REPUBLIC OF PERU

REPORT ON GEOLOGICAL SURVEY

OF

THE TAURI AREA, SOUTHERN PERU

Vol. IV

GEOLOGICAL REPORT

November 1977

OVERSEAS TECHNICAL COOPERATION AGENCY
METAL MINERALS EXPLORATION AGENCY
GOVERNMENT OF JAPAN

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LOCATION MAP OF THE YAURI AREA, SOUTHERN PERU

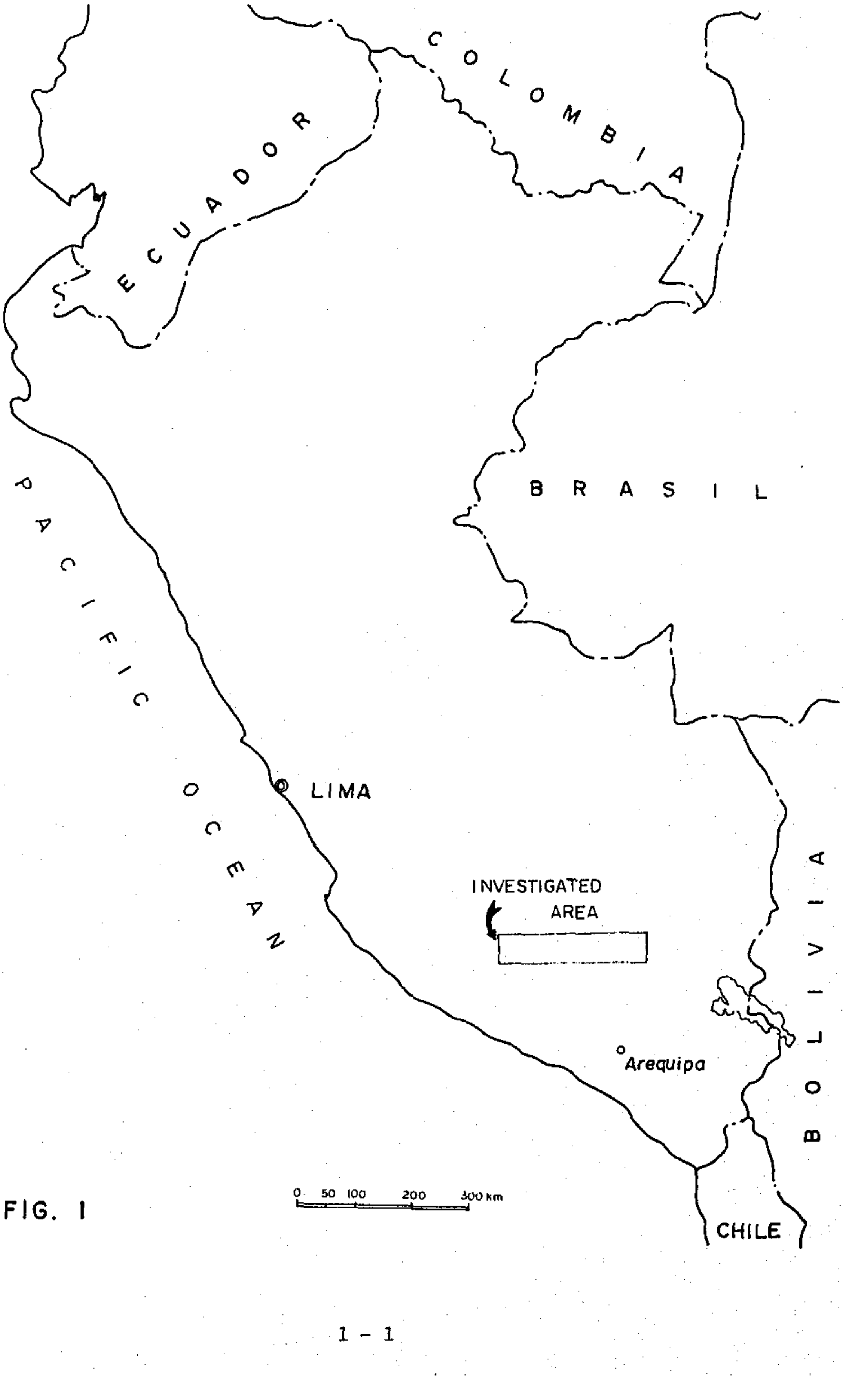

FIG. 1

LOCATION MAP OF THE YAURI AREA, SOUTHERN PERU

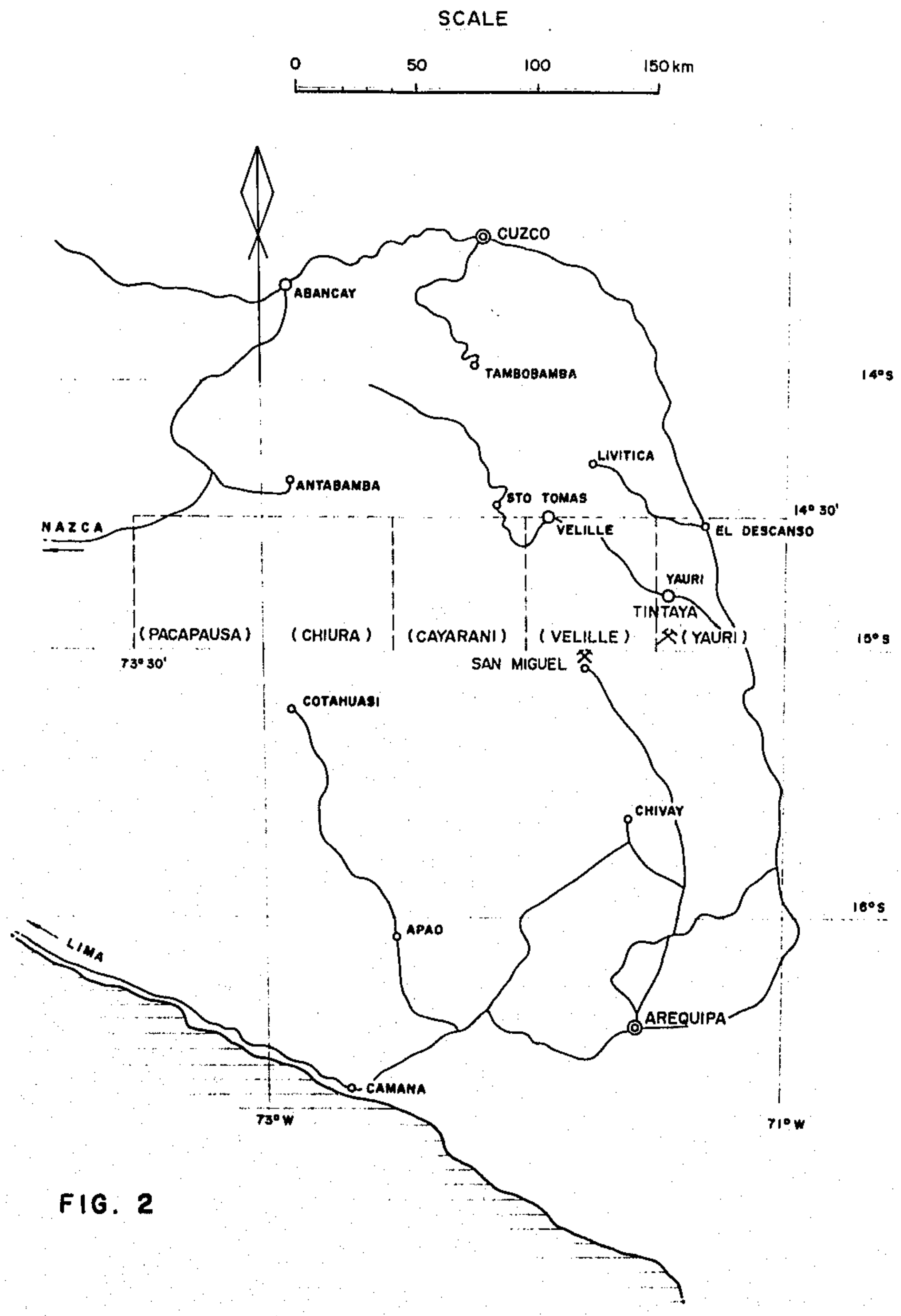

FIG. 2

CHAPTER 1. OUTLINE OF SURVEY

1-1 Purpose of Survey

The aim of the first year's survey was to acquire a general grasp of the knowledge concerning the geological structure and mineral resources in the Yauri area.

The programs in 1971 consisted of a geological field reconnaissance, combined with an aeromagnetic survey and a photogeological survey.

1-2 Outline of Survey (Figs. 1 & 2)

1-2-1 Survey area

The project area is bounded by latitudes 14°30'S (northern limit) and 15°00'S (southern limit), and by longitudes 71°00'W (eastern limit) and 73°30'W (western limit), covering about 15,000 km^2.

From the project area, several areas were selected in such a way as each of which had a standard geological setting, and then in each of the area survey routes were determined on the basis of its topography and accessibility.

1-2-2 Survey period

Staying period in Peru:

Twenty-seven days from October 22 to November 17, 1971.

Period of field reconnaissance survey:

Fourteen days from October 27 to November 9, 1971.

1-2-3 Survey method

The field reconnaissance survey of the main routes were conducted for two weeks by three teams of A, B, and C including three geologists of the Geological Survey of the Republic of Peru, jeeps and horses being employed wherever available, otherwise on foot.

The western area is especially scarcely populated, so that the survey was carried out mostly in camp.

1-2-4 Main routes (Fig. 3)

(A) The team A covered a 80-km route for 8 days on horse back, from Antabamba in the north of Chiura quadrangle-area to Cotahuasi in the south of Chiura quadrangle-area. Victor

Pecho, a geologist of the Geological Survey of the Republic of Peru, and Masao Saito were engaged in the survey of this route.

(B) The team B covered a 100-km route from Velille through Esquina up to the San Miguel mine (7.5-km south of the Velille quadrangle), and a 90-km route around the Tintaya mine for 9 days.

Luis Reyes, a geologist of the Geological Survey of the Republic of Peru, Kaneo Kakegawa, and Ken Obara were engaged in the survey of this route.

(C) Team C covered a 190-km route for 13 days in the surrounding area of Yauri and between Yauri and El Descanso. Jorge Galdos, a geologist of the Geological Survey of the Republic of Peru, Kiyohisa Shibata, and Yukichi Tagami were engaged in the survey of this route.

The total length of the routes surveyed was more than 460-km.

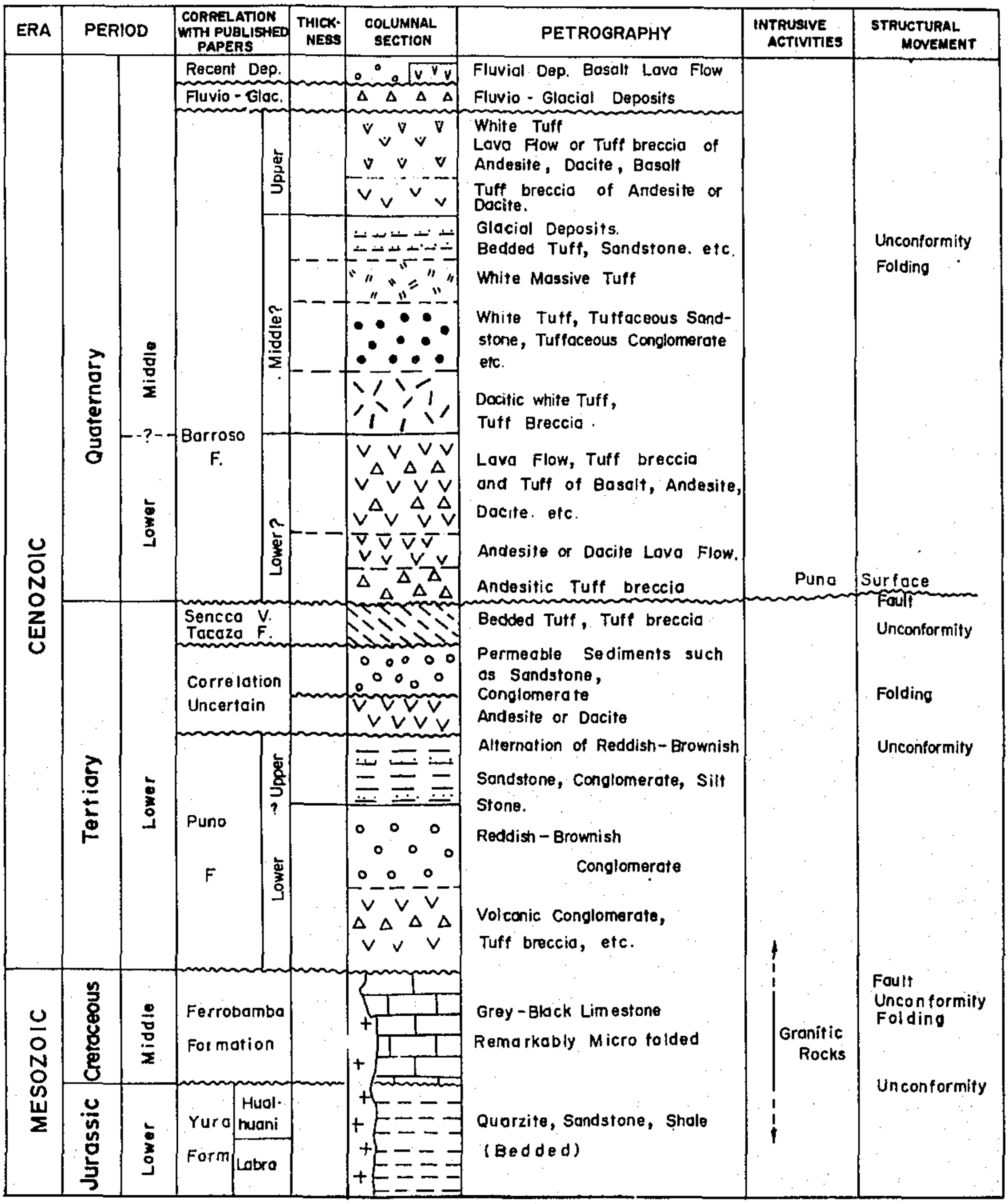

FIG. 4 GENERALIZED COLUMNAR SECTION

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(Prepared by MITSUI KINZOKU ENGINEERING SERVICE CO., LTD.)

CHAPTER 2. GEOLOGY

2-1 Geology of Each Route (Figs. 5-A, 5-B)

The stratigraphy of the individual formations distributed in the project area is shown in the generalized columnar section of Fig. 4 on the basis of the literatures on the surrounding areas although stratigraphical correlations were insufficient due to limited field surveys. The nomenclatures of the formations described below are in accordance with those of the columnar section.

2-1-1 Antabamba-Cotahuasi Route (Figs. 5-B, 6 & 7)

(A) Rocks distributed

Traversing from north to south in the middle of the Chiura quadrangle, this route is situated mainly in the highlands of more than 4,500 m above sea level.

This route is mostly covered with volcanic rocks and pyroclastic rocks. The Pre-Tertiary rocks are exposed only in the lowland, the northernmost part of this route.

(B) Pre-Tertiary formations

The lower part of these formations consists of red sandstone, tuffaceous red sandstone, and quartzite; the upper part consists of limestones.

The former is distributed widely in the neighborhood of Mollebamba locating to the north of the quadrangle, which is correlated with the Hualhuani Sub-Formation in the Mesozoic Yura Formation or with the Labra Sub-Formation in the Yura Formation; the latter is considered to be correlated with the Cretaceous Ferrobamba Formation. Such correlations are based on the literature.

It is considered that the Hualhuani Sub-Formation is composed mainly of quartzite, and the Labra Sub-Formation consists mainly of black shale, and sandstone; therefore, these should be lithologically correlated with the Yura Formation.

The beddings of the formations generally show N20°W in strike, and nearly 25°W in dip, being somewhat subjected to folding. In the middle of the route, 4,700 m above sea level, there is an outcrop of tuffaceous red sandstone and quartzite for more than 1-km, with both sides of it bounded by dacitic tuff. This is conceivably a protuberance of the basement of the Yura Formation.

The Ferrobamba limestone comprises greyish white, fine-grained rocks.

Both the Formations of Yura and Ferrobamba, are intruded by granodiorite which ranges from coarse-grained granodiorite to fine-grained quartz diorite in lithofacies, containing hornblend and biotite.

(C) Mid-Tertiary Tacaza Formation

White tuff is distributed overlying the Pre-Tertiary Formation. The photogeological map refers to it as the Tacaza Formation, while, it is geologically considered to be the upper-Barroso Formation of Quaternary era; however, it is difficult to pass judgement on this question solely on the basis of this survey.

(D) Quaternary volcanic rocks

Along this route, andesitic pumiceous tuff, andesite lava flow, dacite lava flow, and andesitic tuff-breccia are distributed, dipping gently or horizontally. On the top of these rocks, black basalt lava flows are partially distributed. Near the summit in the middle of the route, white tuff exists. The andesitic rocks are dark to grey colored compact rocks, which are rich in biotite and contain plagioclase occasionally with hormblende and pyroxene. As the rocks become basaltic in rock facies, they contain olivine. Calcite, chlorite, epidote, and white mica occur as alteration products. The basaltic rocks are black, partly yellowish grey, compact rocks containing hornblende, plagioclase, pyroxene, and magnetite.

The thickness of the volcanic rocks reaches 700 m. The lower part is inferred to be the Tacaza Formation, however, most part may be the Barroso Formation.

These rocks are derived from a series of eruptions of volcanic and pyroclastic materials, which range from acidic to basic in rock facies.

2-1-2 Velille-Esquina-San Miguel route (Figs. 5A, 8 & 9)

(A) Rocks distributed

In the area north of Esquina, there occur the Pre-Tertiary intrusive rocks and limestones locally. In other portion of the route these rocks are overlain by tuff-breccia, which are again covered with dacitic rocks.

(B) <u>Pre-Tertiary Formation</u>

The limestone shows re-crystallized massive forms and is considered to belong to the Ferrobamba Formation.

The intrusive rocks correspond to the extension of those distributed around Velille. They are coarse-grained compact rocks, composed mainly of pyroxene-hornblende-granodiorite. The relationship between the limestone and the intrusive rocks has not been made clear.

(C) Tertiary Tacaza Formation

The Pre-Tertiary rocks are overlain by tuff-breccia, locally intercalated with sandy tuff layers, and are considered correlative with the Tacaza Formation. The rocks are subjected to the development of joints trending E-W or N-S, and they rest on the basement with unconformity. Grey in color and rather compact, they contain pebbles of 5 cm in diameter.

(D) Quaternary Barroso Formation

The above tuff-breccia is overlain by andesite, greyish purple dacite and dacitic tuff, which are 40 m - 300 m in thickness each, and part of which shows beddings. These rocks are thought correlative with the lower-middle Barroso Formation. Some of them are bluish grey, compact basaltic andesite, containing microcrystalline olivine, pyroxene, feldspar and magnetite, and others are dark colored dacitic tuff, including scattered crystal fragments of quartz, feldspar, and mica. These rocks are again overlain by basalt lava flow, which is likely correlative with the upper Barroso Formation. It is distributed horizontally on the tops of mountains, and is a dark purplish brown, coarse-grained compact rock with the phenocrysts of olivine and augite, and magnetite.

2-1-3 Velille-Yauri route (Figs. 5-A, 11 & 12)

(A) Rocks distributed

Around Velille and the area north of Yauri, the Pre-Tertiary strata of black sandstone, shale and limestone, and the intrusive rocks that have intruded these sediments are distributed.

Overlying the above rocks, andesite, basalt, and local tuff of the Barroso Formation are distributed, forming a mountain mass of over 4,500 m above sea level, between Velille and Yauri.

(B) Pre-Tertiary Formation

The Yura Formation around Velille comprises an alternation of tuffaceous sandstone and black shale, generally showing its strike of N-S and its gentle dip of W, while near Velille, the dip is reversely eastward, where it is conformably overlain by the Ferrobamba limestone.

These rocks are all intruded by granitic stocks and dykes.

(C) Intrusive rocks

In a NNW-SSE trending contact with the Tertiary strata, the intrusive rocks are subjected to the development of NS and EW trending joints, partly associated with foliations. The rocks are granodiorite porphyry and are coarser-grained in texture than the coarse-grained, holocrystalline rocks located west of Velille. The rocks are composed mainly of rocks comprising phenocrysts of mica, hornblende, oligoclase and alkali feldspar-quartz microlites, and a granodioritic rock including pyroxene, plagioclase and minute grains of quartz.

The intrusive rocks observed north of Coporaque are granodioritic rocks containing hornblende and, in part, mica and quartz.

(D) Quaternary Barroso Formation

On the above-mentioned formation rest andesitic rocks that are correlative with the Barroso Formation, forming the mountain mass between Yauri and Velille, and overlying unconformably the intrusive rocks in the surrounding area of Yauri.

This formation becomes dacitic tuff downward, containing fragments of andesite and fine fragments of mafic minerals. Many of the andesitic rocks are dark to black, compact mica-pyroxene andesite.

On the other hand, on the top of the mountain mass between Yauri and Velille, there is a basaltic rock, including olivine and pyroxene, showing a flow texture in it.

Terrace deposits are developed in the plains in and around Yauri.

2-1-4 Yauri-Hector Tejada route (Figs. 5-A, 10, 11 & 12)

(A) Rocks distributed

In the south of Yauri are the Pre-Tertiary quartzites and shales distributed trending N-S, in the neighborhood of which the limestones are widely distributed. These rocks are intruded by batholiths, stocks and dykes.

The above rocks of sediments and intrusives are associated with many metallic mineral deposits, forming a metallic mineral belt in the area. Between Yauri and Hector Tejada, sandy tuff, muddy tuff, and conglomerate of the middle Barroso Formation are widely exposed, overlying the above rocks.

In and around the area 22 km east of Hector Tejada, a conglomerate - sandstone alternation of the Puno Formation is distributed in a NNW-SSE direction.

(B) Pre-Tertiary Formation

Quartzites and shales are exposed in the south-east of Yauri, extending 10 km in length and 3 km in width. Their beddings show a strike of NNW-SSE, in which folding structures with N-S axes are observed. In the Quechua district, these rocks are highly silicified, black shales being altered into greyish white compact rocks. In many cases limestone is a fine-grained, dark to greyish white rock with fine-banded stratifications. It is distributed in the neighborhood of the above-mentioned quartzites and shales, and is in contact with them with unconformity or fault. Folding structures with the NNW-SSE axes are shown in the limestone.

Polymorphininae (from the Cretaceous period to Recent) and Oolininae (from the Jurassic period to Recent) of Foraminifera, and Carpionelia (many of them are said to be of upper Jurassic to lower Cretaceous period) of Tintinoids are contained in the limestone 2 km north of the Ataraya mine. This suggests that the limestone is of Cretaceous period; therefore, the Ferrobamba Formation that includes this limestone is estimated to be of Cretaceous period, and the underlying quartzites and shales be correlative with the Yura Formation.

(C) Tertiary Puno Formation

Consisting of conglomerate and sandstone, this formation outcrops east of Hector Tejada. Its strike is NNW-SSE and its dip is steeply to the west. Pebbles of the conglomerate range from 5 to 15 cm or less in diameter, and are composed mainly of granite, diorite, andesite, limestone and shale, which are cemented by coarse-grained sandstone. The sandstone is greyish white to dark grey, coarse-to medium-grained hard rock. In view of its lithology this rock is presumed to be correlated with the Puno Formation developed in the area near the Lago Titicaca. And the materials of the pebbles indicate that the Puno Formation has been formed after emplacement of the intrusives.

(D) Quaternary middle Barroso Formation

White tuff is widely distributed, overlying the above formation (C). It consists of sandy tuff, muddy tuff, fine-grained pumiceous tuff and alternations of these rocks, which are rather loose sediments.

The strike of beddings varies from NE-SW to NW-SE and the dip is gentle. These rocks are lake deposits partly containing plant fossils. As for the calcareous tuff distributed predominantly in and around the Ataraya mine, it is considered that the abundant limestone deposited in this area was erroded and flowed down, mixed with volcanic materials derived from erosion and eruption, and this formation was formed.

(E) Intrusive rocks

Intrusive rocks observed in this route are granodiorite, quartz monzonite, diorite, and local quartz porphyry. These rocks intruded the above-mentioned quartzite and shale, and are distributed in the forms of batholiths, stocks or dykes.

Granite around the Ataraya mine is a coarse-grained holocrystalline rock including mica and hornblende, while at the point 4 km south of Hector Tejada, limestones are intruded by granodiorite porphyry in a N-S direction, containing pyroxene and plagioclase. These intrusive rocks are considered to be of end-Cretaceous period on the basis of the fact that they intruded the Cretaceous limestone and that they are included in the pebbles of the Tertiary Puno Formation.

2-1-5 Quechua - Yauri - El Descanso route (Figs. 5-B, 10 & 11)

(A) Rocks distributed

In the area north of Yauri, intrusive rocks are exposed overlain by tuffaceous rocks of the middle Barroso Formation, such as white tuff, sandy tuff and muddy tuff which are widely distributed in the area. Around El Descanso, there are conglomerates and sandstones of the Puno Formation with a NNW-SSE strike and a W dip.

(B) Intrusive rocks

The intrusive rocks observed in this route consist of granodiorite which continue to those of the coarse-grained holocrystalline rocks with pyroxene and hornblende, as described in the section 2-1-3. At the point 12 km north of Yauri, pyrite and chalcopyrite occur as disseminations in the intrusive rocks.

(C) The Tertiary Puno Formation

This is widely distributed in the area south of El Descanso comprising conglomerate and sandstone. Pebbles of the conglomerate are less than 20 cm in diameter, and include rounded or sub-angular fragments of limestone, quartzite, andesite and dacite, which are cemented by a coarse-grained sandstone. The strike of beddings is NNW-SSE, and the dip varies 25°-60°

westward. The sandstone consists of coarse-grained sandstone, mudstone, muddy tuff and tuffaceous sandstone, each of which is indicative of a neritic sediment.

(D) Quaternary middle Barroso Formation

Overlying the Puno Formation with unconformity, sandy tuff, muddy tuff and pumiceous tuff occur, showing their gentle dips. This formation builds up the gentle sloping landforms of the Yauri basin, and continues to a similar formation distributed near Hector Tejada. They are lake sediments with an estimated thickness of about 100 m, and are conceivably the Quaternary middle Barroso Formation.

2-2 Summarized Geology of Routes

The geology of each route is summarized as follows:

(A) The Jurassic Yura Formation is consisted of black shale, sandstone, and grey quartzite, and is lithologically correlated with the Labra Sub-Formation and the Hualhuani Sub-Formation which are comprized in the Yura Formation. This formation is recognized in the middle-north of the Antabamba-Cotahuasi route and also in the south of the Yauri district.

(B) The Cretaceous Ferrobamba Formation consists mainly of limestones. The fossils were found in this formation north of the Tintaya mine, which is correlated with the Cretaceous formation. It is widely exposed in the area south of Yauri, and is also recognized in the south of Velille and in the north of Chiura. It is distributed around the above-mentioned quartzite of the Yura Formation and the trends of its folding and faulting are similar to those of the Yura's. This suggests that it was formed, following the sedimentation of the Yura Formation.

(C) The end-Cretaceous intrusives show various rock facies, such as granite, granodiorite, diorite, monzonite, dioritic porphyrite and quartz porphyry. These rocks are distributed widely in the Yauri and the Velille districts and are also exposed on a small scale in the north of the Antabamba-Cotahuasi route. They intruded quartzites and limestones, as batholiths, stocks or dykes, probably during the end-Cretaceous period.

The important factor concerning the formation of ore deposits is the association of the above-mentioned sediments and intrusive rocks.

(D) The early Tertiary Puno Formation is composed of conglomerate, sandstone and sandy tuff, and is correlated with the lower Tertiary formation. This correlation is based on the fact that the fragments of the conglomerate comprise the pre-Tertiary rocks, such as limestone and quartzite, and the rounded pebbles of granitic rocks. It is a neritic sedimentary rock showing various facies, and is distributed in a NNW-SSE direction, extending from El Descanso to the east of Hector Tejada.

(E) The middle Tertiary Tacaza Formation consists of intermediate volcanic rocks and tuff-breccia.

In the area south of Velille, there are andesitic tuff and sandy tuff, which the photogeological interpretation referred to as "Tacaza Formation"; however, this is not conclusive yet, because the contact between these rocks and the overlying andesite or dacite has not been made clear.

In the north of the Antabamba-Cotahuasi route, there occurs white tuff, overlying the pre-Tertiary formation, which is also regarded as "Tacaza Formation" in the photogeological interpretation; however, the study of the cross-section through this area suggests that it is correlative with the mid-Quaternary volcanics.

The formation which is regarded as the Tacaza Formation in the reconnaissance survey is that distributed in the surrounding area of Esquina. Thus, the final conclusion on this subject requires further detailed investigations.

(F) The Quaternary volcanic rocks comprise tuff-breccia and white tuff, and lava flow of andesite, basalt and dacite. The direction of their distribution is not clear; and many of the strata have a gentle dip or are horizontal. These occupy the western part of the Yauri-Velille quadrangle-area and most part of the Chiura quadrangle-area.

It was found that the rock facies graded from acidic, through intermediate, into basic facies as they got younger.

(G) The lake sediments of the middle Barroso Formation are deposited in the Yauri basin, overlying the pre-Tertiary rocks and the Puno Formation. The sediments are composed of sandy tuff, sandstone, muddy tuff and pumiceous tuff.

2-3 Geological Structure

As a result of the geological reconnaissance survey, the geological structure has been made partly clear in the project area as follows:

2-3-1 Pre-Tertiary formations and intrusive rocks

(A) The Yura Formation and the Ferrobamba Formation show folding structures with N-S or NNW-SSE axes, and are subjected to fault movements of N-S direction.

Directions of the structural lines in both formations have much in common.

(B) These formations are intruded by the intrusive rocks largely in a N-S direction: there are many N-S trending dykes recognized in them. On the contrary, dykes of E-W and NW-SE directions have been locally observed, and these NW-SE and NE-SW trending faults are also found in these formations.

(C) The pre-Tertiary formations and intrusive rocks are distributed roughly in a NW-SE direction, in view of the fact that ones exposed near Velille-Esquina, and the others exposed in the south of Yauri are aligned in the NW-SE direction.

In the area east of the NW-SE trending line passing through Hector Tejada and Santa Lucia de Pichigua, no outcrop of these rocks has been known to exist.

(D) The pre-Tertiary formations are found in the northern end and the south of the Antabamba-Cotahuasi route. In the south, the quartzite of this formation is exposed as a horst-like mass, protruding through younger volcanic rocks. This may have left uneroded during the time when the Puna erosion surface was formed.

2-3-2 Tertiary formation

The Tertiary Puno Formation has a strike of NNW-SSE, and a dip steeply to the west. The west side of this formation is in contact with white tuff of lake deposits. Along near the contact, hills of dacite lava flows are distributed in a NNW-SSE direction. This fact suggests that there is a line of structural weakness along the west side of the Puno Formation, and that the lava flows erupted along this line.

2-3-3 Tertiary and Quaternary volcanic rocks

These rocks are relatively gently dipping accumulations of volcanics and pyroclastics, their strikes and dips being not clear. However, it is found that they vary slightly according to their rock facies, such as andesite, basalt and white tuff.

The flow textures observed in these volcanic rocks are largely of a NW-SE trend, and partly of N-S and E-W.

The lake deposits in the surrounding area of Yauri show strikes of NNW-SSE with gentle dips.

2-4 Mineral Resources

Among the ore deposits or mineral indications so far known in the project area, the major ore deposits are as listed below:

Name of mine	Type of deposit	Host rock
Tintaya	Skarn - copper	Limestone
Ataraya	" "	"
Quechua	Porphyry copper	quartz monzonite porphyry, quartzite

2-4-1 Known deposits

During the survey, three deposits of Tintaya, Ataraya and Quechua mines were investigated.

A. <u>Tintaya</u>

The area is overlain by limestone and quartzite, which are intruded by diorite and quartz monzonite porphyry. The Tintaya copper deposit is of skarn type, formed in the contact of limestone with quartz monzonite porphyry. The ore is localized along the periphery of limestone remaining as a roof pendant in a intrusive mass. It consists of skarn minerals, such as epidote, garnet, magnetite, hematite, diopside and siderite, and also of sulphide minerals, such as chalcopyrite, chalcocite, pyrite and molybdenite. The oxidized zone extends to a depth of several tens of meters, forming the secondary enrichment zone, including malachite, chrysocolla, azurite and cuprite. Underlying primary zone contains copper sulphides. The rocks are highly chrolitized and sericitization and argillic alteration are also recognized.

B. <u>Ataraya</u>

This deposit is also of skarn type similar to Tintaya. It is rich in copper minerals and slightly poor in magnetite. This area is overlain with limestone, intruded by diorite and quartz porphyry. The ore is formed in a vein-like shape along the contact between limestone and intrusives. The deposit is currently mined by the underground operation with a shaft, the sulphide ore being processed in a 300 t.p.d. mill.

C. <u>Quechua</u>

This is situated 10-km south of the Tintaya mine, where quartzite and limestone are distributed with a intercalation of shale and sandstone. These sediments have folding structures with NS trending axes, which are intruded by diorite, quartz monzonite porphyry and quartz porphyry.

The ore deposit is localized near the contact between limestone-quartzite and quartz monzonite porphyry that intruded them, where copper and molybdenum minerals occur as disseminations. ("Porphyry copper" type) Quartzite is subjected to the development of fractures with oxide copper stains on the surface in several places.

The ore deposit including chalcopyrite, chalcocite and sulphide iron such as pyrite is under exploration.

2-4-2 Mineralized area

The mineralized area discovered during the survey is found in the south side of the road at the point 12 km north of Yauri (750 m west of Santa Lucia de Pichigua), where porphyritic diorite is exposed. In this rock, there occurs a vertical fissure trending NE-SW, both side of which, 10 m - 20 m wide each, are slightly silicified and mineralized with chalcopyrite, bornite and pyrite as disseminations. Chrysocolla, malachite, and partial chalcocite are observed along this fissure. The copper grade of the mineralized zone along the fissure is estimated to be more or less 0.1% cu. In some places of the area, pyrite occurs as disseminations in granodiorite. As the area is largely covered with younger volcanics, other concealed mineralized area may be exist under these volcanics.

CHAPTER 3. LABORATORY WORK OF ROCKS

3-1 Study of Rocks

3-1-1 Outline of the study

Representative rock samples were collected in various places along the survey routes and were observed under the microscope.

Microphotographs of parts of thus collected samples were prepared (Table 1).

Rock facies, interrelations of rocks, lithological descriptions and geological descriptions, such as strike and dip of beds, are shown in the route map. (Figs. 5-A & 5-B).

The results of microscopic observation of each rock are shown in Table 3; microphotographs in Table 4.

Several kinds of tuffs are examined by the X-ray diffractive analysis and the constituent minerals of each rock were made clear. (Table 5)

As for fossils, four samples were examined by the Geological Survey of Japan. As a result of this, it has been concluded that the sample collected from the limestone formation located north of the Tintaya mine contains small foraminifera, which gave a basis of the assumption that the limestone formation is of Cretaceous period. No fossils were recognized in other samples than this (Table 2).

3-1-2 Results of microscopic observation of each sample (Table 3 & 4)

The results of observation of twenty thin sections are described below. These sections were prepared from the representative samples which were collected from each route.

(A) Andesites of Antabamba-Cotahuasi route

All of the three samples of dacite (Sample No. A4), andesite (Sample No. A3) and pyroxene andesite (Sample No. A9) are rocks of the lower Barroso Formation. The phenocrysts in the dacite (A4) are plagicoclase (Andesine - Oligoclase), mica and quartz, while pyroxene andesite (A9) includes mica, pyroxene and olivine, and also includes laths of plagioclase microcrystals. Andesite (A3) is of the intermediate mineral composition between A4 and A9. In many cases, they contain magnetite as accessory minerals. These observations indicate that andesites of the Barroso Formation along the route are acidic to basic in composition. No. A8 sample collected as basalt lava flow is black basic rock including amphibole, pyroxene, plagioclase (An 50) and magnetite as main phenocrysts.

(B) Intrusive rocks

Holocrystalline rocks are granite (K 31) and granodiorite (A1), in which hornblende, plagioclase (andesine - oligoclase), quartz and sometimes mica are included, and calcite, magnetite and mica are seen as secondary minerals.

As to porphyry, there are quartz diorite porphyry, Sample No. S-1, K-6 and T-11. Main constituent minerals are quartz, hornblende and plagioclase (An 30 - 40) and sometimes augite is included, and apatite, zircon, magnetite and sphene are also included as accessory minerals. These three samples are very similar in composition. S-1 and T-11 are the samples collected from the intrusive rock found in the northern part of Coporaque, while K-6 is the intrusive rock in the northern part of Esquina.

Besides, there is S-6 of granodioritic porphyry. It is fine to middle-grained rock and includes plagioclase, hornblende, mica and small quantity of quartz as essential minerals, and sphene, apatite and zircon as accessory minerals.

There are T-4 and S-8 as dioritic porphyrite including feldspar, quartz and pyroxene which is completely altered into calcite. Mica in T-4 is altered into chlorite. T-4 is the dyke rock intruding the limestone and, in many cases, is often altered. There is also S-3 as dioritic porphyrite. It consists of hornblende, biotite and plagioclase, (andesine - albite) associated with apatite, zircon, sphene, magnetite as accessory minerals.

The above-mentioned intrusive rocks consist chiefly of hornblende, mica, plagioclase (An 30 - 40) and quartz, with partial pyroxene, regardless of their rock facies or forms. Accessory minerals are apatite, zircon, sphene and magnetite, and in many cases, they are altered to the secondary minerals, such as calcite and mica.

(C) Rocks of the Tacaza Formation around Esquina (Fig. 5A, Table 3)

As a Tacaza Formation rock there is K-8 of dacitic agglomerate. This sample is a grey rock including sub-angular fragments of 5 cm. in diameter. As phenocrysts, hornblende, pyroxene, biotite and feldspar are enclosed in a fine-grained groundmass of quartz, feldspar, hornblende, mica, apatite and magnetite.

(D) Rocks of the lower Barroso Formation in the Velille-Yauri District

There are two samples of dacite tuff (K-15) and andesitic tuff (S7). K-15 includes quartz, plagioclase (oligoclase - andesine) and biotite as phenocrysts, and is accompanied by irregular sub-angular fragments and quartz fragments, and is altered partly into montmorillonite.

S-7 includes some andesite fragments, and consists of phenocrysts of quartz, plagioclase, pyroxene, and magnetite in the groundmass of quartz and feldspar. Both samples are acidic to intermediate tuff with angular fragments.

(E) Rocks of the upper Barroso Formation in the Velille-Yauri District

There are basalt (K-19) (K-15') and andesite (K-34, S-5). Each of them is dark to purplish grey hard rock. The basalt includes phenocrysts or microcrystals of olivine, pyroxene, magnetite and plagioclase, while andesite has the phenocrysts of pyroxene, plagioclase (andesine) and biotite. Therefore, the upper Barroso Formation is composed mainly of the intermediate - basic volcanic rocks.

S-4 is a dark purple augite basalt, referred to as the lower Barroso Formation, with phenocrysts of olivine, and augite in a groundmass of plagioclase, olivine, pyroxene and magnetite. Judging from its rock facies, it seems to be similar to the rock of the upper Barroso Formation.

3-2 Measurements of Magnetic Characters

(A) In order to contribute to the interpretation of aeromagnetic survey, measurements of susceptibility of the rock samples were carried out, which where collected during the geological survey of the main routes. Bison Instruments Model 3101 was used for the measurement. (Table 1)

Name of rock	Piece number	Susceptibility x 10^{-3} c.g.s.e.m.u/cc
Andesite group	15	0.88
Tuff group	12	0.29
Pre-Tertiary sedimentary rocks	3	0.02
Younger sedimentary rocks	4	0.34
Granite group	12	0.65 (one piece excluded)
Puno Formation	1	2.22

The average values by rocks are shown above.

According to Table 1, the andesite group and granite group show the high susceptibility values compared with other rocks while the sedimentary rocks show small values. According to Table 6, however, the value of susceptibility of the granite group shows such a wide range as from 10^{-3} to 10^{-5} c.g.s.e.m.u/cc, which indicates the presence of considerable difference according to samples. Similar to the granite group, the andesite group also shows the wide range of susceptibility values, while the basalt shows comparatively high values. It is confirmed by the microscopic observation that the basaltic rocks have larger amounts of magnetite, compared with other rocks. The conglomeratic sandstone of the Puno Formation shows very high values (2.22×10^{-3} c.g.s.e.m.u/cc). This is because out of the component pebbles, part of very high susceptibility was accidentally sampled and measured.

Although these samples are limited in number, it is considered that the above-mentioned values classified by rocks indicate a general tendency.

(B) Measurements of remmant magnetization

An astatic magnetometer made by "Sokkisha" was used for the measurements of remmant magnetization. The results are shown in Table 1.

3-3 Relation between Photogeological Survey and Field Survey

In carrying out the interpretation of photogeological survey, the route map of field geological reconnaissance survey was employed and correlations were carried out with respect to the photographical characteristics corresponding to the respective geological features. In many cases, the interpretation map of photogeological survey corresponds well with the results of field geological survey, and it was found that the photogeological survey was very effective in order to judge the geology and geological structure of a wide area in a short period.

In the geological survey, it has been recognized that the quartzite of the pre-Tertiary Formation is exposed for more than 1 km in the Antabamba - Cotahuasi route. In the photogeology, however, it can not be discriminated from volcanic rocks. In the eastern part of Hector Tejada, near the contact between the Puno Formation and the younger tuffs, the lava flow of dacite has been recognized, but it is hardly observed in the photogeological map. These facts, indicate that the interpretation of photogeological survey has its own limit although the photogeological survey is very effective for the quick survey of a wide area, and that it is necessary to confirm the actual outcrops by on-the-spot geological survey.

3-4 Relation between Aeromagnetic Survey and Field Survey

In carrying out the interpretation of aeromagnetic survey, the geological characteristics observed by the field geological survey were also taken into consideration.

Compared with the area of aeromagnetic survey, only the limited routes were surveyed in the field geological survey, so that the detailed relations between the results of aeromagnetic survey and the field geological survey could not be obtained. Yet the geology of the surveyed route and the results interpreted by the aeromagnetic survey correspond well with each other.

It is observed by the field geological survey that the volcanic rocks such as andesite and basalt are abundant between Antabamba and Cotahuasi. Besides, as a result of the aeromagnetic survey, there are many magnetic anomalies due to magnetic body existing at shallow depths distributed in this district, which, in turn, supports the results of field geological survey.

In the area near Yauri, the outcrops of volcanic rocks are less distributed, compared with Antabamba - Cotahuasi district, and the outcrops of intrusive rocks are observed there. In the aeromagnetic survey too, the anomalies due to deep-seated magnetic bodies are predominent in this area.

There are some parts where the distribution of exposed intrusive rocks well accords with the distribution of anomalies due to near-surface magnetic bodies delineated by the aeromagnetic survey, while there are other parts where the two do not correspond with each other. This is perhaps because the susceptibility of an intrusive rock has a variation in value from low to high, as shown in Table 6.

As mentioned above, the correspondence between the aeromagnetic survey and field geological survey is comparatively good, so that it is desirable to make further study of the relations between an aeromagnetic survey and field geology by carrying out a detailed geological survey.

CHAPTER 4. OPINIONS ON FURTHER SURVEY

In view of the results of the field reconnaissance survey, the following survey is recommended to acquire a more detailed grasp of the geology in the area:

(A) Preference should be taken as to the eastern part of the area, where the pre-Tertiary sedimentary rocks and volcanic rocks are widely distributed. In this area, there is better possibility of the localization of ore deposits. Geological survey of the eastern part on the whole should be carried out to clarify the geology and character of the mineralization.

(B) The systematic sampling of stream sediments in the whole area should be done to delineate quickly potential areas for mineralization.

(C) Collection of fossils, microscopic study of rocks, determination of rock's absolute age and study of basic geological data should be made in order to establish the chronological relationship of the rocks in the area.

(D) Detailed geological survey should be carried out in the selected promissing potential area for mineralization to acquire a better knowledge concerning the structure and other features of the potential ground for the localization of ore deposits.

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APPENDIX

APPENDIX

TABLE 1 LIST OF ROCK SAMPLES

Q: QUADRANGLE

SAMPLE NO.	ROCK NAME	FORMATION GROUP	LOCATION	MAGNETIC MEASUREMENT SUSCEPTIBILITY $\times 10^{-3}$ c.g.s.e.m.u./cc	MANUFACTURE OF THIN SECTION	PHOTOGRAPH UNDER MICROSCOPE	X - RAY DIFFRACTIVE ANALYSIS	FOSSIL	REMNANT MAGNETIZATION Jr. 10^{-3} emu/cc	D	I
A 1	GRANODIORITE	GRANITE GROUP	MOST NORTHERN PART OF Q. CHIURA	2.18	○						
A 2	DACITE	LOWER BARROSO F.	49 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	0.02							
A 3	ANDESITE	LOWER BARROSO F.	48 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	0.23	○						
A 4	BIOTITE DACITE	LOWER BARROSO F.	41 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	0.53	○	○ ○					
A 6	DACITIC VOLCANIC BRECCIA	MIDDLE BARROSO F.	36 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	0.84							
A 7	ANDESITIC TUFF BRECCIA	MIDDLE BARROSO F.	34 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	0.05							
A 8	BLACK BASALT	BASALT LAVA	23 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	2.26	○	○ ○					
A 9	BASALTIC ANDESITE	LOWER BARROSO F.	18 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	1.13	○	○					
A 10	DACITE TUFF	LOWER BARROSO F.	13 KM NORTH OF CHUMPAYO LOMAS IN Q. CHIURA	0.28							
A 11	WHITE TUFF	MIDDLE BARROSO F.	2 KM WEST OF CHUMPAYO LOMAS IN Q. CHIURA	0.30							
A 12	TUFF WITH SHALE	〃 〃	〃 〃 〃	—		○					
A 15	ANDESITE	LOWER BARROSO F.	5 KM SOUTH WEST OF CHUMPAYO LOMAS IN Q. CHIURA	0.87							
K 1	HORNBLENDE BIOTITE DIORITE	GRANITE GROUP	10 KM NORTH OF TAMBOPATA	0.09					0.093	210	+41°
K 2	LIMESTONE	FERROBAMBA F.	11 KM SOUTH OF VELILLE IN Q. VELILLE	0.03							
K 6	DIORITE	GRANITE GROUP	13 KM NORTH WEST OF ESQUINA IN Q. CAYARANI	0.09	○						
K 8	TUFF BRECCIA	TACAZA F.	4 KM WEST OF ESQUINA IN Q. CAYARANI	0.24	○	○ ○ ○					
K 11	BIOTITE ANDESITE	TACAZA F. ?	3 KM NORTH WEST OF TAMBOPATA	1.89					0.291	330	-33°
K 15	DACITIC WELDED TUFF	LOWER BARROSO F.	5 KM SOUTH EAST OF TAMBOPATA IN Q. VELILLE	0.27	○	○					
K 15'	OLIVINE BASALT	UPPER BARROSO F.	〃 〃 〃	1.13	○	○ ○ ○					
K 19	GREY ANDESITE	UPPER BARROSO F.	5 KM SOUTHEAST OF CAYANCA IN Q. VELILLE	2.74	○						
K 20	LAPILLI TUFF	TACAZA F. ?	7.5 KM SOUTH OF Q. VELILLE SAN MIGUEL MINE	—	○	○					
K 23	BRECCIA PIPE	?	〃 〃 〃	—							
K 28	PEARLITIC ANDESITE	—	8 KM EAST OF SAN MIGUEL MINE	0.07					0.077	210	-22°
K 29	PUMICEOUS WHITE TUFF	MIDDLE BARROSO F.	AYAPATA. IN Q. VELILLE	0.05			○				
K 30	CALCAREOUS GREY TUFF	MIDDLE BARROSO F.	10 KM NORTH OF ATARAYA MINE IN Q. YAURI	0.12							
K 31	GRANITE	GRANITE GROUP	2 KM NORTH OF ATARAYA MINE	1.76	○	○					
K 33	LIMESTONE	FERROBAMBA F.	〃 〃 〃					○			
K 34	GREY ANDESITE	UPPER BARROSO F.	3 KM SOUTH OF QUECHUA IN Q. YAURI	0.05	○						
K 10	TUFF	TACAZA F.	7 KM SOUTH OF ESQUINA IN Q. VELILLE				○				
S - 1	QUARTZ DIORITE	GRANITE GROUP	10 KM NORTH WEST OF YAURI IN Q. YAURI	0.36	○	○ ○					
S - 2	PURPLISH ANDESITE	LOWER BARROSO F.	5 KM NORTH OF COPORAQUE IN Q. VELILLE	0.03							
S - 3	DIORITE PORPHYRITE	GRANITE GROUP	17 KM NORTH WEST OF YAURI IN Q YAURI	1.55	○						
S - 4	PURPLISH BASALT	LOWER BARROSO F.	31 KM NORTH WEST OF YAURI IN Q. VELILLE	0.11	○						
S - 5	PURPLISH GREY ANDESITE	UPPER BARROSO F.	20 KM SOUTH EAST OF VELILLE IN Q. VELILLE	1.29	○	○					
S - 6	GRANODIORITE PORPHYRITE	GRANITE GROUP	12 KM EAST OF VELILLE IN Q. VELILLE	0.69	○	○					
S - 7	SILICIFIED TUFF	LOWER BARROSO F.	11 KM EAST OF VELILLE IN Q VELILLE	1.94	○						
S - 8	DIRITE PORPHYRITE	GRANITE GROUP	8 KM EAST OF VELILLE IN Q VELILLE	0.03	○						
S - 9	TUFFACEOUS SANDSTONE	YURA F.	4 KM EAST OF VELILLE	0.03							
S -10	DACITIC PORPHYRY	GRANITE GROUP	1 KM EAST OF VELILLE	4.73							
S -12	GRANODIORITE	GRANITE GROUP	13 KM NORTH EAST OF HECTOR TEJADA								

SAMPLE NO.	ROCK NAME	FORMATION GROUP	LOCATION	MAGNETIC MEASUREMENT SUSCEPTIBILITY	MANUFACTURE OF THIN SECTION	PHOTOGRAPH UNDER MICROSCOPE	X – RAY DIFFRACTIVE ANALYSIS	FOSSIL	REMNANT MAGNETIZATION		
				$\times 10^{-3}$ c.g.s.e.m.u./cc					10^{-3} Jr. emu/cc		
S – 13	Py–DIORITE – PORPHYRITE	GRANITE GROUP	12 KM NORTH OF YAURI								
S – 14	ANDESITE	MIDDLE BARROSO F.	13 KM NORTH OF YAURI								
S – 15	HORNBLENDE BIOTITE DIORITE PORPHYRITE	GRANITE GROUP	8 KM NORTH WEST OF COPORAQUE	0. 29					0.580	330	– 57°
S – 16	DACITIC TUFF	MIDDLE BARROSO F.	16 KM SOUTH EAST OF VELILLE	0. 05					0.003	0	+ 41°
S – 20	SANDSTONE	MIDDLE BARROSO F.	11 KM NORTH EAST OF YAURI	—					—	—	—
T – 1	SANDY TUFF	MIDDLE BARROSO F.	1 KM NORTH OF YAURI IN Q. YAURI	0. 13							
T – 2	QUARTZITE	YURA F.	17 KM SOUTH EAST OF YAURI IN Q. YAURI	0. 03	O	O	O				
T – 3	LIMESTONE	FERROBAMBA F.	5 KM SOUTH OF HECTOR TEJADA IN Q. YAURI	0. 01							
T – 4	PORPHYRITE	GRANITE GROUP	11 KM EAST OF TINTAYA MINE IN Q. YAURI	0. 03	O						
T – 5A	SANDY TUFF	MIDDLE BARROSO F.	7 KM SOUTH EAST OF HECTOR TEJADA IN Q. YAURI	0. 02							
T – 5B	SANDY TUFF	" "	" " "	—			O				
T – 6	SANDSTONE	PUNO F.	22 KM EAST OF HECTOR TEJADA IN Q. YAURI	2. 22							
T – 7	MUDSTONE	MIDDLE BARROSO F.	13 KM NORTH EAST OF YAURI IN Q YAURI	0. 02			O				
T – 8	SANDSTONE	" "	15 KM NORTH EAST " "	0. 98							
T – 9	SANDSTONE	" "	" " " "	0. 36							
T – 10	WHITE TUFF	" "	8 KM NORTH OF HECTOR TEJADA IN Q. YAURI	0. 03							
T – 11	QUARTZ DIORITE PORPHYRITE	GRANITE GROUP	12 KM NORTH OF YAURI IN Q. YAURI	0. 07	O						

TABLE 2. FOSSIL

Sample No. : K - 33

Geological Group : Ferrobamba Formation

Location : 2km North of Ataraya Mine

Rock Name : Limestone

Fossils : Foraminifera Range indicated

Family Polymorphininae (genus and sp. indet.)
Triassic to Recent

" Oolininae (genus and sp. indet.)
Jurassic to Recent

Tintinoids

Carpionella sp.

(Range : from Jura. to Low Creta. in Alps Mts.)

This Ferrobamba Formation can be assumed from Jura. to Low Creta. in Geologic time.

Rock No. : K - 30

Rock Name : Calcareous grey Tuff

Geological Group : Middle Barroso Formation

Location : 10km North of Ataraya Mine

Sample does not contain any Fossils.

Rock No. : K - 2

Rock Name : Limestone

Geological Group : Ferrobamba Formation

Location : 11km South of Velille in Q. Velille

Sample does not contain any Fossils.

Rock No.: ATARAYA

Rock Name : (Calcarenite) Calcareous Tuff

Geological Group : Ferrobamba Formation

Location : Ataraya Mine

Sample does not contain any Fossils.

TABLE 3

Microscopic Observation of Rocks

No. S-1

Name : Hornblende quartz diorite

Location : 10 km northwest-west of Yauri in Quadrangle Yauri

Geological Group : Granite group

Macroscopic Observation :

White color with black dots. Partly with porphyritic texture. A black gabbroic xenolith shows an 1-cm aggregate of mafic minerals.

Microscopic Observation :

Texture granular (granitic), partly porphyritic and allotriomorphic-granular with laths of plagioclase, quartz and hornblende are mostly allotriomorphic.
Hornblende: pleochroic with X=light green, Y=light brown, Z=green: sometimes containing numerous inclusions of quartz and feldspar and rarely those of augite.
Plagioclase: An30-40 (n=quartz)
Accessories: apatite, sphene.
Altered minerals: magnetite, muscovite.

No. S-3

Name : Hornblende biotite diorite porphyrite

Location : 17 km northwest-west of Yauri in Quadrangle Yauri

Geological Group : Granite group

Macroscopic Observation :

Compact hard rock partly with foliation recognized. Color grey, containing white salic minerals mixed with mafics of black minerals of 2 - 3 mm size.

Microscopic Observation :

Phenocrysts of hornblende, biotite and plagioclase (mainly andesine) are scattered in a sub-trachytic matrix of plagioclase and alkali-feldspar laths with accessory grains of zircon, allanite, epidote, sphene, fluorite and iron ore.

Hornblende, pleochroic with X=light brown, Y= reddish brown, Z=reddesh brown, is considerably opacitized. Biotite also opacitized, has pleochroism of X=yellow, Y and Z=reddish brown.

Some phenochrysts of plagioclase with oscillatory zoning, change occasionally its composition from central andesine to marginal albite.

No. S-4

Name : Olivine augite basalt

Location : 31 km north-west of Yauri in Quadrangle Velille

Geological Group : Lower Barroso Formation

Macroscopic Observation :

Dark purple-colored, compact rock.
A phenocryst of feldspar is 1 cm in size.

Microscopic Observation :

Phenocrysts of olivine and augite are scattered glomero-porphyritically in a semi-holocrystalline matrix with distinct trachytic texture, which consists of feldspar microlite and smaller amounts of olivine, augite and opaque minerals (possibly magnetite).
Most crystals of olivine are strongly altered into reddish brown iddingsite. Large phenocrysts of augite sometimes contain plagioclase poikilitically.
A large crystal of quartz rimmed with greenish brown glass, and fine-grained aggregates of greenish brown biotite, glass and opaque minerals are probably resorbed xenoliths or xenocrysts.

No. S-5

Name : Biotite augite andesite

Location : 20 km south-east of Velille in Quadrangle Velille

Geological group : Upper Barroso Formation

Macroscopic Observation:

A dark to black colored, compact hard-rock with phenocrysts of white feldspar (2-5mm size).

Microscopic Observation :

Phenocrysts of plagioclase (andesine), augite, biotite lie in a cryptocrystallinal matrix with scattering andesine laths and specks of augite, biotite, apatite, zircon and magnetite.

Some large phenocrysts of plagioclase have very abundant liquid inclusions, and occasionally include augite, biotite, and magnetite.

Augite is altered in part to greenish brown chlorite-like minerals. Biotite is comparatively fresh with reddish brown pleochroism.

No. S-6

Name : Biotite hornblende granodiorite porphyry

Location : 12 km east of Velille in Quadrangle Velille

Geological Group : Granite group

Macroscopic Observation :

Dark grey-colored, fine to medium grained.
A phenocryst of feldspar is 7 mm in size, and a mafic black crystal is 5 mm in length.

Microscopic Observation :

Phenocrysts of oligoclase, hornblende, biotite and a little quartz lie in a cryptocrystallinal matrix composed mainly of alkali feldspar and quartz with apatite, zircon, sphene and opaque iron ore.
Crystals of sphene and apatite both showing euhedral forms, grow often up to microphenocrysts.
Hornblende is relatively fresh and pleochroic with X= light green, Y=light brown, Z=greenish brown.
Biotite, marginally opacitized shows pleochroism of X=light yellow, Y and Z=dark brown.

No. S-7

Name : Andesitic lithic-crystal tuff

Location : 11 km east of Velille in Quadrangle Velille

Geological Group : Lower Barroso Formation

Macroscopic Observation :

Microcrystalline, grey compact rocks, containing black mafic mineral aggregates (1 mm size),
Medium grained, hard rocks.

Microscopic Observation:

Andesitic fragments and crystals of quartz, plagioclase, augite, green hornblende and magnetite are scattered in a base of vitrified glass with minute grains of quartz, feldspar and chlorite.
Excepting quartz and hornblende, all minerals are distinctly altered. Hornblend shows a pleochroism of X=light green. Y=light brown and Z=green.

No. S-8

Name : Diorite porphyry

Location : 8 km east of Velille in Quadrangle Velille

Geological Group : Granite group

Macroscopic Observation :

Dull yellowish in color, medium to fine grained rocks containing dull grey xenolith, partly darker in color.

Microscopic Observation :

Texture sub-ophitic.
Phenocrysts of plagioclase and strongly altered pyroxene are filled with interstitial quartz grains (showing sub-ophitic texture).
Plagioclase is andesine. Accessory minerals are sphene (comparatively rich), epidote and green biotite.
Pyroxene is almost completely altered to calcite and brown chloritic minerals.

No. T-2

Name : Quartzite

Location : 17 km south east of Yauri in Quadrangle Yauri

Geological Group : Yura Formation

Macroscopic Observation :

A white, transparent hard brittle rock with fine crystals of quartz, partly impregnated with pyrite.

Microscopic Observation :

Mozaic aggregates of quartz.

No. T-4

Name : Diorite porphyry

Location : 11 km east of Tintaya mine in Quadrangle Yauri

Geological Group : Granite group

Macroscopic Observation :

A yellowish dull grey, hard rock partly with porous druses of 2 - 3 mm size.

Microscopic Observation :

Texture sub-ophitic, with interstitial quartz and biotite.

Biotite, altered partly to chlorite, shows pleochroism of green to colorless.

Phenocrysts are pyroxene, and altered to calcite and mica-like minerals (chlorite-hydromica).

Plagioclase is andesine, an accessory mineral is apatite.

No. T-11

Name : Augite hornblende biotite quartz diorite

Location : 12 km north of Yauri in Quadrangle Yauri

Geological Group : Granite Group

Macroscopic Observation :

Black to grey in color; phenocrysts of feldspar show 1-cm long rods and a black mafic mineral is 0.2 - 0.5 mm in size.

Microscopic Observation :

Coarse-grained, holocrystalline; allotriomorphic quartz, biotite and a little potash feldspar fill interstitially between crystals of idiomorphic plagioclase.

Mafic mineral are in glomeroporphyritic aggregates.

Augite is distinctly altered, along the margin of which are hornblende and biotite.

Hornblende is pleochroic with X=light yellow, Y=green, Z=dark green, and biotite with X=light yellow, Y=Z= reddish brown.

Plagioclase shows same index as quartz, An30-40 (acidic andesine).

Accessory minerals are apatite (relatively large crystal), zircon, magnetite.

No. A-1

Name : Hornblende biotite granodiorite

Location : Northernmost part in Quadrangle Chiura

Geological Group : Granite Group

Macroscopic Observation :

Mozaic, coarse-grained;
grey in color with black mafic (2 - 3 mm) scattered.

Microscopic Observation :

Coarse-grained, holocrystalline

Plagioclase --- distinct normal zoning, sub-idiomorphic, rimmed with oligoclase.

Quartz ----- allotriomorphic --- hypidiomorphic.

Biotite ---- almost fresh, partly altered to muscovite.
X=light green, Y=light brown, Z=green.

Hornblende --- nearly fresh, lesser than biotite in amount.
X=light green, Y=light brown, Z=green.

Accessory minerals --- distinct large crystal of sphene, apatite.

Secondary minerals --- calcite, muscovite, magnetite.

No. A-3

Name : Altered andesite or dacite flow

Location : 48 km north of Chumpayo Lomas in Quadrangle Chiura

Geological Group: Lower Barroso Formation

Macroscopic Observation :

Dark to black, compact rock; fine-grained with relatively pure black and grey to black matrix.

Microscopic Observation :

Phenocrysts of plagioclase (andesine?), pseudomorphs after biotite, hornblende and augite, and microphenocrysts of quartz lie in a cryptocrystallinal matrix of plagioclase laths and quartz granules with accessories of apatite and magnetite.

Mafic minerals are almost completely altered into calcite, chlorite, opaque minerals etc. and secondary calcite is also formed in matrix.

No. A-4

Name : Biotite dacite

Locality : 41 km north of Chumpayo Lomas in Quadrangle Chiura

Geological Group : Lower Barroso Formation

Macroscopic Observation :

Grey and slightly light brown,
compact hard rock with flow bandings recognized.

Microscopic Observation :

Phenocrysts of plagioclase (andesine - basic oligoclase), biotite and quartz soattered in a cryptocrystallinel matrix with abundant quartz, plagioclase, biotite plus accessory zircon, apatite, sphene and magnetite.

Biotite shows a distinct pleochroism with X=yellow, Y and Z=dark brown.

No. A-8

Name : Augite hornblende trachybasalt or Trachyandesite

Location : 23 km north of Chumpayo Lomas in Quadrangle Chiura

Geological Group : Basalt Lava flow

Macroscopic Observation :

Pure black compact rock with white felspar scattered.

Microscopic Observation :

Phenocrysts composed of hornblende, plagioclase, augite, magnetite with minor amounts of olivine and hypersthene are scattered in the sub-trachytic or hyalopilitic matrix of plagioclase microlite and glass.

Hornblende is brown in color, opacitized in its margin, and rarely contains poikilitic crystals of augite and plagioclase.

Augite is less in amount and of a smaller grain than hornblende.

Olivine is rarely recognized as glomeroporphyritic phenocrysts.

Plagioclase phenocrysts generally show normal zoning with the core of An50.

Some large phenocrysts of plagioclase contain hornblende and magnetite.

No. A-9

Name : Biotite augite andesite

Location : 18 km north of Chumpayo Lomas in Quandrangle Chiura

Geological Group : Lower Barroso Formation

Macroscopic Observation :

Dark grey, partly yellowish grey, comparatively compact rock, with white aggregates (3 - 5 mm) scattered; a dark aggregate of mafic minerals is 5 mm in size.

Microscopic Observation :

Phenocrysts of plagioclase (chief constituent and andesine) augite, biotite and olivine, lie in a sub-ophitic groundmass of plagioclase laths (andesine) filled interstitially with quartz and brown glass.

Augite and olivine phenocrysts are comparatively fresh, and some of olivine include picolite-like opaque minerals.

Plagioclase shows weak normal zoning.

Biotite, having reddish brown color, is remarkablly apacitized.

In the matrix, calcite, epidote, biotite and muscovite are formed by week alteration.

No. K-6

Name : Augite hornblende quartz diorite

Location : 13 km north-west of Esquina in Quadrangle Cayarani

Geological Group : Granite Group

Macroscopic Observation :

Hard compact, dark grey in color.
Partly porphyritic, coarse-grained.

Microscopic Observation :

Texture Sub-ophitic, holocrystalline.
Quartz grains filled interstitially between idiomorphic crystals of plagioclase.
Plagioclase shows distinct normal zoning, the core of which is basic andesine, and its margin acidic oligoclase.
Mafic minerals of hornblende are mostly altered.
Pleochroism of hornblende: X=light brown, Y=dark green, Z=brown.
Accessory minerals are apatite, zircon, epidote, sphene, calcite, magnetite and chlorite.

No. K-8

Name : Augite-biotite-hornblende dacitic agglomerate

Location : 4 km west of Esquina on Quadrangle Cayarani

Geological Group : Tacaza Formation

Macroscopic Observation :

A grey compact rock with black mafic minerals spotted. Phenocrysts of white feldspar (3 mm) are rarely found. Pebbles (5 cm in diameter) are contained to give a porphyritic appearance.

Microscopic Observation :

Phenocrysts of hornblende, biotite, augite and plagioclase lie in a cryptocrystallinal groundmass stippled with quartz, plagioclase, hornblende, biotite, apatite and magnetite.

Hornblende, somewhat opacitized, is the most abundant mafic mineral and has a characteristic pleochroism like bassltic hornblende with X=yellowish brown, Y=reddish brown, Z=dark brown.

Biotite shows also weak apacitization and pleochroism of X=yellow, Y and Z=dark brown.

Most phenocrysts of plagioclase are andesine and some show oscillatory zoning.

A little calcite is formed partly in a matrix.

No. K-15

Name : Biotite dacitic welded tuff

Location : 5 km south east of Tambopata in Quadrangle Velille

Geological Group : Lower Barroso Formation

Macroscopic Observation :

A dark colored rock with white spots of kaolinized feldsper (1-2mm), and dark to black round pebbles (2 cm). Biotite is abundant.

Microscopic Observation :

Broken crystals and fragments of quartz, plagioclase (oligoclase - andesine) and biotite with accessory apatite and magnetite granules scattered in a glassy matrix.

Most of fragments are angular, but some of quartz fragments are partly corroded.

Biotite showing pleochroism of X=yellow, Y and Z= dark brown, is elongated and often bended.

Montmorillonite - like mineral occurs in part as veinlets.

No. K-15'

Name : Olivine basalt (Andesite)

Location : 5 km south-east of Tambopata in Quadrangle Velille

Geological Group : Upper Barroso Formation

Macroscopic Observation :

Dark purple-brown in color, fine-grained, comparatively compact.

Mafic minerals are brown altered o.1 mm - 3 mm in size.

Microscopic Observation :

Phenocrysts of olivine and microphenocrysts of augite are scattered in a fluidal groundmass of sub-parallel plagioclase microlites with augite, olivine, magnetite and a little brown glass.

Olivine is mostly altered to iddingsite, and augite often shows zonal texture.

The composition of plagioclase microlite is not completly determined but is estimated to be sanidine or more basic one, as its index is higher enough than that of cement.

Muscovite, probably a alteration product, is recognized in part.

No. K-19

Name : Basaltic andesite or Aphyric basalt

Location : 5 km south-east of Cayanca in Quadrangle Velille

Geological Group : Upper Barroso Formation

Macroscopic Observation :

Blue-grey in color, microcrystalline, compact.
Elongated druses with feldsper crystals contained.

Microscopic Observation :

A typical phenocryst is absent, and small crystals of plagioclase (sanidine - labradorite), augite and olivine, accompanied by abundant granular magnetite make up sub-trachytic texture.
The chief constituent is plagioclase and then follows augite.
Olivine is partly rimmed with iddingsite and rarely grows up to microphenocryst.

No. K-20

Name : Altered lapilli tuff

Location : San Miguel Mine, 16.5 km south-east of Cayarani in Quadrangle Velille

Geological Group : Tacaza Formation ?

Macroscopic Observation :

Mozaic, relatively compact
grey, partly yellow-green in color,
green aggregates of Chlorite (?) (1 cm).

Microscopic Observation :

Mainly crystal fragments of quartz, feldspar and altered mafic minerals scattered in a base of microcrystallines composed of quartz, chlorite, calcite, etc.

A mafic mineral, now altered into a pale green chlorite-like mineral and calcite, seems to be pyroxene from its crystal form.

No. K-31

Name : Biotite-hornblende-quartz Granite

Location : 5 km north west of Ataraya Mine in Quadrangle Yauri

Geological Group : Granite Group

Macroscopic Observation :

Grey to black, holocrystalline, with
black mafic minerals scattered; hornblende is 1-2 mm in
size; feldspar is white.

Microscopic Observation :

Texture holocrystalline; with coarse grained, idiomorphic
quartz, hornblende, biotite scattered allotriomorphic-
interstitially in plagioclase, showing sub-ophitic texture.
Plagioclase with normal zoning; its margin consists of
oligoclase (n=smaller than quartz, larger than cement),
its core being more basic andesine.
Hornblende relatively altered to chlorite and calcite,
and pleochroic from pale green to colourless.
Biotite is fresh with X=light yellow, Y=Z=reddish brown.
Accessories ----- Zircon, garnet, magnetite.
Secondary minerals ----- Calcite, white mica, chlorite,
magnetite.

No. K-34

Name : Augite andesite

Location : 3 km south of Quechua Mine in Quadrangle Yauri

Geological Group : Upper Barroso Formation

Macroscopic Observation :

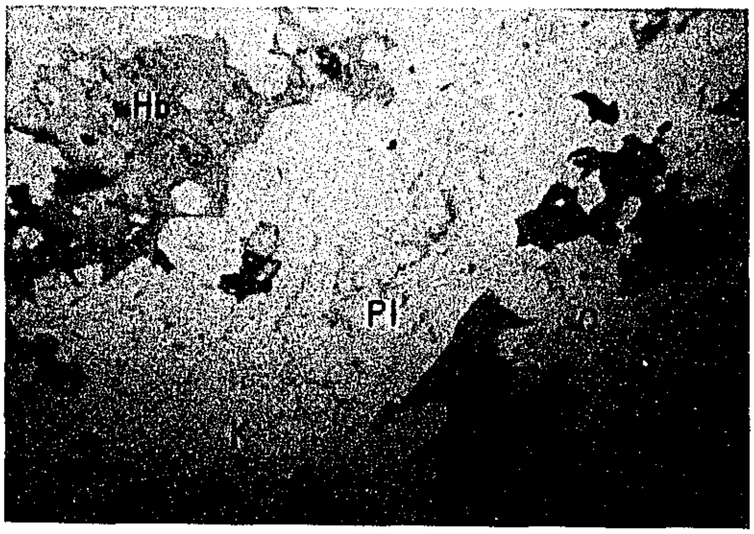
Purple-grey, dark in color.
Compact, fine-grained, with dark to black spots of decomposed mafic minerals of 1-2 mm size.

Microscopic Observation :

Phenocrysts of major augite and minor plagioclase and olivine lie in a matrix of feldspar accompanied by augite, opaque minerals and rare sphene.
Augite phenocrysts, generally shows glomeroporphyritic, and texture are often rimmed by small grains of brownish opaque minerals (ilmenite?), and some large ones contain poikilitic plagioclase.
Olivine occurs also as glomeroporphyritic crystals, but most of them are altered into aggregates of brown iddingsite and opaque minerals.
Groundmass is composed of euhedral and subparallel andesine laths filled with auhedral feldspar and a, little augite, showing subtrachytic and sub-ophitic textures.
The above mentioned auhedral feldspar changes its composition from central oligoclase to marginal alkali-feldspar.
Quartz phenocrysts surrounded by reddish brown mica-minerals are rarely recognized.

TABLE 4

Microphotographs of Rocks



Open Nicol 0 1 mm

S - 1 Hornblende quartz diorite

Location : 10 km north westwest of Yauri in Quadrangle Yauri

Geological Group : Granite Group

K : Potash feldsper

Pl : Plagioclase

Q : Quartz

Hb : Hornblende

Crossed Nicols 0 1 mm

S - 1 Hornblende quartz diorite

Location : 10 km northwest-west of Yauri
in Quadrangle Yauri

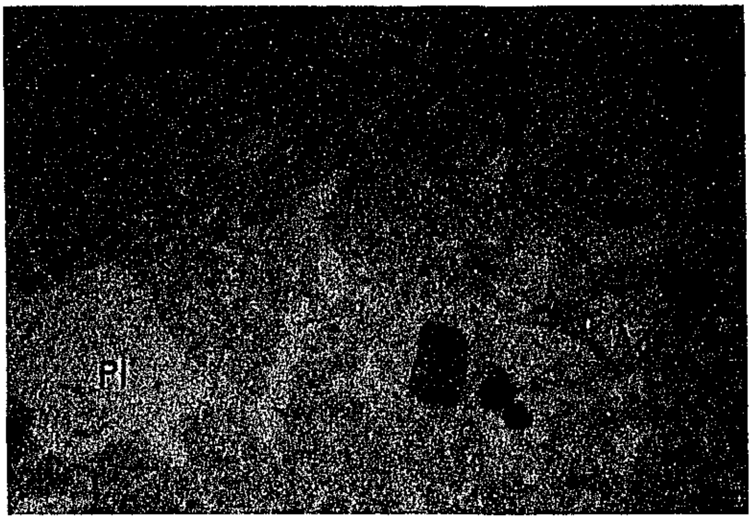
Geological Group : Granite Group

K : Potash feldsper

Pl : Plagioclase

Q : Quartz

Hb : Hornblende

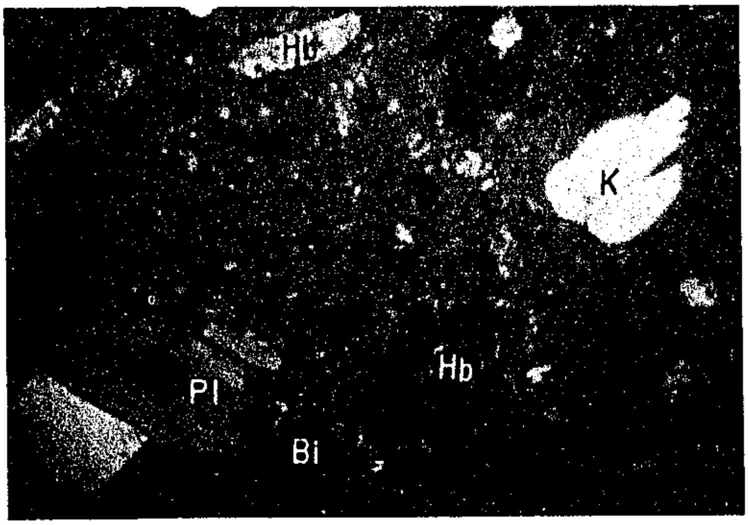


Open Nicol 0 0.5mm

S - 5 Biotite augite andesite

Location : 20 km south-east of Velille
in Quadrangle Velille
Geological Group : Upper Barroso Formation

Pl : Plagioclase
Bi : Biotite
Ag : Augite



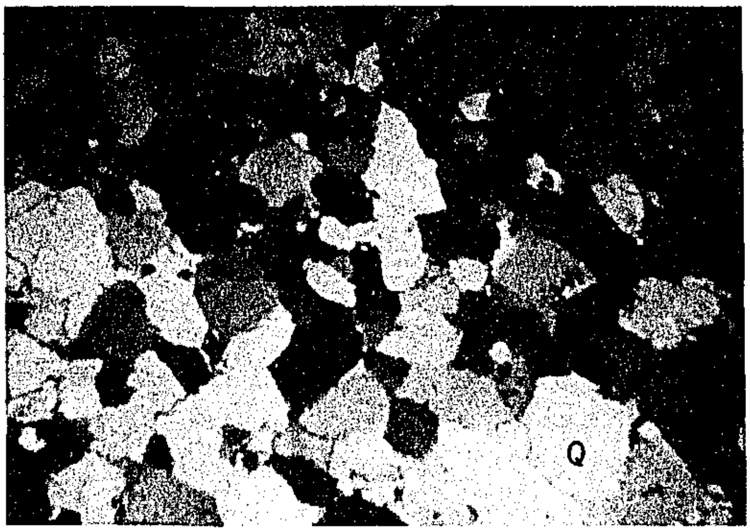
Crossed Nicols   0 ———— 1mm

S - 6 Biotite hornblende granodiorite porphyry
(or Dacitic porphyry)

Location : 12 km east of Velille
in Quadrangle Velille

Geological Group : Granite Group

Pl : Plagioclase
K : Potash feldsper
Hb : Hornblende
Bi : Biotite



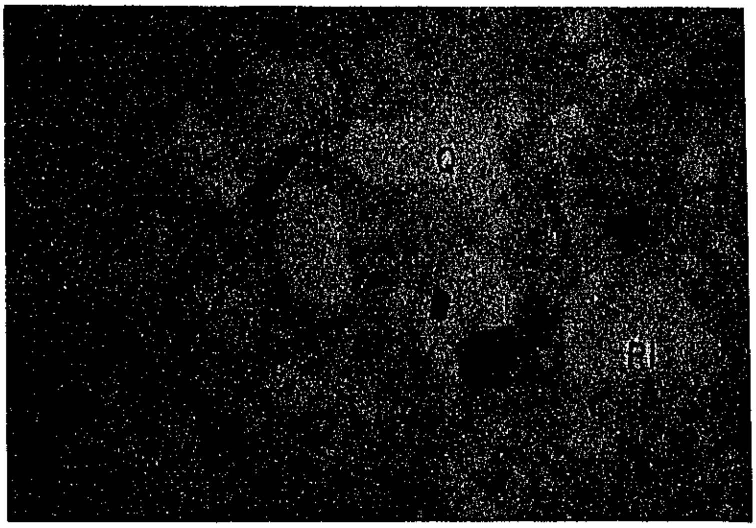
Crossed Nicols 0 1mm

T - 2 Quartzite

Location : 7 km north-east of Tintaya Mine in Quadrangle Yauri

Geological Group : Yura Formation

Q : Quartz

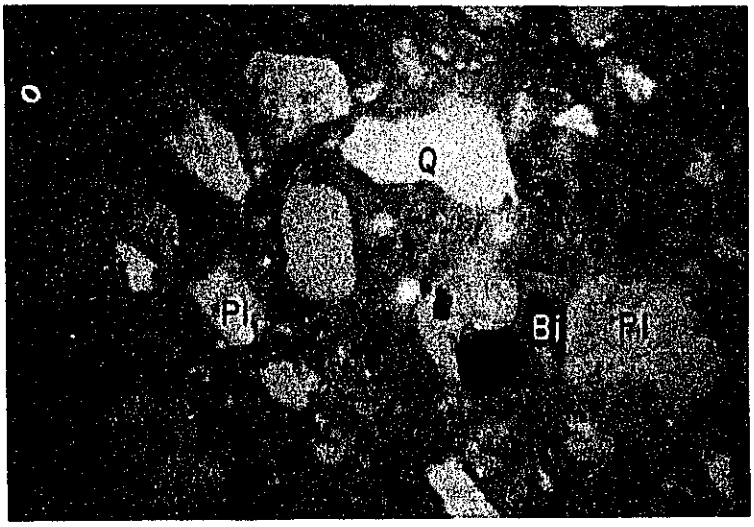


Open Nicol　　0 ——— 1 mm

A - 4　Biotite dacite

Location　　　:　41 km North of Chumpayo
　　　　　　　　　Lomas in Quadrangle Chiura
Geological Group :　Lower Barroso Formation

Q　:　Quartz
Pl :　Plagioclase
Bi :　Biotite



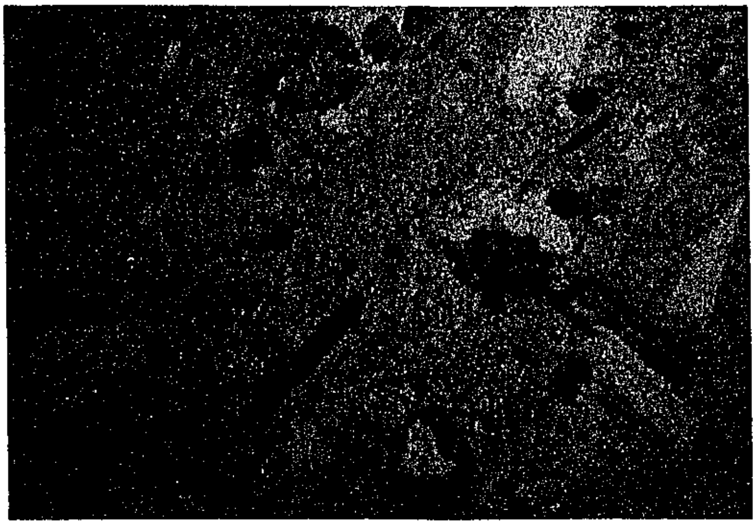
Crossed Nicols

0 1 mm

A - 4 Biotite dacite

Location : 41 km north of Chumpayo
Lomas in Quadrangle Chiura
Geological Group : Lower Barroso Formation

Q : Quartz
Pl : Plagioclase
Bi : Biotite



Open Nicol

0 1mm

A-8 Augite hornblende trachybasalt

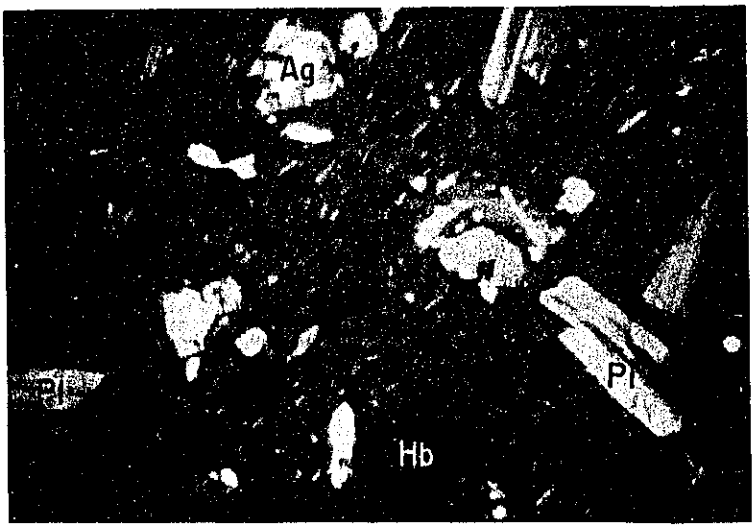
Location : 23 km north of Chumpayo Lomas in Quadrangle Chiura

Geological Group : Basalt lava flow

Pl : Plagioclase

Ag : Augite

Hb : Hornblende



Crossed Nicols 0 1mm

A - 8 Augite hornblende trachybasalt

Location : 23 km north of Chumpayo
Lomas in Quadrangle Chiura
Geological Group : Basalt lava flow

Pl : Plagioclase
Ag : Augite
Hb : Hornblende

Crossed Nicols 0 1mm

A - 9 Biotite augite andesite

Location : 18 km north of Chumpayo Lomas
in Quadrangle Chiura

Geological Group : Lower Barroso Formation

Pl : Plagioclase

Bi : Biotite

Ag : Augite

Open Nicol

A - 12 Tuffaceous shale

Location : 6 km south-west of Chumpayo Lomas in Quadrangle Chiura

Geological Group : Middle Barroso Formation

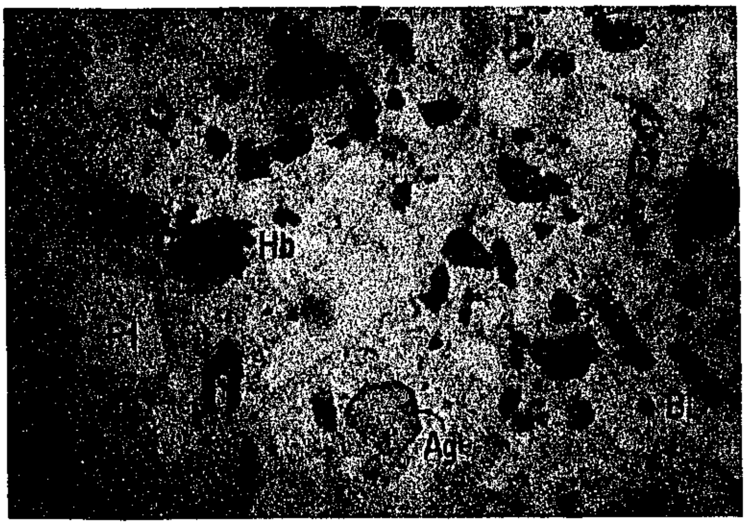
Crossed Nicols 0 1mm

K - 8 Augite biotite hornblende dacitic agglomerate

Location : 4 km West of Esquina in Quadrangle Cayarani

Geological Group : Tacaza Formation

Pl : Plagioclase
Bi : Biotite
Hb : Hornblende
Ag : Augite



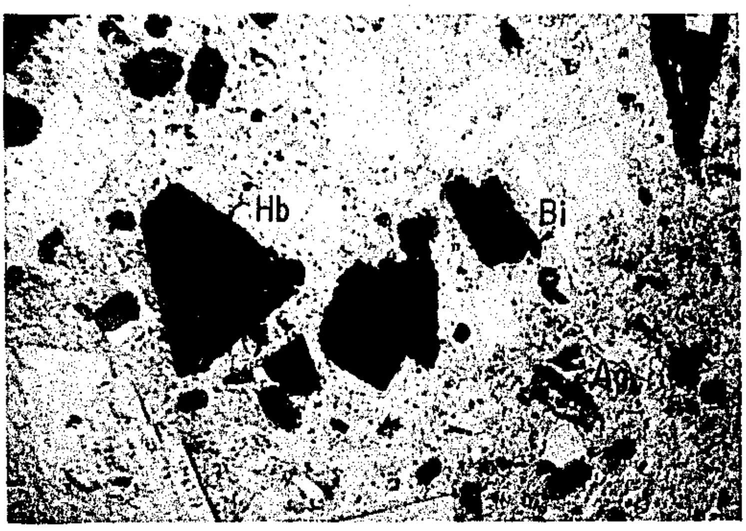
Open Nicol 0 0.5 mm

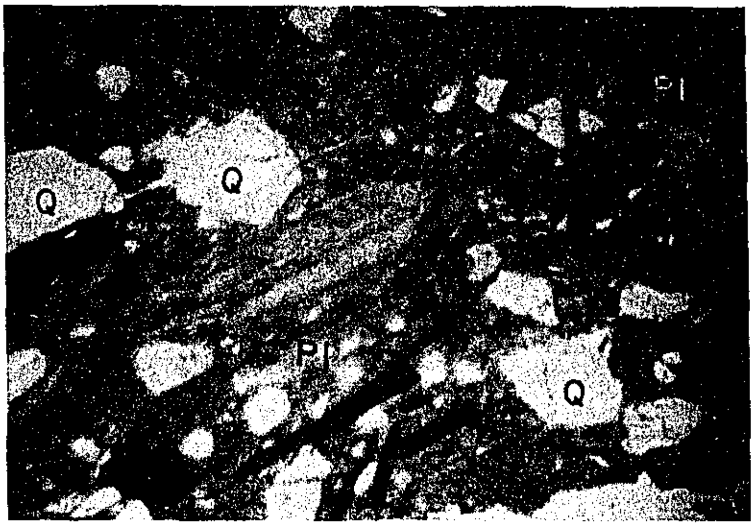
K - 8 Augite biotite hornblende dacitic agglomerate

Location : 4 km west of Esquina on Quandrangle Cayarani

Geological Group : Tacaza Formation

Pl : Plagioclase
Bi : Biotite
Hb : Hornblende
Ag : Augite



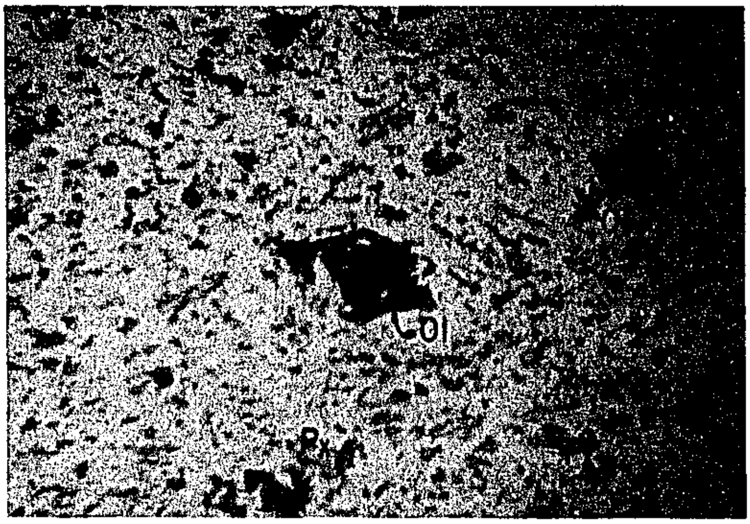


Open Nicol 0 1mm

K - 15 Biotite dacitic welded tuff

Location : 5 km south-east of Tambopata in Q. Velille
Geological Group : Lower Barroso Formation

Q : Quartz
Pl : Plagioclase



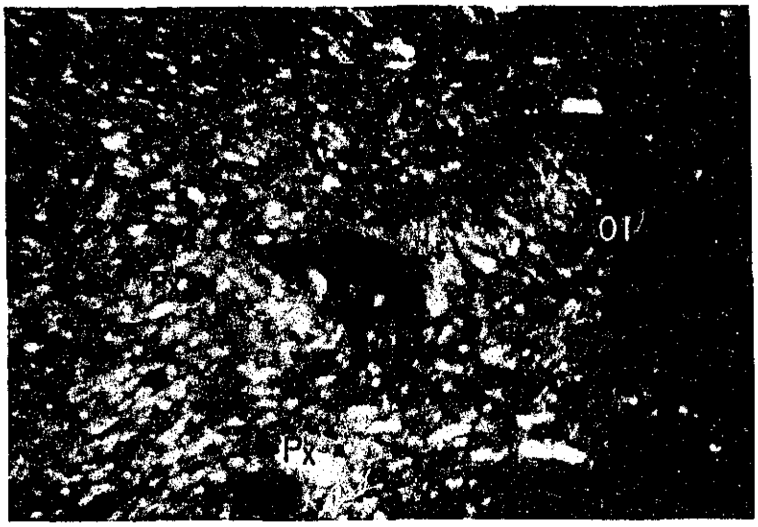
Open Nicol

0 1mm

K - 15' Olivine basalt

Location : 5 km south east of Tambopata in Q. Velille
Geological Group : Upper Barroso Formation

Ol : Olivine
Px : Pyroxene



Crossed Nicols 0 ———— 1 mm

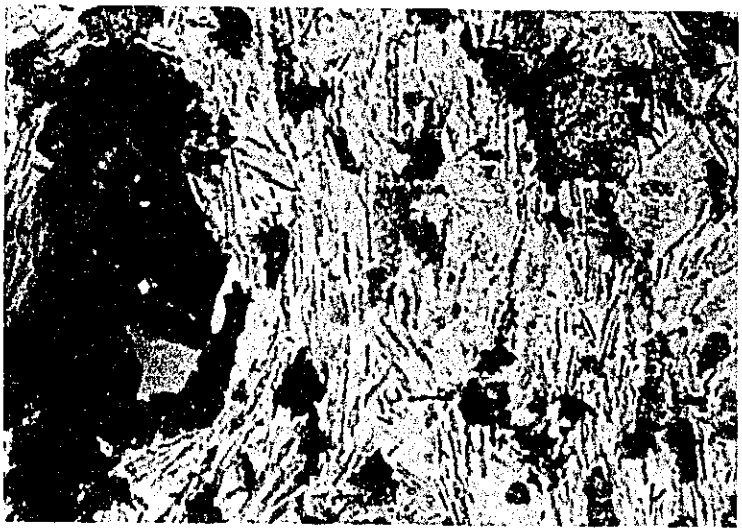
K - 15' Olivine basalt

Location : 5 km south-east of Tambopata
Quadrangle Velille

Geological Group : Upper Barroso Formation

Ol : Olivine

Px : Pyroxene

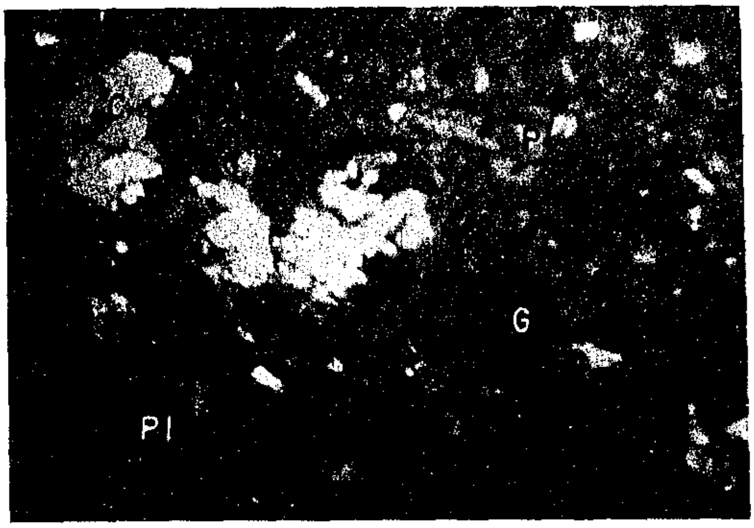


Open Nicol

K - 15' Olivine basalt

Location : 5 km south east of Tambopata
in Quadrangle Velille
Geological Group : Upper Barroso Formation

Olivine phenochryst is altered to Iddingsite.
Granular microphenochryst of augite scattered.



Crossed Nicols 0 1 mm

K - 20 Altered lapilli tuff

Location : Mina San Miguel 7.5 km south of Quadrangle Velille

Geological Group : Tacaza Formation?

C : Calcite after Pyroxene

Pl : Plagioclase

G : Glassy part

Crossed Nicols 0 1mm

K - 31 Biotite-hornblende granite

Location : 5 km north-west of Ataraya
in Quadrangle Yauri

Geological Group : Granite Group

Pl : Plagioclase

Q : Quartz

Bi : Biotite

TABLE 5

X-ray diffractive analysis

Sample No: T-1
Geological Group: Middle Barroso Formation
Location: 1 km north of Yauri
Rock name: Sandy tuff
Recognized minerals: Andesine?
Alpha-Quartz?
Cristobalite?

Sample No: T-5-B
Geological Group: Middle Barroso Formation
Location: 7 km SE of Hector Tejada in Quadrangle Yauri
Rock name: Sandy tuff
Recognized minerals: Labradorite?
Montmorillonite
Alpha-Quartz?

Sample No: T-7
Geological Group: Middle Barroso Formation
Location: 13 km NE of Yauri in Quadrangle Yauri
Rock name: Mudstone
Recognized minerals: Calcite
Alpha-Quartz?

Sample No: K-29
Geological Group: Middle Barroso Formation
Location: Ayapata in Quadrangle Velille
Rock name: Pumiceous white tuff
Recognized minerals: Orthoclase?
Cristobalite
Andesine

Sample No.: K-10

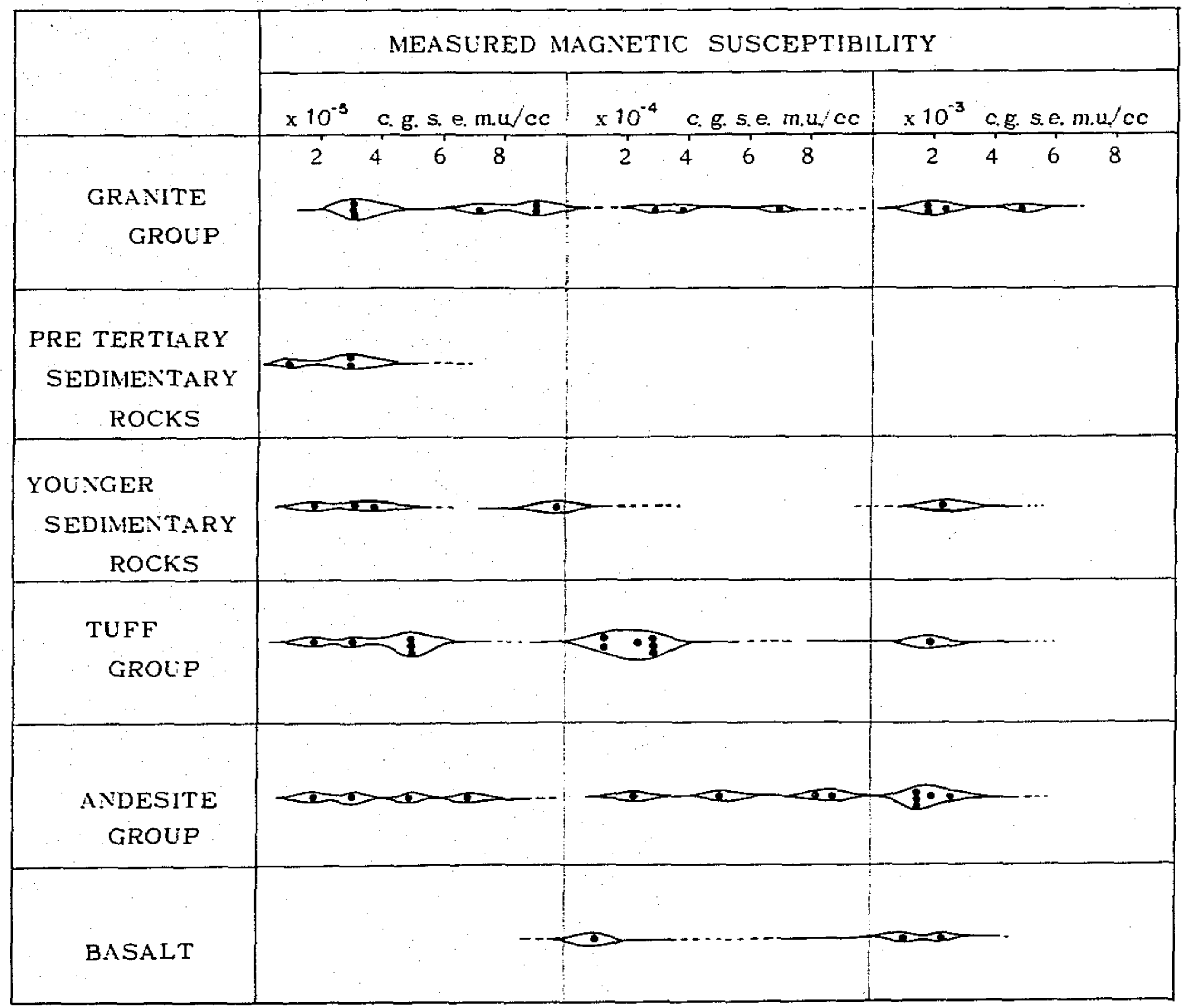
Geological Group: Tacaza Formation

Location: 7 km south of Esquina in Quadrangle Velille

Rock name: Andesitic tuff

Recognized minerals: Labradorite-Andesine?
Alpha-Quartz?

TABLE 6


MEASURED MAGNETIC SUSCEPTIBILITY
x 10^{-5} c. g. s. e. m.u/cc
x 10^{-4} c. g. s. e. m.u/cc
x 10^{-3} c. g. s. e. m.u/cc
2 4 6 8
2 4 6 8
2 4 6 8
GRANITE GROUP
PRE TERTIARY SEDIMENTARY ROCKS
YOUNGER SEDIMENTARY ROCKS
TUFF GROUP
ANDESITE GROUP
BASALT