REPORT ON GEOLOGICAL SURVEY

OF

LAS CANITAS AREA

DOMINICAN REPUBLIC

PHASE I

JULY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to the request of the Government of the Dominican Republic, decided to conduct the investigation in relation to the survey of the ore deposit including geological survey in order to confirm the potential of occurrence of mineral resources in the Las Canitas area, and entrusted its execution to the Japan Interantional Cooperation Agency (JICA). Because of its essential qualities that it belongs to a special field involved in the survey of geology and mineral resources, JICA consigned it to the Metal Mining Agency of Japan (MMAJ).

The survey is scheduled to be performed for three years from fiscal 1983, and this firscal year is the first year. MMAJ organized a team for field survey consisting of four members and dispatched it to the Dominican Republic from November 15, 1983 to February 3, 1984.

The survey was accomplished as scheduled under close cooperation with the Government of the Dominican Republic and its various agencies, especially with Direcion General de Mineria (DGM) of the Ministry of Commerce and Industry.

This report is the compilation of the survey of the first phase and will form a portion of the final report.

We wish to express our heartful gratitude to the Government of the Dominican Republic and its appropriate agencies including D.G.M. of the Ministry of Commerce and Industry as well as the Ministry of Foreign Affairs, the Ministry of International Trade and Industry, the Embassy of Japan in the Domincan Republic and the companies concerned for the cooperation and support extended to the Japanese survey team.

May 1984

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

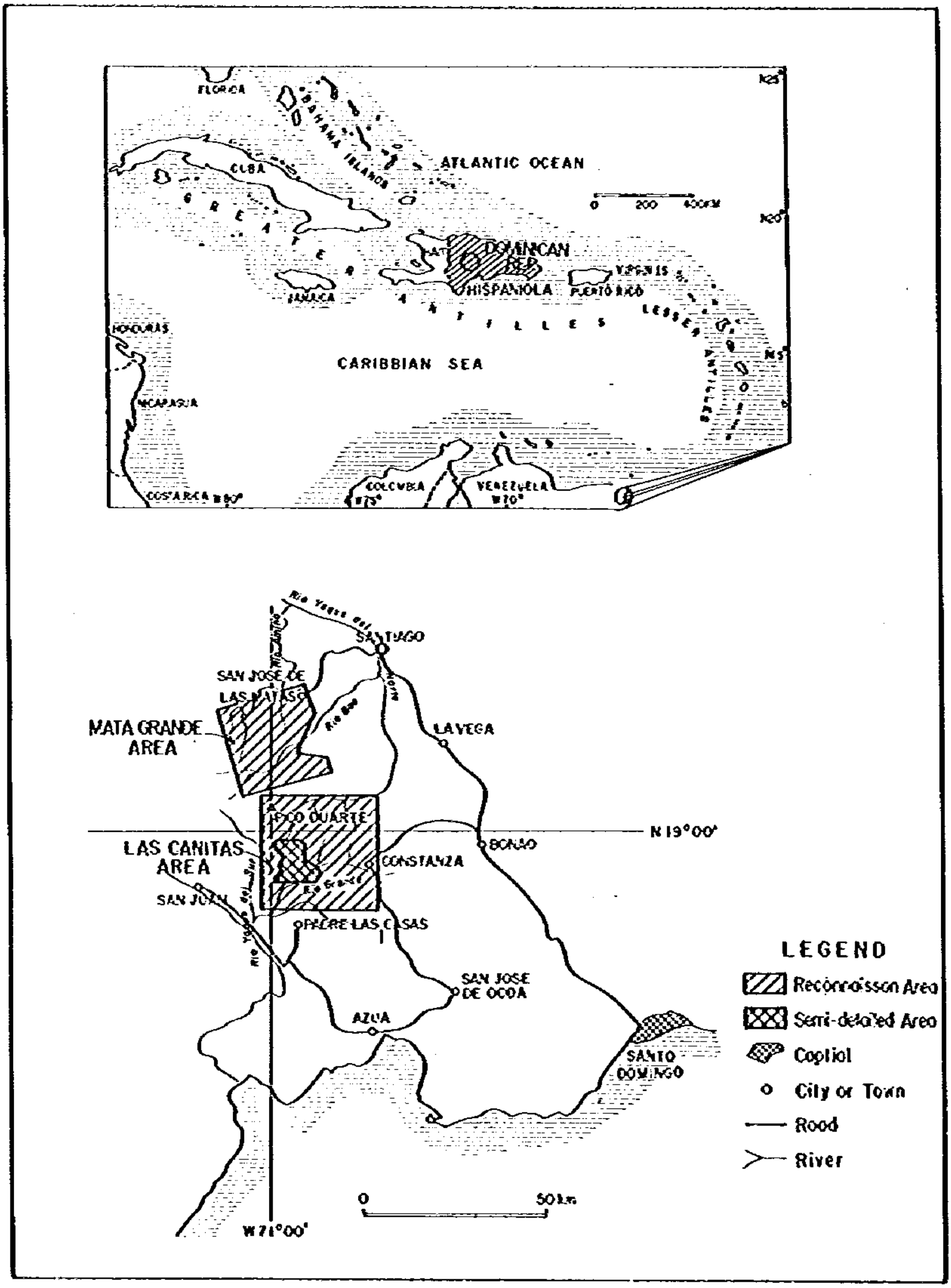

Fig. 1 Location Map of the Project Area

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ABSTRACT

In the survey of the first phase of the collaborative mineral exploration conducted in the Las Canitas area in the Dominican Republic, reconnaissance geological survey, semi-detailed survey an geochemical survey were carried out in the area with an extent of about 2,000 square kilometers for the purpose of extracting the promising areas for emplacement of ore deposits by grasping the stratigraphy, geologic structure, igneous activity and mineralization, and also making clear the relationship between them.

In this survey, the stratigraphy of ore-bearing horizon and classification of igenous activity were established and the relationship between these and the mineralization was made clear.

The pre-Cretaceous Duarte formation consists mainly of basic volcanic rocks and its pyroclastic rocks, and is divided into two members. The Cretaceous Tireo formation is mainly composed of acidic and intermediate volcanic rocks and its pyroclastic rocks, and divided into three members. The metallic ore deposits are emplaced in and below the middle member of the Tireo formation. The dominant geologic structures include the major tectonic lines of WNW–ESE system which are the framework of the Hispaniola Island, and the shearing faults associated with the above such as those of NW–SE and NE–SW systems.

The tonalite masses are classified into batholith and stock (or dyke), and the latters are distributed in associated with the shearing faults of NW–SE system. The intrusives which take the form of stock or dyke are likely to be the igneous rocks associated with formation of the ore deposits.

The mineralization distributed in the survey area includes the three types such as vein, porphyry copper and pyrite dissemination. These mineralized zones are the hydrothermal origin which have the genetic relation with the igenous activity of the Laramide orogeny, being present in positional relation to the tectonic lines of NW–SE system and/or the intrusive masses.

The vein-type mineralized zones are emplaced in the Duarte formation, the Tireo formation and the intrusives, and take the forms such as network to disseminated veins or single veins.

The mineralized zones in the Sabana area are the network copper veins occurred in the middle Tireo member, showing a distribution extending northwesterly on the whole, and have a positional relation to the faults of NW–SE system. The minealized zone at the south of Constanza is the copper, lead and zinc vein emplaced in the middle Tireo member, surrounding concentrically the tonalite stock. It has a positional relation to the intrusive. The mineralized zone in the Mata Grande area is the copper vein occurred in the Duarte formation and partly in the tonalite, and it seems to be the mineralized zone to be associated with the tonalite dykes extending

northwesternly or the faults of NW direction.

The porphyry copper-type mineralized zone is a zone of floats newly discovered on the eastern slope of Pico Duarte, in which copper and molybdenum are disseminated.The host rock is granodiorite. Mineralized zone has an important relationship with the granodiorite intrusive.

The mineralized zone of pyrite dissemination is the one emplaced in dacite and its pyroclastic rocks of the middle Tireo member and the green schists of the Duarte formation, and have a positional relation to the intrusives.

The result of geochemical survey well corresponds to the distribution of the mineralized zone, and the main geochemical anomalies of copper and zinc are distributed in the Sabana area and the Constanza area. The anomalies of gold are distritured in the Mata Grande area.

As the result of geological survey and geochemical survey, south of Constanza and Mata Grande, which have the areas for survey of vein-type deposit, and the east of Pico Duarte which is the area for the survey of porphyry copper deposit, were extracted as the favorable areas.

I. INTRODUCTION

CHAPTER 1 DETAILS AND PURPOSE OF THE PROJECT

1–1 Details of the Project

The Cordillera Central district of the Dominican Republic has been known since old time as an area of gold and copper deposits. The Government of the Dominican Republic planned to carry out a comprehensive survey of metallic deposits in the Las Canitas area which has the highest potential of occurrence of metallic ore deposit in the district. And for promotion of the project, it requested in December 1981 the execution of the collaborative mineral exploration to the Government of Japan.

The Government of Japan, in response to the request of the Government of Dominican Republic, dispatched in September 1983 a survey mission to that country, and made the members of mission investigate in detail and consult on the survey plans and the matters of cooperation to be made by the Japan side, and at the same time, made them conduct the preliminary survey of the site.

As the result, an agreement was reached between the mission and Direccion General de Mineria (DGM) of the Ministry of Industry and Commerce of the Dominican Republic on execution of the survey of the Las Canitas area, and the Scope of Work was concluded on September 20, 1983.

1–2 Purpose of the Project

The purpose of survey of this phase was to extract the high potential areas of occurrence of the ore deposit by grasping the actual conditions of geology and ore deposit in the survey area and by making clear the mutual relationship between the mineralization and geology, structure and igneous activity. For this purpose, establishment of the stratigraphy, classification of the igneous rocks, analysis of the geologic structure, grasp of actual condition of the ore deposits and elucidation of mutual relationship between the mineralization and geology, structure and igneous activity, were taken up as the major subjects, which resulted in the execution of surveyof geology and ore deposit and geochemical survey.

CHAPTER 2 OUTLINE OF THE SURVEY

2–1 Outline of the Survey Area

The survey area is situated at the center of the Cordillera Central about 100 kilometers to the northwest of Santo Domingo, the capital city of the country, at about lat. 19°N and long. 71°W (Fig. 1). Mt. Pico Duarte, the highest mountain in the Dominican Republic, rises between the survey areas on the north and the south, and they are contained within the approximate extent, of which San Jose de las Matas is situated at the northern end, Padre Las Casas at the southern end, Constanza at the eastern end and San Juan at the western end.

In terms of the access of the area, although there are car roads up to the adjacent areas centering on Constanza, San Jose de las matas and Padre Las Casas, the mule roads are the only access in the western part of the survey area. Eventually the access is not so good on the whole. It takes about four hours by car from Santo Domingo to Constanza where the base camp was set during the survey of this time.

To reach Padre Las Casas which was the base of the southern part, it takes about four hours through San Jose de Ocoa and Azua from Constanza.

To reach Mata Grande and Diferencia which were the bases in the northern part, it takes about two hours respectively via San Jose de las Matas from Santiago, the second large city in Dominica.

The topography of the survey area is composed of mountains of Cordillera Central 1,000 to 3,000 meters above sea level extending northwesterly. The watershed runs in the direction of NW–SE in the central part of the survey area. The drainage system in the northern part flows northward on the whole in the survey area and joins the Rio Yaque del Norte which flows northwestward into the Atlantic Ocean. The drainage system in the southern part flows southwestward on the whole and joins the Rio Yaque del Sur which flows southward into the Caribbean Sea.

The topography of the area reflects the geology, and a steep and rugged landform is shown in the terrains of green schists of the Duarte formation, acid to intermediate lavas and pyroclastics of the Tireo formation, the Tertiary sedimentary rocks and Quaternary volcanic rocks, while a gentle landform is shown in those of tonalite.

As for the climate, the mean temperature through the year for the latest four years in the capital city of Santo Domingo is 25.8°C, and the annual precipitation is 1,382 millimeters. Although there is a little difference in climate in the survey area between the north and the south of the Cordillera Central, the mean temperature through the year is 18.2°C and the annual precipitation is 1,026 millimeters in Constanza situated in the central part of the survey area.

The rainy season is from May to June. The hurricane often sweeps over the island during September to October, and the except these tend to be dry season in general.

2–2 Contents and Method of the Survey

The survey areas of the first phase include the Mata Grande area in the northern part and the Las Canitas area in the southern part with an area of 1,953 square kilometers in total. In order to effectively accomplish the purposes mentioned in the previous clause, the areas were divided into the semi-detailed survey area and the reconnaissance survey area, in which the surveys for geology and ore deposit and geochemical survey were performed. The semi-detailed survey area occupies an area of 180 square kilometers in the central part of the Las Canitas area, and the rest were the reconnaissance survey areas.

The survey of geology and ore deposit was started on November 23, 1983 in parallel with the sampling of geochemical samples, which was completed on January 20, 1984. The total length of survey routes was 540 kilometers, and the number of geochemical samples taken were 1968 in total.

The results of survey were compiled to the geological map of 1:25,000 scale by means of the route maps of 1:10,000 scale for the semi-detailed survey area, and to the geological map of 50,000 scale for the reconnaissance survey area by the use of the rout maps of 25,000 scale.

The geochemical samples were analyzed for six elements such as Au, Ag, Cu, Pb, Zn and As, which were used for analysis of single component and multivariate analysis. These were expressed on the geochemical anomaly map of 1:100,000 scale.

In terms of the survey of ore deposit, the location maps of the mineralized zones were drawn in the scales of 1:1,000 or 1:2,000, and the sketches of 1:100 or 1:200 were produced for the main mineralized zones.

Ninety two ore samples taken in the survey of ore deposit were analyzed for five elements of Au, Ag, Cu, Pb and Zn, which was used for the data of evaluation of the ore deposit.

Table 1 and Table 2 show the content of survey of this phase and the details of various samples tested.

2–3 Members of the Survey Team

The personnel who participated in the survey are as follows:

Japanese members for planning and negotiation

Katsuzo Sawaya	Metal Mining Agency of Japan (MMAJ)
Yozo Baba	do.

Takashi Ogitsu	Metal Mining Agency of Japan (MMAJ)
Tadaaki Ezawa	Japan International Cooperation Agency (JICA)
Hideki Okamoto	Ministry of International Trade and Industry

Dominican members for planning and negotiation

Miguel Antonio Peña	Direction General de Mineria (DGM)
Gerald M. Ellis	do.
Ramón Alburquerque Ramírez	do.
Orlando A. Pizano	do.
Gisela de Perdomo	do.
Hector P. Tovar	Secretario de la Presidencia

Japanese members of the survey team

Katsuzo Sawaya	MMAJ
Yozo Baba	do.
Tadaaki Ezawa	JICA
Hideo Kuroda	MMAJ
Kazuo Kawakami	do.
Atsuyiki Endo	do.
Hiroshi Takahashi	do.

Dominican members of the survey team

Héctor Ramon Santos	DGM
Victor Manuel Garcia	do.

CHAPTER 3 SURVEY AND RESEARCH IN THE PAST

The survey areas are situated in the central part of the Cordillera Central, in which various kinds of metamorphic rocks, sedimentary rocks and igneous rocks are distributed. The stratigraphy of the central part of the Cordillera Central which contains the survey area was first framed by BOWIN (1960). After that, PALMER (1963) made more clear the stratigraphy of the southern foot of the Cordillera Central.

An abundant copper mineralization is observed in the Cordillera Central, and especially the Las Canitas area and the Mata Grande area situated in the survey area are famous for it.

MITSUBISHI METAL Co., Ltd. conducted the geochemical prospecting from 1965 to 1971 in the area of about 7,700 square kilometers on the western side of the Cordillera Central. In the Mata Grande area, NORANDA conducted in 1970 the geological survey, geochemical prospecting and geophysical prospecting entrusted by D.G.M. J.E. Espailat-Lamarche reported on the geology and ore deposit of the Mata Grande in 1980.

Although a considerable amount of exploration has been made in the Las Canitas area, no systematic ones have been seen. In recent years, PEYNADO conducted exploration in 1972 and FALCONBRIDGE NICKEL in 1974. In 1979, D.G.M. commissioned the exploration to B.R.G.M. (Bureau de Recherches Géologiques Miniére) of France, and the report was submitted in 1980.

Table 1 Outline of Phase I Work Schedule

	Period	Length of Route Traversed	Number of Stream Sediments
Preparation and Orientation	Nov. 15 ~ Nov. 22, 1983		
Reconnaissance Geological Survey	Nov. 23, 1983 ~ Jan. 20, 1984	478 km	1,777 samples
Semi-detailed Geological Survey	Dec. 7 ~ Dec. 29, 1983	62 km	191 samples
Compilation	Jan. 21 ~ Jan. 31, 1984		
Data Processing and Report	Feb. 4 ~ May. 15, 1984		

Table 2 Numbers of Tested Samples

	Reconnaissance Survey Area	Semi-detailed Survey Area	Total
Rock and Ore Samples			
Thin Section	30	4	34
Polished Section	19	6	25
X-ray Diffractive Analysis	6	5	11
Chemical Analysis of Rock	10	2	12
Chemical Analysis of Ore	62	30	92
Stream Sediment Samples	1,777	191	1,968

Ⅱ. PARTICULAR GEOLOGICAL SURVEY · GEOCHEMICAL SURVEY

CHAPTER 1 OUTLINE OF REGIONAL GEOLOGY

1−1 General Geology of Dominica

The Dominican Republic, sharing the border with Haiti Republic, occupies about the eastern two-thirds of the Hispaniola Island.

The Hispaniola Island composes a part of the Greater Antiles together with the islands such as Cuba, Jamaica, Puerto Rico and the Virgin Islands. The Greater Antiles form so-called the Caribbean island arc together with the Lesser Antiles (Fig. 1).

The Caribbean island arc belongs to the Circum-Pacific orogenic belt, the western extension of which turns southward from the western end of Cuba and runs through the eastern coast of the Yucatan Peninsula, turning again to the west in Guatemala, and continues to the Mexican orogenic zone to the north. The eastern extension bends southward and enters Venezuela through Trinidad to connect to the Andes orogenic zone extending southwestward.

The Greater Antiles belong to the area of eugeosyncline formed from late Jurassic to early Tertiary, and a volcanic archipelago had been assumed to have existed in Cretaceous time (Woodring 1954).

In recent years, the introduction of the plate-techtonic theory led to an assumption that the Great Antiles would be an island arc which came into existence on the west of the Atlantic Ocean as a result of expansion of the Atlantic plate along the northern side of the Caribbean plate (Khudoley & Meyerhoff 1971).

The geology and tectonic of the Hispaniola Island are outlined as follows (Fig.2 and 3). The pre-Tertiary system is mainly distributed in the Cordillera Central, and the Cordillera Oriental situated to the east and running parallel with the former. The pre-Tertiary system is roughly divided into the pre-Cretaceous and the Cretaceous.

The pre-Cretaceous is composed of the metamorphic rocks of green schist facies excepting for a part of glaucophane- chlorite-epidote schist. Although the time of these metamorphic rocks is unknown because of absence of the fossils, they are considered to belong to pre-Cretaceous because the strata identified to be early Cretaceous has hardly undergone such metamorphism. The Cretaceous consists of intermediate to acidic lava and pyroclastic rocks, locally accompanied by mudstone, sandstone and limestone. The identification of foraminifera in the limestone showed that the older one was early Cretaceous. (BOWIN, 1960)

The Cretaceous system contains the important strata for the field of emplacement of copper deposits. Most of the Tertiary and Quaternay systems compose the lowlands other than the nucleus of the Cordillera Central and are distributed in a form to be cut by the grabens such

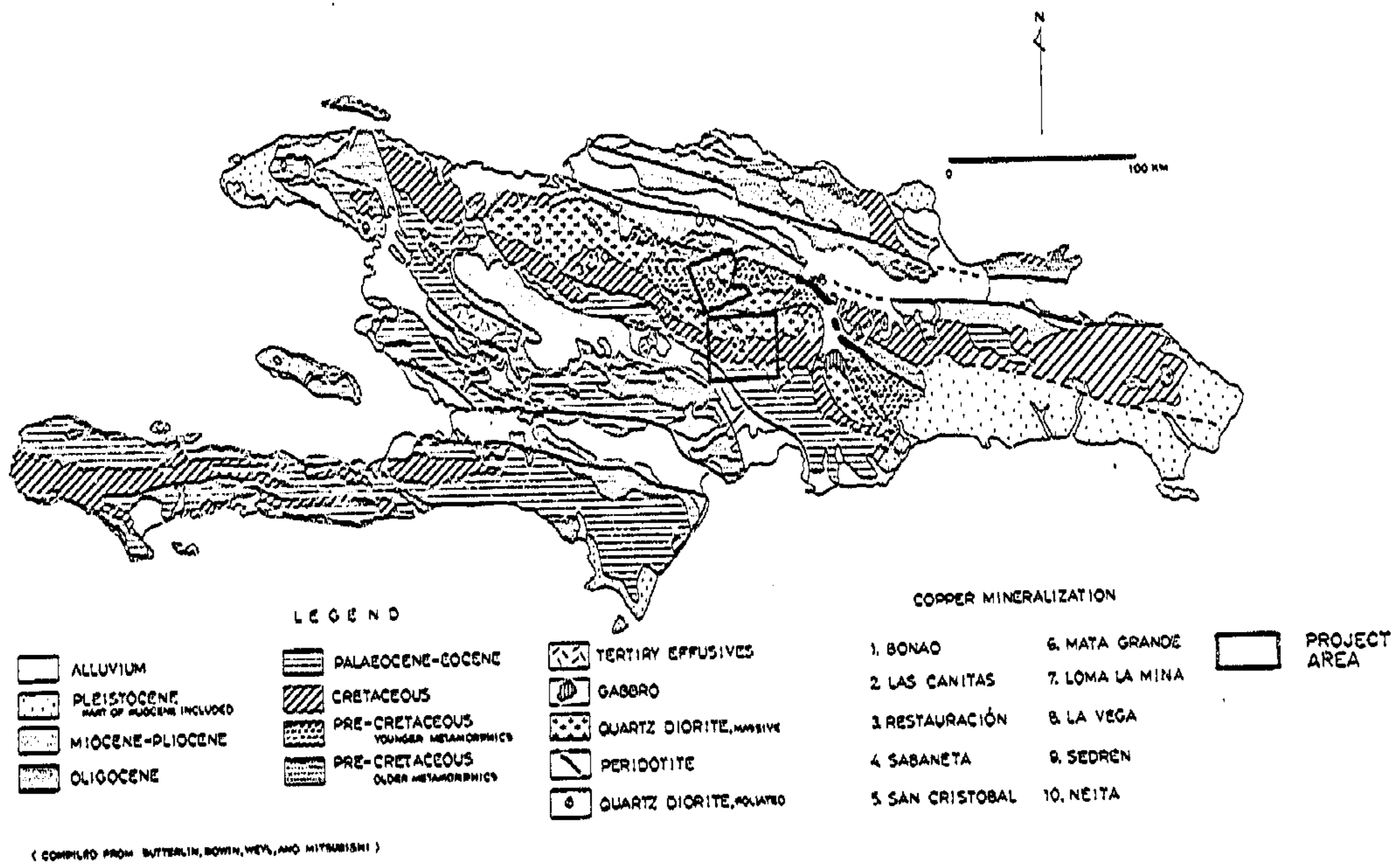


Fig. 2 Geological Map of the Hispaniola Island

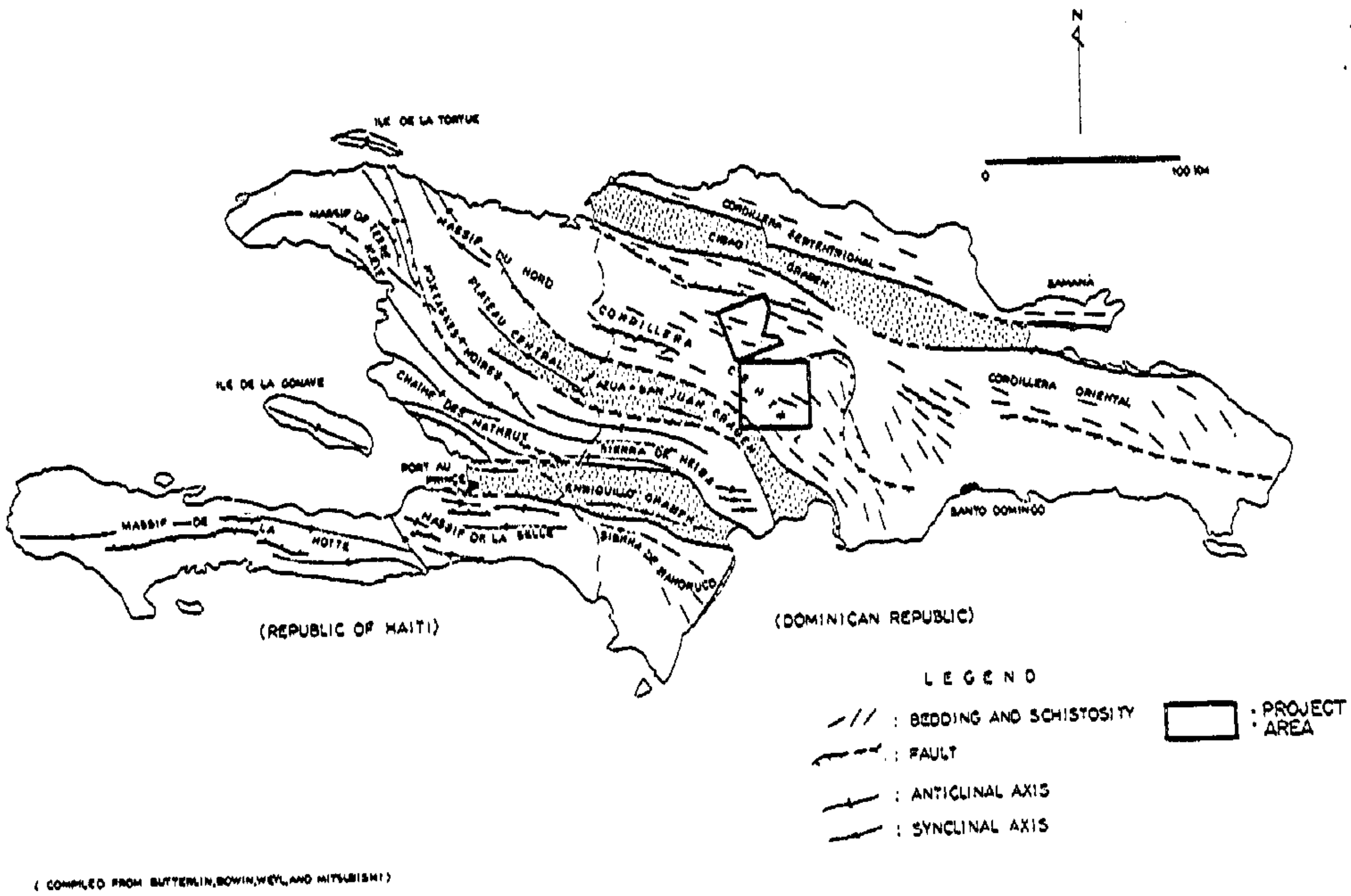


Fig. 3 Tectonic Map of the Hispaniola Island

as Cibao, Azua-San Juan, or covering those.

The Palaeocene and Eocene series are composed of strata of terrigenous to neritic origin consisting of conglomerate and sandstone in the lower part, while of thick beds of limestone in the upper part. The bauxite deposits of terra rosa type are found in the limestone distributed in the area adjacent to the border along the southern coast.

The Oligocene series is distributed in the zones of graben, consisting of thick beds of limestone. The Miocene to Pleistocene series are also distributed in the grabens and consist of neritic sediments intercalated with limestone layers in contrast to the above.

The Pleistocene series is composed of coral limestone and forms the marine plateaus.

The Holocene series consists of sand, gravel and clay, showing an extensive distribution filling the grabens.

The plutonic rocks including tonalite are distributed in the Cordillera Central, having intruded mainly the pre-Tertiary system. The time of their activity is considered to have been during the period from late Cretaceous to early Tertiary. Serpentinized peridotite forms the peculiar intrusives showing a trend of NW–SE from the northeastern foot of the Cordillera Central toward the southeast. The large scale lateritic nickel deposits are found near the surface of these masses. Almost all these igneous rocks are characterized by the calc-alkaline rocks.

The strike of bedding, schistosity and fold axis show a marked trend of NW to WNW in general, though that of E–W is seen in some places. The strike of the major faults and grabens, and also the intrusive direction of igneous rocks are consistent with the above. The formation of geologic structure in the above took place as a link of the Laramide orogeny.

1–2 Geotectonic Setting of the Project Area

The survey areas are situated at the northern and the southern foots of the mountain range surrounding Mt. Pico Duarte, the highest peak of the Cordillera Central. The Mata Grande area is in the northern foot and the Las Canitas area in the southern one.

The stratigraphy of the survey area is a sequence from the bottom upward such as Pre-Cretaceous, Cretaceous, Tertiary and Quaternary. The igneous activity includes markedly the tonalitic rocks. The pre-Cretaceous system is composed of the Amina formation in the lower part and the Duart formation in the upper part. The Cretaceous system is called the Tireo formation.

The Amina formation is distributed at the northern end of the Mata Grande area in the northern side. It consists of schistose rocks mainly derived from acidic to intermediate tuff, in which gentle folding is seen.

The Duarte formation is widely distributed in the Mata Grande area and consists of meta basalt and green schist derived from basalt lava and its tuff. The schistosity and bedding plane are parallel, and the rocks have been intensely folded in some places. Both the Amina and the Duarte formations have been subjected to regional metamorphism, which belong to green schist facies in most part.

The Tireo formation is extensively distributed in the Las Canitas area, and consists of intermediate to acidic lava and pyroclastic rocks. Different from the Amina and the Duarte formations of the lower sequences, it has not undergone metamorphism.

The Oligocene series is the only Tertiary system found in the area and is distributed in the southern part of the Las Canitas area. This series is found along the southern margin of the Azua-San Juan graben. This consists of shale and limestone, being strongly folded. In Mata Grande area, the Oligocene series composed of conglomerate underlies the narrow graben zone bounded on both sides by the Amina and Duarte formations respectively.

The Quarternary system is found along the main stream of Rio Grande in the southern part of the Las Canitas area. The volcanic activity of dacite occurred in Quaternary, having an extensive distribution to the south of Constanza at the eastern end of the area. The geothermal showings have been known in the whole neighborhood.

The tonalite which represents the igneous activity of the area intruded as the two big batholiths called El Rio and El Bao and extensively exposed in the Las Canitas are and the Mata Grande area respectively.

In the survey areas and in their surroundings, the formations such as Amina, Duarte and Tireo, and the Tertiary system, are distributed in this chronologic order from the north toward the south with the trends of NW–SE to WNW-ESE, being in contact with the faults each other. The tonalite also intruded along the faults in a form of batholith.

Such an arrangement of the formations might be assumed to be a result of subduction of plate from the north toward the south.

The mineralization of copper and gold is important, and it has been the target of this survey.

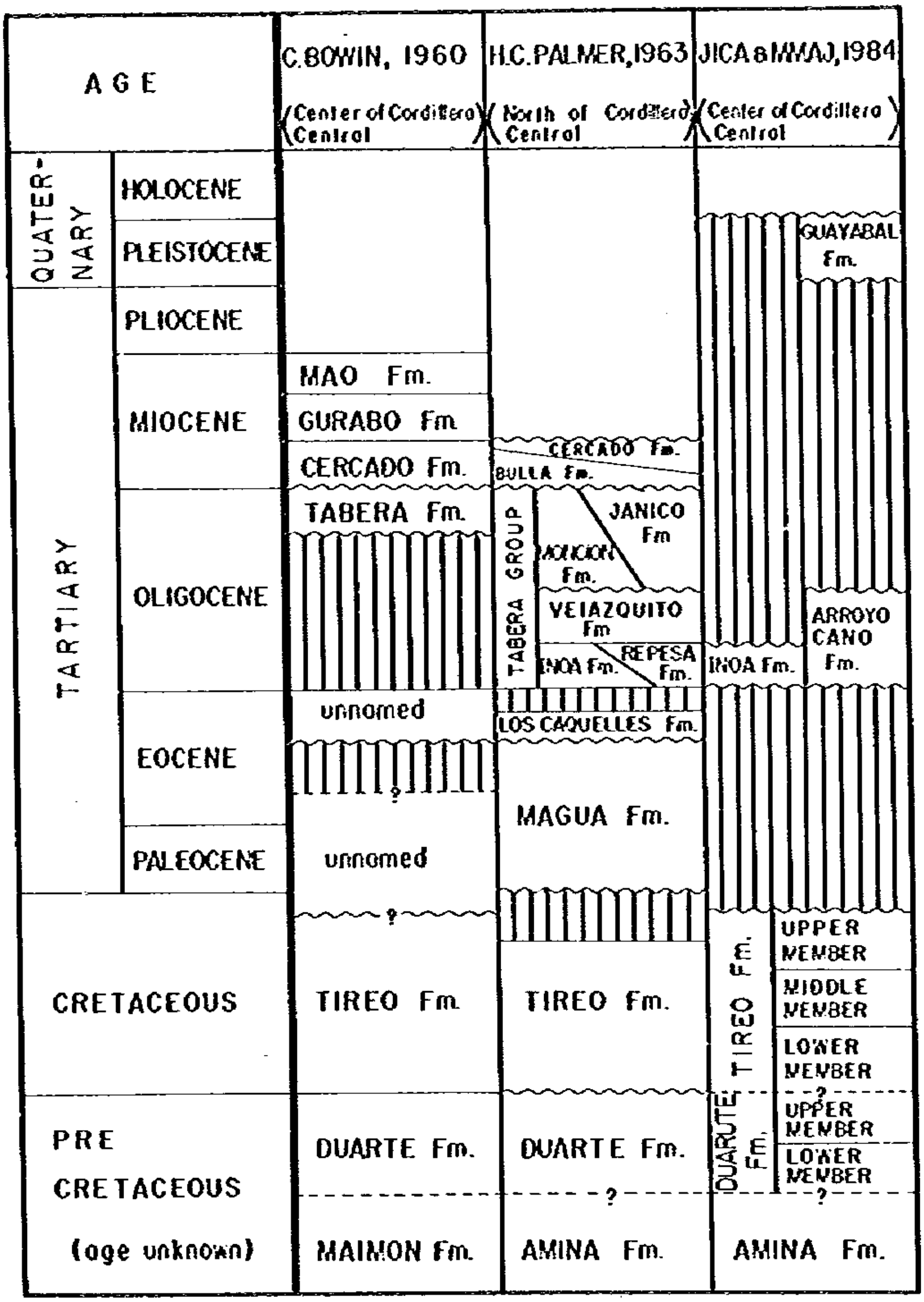
The copper mineralization is closely associated with the tonalitic intrusive, and the Duarte and Tireo formations are the country rock for ore emplacement. The ore deposits are vein type, and scattered in the vicinities of the Las Canitas and the Mata Grande in the survey areas.

In the vicinites of the Las Canitas, the group of the veins tends to strike NW–SE to WNW–ESE, thus the relationship with the main tectonic lines is to be assumed.

Furthermore, a porphyry copper ore was discovered on the eastern slope of Mt. Pico Duarte in this survey.

Although the original location of the gold mineralization has not been known, gold mineralization is observed widely in the Mata Grande area as placer gold.

Table 3 Stratigraphic Correlation



CHAPTER 2 GEOLOGICAL SURVEY

2-1 General Remarks

In this survey, the geological survey was conducted for the purpose of extracting the areas of high potential of emplacement of ore deposit by making clear the relations of the gology to ore deposits in an area of 2,000 square kilometers of Las Canitas and Mata Grande. The abstract of the survey of this term is shown in the following.

1. Stratigraphy

Although the stratigraphy of the Duarte and the Tireo formations which are the strata with ore deposits had not been established, it was made clear that the Duarte formation could be divided into two members and the Tireo formation into three from the transition of igneous activities and the characteristics of their rock facies as the result of the survey, which led us to be able to make stratigraphical positioning of ore occurrence.

2. Classification of Igneous Rocks

The tonalitic rocks were classified into batholiths and intrusives. The intrusives were further subclassified into tonalite, porphyritic tonalite and granodiorite. The relation of the intrusives to mineralization was made clear.

3. Relationship between Mineralization and Igneous Rocks as Well as Geological Structure

While the results of the former survey were limited to the description of the individual ore deposits, this survey made clear the relationship between the ore deposits and igneous rocks and geological structure as described in the following.

(1) The copper ore veins in the southwest of Constanza seem to surround concentrically the tonalite intrusives. That is thought to be in close association with the mineralization.

(2) The vein-type copper deposits in the Sabana area are distributed generally in the direction of NW–SE, which is consistent with the geologic structure of the survey area. Further, the distribution of many intrusives of quartz-plagioclase porphyry in the vicinity of ore deposits leads to an estimation of the relation to geotectonic line.

(3) A porphyry copper deposit was discovered on the eastern slope of Mt. Pico Duarte. The country rock is a granodiorite intrusives subjected to sericitization and silicification. The trend of intrusion is NW–SE.

(4) The vein-type copper deposits and the pyrite mineralization zones in the Mata Grande-

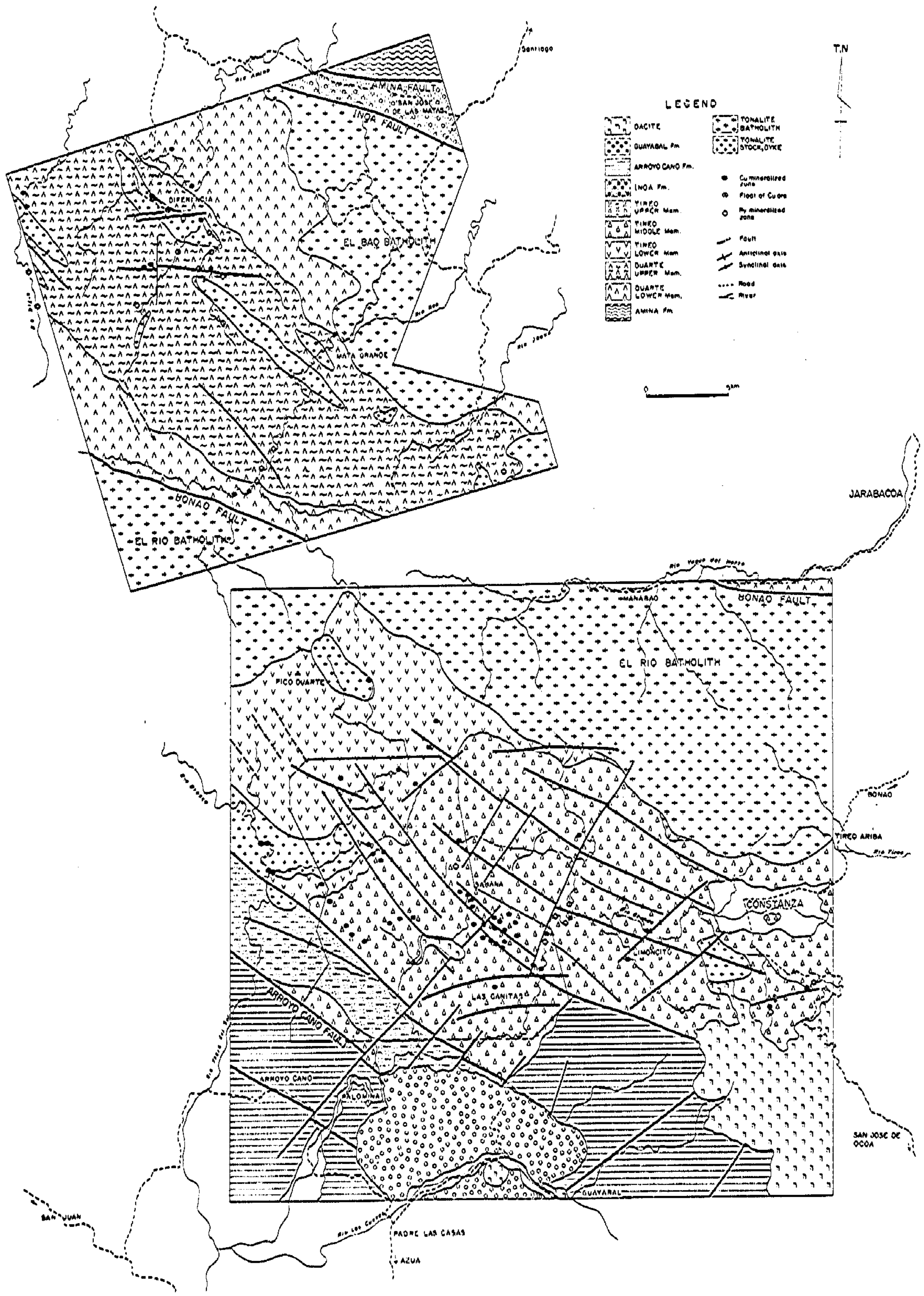


Fig. 4 Geological Map of the Survey Area

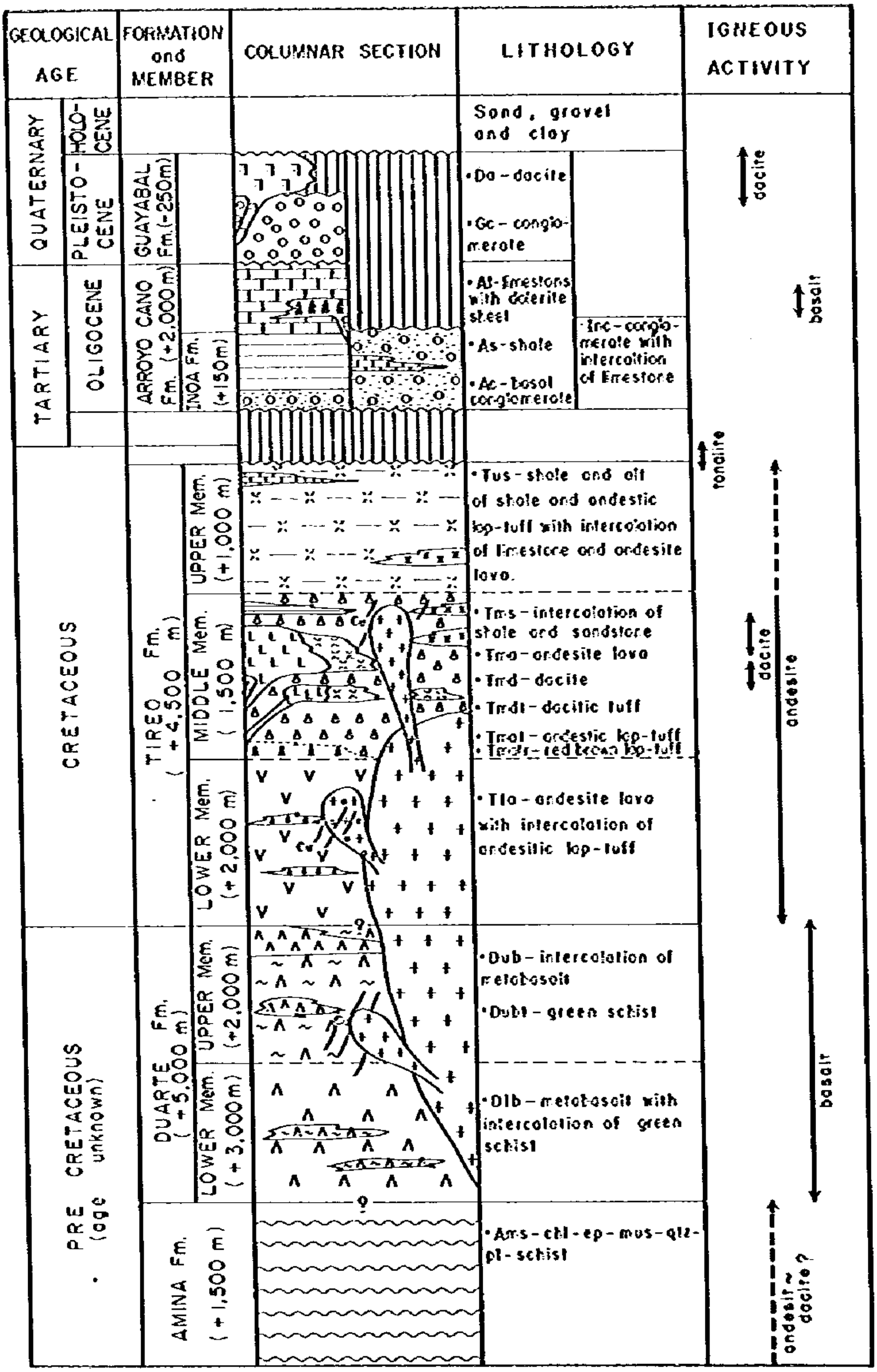


Fig. 5 Generalized Stratigraphic Columnar Section in the Survey Area

Diferencia area have a positional relation with the schistose tonalite which extend northwesterly.

2–2 Geology (PL. 1 ~ 5, Fig. 4 · 5)

The stratigraphy of the survey areas is composed of the pre-Cretaceous Amina formation and Duarte formation, the Cretaceous Tireo formation, the Tertiary Oligocene Inoa formation and Arroyo Cano formation, and the Quaternary Guagabal formation in ascending order. Table 3 shows the correlation stratigraphy.

In respect to the name of the formations, the Amina formation at the bottom followed PALMER (1963), and the formations such as Duarte and Tireo followed BOWIN (1960). The Duarte formation was subdivided into two members and the Tireo formation into three members. The Inoa formation in the Mata Grande area followed PALMER (1963). The formation consisting of shale and limesotne distributed extensively in the Las Canitas area was named the Arroyo Cano formation correlating to the formations such as Repesa and Veiazaquito of PALMER (1963). A conglomerate bed is extensively distributed in the southern part of the Las Canitas area, it had been described by BOWIN (1960) and PALMER (1963). The conglomerate bed was newly named as the Guagabal formation.

The igneous activity is represented by the tonalitic rocks, the tonalitic stocks and dykes were also discovered in this survey beside the batholith type. Thus, they were classified into four types such as tonalite batholith, tonalite stock and dyke, porphyritic tonalite stock and dyke and granodiorite stock.

2–2–1 Stratigraphy

1. Amina Formation

Although the age is unknown, the Amina formation (PALMER, 1963) has been considered to form the basement of the Hispaniola Island, and it is composed of metamorphosed schistose rocks. Acidic to intermediate volcanic tuff are considered to be the source rocks.

Distribution and Thickness:

This formation is narrowly distributed in San Jose de las Matas at the northwestern end of the Mata Grande area. It is more than 1,500 meters thick.

Rock Facies:

The formation consists of schists (Ams). They are greenish gray to pale green, and mainly consist of quartz-plagioclase-muscovite-epidote schist, partly accompanied by chlorite-epidote-platioclase-quartz schist. The origin of these schists seems to be acidic to intermediate tuff from the view of the constituents and the homogeneity.

The schists have a distinct schistosity, which is parallel to the bedding.

A gentle folding with the wave length of 200 to 300 meters is observed along the road between San Jose de las Matas and Santiago outside the survey area.

Microscopic observation of a typical schist is as follows.

MK037 muscovite-chlorite-epidote-plagioclase schist (San Jose de las Matas)

Texture: lepidoblastic texture

Constituent minerals: plagioclase > epidote > chlorite > muscovite

Plagioclase have the crystal aggregate of elongated form up to maximum 0.1 millimeter long, arranged in zones. Epidote and chlorite are arranged in zones as aggregate, partly filling the interstices of plagioclase grains together with muscovite. The plagioclase dominant zone and epidote dominant zone forms alternating zones about one to two millimeters wide.

Stratigraphical Relation:

Although the age is unknown because no fossil has been found in the formation, it has been considered to be the oldest formation in Hispaniola Island (PALMER 1963).

2. Duarte Formation

The age of the Duarte formation (PALMER 1963) is also unknown. This formation is characterized by the basic volcanic activity, and consists mainly of metamorphosed basaltic rock and its tuff. It is extensively distributed in the Mata Grande area, forming thick strata.

The formation vary in rock facies with the stratigraphical units, and it is roughly divided into two units. The lower part mainly consists of lava and the upper is pre-dominated by tuff. They are called the lower member and the upper member.

(1) Lower Duarte Member

Distribution and Thickness:

The member is extensively distributed in the Rio Amina, Rio Inoa and Rio Bao in the southern part of the Mata Grande area. The thickness is estimated to be more than 3,000 meters. The member is also narrowly distributed in the vicinity of the Manabao at the northeastern end of the Las Canitas area.

Rock Facies:

The member consists mainly of metabasalt (Dlb) undergone to regional metamorphism, and partly intercalated with green schist (Dlt) derived from basic tuff.

Metabasalt is dark green, and the phenocrysts of pyroxene and plagioclase are observed with the naked eye. Some parts are disseminated by pyrite. Although the rock is generally massive, weak schistosity is found partly in the rock.

Metabasalt is often interbedded with thin green schist layers. Green schist has a distinct schistosity, most of which are consistent with the bedding.

The metabasalt distributed near the Manabao seems to have formed roof pendant as a result of the intrusion of the El Rio batholith, which was classified as metabasalt of the member from the point of rock facies.

The metamorphic facies belongs to green schist facies.

Microscopic observation of a typical rock is as follows.

MT006 Metabasalt (Rio de los Negros)

Texture: schistose texture and ophitic texture

Constituent minerals: plagioclase > augite-orthopyroxene-chlorite-epidote > quartz-iron mineral

Plagioclase occurs as subhedral relic mineral 0.5 millimeters across, partly replaced by calcite and sericite. Augite and orthopyroxene occurs as euhedral to subhedral relic mineral 0.5 millimeters across. Epidote fills the interstices of the grains of plagioclase and augite. Chlorite and quartz are arranged in zones.

Stratigraphical Relation:

The age of the member is unknown because no fossil has been discovered in it. The stratigraphical relation with the underlying Amina formation is not known. The member is the lower part of the Duarte formation.

(2) Upper Duarte Member

Distribution and Thickness:

The member is extensively distributed in the basins of Rio Bao and Rio Amina in the center of the Mata Grande area in a form surrounded by the lower member. The thickness is more than 2,000 meters.

Rock Facies:

The member consists mainly of green schist(Dubt)derived from basaltic tuff in contrast to the lower member, and interbedded with metabasalt (Dub).

Green schist (Dut) is green to pale green, having a distinct schistosity. The schistosity is parallel with the bedding. The main mineral assemblage is actinolite-epidote-chlorite-plagioclase, and pumpellyite is often contained.

Metabasalt(Dubl) is dark green. Although it has a weak schistosity in general, massive part is also found. In the surroundings of tonalite intrusion, porphyroblasts of biotite and hornblende are formed in green schist and metabasalt cutting tthe schistosity by the contact metamorphism of them.

These metamorphic rocks are the favorable country rocks for the copper veins represented by the Mata Grande deposit, and a considerable amount of pyrite dissemination and quartz veins is observed in those metamorphic rocks.

Microscopic observation of a typical rock is as follows.

MT008 epidote-chlorite-actinolite green schist (in the upper reaches of Rio Bao)

Texture: lepidoblastic texture

Constituent minerals: plagioclase > actinolite, chlorite, epidote, quartz, pyrite > pumpellyite

Plagioclase and quartz are arranged in zones as the aggregates of the grains less than 0.05 millimeter across. Actinolite occurs as acicular crystals 0.1 millimeter long. Chlorite and epidote are arranged in a form of alternating beds with the zones of plagioclase and quartz with a width of about one millimeter, in which tiny crystals of pumpellyite are observed. Pyrite displays euhedral crystals about 0.1 millimeter across.

Stratigraphical Relation:

The member conformably overlies the lower Duarte member.

3. Tireo Formation

Since the Tireo formation (BOWIN, 1960) has not been subjected to regional metamorphism different from the Amina formation and the Duarte formation mentioned above, the age has been identified as late Cretaceous by fossils.

The formation is characterized by the intermediate to acidic volcanic activity, the neritic sediments are dominant in the upper part. It is extensively distributed in the Las Canitas area, forming thick strata.

The formation varies in the rock facies with the horizons, and is roughly divided into three units such as the lower consisting mainly of andesite, the middle composed of andesitic pyroclastic rock intercalated with dacite and the upper characterized by the two beds such as andesitic pyroclastic rocks and the neritic sediments including shale. These are named as the lower, the middle and the upper members.

(1) Lower Tireo Member

Distribution and Thickness:

This member is extensively distributed in the northwestern part of the Las Canitas area. In the detailed survey area, it is distributed in the basin of Rio Yaque del Sur in the northern part of the area. It is exposed in a form of fenster in the upper reaches of the Arryo Limon Creek in the central part. The thickness is more than 2,000 meters.

Rock Facies:

The member mainly consists of andesite lava (Tla), interbedded with thin layers of andesitic pyroclastic rocks.

The andesite lave (Tla) is greenish gray to greenish blue, and massive.

The flow unit of lava (50 to 100 meters) is distinctly observed in the vicinity of Mt. Pico Duarte and along the River Rio Yaque del Sur in the semi-detailed survey area. Amygdales are often observed in the upper part of the unit, filled with quartz and epidote.

Quartz and epidote veins can be observed everywhere in the andesite.

Microscopic observation of a typical rock is as follows.

LT094 augite andesite (the upper reaches of Rio Yaque del Sur)

Texture: porphyritic and intergranular texture

Phenocryst: augite

Augite displays euhedral to subehdral crystals, 0.5 millimeter across. It is partly replaced by chlorite.

Groundmass: plagioclase > iron mineral

Plagioclase displays tiny prismatic crystals, filling up a gap between the phenocrystal augite. It is partly replaced by sericite and epidote.

Stratigraphical Relation:

Although the relation with the underlying Duarte formation is not clear, it has been considered to be the upper of the metamorphosed Duarte formation since the member has not been undergone to regional metamorphism.

(2) Middle Tireo Member

Distribution and Thickness:

This member is extensively distributed in the central part of the Las Canitas area. It is distributed almost throughout the whole area in the semi-detailed survey area. The thickness is about 1,500 meters.

Rock Facies:

The member consists mainly of andesitic lapilli tuff (Tmat) interbedded with dacite (Tmd) dacitic tuff (Tmdt), andesite lava (Tma) and shale (Tms).

Andesitic lapilli tuff (Tmat) is pale green to dark green, being sometimes variegated. It is very hard and compact. Although it is non-stratified in general, some part show a stratification by sorting in water. The rock facies varies with the size of grains from coarse tuff to tuff breccia, the lapilli tuff is the most dominant. Its matrix is andesitic, and the grains are angular to subangular. Although the fragments of andesite are most abundant, those of dacite increase in content in the upper part of the member. In the semi-detailed survey area, it became clear that the reddish brown andesitic lapilli tuff (Tmatr) distributed immediately above the lower member is to be the key bed for the lowermost part of the member. The grains are greenish blue andesite fragments, and the matrix has been hematitized to show a characteristic reddish brown color. The rock facies is in the upper part of the member as thin layers of poor continuity.

Dacite (Tmd) is white to gray and developed with columnar joints. Although it takes a form of dyke in the vicinity of Lama da Tasajera in the semi-detailed surveyed area, it has a form of lava in the surroundings of the Las Canitas settlement in the southern part of the area. In the surrounding area of dacite, dacitic tuff (Tmdt) is white to gray and massive, and pyrite dissemination is often observed.

Andesite (Tma) is massive and greenish blue in general and dark green in some altered part. It is found in the upper part of the member, and distributed to the west of Constanza.

Shale (Tms) is dark gray and tuffaceous, and calcareous in some part. Bedding is distinct, partly intercalated with siltstone to fine-grained sandstone.

Microscopic observation of the typical rocks is as follows.

LA014 andesitic lapilli tuff (Arroyo Hondo)

Texture: pyroclastic texture

Fragment: andesite > andesitic tuff > augite-plagioclase-volcanic glass

The fragments occupy about 80 percent of the whole volume, being subround to subangular. Andesite fragments are three millimeters across, andesitic tuff fragments tow millimeters across and augite, plagioclase and volcanic glass 0.5 millimeter across. Secondary minerals are chlorite and calcite.

Matrix: volcanic glass > quartz-silica mineral

Hematite surrounds the grains and the volcanic glass fills the gap around those. Secondary quartz or silica minerals have partly been formed.

LK038 dacite (Las Canitas)

Texture: hyaline porphyritic texture

Phenocryst: quartz > plagioclase

Quartz and plagioclase are 0.5 to one millimeter across, and platioclase shows zonal structure.

Matrix: quartz-silica minerals > plagioclase > volcanic glass

Quartz and silica minerals have formed in abundance as the secondary minerals of volcanic glass.

Stragitraphical Relation:

The member conformably overlies the underlying lower member.

(3) Upper Tireo Member

Distribution and Thickness:

The member is distributed in the western part of the Las Canitas area and at the south-western end of the semi-detailed survey area. The thickness is more than 1,000 meters.

Rock Facies:

The member mainly consists of shale (Tus), interbedded with andesitic pyroclastic rocks.

Shale (Tus) is black, and interbedded with fine-grained siltstone, showing distinct bedding. It often becomes calcareous intercalated with thin layers of limestone.

The intercalated andesitic pyroclastic rocks have the various rock facies from lapilli tuff to fine-grained tuff, pale green to green in color. It is a characteristic of the member to contain the pebbles of shale beside the essential andesite fragments. A rhythmical alternation with a unit with from 015 to five meters is overved in the part where the pyroclastic rocks and shale form alternating beds.

Stratigraphical Relation:

The member conformably overlies the underlying middle member. The upper Tireo member has been identified to be late Cretaceous from foraminifers obtained from calcareous shale (BOWIN, 1960).

4. Arroyo Cano Formation

Although the Tertiary system in the area had been lumped together in the former survey, the sedimentary rocks distributed in the southern part of the area and the strata dominated by limestone were named as the Arroyo Cano formation in this survey, having been crrelated to the Tertiary system on the northern side of Cordillera Central in which the Repesa formation and the Veiasquito formation, named by PALMER (1963).

The formation is composed of the sedimentary rocks and the carbonate rocks, and shows a considerable thickness. It total thickness exceeds 2,000 meters.

Distribution:

The formation is distributed in the surroundings of the Arroyo Cano and along the River Las Cuevas in the southern part of the Las Canitas area, and has a limited distribution at the southwestern end of the semi-detailed survey area.

Rock Facies:

This formation is composed of basal conglomerate (Acq), shale (As) and limestone (Al). Basal conglomerate (Acq) is found along Rio Las Cuevas. The boulders are round to subround, and the size is 20 to 30 centimeters in diameter. The kind of boulders are andesite and its pyroclastic rocks of the underlying Tireo formation, and also the boulders of mineralized rocks of the Tireo formation.

Shale (As) is found in the lower part of the formation and the sedimentary unit is 20 to 30 meters. It is sometimes intercalated with fine-grained sandstone and limestone less than five centimeters thick, and has a very distinct bedding.

Limestone (Al) is dominant in the upper part of the formation. It is white and has a distinct bedding. It is relatively highly consolidated and in some places it is compact and massive. The fossils of foraminfers are contained in the limestone. Dolerite has intruded into that. Shale and limestone in the formation have been highly folded, and a brecciation is likely to have been associated with the folding in some part. In these part, the calcite, which generally seems to be the hydrothermal origin, is found as the breccia filling.

Stratigraphical Relation:

The formation is in contact with the underlying middle Tireo and upper Tireo members by fault. The formation has been identified to be Oligocene time by foraminifers obtained from the limestone (PALMER, 1963).

5. Inoa Formation

The Inoa formation (PALMER, 1963) is a Oligocene stratum, being composed of terrigenous conglomerate, and it is correlated to the lower part of the Arroyo Cano formation in the Las Canitas area.

Distribution and Thickness:

It shows a narrow distribution at the northeastern end of the Mata Grande area. The thickness is more than 150 meters.

Rock Facies:

The formation consists of conglomerate (Inc), intercalated with thin layers of limestone.

Conglomerate is red and its sorting and grading are poor. The pebbles are round to subround, though the cobbles about 20 centimeters in diameter are often contained. The kinds of pebble include metabasaltic rocks and tonalitic rocks, and no pebbles derived from the Tireo formation have been known. Pebbles of sandstone and limestone are contained in some part.

Stratigraphical Relation:

The formation is in fault contact with the pre-Cretaceous Amina formation in the northern part and the pre-Cretaceous Duarte formation in the southern part respectively.

6. Guayabal Formation

The Guayabal formation is a Pliocene stratum newly named in this survery.

Distribution and Thickness:

The formation is distributed in the surrounding area of Rio Grande and Rio Cuevas in the southern part of the Las Canitas area. The thickness is about 250 meters.

Rock Facies:

The formation consists of conglomerate (Gc). The conglomerate (Gc) contains the boulders of a size of human head consisting of the rocks of the Tireo formation and the Arroyo Cano formation. Its Matrix is clay and sand, brownish gray. The degree of compaction of the matrix is a little higher than that of the Recent river sediments.

Stratigraphical Relation:

The formation unconformably overlies the upper Tireo formation and the Arroyo Cano formation. The formation is thought to be the early Pleistocene stratum because it has been intruded by dacite of middle to late Pleistocene.

7. Quaternary Dacite

The rock is a grey hornblende dacite lava, partly accompanied with its pyroclastic rocks. It is extensively distributed at the south of Constanza and exposed in the middle reaches of the Arroyo Limon creek in the central part of the semi-detailed survey area. The time of activity of the rock were determined by D.G.M. (1983) to be 0.5 m.y. for the one at the south of Constanza and 0.8 ~ 0.6 m.y. for the other in the semi-detailed survey area, which correspond to Pleistocene.

8. Alluvial Sediments

The alluvial sediments consist of sand, gravel and clay, and are distributed in the Constanza basin, and in the lower reaches of the rivers such as Rio Grande and Rio Las Cuevas.

2–2–2 Igneous Rock

The igenous rocks of the areas include the volcanic rocks which compose the systems such as pre-Cretaceous, Cretaceous, Neogene Tertiary and Quaternary, and the tonalitic rocks of the Cretaceous.

The age of the pre-Cretaceous Amina formation is not known, extrusion of basalt on a large scale took place during the time of Duarte formation. During the time of deposition of the Cretaceous Tireo formation, there were several igneous activities; such as extrusion of andesite in the lower part, extrusion of andesite and dacite in the middle part, and extrusion of andesite on a small scale in the upper part showing a decline of igneous activity. After the deposition of the Tireo formation, intrusion of the tonalitic rocks on a large scale took place, which led to be followed by the intrusion of a large number of stocks and dykes in the surrounding part of the batholiths. Although intrusion of dolerite on a small scale took place during the time of the Arroyo Cano formation of Tertiary, the volcanic activity was insignificant. Activity of dacite on a large scale can be seen during the Pleistocene time.

The volcanic rocks is mentioned above (2−2−1).

The intrusive rocks include tonalitic rocks basaltic dykes and dolerite.

1. Tonalitic Rocks

The tonalitic rocks are classified into five categories according to the form of intrusion and the lithology, such as tonalite batholith (Tnb), tonalite stock and dyke (Tns), porphyritic tonalite stock (Tnp) and granodiorite stock. (Gd).

(1) Tonalite Batholith (Tnb)

Two big batholiths intruded the Duarte formation and the Tireo formation in the survey area.

Distribution:

The El Rio batholith is distributed in the northern part of the Las Canitas area and the El Bao batholith in the eastern part of the Mata Grande area.

Rock Facies:

The rock is medium to coarse-grained, and generally grayish white, partly dark gray. The El Rio batholith is composed of biotite hornblende tonalite, in which hornblende is always more abundant than biotite. Xenolith has a well elongated structure. While the batholith is in fault contact with the Duarte formation on its northern side to the south of Mata Grande, it intruded into the Duarte formation at the boundary in a form of alternation, which suggests that the rock intruded along the fault. Moreover, the rock has been metamorphosed along a zone two kilometers wide from the fault, where distinct schistosity can be observed. schistosity can be observed.

The El Bao batholith is composed of hornblende tonalite with very small amount of biotite, which is leucocratic as compared with the El Rio batholith. Similar to the El Rio batholith, the schistosty consistent with that of the rocks of the Duarte formation is observed in the peripheral part.

Microscopic observation of the typical rocks of the El Rio and El Bao batholiths is as follows.

LH007 biotite hornblende tonalite (El Rio batholith, to the north of Constanza)

Texture: holocrystalline, equigranular texture

Main constituent minerals: plagioclase·quartz > hornblende > biotite

Accessory minerals: iron mineral·ilmenite·apatite

The plagioclase is euhedral to subhedral andesine. The size of crystals is one to three millimeters across. It is partly replaced by sericite. Hornblende is uehedral, one to two millimeters across in size, and altered to chlorite. Biotite is anhedral, one to two millimeters across in size, and altered to epidote and chlorite.

MS006 hornblende tonalite (El Bao batholith, to the west of Mata Grande)

Texture: holocrystalline, equigranular texture

Main constituent minerals: plagioclase·quartz > hornblende ≫ biotite

Accessory minerals: iron mineral·ilmenite·apatite

The plagioclase is andesine, and euhedral to subhedral. The size of crystals is two to three millimeters across, showing albite and Carlsbad twinnings. Quartz is euhedral, and one to two millimeters across in size. Hornblende is euhedral, and two millimeters across in size, being partly replaced by epidote. Biotite is very small in size, and anhedral.

(2) Tonalite Stock and Dyke (Tns)

Although the tonalite stocks and dykes are schistose in the Mata Grande area, they are massive in the Las Canitas area.

Distribution:

The rocks are distributed in the central part of the Mata Grande area having a trend of NW–SE. The largest one is about two kilometers wide and about 10 kilometers long. On the other hand, it is distributed in the Las Canitas area in a form of a deformed ellipse about two to three kilometers in diameter at the southwest of Constanza.

Rock Facies:

Those distributed in the Mata Grande area are hornblende tonalite intruded into the lower and upper Duarte members in the direction of NW–SE, having a schistosity harmonious with the metamorphic rocks of the Duarte formation. This schistose structure is clearly observed by elongation of chloritized mafic minerals.

Since the copper veins have been occurred in the tonalite masses and the metamorphic rocks of the Duarte formation in the surroundings, it is thought that these masses have a relationship with the mineralization.

Although the panning of placer gold is commonly carried out in the surroundings of the masses, the relationship between the rock and gold mineraliation has not been cleared.

In contrast to the schistose tonalite, no schistosity can be observed in the tonalite intruded in the Las Canitas area.

The rock is a massive hornblende tonalite intruded into the middle Tireo member, and it is gray and medium to fine-grained.

The copper veins are distributed concentrically in the surrounding area of the rock mass. Thus it is important for the relation to the copper mineralization.

Microscopic observation of the typical rocks of the schistose and the massive tonalite is as follows.

MA050 schistose hornblende tonalite (Rio Amina)

Texture: schistose texture, holocrystalline equigranular texture

Main constituent minerals: quartz · plagioclase ≫ hornblende

Accessory minerals: iron mineral

Quartz and plagioclase were elongated with a length of 0.5 to one millimeter. Hornblende occurs as if it fill the interstices between the above two minerals, and it is partly replaced by epidote.

LK009 hornblende tonalite (southwest of Constanza)

Texture: holocrystalline equigranular

Main constituent minerals: plagioclase · quartz > common hornblende

Accessory minerals: iron ore · ilmenite

Plagioclase is euhedral to subhedral and 0.5 millimeter across. It is partly replaced by sericite and calcite. Quartz is euhedral and 0.5 to one millimeter across. Hornblende is euhedral and 0.5 millimeter across, being partly replaced by epidote and chlorite. Chlorite and epidote fill the interstices of the above minerals.

(3) Porphyritic Tonalite Stock and Dyke (Tnp)

In contrast to the equigranular texture in the tonalitic rocks mentioned above, the rock of this category has a porphyritic texture.

Distribution:

This rock is extensively exposed in the upper reaches of Rio Yauqe del Sur to the west of Las Canitas, and small dykes trending northwesterly are scattered throughout the semi-detailed survey area.

Rock Facies:

The rock extensively intruded in the upper reaches of Rio Yaque del Sur is porphyritic tonalite. The rock is white and has porphyritic texture with quartz phenocryst one centimeter across. Epidote-quartz veinlets are found throughout the mass, and copper mineralization is observed in several places of these veins.

The small dykes scattered in the semi-detailed survey area are mostly several tens to several meters wide reaching up to 200 meters. The rock facies is quartz-plagioclase porphyry. The rock is pale green and contains phenocrysts of quartz and plagioclase five millimeters across. Quartz is white inclining toward transparent, but plagioclase is pale pink. The copper mineralization is observed in the vicinity of the dyke, leading to the assumption that it is in close relaiton to copper mineralization.

Microscopic observation of the typical rocks is as follows.

LT038 porphyritic hornblende tonalite (upper reaches of Rio Yaque del Sur)

Texture: holocrystalline porphyritic texture

Main constituent minerals: plagioclase > quartz ≫ hornblende

Accessory mineral: iron mineral

Plagioclase is euhedral to subhedral, one to two millimeters across, and partly altered to sericite. Quartz occurs asphenocrysts four millimeters across. Hornblende is euhedral to subhedral, 0.5 millimeters across, being partly replaced by chlorite. The brecciated portions were filled with epidote and chlorite.

LH043 quartz-plagioclase porphyry (Sabana)

Texture: holocrystalline, porphyritic texture

Main constituent minerals: quartz · plagioclase ≫ hornblende

Accessory minerals: iron mineral

Quartz and plagioclase are present as phenocrysts two millimeters and one to two millimeters across respectively. Plagioclase is partly replaced by sericite. Hornblende is 0.5 millimeter across, being replaced by epidote. These phenocrysts are buried in the minute crystals of quartz and plagioclase.

(4) Granodiorite Stock (Gd)

The rock shows equigranular texture, different from other stocks and dykes.

Distribution:

The stock intruded into the lower Tireo member on the eastern slope of Pico Duarte in the northwestern part of the Las Canitas area in a form of elongated ellipse two kilometers wide and four kilometers long.

Rock Facies:

The rock is gray and medium to coarse-grained biotite hornblende granodiorite. The rock is the host of so-called porphyry copper in which copper dissemination is observed in a part accompanied by silicification and sericitization.

Microscopic observation of a typical rock is as follows.

LH091 hornblende-biotite granodiorite (eastern slope of Pico Duarte)

Texture: holocrystalline, equigranular texture

Main constituent minerals: Plagioclase・quartz > biotite > hornblende・potash feldspar

Accessory minerals: iron mineral

Plagioclase is euhedral and 0.5 to one millimeter across, being partly replaced by sericite and epidote. Potash feldspar is anhedral and 0.5 millimeter across, showing perthetic structure. Quartz is euhedral and one millimeter across. Hornblende is euhedral and 0.5 to one millimeter across. Biotite is anhedral and partly replaced by epidote.

Table 4 shows the chemical component of the typical samples of the tonalitic rocks described in the above.

A Q–Pl–Kf diagram (Fig. 6) by normative minerals was drawn on the basis of the above component. As the result, all the tonalitic rocks are concentrated at the boundary between tonalite and granodiorite.

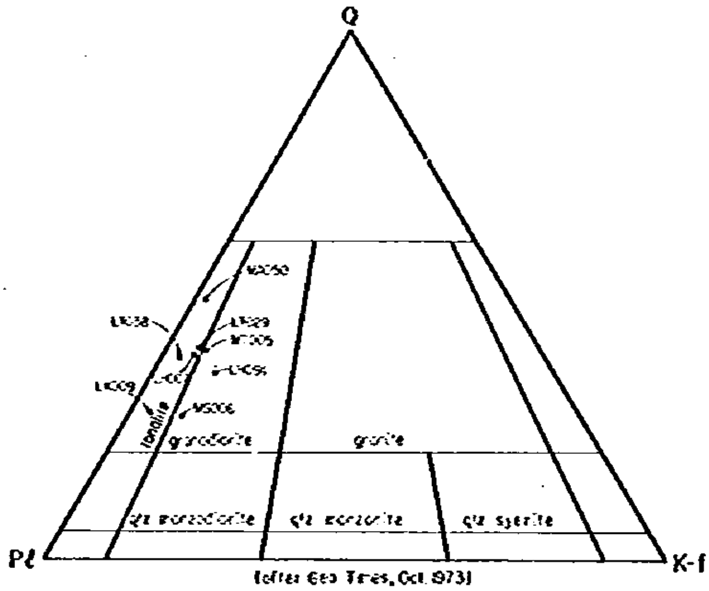


Fig. 6 Normative Q-Kf-Pl Diagram of Tonalitic Rocks

2. Basalt Dykes

The basalt dykes intruded into the Duarte formation and the Tireo formation. The maximum width of the dykes is several tens of meters, being several meters in most cases, so they are not expressed on the geological map (1:50,000 and 1:25,000 in scale). The systems such as N–S and E–W are the dominant trends of intrusions, and they are observed throughout the whole survey area.

Table 4 Result of Chemical Analysis of Rock Samples

		Sample No.	LA041	LK038	LH007	LT029	MT005	MS006	MA050	LK009	LT038	LH091	LT040	LG042
		Location	Rio Grande, Ar. Limoncito	Las Canitas	North of Constanza (El Rio)	Rio Tireo (El Rio)	Rio Bao (El Rio)	Rio Bao (El Bao)	Rio Magua	Rio Grande	Rio Branco	Pico Duarte	Rio Branco	Rio Las Cuevas
		Rock Name	Silicified dacitic tuff (Tmdt)	Dacite (Tmd)	Bi-hb-tonalite (Tnb)	Bi-hb-tonalite (Tnb)	Bi-tonalite (Tnb)	Hb-tonalite (Tnb)	Schistose hb-tonalite (Tns)	Hb-tonalite (Tns)	Porphyritic hb-tonalite (Tnp)	Hb-bi-granodiorite (Gd)	Basalt	Dacite (Da)
Chemical Composition		SiO_2 %	78.56	77.38	69.20	69.61	70.09	60.91	78.08	64.16	74.27	69.15	51.41	66.52
		TiO_2	0.16	0.24	0.55	0.59	0.44	0.50	0.31	0.90	0.34	0.57	0.73	0.34
		Al_2O_3	11.56	11.25	12.73	13.46	13.37	13.71	11.50	13.98	13.41	13.93	14.15	15.51
		Fe_2O_3	2.04	2.70	2.33	2.70	1.76	3.07	0.86	2.46	2.37	2.20	2.13	2.75
		FeO	0.13	0.13	3.03	3.09	2.45	5.22	0.58	4.64	1.03	3.03	8.12	1.03
		MnO	0.01	0.03	0.10	0.12	0.10	0.17	0.02	0.13	0.07	0.10	0.21	0.08
		MgO	0.40	1.41	3.21	1.83	1.41	3.99	0.48	2.17	0.83	1.98	8.69	1.46
		CaO	0.01	0.54	4.66	5.36	4.82	6.46	3.16	4.20	2.88	4.34	6.62	4.35
		Na_2O	0.67	5.29	3.42	3.21	3.37	2.96	4.04	4.66	5.12	3.46	2.96	4.29
		K_2O	2.76	0.33	0.70	0.76	0.94	1.06	0.30	0.49	0.46	1.49	0.91	3.00
		P_2O_5	0.03	0.09	0.09	0.11	0.08	0.18	0.08	0.39	0.08	0.08	0.07	0.27
		Igloss	3.22	1.67	1.56	0.33	1.20	0.98	0.38	2.48	1.10	1.19	4.47	0.80
		BaO	0.30	0.01	0.03	0.02	0.05	0.10	0.01	0.01	0.01	0.04	0.01	0.30
		Total	99.85	101.07	101.61	101.19	100.08	99.31	99.80	100.67	101.97	101.56	100.48	100.70
CIPW Normative Minerals		Q %	63.33	42.34	31.90	34.14	34.57	19.47	46.77	22.20	35.87	30.55	0.25	20.45
		C	7.33	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		or	16.31	1.95	4.14	4.49	5.56	6.29	1.77	2.90	2.72	8.81	5.38	17.73
		ab	5.67	44.76	28.94	27.16	28.52	25.05	34.19	39.43	43.32	29.28	25.05	36.30
		an	0.39	2.10	17.32	20.07	18.58	20.99	12.36	15.78	12.25	18.08	22.64	14.20
		ne	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	di	wo	0.00	0.00	2.20	2.44	2.05	4.20	1.17	1.05	0.64	1.25	4.08	2.57
		en	0.00	0.00	1.49	1.45	1.15	2.42	1.01	0.52	0.55	0.74	2.46	2.22
		fs	0.00	0.00	0.54	0.86	0.82	1.59	0.00	0.51	0.00	0.45	1.40	0.00
	hy	en	1.00	3.51	6.51	3.11	2.37	7.52	0.18	4.88	1.52	4.19	19.18	1.42
		fs	0.00	0.00	2.37	1.83	1.69	4.95	0.00	4.74	0.00	2.54	10.93	0.00
	ol	fo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		mt	0.00	0.00	3.33	3.91	2.55	4.45	1.04	3.57	2.56	3.19	3.09	2.60
		hm	2.04	2.70	0.00	0.00	0.00	0.00	0.15	0.00	0.60	0.00	0.00	0.96
		il	0.30	0.34	1.04	1.12	0.84	0.95	0.59	1.71	0.65	1.08	1.39	0.65
		ru	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		ap	0.07	0.21	0.21	0.25	0.19	0.42	0.19	0.90	0.19	0.19	0.16	0.63
		Total	96.44	99.39	100.03	100.85	98.85	98.27	99.41	98.18	100.86	100.35	96.01	99.71

* bi-biotite hb-hornblende

The rock is black and compact augite basalt.

Microscopic observation of a typical rock is as follows.

LT040 augite basalt (Rio Branco)

Texture: porphyritic, intergranular texture

Phenocryst: augite

Phenocrysts are small in amount. Augite is 0.2 millimeter across.

Groundmass: plagioclase, iron mineral

Augite is buried in minute prismatic crystals of plagioclase. Secondary outgrowth of quartz is observed.

3. Dolerite (Do)

The dolerite has intruded into the Oligocene limestone in a form of sheet.

Distribution:

The rock is distributed along a tributary of Rio Las Cuevas on the southeastern end of the Las Canitas area. Two sheets 10 to 20 meters thick are observed.

Rock Facies:

The rock is black, and a little rugged and loose. Small phenocrysts of plagioclase became turbid white, and outgrowth of chlorite is seen in amigdales. The columnar joint is prominent, and the rock is strongly folded together with the adjacent limestone.

Microscopic observation of a typical rock is as follows.

LK084 dolerite (Arroyo Guarico)

Texture: ophitic texture

Phenocryst: plagioclase > augite

Phenocrysts of plagioclase and augite are 0.5 millimeter across, and the plagioclase is turbid.

Groundmass: volcanic glass

Phenocrysts are buried in volcanic glass. A part of the glass has been replaced by chlorite.

Table 4 shows the chemical components of the typical samples of the igneous rocks in the above. A SiO_2 – total FeO/MgO diagram was drawn on the basis of the component. It showed that most of the igneous rocks belong to calc-alkaline rock series.

Table 5 Result of X-ray Diffractive Analysis

No.	Sample No.	Location	Description	Plagioclase	Hornblende	Quartz	α-Cristbalite	Chlorite	Montmori-llonite	Sericite	K-Feldspar	Epidote	Prehnite	Pyrite	Remarks
1	LA041	Ar. Limoncio	Silicified dacitic tuff Tireo Fm.	R		A				L				L	Silicified. Py disseminated
2	LA042	do.	do.			A		L						R	do.
3	LA055	do.	do.	A		A		A		R					do.
4	LH058	Roblito	Chloritized andesite Tireo Fm.			A		A							Wall rock of Roblito dep.
5	LH059	do.	Andesite Tireo Fm.	C		A		A							do.
6	LH068	Sabana	White arg. rock Tireo Fm.		C	C		R				L	C		Wall rock of Sabana dep.
7	LH069	do.	Andesitic tuff Tireo Fm.	A	C		C	R	R						do.
8	LT076	Rio Yaque del Sur	Andesite Tireo Fm.	A		L		R				C			Diagenetic alterd
9	LT087	do.	Altered granodiorite	A		A		L		L					Ore of porphyry copper
10	LT095	do.	do.			A		L		R	A				do.
11	MH009	Mata Grande	Altered green schist Duarte Fm.		A			C							Wall rock of Meta Ground dep.

Abundant : A　Common: C　Little: L　Rare: R

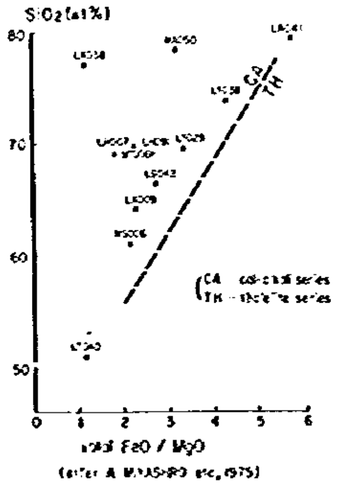


Fig. 7 SiO_2— total FeO/MgO Diagram of the Igneous Rocks

2–3 Metamorphism and Rock Alteration

The metamorphism observed in the survey area includes regional metamorphism and contact metamorphism.

The regional metamorphism took place during the stage of the Laramide orogeny, having formed the metamorphic rocks of the pre-Cretaceous Amina and Duarte formations.

The mineral assemblage of metamorphic rocks of the Amina formation is epidote-chlorite-muscovite, which belongs to muscovite-chlorite subfacies of green schist facies.

The metamorphic rocks of the Duarte formation has an assemblage of actinolite-chlorite-epidote-plagioclase, which belongs to green schist facies.

A schistose structure to be consistent with that of the Duarte formation is also observed in the tonalitic rocks which intruded into the Duarte formation. The El Rio batholith intruded into the Duarte formation in the northern part and into the Tireo formation in the southern part. A schistose structure is observed in the batholith for a width of about two kilometers at the boundary with the Duarte formation in the northern part. That becomes indistinct toward the south. So the southern part of the El Rio batholith and the Tireo formation have not been subjected to metamorphism. As mentioned above, the tonalitic rocks intruded in late Cretaceous have been subjected to metamorphism especially in the Mata Grande area.

The contact metamorphism is dominant in the surrounding area of the tonalitic instrusive rocks, while it is not prominent in the surroundings of the batholithic masses.

Biotite and amphibole were formed as porphyroblasts in the surrounding area of the tonalitic rocks, which is conspicuous especially in the surroundings of the tonalite stock at the southeastern end of the Mata Grande area. Further, the hornfelsic rocks are observed in the adjacent area of the porphyritic tonalite mass in the Las Canitas area.

The alteration in the survey area includes those caused by diagenesis and hydrothermal fluid.

10 smaples were brought for X-ray analysis in order to grasp these characteristics. The results are shown in Table 5.

The rocks of the Cretaceous Tireo formation are cited as those caused by diagenesis. Chloritization of andesite and its pyroclastic rocks in the Tireo formation is conspicuous. Epidotization and sericitization are also accompnaied. The rocks are dark green to pale green. The rock has been subjected to so-called "propylitization".

The rocks after the Tireo formation are fresh and diagenesis is not conspicuous.

The hydrothermal alteration has a close relationship to the mineralization, which can be observed at the adjacent of the wall of quartz veins accompanied by copper ore. The hydrothermal alteration is composed of silicification and argillization. The caly minerals includes chlorite, sericite and epidote. Prehnite has been formed at the wall of vein of the Mata Grande deposit.

2–4 Geological Structure

The faults and the folding structures formed by the Laramide orogeny and the tectonic movements after that are found in the systems in the survey area such as in the pre-Cretaceous, the Cretaceous and the Tertiary.

1. Faults

The faults running in the direction of WNW–ESE and NE–SW which are the major tectonic lines in the Hispaniola Island belong to those of the first order. The second order faults is those of WNW–ESE to NW–SE and NE–SW system. The fractures including epidote-quartz veins belong to those of the third order, which has a variety of directions.

(1) First Order (WNW–ESE)

The Amina fault and the Inoa fault run parallel at the northeastern end of the Mata Grande area. These two faults belong to the Hispaniola fault group.

The Amina fault borders the Amina formation on the northern side and the Inoa formation on the southern side. On the south, the Inoa fault separates the Inoa formation from the

Duarte formation. Thus the zone between the Amina fault and the Inoa fault has a form of graben. The relationship between the two formations bordered by the Amina fault can be observed along the road between San Jose de las Matas and Santiago, where the Amina formation thrust up over the Inoa formation.

It is assumed that the activity of the Amina fault continued even after Oligocene when the Inoa formation was deposited.

The Bonao fault runs from the southern part of the Mata Grande area to the northern part of the Las Canitas area. This fault borders the Duarte formation on the northern side and the El Rio tonalite batholith on the southern side. The fault dips 70° northward.

The Arroyo Cano fault runs in the southwestern part of the Las Canitas area, and borders the Tireo formation on the north and the Arroyo Cano formation on the south. The southern extension of the fault is covered by the Pleistocene Guayabal formation.

(2) Second Order (WNW–ESE ~ NW–SE system, NE–SW system)

The fault systems involved in this category are dominant in the Las Canitas area, and markedly dominant in the Sabana area, where those dipping 70° to 80° northward were measured at several places.

These faults are accompanied by those of NE–SW system in many palces, and form the blocks together with those of WNW–ESE to NW–SE systems. While these blocks show a comlicated block movement, there is a tendency that those on the southern side slipped down little by little by the faults of WNW–ESE to NW–SE systems.

The faults of NE–SW system predominate in the southern part of the Las Canitas area, and a tendency of left hand-side displacement of the faults of WNW–ESE to NW–SE systems, can be observed. These accompany the faults of E–W system.

Thus the faults of NE–SW system are distributed in the Las Canitas area as two separate groups in the northern part and the southern part. In contrast to those in the northern part which is in conjugate relation to those of NWW–SEE system, those in the southern part are the independent ones formed by faulting after the movement of those of NWW–SEE to NW–SE systems.

The faults of NW–SE system are found in the northern part of the Mata Grande area, which belong to a strike fault to be harmonious with the schistosity in the surroundings. The faults of E–W system distributed in the southern part showing a right hand-side displacement are cut by those of N–S system which shows a left hand-side displacement.

(3) Third Order

The veins often filled with quartz and epidote, and the calcite veins which is rarely found in the survey area, belong to the fractures of the third order.

It can be observed in the vicinity of the showing along the Arroyo Pinar Bonito creek at the south of Constanza that the epidote-quartz veins are cut by the calcite veins.

In the Las Canitas area, the epidote-quartz veins have a variety of directions, in which copper mineralization is observed in some part.

Many groups of veins are found in the Sabana area, in which the copper veins of NE system are dominant,being arranged in the direction of NW–SE which is consistent with the faults of the second order.These ore veins are likely to have filled the open fractures formed in the incipient stage of formation of those of the first order.

On the other hand, the quartz veins along the schistosity of NW–SE system are abundant. in the Mata Grande area.

2. Folds

Folds are observed in the survey area in all strata excepting for the Quaternary system.

The gentle fold of WNW–ESE system is found in the pre-Cretaceous Amina formation.

An intense folding is observed on the outcrops of the pre-Cretaceous Duarte formation where a steeply dipping schistosity is seen. In these places, a synclinal structure of NW–SE system on a large scale is assumed to be present from the standpoint of macrostructure in the central part of the Mata Grande area, and the synclinal axis seems to curve toward the direction of WNW–ESE from NW–SE.

In the Cretaceous Tireo formation, a series of structures such as syncline, anticline and syncline extending in the direction of NW–SE to WNW–ESE are found macrostructurally from the north toward the south in the Cretaceous Tireo formation. The wave length of folding is assumed to be about 10 kilometers. The folding axes plunge southeastward due to upheaval of the northwestern part of the Las Canitas area. Most part of the semi-detailed survey are are positioned at the anticlinal part, where the syncline and anticline of E–W system are present having the wave length of about two kilometers. Although the fold structures smaller than the above have not been observed in the lower and the middle member, they are observed in the upper member which is distributed between the faults of WNW–ESE system. The gentle fold structures of E–W to WNW–ESE about 250 meters of wave length and about 50 meters of amplitude, were observed along Rio Yaque del Sur where the upper member is exposed.

Intense folding is observed in the Tertiary Arroyo Cano formation, and the fold structures of NW–SE system, about 60 meters of wave length and about 10 meters of amplitude, are observed along Rio Yaque del Sur. Intense folding is seen on the north of Guayabal, and a basin structure extending northwesterly is also indicated macrostructurally.

On the basis of the geologic structure above mentioned, the following geotectonic history is to be discussed.

The formations bordered by the fault of the first order of WNW–ESE system become younger step by step toward the south successively from the Amina formation in the north through the Duarte formation (the Amina fault and the Ino fault are considered macrostructurally as the Hispaniola fault zone) to the Tireo formation.

The subduction of plate from the north southward is assumed to be an appropriate interpretation of this phenomenon. It is nothing less than that the subduction of plate was the cause of the Laramide orogeny.

While the two hypotheses are to-day's controversial subject on the origin of the basic rocks whether they belong to the oceanic crust type or the island arc type, the latter is rather prevailing in recent years.

Although the time of the movement is unknown as mentioned above, the faults of the first order were formed as the result of the subduction of plate from the north to southward, having formed the metamorphic rocks of the Amina formation and the Duarte formation. Although after that the subduction declined in Cretaceous time, an volcanic activity on a large scale took place in the southern part which was the inside of the island arc, having resulted in the depeostion of the Tertiary formation.

The fault movement continued thereafter having led to the intrusion of tonalite as batholith along the faults of the first order, accompanied by the intrusion of tonalitic rocks as stocks and dykes.

In association with these activity, epidote and quartz filled the fractures of the third order, accompanied by copper mineralization in some of them.

The subduction ceased completely in Oligocene, and the field of compression was substituted by that of tension, having resulted in to form the grabens in which the Tertiary formations were deposited.

In the incipient stage of Quaternary, the fault movement of NE system with right handside displacement thrust up, which caused extrusion of dacite at the intersection between these faults and those of WNW–ESE system in the southern part of the Las Canitas area.

The cause of these fault movement is considered to be a new subduction from the south to northward.

2–5 Mineralization

As the result of survey of the first phase, the relationship between the known deposits such as the vein-type copper deposits and pyrite-dissemination deposits, and the geologic structure as well as the igneous rocks, was made clear. Moreover, a typical porphyry copper ore was for the first time discovered in the area. These mineralized zones are the hydrothermal deposits having genetic relationship to igneous activity of Laramide orogeny, and they have a positional relation to the NW–SE tectonic lines or the intrusives in their distribution (PL. 6). They are mainly distributed in the Duarte formation, the Tireo formation and the intrusives and very rarely found in the Amina formation and the tonalite batholith. Although the manganese deposits are emplaced in the Tertiary Oligocene strate (BRGM., 1980), no metallic ore deposit has been observed in it.

PL. 7 shows the location of mineralized zones and Table A–5 shows the assay results of the ore samples. Description on each mineralized zone is made in the following.

2–5–1 Vein-type Copper Deposits

A number of vein-type copper mineralized zones are distributed in the Duarte formation and the Tireo formation, in them the three areas, Sabana, southern Constanza and Mata Grande, are important.

1. Sabana Area

The mineralized zones of the area are the network-vein copper deposits emplaced in andesite lava and its pyroclastic rocks of the middle member of the Tireo formation, and they are distributed concentrically between the Sabana deposit and the Roblito deposit. The mineralized zones correspond to oxidation zone and/or secondary enrichment zone from the assemblage of ore minerals, and the primary zone is not exposed.

The ore minerals consist mainly of malachite and specularite, and small amount of chalcocite, covelline, bornite, chalcopyrite, sphalerite and magnetite, and accompanied by quartz, epidote and chlorite as gangue minerals. The ore and gangue minerals occur in the country rocks in the form of network, banding and dissemination showing an irregular lenticular form as a whole.

Many small intrusive masses of plagioclase-quartz porphyry generally occur in the vicinity of the ore deposits. Further the mineralized outcrops are distributed in the direction of NW–SE in general. The direction is consistent with the trend of the geologic structure. This suggests the existence of shear zone of NW system in the depth, which indicates the presence of an important genetic relation between the structure and/or igneous activity and mineralization.

(1) Sabana Deposit (S–1)

The deposit is located on the flat at the top of a mountain 16 kilometers to the west of Constanza, and about 4 kilometers to the north of Las Canitas. It takes about an hour and a half to the north of Lemoncito by jeep, then for about four hours and a half from there to the site by mule.

The ore deposit is a vein-type copper deposit in andesite lava, andesitic tuff and lapilli tuff of the middle member of the Tireo formation. The ore minerals mainly consist of malachite, specularite, limonite, and very small amount of bornite and chalcocite. The gangue minerals are quartz, epidote and chlorite. The ore minerals occur in a form of network and/or dissemination in country rocks. The form of mineralized zone has an irregular lenticular as a whole. Malachite occurs as shreds along the cracks of the rocks in many cases.

As for the size of the mineralized zone, the details are not known because most of the ore has been mined out by test pits or trenches. However, the mineralized zones seems 0.1 meter to several meters wide, several meters to a little more than a dozen meters long. The mineralized zone extends northeast.

Silicification is the dominant alteration in the mineralized zone, epidotization and chloritization also occur. The surrounding rock of the mineralized zone have been argillized to white clay.

Prospecting by pits and trenches was done at seven places as follows. The location of these is shown in Fig. 8.

No.	Size width x length x depth	Description
No.1	3m x 40m x 2m	Malachite, chalcocite, specularite, limonite, quartz and epidote are present as network veinlets and dissemination along the sheared fractures of gentle dip in andesitic lapilli tuff. Malachite is observed on the wall of tranches. The extent of mineralization is only about eight meters, and the copper grade as a whole is about 1.5%. The alteration of the country rock is the mixture of chloritization and white argillization. The assay result of the ore rich in malachite is as follows:

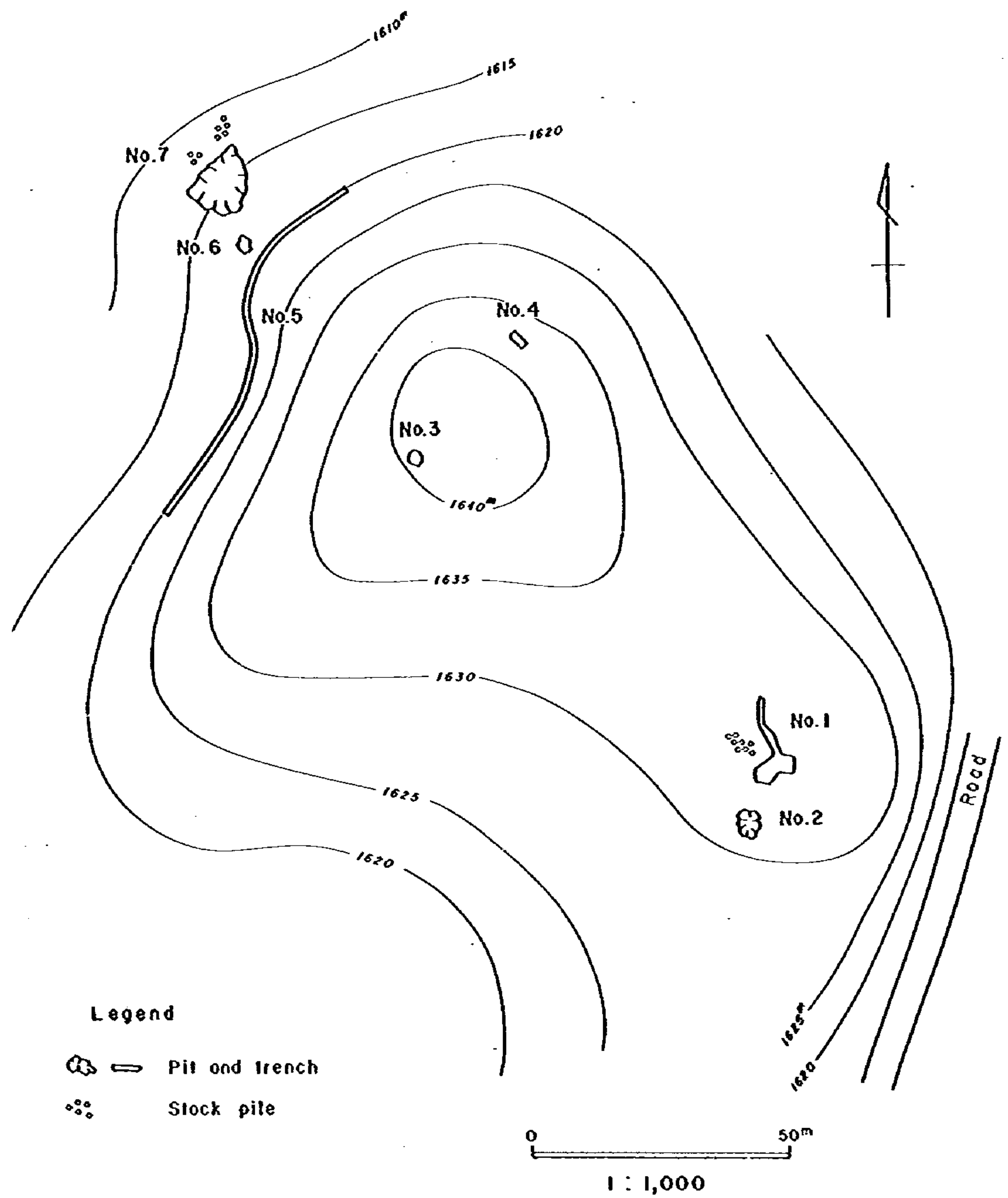


Fig. 8 Location Map of Pits and Stock Piles in the Sabana Deposit

No.	Size width x length x depth	Description
			Au g/t Ag g/t Cu % Pb % Zn % LK046 0.1 0.7 2.15 0.03 0.02 About 10 tons of stockpile of the ore, which seems to have been mined from this trench, is seen beside this trench. The grade of the whole stockpile is about two percent in copper.
No.2	3.5m x 6m x 1m	The pit is in the weathered zone on the slope of the hill. Specularite is found as network veins and bands in white argillized rock. Specularite veins strike N50°E and dip 50°N.
No. 3	2m x 2m x 1m	The pit is made in weathered andesitic sandy tuff. No mineralization is observed.
No. 4	1.5m x 2.7m x 1m	Mineralized zone consisting of network veinlets and dissemination of malachite, specularite, limonite, quartz and epidote is found in black siliceous rock of unknown origin.
No.5	(1 ~ 2)m x 83m redx (0.5 ~ 1)m	The trench is in the weathered zone. The wall consists of dish brown weathered rock of unknown origin. Mineralization is hardly observed. Some floats consisting of malachite, specularite and quartz are found in the pit.
No. 6	2m x 2m x 2m	A pit in the weathered zone. Network veinlets consisting of specularite, epidote and quartz are found in reddish brown clayey rock which seems to have been derived from andesitic lapilli tuff.
No. 7	10m x 12m x 3m	The largest pit for surveing the mineralized zone in the Sabana deposit. Network-veinlets and dissemination of malachite, specularite, chalcocite and quartz are found in dark green siliceous rock which seems to have been derived from andesitic lapilli tuff. Although the details on the size of the mineralized zone are not known because the zone has been mined out, the observation of a remained part leads to an assumption of the size that it had an approximate extend of 10m x 7~8m.

No.	Size width x length x depth	Description
		About 10 tons of ore probably from the pit are separately stockpiled at three places beside the pit. The grade seems to be 1.5 percent as a whole. Silicification and argillization are the alteration of country rock in the mineralized zone, the former is dominant in the part rich in copper minerals, and chlorite tends to increase with the distance from it.
		The assay results of the ores from the remained mineralized zone along the pit wall both on relatively high-grade part and on tail end are shown in the following.

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LK050	tr.	tr.	3.02	0.03	0.02
LK052	tr.	tr.	0.93	0.04	0.05

(2) New Ore Body at the North of Sabana (S−2)

The new ore body was discovered by this survey near at the top of a mountain about 500 meters to the north of the Sabana deposit. Geology of the surroundings of the ore body is made up of andesitic lapilli tuff of the middle member of the Tireo formation, and the ore body is network vein-type copper one same as the Sabana deposit.

The outcrop of the ore body extends N40°E for 16 meters with the maximum width of 4.5 meters. Fig. 9 shows a sketch of the occurrence of the ore body.

The ore minerals consist mainly of malachite and specularite, and a small amount of chalcocite, chalcopyrite, bornite, sphalerite, pyrite and limonite, accompanied by gangue minerals such as quartz, epidote and chlorite. In Sabana, Fortuna and Roblito, the sulphide minerals can not easily be observed if observed there are very little. However, they are commonly found in this ore body.

The inside of the mineralized zone is highly silicified and weakly chloritized and epidotized, while the surroundings of it are characterized by white argeillized zone. In terms of paragenesis of the ore minerals, copper and iron minerals coexist in the interior of the mineralized zone, and copper minerals decrease toward the peripheral part, where specularite is the only ore mineral. A kind of zonal arrangement can be recognized.

The structure of the ore body can not be made clear, because more than a half of the ore

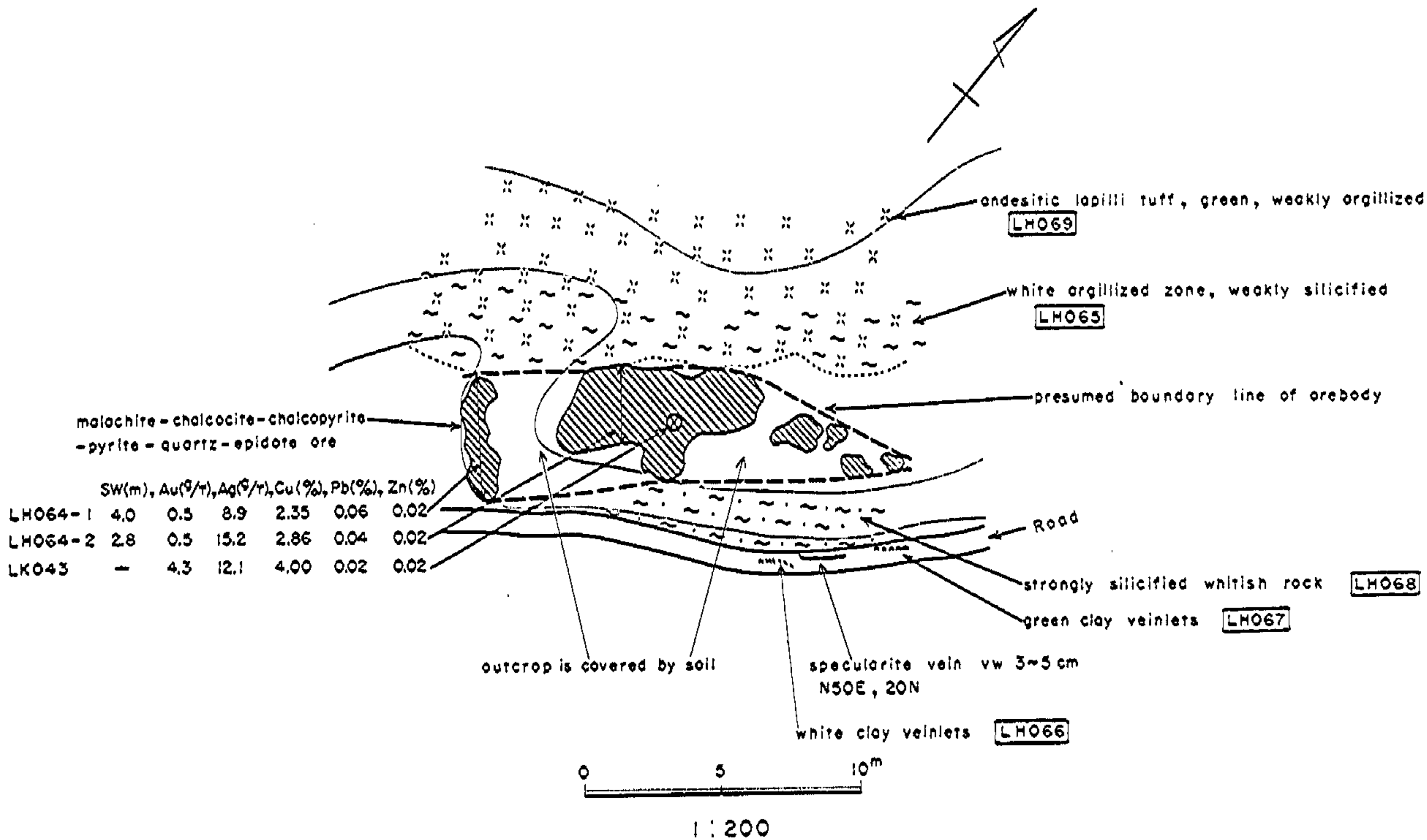


Fig. 9 Sketch of the Sabana North New Orebody

body is covered by the surface soil. However, it is assumed that the ore body dips northward, because the specularite vein found in the peripheral of the ore body has the strike of N50°E and the dip of 20°N.

The assay results of the ore are as follows:

	Sampling width	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LH064-1	4.0 m	0.5	8.9	2.35	0.06	0.02
LH064-2	2.8	0.5	15.2	2.86	0.04	0.02
LK043	(grab sample)	4.3	12.1	4.00	0.02	0.02

Microscopic observation of LH064-1, LH064-2 and LK045 shows that chalcopyrite is abundantly present in granular shape and/or irregular shape with less than two milimeters across or in agrregate, showing an occurrence surrounded by limonite which is the secondary alteration product by oxidation. A part of chalcopyrite has been altered to bornite. Covelline is also observed as small crystals of alteration product. Pyrite is present in a very small amount, and specularite is found along the cracks.

(3) Roblito Deposit (S-3)

The deposit is situated on the southern slope of a mountain about 15 kilometers to the west of Constanza. It takes about an hour and a half from Constanza to Lemoncite by jeep and about three hours and a half to reach the site from Lemoncite by mule.

This is a network vein-type copper deposit in andesitic tuff and lapilli tuff of the middle member of the Tireo formation. Although it has been tested at three places by trenching in a direction of N80° ~ 85°W, the mineralized zone is small and low grade.

The ore minerals consist mainly of specularite and a small amount of malachite and limonite, accompanied by gangue minerals such as quartz, epidote and chlorite. The mineralized zone is a congregated one composed of network and banded veins about one centimeter wide filling the fractures in the country rocks.

Although veinlets trend NW, NE and EW, the NE direction is dominant among them.

Chloritization is the most predominant alteration. Silicification and epidotization are partly observed. The location of the trenches is shown in Fig. 10 and a sketch of the typical occurrence in Fig. 11.

The observation of the trenches is described in the following.

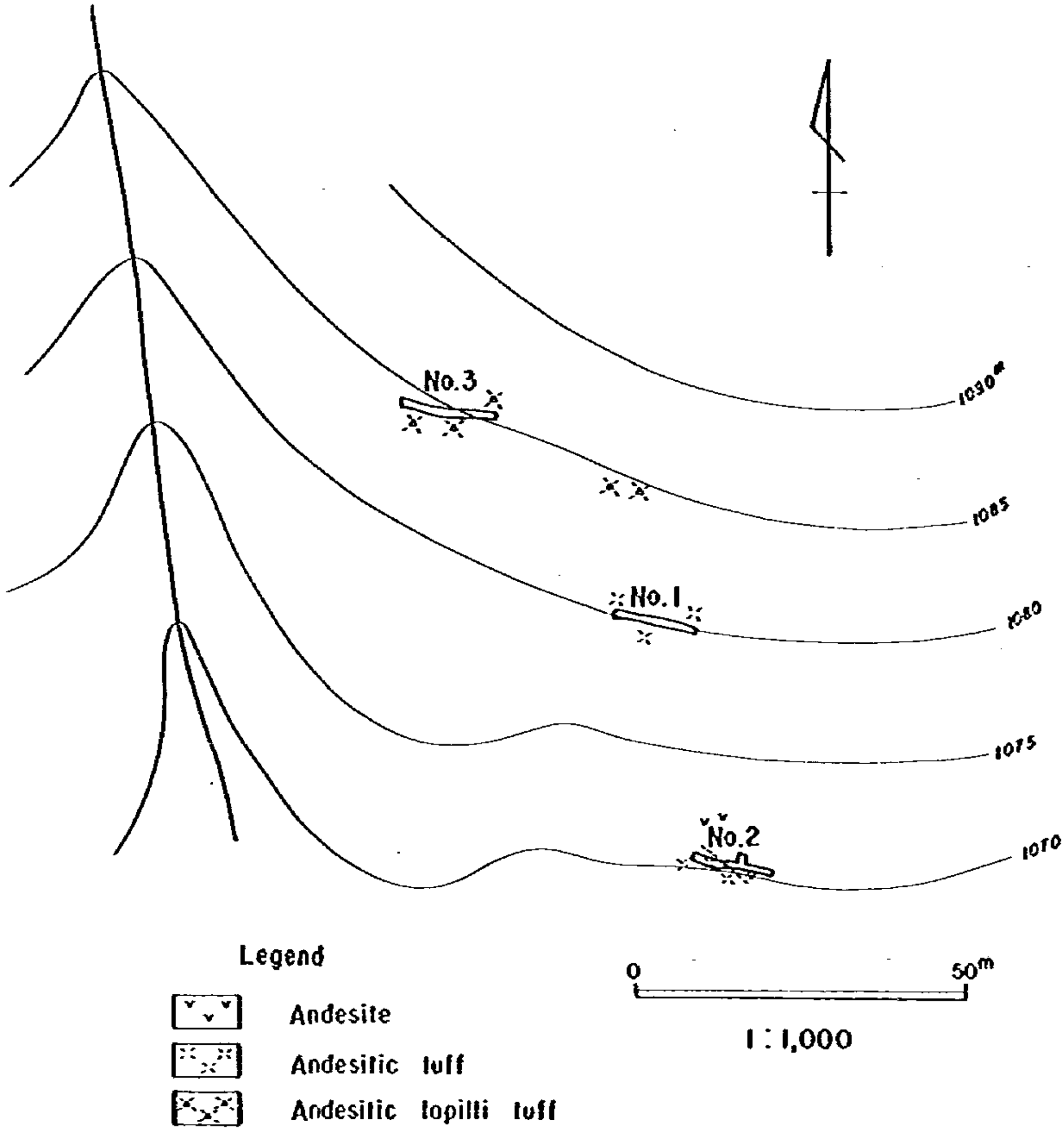


Fig. 10 Location Map of Trenches in Roblito Deposit

No.	Size width x length x depth	Description
No.1	1.5m x 13m x 1.5m	The trench extends N80°W. Specularite containing a very little amount of malachite partly remains on the wall. The country rock is andesitic tuff and lapilli tuff. Chloritization is the dominant alteration, with a local epidotization. The assay results of the specularite veinlets are as follows:

	Vein width	Au g/t	Ag g/t	Cu%	Pb%	Zn%
LH051	5 cm	0.4	4.8	1.01	0.32	0.02
LH053	2	tr.	tr.	0.30	0.04	0.02

No.	Size width x length x depth	Description
No.2	1.5m x 13.5m x 1m	The trench extends N80°W. Network and banded veinlets consisting mainly of specularite and a small amount of malachite are present at the wall. No mineralization is observed beyond that extent. The country rock consists of andesite lava and its tuff. Chloritization is notable and silicification is also recognized locally. The assay result of the mineralized zone are as follows:

	Vein width	Au g/t	Ag g/t	Cu%	Pb%	Zn%
LH054	0.80 m	tr.	tr.	0.26	0.08	0.02
LH055	1.00	0.1	1.0	1.34	0.06	0.02
LH056	1.00	tr.	tr.	0.15	0.07	0.02

No.	Size width x length x depth	Description
No. 3	0.5m x 15.5m x 1m	The trench extends N85°W. Two network veins of malachite-specularite-epidote-quartz, 35 centimeters and two centimeters wide for each, and specularite veinlet one centimeter wide are the only mineralization observed. The country rock consists of andesitic tuff and lapilli tuff. Chloritization and weak in silicification and epidotization are notable as rock alteration. The assay result of the mineralized zone is as follows:

	Vein width	Au g/t	Ag g/t	Cu%	Pb%	Zn%
LH057	0.35 m	0.3	0.8	2.84	0.04	0.02

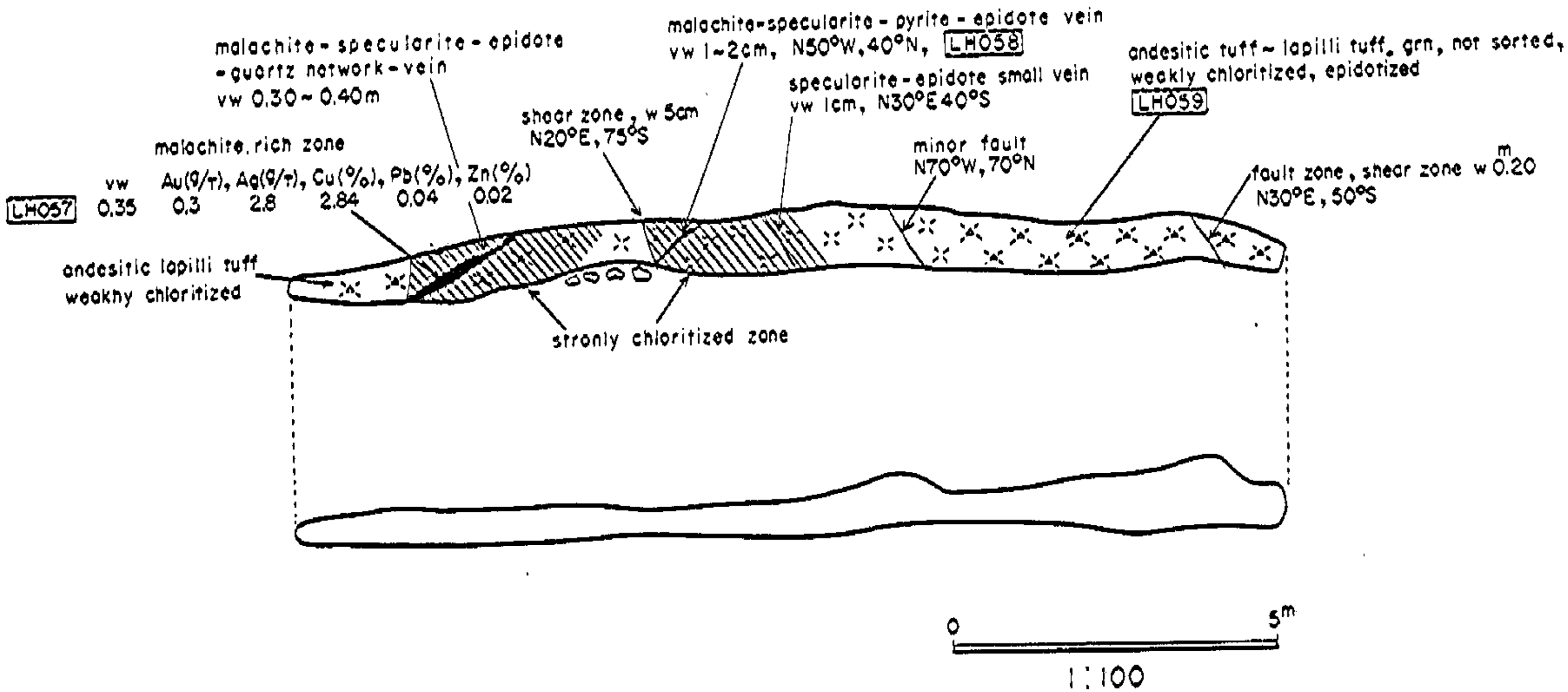


Fig. 11 Sketch of Northern Face of No.3 Trench in the Roblito Deposit

(4) Fortuno Deposit (S-4)

The deposit is situated on the northern slope of a creek flowing eastward about 15 kilometers to the west of Constanza.

The ore deposit is a vein-type copper deposit in andesitic tuff in the middle member of the Tireo formation and an intrusive of plagioclase-quartz porphyry. The ore minerals consist of malachite, specularite and limonite and a small amount of chalcocite, bornite, covelline, chalcopyrite and pyrite, accompanied by the gangue minerals such as quartz and epidote.

The mineralized zone shows an occurrence that ore minerals and gangue minerals fill the fractures developed along the bedding plane in andesitic tuff and the irregularly trending fractures in the intrusive mass, forming a congregated zone consisting of network and banded veins.

Although the accurate size of the mineralized zone can not be known because most of the ore have been mined out from the pits and the trenches, the mineralized zone in the No. 3 pit shows a width of about two meters and length of several meters. Many veins strike northeasterly and dip toward the north.

Silicification is notable and weak epidotization is also recognized. Many small intrusives of plagioclase-quartz porphyry are distributed in the surrounding area of the Fortuno deposit. This suggests the existence of the genetic relation between the intrusives and mineralization.

In this deposit, prospecting by trench or pit has been performed at six places. Fig. 12 shows the locations. The present aspect of the trenches is as follows.

No.	Size width x length x depth	Description
No. 1	1.5m x 5m x 1.7m	The trench extends N5°W. A congregated zone consisting of malachite and specularite 1.10 meters wide is found in andesitic tuff, and specularite veinlets are partly present further outside of the zone. The veinlets strike northeasterly and dip northward. Epidotization is dominant. The assay results of the mineralized zone above mentioned and the specularite veinlets are as follows:

	Sampling width	Au g/t	Ag g/t	Cu%	Pb%	Zn%
LH039	1.10 m	tr.	tr.	1.41	0.05	0.05
LH040	0.10	tr.	tr.	0.21	0.04	0.02

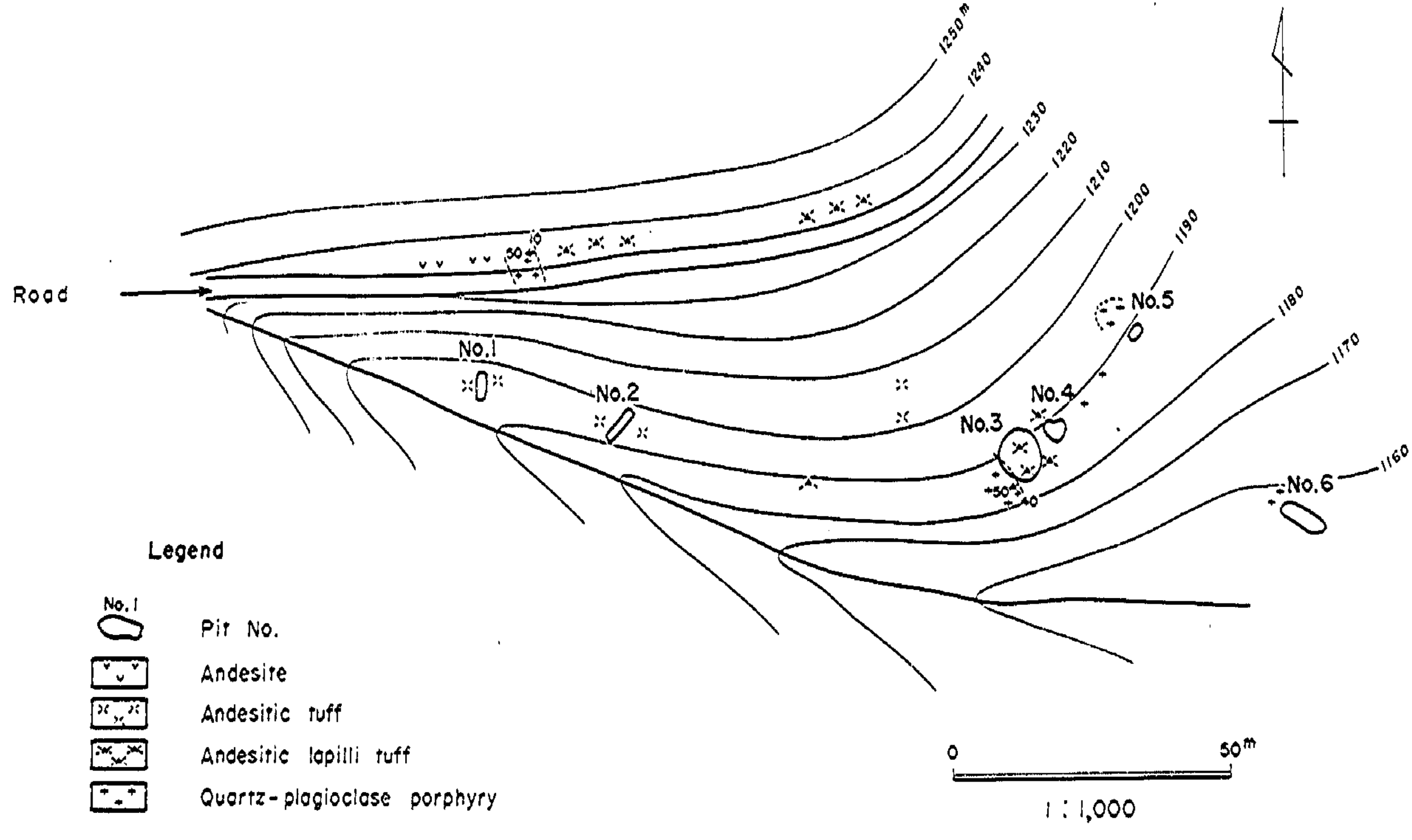


Fig. 12 Location Map of Pits in the Fortuna Deposit

No.	Size width x length x depth	Description
No.2	1m x 10m x 2m	The trench extends N40°W on the hillside. Specularite veinlets are present in the highly chloritized and epidotized rock. A small amount of malachite is locally found in a form of network of dissemination. The veinlets extend northeasterly and dip northward. The assay result of the specularite veinlets containing a very small amount of malachite is shown in the following.

	Sampling width	Au g/t	Ag g/t	Cu%	Pb%	Zn%
LH041	1.00 m	tr.	tr.	0.21	0.04	0.02

No.	Size width x length x depth	Description
No.3	10m x 14m x 12m	The pit is seen on the hillside. The prospecting was carried out for the mineralized zone formed along the boundary between well bedded andesitic tuff and plagioclase-quartz porphyry intruded into the above. The mineralized zone is a congregated zone of network veins and dissemination consisting of malachite, specularite, quartz and epidote formed in the fractures along the bedding plane of tuff and those in the intrusives. The mineralization in tuff is stronger. Although two sheets rich in malachite two meters wide each can be observed, they extend only about five meters. The veinlets extend northeasterly and dip northward. Silicification is notable. The assay results of the part rich in malachite and the part of specularite veinlets in the surroundings are as follows.

	Sampling width	Au g/t	Ag g/t	Cu%	Pb%	Zn%
LH042	0.50 m	0.2	2.3	3.96	0.08	0.05
LH047	0.30	tr.	tr.	0.34	0.02	0.02

No.	Size width x length x depth	Description
No.4	4m x 4m x 1.5m	Specularite-quartz network veins are mainly found in the fractures formed along the bedding plane of andesitic tuff. Very small amount of malachite is partly present. Silicification is notable.

No.	Size width x length x depth	Description
No.5	1m x 5m x 1.5m	Only specularite veinlets are found in the fractures in plagioclase-quartz porphyry. The country rock has been silicified.
No.6	(1~4)m x 11m x 1.5m	A test pit excavated at the boundary between plagioclase-quartz porphyry and the altered rock subjected to epidotization. Malachite-specularite network veins are found in the altered rock. The width is more than 20 centimeters. Porphyry has been silicified. The assay result of the mineralized zone is as follows:

	Sampling width	Au g/t	Ag g/t	Cu%	Pb%	Zn%
LH046	0.20 m	0.1	1.0	0.34	0.02	0.02

2. Southern Constanza Area

The mineralized zones are vein-type copper deposits emplaced in andesite lava, and its tuff and lapilli tuff in the middle and the upper member of the Tireo formation. The group of vins of the area shows a concentric distribution surrounding the intrusive of tonalite megascopically (PL.6), suggensting a possibility that there might be an important relationship between the intrusive and the mineralization.

The type of the mineralized zones of the zrea are roughly divided into the following three kinds which show somewhat different characteristics in places, such as chalcopyrite-galena-sphalerite-pyrite-specularite-epidote vein (Pinar bonito etc.), veins in a form of network to dissemination mainly consisting of malachite (Limoncito etc.) and pyrite dissemination zone in dacitic tuff to be mentioned later.

(1) Pinar bonito Mineralized Zone (C−1)

The mineralized zone is situated seven kilometers to the southeast of Constanza, and composed of chalcopyrite-galena-sphalerite-pyrite-specularite-quartz-epidote veins in andesitic tuff, lapilli tuff and andesite lava in the middle member of the Tireo formation.The outcrops are ovserved at four places within a distance of about 700 meters along a tributary of Rio Grande. The veins are small having the width of 0.10 to 0.30 meter. The veins of the area are characterized by the ore minerals mainly consist of sulphide minerals with small amount of oxides. The character is different from those of other areas. That is to say, while the outcrops of other areas correspond to the oxide zone or secondary enrichment zone, those in this area correspond to the position of the primary zone.

Two kinds of rock alteration such as chloritization and epidotization are observed in the area; chloritization is dominant in some veins, while epidotization is dominant in the other veins.

The details of the outcrops are as follows:

No.	Vein width	Description
No.1	0.10 m	A vein with a small scale in andesite lava having mineral assemblage of chalcopyrite-galena-sphalerite-pyrite-specularite-quartz. It strikes N20°W and dips 60°N, and the outcrop can be traced for about two meters along lateral extension.

The result of assay of the vein is as follows.

	Sampling width	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LH023	0.10 m	0.2	2.1	0.96	0.90	2.26

No.	Vein width	Description
No.2	0.30 m	Chalcopyrite-sphalerite-galena-pyrite-specularite-quartz vein in andesite lava. It strikes N20°E and dips 40°N. Molybdenite is present in very small amount. Under the microscope, sphalerite is the most abundant ore mineral, forming granular aggregate. Chalcopyrite occurs as tiny grains or lamellas, showing so-called chalcopyrite disease texture. Epidotization is dominant.

The estimated grade of the vein for the whole width of 30 centimeters is 0.3% Cu, 0.1% Pb, and 3.5% Zn.

No.	Vein width	Description
No.3	0.10 m	Chalcopyrite-galena-sphalerite-malachite-covelline-pyrite-specularite-quartz vein in andesitic lapilli tuff.

Five small veins five to ten centimeters wide, striking N60°E and dipping 60°N are observed within the width of 1.50 meters. These extend for about 10 meters along the stream. The country rock has been dominantly subjected to chloritization.

The assay result of the veins is as follows:

	Vein width	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LH027	0.10 m	0.3	7.9	0.97	5.62	0.05

No.	Vein width	Description
No.4	0.05 m	Chalcopyrite-sphalerite-pyrite-quartz vein in andesitic lapilli tuff. A small vein three to ten centimeters wide strikes N10°W and dips 70°N.

(2) C–2 Mineralized Zone

The mineralized zone is network copper veins emplaced in andesitic lapilli tuff in the middle member of the Tireo formation. The showings are found at five places within the distance of about 100 meters along a tributary of Rio Grande. The ore minerals consist mainly of pyrite with minor amount of malachite, chalcopyrite, sphalerite and specularite. The gangue mineral is quartz. The paragenesis of ore minerals varies with veins from those rich in chalcopyrite to others rich in sphalerite. Silicification is the main alteration of the country rock. The mineralized zone is small on a scale with vein width of 0.10 to 0.60 meter. The veins strike northeasterly and calcite veins have the trends of NW and NE systems. The faults cutting the veins have the trends such as NW and NE systems.

The direction of NE shown by the trend of the ore veins in this zone is the same as that of the Sabana area, which suggests the relationship between the shear plane of NE system in the field of lateral pressure in the NS direction and the mineralization of the area.

The assay results of the veins are as follows:

		Vein width (m)	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LT011	No.1 vein	0.60	0.2	1.1	0.07	0.02	0.29
LT012	No.2 vein	0.60	0.1	0.7	0.18	0.07	0.14
LT013	No.3 vein	0.25	0.2	1.7	0.90	0.02	0.02
LT013	No.4 vein	0.10	0.3	3.9	1.57	0.06	0.05

Occurrence of the ore minerals observed under the microscope is as follows.

Pyrite is found in abundance as euhedral crystals less than several milimeters across, being cut by the veinlets of chalcopyrite. Chalcopyrite is present as aggregates up to several milimeters in diameter or grains about 0.4 milimeters across. Sphalerite forms grains less than 1.5 millimeters across, in which "chalcopyrite disease" texture of fine chalcopyrite is partly seen (LT009 from No.1 vein).

(3) Limoncito Deposit (C–3)

The deposit is composed of network and disseminated copper veins emplaced in andesitic tuff and lapilli tuff of the middle member of the Tireo formation. The outcrops of the mineralized zone are distributed within the extent of the width of 80 meters and the length of about 200 meters, being spread on the eastern slope of a mountain. The ore mineral mainly consists of malachite. Although a small amount of pyrite is observed as sulphide mineral, most of it has been oxidized to limonite. Malachite is present in a form of network or dissemination filling the fractures of the country rocks. The country rocks have been subjected to silicification and epidotization. The content of malachite is about one percent in the lower part of the slope and about five percent in the upper part, showing an increase toward the higher altitude. The grade of copper of the outcrop throughout the mineralized zone is about one percent. Three drill holes cut in the past to test the lower part of the mineralized zone seems to have failed to encounter the primary zone.

The assay results of the high grade ore containing malachite in abundance and the average grade ore are as follows:

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LH012 (grab sample)	0.2	3.4	0.96	0.05	0.02
LH016 (")	0.2	2.3	2.98	0.08	0.02

(4) C–4 Mineralized Zone

The mineralized zone consists of a cupriferous quartz vein in andesite lava in the middle member of the Tireo formation, being situated at Rio Grande. The quartz vein strikes N50°E and dips 50°N, having a width of about 5 meters. The ore minerals consist mainly of malachite and very small amount of chalcopyrite, sphalerite and pyrite are observed. Malachite is mainly found in the cracks in quartz vein. Limonite is present in abundance as oxide.

The assay result of the ore sampled from a high-grade part in the quartz vein is as follows:

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LK025 (grab sample)	0.4	5.3	2.63	0.02	5.90

3. Mata Grande Area

The mineralized zones of the area include vein-type copper deposits emplaced in green schist in the Duarte formation and partly in tonalite. The zones are distributed having a correlation with the tonalite mass and the latent tectonic line of NW system (PL. 6), suggesting a close relationship between the mineralized zones and both the intrusives and tectonic lines. The most important deposit in the area is the Mata Grande deposit, which is mentioned below.

(1) Mata Grande Deposit (M–1)

The deposit is situated near the northern side of Rio Bao about 15 kilometers to the southwest of San Jose de las Matas.

It is said that the exploration of the deposit was carried out by pitting by Industria del Acero until 1974 and after that by drilling by D.G.M. However, the work for exploration has been suspended since then, only the dressing plant controlled by D.G.M. remains at the mine site.

The ore deposit is a vein-type copper deposit emplaced in green schist of the Duarte formation and partly in tonalite, which is situated megascopically near the southwestern end of the El Bao tonalite batholith. The deposit has the strike of N70° ~ 80°W and the dip of N40° ~ 85°.

The mineralized zone shows a lenticular form as a whole and includes a network and disseminated vein which ore minerals together with gangue minerals fill the fractures in the country rock and a single ore vein. The ore minerals consist of chalcopyrite, pyrite, bornite, chalcocite, covelline and malachite, accompanied by gangue minerals such as quartz and chlorite. The dominant alteration of the country rock is silicification and chloritization. The former is notable along the wall of the vein, while the latter on the outer side of it. Silicification tends to be stronger in the high-grade part. Toward the both side of NW and SE from the test pit, a considerable size of the outcrops of the vein are spotted, and especially on the southeastern side, they are traced for about 1 kilometer. The width of the outcrops is 0.10 to 1 meter.

As shown in Fig. 13, the open pit was excavated for exploration on the mountain side in a considerable size with a width of about 80 meters and a height of about 100 meters. The upper part of the pit wall consists of tonalite and the lower part green schist. The mineralized zone is found at the boundary of the both rocks, being emplaced both in the green siliceous altered rock derived from green schist and tonalite porphyry. The mineralized zone has a general attitude striking northwesterly and dipping northward. Three barren quartz veins one to several meters wide are intercalated in the zone at intervals of 10 to 15 meters. The quartz veins strike N60° ~ 70°W and dip 50° ~ 60°N, being consistent with the structure of the mineralized zone. Although it is said that prospecting was ever performed on a lenticular high grade vein in the lower part of the central part of the pit, the detail is not known because of covering by the caved materials from the pit wall and the benches. It is assumed, however, from the ore remained on the wall that following two kinds of ore would have been present in the pit.

(i) Dissemination or/and network of malachite and covelline in quartz vein (MH001).

(ii) Chalcopyrite, bornite and chalcocite coexisting with quartz in abundance (MH002).

The assay results of these are as follows:

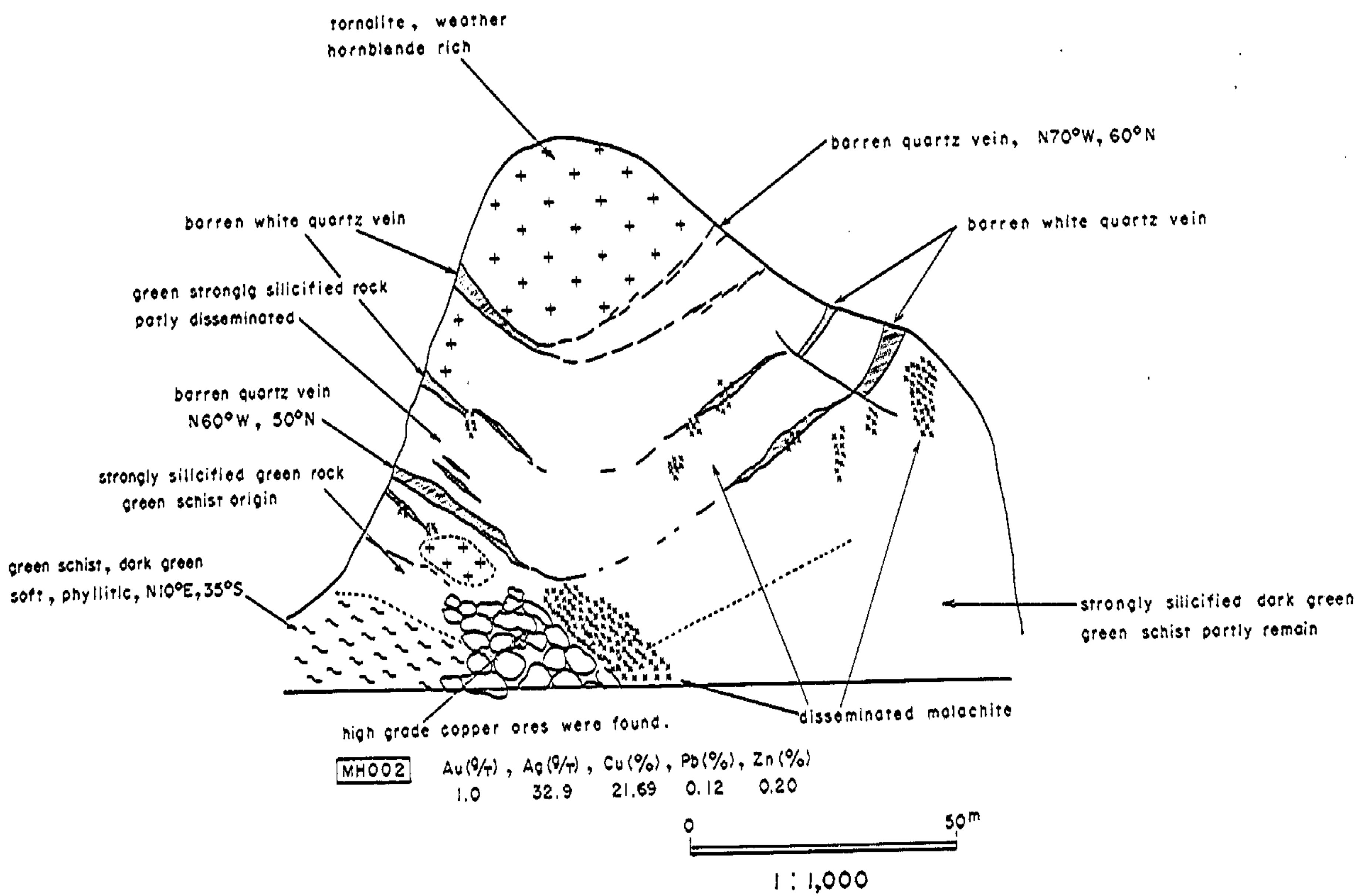


Fig. 13 Pit Face of Mata Grande Deposit

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
MH001 (grab sample)	tr.	tr.	1.07	0.03	0.01
MH002 (")	1.0	32.9	21.69	0.12	0.20

Microscopic observation of the ore minerals resulted into identification of the minerals mentioned above. Chalcopyrite and bornite are present filling the interstices of the grains of gangue minerals. Bornite of this deposit exists as a primary one different from that of the deposits of other areas, taking no form of having replaced chalcopyrite. Chalcocite and covelline are present as tiny grains between the grains of gangue minerals. In some parts, the remains of the two minerals of the former can be observed at the center. This shows that these minerals are the altered minerals from the former two.

4. Other Areas

Another vein-type mineralized zones are found in the Duarte formation, the Tireo formation and the intrusive rocks, beside those described in the above. The main mineralized zones among these are described in the following.

(1) Tasajera Deposit (T–1)

The deposit is situated near the uppermost reaches of the Arroyo Limon creek on the southern slope of the Tasajera mountain ridge about 20 kilometers to the north of Padre Las Casas. The deposit is network and disseminated copper vein occurred in andesite lava, and its lapilli tuff and tuff breccia in the middle member of the Tireo formation. Mineralized zone shows an irregularly lenticular form on the whole.

The ore minerals consist mainly of malachite and specularite and a small amount of chalcocite, bornite and covelline, accompanied by gangue minerals such as quartz and epidote. Epidotization and silicification are dominant in the host rocks.

Although the exploration by trenching and tunneling was carried out in the past, the detail can not be known because of cave-in of the walls. The scale of each ore body, therefore, is not clearly known, but lateral extension of the veins seem to be several meters.

The assay result of relatively high grade ore from the mineralized zone is as follows:

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LH060 (ore from Trench No.1)	0.2	2.3	4.36	0.05	0.02

by the microscopic observation, chalcocite, covelline, bornite and specularite were identified. Chalcocite is the most abundant mineral, being present as aggregates less than 2 milli-

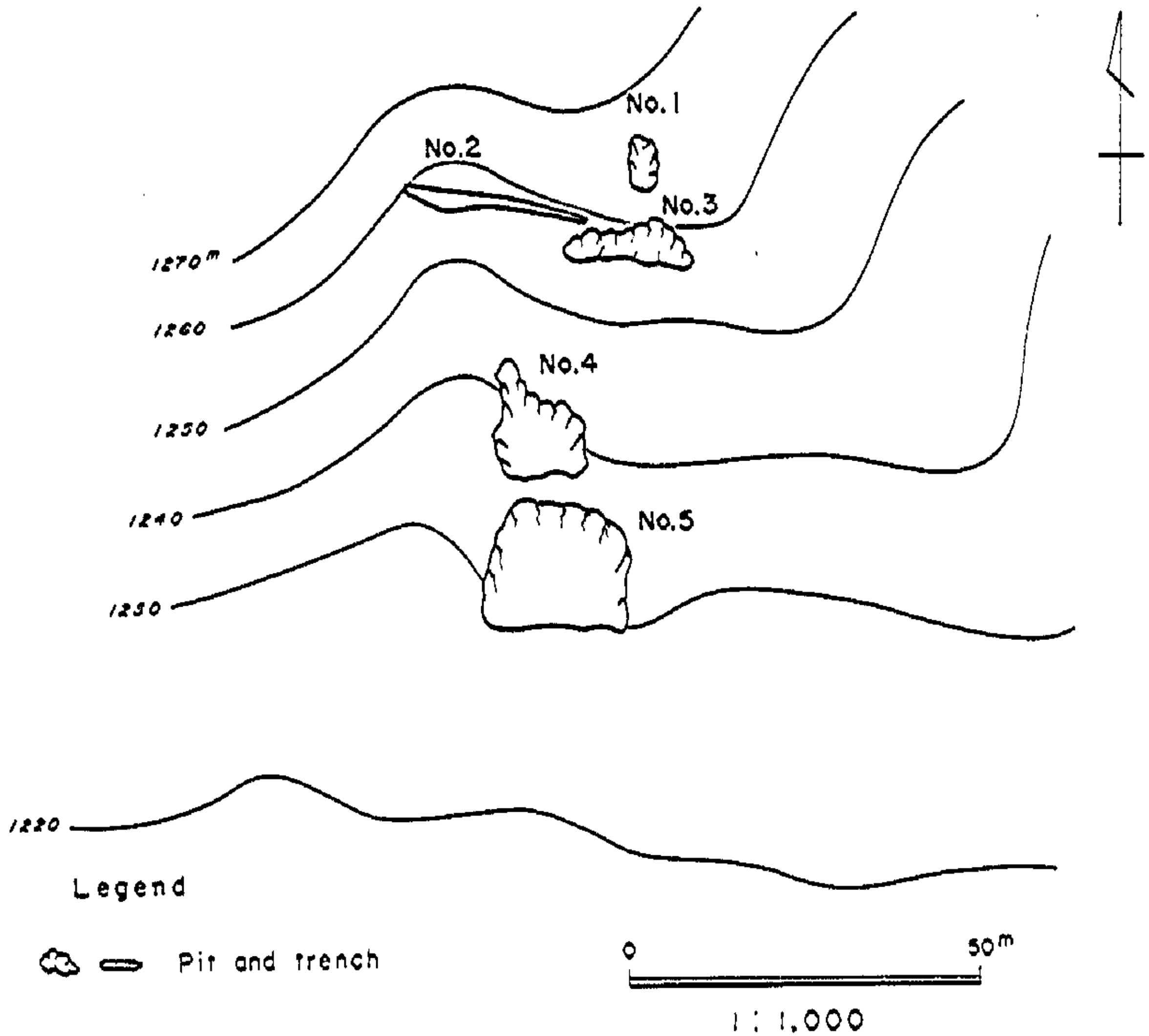


Fig. 14 Location Map of Pits in Tasajera Deposit

meters across or fine veinlets. Some contain small grains of bornite at the center. Covelline is present as fine grains with distinct cleavages less than one millimeter surrounding chalcocite grains and as flakes at the similar position. Bornite (bn) is present inside the chalcocite grains showing an occurrence as shown in the Fig. 15 Specularite coexists with the above minerals in a form of fine flakes.

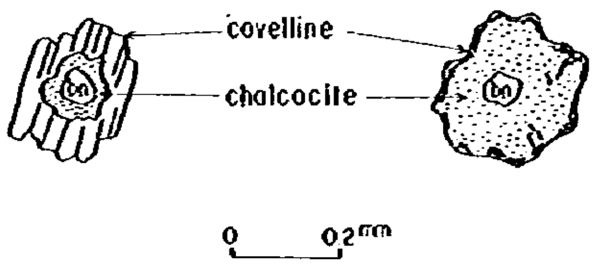


Fig. 15 Occurrence of Ore Minerals in Polished Section from Tasajera Deposit

The deposit has been prospected by trenching or stripping at five places, and the present aspect is as in the following. Fig. 14 shows the locality.

No.	Size width x length x depth	Description
No.1	3m x 7m x 1m	A trench on the slope to test the altered andesite lava. Brecciated ore consisting of malachite, chalcocite, covelline, epidote, quartz is observed in the trench. The mineralized zone is poor in continuity, and the ore is present within the extent of one meter on the side wall. Epidotization and chloritization are common alteration. The assay result of the high-grade part is as follows: Au g/t Ag g/t Cu% Pb% Zn% L11060 (grab sample) 0.2 2.3 4.36 0.05 0.02
No.2	1.5m x 25m x 1.5m	A trench excavated through the gravel bed composed of pebbles of andesitic tuff and soil. No mineralization is observed.

No.	Size width x length x depth	Description
No.3	5m x 20m x (1~2)m	A trench in andesite lava, and its lapilli tuff and tuff breccia. Only the veinlets of specularite are observed. Silicification and chloritization are common alteration.
No.4	10m x 15m	Only the trace of stripping remains on the slope. A small tunnel which is said to have been excavated can not be found because of cave-in and being buried. No mineralization is observed other than chloritized andesitic tuff.
No.5	17m x 20m	Only the trace of stipping remains on the slope. No mineralization can be observed other than veinlets of epidote and quartz in silicified and chloritized andesitic tuff breccia.

(2) T-2 Mineralized Zone

The mineralized outcrop is found at about 700 meters to the southwest of the Tasajera deposit, consisting of a small network vein having lateral extension of about 1 meter and the length along the dip of about one meter. The ore minerals consist of malachite, specularite, chalcocite and covelline. The country rock is andesitic tuff of the middle member of the Tireo formation. The vein strikes N50°W and dips 20°N. The network veinlets show an occurrence to have filled the fractures in the country rock, and no gangue mineral is observed. The country rock has been chloritized.

The assay result of the high-grade part of the outcrop is as follows:

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LK040 (grab sample)	tr.	tr.	4.21	0.23	0.20

Microscopic observation of the ore minerals is shown in Fig. 16, chalcocite is present abundant in surrounding bornite. In this part, many cracks are found and covelline has been produced along the cracks. It shows a process of oxidation.

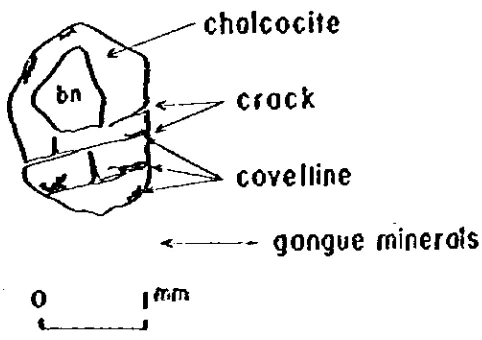


Fig. 16 Occurrence of Ore Minerals in Polished Section from Tasajera (T—2)

(3) T–3 Float

The floats were found at about 800 meters to the east of the Tasajera deposit. The floats contain network veins consisting of malachite, quartz and epidote. The country rock is andesitic lepilli tuff, which has been silicified and epidotized. The floats 10 to 30 centimeters in diameter are scattered in abundance in the creek.

The assay result of the typical float is as follows:

Microscopic observation of occurrence of the ore minerals is as follows.

Chalcopyrite is separated into the grains less than two millimeters diameter by oxidation, and the peripheral had been altered to covelline. It had been altered into limonite further outside as shown in Fig. 17. This indicates a process that copper in chalcopyrite was leached out to make malachite by the oxidation, and iron remained as limonite.

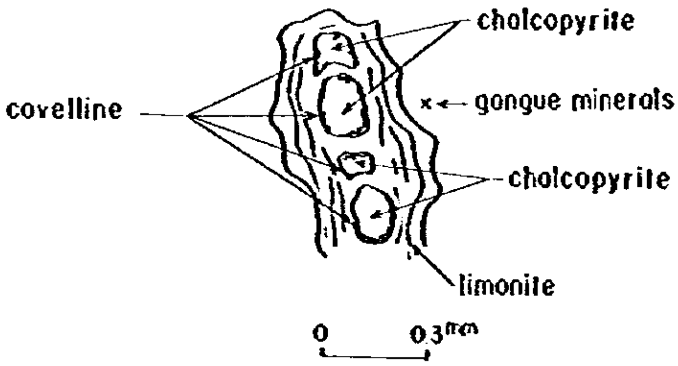


Fig. 17 Occurrence of Ore Minerals in Polished Section from Tasajera (T—3)

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LK042 (grab sample)	0.1	1.2	1.16	0.03	0.10

(4) T–4 Mineralized Zone

The mineralized zone, being located on the northern slope of the Tasajera mountain ridge includes a small-scale copper vein five centimeters wide and 1.5 meters long. The ore minerals consist mainly of malachite and very small amount of chalcopyrite, accompanied with gangue minerals such as quartz and chlorite. The country rock is tonalite porphyry with coarse quartz phenocrysts, and the ore vein strikes N70°W and dips vertically. An easterly trending quartz vein and an epidote vein striking northerly and dipping westerly are found cutting the ore vein.

The assay result of the vein is as follows:

	width	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LT059	5 cm	0.1	1.8	0.96	0.02	0.15

(5) T–5 Floats

Many floats of quartz vein are present close together in an extent about 5 meters wide and about 15 meters long. Limonite and epidote are contained in relatively porous quartz vein. The floats of quartz vein are found at the boundary between the tonalite porphyry intrusive and andesite lava in the lower member of the Tireo formation. It is likely that these are a part of quartz vein of hydrothermal origin ascended through the boundary as its passage.

The assay results are as follows:

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LT067 (grab sample)	tr.	tr.	0.04	0.07	0.02
LT068 (")	tr.	tr.	0.03	0.08	0.02
LT069 (")	0.1	1.0	0.08	0.03	0.02

(6) B–1 Mineralized Zone

The mineralized zone consists of copper veins exposed along Rio Blanco being situated at the western end of the surveyed area. The geology is composed of tonalite porphyry with quartz phenocrysts, and the copper mineralization is scattered at a few places along the river showing bluish green stain. The copper veins show two kinds of trend such as E–W and N–S, seems to be in conjugate relation. The EW system dips 40°N and the NS system is vertical, and the structures of these are consistent with those of epidote-quartz veins, plagioclase-quartz porphyry dykes and fine-grained diorite dykes. This suggests that the mineralized zone has genetical relationship with the above mentioned dykes.

The ore minerals consist mainly of malachite and small amount of magnetite, chalcopyrity, pyrite and hematite. The gangue minerals include quartz and epidote.

Under the microscope, magnetite occurs in abundance as grains less than one millimeter across, and has been replaced by fine hematite in a form of lattice. It is partly cut by pyrite veinlets. Chalcopyrite is present in a very small amount as grains less than 0.3 millimeter across. Pyrite is seen independently as grains less than 1.5 millimeters across or as aggregates, sometimes cutting magnetite as veins.

The assay result of the vein seemingly of the most high grade among the mineralized zone is as follows:

	width	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LT039	4 cm	0.8	17.7	3.59	0.09	0.02

2–5–2 Porphyry Copper Deposit (P–1)

The floats of ore of porphyry copper type disseminated by chalcopyrite and molybdenite in hydrothermally altered granodiorite were discovered in abundance at a place about 5 kilometers to the east of Mt. Pico Duarte. The place is in a distributed zone of granodiorite which intruded into andesite of the lower member of the Tireo formation with northwesterly trend. This may suggest that the deposit has an important genetical relationship with the intrusive. The host rock has been silicified and sericitized.

It is regrettable that the outcrop of the ore deposit itself could not be found out in this survey. However, it is assumed that the main part of the mineralized zone would be in the southeastern part of the granodiorite mass, because rock alteration is weak and no mineralization has been observed in the northwestern part of the mass.

The ore minerals are composed of chalcopyrite, pyrite, molybdenite, bornite, covelline, malachite and limonite. Under the microscope, chalcopyrite and bornite have been altered to limonite which shows an irregular form less than 0.3 millimeter as shown in Fig. 18, showing an occurrence of advanced oxidation. A very small amount of chalcopyrite lamellae is contained in bornite. Covelline is found in limonite surrounding bornite as aggregates of tiny crystals.

The assay results of low grade ore and typical one are as follows:

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LT085 (grab sample)	tr.	tr.	0.20	0.03	0.02
LT087 (")	0.5	3.5	0.76	0.02	0.02

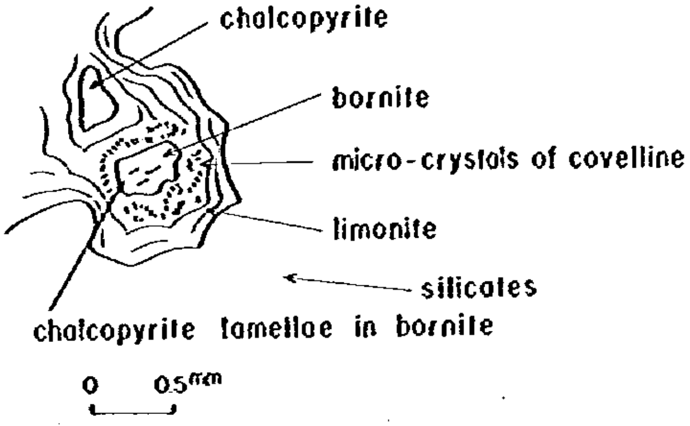


Fig. 18 Occurrence of Ore Minerals in Polished Section from Porphyry Copper Deposit

2–5–3 Pyrite Dissemination Zone

The pyrite dissemination zones are present in green schist of the Duarte formation and dacitic pyroclastic rocks in the middle member of the Tireo formation. The mineralized zones of this kind are distributed showing a positional relation to the intrusives. The typical zones are described in the following.

1. Mineralized Zone of the South of Constanza

A pyrite mineralized zone is found along Rio Grande about 7 kilometers to the south of Constanza. The mineralized zone consists of concentration of pyrite showing euhedral crystals in dacitic tuff and lapilli tuff in the middle member of the Tireo formation. The content of pyrite is 5 to 20 percent in weight percent.

The mineralized zone is one to several meters thick, being spread over widely in the strate above mentioned. In this place, the zone is observed for an extent of about 2 kilometers along Rio Grande.

The part of pyrite dissemination is generally subjected to argillization, which was identified to be sericitization and chloritization by X-ray analysis. The mineralized zone is situated at a position to surround the tonalite intrusive mass at the south of Constanza together with the vein-type copper deposits previously mentioned, suggesting an important relation involved genetically.

The assay result of the pyrite-dissemination zone of this place is as follows:

	Au g/t	Ag g/t	Cu %	Pb %	Zn %
LA042 (grab sample)	tr.	tr.	0.06	0.03	0.05

Under the microscope, pyrite displays euhedral cubic crystals less than one millimeter across, containing quartz as inclusion.

2. Mineralized Zone from Mata Grande to Diferencia Area

Many pyrite-dissemination zones are found in green schists of the Duarte formatin of the area. The mineralized zone is several tens centimeters thick, being spread laterally, and is generally small on a scale. The country rock in which the dissemination zone is contained is green schist of distinct schistosity derived from basic tuff. The country rock has been subjected to chloritization and sericitization. In the dissemination zone quartz veins are present partly along the schistosity. The localities of these dissemination zone is megascopically consistent with the distribution of tonalite intrusives extending northwesterly. Moreover, the distribution of the intrusives are also consistent with the localities of panning sites of placer gold. This suggestes that the instrusives occupy an important position as a forerunning igneous activity of these mineralization.

Under the microscope, pyrite is the only ore mineral, and displays euhedral crystals.

The assay results of the samples from typical localities are as follows:

	Width dissemination zone	Au g/t	Ag g/t	Cu %	Pb %	Zn %
MG013	1.00 m	tr.	tr.	0.05	0.02	0.01
MA032	0.25 m	tr.	tr.	0.05	0.02	0.01

CHAPTER 3 GEOCHEMICAL SURVEY

3-1 General Remarks

In this phase, the geochemical survey by stream sediment was performed in the whole survey area.

The sampling was started at the end of November of 1983 and completed in January 1984. 1968 samples of stream sediment were taken.

The samples were analyzed for six elements such as Au, Ag, Cu, Pb, Zn and As. The result of these analysis was statistically processed by computer, and analysis of single component and multivariate analysis by factor analysis method were carried out.

The geochemical anomaly areas extracted as the result include the Sabana Cu anomaly area in the central part of the Las Canitas area, the south Constanza Cu-Zn anomaly area and the Mata Grande and Diferencia Au anomaly area in the Mata Grande area. The geochemical anomalies are well consistent with the result of geological survey, which demonstrated the effectiveness of geochemical survey in the area.

3-2 Sampling and Method of Analysis

3-2-1 Sampling

The location of sampling point of the stream sediment was planned in Japan beforehand using the topographical map of 1:50,000 scale. At the time of planning, the attention was paid to cover the whole survey area and to unify the order of the drainage system.

At the sampling point, the stream sediment sample under 80 mesh sifted out in water was taken, and the number of sample and rock type were recorded on the sampling list. In this way, 1,968 samples were taken in the whole survey area.

The samples taken were dried by natural seasoning at the office at Constanza where the base camp was set, and those of about 15 grams each divided by quartering were taken back to Japan.

3-2-2 Method of Analysis

The samples of stream sediment were chemically analyzed in Japan. The chemical analysis were made on Au, Ag, Cu, Pb, Zn and As. As the method of analysis, atomic absorption method was used for Au, and plasma luminescence spectrochemical analysis for Ag, Cu, Pb, Zn and As.

The limit of detection of each element was 0.01 ppm in Au, 0.1 ppm in Ag, 1 ppm in Cu, Pb and Zn, and 0.1 ppm in As.

3–3 Data Processing

The result of analysis of the 1968 samples for six elements is as shown in Table A–6. The results of these analysis were input into the computer together with the rock type (the geology in the adjacent area of sampling point).

3–3–1 Single Component Analysis

The histograms were produced for each component for the purpose of extracting the anomalous values (Fig. 19).

In the case of Au, Ag and As, the values under limit of detection occupied 92.4 percent in Au, 68.3 percent in Ag and 75.5 percent in As respectively, and any accurate logarithmic normal distribution was not shown. On the other hand, a correct logarithmic normal distribution was shown in relation to Cu and Zn, and Pb is close to them.

The analytical data were accumulated for each element from the higher value and plotted on the logarithmic probability paper to produce cumulative histogram. Each point of each element plotted shows a linear distribution, and no distinct turning is not observed (Fig.20).

On the basis of these, for the anomalous threshold, x + 2s (t) value which occupies about 2.5 percent of the whole was adopted, which is generally used in geochemical survey. In order to generally grasp the tendency of distribution of anomalous values, the value (t') which occupies about five percent of the whole was determined to be supplementary anomalous threshold. Following this way, the values higher than "t'" and below "t" were determined to be the lower anomalous values and those higher than "t" the higher anomalous values.

To determine "t" and "t'" of each element, cumulative histograms were simply used. "t" and "t'" of each element shown in Table 6 were determined by taking out the value of 2.5 percent for "t" and that of five percent for "t'" and by taking the limit of detection into consideration. Regarding Ag, 0.3 ppm was applied for "t" because the values higher than 0.3 ppm occupy 3.2 percent of the whole and that higher than 0.2 ppm occupy 12 percent of the whole, leading to be impossible of taking out the values of 2.5 percent and five percent.

The correlation of each element is as shown in Table 7. According to it, a slight correlation is observed between Cu and Zn, and that between Zn and Pb is weak. Thus it is understood that the correlation among each element is generally low.

3–3–2 Multivariate Analysis

Although various methods are used for analysis of multivariate geochemical data, factor analysis method was attemted this time.

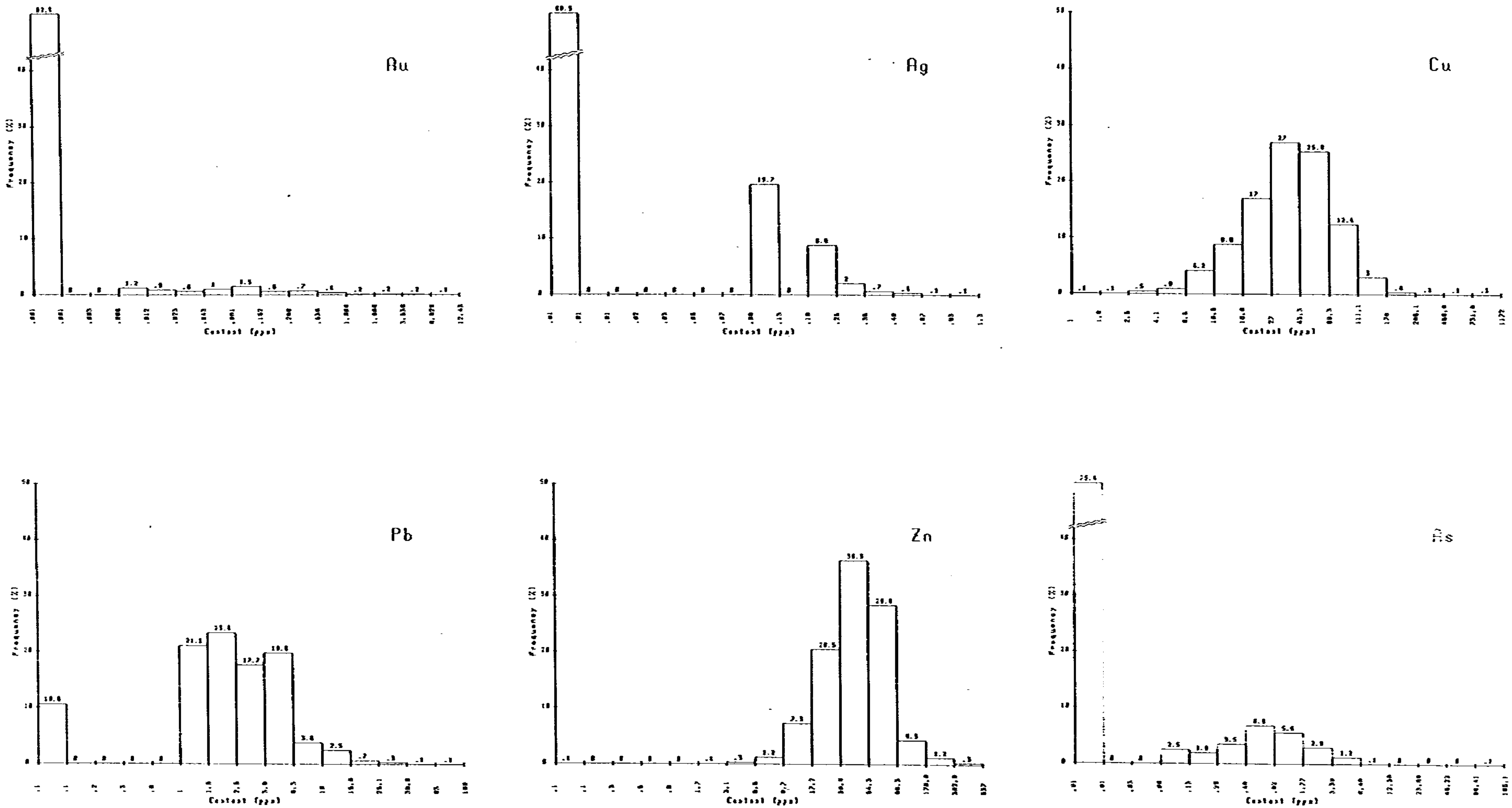


Fig. 19 Histagram of Geochemical Data, Au, Ag, Cu, Pb, Zn, As,

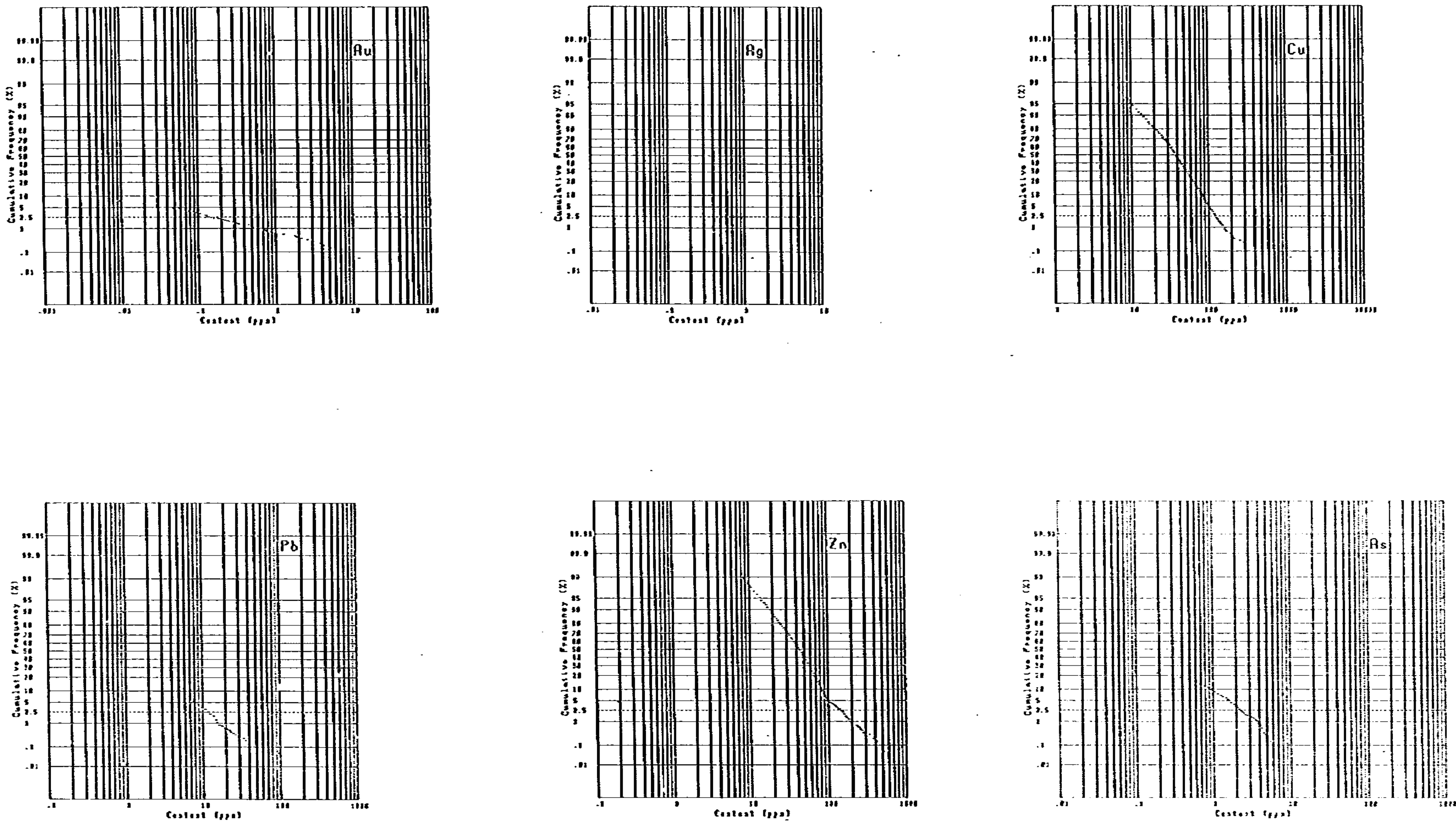


Fig. 20 Cumulative Freguency Distribution of Au, Ag, Cu, Pb, Zn, As,

Table 6 Result of Simplified Statistical Treatment of Geochemical Data

Element \ Factor no.	Factor loadings (varimax rotation) Factor 1	Factor 2	Factor 3	Communality
Au	-0.036	-0.064	0.279	0.0828
Ag	0.193	0.186	0.389	0.2233
Cu	0.438	0.584	-0.060	0.5507
Pb	0.618	-0.060	0.060	0.3967
Zn	0.625	0.428	0.048	0.5761
As	0.024	-0.379	-0.005	0.1833
Factor contributions	71.588%	16.986%	11.043%	

Table 7 Correlation Matrix of 6 Elements of Geochemical Data

	Au	Ag	Cu	Pb	Zn	As
Au	1.000					
Ag	0.058	1.000				
Cu	-0.064	0.169	1.000			
Pb	0.005	0.124	0.210	1.000		
Zn	-0.035	0.224	0.539	0.385	1.000	
As	0.021	-0.058	-0.181	0.025	-0.160	1.000

Table 8 Result of Factor Analysis of Geochemical Data

Element	Max. (ppm)	Min (ppm)	Mean (ppm)	t' (ppm)	t (ppm)
Au	12.43	0.00	–	0.04 (2.7%)	0.14 (2.6%)
Ag	1.3	0.0	–	–	0.30 (3.2%)
Cu	1172	1	38	102 (2.5%)	124 (2.5%)
Pb	100	0	2	8 (2.5%)	12 (2.5%)
Zn	537	0	44	102 (2.5%)	145 (2.5%)
As	165.1	0.0	–	1.6 (2.7%)	2.2 (2.7%)

The data used for factor analysis are those of chemical analysis of stream sediments sampled from the rivers distributed by the Duarte formation, the Tireo formation and the tonalitic intrusive rocks in which the anomalous zones of each element to be mentioned later are distributed and occurence of the mineralization is expected. The codes of rocks are DF, TF and Tns. The number of data analyzed are 1,258.

The factor analysis is a technique in which what extent of factors are possessed by each sample is expressed by factor marks obtained by establishing a small amount of temporary variates (factors) from many variates. In the case of geochemical data, some of these factors are expected to indicate some kind of mineralization, and therefore, it is assumed that the extent of mineralization of each sample can be explained by the factor marks obtained.

The calculation was made by computer and processed by varimax method.

As the result, three factors were obtained including the first factor of Zn–Pb and the second factor of Zn–Cu. The factor loadings, community and contributions of each factor are shown in Table 8.

3–4 Result of Analysis

3–4–1 Result of Single Component Analysis

The anomalous values of each element obtained in the stage of data processing were plotted on the topographical map of 1:100,000 scale (PL. 10 ~ 15).

1. Gold

The anomalous values of gold are dominant in the Mata Grande area and extracted as six anomaly zones. In the Las Canitas area, the anomalous values are scattered in small numbers, being insufficient to form any anomaly zones.

(1) Au–1, 2 and 3 anomaly zones.

Au–1 anomaly zone is distributed in the surroundings of the Mata Grande settlement. The area is a zone famous for panning of placer gold.

Au–2 and Au–3 anomaly zones seem to be the similar kinds to the Au–1, and is distributed along Rio Jamanu, a tributary of Rio Bao.

(2) Au–4 anomaly zone

The zone is found in the upper reaches of Rio Jagua, and this survey revealed that tonalite intruded the Duarte formation in this zone. Abundant quartz veins and pyrite dissemination along the schistosity were also discovered. The assay result of the ore from the latter shows 1 g/t Au, which leads to the assumption of relationship with the anomaly zone.

(3) Au–5 anomaly zone

The anomaly zone is located in the upper stream of the Diferencia area which is a famous placer gold zone similar to the adjacent area of the Mata Grande settlement. The density of concentration of anomalies is high.

(4) Au–6 anomaly zone

The anomaly zone in the upper reaches of Rio Bao contains the gold bearing pyrite dissemination zones in green schist of the upper Duarte member. The pyrite dissemination zones are found along the schistosity of NW–SE direction.

(5) Au–7 anomaly zone

The anomaly zone is distributed in the lower reaches of Rio La Guacara, a tributary of Rio Bao.

2. Silver

The anomalies of silver are rarely found in the Mata Grande area, and most of them are distributed in the Las Canitas area.

In the Mata Grande area, although an abundant anomalies of gold were extracted in the Mata Grande-diferencia area, those of silver were not present at all.

In the Las Canitas area, although the anomalies are present in abundance, they are dispersed, having resulted in not to extract the anomaly zone. There is a tendency that the their occurrence is harmonious with the distribution of copper-mineralized zone, which is especially conspicuous along the Ar. La Sabana creek and in the surroundings of Constanza.

3. Copper

The anomalies are dominant in the Las Canitas area similar to those of silver, which are rarely found in the Mata Grande area.

Sixteen anomaly zones were extracted in the Las Canitas area.

(1) Cu–1 ~ Cu–6

These anomaly zones show the mineralized zones such as the known ones including Pinar Bonito and Limoncito, and those discovered in this survey.

(2) Cu–7 ~ Cu–12

Cu–10 anomaly zone contains the concentrated zone of the Sabana area which is the largest copper belt in the Las Canitas area. Cu–11 and Cu–12 contain the copper-mineralized zones in the surroundings of the Sabana area. Although any mineralized zone has not been discovered in Cu−7, Cu−8 and Cu−9, copper ore floats of high grade was discovered in the upstream of Cu−9.

(3) Cu−13 ~ Cu−16

These anomaly zones contains the copper-mineralized zones seem to have relation to the porphyritic tonalite stock.

4. Lead

The six anomaly zones were extracted, similar to those of silver and copper, only in the Las Canitas area.

(1) Pb−1 ~ Pb−5

These anomaly zones are distributed in the southern part of the Las Canitas area. Dacite and dacitic pyroclastic rocks disseminated by pyrite are distributed in the vicinity, and the copper-mineralized zone is also present.

(2) Pb−6

The anomaly zone is located on the southern slope of Mt. Loma la Tajarera, where no mineralized zone has been known.

5. Zinc

The zinc anomalous zone has not been extracted in the Mata Grande area similar to those of silver, copper and lead. Three anomaly zones were extracted at the south of Constanza, where the distribution of these zones are well consistent with those of lead.

6. Arsenic

The anomalies are distributed scatteringly. They are, however, a little collectively distributed in the El Bao tonalite batholith area in the Mata Grand area and the Guayabal area. The showings of hot spring are observed in the vicinity of these areas. Therefore, the anomalies may be derived from the hot spring water.

3−4−2 Multivariate Analysis

While the first factor (Zn−Pb) and the second factor (Cu−Zn) show the high values in factor loadings and factor contributions, those of the third and the fourth factors are low. Therefore, the analysis was used only for the first and the second factors (PL. 16 · 17).

1. The First Factor (Zn−Pb)

The high score zones of the factor higher than one are distributed in abundance in the Las

Canitas area. They are dominant on the south of Constanza.

The distributions of the high factor score zones are well consistent with the distributions of the Zn and Pb anomaly zones. But they are hardly consistent with those of copper anomaly zone.

A characteristic point of these high factor score zones is that dacite and its tuff are distributed in these zones and/or in their surroundings, and which are disseminated by pyrite.

As mentioned in the above, the factors does not characterize the copper mineralization, but they might reflect the properties of the host rocks including dacite and the mineralization which formed the pyrite dissemination.

2. The Second Factor (Cu–Zn)

A lot of the high factor score zone higher than 0.5 are distributed in the Las Canitas area.

These high score zones are well consistent with the copper anomaly zones extracted by single component analysis. This may indicate that the factor is characterized by the copper mineralization of this area.

3–5 Relationship between Geochemical Anomaly Zones and Mineralization

By single component analysis, multivariate analysis and the investigation of the relationship between these anomaly and the mineralization, four important geochemical anomaly areas as follows were tracted (PL. 18, Fig. 21).

1. Sabana Cu Geochemical Anomaly Area

In the Sabana area and its surroundings, the distribution of copper-mineralized zone and copper anomaly zones extracted by single component analysis and the high score zones of the second factor (Cu–Zn) obtained by factor analysis are well consistent. A small amount of zinc is contained generally in all of mineralized zones. This supports that the second factor is the one of mineralization. From the above fact the Sabana area which is large copper anomaly zone and high score zone of the second factor, the Arroyo Sabina creek and the lower reaches of Rio Yaquesillo are thought to be the important geochemical anomaly area. Although any mineralized zone has not been discovered in this part, there is a high possiblily of discovery of new mineralized zone.

2. South the Constanza Cu–Zn Geochemical Anomaly Area

The copper-mineralized zones are distributed at the south of Constanza surrounding the tonalite intrusive rock. These mineralized zones were extracted as the copper geochemical anomaly zones and the high score zones of the second factor.

3. Mata Grande and Diferencia Au Geochemical Anomaly Area

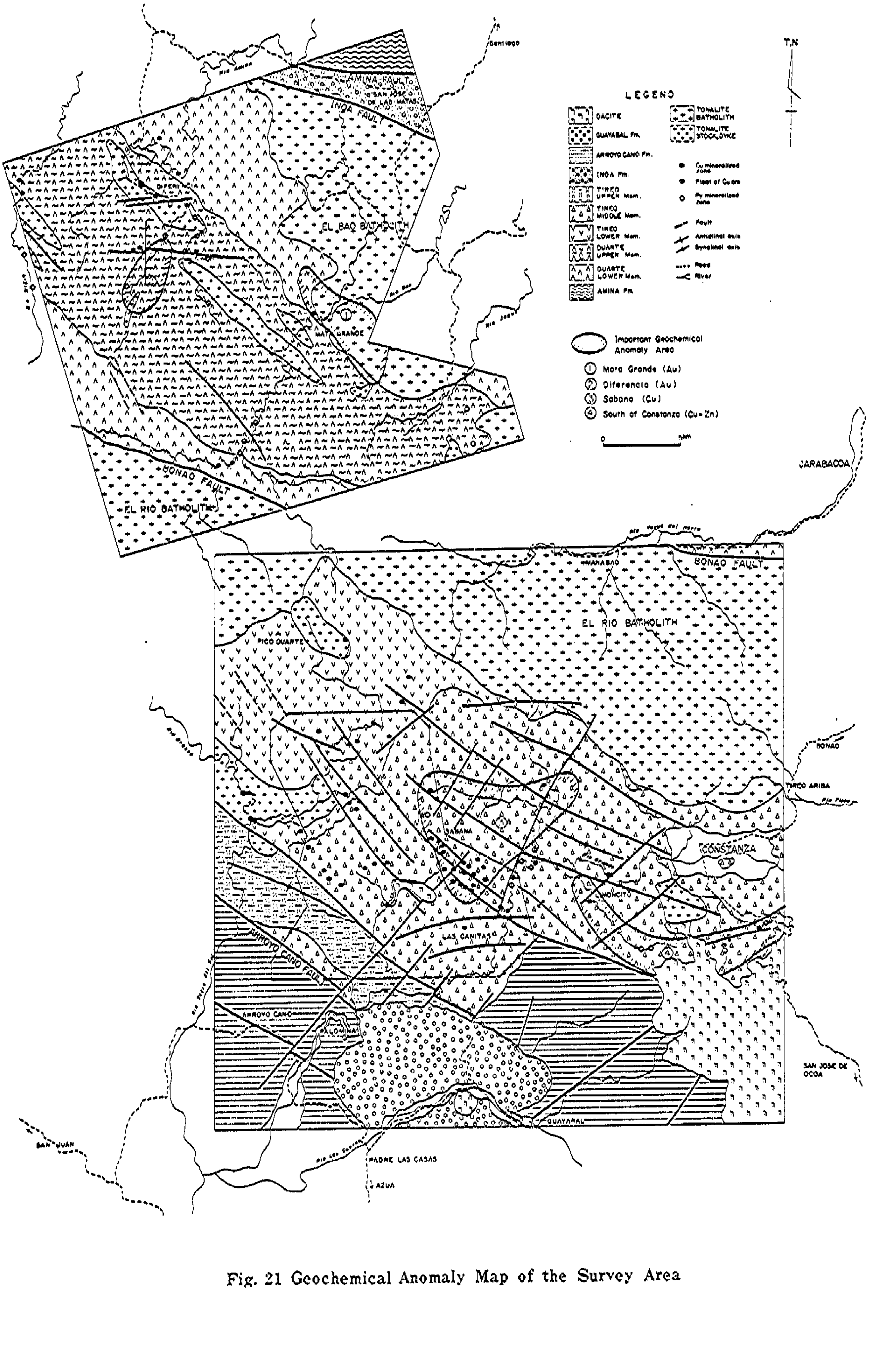


Fig. 21 Geochemical Anomaly Map of the Survey Area

Although the area is famour for the place of panning of placer gold, there are many points remained unclear as to the origin of gold.

In the Mata Grande area, the Au–1 and Au–2 geochemical anomaly zones are important from the density of concentration of anomalies.

The important geochemical anomaly zone is the Au–5 anomaly zone, because the density of concentration of anomalies is high, and the panning site of placer gold is located in the up-stream of the anomalies.

CHAPTER 4 CONCLUSION AND RECOMMENDATIONS

4–1 Conclusion

In the survey of the first phase, geological survey and geochemical prospecting were carried out for the purpose of extracting the high potential areas of occurrence of ore deposit by making clear the geology and ore deposit and the mutual relationship. The conclusions obtained by the survey are as follows.

1. The stratigraphy of the pre-Cretacous Duarte and the Cretaceous Tireo formations, which contain the horizons of mineralized zone, were established by the survey. The Duarte formation was divided into two members, the Tireo formation into three members, on the basis of the transition of igneous activity and the characteristics of rock facies. Further, it was made clear that the metallic ore deposits are emplaced from the middle Tireo member to the lower Duarte member, and especially that the mineralized zone are present most in abundance in the middle Tireo member.

2. The geologic structure of the area is composed of the major tectonic lines of WNW–ESE system which form the frame of the Hispaniola Island, the faults of NW–SE and NE–SW systems accompaning with the above and the fractures of NS and EW systems filled with epidote and quartz.

   The tectonic movement of the area is considered to be the lateral stress of NS direction and the former two faults seem to be the shearing and the third the tension nature. The vein-type deposits have been emplaced in the faults and the fractures of the second and the third categories.

3. The tonalite masses were divided into batholiths and stocks (or dykes). The stocks (or dykes) were divided into tonalite masses, granodiorite masses and quartz-plagioclase porphyry masses based on the rock facies. Because the ore deposits show a positional relaiton to the stocks (or dykes), it is thought that the mineralization has a genetical relation to the igneous activity.

4. The mineralizations of the area show three types of ore deposit such as copper vein, porphyry copper and pyrite dissemination. These mineralized zones have the positional relations to the tectonic lines of NW–SE system and/or the intrusive masses.

   (1) The vein-type mineralized zone includes copper-dominant type and copper, lead and zinc type. Most of the veins in the Sabana and the Mata Grande areas belong to the former and the veins located in the south of Constanza to the latter.

   (i) In the Sabana area, the copper veins occur in most abundance in the survey area. The mineralized zones are found 16 places in the area. The largest one among them is the new ore body discovered in the northern part. It has a maximum strike length of 16 meters at the outcrop, with the average width of 2.5 meters, showing the copper grade of about 2.5 percent. The mineralized zones of the area are generally distributed in the direciton of NW–SE.

(ii) The copper mineralized zones of the Mata Grande area are distributed showing a positional relation to the tonalite intrusive masses or the latent faults of NW--SE system. The important deposit in the area is the Mata Grande deposit. The outcrops of the vein 0.1 to 1.5 meters wide are traced for about one kilometer. A high-grade part showing 21.7% Cu is seen in a test pit.

(iii) The copper veins in the south of Constanza has a positional relationship with the tonalite stock, which surround it concentrically. The deposits mainly consist of copper, lead and zinc veinlets.

(2) The porphyry copper mineralized zone refers to the distributed zone of disseminated floats of copper and molybdenum which discovered in abundance in the terrain of granodiorite in the eastern part of Mt. Pico Duarte. The assay result of the sample showed 0.76% Cu.

(3) The mineralized zones of pyrite dissemination are the zones of pyrite concentration emplaced in the dacitic pyroclastic rocks in the Tireo formation at the south of Constanza and in green schist of the Duarte formation at the Mata Grande and Diferencia. An extent of one to several meters in thickness and about two kilometers in extension is shown in the south of Constanza. The distribution shows a positional relationship with the intrusives.

5. The time of mineralization is considered to be from late Cretaceous to before Oligocene because the ore deposits of the area have a relationship with the intrusive rocks intruded during the time of Laramide Orogeny, which is emplaced in the strata of late Cretaceous, and because round pebbles of ore composed of the mineralized Tireo formation were found in the Oligocene bed.

6. The result of geochemical survey well corresponds to the result of survey of geology and ore deposit. The main geochemical anomalies of copper and zinc are distributed in the Sabana area and the south of Constanza area. The gold anomalies are distributed in the Mata Grande area.

7. The favorable areas extracted by the geological survey and the geochemical survey are as follows.

(1) Sabana area: the area of occurrence of vein-type copper mineralized zones

(2) South of Constanza area: the area of occurrence of vein-type copper mineralized zones

(3) Pico Duarte area: the area of occurrence of porphyry copper mineralized zones

(4) Mata Grande ~ Diferencia area: the area of occurrence of vein-type copper mineralized zones and gold deposit

4–2 Recommendations

On the basis of the conclusion in the above, the following three areas were selected for the surveys in and after the second phase (Fig. 22).

1. Southwest of Constanza area

The area is that of occurrence of vein-type copper-mineralized zones including the Sabana area to the south of Constanza. A large number of outcrops of ore veins and geochemical anomalies are distributed in the area, in which the discovery of new ore deposit is expected.

Detailed geological survey and geochemical prospecting by soil are desirable as the survey of the second phase.

2. Pico Duarte area

The distributed area of the floats of typical porphyry copper-type ore, the first discovery in the Dominican Republic, is in the terrain of granodiorite intrusive, in which a favorable condition for prospecting is provided geologically.

To make clear the whole aspect of the deposit, it is desirable that detailed geological survey and geochemical survey by soil are used as the work of the second phase.

3. Mata Grande area

The Mata Grande deposit which is a typical vein-type copper deposit is relatively high in copper grade, and the outcrops of vein are scattered for about one kilometer. It needs to make clear the whole aspect of the deposit, and to probe the origin of gold in the gold-geochemical anomalies.

Therefore, detailed geological survey and geochemical survey by soil are desirable as the work of the second phase.

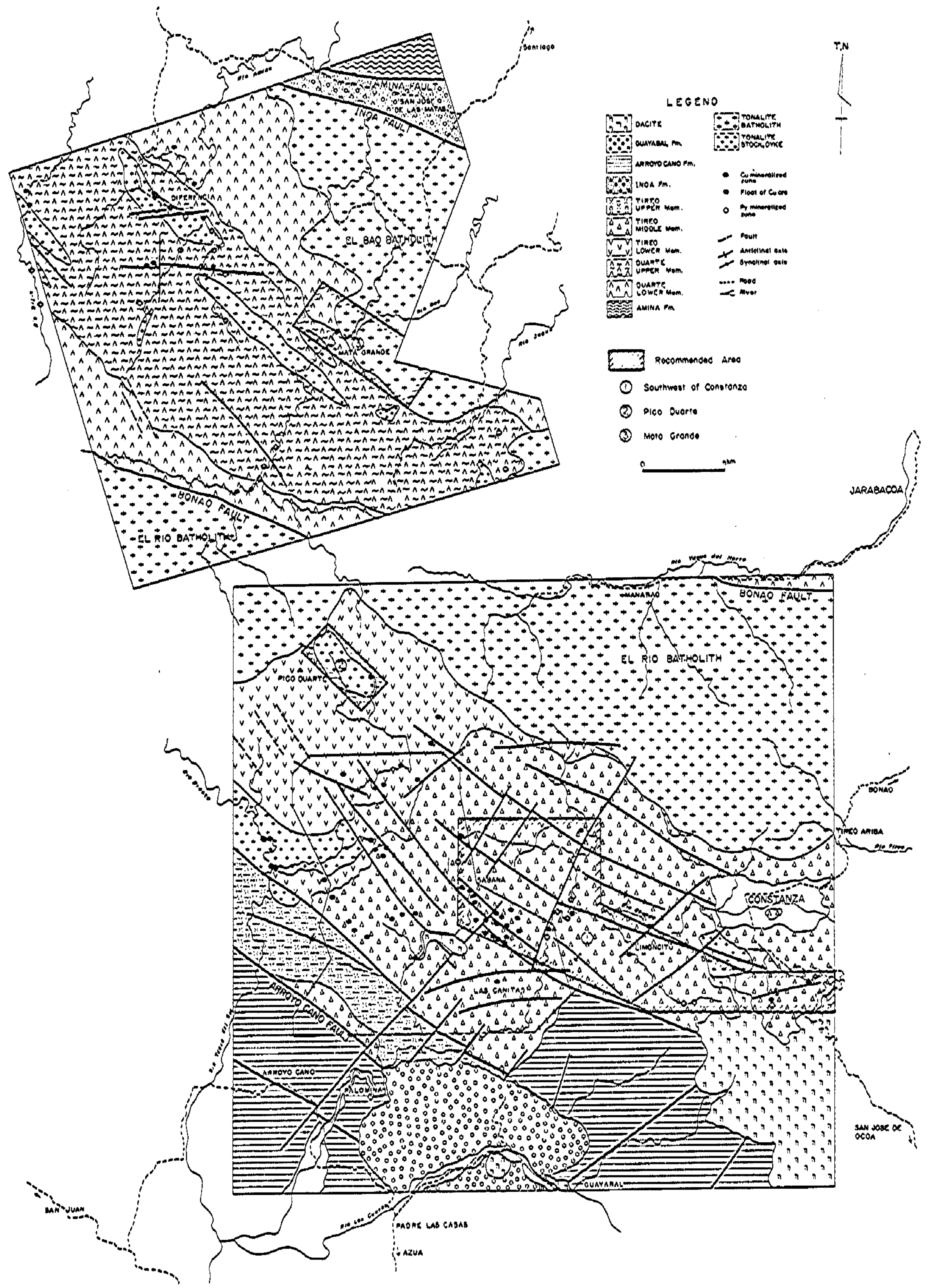


Fig. 22 Recommended Areas for Phase II Follow-up Work

REFERENCE

Barabas, A.H. (1982): Potassium-argon dating of magmatic events and hydrothermal activity associated with porphyry mineralization in west central Puerto Rico. Econ. Geol., 77, p109–126.

Bowin, C.O. (1960): Geology of Central Dominican Republic. Princeton Univ. Ph. D. Thesis, 211.

Bowin, C.O. and Nagle (1980): Igneous and metamorphic rocks of northern Dominican Republic: an uplifted subduction zone complex. 9th Caribbean Geological Conference, Santo Domingo, Dominican Republic, p39–50.

B.R.G.M. (1980): Exploracion minera del area Las Canitas. D.G.M., Santo Domingo, República Dominicana.

D.G.M. (1983): Estudio de Pre-factibilidad del Area Geotermica Yayas-Constanza. Santo Domingo, Republica Dominicana.

D.G.M. (1984): Resultados preliminares de los recientes trabajos de exploracion geotermica en la Republica Dominicana. Analysis de la demande Futura de expertos en esta area. Santo Domingo, Republica Dominicana.

Espaillat-Lamarche, J.E. (1981): The Mata Grande deposit. University College, Cardiff.

Khudoley, K.M. and Meyerhoff, A.A. (1971): Palaeogeography and geological history of Greater Antilles. Geol. Soc. America, Mem. 129, 199.

Lewis, J.F. (1980): Cenozoic tectonic evolution and sedimentation in Hispaniola. 9th Caribbean Geological Conference, Santo Domingo, Dominican Republic, p65–73.

Palmer, H.C. (1963): Geology of portion of North-Central Dominican Republic. Princeton Univ. Ph. D. Thesis, 256.

Walper, J.L. (1980): Geologic evolution of the Greater Antilles. 9th Caribbean Geological Conference, Santo Domingo, Dominican Republic, p11–21.

Watanabe, W. et al. (1972): Geochemical investigation in the Cordillera Central Dominican Republic. Min. Geol. Japan, 22, p177–190.

Watanabe, W. (1974) : Geology and Copper Mineralization of the Island of Hispaniola, Greater Antilles, West Indies. Min. Geol. Japan, 24, p323–333.

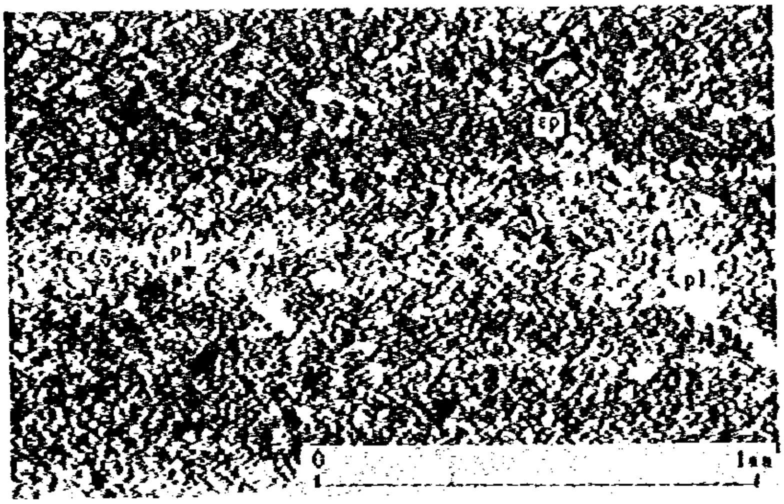
Woodring, W.P. (1954): Caribbean land and sea through the ages. Geol. Soc. America, Bull. 65, p719–732.

APPENDICES

Photo. 1 Microphotograph of Thin Section

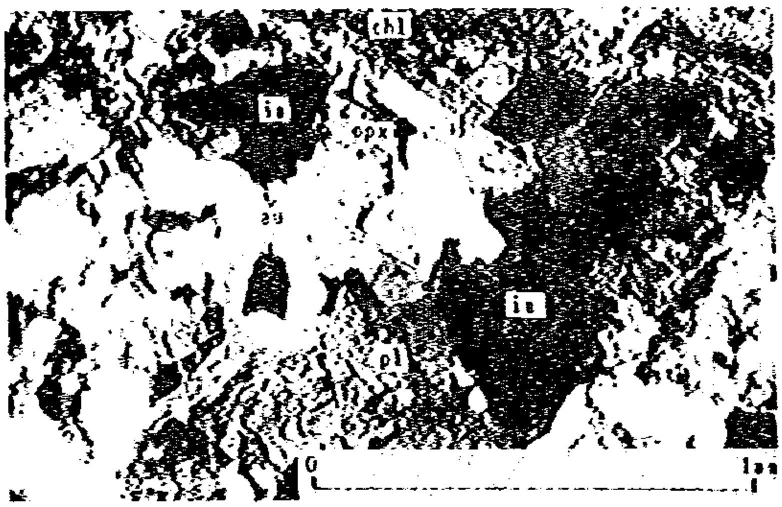
Abbreviation

qz	:	quartz
pl	:	plagioclase
au	:	augite
opx	:	orthopyroxene
hb	:	hornblende
bi	:	biotite
mus	:	muscovite
act	:	actinolite
ep	:	epidote
chl	:	chlorite
cal	:	calcite
ser	:	sericite
py	:	pyrite
im	:	iron mineral



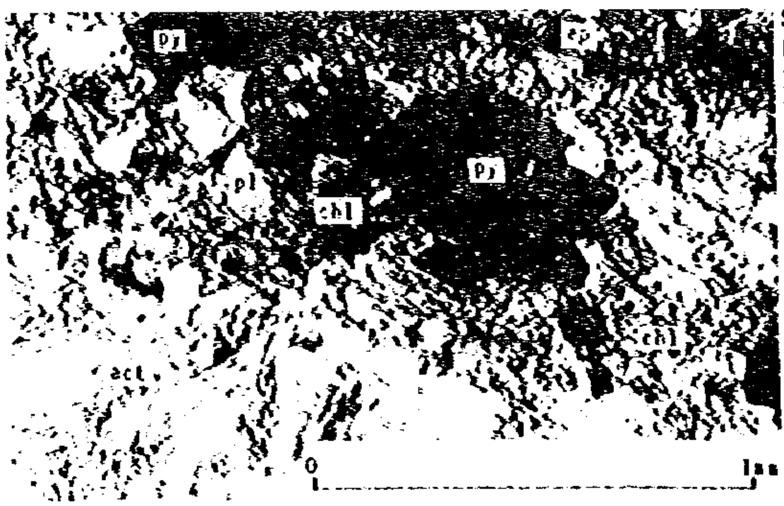
crossed polars

Sample No. : MK037
Location : San Jose de las Matas
Rock Name : mus-chl-ep-pl-schist (Ams)
Texture : lepidoblastic



crossed polars

Sample No. : MT006
Location : Rio Bao
Rock Name : metabasalt (Dlb)
Texture : schistose, phitic

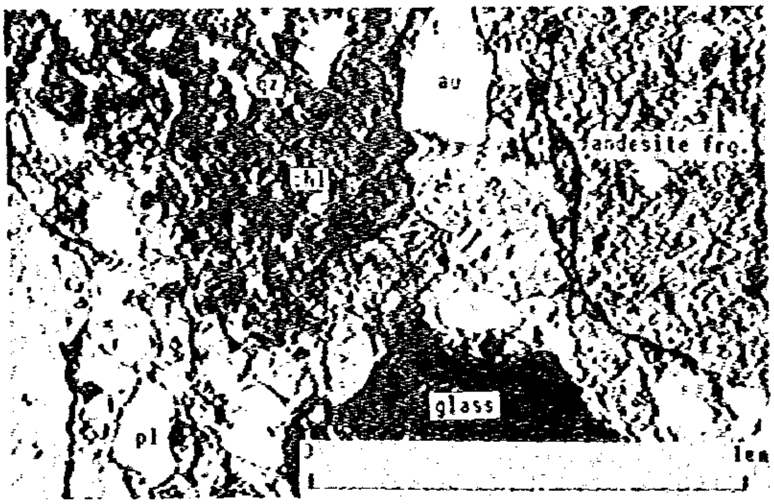


crossed polars

Sample No. : MT003
Location : Rio Bao
Rock Name : ep-chl-act-green schist (Dubt)
Texture : lepidoblastic

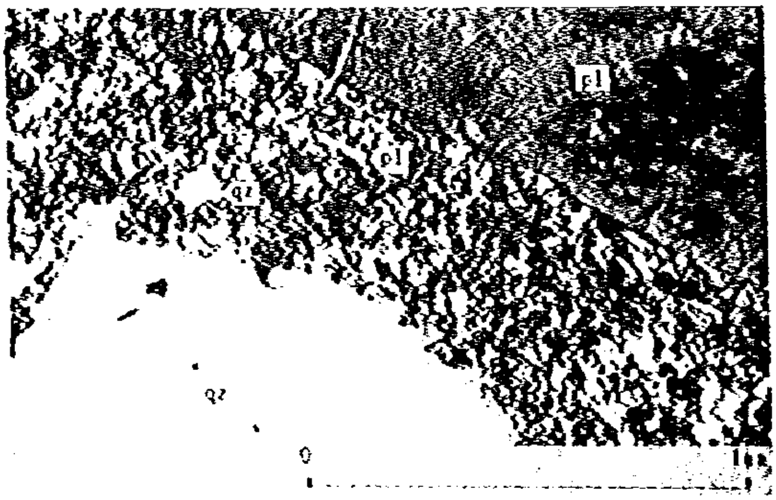
crossed polars

Sample No. : LT094
Location : Río Yaque del Sur
Rock Name : aug-andesite (Tla)
Texture : porphyritic, intergranular



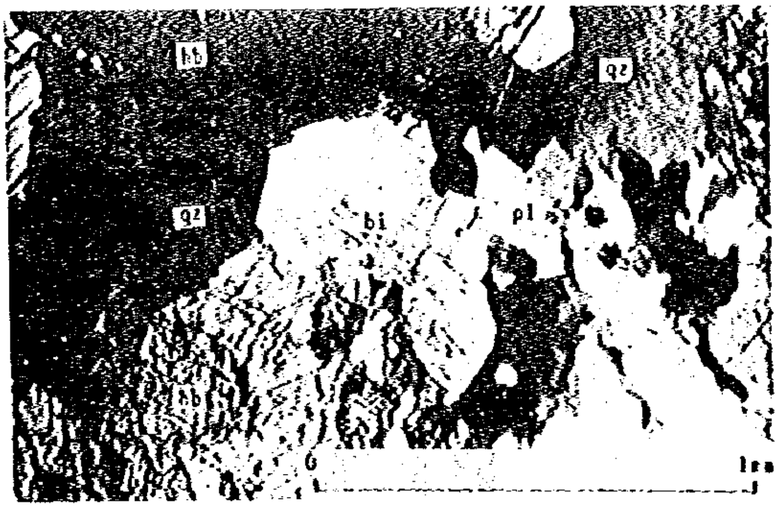
only lower polar

Sample No. : LA014
Location : Ar. Hondo
Rock Name : andestic lapilli tuff (Tmat)
Texture : pyroclastic



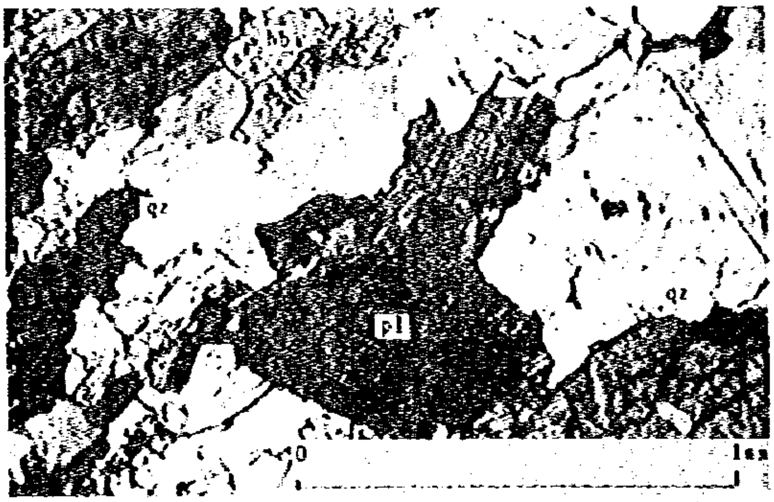
crossed polars

Sample No. : LK038
Location : Las Canitas
Rock Name : dacite (Tmd)
Texture : hyaline porphyritic



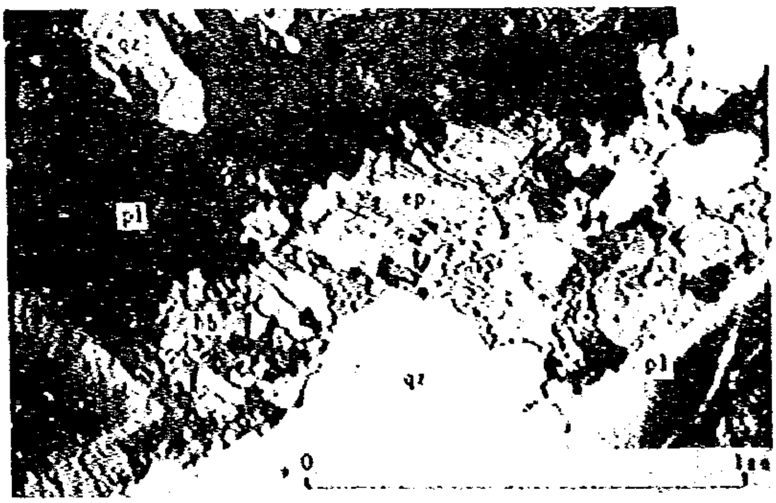
crossed polars

Sample No. : LH007
Location : El Rio batholith
Rock Name : bi-hb-tonalite (Tnb)
Texture : holocrystalline, equigranular



crossed polars

Sample No. : MS006
Location : El Bao batholith
Rock Name : hb-tonalite (Tnb)
Texture : holocrystalline, equigranular



crossed polars

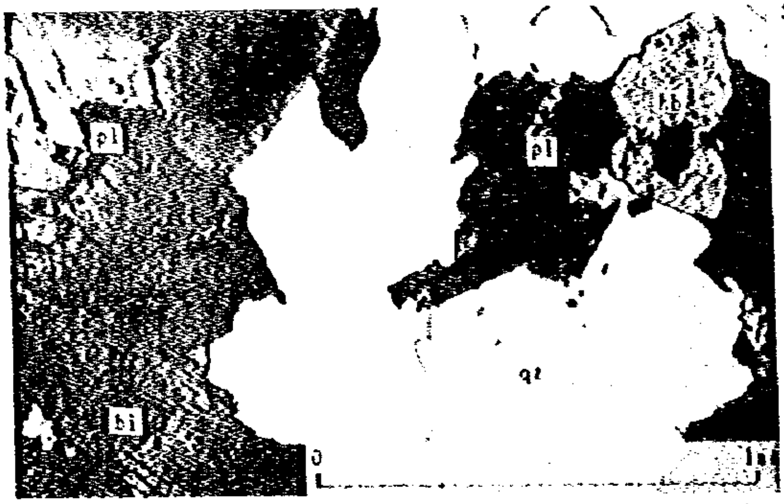
Sample No. : MA050
Location : Rio Amina
Rock Name : schistose hb-tonalite (Tns)
Texture : schistose, holocrystalline, equigranular

crossed polars

Sample No. : LK009
Location : Southwest of Constanza
Rock Name : hb-tonalite (Tns)
Texture : holocrystalline, equigranular

crossed polars

Sample No. : LT038
Location : Rio Yaque del Sur
Rock Name : porphyritic hb-tonalite (Tnp)
Texture : holocrystalline, porphyritic



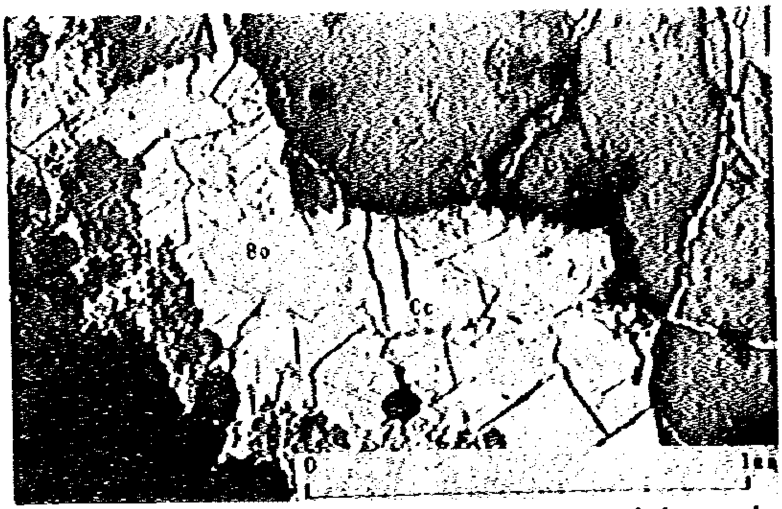
crossed polars

Sample No. : LH091
Location : Pico Duarte
Rock Name : hb-bi-granodiorite (Gd)
Texture : holocrystalline, equigranular

Photo. 2 Microphotograph of Polished Section

Abbreviation

Py	:	Pyrite
Sph	:	Sphalerite
Gl	:	Galena
Cp	:	Chalcopyrite
Bo	:	Bornite
Cc	:	Chalcocite
Cv	:	Covelline
Mal	:	Malachite
Spc	:	Specularite
Hm	:	Hematite
Mt	:	Magnetite
Lm	:	Limonite



Sample No. : LK040
Location : Tasajera (T–2)
Ore Name : Spc-Cv-Bo-Cc-Ore

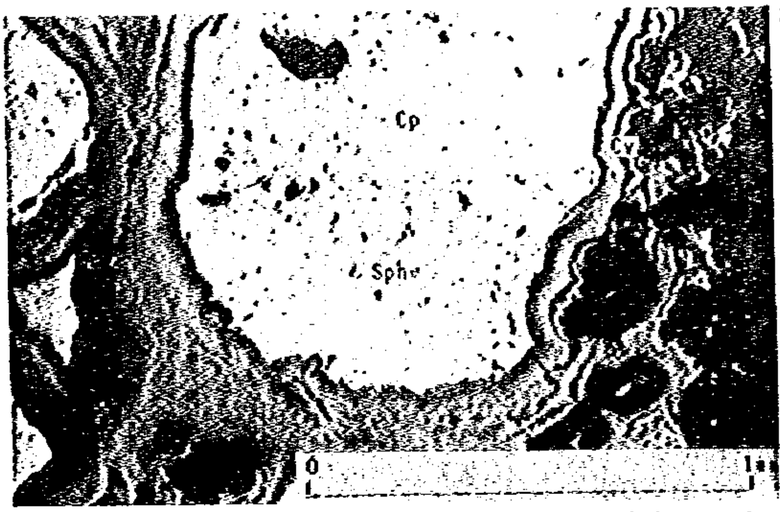
only lower polar

Sample No. : LK042
Location : Tasajera (T–3)
Ore Name : Cv-Lm-Cp-Ore

only lower polar

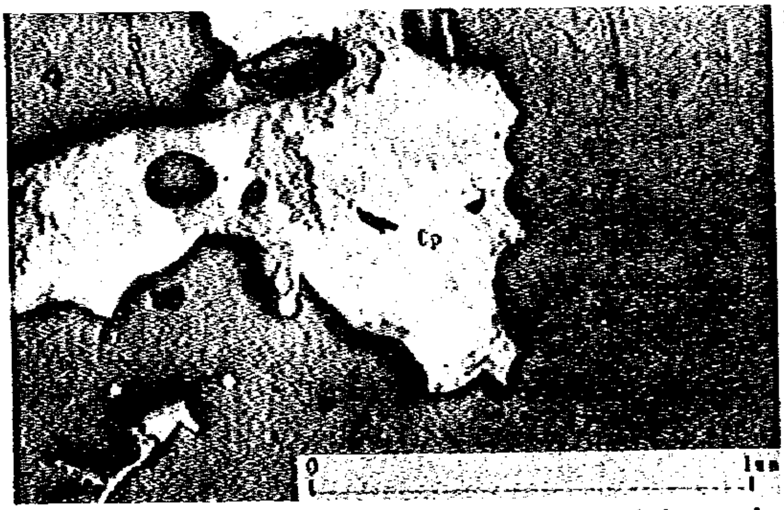
Sample No. : LH060-1
Location : Tasajera (T–1)
Ore Name : Cv-Bo-Mal-Cp-Spc-Ore

only lower polar



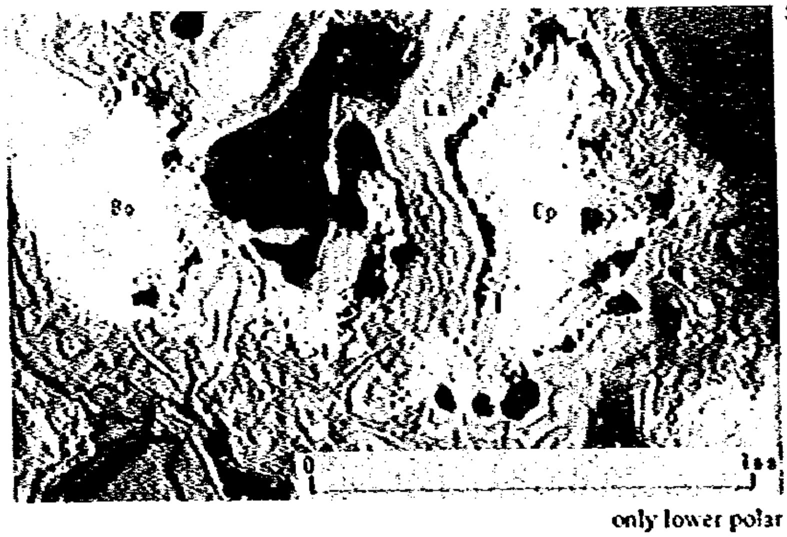
only lower polar

Sample No. : LK045
Location : Sabana (S-1)
Ore Name : Cv-Sph-Mal-Spc-Cp-Ore



only lower polar

Sample No. : LH064-2
Location : Sabana (S-2)
Ore Name : Mal-Bo-Cp-Ore



only lower polar

Sample No. : LT087
Location : Pico Duarte (P-1)
Ore Name : Cv-Bo-Cp-Ore

Table A-1 Result of Thin Section Examination

(1)

Metamorphic rocks

No.	Sample No.	Location	Rock Name	Texture	Quartz	Plagioclase	Augite	Orthopyroxene	Actinolite	Epidote	Chlorite	Pumpellyite	Muscovite	Calcite	Sericite	Pyrite	Iron Mineral	Remarks
1	MK037	San Jose de las Matas	Mus-chl-ep-pl-schist (Ams)	Lepidoblastic		A				C	L		L					
2	MK038	do.	Chl-ep-pl-qz-schist (Ams)	do.	A	A				L	L							
3	MA053	Diferencia	Metabasalt (Dib)	Schistose, ophitic		A	C	L		C	C			L	L		L	
4	MT002	Rio Bao	do.	do.		A	C	L		C	C			L	L		L	
5	MT006	do.	do.	do.		A	C	L		C	C			L	L		L	
6	MS022	Rio Jagua	do.	Porphyroblastic	A	C				L								Amphibole: A
7	MT008	Rio Bao	Ep-chl-act-schist (Dubt)	Lepidoblastic		C			A	L	C	L				L		Py disseminated
8	MS013	Mata Grande	Metabasalt (Dub)	Schistose, ophitic		A	C	L		C	C				L		L	

Igneous rocks (2)

No.	Sample No.	Location	Rock Name	Texture	Phenocryst: Quartz	Phenocryst: Plagioclase	Phenocryst: Hornblende	Phenocryst: Biotite	Phenocryst: Augite	Phenocryst: Iron Mineral	Groundmass: Quartz	Groundmass: Plagioclase	Groundmass: Volcanic glass	Groundmass: Iron Minerals	Secondary Mineral: Epidote	Secondary Mineral: Chlorite	Secondary Mineral: Sericite	Secondary Mineral: Calcite	Secondary Mineral: Quartz and silica mineral	Remarks
9	LT063	Rio Yaque del Sur	Aug-andesite (Tla)	Porphyritic, intergranular		C			C			Λ		L	L	L	L	L	L	Lava, altered
10	LT094	do.	do.	do.		C			C			Λ		L	L	L	L			Lava
11	LK038	Las Canitas	Dacite (Tmd)	Hyaline, porphyritic	C	C	C				C	C	L	L			L		C	Lava
12	LT055	Loma de Tasajera	do.	do.	C	C	C				C	C	L	L			L		L	Lava
13	LG042	South of Constanza	Dacite (Da)	do.	L	L	C				C	C	L	L						Lava
14	LH007	Constanza	Bio-hb-tonalite (Tnb)	Halocrystalline, equigranular	Λ	Λ	C	L		L					L	L	L			El Rio batholith
15	LT029	Manabao	do.	do.	Λ	Λ	C	L		L					L	L	L			do.
16	MT005	Rio Bao	do.	Schistose, equigranular	Λ	Λ	C			L					L	L	L			do.
17	MS006	Mata Grande	Hb-tonalite (Tnb)	Halocrystalline, equigranular	Λ	Λ	C	L		L					L					El Bao batholith
18	MA050	Rio Magua	Schistose hb-tonalite(Tns)	do.	Λ	Λ	L			L					L					Stok
19	LK009	Rio Grande	Hb-tonalite (Tns)	do.	Λ	Λ	L			L					L	L	L	L		do.
20	LH043	Sabana	Pl-qz-porphyrite (Tnp)	Porphyritic, halocrystalline	Λ	Λ	L			L					L		L			Dyke
21	LT038	Rio Branco	Porphyritic hb-tonalite (Tnp)	do.	Λ	C	L			L					L	L	L			Stok
22	LH091	Pico Duarte	Hb-bi-granodiorite (Gd)	Halocrystalline, equigranular	Λ	Λ	L	C		L					L	L	L			Stok, Ptash feldspar: L
23	LT085	Rio Yaque del Sur	do.	do.	Λ	Λ	L	L		L					L	L	L		L	Stock do.
24	LT040	Rio Branco	Aug-basalt	Porphyritic, intergranular					L			Λ		L	L	L			L	Dyke
25	LK084	Ar. Guarico	Dolerite (Do)	Ophitic		Λ			C				C	L		L				Sheet

Pyroclastic rocks

(3)

No.	Sample No.	Location	Rock Name	Texture	Fragment							Matrix			Secondary Mineral					Remarks
					Andesite	Andesitic tuff	Dacite	Volcanic glass	Quartze	Plagioclase	Augite	Volcanic glass	Pyrite	Hematite	Quartz and silica mineral	Epidote	Chlorite	Calcite	Sericite	
26	LA014	North of Constanza	Andestic lap-tuff (Tma)	Pyloclastic	A	L		L		L	L	L		C	L	L	L	L		Alterd
27	LT056	Loma de Tasajera	do.	do.	A		L			L	L	L			L	L				do.
28	LT057	do.	do.	do.	A		L			L	L	L			L	L				do.
29	LA041	South of Constanza	Dacitic tuff (Tmdt)	do.					A	L		L	L		L				L	Silicified, Py disseminated
30	LK058	Ar. Limon	Andestic coarse tuff (Tus)	do.	A					L		L			L		L		L	Shale frg: L

Sedimentary rocks

(4)

No.	Sample No.	Location	Rock Name	Fragment			Matrix			Remarks
				Metabasalt	Green schist	Quartz	Quartz	Sericite	Calcite	
31	LS013	Palomia	Shale (Tus)				C	A		Taffaceous
32	LK057	Ar. Limon	Limestone (Tus)				C	L	A	Mudy
33	MK035	Rio Inoa	Conglomerate (Inc)	A	L	L	L		L	Pebble size
34	LK087	South of Constanza	Limestone (Al)				C		A	With fossil

Abundant : A Common : C Little : L

Table A-2 Result of Polished Section Examination

No.	Sample No.	Location (Mineralized Zone No.)	Ore Name	Pyrite	Sphalerite	Galena	Chalcopyrite	Bornite	Chalcocite	Covelline	Malachite	Specularite or Hematite	Magnetite	Limonite	Molybdenite
1	LH023	Pinar Bonito (C-1)	Gl-Py-Sph-Cp-Ore	L	C	L	C								
2	025	do.	Spc-Cp-Sph-Py-Ore	A	C		L					L			?
3	027	do.	Cv-Gl-Cp-Ore			L	A			L					
4	042	Fortuna (S-4)	Py-Mal-Ore	L							C				
5	057	Roblito (S-3)	Spc-Ore									A			
6	060-1	Tasajera (T-1)	Cv-Bo-Mal-Cp-Spc-Ore				C	L		L	L	A			
7	060-2	do.	Spc-Bo-Cv-Cp-Ore				C	L		L		L			
8	064-1	Sabana (S-2)	Sph-Py-Bo-Cp-Ore	L	L		A	L							
9	064-2	do.	Bo-Cp-Ore				C	L							
10	LK040	Tasajera (T-2)	Spc-Cv-Bo-Cc-Ore					L	A	L	L				
11	042	Tasajera (T-3)	Cv-Lm-Cp-Ore				C			L				L	
12	045	Sabana (S-1)	Cv-Sph-Mal-Spc-Cp-Ore		L		A			L	L	C			
13	LA042	Ar. Limoncito (C-5)	Py-Ore	A											
14	055	do.	Py-Ore	A											
15	LT009	Pinar Bonito (C-2)	Cp-Sph-Py-Ore	A	L		L								
16	041	Rio Branco (B-2)	Hm-Py-Cp-Mt-Ore	L			L				L	L	A		
17	060	Tasajera (T-4)	Cv-Sph-Cp-Ore		L		C			L					
18	087	Pico Duarte (P-1)	Cv-Bo-Cp-Ore				L	L		L					
19	LG020	Rio Grande (SS-3)	Py-Ore	C											
20	LG033	Ar. Guarico (G-1)	Py-Ore	C											
21	MH002	Mata Grande (M-1)	Cv-Bo-Cp-Ore				A	C		L					
22	003-1	do.	Cv-Bo-Mal-Cc-Ore					L	C	L	L				
23	003-2	do.	Bo-Cc-Cv-Mal-Cp-Ore				C	L	L	L	L				
24	003-3	do.	Cv-Bo-Cp-Mal-Ore				L	L		L	L				
25	MG003	Diferencia (D-1)	Cv-Cp-Ore				C			L					

Table A-3 List of Main Mineralized Zones in the Survey Area

Ser. No.		Name and/or Number of Mineralized Zone	Kind of Ore	Type	Location	Host Rock	Structure and Scale of Mineralized Zone: Strike and Dip	Lateral Extension	Average Width	Grade: Au (g/T)	Ag (g/T)	Cu (%)	Pb (%)	Zn (%)	Description of Samples	Ore Minerals	Sample No.
1	Sabana Area	Sabana (S-1)	Cu	Vein	Sabana	Andesitic lap. tuff	N40°E, 20°N	8m	1.50m	0.1	0.7	2.15	0.03	0.02	High grade ore from Pit No.1	Mal, Cc, Bo, Spc, Lm,	LK046
								10m	7～8m	tr.	tr.	3.02	0.03	0.02	High grade ore from Pit No.7	do.	LK050
										tr.	tr.	0.93	0.04	0.05	Ore from Pit No.7	do.	LK052
2		Sabana North New Orebody (S-2)	do.	do.	do.	do.	N50°E, 20°N	16m	2.5m	0.5	8.9	2.35	0.06	0.02	Sampling width: 4.0m	Mal, Cc, Bo, Cv, Cp, Py, Spc, Lm,	LH064-1
										0.5	15.2	2.86	0.04	0.02	Sampling width: 2.8m	do.	LH064-2
										4.3	12.1	4.00	0.02	0.02	Ore	do.	LK043
3		Roblito (S-3)	do.	do.	Ary. Fortuna	do.	N30°E, 40°S N50°W, 40°N N80°E, 75°N	+3m	0.35m	0.3	2.8	2.84	0.04	0.02	Mineralized zone from Pit No.3 Sampling width: 0.35m	Mal, Py, Spc, Lm,	LH057
4		Fortuna (S-4)	do.	do.	do.	do.	N60°E, 65°N	+3m	1.10m	tr.	tr.	1.41	0.05	0.05	Mineralized zone from Pit No.1 Sampling width: 1.10m	Mal, Spc, Lm,	LH039
								+5m	0.50m	0.2	2.3	3.96	0.08	0.05	Mineralized zone from Pit No.3 Sampling width: 0.50m	do.	LH042
5	Constanza Area	Pinar Bonito (C-1)	Cu-Pb-Zn	do.	South of Constanza	Andesitic lap. tuff	N60°E, 60°N	10m	1.50m	0.3	7.9	0.97	5.62	0.05	A vein in the mineralized zone Vein width: 0.10m	Cp, Gl, Sph, Mal, Cv, Py, Spc,	LH027
							N20°W, 60°N	+2m	0.10m	0.2	2.1	0.96	0.90	2.26	Vein width: 0.10m	do.	LH023
6		C-2	do.	do.	do.	do.	N65°E, 20°N	several m	0.60m	0.1	0.7	0.18	0.07	1.14	Vein width: 0.60m	Mal, Cp, Sph, Py, Spc,	LT012
							N65°E, 50°N	do.	0.10m	0.3	3.9	1.57	0.06	0.05	Vein width: 0.10m	do.	LT014
7		Limoncito (C-3)	Cu	do.	S.W. of Constanza	do.		200m	80m	0.2	3.4	0.96	0.05	0.02	Ore	Mal, Cv, Spc, Lm,	LH012
										0.2	2.3	2.98	0.08	0.02	Ore	do.	LH016
8		C-4	do.	do.	do.	Andesite	N50°E, 50°N	several m	5m	0.4	5.3	2.63	0.02	5.70	Ore	Mal, Cp, Sph, Py, Lm,	LH025
9		C-5	Py	Dissemination	do.	Dacitic lap. tuff		2km	(Thickness) (1～several m)	tr.	tr.	0.06	0.03	0.05	Ore	Py,	LA042
10	Other Areas	Tassjera (T-1)	Cu	Vein	Ary. Limon	And., andesitic lap. tuff		+1m		0.2	2.3	4.36	0.05	0.02	High grade ore from trench No.1	Mal, Cc, Cv, Spc,	LH060
11		T-2	do.	do.	do.	do.	N50°W, 20°N	+1m	0.15m	tr.	tr.	4.21	0.23	0.20	Ore	Mal, Cc, Cv, Cp, Bo, Spc,	LK040
12		P-1	do.	Porphyry Cu	Pico Duarte	Granodiorite				0.5	3.5	0.76	0.02	0.02	Ore	Cp, Cc, Bo, Mal, Cv, Mo, Py, Lm,	LT037
13		Mata Grande (M-1)	do.	Vein	Mata Grande	Greenschist, tonalite	N60°～80°W, 40°～85°N	1km		tr.	tr.	1.07	0.03	0.01	Ore	Cp, Cc, Bo, Mal, Cv, Py, Lm, Spc,	MH001
										1.0	32.9	21.69	0.12	0.00	Ore	do.	MH002
14		B-1	do.	do.	Rio Branco	Tonalite	N-S, 90° EW 40°N	several m	0.04m	0.8	17.7	3.59	0.09	0.02	Ore	Mal, Cp, Py, Mt, Spc,	LT039

Abbreviation

Bo :	Bornite	Mal :	Malachite
Cc :	Chalcocite	Mt :	Magnetite
Cp :	Chalcopyrite	Py :	Pyrite
Cv :	Covelline	Spc :	Specularite
Gl :	Galena	Sph :	Sphalerite
Lm:	Limonite		