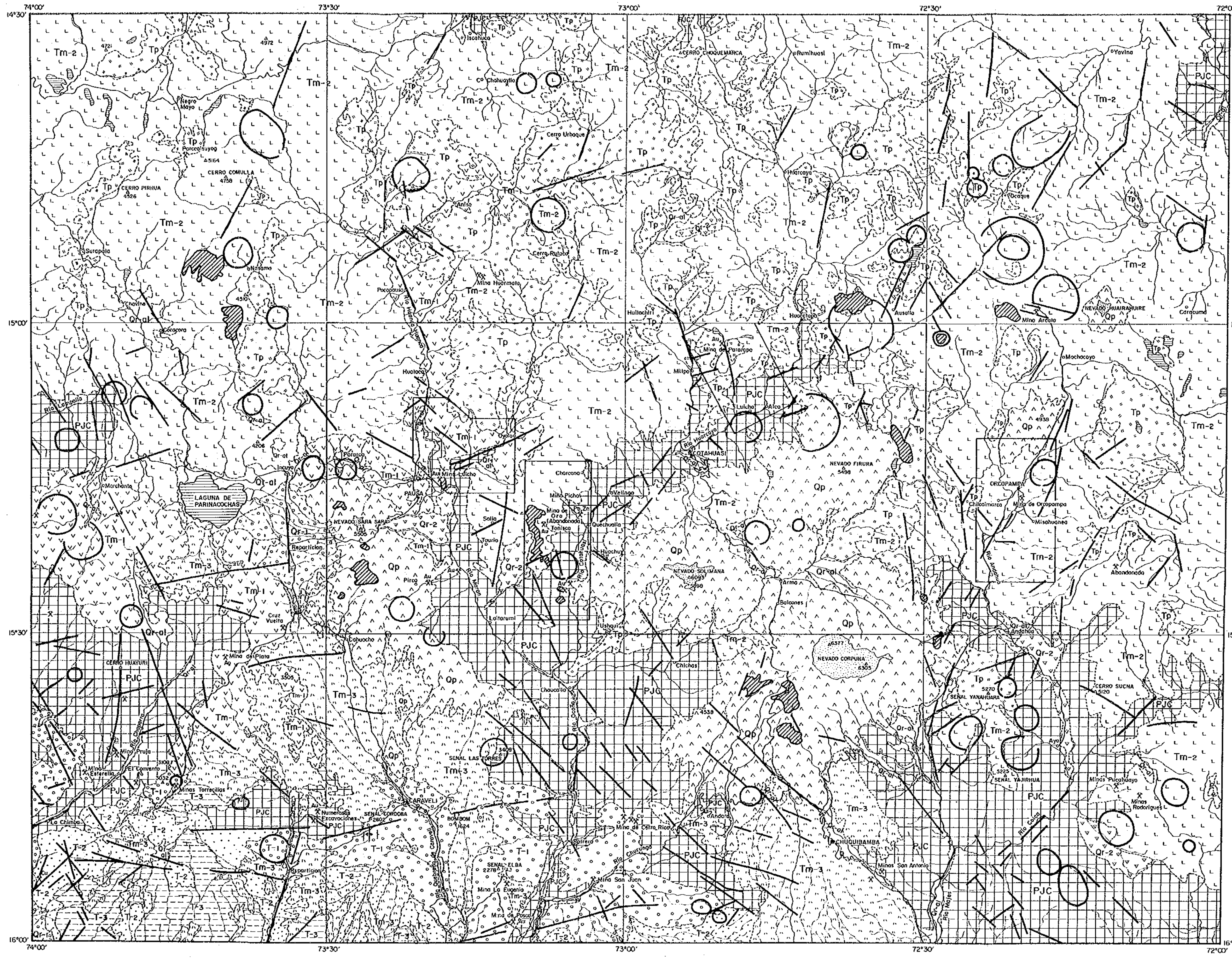


1	20927-13452 ,	06 AUG 77 ,	S14-18 ,	WO71-37 ,	POO3 R70 ,	SICUANI PERU
2	20279-14073 ,	28 OCT 75 ,	S15-48 ,	WO72-03 ,	POO3 R71 ,	AREQUIPA PERU
3	22116-14134 ,	07 NOV 80 ,	S14-24 ,	WO73-12 ,	POO4 R70 ,	SANTO TOMAS PERU
4	22116-14141 ,	07 NOV 80 ,	S15-50 ,	WO73-33 ,	POO4 R71 ,	RIO OCONA PERU

Fig. 3-1 Index Map of Landsat Data

Table 3-1 Standard of Classification for Geological Unit by LANDSAT False Color Image

Geological unit		Color	Photographic tecture	Drainage: Pattern	Drainage: Density	Drainage: Length	Resistivity	Topography: Form	Topography: Section (Valley, Ridge)	Others	Probable lithology	Known geologic data*
Cretaceous Jurassic Precambrian	PJC	Bluish grey, Whitish blue, Light purplish brown	Rugged to smooth	Parallel, dendritic	Medium	Short to medium	Weak-medium	Medium-long range			Sedimentary rocks, Intrusive rocks	Gneiss of Precambrian Jura Group (volcanic rocks, limestone, quartizite, shale, sandstone)
Tertiary												Coasto batholith (composite rocks)
	T-1	Greyish green	Coarsely rugged partially smooth	Reticular, Dendritic	Dense to medium	Short to medium	Medium	Short-medium range			Sedimentary rocks	Caraveli Formation (conglomerate, shale)
	T-2	Dark greyish green to greenish grey	Rugged	Reticular	Dense	Short	Medium	Short range			Sedimentary rocks	Paracas Formation (sandstone, shale, limestone)
	T-3	Light greenish grey	Fine rugged	Dentritic, reticular	Dense	Medium	Medium	Medium range		Partially bedded	Sedimentary rocks	Camana Formation (thick bedded sandstone)
	Tm-1	Brown, reddish brown, Brownish grey	Smooth partially rugged	Dentritic, irregular	Poor to medium	Medium to long	Medium-strong	Long-medium range		Partially bedded	Pyroclastic rocks and lava	Tacaza Formation (andesitic ∿ dacitic flow with pyroclastics)
	Tm-2	Blue, Light blue Bluish grey, Greyish brown, Brown, Reddish brown	Rugged, Dappled, partially smooth	Irregular	Poor to medium	Medium	Strong	Medium range		Red and reddish brown color is assumed to show dense vegitation	Pyroclastic rocks and lava	Alpabamba volcanics (tuff breccia, dacitic tuff, barrier beach)
	Tm-3	Pale orenge, Cream yellow, Whitish yellow	Fine rugged	Parallel, Dendritic	Medium	Long	Weak	Long range			Pyroclastic rocks	Huaylillas Formation (mainly dacitic ∿ rhyolitic tuff)
	Tp	White, Bluish white, Partially light grey	Fine smooth, and fine rugged	Irregular	Poor(flat part) Medium (rugged)	Medium to short	Medium	Flat Circular			Pyroclastic rocks	Sencca volcanics Barroso group (upper) (dacitic tuff)
Quaternary	Qp	Dark grey to grey, Dark greyish brown, Brown	Smooth and fine rugged	Parallel and radial	Medium	Long	Strong	Long range			Mainly lava flow partially pyroclastic rocks	Barroso group (lower) (lava with intercalation of tuff, conglomerate, breccia)
	Qr-1	Light purplish grey	Fine rugged	Irregular	Poor	Long	Weak	Flat			Pyroclastic rocks, Sedimentary rocks	Volcanic rocks of Sara Sara (pyroclastic rocks and sediment)
	Qr-2	Dark brownish grey	Rugged	Irregular	Poor	Medium	Medium	Flat			Lava flow	Mollebamba volcanism (basaltic lava)
	Qr-al	Red, Bluish grey	Smooth and fine rugged		Poor	Medium	Weak	Flat		Red color is assumed to show dense vegitation	Sediment	Alluvium deposits



74°00'
73°30'
73°00'
72°30'
72°00'
14°30'
15°00'
15°30'
16°00'
CERRO PIRHUA
CERRO COMULLA
LAGUNA DE PARINACOCHAS
NEVADO SARA SARA
PAUSA
COTAHUASI
NEVADO FIRURA
NEVADO SOLIMANA
NEVADO CORUPUNA
ORCOPAMPA
CERRO CHOQUEMARCA
NEVADO HUAIRAHUIRE
Mina Arcata
CERRO SUCNA
SEÑAL YANAHUARA
SEÑAL YAJIRHUA
CERRO HUAYURI
SEÑAL LAS TORRES
SEÑAL CORDOBA
CARAVELI
SEÑAL ELBA
CHUQUIBAMBA
Minas San Antonio
Minas Rodriguez
Minas Torrecillas
Mina de Plata
Mina de Cerro Rico
Mina San Juan
Mina La Eugenia
Minas Pucahuayo
Mina de Orcopampa
Tm-1
Tm-2
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Tp
Qp
PJC
Qr-al
Qr-1
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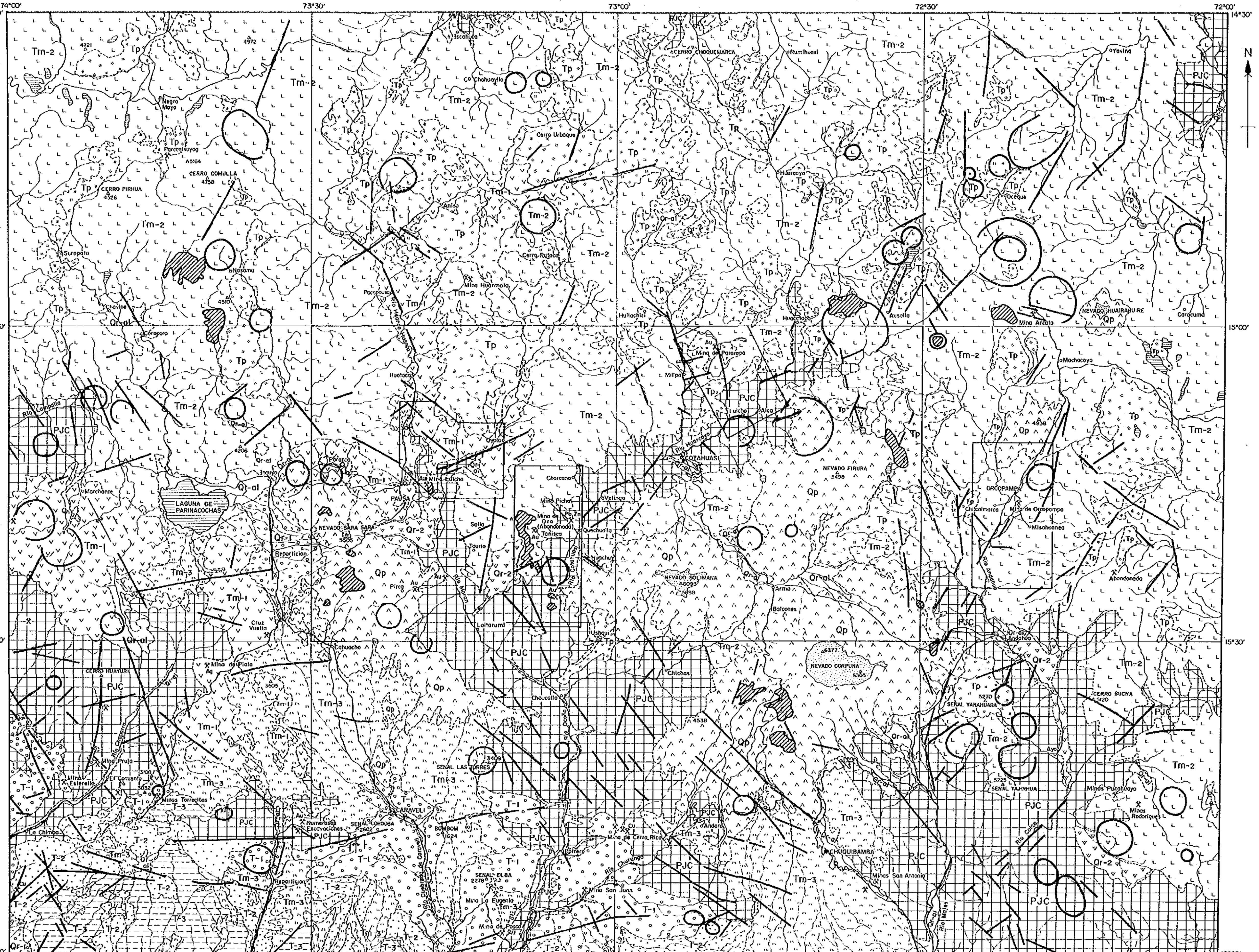
T-1
T-2
T-3



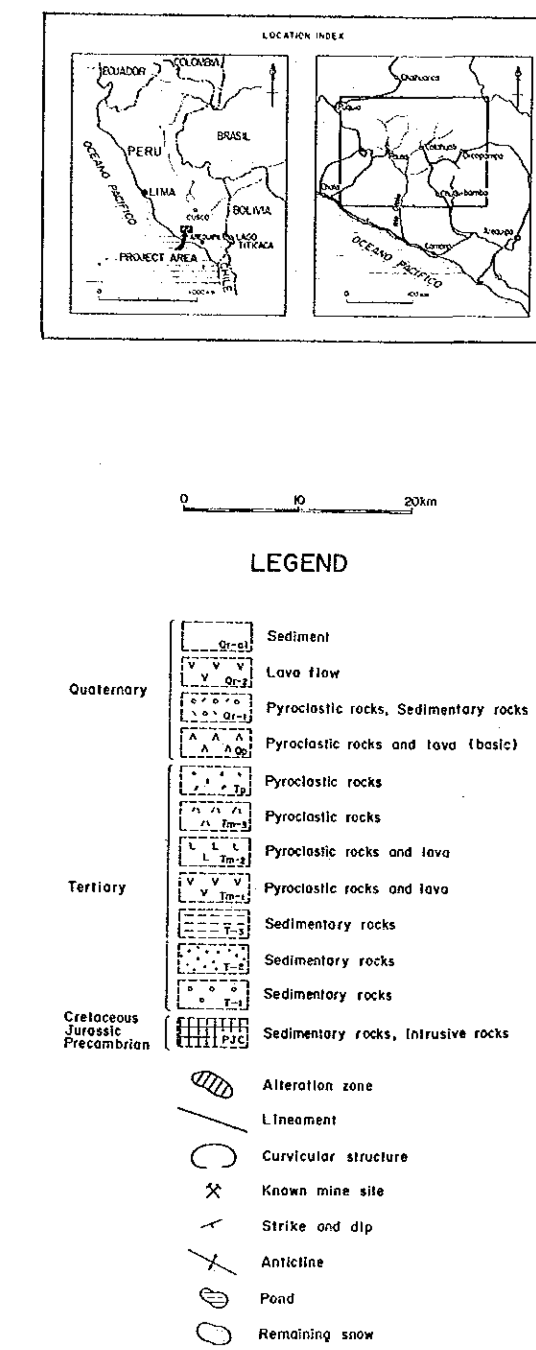


Fig. 3-2 Interpretation Map of Landsat False Color Images

CHAPTER 4 GEOLOGICAL SURVEY

CHAPTER 4 GEOLOGICAL SURVEY

4-1 Method of Survey

In the survey area valleys of 1,000 to 2,500 m in specific height are found and major communities are located in small level surfaces scattered in these valleys. For this reason, it is impractical to cover the entire survey area by undertaking one-day survey trips from the communities in the valleys or base camps. There is a wide area of mountains as high as 5,000 m where one is apt to suffer from altitude sickness. Taking all this into consideration, all the members of the survey team made one-day survey trip to areas near the base camp every day for about a week after entering the survey area in order to adapt themselves to highland life. Then the survey team carried out wide-area surveys in a caravan equipped with compact lightweight camping outfits. During the surveys carried out in a caravan, goods and personnel were carried by horses and as it passed villages, the survey team picked up bits of information, such as the conditions of mountain paths, existence of mineralized zones or traces of mining operation, topographical features and availability of camping sites with potable water supply.

The eastern and western halves of the survey area were surveyed with a base camp set up in Cotahuasi and Pausa, respectively, and necessary food was mostly procured in Arequipa.

A topographical map drawn on 1/100,000 scale published by the El Instituto Geográfico Militar, Lima-Peru was used as a basic map for surveying the regional survey area and 1/50,000 scale topographic maps enlarged from the 1/100,000 scale map were used for reconnaissance. The reconnaissance routes were selected using the existing geological maps (Pausa and Cotahuasi ones) in such a way as to facilitate grasping geological structures. The results of interpretation of aerial photographs and LANDSAT images were also used in selecting routes. Geological reconnaissance was performed simultaneously with geochemical sampling and the results were compiled in 1/50,000 scale route maps and 1/50,000 scale geological maps covering the regional survey area.

In detailed survey areas, geological reconnaissance and ore deposit survey were carried out on the basis of new topographical maps enlarged from the 1/100,000 scale map and redrawn on 1/25,000 scale and the results of these detailed surveys were also compiled on 1/25,000 scale geological maps.

4-2 Survey Results

For the western half of the survey area, a geological map of the Pausa area (scale: 1/100,000) published by INGEMMET is available and for the eastern half unpublished geological map (same scale) of the Cotahuasi area is available. The present field survey has resulted in big modifications to the extent of distribution of the Tacaza Group shown on the existing geological map of the Cotahuasi area, but no major modification was necessary with respect to the stratigraphy of this area.

It was decided, therefore, to adopt in general the stratigraphic sequence and the names of formations classified on the two existing geological maps, for the purpose of this report.

4-2-1 Stratigraphy

Rocks of the survey area comprises the Precambrian Basement, the Jurassic, Cretaceous, and Tertiary systems, intrusive rocks through these Basement and systems, and the Quaternary System which is widespread in the Altiplano highlands (See Figs. 4-1 and PL.1 to PL.9).

The geology of the survey area is described below in accordance with the generalized stratigraphic column (Fig. 4-2), in ascending order.

[1] Basement (Gn)

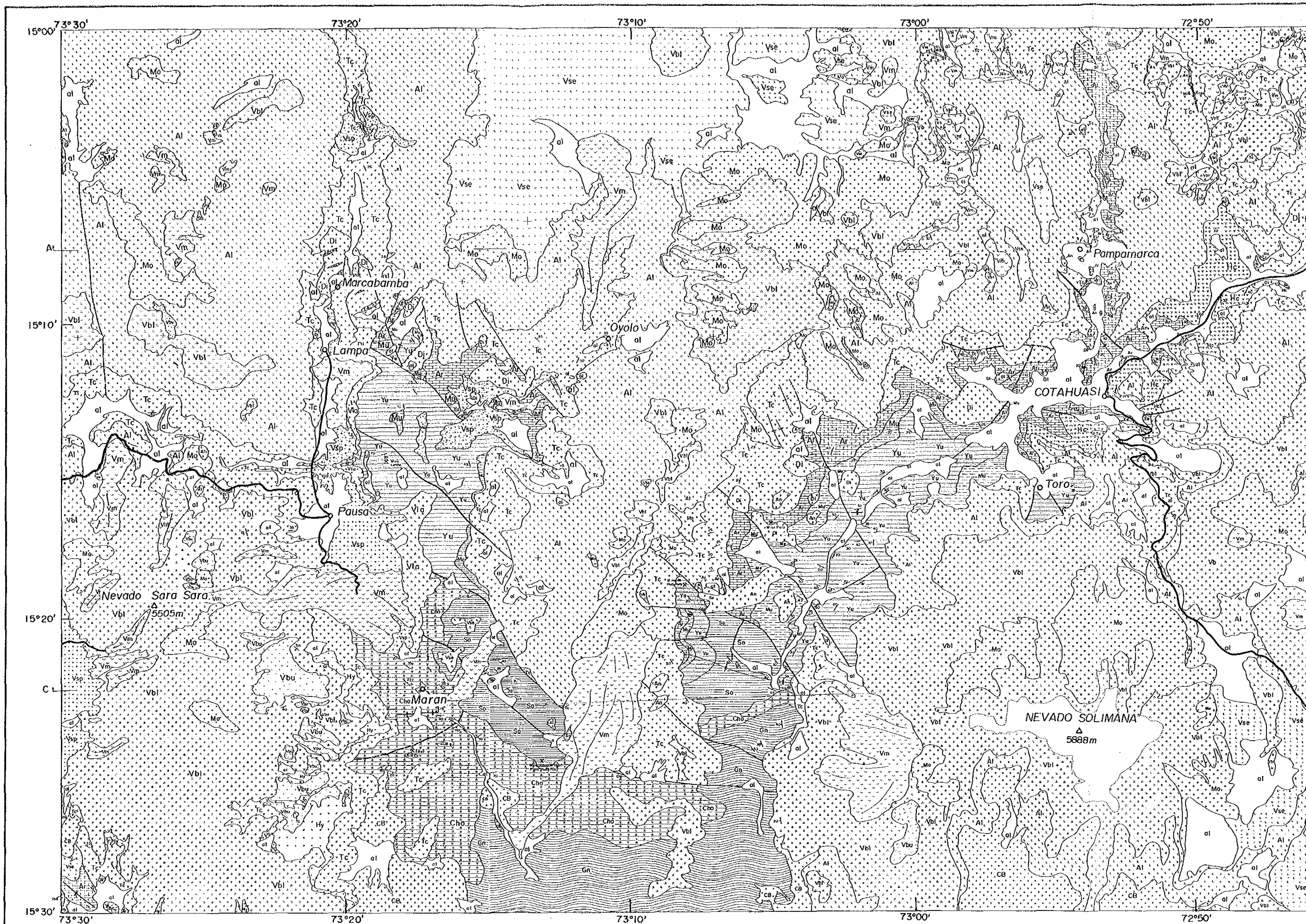
The Basement distributed in the survey area consist of composite bodies of gneissosed granite to diorite rich in varying facies.

Distribution

Forming steep landforms, the composite rock bodies are distributed between the right bank of the Cotahuasi River in the south of the survey area and the Maran River to the west. The composite rock bodies continue to the south beyond the survey area.

Rock Facies

The composite rock bodies are composed of greenish grey gneissosed granites to diorites. To be more specific, the gneissosed diorites contain generally slightly opaque feldspars displaying irregular lens shapes surrounded by aggregates of green to dark green fine-grained hornblendes in a banded arrangement and the gneissosed granites contain potassium feldspars and aggregates of fine-grained crystals of biotites in a banded arrangement. Under the microscope, a sample of greenish grey gneissosed collected in the south of Cotahuasi contains prismatic to tabular


73°30'
73°20'
73°10'
73°00'
72°50'
15°00'
15°10'
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15°30'
A
C
Marcabamba
Lampa
Pausa
Oyolo
Pampamarca
COTAHUASI
Toro
Nevado Sara Sara
5505m
Maran
NEVADO SOLIMANA
5888m

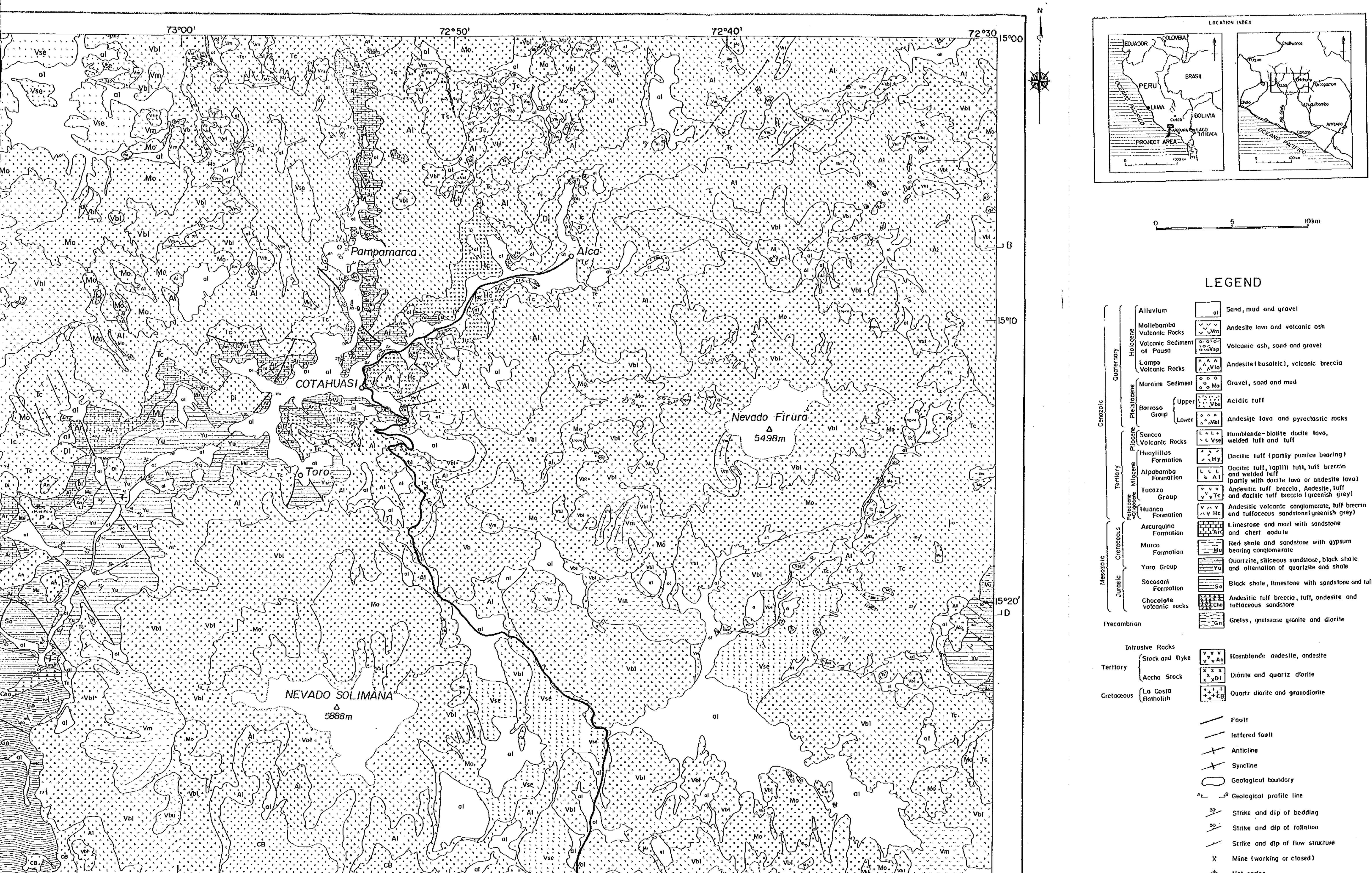
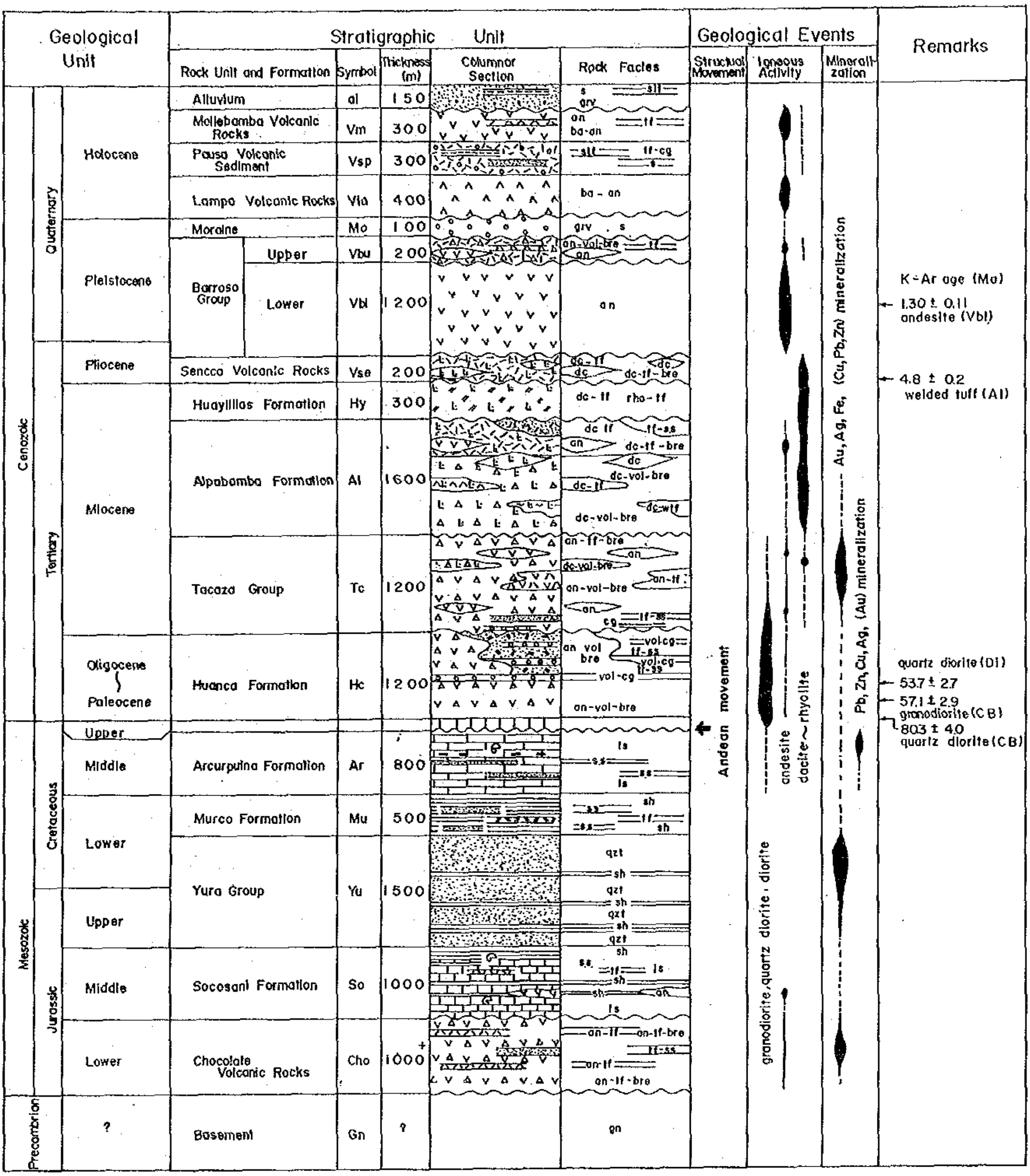


Fig. 4-1 Geological Map of the Cotahuasi Area



Abbreviations

gn	gneiss, gneissose diorite	qzt	quartzite	ba-an	basaltic andesite lava
an-tf-bre	andesitic tuff breccia	vol-cg	volcanic conglomerate	tf-cg	tuffaceous conglomerate
an-tf	andesitic tuff	cg	conglomerate	slt	silt
tf-s.s.	tuffaceous sandstone	dc-vol-bre	dacitic volcanic breccia	grv	gravel
ls	limestone	an-tf-bre	andesitic tuff breccia		
an	andesite lava	dc-wtf	dacitic welded tuff		
sh	shale	dc-tf	dacitic tuff		
tf	tuff	dc	dacitic lava		
s.s.	sandstone	rho-tf	rhyolitic tuff		

Fig.4-2 Generalized Stratigraphic Column of the Survey Area

Table 4-1 Stratigraphic Correlation of Geological Units around the Cotahuasi Area

Era	Period	Geological Unit \ Area	Caravel : Area (Victor Pecho G.1983)	Pausa : Area (Victor Pecho G.1983)	Cotahuasi : Area (JICA and MMAJ 1986)	Cotahuasi : Area (Unpublication data INGEMMET)	Orcopampa : Area (Jurio Caldas V.1975)	Huambo : Area (Jurio Caldas V.1975)
Cenozoic	Quarternary	Holocene	Alluvium	Alluvium Mollebamba V. Pausa V. Sed Lampa V.	Alluvium Mollebamba V. Pausa V. Sed Lampa V.	Recent V. Alluvium	Andahua Group Alluvium	Andahua Group Alluvium
		Pleistocene	Barroso Group: Lower	Morain Deposits Barroso Group: Upper / Lower	Morain Deposits Barroso Group: Upper / Lower	Morain Deposits Barroso Group: Barroso V. / Chila V.	Glacial Deposits Barroso Group	Glacial Deposits Barroso Group
	Tertiary	Pliocene	Sencca V.	Sencca V.	Sencca V.	Sencca V.	Sencca V.	Sencca V.
		Miocene	Huaylillas Fm. Camana Fm.	Huaylillas Fm. Alpabamba Fm. Tacaza Group	Huaylillas Fm. Alpabamba Fm. Tacaza Group	Millo Fm. Tacaza Group	Chailahuire Fm. Tacaza Group / Orcopampa Series	Millo Fm. Tacaza Group Orcopampa Series
		Oligocene			Huanca Fm.	Huanca Fm.		Huanca Fm.
		Eocene	Paracas Fm. Caraveli Fm.: Altos de Colpa M.					
		Paleocene	Caraveli Fm.: Cuno Cuno M., Cruz Blanca M. Sun José Fm.					
Mesozoic	Cretaceous	Upper						Seraj Fm.
		Middle	Arcurquina Fm.	Arcurquina Fm.	Arcurquina Fm.	Arcurquina Fm.	Arcurquina Fm.	Arcurquina Fm.
		Lower		Murco Fm.	Murco Fm.	Murco Fm.	Murco Fm.	Murco Fm.
		Lower / Upper	Yura Group: Hualhuani Fm., Labra Cachios Fm.	Yura Group: Hualhuani Fm., Labra Cachios Fm.	Yura Group	Yura Group	Yura Group	Yura Group
	Jurassic	Middle		Socosani Fm.	Socosani Fm.			Socosani Fm.
		Lower		Chocolate Fm.	Chocolate Fm.			
Palaeozoic	Ordovician	Upper ~ Lower						Ongoro Fm.
Proterozoic	Precambrian	?	Basement	Basement	Basement			Majes-Coka Complex

plagioclase of 2 to 4 mm in length intercalated with aggregates of long-prismatic hornblende (1 to 2.5 mm long) arranged in one direction. Plagioclase and hornblende are interspaced by granoblastic quartz (0.5 to 1.5 mm). The relict plagioclases contain 33 to 38% An and are generally albitized, sericitized and epidotized. The rock is considered to be gneisse of granodiorite origin.

Thickness

Although the exact thickness of the Basement is unknown, it is presumed to be over 3,000 m thick.

Age

Dating of rocks of Basement was not included in the survey. According to the explanatory notes of the geological maps of the Pausa and Caraveli areas, dating by the Rb/Sr method gives the Basement 600 to 2,000 Ma which corresponds to the Proterozoic.

[2] Jurassic System

The Jurassic System of the survey area consists mainly of Chocolate Volcanic Rocks (Cho), Socosani Formation (So) and Yura Group (Yu). Though the upper part of the Yura Group are reported to be the Cretaceous, it is described in this clause together with the other parts.

(1) Chocolate Volcanic Rocks (Cho)

These consist mainly of altered andesitic volcanic rocks and form the lowermost part of the Jurassic System of the survey area.

Distribution

The Chocolate Volcanic Rocks are widely distributed in areas of steep cliffs along the Maran River and neighborhood between the village of Maran in the southwest of the survey area and the southeast of the area. The volcanic rocks are also occur on the south slopes of Mt. Ccorihuayrachina and Mt. Jatunnasa, both located in the south of the detailed survey area B.

Rock Facies

The Chocolate Volcanic Rocks are composed mainly of green to greenish grey andesitic tuff breccias and tuffs and are partly interbedded with altered andesites, andesitic volcanic breccias, tuffs, tuffaceous sandstones and shales. The rocks are relatively rich in rock facies variations. The lower to the middle part of the rocks shows schistosed structure by regional metamorphism and the rocks manifests green or black semischists locally. Massive green rocks of andesitic rock origin are spotted with albites. These metamorphism are weak in the upper part of the

Chocolate Volcanic Rocks and original rock structures are conspicuous there.

In thin section, a specimen of dark greenish grey semischists collected from the lower part of the Chocolate Volcanic Rocks consists of sericite, quartz and relict plagioclose. Plagiocloses contain 30 to 38% An and exhibit an augen structure. Sericites are formed abundantly in fractured zones in mesh-like and nematoblastic forms. Fine grains of quartz and sericite are observed in mortar shape.

Altered andesitic tuff breccias which are observable most conspicuously in the region from the middle to upper parts of the Chocolate Volcanic Rocks are dark greenish grey and contain an abundance of essential fragments of andesite and accidental fragments of cherts and rhyoritic rocks.

The matrix consists of essential microfragments and andesitic tuffaceous materials.

Samples of altered andesites collected in the upper part of the Chocolate Volcanic Rocks are strongly chloritized dark green porphyritic altered andesite.

Tuffs are dark green to green and often alternate with beds of light greenish grey tuffaceous sandstones and dark grey tuffaceous shales. These alternating beds are intercalated in tuff breccias.

Structure of the Chocolate Volcanic Rocks vary at places, but generally they strike N60° to 70°E and dip 20° to 30°SE in the south and strike N50° to 55°W and dip 20° to 30°NW in the neighborhood of Maran in the north.

Thickness

The Chocolate Volcanic Rocks are dislocated by block-faulting and folded locally, so the thickness of the rocks is unknown, but judging from its distribution and geological structure, the rocks are presumed to be over 1,000 m in thickness.

Stratigraphical Relations

The contact between the rocks and the Basement was not verified, but judging from its distribution, the rocks are presumed to cover the Basement unconformably.

Age

The age of the Chocolate Volcanic Rocks remain to be unknown, but the geological maps covering the Pausa and Caraveli areas correlate based on a comparison of stratification the rocks to the Early Jurassic.

(2) Socosani Formation (So)

Distribution

The Socosani Formation is distributed from Mt. Punacullaca on the east of the Maran River in the southwest of the survey area to Mt. Puca Puca and neighboring areas and from Mt. Tanizca in the middle of the detailed survey area B to Mt. Ccorihuayrachina to the south.

Rock Facies

Alternating beds of grey to black limestone and light grey sandstone predominate in the lower part of the Socosani Formation and these alternating beds contain intercalated beds of thin beds of dark shale. Black calcareous shales are prevalent in the middle to upper part of the Formation and thin beds of quartzite, grey limestone and sandy tuff are locally interbedded. An intercalated bed of andesite lava is reported, although it was not confirmed by the present survey.

Thickness

Judging from its distribution and geological structure, the Socosani Formation is estimated to be about 1,000 m thick.

Stratigraphical Relations

The formation covers the Chocolate Volcanic Rocks unconformably. According to the geological maps of the Pausa and Caraveli areas, fossils including *Bostra escutliana* (DOUGLAS), *Bositra radiata* (GOLDF), *Trebratula* cf. *T. perovilis* SOW, *Sonninidae* are reported and the formation is correlated to the middle Jurassic period.

(3) Yura Group (Yu)

The geological map of the Pausa area classifies this group into the Labra-Cachios Formation and the Hualhuani Formation. However, the present field survey showed that both these two formations consist mainly of sandstone and quartzite and it was practically difficult to distinguish between both formations. Therefore, the two formations are classified under the Yura Group in this report.

Distribution

The Yura Group has a wide distribution in the region between the Huanca Huanca River in the southwest of detailed survey area A and the Uchubamba River to the east. It is also widespread along the Cotahuasi River in the region between the east of detailed survey area B and Pampa Echunga to the northeast.

Rock Facies

The Yura Group is composed mainly of light grey to light brownish grey fine to medium-grained sandstones in thick beds and contain locally intercalated thin beds of dark grey shale. In the Cotahuasi River about 1.5 km southeast of the village of Velinga strata of dark grey to black shale about 50 m in thickness predominate and there platy phyllitic shales alternate with a thin strata of light yellowish grey sandstone.

Sandstones are microscopically equiganular medium-grained alcose sandstones exhibiting a compact sedimentary structure consisting primarily of sub-rounded quartz particles and in which accidental rock fragments are not observable. The matrix of sandstones, though amounts is very little, is composed essentially of microfragments of quartz and plagioclase and a small quantity of muddy materials.

The thick sandstone beds generally have well developed joints and cracks accompanied by contamination of ferrous oxide and their outcrops exhibit light brown to yellowish brown colors and interbedded thin strata of black shales manifest a banded structure.

Structure

The Yura Group strikes N30° to 40°E and dips 20°NW in the area along the Huanca Huanca River, and strikes N10° to 30°E in the area along the Cotahuasi River, and dips 10° to 20°NW on the right bank and 10° to 20°SE on the left bank. The Yura Group has NW-SE faults and its strike and dip is dislocated locally.

Thickness

Judging from its distribution and geological structure, the Yura Group is estimated to be over 1,500 m in thickness.

Stratigraphical Relations

The Yura Group contacts with the underlying Socosani Formation through faults and the stratigraphical relations between them are not known. Previous reports describe the relations as unconformability.

Age

The geological maps of the Pausa and Caraveli areas correlate the lower part (the formation corresponding to the Labra-Cachios Formation) of the Yura Group to the Oxfordian to Tithonian stage of the Jurassic and the upper part (the formation corresponding to the Hualhuan Formation) to the Neocomian stage of the Lower Cretaceous.

[3] Cretaceous System

The Cretaceous System of the survey area consists of the upper part of the Yura Group above mentioned, the Murco Formation (Mu) and the Arcurquina Formation (Ar).

(1) Murco Formation (Mu)

Distribution

On the steep slopes of the banks of the Cotahuasi River southwest of the village of Cotahuasi, the Murco Formation covers the Yura Group and is distributed in a belt to continue to the eastern slope of Mt. Tanisca in the central eastern part of detailed survey area B. In detailed survey area A, the Murco Formation covers the Yura Group and has a small-scale distribution in eight different zones.

Rock Facies

The Murco Formation is generally characterized by reddish brown to brown colors. The lower part of the formation consists of alternating beds of yellowish brown quartzite and reddish brown to brown sandstone, marl and shale, which thin alternating beds of reddish brown shale to calcareous shale and red sandstone predominate in the upper part and conglomerate strata composed of subrounded gravels (5 cm or less) are intercalated locally.

The reddish brown marl beds consist of very thin alternating layers of sandy mudstone and marl. The sandy mud layer is composed mainly of fine particles of quartz and plagioclase and the matrix is composed of illites, calcites, limonites and Carbonaceous materials. The marl layer contains an abundance of fine particles of calcite.
mm), but not those of augite. These andesite stocks have undergone alteration, resulting in

Thickness

The Murco Formation is estimated to be approximately 500 m in thickness.

Stratigraphical Relations

The Murco Formation covers the Yura Group conformably. Nothing definite is known on the age of this formation at this time, for no occurrence of fossils has been reported from it. However, the formation is correlated to the Neocomian, since it is interstratified between the Yura Group and the overlying Arcurquina Formation.

(2) Arcurquina Formation (Ar)

Distribution

This formation is distributed mainly on the right bank of the Cotahuasi River and continues in a belt from Taurisma in the north of the survey area southwestward to the upper part of the steep slopes of Mt. Tanizca via the villages, such as Mungui and Charcana. On the northeast of Mungui the Arcurquina Formation extends along the Pampamarca River, branching off northward from the Cotahuasi River, to the neighborhood of the northern end of the survey area. In detailed survey area A, the formation is distributed around Mt. Accha and on the northwest and southeast of the mountain.

Rock Facies

The Arcurquina Formation consists mainly of dark grey thickly stratified limestones (single stratum of 2 to 5 m in thickness). In its lower part, the formation is interbedded thinly with brown calcareous sandstones, conglomerates and shales. In the upper part light grey limestones predominate and the bedding planes are observable rather clearly. The limestone layers are interbedded with clastic to conglomeratic limestones. The massive limestone layers often contain irregular lenticular nodules of chert of 5 to 20 cm in thickness.

The limestone beds distributed on a small scale in the stream about 3 km northwest of Huaynacotas in detailed survey area C contain foraminifer fossils.

Structure

The strike and dip of the Arcurquina Formation vary because of folds, but generally it strikes NE and dips gently to northwest.

Thickness

The upper part of the Arcurquina Formation is eroded and covered by the Tertiary System unconformably. For this reason, the entire thickness of the formation is unknown, but it is estimated to be more than 800 m.

Stratigraphical Relations

The Arcurquina Formation covers the underlying Murco Formation unconformably. Although foraminifer fossils were collected from this formation during the present field survey, it was impossible to identify it. According to the geological maps covering the Pausa and Caraveli areas, *Cerithium* cf. *C. sergipensis* MAURY, *Epitonium* sp. *Exogyra* sp., *Cardita* cf. *C. subparalela* GERHARDT are reported from the lower part of this formation, and it is correlated to the Albian to the Turonian.

[4] Tertiary System

Tertiary System of the survey area consists of the Huanca (Hc) Formation, Tacaza Group (Tc), Alpabamba Formation (Al), Hylillas Formation (Hy) and Sencca Formation (Vse).

(1) Huanca Formation (Hc)

Distribution

This formation is distributed on the slopes of the banks of the Cotahuasi River between the village of Cotahuasi and the village of Huaynacotas to the northeast. In addition, it is also distributed in a belt on the piedmont south of the village of Cotahuasi.

Rock Facies

That part of the Huanca Formation distributed on the left bank of the Cotahuasi River is composed of alternating beds of greenish grey tuffaceous conglomerate and reddish brown or greenish grey tuffaceous sandstone. The conglomerates contain subrounded to rounded gravels of greenish grey tuff, tuffaceous sandstone and altered andesite, and its matrix is same as the tuffaceous sandstones. These alternating beds of sandstone and conglomerate are each only 10 to 50 cm in thickness.

However, that part of the Huanca Formation distributed near Huaynacotas on the right bank of the Cotahuasi River exhibits different rock facies and is composed mainly of brown to reddish brown tuffaceous conglomerates and rarely contains intercalated beds of sandstone.

In the same stream located opposite the village of Tomemampa the alternating beds of greenish grey fine-grained tuffaceous sandstone and medium-grained sandstone are thinly interstratified with rock salt layers.

Structure

The strike and dip of the Huanca Formation are N10° to 40°W and 35° to 40°NE, respectively, in the west N30° to 50°E and 30° to 40°SE, respectively, in the northeast the strike changes gradually from southwest to northeast.

Thickness

The thickness of the Huanca Formation is estimated at approximately 1,200 m.

Stratigraphical Relations

The Huanca Formation covers the underlying Arcurquina Formation unconformably. In the explanatory notes to the geological maps the Huambo Formation is correlated to the Palaeocene to the Oligocene.

(2) Tacaza Group (Tc)

Distribution

The Tacaza Group covers the Basement, the Jurassic System, the Cretaceous System and the Huanca Formation of the Tertiary System unconformably and forms the lowermost part of the Altiplano. The group is distributed in the region between the middle and the northwest of the survey area, along the Cotahuasi River, Huarcaya River and Pampamarca and Sumana, both tributaries of the Cotahuasi. In the west of the survey area, the group is distributed in the upper part of the steep slopes along the Maran River, in the middle reaches of the Oyolo River (upstream of the Maran), in the middle to upper reaches of the Huanca Huanca River, and along the Pararca River which branches off westward. In addition, the Tacaza Group has a widespread distribution near the eastern end of the survey area.

Rock Facies

The Tacaza Group consists of light grey, light brown, brown and purple grey altered andesitic volcanic rocks which are composed mainly of altered andesite lavas, volcanic breccias and tuff breccias.

The altered andesites generally occur as lava flows of dark grey to purple grey hornblende andesite or pyroxene andesite with massive compact or massive porphyritic structure. The Tacaza Group has generally undergone alteration, that is, plagioclase has been sericitized, resulting in bleached crystal, hornblende has been altered to epidote and zoisite and is observable as relict crystal, and pyroxene has been altered completely to chlorite.

Volcanic breccias and tuff breccias generally exhibit a brown color and their gravels are of the same nature as andesite lava. The matrix consists of a brown tuffaceous materials.

In the lower part of the Tacaza Group tuffaceous conglomerates and sandstones are thinly interbedded and a stratum of dacitic volcanic breccia is intercalated in the middle.

Thickness

The Tacaza Group, composed of volcanic rocks, varies in thickness from place to place and the thickest part of the group is estimated to be about 1,200 m.

Stratigraphic Relations

The Tacaza Group covers all the underlying formations unconformably. Accordingly to the explanatory notes to the geological maps of the Pausa and Caraveli areas, dating of the volcanic rocks occurring in Corcopampa and Humbo (unpublished data of J. CALDAS) puts the volcanic rocks in the lower part of the group at 19.1 Ma and those of the upper part at 18.9 Ma which corresponds to the Early Miocene.

(3) Alpabamba Formation (Al)

Distribution

The Alpabamba Formation is widely distributed in most of the northern part of the survey area. In particular, it forms the Altiplano platean in the upper reaches of the Cotahuasi River and Maran River systems.

Rock Facies

The Alpabamba Formation is composed mainly of brown, brownish grey, purple grey and light grey rhyolitic to dacitic volcanic breccias, tuff breccias, lapilli tuffs, tuffs and welded tuffs. It is often interbedded with rhyolite to dacite lavas. The rhyolite to dacite lavas exhibit porphyritic structure and some of them have conspicuous flow structure and others have massive compact structure. Both contain phenocrysts of plagioclase, quartz, biotite and hornblende. The groundmass consists of glass and has partly undergone devitrification.

Around the village of Alca in the south of the detailed survey area C welded tuffs are distributed and they contain a variety of rock fragments. Welded texture of brown glass fragments is clearly observable in the matrix. Mordenite and aggregate of chalcedony and cristobalite are assembled in lens-form parallel with the welded texture.

Volcanic breccias, tuff breccias and tuffs in the Alpabamba Formation are rhyolitic to dacitic, and contain biotite fragments characteristically. Gravels contained in these rocks are of the same properties as lava. The Alpabamba Formation is partly interbedded with thin layers of fine-grained andesite lava and is accompanied by stratified tuffaceous sandstones.

Thickness

The Alpabamba Formation, composed essentially of volcanic rocks, varies in thickness from place to place. Its thickest part is estimated to be about 1,600 m.

Stratigraphic Relations

The formation covers the underlying Tacaza Group unconformably and partly covers the Basement complex, Cretaceous System and the Huanca Formation of Tertiary age unconformably.

K-Ar dating of samples (Ca-B) obtained from the Alpabamba Formation south of Alca shows 4.8 $\pm$ 0.2 Ma which correspondes to the Pliocene.

The explanatory notes of the geological maps of the Pausa and Caraveli areas estimate the time of volcanic activity of the Alpabamba Formation to be from the Middle to the Late Miocene. Judging from the results of the dating, however, it is possible that the geological time of the formation ranges upto the Pliocene. The test piece of the welded tuff used for the dating appeared to be fresh. Microscopic observation, however, revealed the occurrences of lens-like aggregates of mordenite or aggregates of chalcedony and cristobalite in parallel with welded texture of the matrix. Moreover, devitrification is also observable. For this reason, the dating presumably gave a younger age for the Alpabamba Formation. It is necessary, therefore, to make further examination of this formation.

(4) Huaylillas Formation (Hy)

Distribution

This formation covers the Tacaza Group at the west of the village of Maran in the southwest of the survey area and is distributed on a small scale in a belt on the breasts of steep slopes.

Rock Facies

The formation consists of grey to greyish white dacitic(rhyolitic) tuffs containing biotites characteristically and pumices.

Thickness

The Huaylillas Formation is estimated to be about 300 m thick.

Stratigraphic Relations

This formation covers the Tacaza Group unconformably. Direct relationship between the Huaylillas Formation and the stratigraphically underlying Alpabamba Formation remains unknown. According to the explanatory notes of the geological maps of the Pausa and Caraveli areas, the Huaylillas Formation is correlated to the Late Miocene.

(5) Senca Volcanic Rocks (Vse)

Distribution

These rocks cover the Alpabamba Formation and is widely distributed in a flatland slightly to the west of the north of the survey area.

Rock Facies

The Senca Volcanic Rocks are composed of grey to light purple grey hornblende-biotite dacite to rhyolite lavas, welded tuffs, and tuffs. The lavas are rather porous and contain phenocrysts of plagioclase and biotite. Its groundmass consists mainly of light brown glass and exhibits flow structure and devitrified structure.

Thickness

The Senca Volcanic Rocks are estimated to be about 200 m in thickness.

Stratigraphic Relation

The Senca Volcanic Rocks cover the Alpabamba Formation unconformably. According to the explanatory notes of the geological maps of the Pausa and Caraveli areas, dating of this rocks shows to 4.3 Ma and 2.0 Ma, which correspond to the Middle to Late Pliocene.

[5] Quaternary System

The Quaternary System of the survey area consists mainly of the Barroso Group comprising the Lower Formation (Vbl) and Upper Formation (Vbu), Moraine deposits(Mo), Lampa Volcanic Rocks (Vla), Pausa Volcanic Sediments (Vsp), Mollebamba Volcanic Rocks (Vm) and Alluvium (Al).

(1) Barroso Group

Distribution

In the southeast of the survey area, the Lower Formation (Vbl) of this Group is widely distributed around Mt. Solimana and Mt. Firura and in the southwest it has a widespread distribution around Mt. Sara Sara and toward the south. The formation is also distributed relatively widely in the Altiplano district.

The Upper Formation (Vbu) is distributed on a small scale along the ridges of Mt. Potrero in the southwest of the survey area to Mt. Pirca to the south. It has also a limited distribution on the southwest of Mt. Solimana.

Rock Facies

The Lower Formation (Vbl) consists of dark grey, grey and partly dark brown two-pyroxene andesite lavas, dark grey basaltic hornblende andesite lavas, pyroclastic rocks and subordinate dacite lavas. The most widespread two-pyroxene andesites are dark grey fresh massive rocks and under microscope they have porphyritic texture and contain phenocrysts of plagioclase, augite, hypersthene and partly of hornblende. The groundmass consists of glass and microcrystals of plagioclase, augite, hypersthene and opaque minerals. No alteration and devitrification are observable for the rocks. In thin section the grey dacite collected from the lower part of the formation contains phenocrysts of plagioclase (1 to 1.7 mm), quartz (0.4 to 0.8 mm), and hornblende (0.5 to 1.7 mm). The groundmass consists of glass which include plagioclase (less than 1 mm) and manifests a weak flow strucutre. The rock has strongly undergone devitification. The pyroclastic rocks show dark grey to brown colour and are rich in variation of facies.

The Upper Formation is composed of light grey dacitic tuff breccias and is locally interbedded with tuffs and biotite andesite lavas.

Thickness

The Lower Formation is estimated to be about 1,200 m in thickness, while the Upper Formation is presumed to be approximately 200 m thick.

Stratigraphic Relations

The Lower Formation of the Barroso Group covers the underlying Huaylillas Formation and Alpabamba Formation unconformably. In the south of the survey area it also covers the Basement unconformably.

The K-Ar dating of a sample (G6-58) collected from the Lower Formation during the field survey shows 1.30 $\pm$ 0.11 Ma which corresponds to the Pleistocene. The explanatory notes of the geological maps of the Pausa and Caraveli areas correlate the period of activity of the Lower Formation to the Late Pliocene to the Pleistocene.

(2) Moraine (Mo)

Distribution

Moraines are distributed widely in the gentle slopes of Mt. Firura in the east of the Altiplano and Mt. Solimana in the south. THey are also distributed, but on a swaller scale, in the gentle slopes of Mt. Sara Sara in the west and in flatlands in the north.

Rock Facies

The moraines are composed mainly of subrounded to rounded gravels of augite and hypersthene andesites belonging to the Lower Formation of the Barroso Group. The fine-grained materials which fill the speces between these gravels are granules of the same rock and coarse sands. The moraines are interspersed conspicuously with lateral moraines and terminal moraines as are commonly found in ordinary moraines.

Thickness

The thickness of the moraine varies with their deposition environment. The thickest layer is estimated to be approximately 100 m.

Stratigraphic Relations

The moraines cover the underlying Barroso Group unconformably and are presumed to have been formed during the glacial period of the Late Pleistocene.

(3) Lampa Volcanic Rocks (Vla)

Distribution

The Lampa Volcanic Rocks are distributed in a belt along the Maran River and the Huanca River in the area extending from a location about 2 km north of the village of Maran to the village of Marcabamba and vicinity.

Rock Facies

The Lampa Volcanic Rocks consist mainly of dark grey to blackish grey massive compact andesite lavas and are locally accompanied by volcanic breccias. The andesites are macroscopically non-porphyritic. In thin section they are unaltered glassy hornblende andesites containing microphenocrysts of hornblende and plagioclase and whose groundmass consists of glass and micrograined plagioclase and hornblendes.

Thickness

The Lampa Volcanic Rocks, consisting mainly of lava flows which filled valleys, is nearly 400 m thick at its thickest part.

Stratigraphic Relations

The Lampa Volcanic Rocks cover or abut on the Jurassic and Cretaceous systems and the Tacaza Group of the Tertiary unconformably, at the bottom of Valleys.

(4) Pausa Volcanic Sediments (Vsp)

Distribution

The Pausa Volcanic Sediments are distributed on gentle mountain slopes and in flatlands in the area extending from Mt. Negro southeast of Pausa to the lower reaches of the Mirmaca River. They are also distributed on the northwest of the village of San Jose de Ushua located in the central part of the detailed survey area A.

Rock Facies

The lower part of this formation consists of greyish brown andesitic volcanic conglomerates to volcanic breccias and is locally intercalated with volcanic mud flows. The middle to upper part of the formation is composed of grey to greyish white tuffs and tuffaceous sandstones and siltstones. All these rocks have been deposited almost horizontally. They have generally been not well consolidated and that part of them found along valleys or small valleys have highly been eroded, resulting to form steep landforms or V-shaped valleys.

Thickness

The Pausa Volcanic Sediments vary in thickness from place to place. Their