REPORT ON GEOLOGICAL SURVEY

OF

LAS CANITAS AREA

DOMINICAN REPUBLIC

CONSOLIDATED REPORT

MARCH 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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 International 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 was performed for three years from fiscal 1983 to 1985.

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

This report is the compilation of the survey of Phase I, II and III.

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.

February 1986

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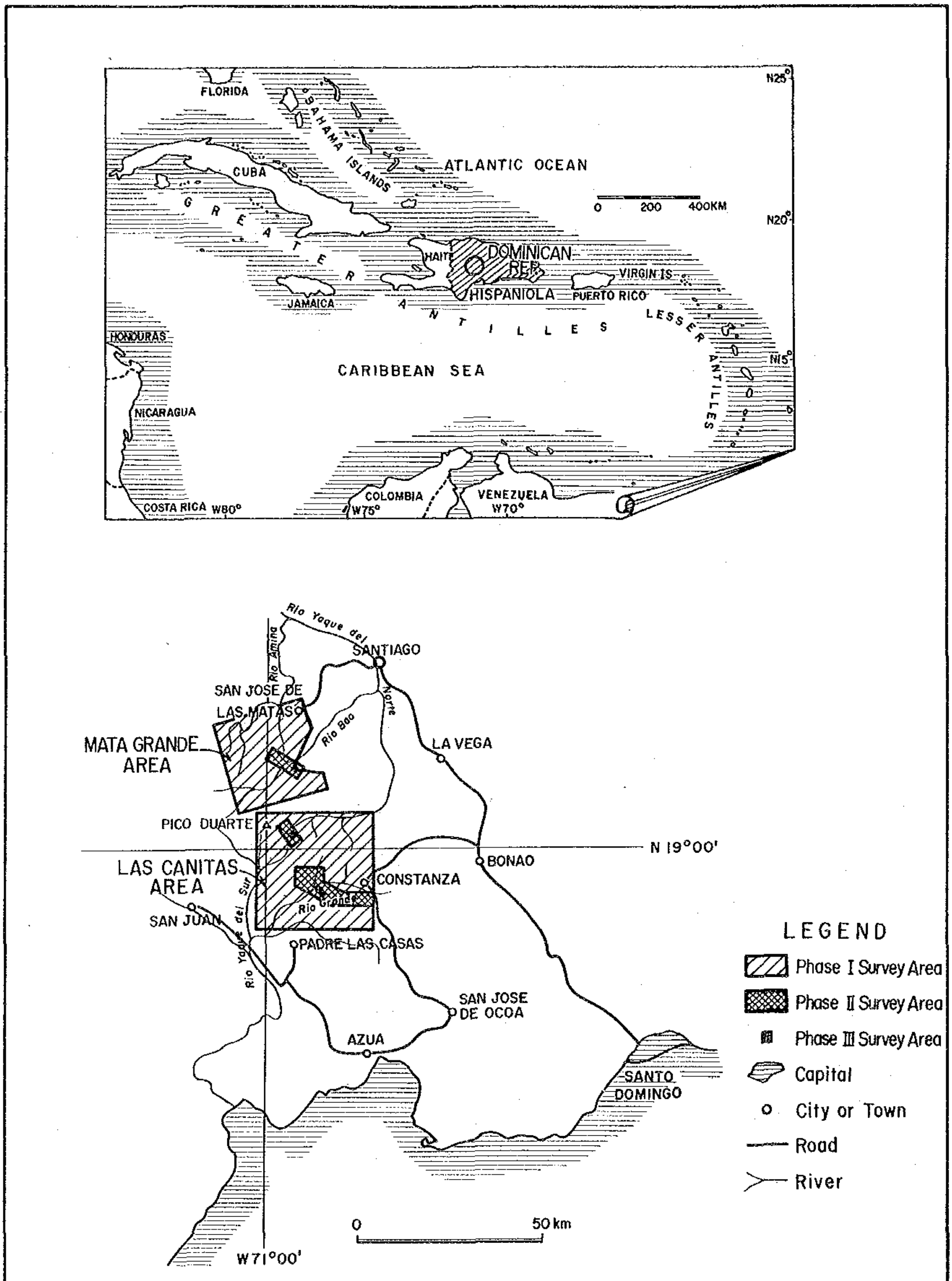

Fig. 1 Location Map of the Survey Area

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ABSTRACT

The project, "Collaborative Mineral Exploration in the Las Canitas area" in the Dominican Republic was conducted for three years from fiscal 1983. The purpose of the project is to evaluate the possibility of development of the ore deposit by extracting the promising area by illuminating the characteristics of stratigraphy, geologic structure, igneous activity and mineralization, and elucidating the relationship between them.

In the first phase, geological survey and geochemical survey (stream sediment) were carried out in order to grasp the outline of stratigraphy, geologic structure, igneous activity and mineralization in the survey area of about 2,000 square kilometers.

As a result, it was made clear that the pre-Cretaceous Duarte formation could be divided into two members, the Cretaceous Tireo formation into three members, and the tonalite masses into batholiths and stocks (or dykes), and also the relationship between the horizon of mineralized zones · igneous rocks and mineralization became clear.

It was defined that the mineralized zones distributed in the survey area was classified into three types such as vein, porphyry copper and pyrite dissemination and that the mineralization was related to the tectonic lines of NW-SE system and/or tonalite stocks (or dykes).

In the second phase, geological survey and geochemical survey (soil) were conducted in three areas selected in the first phase, and the new outcrops of copper vein-type and porphyry copper-type mineralization were discovered. In the Constanza area, the copper vein-type mineralization at El Gramoso and Hato de Los Rodrigues which are associated with the NW-SE tectonic lines and/or the tonalite intrusive masses, and the copper and copper-lead-zinc vein-type mineralized zones in the south of the Constanza, were discovered.

In the Pico Duarte area, porphyry copper-type mineralization was discovered in granodiorite.

In the Mata Grande area, it became clear that the copper veins were composed of three veins arranged in a form of echelon.

In the third phase, the surveys were conducted in the Constanza area and the Pico Duarte area of the promising mineralized zones selected in the second phase. Geological and drilling surveys were performed in the former and geophysical survey in the latter.

It was made clear that the copper vein-type mineralized zones at El Gramoso in the Constanza area had the center in the vicinity of the top of Mt. Loma Sito Grande and that it was related to the tonalite intrusive mass. The two drill holes out of five drilled encountered the veins which were much the same quality as the outcrops.

As the result of geoelectric survey by SIP method for the porphyry copper-type mineralized zone in the Pico Duarte area, the scale of silicification zone associated with the mineralization, was made clear.

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 metalic deposits in the Las Canitas area which has the highest potential of occurrence of metalic 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 the 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 the project 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, geologic 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 mutal relationship between the mineralization and geology, geologic structure and igneous activity, were taken up as the major subjects, which resulted in the execution of geological, geochemical, geophysical and drilling surveys.

CHAPTER 2 OUTLINE OF THE SURVEY

2-1 Outline of the Survey Area

The survey area is situated at the center of the Cordillera Centra 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 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.

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 Crande 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 Dominican republic.

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 pyrocrastics 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 was conducted for an extent of 1,953 km^2 of the Las Canitas area for three phase from 1983.

The survey began with reconnaissance survey of regional scale, then was stepped up successively to semi-detailed and detailed surveys, narrowing down the areas to promising ones.

The survey methods includes geological, geochemical, geophysical and drilling surveys, which were conducted properly in compliance with the stage of exploration. The survey methods in each phase were as in the following.

2–2–1 Survey in the First Phase

Geological and geochemical surveys were performed with the purpose of obtaining the guideline of survey in future by recognizing the outline of geology, geologic structure, igneous activity and mineralization, and geochemical characteristics.

Geological survey was made for semi-detailed survey area (180 km^2) in the central part of the Las Canitas area and other reconnaissance survey area, along the routes selected based on the study of existing data, and the results were compiled to 1 : 25,000 scale geological map for the semi-detaled area and 1 : 50,000 scale for the reconnaissance survey area.

Geochemical survey was carried out by samples of stream sediment along the main rivers and creeks in the whole survey area, and single component and multivariate analyses were conducted for selecting the promising areas.

The outcomes from the above resulted in to make clear the stratigraphy and the relationship between igneous activity and mineralization. That is, it became clear that the mineralized zones were distributed in association with the northwesterly trending tectonic lines and acidic intrusive rocks and that they occurred most predominantly in the middle member of the Tireo formation. In addition, the boulders of porphyry copper-type ore, chalcopyrite dissemination in granodiorite, was discovered in a creek at the southern foot of Mt. Pico Duarte, which suggested the necessity to trace the source in the upstream.

These results as well as the geochemical anomalies led to extract the three promising areas for occurrence of ore deposit in the area of about 181 km^2 in total.

2–2–2 Survey in the Second Phase

In the survey of the second phase, geological survey and soil geochemistry were conducted to select the promising area for occurrence of ore deposit in the following three areas.

Geological survey was made for the entire survey areas to grasp the relationship between the mineralized zones and the stratigraphy, geologic structure and igneous activity, and also the regularity of the location of mineralized zones. In the geochemical survey, soil samples (B-bed) were collected to analize single component and multi-variates, having led to detect geochemically anomalous zones.

1. **Constanza Area**

Geological survey was done over the whole survey area of 140 km^2, and the detailed data on geology and ore deposit were collected. Geochemical survey was performed for an extent of about 90 km^2 putting emphasis on the areas distributed by the mineralized zones and the geochemically anomalous zones. It is worthy of special mention that numerous outcrops of ore vein were discovered at El Gramoso and Hato de Los Rodrigues.

2. **Pico Duarte Area**

Geological, geochemical and magnetic susceptibility surveys were carried out for the whole survey area to confirm the outcrop of porphyry copper-type mineralization and to make clear the occurrence of mineralized zones and alteration zones.

3. **Mata Grande Area**

Geological survey was carried out for the whole survey area of 26 km^2, and in geochemical survey, samples were collected in the direction perpendicular to the trend of the Mata Grande veins in a form of grid, having resulted in to elucidate the occurrence of the Mata Grande veins.

2–2–3 Survey in the Third Phase

The following surveys were conducted in the third phase in the promising areas extracted in the first and second phases to illuminate occurrence of the ore deposit.

1. **Constanza Area**

Detailed geological survey was carried out in the whole survey area of 6 km^2 with the excavation of five trenches, having resulted in to make clear the relationship between the mineralization and geologic structure, and the igneous activity. In addition, drilling was made at five sites to evaluate the scale of the mineralized zones.

2. **Pico Duarte Area**

Geoelectrical survey by spectral IP method was made in the area to make clear the lateral and downward extension of the mineralized zone.

2–3 Members of the Survey Team

The personnel who participated in this survey are shown in Table 2.

Table 1 Outline of Field Work in Phase I, II and III

Item	Phase I	Phase II	Phase III
Survey Period	Nov 23 ~ Dec. 29, 1983	Aug. 1 ~ Oct. 16, 1984	Jul. 18 ~ Nov. 13, 1985
Geological Survey	Nov. 23 ~ Dec. 29, 1983	Aug. 1 ~ Oct. 16, 1984	Jul. 18 ~ Oct. 27, 1985
Area Surveyed	1,953 km^2	181 km^2	6 km^2
Length of Route Traversed	540 km	310 km	46.2 km
Geochemical Survey	Nov. 13 ~ Dec. 29, 1983	Aug. 1 ~ Oct. 16, 1984	–
Area Surveyed	1,953 km^2	131 km^2	
Stream Sediment Samples Collected	1,968	–	
Soil Samples Collected	–	962	
Geophisical Survey	–	–	Jul. 18 ~ *Sep. 2, 1985*
Spectral I.P. Method			
Total Length Surveyed			6.5 km
Drilling Exploration	–	–	Jul. 28 ~ Nov. 13, 1985
Number of Holes			5
Total Length Drilled			1,002.5 m

Table 2 List of the Survey Members

		Phase I	Phase II	Phase III
Japanese Member (MMAJ)	Planning and Negotiation	Katsuzo Sawaya Takashi Ogitsu Tadaaki Ezawa Hideki Okamoto Yozo Baba	Yasuhisa Yamamoto Yozo Baba Yoshiyuki Kita Tsuyoshi Ogitsu	Makoto Ishida Toshio Sakasegawa Tadaaki Ezawa Akio Hoshino
	Geological Survey	Hideo Kuroda Kazuo Kawakami Atsuyuki Endo Hiroshi Takahashi	Hideo Kuroda Yoshinori Tsuguma Hiroshi Takahashi	Hideo Kuroda
	Geophysical Survey	–	–	Tomio Tanaka Masatane Kato Hiroshi Takahashi
	Drilling Survey	–	–	Mahito Hamazaki Shigeo Sekiguchi Teruo Omori
Dominican Member (DGM)	Planning and Negotiation	Miguel A. Peña Gerald M. Eellis Ramón E. Ramíres Orlando A. Pizana	Miguel A. Peña Alejandro Alejandro Ramón E. Ramíres	Alejandro Alejandro Victor Montero Ramón E. Ramíres Victor M. Garcia
	Geological Survey	Hector R. Santos Victor M. Gracia	Hector R. Santos Victor M. Garcia Giovanni Bloise	Octavio Lopéz José A. Pérez
	Geophysical Survey	–	–	José Santilises
	Drilling Survey	–	–	Angel D. Sato Publio Casilla

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 he 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 system side of the Cordillera Central. In the Mata Grande and, 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 Falonbridge 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.

II. GEOLOGICAL SURVEY

CHAPTER 1 OUTLINE OF REGIONAL GEOLOGY

1–1 General Geology of Dominican Republic

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

The Hispaniola Island composes a part of the Greater Antiles together with the island 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 Cordilera 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 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 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 constrast 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 periotite 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 Quaternay. 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

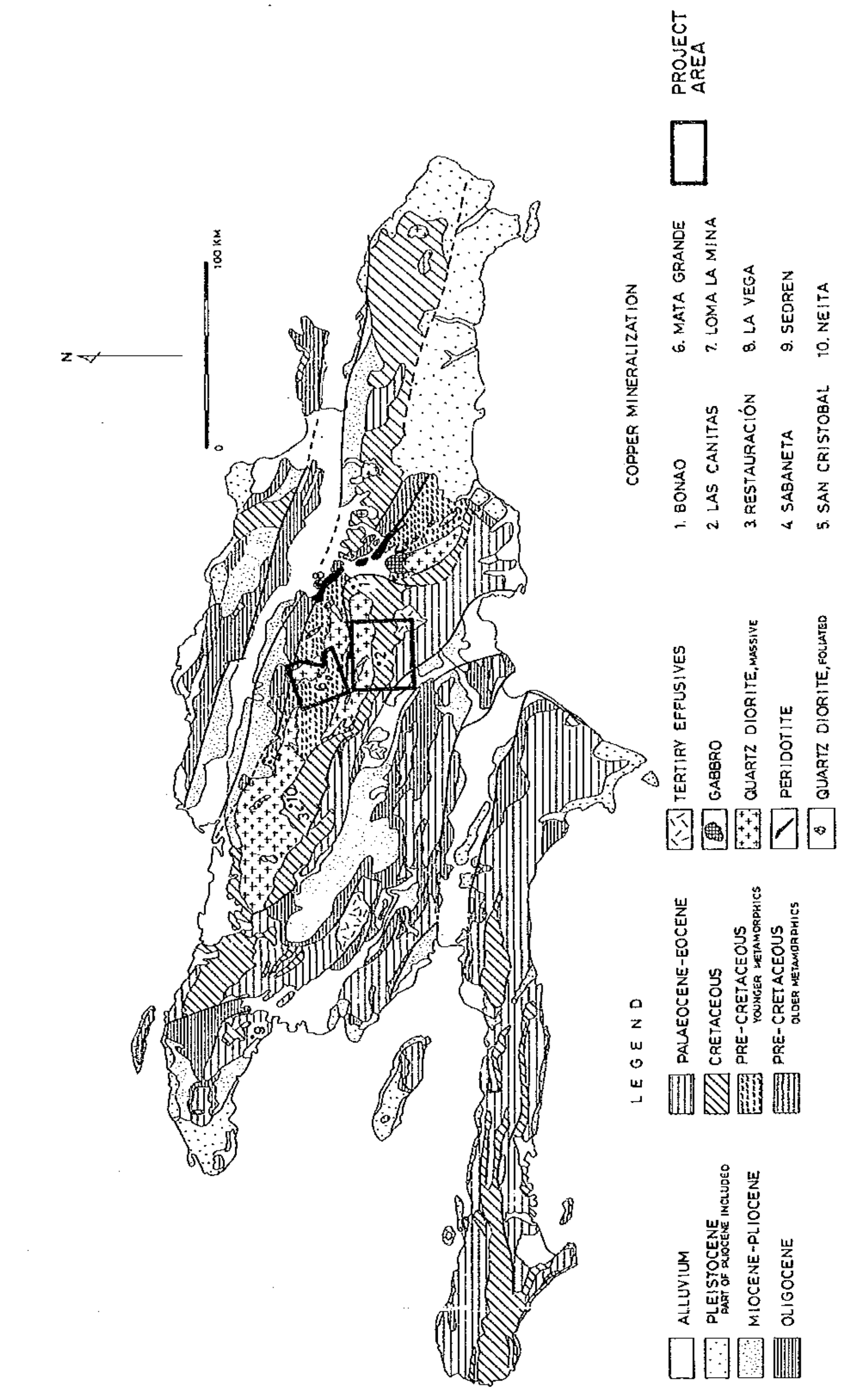


Fig. 2 Geological Map of the Hispaniola Island

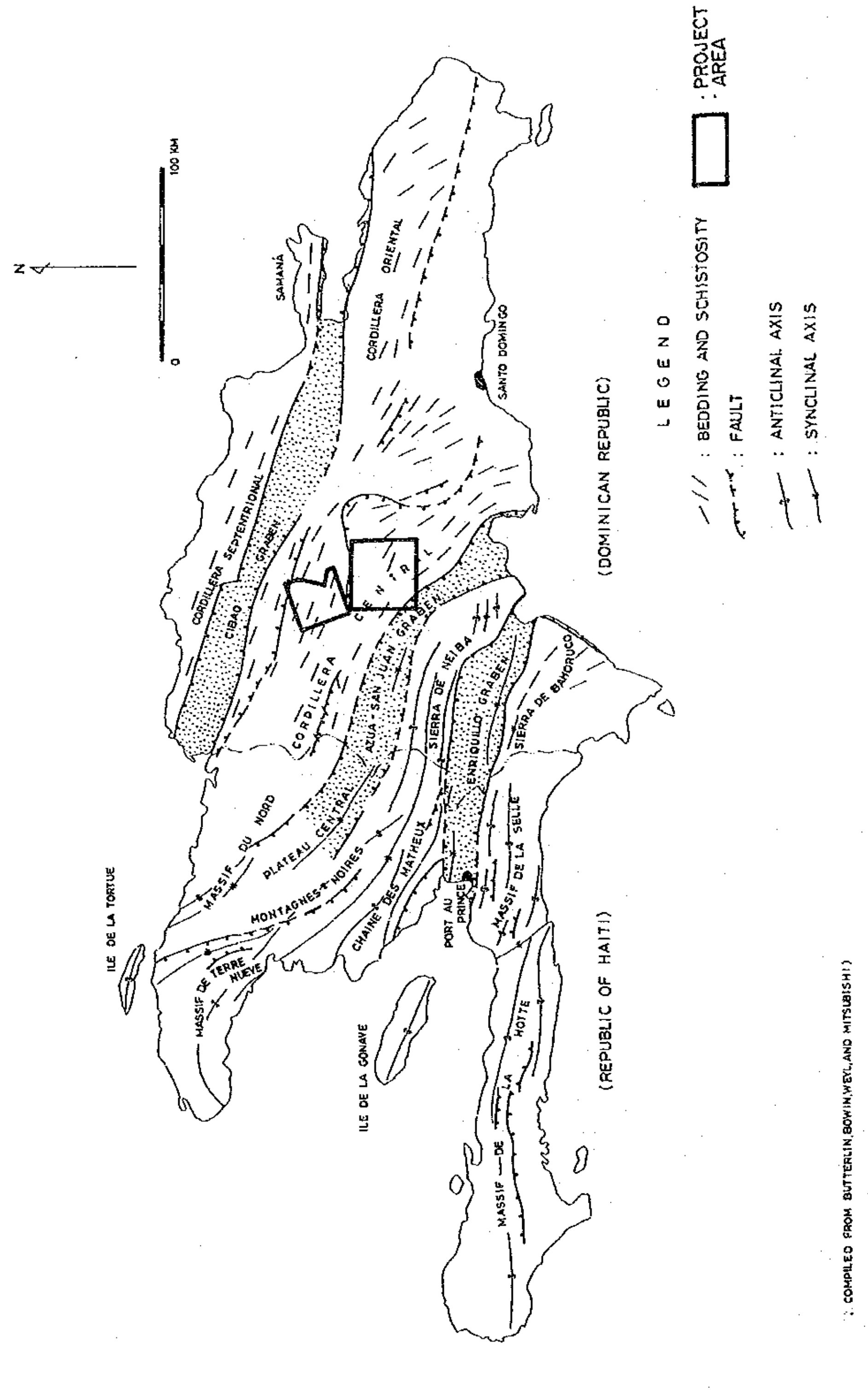


Fig. 3 Tectonic Map of the Hispaniola Island

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 batholithis 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.

Mineralization in the survey area includes copper mineralized zones such as vein-and porphyry copper-types, and placer gold mineralized zone. A number of vein-type mineralized zones are distributed int ehe El Gramoso, Las Canitas, south of Constanza and Mata Grande. They occur in the formation of the Duarte and Tireo and in the intrusive rocks having close relation with NW–SE fault and/or tonalite intrusives. Porphry copper mineralized zone was discovered in granodiorite at the southeast slope of the Mt. Pico Duarte. Placer gold mineralized zones are distributed along the river of the Mata Grande area.

CHAPTER 2 GEOLOGY

2–1 General Remarks

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. Figure 4 shows the correlation statigraphy.

In respect to the name of the formations, the Amina formation at the bottom followed Plamer (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 Plamer (1963). The formation consisting of shale and limestone distributed extensively in the Las Canitas area was named the Arroyo Cano formation correlating to the formations such as Repesa and Veiazaquito of Plamer (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 rocks are 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 Geological Stratigraphy (Fig. 5, 6)

1. Amina Formation

Although the age is unknown, the Amina formation (Plamer, 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.

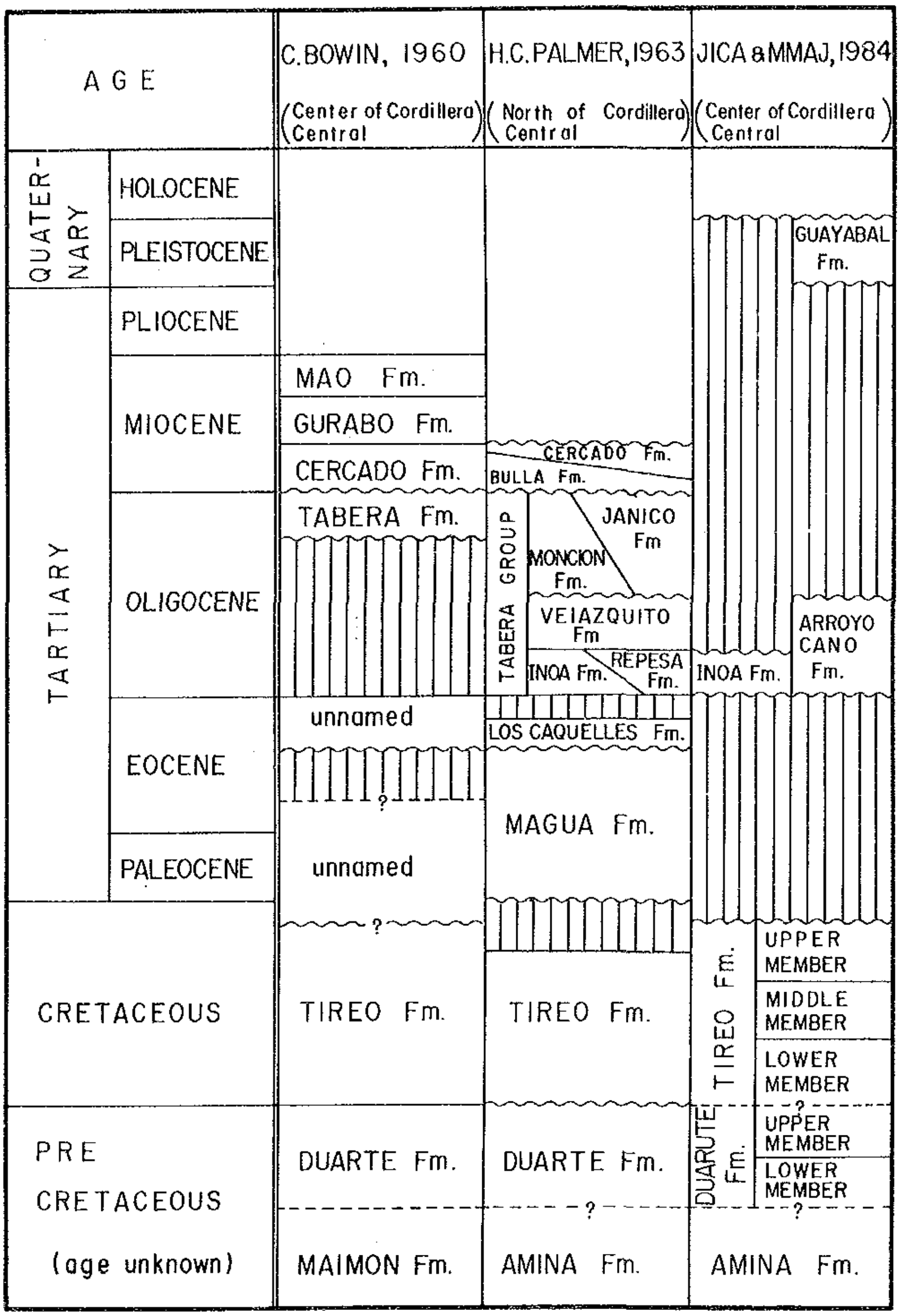
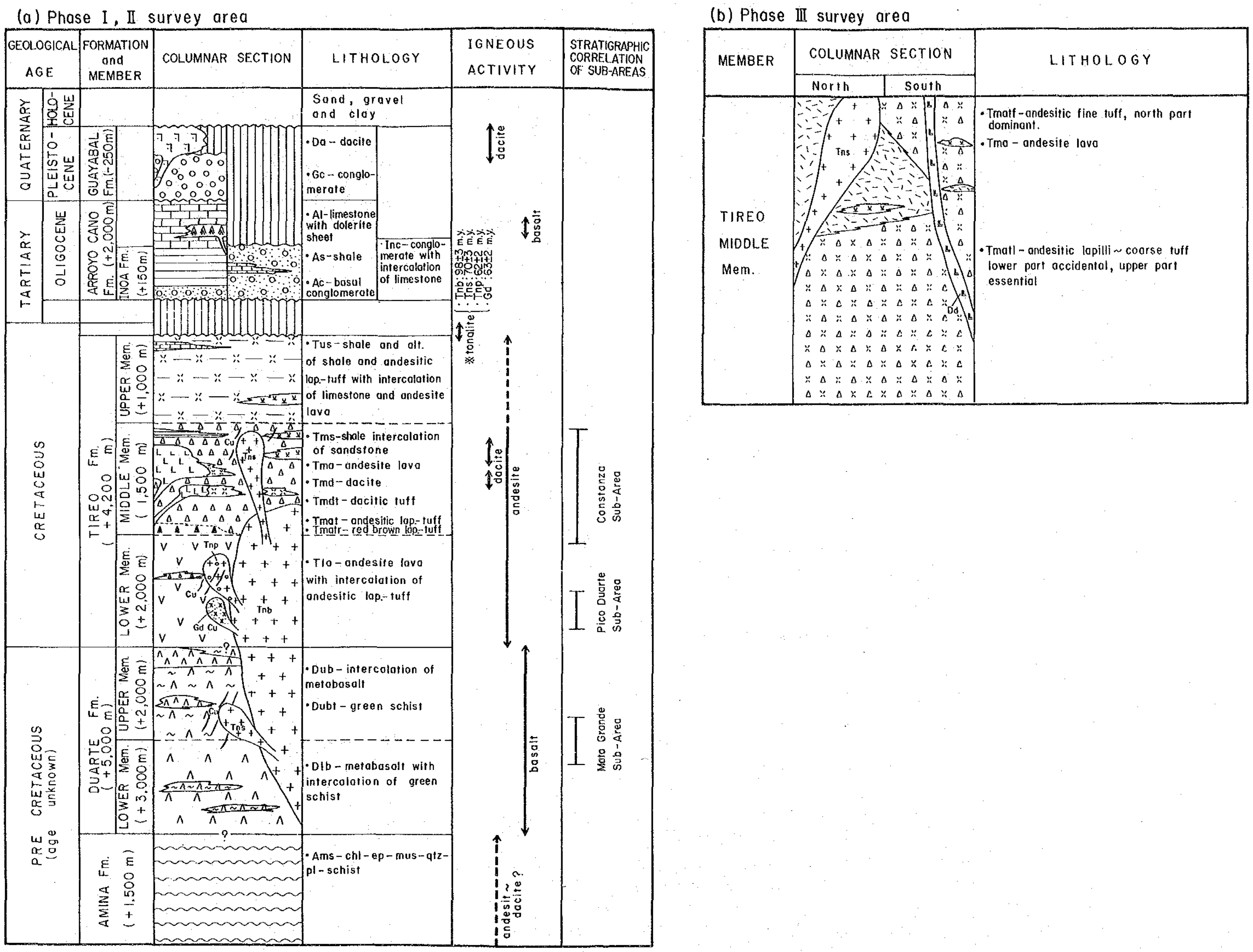


Fig. 4 Stratigraphic Correlation



※Tnb : tonalite batholith, Tns : tonalite stock a dyke
Tnp : porphyritic tonalite stok a dyke
Gd : granodirite stock

Fig. 5 Generalized Stratigraphic Columnar Section

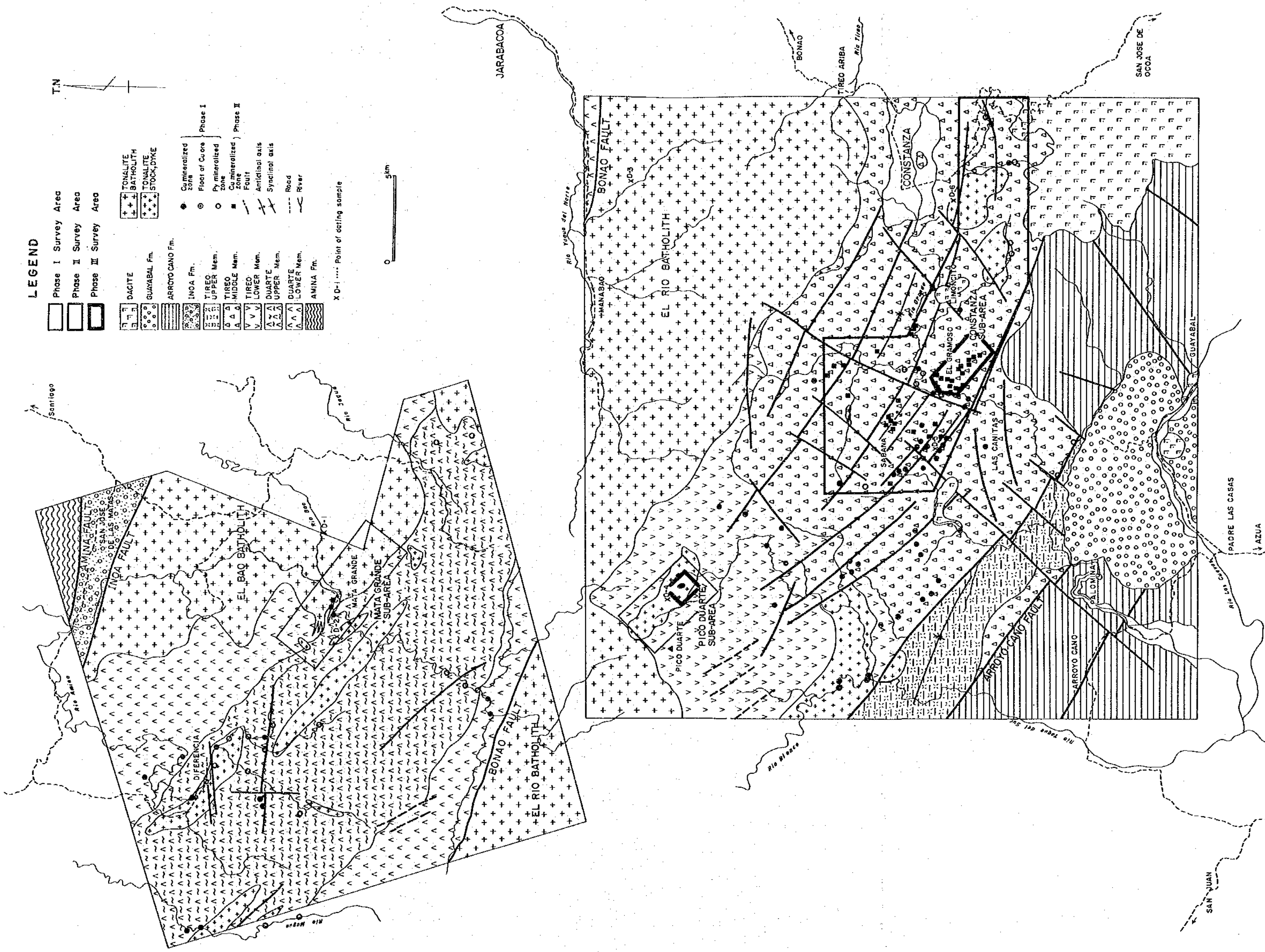


Fig. 6 Geological Map of the Survey Area

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.

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 Hspaniola Island (Plamer 1963).

2. Duarte Formation

The age of the Duarte formation (Plamer 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 poing of rock facies.

The metamorphic facies belongs to green schist facies.

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 (Dubt) 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 the 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.

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 andesitic lava (Tla), interbedded with thin layers of andesitic pyroclastic rocks.

The andesitic lava (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.

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), andesitic 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 wtaer. 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 andesitic 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 (Tmadt) 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.

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 southwestern 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 silstone, 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 observed 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 5 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 (Plamer, 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 survey.

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.

2–3 Igneous Activity

The igneous 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.

2–3–1 Intrusive Rocks

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 Canita 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.

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.

(2) Tonaolite 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 are 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 mineralization 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.

(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 Yaue 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 minieralization is observed in the vicinity of the dyke, leading to the assumption that it is in close relation to copper mineralization.

(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.

Table 3 shows the chemical component of the typical samples of the tonalitic rocks described in the above.

A Q–Pl–Kf diagram (Fig. 7) 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.

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.

The rock is balck and compact augite basalt.

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.

Table 3 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 (Fig. 8). It showed that most of the igneous rocks belong to calc-alkaline rock series.

2–3–2 **Radiometric Age Determination of Igneous Rocks**

For the purpose of making clear the relationship between the igneous activity and the mineralization, radiometric dating by K–Ar method was conducted on the tonalite intrusive rocks and the batholith.

The samples provided for the determination are the six samples obtained from tonalite batholith (Tnb), tonalite stock (Tns), porphyritic tonalite stock and dyke (Tnp), and granodiorite stock (Gd). Fig. 6 shows the location of the sampling point, and Table 4 the result of determination. The geologic time table of Harlano and others (1982) was used for determination.

The age dating of the El Bao batholith provided ages of 41 ± 3 m.y. and that of the El Rio batholith 98 ± 3 m.y.

According to Kesler and others (1977), the age determination by Bowen (1975) indicated 86 ± 3 m.y. for the intrusion of El Rio batholith.

The ages obtained this time, however, showed the time a little older than that in the above,

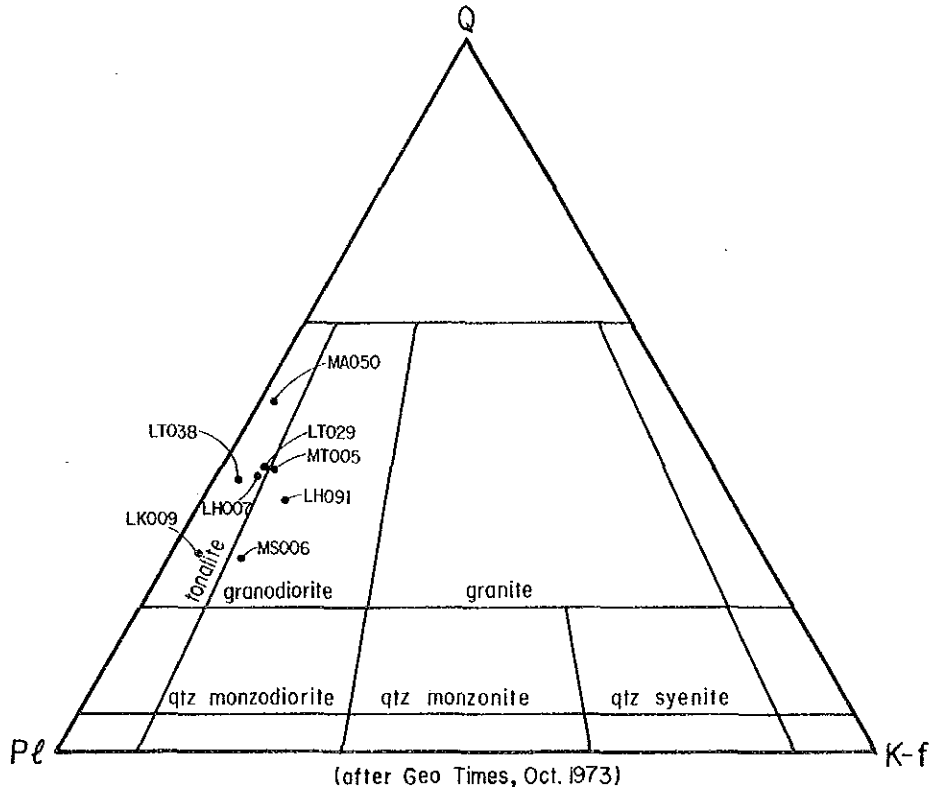


Fig. 7 Normative Q-PL-Kf Diagram of Tonalitic Rocks

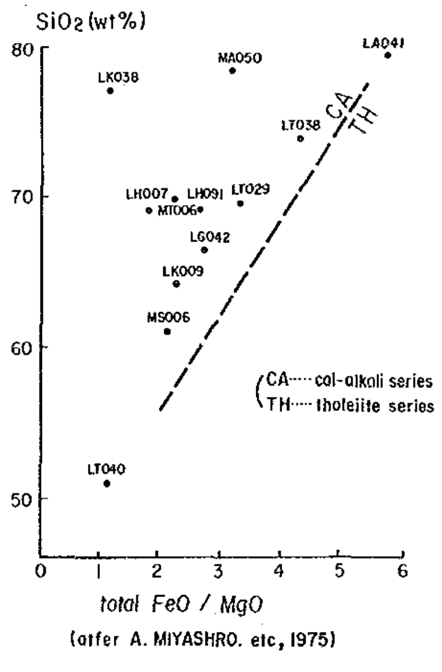


Fig. 8 SiO_2-total FeO/MgO Diagram of Igneous Rocks

Table 3 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. Limon-cito	Las Canitas	North of Constanza (El Rio)	Rio Tireo (El Rio)	Rio Bao (El Rio)	Rio Bao (El Bao)	Rio Magua	Rio Grande	Rio Blanco	Pico Duarte	Rio Blanco	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
	di 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
	di 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
	hy 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
	ol 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

Table 4 K-Ar Age Determination of Igneous Rocks

Sample No.	Rock Name	Location	Mineral	K(%)	Radiogenic ^{40}Arcc STP/g	Radiogenic ^{40}Ar/total ^{40}Ar (%)	Absolute age (m.y. $\pm\sigma$)	Remarks
D–1	Tonalite (Tnb)	Mata Grande (El Bao)	Whole rock	0.985	1.578×10^{-6}	62.72	40.76 ± 1.41	Altered, meta morphosed
D–2	Tonalite (Tns)	Mata Grande	Whole rock	0.340	7.427×10^{-7}	62.27	55.34 ± 1.92	do.
D–3	Tonalite (Tnb)	Manabao (El Rio)	Whole rock	0.225	8.776×10^{-7}	61.02	97.66 ± 3.43	
D–4	Granodiorite (Gd)	Pico Duarte	Whole rock	0.640	1.606×10^{-6}	79.69	63.42 ± 1.99	
D–5	Pl-Q-Porphyry (Tnp)	Sabana	Whole rock	0.815	2.009×10^{-6}	68.97	62.33 ± 2.06	
D–6	Tonalite (Tns)	South of Constanza	Whole rock	0.750	2.086×10^{-6}	58.12	70.16 ± 2.53	

* Analized by CENTRAL RESEARCH INSTITUTE MITSUBISHI METAL CORPORATION.

$$\text{Age (m.y.)} = \frac{1}{\lambda_e + \lambda_\beta} \ln\left[\frac{\lambda_e + \lambda_\beta}{\lambda_e} \times \frac{\text{Radiogenic}^{40}\text{Ar}}{K^{40}} + 1\right]$$

$$\lambda_\beta = 4.962 \times 10^{-10}/Y$$
$$\lambda_e = 0.581 \times 10^{-10}/Y$$
$$K^{40}/K = 0.01167 \text{ atom \%}$$

corresponding to middle Cretaceous.

The ages for the El Bao batholith are very young as compared with that of the El Rio batholith. It seems to be caused by the effect of regional metamorphism and hydrothermal alteration continued until after Cretaceous.

The ages of the intrusive rocks which are related to the mineralization such as tonalite stock, porphyritic tonalite and granodiorite are approximately 60 ~ 70 m.y. except for those of the Mata Grande area, which correspond to late Cretaceous to early Palaeocene.

The rocks in the Mata Grande area is likely to have been affected by regional metamorphism and hydrothermal alteration.

Generalization of the results in the above leads to the following discussion, although the number of the sample is scarce.

The tonalite batholith intruded in the middle to late Cretaceous as a link of the Laramide Orogeny. After that followed the intrusion of tonalitic rocks of the form of stock and dyke in the vicinity of the batholith from late Cretaceous to early Palaeocene. The regional metamorphism associated with the orogeny continued at leaast to late Palaeocene.

The copper mineralization in the survey area is closely related to the tonalite intrusive rocks which show the form of stock and dyke, and it is assumed that the time of copper mineralization took place after the intrusion of tonalite intrusives in Paleocene.

2–4 Metamorphism and 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.

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 accompanied. 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.

2–5 Geological Structure and Development

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 places, 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 WNW–ESE system, those in the southern part are the independent ones formed by faulting after the movement of those of WNW–ESE 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 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.

CHAPTER 3. MINERALIZATION

3-1 General Remarks

Mineralization which had been known brefore this project was only vein-type and pyrite disseminated minaralized zones which are distributed in the Constanza and Mata Grande areas. But in this project, porphyry copper mineralized zones were discovered at the Mt. Pico Duarte in the first time in this country and a number of vein-type mineralized zones were found in the El Gramoso, Hato de Los Rodriquez and Los Vallecitos areas. The Relationship butween mineralization, and geologic structure and igneous rocks also was made clear.

The mineralized zones are the hydrothermal origin which have a genetic relation with the tectonic movement and igneous activity in the later stage of the Laramide Orogeny, being present in positional relation to tectonic line of NW-SE system and /or intrusive masses.

The mineralized zones mainly occur in the Duarte and Tireo formations, and intrusive rocks and are rarely present in the Amina formation and tonalite batholishs. PL.1 shows the location of the mineralizations. The descriptions of mineralized zones are as follows.

3–2 Vein-Type Mineralized Zone

Vein-type copper mineralized zones occur in the Duaurte, Tireo formations and intrusive rocks. A number of them are distributed at the El Gramoso, Hato de Los Rodriguez, Sabana, the south of Constanza, Mata Grando and Los Vallecitos.

3–2–1 Occurrence of mineralized zones

1. El Gramoso

The area is situated about 12 kilometers west-south-west of Constanza. It takes about one hour and a half from Constanza to get to northern place of Limoncito by jeep. From there, the site can be reached within about one hour and a half on mule back.

Geology of the El Gramoso area mainly consists of andesite lava, lapilli tuff and tuff breccia of the same source which belong to the middle member of the Tireo formation, and partly accompanied by small intrusive bodies of tonalite and dacite.

The ore veins discovered at 22 places (51 outcrops) consist of gold bearing copper veins. The ore minerals are composed of malachite, chalcopyrite, bornite, chalcocite, pyrite, specularite, and limonite, accompanied by gangue minerals such as quartz, chlorite, and epidote.

The veins mostly occur as a network vein, although a single and dissemination are partly contained. The veins are uniform in their width, and extend laterally for a considerable distance as compared with those in the Sabana area.

The scale of the veins observed at the outcrops is 0.3 to 1.5 meters wide and several meters to 70 meters long along the strike. The grade of copper is one to 10 per cent, and gold is 0.2 to 0.5 gram per ton ubiquitously.

Most of the veins strike northwesterly and dip northward. They are distributed in parallel with good continuity in the northwest direction (Fig. 9, 10, PL1).

The extent of distribution of these veins is about 1 kilometer wide and about 3 kilometers long, which extends continuously from the north of the El Gramoso settlement to southern part along the hillside of the Loma Sito Grande Mountains. Although the outcrops are likely to be distributed further to the northeast of the area, the whole aspect of these has not yet been made clear because the time for survey was restricted in this work.

The strike of each vein as well as the general tendency of distribution of the vein group at El Gramoso are consistent with the direction of the tectonic lines of the NW-SE system which is the main structure of geology of this area. It is thought that the mineralization has a genetic relation with the NW-SE structure. There is a contrast to strike of the veins in the Sabana area, where they trend northeasterly, which was described in the report of the Phase I.

Silicification is a most strong alteration observed in the area, which is accompanied by chloritization and partly by epidotization. This point is also different from those of the Sabana area, where chloritization, epidotization and white-argillization are the main ones.

In addition, although malachite is a main ore mineral in the vein-outcrops in the Sabana area, chalcopyrite is found in abundance in the outcrops in the El Gramoso area. This face suggets that the primary sulfide zone is positioned near the surface in the El Gramoso area.

The descriptions are made in the following on the vein outcrops discovered in this survey. Their positions are shown in Fig. 10 and PL 1.

(1) G–1

This portion is situated at Hondo Valle to the north of the El Gramoso settlement, and the small outcrops of copper veins are scattered at four places within the distance of about 40 meters in a direction of northwest.

Geology of the adjacent area mainly consists of andesitic lapilli tuff and partly of andesite lava. The copper veins show a form of network and single vein. They are present as small outcrops 0.1 to 0.3 meter wide and 1 to 3 meters long extending northwestward. The country rocks have suffered chloritization and silicification and were partly accompanied by epidotization. The assay result of main outcrop is as follows:

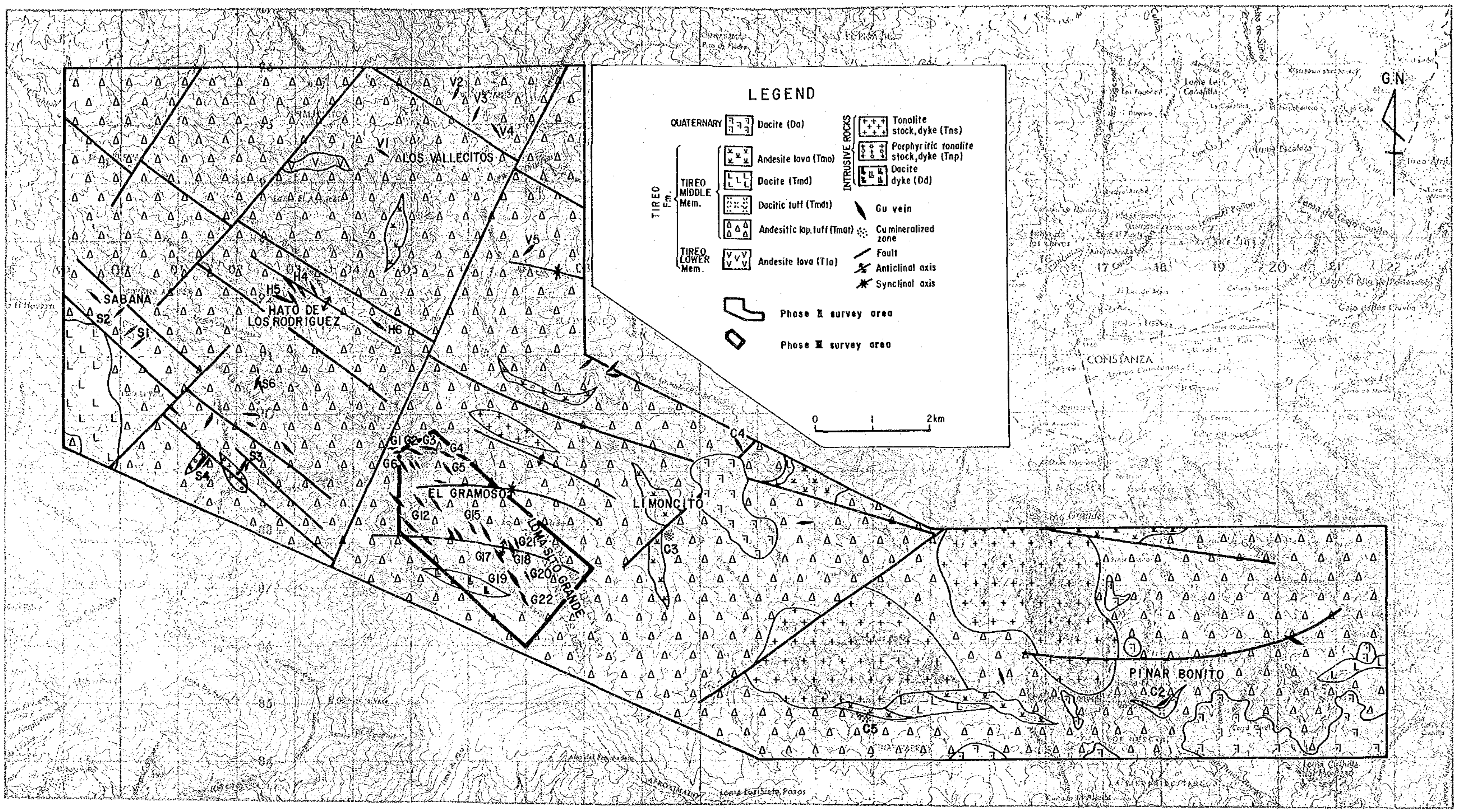


Fig. 9 Geological Map of the Constanza Area

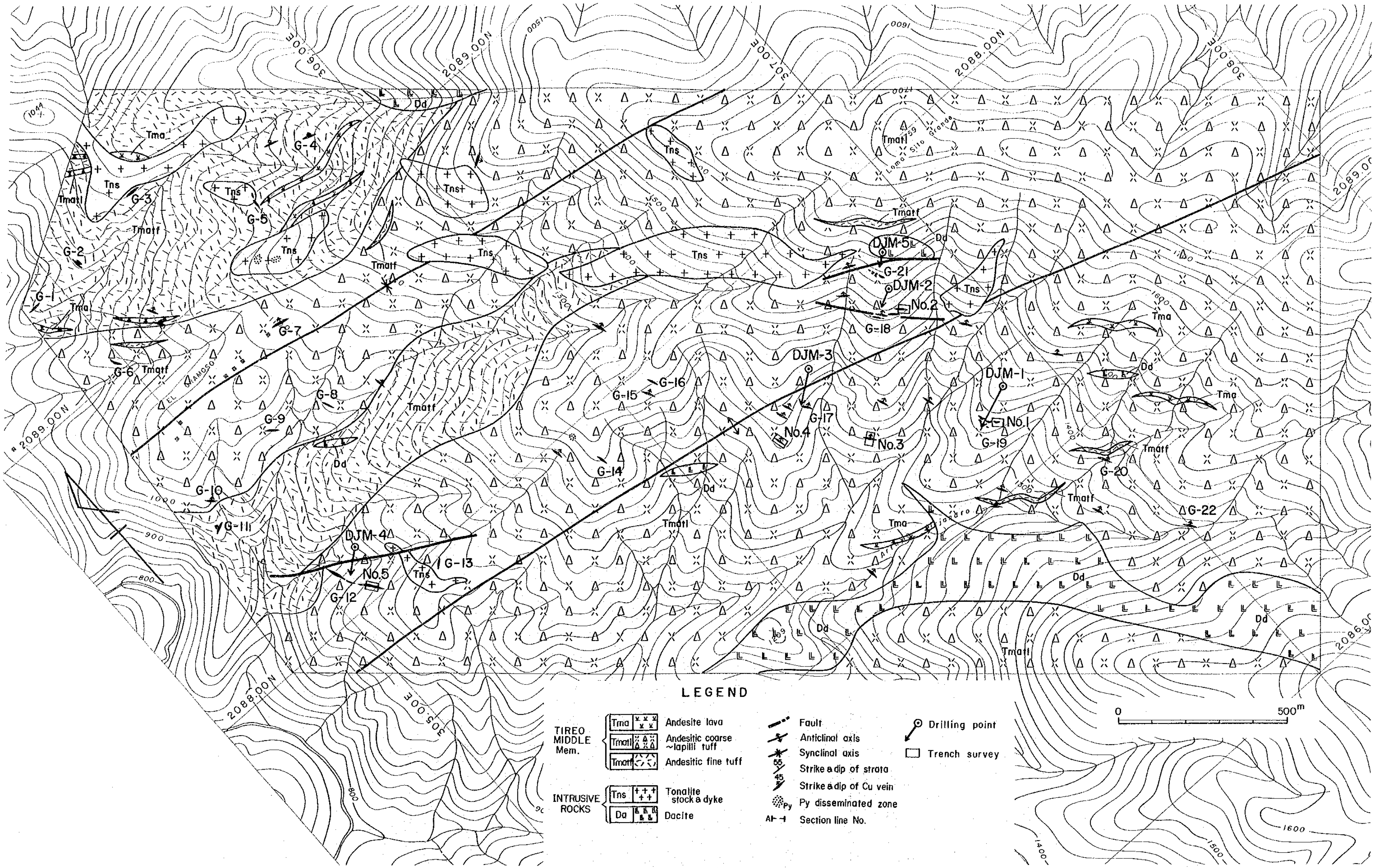


Fig. 10 Geological Map of the El Gramoso in the Constanza Area

	Size (m)	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK076	0.5 in diameter	0.50	0.90	17.7	4.18	0.15	0.02

(2) G–2

The spot is situated at Hondo Valle. The outcrops of copper veins were discovered at three places. There are two veins. The one is network vein about 2 meters wide and 7 meters long. The other is a single vein 0.1 meter wide and 1 meter long.

The country rock is hematitized andesitic lapilli tuff. The alteration consists mainly of chloritization, and weak silicification and epidolization are observed in the near of vein. The assay results of the two outcrops are as follows:

	Size w(m)xℓ(m)	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK079	2 x 7	0.20	0.20	5.9	1.89	0.91	0.02
SK080	0.1 x 1	0.10	0.20	6.5	2.65	0.12	0.04

From the microscopic observation of KS079, chalcopyrite occurs in a form surrounded by limonite which is the secondarily altered mineral by oxidation. Limonite forms a banded texture of concentric circle containing the small grain of chalcopyrite at the center. Covelline is formed at the boundary between these two minerals.

(3) G–3

The spot is situated at Hondo Valle. The outcrops of copper veins were discovered at 6 places in the section of about 40 meters. The outcrops are composed of three groups of veins trending northeasterly, among which the largest one is 0.4 meter wide and 17 meters long along the strike of outcrop (Fig. 11). The country rock is andesite, and the alteration is chloritization. The assay results of main outcrops are as follows:

	Size w(m)xℓ(m)	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK082	0.4 x 17	0.40	0.33	16.5	6.15	0.14	0.10
SK082	0.3 x 1.5	0.30	0.10	2.8	0.99	0.05	0.10

(4) G–4

The spot is situated at Hondo Valle. The outcrops of copper veins were discovered at 2 places in the area. They are a network vein composed of chalcopyrite, bornite, malachite and specularite, extending N70° to 80°W. The outcrop is small in size, being 0.2 to 0.3 meter wide and 0.5 meter long.

The country rock is andesitic tuff, and the alteration is remarkable in silicification and chloritization.

The assay result of the ore from the outcrop is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SY005	0.50	0.02	0.02	1.90	0.07	0.02

(5) G–5

The spot is situated in the northeast of the El Gramoso settlement, and many floats of copper vein and outcrops were discovered there. The geology is composed of andesitic tuff, lapilli tuff and tonalite, and the mineralization can be seen in the both rocks. The mineralized floats and outcrops are found at 3 places at the intervals of 50 meters (Fig. 12).

The mineralized zone is aggregate of veinlets composed of malachite, chalcopyrite, chalcocite, limonite and quartz. The mineralized zone is 1 to 2 meters wide and 4 to 20 meters long or spread 5 to 20 meters wide in the case of the floats. The assay results of outcrops ore as follows:

	Size w(m)xℓ(m)	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK084	1 x 5	0.50	1.00	43.1	29.83	0.12	0.06
SK085	5 x 20	1.70	0.20	5.0	1.97	0.08	0.02

Another malachite-Chalcopyrite-limonite-quartz vein is exposed on the road about 150 meters to the northwest of the outcrops above mentioned. It is 10 centimeters wide and 7 meters in extension, showing the structure of N25°W and 40°N. The country rock is andesitic lapilli tuff, which is highly chloritized. Alteration zone is about 70 centimeters wide.

The assay result of the vein is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK073	0.10	0.30	11.2	2.58	0.17	0.06

(6) G–6

The spot is situated along the road of the Rio en Medio which is situated in the north of the El Gramoso settlement. The outcrops were discovered at 5 places in this portion. The outcrops consist of copper veins occurred in andesitic lapilli tuff. There are two ore veins extending northwesterly. The ore minerals are malachite, chalcopyrite, bornite, hematite and limonite, accompanied by gangue minerals such as quartz and epidote. The veins which contain the ore minerals grade into barren quartz veins and silicified rock at the terminal part. The country rock has been silicified and chloritized. An outcrop (SK054) found on the road is 0.50 meter wide and 8 meters in extension, showing the structure of N45°W and 50°N. The other outcrop (SK072) found on the northern downside of the road is 3 meters wide and 20 meters in extension, extending in the direction of N20°W.

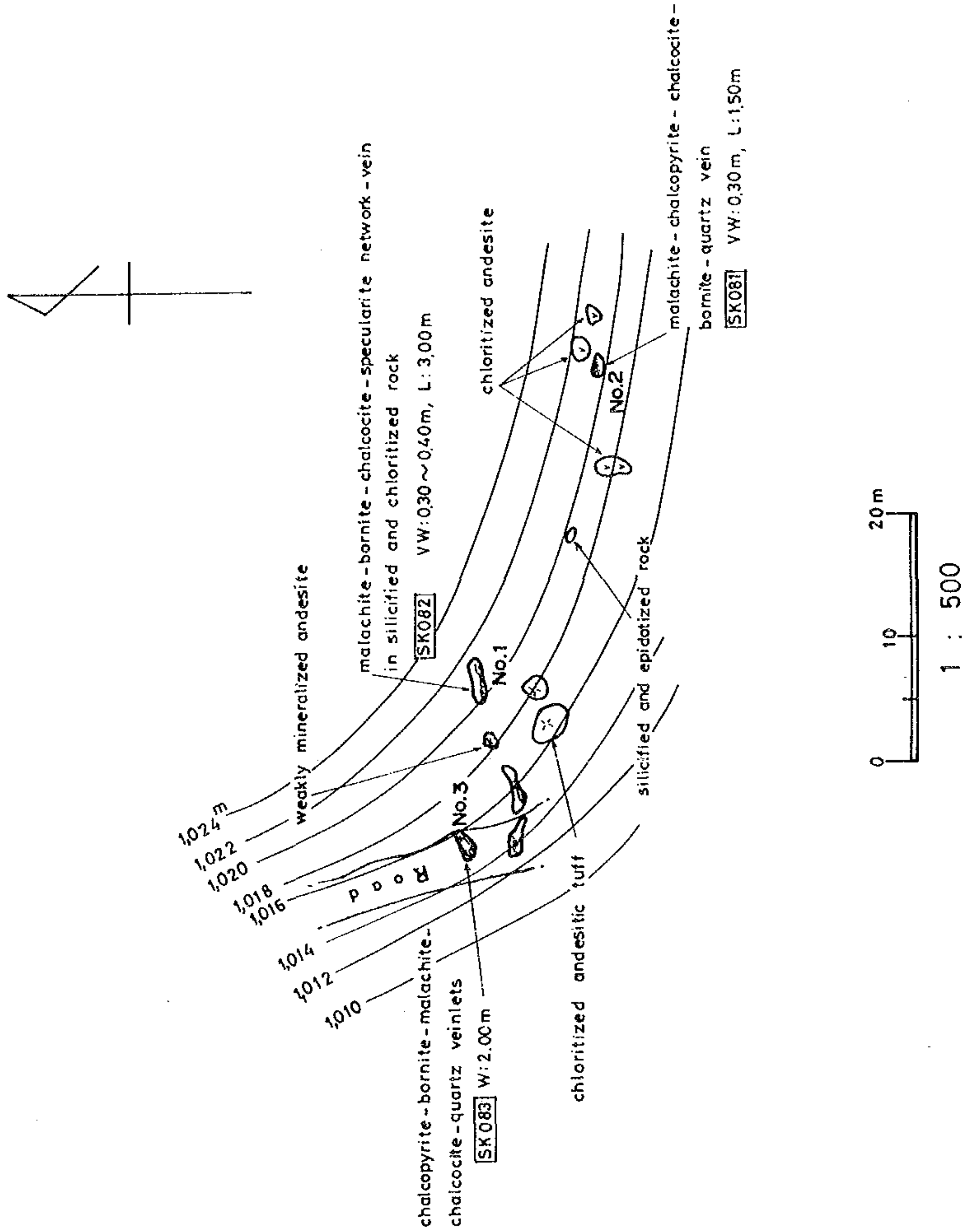


Fig. 11 Survey Map of the Outcrop G-3

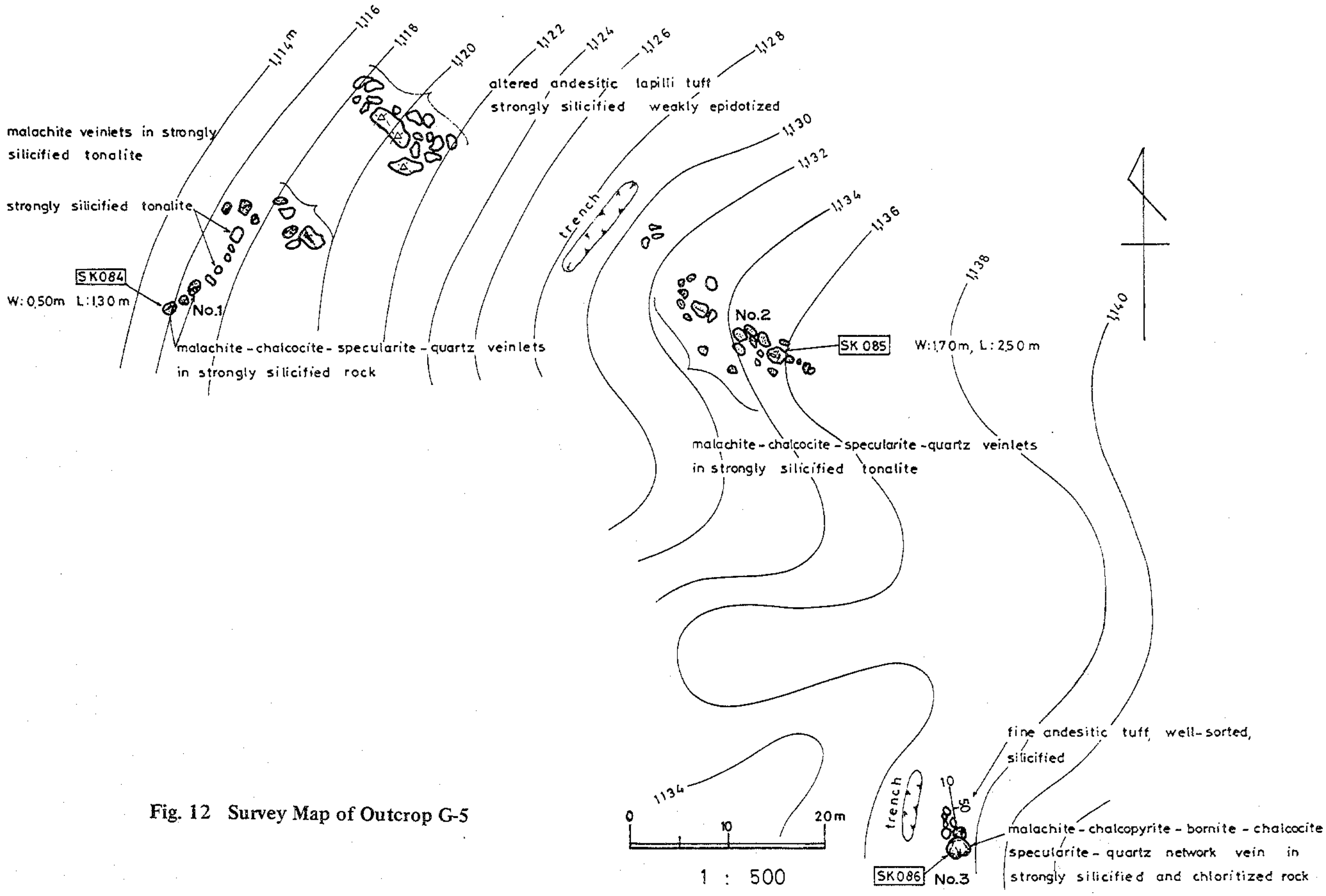


Fig. 12 Survey Map of Outcrop G-5

The assay result of these veins is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK054	0.50	0.30	7.0	1.27	0.16	0.04
SK072	3.00	tr.	1.0	0.68	0.08	0.02

(7) G–12

The outcrop is a large copper bearing quartz vein discovered at 600 meters to the south of the El Gramoso settlement by the survey of the second phase.

The lateral length of about 70 meters was confirmed in the survey of the second phase, and it was shown to be 1.5 meters wide in average. The average values were 0.3 g/T Au, 17 g/T Ag and 3.2 % Cu. The follow-up survey and trenching performed this phase along the south-eastern extension resulted in to confirm the presence of scattering outcrops, and the total length of the group of outcrops became 180 meters. The ore minerals of the outcrops are malachite, chalcopyrite, chalcocite, covelline and limonite, which are contained in quartz vein in a form of network veinlets and dissemination. The country rock is andesitic lapilli tuff, which has been highly chloritized and has undergone weak silicification.

The grade of the outcrops is high in the large northern outcrop with an extension of 70 meters and the one centering on the trench in the southern part (Fig. 10).

Although no precise description can be made because of absence of outcrop between the two parts, the interval between the ends of the two outcrops seems to be barren because the southern end of the northern outcrop and the northern end of the southern outcrop become poor in ore minerals and because of changing of both ends to quartz vein. The vein strikes N50°W and dips 50°N in the northern part, and N45° to 55°W and 45° to 30°N in the southern part respectively. The vein width is greater in the north and smaller in the south. These outcrops are distributed scattering in the general trend of N20°W macroscopically taking the topographic relation into account.

It seems that the northwestern extension of the outcrop has been displaced toward the west by the fault exposed at a creek in the northern part, which was made clear by the drilling survey, and that the vein continues to the small outcrop of malachite-limonite quartz network vein found in the northeastern part.

The part centering on the trench confirmed this survey is about 40 meters long along strike and 0.27 meter wide in average. The average grades are 0.29 g/T Au, 23.8 g/T Ag, 2.85 % Cu, 0.04 % Pb and 0.02 % Zn.

(8) G–17

The outcrop is located at about 1.5 kilometers to the southeast of the El Gramoso settlement.

A copper bearing quartz vein 0.2 to one meter wide and about fifteen meters long along strike was found on the southern slope of the hill. The ore minerals include malachite, chalcopyrite, pyrite and limonite, being present concentratedly on the hanging-wall side of the vein. Quartz is the main gangue mineral, associated with a small amount of epidote. The vein strikes N20°W and dips 55° to 70° westward. The country rock is andesitic lapilli tuff. The country rock has been strongly chloritized, and silicified zone is found on the footwall side.

The assay result of the part of the vein is as follows.

Sample No.	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK064	0.2	0.40	4.6	0.32	0.02	0.05
GK067	0.7	0.10	1.2	0.08	0.02	0.02

About 200 meters to the south of the above vein, outcrops of copper bearing quartz vein 0.2 to one meter wide which was confirmed by the trench No.3 are scattered for about 40 meters. It is likely that the vein in the above would continue to this vein.

On the other hand, a copper bearing quartz vein 0.1 to 0.5 meter wide, striking northward and N20°E is found 100 meters to the north of the vein described in the first phase, and it seems that these are continual for each other (Fig. 10, PL. 1).

(9) G–18

The outcrop is located 1.7 kilometers to the southeast of the El Gramoso settlement, and is distributed on the southern steep slope of a ridge of Mt. Loma Sito Grande. The outcrop consists of four systems of copper bearing quartz veins such as (A) to (D), and each vein can be traced for 20 to 50 meters (Fig. 13). These veins strike N20° to 30°W and dip 45° to 55° northward. Each vein is 0.1 to 1.2 meters wide.

The ore minerals include malachite, chalcocite, chalcopyrite, covelline and limonite, and these are present in quartz veins as network and dissemination. The country rock is composed of andesitic lapilli tuff and tuff. Wall rock alteration include chloritization and silicification. The ore minerals decrease toward the tail end of the veins to grade into barren quartz vein.

The location of each outcrop is shown in Fig. 13, and the assay results are made for each vein in the following. Trenching was performed for the outcrop (D), which is described later.

Name of vein	Scale w(m)xℓ(m)	Sample No.	Sampling	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
A	(0.7~0.3)x35	GK042	0.70	0.10	2.2	1.94	0.02	0.05
		GK045	0.30	0.10	0.9	0.04	0.02	0.02
B	(0.1~0.2)x20	GK043	0.10	0.30	4.3	2.99	0.04	0.01
		GK044	0.20	0.20	3.6	0.93	0.02	0.05
C	(0.2~1.2)x35	GK046	1.20	0.10	1.2	0.19	0.02	0.05
		GK047	0.20	0.50	15.0	2.37	0.02	0.05

A copper bearing quartz vein one to three meters wide and 20 meters long is found about 250 meters to the southeast of the veins mentioned in the above (PL. 1). The ore minerals are malachite and limonite, and the assay result of the massive ore is 0.5 g/T Au, 65.5 g/T Ag, 2.00 % Cu, 0.04 % Pb and 0.01 % Zn. The vein strikes N40°W and dips 50° northward, and it seems that the vein is of the same system as the G–18 outcrop and that the southeastern extension of G 18 would continue to this outcrop. A quartz vein 0.5 meter wide is found about 100 meters to the northwest of the outcrop G–18, corresponding to the northern extension of it (PL. 1), and they seem to be continual each other.

(10) G–19

The outcrop is located 2 kilometers to the southeast of the El Gramoso settlement. The outcrop is an aggregate of copper bearing network quartz veinlets. The ore minerals are malachite, chalcopyrite, chalcocite and limonite. The gangue minerals consist mainly of quartz, associated with chlorite. The outcrop on the ridge is about 1 meter wide and 6 meters long, and shows the average grades such as 0.4 g/T Au, 31 g/T Ag, 4.2 % Cu, 0.7 % Pb and 0.3 % Zn. The vein strikes N20°W and dips 60° northward, which continues to the other outcrop found on the southern slope of the ridge further to the southeast of the trench excavated in the southeastern part of the outcrop G–19. The confirmed length of the vein is about 35 meters. The ore minerals decrease toward the south on the whole, becoming poor in grade.

The country rocks are andesitic lapilli tuff and fine-grained tuff. Chloritization is the main alteration of the wall rock, which is associated with silicification close to the vein wall.

An outcrop of copper bearing quartz vein seems to be another system is found about 25 meters to the northeast of the outcrop on the ridge.

An outcrop of copper bearing quartz vein 0.2 meter wide, striking N30°W and dipping 50° northward, is found about 150 meters to the northeast of the outcrop G–19 (PL. 1, Fig. 12). The mineralization observed at the outcrop is malachite-chalcopyrite-chalcocite-limonite quartz network. It is likely that this outcrop corresponds to the northeastern extension of the outcrop G–19.

The assay result of the outcrop is as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK039	0.20	0.40	20.4	1.45	0.02	0.02

A malachite-limonite-quartz epidote vein 0.3 meter wide is found on the ridge further 150 meters to the northeast of the outcrop. The vein strikes N20°W and dips 35° northward. This is also a series of the vein together with the outcrop G–19.

(11) G–21

It is the new outcrop discovered in the survey of third phase, located on the southern steep slope of Mt. Loma Sito Grande about 2 kilometers to the southeast of the El Gramoso settlement.

The outcrop consists of copper bearing network quartz vein, being distributed scattering in the direction of N20°W (Fig. 14). The lateral extension confirmed at the outcrop is 35 meters. The vein is 0.8 to 2.5 meters wide and the average grades are 0.2 g/T Au, 28 g/T Ag, 4.87 % Cu, 0.16 % Pb and 0.05 % Zn. Although the dip of the vein can not be measured precisely at the outcrop, the general dipping of 60°N is shown. The ore minerals are malachite, chalcopyrite, chalcocite and limonite, and the gangue minerals are quartz and a small amount of chlorite. The vein shows the occurrence of network and dissemination. The country rock is andesitic lapilli tuff, and wall rock alteration includes silicification (metasomatic) and chloritization, especially silicification is notable. The width of silicified zone reaches up to 5 meters in some place. Fig. 14 shows the sketch map of the outcrop.

An outcrop consisting of malachite-limonite-quartz epidote vein is found to the northwest of the outcrop G–21. The vein is 0.2 meter wide and shows the assay results such as Tr Au, 0.8 g/T Ag, 1.17 % Cu, 0.02 % Pb and 0.02 % Zn. It strikes N70°W and dips 60° northward. It is likely that the northern extension of the outcrop G–21 continue to this outcrop.

(12) G–22

The outcrop was newly discovered in the survey of this phase in a creek about 3 kilometers to the southeast of the El Gramoso settlement (PL. 1, Fig. 12). The outcrop is a copper bearing vein, which contains sphalerite in abundance. It is a fact to be note worthy that the vein contains much zinc minerals despite the ore veins in the El Gramoso area is mainly composed of copper minerals.

The vein is 0.2 meter wide and the grades are 0.38 g/T Au, 10.6 g/T Ag, 2.27 % Cu, 0.07 % Pb and 12.56 % Zn (GL008). The vein strikes N30°W and dips 50° northward. The country rock is andesitic lapilli tuff, and wall rock alteration is mainly chloritization. Although lateral length of

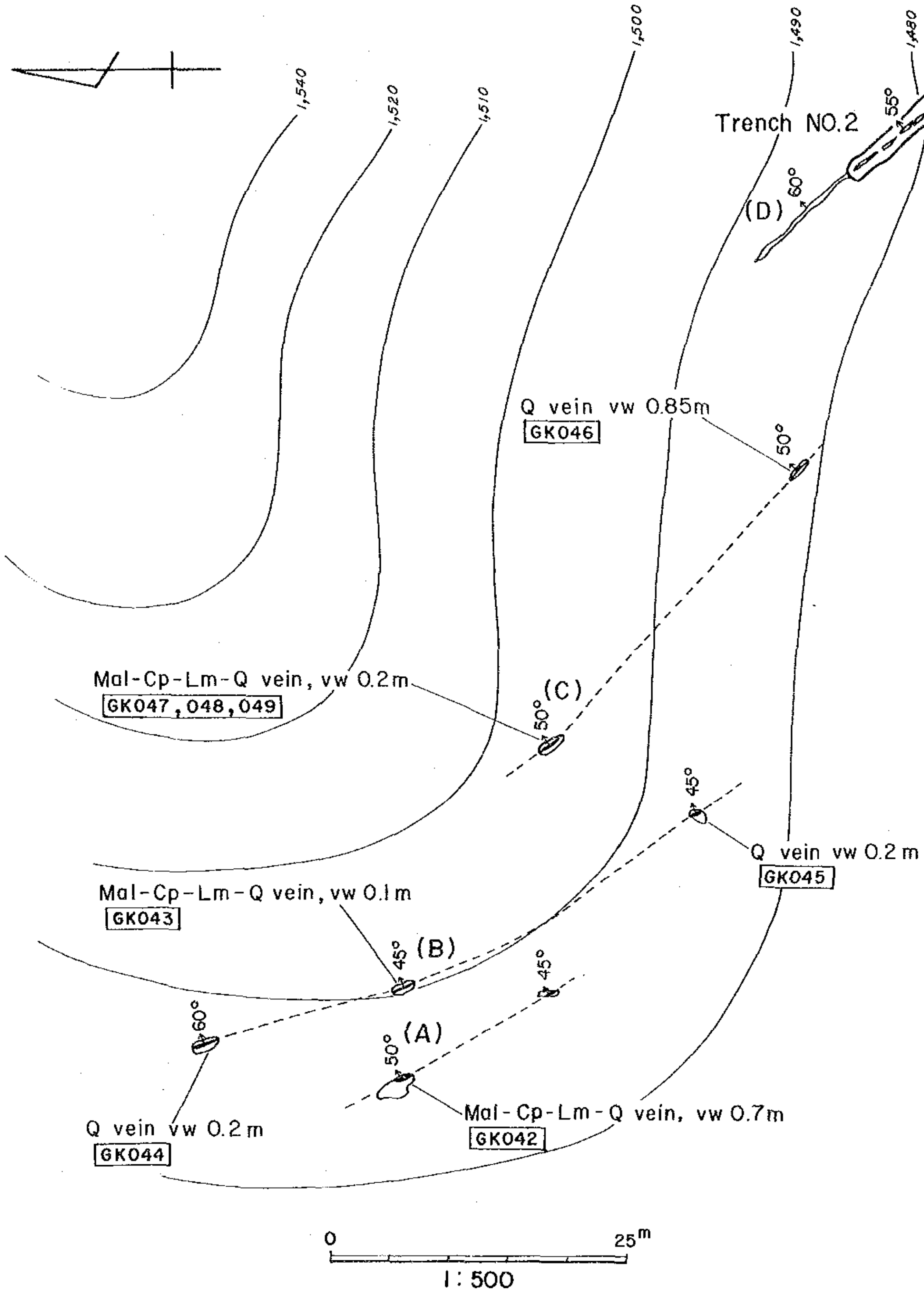


Fig. 13 Survey Map of Outcrop G-18

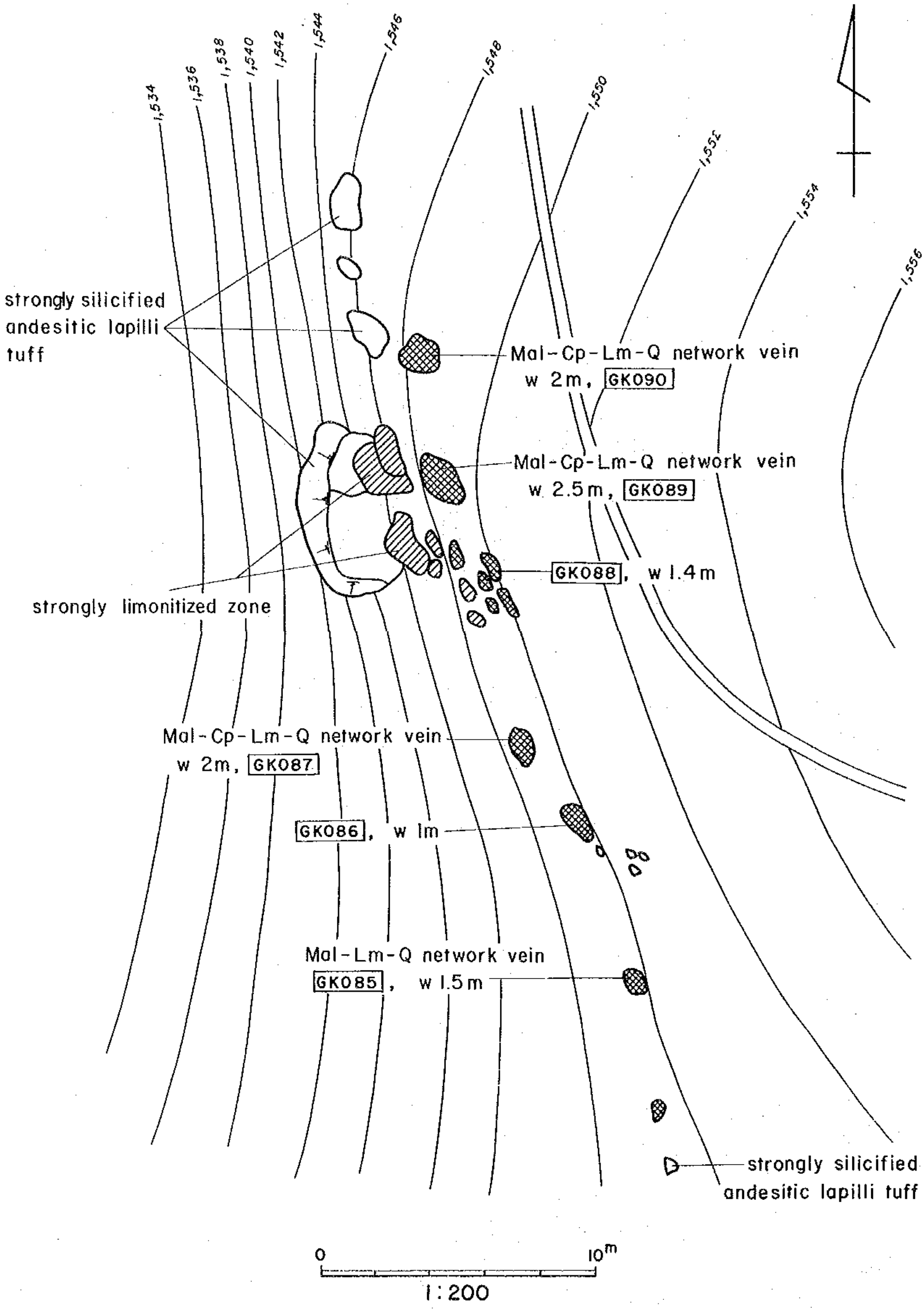


Fig. 14 Survey Map of Outcrop G-21

4 meters was confirmed, the extension could not be made clear because of thick cover of overburden.

2. Hato de Los Rodriguez

The area is situated about 13 kilometers west of Constanza (Fig. 9). The access from Constanza to the site is at first to drive jeep for one hour and a half to the north of Limocito, then it takes about two hours to reach the site on mule back.

The geology in the vicinity of Hato de Los Rodriguez consists mainly of andesitic tuff, lapilli tuff, tuff breccia and partly interbedded with andesite lava of the middle member of the Tireo formations.

The veins at 6 spots (the total number of outcrops includes the 14 places discovered in the survey) are composed of network and single copper veins emplaced in these rocks. The ore minerals include quartz, epidote and chlorite. The veins are 0.1 to 1.5 meters wide and 1 meter to 30 meters in lateral extension at the outcrops. The copper content is 1 to 10 per cent, showing that these are relatively high-grade ore veins.

Most of these veins show the structure striking northwest and dipping northward the same as those in the El Gramoso area, and it is thought that the mineralization of this area has a genetic relation with the geologic structure of NW-SE system.

The alteration of mineralization zone of this area is notable in chloritization and silicification, and accompanied by epidotization. The surrounding area of these is generally subject to hematitization.

It is shown that chloritization spreads 30 centimeters to 2 meters in wall rocks of vein, silicification 10 centimeters to 2 meters, epidotization 30 centimeters to 5 meters, and hematitization 100 to 400 meters an extent up to several hundred meters. In the marginal part of hematitization, it tends to take a form of banding or vein with a survived unaltered part several tens centimeters to several meters wide. The similar form is also shown in a zone of epidotization.

Among the alteration of the wall rocks, chloritization and silicification can be said to be the narrow hydrothermal alteration, while hematitization would have to be called the regional hydrothermal alternation. Regarding the constituent minerals, the difference is also recognized between those in the central part and the peripheral part.

The veins which contain the metallic minerals vary to quartz vein or quartz-epidote vein at the tail end. The tendency is recognized in the whole veins distributed in this area. In the outside of the zone of ore veins, quartz veins and quartz epidote veins are distributed.

(1) H–4

The spot is situated on the southern slope north of Hato de Los Rodriguez. Three series of outcrops of copper veins consisting of seven small outcrops were discovered (Fig. 9).

The geology in the vicinity is composed of andesitic lapilli tuff which have generally been subject to hematitization and chloritization.

Exploration by trenching has been done at two places in the northern and southern parts of the vein. The assay results of the outcrops are as follows:

	Size w(m)xℓ(m)	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK039	0.25 x 2.5	0.25	0.20	13.0	2.61	0.02	0.04

(2) H–5

The spot is situated in the southern slope north of Hato de Los Rodriguez, where three series of outcrops of copper veins were discovered. The largest one is 1.6 meters wide and 12 meters in extension. The geology in the vicinity is composed of fine-grained and coarse-grained andesitic tuff. There are two trench, the assay results of main outcrops are as follows:

	Size w(m)xℓ(m)	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK046	1.6 x 12	1.10	tr.	1.3	1.53	0.03	0.10
SK049	0.7 x 1.5	0.7	tr.	tr.	4.93	0.22	0.10

(3) H–6

The spot is situated on a hilltop east of Hato de Los Rodriguez, where three outcrops of ore vein were discovered. These outcrops continue northwesterly trending, having a whole extension of about 12 meters. A trench was excavated on the southeastern extension of the above. The country rocks are andesitic coarse tuff and fine tuff, and the alteration is chloritization and silicification.

	Size w(m)xℓ(m)	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK022	0.1 x 2	0.10	0.67	21.3	8.02	0.08	0.10

3. Sabana

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 and the Roblito. 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.

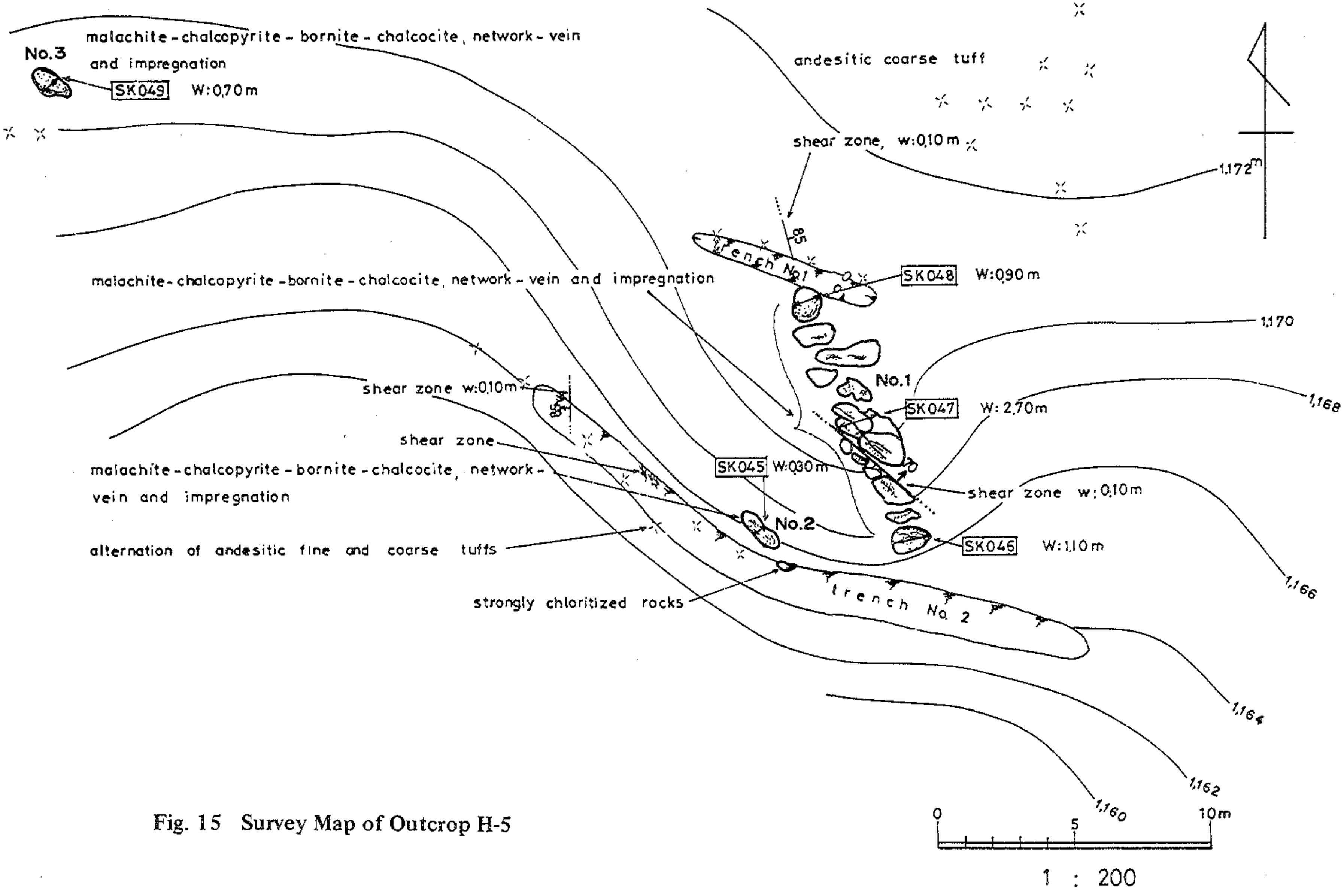


Fig. 15 Survey Map of Outcrop H-5

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 (Fig. 9). 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 (S–1)

The mineralized zone 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 one 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 mineralized zone 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 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. Malachite, 8m extension, is observed on the wall of the one of trench. The copper grade is about 1.5%.

(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 mineralized zone.

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 decreased 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 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(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
LH064-1	4.0	0.5	8.9	2.35	0.06	0.02
LH064-2	2.8	0.5	15.2	2.86	0.04	0.02

(3) Roblito (S–3)

The mineralized zone is situated on the southern slope of a mountain about 15 kilometers to the west of Constanza. It takes about one 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 mineralized zone 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.

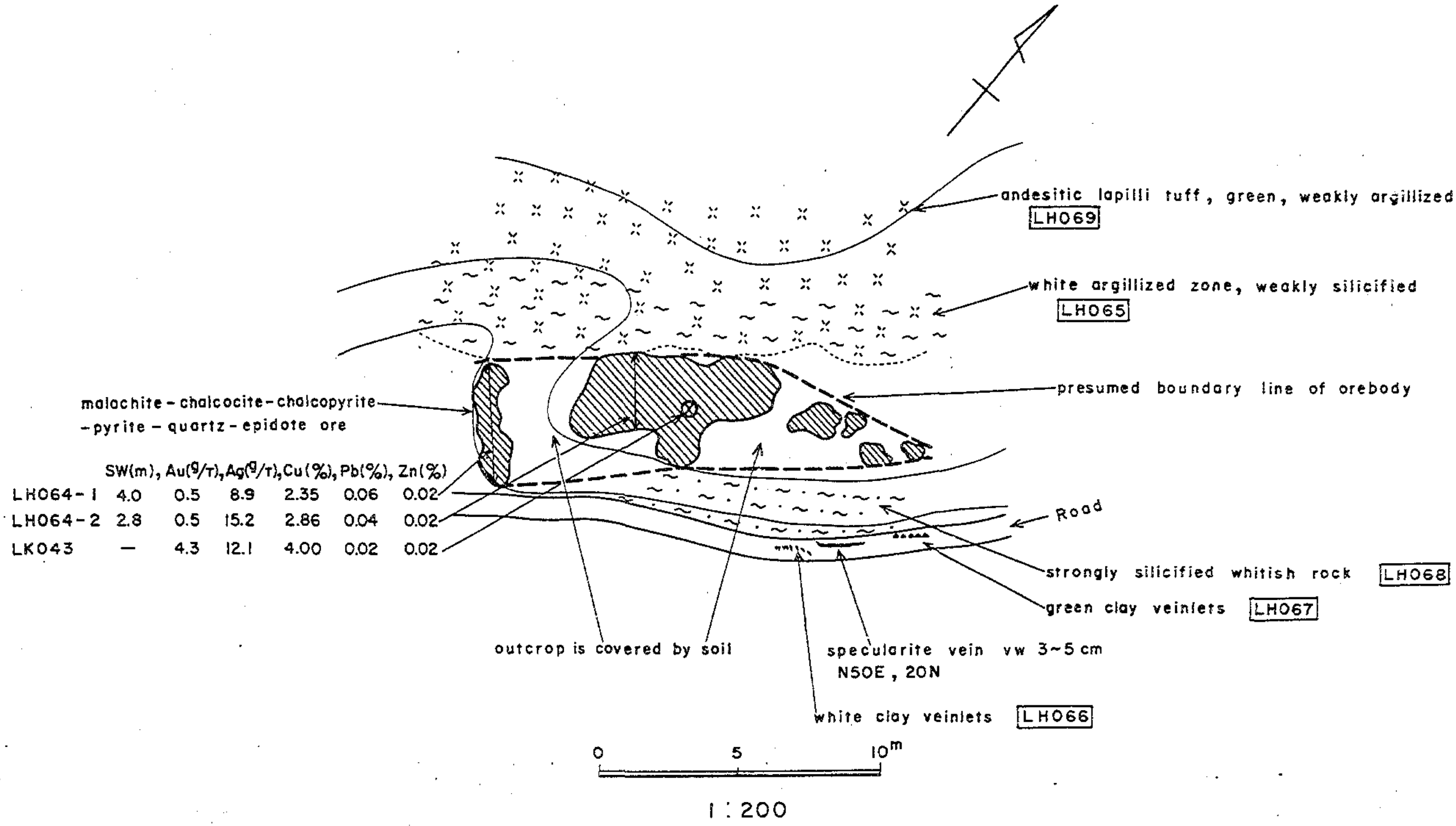


Fig. 16 Survey Map of Outcrop S-2

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 assay result of the main mineralized zone of trench is as follows:

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

(4) Fortuno (S–4)

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

The mineralized zone 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 six places of pits and trenches, the mineralized zone in the one of the 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. This suggests the existence of the genetic relation between the intrusives and mineralization.

The assay result of main mineralized zone in trench is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pt(%)	Zn(%)
LH039	1.10	tr.	tr.	1.41	0.05	0.05

4. Southern Constanza

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 this area shows a concentric distribution surrounding the intrusive of tonalite megascopically (Fig. 9), suggensting a possibility that there might be an important relationship between the intrusive and the mineralization.

The type of the mineralized zones of the area 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 (C–1)**

The mineralized zone is situated 7 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 observed at 4 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 assay result of the one of vein, striking N20°W and dipping 60°N is as follows;

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

(2) C–2

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 5 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 is 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

(3) Limoncito (C–3)

The mineralized zone 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

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 samples)	0.4	5.3	2.63	0.02	5.90

5. 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–SE system (Fig. 17), 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.

Although it has been thought that the vein in the vicinity of the mine was one vein, it was made clear by this survey that the Mata Grande deposit was composed of three veins of NW-SE system which were arranged in echelon within an extent of 1.2 kilometers in the direction of northwest (Fig. 17). The veins strike N40° to 70°W and dip 60° to 70° northward. The extension of the outcrops can be traced for about 200 meters in the northern part (M–1) which are being explored by pitting or being mind for about 150 meters in the central part (M–2) on the top of ridge, and about 500 meters in the southern part (M–3) which continue from the creek to the hilltop (Fig. 17). The veins in the southern part show the longest extension and are stable in scale and grade, being 0.1 to 1.5 meters wide. The outcrops are 1 to 6 meters long in extension, trending N50° to 70°W. The veins include network and disseminated ones and the single veins, which show lenticular in the whole. The ore minerals are composed of chalcopyrite, bornite, chalcocite, covelline, malachite, pyrite and limonite, and the gangue minerals are quartz, epidote and chlorite. Variation of mineral assemblage in the vein is recognized on the outcrop. The ore minerals decrease at the tail end, grading to quartz vein or quartz epidote vein.

Geology in the pit in the northern part (M–1) is composed of tonalite in the upper part and green schist in the lower part. Mineralized zone is found at a boundary between the two rocks, being occurred in green siliceous rock derived from green schist and tonalite. The mineralized zones strikes N60° to 70°W and dips 60° northward. Two types of ore are found. The one is

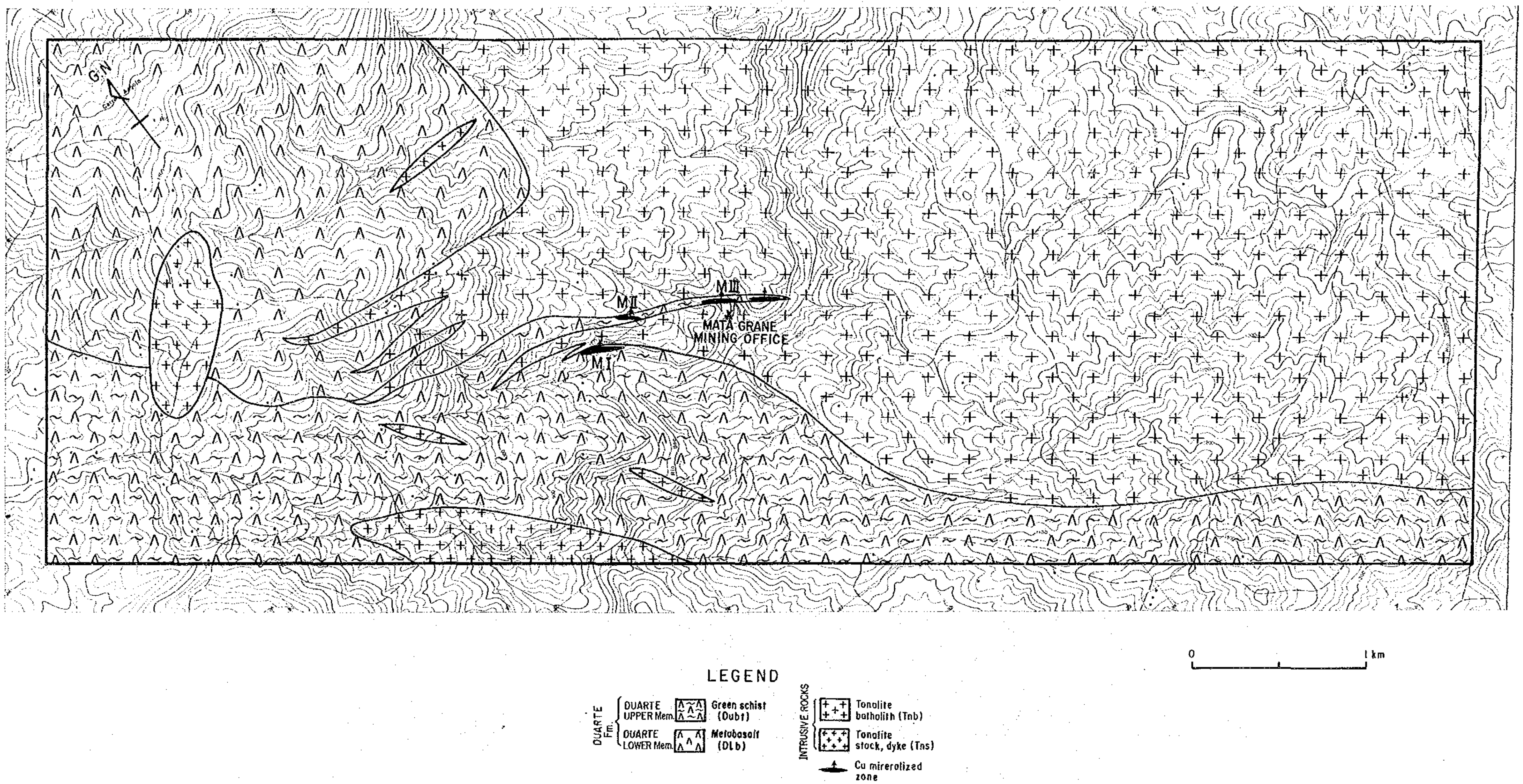


Fig. 17 Geological Map of the Mata Grande Area

network and disseminated malachite and covelline in quartz vein, and the other is that plenty of chalcopyrite, bornite and chalcocite coexist with quartz. The latter is high grade, and the assay value of a massive ore in the survey of first phase showed 21.6 % Cu. In this part, the mineralized zone in the pit can be traced further northward for about 50 meters.

The outcrops in the central part (M–2) occur in the tonalite, and green schist which is the intercalated layers in tonalite. The outcrops of the veins on the hilltop are 0.1 to 0.4 meter wide and 30 meters long. The trenches were excavated at four places. The northwestern extension of the vein grades into barren quartz vein several tens centimeters wide. The country rock is green schist, which is silicified and chloritized.

The assay results of the mineralization are as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)
MK001	0.40	tr.	tr.	1.71
MK002	0.10	1.0	14.0	6.71

Under the microscope, it is well observed that the network veins consisting of chalcopyrite and bornite are present in quartz and that these have been altered to chalcocite → covelline → limonite by weathering. Malachite is found as a form of vein in gangue minerals in the outside of limonite.

Although bornite is in contact with chalcopyrite in a form of ameba similar to those in the Constanza area, no relation including replacement can not be observed, which leads to a strong possibility that bornite would be primary mineral.

It was confirmed that the outcrops in the southern part (M–3) have an extension of about 500 meters in the whole. The veins are megascopically present in tonalite zone, which is composed of the banding of green schist and tonalite each of which is 1 to 10 meters wide. The size of the outcrops is 0.2 to 1.5 meters wide and 0.5 to 6 meters long, and they strike N40° to 70°W and dip 60° northward to 80° southward. The veins somewhat vary in occurrence from place to place.

The outcrops in a small vein on the northern side show two modes of occurrence: the one includes the mineralized lenses mainly composed of sulfide and quartz, occurred in green schist, and the other includes the vein in tonalite. The former occurs in green schist layer 5 meters wide intercalated in tonalite, and the mineralized lens is emplaced along the schistosity of green schist which is striking N50°W and dipping 60° northward. The scale of the lenses is 0.3 x 0.7 to 0.1 x 0.2 meter. The constituent minerals consist mainly of chalcopyrite and quartz, accompanied by a small amount of malachite, bornite and chalcocite. The ore minerals in these lenses are fine-grained, and show a peculiar appearance seemingly to be of massive ore.

The veins in tonalite are the copper quartz vein containing malachite, chalcopyrite, bornite, chalcocite and covelline. The country rock surrounding the veins is chloritized fine-grained, pale green altered rock showing the schistosity. These are 5 to 30 centimeters wide and 70 centimeters long. The northeastern extension of these veins grade into the barren quartz veins several tens centimeters to 2 meters wide.

The assay result of these mineralized zones is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)
Lens in green schist (MK008)	0.30	0.20	8.0	8.39
Vein in tonalite (MK006)	0.20	0.50	12.8	7.22

The outcrops on the hilltop in the sourthern part are composed of single or network veins consisting of malachite, chalcopyrite, chalcocite, covelline, limonite and quartz. The country rock is green schist intercalated in tonalite.

The outcrops are 0.4 to 1.5 meters wide and 1 to 6 meters long, striking N40° to 50°W and dipping 60° northward to 80° southward. In the southern extension of the vein, ore minerals decrease gradually, grading into quartz vein. Chlorite is a remarkable alteration mineral. The assay result of the typical ores obtained from the outcrops is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)
MK015	0.50	0.30	8.9	1.37
MK016	1.50	0.50	4.7	4.47
MK017	0.40	0.25	0.8	0.88
MK018	0.50	0.20	2.5	1.71

(2) **Quartz Vein**

The survey to purpose the origin of gold was conducted in this work, because the gold deposit of alluvial type is distributed in the Mata Grande area and because the geochemical anomaly of gold was detected in the geochemical survey of the first phase.

The survey was preponderantly directed to the investigation of quartz vein since it is said that the middling of alluvial gold consists of quartz. Many quartz samples were obtained, and typical ones were chemically analyzed, but no gold was detected.

The quartz veins are classified into two kinds as in the following.

(i) Quartz Vein Associated with Copper Vein:

It is distributed at the tail end of the copper veins of the Mata Grande mine and in the vicinity of them mentioned in the above, and it is related to the mineralization of copper. Some variation of mineral assemblage is observed according to the locality, such as quartz vein, quartz-epidote vein and quartz-chlorite vein. Quartz of low crystallinity and milky white in color is dominant. The veins are 10 centimeters to 2 meters wide, striking northwesterly and dipping northward.

Chemical analysis of the quartz vein at the tail end of the northern vein of the Mata Grande copper vein (MK005) and the quartz vein at the northern end of the southern vein (MK013) revealed no content of gold.

Gold is ubiquitously contained in the Mata Grande copper vein where copper mineral is present in such grade as 0.1 to 0.5 g/T. The facts in the above mean that gold exists in close association with copper.

(ii) Independent Quartz Vein

Many quartz veins and quartz-epidote veins several centimeters to 2 meters wide are found in tonalite and green schistose rocks. A large number of quartz veins and epidote-quartz veins several centimeters to several tens centimeters wide were discovered in tonalite batholith in the basin of Rio Jamamun in the southeastern part of the survey area where gold geochemical anomalies were detected. Most of them strike northwesterly and dip northward. The quartz is generally of high crystallinity and white in color. Although the alteration of the country rock is weak, silicification and montmorillonitization are observed. Chemical analysis of the typical vein among these (MK034) led to detect no gold.

Many quartz veins are also found in tonalite and green schistose rocks to the west of the Mata Grande mine, and the typical veins (MS011, MS012, MT006, MT011) were analyzed but no gold was detected.

6. Los Vellecitos

The area is situated about 11 kilometers west-northwest of Constanza (PL. 1).

The access to the site from Constanza is at first to drive jeep for about one hour to the north of Los Corrales, then it takes about two hours to reach the site on mule back.

The geology of Los Vallecitos mainly consists of andesite lava, and lapilli tuff and tuff breccia of the same source of the middle member of the Tireo formation. The outcrops of ore vein discovered in 5 spots are composed of gold bearing copper veins emplaced in these rocks. The ore minerals include malachite, chalcopyrite, bornite, chalcocite, pyrite, specularite and limonite, accompanied by gangue minerals such as quartz, epidote and chlorite. The copper veins show the form of network and dissemination. The veins are small in scale in many cases, being several tens centimeters wide and several meters in extension.

The discovery of these outcrops in the survey resulted in to make clear the source of geochemical anomalies detected by geochemical survey conducted in the first phase.

PL. 1 shows the position of the outcrops. The detail on the outcrops is described in the following.

(1) V–2

The spot is situated about 2 kilometers north of the confluence of the Rio Yaquesillo and the Arroyo La Sabina. The geology in the vicinity is composed of hematitized andesitic tuff breccia.

The ore veins are emplaced along the fractured fissures in the rock. The ore minerals include malachite, chalcopyrite, bornite, chalcocite and limonite, accompanied by quartz as the gangue mineral. The mineralized zone is 1.5 meters wide, in which several small veins 1 to four centimeters wide are present. The extension of the vein is considered to be about 5 meters from the length of the pit excavated. The vein strikes N-S to N10°E and dips 60° to 65°W. Chloritization is notable in the country rock. Pitting was conducted in the past, and a small amount of ore is piled in the vicinity of the pit.

The assay result of the vein is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SY023–1	0.04	0.33	21.0	4.77	0.16	0.10

(2) V–4

The spot is situated about 1 kilometer north of the confluence of the Rio Yaquesillo and the Arroyo La Sabina. The outcrops of the ore veins were discovered at five places. (Fig. 15). The outcrops are composed of the network veins consisting of malachite, chalcopyrite, bornite, chalcocite, pyrite, specularite, limonite and quartz. Two trends of veins such as NW-SE system and NE-SW system are seen, and the veins are emplaced in the fractured fissures.

The geology in the vicinity consists of andesitic tuff and tuff breccia, and chloritization and silicification are common alteration of the country rock. The veins of NW–SE system found in the southern part are 0.2 to 0.9 meter wide, striking N20° to 25°W and dipping 60° to 80°S, which can be traced for about 20 meters laterally.

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

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SY024–3	0.25	1.10	193.7	18.31	0.16	0.20

7. Others

(1) Caño del Gallo (S–6)

The spot is situated about 15 kilometers west of Constanza, in the northeastern part of the vein groups in the Sabana area (Fig. 9, PL. 1). The geology in the vicinity consists of andesitic lapilli tuff of the middle member of the Tireo formation. The mineralized zone is composed of copper veins in the form of network and dissemination. The main mineralized zone observed in this spot is only the outcrops distributed between the pits No.1 and No.2, and others have been mined out by pitting and trenching (Fig. 16).

Six outcrops of the ore veins are found in an extent of 4 m x 1.5 m. These are the veins of network and dissemination consisting of malachite, specularite, limonite and quartz. The largest outcrop is 0.4 m x 1.2 m in size, and the assay result of it is as follows:

	Sampling width (m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
SK004	0.40	tr.	tr.	9.36	0.22	0.44

(2) C–4

The spot is situated about 6 kilometers west-southwest of Constanza, and the outcrop is located on the left bank of the Rio Grande. The geology of the surrounding area consists of coarse-grained andesitic tuff of the middle member of the Tireo formation, and the outcrop is composed of copper bearing quartz vein emplaced in the rock. The maximum width of the quartz vein ls 6 meters, among which copper mineralization is observed in a width of 2 meters in the lower part. The ore minerals consist of chalcopyrite, pyrite, malachite and limonite, being relatively rich in sulfide minerals. The vein is 1.5 to 2.0 meters wide in the southern extension on the hill side, which is traceable for about 100 meters. While the northern extension is difficult to trace because it runs along with the Rio Grande in the stream.

The assay result of the outcrop is as follows:

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
CT002	2.0	tr.	1.1	0.93	0.18	1.10

(3) Tasajera (T–1)

The mineralized zone 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 mineralized zone 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

(4) T–2

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

3–2–2 Consideration

There are many mineralized zones in the Constanza area, such as the vein-type mineralized zones distributed at El Gramoso, Hato de Los Rodriguez and Los Vellesitos, Sabana and the south of Constanza and the pyrite dissemination zone distributed at the south of Constanza. These occur in the lower and the middle members of the Tireo formation and the acidic intrusive rocks.

The mineralized zone in the area include those associated with the tectonic line of NW-SE system and those with the intrusive masses of tonalite.

The vein-type copper mineralized zones at Hato de Los Rodriguez and Sabana correspond to the former, and vein-type copper mineralized zones and copper, lead and zinc mineralized zones at El Gramoso Pinar Bonito and at (C–4) along the Rio Grande to the latter.

The copper veins at Hato de Los Rodriguez strike northwesterly and dip northward, and the whole trend of distribution of the veins extends a northwesterly.

Each copper vein at Sabana strikes northeasterly and dips northward, and both the whole trend of distribution of the veins and that of the quartz-plagioclase porphyry extend northwestward. These facts suggest that the mineralization in both cases is related to the tectonic movement of the second order of the northwestern direction, and that the formers were occurred in the shearing fissures of NW-SE system and the latters in the fracturing fissures of NE-SW system formed in association with the tectonic lines of NW-SE system.

Because the veins and the pyrite dissemination zone at the south of Constanza previously mentioned are megascopically positioned on the southeastern extension mentioned above, and because the mineralized zones of the area surround the intrusive mass of tonalite (Fig. 9), it is thought that the mineralization is closely related to the intrusive mass, though the relation with the tectonic lines of the northwesterly trend can not be neglected.

The time of mineralization of the area is considered to be in the period between Paleocene and before Oligocene, because (1) the mineralization is observed in the acidic intrusive bodies intruded into the Cretaceous Tireo formation, because (2) the time of intrusion of tonalite intrusives is considered to be from late Cretaceous to early Paleocene because the age of the intrusives which obtained from rediometric age determination was from 60 to 70 m.y. and because (3) the pebbles of ore which was formed in the country rocks belonging to the Tireo formation is found in the basal conglomerate of the Oligocene formation. In other words, it is thought that the mineralized zones of the area were formed by mineralization accompanied by tectonic movement and igneous activity in the later stage of the Laramide Orogeny.

The variation of assemblage of constituent minerals of the veins is observed in the copper veins as well as the copper, lead and zinc veins in the area. That is, when a vein is traced laterally, the ore minerals decrease toward the tail end of the vein to become the quartz vein or quartz epidote vein.

This variation is recognized in the area where the plural veins are distributed: quartz vein or quartz-epidote vein is generally distributed surrounding the outside of the veins containing the ore minerals. Similar tendency is recognized in alteration of the country rocks, though there is some difference according to the characters of the veins. For example, in the case of strong copper mineralization, (1) silicification and chloritization are notable: El Gramoso area, northern Sabana area and southern Constanza area, (2) chloritization is notable: Fortuno and Roblito deposits in the Sabana area and a part of the veins at Hato de Los Rodriguez, and (3) silicification and epidotization is notable a part of the veins at Hato de Los Rodriguez and El Gramoso. Thus the alteration becomes weak toward the outside of the group of veins.

The characteristics of the copper veins and the copper, lead and zinc veins of the area above mentioned are (1) scanty in pyrite and abundance in specularite, and (2) bornite occurs as the primary mineral, as compared with the common vein-type deposit.

These facts suggest that the hydrothermal solution which formed the copper vein and the copper, lead and zinc vein of the area was relatively low in partial pressure (fugacity) of sulfur.

The area is likely to be a zone subjected to a great amount of erosion after the formation of mineralized zone. That is, the presence of ore pebbles in basal conglomerate of the Oligocene formation distributed in the south of the area indicates that the area had become the land and the erosion had advanced from the surface to the deeper part where the ore minerals had been deposited.

The amount of erosion before the Pleistocene has not been made clear. But, although the amount of erosion after the extrusion of the Pleistocene dacite (0.5 m.y. in absolute age) is different from place to place, the rocks in the south of Constanza have been eroded 150 to 300 meters vertically (the amount of erosion is 0.3 to 0.6 milimeter annually).

The tectonic movement of the area is basically the block movement in which the blocks might moved downward or upward, and it is thought from the situation of distribution of the Tireo formation that the northwestern edge was elevated and the southeastern edge was depressed in a direction from the northwest to the southeast. Therefore, it is assumed that the amount of erosion was greater in the northwestern part than the southeastern part taking the present topographical condition into consideration.

This is supported by the fact that the ore deposits of Sabana, El Gramoso and Hato de Los Rodriguez which are distributed in the northwestern edge of the area are composed of the veins mainly consisting of copper ores, and that the ore veins at the south of Constanza include a number of copper, lead and zinc veins. This is consistent with the fact that the copper ratio is greater in the northwestern part in terms of the abundance of elements in geochemical survey, and that the lead and zinc ratio is greater in the southern part. Therefore, it is important, when the exploration is to be considered, to evaluate the amount of erosion together with that of scale of the mineralized zone.

Regarding the copper minerals, a component in the veins of the area, the variation from the center to the outside is observed in such a way, chalcopyrite·bornite through chalcocite·covelline →limonite to malachite, in which the process of oxidation in association with weathering can be read.

The Mata Grande deposit consists of copper veins occurred in the country rocks such as green schistose rocks of the Duarte formation and tonalite. The deposit is composed of three veins arranged in echelon trending northwesterly.

The outcrops of the veins are approximately 150 meters, 200 meters and 500 meters in extension respectively from northwest to southwest, being distributed in an extent of 1.2 kolometers.

The result of geochemical survey shows that the copper anomalies continue to both sides of northwest and southeast, reaching 3 kilometers in total extension. Some copper anomalies extending northwesterly were detected to the south of the above, which suggests the potential existence of the parallel veins.

It is thought that these veins were formed by mineralization associated with the potential tectonic lines of NW-SE system of the first and the second orders.

The assemblage of the ore minerals and the alteration of sulfide minerals by oxidation show the same type as in those of the Constanza sub-area. The difference is that although the outer periphery of chalcopyrite at Constanza has been limonitized, the Mata Grande deposit is deficient in limonite, which leads to the assumption that in the latter, leaching of iron has been advanced as compared with that of copper.