REPUBLIC OF COLOMBIA

REPORT ON GEOLOGICAL SURVEY

OF

PIEDRANCHA AREA

PROJECT OF INGEOMINAS

CONSOLIDATED REPORT

MARCH 1983

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

The Government of Japan, in response to the request of the Government of the Republic of Colombia, decided to conduct collaborative mineral exploration in the Piedrancha and entrusted its execution to Japan International Cooperation Agency(JICA)and Metal Mining Agency of Japan(MMAJ).

The survey and investigation of the Piedrancha area were carried out over three years from 1980 to 1982 and completed on schedule under close cooperation with the Government of the Republic of Colombia and its authorities.

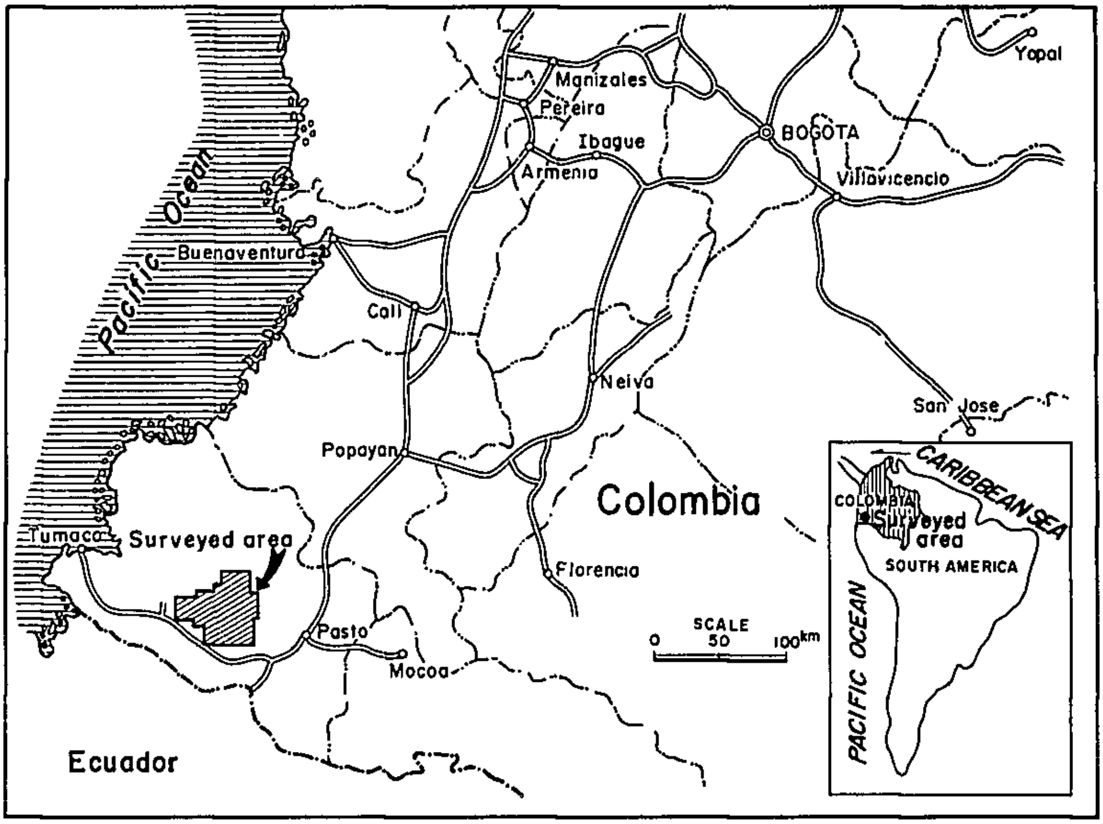
This report summarizes the results of the survey and investigation executed during three years.

We wish to express our appreciation to all of the organizations and members who bore the responsibility for the project, the Government of the Republic of Colombia, Instituto Nacional de Investigaciones Geologico-Mineras, and other authorities and the Embassy of Japan in Colombia.

Feburuary 1983

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan



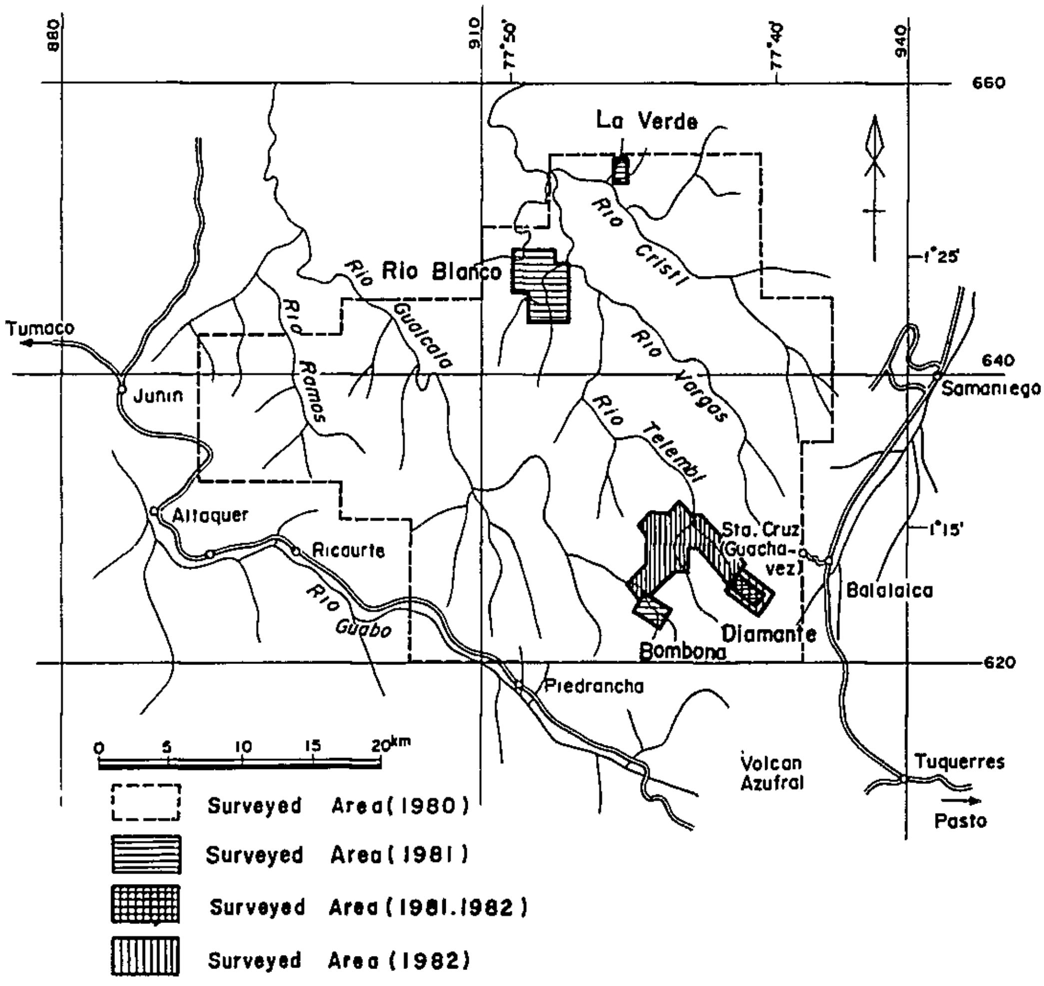


Fig. CR-1 Location Map of the Surveyed Area

SUMMARY

This report summarizes the result of a cooperative basic survey for developing mineral resources which was performed over the three years from 1980 to 1982 in the Piedrancha Area, Republic of Colombia. The purpose of this survey is to clarify the geological structure, mineralization, and relationship between them, and to obtain a useful guideline for mineral exploration and mine development in the next stage.

Piedrancha Area is a 1,000 Km^2 area covering the rugged western slopes of the West Range, and is located some 60 Km west to Pasto City, the capital of Nariño Department which situates at the south-western tip of the Republic of Colombia. For this area, a geological survey and geochemical exploration were performed in stages over three years. As a result, five sites of porphyry copper deposit type copper-molybdenum mineralized zone, three sites of auriferous polymetallic vein type deposit zone, and two indicated sites of alluvial gold deposit were singled out as prospective sites. Of them, semi-detailed or detailed surveys were made to two sites of copper-molybdenum mineralized zone and to an auriferous polymetallic vein-type deposit zone. Furthermore, of these, a drilling survey was made to Diamante principal vein. In these operations, a total of fifteen holes were drilled with an aggregate length of 2,093.1 m.

General geology of this area is composed mainly of Cretaceous volcanic rocks, pyroclastic rocks and sedimentary rock. And batholithic granodiorite intrudes into its central portion in a prolonged shape from south to north. The copper-molybdenum mineralized zones accompany mini-stocky porphyry which distributes in the western part of this granodiorite body, while the auriferous polymetallic veins are fissure-filling type deposits embodied in the Cretaceous sedimentaly rock and granodiorite body. During the three-

years, analized were 1,425 stream sediment samples for geochemical exploration, 3,176 samples for soil geochemical exploration, 147 ore samples, and 145 boring core samples. In addition, have been studied eight samples for age-determination, 13 samples for whole-rock analysis, 195 samples for microscopic determination of rocks/ores, 60 samples for X-ray analysis, and 20 samples for fluid inclusion studies. Thus, the geology and the mineralization were scrutinized.

Due to these all-out surveys, the geological structure, the igneous activities, the potential mineralized zones, the characteristics of mineralization, and the relationship between the mineralization and the geological structure were clarified. In particular, a detailed geological and geochemical survey which was concentrated on the exploration of gold vein during our last survey year in an area 5 to 10 Km west to Guachavez Town proved very effective. Also, the drilling survey of Diamante mining area proved to exist a convenient size of deposit for development studies though on a small scale. Before studying the mining development in this area, however, problems as stated below still remain, and it is hoped that the survey will be continued.

In other words, of the 5 indicated copper-molybdenum deposit sites, two sites were semi-detailed surveyed but the presence of high-grade ore of economical value is yet to be confirmed. With respect to the auriferous polymetallic vein deposits, there have been found out the possible distribution of numerous veins as stated above. However, a full study of an economically efficient dressing method will be a prerequisite to the future progress of their exploration development, because their ore-quality belongs to that of the so-called refractory ore. Furthermore, with respect to the alluvial gold showings, a land-survey for probing the sedimental distribution and a survey for confirming the gold content by digging a considerable number of pits will be necessary.

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CHAPTER 1. INTRODUCTION

1-1 History and Purpose of Survey

Piedrancha Area is situated at the southern tip of Colombia's Western Range covering approximately 1,000 Km^2 and includes jungles in the area about 500 m from its 3,000m high ridge.

As to this area, geochemical work of major rivers' bed sediments were performed as a part of the base metal exploration project which started in 1973, supported by the United Nations Development Program (UNDP). In the course of these prospects, some anomalous zones of copper, molybdenum, lead and zinc were detected. Thereafter, however, no surveys were made and they have been left as they had been due to their unfavorable topographical conditions and the "first probe" policy.

After the conclusion of a basic agreement for technical cooperation between Colombia and Japan in December 1976, the Japanese side was requested in 1978 for a cooperative survey on mineral resources. In response to this request, the Japan International Cooperation Agency and the Metal Mining Agency of Japan made a consultation with the local authorities on the feasibility of a "Basic Survey on Resources Development Cooperation", and dispatched their "Project Survey Team" in 1979. As the result of their field survey and later negotiations, the "Scope of Work" was agreed upon and Piedrancha Area in Nariño Department was specified as the survey area in May, 1980.

This survey has been performed since 1980 in accordance with the Scope of Work established as the result of above history. Its concrete purpose of survey is as follows:

To perform geological surveys, geochemical prospect and drilling surveys, etc. in this area, to clarify the geological structure, to determine ore deposit sites, and at the same time, to clarify the relationship between the geological structure and mineralization, and thus to obtain a beneficial guideline for the probing activities in the next stage as well as mining development.

1-2 Members of Survey Team

Field operations and analytical operations of this survey were performed by the Mitsui Mineral Development Engineering Co., Ltd. with the assistance of the Instituto Nacional de Investigaciones Geologico-Mineras (INGEOMINAS) of Republic of Colombia. Survey programs, liaison officers and members of the survey team for each year are shown on Table CR-1.

1-3 Outline of Survey Area

1-3-1 Location, Transportation and Communication

The survey area is situated roughly near the central portion of Nariño Department of the Republic of Colombia administratively covering the municipalities of Samaniego, Santa Cruz, Piedrancha, Ricaurte and Barbacoas.

The geographical location of the survey area is Lat. 1°10' --1°30' N and Long. 77°30' --78°00' W.

Transportation to the survey area: It takes about one hour flight by domestic airlines from Bogota, the capital of the Republic of Colombia, to Pasto, the capital of Nariño Department. From Pasto to Samaniego or Guachavez, the eastern base leading to the survey area, there is 109 Km taking about 3 hours to cross by car. Or, from Pasto to Piedrancha, the southern base, it is 126 Km by road again taking about 3 hours by car.

Although there are national and provincial highways encircling the survey area from the east, south and west, no road leads into the survey area, so transportation is dependent upon horse tracks and foot paths.

Communications rely upon the national telegraph offices placed at Samaniego, Guachavez, Piedrancha, etc. The survey group, however, established its own radio stations at site camps, Diamante Mine, Samaniego Office (1st year), and Guachavez Office (2nd and 3rd year) to comunicate with each other and with INGEOMINAS's Bogota and Poyayán offices.

1-3-2 Local Situation

The survey area is situated at the southern tip of the Western Range extending from NNE to SSW along the Pacific coast of Colombia, and covers an area from its watershed to the west slope. The whole area is sculptured by rivers flowing to the northeast presenting a steep mature topography. Therefore, the current land used is limited to farms and ranches reclaimed along major rivers and the vicinities of minor gold mines.

Although the survey area is near the Equator (about Lat. 1°N) and in a tropical rain zone, the rainfall, temperature and vegetation vary greatly by area due to large differences in altitudes. In other words, the annual rainfall is 2,000--5,000 mm while the annual average temperature is 15--27°C.

There are many rainy days in the year, but fine days continue in the July - September season.

Table CR-1 Member List of the Survey Team

Allotment of Duties	Phase I (1980)	Phase 2 (1981)	Phase 3 (1982)
Persons in charge of survey planning and negotiation in Japanese side JICA . MMAJ	Kyuzo Tadokoro Shozo Sawaya Toshio Koizumi Satoshi Yoshikawa Hideaki Mukai	Kyuzo Tadokoro Shozo Sawaya Toshio Koizumi	Toshio Koizumi Yozo Baba
Persons in charge of survey planning and negotiation in Colombian side INGEOMINAS	Michel Hermelin General Director Hernan Duque-Caro Sub Director Carlos Jairo Vesga Sub Director Luis Jaramillo Coordinator of Base Metal Project Ricardo Escovar Geologist Hector Castro Paez Geologist	Alfonso Lopez Reyna General Director Hernan Duque-Caro Sub Director Francisco Zambrano Sub Director Pedro Antonio Marin Coordinator of Base Metal Project	Alfonso Lopez Reyna General Director Raul Duran Rodriguez Sub Director Joaquin Buenaventura Coordinator of Base Metal Project Humberto Gonzalez Regional Director of Medellin
(Chief) Members of survey team in Japanese side MINDECO	Junnosuke Oikawa Yoshihiro Nagumo Yasuhiro Kayano Tetsuo Hatasaki Nobuyuki Goto Hiroshi Takahashi Shigemi Kimura	Junnosuke Oikawa Yoshihiro Nagumo Norio Ikeda Shigehisa Fujiwara Kiyotaka Obase Masao Kimura Kiyoshi Sakashita	Junnosuke Oikawa Yoshihiro Nagumo Minoru Saito Shigehisa Fujiwara Kiyotaka Obase Tadatoshi Nasu Yoshihiro Nagata Kiyoshi Sakashita
Members of survey team in Colombian side INGEOMINAS	Pedro Antonio Marin Regional Director of Popayan	Pedro Antonio Marin Coordinator of Base Metal Project Abigail Orrego Lopez Regional Director of Popayan Raul Muñoz A. Geologist of Medellin	Abigail Orrego Lopez Regional Director of Popayan Raul Muñoz. A. Geologist of Medellin Humberto Caballero Geologist of Medellin

CHAPTER 2. OUTLINE OF SURVEY

2-1 Survey Items by Year

Since cloudiness is extremely high throughout the year in the survey area, aerial photo-taking was delayed and topographic maps are not yet complete. Therefore, the survey operation began with the preparation of topographical map with drainage patterns maps for the use on a 1:50,000 scale and based upon existing materials. Also, the geological structure was analyzed by means of SLAR (Side Looking Radar Image), Landsat Images, etc. used for the preparation of Topographical Maps, and thus the basic materials were prepared.

Following the above-mentioned preparation of maps and photogeological analysis, field regional geological surveys and regional geochemical prospect also by means of stream sediment samples were performed in the 1st year. In the 2nd year, out of the 5 sites (La Verde, Rio Blanco, Gualcala-E, Santa Rosa, and Ramos) having porphyry copper deposit type copper-molybdenum mineralizations indicated by the above surveys, the two sites of La Verde and Rio Blanco were investigated in detail. And also Diamante Mine area and Bombona Mine area which are of auriferous polymetallic vein type deposits were surveyed geologically and geochemically in detail. Among them, the principal vein of Diamante Mine was investigated by drilling. In the 3rd year, while continuing the drilling-survey of Diamante Mine's principal vein, geochemical prospect and geological detail surveys were performed all over its northwestern part, including the northern part of Bombona Mine for exploring prospective vein.

The above-stated survey workloads and the numbers of analysed/examinated samples by year are shown on Table 2. Their respective surveying methods are as stated below.

2-2 Survey Method

2-2-1 Photogeological Analysis

The materials used for making the Quasi-topographic drainage Map and their use-purposes are as follows:

Landsat images : Scale 1 : 250,000.
Two kinds of images were obtained.
Mostly for identifying major rivers' locations.

Radar photos : To read more detailed topography than shown on Landsat images such as tributaries and ridge lines.

Aerial photos : Using 11 sheets of aerial photos covering the central portion of the Eastern Area, we prepared aerial photographic topographical maps covering an area of approx. 7 Km east to west by approx. 24 Km south to north.

1:100,000 drainage maps : Prepared by Colombian Geographical Institute from radar photos. The Eastern Area connects to the 1:100,000 topographic map "PASTO". Eastern grid-line locations were used, however the western part contains inaccurates.

Mine distribution map : Prepared by Pasto Mining Bureau (1:500,000). This was used for referencing names of streams and mine locations.

Of the above materials, radar photos were mostly used for photogeological analysis. From the Landsat images, we prepared pseudo color composite photos consisting of 1:250,000, Bands 4,5 and 7 as well as monochrome photo of Band 5. Then we made linearment extraction by pseudo stereoviewing the both photos., However, all photos had cloudiness so, the whole area could not be observed. Therefore, they were used simply as auxiliary measures for analysing radar photos. Also, though extremely limited to the smaller parts, aerial photos were stereo-observed. The The photo-analytical results using these methods were charted in 14-unit breakdowns according to the features of the drainage pattern, tectonic lines, bedding planes, topographical unevenness, etc. This chart was used for assuming the distribution of sedimentary rock, pyroclastic rocks, lavas, and granites as well as for discussing the arrangement of fault systems.

2-2-2 Field Geological Survey

In the 1st year, an aggregate geological survey approximately 540 Km was made mostly along the major rivers throughout the survey area (approx. 1,000 Km^2). The survey was performed separately by six survey teams. They made geological entries into 1:50,000 maps by surveying along the survey routes with measure-tapes, clinometers and handlevels, while collecting samples for geochemical survey. However, pacing and eye-measuring were used in case of the steep terrain. These results were summarized into 1:50,000 geological maps.

In the 2nd and 3rd years, semi-detailed surveys for geological/geochemical survey were performed by 4 survey teams, which land surveyed along all routes with handy transits and tape-measures for assuring the correct positions of outcrops, old abandoned pits and sample-collection points.

2-2-3 Geochemical Investigation

During the regional survey in the 1st year, a geochemical survey was made by the collection of stream sediment samples. The samples were collected every 300 - 500 m in general and every 100 - 300 m in supposedly mineralized zones. Samples of 80 mesh or finer were collected for analysing the five elements of gold, copper, lead, zinc and molybdenum. At the same time, the presence or absence of gold and platinum alluvial deposit was checked by panning (though no platinum was detected), while surveying the presence or absence of copper was performed by the simplified qualitative test of copper using biquinolin method at strategic points. In the course of these surveys, 5 sites indicating copper/molybdenum mineralization and 2 sites indicating alluvial gold were extracted out as potential sites. (cf. Table CR-2 and Fig. CR-2)

Geochemical prospect in the 2nd year's survey were made by collecting soil samples at sites indicating copper/molybdenum in La Verde and Rio Blanco as well as at vein type deposits in both Diamante and Bombona gold mine zones. At either site, samples were collected every 50 m along the ridges in the site. Meanwhile, analyses were made for Cu and Mo for the former, and As and Zn for the latter. As the result, grasped was an outline of porphyry copper deposit type mineralized zones in La Verde and Rio Blanco areas, and in addition, it was revealed that the gold vein prospect by means of As and Zn is very effective in these areas.

The 3rd year's survey was concentrated to detailed surveys of auriferous polymetallic vein type deposit areas in Diamante, Paraiso and Bombona. The method employed was to establish a geochemical exploration line crossing the general strike of veins at roughly right angles and to collect samples every 25 m in areas to be precisely surveyed. The surface soil at most sites was as deep as 1 - 3m, and were used handaugers in most sample collecting operations. Analyses were made for As and Zn as in the 2nd year, and it was succeeded in obtaining effective results. The number of samples collected reached 2,256 pieces. In addition to the above-mentioned four survey teams, two Colombian geologists organized one team and joined the survey for the partial purpose of on-the-job training.

The respective analytical results of geochemical survey were statistically processed by computer, and studies were made on the preparation of histograms, determination of threshold values, backgrounds, by country rock, correlationship, etc.

2-2-4 Method of Drilling Survey

In order to survey the size, grade and structure of Diamante Mine's principal vein which is most potential in terms of ore reserve, drilling surveys were made in the 2nd and 3rd year with a total of 15 holes drilled or 2,093.10m in aggregate in the two-year period. One complete set of drilling machine including Main machine TOM-3, pumps, rods and all other accessories were shipped from Japan. Since in the 2nd year, there existed no road leading to Diamante Mine, machinery was transported by helicopters. In the 3rd year, however, materials were transported by a road constructed for the operation. Drilled cores containing ore minerals were split into halves, one for analysis samples and the other for delivery to the INGEOMINAS.

Table CR-2 Area and Number of Samples

	Phase	Phase I (1980)	Phase II (1981)	Phase III (1982)	Total	Remarks
Survey Method	Geological and Geochemical Survey					
	Quasi-topographic map for field survey (Km^2)	1,000			1,000	Landsat and Radar image, aerophotos
	Photo geological study (Km^2)	1,000			1,000	Radar image, aerophotos
	Regional survey (Km^2)	1,000			1,000	N-S 37Km, E-W 45Km
	Semi-detailed survey (Km^2)		26.5	18.2	44.7	La Verde, Rio Blanco, Diamante, Bombona, Paraiso
	Detailed survey (Km^2)			5.8	5.8	Diamante, Bombona, Paraiso, Delicia
	Geochemical survey (type of samples)	1,425 (stream sediments)	920 (soil)	2,256 (soil)	4,601	Stream sediments Elements: Au, Cu, Pb, Zn, Mo Soil Elements: Cu, Mo or As, Zn
	Drilling Exploration					
	Drilling total length(m) (No. of drill holes)		757.2 (7)	1,335.9 (8)	2,093.1 (15)	Planned 2,080m in total Finished with BX size
Laboratory Works	Thin section (No. of samples)	36	54	32	122	
	Polished section (ditto)	10	24	39	73	
	Chemical analysis of rocks (ditto)	5	5	3	13	Whole elements for normative analysis
	Age determination of rocks (ditto)	3	3	2	8	
	X-ray diffractive analysis (ditto)	2	15	43	60	Alteration zone
	X-ray micro analysis(EPMA) (ditto)	2	10	10	22	Determination of metallic minerals
	Chemical analysis of ore minerals (ditto)	46	51	50	147	Samples from outcrop and old tunnel
	Chemical analysis of D.D.H. cores (ditto)		65	80	145	Au, Ag, Cu, Pb, Zn, As (Sb)
	Chemical analysis of altered rocks (ditto)			33	33	As, Sb, Si, Ca, S
	Fluid inclusion study(homoginizing temperature) (ditto)			20	20	Quartz of D.D.H. core

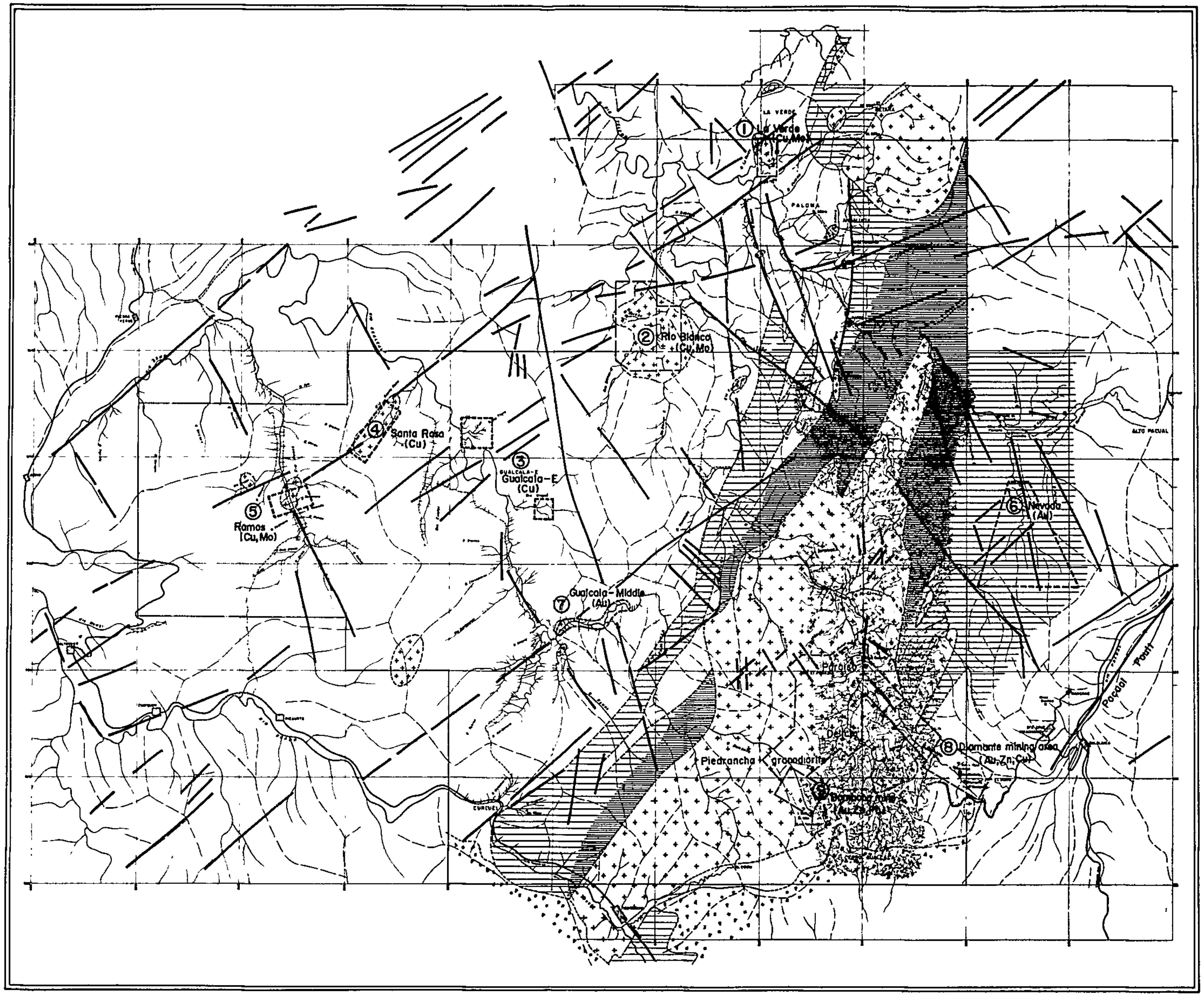
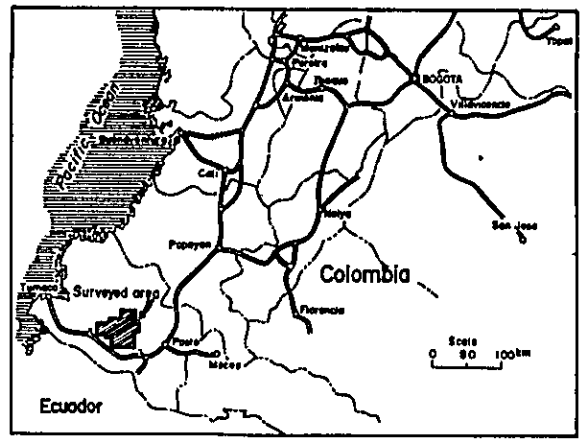


Fig. CR-2

GEOLOGICAL SURVEY OF PIEDRANCHA AREA COLOMBIA

CONSOLIDATED REPORT

GEOLOGIC MAP AND PROSPECTIVE AREA IN THE SURVEYED AREA



0 2 4 6 8 10 km

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY

FEBRUARY 1983

Prepared by MINDECO

LEGEND

- Drainage
- Ridge
- Car road
- Foot path, trail
- Active and non active mine
- Water wheel mining plant
- School house
- Town
- EL 820 m — Elevation by barrometer
- Latest volcanics
- Sedimentary rocks
- Sedimentary rocks, weakly metamorphosed
- Green volcanic rocks
- Granodiorite, diorite
- Fault, lineation after photogeological study
- ② Prospective area, recommended for the 2nd phase
- Detailed surveyed area in 2nd and/or 3rd phase

Table CR-3 Mineralization Showings in the Surveyed Area

Name (Evaluation) Main mineral	Location (Map)	Grid posi-tion (Figure)	Area of mineral.& alteration (Area to be surveyed) km²	Number of geochemical samples in anomaly				Geological comments
				El.	wk	st	Tt	
1.La Verde (Prospective) Cu,Mo	North-central (PL.4-2-E,No.2) (PL.4-3-E,No.2)	E920N654 (Fig.6-A)	1.2x1.2 (1)	Cu Mo Zn	8 6 10	2 4 5	19 19 19	Abundant py with rare cp and Mo are visible in network of small veinlets,in porphyrite and porphyritic diorite.
2.Rio Blanco (Prospective) Cu,Mo	North-central (PL.4-2-E,No.3) (PL.4-3-E,No.4)	E915N645 (Fig.6-B)	2x5 (11)	Cu Mo Zn	5 2 11	9 8 1	18 18 20	Anomaly is in the diorite intrusive with quartz veinlets. Limits of mineralization toward NW and SE are not determinated.
3.Gualcala-E (Prospective) Cu	North-central (PL.4-2-W,No.8)	E806N640 E909N638	1.5x1.5 1 x 1 (3.3)	Cu Mo Pb Zn	30 0 9 5	0 0 0 0	83 83 49 49	Two anomalies are extracted from Agua-Tigre and Rio Blanco. Mainly altered andesite is their country rock. It is relatively low grade anomaly but wide area.
4.Santa Rosa (Prospective) Cu	North-western (PL.4-2-W,No.10)	E902N642 (Fig.6-C)	1 x 3.5 (3)	Cu Mo	9 1	0 1	22 22	Microdiorite is suffered chloritization and pyritization with relatively poor Cu mineralization and very poor molibden.
5.Ramos (Prospective) Cu,Mo	Western (PL.4-2-W,No.11)	E897N637 (Fig.6-D)	1 x 1 (2)	Cu Mo	5 1	3 7	8 8	Southern part of porphyritic granodiorite(1.5x2km²) is mineralized with py-cp-Mo. Contact zone is more oxidated but central part of intrusive is very fresh.
6.Nevada (Prospective) Au	Eastern (PL.4-2-E,No.1)	E933N637	1 x 3 (15)	Au Zn Pb	3 2 4	3 6 1	12 12 12	The area is on the south of the Concordia-Floresta gold mines, and in black slate and shale. There is not known old mine.
7.Gualcala-Middle Au	South-central (PL.4-2-E,No.7) (PL.4-3-E,No.5)	E912N632	0.5x 4 (2.5)	Au Mo Pb	5 11 4	1 9 18	36 36 24	Boulders and gravels of granodiorite are abundant in wide valley, and the old gold mi-"Bombona"is to the south-East upper stream. Placer gold deposit will be prospective.
8.Diamante mining area (Prospective) Au,Zn,Cu	South-eastern (PL.1-E)	E930N625 (Fig.6-E)	0.8x2.5 (2)	—		-	-	The principal vein has 600m and more length with direction of N 60W dipping to NE60,with 1.2m to several meters wideness. Au(3.3-32.0g/t),Zn(1-2%),Cu(0.3-1.5%), and As(0.5-32.0%) are main constituent elements of ore minerals. Only superficial soft oxidized ore has been mined in small scale.
9.Bombona mine (Area very required detailed survey) Au,Zn,Cu	South-eastern (PL.1-E)	E922N623	1 x 2 ? (2)	—		-	-	No geological survey has been carryed out,but as the most famous old mine,this had a record of gold production up to twenty and more kilogram a month in past. Being similar to Diamante mine,it may expect considerable remained sulfide ore reserves.
10.Desquite mine Au,Zn	Eastern (PL.1-E)	E925N630	0.2x0.3	—		-	-	Gold bearing sphalerite-pyrite vein with 0.2-1.0m wideness and 250m length is in small scale mining. Vein occures in granodiorite and E-W is general direction, and dipping steeply.
11.Concordia mine Au	Eastern (PL.1-E)	E932N642 (Fig.6F)	0.5x0.5	—		-	-	One milky white quartz vein with breccia had been mined in several decade years ago. It contents 10 ±g/tAu in 20-200cm.
12.El Tabano mine Au	North-eastern (PL.1-E)	E924N644 (Fig.6-F)	0.3x0.3	—		-	-	Slow dip—horizontal milky white quartz vein,0.5-2m wideness, has been mined out almostly. North corner of tunnel has a quartz pyrite vein with 16 g/t Au and 50cm wideness,which is now producing small tonnage by 10—15 miners.
13.Floresta mine Au	Eastern (PL.1-E)	E932N642 (Fig.6-F)	0.1x0.1 (Old mining area:0.5 x 0.5)	—		-	-	A milky white quarts vein(20-30cm) with a few sulfide is principal source(Au 10g/t) for Socorro Plant,located at 500m NW from Floresta tunnel.Many other old adits distribute nearby.
14.Patoquilia mine Au	North-eastern (PL.1-E)	E925N650 (Fig.6-F)	0.2x0.2					Narrow white quartz vein is in black shale,dislocated by several fault. Sulfide part with its oxide contains more Au.
15.Telembi-middle-north Cu	East-center (PL.4-2-E,No.4)	E920N638	1 x 2	Cu Mo	5 0	0 1	5 5	Weak copper anomaly is checked in a valley only. It may be an indication of vein like mineralization. No appears Au anomaly.

CHAPTER 3. OUTLINE OF THE GEOLOGY

3-1 General Geology

The geology of Colombia mainly consists of the Guayana Shield in the east and the Andes Orogenic Zone distributing in the central and western parts formed after the Paleozoic. The Guayana Shield, along with the Brasillian Shield, forms the central core of the South America Continent, while the Andes Orogenic Zone was formed through folding and upheaval of a geosynclinal sediments occuring in the northwest part.

In Nariño Department existing in the southwest part of Colombia, in which the survey area is included, three parallel mountain systems in the northern part coverge as they run to the south, forming a hilly region having a width of approximately 150 Km from east to west. Its central part mainly consists of Paleozoic layers, and in the both sides of the east and west parts Cretaceous systems and Tertiary systems are lying. While the west part consists of basic volcanic rocks of a eugeosyncline type and slate and quartzite metamorphosed from shale and sandstone deposited on the upper part, the east part consists of miogeosyncline sediments, namely sandstone, conglomerate, shale and limestone.

In the survey area located in the south edge of the western mountains, basic green volcanic rocks, sandstone and shales, and metamorphic rocks such as slate and quartzite assumedly belonging to Cretaceous systems are distributed widely, and through them Tertiary granodiorite is distributed in the form of batholith and small stock rock bodies. Three tectonic lines of NE-SW, NW-SE and N-S Systems are dominant in the survey area, and in addition a E-W tectonic line can be slightly observed.

Two kinds of mineralization are observed in the survey area; porphyry copper deposit type with copper-molybdenum dissemination, and auriferous polymetallic vein type deposit. The former is connected with small stock-like intrusives distributing in the west in NE-SW direction, and the latter is a fissure-filling vein type deposit of NW-SE system running through the youngest granodiorite body.

3-2 Green Volcanic Rocks

Green volcanic rocks are distributed in a wide area covering the central to western parts, and in a narrow exposure in the southeast part of the survey area.

The constituent rocks are dark green - dark grey, medium to fine grained andesites, basaltic lavas, basalt dike sheet, and tuff breccia of the same origin. The pillow structure of the lava shows submarine eruption.

As partings of the green volcanic rocks, in the middle and down stream of the River Telembi green tuffaceous sandstone and shale (80m thickness), and in tributaries of middle Gualcala River black shale and slate (some 5m thickness, four layers) can be observed.

Also, in the upper area of Ramos River blue colored siliceous shale is exposed in the river bed, but whether it is a parting of the green volcanic rocks or a basement layer is not known, because the exposure is too narrow. These green volcanic rocks are generally massive and non-stratified, so that it is difficult to correlate with one basin to another.

The tuff breccia distributed most widely in the rocks and is composed of sub-round gravel of the same origin with a 5 to 80 cm size.

The part forming sub-breccia is black, porphyritic pyroxene andesite, and under a microscope light-brown augite and plagioclase are observed uniformly as phenocrysts. A part or whole part of pyroxene was subjected to weak alteration to chlorites and epidotes. Also, uralitization can be observed frequently. The plagioclase has almost albitized strip-like crystals of 0.3 to 0.7mm, and zoning is hardly seen. The groundmass mainly consists of plagioclase and magnetite, and partly contains quartz, albitized plagioclase and volcanic glass. Partly it has spherical caves, which are filled with epidote, quartz, occassionally magnetite and chalcopyrite.

In the periphery of the granitic intrusive contained in these green volcanic rocks, contact metamorphic minerals inclduing chlorite, calcite, epidote, and biotite amphibole (partly actinolite) are formed.

3-3 Sedimentary Rocks

The sedimentary rocks distribute in the east part of the survey area, developing very well in the middle to upper areas of Cristal River and Vargas River.

The rocks consist of black shale, slate, fine-grained sandstone and their weak metamorphic rocks, but lithology varies according to place. That is, in the central part, black shale is dominant, while in the upper stream of River Vargas and in upper River Cristal and on the slope near Alto Pacual, the shale layers sandwitch fine to medium-grained sandstone and conglomerate. In the boundary between them and green volcanic rocks in middle River Telembi, dark grey limestone of about 10m thickness can be observed.

The general strike of the sedimentary rocks is NS-N30°E and inclination of 50° - 80° east is dominant.

Piedrancha granodiorite intrudes through the sedimentary rocks, forming a contact metamorphic zone, which contains a large quantity of porphyritic crystals of andalusite with a 500 to 1,500m width in the surrounding shale. Under a microscope, re-crystalization and paragenisis of biotite can be seen, but the presence of a lot of xenomorphic crystals indicates that the shale in this region is abundant in Al_2O_3 and andalusite and then biotite were recrystallized. Near the intrusive body crystallization of the biotite improves, and with the increasing granular size of the re-crystallized minerals, cordierite is formed into cordierite-muscovite-hornfels. This belongs to the amphibolite facies in metamorphyic facies series.

The sedimentary rocks change gradually in their directional relation with the above-mentioned green volcanic rocks. Their basement part is abundant in green tuff as a parting of the shale, and disappears completely in the middle and upper parts. The general sequence of strata is lenticular, dark grey limestone with an approximately 10m thickness from the lower to the upper parts, and then black shale of more than 2,500m thickness at least. The black shale becomes partly slate-like and its upper horizon sandwitches fine to middle grained sandstone and contains a lot of conglomerate in places. The sedimentary rocks in which black shale is dominant, seem to be included in the Diabase layers of the Upper Cretaceous considering the transitional change of the previous mentioned green volcanic rocks, although no fossils could be found to assist determination of the age.

3-4 Igneous Rocks

The igneous rocks in the survey area are acidic to intermediate igneous rocks, basaltic andesite and new igneous rocks as mentioned below.

3-4-1 Acidic to Intermediate Igneous Rocks

Acidic-intermediate, hypabyssal-plutonic rocks are distributed over the whole survey area forming small to large scale intrusive bodies, and of which a body extending north east from Piedrancha in the south of the area is the largest, and is called the Piedrancha granodiorite.

The size of this intrusive is a maximum of 10 Km on the minor axis, and more than 35 Km in the direction of extension, and intrudes mainly to the sedimentary rocks (black shale). It is largely composed of medium to coarse grained holocrystalline amphibole-biotite granodiorite, and contains much hexagonal biotite euhedral/anhedral crystal and columnar amphiboles. The granular size and faces of the rock body are rather uniform having little alteration. Under a microscope, light-green-brown biotite, ferromagnesian minerals of light-brown-green amphiboles of 2mm$\pm$, andesine, quartz, and small amounts of orthoclase can be seen. Also, based on the result of norm calculation of chemical analysis of all the rocks and plotting this on the USGS's Granite Classification Diagram, it can be categorized as "granite". (cf. Fig. CR-4)

As coarse-grained holocrystalline acidic rocks, in addition to the above-mentioned rock body, the Canellera intrusive distributes in a circle with a 7 Km diameter on the north-east extension. This body is composed of coarse-grained holocrystalline diorite abundant in amphiboles, but generally contains a little or no biotite. This coincides with the observation that the K_2O content in this rock is lower than that of other Piedrancha granodiorites. In the south-west-edge of this rock body, diorite dike with a several meters to several ten meters width to sedimentary rocks can be observed, and this accompanies mineralization of small amounts of chalcopyrite. This mineralization is strong only in the peripheral regions, while in the central region it is relative fresh.

In the area where green volcanic rocks are distributed 10 to 15 Km west of these Piedrancha granodiorite body and Canellera diorite body, there are a number of porphyritic intrusives which are closely connected with copper-molybdenum mineralization. This porphyry is composed of medium to fine-grained porphyritic diorites extending from several hundred meters to several kilometers in diameter with columnar or acicular amphibole and small amounts of biotite. Generally, they were altered, and in particular in places of the copper-molybdenum mineralization, chloritization and sericitization are prominent. Occasionally, in the eastern part of the Piedrancha granodiorite, small diorite stocks exist. They can be seen in El Tabano Mine, the southeast part of Diamante Mine, and Drill site PD-8.

The third year's precise investigation discovered a wide distribution of fine-grained granodiorite which is intruded by coarse-grained granodiorite near the ridge of northeast Bombona Mine. Results of dating show that fine-grained porphyritic stock-like diorite was formed before intrusive activities of coarse-grained, uniform, so-called Piedrancha granodiorite rock body.

3-4-2 Basaltic Andesite

A number of dikes and sheet of andesite and basaltic rock can be observed within the sedimentary rocks along Cristal River and the outcrops along west Ramos River. The groundmass of these rocks is aphanitic, homogenous and dense, contains phenocrysts with pyroxene, olivine and occasionally amphibole, and is generally dark grey or black. In the outcrops of these dikes, the thickness varies from 50 cm in the thinnest one to several tens of meters. These rocks, which do not have characteristics such as a boundary between upper and lower parts like lava, are uniform and cut the shale wall rock in some places.

Near the Medio entrance of the Marina deposit in the area of Diamante Mine, a dike with of approximately 3m width running through green tuff breccia can be observed. Also, in drilling cores in the Diamante vein, a number of black, dense and aphanitic basaltic andesite can be seen. Vitrified nature and flow structure of the rock in the cores as well as the presence of spotted caves in places to produce indicate that this rock is lava. In general it was subjected to regional metamorphism chloritization, epidotization, sericitization and biotitization. Since the andesitic breccia in the tuff breccia has a similar character with this lava or dike andesite, and also no basaltic andesite intrusions through the previously mentioned granodiorite and poryphyrite were discovered, it is assumed that intrusions occured in the Cretaceous period to the early Tertiary period when the green tuff breccia erupted. Because of strong alterations the two dating trials were not successful.

3-4-3 New Volcanic Rocks

New volcanic rocks are widely distributed as lava covering the ridge region along the southern edge of the survey area extending from Piedrancha Town to Tuquerres Town along a roadway. The rocks are black, dense and aphanitic occasionally with 1 to 3mm needle amphiboles. Frequently in outcrops plate or columnar joints develop with 10 to 50 cm intervals. In the survey area, new age lava cannot be seen, while tuff or volcanic ash are widely distributed. They were observed in the survey by cutting of mountainous roads and geochemical investigation using handaugers and are yellow to white with a 50 cm to 2 m thickness. They cover the above-mentioned rocks and in some cases lie above the rock, while in other cases distribute sandwitched lenticularly in the black brown humus.

3-5 Geological Structure and History

Roughly speaking the geology of this survey area, in the eastern part has black shale/slate dominant layers which are intruded by a huge granodiorite, while from the central to western parts green volcanic rocks and small intrusives of diorite to granodiorite are exposed.

The geological structure dominant in this region shows NNE-SSW or NE-SW directions judging from strike and schistosity directions of the sedimentary rocks in the east and extension direction and arrangement of the intrusive rocks. Also, the green tuff breccia area in the west moderate anticlinal structure has a NE-SW axis to the direction of the diorite distribution, (namely, from Richaurte Town to Rio Blanco), can be observed.

In the survey area, three fault systems, NE-SW system, NW-SE system and N-S system, can be seen very clearly from the photogeological analysis. Also, the fissure systems in the area where a precise survey was conducted shows almost similar directions. As to the nature of these three directions, there is a tendency that the north west side is changed to a north-east direction by the NE-SW fault, and the NW-SE fault changes on the north-east side to a northwest direction. Since these two fault lines have cut each other, it is assumed that both of them were formed in an almost same period and they form a conjugate shear plane. Because of the relatively good continuity of the N-S fault it is assumed that the fault was formed in relatively recently after the formation of the above two faults. The NW-SE system fault, which regulates the direction of quartz veinlets existing in the Rio Blanco and Gualcala-E mining areas as well as that of vein systems including Diamante, Bombona and Patoquilia, as mentioned later, is a noticiable structural direction in ore deposit investigation. The Diamante mineralized zone is a fissure group developing in the green volcanic rocks, while the Bombona mineralized zone develops in the Piedranche granodiorite. The Diamante zone is cut by the N-S fault group to change its west side to the north.

In summary of the above-mentioned geological history including mineralization, the geology developed in the following order. (1) sedimentation of green volcanic rocks by submarine volcanic activities in the western part of Colombia in the early to middle Cretaceous, (2) deposition of sedimentary rocks through development of eugeosyncline (basic volcanic activities continued), (3) folding and sinking of the eastern part of the survey area by west-east horizontal pressure, and resultant development of NNE-SSW fold structure and metamorphism, (4) intrusion of acidic small rock bodies in the western part in the Paleogene period followed by mineralization of porphyry copper deposit, and then movement of the center of igneous activities to the east followed by intrusion of granodiorite, (5) intrusion of Neogene Piedrancha granodiorite and metamorphism, (6) development of the NE-SW fissure zone and formation of polymetallic vein type deposit group (7) development of the N-S fault, and (8) Quarternary volcanic activities.

The above-described geological history is a conclusion on the part connected with the mineral resources investigation of this survey area. However, several problems still remain unsolved with respect to volcanic activities of the green volcanic rocks distributing in the western mountains including the survey area and the sequence of sedimentary rocks, and so further discussion based on wider-ranging data is required.

Table CR-4 Age-Determination of Igneous Rocks

Year	Sample No.	Locality	Rock Name	Mineral	Ar40 ppm	K40 ppm	40ArR/40K	Age M.Y.	Remarks
1980	0-15	Rio Canellera	Quartz diorite	Hornblende	0.001558	1.010	0.001541	26.2±1.5	
	0-17	Rio Canellera	Hornblende-biotite granodiorite	Hornblende	0.001520	0.902	0.001684	28.6±1.7	Dyke rock
	637	Rio Vargas	Basic hornfels	Whole rock	0.001890	1.069	0.001766	29.9±1.7	Metamorphosed green volcanic rock
1981	R-253	Rio Blanco	Micro diorite	Biotite	0.001841	0.542	0.003391	57.1±4.3	Biotite very chloritized
	ND-52	Diamante	Granodiorite	Biotite	0.000939	0.391	0.002398	40.5±3.0	Biotite very chloritized
	B-22	Bombona	Granodiorite	Biotite	0.01015	8.340	0.001217	20.7±0.8	
1982	RM-6	El paraiso	Granodiorite	Hornblende	0.000192	0.503	0.000382	6.5 ±2.7	* 1
	PD-1088	Diamante	Basaltic andesite	Whole rock	0.000996	0.791	0.001259	21.4±1.5	Altered rock

*1 Hornblende concentrate, -80/+200 mesh. Treated with dilute HF and HNO_3 to remove alteration.

$\lambda e = 0.585 \times 10^{-10}$/year $\qquad$ 40k/k = 1.22×10^{-4} g/g

$\lambda\beta = 4.72 \times 10^{-10}$/year $\qquad$ 40ArR = Radiogenic argon 40

$$AGE = \frac{1}{\lambda e + \lambda\beta} \ell n \left[\frac{\lambda\beta + \lambda e}{\lambda e} \times \frac{Ar40}{K40} + 1 \right]$$

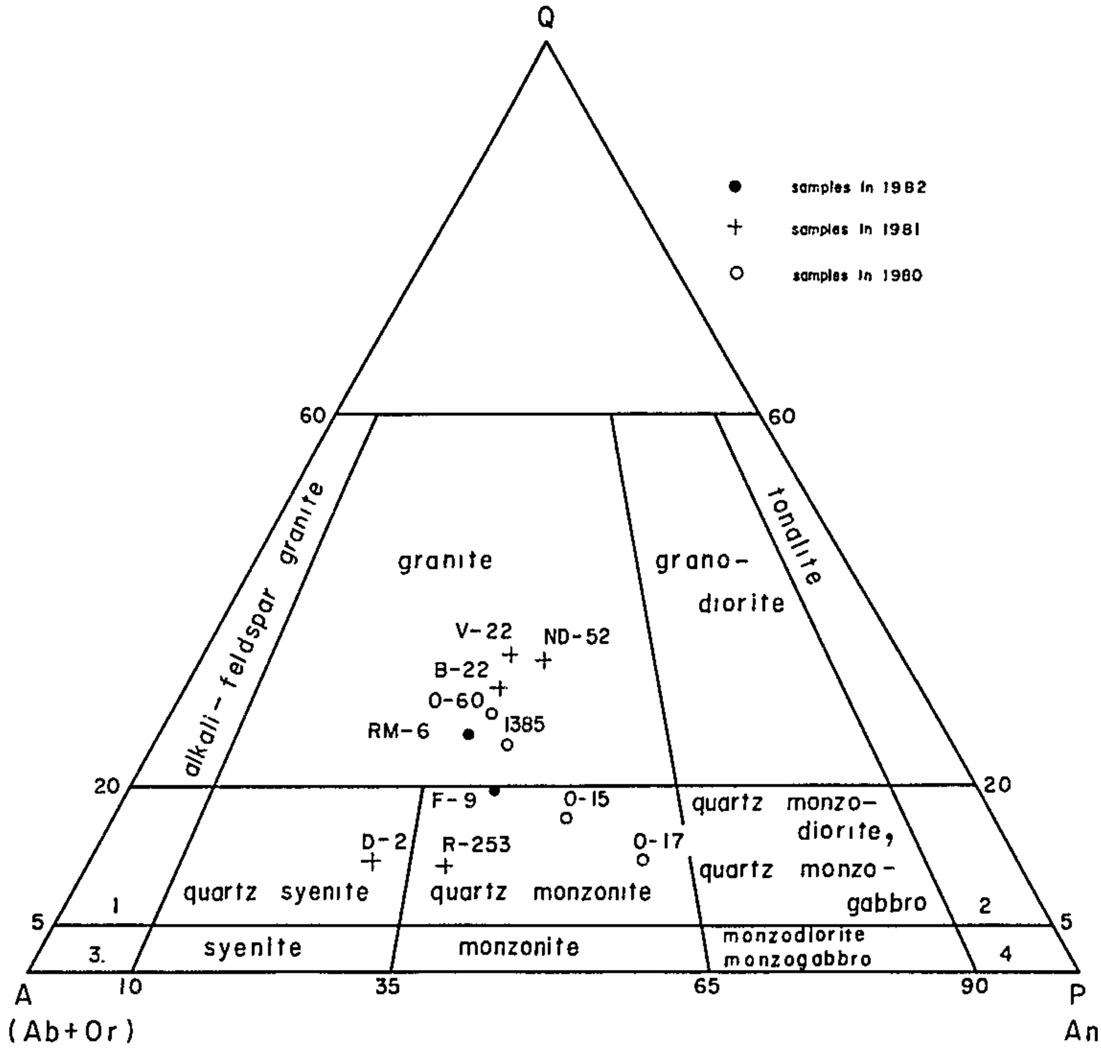


Fig CR-3 Normative Plagioclase (anorthite) — Alkali Feldspars (orthoclase + albite) - Quartz Diagram (Geotimes, 1973)

1 alkali - feldspar quartz syenite 2. quartz diorite, quartz gabbro, quartz anorthosite 3. alkali - feldspar syenite 4. diorite, gabbro, anorthosite

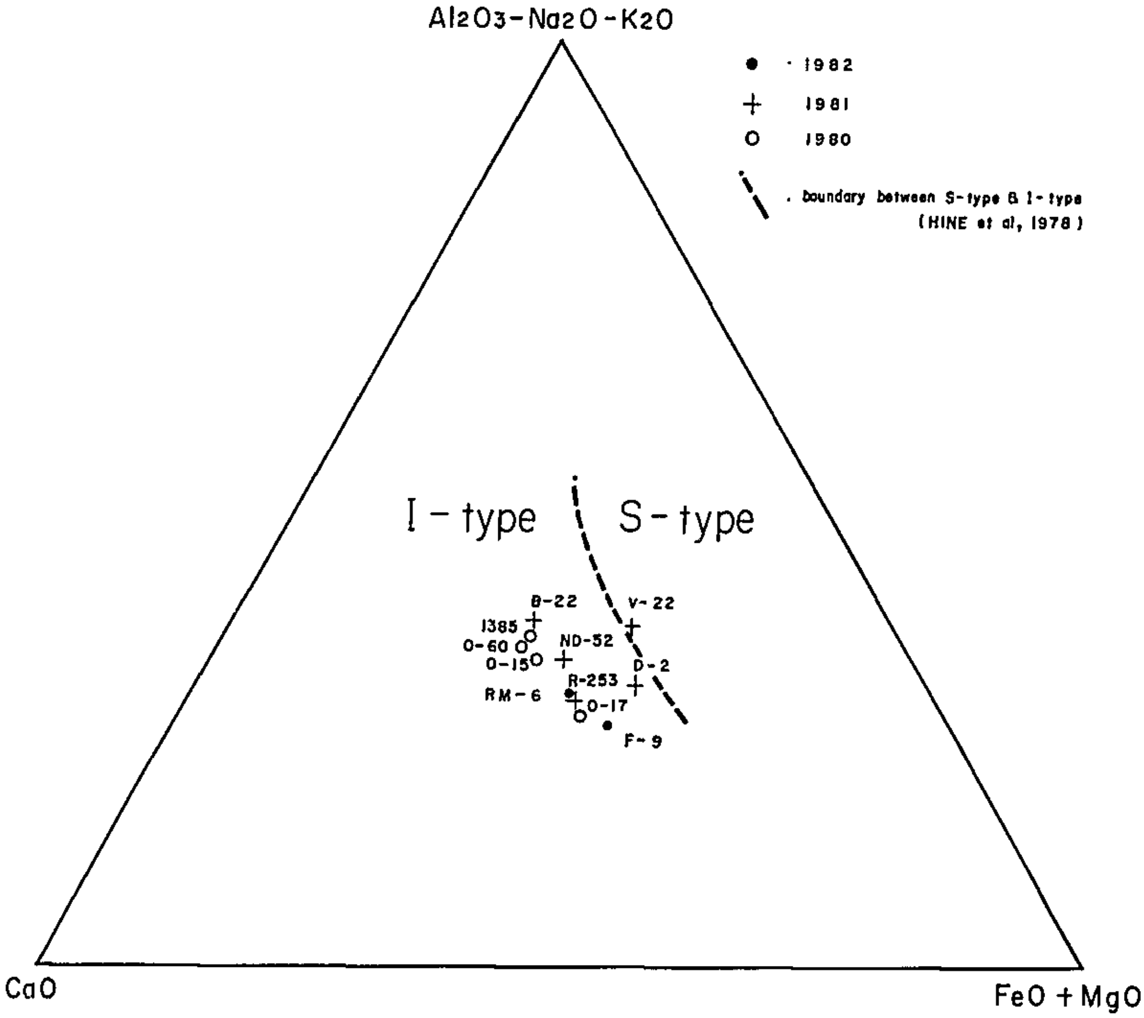


Fig. CR-4 ACF Diagram (molar ratios, A = Al_2O_3 - Na_2O - K_2O, C = CaO, F = FeO + MgO) for Granitic Rocks

CHAPTER 4 OUTLINE OF MINERAL DEPOSIT

4-1 General Description

Potential mineral deposit areas and known mineral deposits extracted by the regional investigation of the first phase are shown in the Table CR-3. These are roughly classified into the following 3 groups by type of mineralization.

Potential porphyry copper ore deposit;

La Verde, Bio Blanco, Gualcala-E, Santa Rosa and Ramos potential mineral deposit areas.

Auriferous polymetallic vein type deposit:

Diamante, Bombona, Desquite, El Tabano, Concordia, Pataquilia, Floresta Mines

Alluvial gold deposits showings;

Gualcala-Middle, Navada areas.

All of the said potential porphyry copper ore deposit areas are distributed in an area about 10 Km wide in a NE-SW direction on the west side of the Piedrancha granodiorite intrusive body. The mineralized country rock is constituted of green volcanic rocks, sedimentary rocks, and those intrusives of diorite and granite porphyry. Mineralization is mainly pyrite accompanied by small amounts of chalcopyrite, and molybdenite in places. Of the five potential mineral districts the La Verde, Rio Blanco areas, where mineralization and alteration are considered to be relatively strong, had soil-geochemical exploration performed in the second phase.

Furthermore, many potential polymetallic vein type deposits occur in this area, and some have been long on a small scale, or are presently being operated.

As the result of investigation of these potential areas in the first phase, it was concluded that the veins located in north-east area as El Tabano, Concordia, Patoguilia, Floresta, etc., have little residual ore, and meagre prospect, however, the vein groups scattered in the south-east area such as the mines of Diamante, Bombona, etc., have the possibility of future growth with investigations to the deeper part and/or horizontal extensions to the present veins. Therefore, geological survey and geochemical exploration are performed in detail including drilling survey during the second and third phases. Furthermore, alluvial gol] showing, particularly in the Gualcala-middle district have not been allowed through. This area, being downstream from the Bombona mine area, is a potential target.

A general explanation of each potential mineralized area is made as follows:

4-2 Potential Porphyry Copper Deposits

4-2-1 La Verde Area

Location: The area is in the lower reaches of La Verde which is a branch of Rio Cristal River, and stretches about 500m east-west, about 1,500m south-north, and is 450 - 700m above sea level.

Geology and Mineralization: The country rock consists of fine grain diorite, etc., intruded in sandstone, shale and basaltic lava. There are some disseminated mineralized alteration zones consisting mainly of pyrites and small amounts of chalcopyrite. There is the tendency for portion of high grade copper ore to be one-sidedly distributed in the side of the south end of the intrusive rock. The alteration of the country rock appeared mainly in the choritization of mafic mineral, and a weak silification was observed. Furthermore, to the west and north-west of high grade copper portions veinlet groups of quartz-zeolite were observed. Under microscope, it was observed that part of plagicolase appears to be altered into potassium feldspar or sercite. Fissures are developed in the three directions, NE-SW, NW-SE and N-S, controlling the direction of the intrusive rock, and an E-W fault group was also observed in the east side sedimentary rock.

Anomalies of Geochemical Exploration: Soil was sampled at 50m interval of the route along the ridge, and the Cu and Mo contents analyzed. The value of Cu is 17 to 997 ppm (mean value is 204.2 ppm). The correlation coefficient of the Cu/Mo becomes 0.538, and a positive correlation was observed. An anomalous value for each element was chosen, giving the content over the mean value + standard deviation as a weak anomalous value, and over the mean value + 2 x standard deviation as strong anomalous value. As a result, a weak anomalous zone of 800m south-north and 300m east-west for Cu, and 1,200 x 300m for Mo were recognized. From the results of the above investigation, mineralization and alteration of this district and considered to the porphyry copper type deposit. Also, it was recommended that detailed geochemical exploration and geophysical exploration along grid are necessary to determine the position of copper deposits more accurately.

4-2-2 Rio Blano District

Location: The district is in the north-west of the survey area, and is in a jungle about 2 km west from the diverging point of the Rio Telembi and its branch the Rio Blanco (500m to 1,200m above sea level), and the alteration zone makes an oval shape of 600m north-south, and 2,000m east-west. The place is at about 25 km west from Guachavez Town, and in 3 days travel on horseback.

Geology and Mineralization: The mineral indications are in the north part of a fine grained diorite body 4 km x 4 km in the basin of the Rio Blanco. The Dorada Creek runs east-west across the center of the mineralization and, alteration zone, a fractured zone with iron oxide gossan crops out, and pyrites and small amounts of chalcopyrite are observed. Outcrop sample analysis indicated a copper content of 0.04%to 0.25%. ENE-SWS and NNW-SSE tectonic line systems are developed, and silicification-chloritization zone and epidote-chloritization zone show zonal distribution. Pyritization is strong in the silicification-chloritization zone.

Anomalies of geochemical exploration: As in the La Verde area, soil samples along major ridges were collected, and analyzed for Cu and Mo. The analysis value indicated 1 ppm to 2,501 ppm of Cu (mean value 49.5 ppm), 1 ppm to 14 ppm to of Mo (mean value 1.9 ppm). The areas where anomalous value concentrates were extracted as anomalous zones for each element giving over mean value + standard deviation as a weak anomalous value, and over mean value + 2 x standard deviation a- a strong anomalous value. In the anomalous zone was obtained a 100m x 400m Cu strong anomalous zone with Dorada Creak at its center, and a 300m x 1,900m Cu weak anomalous zone surrounding the above indicates a harmonized distribution of a silicification-chloritization zone, and a weak Mo anomalous zone also distributed within this area. It is clear from the alteration anomalies of geochemical exploration and the network sulfide dissemination at the outcrop in the Creek, that porphyry copper deposits exist. Although the mineral possibilities judging from the state of the ground surface is rather weak, the mineral potential of the deeper part is still unknown, and results of test drilling are expected to be positive. However, development of this area has the problem that the ore shoot is expected to be the farther lower side of Dorada Creek, and also, in consideration of the inconvience of transportation, a prudent attitude shall be taken before proceeding on the future investigations.

4-2-3 Gualcala-E Area

A pyrite mineralization zone with andesite as the country rock is observed between the branch river Agua Tigre of the east bank of Gualcala River and the Blanco River. It was recognized that the range of mineralization stretches in a wide range as 1.5 km x 1.5 km Cu anomalous zone in the basin of Agua Tigre, and another 1 km x 1 km in the basin of Rio Blanco were extracted as a result of river sand analysis with biquinoline method. Andesite in the district is subjected to weak regional alteration, and the amphibole was partially changed to chlorite, however, in the mineralized zone, silification, argilization (chlorite, montmorillonite and sercite) and epidotization were also observed.

The mineralization is strongly controlled by fissures, and dissemination into the rock is weak. As for the direction of the fissure, two series N60°-70°W and N40°-50°E are dominant.

4-2-4 Santa Rosa Area

The district is a mineralization-and-alteration zone located to the north-west of the investigated area, and is in the Santa Rosa River, a branch of Gualcala River down stream crossing the survey area south-east to north-west. The mineralization is along joints in the diorite, and small amounts of chalcopyrite accompany the disseminate pyritization into the country rock. Outcrops are observed intermittently on the river bed and are distributed over 1.2 km. It is not clear whether the river bed is the center of the mineralized zone, so further detailed investigation is necessary.

4-2-5 Ramos Area

In around mid-stream of the main stream of Ramos River, intrusive rock of diorite or granodiorite exists, and mineralized zone of pyrite, chalcopyrite and molybdenite exists to the south-west and south-east of the oval-shaped intrusive rock body. As the result of stream sediment analysis, out of eight samples taken at near to this place, four weak anomalous values of copper and four strong anomalous values were detected. To the west bank of Ramos main stream, along the Creek in anomalous zone, oxdized silicified rock, outcrop of so called "GOSSAN", and argillized fracture zone were observed. The range of the mineral indications including such alterations of rock outcrops is about 0.5 km x 1 km.

However, the center part of the intrusive rock of granodiorite in the main stream of Ramos and eastwards extending branch Mirador River is relatively fresh, and mineralization is likely to be limited to the boundary parts of the south-west and south-east. The district flourishes with vegetation and outcrops are few. Therefore, future detailed examination by geochemical exploration and geophysical exploration is necessary.

4-3 Auriferous Polymetallic Vein Type Deposit

Vein type gold ore deposits are generally classified into vein groups near the El Tabano-Concordia Mine distributed in the north-east part of the survey area, and vein groups of the Diamante, Bombona mines around the south-east part from Gauchavez Town to Gualcala Mountain, and their outline is as follows:

4-3-1 El Tabano - Concordia Mine District

Many old gold mines are in the basin of the Cristal River which flows through the north-east of the survey area, and some of the mines are being re-developed due to the recent boom. Among these, El Tabano Mine, located to the south of Sande Village in the mid stream near the pass to the

Vargas River, had a hydraulic power plant some decades ago, and mechanized mining and mineral dressing were performed and now the past prosperity is being handed down among the inhabitants. Presently, the mine continues to be manually operated by about 20 people. The presently operated tunnel is at a height of about 1,250m above sea level, and the arrangement of the tunnels is as shown in the Fig. CR-7. The vein has a very gentle slope and is sometimes almost horizontal and composed of an milky white quartz vein of 50 cm to 20 cm thickness. Within the above vein, angular and sub-angular breccia of about 10 cm x 20 cm are included, and either ring-form sediments of pyrite surround it or 5 cm to 30 cm pyrite layers are formed to the upper or lower boundary of the quartz vein with gold included within the vein. The country rock can only be observed underground to a limited degree. However, it consists of green rocks of basaltic andesite or tuff, etc., penetrated with diorite as the form of stock of dike and has mineralized quartz and pyrite filling the gentle slope fissure later generated. The ore grade of one front presently mining was Au 16.0 g/t with a vein width of 50 cm. The ore contains a few arsenopyrite, but the sphalerite, etc., is hardly seen.

Concordia Mine is further upstream on Cristal River where it branches with Nevada River 2 km upstream from the Socorro ore dressing site, and the vein consists mainly of milky quartz with fewer sulphides. The vein has a gentle slope and the country rock is of black slate formation.

Other than the above, Floresta mine which is delivering ore to Socorro Ore Dressing Site is at the south bank mid-way to Concordia Mine, and many old mines are distributed at the north bank. The vein of the Patoquilia mine is near the north bank of the Patoquilia Creek in the down stream and is also a veinlet of milky quartz vein accompanying pyrite of 10 cm to 20 cm. The vein is in host rock of black shale and has been moved by many faults.

(cf. Fig. CR-7)

Common to the nature of the deposits in this district are gold mines which are irregular in the direction of the vein, quartz is generally milky white and includes very little sulphide, except in pyrite. These mines have been exploited for a relatively long time and because horse tracks have been opened along the Rio Cristal River, remaining small ore reserves.

4-3-2 Diamante - Bombona Mine Area

In this area there are many small operating mines such as Diamante, Marina, Gitana segunda, Desquite, Paraiso, Delicia, Bombona, etc. Each mine is manually operated by several workers, and gold is collected by panning after crushing and grinding by water wheel power. As a result of geochemical detailed exploration in this area in the third phase, indication of many new veins were found, and the area was determined to be one of high potential for future prospecting activities. The outline of each mine is given in the following:

The results of geological and ore deposit study of this area are described collectively in the next chapter "Diamante - Paraiso - Bombona area".

(1) Diamante Mine

Diamante Mine is 4 km to the south-west of Santa Cruz and is upstream of Telembi River in the Diamante Creek. Many old tunnels are scattered 2,500m to 2,700m above sea level, and 4 of the old tunnels were reopened as a result of the recent high price of gold, and remining and prospecting in the old mines has been performed. Four mining sites are located within 1 km and places where gold is collected by panning after crushing and grinding by water wheel power (four places) are built.

The mineral deposit is a fissure filling mineral vein in green volcanic rocks consisting of tuff breccia and basaltic andesite. The composition of minerals between tunnels changes a little and is as follows:

Hormiga Pit:

Total tunnel length is 20m; vein's direction N40°W; its dip is 65° NE; The ore is oxidized up to 10m from entrance and the analysis grade of the sulphide mineral sampled beyond the oxide area is Au 17.0 g/t, Ag 143 g/t for the sampled width of 25 cm. However, the analysis was rich in arsenopyrite, As 23%.

Hormiga W Pit:

Tunnel is running in the direction of N50 W: vein inclination is 50 NE; consisting of oxide mineral vein with clay mineral, vein width 20 to 30 cm. Tunnel is 12m long. Mineralization is rather weak.

Auxiliadora Pit:

A net-work type dissemination ore body mixed with many veinlets running mainly N60°W with pyrite and a small amount of arsenopyrite dissemination. Analysis of 120 cm from relatively strong mineralization indicated: Au 15.7 g/t and Ag 13 g/t. Further at the end of the south-east side of the tunnel, sample shows Au 3.3 g/t and Ag 90 g/t. A small amount of sphalerite was also found. A part of the country rock is whitened, showing the appearance of quartz porphyry; but, this was shown by microscopic inspection to be all the country rock are agglomeratic tuff breccia subjected to silicification and sericitization, and nothing other than tuff breccia was found by the drilling PD-1 performed 20m north of the main tunnel.

Diamante Pit:

At the depth of about 100m crosscut, a wide vein zone (20m +) was met and is being mined in the more accessible sections, is now being dressed. A 2m table type gravity concentration equipment is placed in the water wheel ore dressing site. Gathering gold with sulphide minerals, the cyanide method is partly being tested. To the north side wall at the deep end of the tunnel, massive pyrite exists to the east side; in the central, several veinlets of quartz - arsenopyrite - galena are irregularly distributed in weakly argillized country rock; to the west, a 70 cm to 80 cm wide compact massive vein of sphalerite - pyrite - arsenopyrite - quartz exists dipping about 60° eastwards. Further to the west side, a filled old tunnel is located, and it is assumed that a vein of pyrite rich clay type had existed. The total width of these veins is a width of 20m or more. Eight samples were taken from the mined ore and analysed, and the average grade is: Au 7.9 g/t, Ag 76 g/t, Cu 0.2%, Pb 0.2%, Zn 1.7%, and As 3.3%.

Gualquilia Norte Pit:

Massive iron sulphide ore of the above ore classification is seen near the front; however, the vein is lost by a later fault in the north-south direction. Although the width of the vein is considered to be wide, it couldn't be observed well by pillar. During the investigation, the upper part was dug.

Gualquilia Sur Pit:

Vein width seemed to be 50 cm - 80 cm; however, sufficient observation and sampling could not be done due to being hindered by old pillar.

San Sebastean Pit:

Siliceous iron sulphide ore of the vein width of 30 to 40 cm with strike of N70°W and dip of 80° NE is seen in the southward front face. A vein is also seen at the roof, and a stain of green copper oxide ore is attached. Mean value of the analysis of two samples are: vein width 35 cm, Au 6.1 g/t, Ag 306 g/t. It is characterized by a high silver content, and the content of copper and lead is also high.

(2) Marina Mine:

The mine is about 1 km north-north-east of Auxiliadora Pit, 2,570m above sea level. One vein is in the south bank and three veins are distributed in the north bank. A water wheel stamping house is in operation and small scale operations are being performed. The vein of the south bank is cut 20m toward inside at 2,570m above sea level, 60 to 80 cm oxide ore vein runs up to 10m inside and sulphide ore is seen at the inside.

About 10m above the tunnel, several strip mines and old tunnel entrances exist; however, the status is not clear because they are in ruin.

The inclination of the three veins running in the north bank are N30°W, 80° - 90°NE, N55°W, 75°NE and N70°W, 75°N respectively, and they are directed to south to converge and connect with the said south bank vein. (cf. Fig. CR-9)

(3) Gitana Segunda Mine:

This mine is at a point about 500m north-west of Marina Mine, 2,500m above sea level. The mine has a water wheel house, and is being operated on a small scale. Three veins were observed, three tunnels were built on the north side, and another three in the south side. The vein width is 20 cm to 120 cm and the vein characteristic is mainly oxide ore including clay and pyrite ore is seen to some extent (cf. Fig. CR-10). Gitana Primera (or Yela) Mine is about 500m further north-west from the above mine. The tunnel goes into 10m at 2,500m above sea level, and is opened for the length of 16m in the direction of S70°E. The veinlet is about 20 cm width and dip of 70°NE and is constituted by quartz including a large quantity of arsenopyrite. The gold ore grade was low with the value of 1.2 g/t. In addition to those, old tunnel is at about 300m west; however it is already collapsed and the inside is unknown. All of those are fissure filled veins in the green volcanic rock.

It has been demonstrated by the third phase's geochemical exploration that the above mentioned mine groups belong to the same mineralization zone running in a NW-SE direction.

(4) Desquite Mine:

This mine is about 7 km north-west from the Diamante Mine, and the tunnel is in the east bank of Rio Telembi River. The country rock is granodiorite, and the tunnel is timbered due to oxidation and argillization. Detailed conditions are unknown; however, the general strike direction of vein is N40°W, inclination is 70°NE and vein width is 4 cm to 40 cm.

(5) Paraiso Mine:

Outcropping veins were discovered at 4 points on the opposite bank of the Desquite Mine; among those, the San Antonio Outcrop is being intermittently mined by small scale strip mining.

The San Luis Vein, discovered about 1 km west, is in a small river bed, and gold grains can be observed through rough panning. It has been shown by the third phase's geochemical exploration that many unidentified veins may still exist around the site.

(6) Delicia Mine:

This mine is about 2 km south of the Paraiso Mine area, and the old mine is now being reopened. The country rock is fine grain porphyry granodiorite and medium to coarse grain granodiorite, separated at about 2,400m above sea level, with the former distributed in the higher place. Presently, veins to be aimed for in mining are yet to be found, and only several fine quartz clay veins can be seen in the creek.

(7) Bombona area:

The district is 12 km west-south-west of Guachavez village, occupying the basin of the Bombona River, which is a tributary of the Gualcala River. The district is a steep mountainous area ranging between 2,200 and 2,800m above sea level, with flourish vegetation of tropical broad-leaved trees and bamboos. To reach the district, about 7 hours horse riding is necessary from Guachavez through a ridge about 3,100m above sea level. Mineral deposits in this district are said to have been prosperously operated in the 1,950, many old tunnels exist in the district and foundation of old ore dressing sites remain. However, most of the old tunnels are collapsed at the entrance and it is impossible to get into the tunnels.

Presently, small mining operations are being performed at two places in the district. Veins around the old tunnels are mined by several workers, crushed by hydraulic ore stamper, and gold is segregated and recovered by panning and amalgamation. No systematic ore prospecting is being done. During the second phase of the investigation, detailed examination around the mine was implemented, soil samples were taken along the ridge crossing the vein strike for the purpose of prospecting the extension of the vein as well as the geological investigation of known veins. Geochemical exploration was performed, using arsenic and zinc, which are largely contained in the vein, as indicative elements. As the results of this investigation, it was expected that the mineralized zone further extends to the north west; therefore, in the third phase investigation, geochemical detailed exploration was performed for the district extending north of these areas taking soil samples on lines at 150m intervals at a pitch of every 25m. The veins can only be observed at around the tunnel entrance, and the veins are generally veinlets of the width of 5 to 40 cm, consisting of fissure filled quartz veins in small or medium grain granodiorite. The vein runs in the direction of N60°W, dipping 70°N - 80°S, and the extension is relatively short, and at a glance it is seen to be in the distribution of the form of three parallel lines.

(8) Other Mines:

Other than the above, Porvenir Mine is at about 4 km west of the Bombona Mine, and El Salado Mine is at about 7 km south of Guachavez Town.

However, both of those mines are being closed, and were not investigated in spite of being said to be similar mines.

4-4 Alluvial Gold Showings

4-4-1 Gualcala-Middle Area

Gold-molybdenum-lead anomalous zone was detected at the middle of Gualcala river running through the southern central part of surveying area, by means of stream sediment geochemical exploration conducted in the first phase.

The anomalous zone occupies 3.5 Km-long river bed of the Gualcala which flows 5 Km toward west-southwest.

The Gualcala runs deep and wide with 50 to 100m width and changes its direction from northwest to west-southwest at anomalous zone and again to northwest after passing the anomaly.

Among thirty-six samples taken in this area, high gold value samples are concentrated along the main stream where 5 of 15 samples show weak anomalous value of Au 1.4 - 2.5 ppm, one of 15 samples strong anomalous value of Au 9.4 ppm and the rest of 15 samples show higher value of Au 0.4 - 0.8 ppm than background.

The metals source of this anomalous zone is located upstreams of the Gualcala main, since no branch rivers reveal an anomalous value.

In the uppermost of the Gualcala there exist gold deposits such as Bombona Mine and various veins in the Paraiso-Bombona area.

Those mines and veins made sources to Gualcala-middle area where precipitate metals at a flat and bending part of the river.

This is an interesting mineralized area and is still lacking lots of geological informations.

4-4-2 Nevada Area

The Nevada river branches out toward south near the Concordia mine situated at upstreams of the Rio Cristal.

Geochemical exploration on the stream sediments of the first phase, discloses the following anomalous zone along the Nevada river where contains 3 weak anomalous values of gold (1.4 - 5.2 ppm), 3 strong anomalous values of gold (over 5.2 ppm), 8 anomalous value of zinc (more than 209 ppm) and 5 anomalous value of lead (more than 34 ppm).

This area locates 10 Kms to the north of Guachavez and rugged terrane prevents person to settle in.

The anomalous area covers 2.5 Km N-S x 0.5-1 Km E-W and the further upstream remains unexplored.

In addition to the survey for alluvial gold deposit, geological and geochemical exploration work covering whole the area will be recommended to clarify the sources of gold-zinc-lead anomaly.

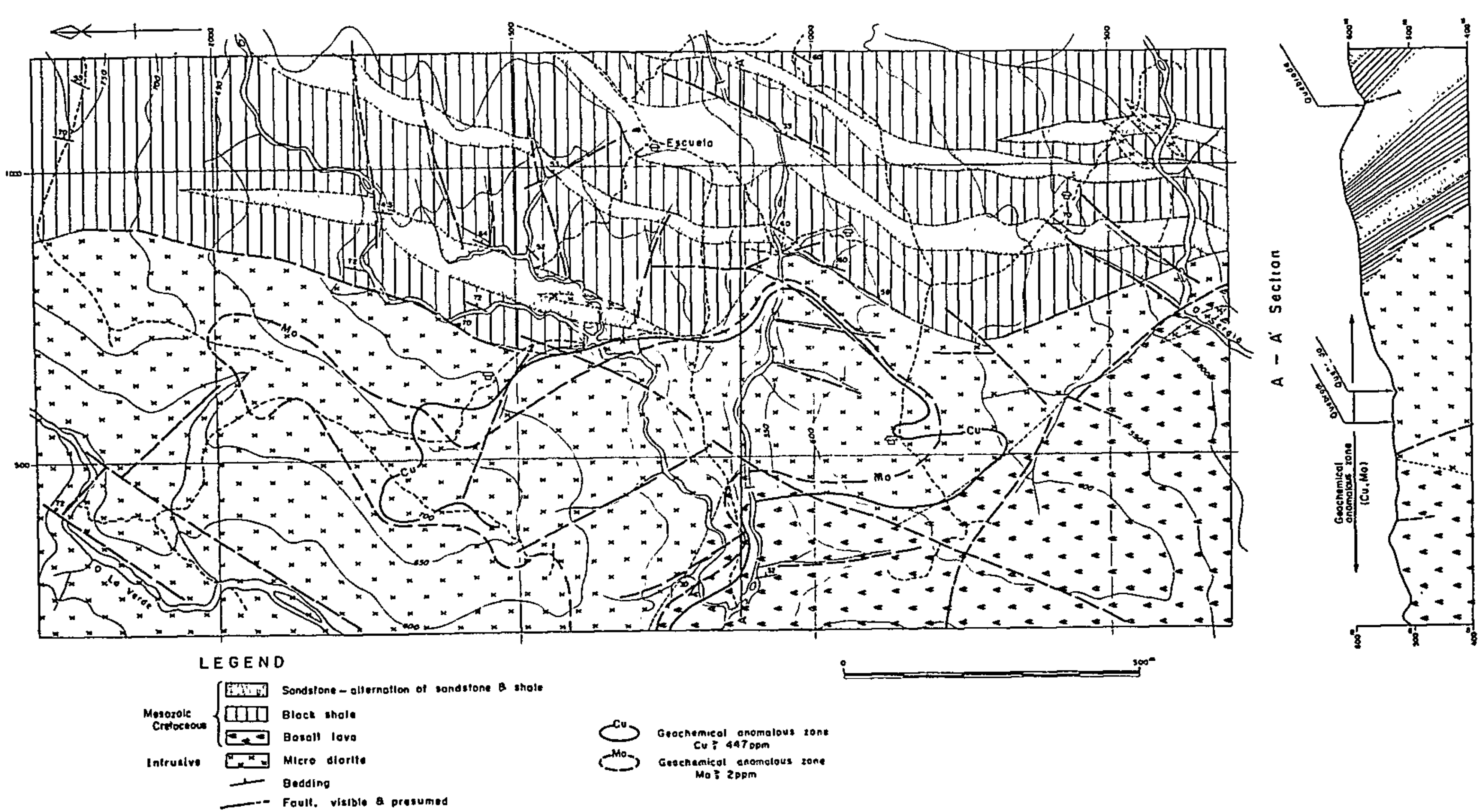


Fig CR-5 Compiled Map of La Verde Area

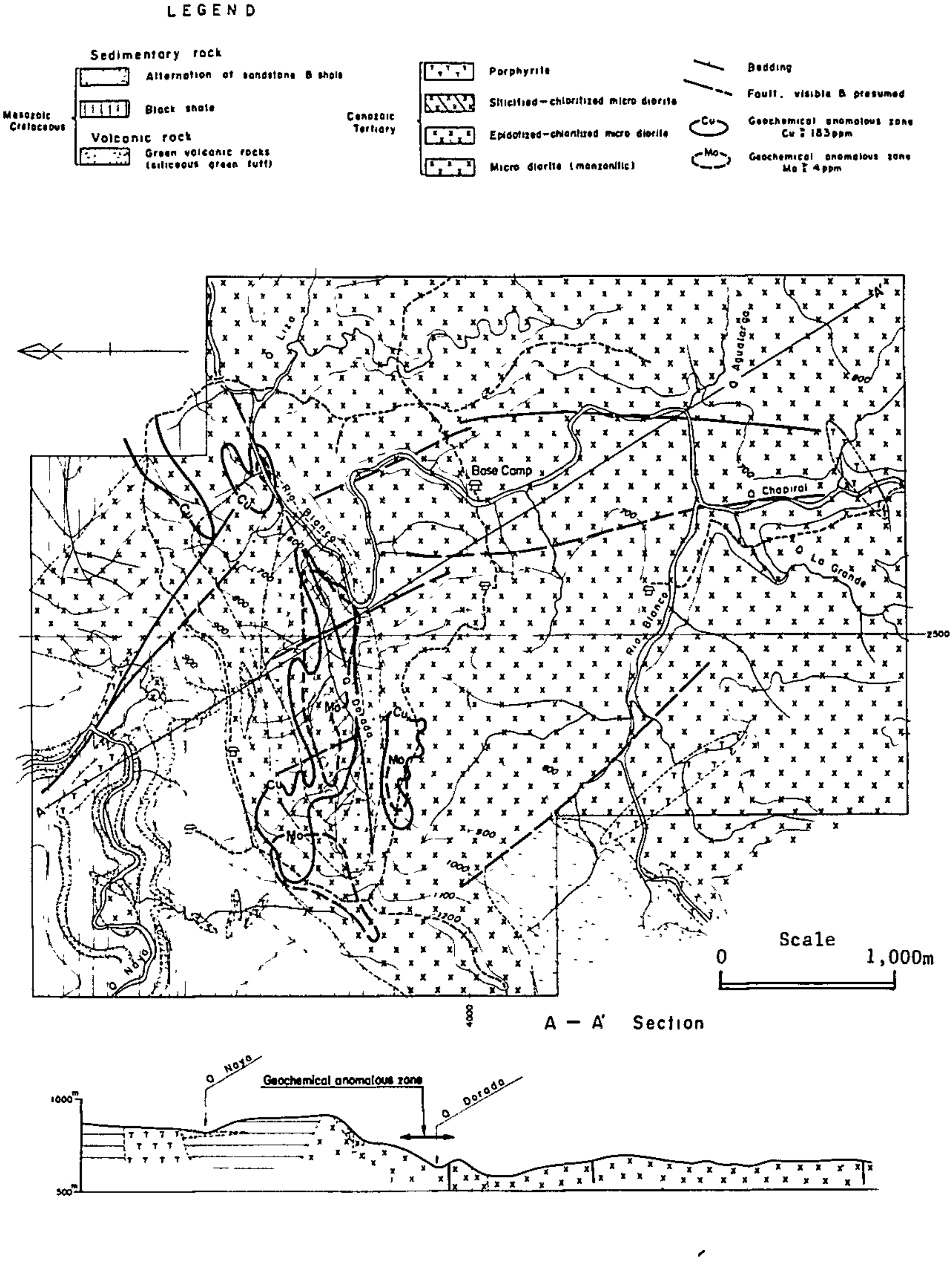
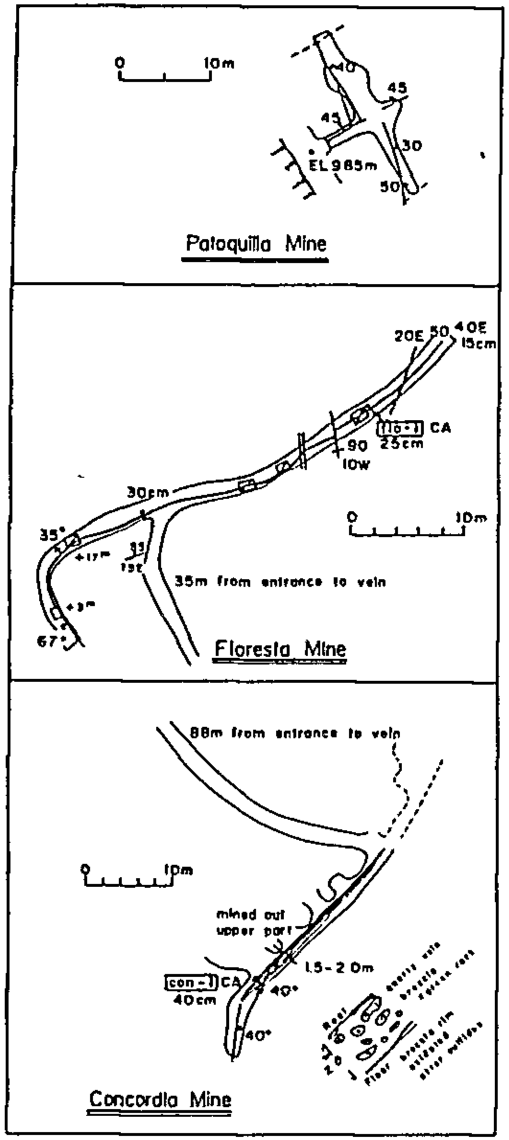
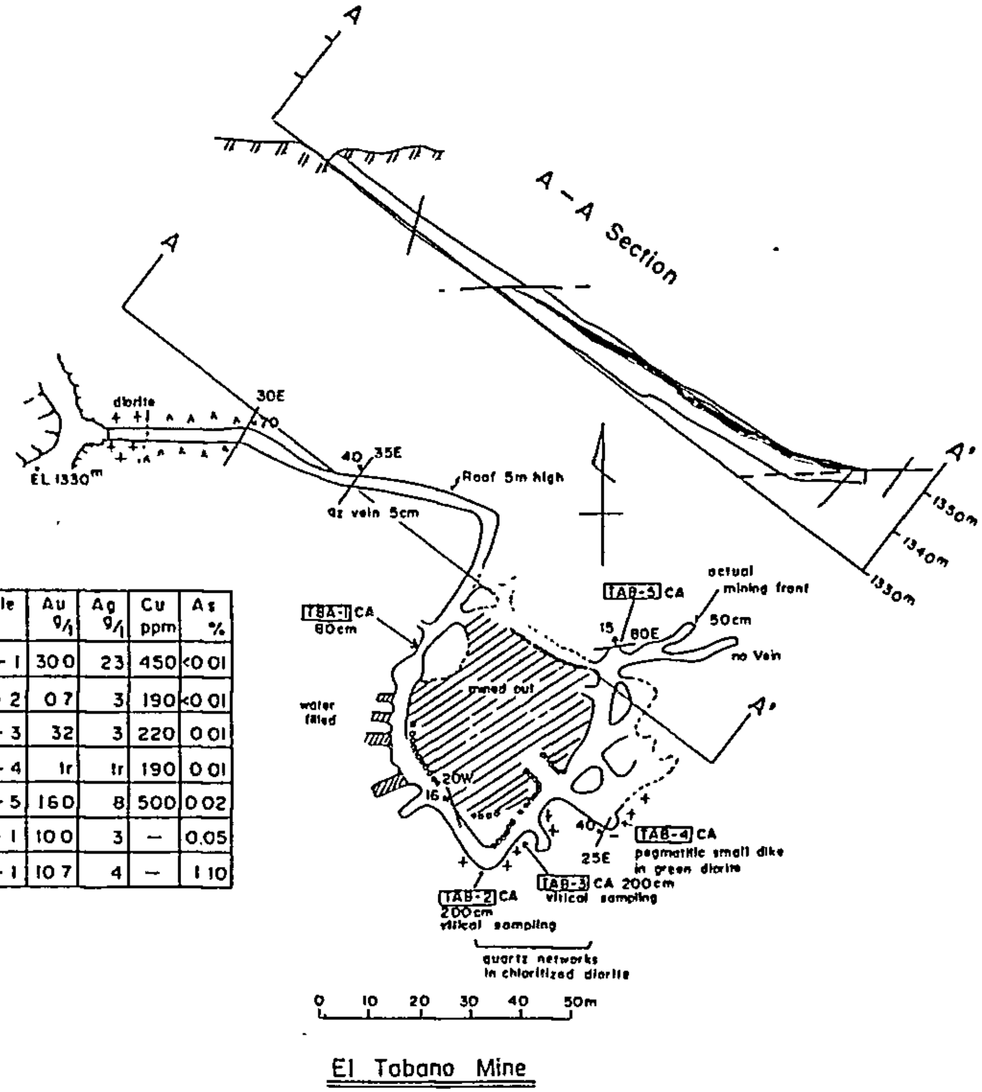


Fig CR-6 Compiled Map of Rio Blanco Area





Sample No	Au g/t	Ag g/t	Cu ppm	As %
TAB-1	30.0	23	450	<0.01
TAB-2	0.7	3	190	<0.01
TAB-3	32	3	220	0.01
TAB-4	tr	tr	190	0.01
TAB-5	16.0	8	500	0.02
flo-1	10.0	3	—	0.05
con-1	10.7	4	—	1.10

Fig CR-7 Geological Sketch of El Tabano, Patoquilia and Concordia mines

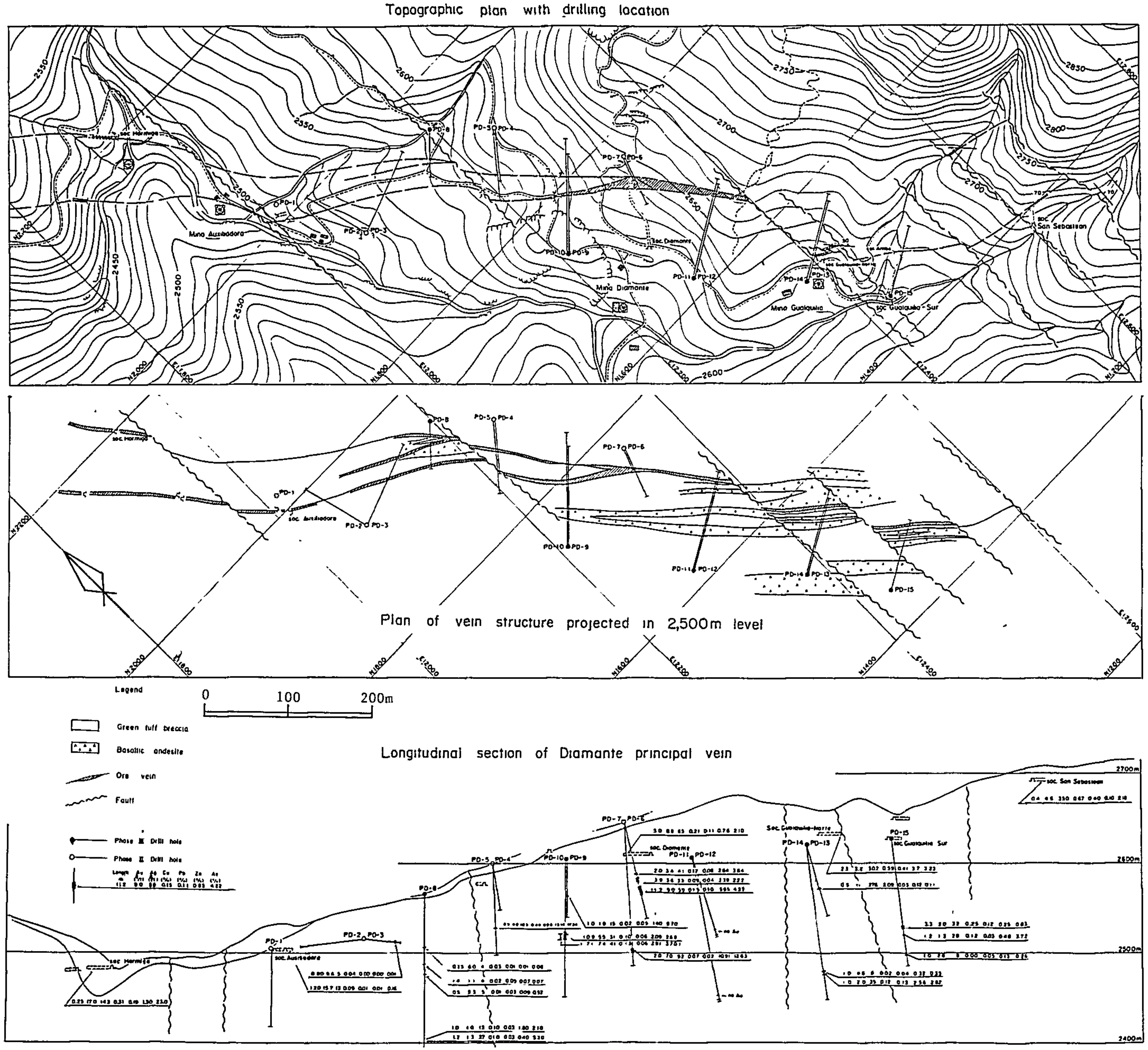
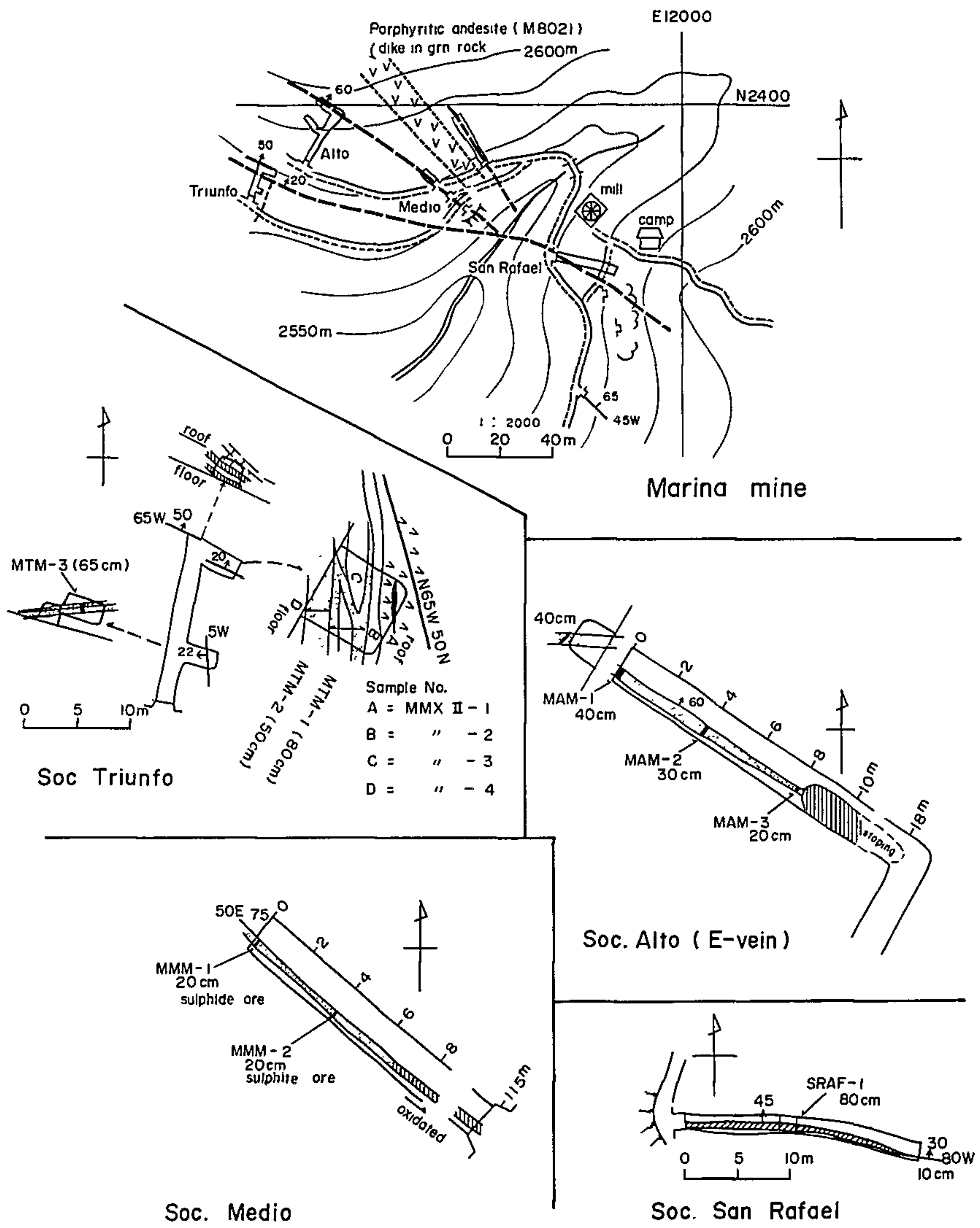


Fig. CR-8 Diamante Mining Area.



Analysis of ore

Sample No. (width cm)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	As (%)
MTM-1 (80)	tr	tr	1 03	0 06	0 09	0 41
MTM-2 (50)	10.8	47	0 08	0.23	0 59	0 76
MTM-3 (65)	tr	tr	0 03	0.03	0 04	0 39
MAM-1 (40)	2 6	21	0 05	0.08	0 04	2.32
MAM-2 (30)	2 3	15	0 11	0 09	0.15	2 12
MAM-3 (20)	8.2	39	0 08	1 07	0 18	2 67
MMM-1 (20)	7 2	40	0 12	0 21	0.90	6.24
MMM-2 (20)	11.4	112	0.21	0.56	1 10	6 13
ARAF-1 (80)	X 17.6	56	0.04	0.40	0 04	9.4

X analyzed in 2nd phase

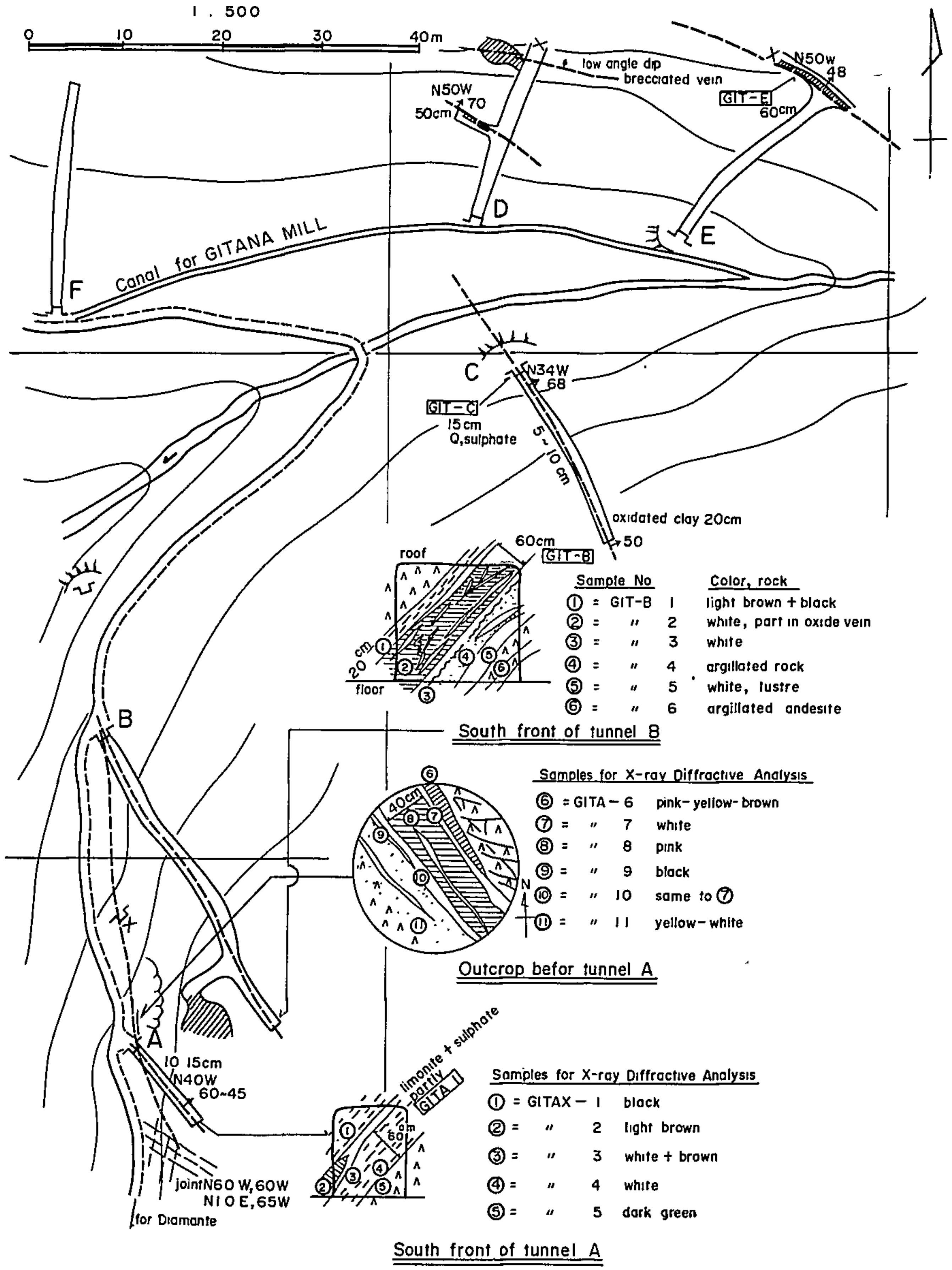
Study of alteration minerals

Sample No	X-ray diffractive analysis				As %	Sb %	Si %	Ca %	S %
	Ser	Mon	Kao	Oth					
MMX II-1	L	M	S		0 12	0.03	34 63	0 40	0 01
" -2	L	M	S		0 07	0 02	37.96	0 29	0 01
" -3	C			S?	1 19	0 03	35 39	0.06	0 05
" -4	L	L		V	0.39	0.04	28 49	0 57	0.02

X-ray Diffractive analysis
V very much > M much > C common >
L less > S scarcely

Ser : Sericite , Mon . montmorillonite
Kao . Kaolin, Oth Plagioclase

Fig CR-9 Vein and Sampling Location of Marina Mine



Analysis of ore

Sample No (width cm)	Au g/t	Ag g/t	Cu (%)	Pb (%)	Zn (%)	As (%)
GITA-I (15)	9.4	53	0.17	0.07	0.07	0.76
GIT-B (60)	2 1	1 3	0.09	0.04	0.05	1.99
GIT-C (15)	11.8	114	0.98	0.07	0.14	1.45
GIT-E (60)	2.0	34	0.07	0.05	0.17	2.07

Study of alteration minerals

Sample No	X-ray diffractive analysis					As	Sb	Si	Ca	S
	Ser	Mom	Kao	Ana	Oth	(%)	(%)	(%)	(%)	(%)
GTAX-01	C		C	S		0.19	0.03	35.60	0.18	0.02
〃 02	C	C	L	S		0.10	0.01	47.46	0.15	0.01
〃 03	V	C		S		0.08	0.01	40.08	0.08	0.01
〃 04	V			L		0.10	0.01	50.98	0.11	0.005
〃 05					M	0.24	0.04	39.59	2.66	0.03
〃 06	C	C	L	S		0.05	0.03	44.96	0.16	0.01
〃 07	C	C		L		0.07	0.02	32.81	0.16	0.01
〃 08	S		V			0.09	0.02	41.67	0.16	0.01
〃 09	S				S,M	0.06	0.02	37.33	0.10	0.01
〃 10	C	C	L	L		0.03	0.02	71.41	0.22	0.01
〃 11	C	C	L	S		0.02	0.01	43.83	0.19	0.005
GITBX-01	S				L	0.36	0.03	42.94	0.26	0.02
〃 02	M			S		0.08	0.01	54.70	0.10	0.003
〃 03	L	M	M	S		0.19	0.03	29.60	0.28	0.01
〃 04					M	0.15	0.04	39.12	0.40	0.02
〃 05	L	M	C	S		0.06	0.03	25.89	0.32	0.01
〃 06					M	0.21	0.04	25.06	1.72	0.02

X-ray Diffractive Analysis
V: very much > M: much > C: common > L: less >
S: scarcely
Ser: Sericite, Mon: montmorillonite, Kao: kaolin
Ana: anatase
Oth: others GITAX-05 ---- plagioclase, hornblende, phlogopite are M, chlorite is S
GITAX-09 ---- chlorite is S, halloysite is M
GITBX-01 ---- hornblende is S, chlorite and loughlinite are L
GITBX-04 ---- loughlinite is M
GITBX-06 ---- hornblende and loughlinite are M.

Fig. CR-10 Vein and Sampling Location of Gitana II Mine

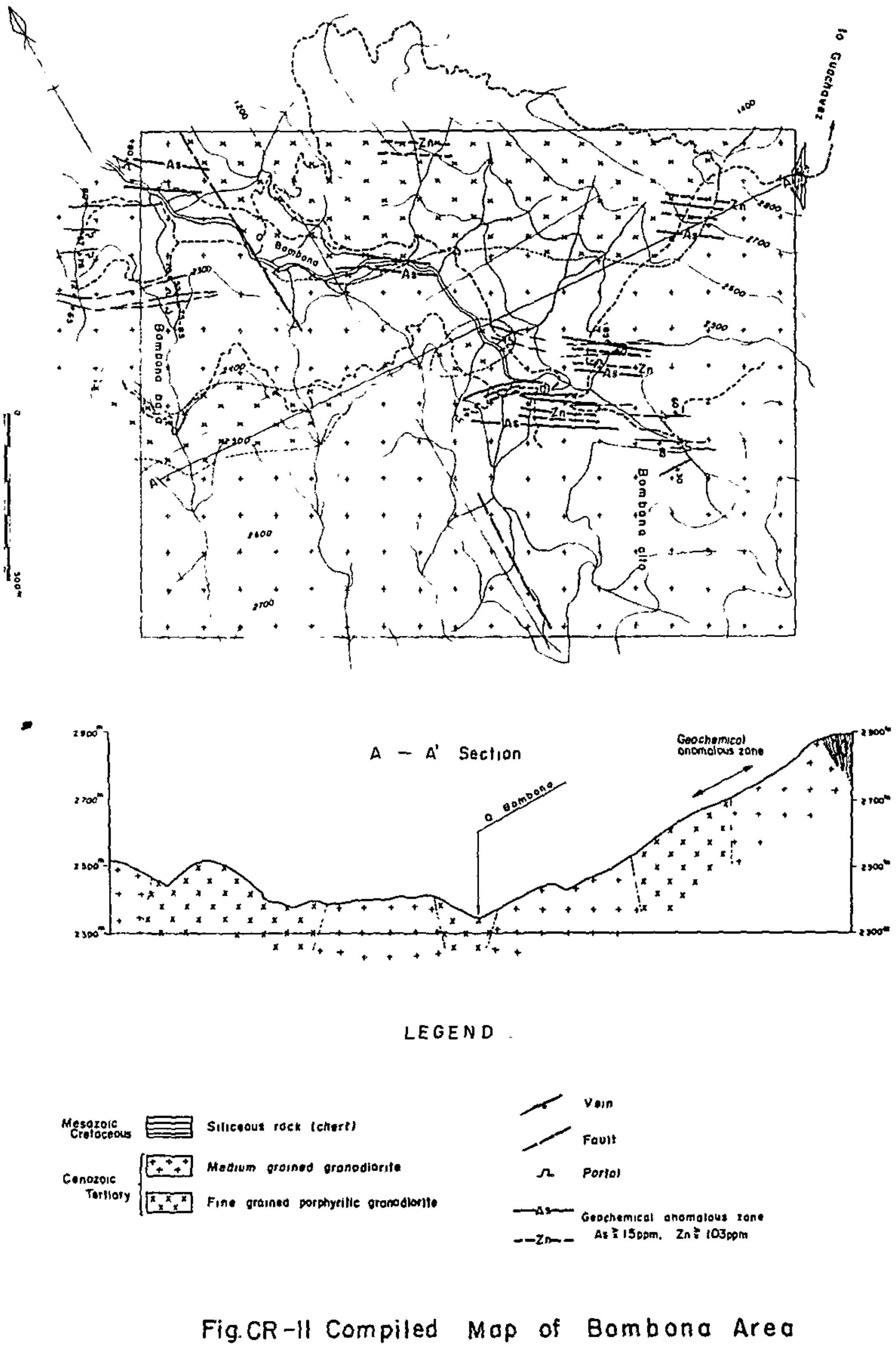


Fig.CR-11 Compiled Map of Bombona Area

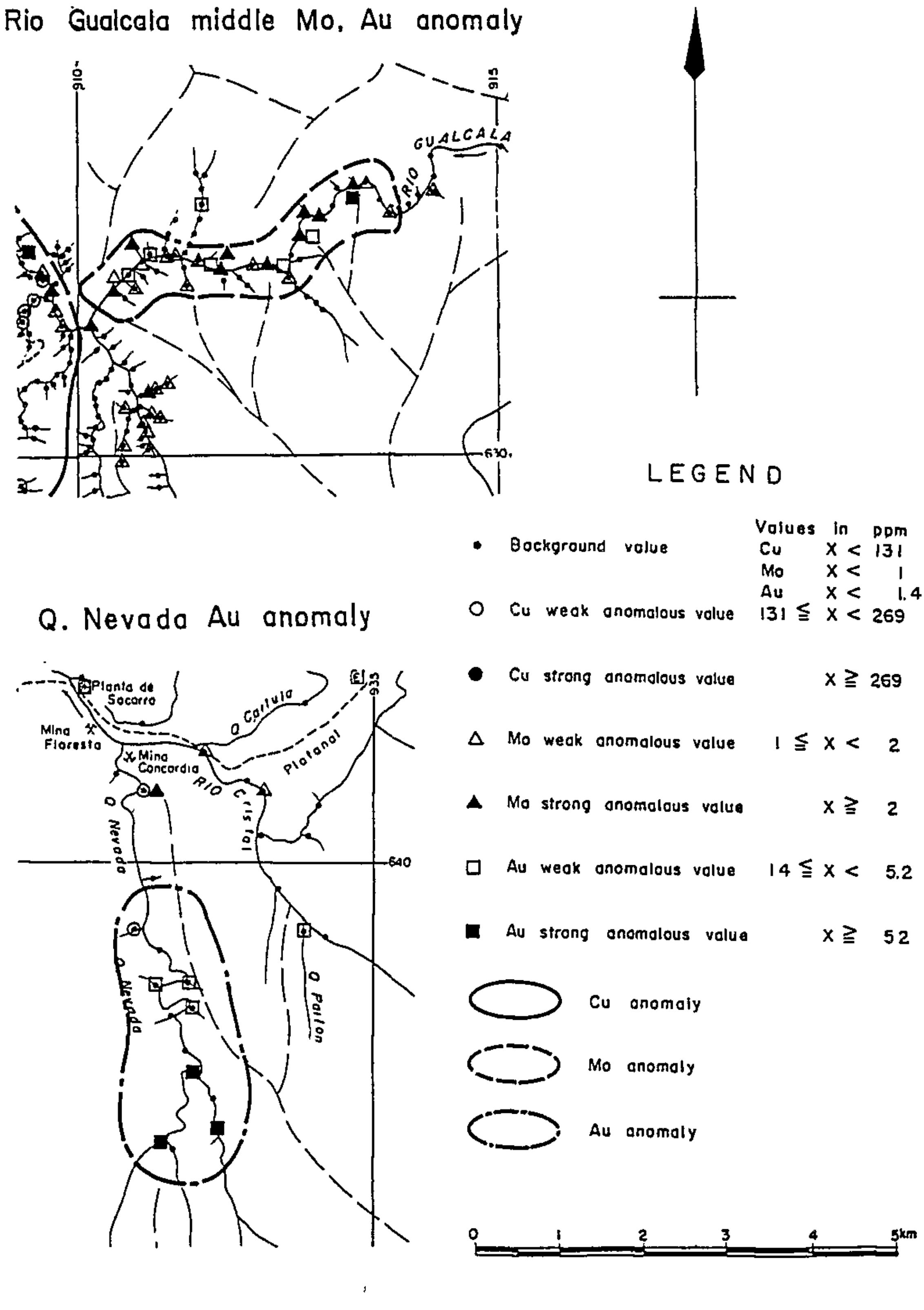


Fig. CR-12 Geochemical Map of Gualcala — Middle and Nevada Area

CHAPTER 5. DIAMANTE-PARAISO-BOMBONA AREA

Individual gold mines and mineral showings in this area are described in the previous Chapter 4-3-2 (1) to (7). During the third phase, detailed geological survey and detailed geochemical exploration found many anomalous zones.

The relation between anomalous zone and mineral showing in the known ore deposit suggests that there exists high possibility of existence of unknown ore veins (cf. Table CR-5 and Fig. CR-15).

During last two years, fifteen holes were drilled to the principal vein of Diamante ore deposit which is the largest known bonanza in this area. The samples collected during the survey in this area were studied under microscope, X-ray diffractometer, electron probe microanalyzer etc. The results of the study show useful guideline not only for exploring the extension of Diamante mine area but exploring the above mentioned new prospective veins. The following are noticeable.

5-1 Vein Structure

(1) Strikes of veins are mostly in NW-SE direction. There are recognized three mineralized zones where many veins are concentrated and their total width are several hundreds meters. The country rock is granodiorite except in the south eastern part of Diamante area where the country rock is tuff breccia. The change of strike due to the difference of the country rock types has not been recognized.

(2) The vein structure has generally NW-SE strike. However, there are two differently directed veins, the one with N45°W strike and vertical and the other N65°W strike and about 60°NE dip. The latter veins tend to form bonanza. The direction of the latter veins are seemed to be following a

direction of spaces which was formed when the northeastern part, being separated by faults, moved to north-east direction.

(3) Dip of the bonanza of Diamante Mine is about 45°NW and its strike is the intersection of the two directions shown in the previous paragraph (cf. Fig. CR-14)

(4) The part containing gold ore in the veins is 5 cm to 80 cm wide and 100m to 200m long. Diamante ore deposit was formed in tuff breccia, where the vein has a spreaded bonanza of 5m thick or more whereas Bombona ore deposit was formed in granodiorite, where the veins are generally narrow.

(5) After mineralization, veins were cut by N-S fault and moved in such a way that the western side moved to north.

5-2 Mineralization

(1) Constituent minerals of the veins are quartz, dolomite, pyrite arsenopyrite, sphalerite, chalcopyrite and galena. Furthermore, by microscopic study and electron probe microanalyzer study, tetrahedrite, argentite, polybasite, pyrargyrite, proustite, freibergite and argentiferous Pb-Bi mineral were also found with very minor amount.

(2) Irregularly shaped gold grains of a few μ to 100 μ are in quartz and arsenopyrite and between sulphide minerals as a form of electrum.

(3) Gold contents in the veins are generally 4 to 10 g/t. Among all analysis samples collected during three years, the samples with high gold content are as follows:

Oxide ore of 40 cm width from Bombona Mine: 80 g/t

35 cm of Bombona Q 18 outcrop: 43.6 g/t

1m width in the Diamante tunnel: 25.5 g/t

Between 90.9m and 93.0m of the drilling No. PD-6: 25.4 g/t

Between 109.0m and 110.0m of the drilling No. PD-10: 24.8 g/t

(4) Sequence of crystallization in Diamante Mine is inferred from microscopic study as follows: (a. earliest to d. latest)

a. pyrite, arsenopyrite, electrum

b. sphalerite, chalcopyrite, galena, argentiferous Pb-Bi mineral, tetrahedrite

c. pyrite, marcasite, argentiferous Pb-Bi mineral

d. Argentite, pyrargyrite, proustite

Between b and c, a faulting movement occurred and crystalized minerals were brecciated. Minerals of c and d are observed between those brecciated minerals in a form of veinlets.

5-3 Alteration

(1) The alteration in the area is zoned into sericite-montmorillonite zone along ore veins and kaolinite-chlorite zone at the outside. However, alteration is generally limited only a few tens of centimeters from veins.

(2) Quartz veins as silicified zone were seen in a few meters away from vein structures, but within several tens of centimeters from veins, silica content decreases, devitrification was recognized and argillization like montmorillonitization became dominant. Ore veins accompany quartz veins and large amount of sericite.

(3) The distribution of silica is as stated above. Calcium content increases with increase of the distance from ore veins and arsenic decreases with the distance from ore veins. Calcium is contained more in country rock, especially green volcanic rocks.

(4) Where green volcanic rock, country rock of Diamante ore deposit, suffered alteration along ore veins, its color changed from dark black to grey through light brownish color. However, grade of alteration

in this ore deposit does not have direct relation with ore grade.

5-4 Fluid Inclusion Study

Twenty quartz samples were collected from drilling's core of Diamante principal vein and homogenizing temperatures were determined about them. The size of inclusion was too small to examine their salinity.

Inclusion's grain size is 3 to 15 μ, and rarely 20 μ at its maximum, composing of aqueous and gaseous phases.

Three-phase inclusion were not observed. LINKAM-JH600 type equipment was used for the temperature measurement, and about ten or more in number of inclusions were measured for each sample. The results are shown in Fig. CR-16. Although the number of samples for such examination are too small, it may be useful to enumerate following items as a result.

(a) Temperature shows a variation from 188°C to 390°C, making a predominent peak around 345° and another small peak around 250°C.

(b) Two pairs of samples which locate very close each other, show very different temperature. This may indicate a character of complex ore vein.

(c) When the temperature is high, gold content shows higher value in general. This may coincide with the results of microscopic observation of ores saying that electrum precipitated in the early stage of mineralization.

(d) In the quartz samples from non-mineralized part, the inclusions are scarce and very fine grained.

Table CR-5 List of Drilling Holes in the Diamante Mine

Drill.Hole No.	Coordinate N	E	Elevation (m)	Direction	Inclination	Depth (m)
PD - 1	2,017	12,014	2,501.9	0°	-90°	83.50
PD - 2	1,922	12,063	2,513.4	345°	-5°	81.00
PD - 3	1,922	12,063	2,513.4	70°	-5°	90.60
PD - 4	1,900	12,248	2,598.1	220°	-35°	100.10
PD - 5	1,900	12,248	2,598.1	220°	-60°	120.70
PD - 6	1,771	12,330	2,644.0	200°	-60°	120.60
PD - 7	1,771	12,330	2,644.0	200°	-80°	160.70
PD - 8	1,950	12,196	2,564.5	225°	-75°	180.50
PD - 9	1,740	12,208	2,604.4	45°	-30°	131.00
PD -10	1,740	12,208	2,604.4	45°	-50°	200.50
PD -11	1,619	12,290	2,606.6	60°	-40°	140.50
PD -12	1,619	12,290	2,606.6	60°	-55°	200.20
PD -13	1,524	12,377	2,618.8	60°	-40°	121.50
PD -14	1,524	12,377	2,618.8	60°	-60°	200.20
PD -15	1,443	12,434	2,624.1	60°	-60°	161.50
Total						2,093.10

Table CR-6 List of Geochemical Anomalous Zone

		Anomalous Zone	Direction	Width and Length (m)	Number of Anomalous Samples: As			Zn		Related geology
					S	S+I	S+I+W	S	S+W	Mine, vein
1		Gitana-Marina	N50°W	100 x 1000	1	1	7	1	1	Mina Gitana Segunda Mina Marina
2	Gitana-NW	Gitana-NW (A)	N45°W	30∿120x200+	2	3	6	1	1	
		" (B)	N50°W	100∿200x600+	8	13	28	4	6	Granite dyke
		" (C)	N45°W	50 x 400?	/	/	11	/	2	
		" (D)	N55°W	50 x 800?	1	3	8	1	1	Mina Gitana primera
		" (E)	N55°W	70 x 800?		6	11	/	1	
3		Desquite	N45°W	100 x 700	/	/	3	4	11	Mina Desquite
4		Q. Lulo	N60°W ∿N45°W	200 x 1500?	/	1	20	/	3	Quartz vein
5		San Antonio	N70°W	300 x 1600?	/	4	17	/	3	Mina San Antonio vein
6		San Antonio-(S)	N55°W	300? x 2400?	/	3	23	/	4	Vein
7		San Luis	N50°W	200∿400x2000+	9	21	60	/	4	Mina San Luis vein
8		San Luis-W (1)	N50°W	100∿400x1200+	4	13	29	/	3	
9		San Luis-W (2)	N35°W	100∿300x 700+	3	14	20	/	4	
10		Delicia	N55°W	100∿400x2000?	5	19	44	2	5	Mina Delicia vein
11		Delicia - NW	N55°W	400? x 1500?	3	7	17	2	4	
12		Delicia - W	N55°W	100∿200x1000?	/	1	6	/	2	
13		Bombona - N	N55°W	250 x 1000+	2	3	12	/	2	
14	Bombona-NW	Bombona-NW (A)	N40°W	50∿100x1000?	1	6	16	/	1	
		" (B)	N50°W	200 x 800+	3	16	31	/	2	vein
		" (C)	N55°W	200 x 800+	5	16	40	2	4	vein

S: Strong anomaly, I: Intermediate anomaly, W: weak anomaly

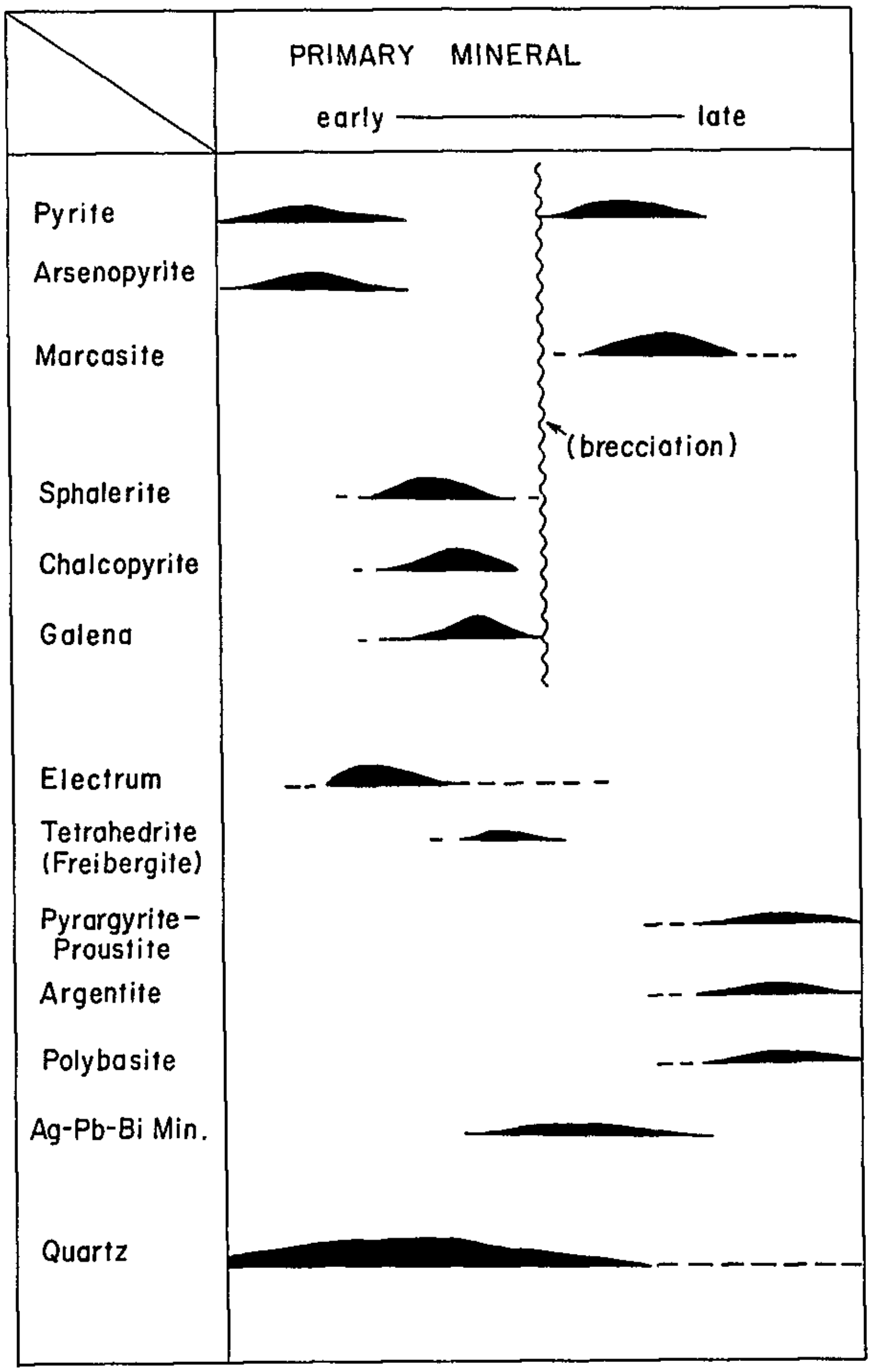


Fig. CR-13 Paragenetic Sequence of Minerals in the Diamante Principal Vein

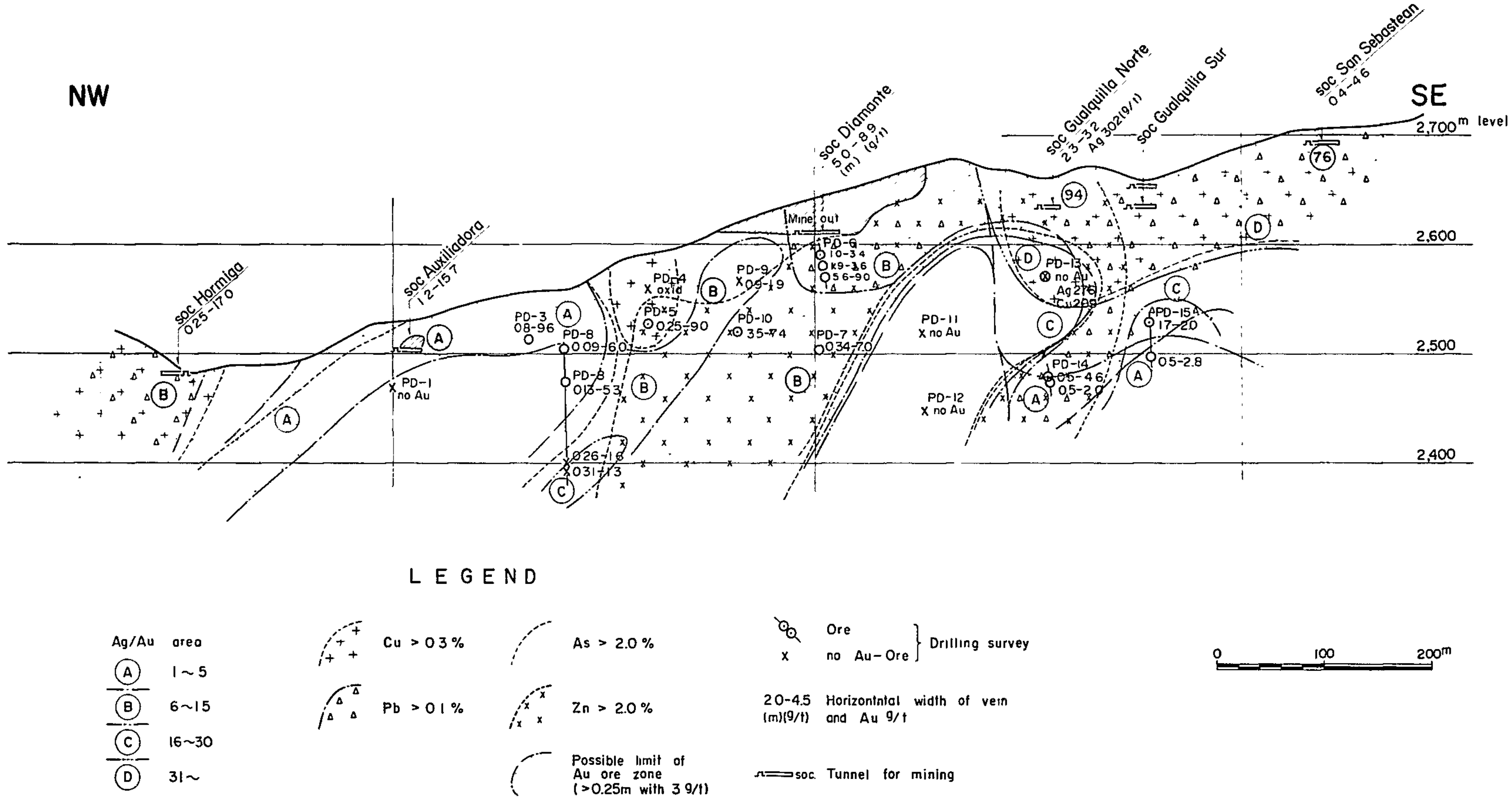


Fig. CR-14 Longitudinal Section of Diamante Principal Vein for Studying Survey Results

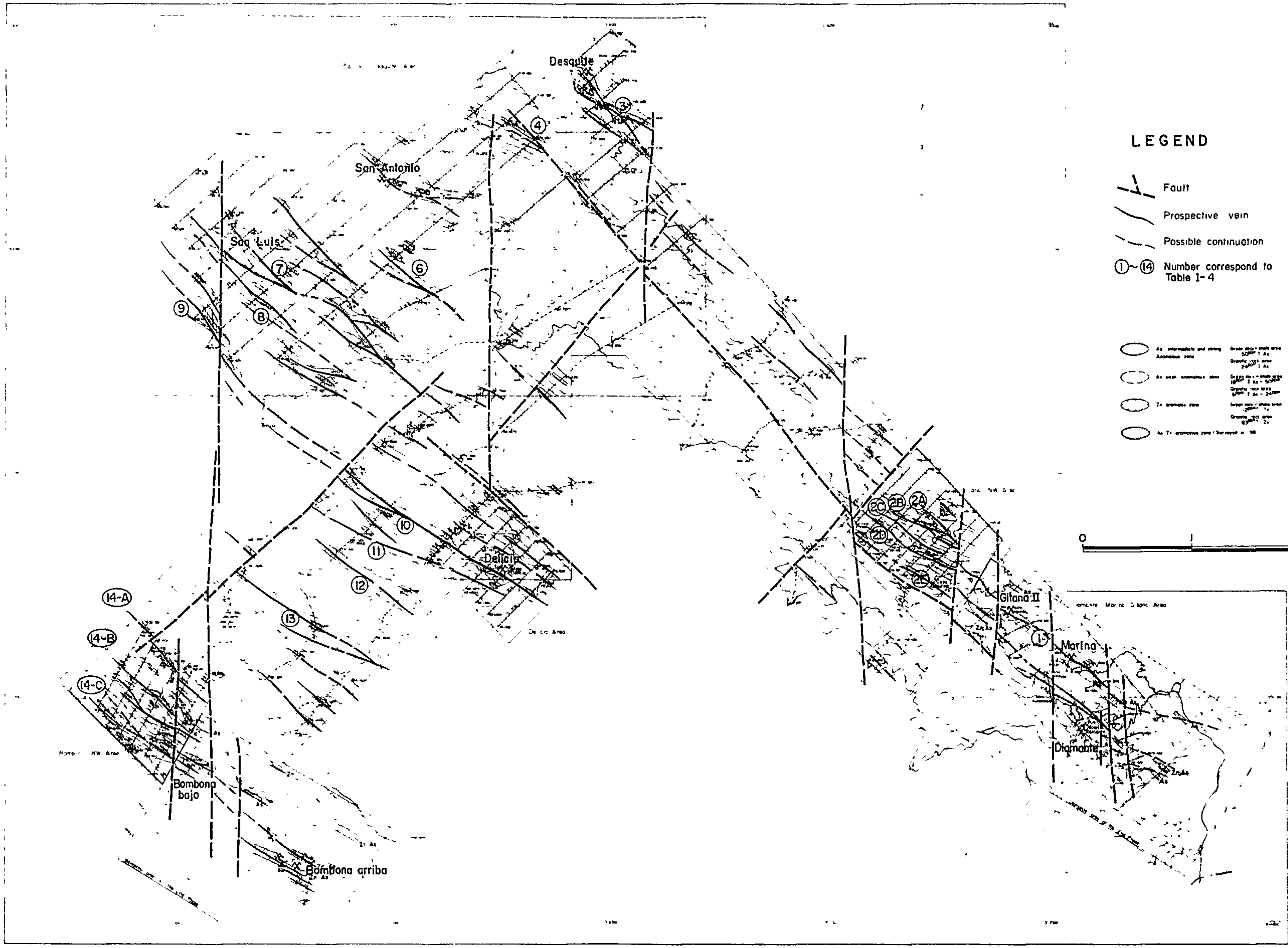
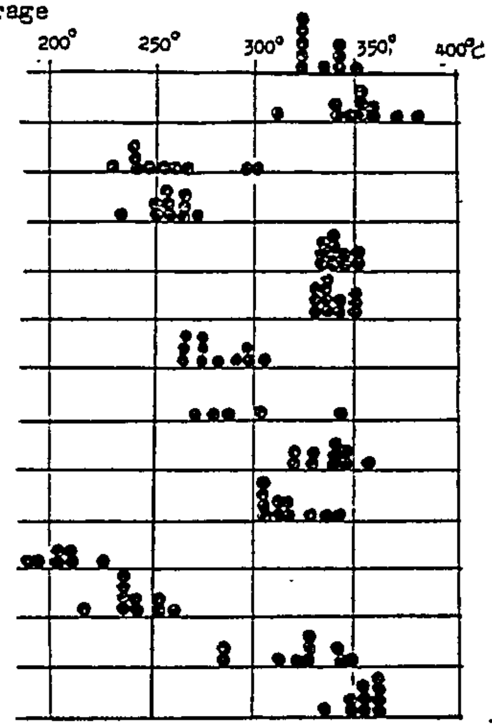
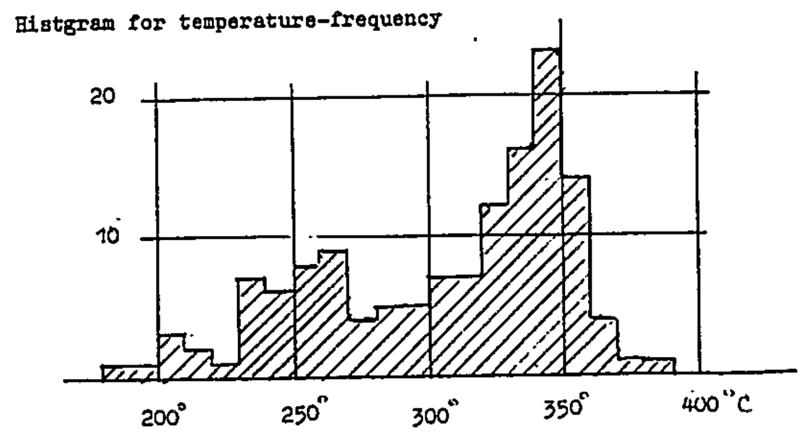


Fig. CR-15 Prospective Zones extracted after Geochemical Survey in the Diamante — Paraiso — Bombona Area

Sample No.	Location D.D.H.	-depth m	TEMPERATURE min.-max. °C	Num.	Average °C
3	PD-10	111.5	322°--351°	10	334°
4	PD-10	114.6	312°--380°	11	352°
7	PD-12	191.6	230°--300°	10	257°
8	PD-12	193.6	233°--269°	10	256°
13	PD-15	115.7	294°--352°	10	337°
15	PD-15	148.9	329°--351°	12	389°
17	PD-1	33.6	262°--306°	11	281°
18	PD-5	105.7	271°--343°	5	297°
19	PD-5	109.2	319°--355°	10	336°
20	PD-6	64.8	303°--342°	11	317°
21	PD-6	93.8	188°--226°	7	205°
22	PD-7	142.2	217°--260°	10	240°
23	PD-7	144.8	284°--347°	10	321°
24	PD-8	90.6	334°--363°	10	353°



note;Sample No.6(PD-11 134.5m),No.9(PD-13 101.5m),No.11(PD-14 126.8m) No.12(PD-14 163.0m),No.25(PD-8 119.8m),No.26(PD-9 81.5m) are not determinated because their inclusion are too small and scarece.



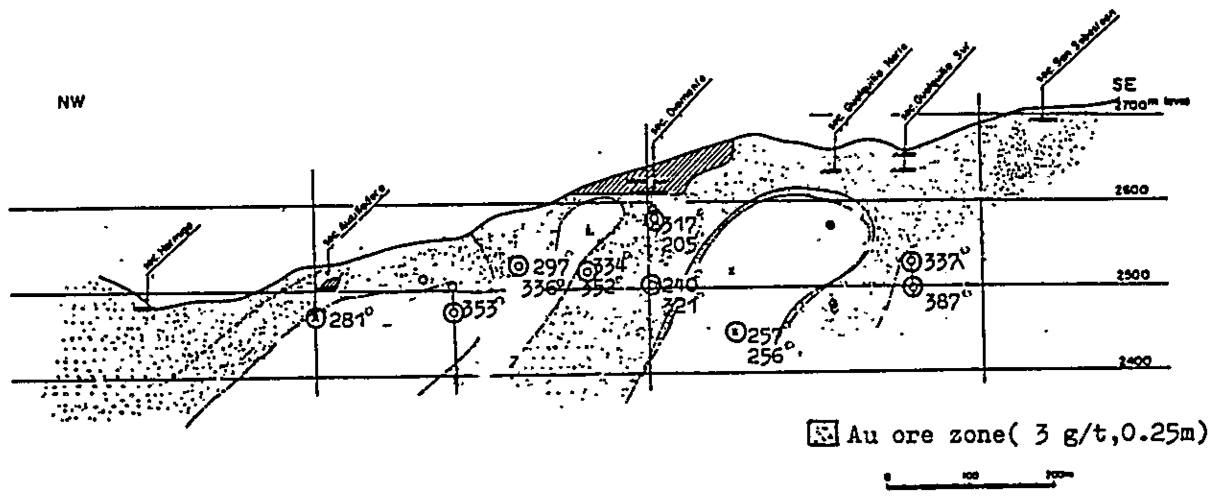


Fig.CR-16 Location of Samples for Fluid Inclusion Study and their Results

CHAPTER 6. CONCLUSION AND RECOMMENDATION

1. Conclusion

(1) Three types of ore deposits, porphyry copper, auriferous polymetallic vein and alluvial gold are expected to occur in the surveyed area.

(2) Five showings of porphyry copper deposit were detected in the north western part of the surveyed area. Two of the five showings were investigated by geological and geochemical survey which led to conclusion that the mineralization appears to be weak and low grade judging from the alteration and dissemination of copper minerals in wall rock.

(3) The auriferous polymetellic vein type deposits, mainly occur in the north eastern and south eastern parts of the surveyed area have been worked in a small scale.

After investigation of those mines, it was concluded that the group of mines, distributed in the north eastern part such as El Tabano and Concordia, were almost mined out whereas the others, distributed in the south eastern part, such as Diamante, Bombona, have a possible remaining ore reserves.

Drilling exploration conducted at Diamante mine disclosed an extension of the mineralized zone and existence of sizable ore bodies.

Geological survey and detailed geochemical exploration carried out in the area covering Diamante, Paraiso and Bombona revealed the presence of several unknown mineralized zones.

In addition to that, an effective guidance for future exploration was obtained through various studies such as vein pattern, mineral paragenesis and distribution of elements etc.

(4) Two alluvial gold showings, Nevada and Gualcala-middle, were extracted for further exploration target. Nevada is located in a rugged terrane

and the origin of placer gold is unknown yet. Gualcala-middle which has a fairly large river sediments, is presumed to be derived from Bombona mine situated in the upper stream.

2. Recommendation

At the closure of the survey of Japanese Government's technical cooperation, it is recommended that the following work are required to persue mineral development in this project area.

(1) Auriferous polymetallic vein type deposit: It is recommended to study a possibility to develop and operate a small scale Diamante mine (75 - 150 TPD) on principal vein, Marina veins and Gitana veins. Exploration of Paraiso and Bombona areas can be accelerated by the development of these mines.

Since the Diamante ore contains much arsenic which causes metallurgical problem, it is advisable to conduct a metallurgical test and preliminary feasibility study. Results of these study will greately contribute to the development of the similar type of deposits in the surrounding area.

(2) Alluvial gold showings

Further exploration in Gualcala-middle and Nevada areas is recommendable. As to Gualcala-middle, it is recommended to conduct a topographical survey and a systematic sampling in order to grasp the ore reserves to the geochemical anomalous area delineated by the first phase survey.

In Nevada it is advisable to conduct a geological and geochemical prospecting covering entire vicinity in addition to systematic survey to the anomalous area.

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Appendices

A. CR- 1 ～ 8　Geological Section for Drillings PD. 1 ～15

Geologic Drill Log PD- 1 ～15

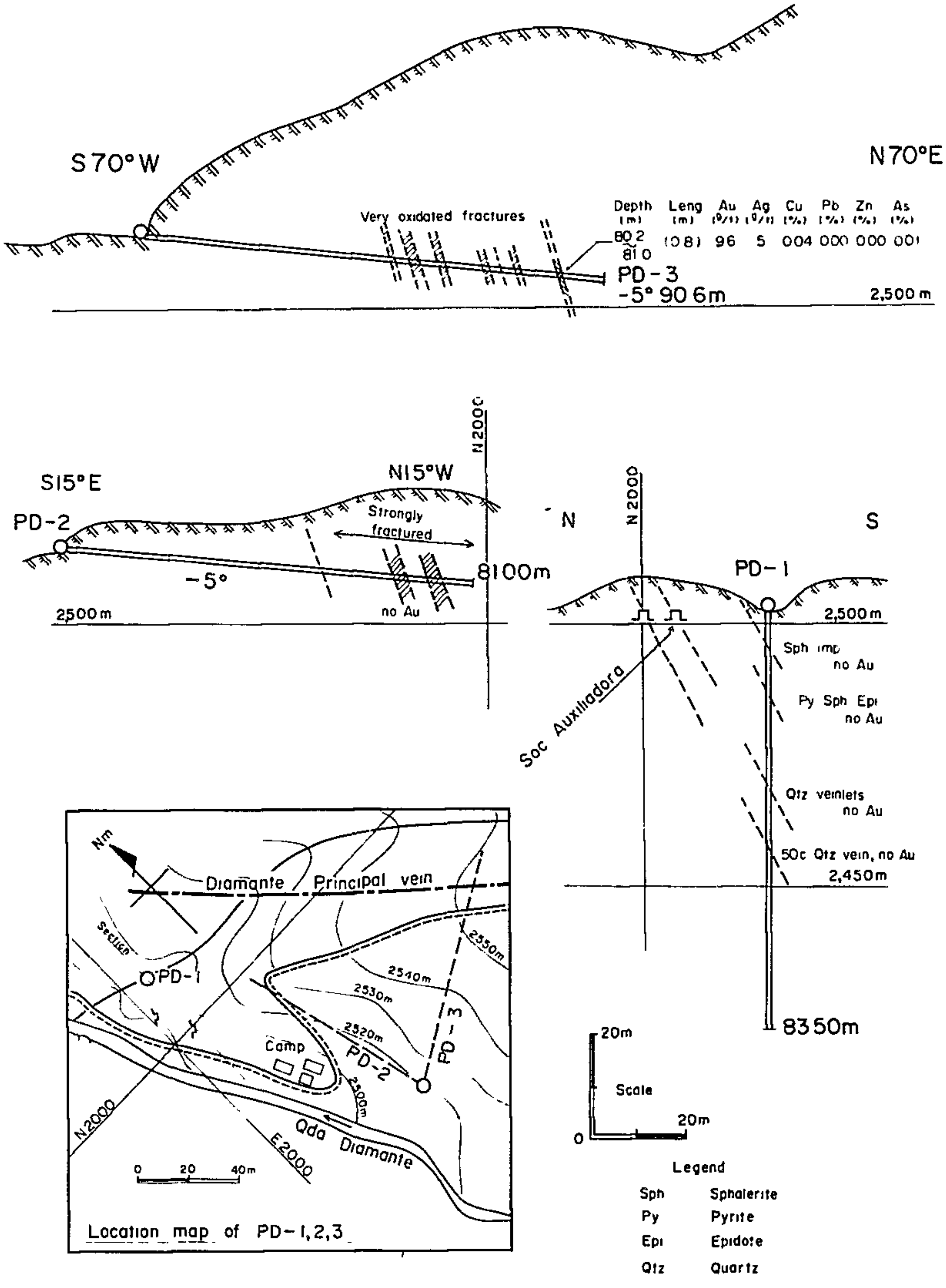


Fig. A.CR-1 Geological Section for PD-1, PD-2, PD-3

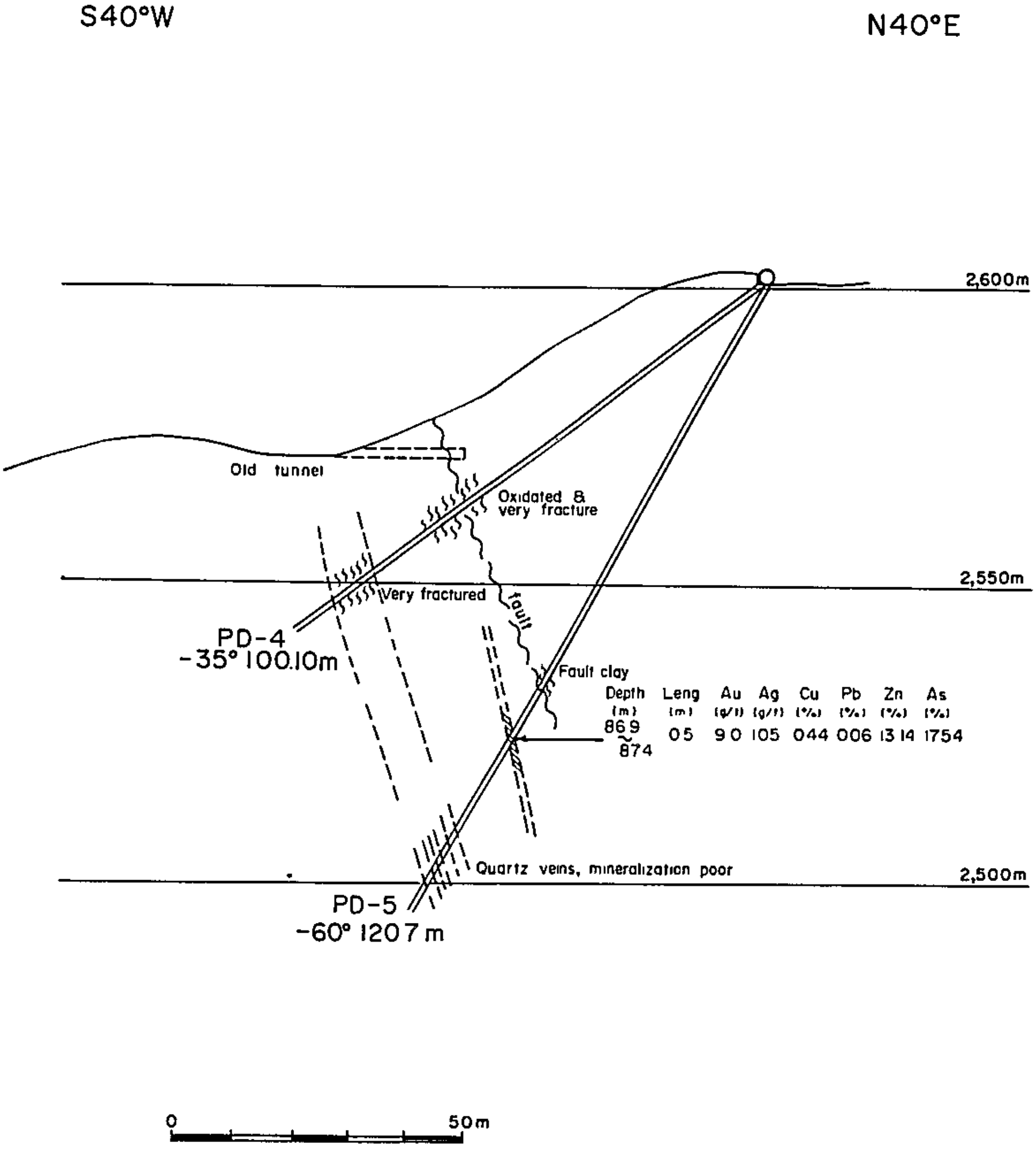


Fig. A.CR-2 Geological Section for PD-4, PD-5

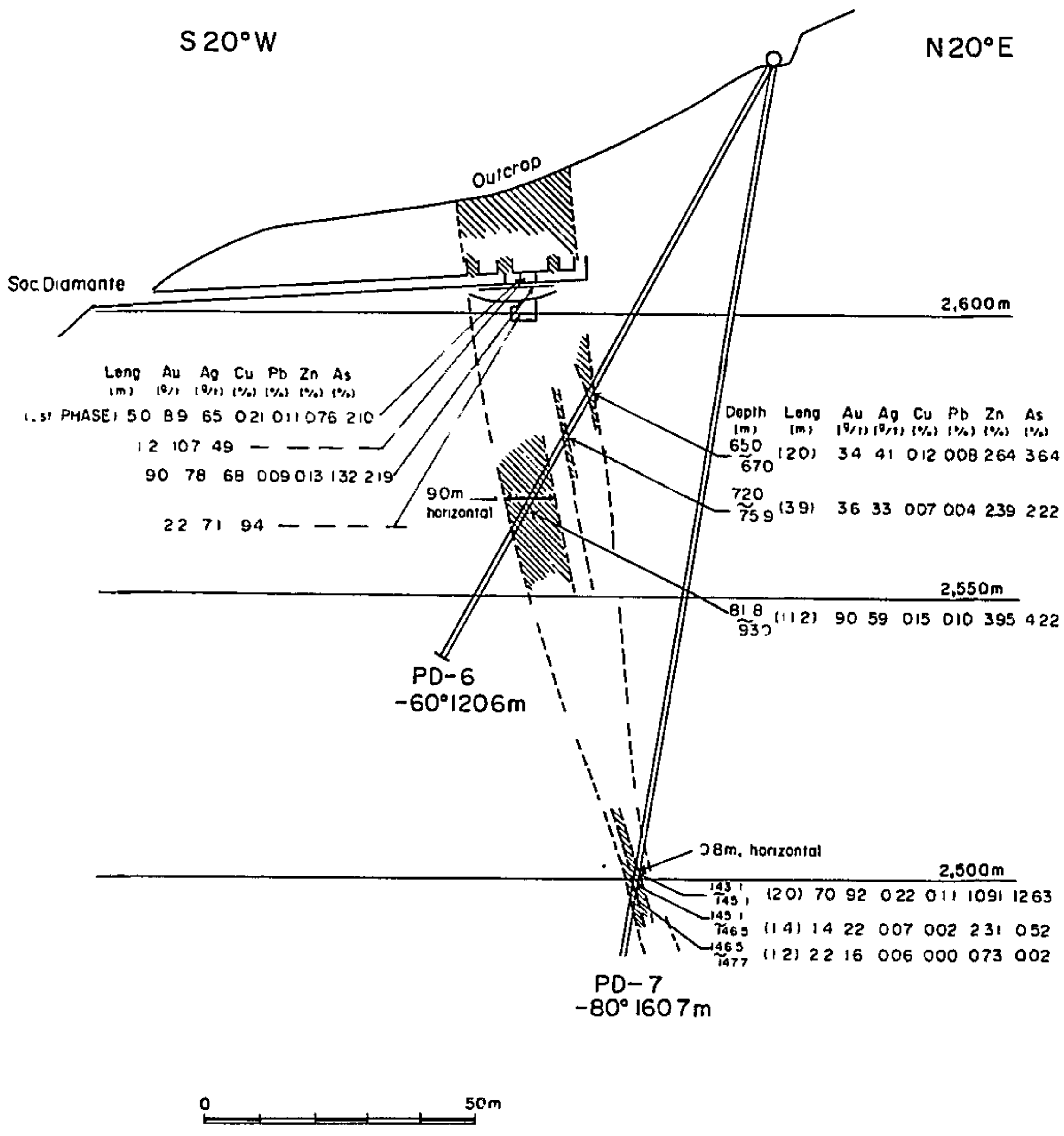


Fig A.CR-3 Geological Section for PD-6, PD-7

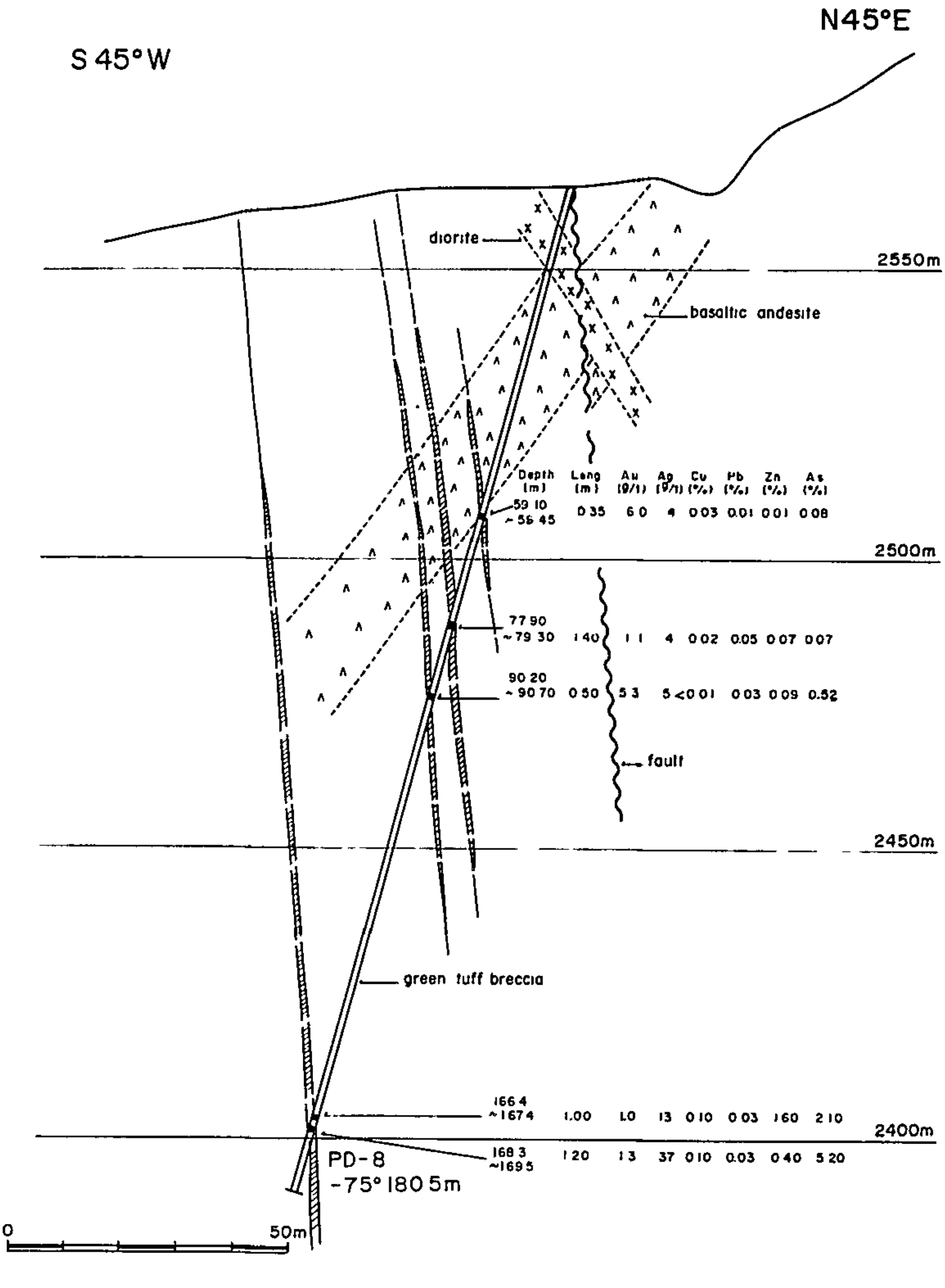


Fig. A. CR-4 Geological Section for PD-8

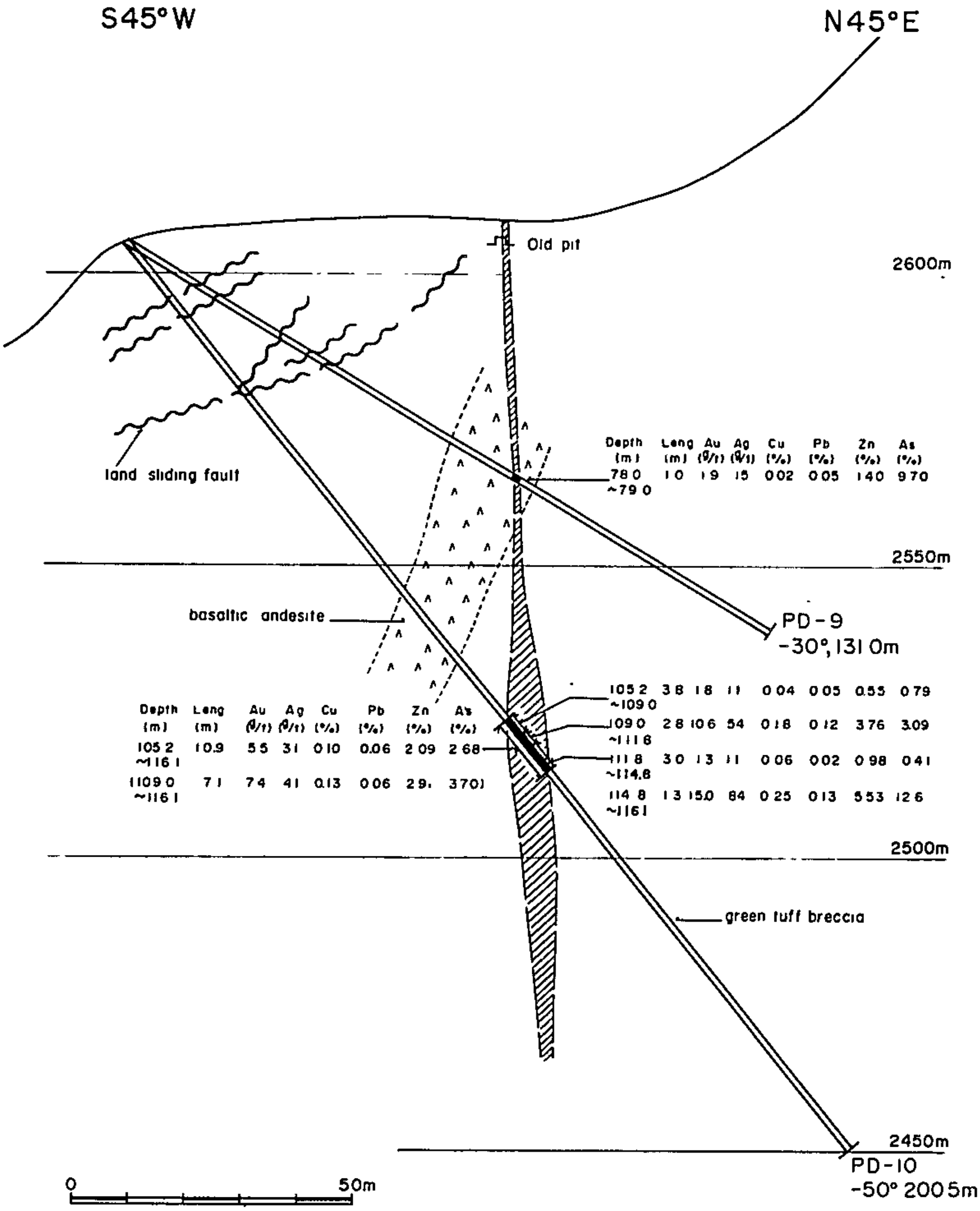


Fig. A.CR-5 Geological Section for PD-9, PD-10

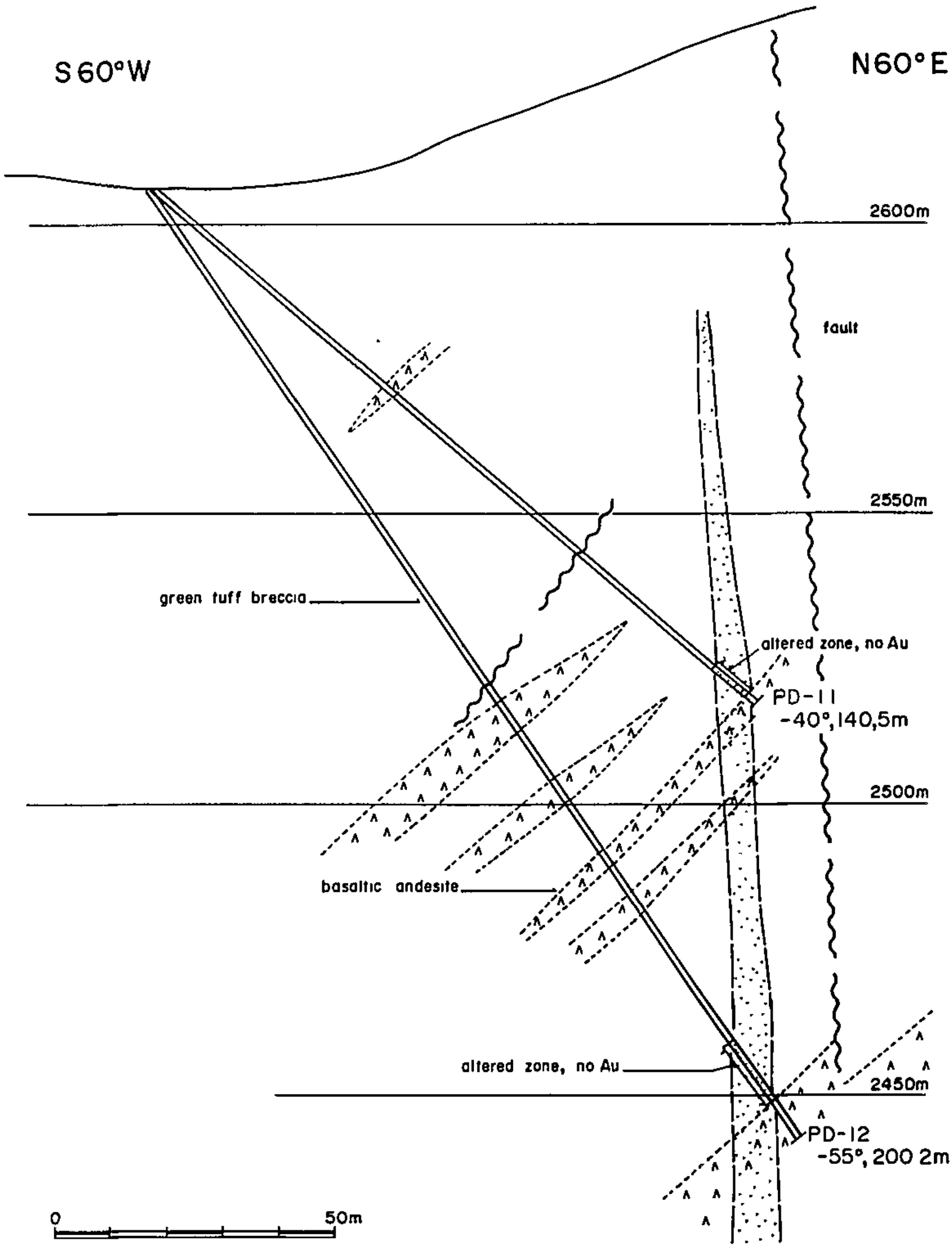


Fig. A.CR-6 Geological Section for PD-11, PD-12

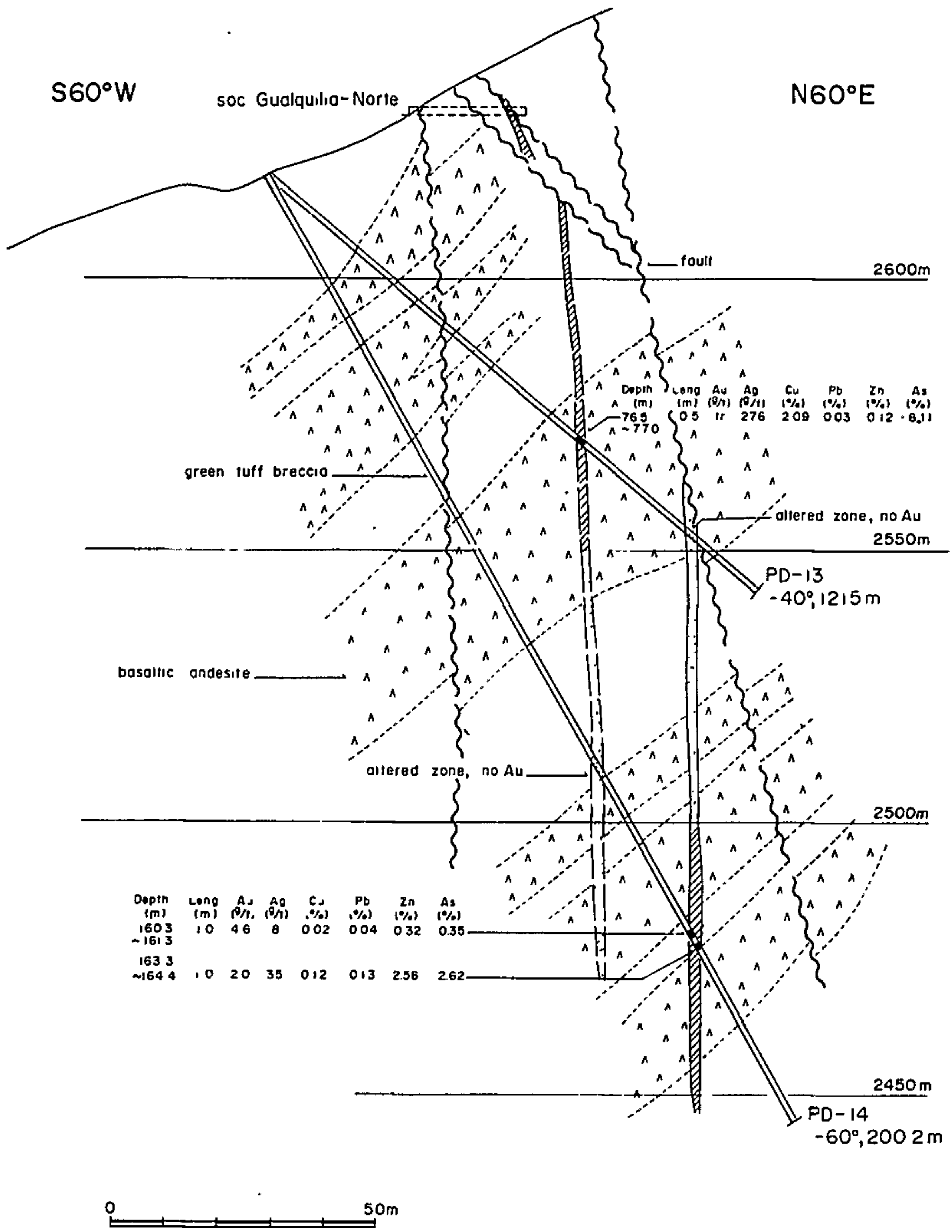


Fig. A.CR-7 Geological Section for PD-13, PD-14

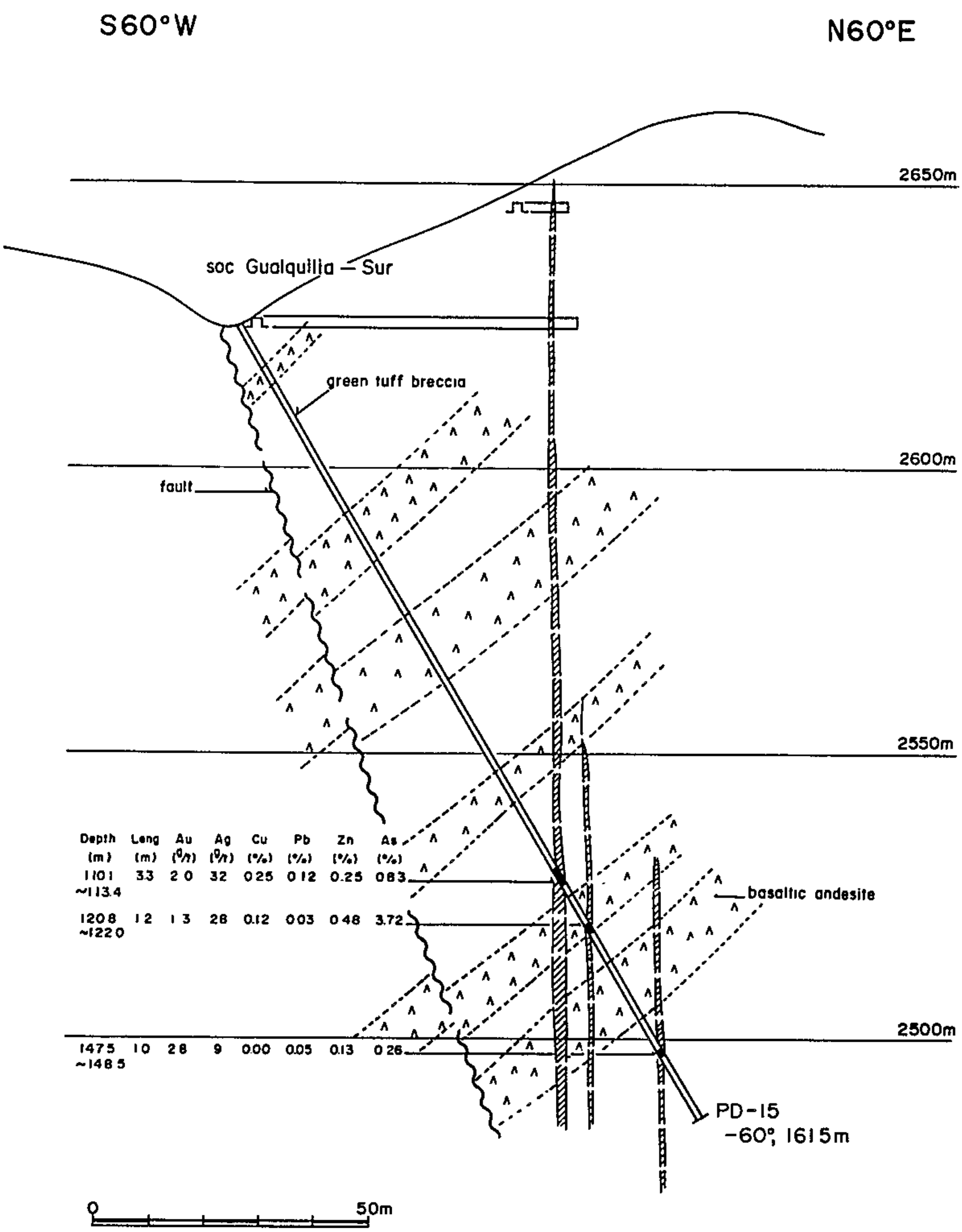
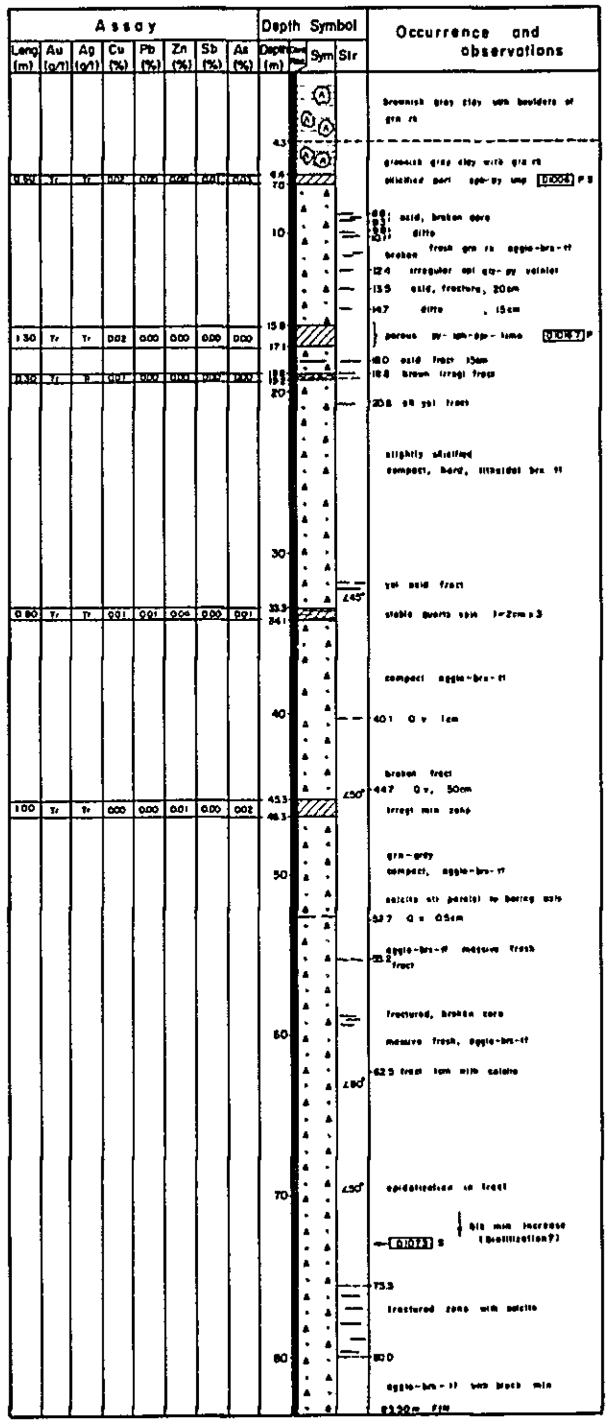
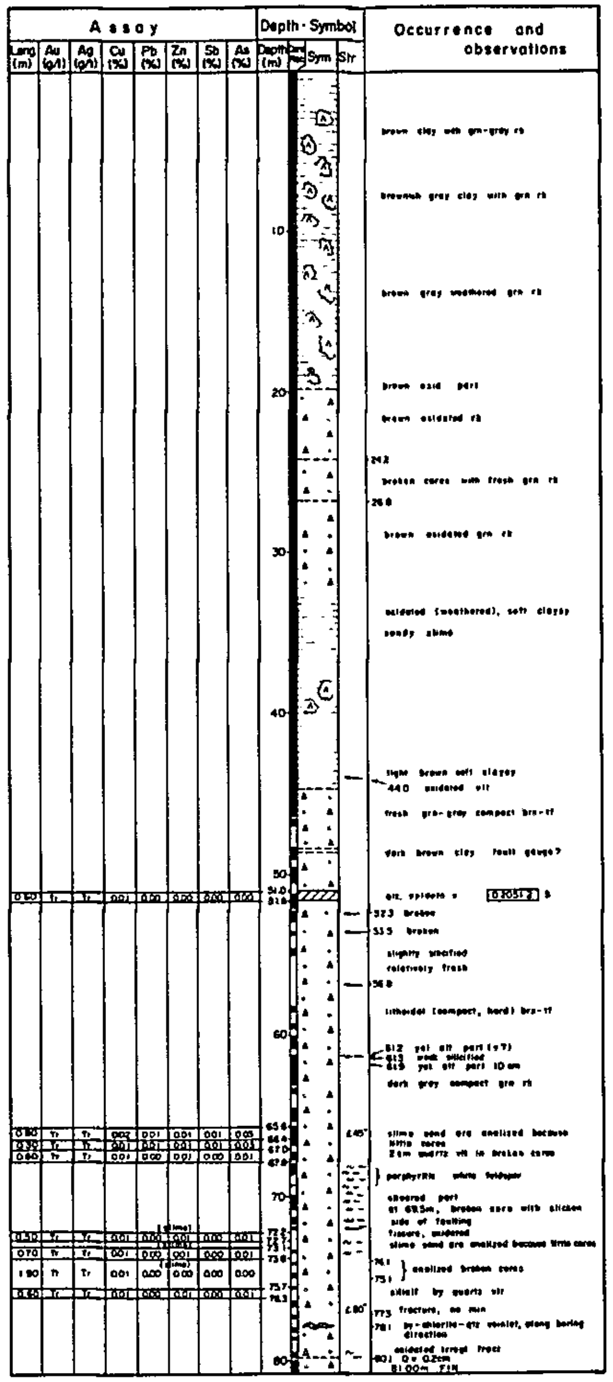


Fig. A.CR-8 Geological Section for PD-15

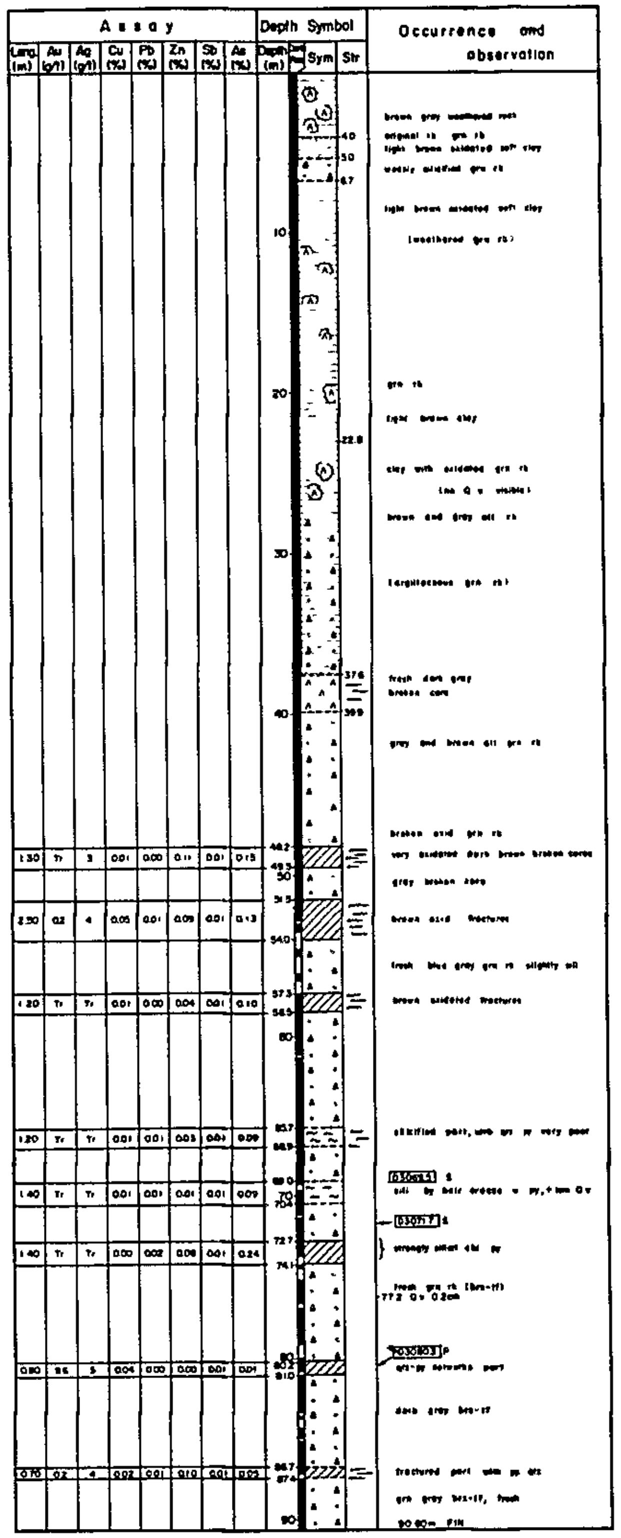
DDH No PD-1
Direction — Coordinate N 2022
Inclination -90° E 2010
Total Depth 83.50m Elevation 2502.5m



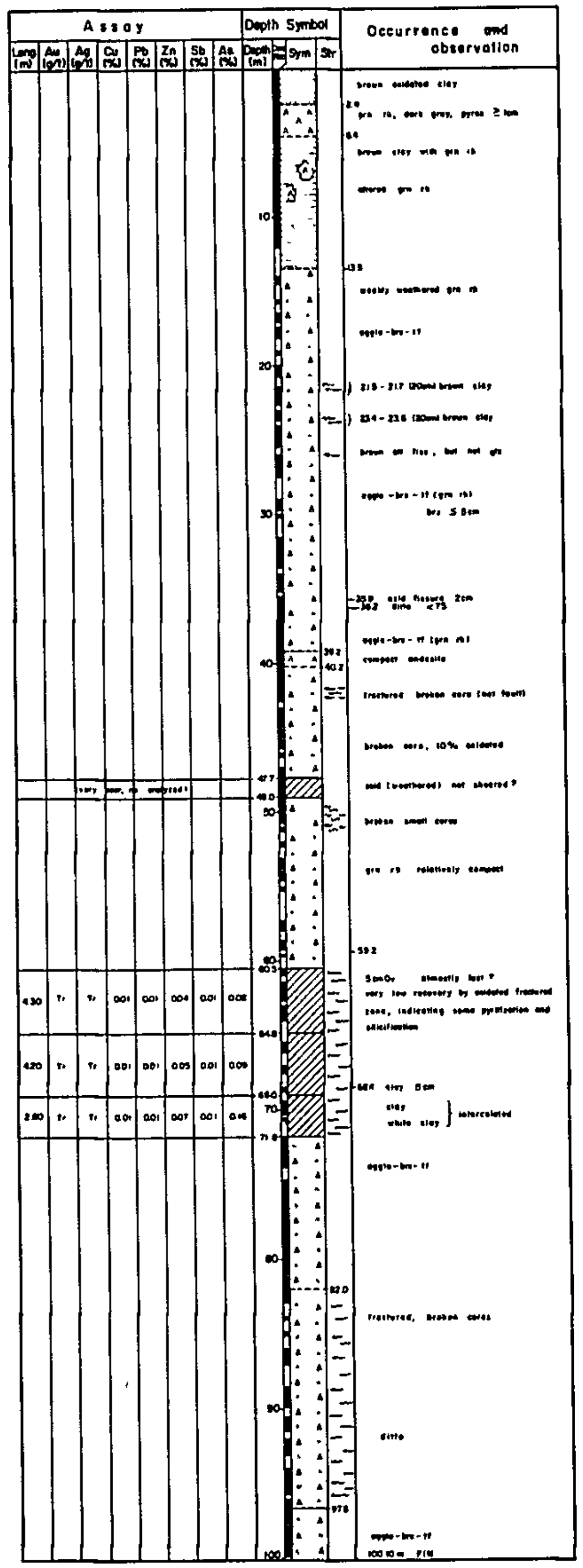
DDH No PD-2
Direction 345° Coordinate N 1919
Inclination -5° E 2058
Total Depth 81.00m Elevation 2513.5m



DDH No PD-3
Direction 70° Coordinate N 1919
Inclination -5° E 2058
Total Depth 90.60m Elevation 2513.5m



DDH No PD-4
Direction 220° Coordinate N 1912
Inclination -35° E 2248
Total Depth 100.10m Elevation 2602.0m

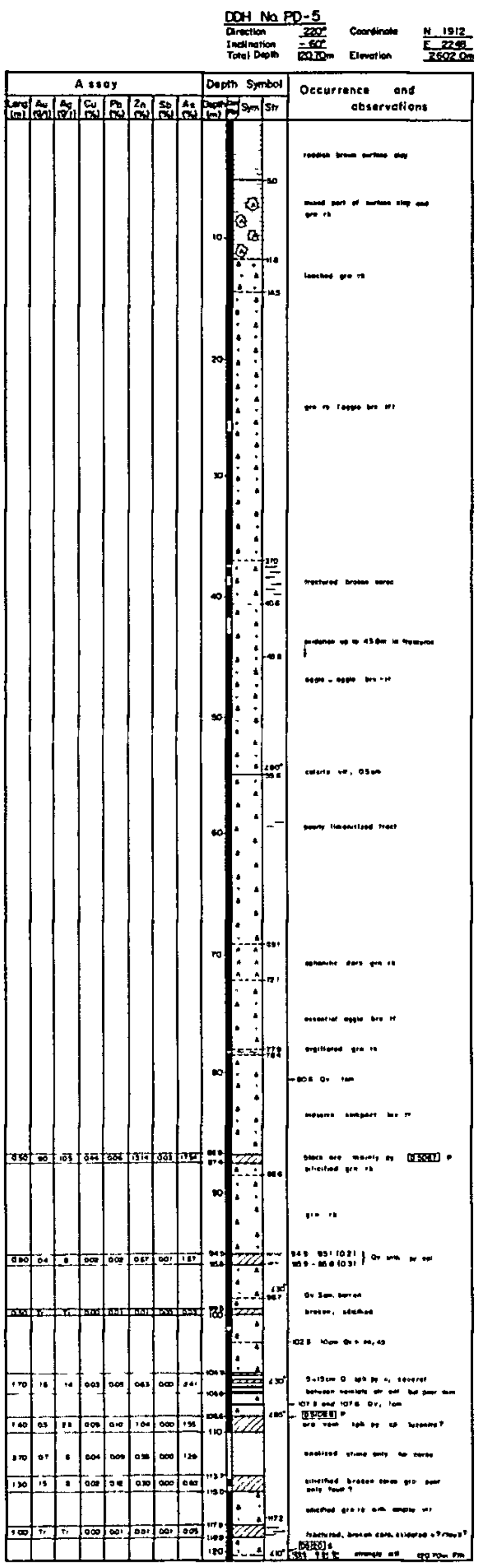


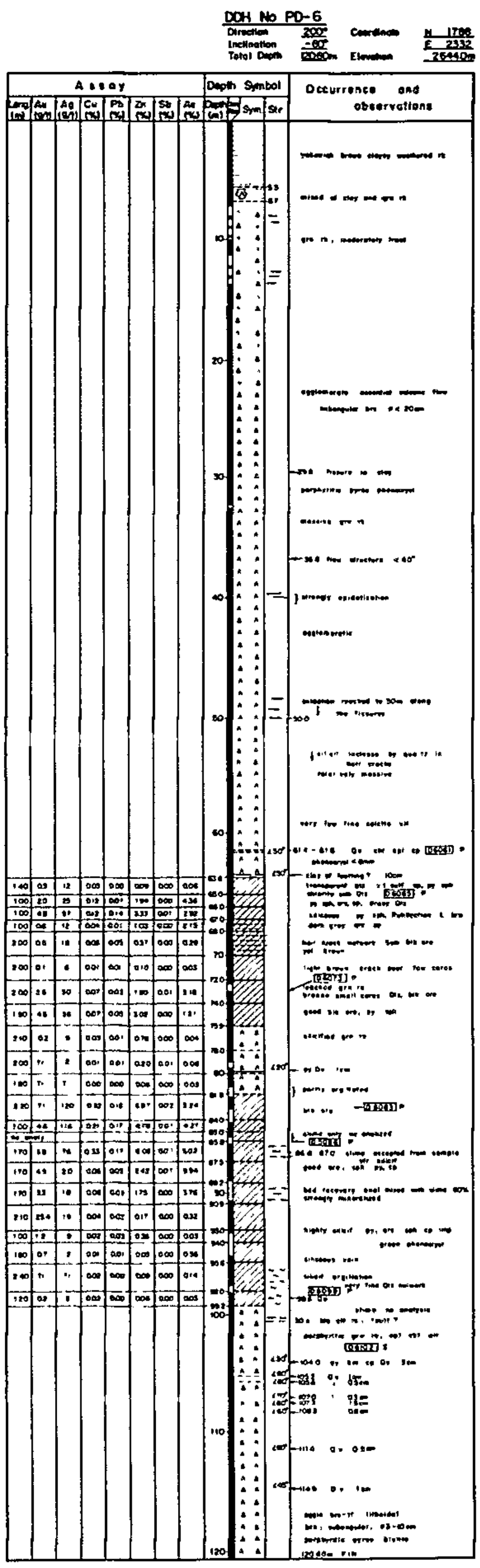
LEGEND

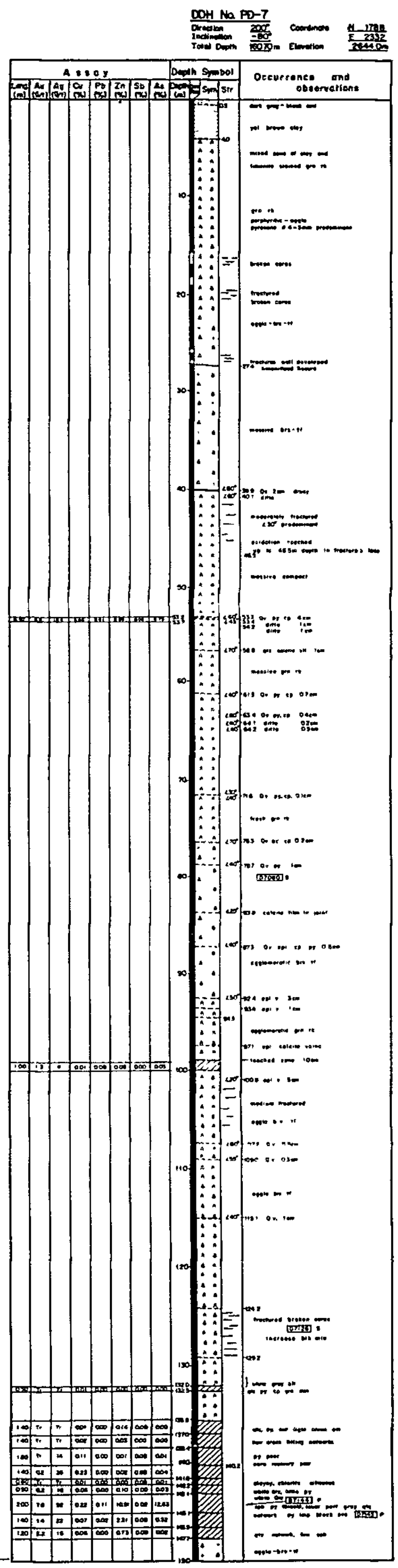
- Green rock
- Tuff breccia
- Agglomerate
- Sandy slime
- Mineralized vein
- Sheared zone
- Fracture

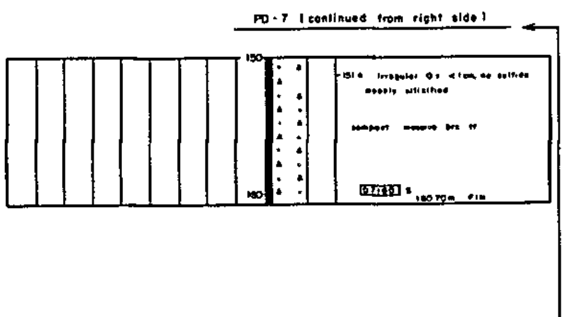
ABBREVIATION

rk	Rock
agglo	Agglomerate
tf	Tuff
fiss	Fissure
vlt	Veinlet
fract	Fracture
net	Network
brs	Breccia
irregl	Irregular
str	Strong
Qv	Quartz vein
sph	Sphalerite
py	Pyrite
cp	Chalcopyrite
ars	Arsenopyrite
hm	Hematite
epi	Epidote
qtz	Quartz
chl	Chlorite
pyrox	Pyroxene
min	Mineralization
imp	Impregnation
limo	Limonitization
oxid	Oxidation
silicif	Silicification
grn	Green
yel	Yellow
L-brw	Light brown
blk	Black









LEGEND

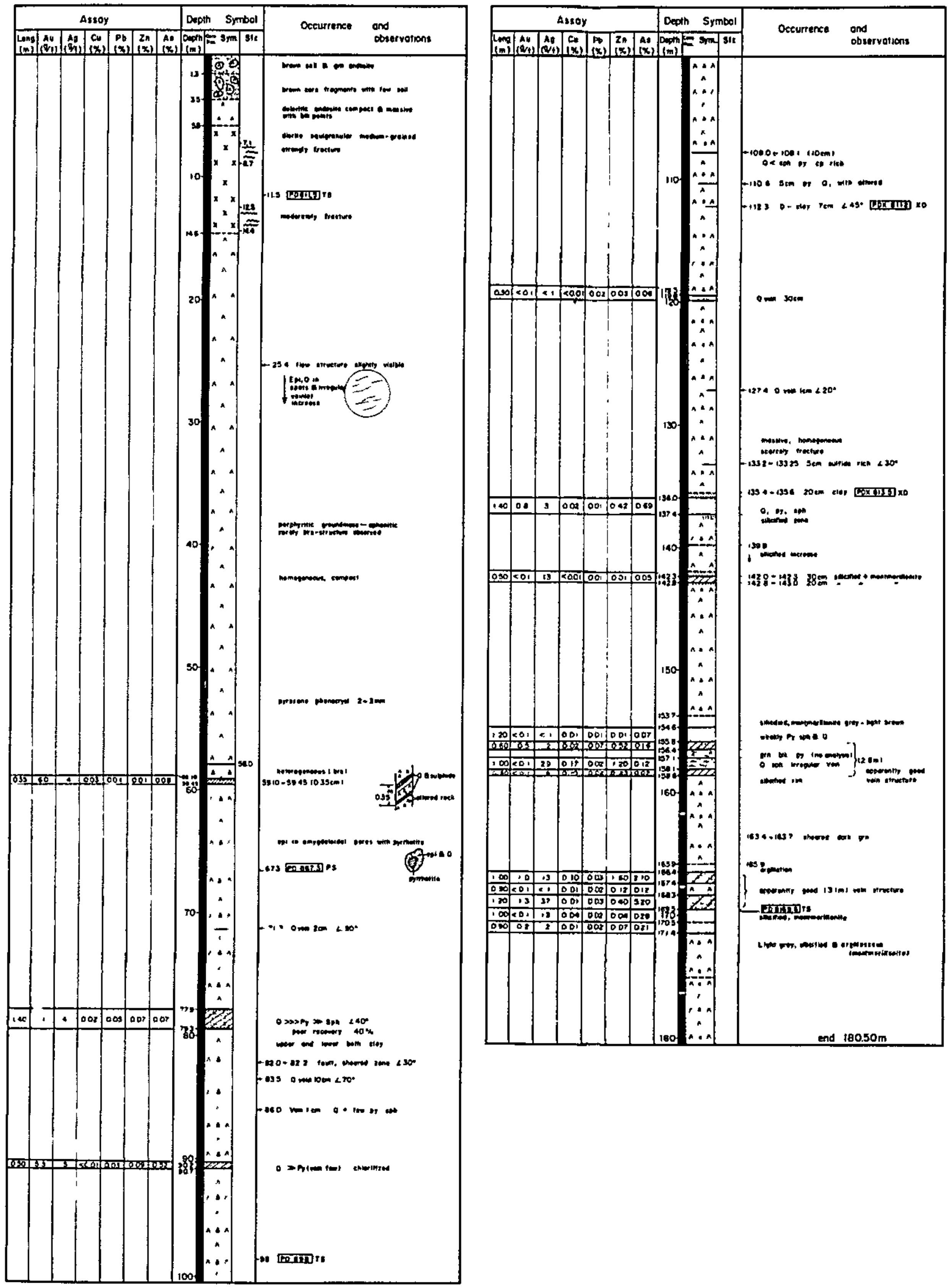
- Green rock
- Tuff breccia
- Agglomerate
- Sandy slime
- Mineralized vein
- Sheared zone
- Fracture

ABBREVIATION

rk	Rock
agglo	Agglomerate
tf	Tuff
fiss	Fissure
vlt	Veinlet
fract	Fracture
net	Network
brs	Breccia
irregl	Irregular
str	Strong
Qv	Quartz vein
sph	Sphalerite
py	Pyrite
cp	Chalcopyrite
ars	Arsenopyrite
hm	Hematite
epi	Epidote
qtz	Quartz
chl	Chlorite
pyrox	Pyroxene
min	Mineralization
imp	Impregnation
limo	Limonitization
oxid	Oxidation
silicf	Silicification
grn	Green
yel	Yellow
L-brw	Light brown
blk	Black

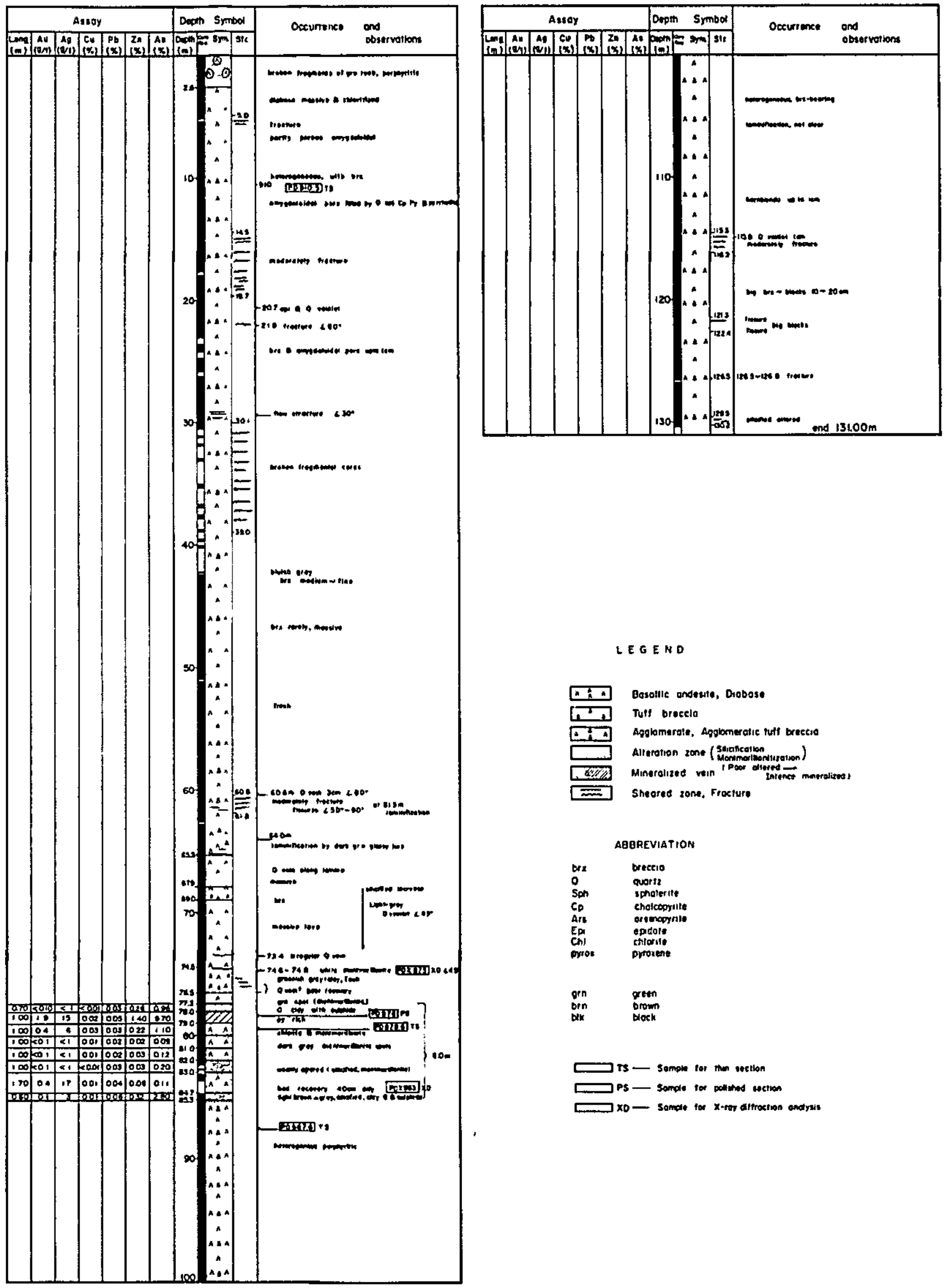
DDH No. PD-8

Direction 225° Coordinate N 1,950
Inclination −75° E 12,196
Total Depth 180.50m Elevation 2,564.5m



DDH No. PD-9

Direction 45° Coordinate N 1,740
Inclination −30° E 12,208
Total Depth 131.00m Elevation 2,604.4m



L E G E N D

- Basaltic andesite, Diabase
- Tuff breccia
- Agglomerate, Agglomeratic tuff breccia
- Alteration zone (Silicification, Montmorillonitization)
- Mineralized vein (Poor altered → Intence mineralized)
- Sheared zone, Fracture

ABBREVIATION

brz	breccia
Q	quartz
Sph	sphalerite
Cp	chalcopyrite
Ars	arsenopyrite
Epi	epidote
Chl	chlorite
pyrox	pyroxene
grn	green
brn	brown
blk	black

- TS — Sample for thin section
- PS — Sample for polished section
- XD — Sample for X-ray diffraction analysis

DDH No. PD-10

Direction	45°	Coordinate	N 1,740
Inclination	-50°		E 12,208
Total Depth	200.50m	Elevation	2,604.4m

Leng (m)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	As (%)
0.6	5.2	17	0.05	0.11	1.75	2.42
1.6	0.5	8	0.03	0.02	0.04	0.11
0.6	4.3	25	0.08	0.09	1.20	1.60
1.0	0.4	4	0.01	0.03	0.26	0.40
1.0	24.8	42	0.13	0.16	2.09	2.34
1.0	3.4	70	0.22	0.13	4.98	4.26
0.8	1.9	50	0.18	0.06	4.33	2.30
1.0	tr	tr	0.01	0.02	0.17	0.15
0.8	2.1	11	0.04	0.01	1.35	0.64
0.8	1.9	19	0.12	0.03	1.49	0.47
1.3	15.0	84	0.25	0.13	5.53	12.6

end 200.5m

DDH No. PD-11

Direction	60°	Coordinate	N 1,590
Inclination	-40°		E 12,290
Total Depth	140.50m	Elevation	2,606.6m

Leng (m)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	As (%)
0.5	tr	tr	0.01	0.04	0.20	0.66
1.2	tr	tr	0.00	0.02	0.02	0.13
0.8	tr	tr	0.06	0.04	0.06	0.12
1.0	tr	tr	0.01	0.02	0.03	0.10
1.0	tr	tr	0.01	0.03	0.17	0.20
1.0	tr	tr	0.01	0.02	0.06	0.10

end 140.50m

LEGEND

- Basaltic andesite, Diabase
- Tuff breccia
- Agglomerate, Agglomeratic tuff breccia
- Alteration zone (Silicification, Montmorillonitization)
- Mineralized vein (Poor altered — Intence mineralized)
- Sheared zone, Fracture

ABBREVIATION

brx	breccia
Q	quartz
Sph	sphalerite
Cp	chalcopyrite
Ars	arsenopyrite
Epi	epidote
Chl	chlorite
pyrox	pyroxene
grn	green
brn	brown
blk	black

TS —— Sample for thin section

PS —— Sample for polished section

XD —— Sample for X-ray diffraction analysis

DDH No PD-12

Direction	60°	Coordinate	N 1,619
Inclination	−55°		E12,290
Total Depth	200.20m	Elevation	2,206.6m

Columns: Assay (Leng (m), Au (g/t), Ag (g/t), Cu (%), Pb (%), Zn (%), As (%)) · Depth Symbol (Depth (m), Core Rec, Sym, Str) · Occurrence and observations

Leng (m)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	As (%)
1.0	tr	tr	0.02	0.03	0.04	0.11
1.4	tr	tr	0.02	0.02	0.07	0.14
0.8	tr	tr	0.01	0.00	0.04	0.05
1.0	tr	tr	0.01	0.01	0.13	0.05
1.0	tr	tr	0.00	0.01	0.03	0.07
1.0	tr	tr	0.07	0.01	0.06	0.08
1.0	0.9	1.0	0.11	0.02	0.07	0.09
1.0	tr	tr	0.00	0.00	0.02	0.06
0.9	tr	tr	0.02	0.02	0.04	0.10
1.2	tr	tr	0.01	0.01	0.01	0.06
1.0	tr	tr	0.00	0.01	0.00	0.06
0.8	tr	7.5	0.00	0.01	0.05	0.06

Observations (legible):
- argillization, PS; Py & Q, impregnated; core recovery 50 %
- (broken core 70 %) (70 %) (70 %) (70 %) (50 %) — Q, clay
- no core; PS; silicified altered zone, gray
- light-brn, silicified zone
- 196.3
- 198.0–199.1 silicified zone
- end 200.2m

DDH No PD-13

Direction	60°	Coordinate	N 1,324
Inclination	−40°		E 12,377
Total Depth	121.50m	Elevation	2,610.0m

Columns: Assay (Leng (m), Au (g/t), Ag (g/t), Cu (%), Pb (%), Zn (%), As (%)) · Depth Symbol (Depth (m), Core Rec, Sym, Str) · Occurrence and observations

Leng (m)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	As (%)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.1	tr	tr	0.01	0.03	0.02	0.11
0.8	tr	tr	0.01	0.02	0.03	0.10

Observations (legible):
- milky Q & chlorite ∠ 30° (Q, chlorite, Q, chlorite)
- fault
- end 121.5m

LEGEND

- Basaltic andesite, Diabase
- Tuff breccia
- Agglomerate, Agglomeratic tuff breccia
- Alteration zone (Silicification / Montmorillonitization)
- Mineralized vein (Poor altered — Intence mineralized)
- Sheared zone, Fracture

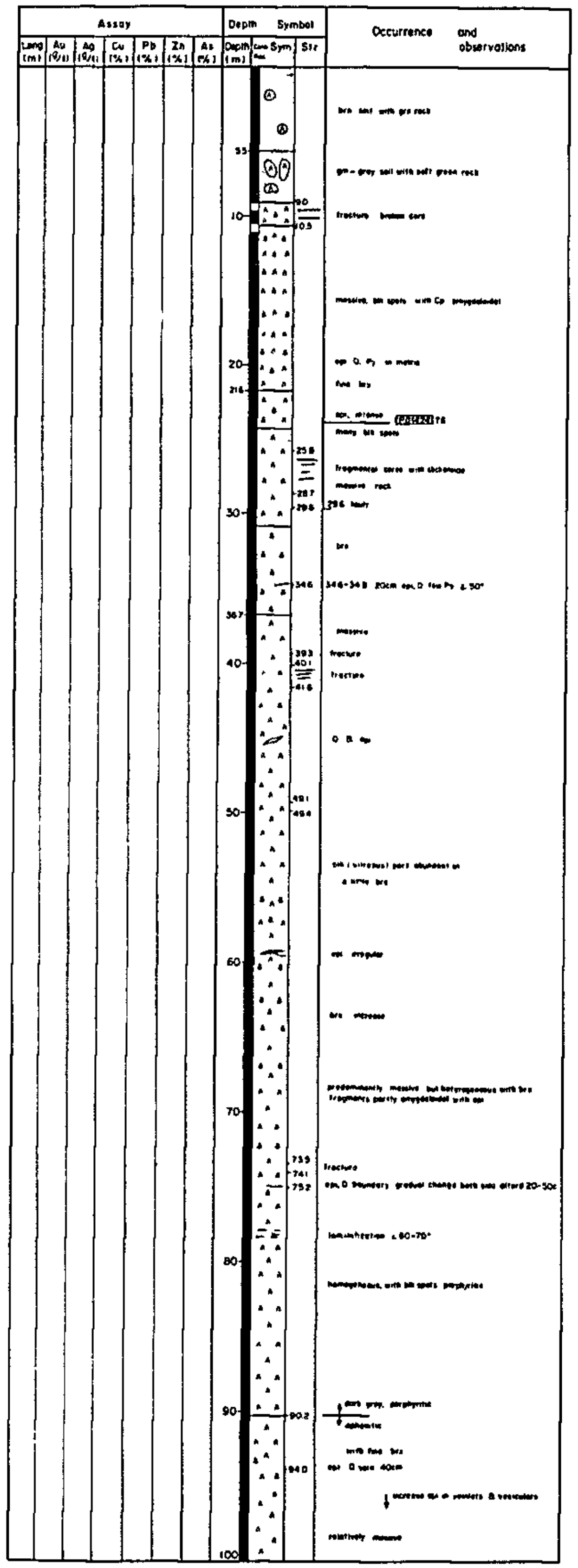
ABBREVIATION

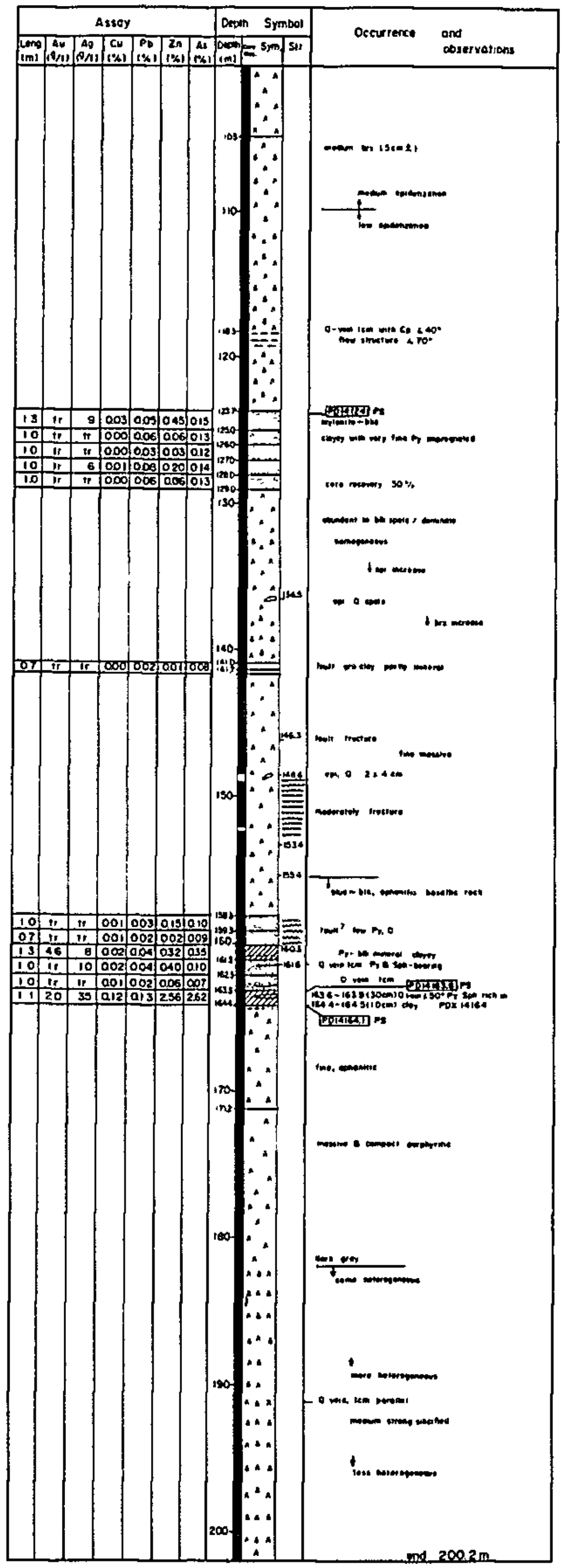
brz	breccia
Q	quartz
Sph	sphalerite
Cp	chalcopyrite
Ars	arsenopyrite
Epi	epidote
Chl	chlorite
pyrox	pyroxene
grn	green
brn	brown
blk	black

- TS — Sample for thin section
- PS — Sample for polished section
- XD — Sample for X-ray diffraction analysis

DDH No. PD-14

Direction	60°	Coordinate	N 1,524
Inclination	-60°		E 12,377
Total Depth	200.20	Elevation	2,618.6m



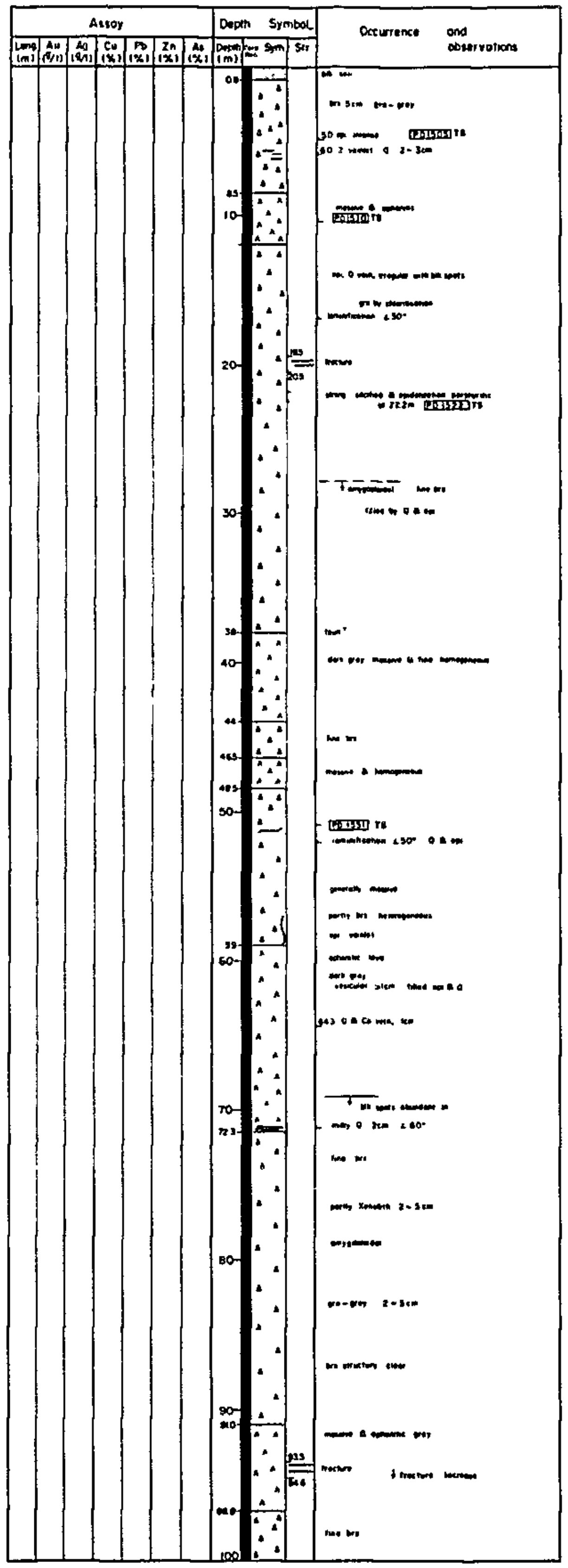


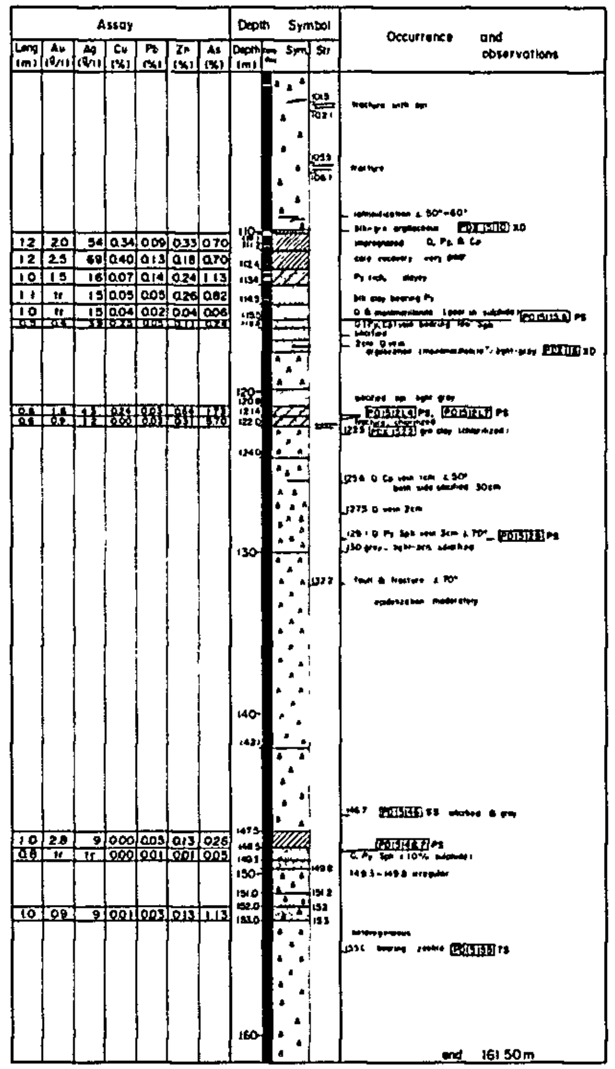
Assay, DDH No. PD-14

Leng (m)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	As (%)
1.3	tr	9	0.03	0.05	0.45	0.15
1.0	tr	tr	0.00	0.06	0.06	0.13
1.0	tr	tr	0.00	0.03	0.03	0.12
1.0	tr	6	0.01	0.06	0.20	0.14
1.0	tr	tr	0.00	0.06	0.06	0.13
0.7	tr	tr	0.00	0.02	0.01	0.08
1.0	tr	tr	0.01	0.03	0.15	0.10
0.7	tr	tr	0.01	0.02	0.02	0.09
1.3	4.6	8	0.02	0.04	0.32	0.35
1.0	tr	10	0.02	0.04	0.40	0.10
1.0	tr	tr	0.01	0.02	0.06	0.07
1.1	2.0	35	0.12	0.13	2.56	2.62

DDH No. PD-15

Direction	60°	Coordinate	N 1,443
Inclination	-60°		E 12,434
Total Depth	161.50m	Elevation	2,624.1m





Assay, DDH No. PD-15

Leng (m)	Au (g/t)	Ag (g/t)	Cu (%)	Pb (%)	Zn (%)	As (%)
1.2	2.0	54	0.34	0.09	0.33	0.70
1.2	2.5	69	0.40	0.13	0.18	0.70
1.0	1.5	16	0.07	0.14	0.24	1.13
1.1	tr	15	0.05	0.05	0.26	0.82
1.0	tr	15	0.04	0.02	0.04	0.06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.9	[illegible]	[illegible]	[illegible]	[illegible]	0.70
1.0	2.8	9	0.00	0.05	0.13	0.26
0.8	tr	tr	0.00	0.01	0.01	0.05
1.0	0.9	9	0.01	0.05	0.13	1.13

LEGEND

- Basaltic andesite, Diabase
- Tuff breccia
- Agglomerate, Agglomeratic tuff breccia
- Alteration zone (Silicification / Montmorillonitization)
- Mineralized vein (Poor altered — Intence mineralized)
- Sheared zone, Fracture

ABBREVIATION

bra	breccia
Q	quartz
Sph	sphalerite
Cp	chalcopyrite
Ars	arsenopyrite
Epi	epidote
Chl	chlorite
pyrox	pyroxene
grn	green
brn	brown
blk	black

- TS —— Sample for thin section
- PS —— Sample for polished section
- XD —— Sample for X-ray diffraction analysis