REPORT ON GEOLOGICAL SURVEY

OF

LAS CANITAS AREA

DOMINICAN REPUBLIC

PHASE Ⅲ

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 scheduled to be performed for three years from fiscal 1983, and this fiscal year is the third phase. MMAJ organized a team for field survey consisting of 7 members and dispatched it to the Domican Republic from July 16, 1985 to November 22, 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 the third phase and will form a portion of the final report.

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

February 1986

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

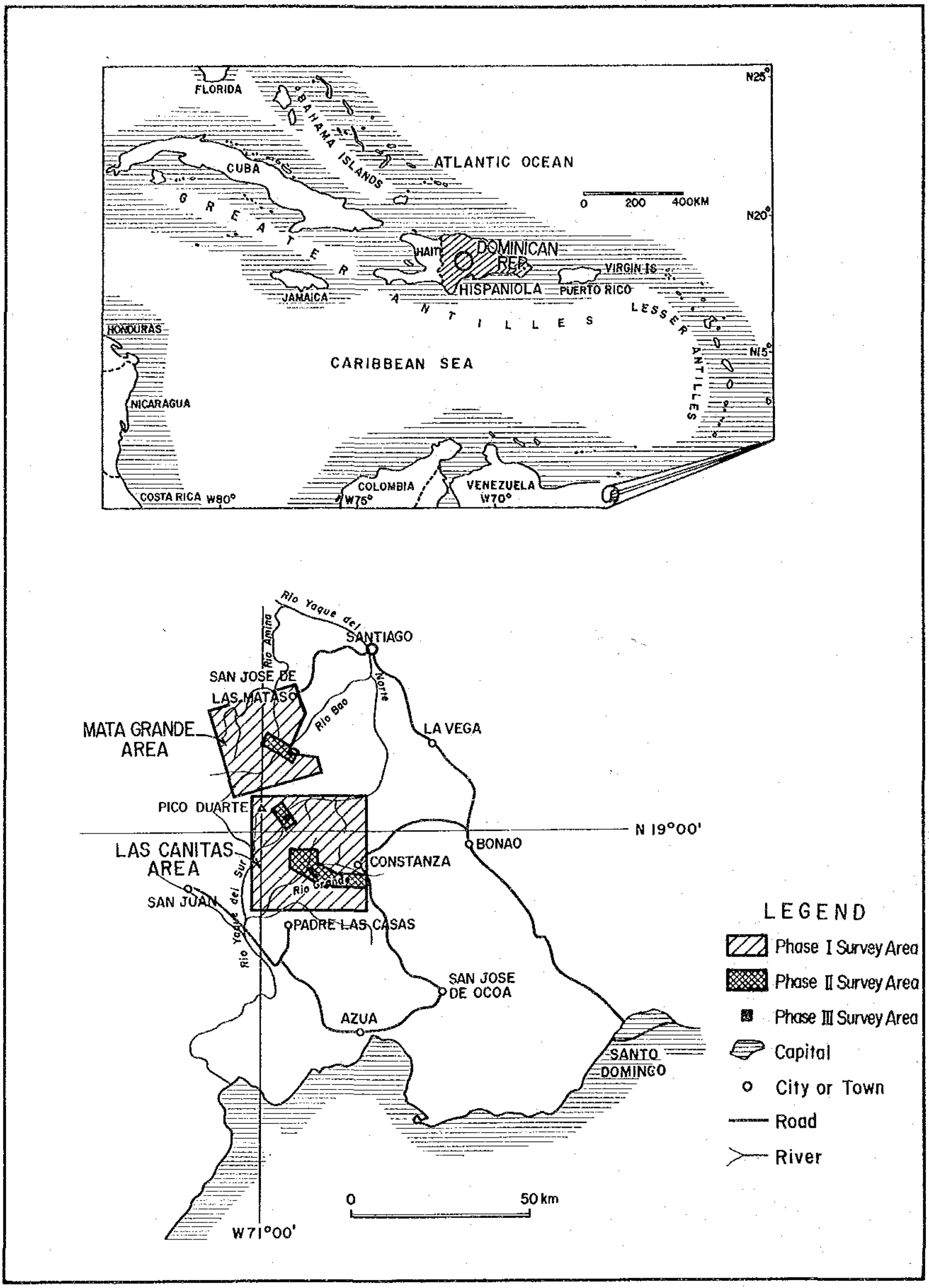

Fig. 1 Location Map of the Survey Area

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ABSTRACT

The survey of the third phase of the project, "Collaborative Mineral Exploration in the Las Canitas area" in the Dominican Republic was conducted for the two target areas such as Constanza and Pico Duarte extracted as the result of geological and geochemical surveys in the first and the second phases to illuminate the occurrence of the ore deposit. Geological survey (detailed survey) and drilling were performed in the Constanza area and geophysical survey in the Pico Duarte area. The outcomes are as follows.

1. Constanza Area

(1) Geological Survey (Detailed Survey)

The area is mainly composed of andesitic lava and its pyroclastic rocks of the middle member of the Cretaceous Tireo formation, and the intrusive rocks including tonalite and dacite. Numerous groups of NW-SE trending copper bearing quartz veins are distributed in the area as the same direction as the main geologic structure and the intrusive rocks. These veins are distributed along the southern flanks of the tonalite intrusive mass, indicating the genetic relationship between them. The center of the mineralized zone is estimated to be located in the vicinity of the top of Mt. Loma Sito Grande based on the geochemically anomalous zone and occurrence of the ore veins. The scale and grade of veins become more superior toward the top of the mountain.

(2) Drilling

(i) Hole DJM-1

It became clear that the downward extension of the outcrop G-19 became poor in both size and grade and that many veins consisting of gangue minerals were found around the ore veins.

(ii) Hole DJM-2

It was made clear that the vein of the outcrop G-18 continued downward and that the size and grade were much the same as that of the outcrop.

(iii) Hole DJM-3

It became clear that although many veinlets were found at the downward extension of the outcrop G-17, it did not warrant economic operation because of its poor grade.

(iv) Hole DJM-4

The downward extension of the outcrop G-12 could not be encountered because it had been displaced by a fault.

(v) Hole DJM-5

It became clear that the vein of the outcrop G-21 continued downward maintaining much the same quality and that it was accompanied by a wide silicified zone.

2. Pico Duarte Area

(1) Geophysical Survey (SIP Method)

The porphyry copper-type mineralized zones were found in the granodiorite mass of the area. The P-1 mineralized zone, the largest one in the area, showed small IP effect, but it was made clear that the high resistivity zone reflecting the silicified zone which might be closely related to the mineralization was found to have an extent 300 meters long, 300 meters wide and 150 meters deep.

I. INTRODUCTION

CHAPTER 1　OUTLINE OF SURVEY OF THIRD PHASE

1–1　Outline of Survey Area

The areas surveyed this phase are those two such as Constanza and Pico Duarte extracted as the promising areas for occurrence of ore deposit as the result of the surveys of the first and second phases (Fig. 1, 2).

The Constanza area is the area having an extent of six square kilometers centering on the El Gramoso settlement about fifteen kilometers to the west-southwest of Constanza Town. The geology is composed of acidic and intermediate volcanic rocks of the middle member of the Cretaceous Tireo formation, and many outcrops of copper bearing quartz veins are distributed in this area.

The Pico Duarte area is situated on the southeastern slope of Mt. Pico Duarte. Porphyry copper type mineralized zones emplaced in granodiorite were found in this area.

1–2　Purpose of Survey

The purpose of survey of this phase was to make clear the occurrence of ore deposit by elucidating the geology in detail. The main objectives were determined as in the following because of different characteristics of mineralization of each zone.

1.　*Constanza Area*

A number of copper bearing ore veins of NW system running in the same direction as the main geologic structure are distributed in this area. The geological survey (detailed survey) and drilling survey were conducted in this phase. The geological survey was carried out for the main objectives such as to make clear the relationship between the mineralization and the geological structure as well as geochemical anomalies. The drilling survey was conducted for the main objectives to examine the occurrence of mineralized zone.

2.　Pico Duarte Area

Porphyry copper type mineralized zones are distributed in this area. In this phase, geophysical survey (SIP method) was carried out for the P-1 mineralized zone which is the largest outcrop in the area. The main objectives were to make clear the continuity of the mineralized zone to the depth, to extract the anomalous zone and to make clear the characteristics.

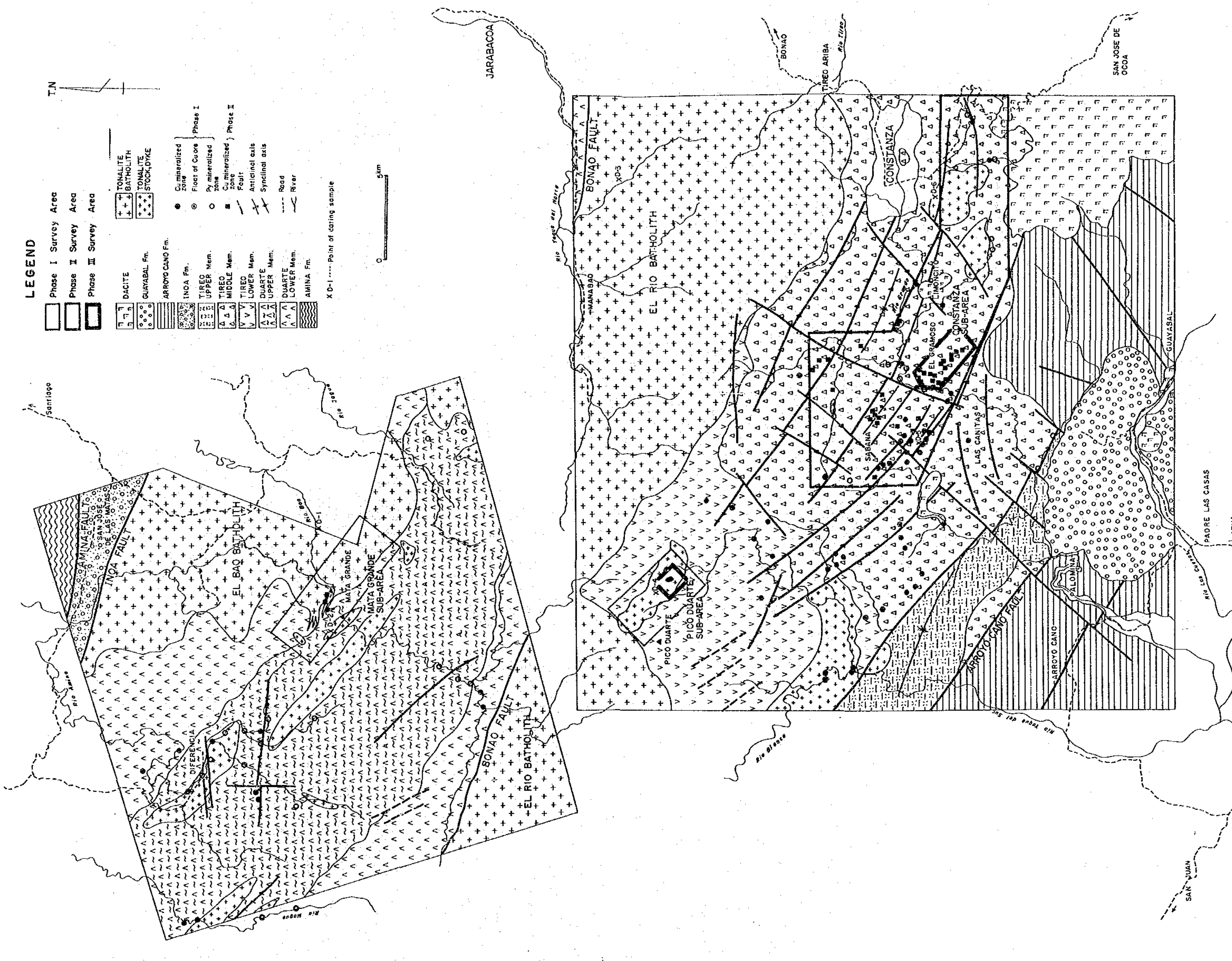


Fig. 2 Geological Map of the Survey Area

1–3 Details and Method of Survey

1–3–1 Constanza Area

(1) Geological Survey (Detailed Survey)

Geological survey was conducted in detail for six square kilometers of the survey area with trenching, and geological mapping was done for the total survey route of 46.2 kilometers and trenching for the total extension of 70.5 meters.

The detail of survey is shown in Table 1.

(2) Drilling Survey

Drilling Survey was performed for five holes with total length of 1,002.40 meters toward the lower extension of the main outcrops. Table 1 shows the detail.

1–3–2 Pico Duarte Area

(1) Geophysical Survey (SIP Method)

Electric prospecting by spectral IP method was performed in the P-1 mineralized zone for the total length of survey line of 6.5 kilometers. Table 1 shows the detail.

1–4 Members of Survey Team

The personnel who participated in this survey are as follows.

Survey Planning, Investigation of Result of Survey, and Negotiation

Japanese Counterparts

Makoto Ishida	Metal Mining Agency of Japan (MMAJ)
Toshio Sakasegawa	〃
Tadaaki Ezawa	〃
Akio Hoshino	〃 (Resident Representative in Mexico)

Dominican Counterparts

Alejandro Alejandro	Direccion General de Mineria (DGM)
Victor Montero	〃
Ramón E. Ramíres	〃
Victor M. Garcia	〃

Field Survey

Japanese Side

Hideo Kuroda	Geological Survey and Management	BEC
Tomio Tanaka	Geophysical Survey	〃
Masatane Kato	〃	〃

Hiroshi Takahashi	Geophysical Survey	BEC
Naoto Hamazaki	Drilling Survey	〃
Shigeo Sekiguchi	〃	〃
Teruo Omori	〃	〃
Dominican Side		
Octavio Lopez	Geological Survey	DGM
Jose A. Perez	〃	〃
Jose Santilises	〃	〃
Angel D. Soto	Drilling Survey	〃
Publio Casilla	〃	〃

Table 1 Details of the Survey

Type of Work	Contents
Geological Survey (Detailed Survey)	
Survey Area	Constanza
Area Surveyed	6 km^2
Length of Route Traversed	46.2 km
Length of Trench	70.5 m
Thin Section	10
Polished Section	10
X-ray Diffractive Analysis	51
Chemical Analysis of Ore	60
Drilling Survey	
Survey Area	Constanza
Number of Holes	5
Total Depth Drilled	1,002.5 m
Polished Section	10
X-ray Diffractive Analysis	18
Chemical Analysis of Ore	61
Geophysical Survey (S.I.P. Method)	
Survey Area	Pico Duarte
Total Length of Survey Lines	6.5 km
Number of Observation Points	195
Laboratory Measurement of Rock	10

II. PARTICULAR

CHAPTER 1 CONSTANZA AREA

1–1 Geological Survey (Detailed Survey)

The detailed survey area of this phase was an area of six square kilometers centering on the El Gramoso settlement extracted as a promising area for occurrence of ore deposit as a result of survey of the second phase (Fig. 2). The area is situated at 12 kilometers to the west-southwest of Constanza. The access from Constanza is to drive jeep for about one and a half hours to the north of Limoncito, and from there, further to go on muleback for 1.5 hours to reach the area.

1–1–1 Purpose and Method of Survey

The purpose of the survey was to make clear the occurrence of ore deposit in the area with the main objectives such as analyzing the fissure system associated with the mineralization, elucidating the relationship between the mineralization and geologic structure as well as the geochemical anomalies, and also to make clear the continuity of the veins.

The detailed geological survey was conducted with trenching, and the geological mapping was done for the total distance of survey route of 46.2 kilometers and trenching for the total extension of 70.5 meters at five places.

The period of survey was from July 18, 1985 to October 27, 1985.

The result of geological survey was compiled on the geological map of 1 : 5,000 scale on the basis of the route map of 1 : 2,000 scale.

The result of trenching was compiled on the survey map of 1 : 100 scale. Sixty one samples collected from the veins were analized for Au, Ag, Cu, Pb and Zn.
Table 1 shows the details of survey and the items of samples.

1–1–2 Geology and Geologic Structure

1. Geology

Geology of the area consists of the middle member of the Cretaceous Tireo formation and the intrusive rocks including tonalite intruded into the above (Fig. 3, 4).

The middle member of the Tireo formation is mainly composed of andesitic pyroclastic rocks (Tmat) interbedded with andesite lava (Tma). The pyroclastic rocks mostly consist of lapilli tuff. In order to make clear the detailed geological sequence, the andesitic pyroclastic rocks were classified into lapilli tuff to course-grained tuff (Tmatl) and fine-grained tuff (Tmaft) (Fig. 3).

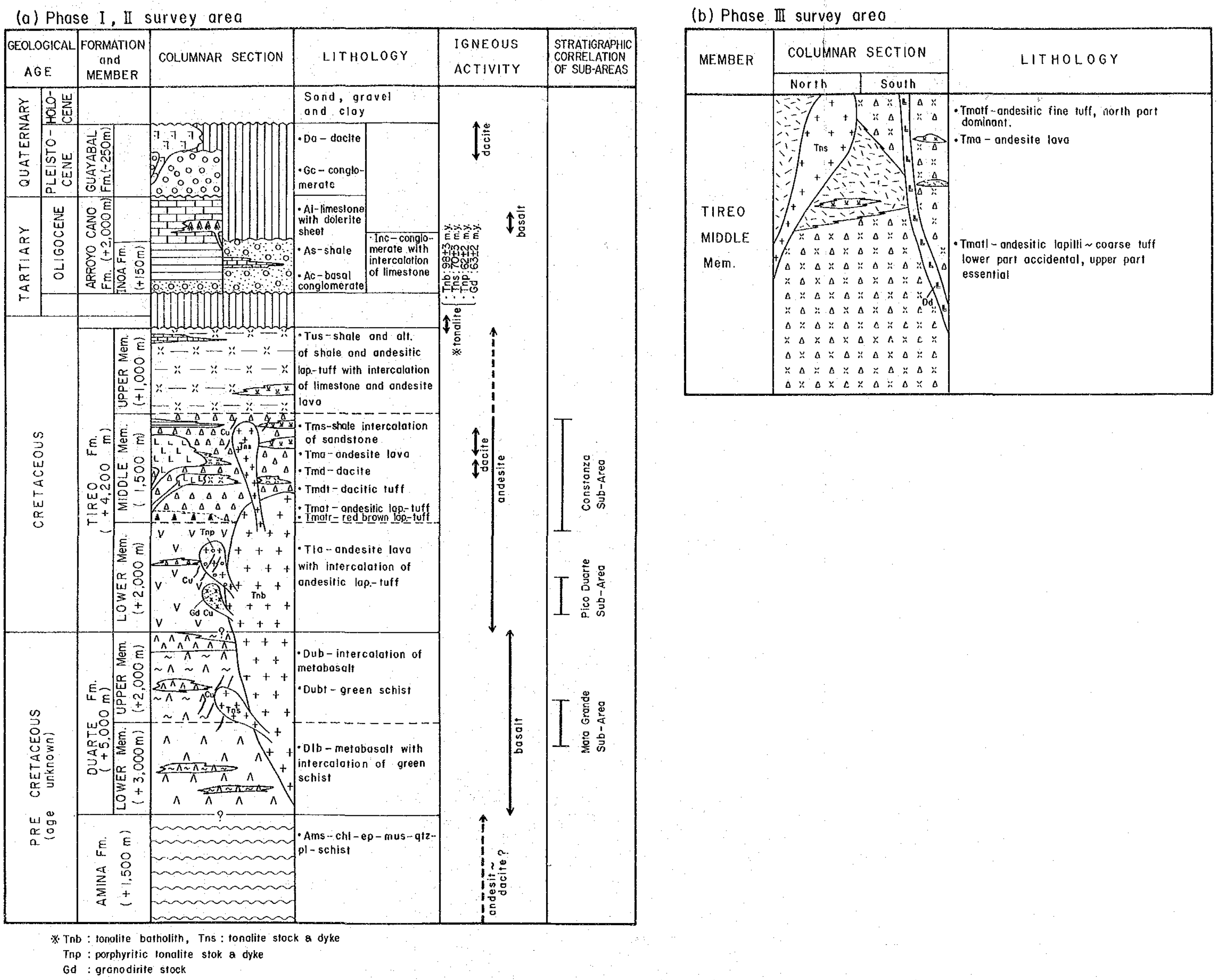


Fig. 3 Generalized Stratigraphic Columnar Section in the Survey Area

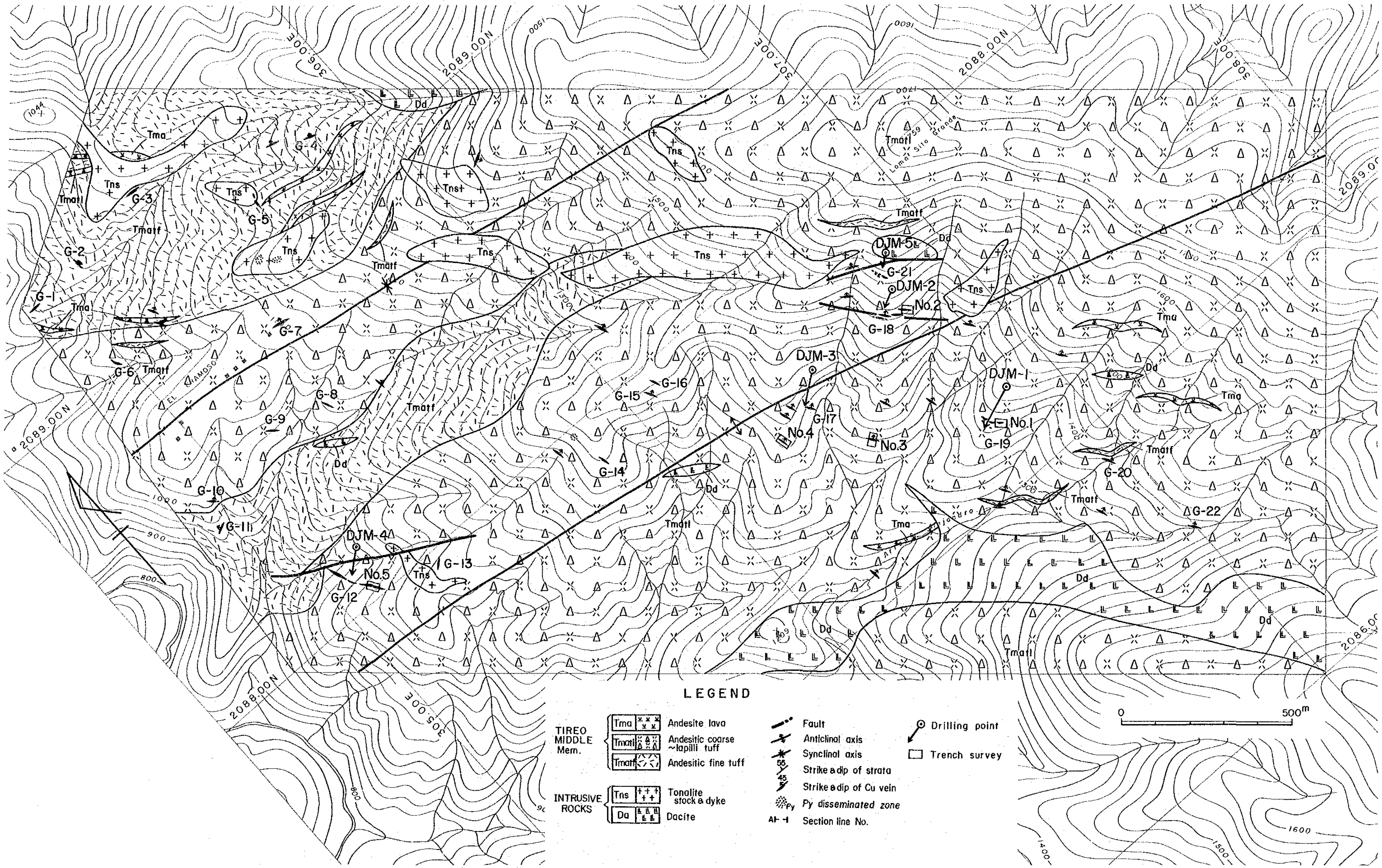


Fig. 4 Geological Map of the Constanza Area

Andesitic lapilli tuff to course-grained tuff (Tmatl) is extensively distributed in the southern part. The rocks are pale to dark green, sometimes variegated in color. Stratification is locally shown as the result of sorting in water. The pebbles are angular to subangular andesite. They generally consist of shards of andesite, rarely of decite. The groundmass is andesitic and shows green tint, which sometimes shows characteristic reddish brown color having undergone hematitization.

The characteristics under the microscope of the typical rock are as follows.

GL014 Andesitic course-grained tuff (in the vicinity of Mt. Loma Sito Grande)

Texture: Pyroclastic texture

Pebble: Andesite > andesitic tuff

Pebbles occupy about forty per cent of the whole rock, and are subround to subangular. They are about one milimeter in diameter.

Groundmass: Highly altered, and hard to discriminate the pebbles from groundmass. Epidote, chlorite and quartz have been produced both in pebbles and groundmass as the secondary minerals.

The accidental pebbles of dacite shards are present in abundance in the stratigraphically lower part, and the rock grade into the essential andesitic tuff toward the upper part.

Andesitic fine-grained tuff (Tmatf) is dominantly distributed in the northern part, and in southern part, it occurs as thin beds in andesitic lappili tuff and course-grained tuff.

The rock is greenish blue and massive, partly containing boulders.

The characteristics under the microscope of the typical rock is as follows.

GK005 Andesitic fine-grained tuff (tributary of Arroyo Alejandro)

Texture: Pyroclastic texture

Shard: Andesite

A small amount of andesite shards are contained. They are commonly 0.2 milimeter in diameter, sometimes reaching to one milimeter.

Groundmass: The original texture has completely disappeared, being replaced by quartz and chlorite.

Calcite veinlets one milimeter wide arranged in parallel with a spacing of two milimeters can be observed.

Andesite lava (Tma) is intercalated in andesitic pyroclastic rocks as thin layers, and its distribution is limited. The rock is greenish blue and massive, often showing amygdaloidal texture, and the vesicles are filled with quartz, calcite and epidote.

The occurrence of andesitic pyroclastic rocks show the characteristics as in the following.

Lapilli to course-grained tuff with pebbles of greater diameter is dominant in the southern part. Toward the northern part, fine-grained tuff becomes to be dominant, and grades from lapilli to course-grained as contemporaneous heterotopic facies.

As to the kind of pebbles, the upper sequence contains only essential ones, while the lower part contains those of accidental. These facts suggest that the center of volcanic activity was to the south of the area.

The intrusive rocks include tonalite and dacite. Direction of these masses shows the trend of northwesterly in general.

Nine masses of tonalite (Tns) intruded into the middle member of the Tireo formation in the northern part of the area as stocks and dykes. The largest one shows an extent about two hundred meters wide and about one kilometer long in the central part of the area. The rock is gray, fine-grained common hornblende tonalite, often showing varied rock facies to have an appearance of plagioclase-quartz porphyry to dacite.

The result of microscopic observation of the typical rock is as follows.

GK009 Common hornblende tonalite (in the vicinity of El Gramoso)

Texture: Holocrystalline equigranular texture

Main constituent minerals: Plagioclase, quartz ≫ common hornblende

Accessory minerals: Iron minerals

Plagioclase takes euhedral to subhedral crystal form one to two milimeters across, showing myrmekitic structure. Quartz are present in plagioclase in a vermicular form or in an independent euhedral form. Common hornblende is 0.5 milimeter across and has been mostly replaced by chlorite and epidote.

Dacite intruded into the middle member of the Tireo formation as four dykes in the southern part of the area showing the northwestern trend. The greatest one is 200 to 300 meters wide and more than 1.5 kilometers long. The rocks of the middle member of the Tireo formation surrounding the dykes are silicified and disseminated by pyrite. The dacite is white to gray colour and contains quartz pheocrysts one milimeter acorss. The rock is generally massive and homogeneous, partly showing flow structure.

The characteristics under the microscope of the typical rock sample is as follows.

GK002 Common hornblende dacite (Arroyo Alejandro)

Texture: Holocrystalline porphyritic texture

Phenocryst: Plagioclase, quartz ≫ common hornblende

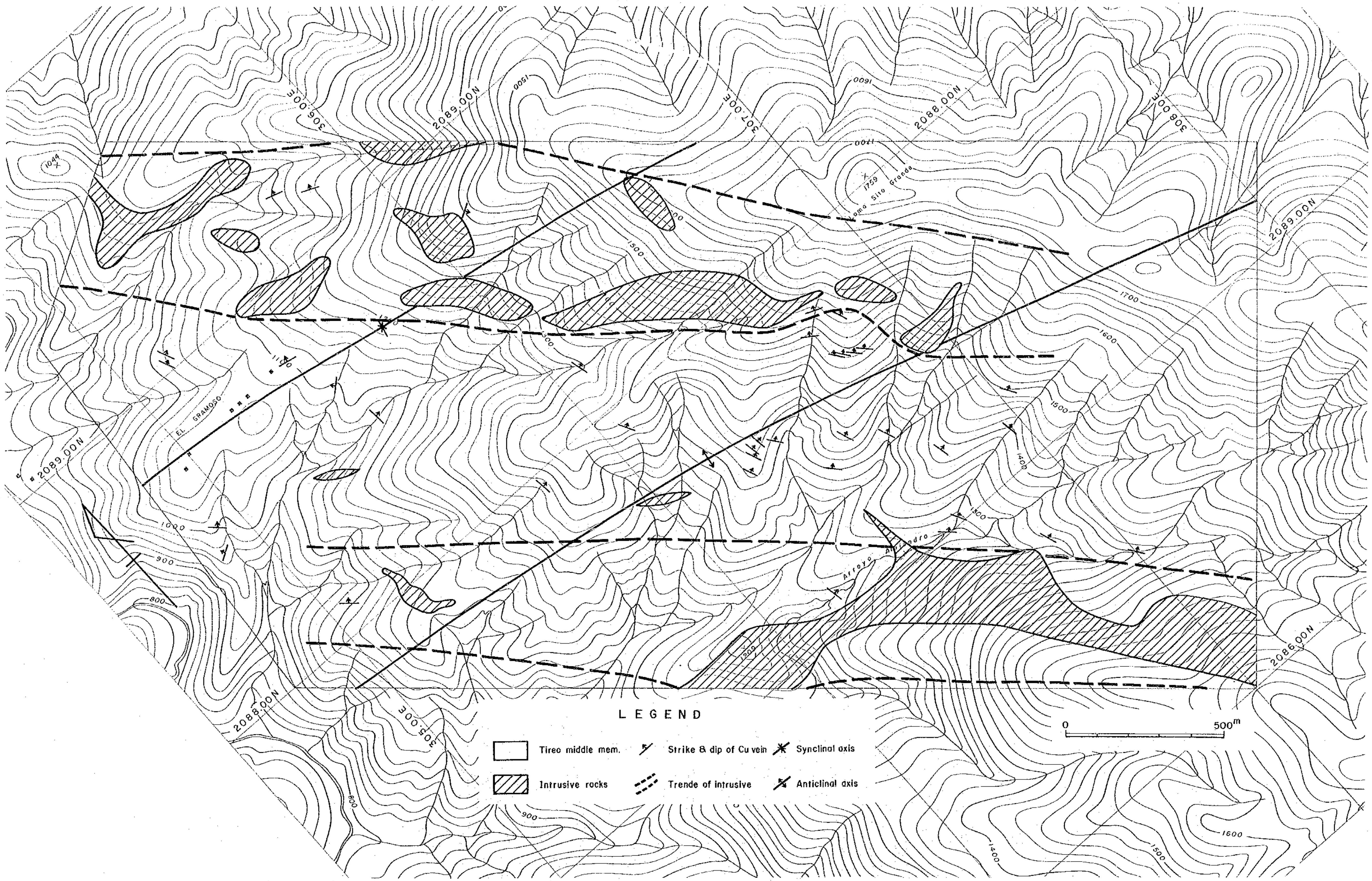


Fig. 5 Distribution Map of Veins and Intrusive Rocks

Plagioclase is less than one milimeter across, sometimes showing glomeroporphyritic aggregate one to two milimeters across, which has been partly replaced by chlorite and epidote. Quartz takes anhedral crystal form one to two milimeters acorss. Common hornblende is one milimeter acorss, being chloritized.

Groundmass: Plagioclase and quartz

Chlorite has been formed in the interestics of plagioclase and quartz.

2. Geologic Structure

In the regional survey area surrounding the detail survey area, fault and fold structures formed by the tectonic movement associated with the Laramide orogeny were developed in the Tireo formation and the intrusive rocks excepting for the Quaternary formation. Complicated forms of blocks were formed in the area by development of the faults of WNW-ESE system, and those of NE-SW system which seems to be in conjugation with the formers.

Macroscopically, these blocks were arranged along the main faults of WNW-ESE to NW-SE system and show the relative arrangement of the zones of upheaval, subsidence and upheaval from the north toward the south, and also this area plunges northeastward due to upheaval of Mt. Pico Duarte area located to the northwest of this area. Thus the survey area is positioned, in the block belonging to a relative upheaval zone on the southern side.

A model of fissure formation is discussed in the following based on the data of the geologic structure obtained by the survey of the first phase up to that of this phase.

(1) Regional geologic structure (Data from the First Phase)

Many faults were formed in Hispaniola Island caused by the Laramide orogeny. Those of the first order show a trend of E-W system, thrusting up southward, showing a log dipping toward the north.

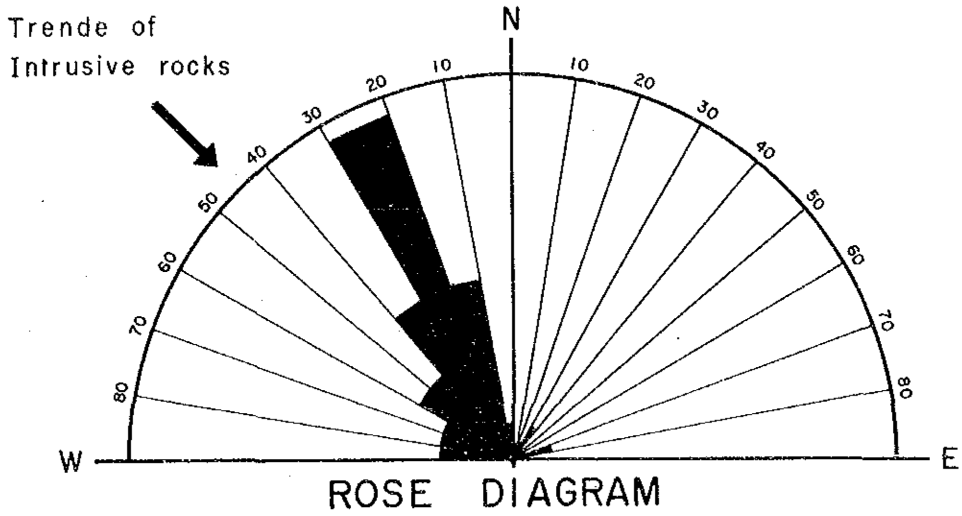
(2) Constanza Area (Data from the Second Phase)

A block movement bordered by the faults of the second order belonging to the two systems seems to be in conjugation to each other, is observed.

(3) El Gramoso Area (Data from the Third Phase)

The area is located in one block mentioned in the above, in which a large number of dykes and vein fractures are found. Fig. 5 shows the distribution of these fissures. The intrusive rocks show two zones running N45°W. This direction is in consistent with that of the faults of the second order, suggesting that the latent weak lines exists along the intrusive rocks.

Two systems of the trend of vein fractures such as N20°W, 40°N and N70°W, 50°N are



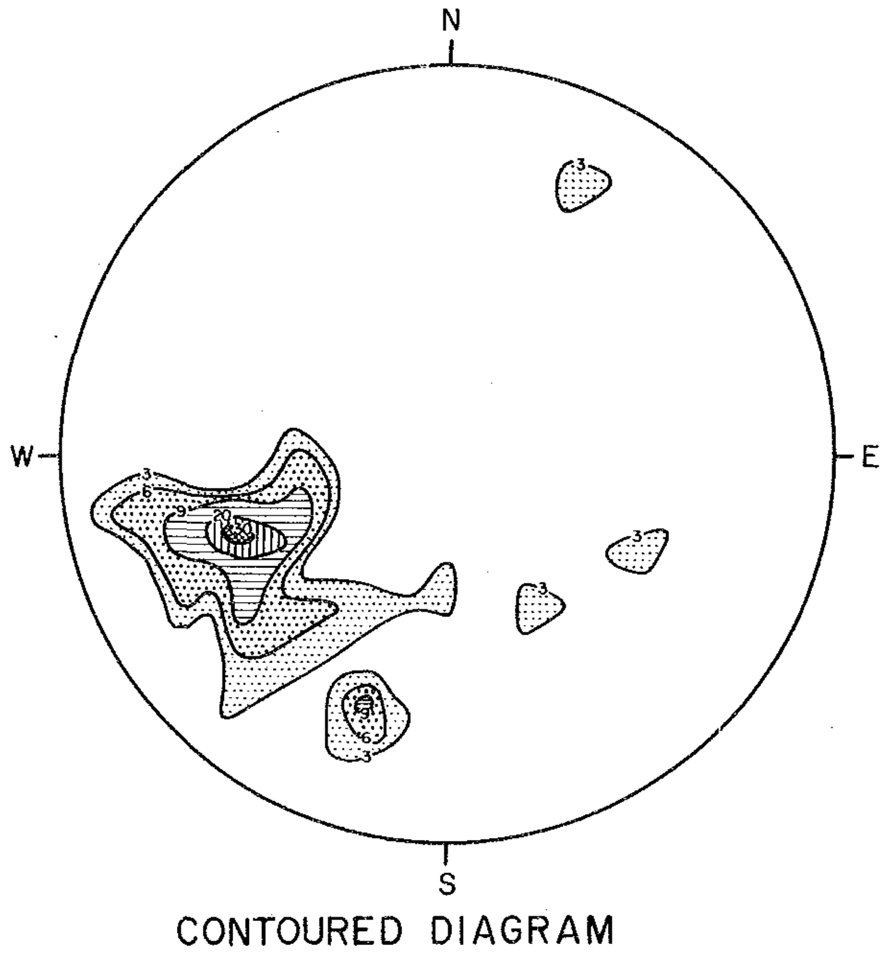


Fig. 6 Analytical Map of Fissures and Dykes

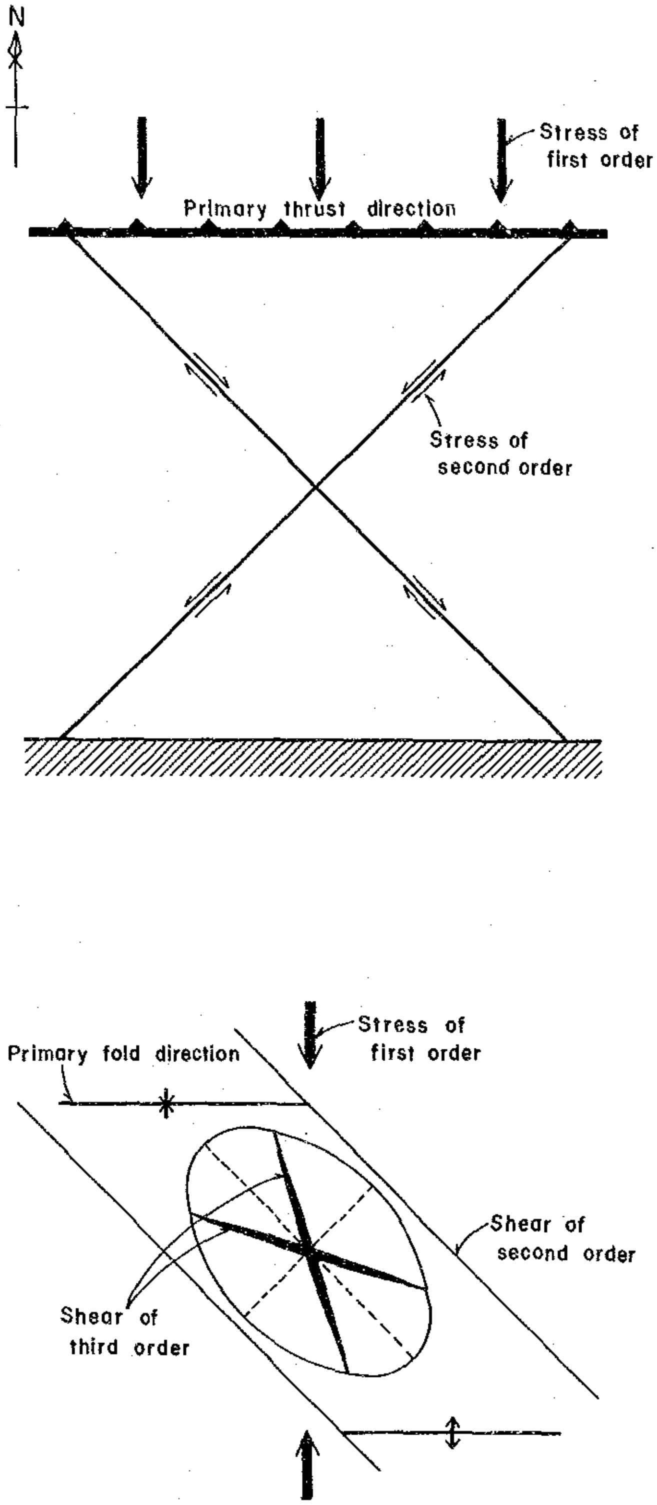


Fig. 7 Model of the Formation of Vein-Fissures

dominant (Fig. 6).

Other geologic structures include the synclines and anticlines having the axis trending almost east to west.

Based on positioning of the geologic structures, a model of vein fractures was worked out.

(1) Fault of the First Order

It is thought that the Laramide orogeny was caused by subduction of the plate from the north toward the south (Khudoley et al., 1971, Malfait et al., 1972). As a result, a stress toward the south was generated, and the southern part acted as a fixed plane. The faults of the first order of almost E-W system generated by the stress thrust up toward the south.

(2) Fault of the Second Order

The southward pressure caused to form the conjugate faults such as NW-SE system and NE-SW system.

(3) Fissure of the Third Order (Vein Fractures)

The presence of fold structure having an axis running approximately in the east to west direction in the El Gramoso area indicates that the southward stress has acted. Fig. 7 (b) shows the stress distribution and the fissures in a strain ellipsoid.

The fissures are assumed to be of two systems, which is consistent with the fact that the two systems such as N20°W, 40°N and N70°W, 50°N are dominant in the trends of the main ore veins in the El Gramoso area.

1–1–3 Mineralization

In the survey of the second phase, a number of vein-type mineralized zones were found at El Gramoso in the Constanza area.

It was made clear that these mineralized zones are those of copper vein-type trending north-westerly and that they are emplaced in andesite lava and pyroclastic rocks of the same source belonging to the middle member of the Tireo formation and also in the intrusive rocks intruded into the above formation.

The access to El Gramoso is very poor because the area is surrounded by Mt. Culo de Maco on the southern side, the steep valley of Rio Grande on the north and the west, and the steep Mt. Loma Sito Grande on the east. These severe conditions of topography would have been the cause that the mineralized zones of the area remained undiscovered.

In the third phase, detailed geological survey including trenching and drilling survey were conducted to grasp the occurrence of the vein-type mineralized zones of the area, and the characteristics of the mineralized zones were analyzed.

The survey of this phase resulted in further to confirm the outcrops of new veins in the east and the south of El Gramoto area. Plate 1 and Figure 4 show the location of mineralized zones and Table 4 shows the assay result of the ore samples.

Geology of the El Gramoso area is mainly composed of andesite lava and tuff breccia, lapilli tuff and course to fine-grained tuff of the same source of the middle member of the Tireo formation, which is intruded by the intrusive rocks such as tonalite and dacite. Tonalite dykes extend or scattered northwesterly in the vicinity of the ridge of Mt. Loma Sito Grande. Dacite extends northwesterly as dykes in the southern part of the survey area.

Tonalite is of the same type as the tonalite mass distributed in the south of the Constanza.

The mineralized zones are the gold bearing copper veins. The ore minerals are chalcopyrite, bornite, chalcocite, malachite, pyrite, specularite and limonite, and the gangue minerals are quartz, epidote, chlorite and calcite. The veins show the occurrence such as solid vein, and network and disseminated veins. Many veins contain quartz in abundance as gangue mineral. The size of the veins at the outcrop is 0.2 to 3 meters in width and one to 180 meters in length along strike. The grades are 0.2–0.5 g/T Au and 1–10 % Cu.

These veins were named G–1 to G–20 in the second phase. New outcrops were discovered in the southeastern part and the eastern part of the survey area during the survey of this phase, and the total of the outcrops of the veins became 22 in the number of place (51 outcrops) (Fig.4).

The veins mostly strike northwesterly and dip northward, which are distributed on the southern middle slope of Mt. Loma Sito Grande. The extent of the distribution is 1.0 to 1.5 kilometers wide and 3.5 kilometers long being continued in the direction of northwest to southwest. The distribution of veins take a form to be associated with the intrusive masses of tonalite which are extended or scattered with the northwesterly trend. These veins are distributed along the southern side of them suggesting the genetic relation with the tonalite masses.

Alteration of the country rocks are silicification, chloritization and partly epidotization. Chlorite is observed in all the veins, and silicification becomes stronger toward the top of Mt. Loma Sito Grande.

Detailed geological survey including trenching and drilling survey were conducted in this phase. The largest outcrop discovered by the survey is the G–21 outcrop showing the width of 0.8 to 2.5 meters and the length of 35 meters, and the average grade of 4.7 % Cu.

The outcrops tested by drilling and the new outcrops are described in the following. The location of these is shown in PL.1, 2, Fig. 4.

(1) 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 grades 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 (Fig. 27). 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.

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 50°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 (Fig. 27, PL.2).

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 (Fig. 27, PL.2).

The part centering on the trench confirmed this year 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. The assay results of these are as follows.

Sample No.	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK053	0.20	0.40	8.0	2.61	0.03	0.02
GK054	0.25	0.30	2.6	0.67	0.02	0.02
GK060	0.35	0.10	4.1	1.95	0.03	0.05
GK061	0.20	0.60	34.4	3.56	0.02	0.03
GK076	0.30	0.10	5.4	0.64	0.02	0.01
GK077	0.40	0.20	12.4	0.87	0.03	0.01
GK078	0.50	0.20	71.9	6.61	0.08	0.02
GK079	0.15	0.50	20.9	2.86	0.09	0.03
GK080	0.10	0.20	55.1	5.94	0.04	0.01

The microscopic observation of the samples such as GK060 and GK061 obtained from the outcrops resulted in to identify chalcopyrite, chalcocite, covelline, limonite and malachite. Chalcopyrite has been oxidized, having been altered in the outer rim in the following succession to chalcocite-covelline-limonite toward the outside.

(2) 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 (Fig. 25, PL.2), and it seems that these are continual for each other.

(3) 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. 8). 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, vovelline 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. 8, and the description is made for each outcrop in the following. Trenching was performed for the outcrop (D), which is described later.

Name of vein	Scale width (m) x length(m)	Note
A	(0.7~0.3) x 35	The vein is located at the western end of the outcrop G–18, and consists of three outcrops. The northern outcrop contains the ore minerals, while those at the center and in the south grade into barren quartz. The whole length traced was 35 meters. The northern outcrop is malachite-chalcocite-limonite quartz vein 0.7 meters wide. Both the width and grade are poor in the southern outcrops. The assay results are as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
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

Name of vein	Scale width (m) x length(m)	Note
B	(0.1~0.2) x 20	The vein consists of two outcrops. The outcrops are malachite-chalcopyrite-chalcocite-limonite quartz vein 0.1 to 0.2 meters wide. The whole length traced was 20 meters. The vein strikes N20°W and dips 45° to 60° northward. The northern part is poor in grade and size. The assay results are as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Zn(%)	Pb(%)
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

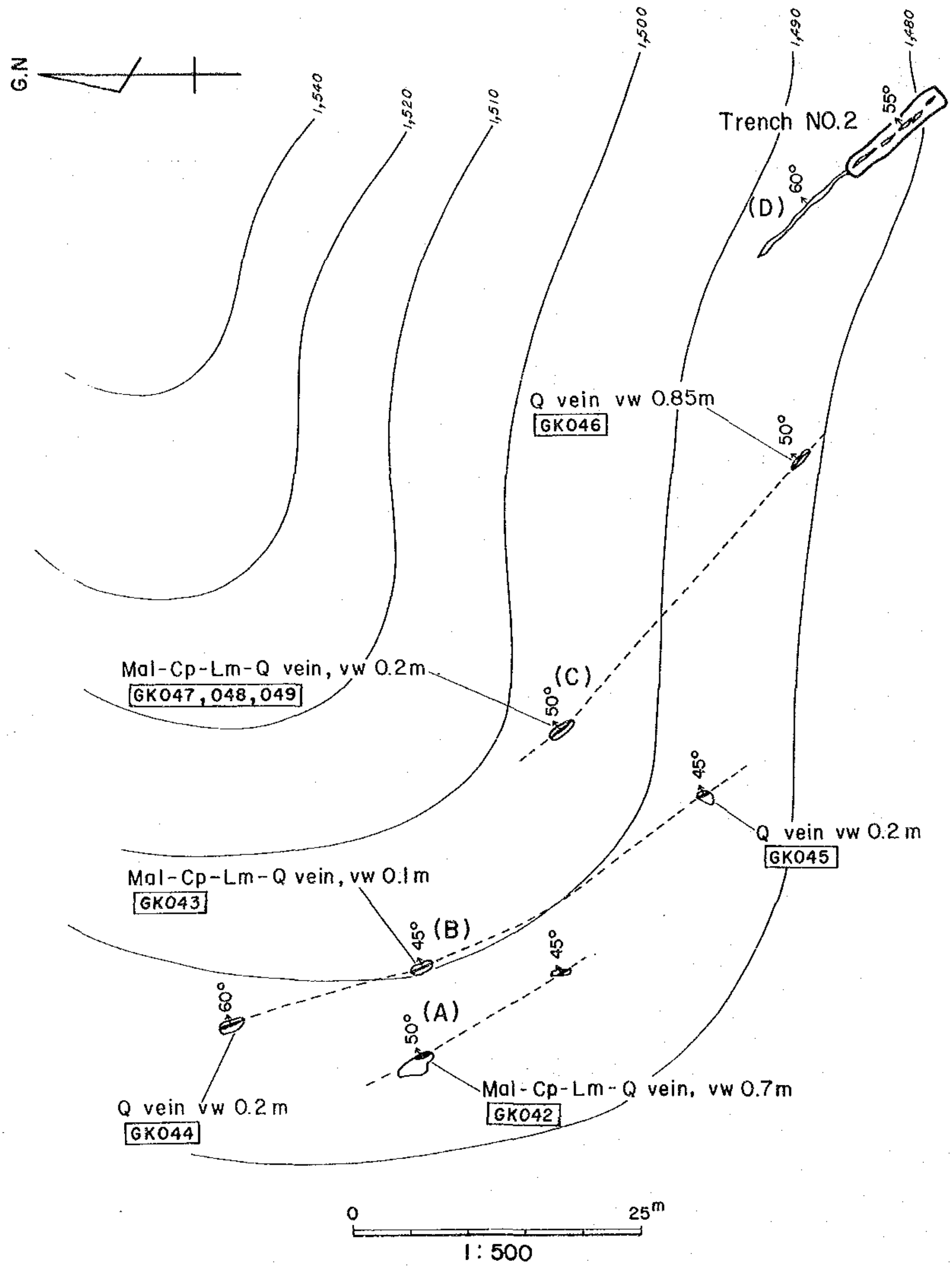


Fig. 8 Survey Map of Outcrop G-18

C	(0.2~1.2) x 35	The vein consists of two outcrops. The northern outcrop is malachite-chalcopyrite-chalcocite-limonite -quartz vein 0.2 meters wide. The ore minerals are hardly observed in the southern one. The whole length traced was 35 meters. The vein strikes N20°W and dips 50° northward. The assay results are as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
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. 2). The ore minerals are malachite and limonite, and the assay result of the massive ore is 0.5 g/T Au, 65.6 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. 2), and they seem to be continual each other. Microscopic observation of GK043 and GK047 samples from the outcrop G–18 resulted in to identify chalcopyrite, chalcocite, covelline, malachite and limonite. The occurrence shows the advanced oxidation, and the periphery of chalcopyrite had been limonitized. Chalcocite and a small amount of covelline had been formed along the crack in chalcopyrite.

(4) 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.

The assay results of the outcrops are as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
Ridge						
GK030	0.90	0.20	19.3	2.81	0.07	0.05
GK031	1.00	0.67	45.9	7.24	0.09	0.03
GK032	1.00	0.30	28.2	2.55	0.04	0.02
Southern slope						
GK034	0.55	0.20	18.1	4.50	0.05	0.02
GK035	0.20	0.10	7.2	1.60	0.07	0.05
GK036	0.15	0.40	17.9	5.13	0.09	0.05
Northern slope						
GK038	0.50	0.50	18.4	1.29	0.02	0.02

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–18 (PL. 2). 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–18.

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–18.

Microscopic observation of the samples such as GK031 and GK032 collected from the outcrop G–18 resulted in to identify the ore minerals described in the above. The vein has an appearance of highly advanced oxidation, where chalcopyrite has been completely altered to limonite.

(5) G–21

It is the new outcrop discovered in the survey of this 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. 9). 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. 9 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 a/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.

The assay results of the ore samples from G–21 are as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK085	1.50	tr	tr	14.41	0.16	0.01
GK086	1.00	0.10	2.8	2.16	0.17	0.01
GK087	2.00	0.10	4.3	1.73	0.15	0.02
GK088	1.40	0.10	4.9	0.36	0.09	0.01
GK089	2.50	0.30	117.9	6.03	0.20	0.21
GK090	2.00	0.50	40.6	4.03	0.22	0.05

(6) 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. 2). The outcrop is a copper bearing zinc quartz 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 %

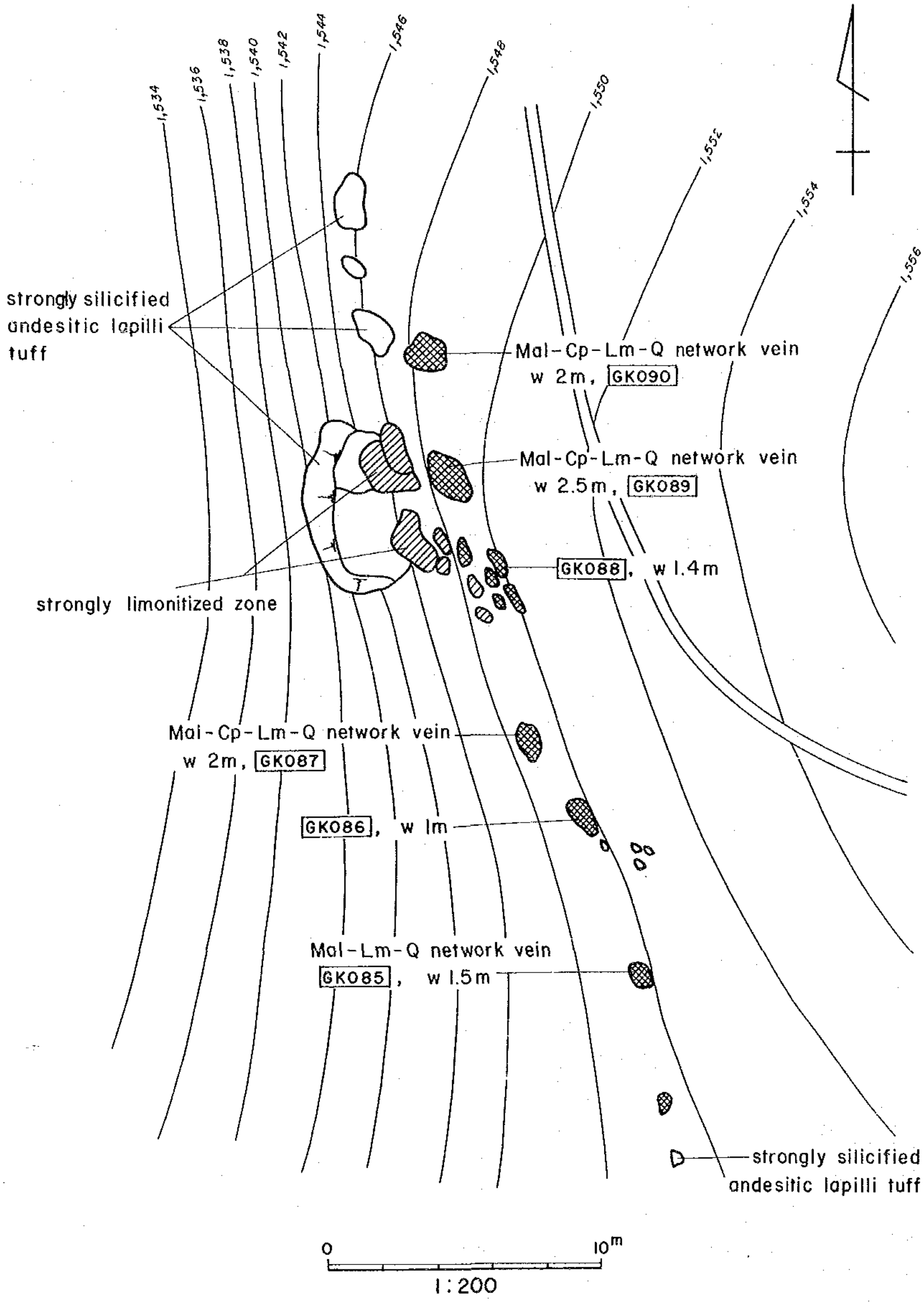


Fig. 9 Survey Map of Outcrop G-21

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 four meters was confirmed, the extension could not be made clear because of thick cover of over-burden.

1–1–4 Results of Trenching

Five trenches were excavated in this phase in order to grasp the continuity of the veins of the main outcrops. The results of trenching are as follows.

(1) Trench No.1

The trenching was performed for the length of 15.4 meters on the southeastern extension of the outcrop G–19. The southeastern extension of the outcrop G–19 is present in the trench being scattered for 14 meters (Fig. 10). The vein in the trench is malachite-chalcopyrite-pyrite-limonite-quartz-epidote network vein showing the width of 0.15 to 0.35 meter. The vein strikes N15° to 50°W and dips 50° to 60° northward. Quartz-epidote veinlets are present on the hanging wall of the copper bearing vein. The country rock is andesitic fine-grained tuff, and chloritization, silicification and epidotization are common alteration of the wall rock. It was made clear that the vein in the trench further continues to the outcrop of malachite-limonite-quartz vein to the south. Thus the total extension of the outcrop G–19 confirmed so far 35 meters.

Fig. 10 shows the sketch map of the trench. The assay result of the samples from the vein in the trench is as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK069	0.20	0.20	4.2	0.41	0.02	0.01
GK070	0.35	0.40	28.1	2.10	0.02	0.01
GK071	0.25	0.20	17.1	0.86	0.07	0.01

(2) Trench No.2

The trench was excavated on the southeastern extension of the quartz vein (D) containing a small amount of malachite at the southeastern end of the outcrop G–18 which is composed of four series of veins (Fig. 8). A malachite bearing specxularite-limonite-quartz-epidote vein is scattered for an extent of 12 meters in the trench. Thus the total length of the vein (D) confirmed became about 25 meters. Malachite is not always contained throughout the vein, but it is found in a part of the vein in the form of network and dissemination. The vein strikes

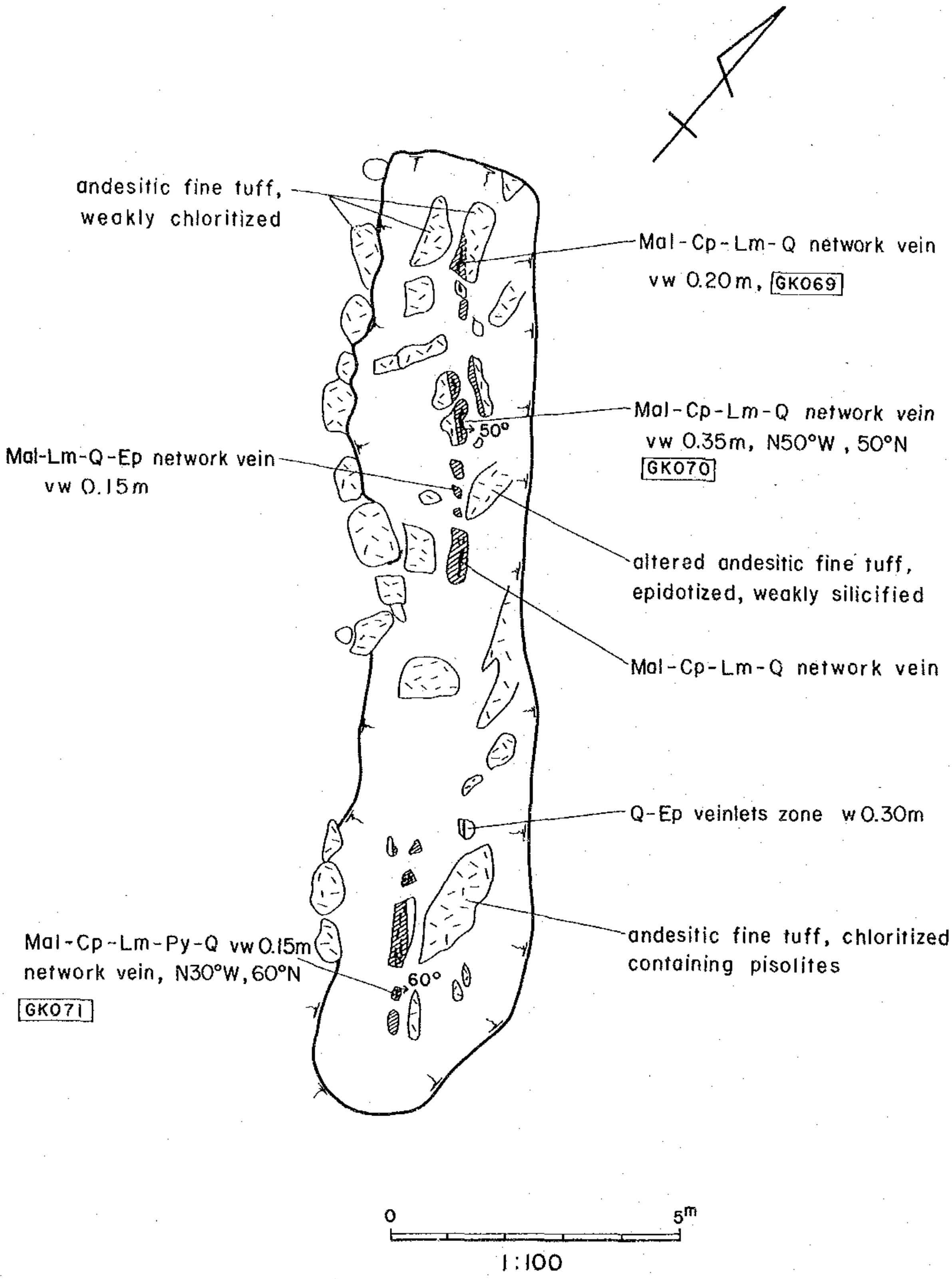


Fig. 10 Survey Map of Trench NO. 1

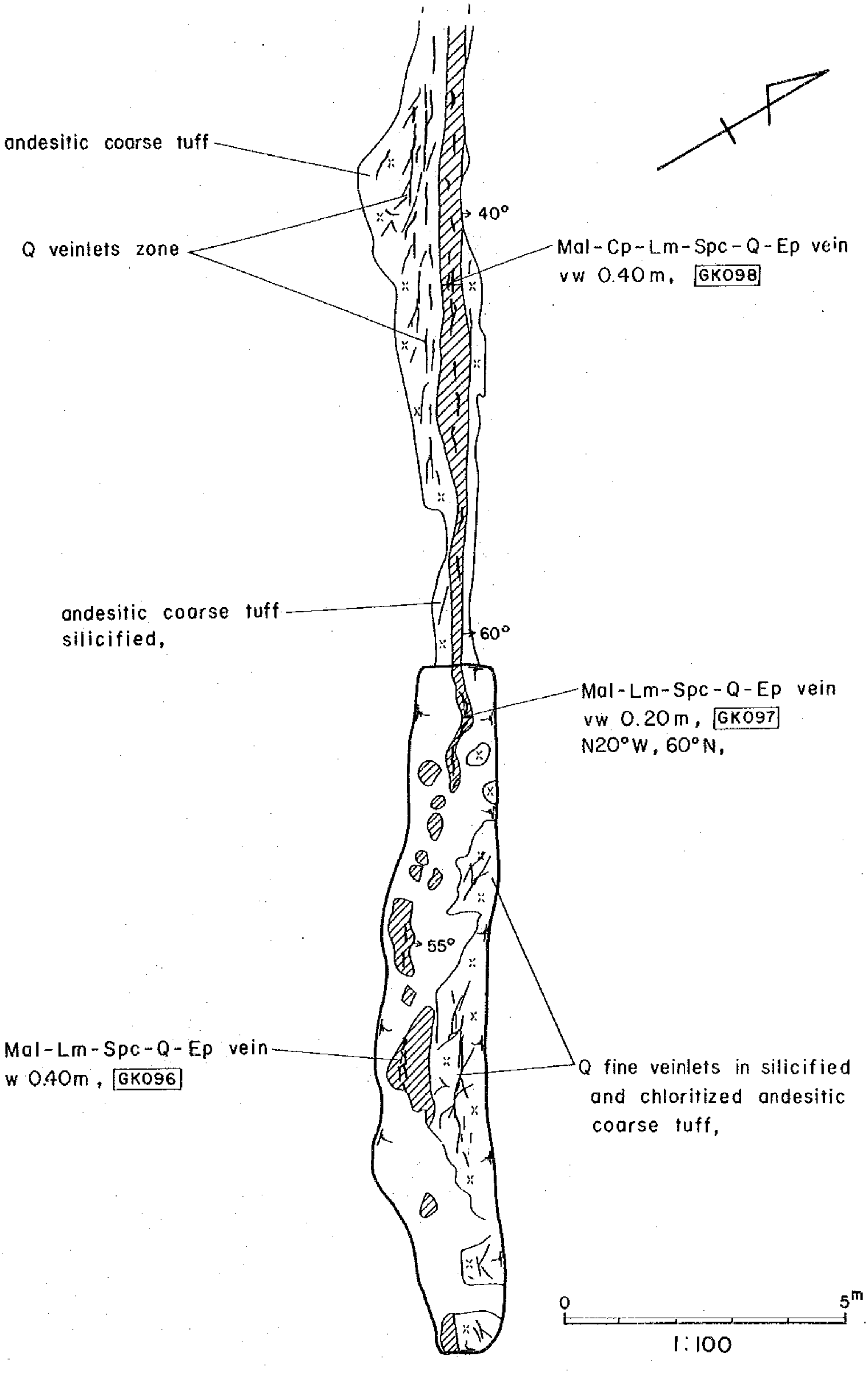


Fig. 11 Survey Map of Trench NO. 2

N20°W and dips 40° to 60° northward. Quartz veinlets are present in both hanging wall and footwall of the vein. The country rock is andesitic fine-grained tuff, and rock alteration includes chloritization and silicification.

Fig. 11 shows the sketch map of the trench and outcrop. The assay result is as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK096	0.40	0.30	8.7	2.88	0.03	0.10
GK097	0.20	tr	tr	0.21	0.02	0.05
GK098	0.40	0.20	3.2	0.83	0.08	0.05

(3) **Trench No.3**

The trench 17 meters long was excavated at a right angle to the vein on the ridge between the outcrops G–17 and G–19. As a result, a quartz vein 0.9 meter wide containing a small amount of malachite was confirmed, and it was further traced for about 10 meters. Consequently, it became clear that outcrops of quartz vein were scattered on the extension and that these outcrops correspond to the southeastern extension of the outcrop G–17. Thus the total length of about 35 meters was confirmed.

The ore minerals of the vein are malachite, chalcopyrite, chalcocite and limonite, and the gangue minerals are quartz and epidote. The vein strikes N40°W and dips 35° northward. The vein consists of network veins showing banded structure. The country rock is andesitic lapilli tuff, and the alteration includes chloritization and silicification.

Fig. 12 shows the sketch of the trench and outcrop. The assay result of the sample of the vein is as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK094	0.80	0.40	19.3	1.73	0.03	0.02

(4) **Trench No.4**

The trench was excavated for the length of 10 meters at the limonitized place to the northwest of the outcrop G–17. As a result, two veins appeared; the one is limonite-quartz-epidote vein containing a small amount of malachite 0.4 meter wide, striking N20°W and dipping 60° northward, and the other one is grayish white clay vein seems to be of derivative of the former, striking northerly and dipping 60° eastward. The neighboring part of the former has been epidotized and silicified. The country rock is weathered andesitic course-grained tuff.

Fig. 13 shows the sketch of the trench. The assay result of the sample obtained from the

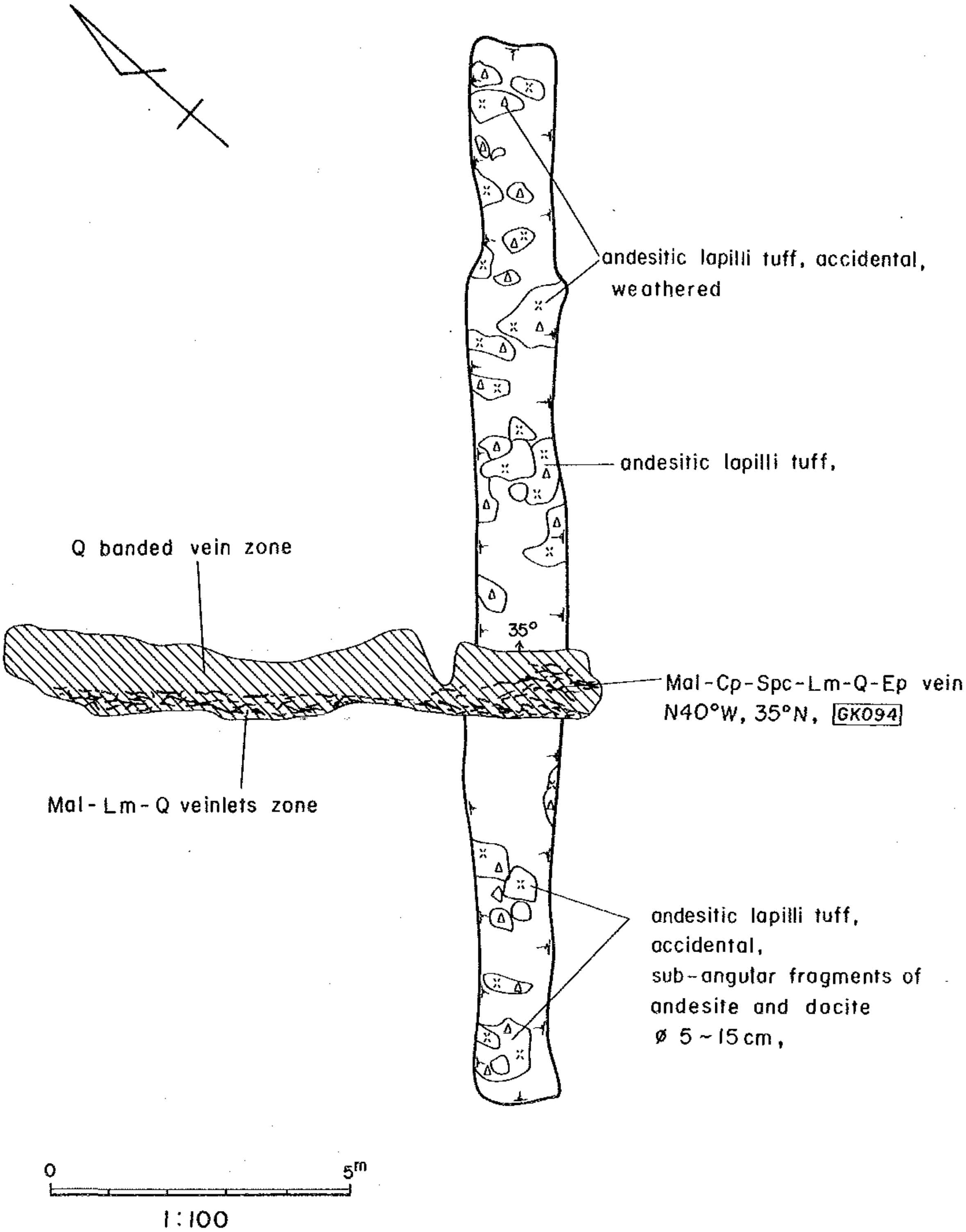


Fig. 12 Survey Map of Trench NO. 3

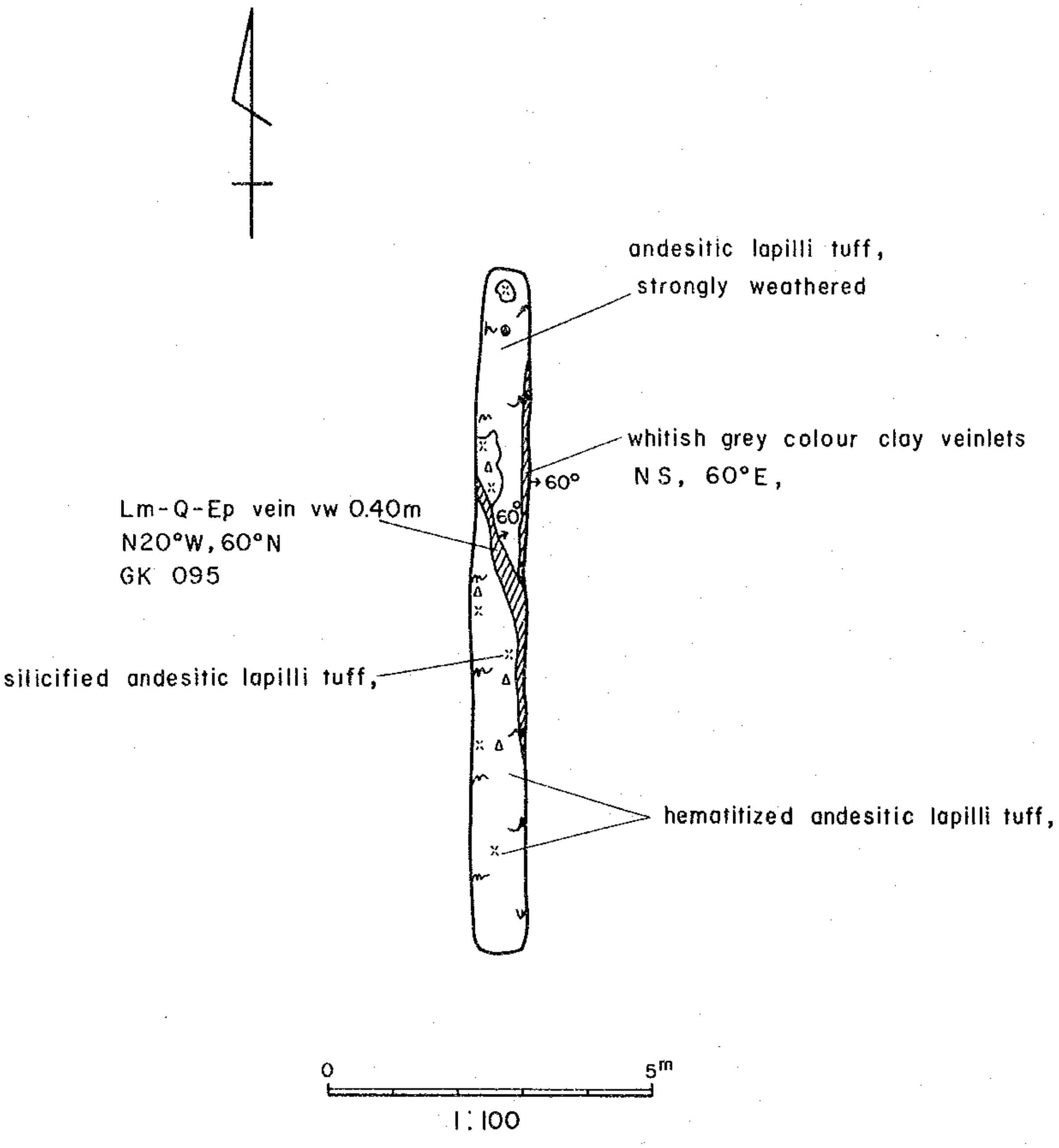


Fig. 13 Survey Map of Trench NO. 4

former is as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK095	0.40	tr	tr	0.19	0.02	0.02

(5) Trench No.5

The outcrop G–12, the most superior in the area, was tested by the trench for its southeastern extension for the length of 15.6 meters. As a result, it was made clear that copper bearing quartz vein of relatively high grade 0.1 to 0.5 meter wide continued for about 30 meters. Further it was confirmed that the outcrops of the same type were scattered at two places within a distance of about 20 meters on the southeastern extension of the above. The ore minerals of the vein are malachite, chalcopyrite, chalcocite and limonite, and the gangue mineral is quartz. The vein strikes N45°~55°W and dips 45° to 50° northward. The country rock is andesitic lapilli tuff, and the alteration include chlorization and silicification.

Fig. 14 shows the sketch of the trench. The assay results of the samples from the vein are as follows.

	Sampling width(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
GK076	0.30	0.10	5.4	0.64	0.02	0.01
GK077	0.40	0.20	12.4	0.87	0.03	0.01
GK078	0.50	0.20	71.9	6.61	0.08	0.02
GK079	0.15	0.50	20.9	2.86	0.09	0.03
GK080	0.10	0.20	55.1	5.94	0.04	0.01

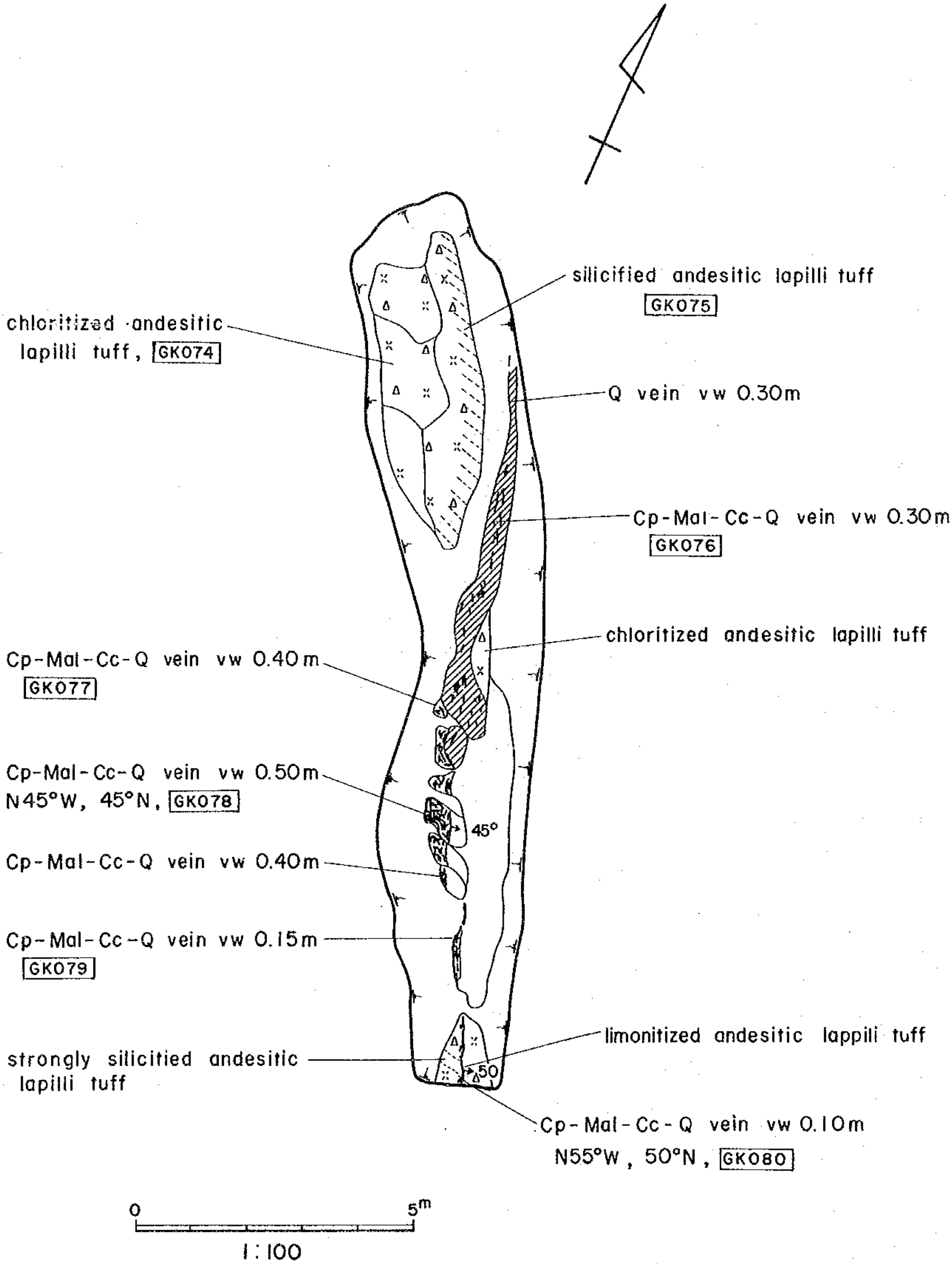


Fig. 14 Survey Map of Trench NO. 5

1–2 Drilling Survey

1–2–1 Purpose of Survey

The survey was conducted for the purpose to inquire the occurrence of the mineralized zone by elucidating the characters of ore deposit and geologic structure in connection with the outcrops of copper vein, together with the data obtained by geological survey.

The drilling survey was performed for five holes with a total drilling length of 1,002.50 meters including the additional works for the new outcrops discovered in this phase. The sites are shown in Fig. 15.

1–2–2 Outline of Works

All the drilling works was completed November 9 1985 by the completion of drilling of the hole DJM-4, having been started on August 14 1985 by the works for the hole DJM-1.

The drilling machine used was a set of Tone Boring TOM-3 (the drilling capacity is 600 meters in NQ size and 790 meters in BQ size).

The drilling was done by three shifts and eight hours per shift. Wireline method was used to improve core recovery and efficiency of drilling.

The amount of the drilling works was as follows:

Area	Name of hole	Direction	Inclination	Drilling length (m)	Core length (m)	Core recovery (excepting surface soil) (%)
Constanza	DJM-1	S70°W	–60°	250.20	247.20	100
	DJM-2	S65°W	–70°	150.50	147.50	100
	DJM-3	S55°W	–70°	250.40	246.40	100
	DJM-4	S50°W	–70°	150.40	147.40	100
	DJM-5	S60°W	–85°	201.00	183.00	99.51

1–2–3 Transportation of Mechanical Equipment and Materials, and Arrangement

(1) Transportation of Mechanical Equipment and Materials

The Transportation of mechanical equipment and materials was performed mainly by helicopter. Because of difficulty of transportation by hanging down the materials from helicoper by the reason of control technique, heliports were set at each drill hole site. At the hole DJM-4, the heliport could not be set close to the hole because of steep slope. The port was prepared at a high part at a distance of 80 meters from the hole, and the road for transportation was constructed between those parts.

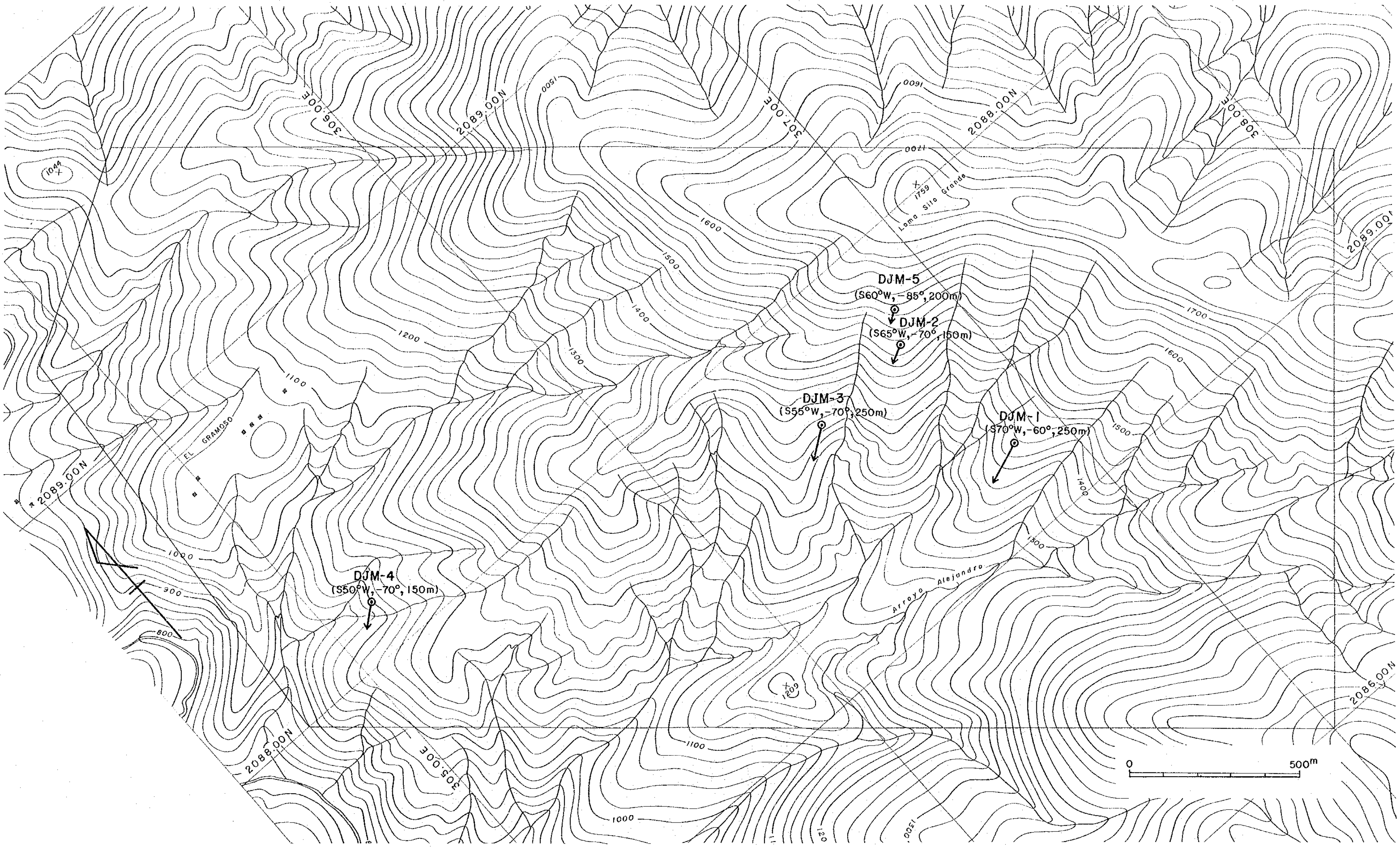


Fig. 15 Location Map of Drill Holes

At first, the heliport was set at the hole DJM-1 and the equipment and materials were carried by helicopter from Constanza airport. It took fairly long time for the transportation because the drilling machines have to be dismantled to house it in helicopter for flying.

The order of the transportation was DJM-1 → DJM-2 → DJM-3 → DJM-5 → DJM-4.

(2) Arrangement

The work of arrangement was begun from the hole DJM-1. Leveling of ground for setting the drilling rig was all made by man power. The construction were completed during the drilling works.

Water for drilling was obtained at first from a creek near the hole DJM-1 to be fed by spontaneous flow. However, because of deficiency of water at the creek and loss of water in the hole, the water was fed by a pump set at the downstream with more plenty water. This pump was used to feed water to the holes such as DJM-1, DJM-2, DJM-3 and DJM-5.

Because the hole DJM-4 was apart from other holes, a creek near the hole was dammed up and water was fed by spontaneous flow. One-inch delivery hose was used for supply of water. The head from the pump station to the holes was as follows:

DJM-1	165 m
DJM-2	260 m
DJM-3	100 m
DJM-5	315 m

1–2–4 Drilling

Overburden was dug by conventional method using 101 mm metal bit. After reaching the bed rock, NQ wireline method was used, and the final stage was worked by BQ wireline method.

The progress of drilling works of each hole is as in the following.

1. Hole DJM-1 (Fig. 16)

Drilling length	250.20 m
Core length	247.20 m (exclusive of overburden)
Core recovery	100 %

Started on August 14, 1985

Completed on August 31, 1985

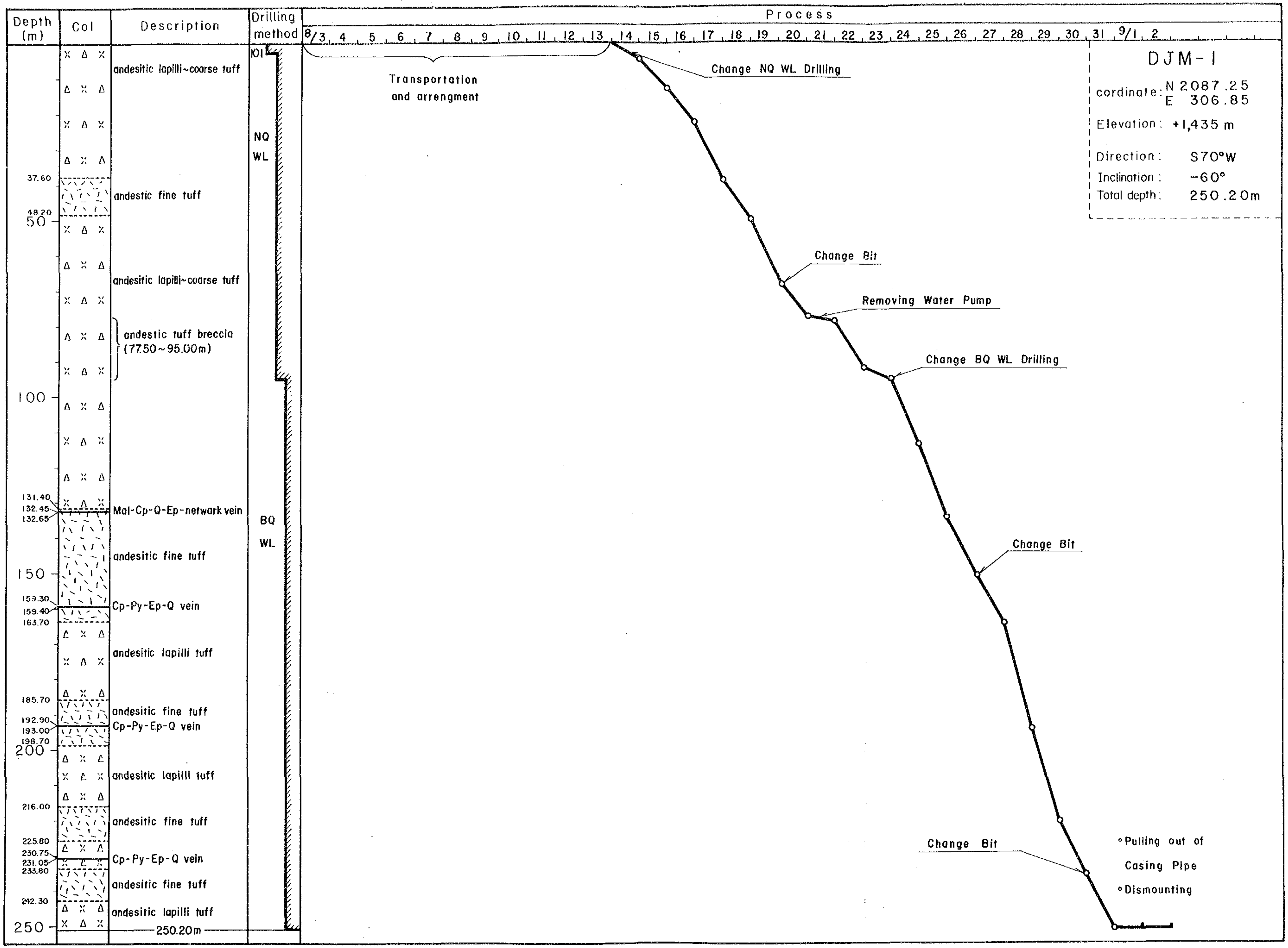


Fig. 16 Progress Record of Hole DJM-1

(a) Section from 0 m to 3.00 m (Diameter: 101 mm, NWCP for 3.00 m)

Clay bed mixed with surface soil and boulder was drilled by 101 mm metal bit with mud water, and NW casing pipe three meters long was inserted and set.

(b) Section from 3.00 m to 92.10 m (Diameter of hole: 76 mm, BWCP for 92.10 m)

The hole was sunk by NQ wireline method using bentonite mud water. The rocks were andesitic tuff and lapilli tuff.

Lost circulation of all the mud was encountered at about 86.00 m, and it could not be restored although the works were done to prevent the loss using Telstop. The hole was sunk, however, up to 92.10 m having been in the condition of lost circulation with combined use of bentonite and mud oil because of stable condition of the rocks, and BW casing pipe was inserted and set.

(c) Section from 92.10 m to 250.20 m (Diameter of hole: 59.6 mm, no casing)

The drilling was done by changing to BQ wireline method. Although all the mud was lost immediately after the start of this section, the hole was continued to be sunk having been in the condition of lost circulation using mud oil because of stable condition of the rocks. The rocks were andesitic tuff and lapilli tuff and the hole was completed at 250.20 m.

The amount of water feed was 40 to 60 liter per minute.

2 **Hole DJM-2 (Fig. 17)**

Drilling length	150.50 m
Core length	147.50 m
Core recovery	100 %

Started on September 9, 1985

Completed on September 17, 1985

(a) Section from 0 m to 3.00 m (Diameter of hole: 101 mm, NWCP for 3.00 m)

The bed consisting of surface soil and boulder was dug by 101 mm metal bit using bentonite mud water, and NW casing pipe was inserted up to 3.00 meters and set.

It was shown that zero to five kilograms per square centimeter in pump pressure, 100 to 120 liters per minute in the amount of water supply and 60 to 90 liters per minute in that of drainage.

(b) Section from 3.00 m to 15.00 m (Diameter of hole: 101 mm, NWCP for 15.00 m)

Although drilling was done by changing to NQ wireline method at 3.00 m, the hole was

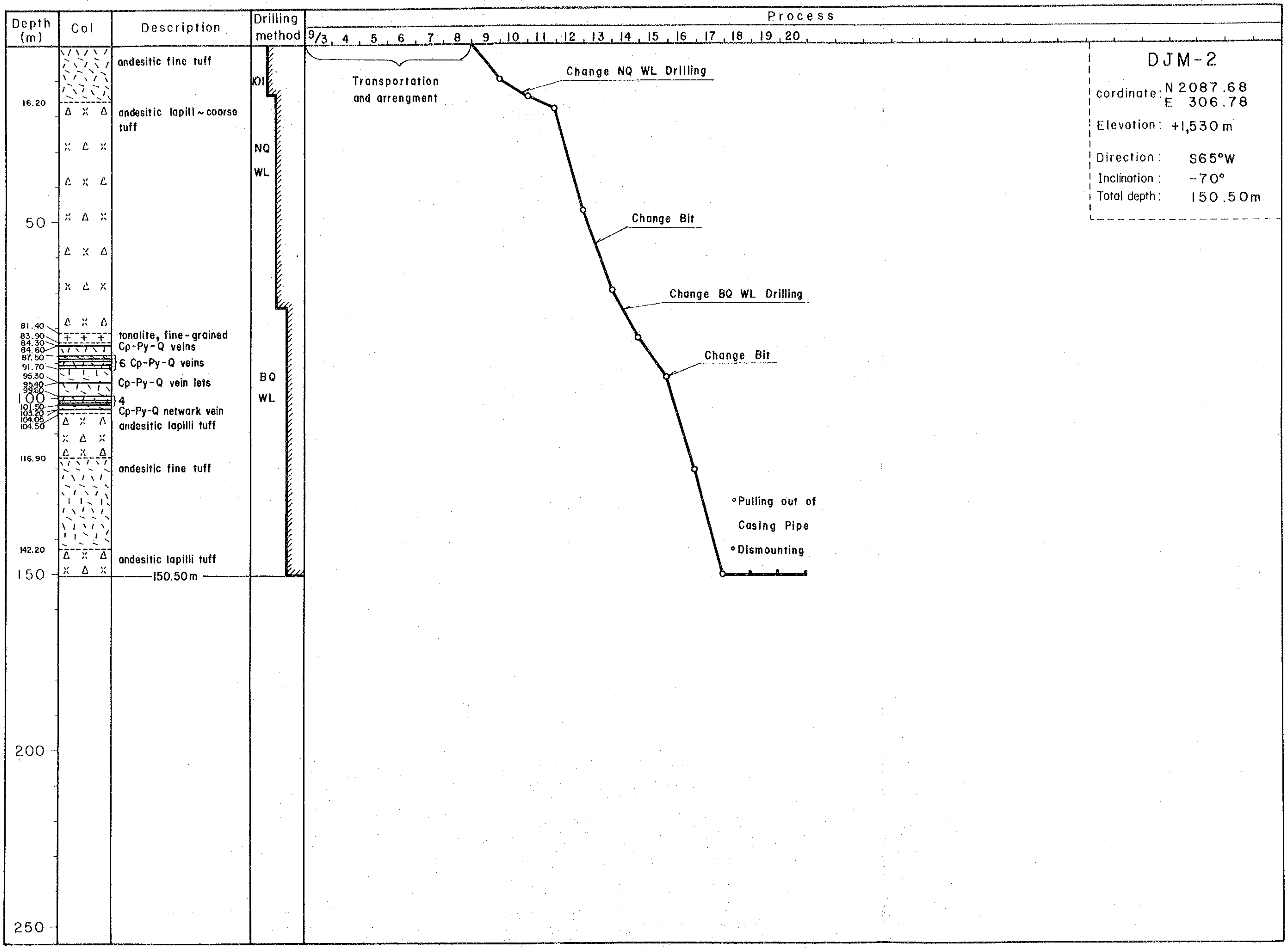


Fig. 17 Progress Record of Hole DJM-2

sunk to 15 m and it was reamed from 3.00 m to 15 m by 101 mm metal bit, and NW casing was inserted additionally because of unstability of the rocks.

(c) Section from 15.00 m to 78.10 m (Diameter of hole: 76 mm, BWCP for 78.10 m)

Drilling was done by NQ wireline method using bentonite mud water. The rocks were andesitic tuff and lapilli tuff.

Although complete lost circulation was encountered at 52.00 m, the hole was continued to be sunk using bentonite and mud oil up to 78.10 m having been in the condition of lost circulation because of stable condition of the rocks, and BW casing pipe was inserted to 78.10 m and set.

(d) Section from 78.10 m to 150.50 m (Diameter of hole: 59.6 mm, no casing)

Although complete lost circulation was encountered immediately after the start of digging of this section by changing to BQ wireline method, the drilling was continued having been in the condition of lost circulation using mud oil because of stable condition of the rocks. The rocks were andesitic tuff and lapilli tuff as in the above, and the hole was completed at the bottom of 150.50 m.

The amount of water supplied was 40 to 60 liter per minute.

3. Hole DJM-3 (Fig. 18)

Drilling length	250.40 m
Core length	246.40 m
Core recovery	100 %

Started on September 24, 1985

Completed on October 4, 1985

(a) Section from 0 m to 4.00 m (Diameter of hole: 101 mm, NWCP for 4.00 m)

The bed consisting of surface soil and boulder was dug by 101 mm metal bit using bentonite mud water, and NW casing pipe was inserted and set.

The pump pressure was zero to two kilograms per square centimeter, the amount of water supply 100 to 120 liters per minute and that of drainage 70 to 100 liters per minute.

(b) Section from 4.00 m to 132.20 m (Diameter of hole: 76 mm, BWCP for 132.20 m)

Andesitic tuff and lapilli tuff was cut by NQ wireline method using bentonite mud water. The rocks were stable and were cut to 132.20 m. BW casing pipe was inserted to 132.20 m and set.

The pump pressure was zero to 10 kilograms per square centimeter, the amount of water supply 60 to 80 liters per minute and that of drainage 50 to 70 liters per minute.

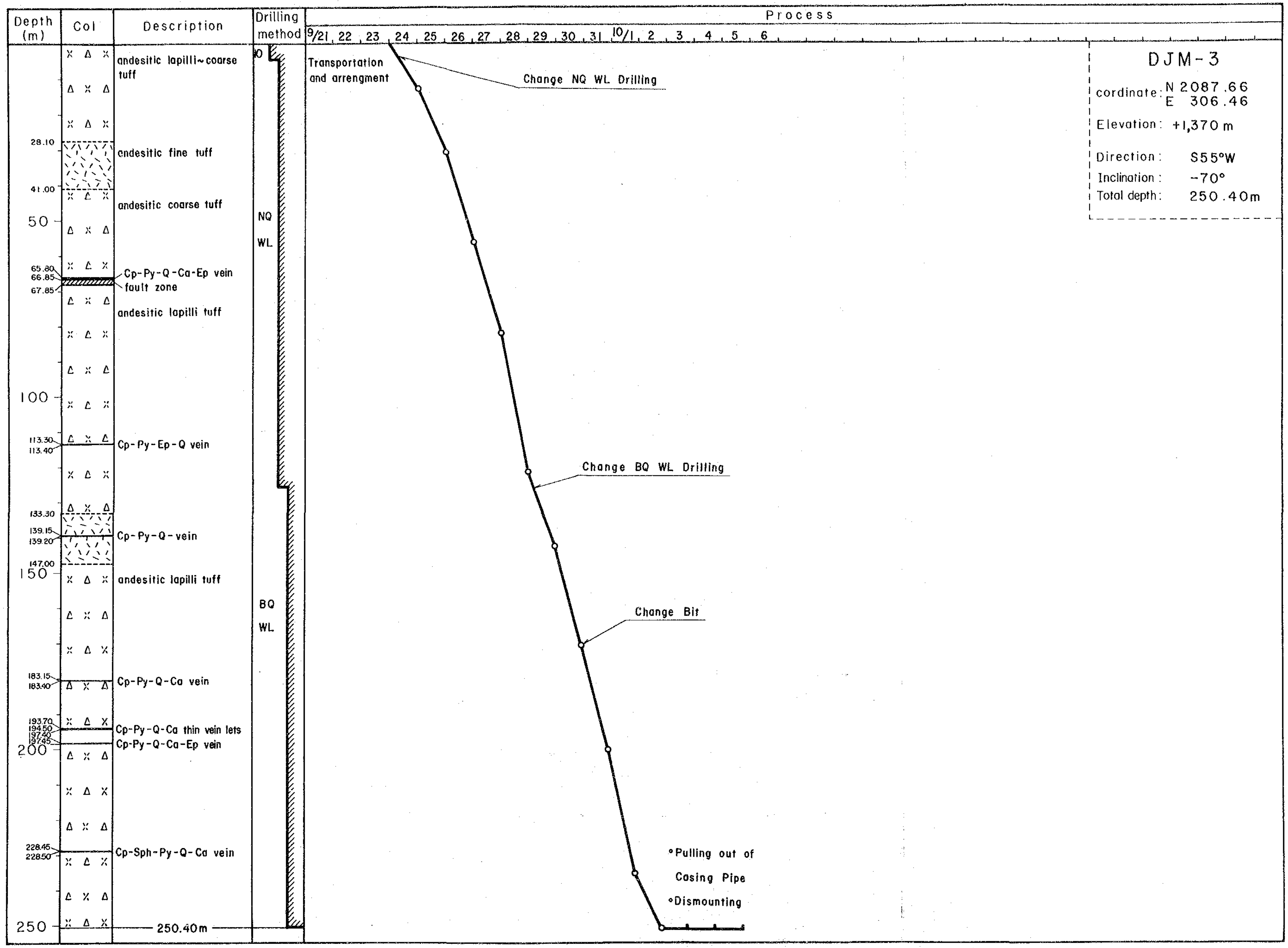


Fig. 18 Progress Record of Hole DJM-3

(c) Section from 132.20 m to 250.40 m (Diameter of hole: 59.6 mm, no casing)

The hole was sunk by changing to BQ wireline method, and the complete lost circulation was encountered at 141.00 m. However, drilling was continued using mud oil having been in the condition of lost circulation up to 250.40 m because of stable condition of the rocks. The rocks were andesitic tuff and lapilli tuff as in the above.

The amount of water supply was 40 to 60 liters per minute.

4. **Hole DJM-4 (Fig. 19)**

Drilling length	150.40 m
Core length	147.40 m
Core recovery	100 %

Started on October 31, 1985

Completed on November 4, 1985

(a) Section from 0 m to 3.00 m (Diameter of hole: 101 mm, NWCP for 3.00 m)

The bed consisting of surface soil and boulder was dug with 101 mm metal bit using bentonite mud water, and NW casing pipe was inserted to 3.00 m and set.

The pump pressure was zero to two kilograms per square centimeter, the amount of water supply 100 to 120 liters per minute and that of drainage 70 to 100 liters per minute.

(b) Section from 3.00 m to 100.20 m (Diameter of hole: 76 mm, BWCP for 100.20 m)

Andesitic tuff and lapilli tuff were cut by NQ wireline method using bentonite mud water.

The rocks were stable and they were cut to 100.20 m, and BW casing pipe was inserted up to 100.20 m and set.

The pump pressure was zero to 10 kilograms per square centimeter, the amount of water supply 60 to 80 liter per minute and that of drainage 50 to 70 liters per minute.

(c) Section from 100.20 m to 150.40 m (Diameter of hole: 59.6 mm, no casing)

Changing to BQ wireline method, andesitic tuff and lapilli tuff were cut using bentonite mud water.

The rocks were stable, and the hole was completed at 150.40 m.

The pump pressure was five to 10 kilograms per square centimeter, the amount of water supply 40 to 60 liters per minute and that of drainage 10 to 20 liters per minute.

5. **Hole DJM-5 (Fig. 20)**

Drilling length	201.00 m
Core length	183.00 m

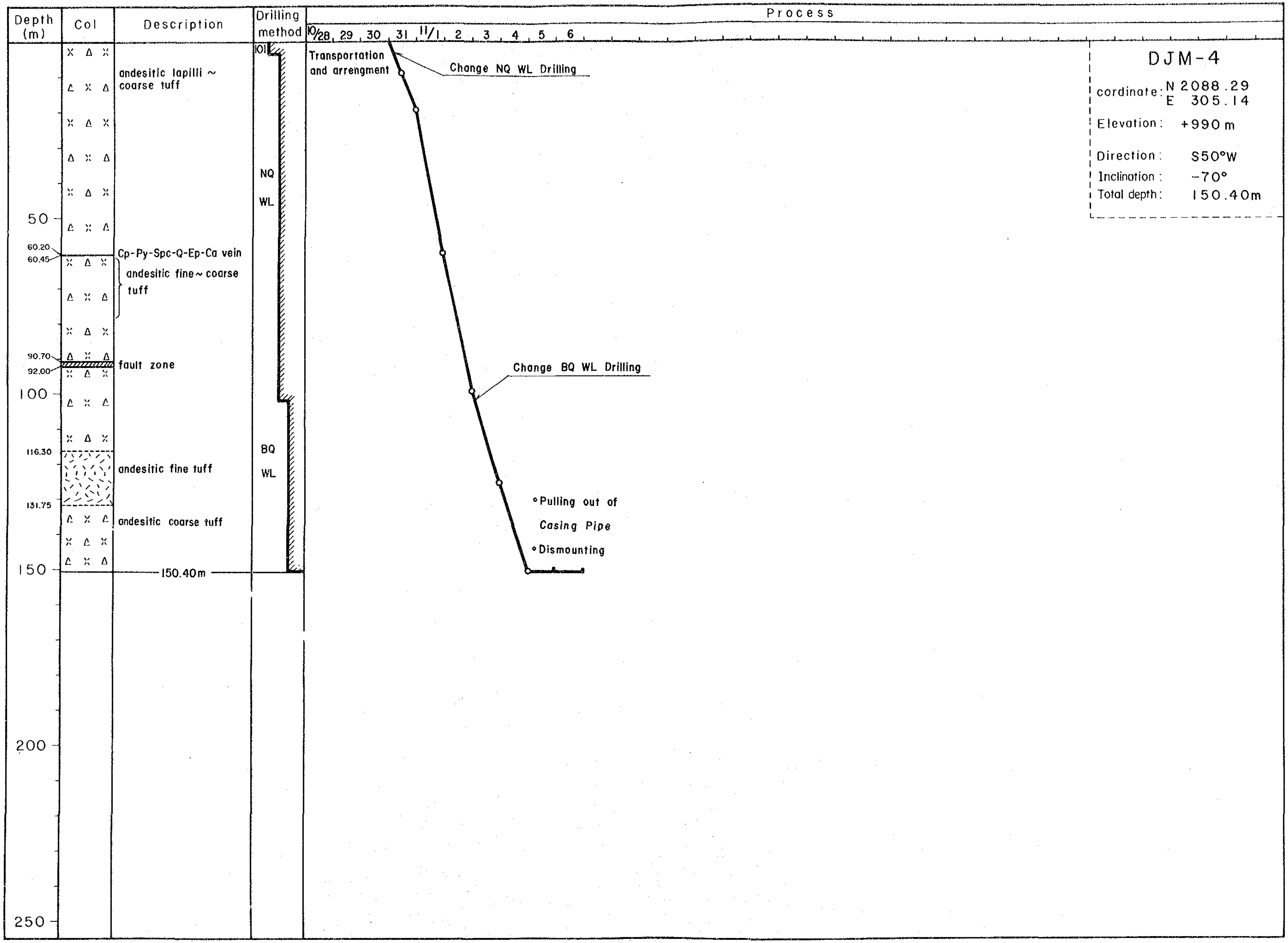


Fig. 19 Progress Record of Hole DJM-4

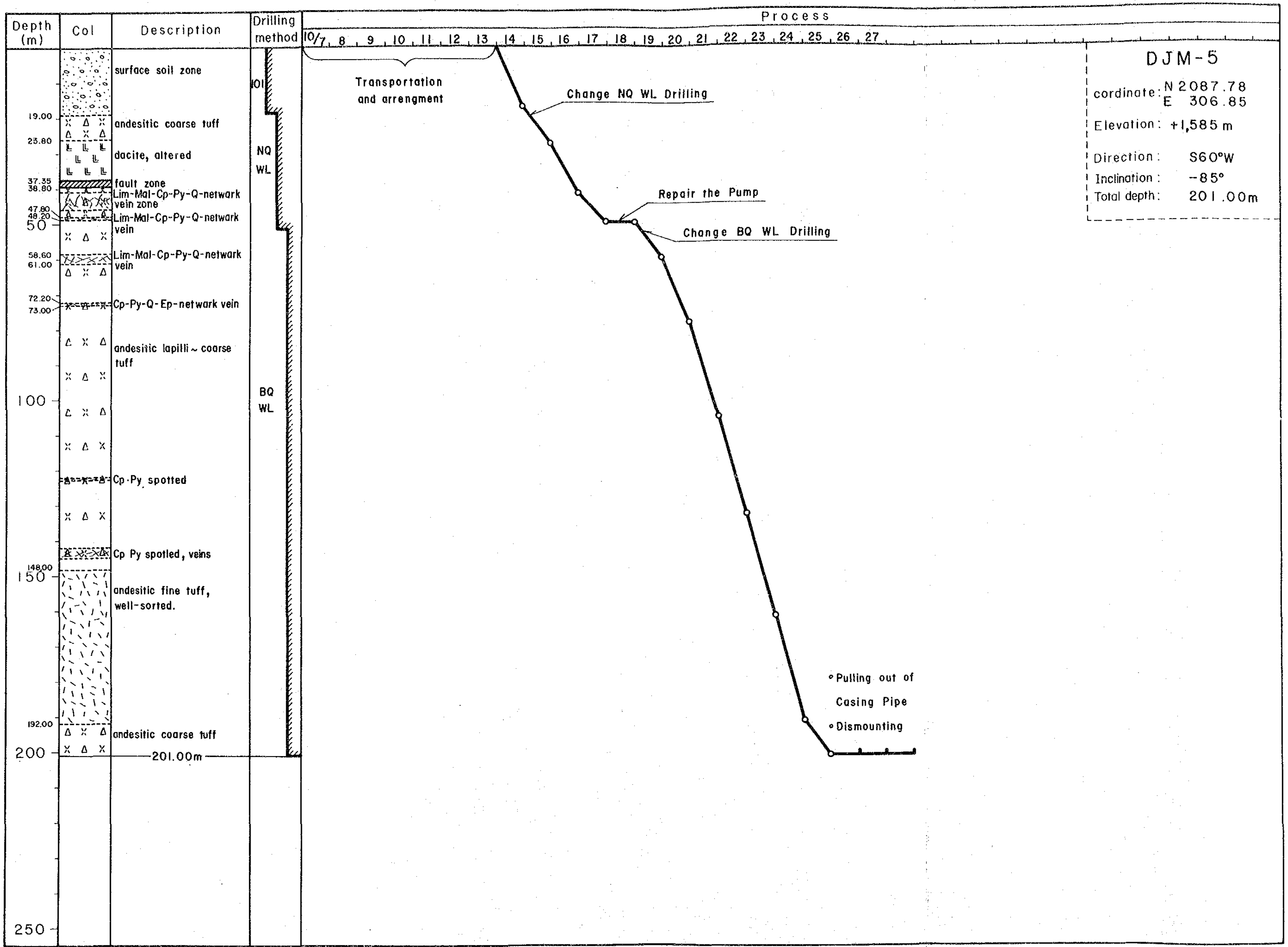


Fig. 20 Progress Record of Hole DJM-5

Core recovery 99.51 %

Started on October 14, 1985

Completed on October 25, 1985

(a) Section from 0 m to 17.10 m (Diameter of hole: 101 mm, NWCP for 17.10 m)

The bed consisting of surface soil and boulders was dug with 101 mm metal bit using bentonite mud water, and NW casing pipe was inserted to 17.10 m and set.

The pump pressure was zero to five kilograms per square centimeter, the amount of water supply 100 to 120 liters per minute and that of drainage 60 to 80 liters per minute.

(b) Section from 17.10 m to 18.00 m (Diameter of hole: 101 mm, NWCP for 18.00 m)

Although drilling was done changing to NQ wireline method at 17.10 m, it was discontinued at 18.00 m because of unstability of the rocks. This part was reamed by 101 mm metal bit, and NW casing pipe was inserted to 18.00 m additionaly.

(c) Section from 18.00 m to 49.70 m (Diameter of hole: 76 mm, BWCP for 49.70 m)

Andesitic tuff and lapilli tuff were cut by NQ wireline method using bentonite mud water. Complete lost circulation was encountered at 30.00 m. However, the hole was sunk having been in the condition of lost circulation to 49.70 m because of stable condition of the rocks. BW casing pipe was inserted to 49.70 m and set.

(d) Section from 49.70 m to 201.00 m (Diameter of hole: 59.6 mm, no casing)

Drilling was done by changing to BQ wireline method and complete lost circulation was encountered immediately. Because of stable condition of the rocks, andesitic tuff and lapilli tuff were cut using mud oil having been in the condition of lost circulation, and the hole was completed at 201.00 m.

The amount of water supply was 40 to 60 liters per minute.

1–2–5 Geology and Mineralization in Drill Holes

Geology of the area is mainly composed of andesite lava and pyroclastic rocks of the same source belonging to the middle member of the Cretaceous Tireo formation. The intrusive rocks including tonalite and dacite are distributed in the northern part and the southern part of the survey area, extending northwesterly. Mineralization is the copper bearing quartz veins with the trend of NW system, and many outcrops are distributed in the vicinity of the El Gramoso settlement.

The drilling survey was conducted for the five holes the following to test the main outcrops. The occurrence of vein of each hole are mentioned below.

1. **Hole DJM-1**

(1) **Situation, Direction and Inclination of the Hole**

Situation: Longitude N2,087.25 Latitude E306.85, Altitude, 1,435 m.a.s.l.

Direction: S70°W

Inclination: −60°

Depth: 250.20 m

(2) **Purpose**

The drilling was made to evaluate the lower part of the outcrop G-19.

The total lateral length of the outcrop G-19 is 35 meters, and the average of the assay results of the samples from the high grade part for six meters long and one meter wide are as in the following. 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.

(3) **Result of the Intersections**

Although the assay results at the ore intersection are shown in Table 4, the results of the main parts of the intersections are as follows.

Depth(m)	Core Length(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
132.45~132.65	0.20	0.1	2.0	0.35	0.02	0.05
132.75~132.80	0.05	tr	1.9	0.35	0.02	0 03
159.30~159.40	0.10	tr	1.5	0.31	0.02	0.83
192.90~193.00	0.10	tr	tr	0.20	0.02	0.01
230.75~231.05	0.30	tr	0.3	0.24	0.02	0.01
242.30~242.60	0.30	tr	tr	0.06	0.02	0.01

The downward extension of the outcrop G-19 corresponds to the veins at 132.45 meter and 132.75 meter in the hole, which were located at the vertical depth of about ninety meters below the surface.

These are malachite-chalcopyrite-limonite-quartz-epidote network veins. Those intersected at 159.30 meter, 192.90 meter, 230.75 meter and 242.30 meter are chalcopyrite-pyrite-quartz-epidote veins and the one at 242 meter is pyrite-hematite-quartz vein. Any outcrop corresponds to these veins has not been confirmed. A number of quartz veins, quartz-epidote veins and quartz-calcite veins are found in the surrounding of ore veins. The veins more than one centimeter wide are 42 in number. Rock control for formation of the veins has not been recognized.

The country rocks include andesitic tuff breccia, lapilli tuff and course-grained to fine-grained tuff. Although the fine-grained tuff is essential tuff, the others contain a small amount of

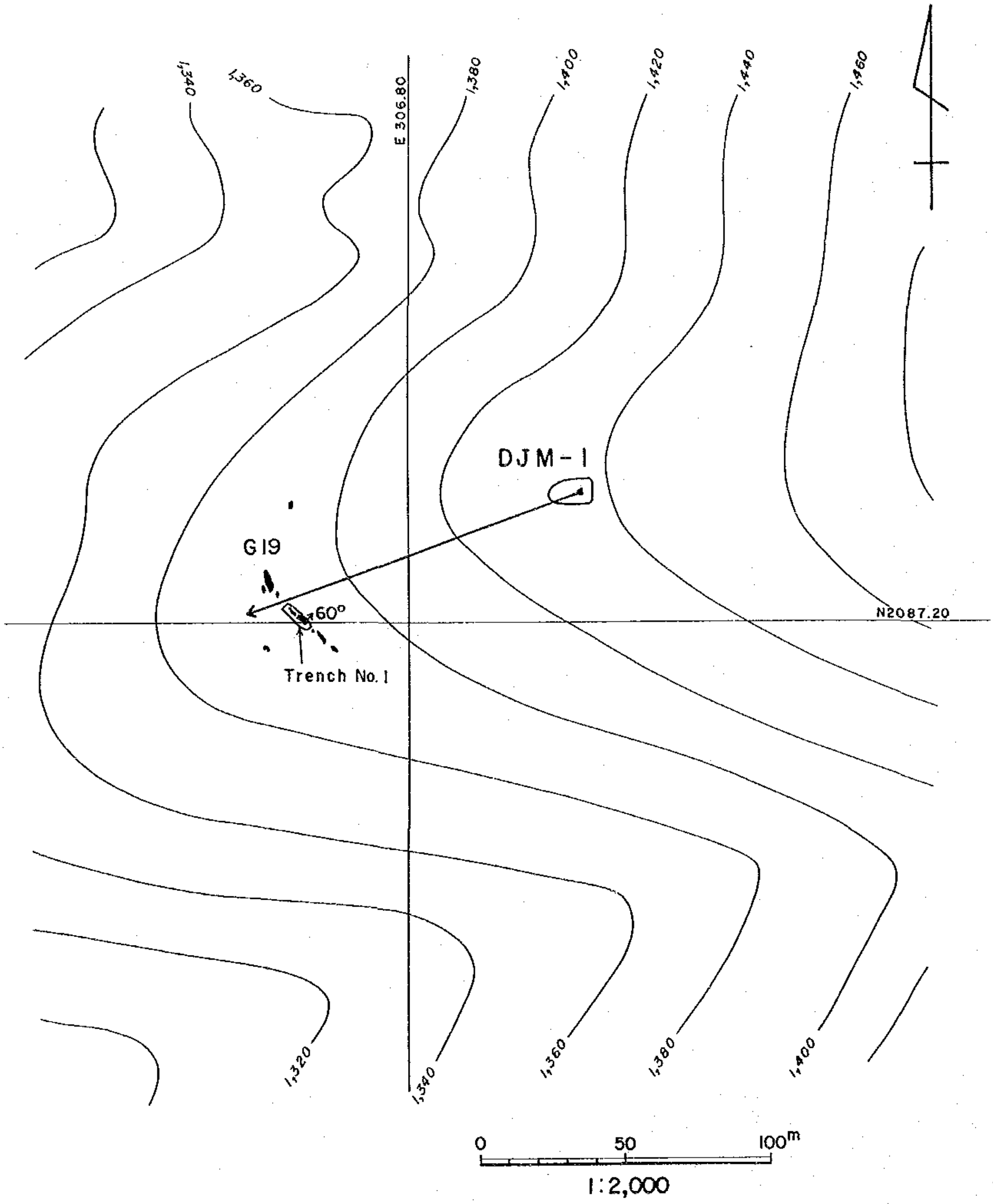


Fig. 21 Location Map of Hole DJM-1

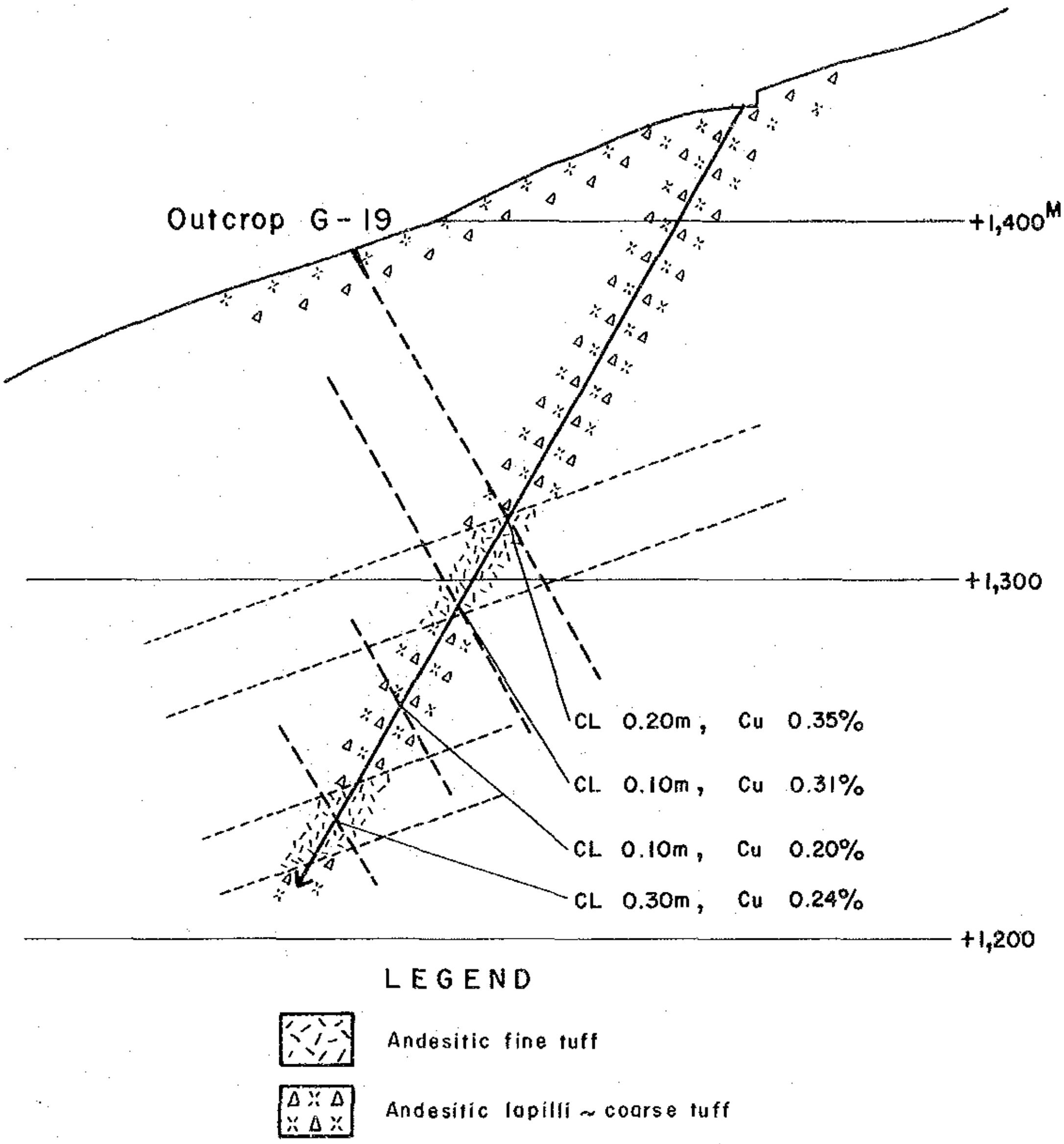


Fig. 22 Geological Section of Hole DJM-1

accidental fragments of dacite. Pisolite is contained in the fine-grained tuff.

Hematitization is observed in the sections such as from 54 meter to 61 meter and deeper than
233 meters.

Fig. 21 shows the location and Fig. 22 shows the geological section.

(4) Considerations

It was made clear from the data of the hole DJM-1 that the size and grade of the outcrop are becoming poor at the depth though the veins continue to the lower part, that the lower extension of the outcrop changes to a zone in which many fractures filled with gangue minerals and that ore minerals are a small quantity. These facts indicate that the fracture zone underneath the outcrop had not been the zone of crystallization of ore minerals, but played a role for the passage of hydrothermal solution. These suggest that the lower limit of the veins was formed in this part.

As a result of geochemical prospecting conducted in the second phase, the center of the El Gramoso mineralization is assumed to be in the vicinity of the top of Loma Sito Grande. The area of this outcrop, therefore, might be the outer peripheral part of the above, and it is disappointing that it has resulted in to be endorsed by the data of this drilling hole.

Because malachite is observed at the intersection of 132.75 meter and no oxide minerals could be recognized in the lower part deeper than 159.30 meters, the extent of oxidation seems to be approximately within 150 meters.

2. Hole DJM-2

(1) Situation, Direction and Inclination of the Hole

Situation: Longitude N2,087.68, Latitude E306.78, Altitude 1,530 m a.s.l.

Direction: S65°W

Inclination: −70°

Depth: 150.50 m

(2) Purpose

The drilling was made to evaluate the lower part of the outcrop G-18. The outcrop G-18 is composed of four series of copper bearing quartz vein 0.1 to 1.2 meters wide and 20 to 35 meters long along strike. The grade at the outcrop was shown to be 0.04 to 2.37 % Cu.

(3) Results of the Intersections

Although the assay results at the ore intersections are shown in Table 4, the results of the main parts of the intersections are as follows.

Depth(m)	Core Length(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
87.50~ 87.65	0.15	0.2	30.3	3.76	0.02	0.02
88.65~ 88.80	0.15	0.1	20.1	2.65	0.02	0.01
89.45~ 89.60	0.15	tr	1.9	0.40	0.02	0.03
89.90~ 90.05	0.15	0.1	11.7	2.94	0.02	0.03
90.40~ 90.75	0.35	0.2	16.4	2.37	0.02	0.05
91.35~ 91.70	0.35	0.1	9.1	1.78	0.02	0.01
95.30~ 95.40	0.10	tr	1.7	0.41	0.03	0.01
99.60~ 99.80	0.20	0.2	12.0	1.97	0.02	0.02
100.80~100.85	0.05	0.3	23.2	3.19	0.01	0.02
101.20~ 01.30	0.10	0.1	7.9	1.38	0.02	0.05
101.50~101.70	0.20	tr	8.4	0.97	0.02	0.02
103.20~104.05	0.85	0.2	22.3	2.71	0.02	0.73

All the veins including the six veins within the range of 4.20 meters from the depth of 87.0 meters to 91.70 meters and those intersected up to 103.20 meters correspond to the downward extension of the outcrop G-18.

The distance between the outcrop and the intersections is about 60 meters. The size and grade of the ore in the drill hole are the same or more superior on the whole as compared with those of the outcrop. These veins are chalcopyrite-pyrite-quartz veins, and most of them are the single solid veins although network veins are found partly.

A number of epidote veins, epidote-quartz veins and quartz-calcite veins are present on the hanging wall side of the ore veins. The total number of the intersections of vein more than one centimeter wide was 18. No notable vein was found in the footwall side of the ore veins (in the part deeper than 104.05 m). The country rocks are andesitic lapilli tuff, course-grained to fine-grained tuff and tonalite. The fine-grained tuff is the essential one and the others contain accidental fragments of dacite. The sections such as 36 to 77 meter and 107 to 117 meter are epidotized.

Fig. 23 shows the location of the hole and Fig. 24 shows the geologic section.

(4) Considerations

It was known from the data obtained from the drill hole DJM-2 that the outcrop G-18 continued to the lower part and that the parts of intersections were much the same in size and grade

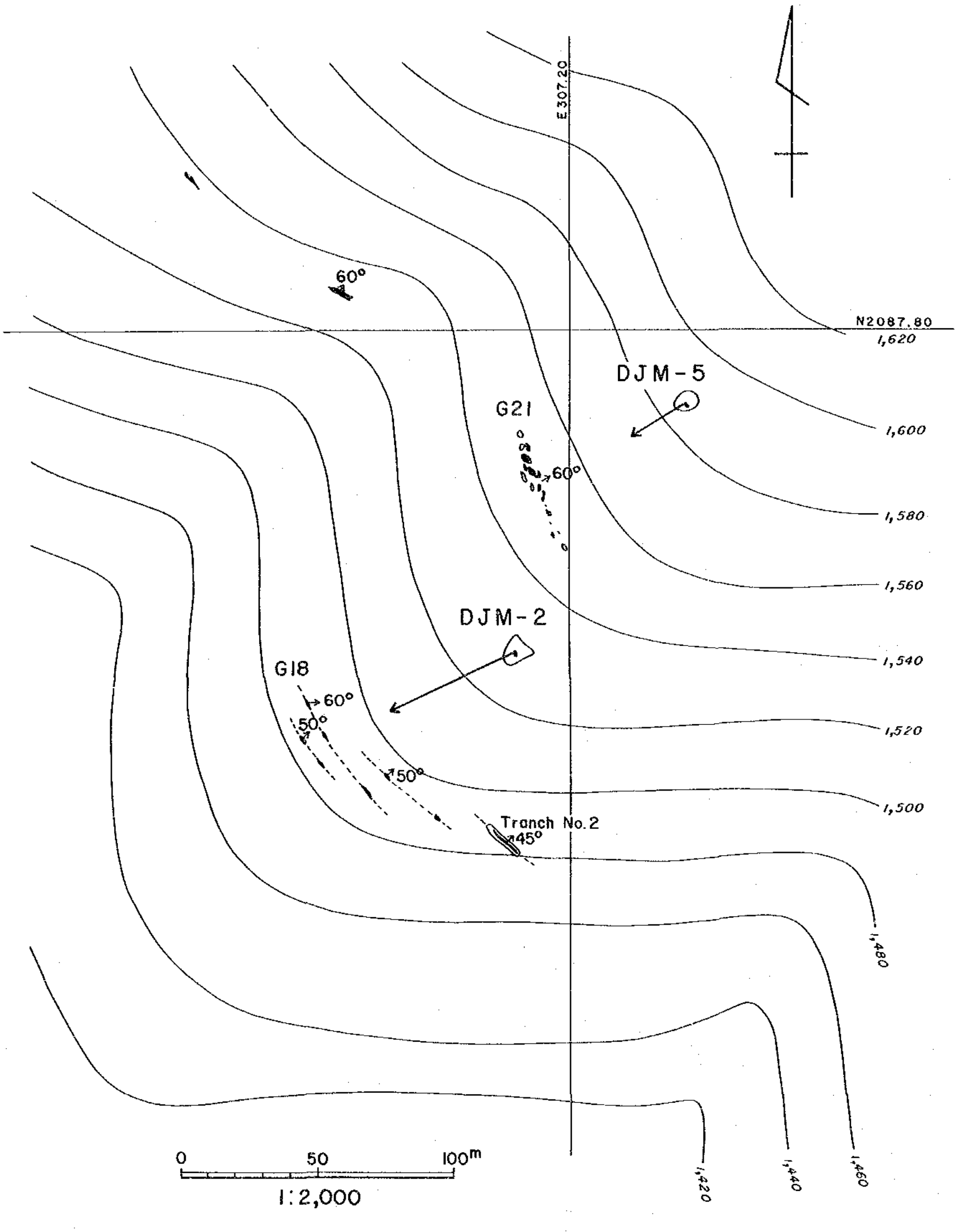


Fig. 23 Location Map of Hole DJM-2

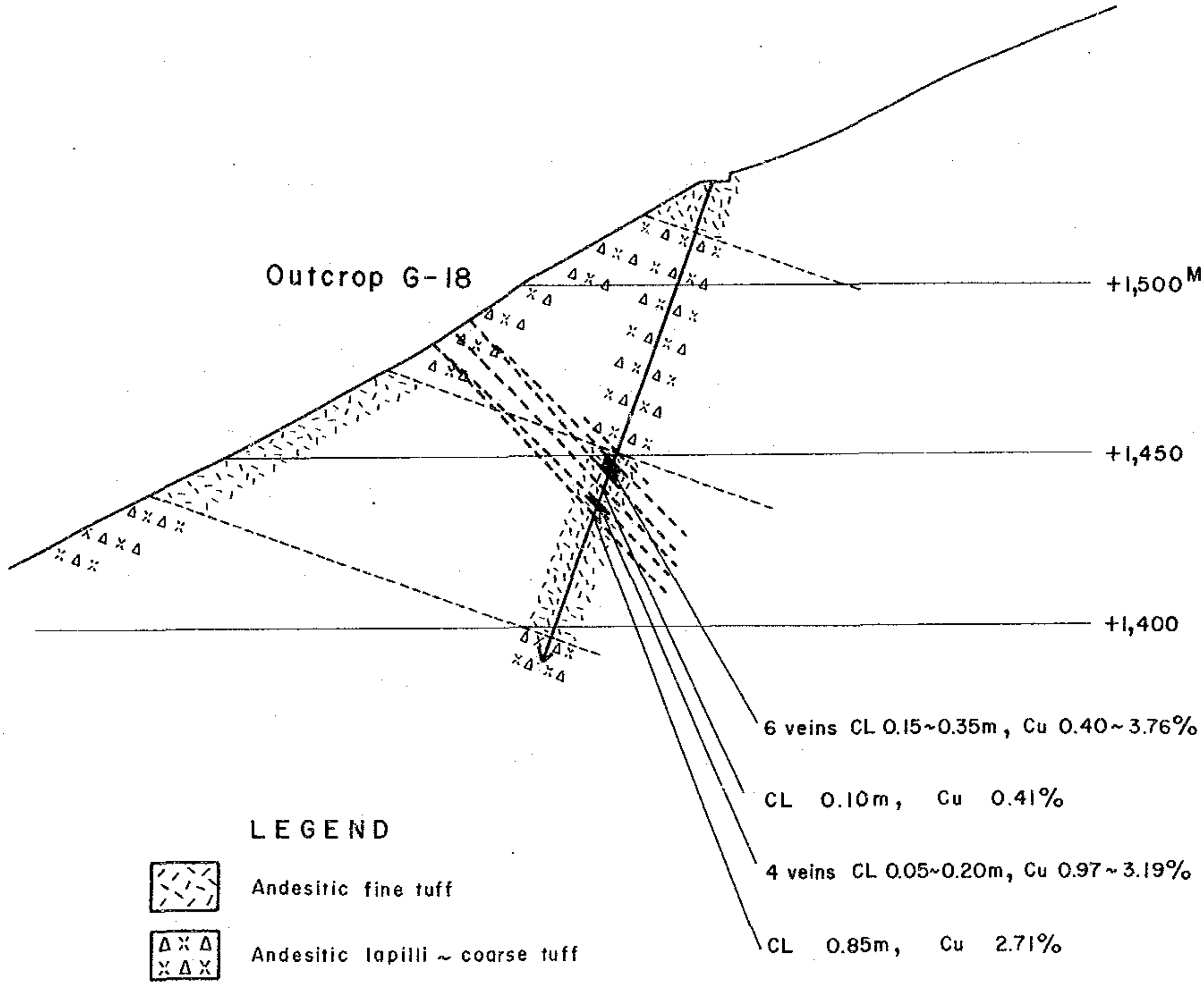


Fig. 24 Geological Section of Hole DJM-2

as the outcrop. Although these facts indicate that the veins would be swollen further in the depth, it is to be turned for the further exploration. The location of this hole is closer to the ridge of Mt. Loma Sito Grande than the holes such as DJM-1 and DJM-3. The superior grade and size of the ore veins as compared with the others suggest that these intersections are getting near the center of the mineralization. It is thought that the extent of oxidation is not deeper than 80 meters below the surface because no oxidation minerals could not be observed in the cores of the intersection.

3. Hole DJM-3

(1) Situation, Direction and Inclination of the Hole

Situation:	Longitude N2,087.66, Latitude 306.46, Altitude 1,370 m a.s.l.
Direction:	S55°W
Inclination:	−70°
Depth:	250.40 m

(2) Purpose

The drilling was made to evaluate the lower extension of the outcrop G-17.

The outcrop G-17 is composed of a copper bearing quartz vein 0.2 to one meter wide and 15 meters long along the strike.

(3) Results of the Intersections

Although the assay result at the ore intersections are shown in Table 4, the results of the main parts of the intersections are as follows.

Depth(m)	Core length(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
65.80~ 66.85	0.05	tr	2.5	0.40	0.02	0.06
113.30~113.40	0.10	tr	1.1	0.29	0.01	0.01
139.15~139.20	0.05	0.1	4.3	0.93	0.02	0.01
156.85~156.88	0.03	tr	0.8	0.29	0.02	0.01
165.60~166.00	0.40	tr	tr	0.07	0.02	0.02
183.15~183.40	0.25	0.1	3.7	0.75	0.02	0.01
192.30~ 92.80	0.50	tr	1.4	0.17	0.04	0.05
193.70~194.50	0.80	tr	2.2	0.41	0.02	0.03
197.70~197.75	0.05	tr	tr	0.23	0.02	0.01
228.45~228.50	0.05	tr	tr	0.16	0.04	2.09

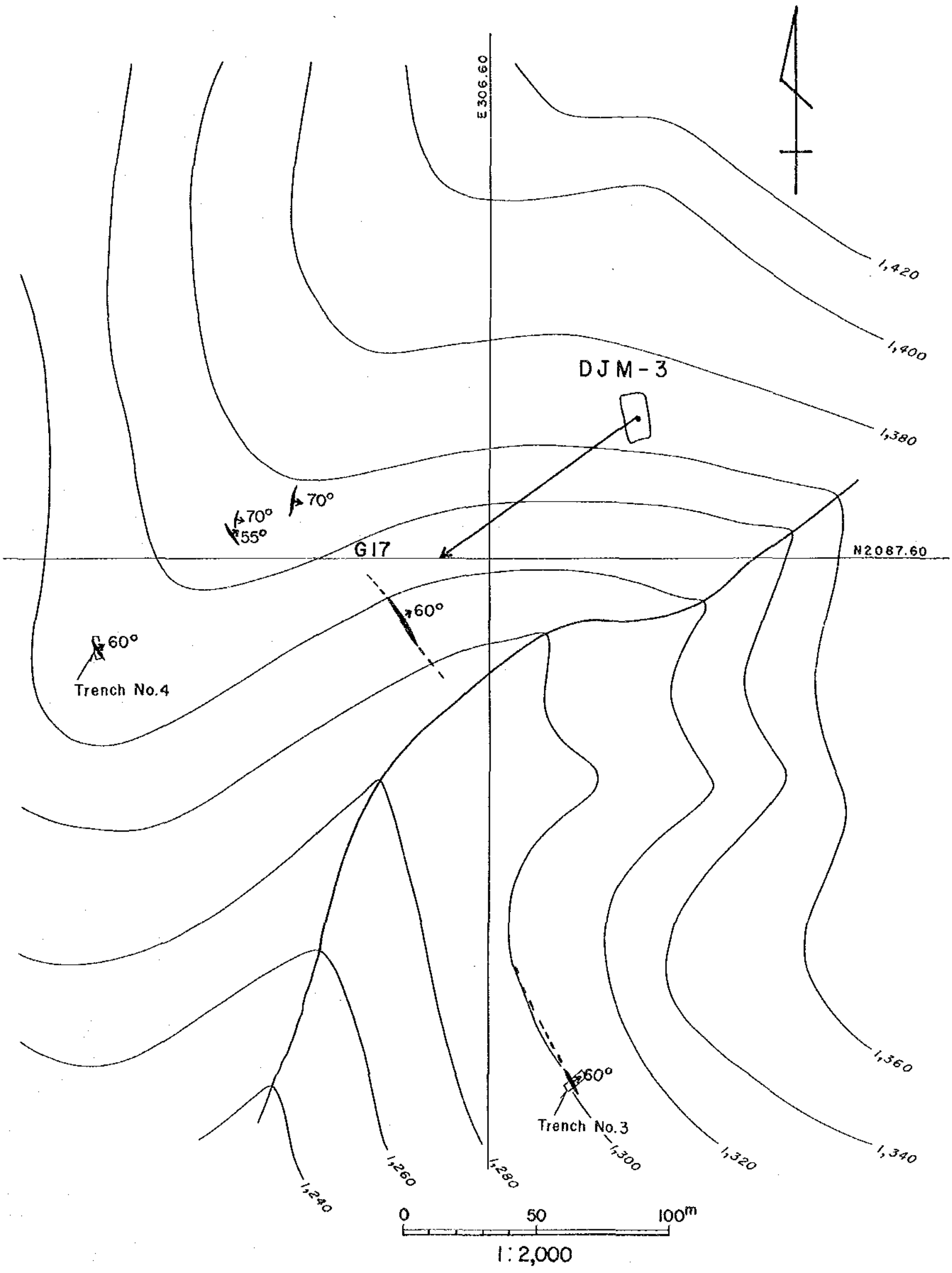


Fig. 25 Location Map of Hole DJM-3

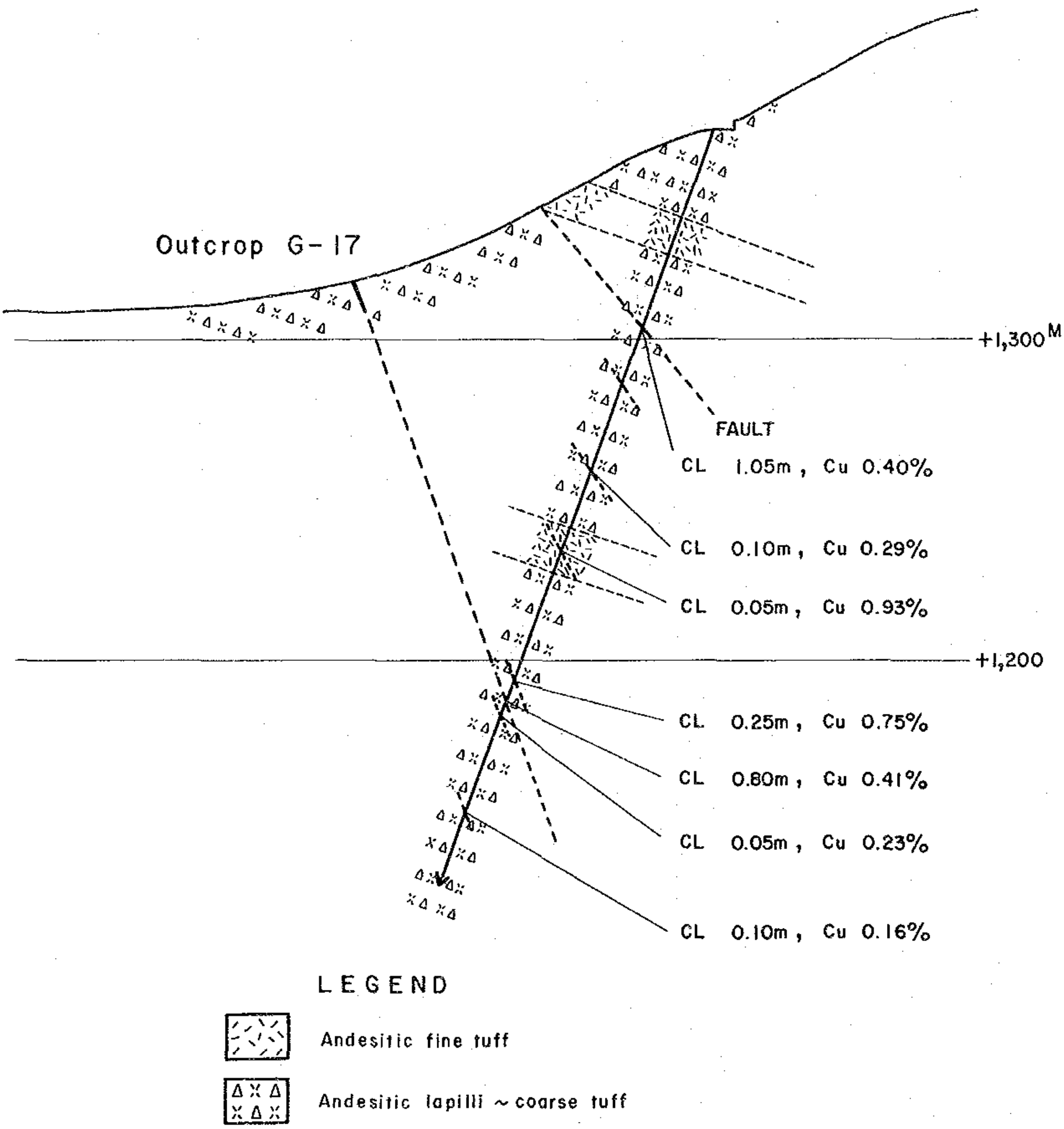


Fig. 26 Geological Section of Hole DJM-3

These are the single solid veins or network veins with mineral assemblage of chalcopyrite-pyrite-hematite-quartz-(epidote)-(calcite). The vein at the depth of 228.45 meters contains sphalerite, and is a little peculiar. Pyrite is commonly found in the veins at this area, although it is rarely found in the veins in the El Gramoso area.

Beside these, 26 veins including the single veins and network veins of pyrite-quartz veins, quartz-epidote veins and quartz-calcite veins were encountered in the hole. No control of the emplacement of the veins by the rocks is recognized.

The country rocks include andesitic lapilli tuff and course to fine-grained tuff. Although fine-grained tuff is essential tuff, the others contain a small amount of accidental fragments of dacite. Epidotization and silicification are the common alteration of the country rocks.

Fig. 25 shows the location and Fig. 26 shows the geological section.

(4) Considerations

It was known from the data of the hole DJM-3 that the lower part of the outcrop G-17 forms the zone occurred by a number of small veins including the veins consisting of only gangue minerals, that pyrite is commonly present, that sphalerite is found in a part of the veins and that these veins are difficult to be operated economically because of low grade of ore.

These facts indicate that the fractures to have been the passage of hydrothermal solution were present at the initial stage of mineralization, and that the main minerals crystallized in the fracture were gangue minerals, and the ore minerals were small in amount. The fact that sphalerite is found in a part of the veins suggests that this part is located in the outer zone of the El Gramoso mineralized zone.

4. Hole DJM-4

(1) Situation, Direction and Inclination of the Hole

Situation: Longitude N2,088.29, Latitude E305.14, Altitude 990 m a.s.l.

Direction: S50°W, Inclination: –70°, Depth: 150.40 m

(2) Purpose

The drilling was made to evaluate the lower part of the outcrop G-12.

The outcrop G-12, the largest one found in the El Gramoso area, has lateral length of 180 meters. The shoot is 70 meters long and 1.50 meters wide and shows the average values such as 0.3 g/T Au, 17 g/T Ag and 3.2 % Cu.

(3) Results of the Intersections

Although the assay results are shown in Table 4, the main intersections are as follows.

Depth(m)	Core length(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
52.45~52.60	0.15	0.1	1.4	0.74	0.02	0 02
60.20~60.45	0.25	0.4	22.5	5.71	0.04	0.26

The vein which was the main target could not be intersected because the hole passed through the fault zone encountered at the depth from 90.70 meters to 92.00 meters, which displaced the vein. The vein intersected is chalcopyrite-pyrite-(sphalerite)-quartz-epidote vein.

Quartz–epidote veins, quartz-calcite veins and hematite-quartz-(calcite)-(epidote) veins are present in abundant at the depth between 40 meters and 120 meters. The number of veins more than one centimeter wide are 18. The country rocks include andesitic lapilli tuff and fine to course-grained tuff. The dominant alteration of the country rocks is chloritization. Strong hematitization is observed at the depth between 112 meters and 118 meters. Fig. 27 shows the situation and Fig. 28 the geological section.

(4) Considerations

The position on the surface of the fault encountered in the hole DJM-4 corresponds to that found on the halfway between the outcrop G-12 and the drill site, and it is likely that the northern extension of the G-12 vein was displaced toward the west to continue to the small outcrops scattered on the slope of the northern ridge.

Because the ore minerals observed at the intersections mentioned in the above consist of chalcopyrite and pyrite and no oxide minerals are found, the extent of oxidation below the surface seems to be shallower than 50 meters.

5. Hole DJM-5

(1) Situation, Direction and Inclination of the Hole

Situation: Longitude N2,087.78, Latitude E306.85, Altitude 1,585 m a.s.l.

Direction: S60°W, Inclination: –85°, Depth: 201 m

(2) Purpose

The drilling was made to evaluate the downward extension of the outcrop G-21 discovered in the survey of this phase.

The vein of the outcrop G-21 is 1.70 meters wide in average and 35 meters long along the strike. The average assay values are 0.2 g/T Au, 28 g/T Ag and 4.7 % Cu.

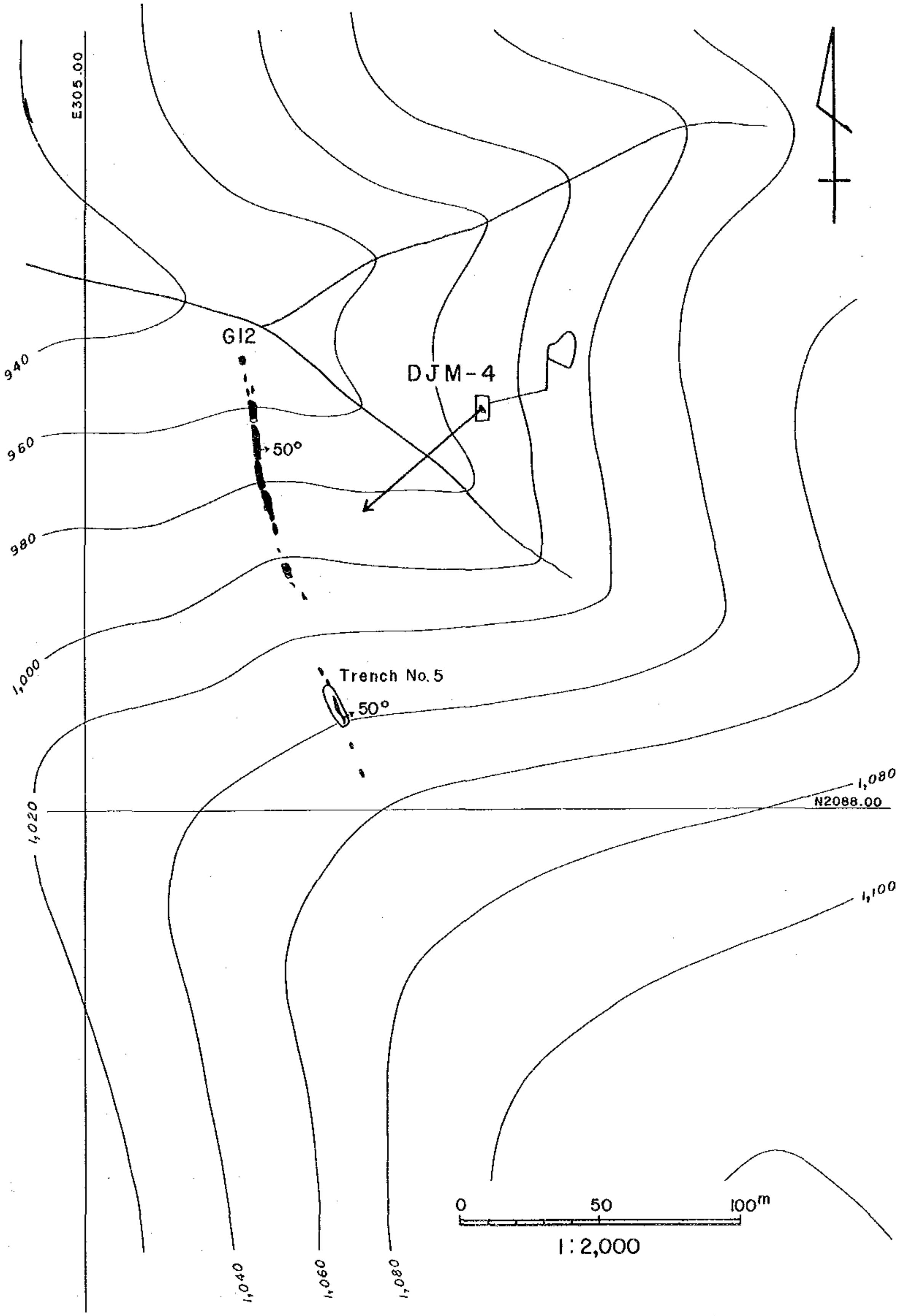


Fig. 27 Location Map of Hole DJM-4

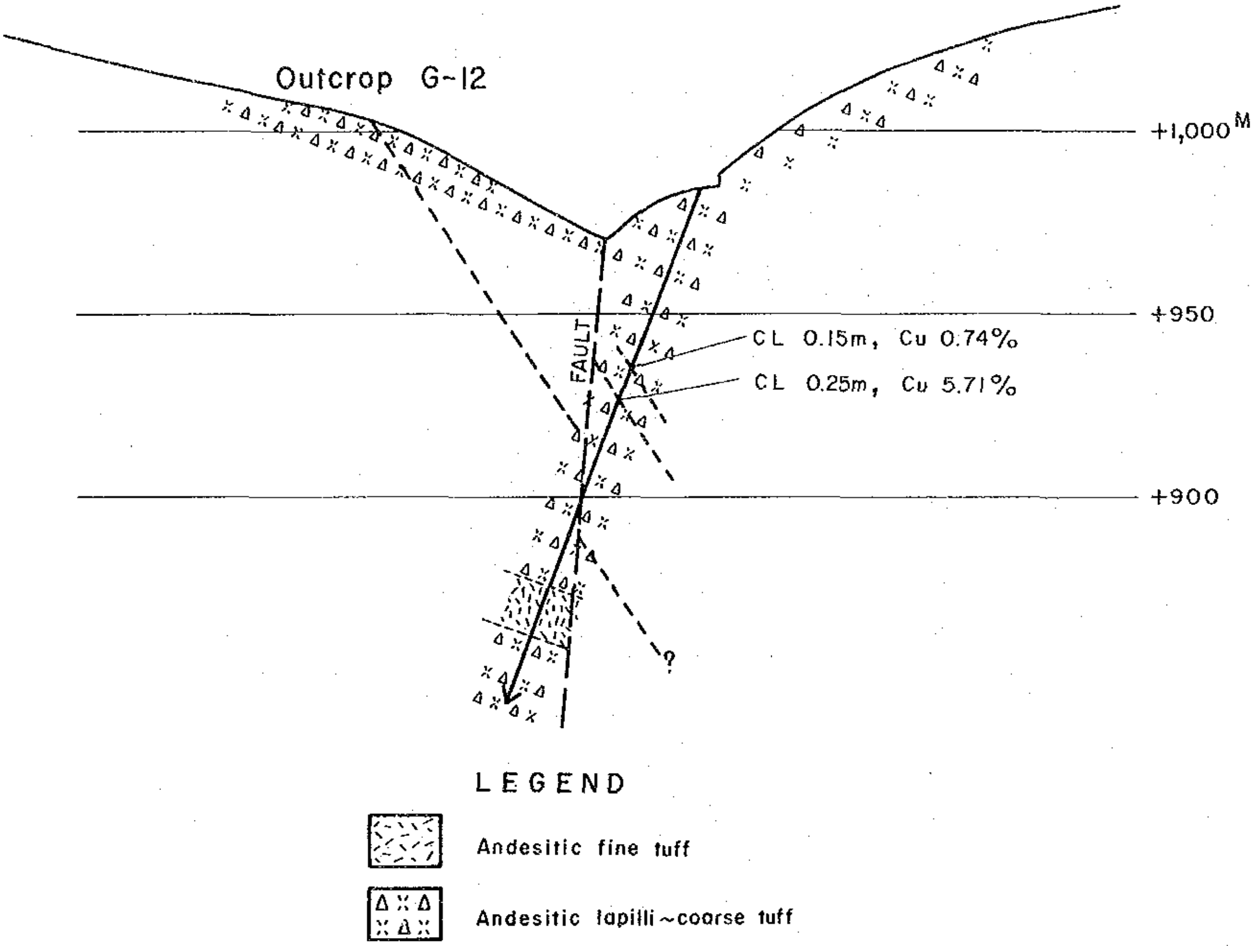


Fig. 28 Geological Section of Hole DJM-4

(3) Results of Intersections

The assay result of the main intersections are as follows although the detail of those is shown in Table 4.

Depth(m)	Core length(m)	Au(g/T)	Ag(g/T)	Cu(%)	Pb(%)	Zn(%)
40.50~45.70	5.20	0.3	13.1	3.43	0.02	0.03
47.80~48.20	0.40	0.2	7.8	1.03	0.02	0.02
58.60~61.00	2.40	tr	1.3	0.43	0.02	0.03
61.50~61.90	0.40	0.6	25.8	5.41	0.10	0.05
71.40~71.60	0.20	0.1	2.0	0.92	0.02	0.01
72.20~73.00	0.80	tr	1.1	0.36	0.02	0.02

The veins found up to the depth of 61.50 meters are malachite-chalcopyrite-chalcocite-pyrite-limonite-quartz network veins and those further in the deeper part are chalcopyrite-pyrite-quartz-epidote veins.

The surrounding part of the former veins is strongly silicified (metasomatic type) for a wide extent. Epidote is conspicuous in the latter veins. The vein intersected at the depth of 40.50 meters corresponds to the lower extension of the outcrop G-21. This vein was positioned in this part as the result of displacement by the normal fault encountered at the depth of 37.35 meters to 38.80 meters (Fig. 30). The ore veins are present in the range of the depth from 40 to 150 meters, and a few small veins consisting of quartz and calcite are found in the deeper part beyond the aboves. The country rocks include andesitic lapilli tuff, course to fine-grained tuff and decite.

Fig. 29 shows the situation and Fig. 30 the geological section.

(4) Considerations

On the basis of the data obtained from the hole DJM-5, it was shown that the size and grade of the veins about 50 meters below the outcrop G-21 were much the same as those of the outcrop and that the rocks were extensively silicified.

The ore veins are stable in size and grade as compared with the results of other holes and the silicified zone of metasomatic type has been extensively formed.

These facts suggest that this part is relatively close to the center of mineralized zone.

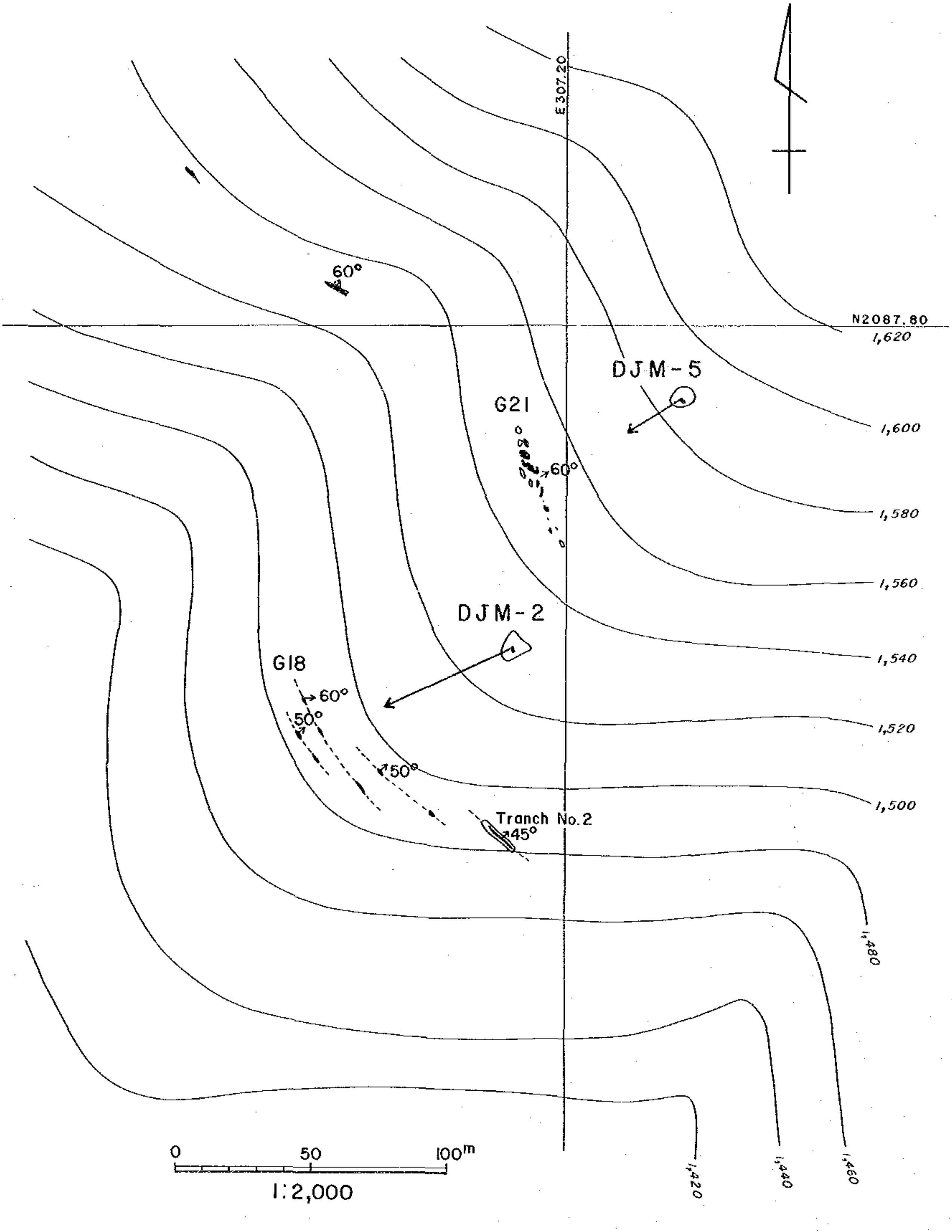


Fig. 29 Location Map of Hole DJM-5

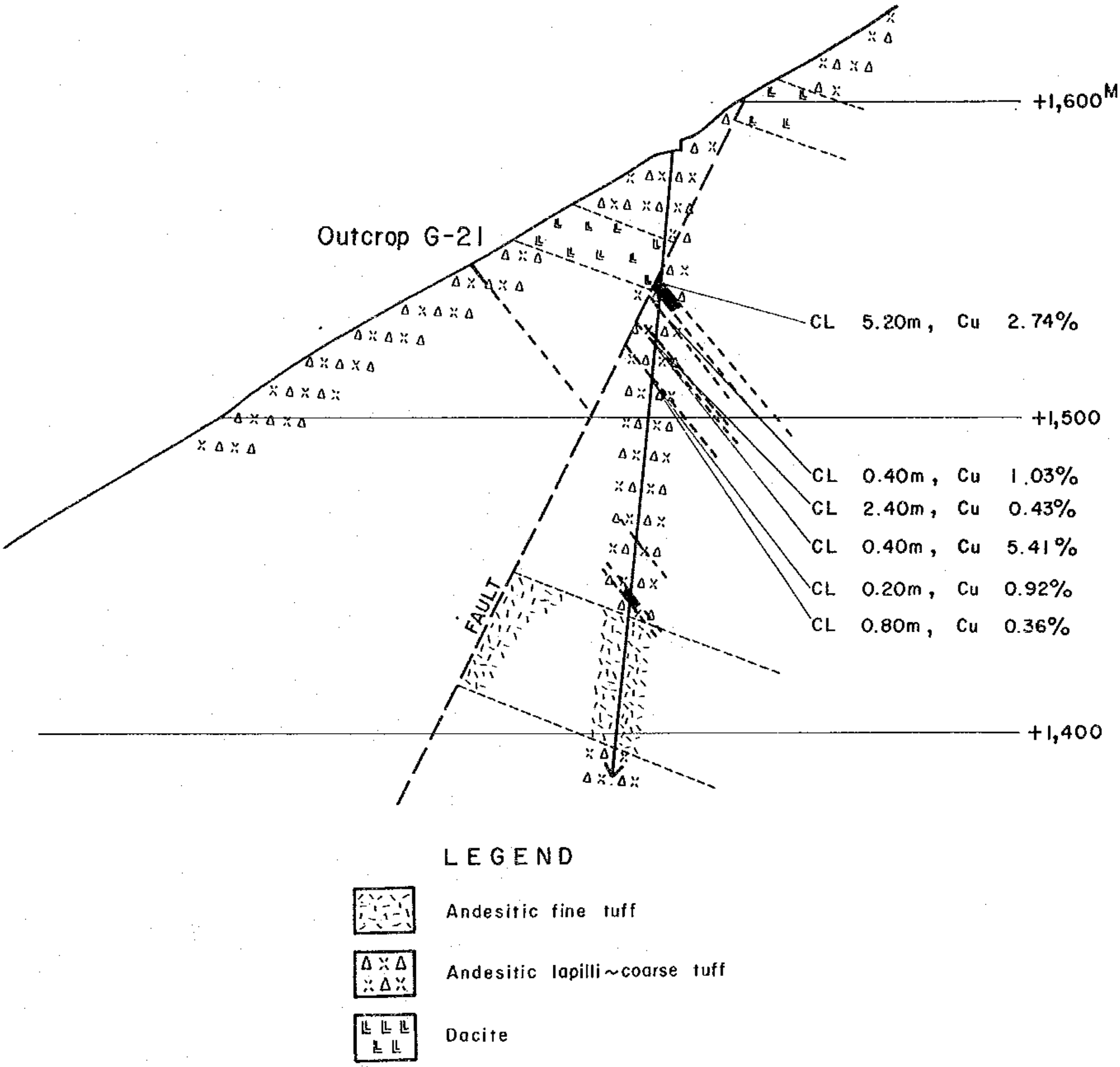


Fig. 30 Geological Section of Hole DJM-5

1–3 Considerations

The El Gramoso copper bearing veins occur in the middle member of the Tireo formation and acidic intrusive rocks. most of the veins in the area strike northwesterly and dip northward, and the veins distribution of the itself extends in the northwestern direction. The vein fractures appear to be the shearing fractures formed in association with the fault of NW-SE system which seems to be caused by the southward stress based on the analysis of geologic structure. The two directions such as N20°W, 40°N and N70°W, 50°N are dominant.

It is estimated from the reasons in the following that the mineralization of the area seems to be centered on Mt. Loma Sito Grande and to be related to the tonalite intrusive masses.

(1) The geochemical anomalies spread over centering on Mt. Loma Sito Grande.

(2) The quality of the veins become increasingly superior and metasomatic silicification becomes stronger toward the top of Mt. Loma Sito Grande.

(3) An intrusive masses analogous to tonalite in the south of the Constanza which is considered to be related to the mineralization are distributed with the northwesterly trend along the ridge of Mt. Loma Sito Grande, and the veins of El Gramoso is distributed along the intrusive masses on the southern side.

From the standpoint of view in the above, one of the reasons that the relatively superior veins were encountered in the holes such as DJM-2 and DJM-5 is that these holes were located at the nearer position to the center of the mineralized zone of the area. In addition, sphalerite is found in some veins such as those at the outcrop G-22 and in the holes DJM-3 and DJM-4, notwithstanding that the ore minerals in the veins of the area coherently consist mainly of copper minerals. The fact suggests the presence of zonal arrangement of the ore minerals in the mineralized zone centering on Mt. Loma Sito Grande.

It might be necessary to consider the erosion when the position of the ore shoot of the mineralized zone of the area is investigated. That is, (1) the ore pebbles in the host rock of the Tireo formation are found in the basal conglomerate of the Oligocene formation and (2) the amount of erosion after the extrusion of dacite of the Pleistocene (0.5 m.y. in absolute age) is 150 to 300 meters (0.3 to 0.6 mm in annual rate of erosion). From this fact, it is suggested that the area had been raised above sea level since the Oligocene time and the erosion was already in progress at that time, which resulted in that the area has been subject to a great amount of erosion up to the present time. It is therefore possible that the poor quality of the ore veins intersected in the holes such as DJM-1 and DJM-3 is the result that the ore shoots have been eroded out, which might have been existed in the upper elevations.

The most dominant veins among the outcrops confirmed so far in the area is G-12 and

G-21. The outcrop G-12 is traced laterally for about 180 meters in which ore shoots 70 meters long and 30 meters long are found separately. The former is 1.5 meters wide in average, showing the grades such as 0.3 g/T Au, 17 g/T Ag and 3.2 % Cu. The latter is 0.27 meter wide in average showing the grades such as 0.3 g/T Au, 24 g/T Ag and 2.8 % Cu.

The outcrop G-21 can be traced for 35 meters and is 1.7 meters wide in average, showing the grades such as 0.2 g/T Au, 28 g/T Ag and 4.8 % Cu.

The number of veins confirmed within six square kilometers of the survey area are 51, leading to be 8.5 per square kilometers in density of distribution. The extent of the mineralized zone of the area is presumed to correspond to that of the geochemically anomalous zone centering on Mt. Loma Sito Grande, which has the area of 12 square kilometers.

When compared this with the vein-type deposits in Japan, the mineralized zone in the survey area is a match for the density of distribution of the vein outcrops and the extent of a mine which produced 5,000 tons of metallic copper or 20,000 tons of metallic lead plus zinc (corresponding to 500,000 tons in crude ore, one per cent Cu or four per cent Pb + Zn). Among the 81 copper or lead and zinc mines in Japan, 32 mines correspond to the above condition, and the average density of them is about 5 per square kilometer and the extent is 11 square kilometers (Kuroda 1973). The fact suggests that it is possible that the mineralized zone with the corresponding quantity of copper metal might occur in the area.

However, because of the oxidation zone developed deeply in the subsurface of the area, it should be necessary to investigate prudently when the economy for the development of the veins in the area be considered in future.

CHAPTER 2 PICO DUARTE AREA

2–1 Geophysical Survey

2–1–1 Purpose of the Survey

In the first and second phase of this project, it was revealed that more than 20 mineralized zones, including of porphyry copper type ore, are in the granodioritic body seen around the Rio Yaque del Sur river, at the southeast of Mt. Pico Duarte.

The third phase of this project, done during the present year, had the purpose of investigating the biggest of the 20 mineralized zones of P-1. For this reason, it was adopted the Spectral Induced Polarization (SIP) method, which would permit to know the continuity of the mineralized zone at depths, by analizing the spectral type of data obtained during the survey.

2–1–2 Survey Area, Outline of the Geology and Mineralization

1) Survey Area

The survey area is located on the south-eastern slopes of the Mt. Pico Duarte, which is the highest peak in the Dominican Republic, with an elevation of 3,078 m.a.s.l. Fig. 31 shows the location map of the survey area.

The topography of the surveyed area is very rugged, with a debris at P-1 zone and with a cliff of 70 m high and 400 m wide in the southern side of the P-1 zone.

2) Outline of Geology and Mineralization

The geology of the area is composed of the lower member of the late Cretaceous Tireo formation, of granodiorite intruded into it and dyke rocks intruded into all of the aboves. The lower member of the Tireo formation consists of andesite lava (Tla). The rock has undergone the so called "propylitization" with green color. Although the rock is generally massive, flow units (0.5–5 m) of lava are distinctly observed along the Rio Yaque del Sur outside of the area. The lower member of the Tireo formation in the area, strikes north and dips toward the east.

The granodiorite (Gd) with a porphyry copper mineralized zone intruded into the lower member of the Tireo formation, strikes northwest. Even though the rock is relatively homogeous, parts of it have an appearance of tonalite.

The dyke rocks include andesite and aplite. Most of them are less than 1 meter in width, however the maximum in width of these dykes is 5 meters.

In this phase, the geophysical survey (SIP) was conducted in the P-1 mineralized zone, which is the biggest among other 21 mineralized zones discovered in the granodiorite body in the second phase survey.

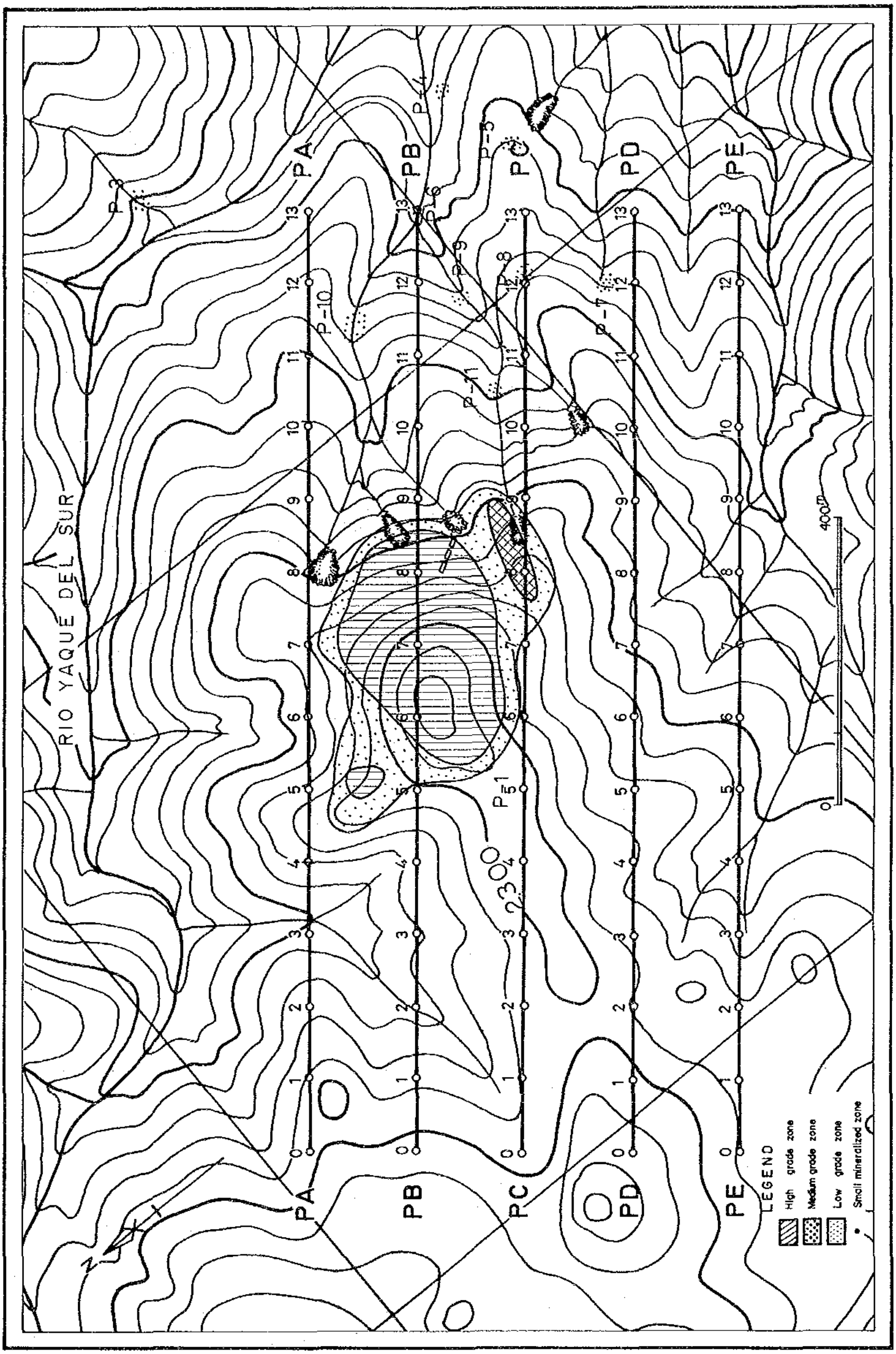


Fig. 31 Location Map of the SIP Surveyed Area

The P-1 mineralized zone is distributed along a ridge extending northwesterly in the area with an extension of 450 x 250 m. The slope of the ridge are covered by the boulders, showing a form of "rubbly terrain" with no vegetation.

The mineralized zone is composed of disseminated ore in white altered granodiorite. The ore minerals consist of chalcopyrite, bonite, etc. and secondary minerals such as chalcocite, malachite and limonite. Silicification is the notable alteration of the country rock, which is accompanied by sericitization and chloritization.

According to the grade of copper, the mineralized zone is classified in high-grade zone, middle-grade zone and low-grade zone. The average grade is 1.0% Cu with 0.5 g/T Au in the high grade zone, 0.3% Cu in the middle and less than 0.3% in the low-grade.

In the second phase, the geochemical anomalous zone of copper were detected within the whole area of the P-1 mineralized zone, being extended further towards the southern part which is covered by surface soil.

2–1–3 Specifications

The details of the surveyed lines for the mentioned geophysical technique is as follows.

Item	Specifications
Method	Spectral IP
Survey Line	5 lines (1.3 km x 5 = 6.5 km)
Observation Points	39 points x 5 lines = 195 points
Line Direction	N50°W
Line Spacing	150 m
Station Interval	100 m
Electrode Separation Factor	n=1 to 5

Table 2 Details of the SIP Survey

2–1–4 Survey Method

The spectral IP method has the advantage over the conventional IP method in that the former, is able to discriminate the anomalous IP source from the frequency responses of the stratum and of the ore body. For practical reasons, the frequency range is often used from 0.1 to 100 Hz. In the present survey, it was used the SIP System of the Zonge Engineering and Research Organization, with frequencies ranging from 0.1125 to 88 Hz.

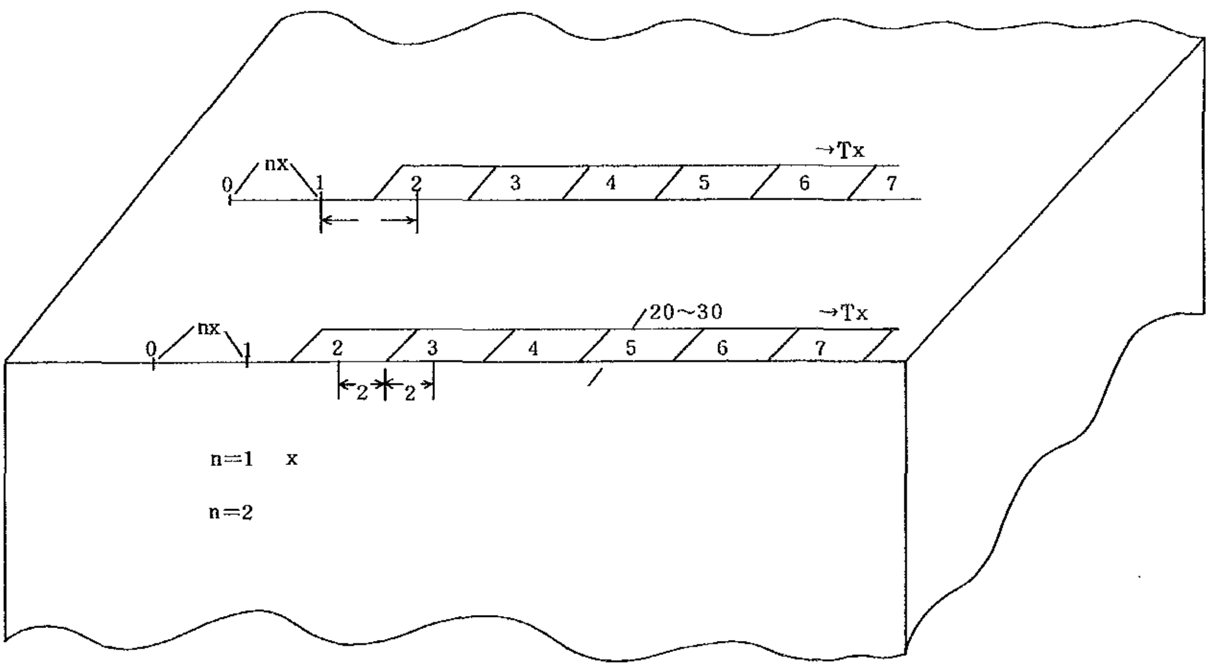


Fig. 32 Schematic Diagram of SIP Measurement

Actually, the SIP survey technique is not so different from the conventional IP, since both of them use the dipole-dipole electrode configuration in the frequency domain. A schematic diagram of a SIP measurement is shown in the Fig. 32.

2–1–5 Measuring Equipment

The equipment used in the survey was manufactured by Zonge Engineering and Research Organization Co., USA. The component parts of the equipment are described in the following table.

Item	Equipment	Amount
Transmitter	Engine Generator (ZMG-5)	1 Pc.
	Transmitter (FT-4)	1 Pc.
	Voltage Regulator (VR-1)	1 Pc.
	Geophysical Data Processor (GDP-12/2GB)	1 Pc.
Receiver	Cassette Printer (CAP-12)	1 Pc.
	Pre-amplifier (FP/1)	2 Pcs.
	Isolation Amplifier (ISO/1)	2 Pcs.

2–1–6 Data Processing

The data from field measurements give the phase shift and the magnitude of eighteen frequencies from 0.125 Hz to 88 Hz. These signals are recorded and input into the Data Processor (GDP-12/2GB), where the real and imaginary parts of each frequency, the resistivity values of the fundamental frequencies (0.125, 1, and 8 Hz), the value of the three point decoupled phase, the raw phase and the percent frequency effect (PFE) are calculated.

Terrain correction is applied to the apparent resistivity and daily calibration measurement is taken. After data processing, some pseudo-section and plan maps are generated. They are:

(1) Pseudo-section of Apparent Resistivity (0.125 Hz)

(2) Pseudo-section of PFE (0.125 ~ 1.0 Hz)

(3) Pseudo-section of Raw Phase (0.125 Hz)

(4) Cole-Cole Diagram

(5) Phase Spectrum

(6) Magnitude Spectrum

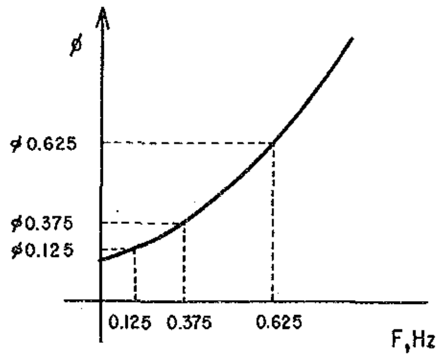
(7) Pseudo-section of 3PT Decoupled Phase

(0.125 ~ 0.375~ 0.625 Hz)

(8) Decouple Spectrum

From the above items, only the ones from 3) to 8) give indication of IP anomalous sources that can be identified by their spectral responses.

As shown in the next Figure, the 3 PT decoupled phase is an approximated phase in direct current using 0.125, 0.375 and 0.625 Hz. It assumes that the phase is represented as the second order polynomial of the frequency. The phase in direct current (C) is given by the following equation: $C = \frac{15}{8} \cdot \phi_{0.125} - \frac{10}{8} \cdot \phi_{0.375} + \frac{3}{8} \cdot \phi_{0.625}$ where $\phi_{0.125}$, $\phi_{0.375}$ and $\phi_{0.625}$ are the phases at 0.125, 0.375 and 0.625 Hz respectively.



3PT Decoupled phase shift

As for the item (8) above mentioned, the Spectral IP data measured show an IP effect as well as an Electromagnetic coupling effect. For that reason, and in order to remove the EM coupling effect, it was used in the data processing a decoupling method by Hallof and Pelton.

The complex impedance, Z(ω), utilized in the SIP data is given by the following equation:

$$Z(\omega) = R_0 \cdot \left\{1 - m_1\left[1 - \frac{1}{1+(i\omega\tau_1)^{c_1}}\right] - m_2 \cdot \left[1 - \frac{1}{1+(i\omega\tau_2)^{c_2}}\right] + m_3 \cdot \left[1 - \frac{1}{1+(i\omega\tau_3)^{c_3}}\right]\right\}$$

where, the first term of the equation represents the IP response ($c_1 < 0.5$), the second term indicates the EM coupling response in a homogeneous earth ($c_2 > 0.5$) and the last term is the EM coupling response due to the conductive body.

In the same equation, R_0 is the value of Z(w) at zero frequency, m the chargeability, τ the time constant, c the frequency dependence and ω, the angular frequency.

The IP effect without EM coupling response is given by using optimum parameters (R_0, m, C). In this survey, the decoupling calculation was done at some points measured around mineralized and nonmineralized zones. The calculation used a Decoupling program of the MMAJ.

On the other hand, the rugged topography strongly affects the apparent resistivity values in the survey area. For this reason, the terrain correction values were calculated on each line by means of a computer program which uses a finite element technique. The pseudo-sections of terrain corrected resistivity values on each line are shown in Fig. 36.

2–1–7 Results of Laboratory Measurements

1) Results

In order to evaluate the results of the resistivities and spectral responses of the magnitude and phase shift of the rocks, 21 rock samples were collected in the survey area. The location where the rock samples were collected is indicated in the Fig. 33. A schematic diagram of the technique used in the measurements is indicated in the Fig. 34. The table 3 shows the results obtained.

From the laboratory measurements it was concluded that:

(1) As indicated in the following table, the granodiorite shows a high resistivity of more than 200 ohm-m and a low IP effect less than 1.0%. However, tonalite shows a higher resistivity than granodiorite and a low IP effect less than 2.0%. From these results, the rocks in the area show a high resistivity and a low PFE.

Rock Name	Resistivity (ohm-m)		PFE (%)	
	Observed	Average	Observed	Average
Granodiorite	2024 ~ 41671	10900	0.27 ~ 2.46	0.79
Tonalite	5236 ~ 14539	8900	1.13 ~ 1.66	1.41

(2) Because of the low phase shift of less than −10 mrad found in the samples, the IP effect were not detected.

(3) The rock samples collected in the area, show mainly an "A" spectral type indicating an increase in the phase shift as the frequency increases in the low frequency range.

Only one sample shows a "B" spectral type, since its phase shift decreases as the frequency increases.

2) Characteristics of the Spectral types

a) Spectral type "A" (Figs 35−1~2)

Among the 21 rock samples collected, 20 of them show a Spectral type "A" in the area. A remarkable peak were detected at the frequencies of 0.625 and 0.875 Hz on the phase spectrum

The phase spectra of tonalite at samples Nos. 13, 16 and 18 show an "A" spectral type. Notable peak was detected at 0.625 Hz. The increase in the phase shift appeared to be lower at the 0.875 Hz frequency.

b) Spectral type "B" (Fig. 35−3)

The phase spectra of granodiorite at the sample No. 20 shows a "B" spectral type. Its phase shift decreases when the frequency increases in the low frequency range.

2−1−8 Model Simulation

In order to analyse the PFE and the resistivity, and IP model was processed on a digital computer for the lines PA to PE. The model takes also into consideration the geological condi-tiones of the area and the physical property of the rocks.

In the numerical calculation, the underground zone is represented by an adequate number of finite elements, where data such as the PFE and resistivity are given to every element. In this technique the calculation is repeated, changing the input data such as the mesh sizes, until the computed values are close enough to the observed values.

Based on the assumed model, printouts of the calculated frequency effect and the resistivity sections, for every line are indicated in Figs. 40−1 to 40−5.

2−1−9 Interpretation Results

Interpretation results are derived for the five surveyed, lines, (PA, PB, PC, PD and PE). They showed that no IP anomalies were detected, since their phase were less than −15 mrad and the PFE less than 1.3%. Output of the results are shown in the figs. 36 to 40.

(1) Pseudosection interpretations

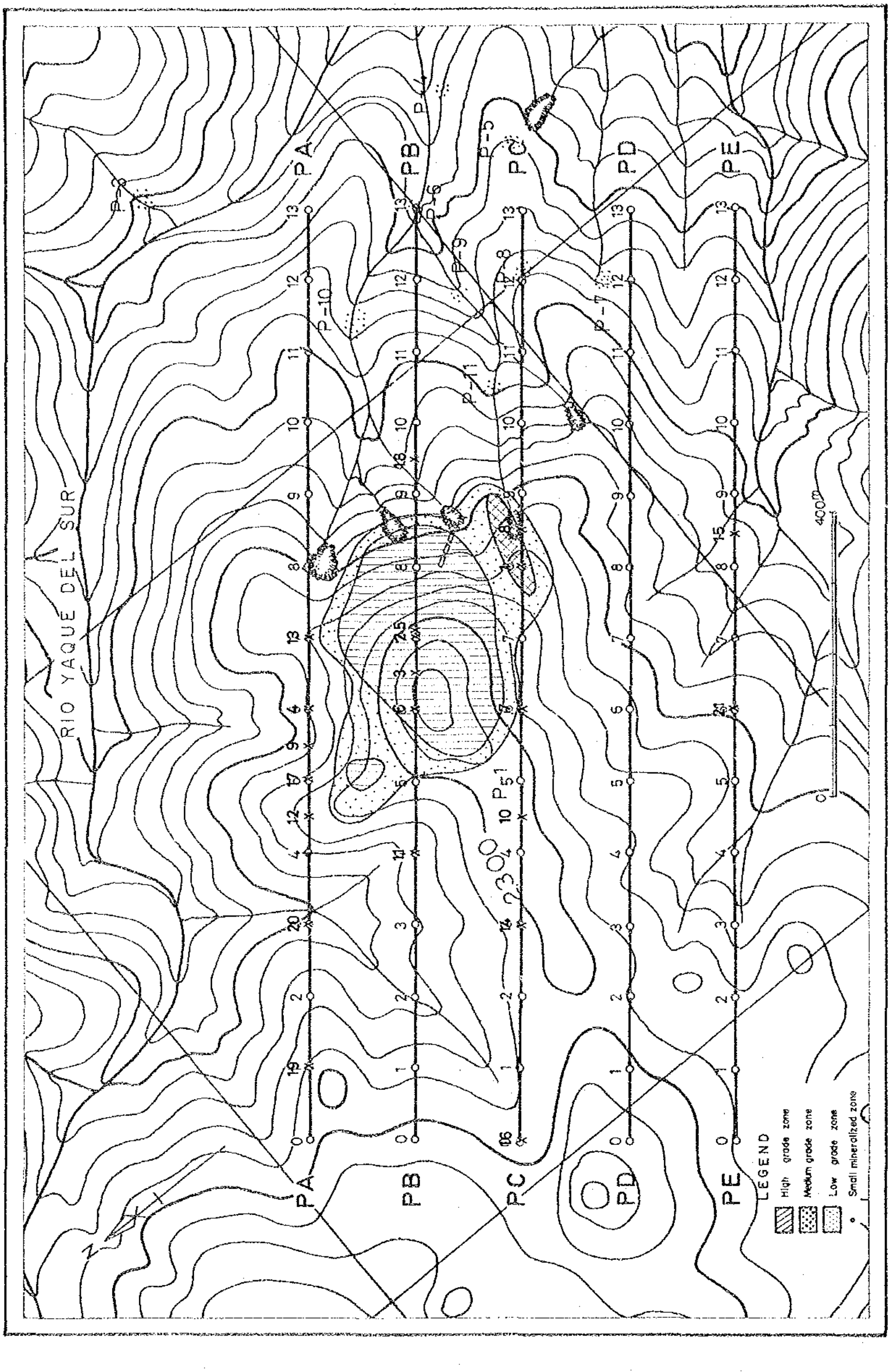


Fig. 33 Location Map of Collected Rock Samples

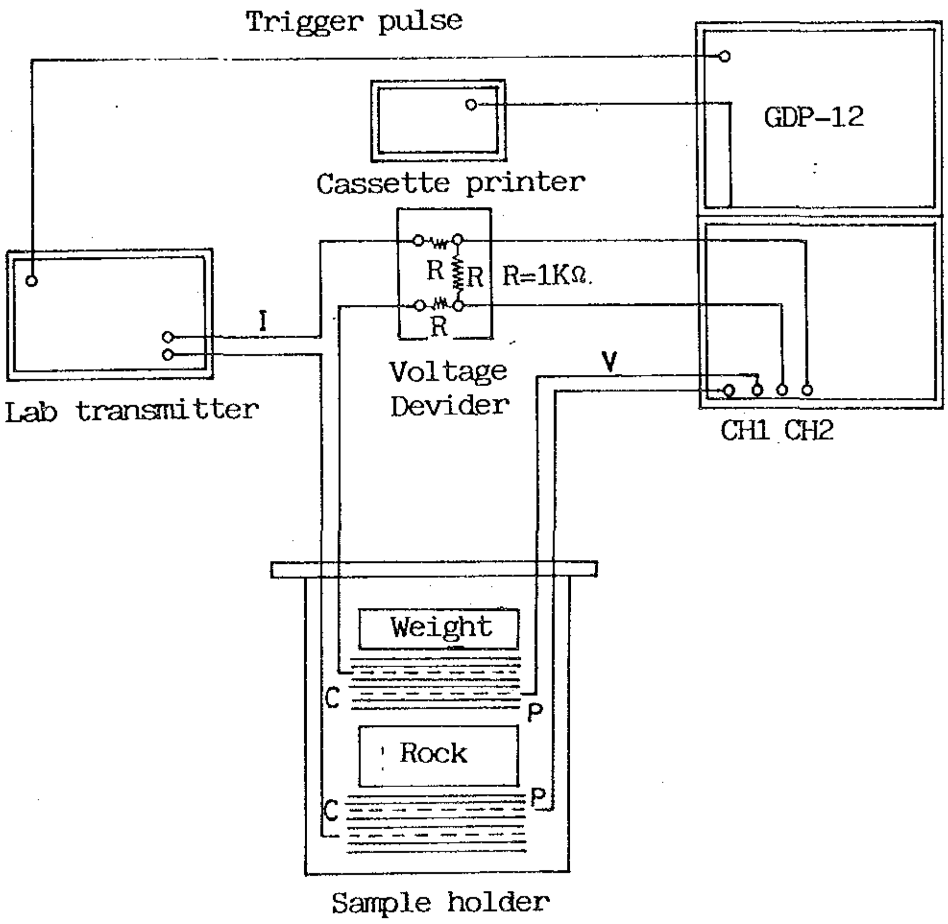
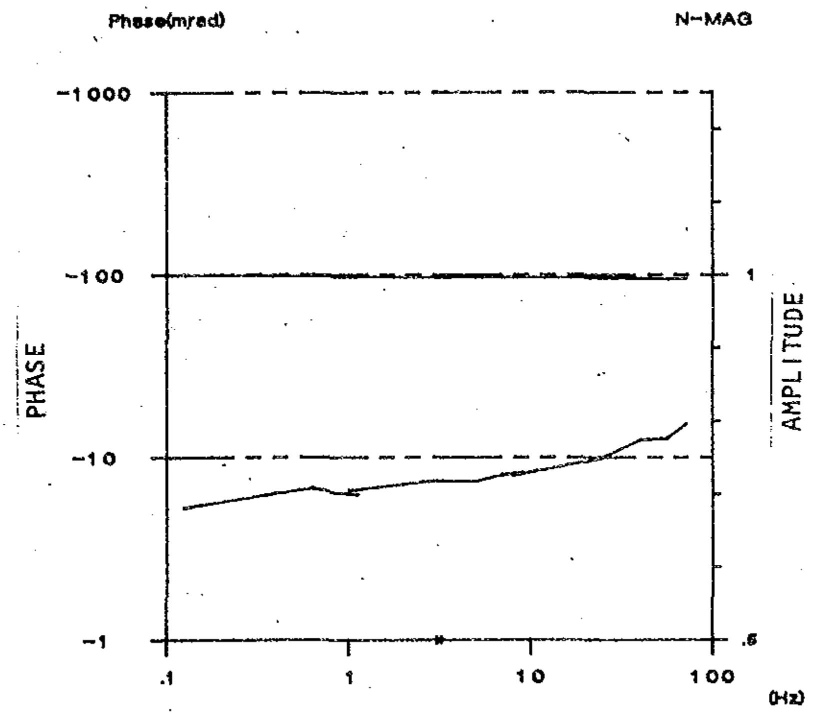


Fig. 34 Schematic Diagram of Laboratory Measurement

Table 3 Results of Laboratory Measurement of Rock Samples

Sample No.	Resistivity (Ω·m)	φ RAW (-mrad)	φ 3-P (-mrad)	P.F.E. (%)	Type of Cole-Cole	Rock Name and Remarks
1	19,237	3.4	3.8	0.45	A	Granodiorite, Cu 1.5%, Cp (Secondary)
2	23,872	7.4	7.0	1.06	A	" , Cu 2.0%, Cp (")
3	4,871	2.1	2.2	0.29	A	" , Cu 1.5%, Cp (")
4	7,028	2.7	2.9	0.39	A	" , Cu 1.0%
5	10,632	3.7	3.1	0.60	A	" , Cu 1.0%
6	8,550	5.3	5.4	0.71	A	" , Cu 0.5%
7	6,875	3.4	3.2	0.46	A	" , Cu 0.8%, Cp (Secondary)
8	2,024	2.6	2.6	0.36	A	" , Cu 0.8%
9	10,062	5.1	4.7	0.74	A	" , Cu 0.5%
10	3,368	6.7	6.5	0.96	A	"
11	3,211	5.3	4.6	0.81	A	" , Cu 0.5%
12	41,671	2.1	2.8	0.27	A	" , Cu 0.5% , Cp (Secondary)
13	5,236	6.6	5.3	1.13	A	Tonalite , Cu 0.5%
14	15,286	5.7	5.9	0.85	A	Granodiorite
15	6,180	8.1	6.1	1.31	A	"
16	14,539	10.4	9.0	1.66	A	Tonalite
17	2,908	3.5	2.9	0.54	A	Granodiorite, weak weathered
18	7,125	8.9	7.3	1.45	A	Tonalite
19	6,230	7.0	6.4	1.13	A	Granodiorite
20	4,330	7.1	7.4	0.84	B	" , weak weathered
21	20,306	16.5	15.1	2.46	A	" , "



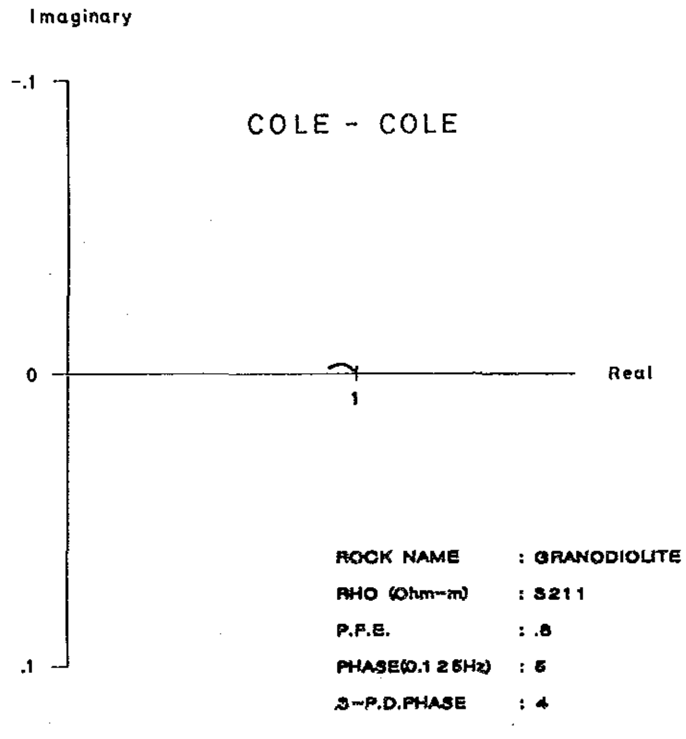
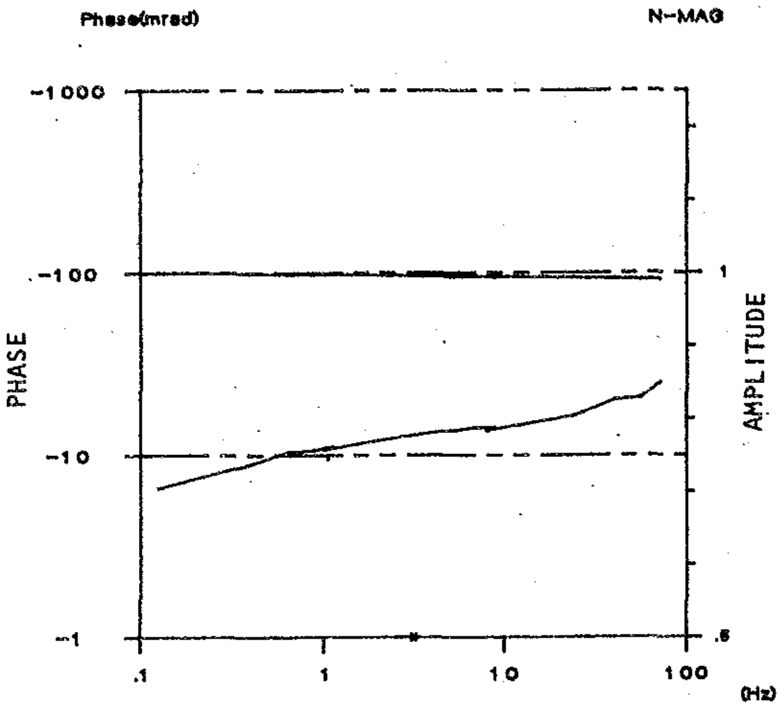


Fig. 35-1 Frequency Response of Rock Samples



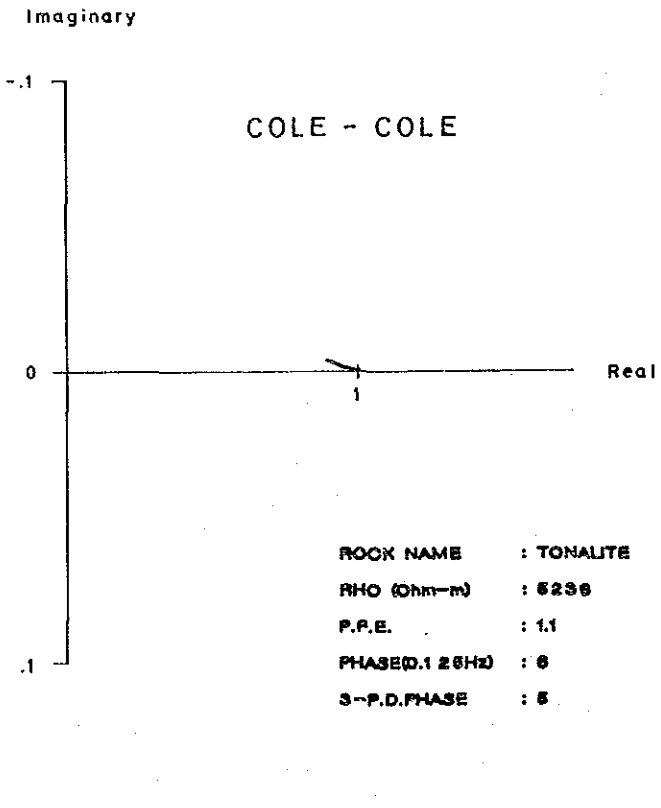
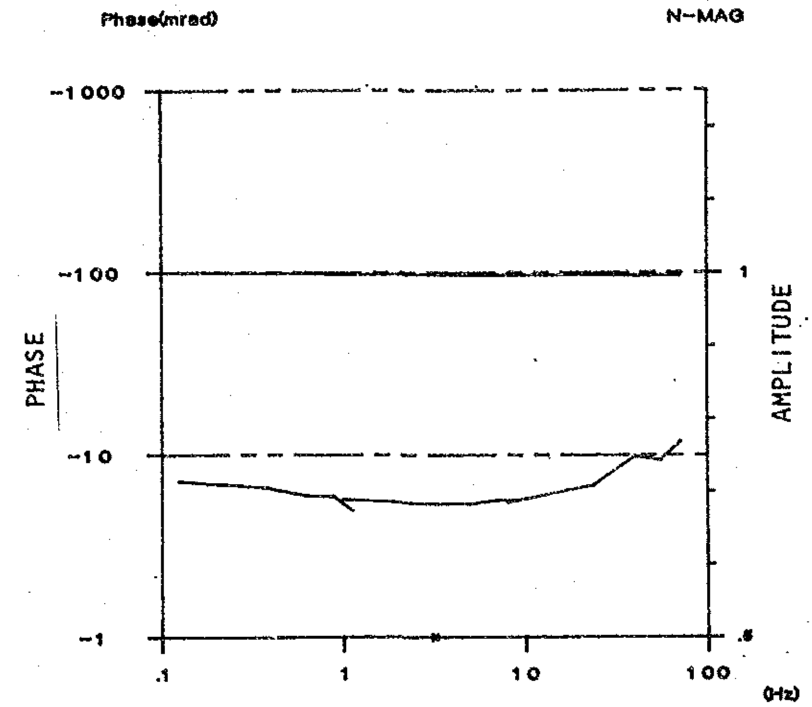


Fig. 35-2 Frequency Response of Rock Samples



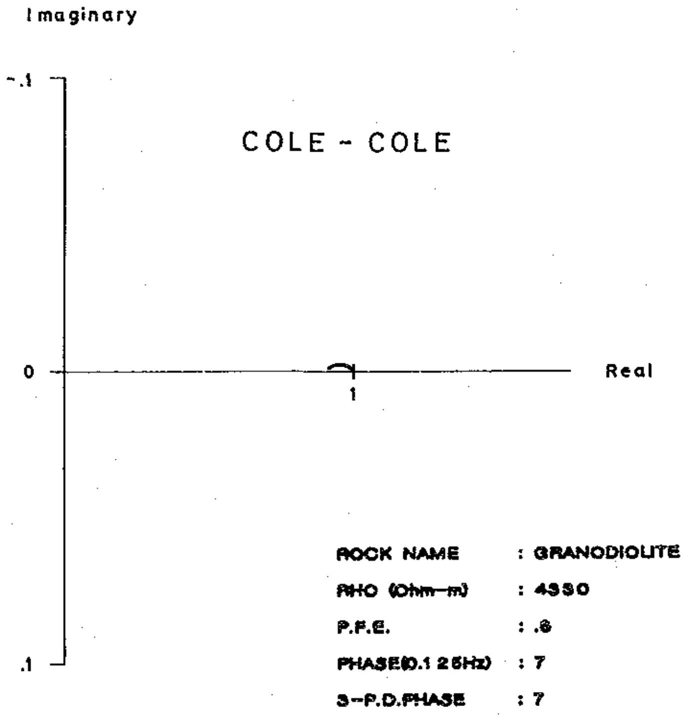


Fig. 35-3 Frequency Response of Rock Samples

o **Line PA**

Apparent resistvity is generally high in the middle of the survey area towards east. The resistive responses are widely seen form the surface to the depths with the highest value at the depth of station No. 8, while comparatively low resistivities, of less than 400 Ωm are detected near the stations No. 3 to No. 5. Accordingly, this resistive zone is considered to be due to silicification accompanied by mineralizaton.

Another conductive zone (less than 400 Ωm) near stations No. 3 and No. 4 is consistent with the fracture developed zone, which suggests that it may reflect the underground water.

o **Line PB**

High resistivity values were detected at the same stations numbers with line PA, showing a typical block shaped resistive source near stations No. 5 to No. 7 and extending to the depths. Another high resistivity was detected east of station No. 8.

o **Line PC**

Resistivity values on this line are generally lower than the ones detected on the lines PA and PB. However, high resistivity zone of more than 400 ohm-m are seen at the depths of stations No. 6 to 9 and east of No. 9. This zone is located on the extension of the high anomaly detected on lines PA and PB, and it is inferred that the resistive source is crossing these lines.

On the other hand and with station No. 6 as its center, low resistivities less than 400 Ωm are detected from the surface slightly dipping west to the depths. This low resistivity seems to relate with the anomaly detected on lines PA and PB.

o **Line PD**

Patterns of resistivity detected on this line are quite different from those of lines PA, PB and PC. These patterns suggest a wide distributed homogeneous body with high resistivity at depth.

The low resistivity detected in the shallow depth form a basin structure with stations No. 5 to No. 7 as its center. The high resistivity is thought to be affected by granodiorite, while low resistivity is due to a thick overburden covering the granodiorite.

o **Line PE**

This line shows almost the same resistivity pattern as Line PD. Judging from the fact that the low resistivity detected in the west of No. 8 suggest a shallower source than that of Line PD, the conductive overburder must be thinner.

A resistive zone with a resistivity of more than 400 Ωm, is distributed widely in the east of No. 6, with a tendency to be extended to the southeast of the area and to the depths. Consequently, the geological conditions of this line are considered to be same as to the Line PD.

(2) **Plan man**

The Topography of the survey area is so steep and the elevation difference of the stations exceeds by several hundreds meters, that plan maps of apparent resistivity and PFE at several elevations such as 1,900 m, 2,000 m, 2,100 m and 2,200 m was necessary to construct.

Apparent resistivity maps are shown in Fig. 41–1 ~ 4, and PFE plan maps in Fig. 42–1 ~ 4. The PFE shown is these maps are so small (less than 1.3%) that the interpretation is neglected.

Apparent Resistivity

There is an eminent resistivity boundary on the 2,100 m plan map between Line PC and Line PD, with a resistive zone more than 400 Ωm in northeastern side and a conductive zone of less than 400 Ωm in southwest side.

Specially high resistivity zone of more than 650 ohm-m are detected around No. 4 ~ 7 on Lines PA and PB, which suggest the shallow resistive source. High resistivity seem to correspond with silicified granodiorite in P-1 mineralized zone.

On the other hand, low resistivity zone covers the whole Line PD and PE except on the level 1,900 m map, which suggest that the low resistivity is caused by a shallow source.

(3) **Spectral maps (Figs. 43 ~ 47–1~5)**

Some spectral changes are seen in low frequency range, which can be divided into two groups.

(1) "A" spectral type measured from rock samples: a phase change is recognized in the frequency range between 0.625 ~ 0.875 Hz. This type is detected in the middle of each line, specially around No. 4 to No. 8. This spectral type, seen in high resistivity zone have little change both in real part and in imaginary part.

(2) "B" spectral type measured from rock samples: a phase decreases with frequency increases in this type, and the imaginary part has bigger change than the real part. "B" type are detected at either side of the survey line and at the depths. As mentioned above, two spectral types can be recognized but mixed together on each line, which makes it difficult to delineate the boundary.

2–1–10 Summary

In the following, it is given a summary of the geophysical SIP method in combination with the geological and geochemical surveys. The Fig. 48 gives the block diagram used in the interpretation procedure.

The investigations carried out in the surveyed zone, led to the following results:

1–A resistivity zone with an apparent resistivity of more than 400 ohm-m, extending in the

NE-SW direction and seen around the station Nos. 4 to 7 on lines PA and PB, seems to have a good correspondence with the geochemical survey results. This resistivity zone is inferred to be due to the silicification.

The model simulation suggests that this resistive body extends to the depth of 150 m on line PB. This information may also be useful to delineate the distribution of silicified granodiorite, which has a close relation with the mineralization.

A spectral type "A" was detected in this area.

2–A conductive zone with a resistivity less than 400 ohm-m was detected surrounding the above mentioned resistive zone. The low resistivity at either side of the resistive zone are thought to be due to the fracturing developed in the west of the resistive zone and to the weathering seen in the east of the zone.

On the other hand, the low resistivity detected in the other area is due to the shallow overburden, with a assumed thickness between 150 and 200 m on the lines PD and PE.

3–From the studies, two spectral types are identified: a type "A" seen in the whole area and a type "B" observed at depths and at the end of the lines. The boundaries of the two types are not clear.

Even though both spectral types "A" and "B" observed in this area, are caused by the sulfide mineralization, the IP effects are very weak. The phase difference is less than −15 mrad at 0.125 Hz and the PFE in the 0.125 ~ 1.0 Hz range is less than 1.3%. The reasons of the mentioned weak response are attributed to the following facts:

a) From the little chalcopyrite seen around P-1 mineralized zone; the pyrite, which is the strongest IP anomalous source among the sulfide mineralization, is not observed.

b) Oxidization is seen only at a considerable depth.

c) Granodiorite is generally compact with a poor development of cracks, making low the mobility of ionic solution.

4–The results of the physical properties of the rock samples show that most of the spectral type detected on granodiorite is of "A" type. The mineralized rocks show also the same behaviour. Among the spectral "A" type, no significant differences are seen in the spectral shape detected from the samples.

5–Consequently, it is concluded that the detected IP effect are unexpectedly low not only because of the wide and deep oxidization zone, but also because of the scattered constituent minerals. The silicified zone very close related to the mineralization, seems to correlate with the resistive model with the assumed dimensions of 300 m long, 150 m deep and 300 m wide on line PB.

As referred to the 2nd phase report, this body must have been eroded out to the considerable depths, suggesting that the resistive body could correspond to the root of the porphyry copper type mineralization.

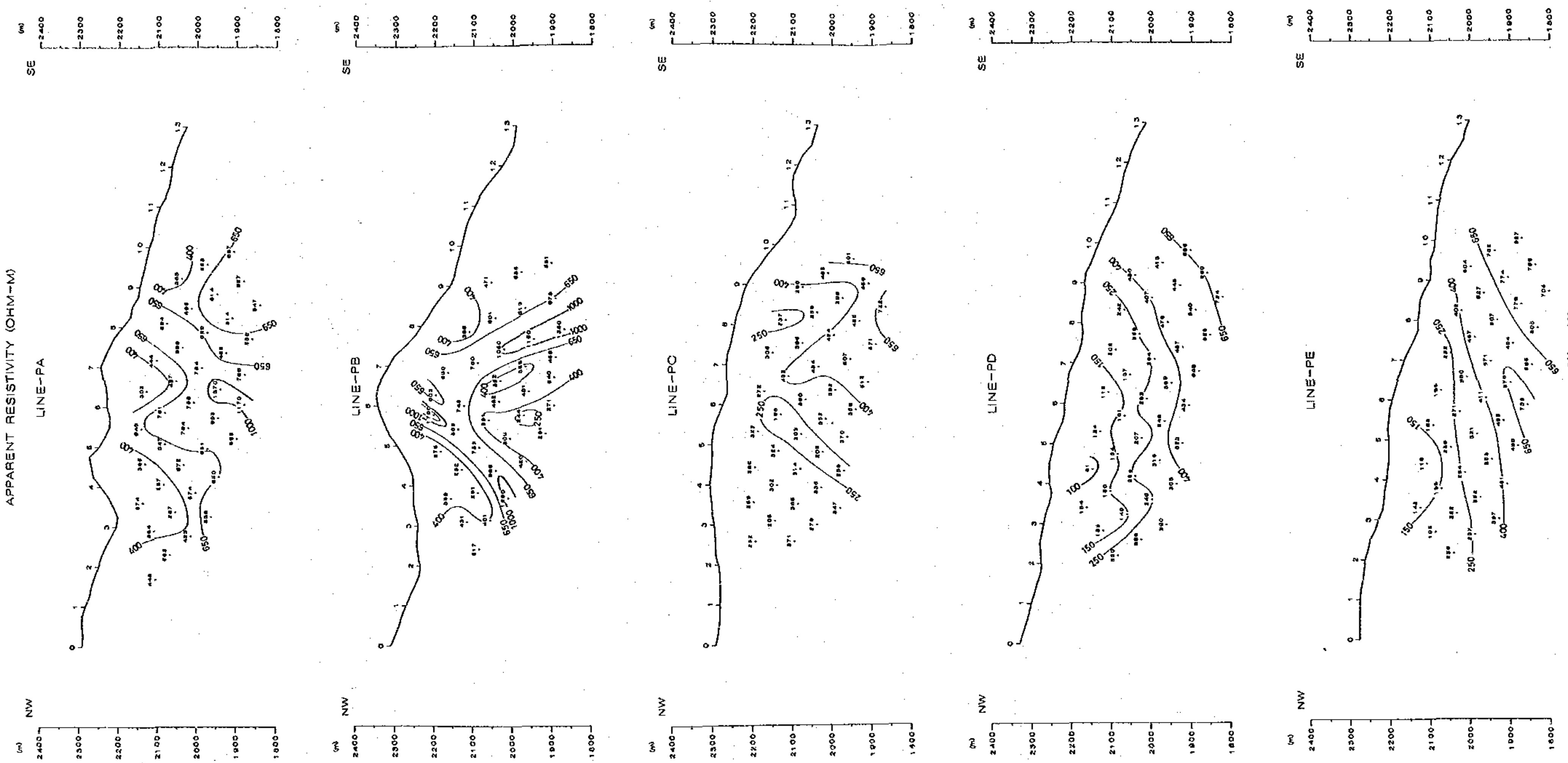


Fig. 36 Pseudo-section of Apparent Resistivity [0.125 Hz]
(Line-PA TO PE)

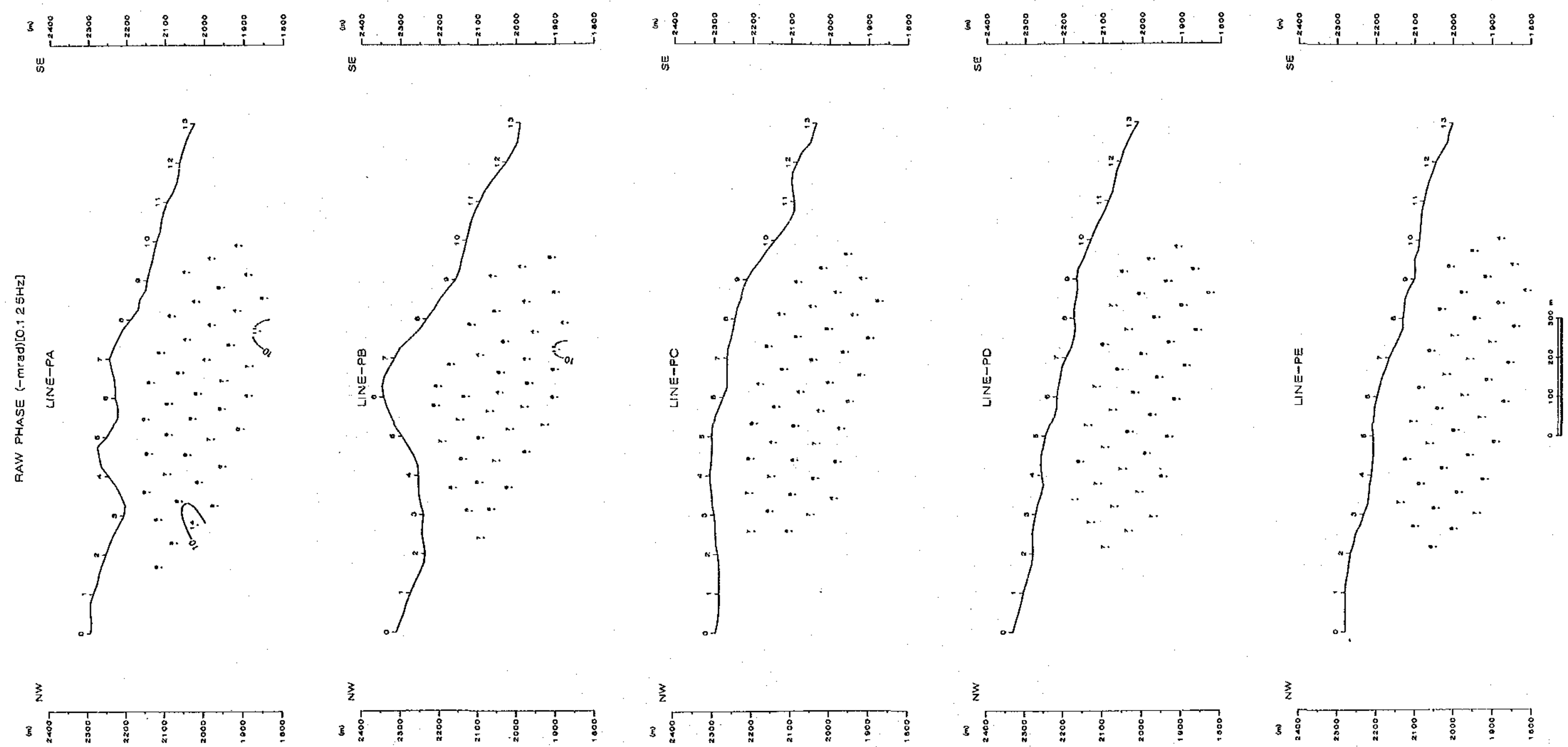


Fig. 37 Pseudo-section of Faw Phase [0.125 Hz]
(Line-PA TO PE)

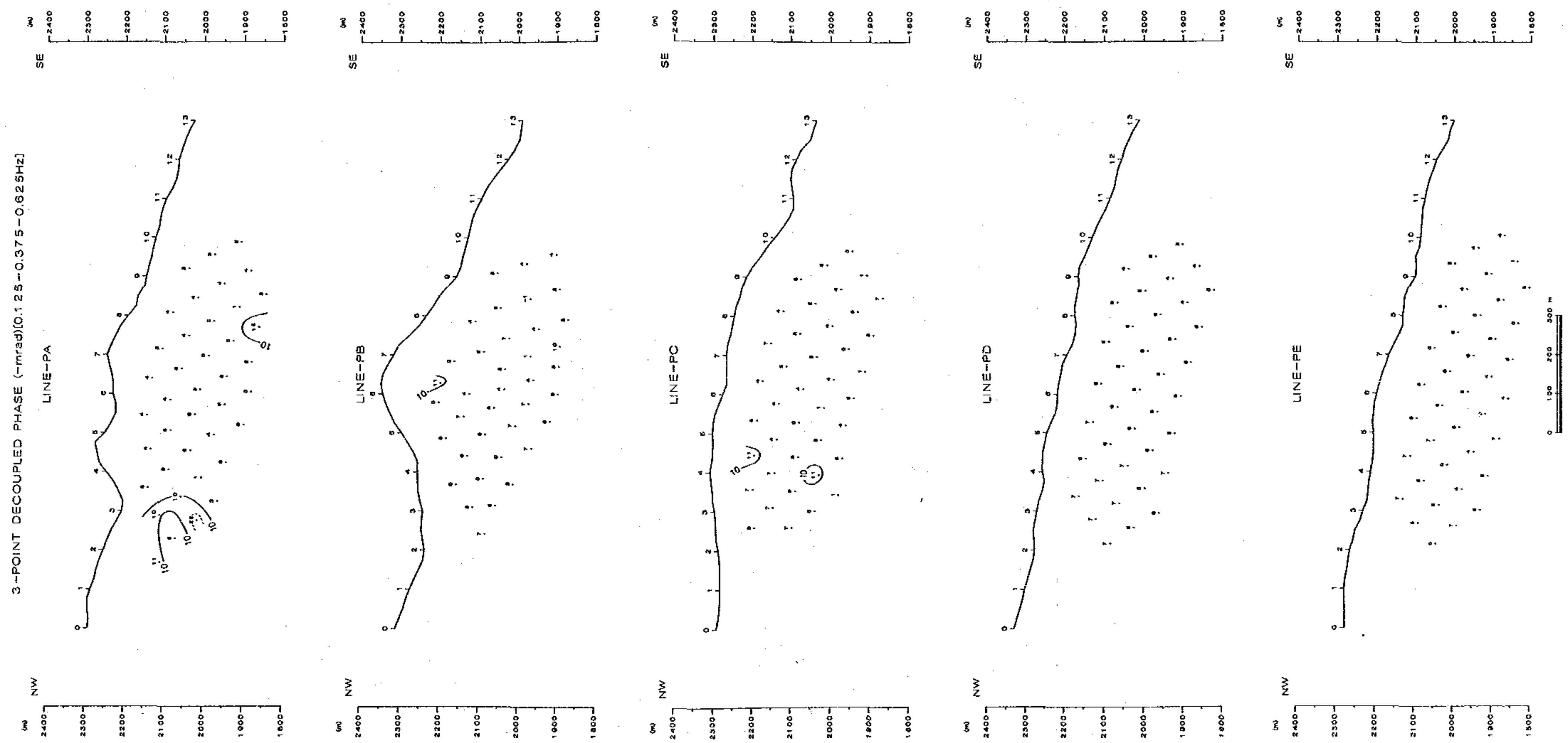


Fig. 38 Pseudo Section of 3-Point Decoupled Phase [0.125–0.375–0.625 Hz]
(Line-PA TO PE)

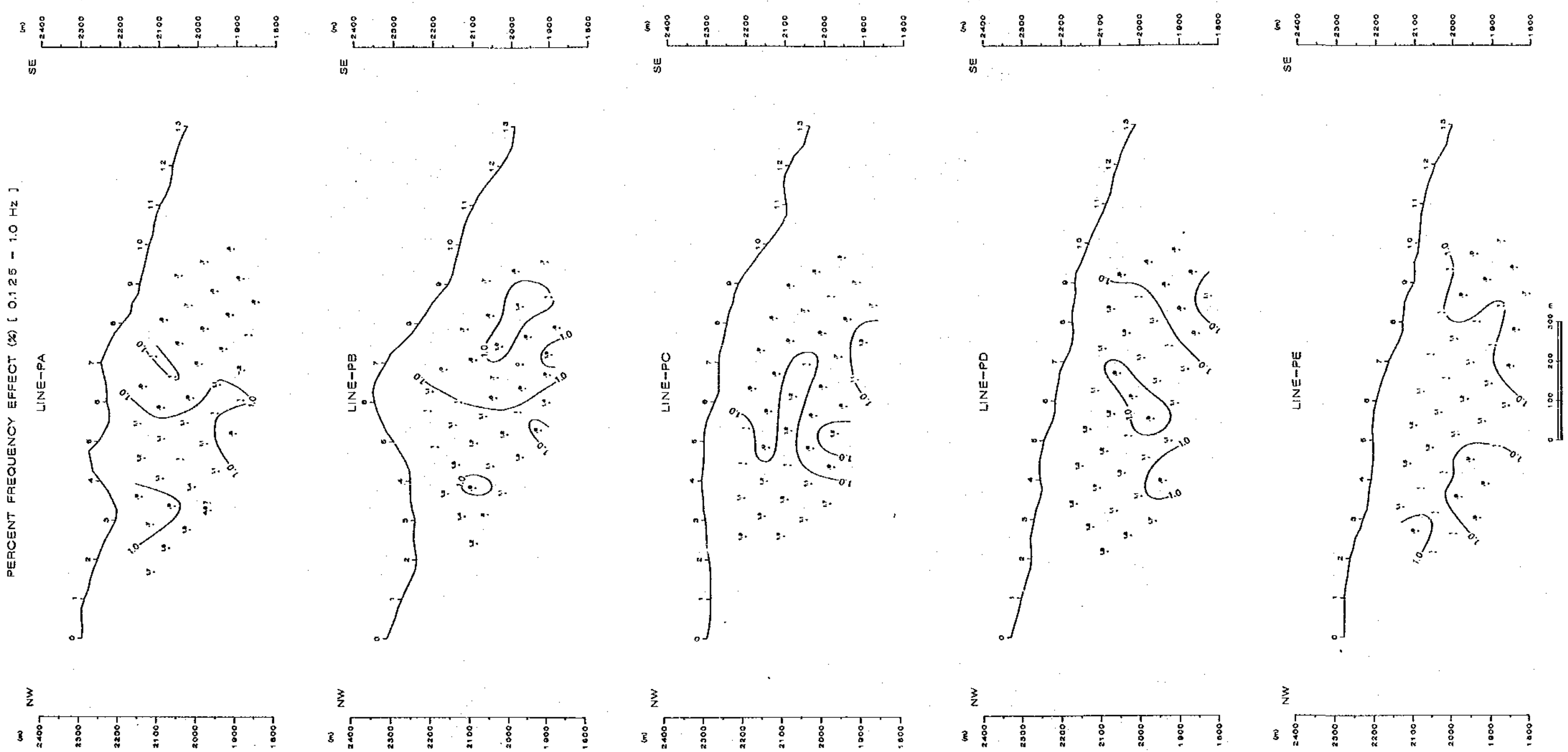
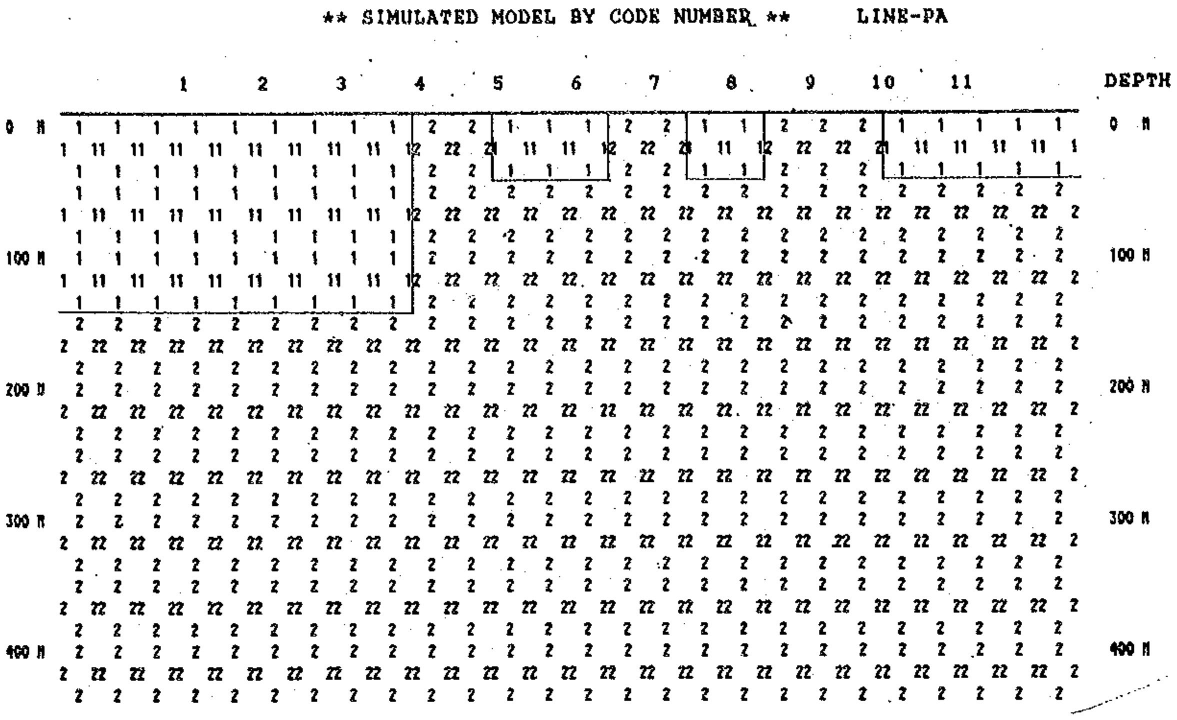
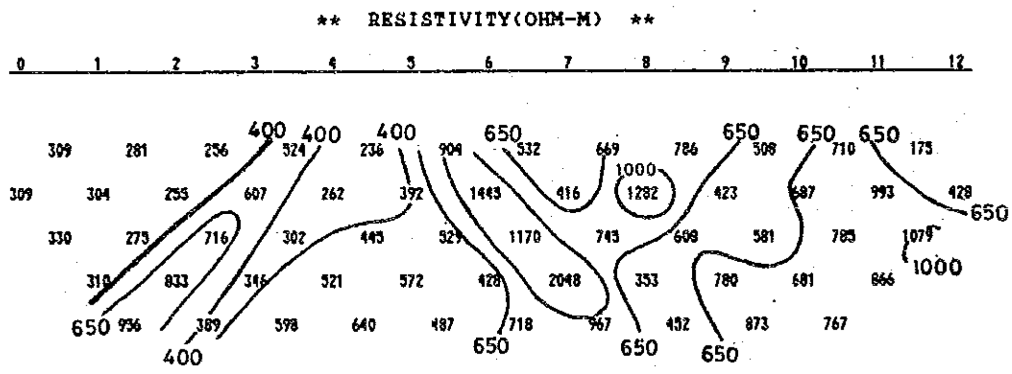


Fig. 39 Pseudo-section of PFE (Line-PA TO PE)



CODE NUMBER	1	2	3	4	5	6	7	8	9
RESISTIVITY(OHM-M)	300	1000	0	0	0	0	0	0	0
FREQUENCY EFFECT(%)	.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0



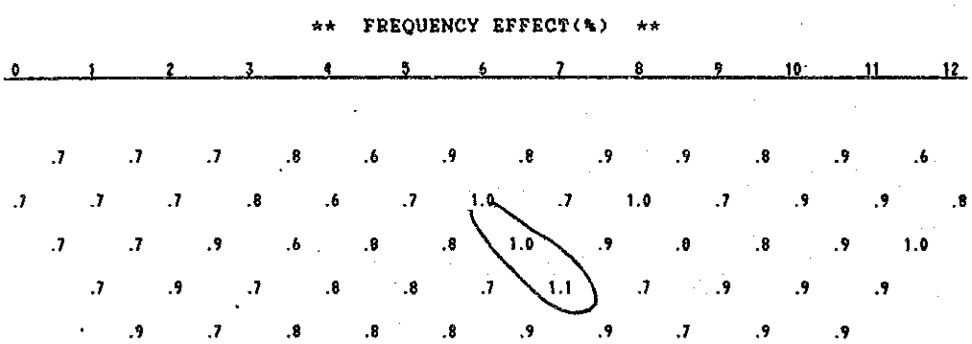
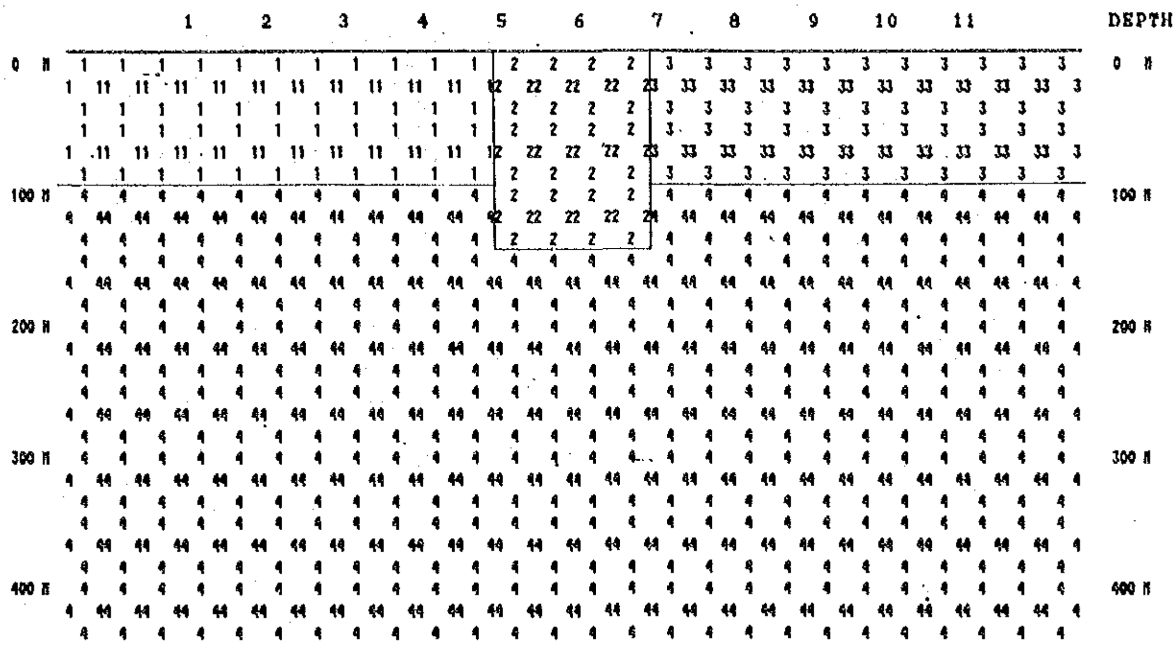


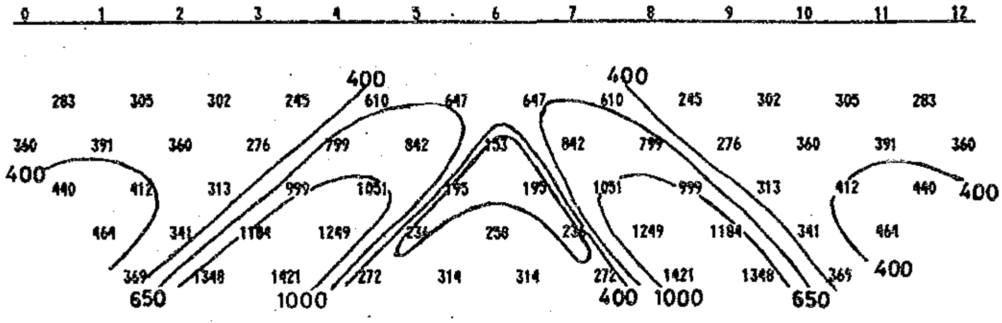
Fig. 40-1 Model Simulation (Line-PA TO PE)

** SIMULATED MODEL BY CODE NUMBER **   LINE-PB



CODE NUMBER	1	2	3	4	5	6	7	8	9
RESISTIVITY(OHM-M)	300	2000	300	1000	0	0	0	0	0
FREQUENCY EFFECT(%)	1.3	1.0	.7	1.0	0.0	0.0	0.0	0.0	0.0

** RESISTIVITY(OHM-M) **



** FREQUENCY EFFECT(%) **

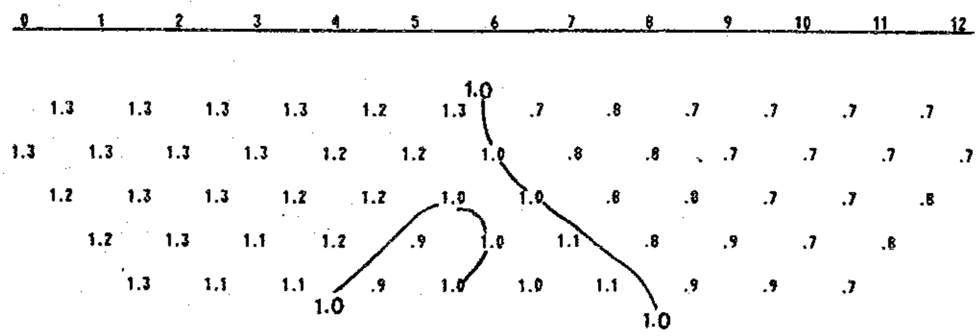
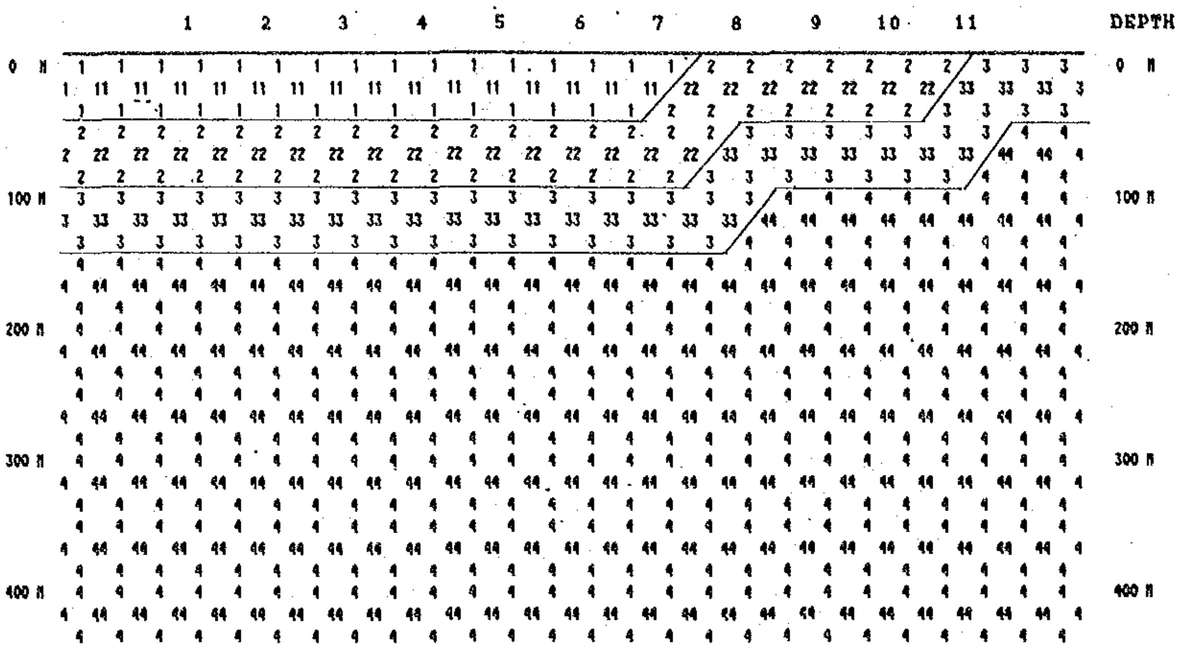


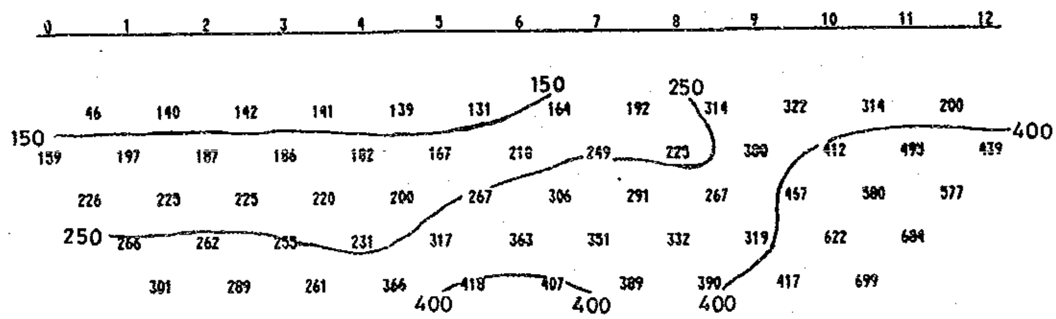
Fig. 40-2 Model Simulation (Line-PA TO PE)

** SIMULATED MODEL BY CODE NUMBER **   LINE-PE



CODE NUMBER	1	2	3	4	5	6	7	8	9
RESISTIVITY(OHM-M)	100	300	300	1000	0	0	0	0	0
FREQUENCY EFFECT(%)	1.3	1.3	.7	1.0	0.0	0.0	0.0	0.0	0.0

** RESISTIVITY(OHM-M) **



** FREQUENCY EFFECT(%) **

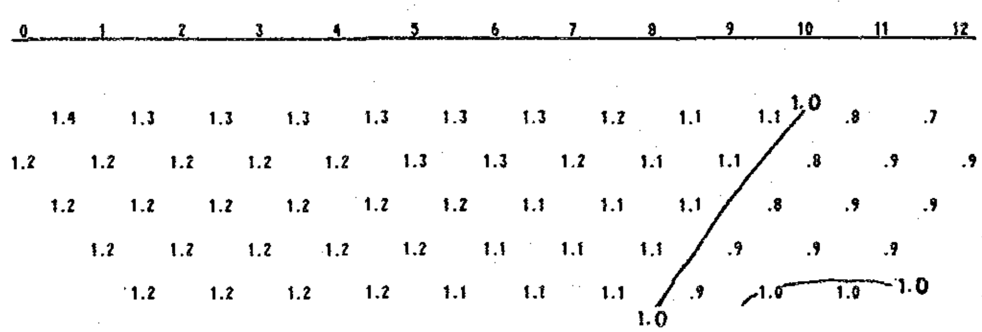


Fig. 40-3 Model Simulation (Line-PA TO PE)