FEDERATIVE REPUBLIC OF BRAZIL
REPORT ON GEOLOGICAL SURVEY OF PALMEIROPOLIS AREA

PHASE I

FEBRUARY 1987

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OF

PALMEIROPOLIS AREA

PHASE II

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JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

FEDERATIVE REPUBLIC OF BRAZIL

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PREFACE

In response to the request of the Government of the Fedrative Republic of Brazil, the Japanese Government decided to conduct a mineral exploration in the Palmeiropolis Project and entrusted the survey to the Japan International Cooperation Agency (J.I.C.A.) and the Metal Mining Agency of Japan (M.M.A.J.).

The survey in fiscal 1986 is the phase I, and MMAJ despatched a six-member survey team to the site for the period between July 8, 1986 and October 10, 1986.

This report is the compilation of the results of the phase I survey which was completed as scheduled under close cooperation with the Government of the Federative Republic of Brazil and its various agencies, including Departamento Nacional da Produção Mineral (D.N.P.M.) of the Ministry of Mining and Energy, and Companhia de Pesquisa de Recursos Minerais (C.P.R.M.).

We hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

We wish to express our deep appreciation to the officials concerned of the Government of the Federative Republic of Brazil for their close cooperation extended to the team.

December 1986

Keisuke Arita
President
Japan International Cooperation Agency

Junichiro Sato
President
Metal Mining Agency of Japan

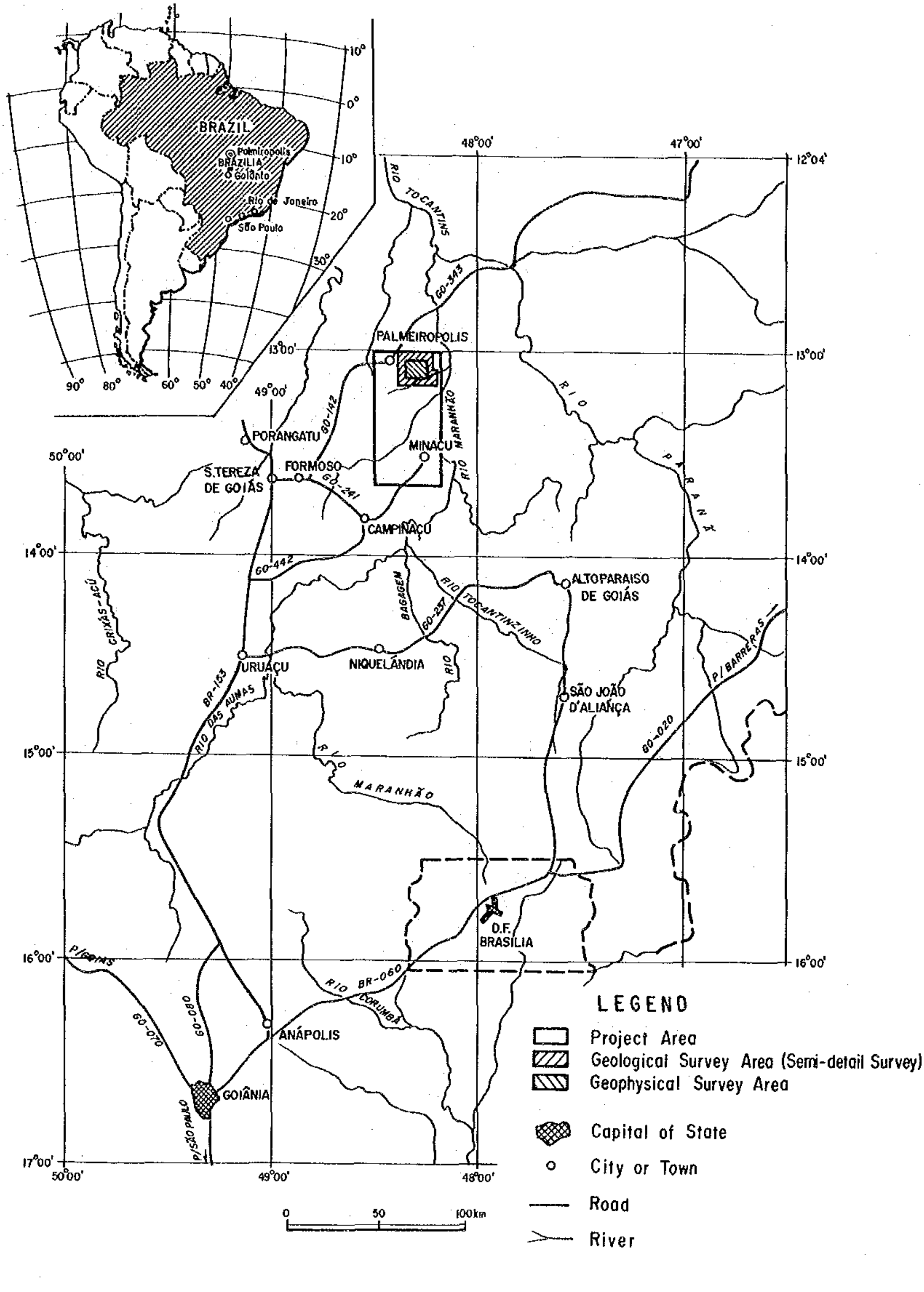


Fig. 1 Location Map of the Project Area

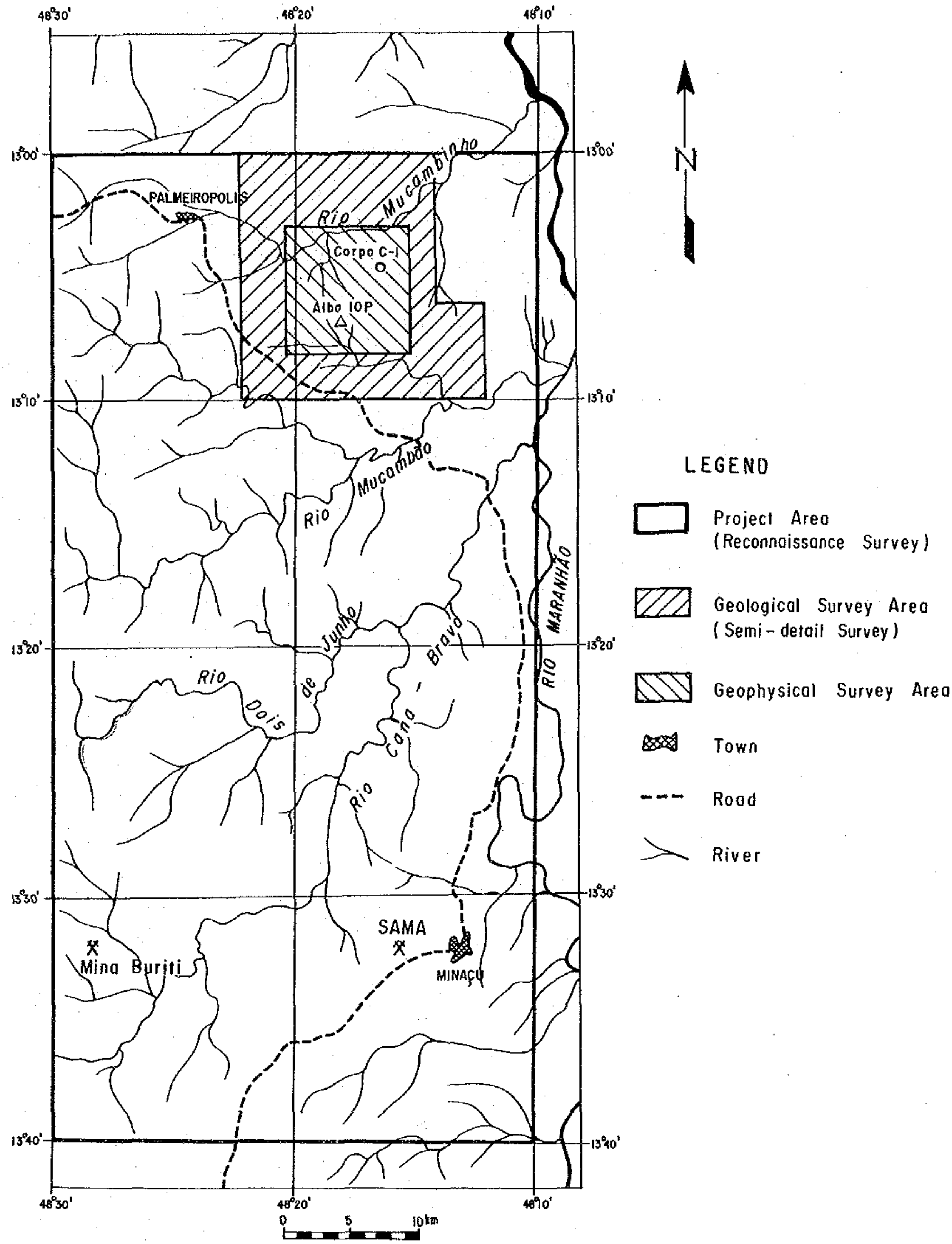


Fig. 2 Location Map of the Surveyed Area

CONTENTS

III GEOPHYSICAL SURVEY

ABSTRACT

The survey conducted in the first year of the natural resources development project in the Palmeirópolis area in the Federative Republic of Brazil covered geological, geochemical and geophysical surveys. The purpose of these surveys were to extract promising areas for occurrence of ore deposit by grasping the characteristics of stratigraphy, geologic structure and mineralization, and by making clear the relationships between them. Prior to the field survey, the area of semi-detailed survey (300km^2) and the extent of geophysical survey (100km^2) were defined based on the compilation of existing data from the past surveys in the areas distributed by the known ore deposites.

The analysis of the field survey data led to the following observations.

1. The geology of the survey area consists of the Precambrian rocks such as the Cana Brava basic to ultrabasic massif belonging to Archaean, and the Palmeiropolis volcano-sedimentary sequence, Serra da Mesa Group, the Rio Maranhao cataclastic zone and the Pranoá Group belonging to the Proterozoic. Granitic rocks and basic to ultrabasic rocks are found intruding the above formations.

It is assumed that the metamorphic grade of the Palmeirópolis volcano-sedimentary sequence belongs to amphibolite facies, and that the temperature and pressure of metamorphism are 300° to 600°C and six to 10 atms respectively.

2. The Palmeirópolis copper, lead and zinc ore deposits are emplaced harmoniously between amphibolites (Pip_3 formation, the wall rock in the footwall) and the intermediate to acidic schistose rocks (Pip_4 formation, the wall rock in the hanging wall) in the Palmeirópolis volcano-sedimentary sequence belonging to the lower Proterozoic. The deposits generally show stratiform to lenticular form.

The country rocks of the C-1 deposit plunge from Alvo 7P in the southwest into the southeast of Alvo 9P.

3. In the geochemical survey of stream sediment carried out for the entire survey area, Cu-Pb-Zn anomalous zones considered to be caused by the mineralization similar to that of the Palmeirópolis deposit were extracted in the central part of the regional survey area distributed by schistose rocks (Pip4vs member).

The soil geochemical survey conducted in the semi-detailed survey area showed the presence of high Cu-Pb-Zn anomalous zone in the surrounding area of the C-1 deposit. Pb-Zn and/or Cu-Zn anomalies were also extracted in Alvo 7P, southeast of 9P, 10P, 13P and east of 11P in the vicinity of the contact between schist and amphibolite.

4. The geophysical survey by the CSAMT method made clear that a block movement took place due to complicated faulting and folding. It was also made clear that a gentle gradient structure of resistivity zones including the C-1 ore deposit and its surroundings was arranged in the direction from the northeast to the southwest toward Alvo 7P and southeast of 9P.

The SIP method led to the assumption that the massive ore of the C-1 deposit would change to a network to dissemination in the deeper part.

A promising anomalous zone was detected at the western end of the survey line 150S.

I INTRODUCTION

CHAPTER 1 Outline of the Survey

1–1 Purpose of the Survey

The survey was conducted for the purpose of extracting the promising areas for occurrence of ore deposit in the survey area by making clear its geological conditions through the application of geological, geochemical and geophysical survey technics in the Palmeirópolis area (Fig. 1 and Fig. 2) in the Federative Republic of Brazil.

In particular, geological and geochemical surveys were conducted to extract the areas of higher potential in the semi-detailed survey area, and in the areas of high potential similar to those in the semi-detailed survey area through a comprehensive analysis of the relationships between geologic structure, alteration and mineralization as well as geochemical characteristics of stream sediment from the regional area and of soil from the semi-detailed survey area.

A geophysical survey was conducted in the detailed survey area with an area of 100km^2 (10km x 10km) within the semi-detailed survey area covering an area of 300km^2. The detailed survey area was chosen on the basis of the existing data, and particular attention was paid to the distribution of ore deposits and alteration zones, as well as their geologic structures.

In the geophysical survey, such electric survey methods as CSAMT and SIP were adopted.

The CSAMT method was purposed to estimate the continuity and trend of distribution of the resistivity structure by grasping the distribution of resistivity in the area surveyed and by making clear the resistivity structure in which ore deposits or mineralized zones are likely to be emplaced.

The SIP method was purposed to estimate the characteristics and the forms of emplacement of ore deposit as well as the lateral extent and continuation to the depth by elucidating the spectral characteristics of the known ore deposit by setting survey lines on it and in its vicinity. The spectral characteristics grasped through this method will be used as indicators for future surveys.

1–2 Substance of the Survey and Survey Methods

In the Phase I survey, geological and geochemical surveys were carried out overing the entire survey area as well as in the semi-detailed survey area (300km^2) in the northern part. A geophysical survey was also conducted for an extent of 100km^2 in the semi-detailed survey area.

Table I–1 shows the substance and quantities of the surveys, and Table I–2 the items and quantities of laboratory works.

Table I–1 Substance of Survey・Survey Figures

Substance of Survey and Area	Survey Figures
Geochemical Survey (Reconnaissance)	Area 2,750 km^2 Stream Sediment 1,031 Samples
Geological・Geochemical Survey (Semi-detail)	Area 300 km^2 Length 245 km Soil 2,555 Samples
Geophysical Survey (CSAMT Method)	Area 100 km^2 Measuring Points 202 Points Measuring Interval 500 ~ 600 m
Geophysical Survey (SIP Method)	Line Length 5.3 km Line Numbers 4 Line (1.3km x 3, 1.4km x 1) Measuring Points 161 Points Measuring Interval 100 m Penetration Depth 300 m

Table I–2 Items Analysed・Numbers

Items Analyzed and Components	Numbers
Thin Section	35
Polished Section	28
X-ray Diffractive Analysis	203
Chemical Analysis	
Rock : SiO_2, Al_2O_3, CaO, MgO, Na_2O K_2O, Fe_2O_3, FeO, MnO, TiO_2 P_2O_5, BaO, LOI	23
Ore : Cu, Pb, Zn, Ag, Au	54 (270 elements)
Geochemical Analysis	
Soil : Cu, Pb, Zn, As	2,555 (10,220 elements)
Stream Sediment: Cu, Pb, Zn, As	1,031 (4,124 elements)
Physical Property	45

1–2–1 Geological and Geochemical Surveys

(1) Regional Area

The geological and geochemical surveys were conducted utilizing existing drainage maps at 1 : 50,000. The geochemical survey was carried out for stream sediment over the regional area, with particular attention to the areas underlain by the Palmeirópolis volcano-sedimentary sequence.

Sediment samples were collected at the confluence of the rivers. The sample size was –80 mesh and the density of sampling was two to three per square kilometer.

Existing geological maps were reviewed in parallel with stream sediment sampling, and a geologic map on a scale of 1 : 50,000 was produced.

(2) Semi-detailed Survey Area

The geological and geochemical soil surveys were conducted in the semi-detailed survey area extracted on the basis of the compilation of existing data.

For this survey, the 1 : 50,000 drainage maps were enlarged to produce route maps at 1 : 10,000. The aerophotographs on a scale of 1 : 20,000 were also used in the field complementally.

Any observations made during the field survey were recorded on the route maps as concretely as possible, and important outcrops were either sketched or photographed.

Because of scarcity of the outcrop in the area, the character of soil was carefully examined at the time of soil sampling to support the geological survey.

Soil sampling for the geochemical survey was performed mainly for the areas underlain by amphibolite and intermediate to acidic schistose rocks of the ore bearing horizon, and the samples were collected along the main roads and rivers. Furthermore, the survey lines were cleared and set in order to collect samples as evenly as possible at the density of 8 to 9/km^2.

1–2–2 Geophysical Survey

The CSAMT method was used for the afore mentioned 100km^2 area chosen in the semi-detailed survey area. Two hundred and two measuring stations were set on the survey lines and creeks or roads approximately perpendicular to the trend of geologic structure with the even line space of about 500 meters.

The SIP method was applied to the area immediately above the known ore body C-1 and along its southern extension. Two survey lines were set on the C-1 ore body, and two more lines along its southern extension, amounting to 5.3km in total length. They were set perpendicular to the trend of ore horizon. The interval of measuring stations was 100 meters.

1–2–3 Period of Investigation

Geological and geochemical surveys

Period of investigation	July 8, 1986 to October 12, 1986
Period of field survey	July 15, 1986 to September 22, 1986

Geophysical survey

Period of investigation	July 29, 1986 to October 12, 1986
Period of field survey	August 4, 1986 to September 29, 1986
Report Preparation	October 13, 1986 to December 25, 1986

1–3 Organization of the Survey Team

The following table shows the members participated in the planning, consultation and field survey, including geological engineers from Departamento Nacional da Produção Mineral (DNPM) and geological and geophysical engineers from Companhia de Pesquisa de Recursos Minerais (CPRM) entrusted by DNPM.

1–3–1 Planning of Survey Project and Consultation

(1) Japanese Counterparts

Takeshi Izumi	Metal Mining Agency of Japan (MMAJ)
Hideyuki Ueda	MMAJ
Katsutoki Matsumoto	MMAJ

(2) Brazilian Counterparts

José Belfort dos Santos Bastos	DNPM
Carlos Oiti Berbert	〃
Bolivar Gonçalves Siqueira	〃
Walter Hugo Schmaltz	〃

1–3–2 Field Survey

(1) Members of Japanese Team

Leader	Tsuyoshi Suzuki	Bishimetal Exploration Co., Ltd. (BEC)
Geologist	Yoshio Takeda	BEC
〃	Norio Ikeda	BEC
Geophysicist	Tomio Tanaka	BEC
〃	Keiji Tanaka	BEC
〃	Kazuto Matsukubo	BEC

(2) Members of Brazilian Team

Leader	Homero Lancerda	DNPM
Geologist	Arpuim Araújo Pereira	DNPM
"	Elias Alvares Lima Junior	DNPM
"	Ivan Wilson Brandão Oliveira	CPRM
Geophysicist	José dos Anjos Barreto	CPRM

CHAPTER 2 Outline of the Survey Area

2–1 Location and Transportation

The area is situated to the east to southeast of the Palmeirópolis settlement in Paranã Municipio in the central part of Goiás State. The Palmeirópolis settlement can be reached from Goiania, the state capital city, through State Highway GO-080, National Highway BR-153 and State Highway GO-343 toward the north with the total distance of 617 kilometers.

2–2 Topography, Climate and Vegetation

Topography:

The area shows the topography of gentle hills and flat land in general, and Morro Solto (758m) forms an isolated peak in the northern part, while Serra Cana Brava (810 to 900m) shows a landform of mountain range in the southern part.

Rio Maranhão, the upper stream of Rio Tocantins flows northward through the eastern end of the area, and its tributaries such as Rio Macanbinho, Rio Macambão, Rio Dois de Junho, Rio Cana Brava and Rio Bonito flow eastward crossing through the area.

Climate:

The area is situated at the southern end of the Amazon zone, and belongs to the tropical hunmid-type climate. The distinction between the rainy season and the dry season is clearly observed. Annual precipitation and temperatures are as follows:

Rainy season	November to March,	Precipitation: 1,300 to 1,800mm
Dry season	April to October,	Almost no precipitation
Temperature	Annual mean	23° to 24°C
	Maximum	41°C
	Minimum	18°C

Vegetation:

The vegetation exhibits the characteristics of cerrado and savanna, with thick growth of shrub and grass. Tall trees as high as more than six meters are also observed in the lateritic low land.

2–3 Outline of Geology and Ore Deposit in the Survey Area

The geology of Brazil is included in the South American Platform from the standpoint of major geologic structure of the South American Continent, and its geologic age goes back to Archaeozoic.

The Precambrian formations occupy the area of about 4,500 thousand square kilometers, more than 50 per cent of that of whole Brazil.

It is the result of the Brazilian orogenic cycle took place from late Proterozoic to early Palaeozoic that the geologic structure of the Precambrian system came to form a hard mass.

The South American Platform was separated later by three large basins (Amazonas, Paraiba and Parana) formed during the period between Silurian to Ordovician, and it is distributed as three large shields (Guiana, Brasil Central and Atlantico) at present (Fig. I–1).

The whole South American Platform was subjected to orogenic cycles such as Jequie Aroense (2,600 – 2,800 Ma), Transamazonian (1,900 – 2,100 Ma) and Brazilian (450 – 700 Ma), It has been known that such orogenic cycles as Espinhaço (1,000 – 1,300 Ma) and Uruaçuano (± 1,150 Ma) in Atlantico Shield and Utauma (1,700 – 1,900 Ma), Paraguazense (1,500 – 1,600 Ma) and Rondoniense (1,000 – 1,300 Ma) in Brasil Central and Guiana Shield.

These shields were divided into several kratons by the fold zones (Nordeste, Sergipana, Rio Preto, Araçuai, Brasilia, Sudeste, Paraguai-Araguaia and Grupi) formed during the Brazilian orogenic cycle (Fig. 1–2).

Many metalliferous ore deposits are found in these fold zones, and have been attracting special attention as the filed of mineral exploration.

The Palmeirópolis area belongs to the Uruaçu zone contemporaneous to the Paraguai-Araguaia and Brasilia zones, and is underlain by Archaeozoic and Proterozoic metamorphic rocks of green schist to amphibolite facies, and granitic rocks.

The main known ore deposits emplaced in the Precambrian formations in Goias State, including the Palmeirópolis area, include Cu-Ni deposits in ultrabasic rock (Niquelandia Deposit and Americano do Brasil Deposit), Asbestos deposit (Cana Brava Deposit), Cu deposit (Mara Rosa Deposit) in basic to acidic volcano-sedimentary metamorphic sequence Cu-Pb-Zn deposit (Palmeirópolis deposit) and Sn-W deposit (Serra da Mesa type) in granitic rocks intruding the above rocks.

The stratigraphy of the Palmeirópolis area is roughly divided into the formations of Archaeozoic and Proterozoic, and the latter is further classified into the lower, middle and upper parts.

The typical stratigraphy of each formation is as follows:

(1) Archaeozoic

Cana Brava basic -ultrabasic rock massif : granulite- basic to ultrabasic complex, granite -gneiss -migmatite complex

(2) Proterozoic

(a) Lower Proterozoic: Palmeirópolis volcano-sedimentary Sequence ... ultrabasic to basic rocks, schist, granite

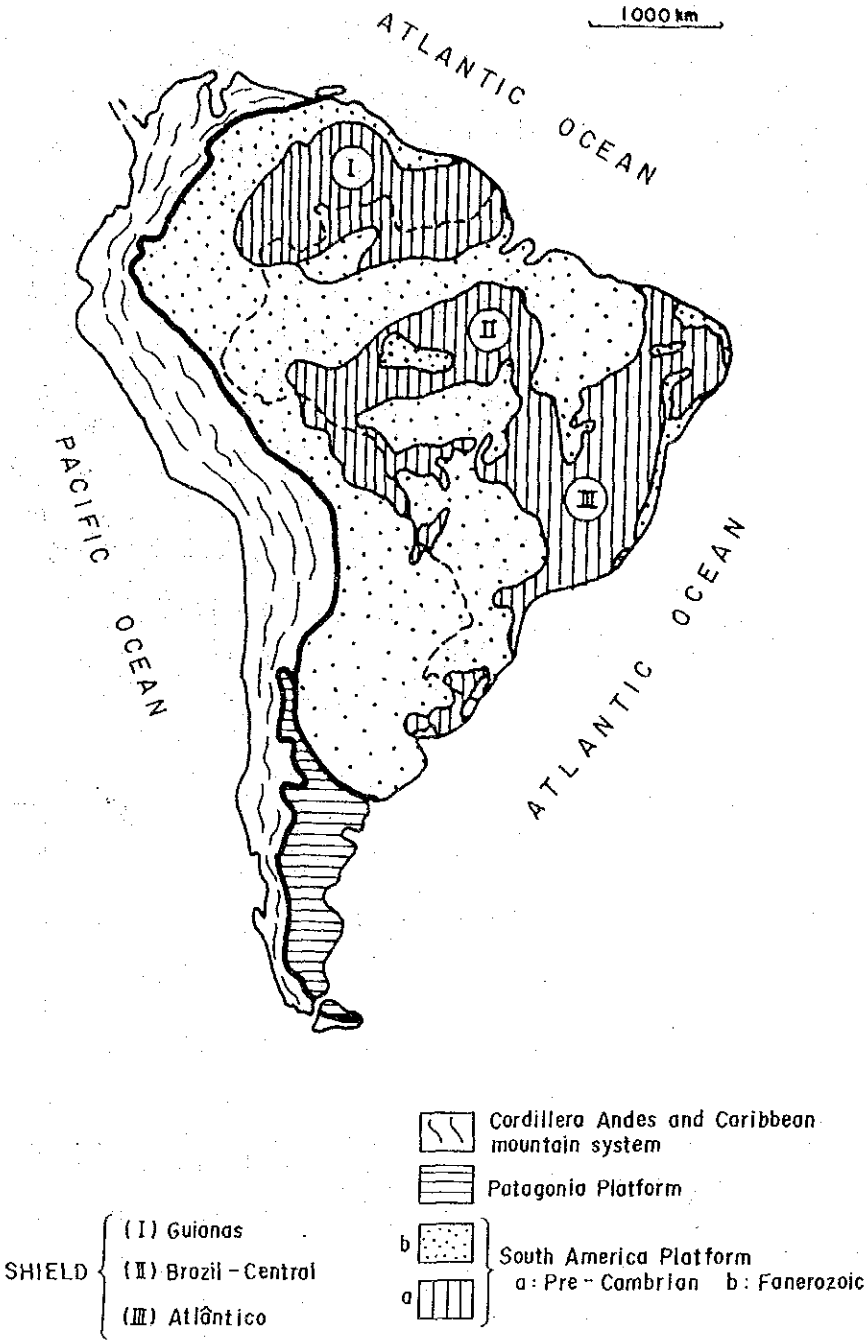


Fig. I–1 Tectonic Division of South America

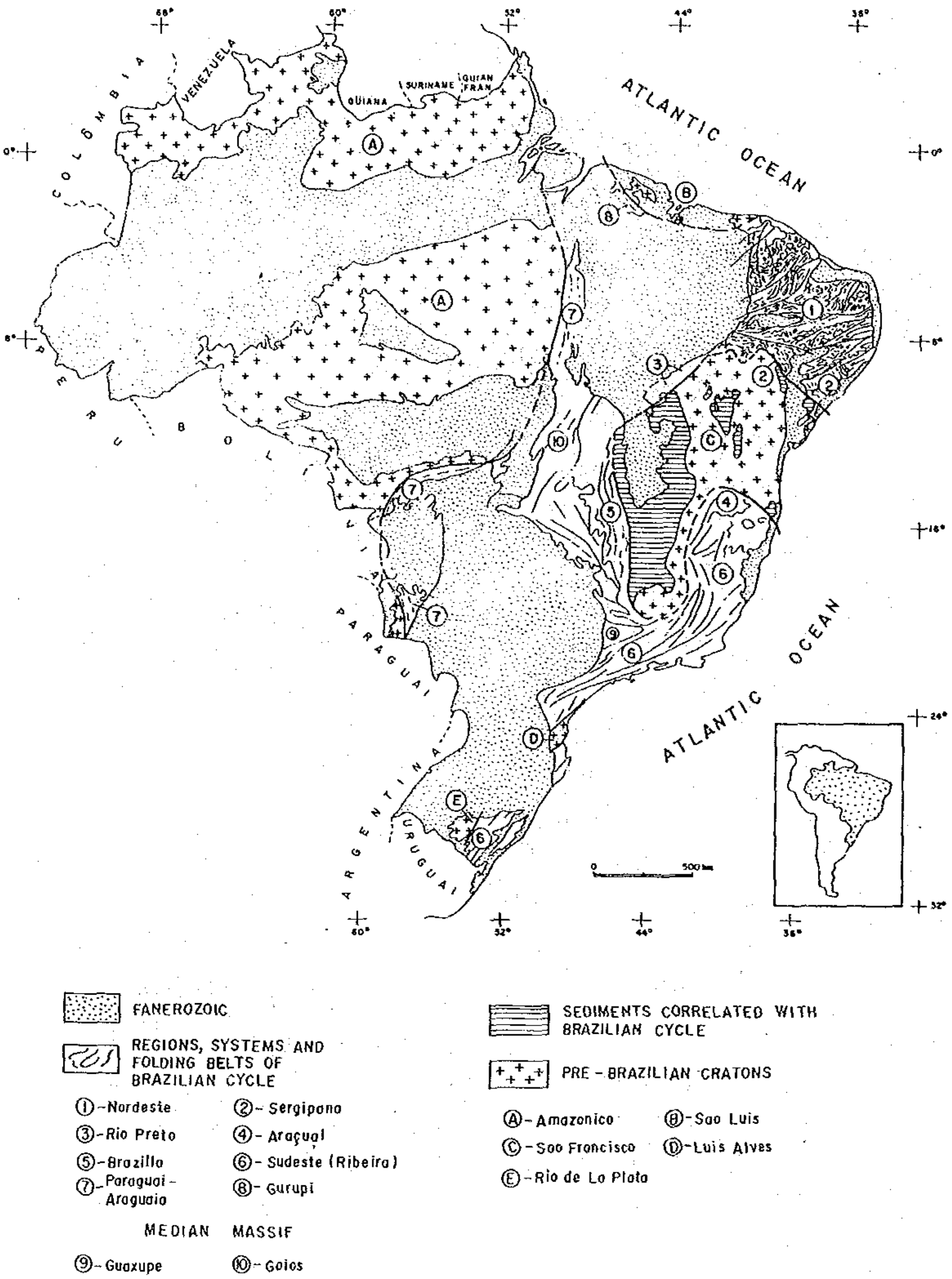


Fig. I–2 Zone Falded of Brazilian Cycle and Cratons Related

(b) Middle Proterozoic: Serra da Mesa Group . . . quartzite, schistose rocks, limestone to marble, basic rocks

Rio Maranhao cataclastic zone . . . quartzite, schistose rocks, gneiss

(c) Upper Proterozoic: Paranoa Group . . . quartzite, dolomite, slate, conglomerate

It has been made clear as the result of exploration by DNPM and CPRM that the Cu-Pb-Zn deposit in the Palmeirópolis area is emplaced in the Palmerópolis volcano-sedimentary sequence of the lower Proterozoic.

The Palmeirópolis volcano-sedimentary sequence has been further subdivided by CPRM into three units: Unidade de Oeste (western unit), Unidade de Central (central unit) and Unidade de Leste (eastern unit). The palmeirópolis ore deposit is emplaced between the intermediate to acidic schistose rocks (hanging wall) and amphibolites (footwall) of Unidade de Central. In addition, it has been also made clear that the similar mineralization exists in the middle part of acidic schist.

CHAPTER 3 Results of Compilation on Previous Exploration Data and Documents

The geology of the vicinity of the survey area has been studied by many researchers and research organizations, and it is known that the area is underlain mainly by the Precambrain rocks.

Cordani et al. (1967) and Hasui et al. (1980) described on the basis of their studies on isotopic age determination that the area was subjected to several orogenies including Brazilian orogenic cycle (500-700 Ma), Transamazonian orogenic cycle (1,700-2,000 Ma) and Jequie orogenic cycle (2,400-2,600 Ma).

While the results of a large number of studies on stratigraphy and geologic structure have been published, it is conspicuous that Almeida (1967) described the regional stratigraphy and geologic structure of the central part of Brazil, and Suszczynski (1966, 1967, 1968) described the relation between the sedimentary basin of the Sao Francisco kraton and Paraguai-Araguia geosyncline.

Also Schobbenhaus et al. (1984) gave a compiled gist of the results of studies of many researchers in the explanatory note on the 1 : 2,500,000 geological map of Brazil.

The major exploration projects conducted in the area and in its vicinity in the past are "Projeto Serra da Mesa" (1972) by DNPM and CPRM and "Projeto Palmeirópolis" (1975-1984) by CPRM.

The aeromagnetic survey performed in "Projeto Serra da Mesa" resulted in detecting both aeromagnetic anomalous zones and radioactive anomalous zones. The aeromagnetic anomalous zone was considered to reflect the basic-ultrabasic rocks, and it was hoped that Cu-Ni deposits might be emplaced in these rocks. The radioactive anomalies were considered to reflect the presence of granitic rocks, and the occurrence of Sn-W deposits was also expected in the area.

CPRM then started further exploration for Cu-Ni deposits based on the survey results of "Projecto Serra da Mesa". With the progress of study for establishment of stratigraphy of volcano-sedimentary rocks, the exploration revealed the presence of a Cu-Pb-Zn sufide deposit which was previously unknown in the area under discussion.

Besides the above mentioned organizations, METAGO (Goias State owned exploration company), Billington Metai Ltda., a company of foreign capital, and S.A. Mineração de Amianto (SAMA), an asbestos mining company, are also conducting exploration in the area.

However, the details of which remain unknown because the exploration data obtained by these companies have not been made public.

As for regional geological maps covering the survey area and its surroundings the following three maps are used in general: Goias SD-22, 1975 at 1 : 1,000,000; Geological Map of Brazil at

1 : 2,500,000, 1981; and Goias SD-22, 1981 at 1 : 1,000,000 of RADAMBRASIL vol. 25.

The CPRM geological map (1982, 1984) at 1 : 50,000 of "Projeto Palmeirópolis" describes in detail the stratigraphy in the vicinities of ore deposit, especially the stratigraphical division of the volcano-sedimentary sequence. However, the extent of application of this classification is limited only to the northern part of the survey area.

Regarding the central southern area (the exploration area by Billington Metais Ltda., METAGO and SAMA), the stratigraphical classification by DNPM and CPRM made on the 1 : 50,000 geological map (1983) of "Projeto Palmeirópolis" (Etapa Preliminar) is the one most useful for the survey of the area.

As the result of compilation of these data, MMAJ selected the areas for reconnaisance and semi-detailed surveys, since it was recognized that the Alvo area which was thought to be of the highest potential for future surveys remained without sufficient investigation.

II GEOLOGICAL SURVEY AND GEOCHEMICAL SURVEY

CHAPTER 1 Geological Survey

1–1 Stratigraphy

Geology of the survey area consists from the base upward, of the Archaeozoic Cana Brava basic-ultrabasic massif (Acb) which is the basement rock of the area, lower Proterozoic Palmeiró-polis volcano-sedimentary Sequence (Pip), middle Proterozoic Serra da Mesa group (Pmsm, Pm), Rio Maranhao cataclastic zone (ct) and upper Proterozoic Paranoá Group (Pspa) as shown in Figures II–1 and II–2 and Plates II–1 to II–4.

Plate II–5 through II–7 show the location of sampling points. These samples were provided for various analysis. Table A–1 shows the results of microscopic observation of thin sections.

1–1–1 Cana Brava Basic-Ultrabasic Massif

The massif constitutes the basement of the area and consists of metagabbro (Acbmg), serpentinite (Acbsp), pyroxenite (Acbpx) and the complex of these rocks (Acbub, Acbmb). Among these, an asbestos deposit is emplaced in serpentinite.

(1) Distribution

The Cana Brava basic-ultrabasic massif forms the Cana Brava mountain range extending in the N-S direction in the eastern to south-eastern part of the area. Lithologically, metagabbro occupies the western two-thirds of the mountain range, and the remaining eastern one-third shows a form of zonal arrangement of other rock facies parallel to the trend of the mountain range.

(2) Lithofacies

Metagabbro (Acbmg) is dark green to grayish green and medium to fine-grained rock, and contains augite in abundance as mafic mineral. Floats are widely found, but the exposure is limited to the areas along the rivers.

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

Hornblende- clinopyroxene metagabbro (NI0085, Acbmg)

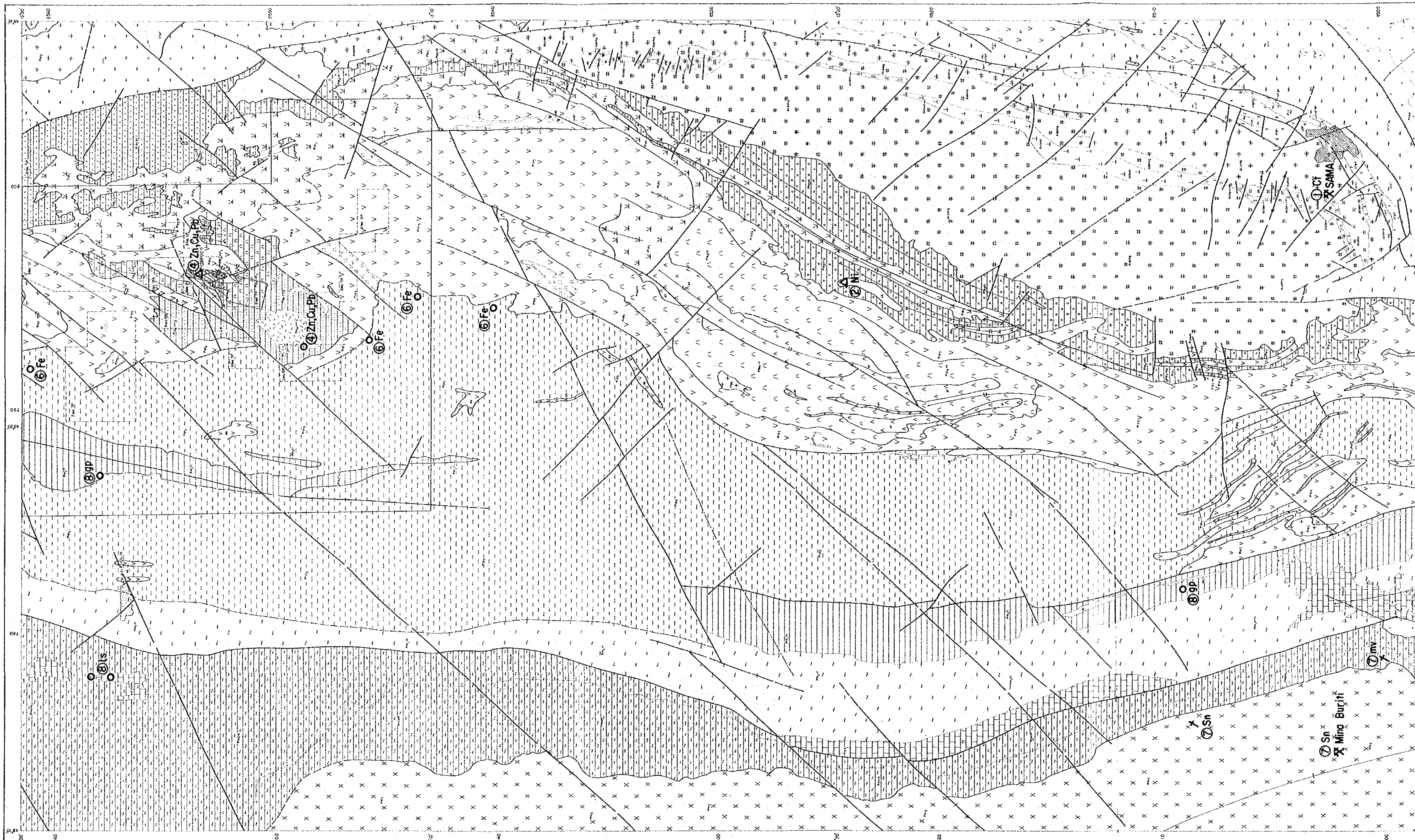
Location: SAMA (795.55, 8503.60)

Texture: granoblastic

Constituent minerals : plagioclase, clinopyroxene > hornblende > opaque minrals, epidote > rhombic pyroxene, carbonate minerals.

Each crystal boundary shows a polygonal shape due to recrystallization.

Two kinds of serpentinite (Acbsp) are found, green and brown ones, and asbestos mineralization is observed in the former.


④Zn,Cu,Pb
④Zn,Cu,Pb
⑥Fe
⑥Fe
⑥Fe
⑥Fe
②Ni
①Cr
SAMA
⑧gp
⑧gp
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⑦Sn
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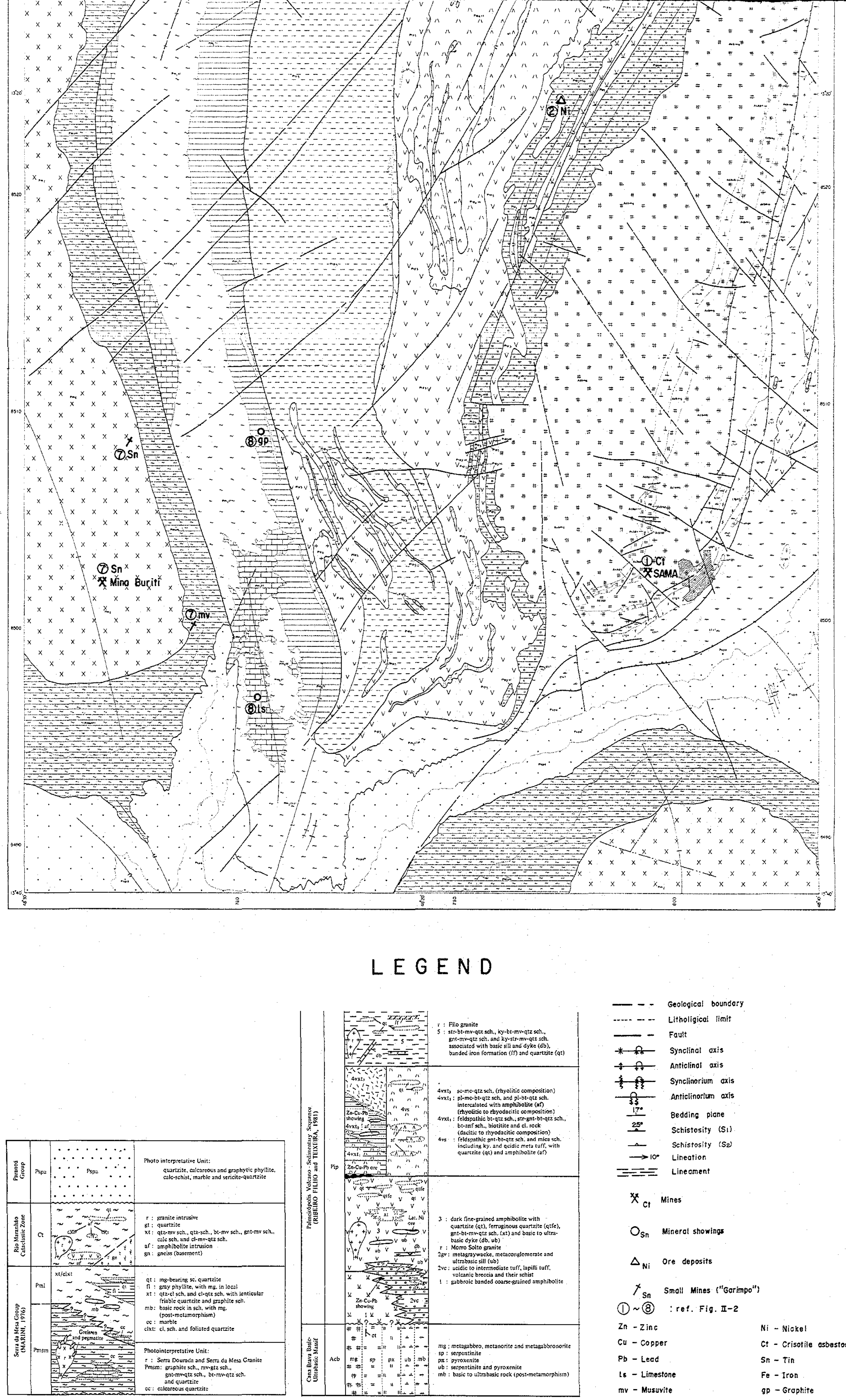
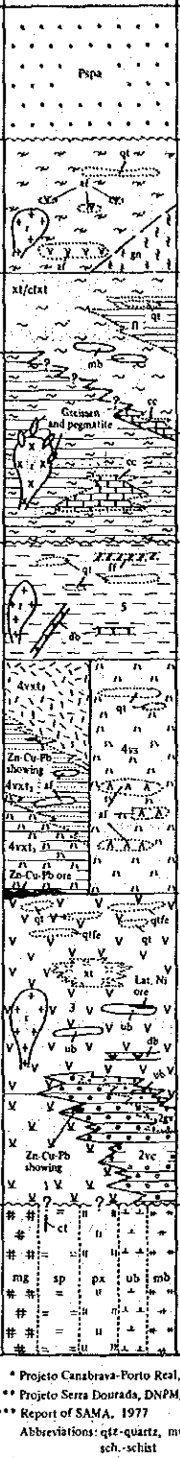


Fig. II-1 Geological Map of the Surveyed Area



Geological Unit	Symbol	Columnar Section	Lithology	Geohistory	Metallogeny	Tectono-Magmatic Cycles	Geologic Age
Paranoá Group	Pspa		Photo Interpretative Unit: quartzite, calcareous and graphytic phyllite, calc-schist, marble and sericite-quartzite	Sedimentation	* Limestone associated with Pb-Zn-Cu-Ag Showings. * Graphite. * Magnetite dissemination and Mn supergene Belt.	Brasiliano Cycle (700–550 m.a.)	Late Proterozoic (1,100–570 m.a.)
Rio Maranhão Cataclastic Zone	Ct		r : granite intrusive gt : quartzite xt : qtz-mv sch., qtz-sch., bt-mv sch., gnt-mv sch., calc sch. and cl-mv-qtz sch. af : amphibolite intrusion gn : gneiss (basement)	Cataclastic metamorphism including basement and orogenic belt	Sn and other minerals associated with pegmatite within and around granitic body.	Uruaçuano Cycle (1,300–900 m.a.)	Middle Proterozoic (1,900–1,100 m.a.)
Serra da Mesa Group (MARINI, 1976)	Pml		qt : mg-bearing sc. quartzite ft : gray phyllite, with mg. in local xt : qtz-cl sch. and cl-qtz sch. with lenticular friable quartzite and graphite sch. mb : basic rock in sch. with mg. (post-metamorphism) cc : marble clxt: cl. sch. and foliated quartzite	Sedimentation with subordinate volcanism. Intrusion of stanniferous granite during orogeny of Serra de Mesa Group.	⑧ Limestone and graphite. Magnetite dissemination in phyllite.		
	Pmsm		Photointerpretative Unit: r : Serra Dourada and Serra da Mesa Granite Pmsm: graphite sch., mv-gtz sch., gnt-mv-qtz sch., bt-mv-qtz sch. and quartzite cc : calcareous quartzite		⑧ ** Barite, limestone and graphite. ⑦ ** Sn, F, Ta, Nb, beril, tourmaline and muscovite.		
Palmeirópolis Volcano-Sedimentary Sequence (RIBEIRO FILHO and TEIXEIRA, 1981)	Pip		r : Filo granite 5 : str-bt-mv-qtz sch., ky-bt-mv-qtz sch., gnt-mv-qtz sch. and ky-str-mv-qtz sch. associated with basic sill and dyke (db), banded iron formation (ff) and quartzite (qt)	Aluminous pelitic sedimentation	⑥ Fe in iron formation. ⑤ Kyanite associated with quartzite along fault.	Transamazonian Cycle (2,200 – 1,900 m.a.)	Early Proterozoic (2,600 – 1,900 m.a.)
			4vxt₃ sc-mc-qtz sch. (rhyolitic composition) 4vxt₂ : pl-mc-bt-qtz sch. and pl-bt-qtz sch. intercalated with amphibolite (af) (rhyolitic to rhyodacitic composition) 4vxt₁ : feldspathic bt-qtz sch., str-gnt-bt-qtz sch., bt-anf sch., biotitite and cl. rock (dacitic to rhyodacitic composition) 4vs : feldspathic gnt-bt-qtz sch. and mica sch. including ky. and qcidic meta tuff, with quartzite (qt) and amphibolite (af)	Volcanism-Sedimentation: acidic-intermediate fissure eruption and "neck" (?). Concentration of base metal and Au.	④ "Stratabound"-type volcanogenic Zn-Cu-Pb massive and disseminated sulfide ore deposits. (Corpo C-1 and Albo 10P)		
			3 : dark fine-grained amphibolite with quartzite (qt), ferruginous quartzite (qtfe), gnt-bt-mv-qtz sch. (xt) and basic to ultra-basic dyke (db, ub) r : Morro Solto granite 2gv : metagraywacke, metaconglomerate and ultrabasic sill (ub) 2vc : acidic to intermediate tuff, lapilli tuff, volcanic breccia and their schist 1 : gabbroic banded coarse-grained amphibolite	Basic fissure eruption with volcaniclastics. Sedimentation of graywacke. Intrusion of Morro Solto Granite and basic to ultrabasic rock.	③ Volcanogenic Zn-Cu-Pb massive sulfide mineralization detected by drilling hole of Billiton Metais. ② Supergene lateritized Ni ore deposit concentrated with ultra-basic "sill" in mine claim of Billiton Metais.	?	?
Cana Brava Basic-Ultrabasic Massif	Acb		mg : metagabbro, metanorite and metagabbronorite sp : serpentinite px : pyroxenite ub : serpentinite and pyroxenite mb : basic to ultrabasic rock (post-metamorphism)	Basic-ultrabasic complex.	① *** Asbestos mineralization consisting of chrysotile (ct), "Stockwork" type in serpentine → SAMA	Jequié Cycle 2,800–2,600 m.a.	Archaean 2,600 m.a.

* Projeto Canabrava-Porto Real, CPRM/DNPM, 1979

** Projeto Serra Dourada, DNPM/FUB, 1974 and report of SAMA, 1977

*** Report of SAMA, 1977

①-⑧: ref. Fig. II-1.

Abbreviations: qtz-quartz, mv-muscovite, sc-sericite, bt-biotite, gnt-garnet, cl-chlorite, str-staurolite, ky-kyanite, pl-plagioclase, mc-microcline, sch.-schist

Fig. II–2 Generalized Stratigraphic Columnar Section in the Surveyed Area

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

Serpentinite (NI0079, Acbsp)

Location: SAMA (798.60, 8501.85)

Texture: serpentinite texture of acicular to foliated

Constituent minerals : serpentine ≫ tremolite.

Veinlets of asbstos (chrysotile) are found.

Pyroxenite (Acbpx) is dark gray fine-grained rock.

Metaultrabasic rock (Acbub) shows a remarkable change in lithofacies, showing an appearance of black fine-grained graphitic rock and green fine-grained talcose one. Locally the rock is accompanied by rodingite and calc-silicate to carbonate rocks.

Metabasic rock (Acbmb) is generally subjected to cataclastic metamorphism and lenses of felsic minerals extends in an orientated direction, which change to more fine-grained mylonite in the vicinity of fault contact.

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

Metabasic rock (NI0084, Acbmb)

Location: SAMA (799.35, 8501.75)

Texture: cataclastic, porphyroblastic

Constituent minerals : biotite, carbonate minerals > quartz, plagioclase, muscovite, epidote > sphene, apatite, zoisite.

Segregation of quartz is observed.

(3) Stratigraphical Relation

The massif has been considered the basement rock of the area, and it is thought that a part of the Goias central block has been exposed in the survey area.

Granitic gneiss is distributed in the Goias central block in addition to the afore mentioned basic-ultrabasic rocks, but has not been observed in the area.

Although it is generally said that the unit massif in unconformable contact with the overlying sequences, no distinct unconformity was observed in the current survey.

1–1–2 Palmeirópolis Volcano-Sedimentary Sequence

CPRM (1982, 1984) has classified this sequence into three members: Unidade de Oeste, Unidade de Leste and Unidade de Central. A Cu-Pb-Zn deposit is emplaced in Unidade de Central. The application of this classification is limited to the semi-detailed survey area in the northern part, and the classification of DNPM/CPRM (1983) was more effective for the whole survey area. According to the classification of DNPM/CPRM (1983), the sequence is divided, from the base upward, into Pip_1, Pip_2, Pip_3, Pip_4 and Pip_5. Although this classification together with the distribution mentioned above encountered some problems in part, the current survey followed this classification since it could sufficiently be utilized for the exploration of ore deposit covering the whole area.

(1) Distribution

The sequence is widely distributed from the northern to the southern parts of the survey area occupying about two-thirds of the area to be surveyed. The rocks of the sequence show a zonal arrangement from east toward west, successively becoming younger from the lowermost Pip_1 toward the uppermost Pip_5. Among these, the uppermost Pip_5 approximately occupies the western half of the area distributed by this sequence.

(2) Lithofacies

Pip_1 Member: The rock is dark green, consisting of gabbroic coarse-grained amphibolite. The fresh rock forms isolated peak including Morro Perado, but most of it has been weathered to become reddish brown fine-grained soil.

The results of microscopic observation of the typical rocks are as follows:

Coarse-grained amphibolite (TS0010, Pip_1)

Locality: semi-detailed survey area (802.95, 8549.80)

Texture: granoblastic

Constituent minerals: hornblende > plagioclase > sphene > carbonate minerals, actinolite. The periphery of hornblende has been partly replaced by actinolite.

Coarse-grained amphibolite (NI0064, Pip_1)

Locality: Rio Cana Brava (803.20, 8533.50)

Texture: nematoblastic

Constituent minerals: hornblende > plagioclase > actinolite, opaque minerals, epidote, carbonate mineral > sericite.

Plagioclase has been replaced by clay minerals. Epidote and actinolite are found more in abundance and metamorphic grade is lower than that of TS0010.

Pip_2 Member: The rocks are distributed intercalated in the Pip_1 member, consisting of acidic to intermediate pyroclastic rocks and schist (Pip_2vc) The rock facies change to metagraywacke and metaconglomerate (Pip_2gv) at the northern end of the area. Although the fresh rocks are gray in both rock facies, they are reddish brown when weathered, and it becomes more difficult when disintegrated into soil to discriminate the rocks of Pip_2 from those of Pip_1 member. Thus the judgement have to be formed based on the float or the differences in characteristics of the soil to be mentioned later.

The results of microscopic observation of the typical rocks are as follows:

Muscovite-quartz schist (YT0020, Pip_2gv)

Locality: semi-detailed survey area (799.10, 8556.90)

Texture: lepidoblastic

Constituent minerals: quartz > muscovite, opaque minerals, graphite, carbonate minerals > biotite

Sericite-plagioclase-biotite-quartz schist (NI0063, Pip_2vc)

Locality: Rio Cana Brava (803.35, 8533.15)

Texture: lepidoblastic, porphyroblastic

Constituent minerals: quartz, plagioclase, biotite > opaque minerals, graphite, sericite, carbonate minerals

The member is locally associated with intrusive rock of ultrabasic sill (ub). Although it was reported that a supergene lateritic nickel deposit was found in the sill lying slightly east of the central part of the area (DNPM/CPRM, 1983), the details remain unknown.

Pip_3 Member : The member consists mainly of dark green fine-grained amphibolite to garnet-amphibole schist, intercalated with quartzite (qt), ferruginous quartzite (qtfe), and garnet-biotite-muscovite-quartz schist (xt).

Morro Preto is formed by fine-grained amphibolite, which is scarce in outcrop with abundant floats. Very fine-grained dissemination of sulfide minerals is often observed in the floats of amphibolite distributed on the eastern and southern foot of Morro Preto. Although the schist distributed in the eastern part of Morro Preto has been considered intercalated in the Pip_3 member, it may be that the schist is correlated to the Pip_4 member, as it is distributed over the Pip_3 member, and from the viewpoint of its lithologic characteristics. Also the fact that the geochemical survey detected Zn-Cu anomaly in the schist and in its vicinity is by itself sufficient enough to attract attention for future exploration.

The results of microscopic observation of the typical rocks are as follows:

Fine-grained amphibole schist (NI0191, Pip_3)

Locality: C-1 deposit, Drill hole No. PM-24, 70.00 m.

Texture: nematoblastic

Constituent minerals: hornblende > plagioclase > opaque minerals > apatite, carbonate minerals

Garnet-amphibole schist (NI0060, Pip_3)

Locality: Billington camp (798.15, 8539.85)

Texture: nematoblastic

Constituent minerals: hornblende>plagioclase, garnet, sphene>quartz>opaque minerals, carbonate minerals.

The member has been intruded by basic to ultrabasic dyke (db, ub) and Morro Solto granite (γ).

Pip_4 Member : The member is composed of schistose rocks of intermediate to acidic chemical composition. The distribution of these rocks is centered on Morro do Acampamento in the semi-detailed survey area. This memeber is subdivided by DNPM/CPRM, from the base upward, into Pip_4vxt_1, Pip_4vxt_2 and Pip_4vxt_3. In the central part of the survey area, however, the rocks are collectively treated as Pip_4vs.

The lithologic characteristics of each submember is as follows:

Pip_4vxt_1 consists of feldspathic biotite-quartz schist, staurolite-garnet-biotie-quartz schist and biotite-amphibole schist.

Pip_4vxt_2 mainly consists of plagioclase-microcline-biotite-quartz schist and plagioclase-biotite-quartz schist, intercalated with thin layers of amphibolite (af).

Pip_4vxt_3 consists of sericite-microcline-quartz schist.

Pip_4vs mainly consists of feldspathic garnet-biotite-quartz schist and mica schist which are similar to the schistose rocks found in the semi-detailed survey area, and is intercalated with quartzite (qt) and amphibolite (af).

These schistose rocks display gray color in fresh part, but are reddish brown in weathering part. Fresh outcrop is very scarce in general, and the rocks have been disintegrated into soil in most part of the area due to severe weathering:

The results of microscopic observation of the typical rocks are as follows:

Garnet-plagioclase-muscovite-biotite-quartz schist (NI0059, Pip_4vxt_1)

Locality: semi-detailed survey area (795.50, 8555.40)

Texture: lepidoblastic

Constituent minerals: quartz > biotite > muscovite > plagioclase, garnet, alkali feldspar, apatite, carbonate minrals

Epidote (zoisite)-quartz schist (NI0188, Pip_4vxt_1)

Locality: C-1 deposit, Drill hole No. PM-24, 50.50 m.

Texture: lepidoblastic, granoblastic

Constituent minerals: quartz > muscovite, opaque minerals, sericite, zoisite > alkali feldspar, sphene, apatite, carbonate minerals. Recrystallized quartz, zoisite and opaque minerals are generally observed.

Plagioclase-muscovite-biotite-quartz schist (TS0009, Pip_4vxt_2)

Locality: semi-detailed survey area (794.30, 8551.85)

Texture: lepidoblastic

Constituent minerals: quartz > biotite, muscovite > plagioclase > alkali feldspar

Quartz-plagioclase-amphibole-biotite schist (NI0261, Pip_4vxt_2)

Locality: Alvo 10P Drill hole No. 52, 104.10m.

Texture: lepidoblastic

Constituent minerals: biotite > plagioclase, hornblende > quartz > opaque minerals, sphene

Microcline-plagioclase-muscovite-biotite-quartz schist (NI0035, Pip_4vxt_3)

Locality: semi-detailed survey area (792.90, 8549.45)

Texture: lepidoblastic

Constituent minerals: quartz > plagioclase, biotite, muscovite > microcline > opaque minerals

Garnet-biotite-plagioclase-quartz schist (NI0068, Pip_4vs)

Locality: Faz. São Salvador (792.70, 8524.85)

Texture: lepidoblastic

Constituent minerals: quartz > plagioclase > biotite > garnet, sphene, carbonate minerals

It is evidnet from the microscopic observation that the Pip_4vxt_3 rocks contain alkali feldspars more in abundance than those of other members. The staining test is to be cited to facilitate identification of feldspars (Bailey and Stevens, 1960). Alkali feldspars were semi-quantitatively classified this time using the staining method for each one sample selected from every subdivided member (Photo A−1). As a result, the alkali feldspar contents in each member were found as follows: moderate amount in Pip_4vxt_3 (NI0035), small amount in Pip_4vxt_2 (NI0037), very small amount in Pip_4vxt_1 (NI0059), and extremely very small amount in Pip_4vs (NI0068). It is therefore considered quite possible that the schistose rocks of Pip_4vs distributed in the central part of the area could be further subdivided according to the ratios of alkali feldspar.

Pip_5 displays yellowish brown to reddish brown in color, and is composed of staurolite-biotite-muscovite-quartz schist, kyanite-biotite-muscovite-quartz schist, garnet-muscovite-quartz schist and kyanite-staurolite-muscovite-quartz schist, and is locally intercalated with gray magnetite-quartz schist (banded iron formation (ff)), quartzite (qt) and light gray compact carbonate-silicate rocks. This member has also been extensively disintegrated into soil by weathering. Within the area underlain by this member, staurolite fragments are characteristically observed in places a little apart from the boundaries with the Pip_3 member. On the other hand, the fragments of kyanite are locally observed in the northern part. The member is intruded by basic sills and dykes (db) and Filo granite (γ).

The results of microscopic observation of the typical rocks are as follows:

Tremolite-diopside-plagioclase-microcline-quartz schist (NI0013, Pip_5)

Locality: semi-detailed survey area (788.50, 8554.60)

Texture: Lepidoblastic

Constituent minerals: quartz > microcline, plagioclase, diopside, tremolite > hornblende, sphene, carbonite minerals.

The original rock is considered to have beein impure dolostone.

Staurolite-sericite-muscovite-quartz schist (NI0039, Pip_5)

Locality: semi-detailed survey area (789.30, 8547.40)

Texture: lepidoblastic

Constituent minerals: quartz, sphene > muscovite, opaque minerals, staurolite, sericite > biotite, andalusite, apatite

(3) Stratigraphical Relation

Although it is said that the rocks unconformably overlie the Cana Brava basic to ultrabasic massif, no distinct unconformity has been observed.

(4) Correlation of Stratigraphy

Regarding the classification of the Palmeirópolis volcano-sedimentary sequence which is an important horizon for exploration of ore depcsits in this survey, CPRM (1982, 1984) and DNPM/CPRM (1983) have used different stratigraphic names (symbols), and the correlation between them is considered as follows:

CPRM (1982, 1984)	DNPM/CPRM (1983)	
$PCPE_1$	ct	
$PCPW_1 \sim PCPW_4$	Pip_5	
PCPC	Pip_4vxt_3	Pip_4vs
PCPC	Pip_4vxt_2	
$PCPCxt_1$	Pip_4vxt_1	
PCPCaf	Pip_3	
$PCPCgb_2$**	Pip_1*	Pip_2**
$PCPCgb_1$*		
$PCPE_2$ **		

Note:
PCPW: Unidade de Oeste
PCPE : Unidade de Leste
PCPC : Unidade de Central

The table above indicates that the geology becomes younger from the east toward the west, and Unidade de Central can be correlated to Pip_1 through Pip_4, and Unidade de Oeste to Pip_5, although the correlation between subdivisions of Unidade de Leste is not necessarily clear.

(5) Weathered Soil

Because of scarcity of outcrop in the area, the characteristics of soil were fully examined at the time of soil sampling to supplement the work for geological mapping.

The characteristics (color, grain size, constituent particle, etc.) of the weathered soil of the area are being applied for mapping as an effective means to estimate the original rocks (especially amphibolite and schist).

The following are the characteristics of the soil derived from amphibolite and schist respectively:

Soil derived from Amphibolite: It is dark reddeish brown to dark purple, and consists mainly of very fine-grained clay containing lateritic particles with magnetism and fine-grained quartz.

Soil derived from Schist: Although it displays various color, it is generally light reddish brown to brown or yellowish brown. In the vicinities of creeks it is grayish brown and in the surrounding areas distributed by basic intrusive rocks, it exhibits dark reddish brown.

Grain size is quite small and it is generally sandy with some silty part.

The constituent particles consist mainly of lateritic grain, and magnetic particles are not observed in general.

Although it is very difficult to discriminate from each other the soil of Pip_2, Pip_4 and Pip_5, the differences between them are as follows:

Pip_2 : Mica is not observed

Pip_4 : A small amount of mica is observed in some part.

Pip_5 : Mica is observed more in abundance compared to Pip_4, and crystals of staurolite and/or kyanite sometimes remained in the soil.

Based on the above mentioned characteristics it was possible to make a general discrimination of amphibolites and schists by soil.

1–1–3 Serra da Masa Group

The group is divided, from the base upward, into the Pmsm formation and the Pm_1 formation.

(1) Distribution

The group is distributed in the northwestern part through the western part to the southern part of the survey area in a form to surround the Palmeiropolis volcano-sedimentary Sequence. In the northern part, it is observed on a small scale in the area distributed by Pip_5.

(2) Lithofacies

The Pmsm formation consists of graphite schist, muscovite-quartz schist, garnet-muscovite-quartz schist, biotite-muscovite-quartz schist and quartzite. It is intruded by Serra Dourada and Serra da Mesa granite (γ).

The Pm_1 formation consists of magnetite bearing sericitic quartzite (qt), gray phyllite (fl), quartz-chlorite schist · chlorite-quartz schist · graphite schist (xt), crystalline limestone (cc) and chlorite schist · banded quartzite (clxt), and is intruded by basic sill (mb).

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

Graphite-muscovite-sericite-quartz schist (NI0045, Pm_1fl)

Locality: semi-detailed survey area (785.80, 8547.40)

Texture: lepidoblastic

Constituent minerals: quartz > muscovite, sericite > opaque mineral, graphite

(3) Stratigraphical Relation

The group unconformably overlies the Palmeirópolis volcano-sedimentary sequence.

1–1–4 Rio Maranhão Cataclastic Zone (Ct)

(1) Distribution

Although the formation has a narrow distribution with a northern trend at the eastern end of the area, the cataclastic zone is observed extending beyond the boundaries of the area as a large structure of an N-S system.

(2) Lithofacies

The zone is composed of quartzite (qt), quartz-muscovite schist · quartz-sericite schist · biotite-muscovite schist · garnet-muscovite schist · calc schist · chlorite-muscovite-quartz schist (xt) and gneiss (gn), and cataclastic texture is conspicuous in general. The rocks are intruded by granite (γ) and amphibolitic basic rock (af).

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

Orthoclase-sericite-muscovite-biotite-quartz schist (NI0001, ct)

Locality: northeastern part (804.65, 8554.75)

Texture: lepidoblastic, cataclastic

Constituent minerals: quartz > orthoclase, biotite, muscovite, sericite

(3) Stratigraphical Relation

The zone is in fault contact with the underlying formations.

1–1–5 Paranoá Group

(1) Distribution

The group is distributed in the southern part of the area and to the east beyond the boundary of the area.

(2) Lithofacies

The group consists of quartzite, calcareous and graphitic phyllite, calc schist, crystalline limestone and sericitic quartzite.

(3) Stratigraphical Relation

The group unconformably overlies the lower formations.

1–2 Intrusive Rocks

The intrusive rocks consist of granitic rocks (γ) and basic to ultrabasic rocks (db, ub). Since age determination has only partly been made on both intrusive rocks, it is difficult to estimate the accurate age of intrusion.

1–2–1 Granitic Rocks (γ)

(1) Distribution and Occurrence

The rocks are widely distributed in the western (Serra Dourade) and southern (Serra da Mesa) parts of the survey area as batholith. It is also found as stock on a small scale at the northern end of the central part (Morro Solto), in the southern part (Filo) and at the northeastern end.

The soil dug out from a well (8.5 meters in depth) at about four kilometers to the southeast of Morro Solto had been kaolinized and is different from the surface soil of the surrounding area. It contains boulders of granite. Therefore it is assumed that any latent granite body not exposed on the surface might exist underneath.

(2) Lithofacies

No characteristic difference of rock facies can be observed between these granitic rocks, and they are two mica granite of gray to pinkish and reddish brown color. Banded structure is observed in general, and it is especially notable in the whole area of Morro Solto and along the eastern periphery of Serra Dourada.

The results of microscopic observation of the typical rocks are as follows:

Biotite-muscovite granite (NI0032, Morro Solto granite)

Locality: Morro Solto (793.60, 8560.40)

Texture: granoblastic

Constituent minerals: quartz > plagioclase > alkali feldspar, biotite, muscovite > opaque minerals, sphene

Muscovite-biotite granite (NI0077, Serra Dourada granite)

Locality: Mina Buriti (773.95, 8501.80)

Texture: Granoblastic

Constituent minerals: quartz, plagioclase, alkali feldspar > biotite, opaque minerals > muscovite

(3) Time of Intrusion

The result of radiometric age determination of Serra da Mesa and Serra Dourada has been made public. Rb-Sr age determinations by Hasui et al. (1980) indicate an age range of 1,550 to 1,100 Ma (middle Proterozoic). Since a banded structure is observed in other stock-like granite, it is assumed that the intrusion of both rocks would have taken place at the time of orogenic movement. However, as no age determination has been made so far, it is interpreted at present that the intrusion took place after the formation of the intruded rocks, because of no data on age determination. Namely, it is thought that Morro Solto granite and Filo granite intruded in early Proterozoic, and that the granite at the northeastern end intruded in middle Proterozoic.

1–2–2 Basic to Ultrabasic Rocks (db, ub)

(1) Distribution and Occurrence

The rocks are scattered in the whole area as sills or dykes.

(2) Lithofacies

The rocks are mainly green to dark green coarse-grained amphibolite, and fine-grained gabbro is locally observed. Very fine-grained sulfide dissemination is found in some places, and the rock at slightly east of the central part is accompanied by supergene lateritic nickel deposit.

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

Amphibolite (YT0029, db in Pip_5)

Locality: semi-detailed survey area (788.95, 8552.45)

Texture: nematoblastic

Constituent minerals: hornblende > quartz > plagioclase > opaque minerals

(3) Time of Intrusion

Since the age deterination of these basic rocks has not been made it has been interpreted as in the case of the stock-like granite that the intrusion possibly took place in early Proterozoic and middle Proterozoic. However, it is worthy of note that some basic rocks of post metamorphism have also been recognized in the Pm_1 formation, though this is not expressed on the geological map.

1–3 Metamorphism

Zoning of metamorphic facies was made for the geological units distributed in the survey area, centering mainly on the Palmeirópolis volcano-sedimentary sequence in the semi-detailed survey area. The zoning is based on the results of the field observation, rock analysis (Table II–1) and microscopic observation of thin sections (Table A–1).

From the result of microscopic observation, the assemblages of metamorphic minerals by each geological horizon are determined as follows:

Pip_1 : actinolite-epidote-hornblende

Pip_2 : (actinolite-zoisite-alkali feldspar-)biotite-muscovite-quartz

Pip_3 : epidote-garnet-hornblende

Pip_4vxt_1 : (epidote-hornblende-alkali feldspar-) garnet-plagioclase-muscovite-biotite-quartz

Pip_4vxt_2 : (zoisite-garnet-alkali feldspar-) plagioclase-muscovite-biotite-quartz

Pip_4vxt_3 : alkali feldspar-plagioclase-muscovite-biotite-quartz

Pip_4vs : (garnet-alkali feldspar-plagioclase-) muscovite-biotite-quartz

Pip_5 : (kyanite-andalusite-) staurolite-garnet-biotite-muscovite-quartz

Pm_1fl : graphite-muscovite-sericite-quartz

Fig. II–3 shows the triangular diagrams (ACF diagrams), wherein each apex represents

Table II–1 Results of Chemical Analysis of Rock Samples

	No.	1	2	3	4	5	6	7	8	9	10	11
	Sample No.	TS0010	NI0064	NI0004	NI0063	TS0004	YT0011	NI0191	NI0060	NI0067	NI0070	NI0059
Coordinates	X	802.95	803.20	802.50	803.35	798.25	795.85	PM-24	798.15	791.25	788.15	795.50
Coordinates	Y	8549.80	8533.50	8553.70	8533.15	8550.50	8560.55	70.00 m	8539.85	8524.65	8526.20	8555.40
	Geological Unit	Pip1	Pip1	Pip2gv	Pip2vc	Pip3	Pip3	Pip3	Pip3	Pip3	Pip3	Pip4vxt1
	Rock Name	coarse amphibolite	coarse amphibolite	sc-mv-qtz sch.	sc-pl-bt-qtz sch.	fine amp sch.	fine amp sch.	fine amp sch.	gnt-amp sch.	fine amp sch.	gnt-amp sch.	gnt-pl-mv-bt-qtz sch.
Chemical Composition	SiO2	48.11	51.18	67.04	57.43	48.73	44.44	48.17	47.83	46.77	46.23	71.74
	TiO2	1.15	1.34	0.51	1.00	1.53	1.53	1.62	2.38	1.39	3.67	0.65
	Al2O3	15.06	14.00	14.24	19.17	14.70	18.49	14.38	16.35	14.00	12.86	12.11
	Fe2O3	2.22	2.17	4.25	1.09	1.64	2.77	1.97	3.09	1.59	3.75	1.67
	FeO	8.68	9.31	3.45	5.11	8.94	8.49	11.23	10.09	9.96	12.45	3.83
	MnO	0.20	0.24	0.13	0.09	0.19	0.19	0.25	0.20	0.22	0.33	0.14
	MgO	8.50	6.85	3.05	3.98	6.71	4.98	7.59	4.51	6.30	4.31	1.60
	CaO	13.10	10.50	0.11	4.13	13.27	14.65	10.21	11.94	16.58	12.01	0.90
	Na2O	1.63	2.28	0.20	3.40	2.47	1.78	2.76	2.26	1.47	0.93	2.09
	K2O	0.18	0.37	2.49	3.17	0.29	0.34	0.35	0.28	0.30	0.70	4.17
	P2O5	0.09	0.13	0.06	0.10	0.13	0.12	0.14	0.30	0.11	1.53	0.20
	Ig loss	0.55	1.08	4.08	1.17	1.17	1.38	0.58	0.38	0.54	0.62	0.84
	Total (%)	99.47	99.45	99.61	99.84	99.77	99.16	99.25	99.61	99.23	99.39	99.94
CIPW Normative Mineral	q	0.00	3.25	50.72	7.83	0.00	0.00	0.00	1.60	0.00	8.26	37.67
	c	0.00	0.00	11.16	2.88	0.00	0.00	0.00	0.00	0.00	0.00	3.00
	or	1.06	2.19	14.72	18.73	1.71	2.01	2.07	1.65	1.77	4.14	24.64
	ab	13.79	19.29	1.69	28.77	20.90	12.38	23.35	19.12	10.71	7.87	17.69
	an	33.24	26.87	0.15	19.84	28.17	41.46	25.81	33.64	30.72	28.85	3.16
	ne	0.00	0.00	0.00	0.00	0.00	1.45	0.00	0.00	0.94	0.00	0.00
	ac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ns	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	wo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	diwo	13.01	10.17	0.00	0.00	15.37	12.71	9.99	9.87	21.22	8.66	0.00
	dien	7.74	5.48	0.00	0.00	8.37	6.53	5.15	4.63	10.59	3.71	0.00
	difs	4.60	4.35	0.00	0.00	6.46	5.86	4.57	5.12	10.18	4.95	0.00
	hyen	9.86	11.58	7.60	9.91	2.58	0.00	4.78	6.60	0.00	7.02	3.99
	hyfs	5.86	9.19	2.22	7.00	1.99	0.00	4.24	7.30	0.00	9.36	4.84
	olfo	2.50	0.00	0.00	0.00	4.04	4.12	6.29	0.00	3.58	0.00	0.00
	olfa	1.64	0.00	0.00	0.00	3.43	4.07	6.15	0.00	3.79	0.00	0.00
	mt	3.22	3.15	6.16	1.58	2.38	4.02	2.86	4.48	2.31	5.44	2.42
	hm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	il	2.18	2.54	0.97	1.90	2.91	2.91	3.08	4.52	2.64	6.97	1.23
	tn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ap	0.21	0.30	0.14	0.23	0.30	0.28	0.32	0.70	0.25	3.54	0.46
	cc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	pr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	98.92	98.37	95.53	98.67	98.60	97.78	98.67	99.23	98.69	98.77	99.10

	No.	12	13	14	15	16	17	18	19	20	21	22	23
	Sample No.	NI0119	NI0120	NI0188	TS0009	NI0037	NI0261	NI0035	NI0040	NI0068	NI0069	NI0039	NI0045
Coordinates	X	inclined shaft	inclined shaft	PM-24	794.30	792.40	PM-52	792.90	793.00	792.70	790.95	789.30	785.80
Coordinates	Y	58.85 - 60.20 m	60.20 61.24 m	50.05 m	8551.85	8547.90	104.10 m	8549.45	8549.75	8524.85	8524.80	8547.40	8547.40
	Geological Unit	Pip4vxt1	Pip4vxt1	Pip4vxt1	Pip4vxt2	Pip4vxt2	Pip4vxt2	Pip4vxt3	Pip4vxt3	Pip4vs	Pip4vs	Pip5	Pm1f1
	Rock Name	gnt-mv-bt-qtz sch.	gnt-amp sch/gnt-qtz-mv-bt sch.	epidote-qtz rock	pl-mv-bt-qtz sch.	mc-pl mv-bt-qtz sch.	qtz-pl amp-bt sch.	mc-pl-mv-bt-qtz sch.	mc-mv-pl-bt-qtz sch.	gnt-bt pl-qtz sch.	mv-bt-qtz sch.	str-sc-mv-qtz sch.	gp-mv-sc-qtz sch.
Chemical Composition	SiO2	49.56	70.83	49.24	72.68	74.30	49.64	71.33	72.60	71.15	62.12	58.10	65.44
	TiO2	0.58	0.66	0.88	0.66	0.57	1.20	0.69	0.66	0.80	1.35	1.06	0.91
	Al2O3	15.27	10.89	15.81	12.37	12.44	14.84	13.10	12.66	13.04	15.43	22.33	18.62
	Fe2O3	3.15	2.30	4.45	1.59	0.77	1.96	1.26	1.10	1.20	12.27	8.94	5.23
	FeO	8.75	4.85	6.00	3.71	2.30	8.45	3.45	3.19	3.96	0.13	0.51	0.51
	MnO	0.51	0.30	0.33	0.11	0.04	0.21	0.07	0.06	0.09	0.34	0.09	0.03
	MgO	9.88	3.07	7.45	1.20	0.63	8.47	1.39	0.93	1.71	0.12	0.63	0.41
	CaO	7.82	2.23	9.46	0.86	2.46	8.78	0.71	0.53	3.27	0.03	0.58	0.56
	Na2O	0.73	1.00	1.13	3.07	2.26	2.33	1.91	2.08	2.49	0.04	0.54	0.43
	K2O	0.80	2.17	1.28	2.28	3.05	2.04	4.71	5.52	1.84	0.18	2.39	3.23
	P2O5	0.12	0.14	0.07	0.13	0.12	0.08	0.12	0.20	0.13	0.07	0.06	0.07
	Ig loss	2.20	0.86	3.10	1.16	1.04	1.55	1.31	0.91	0.40	8.04	4.82	4.05
	Total (%)	99.37	99.30	99.20	99.82	99.98	99.53	100.05	100.44	100.08	100.12	100.05	99.49
CIPW Normative Mineral	q	5.40	44.80	6.26	40.73	42.37	0.00	36.99	35.61	38.10	61.02		
	c	0.00	3.18	0.00	3.60	1.24	0.00	3.86	2.78	1.32	15.17		
	or	4.73	12.82	7.56	13.47	18.02	12.06	27.83	32.62	10.87	1.06		
	ab	6.18	8.46	9.56	25.98	19.12	19.72	16.16	17.60	21.07	0.34		
	an	36.03	10.15	34.29	3.42	11.42	24.01	2.74	1.32	15.37	0.00		
	ne	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	ac	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	ns	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	ks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	wo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	diwo	0.83	0.00	5.09	0.00	0.00	7.94	0.00	0.00	0.00	0.00		
	dien	0.51	0.00	3.47	0.00	0.00	4.76	0.00	0.00	0.00	0.00		
	difs	0.28	0.00	1.22	0.00	0.00	2.77	0.00	0.00	0.00	0.00		
	hyen	24.10	7.65	15.08	2.99	1.57	6.09	3.46	2.32	4.26	0.30		
	hyfs	13.18	6.47	5.29	4.61	2.72	3.55	4.29	3.97	5.13	0.00		
	olfo	0.00	0.00	0.00	0.00	0.00	7.19	0.00	0.00	0.00	0.00		
	olfa	0.00	0.00	0.00	0.00	0.00	4.62	0.00	0.00	0.00	0.00		
	mt	4.57	3.33	6.45	2.31	1.12	2.84	1.83	1.59	1.74	0.00		
	hm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.27		
	il	1.10	1.25	1.67	1.25	1.08	2.28	1.31	1.25	1.52	1.00		
	tn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	pf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	ru	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82		
	ap	0.28	0.32	0.16	0.30	0.28	0.19	0.28	0.46	0.30	0.16		
	cc	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	pr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	Total	97.18	98.44	96.10	98.66	98.94	98.00	98.74	99.53	99.68	92.15		

qtz: quartz
pl : plagioclase
mc : microcline
bt : biotite
mv : muscovite

amp: amphibole
gnt: garnet
str: staurolite
sc : sericite
gp : graphite

Geological units are referred to Fig. II-2

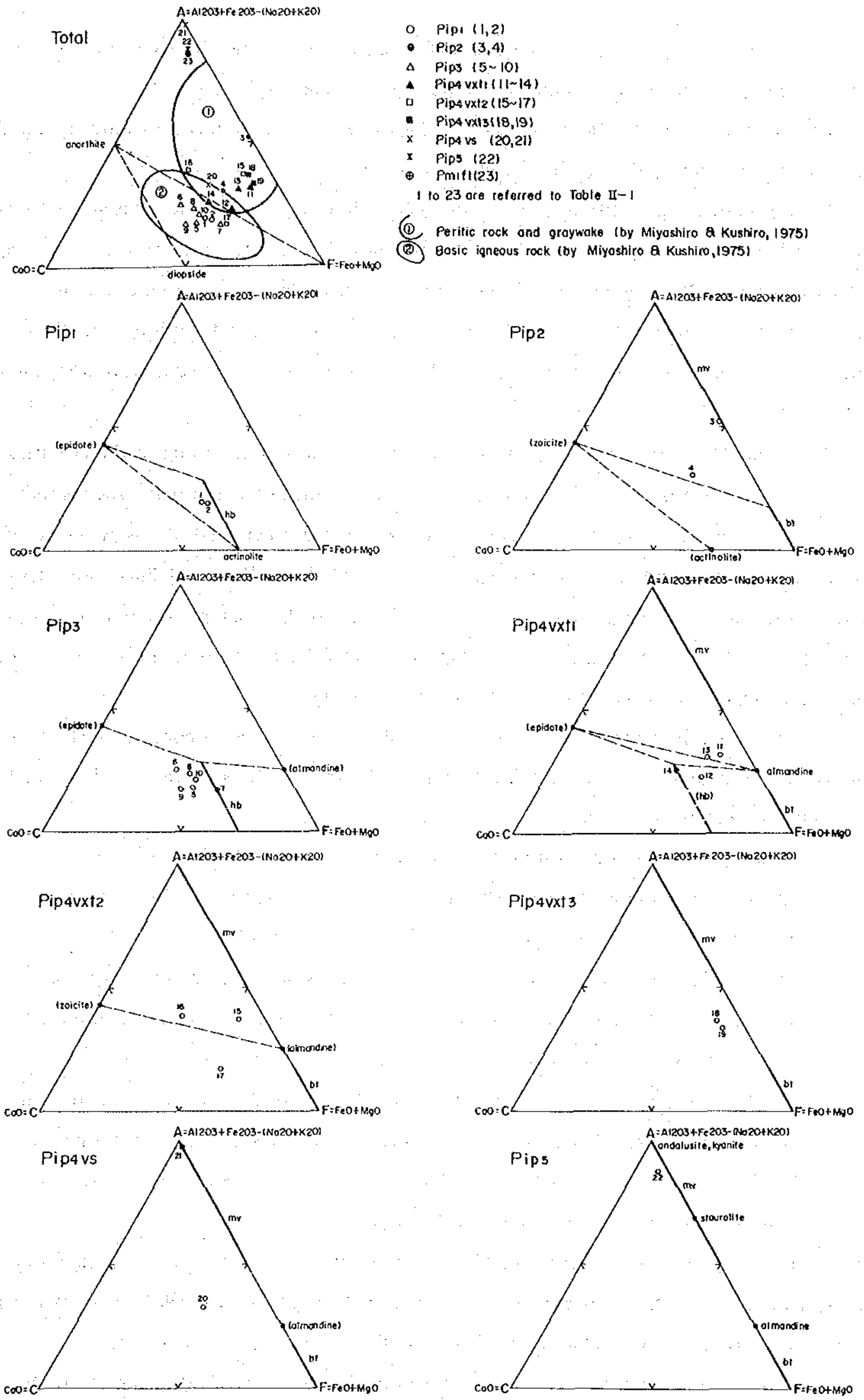


Fig. II–3 ACF Diagrams of Metamorphic Rocks

$Al_2O_3 + Fe_2O_3 - (Na_2O + K_2O)$, CaO and FeO + MgO in mol ratio, showing the relation between chemical composition and mineral components of metamorphic rocks.

The diagrams show that the samples of the Pip_1 and Pip_3 formations consisting of amphibolites belong to metamorphic facies of amphibolite facies.

Their chemical composition of tese falls in the domain of anorthite-diopside-F triangle, corresponding to the composition of basic igneous rock. Among the schistose rocks, the samples of Pip_2 and Pip_4 fall in the domain of anorthite-F-A triangle, and those of Pip_5 and Pm_1fl come close to A near the line A-F. The schistose rocks of the latter coincide with the composition of typical pelitic rock, while the former is considered to indicate that its composition is closer to that of igneous rock.

When the ACF components of all these samples are plotted according to the classification of Miyashiro and Kushiro (1975), the amphibolites fall in the domain of basic igneous rock, and schistose rocks in that of pelitic rock and graywacke. On the other hand, the assay results of the whole rock analysis indicate that the values of amphibolites (Pip_1 and Pip_3) are analogous to the mean chemical composition of basalt, while that of Pip_2 among the schistose rocks to those of andesite to dacite, and those of Pip_4 to that of dacite to rhyolite (however, some of them are analogous to the composition of andesite to basalt).

Basedi on the above mentioned mineral assemblages and chemical compositions, metamorphic zone and metamorphic facies of each geological horizon were assumed (Fig. II−4), and also the original rocks were assumed.

In summary, the following assumptions are made:

- Pip_1 and Pip_3 (amphibolites) belong to (epidote ~ amphibolite facies ~) amphibolite facies and that the original rock is basic igneous rocks (basalt).
- Pip_2 and Pip_4 (shistose rocks) belong to (garnet zone ~) staurolite-andalusite zone (~ andalusite-kyanite zone), and the original rock is composed mainly of intermediate to acidic igneous rock, intercalated with pelitic rocks and basic rocks.
- Pip_5 (schistose rocks) mainly belong to staurolite-andalusite zone changing to staurolite-kyanite zone in the northern part, and the original rock is derived from pelitic rocks.
- Pm_1fl (schistose rocks) belong to chlorite zone-garnet zone, and the original rock is derived from pelitic rocks as in the case of Pip_5.

As to the types of metamorphism of the metamorphic rocks of the area, consideration was given in reference to the metamorphic facies series defined Miyashiro (1965) as shown in Fig. II−5. The figure shows the metamorphic facies and the metamorphic facies series.

Miyashiro (1961) summarized the classification of facies series of regional metamorphism in

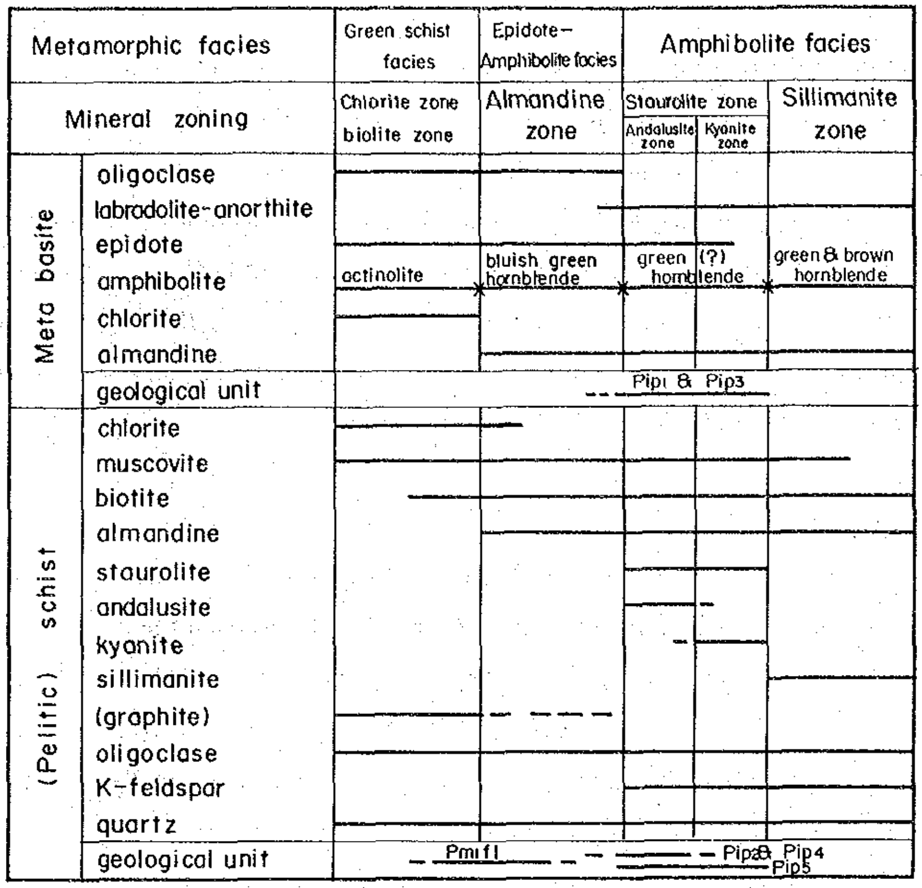
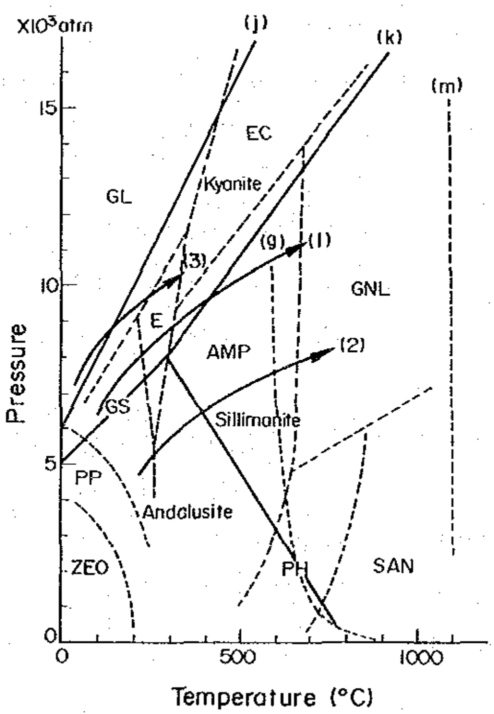


Fig. II-4 Classticatin of Metamorphic Facies



GL : Glaucophene schist facies
EC : Eclogite facies
GS : Green schist facies
E : Epidote amphibolite facies
AMP : Amphibolite facies
GNL : Granulite facies
PH : Pyroxene hornfels facies
SAN : Sanidinite facies
PP : Prehrite-pumpellyite facies
ZEO : Zeolite facies
(j) : Jadeite+quartz = albite
(k) : Kyanite = sillimanite
(g) : Minimum temperature of magmatism
(m) : Maximum temperature of metamorphism
(1) : Kyanite-sillimanite type
(2) : Andalusite-sillimanite type
(3) : Jadeite-glaucophene type

Fig. II-5 P-T Diagram of Metamorphic Facies the world, and classified them into three standard types: (1) kyanite-sillimanite type, (2) andalusite-sillimanite type and (3) jadeite and glaucophane type. To these three standards, Miyashiro further added two intermediate types which fall between (1) and (2), and (1) and (3).

A comparative study of Fig. II–4 and Fig. II–5 leads to the assumption that metamorphic facies series of the Palmeirópolis volcano-sedimentary sequence would be the intermediate type between the kyanite-sillimanite type of intermediate pressure type and the andalusite-sillimanite type of low pressure type. The temperature and pressure of metamorphism are considered to fall in the ranges of 300 to 600°C and 6 to 10 atms respectively.

1–4 Geologic Structure

The geologic structure of the area is consistent with that of N-S system of the Uruaçu orogenic belt among those developed between the Sao Francisco Craton and the Amazonico Craton.

The basement of the area and its surroundings is a part of the Goias block cratonized in the later stage of the Uruaçuano orogeneic cycle, and the geology consists of Archaeozoic gneiss of high metamorphic grade, basic to ultrabasic rocks and granulite complex Part of it is widely distributed with N-S trend in the southeastern part of the area, forming the Cana brava massif.

Amphibolites and schistose rocks of the lower Proterozoic Palmeirópolis volcano-sedimentary Sequence is extensively distributed in the central zone from the northern part to the southern part of the area.

The middle Proterozoic Serra de Masa Group and the Paranoá Group are found on the western side and the eastern side of the above sequence in a form to surround it.

In regard to the fold structure, the N-S system is dominant. On the other hand, an elongated domal structure in the direction of N-S is observed in the surrounding area of Serra da Mesa granite and Serra Dourada granite.

The main fault systems include those of N-S, NW-SE and NE-SW. The faults of N-S system are found dominantly in the eastern and western parts of the area. On the eastern side of the Cana Brava massif in the southeastern part of the area, thrust fault is conspicuous, forming Rio Maranhão cataclastic zone.

With regard to the sense of dislocation of horizontal component of the fault strucrures of NW-SE and NE-SW systems, left hand-side slip is dominant in the former and right handside slip in the latter. Therefore these systems are considered to be in conjugate relation to each other. However, the amount of slip in vertical component is rather great in the vicinity of the C-1 ore deposit and in the surrounding area of the Cana Brava massif, showing a complicated geologic structure having been separated into blocks.

According to the result of the geophysical survey (SCAMT method) conducted in the semi-detailed survey area, structural variation of apparent resistivity is notable, indicating that a severe block movement by faulting would have taken place. Furthermore, apparent resistivity of the lower part underneath the area is higher than that of the Palmeirópolis volcano sedimentary sequence, which leads to the assumption that any rock mass of high density might exist in the depth.

On the other hand, according to the result of the aeromagnetic survey of Projeto Serra da Mesa, magnetic anomaly was detected in the area distributed by the Cana Brava massif at Minaçu in the southeastern part of the survey area and in the Serra da Mesa group extending northerly in the western part of the survey area. These anomalous zones seem to have been caused by ultrabasic rocks.

These facts lead to the possibility that the basement rocks might exist in a relatively shallow part, from the bottom of the Palmeirópolis volcano-sedimentary sequence toward the west.

1–5 Geologic History

There were several orogenic cycles in the South American Platform of Brazil in which the geology of Precambrian era is included. The representative ones include the orogenic cycles of Jequie-Aroense (2,600-2,800 Ma), Transamazonian (1,900-2,100 Ma) and Brasilliano (450-700 Ma).

The survey area was subjected to these orogenic cycles, in addition to the Uruaçuano (900-1,300 Ma) cycle developed in the Atlantico Shield and its surrounding areas.

Jequie Orogenic Cycle

This is the oldest orogenic cycle in the area. Basalt to picrite magma intruded vigorously into granulite, associated with a tectonic movement of the basement rocks. The Cana Brava basic to ultrabasic massif is considered to have been formed during this period.

The asbestos deposit of SAMA (Cana Brava deposit) was formed in association with serpentinization of the ultrabasic rock. The K-Ar and Rb-Sr data of radiometric age dating on the basement rocks of the area indicate an age range of 2,500 to 4,125 Ma (DNPM, 1984).

Transamazonian Orogeneic Cycle

The Palmeirópolis volcano-sedimentary sequence characterized by the products of vigorous basic volcanism, sedimentation and intermediate to acidic volcanism, was formed during this period..

Amphibolite derived from basic volcanic rocks and pyroclastic rocks are found in the lower part, intercalated with quartzite and schistose rocks.

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Transamazonian Orogeneic Cycle

The Palmeirópolis volcano-sedimentary sequence characterized by the products of vigorous basic volcanism, sedimentation and intermediate to acidic volcanism, was formed during this period.

Amphibolite derived from basic volcanic rocks and pyroclastic rocks are found in the lower part, intercalated with quartzite and schistose rocks.

In the upper part, schistose rocks derived from sedimentary rocks, intermediat to acidic volcanic rocks and pyroclastic rocks are developed, intercalated with metachert and quartzite.

In addition, acidic rocks (Morro Solto granite) and basic to intermediate intrusive rocks are observed having intruded the above rocks.

As in the above, various volcanism took place vigorously along the fissures in the continent during this period, and sedimentary rocks were actively deposited during the times of dormancy and cease of volcanism. The characteristics of volcanic rocks change, from the base upward, from basic rocks (partly ultrabasic rock) to intermediate and acidic rocks, showing the differentiation of magma. Mineralization of massive sulfide ore deposit formed associated with these volcanism has been confirmed in the area. The C-1 deposit and other Cu-Pb-Zn deposits were emplaced particularly during the time when basic volcanism ceased and shifted to intermediate to acidic volcanism.

Uruaçuano Orogenic Cycle

This is the orogenic cycle in which the Uruaçu tectonic belt was formed along the western periphery of the Atlantico Shield. It is characterized by the presence of geosynclines and tectonic zones, and sedimentation of the Serra da Mesa Group (accompanied by a small amount of volcanic rocks) and intrusion of the Serra da Mesa type granitic rocks took place. Further, the tectonic movement resulted in forming the Rio Maranhão Cataclasitic Zone in the eastern part of the area.

Tin deposits (Mina Buriti and others) of the albitite and greisen types, and a pegmatite deposit were formed in association with the granitic rocks intruded during this period. Rb-Sr isotopic ages of these granitic rocks have been reported to be in the range of 1,100-1,500 Ma (Hasai et al., 1980).

Brasilliano Orogeneic Cycle

The orogenesis took place during late Precambrian when the geologic structure of the continental crust came to be a hard mass. The sedimentation and folding are conspicuous in this cycle, and the Paranóa group was formed in the eastern part of the survey area.

The lithology is characterized by various sedimentary rocks and carbonate rocks. Metamorphism is weak and the facies belong to the metamorphic zone of green schist facies.

While the metamorphism and the granitic intrusion took place during the ages ranging between 650 and 700 Ma, the granitic rocks of this period are not distributed in the survey area.

1–6 Ore Deposit

1–6–1 Outline of Ore Deposit

Although the survey area is distributed by the deposits of various sizes, large and small as shown in Figures II–1 and II–2, the chief deposits either being surveyed or under operation at present include the Cana Brava asbestos deposit, the Palmeirópolis Cu-Pb-Zn deposit and the Briti tin deposit.

The Cana Brava asbestos deposit is the stockwork-type deposit of chrysotile-type asbestos deposit formed by serpentinization of the ultrabasic rock of the Cana Brava massif.

The deposit is being operated by SAMA (S.A. Mineraçao de Amianto), and 200,000 tons of crude ore (7.5% chrysotile) are annually produced from the two open pits. Two stages of mineralization are observed: low grade asbestos of low temperature type in brown serpentinite was formed by the mineralization of early stage, and high grade asbestos of high temperature type in green serpentinite was formed in the mineralization of the later stage. The ore reserves have been confirmed to be 50 million tons (6.7% chrysotile).

In the Palmeirópolis Cu-Pb-Zn deposit, three ore bodies (C-1, C-2 and C-3) were discovered in the survey of "Projeto Palmeirópolis" conducted by CPRM from 1975 to 1984. The ore reserves are estimated to be about four million tons (0.46-1.24% Cu, 0.33-1.38% Pb and 4.22 -5.85% Zn).

The discovery of this deposit greatly increased the potential of natural resources of the area which had not attracted much attention in the past. Furthermore, since the Palmeirópolis volcano-sedimentary sequence, which is known as the ore bearing horizon, is widely distributed in the area, this particular area was thus selected as the target area of the current project. Further details will be described later.

The Buriti tin deposit is a deposit formed by Sn, F, Ta, Nb, beryl and tourmaline mineralization associated with albitization, greisenization and pegmatitization in and around the Serra Dourada granite mass.

The mineralization associated with albitization forms a small-scale deposit of high grade and the Brumadinho's Buriti mine is mainly operated for this type of deposit.

Besides, it has been reported that the survey of Billington Metais discovered a supergene lateritic nickel deposit associated with ultrabasic intrusive rocks and a weak mineralized zone of copper, lead and zinc of volcanic origin (DNPM/CPRM, 1983). The details, however, are not available.

1–6–2 Palmeirópolis Deposit

The Palmeirópolis deposit is discovered as a result of the survey by CPRM covering the area of about 30,000 ha (southern half of it is included in the semi-detailed survey area of the current project) between 1975 and 1984. CPRM selected 18 promising areas (Alvo) on the basis of the results of geological and geochemical (stream sediment) surveys of the area. The stage of survey for these targets (Alvo) was successively raised thereafter, and CPRM finally discovered three ore bodies (C-1, C-2 and C-3) of Cu-Zn-Pb deposit. Among these, C-2 and C-3 are located on the north beyond the boundary of the area, and CPRM resumed the survey in 1986 in the surrounding areas of the two ore bodies. At Alvo 10P, a drill hole encountered a small-scale mineralized zone similar to that of the C-1 ore body.

Plate II-8 shows the location of CPRM's drill holes performed around the C-1 ore body and Alvo 10P mineralized zone. Figure II–6 shows the index map of the survey conducted in the vicinity of the C-1 ore body.

The three ore bodies in the Palmeirópolis are emplaced between the amphibolitic rocks (Pip_3) and schistose rocks (Pip_4vxt_1), and all of these are more or less positioned in the same horizon.

The approximate sizes of these ore bodies as follows:

C-1 ore body : 1,300 m x 150 m

C-2 ore body : 300 m x 100 m

C-3 ore body : 300 m x 150 m

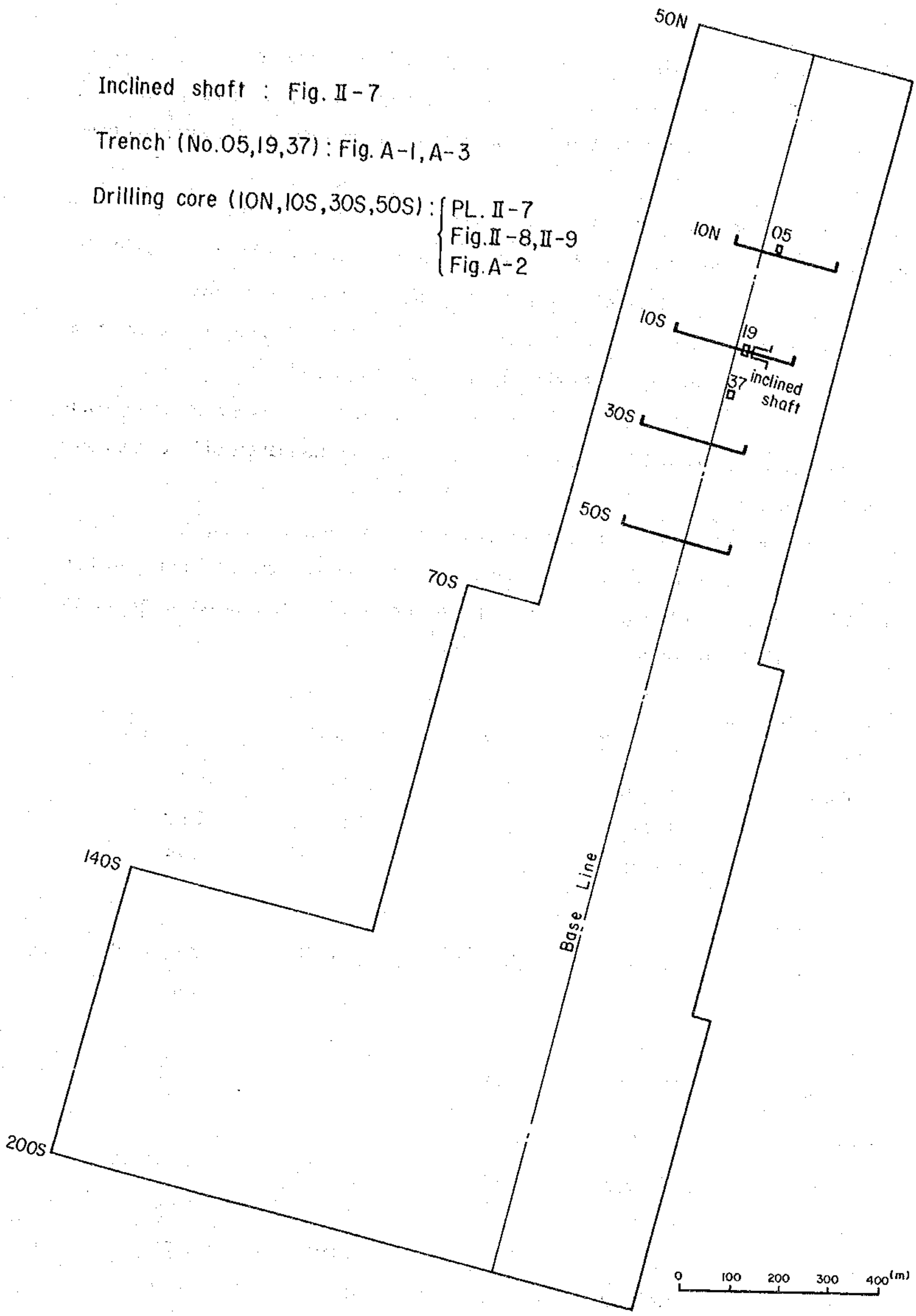


Fig. II-6 Index Map of C-1 Ore Body

The main mineral assemblage of the ore consists of sphalerite, pyrrhotite, pyrite, chalcopyrite and galena. Although the amount of content of each mineral are also in the above order, the C-3 ore body contains a lesser amount of lead, showing a characteristic a little different from other two ore bodies.

The C-1 and C-2 ore bodies are represented by the following two types of ore.

Massive ore: constitutes the high-grade part, and characterized by more than 50 per cent of sulfide (volume percentage) and brecciated texture.

Disseminated ore: found in the surrounding part of the former, rarely containing more than 20 per cent of sulfide (volume percentage)

The C-3 ore body mainly consists of massive and banded ores, accompanied by disseminated ore in the peripheral part. The banded ore is intercalated with thin layers of brecciated ore, though small in amount.

The ore reserves have been estimated to be about four million tons as a result of exploration hitherto conducted by CPRM. All the calculation of ore reserves was made by the cross section method with a spacing of 100 meters based on the drill data. The ore reserves of more than 0.3% Cu (or 3.0% Cu + Zn) in cutoff grade are as follows.

C-1 Ore Body				
Measured	1,252,000 T	1.10 Cu%	1.19 Pb%	4.50 Zn%
Indicated	344,000	1.43	1.74	6.47
Inferred	151,000	2.10	2.14	7.90
Total	1,747,000	1.25	1.38	5.18
C-2 Ore Body				
Measured	186,000 T	0.43 Cu%	1.19 Pb%	6.11 Zn%
Indicated	113,000	0.49	1.06	5.23
Inferred	30,000	0.55	1.46	6.56
Total	329,000	0.46	1.17	5.85
C-3 Ore Body				
Measured	1,689,000 T	1.43 Cu%	0.26 Pb%	4.07 Zn%
Indicated	350,000	1.15	0.40	3.98
Inferred	120,000	0.57	0.19	1.71
Total	2,159,000	1.33	0.27	3.92

CPRM 1985

In the current survey, the investigation of ore deposit was conducted on the C-1 ore body and its surroundings located in the semi-detailed survey area. The purpose of this investigation was to understand the characteristics and nature of the Palmeirópolis deposit and to apply available data to the surveys of the neighboring areas. The same investigation was also made on the samples of gossan discovered in the semi-detailed area.

1–6–3 Result of Survey of C-1 Ore Body and Its Surroundings

The C-1 ore body was discoverd within the area of sub-alvo 2P. The footwall of the ore body is composed of amphibolite and the hanging wall of mica is composed of schist. The ore body is harmoniously positioned between these rocks (Fig. II–7, PL. II–7). The amount of biotite increases in the country rock close to the ore body, especially in the schist. In the main part of the massive ore body, lenses of metachert are often intercalated together with Cu-Pb-Zn sulfide. But both of them have been mylonitized to become brecciated ore.

The fold structures of the ore body and the country rock show isoclinal fold, striking N10° -15°E, dipping 70°-80°E, and the pitch of fold axis is 15° in the direction of S10°-20°W.

Pip_4vxt_1 formation, a country rock of C-1 ore deposit, distributes from C-1 ore body toward the southwest where Alvo 7P, southeast of Alvo 9P and Alvo 10P are located.

The result of soil geochemistry shows that the Zn, Cu and Pb anomaly was consistent with the ore horizon, and its halo is expanded along the direction of extension of the ore horizon.

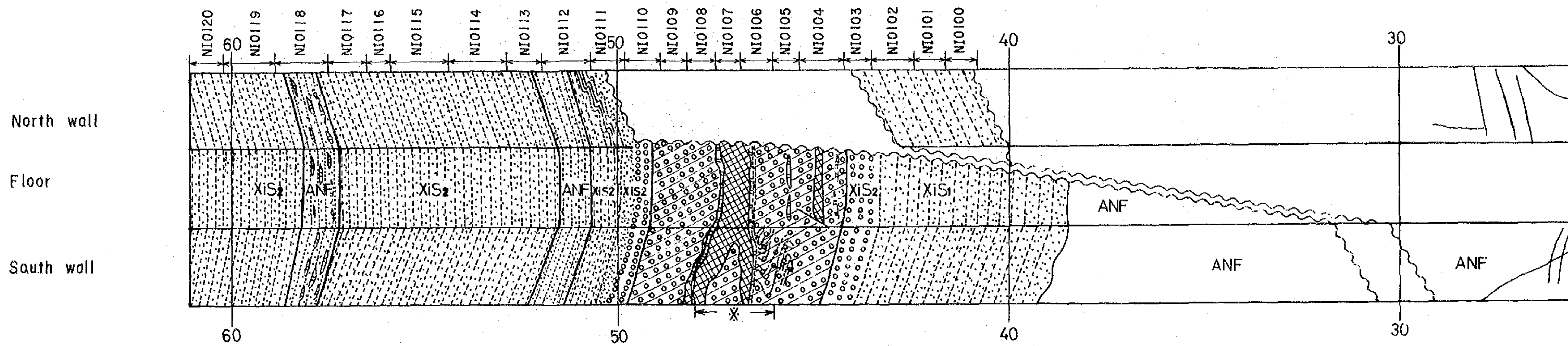
The result of geophysical survey (SIP method) shows that the anomaly showing the presence of massive sulfide deposit at shallow part was clearly detected on the survey line immediately above the ore body. Furthermore, the result of computor model analysis leads to the assumption that the lower extension of the C-1 ore body would change to the network veinlets or disseminated ore body.

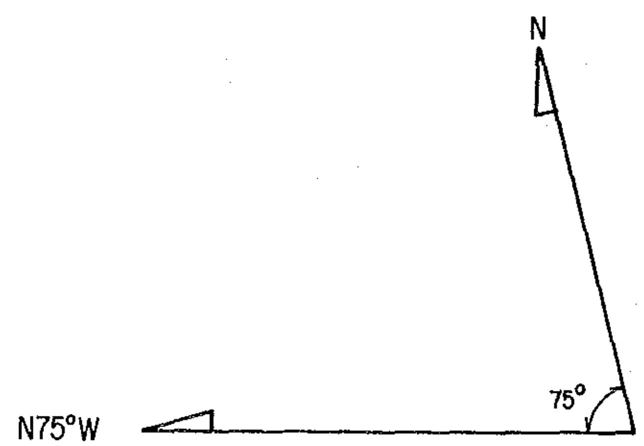
(1) Assemblage of Ore Minerals

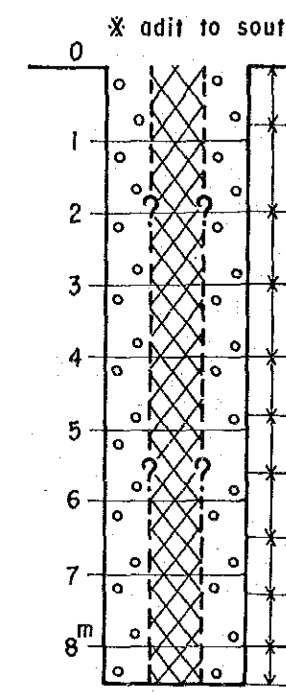
It is impossible at present to go down into the underground of the C-1 ore body because the inclined shaft and the drifts of the C-1 ore body are flooded. However, since the ore and the country rocks from the ore body are preserved on the ground as a sample stockpile and sorted out by the depth, investigation and sampling of the ore were carried out with reference to the sketch map of the inclined shaft drawn by CPRM (Fig. II–7). The drill cores in the neighboring areas of the ore body were also sampled.

Twenty eight ore samples thus obtained were microscopically examined to study their mineral assemblages and characteristics (Table A–2).

The ore is assumed to be that of metamorphosed ore deposit in the country rocks of high





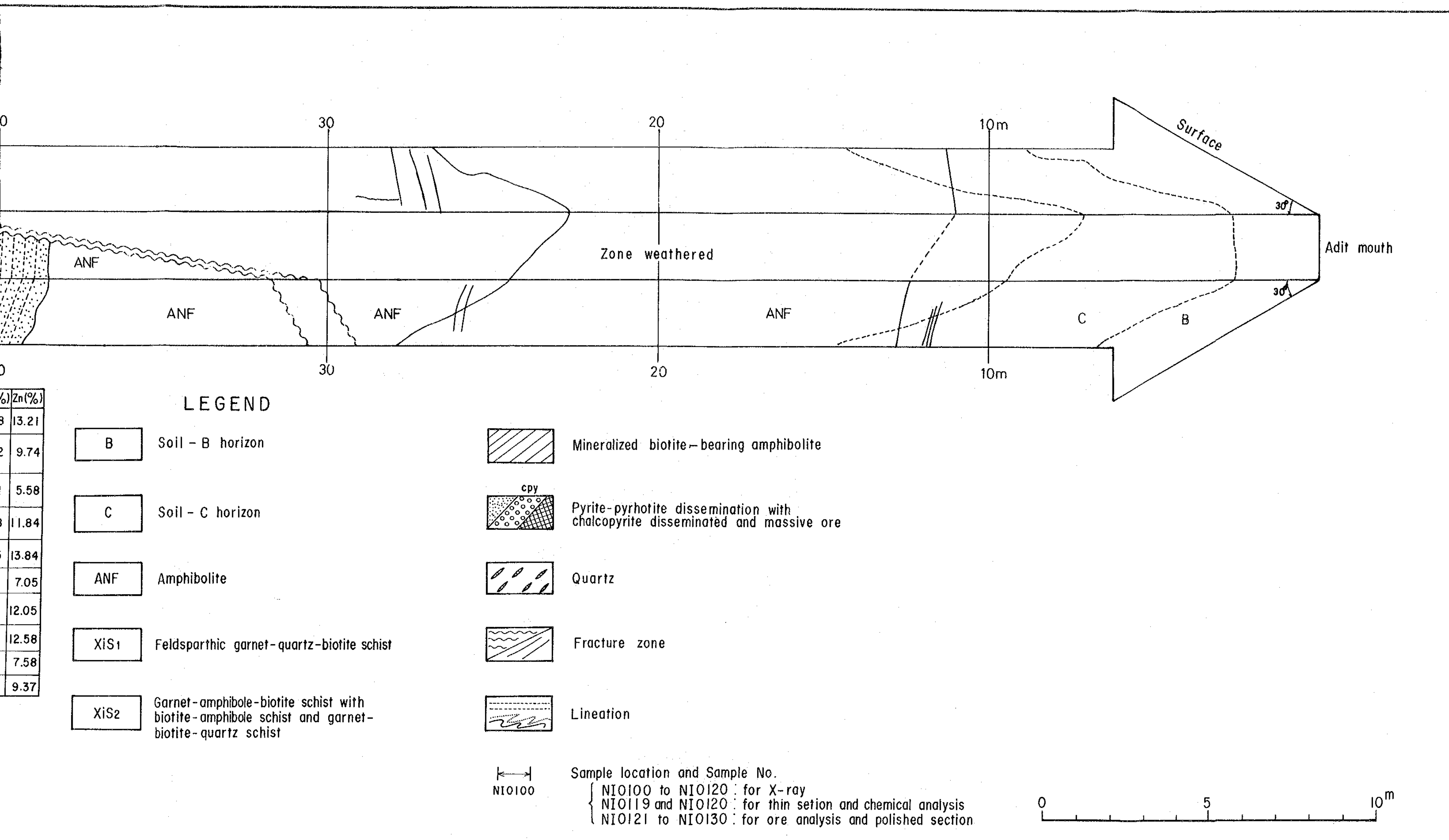


	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)
NI0121	0.3	49.5	1.30	3.38	13.21
NI0122	0.4	48.1	2.20	2.62	9.74
NI0123	0.3	25.3	0.96	1.41	5.58
NI0124	0.5	51.6	1.12	3.28	11.84
NI0125	0.5	52.2	1.02	3.85	13.84
NI0126	0.4	37.6	1.71	2.81	7.05
NI0127	0.3	43.6	1.33	2.81	12.05
NI0128	0.4	48.3	1.44	3.47	12.58
NI0129	0.5	42.7	2.04	2.29	7.58
NI0130	0.2	30.5	0.85	2.14	9.37

LEGEND

B	Soil – B horizon
C	Soil – C horizon
ANF	Amphibolite
XiS1	Feldsparthic garnet-quartz-biotite schist
XiS2	Garnet-amphibole-biotite schist with biotite-amphibole schist and garnet-biotite-quartz schist

Fig. II–7 Geological Sketct of Inclined Shaft in C–1 Ore Body



—7 Geological Sketct of Inclined Shaft in C–1 Ore Body

metamorphic grade. The gangue minerals are likely to be the metamorphosed minerals almost the same kind as those of the country rocks. Generally, the ore is coarse grained and well recrystallized, and the sulfide minerals are very irregularly mixed, being partly coarse grained, and fine grained and compact in other parts.

The sulfide minerals include pyrite (Py), pyrrhotite (Po), chalcopyrite (Cp), sphalerite (Sp) and Galena (Ga) as their main constituents, and other minor or rare minerals are not observed. These five minerals can be observed in most of the polished sections, although the content ratios are variable.

There is few structure or texture showing any particular paragenetic relation between gangue and sulfide minerals, and it is the same among the sulfide minerals themselves, whose relationships appear irregular and unsteady.

Under the reflecting microscope, it is difficult to identify the gangue minerals, and the mineral species can only be estimated from the shape and the cleavage. A large number of species thus estimated and the unsteady character of gangue minerals make it quite difficult to make an accurate description only by the microscopic observation of the polished sections.

The most notable character in the 28 polished sections observed by the naked eye is the structure in which gangue minerals are embedded in the dense aggregate of sulfide minerals in a form of pebble to sand grain. The grain sizes ranges from up to seven to eight milimeters across, to about one milimeter across. The size, distribution and density change for each polished section, and the shape varies from round through subangular to angular, being mostly angular in those of larger size and round in smaller ones in general.

Such a structure is named the "pebble structure", since the grain size reaches up to several milimeters across. However, since the distribution of grain size ranges continuously from large to very small ones under the microscope, reaching to the minimum of 0.02 milimeter.

Taking a general view, the gangue minerals look like the phenocryst of the volcanic rocks in the groundmass of sulfide minerals, showing a texture quite similar to the porphyritic texture.

The large-size pebbles are the aggregate of minerals of more than two kinds, while the microscopically identifiable smaller ones, correspond to phenocryst, and consist of unit crystals of singular minerals, showing an euhedral form. This is observed evidently in gangue minerals taking prismatic form. In these fine grains, it is characteristic that they tend to take a round shape, though they look like euhedral.

The part of sulfide, which corresponds to the matrix of the porphyritic texture, generally shows a granular structure complicatedly crowded with various ore minerals. The ore minerals include sphalerite, pyrite, pyrrhotite, chalcopyrite and galena, among which sphalerite is present most commonly in many polished sections, while other sulfide minerals take a form of inclusion in sphalerite.

Mineral assemblage varies locally in one section, and sizes and ratios of content varie from one sample to another in the same manner.

Sample No. 229 shows the most fine-grained granular texture among the samples, consisting of two kinds of assemblages of Sp-Cp and Sp-Po. Sample No. 137 is composed of Sp-Py-(Ga), being poor in Galena, and a little coarser grained. This kind of structure is observed in almost a half of the sections such as No. 122, 123, 124, 125, 126, 128, 130, 137, 155, 158, 165, 166, 229 and 233. However, some difference in texture and assemblage are observed among these sections.

Although it is common that the outline of pebbles embedded in groundmass is sharp, a different texture is observed in Sample No. 158, where minute sulfide minerals are taken in the pebble, passing into the sulfide part in th surroundings. In other cases, rim texture of sulfide minerals is shown along the periphery of the pebbles.

Regarding the quantity of Sp among the sulfide minerals, it is quite dominant in most cases, in which other sulfide minerals are present as inclusion. In other cases, Sp and other sulfide almost equal in amount. Sample No. 229 shows a ripple mark-like texture of very minute and irregular shape. In some sections, all the minerals are coarse-grained.

The assemblages of sulfide minerals are also various, such as,

Sp $>$ Po $>$ Ga, poor in Py and Cp (Nos. 124, 125, 126, 127 and 128),

Sp $>$ Py $>$ Ga, poor in Po and Cp (Nos. 137 and 155), and

Sp $>$ Cp $>$ py, poor in Po and Ga (Nos. 123 and 158).

These are classified as Type A, and other 14 samples were classified as Type B.

In Type B, no characteristic mineral assemblage and texture are observed, and those not belong to Type A. However, some of them show a transitional type similar to Type A.

Generally, crystallinity of the gangue minerals is coarse, and that of sulfide minerals become coarser in accordance with it. Especially, because the size of individual grain of pyrrhotite can be clearly discriminated from other sulfide according to the anisotropism, it was used as the standard of crystallinity when compared with Type A.

The five sulfide minerals in the above show a remarkable variation in shape, size and state of distribution controlled by gangue minerals. Those included in the gangue minerals of prismatic crystal become large in size according to the magnitude of openings along the cleavage, sometimes becoming minute irregular grains. In some cases, coarse and fine crystals are mixed together, while highly winding veinlets are found along the irregular cracks along gangue minerals, being disseminated in other cases.

The ore minerals are mineralogically composed of five sulfide minerals such as pyrite, pyrrhotite, chalcopyrite sphalerite and galena, besides titanium minerals. Sp is most commonly found in almost all the sections. In Type A, Sp is the base of sulfide part, showing mineral assemblages of Sp-Po and Sp-Cp, of which either Po or Cp being the major accessory component. It is rare that both Po and Cp accompany.

In Sample No. 229, both Po and Cp are found in close paragenetic relation with Sp, showing a mixed type between the two assemblages.

Ga does not accompany the assemblage in a large amount, but it is always contained in a small amount, and also tends to be contained even in Type A though fine in grain size. The characteristic mineral assemblages are Sp-Po-Ga and Sp-Cp-Ga.

Py is sometimes scattered in the sulfide minerals as relatively large euhedral cubic crystals. In some cases, it is characterized by the assemblage of Sp-Py-Ga (Samples No. 154, 155, 156 and 157). Some samples contain only Po, while Py is absent, and others Py without Po. Further investigation will be needed to know whether there is any significance from the standpoint of ore genesis, or whether it is connected to the condition of occurrence in the ore body.

In the sections of Type B predominated by gangue minerals, it is observed that Sp is completely absent as in Sample No. 026 and that Sp is poor in quantity (Samples No. 138 and No. 243). These are assumed to correspond to "gariko" (disseminated ore) in kieslager in Japan, which is often found on the hanging wall or footwall of the main ore body.

Titanium Minerals :

While sulfide minerals generally show a strong reflecting power to the rays of light, silicate and oxide minerals which correspond to the gangue minerals are weak in reflecting power and display dark gray in color. Therefore it is difficult to identify these minerals optically by ore microscope. In the polished sections of the samples from the C-1 ore body, gray minerals which is a little brighter than Sp and have an aspect similar to sulfide ore minerals are observed in no small quantities. Although hardness is greater than Sp, polishing hardness is almost equal to all the gangue minerals, and smooth and good polished surface was obtained. They are evidently anistropic and change the color under the crossed nicols such as light gray to deep blue to dark gray. Sometimes parallel streaks of bright and dark seemingly to be lamelar twins appear, crossing out in two directions. The minerals show distinct schillerization by internal reflection, indicating the characteristic of transparent minerals. Although these are thought to be the minerals of high refractive index other than of the cubic crystal system, it is difficult to identify them only by optical properties through ore microscope. They are assumed to belong to rutile-titanite series as metamorphic minerals. Anatase and brookite are also optically similar to those.

As to the occurrence of minerals, it is thought that they are commonly found in almost all the polished sections. It is present as inclusion in gangue minerals in the sections dominant in gangue minerals except for those classified into Type A. They are granular to short prismatic, and sometimes occur in a close contact with sulfide minerals. Although they tend to be over-looked in the Type A because of the color similar to that of Sp, they would always be present in Type A.

The minerals seem to be more paragenetic with granular minerals than those of prismatic among the gangue minerals. They are round granular, rice grain-like granular, lenticular and round short prismatic in shape. In addition to those scattered in gangue minerals, a large number of grains are scattered in a form of emulsion. They are observed as crystals of large sizes, and in Sample No. 198, the size is as lrge as 0.2 milimeter wide and 0.8 milimeter long. In Sample No. 138, the size observed is 0.35 x 0.7 milimeter. Fine grains smaller than 0.8 milimter are also present and their quantity is not necessarily small. In Sample No. 196, those in the range of 0.02 milimeters to 0.1 milimeter are scattered like the stars in the sky. They are also observed in abundance in Samples No. 121, 154, 184 and 189.

In Sample No. 026, fine grains of 0.1 to 0.3 milimeters long, gray in color and with a lower reflectivity than Sp, are observed in abundance although the occurrence is the same. These grains are thought to be the titanium minerals of a different kind.

Description of Representative Samples :

Sample No. 124

The section shows a distinct pebble structure, in which round, subround and angular gangue minerals of one to two milimeters across and in some case reaching up to four milimeters are embedded in megascopically fine-grained and compact sulfide matrix.

Under the microscope, the pebble structure is clearly observed, and pebble sizes are various from those which can be seen by the naked eye to minute microscopical ones. Large pebbles generally consist of minerals of more than two kinds, but the pebbles consisting of a unit crystal of single mineral are often found. The size is about 0.08 milimeters in small ones, and prisms of 1.0 milimeter long and 0.25 milimeters wide are sometimes found.

It is characteristic of this pebble that even the minute crystals of microscopical size show a round outline. This roundness is observed in all the ore samples, and appears to be the distinct characteristic formed in the process of metamorphism.

In many cases, sulfide minrals and titanium minerals are included in pebble-like gangue minerals as inclusion, some of which reach up to more than 0.2 milimeters. This is considered to represent a kind of porphyriblast introduced in the process of metamorphism.

The openings between the gangue minerals are filled up with compact aggregate of sulfide minerals, which is mainly composed of Sp-Po and is locally accompanied by Ga in this particular section. All of these take a subhedral granular shape with varied grain sizes and content ratios from one place to another. They however generally show a ripple texture like the waves on the water surface with a grain size between 0.03 and 0.2 milimeters.

Surrounding the pebbles of gangue minerals, an arrangement parallel with the pebble periphery of seemingly the rim textue, can be observed. This is assumed to be similar to the original sedimentary structure showing a distinct flow structure as observed in Sample No.229.

Sample No.229

The ore consists of fine-grained compact sulfide minerals with megascopically distinct pebble structure. The pebble size is about two to three milimeters, and the quantity appears small under the naked eye. Under the microscope, however, minute grains are observed in abundance.

As observed in Sample No. 124, the porphyroblastic texture is conspicuous with a considerable amount of inclusion in porphyroblasts, and the pebbles include minute grains smaller than 0.05 milimeters, often showing a mylonitic structure in appearance. The size of inclusion is rather large as compared with the sulphide minerals in matrix.

The most conspicuous characteristic of the secion is that the sulfide minerals of the pebbles are irregular aggregates of Sp, Cp, Po and Ga of 0.002 to 0.006 mm across, and exhibit a black ink flow. Under the microscope, they show a ripple-like texture, locally becoming intricated by the assemblages of Sp-Cp and Sp-Po in the sulfide part. Py is not observed.

It seems appropriate to consider that the ink flow texture was caused by the sedimentary structure of original fine grain ore. However, it is difficult to explain explicitly the cause of the difference bewteen fine and coarse textures which would have been introduced during the process of metamorphism.

Sample No. 166

Although no pebble structure can be observed in this section megascopically, it is composed of overlapping layers of this compact sulfide part of sedimentary structure and the compact gangue part poor in sulfide. The former shows a minute microscopical pebble structure like the other pebble ore, as observed in Sample No. 229.

Sample No. 138

This section is poor in sulfide minerals, being occupied about 95 per cent of the section by gangue minerals megascopically.

Cp is the main sulfide mineral, forming irregular veinlets (0.8 milimeters wide and less than five milimeters long) and fine dissemination, which are arranged in parallel in an orientated direction. Small streaks of Py and Ga are also found crossing the Cp veinlets.

Under the microscope, the sulfide minerals are Cp > Sp > Ga > Py, while Po is absent. Gangue minerals consist mainly of prismatic crystals of mineral likely to be pyroxene of 0.1 to 0.5 milimeter wide and one to three milimeters long. They are mixed with a few kinds of granular minerals; however no definite orientation can be observed as a shole.

The sulfide minerals take the form of irregular vein or dissemination, filling the cleavages and cracks of gangue minerals, and minute interstices between the crystals.

In this section, a mineral assumed to be oxide is observed in a considrably large amount. It is light gray, a little more bright than Sp, in vertical reflecting light as that of sulfide similar to Sp. Although it resembles to hematite, no blue tint is shown, being intermediate in color between Ga and Sp. Hardness is high and it is harder than Sp. Anisotropism is strong. Distinct change from gray to dark blue is observed under the crossed nicols. Internal reflection is distinct. Strong transparency indicates that the mineral belongs to silicate or oxide mineral, not opaque mineral. The color is light brown similar to sphalerite but locally irridescent. Lamellar twinning is sometimes observed as an internal structure. Biaxial twinning bands are also shown. The mineral is scattered along the intestices of the crystals of gangue minerals and as inclusion.

It is round euhedral to subhedral in shape. In addition, lenticular and foliated shapes are also found. The size varies from large to small, generally 0.1 milimeter across reaching up to 0.7 milimeters long and 0.3 milimeters wide.

Sample No. 196

Megascopically, the section is poor in sulfide minerals, and consist mainly of fine-grained Cp disseminated in the massive aggregate of compact gangue minerals. Unknown minerals are contained more in abundance than in Sample No. 138.

The sulfide minerals contained are Cp > Po, and Py, Sp and Ga are either very poor or completely absent. The size varies from large to small. They are scattered through the section, showing irregular shapes.

Although optical properties of the unknown minerals are similar to those of Sample No.138, the shapes are round granular to rectangular or irregular. Roundness is the general characteristic. A large number of inclusions in gangue minerals in a form of drips are scattered over the whole section. The distribution apparently looks like the exsolution texture.

Although the chemical composition of the mineral has not been known, it is assumed to be some kind of titanium mineral from optical properties such as rutile or titanite, and is considered a metamorphic mineral formed by isolation of titanium component during metamorphism of gangue minerals, most of them are included in gangue minerals.

Because of the color similar to that of Sp, it is highly possible that the mineral be overlooked in sulfide ore in many sections other than Sample No. 196. However, presence of anisotropism and internal reflection will lead to make an easy discrimination from Sp.

Sample No. 025

Megascopically, the amounts of gangue and sulfide are almost the same, and Cp, Sp and prismatic to fibrous gangue minerals are mixed quite irregularly with no particular structure or texture. Apparently, gangue minerals and sulfide minerals are promicuously admixed.

Under the microscope, comparatively large-sized prismatic gangue minerals and other various minerals are mixed. Sulfide minerals fill the irregular interstices of gangue mienrals, so that the texture of sulfide part is indefinite and no regularity can be found in their paragenesis.

Sulfide minerals mainly consist of Sp, Cp, Py and Ga, and Po is found in a very small quantity as an inclusion in Sp. Sp is founded the most and is accompanied by many inclusions (Cp and Ga). Py sometimes takes an euhedral form, but anhedral and irregular forms are dominant.

Sample No. 026

Megascopically, gauge minerals occupy more than 90 per cent of this section. A banded texture is shown, in which fine streaks of yellow sulfide minerals mainly of Cp are arranged in an orientated direction. This arrangement may be of schistosity.

Under the microscope, prismatic crystals of gangue minerals mostly two to three milimeters long are arranged in an orientated direction, and sulfide minerals consisting mainly of Cp and Py are sparcely distributed along the interstices of the crystals in the anhedral form of prism to acidular controlled by the shape of gangue minerals.

Sp, Po and Ga are hardly observed. Oxide minerals (titanium oxide) are found as strong reflective minerals besides sulfide minerals (see Samples No. 138 and No. 196). The section will be cited as disseminated country rock.

Sample No. 137

Megascopically, the sample is the one to be called a pebble ore, in which sandy to pebble-like gangue minerals of mostly one to two milimeters across reaching up to the maximum of four milimeters, are embedded in abundance in fine-grained compact sulfide parts.

Under the microscope, pebbles are megascopically observed as the aggregates of more than two or three kinds of gangue minerals (metamorphic minerals). Being very irregular in formation, some pebbles are the aggregates of granular to short prismatic crystals 0.05 to 0.1 milimeter across, while others are the aggregates of crystals of larger size up to one milimeter across. The pebbles of gangue are various in size, megascopically ranging from those larger than one milimeter across to those smaller than 0.1 milimeter across. Among these, euhedral unit crystals of single mineral are sometimes found.

These pebbles are embedded in the groundmass of fine-grained compact sulfide minerals, showing an occurrence similar to the phenocrysts in porphyritic structure of the volcanic rocks. The pebbles generally have a round shape and it is characteristic that even those of single crystal take a rounded shape (Samples Nos. 124 and No. 229).

Sulfide minerals found in the matrix are scattered in the pebbles in a form of dissemination.

The matrix is mostly occupied by Sp, in which abundant Py is contained with Ga as inclusion. Py is distributed over the whole section, sometimes showing a euhedral cubic form of larger size (0.15 to 0.35 mm across) and in other cases as irregular grains (0.03 to 0.15 mm across) in other case. Ga is contained in Sp in abundance next to Py, showing a completely anhedral form (grain size is similar to that of Py and is about 0.03 to 0.15 mm across). Cp is very small in quantity. Po is hardly found.

Sample No. 158

The sample is fine-grained compact sulfide ore showing the texture of pebble ore, and belongs to Type A, although the pebbles are fine grained megascopically.

Under the microscope, minute sulfide grains are contained in abundance in the pebbles of gangue minerals. The boundary between the pebble of gangue part and the surrounding sulfide part often becomes ambiguous, and the minerals in pebbles are rich in fine clayey foliated minerals, often showing a pilling texture.

Gangue minerals are generally fine-grained, ranging from those smaller than 0.1 milimeter across to the maximum of one milimeter.

The sulfide part consists of Sp $>$ Cp $=$ Po $>$ Ga $\gg$ Py with Sp as the main constituent mineral and is accompanied by abundant Cp. Its appearance of close aggregates of gangue and sulfide minerals resembles the texture of "kuroko" (black ore).

It seems that metamorphism of low grade is shown in this part.

Sample No. 184

Megascopically, gangue minerals are a little more dominant than sulfide in quantity, and sulfide minerals seems to form irregular veinlets in gangue minerals.

Under the microscope, the sample is assumed high in crystanity. The gangue minerals varies in size, consisting of primatic crystals of more than 1.5 milimeters long as well as small granular crystals of 0.05 to 0.5 milimeters across. The sulfide minerals are in contact each other by round mutual boundaries.

Although the sulfide minerals are disseminated in a minute texture in the gangue part, the sizes of single minerals such as Sp and Po are larger than those in other samples, thus showing a gentle curve at the boundary with the gangue aprt. Single grains of Po sometimes reache up to 0.3 to 1.2 milimeters across.

(2) Assay Results of Ore Samples

Table A–3 shows the assay results of each ore sample collected from three pits in the vicinity of the C-1 ore body, the sample stockpile of the ore from the inclined shaft of the C-1 ore body, the drill cores of the C-1 ore body and Alvo 10p, and gossan.

Fig. A–1 shows the result of survey of pits, Fig. II–7 sketch of the inclined shaft (CPRM) and the locations of samples. PL. II–7 shows the cross sections of drill holes and sampling positions, and Fig. A–2 the columnar sections of drill holes and assay results.

The assay results in Table A–3 of the samples from the C-1 ore body and drill cores, which are high in metal content, resulted in the classification of these samples into two groups: one which is high in Pb and Zn and the other high in Cu. While the samples high in Ag is included in the group high in Pb and Zn, the reason will be that Ag is contained in galena.

Fig. II–8 shows the triangular diagrams of Cu-Pb-Zn components, showing analytical values of the samples from the drill cores and the inclined shaft. The diagrams show that while the C-1 ore body is high in Zn in general, the tendency of mineral content changes and becomes higher in Cu-Zn, toward the south from the survey lines 30S and 50S.

On the other hand, the Cu : Zn ratio obtained from the table of ore reserves is 0.24 in the C-1 ore body (0.08 in the C-2 ore body and 0,34 in the C-3 ore body).

It is known that the average Cu : Zn ratio is anywhere between 0.12 and 0.28 in the Noranda-type ore deposits in Canada (Sturgeon Lake deposits) formed in association with Precambrian acidic volcanism, and those of the Palmeirópolis ore deposit show almost the same values. The ratios of Pb grade to Pb + Cu + Zn grade (total base) in the C-1 and C-2 ore bodies are about twice as high as those of the Noranda-type ore deposit, while the ratio is almost the same in the C-3 ore body.

(3) Alteration

An investigation was made to find out whether the characters and characteristics of primary hydrothermal alteration of the wall rocks in the hanging wall and footwall of the ore deposit extracted in the area underlain by the rocks of high metamorphic grade as in this region, can be effectively utilized as one of the techniques for the survey of the ore deposit in the surrounding area as well as for the regional survey.

One hundred and thirty-four samples of the wall rock in the hanging wall and footwall of the ore body were collected from the pits around the C-1 ore body, inclined shaft and drill cores,

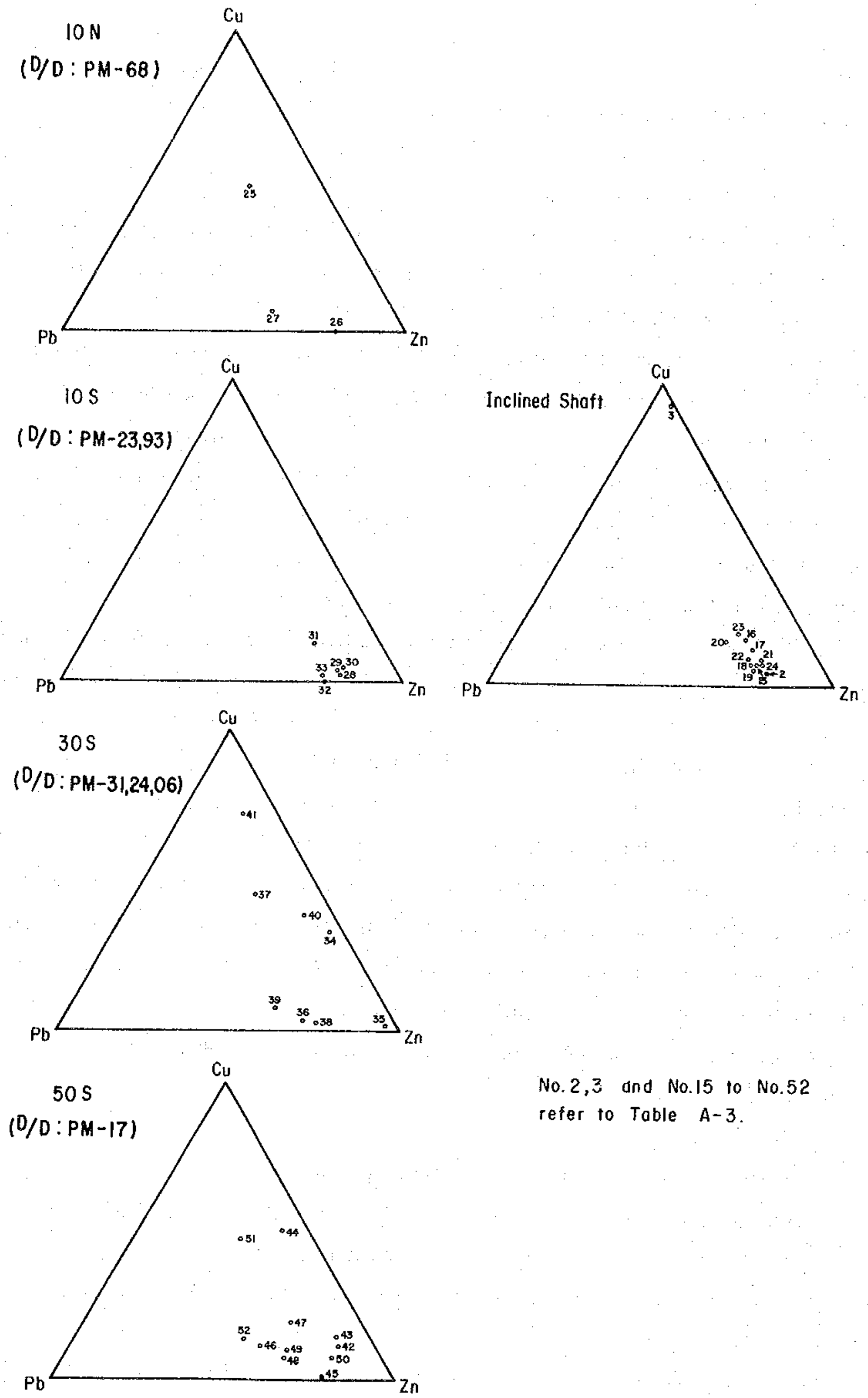


Fig. II–8 Cu-Pb-Zn Diagram of Ore Samples from Inclined Shaft and Drilling Core in C–1 Ore Body in addition to 69 samples from the surface of the survey area. A total of 203 samples were then identified for their alteration minerals by means of X-ray diffraction (Table A–4). Table II–2 shows the conditions of measurement.

Table II–2 Experimental Conditions of X-ray Diffractive Analysis

Experlmental Device	; Philips X-ray Diffractometer
Target	; Cu
Filter	; Monochrometer (graphite)
Voltage	; 45 KV
Current	; 55 mA
Slit	; 1° – 0.2 m/m
Glaneing Angle	; 2° – 50°
Scanning Speed	; 2/min
Chart Speed	; 2cm/min
Full Scale	; 2,000 c/sec.
Time Constant	; 0.5 sec.
Counter	; Saintillation countor

It is difficult to quantify the minerals based on the results of X-ray diffraction, and such subjectively expressions as "large", "moderate" and "small" have been used so far.

It is a tendency at present to quantify the X-ray data by means of quartz index in an attempt to express numerically the intensity of alteration in the geothermal areas in Japan.

Quartz index (Q.I) is an expression by percentage of the strongest X-ray intensity of a certain mineral (Im) in a given sample divided by the strongest X-ray intensity of quartz (Iq) measured under experimental conditions. Thus, it is obtained by the following equation:

$$\text{Quartz index (Q.I.)} = \frac{Im}{Iq} \times 100$$

Under the conditions of the current measurement Iq = 14,300 (cps) .

Zoning of the alteration of C-1 ore deposit was made using the quartz index of the selected minerals such as quartz, plagioclase, tremolite, epidote, calcite and chlorite, among the identified minerals on the 101 samples of the drill cores (Fig. II–9).

Regarding quartz, the samples showing Q.I. of less than five per cent are consistent with the

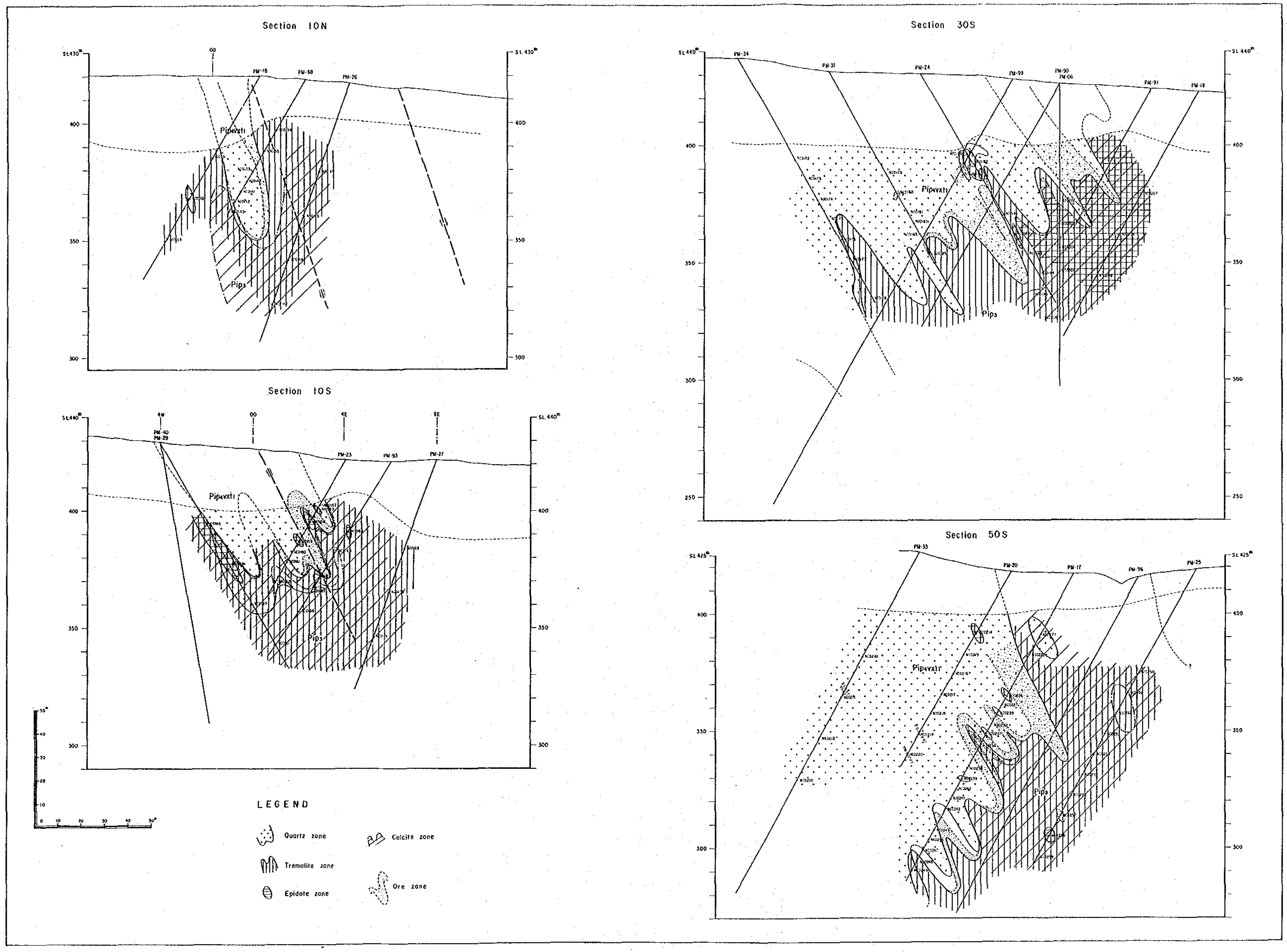


Fig. II–9 Minralized Alteration Zone of C–1 Ore Body

Pip_3 formation.

Regarding plagioclase, those of 10 per cent in quartz index were most abundant in the Pip_3 formation, and the lower value is abundant in the Pipvxt member.

Regarding tremolite, quartz index of about six is consistent with the Pip_3 formation, and zero per cent with the Pip_4vxt_1 member.

Regarding epidote, those showing quartz index of more than one per cent is observed in the Pip_3 formation locally.

Regarding calcite, quartz index of more than one per cent is contained in the Pip_3 formation, and almost zero in Pip_4vxt_1.

No regular pattern was observed in chlorite, and it is assumed to be an alteration mineral formed by diagenesis of biotite and amphiboles.

The weathered alteration products such as kaolinite, gibbsite and goethite are observed in the samples corrected on the surface.

As in the above, zoning by quartz index of minerals is consistent with the boundary between the Pip_3 formation and the Pip_4vxt_1 member. These are not alteration by mineralization, but it is considered to express the characteristics of country rocks of ore deposit. The Pip_3 formation belongs to the tremolite-epidote-calcite zone and the Pip_4vxt_1 member to the quartz-plagioclase zone.

On top of these, the weathered alteration zone less than 50 meters deep composed of kaolinite-gibbsite-goethite, and the diagenesis zone 50 to 150 meters deep consisting of chlorite are overlapped.

Thus, extraction of primary hydrothermal alteration minerals could not be made by mineral assemblages of amphibolite facies.

On the other hand, a measure to extract the alteration zone based on the variation of Na_2O and K_2O content in the country rock has been applied for the survey of "Kuroko" (black ore) and Noranda-type deposits.

In "Kuroko" deposit, addition of MgO and K_2O and leaching of CaO and Na_2O are observed markedly. Applying this phenomenon, an alteration intensity map has been prepared and found quite useful for the survey of "Kuroko" deposit, using the values of $(MgO + K_2O)/(Na_2O + K_2O + MgO = CaO) \times 100$ (Ishikawa et al., 1976). It has been made clear that "Kuroko" deposits are distributed within the extent in which the alteration intensity is greater than 90 per cent.

Fig. II–10 shows the results of alteration intensity obtained from the results of whole rock analysis of the 23 samples collected from each geological horizon of the area. The results show the values of 30 to 40 per cent are shown in amphibolites on the footwall side of the ore horizon, and 45 to 60 per cent in the schistose rocks on the hanging wall side.

Since these values are lower than those of "Kuroko", it is difficult to assume the alteration associated with the mineralization. Because the rocks in the footwall of the ore horizon are amphibolites in which content of K_2O is low, and because it is thought that the schistose rocks would have been derived from acidic volcanic rocks and pyroclastic rocks rich in K_2O, the values described above is considered to indicate the difference between the country rocks on both sides.

As to the Noranda-type deposits in Canada, there is an instance in which the hydrothermal alteration zone was extracted, and it was applied to the survey for ore finding by using the values of $Na_2O + K_2O$ and $K_2O/(Na_2O + K_2O) \times 100$ (meyers R.E. et al., 1983).

It has been made clear in the Noranda-type deposits that the extent of more than 80 per cent in value of $K_2O/(Na_2O + K_2O) \times 100$ corresponded to that of ore horizon, but the values in the C-1 deposit are as low as 50 to 70 per cent. (Fig. II-11).

From the above, it is thought that alteration of the country rocks of the area is weak as compared with the "Kuroko" and Noranda-type deposits.

It may be possible to clarify the chemical characteristics of the C-1 ore body by analysing minor elements of the country rocks and ores.

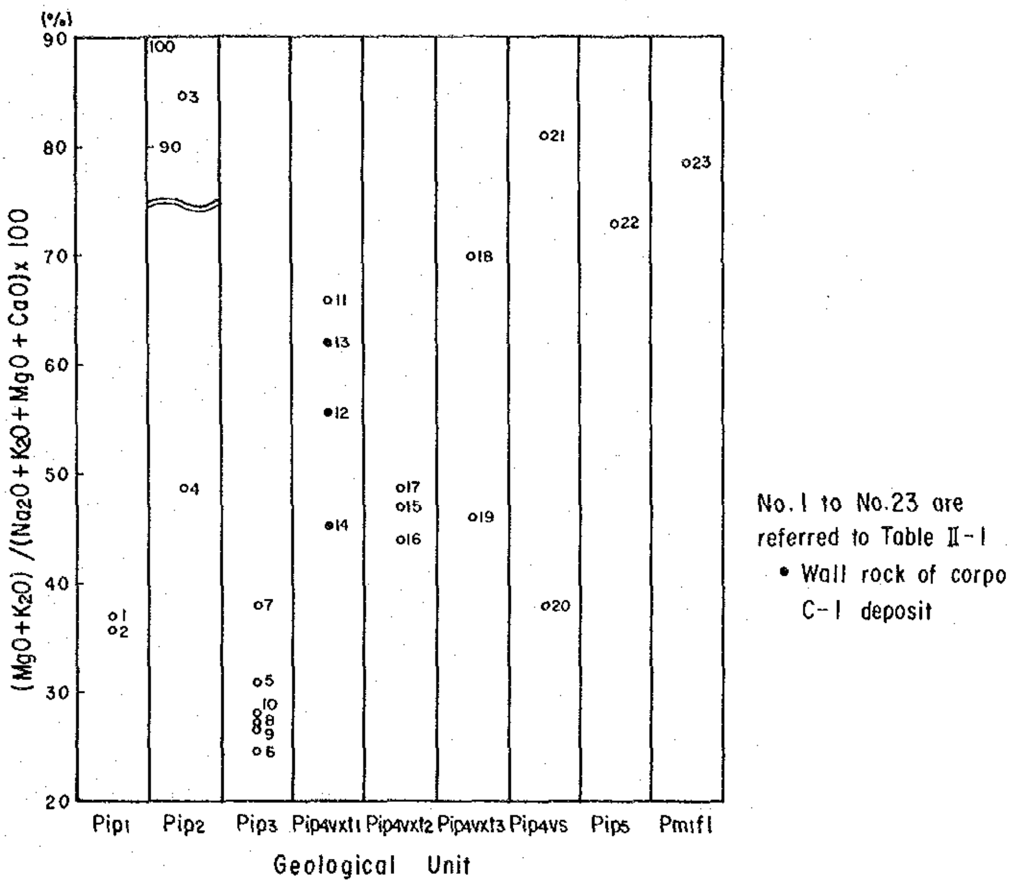


Fig. II–10 Intencity of Hydrothermal Alteration of Each Geological Unit

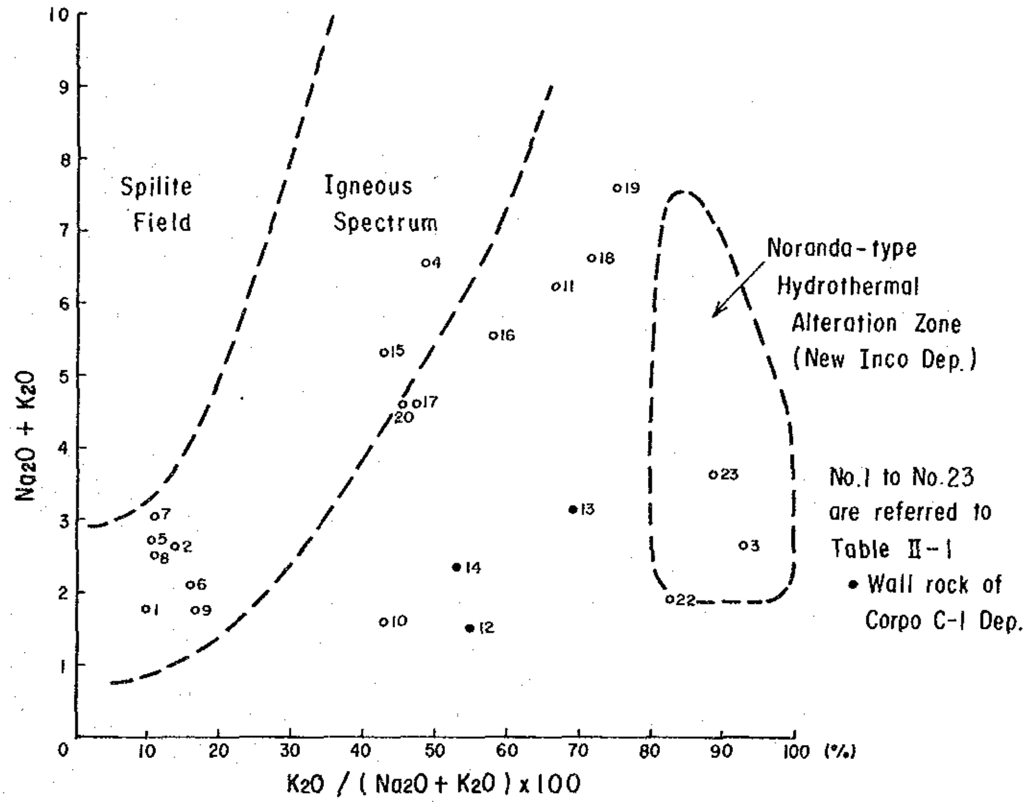


Fig. II–11 $(Na_2O + K_2O) - K_2O/(Na_2 + K_2O) \times 100$ Diagram

CHAPTER 2 Geochemical Survey

2–1 Geochemical Survey of Stream Sediment

2–1–1 Outline

A geochemical survey of stream sediment was conducted mainly in the area underlain by the Palmeirópolis volcano sedimentary sequence within the entire survey area. Since CPRM conducted a geochemical survey in the past in the surrounding area of the semi-detailed survey area in the northern part, sampling was performed along the main rivers only making reference to the survey results of CPRM.

In the central and the southern parts, sampling was carried out for the purpose of extracting geochemical anomalous zones considered to be caused by copper, lead and zinc mineralization.

The samples collected were analyzed for four components: Cu, Pb, Zn and As. The assay results were statistically processed by computor, and multivariate analysis including single component analysis and factor analysis was performed.

These analyses resulted in extracting six areas with geochemical anomaly. The most noticeable one among them is the Cu-Pb-Zn geochemical anomalous zone in the Pip_4vs formation distributed in the basin of Rio Dois de Junho in the central part of the area.

2–1–2 Sampling, Component of Element and Analysis Method

Sampling stations were plotted on the survey planning map (drainage map at 1:50,000 was used), taking sampling density and order of drainage system into consideration.

Stream sediment was sieved in the water to under 80 mesh in accordance with the planning map. Sample numbers, geology and conditions of the sampling stations were recorded on the sampling list. Although the locations of sampling stations as well as sampling densities were more or less changed according to site conditions the sampling was made to collect two to three samples per square kilometer in the geology underlain by the Pip_4vs formation as long as it is possible to do so.

The whole area was divided into four blocks such as A, B, C and D, taking into account the efficiency in the sample preparation and analysis stages, and a total of 1031 samples were collected, of which 139 samples were collected in A Block, 319 in B Block, 304 in C Block and 269 in D block(PL. II–9).

The samples collected were then chemically analyzed for four components such as Cu, Pb, Zn and As by the atomic absorption method.