REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE PALMEIROPOLIS AREA
FEDERATIVE REPUBLIC OF BRAZIL

CONSOLIDATED REPORT

MARCH, 1989

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

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

The survey was conducted for three years from fiscal 1986 to 1988 and accomplished as scheduled under close cooperation with the Government of the Federative Republic of Brazil and its various Agencies, especially with Departamento Nacional da Produção Mineral (DNPM) of the Ministry of Mining and Energy and Companhia de Pesquisa de Recursos Minerais (CPRM).

This report is the compilation of the results of the whole survey during these three years.

We wish to express our heartful gratitude to the Government of the Federative Republic of Brazil and its appropriate agencies and organizations concerned, as well as the Ministry of Foreign Affairs, the Ministry of International Trade and Industry, the Embassy of Japan in the Federative Republic of Brazil and the companies concerned for the operation and support extended to the Japanese survey team.

February 1989

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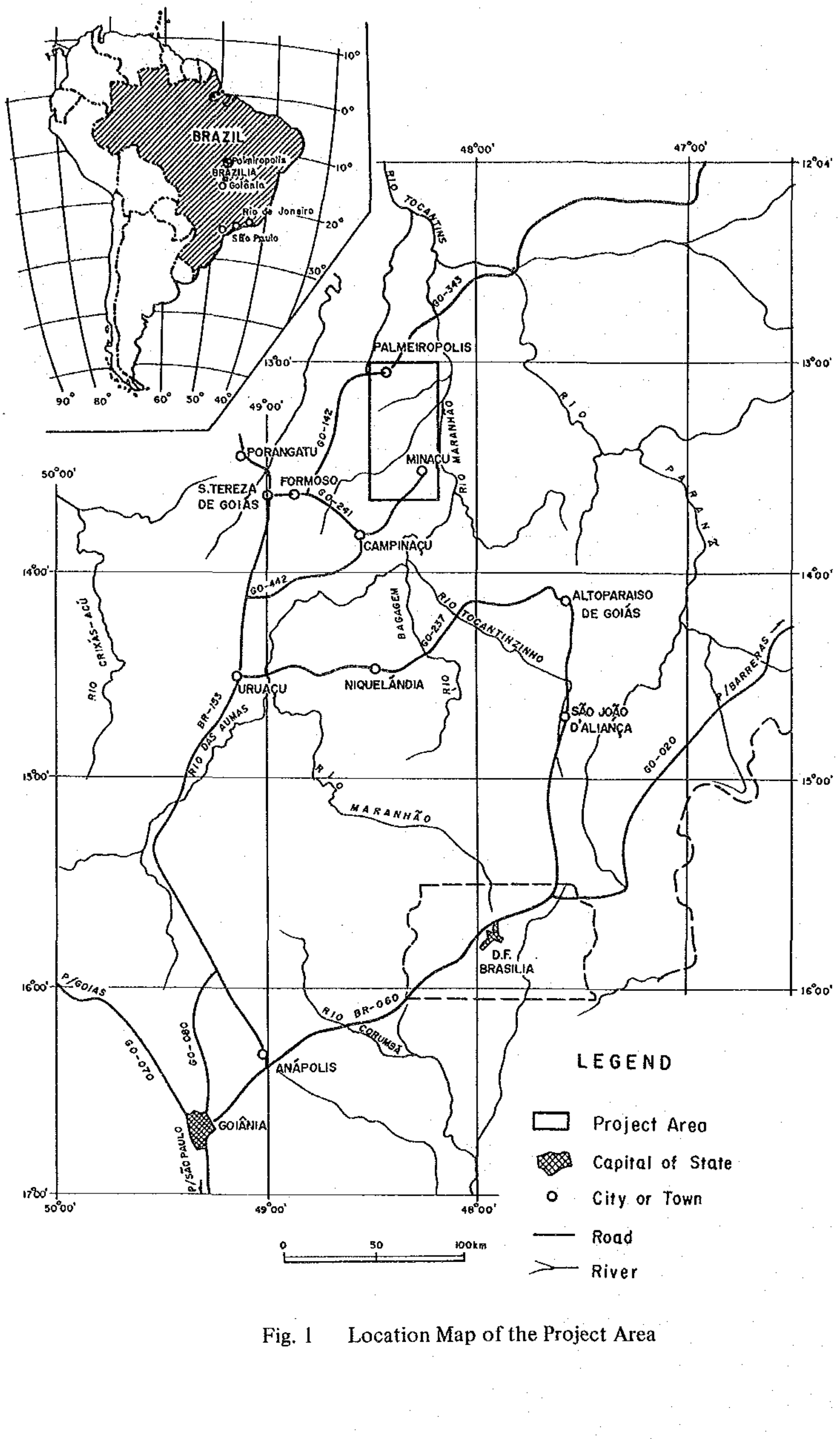

Fig. 1 Location Map of the Project Area

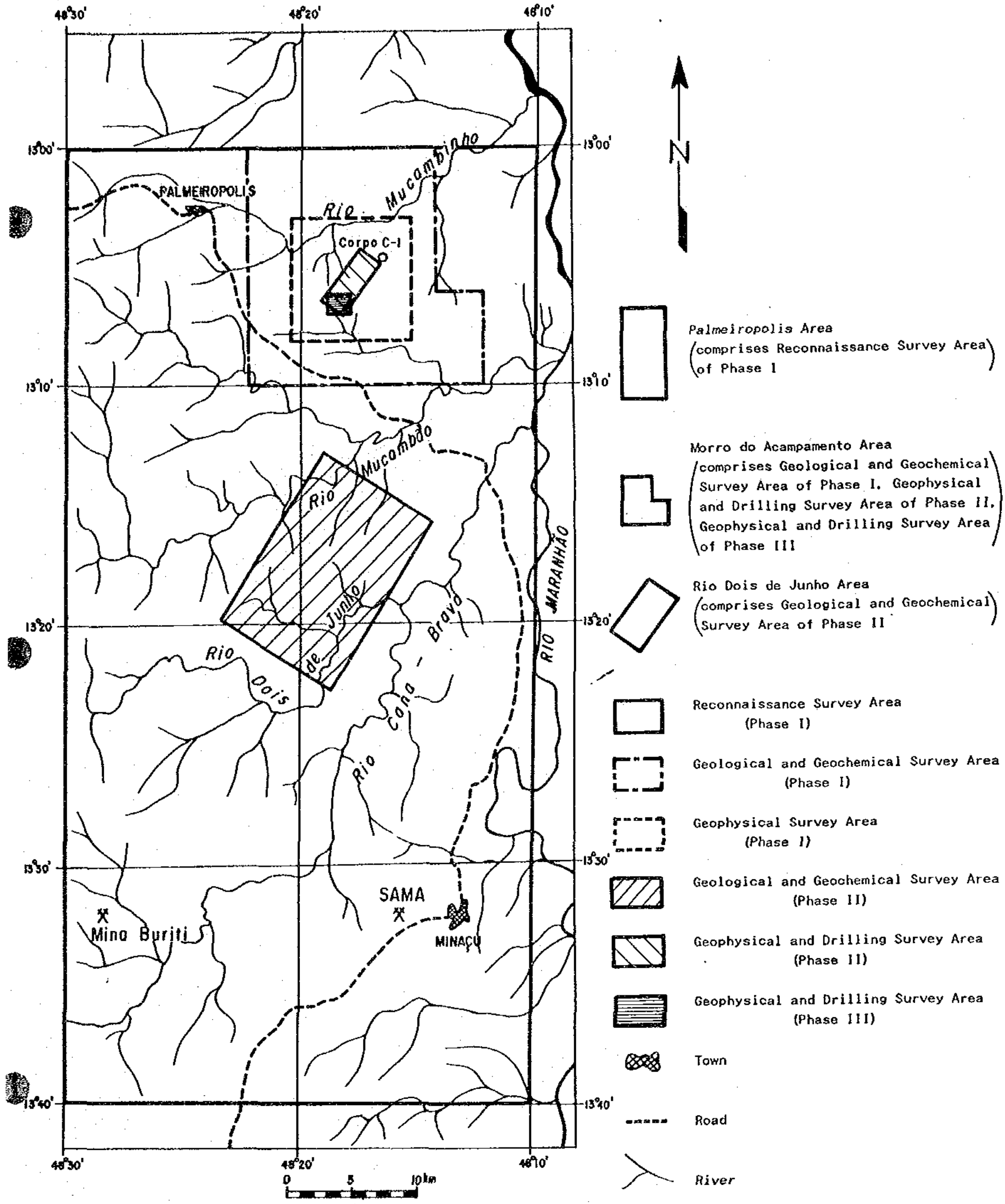

Fig. 2 Location Map of the Surveyed Area

ABSTRACT

In the State of Goias, Federative Republic of Brazil, Precambrian formations predominate and are investigated by many reseachers. "Projeto Serra da Mesa" conducted by Departamento Nacional da produção Mineral (DNPM)/Companhia de Pesquisa de Recurços Minerais (CPRM) (1972) and "Projeto Palmeiropolis" by CPRM (1975-1984) which are the main exploration projects in this area, revealed the stratigraphy of Palmeiropolis volcano-sedimentary sequence in Proterozoic age. Cu-Pb-Zn ore deposits were detected in the area.

Metal Mining Agency of Japan (MMAJ) compiled and examined the data concerning the geology and mineralization of the area and recognized that the Palmeiropolis area, covering an area of 2750km^2 from Pameiropolis in the north to Minaçu in the south, is promising for the Cu-Pb-Zn ore body. As a result, MMAJ agreed to conduct a collaborative mineral exploration project in the area, which was agreed upon and ratified in February,1986, between the Departamento Nacional da Produção Mineral and the MMAJ Mission. The collaborative survey was conducted from fiscal year 1986 to 1988. This report is a compilation of the survey results from 1986 to 1988.

In Phase I, fiscal year 1986, a geological reconnaissance survey and a geochemical survey were conducted in the Palmeiropolis entire area. A geological, a geochemical and a geophysical surveys were also conducted in the semi-detailed survey area, so-called Morro do Acampamento Area. As the results of the survey in Phase I, some zones in Morro do Acampamento Area were regarded as very promising areas and Rio Dois de Junho Area gave indications of being a promising area for Cu-Pb-Zn mineralization.In Phase II, fiscal year 1987, as a result of the semi-detailed geological survey and a geochemical survey in Rio Dois de Junho Area no further survey in the area is considered necessary. A geophysical and a drilling surveys in Morro do Acampamento Area were also conducted to evaluate for Cu-Pb-Zn minerarization. In Phase III, fiscal year 1988, a geophysical and a drilling surveys to the south of Phase II survey area determined pyrite dissemination zones with small amounts of Cu-Pb-Zn sulfides. The followings are the results on the surveys in each area.

(1) Palmeiropolis entire Area

The geology of the Palmeiropolis area is composed of the Archaeozoic formation (Cana Brava basic-ultrabasic complexes), Proterozoic formation (Lower: Palmeiropolis volcano-sedimentary sequence, Middle : Serra da Mesa Group, Rio Maranhao cataclastic zone, Upper :

Paranoa Group) and the intrusions of granites and basic-ultrabasic complexes. Palmeiropolis volcano-sedimentary sequence, which is important for the ore host rock, is divided into four *formations; amphibolites* (Pip_1 *member), pyroclastics and schists* (Pip_2 *member), amphibolites* (Pip_3 member), intermediate to acidic schists (Pip_4 member) and pelitic schists (Pip_5 member). The C-1 ore body of the known Palmeiropolis ore deposits, a stratiform to lenticular Cu-Pb-Zn ore deposit, is bounded by Pip_3 member to the footwall and by Pip_4 member to the hanging wall.

As the result of a geochemical survey by stream sediments in the entire area, geochemical anomalous area of Cu-Pb-Zn were found mainly in Morro do Acampamento area and in Rio Dois de Junho area.

(2) Morro do Acampamento Area

In Phase I, as a result of a soil geochemical survey, some Pb-Zn anomalous areas and a Cu-Zn anomalous area were located. CSAMT geophysical survey detected a similar type of resistivity distribution to the one around C-1 ore body. SIP geophysical survey also revealed the distribution of anomalies around C-1 ore body and pointed a similar spectral pattern to the one around C-1 ore body and to the southwest of C-1 ore body.

In Phase II, drilling was conducted on the anomalous areas detected by SIP survey of Phase I to the northeast and southwest of Morro do Acampamento. Pyrite dissemination and graphite were found there but a massive ore body was not. The horizon of the pyrite dissemination was correlated to the uppermost horizon of Pip_4, same as the ones of C-2 and C-3 ore bodies of Palmeiropolis ore deposit which are both located outside of the survey area.

In Phase III, SIP and IP geophysical surveys and a drilling survey were conducted to the south of the Phase II survey area. Pyrite dissemination with small amounts of Cu, Pb and Zn sulfides were found in Pip_4, but massive ore deposit. However, in the same area with IP anomaly where drilling disclosed the pyrite dissemination, a massive ore body was penetrated by one drilling carried out by CPRM.

From the above mentioned, the stratigraphic relations of two horizons of pyrite dissemination determined in Phase I and Phase II are recommended to further clarify. A more detailed survey in the larger area comprising the horizon of pyrite dissemination detected in Phase III is also recommended for the potenteal evaluation of the area.

(3) Rio Dois de Junho Area

The area was extracted as the anomalous area in Cu, Pb and Zn by the geochemical survey using stream sediments in Phase I. The area was surveyed again by a detailed soil geochemical survey in Phase II. As the result of the soil geochemical survey, anomalous areas in Cu, Pb and Zn were located in Pip_4 formation, same as Palmeiropolis ore horizon. However, since the anomalous areas are on a very small scale, the possibility for the ore deposits to be similar to the Palmeiropolis ore deposit is small. Even if mineralization occurs, the reserves may be very small.

Consequently, it is very difficult to conclude that economic mineral deposits are to be found in this area, therefore this area has no value for further exploration.

As mentioned above, geophysical surveys with different precisions were carried out mainly for the purposes of the disclosure of geological structures and the detection of mineralization over three years in the collaborative exploration project. The IP and SIP methods carried out were useful for the detection of pyrite mineralization. However, they were not effective for the determination of the presence of Cu, Pb and Zn sulfide minerals in the pyrite dissemination or for the localization of those sulfide minerals. The determination and the localization of the disseminations are considered to have been controlled by the relative amounts of Cu, Pb and Zn sulfide minerals to the disseminated pyrite and the scale of Cu-Pb-Zn ore deposit.

Even though the IP – SIP method is at the present time one of the most suitable method to carry out these studies, future research is clearly needed to improve its limits.

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PART I GENERAL REMARKS

CHAPTER 1 OUTLINE OF THE SURVEY

1–1 Area and Purpose of the Survey

In and around this area, Archaeozoic and Proterozoic formations are distributed with acidic and basic to ultrabasic rocks intruding into them. In Palmeiropolis, volcano-sedimentary sequences of Proterozoic age, copper, lead and zinc ore deposits were found during explorations (1975-1984) conducted principally by Compania de Pesquisa de Recursos Minerais (CPRM).

Metal Mining Agency of Japan compiled and examined the information on the geology and the mineralization of the area. As the result of the investigation, in response to the request of the Government of the Federative Republic of Brazil, the Government of Japan agreed to conduct a collaborative mineral exploration project in the Palmeiropolis area in the State of Goias.

The Scope of Work of the project was agreed upon and ratified in February, 1986, between the Departamento Nacional da Produção Mineral (DNPM) and the Japanese mission. The area has an area of 2,750km^2 in the center of the State of Goias.

The area is located to the north of Brazilia, the capital of the Federative Republic of Brazil (Fig. 1). The distance between Goiania, the capital of the State of Goias, and Palmeiropolis in the survey area is 617km through GO-80, BR-153 and GO-343.

The purpose of this survey is to evaluate the potential for ore deposits through various investigations, including the examination of known data, geological survey, geochemical survey, geophysical survey and drilling.

Nomenclature in this report is as follows: Palmeiropolis is the entire area surveyed; Morro do Acampament area corresponds to Semi-detailed survey area of Phase I, including Morro do Acampament area of Phase II and III; Rio Dois de Junho area is that of Phase II (Fig. 2).

1–2 Contents of the Survey

The collaborative mineral exploration program was executed over three years from fiscal year 1986 to 1988. The methods and the amounts of the surveys as shown in Fig. I-1, Fig. I-2 and Table I-1, were properly decided every year depending upon the target area.

(1) Phase I

In phase I, 1986, objective areas were Palmeiropolis entire area covering 2750 km^2 and Morro do Acampamento area covering 300 km^2. These two areas were decided according to the investigation of previous surveys. Morro do Acampamento area was selected as potential area in the north of Palmeiropolis entire area.

The purpose of the survey in the Palmeiropolis entire area was to determine high potential areas through the investigation on geology, mineralization and geochemistry.

Geological reconnaissance survey was carried out by compiling the map on a scale of 1:50,000 and geochemical survey by using stream sediments (1031 samples for Cu, Pb, Zn and As) were carried out. As the results of these surveys, the ore hosting rock was confirmed to be in Proterozoic Palmeiropolis volcano-sedimentary sequence. The Palmeiropolis volcano-sedimentary sequence is divided into five members, which are from the lower upward: amphibolites (Pip_4), pyroclastics and schists (Pip_2), amphibolites (Pip_3), intermediate to acidic schists (Pip_4) and pelitic schists (Pip_5). Rio Dois de Junho area covering 150 km^2 was simultaneously determined as a promising area. It is located about the center of the entire area.

On the other hand, in the Morro do Acampamento area geological survey was carried out by compiling the map on a scale of 1:20,000 and soil geochemical survey by using 2055 samples for Cu, Pb, Zn and As. Both were carried out in semi-detail to determine target areas.

As the results, ore bodies of the Palmeiropolis Cu-Pb-Zn ore deposit were confirmed to be between Pip_3 and Pip_4 members and in Pip_4 member of Palmeiropolis volcano-sedimentary sequence. The Palmeiropolis ore deposit is composed of three ore bodies with total ore reserves of four million tons with a grade of 0.46 to 1.24 % Cu, 0.33 to 1.38 % Pb and 4.22 to 5.85 % Zn. Geochemical anomalies thought to be accompanied by Cu-Pb-Zn mineralization were simultaneously detected in the area.

Geophysical survey by CSAMT method was executed in the area covering 100 km^2 in the Morro do Acampaments area to detect subsurface resistivity distribution and resistivity trend extending from the ore hosting rock. Geophysical survey by SIP method was also adopted for 5.3 line-km and 161 measuring points to detect the electrical characteristics (spectral characteristics) of the Palmeiropolis Cu-Pb-Zn deposit and to determine the area having the same electrical characteristics as the Palmeiropolis ore deposit.

From the results, "Block North" to the northeast of Morro do Acampamento and "Block South" to the southwest of Morro do Acampamento were decided for target areas.

(2) Phase II

In phase II, 1987, objective areas were Rio Dois de Junho area covering 150 km^2 and Block North and Block South. They were decided from the phase I survey.

In Rio Dois de Junho area, geological survey compiling the map on the scale of 1:20,000 and soil geochemical survey using 2008 samples for Cu, Pb and Zn were carried out to determine more promising area. Geochemical anomalous areas on a small scale were determined on the Pip_4 member. The possibility of the presence of similar type of deposit as the Palmeiropolis ore deposit was thought to be negative because of the limits of the scale of the geochemical anomalies and the back of salient mineralizations in the target area. Block North was determined to be promising due to the similarity to the resistivity distribution of the Palmeiropolis ore deposit. Block South was also found to be promising due to the presence of geochemical and IP anomalies.

SIP method was adopted for 16.7 line-km and 559 measuring points to detect electrical characteristics (spectral characteristics) in those areas. In the depth of Block North, sulfide minerals were inferred to be present. In the Block South, graphite quartz schist and sulfide minerals were inferred to be present in the shallow and at depth respectively as the result of SIP survey. Pyrite dissemination was disclosed by drilling (MBP-1, 300.15 m) in the Block North and pyrrhotite-pyrite dissemination in graphite quartz schist with less chalcopyrite was detected by drilling (MBP-2, 300.12 m; MBP-3, 300.10m) in Block South.

(3) **Phase III**

In phase III, 1988, Alvo 10P located to the south of the Block South was targeted because Cu-Pb-Zn mineralization had been formerly detected by CPRM and Cu-Pb-Zn geochemical anomaly had been detected by this collaborative survey of phase I.

Geophysical surveys (SIP method, 13.4 line-km, 488 measuring points; IP method, 10 line-km, 400 measuring points) were adopted to decide the drilling locations. The surveys were carried out to infer the subsurface geology and to disclose the characteristics of IP anomalous sources. Drilling was executed to penetrate the mineralization or ore deposit. Three holes (MBP-4, 400m; MBP-5, 400.45 m; MBP-6, 401.32 m) disclosed the mineralization composed mainly of pyrite dissemination with less chalcopyrite, galena and sphalerite. In the mineralization zone, more sulfide minerals are found than those detected in the Block South, however, the mineralization was not good enough to calculate reserves.

A massive Cu-Pb-Zn sulfide deposit was encountered by the drilling done by CPRM in the same IP anomalous area where MMAJ disclosed the pyrite dissemination. The IP and SIP methods carried out were useful for the detection of pyrite dissemination but not useful enough for the determination of the presence and the location of massive sulfide in the pyrite dissemination.

1–3 Organization of the Mission

The field survey started in July, 1986 and ended in September, 1988. The period and the members for the survey of eacy year are shown in Table. I-2.

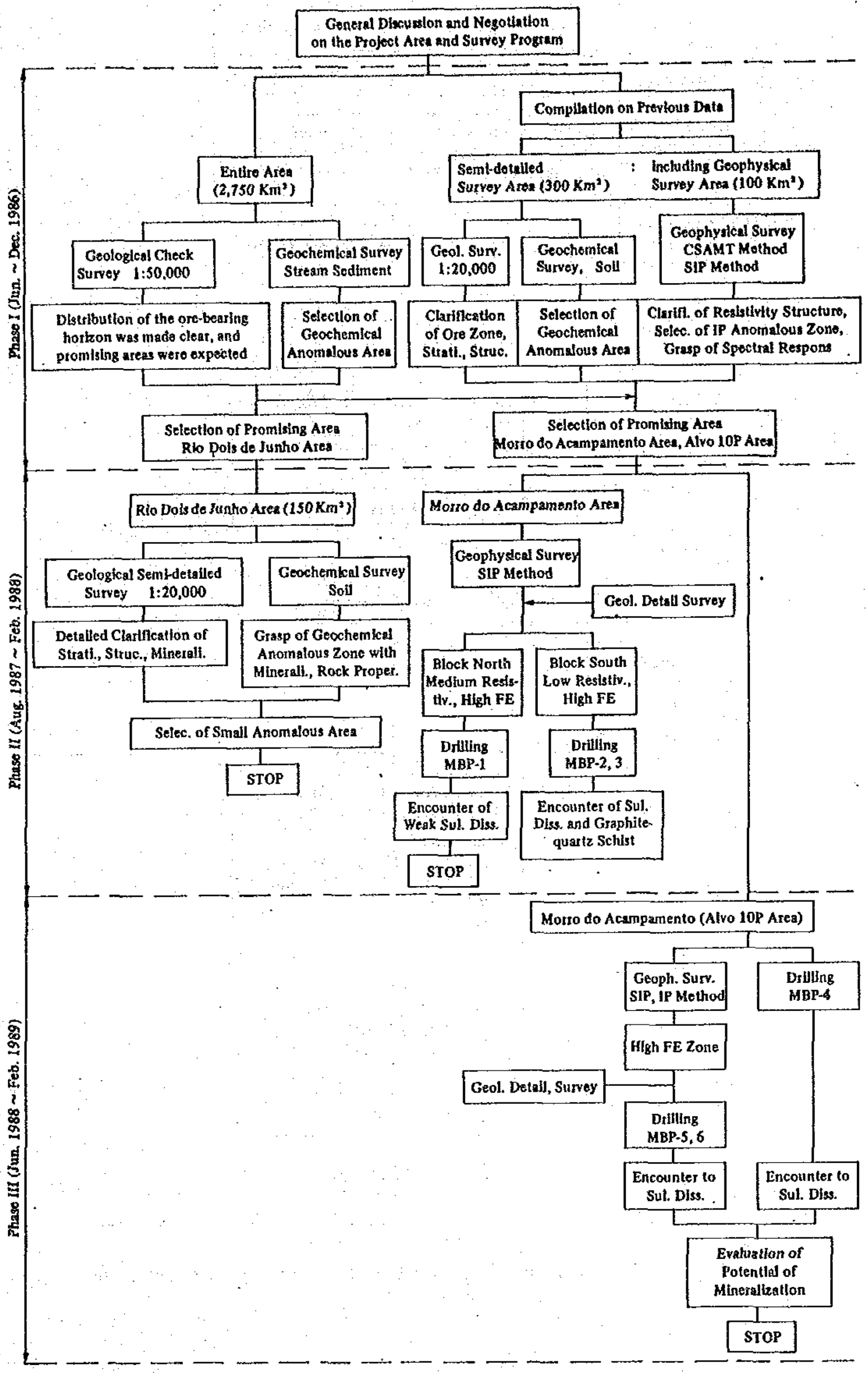


Fig. I - 1 Flowsheet Showing Selection of Each Phase Survey Area ; Palmeiropolis

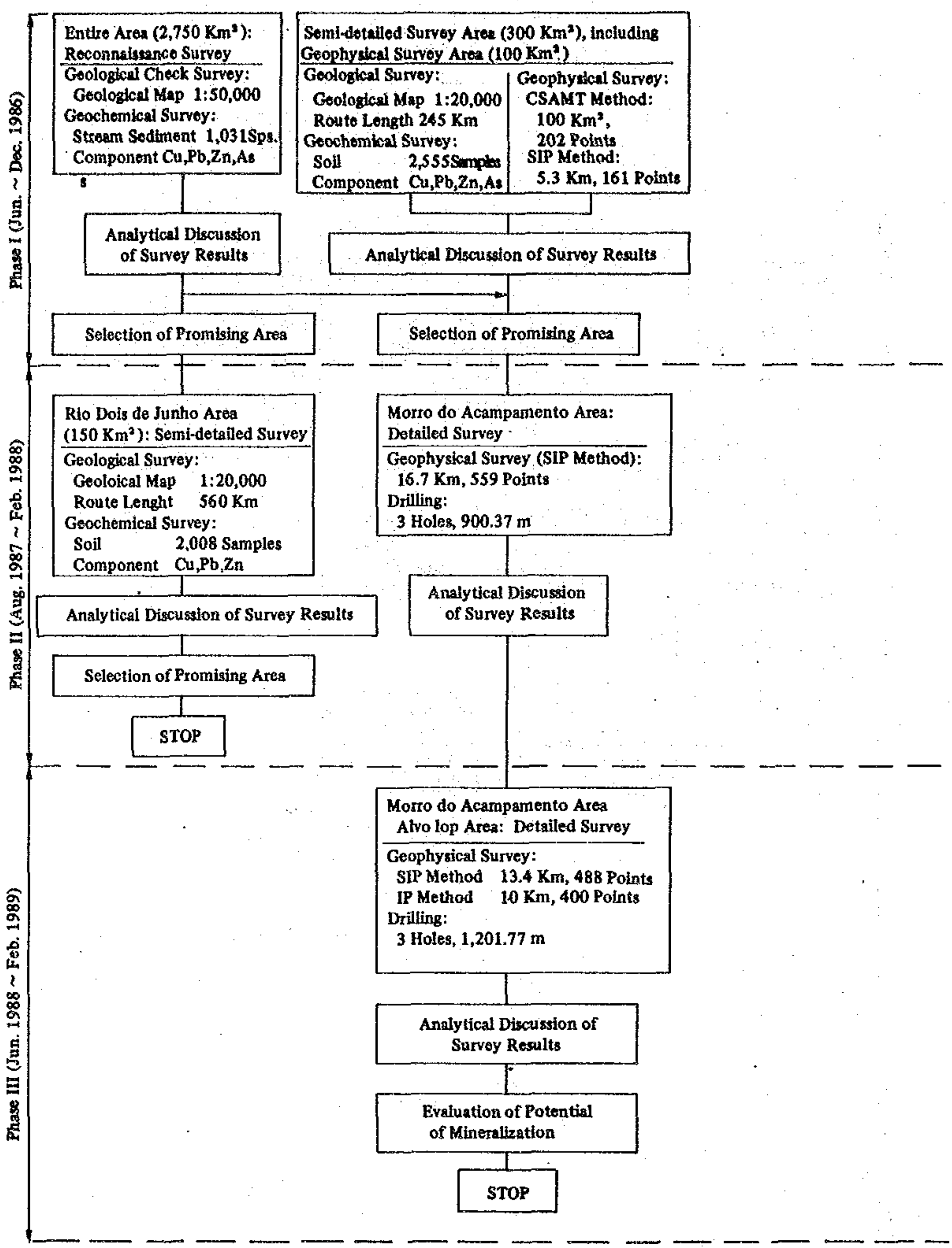


Fig. I - 2 Flowsheet Showing Details of Survey : Palmeiropolis

Table I - 1 Outline of the Method and Amounts of Survey

Items		Phase I (1986)	Phase II (1987)	Phase III (1988)
Geological/Geochemical Surveys				
Reconnaissance Survey		2,750 Km^2 (+) (1:50,000)	–	–
Stream Sediment		1,031 Samples (+)	–	–
Semi-detailed survey		300 Km^2/245 Km (*)	150 Km^2/560 Km (#)	–
Soil		2,555 Samples (*)	2,008 Samples (#)	–
Topographic Mapping		–	20 Km (x) (1:5,000)	–
Geophysical Survey				
CSAMT Method		100 Km^2/202 Points (*)	–	–
SIP Method		5.3 Km/161 Points (*)	16.7 Km/559 Points (x)	13.4 Km/488 Points (x)
IP Method		–	–	10.0 Km/400 Points (x)
Drilling		–	900.37 m/3 holes (x)	1201.77 m/3 holes (x)
Laboratory Studies	Thin Section	35	30	10
	Polished Section	28	5	6
	X-ray	203	–	–
	Chemical Analysis			
	Rock	23	–	–
	Ore: Au, Ag, Cu, Pb, Zn	54 (270 elements)	–	–
	Au,Ag,Cu,Pb,Zn, S	–	10 (60 elements)	60 (360 elements)
	Ag, Cu, Pb, Zn, S	–	10 (60 elements)	–
	Geochemical Analysis			
	Steam Sediment:			
	Cu, Pb, Zn, As	1,031 (4,124 elements)	–	–
	Soil: Cu, Pb, Zn, As	2,555 (10,220 elements)	–	–
	Cu, Pb, Zn	–	2,008 (6,024 elements)	–
	Physical Property :			
	PFE, Resistivity	45	31	27

+ : Entire Area (1:50,000), * : Semi-detailed Survey Area (included in Morro do Acampamento Area) (1:20,000), # : Rio Dios de Junho Area (1:20,000), x : Morro do Acampamento Area (1:5,000)

Table I - 2 Survey Period and Member List of the Survey Team

	Items	Survey Period	Members	
			Japanese Members	Brazilian Members
Phase I (1986)	Planning and Negotiation		Takeshi Izumi (MMAJ) Hideyuki Ueda (MMAJ) Katsutoki Matsumoto (MMAJ-RIO)	José Belfort dos Santos Bastos (DNPM) Carlos Oiti Berber (DNPM) Bolivar Gonçalves Siqueira (DNPM) Walter Hugo Schmaltz (DNPM)
	Geological and Geochemical Survey	July 8, 1986 ~ Oct. 12, 1986	Tsuyoshi Suzuki (BEC) Yoshio Takeda (BEC) Norio Ikeda (BEC)	Homero Lacerda (DNPM) Arpuim Aráujo Pereira (DNPM) Ellias Alvares Lima Junior (DMPM) Ivan Wilson Brandão Oliveira (CPRM)
	Geophysical Survey	July 29, 1986 ~ Oct. 12, 1986	Tomio Tanaka (BEC) Keiji Tanaka (BEC) Kazuto Matsukubo (BEC)	José dos Anjos Barreto (CPRM)
	Report Preparation	Oct. 13, 1986 ~ Dec. 1, 1986		
Phase II (1987)	Planning and Negotiation		Kazunori Kano (MMAJ) Yozo Baba (MMAJ) Toshihiko Hayashi (MMAJ) Katsutoki Matsumoto (MMAJ-RIO)	José Belfort dos Santos Bastos (DNPM) Carlos Oiti Berber (DNPM) Bolivar Gonçalves Siqueira (DNPM) Walter Hugo Schmaltz (DNPM)
	Geological Survey	Aug. 18, 1987 ~ Oct. 6, 1987	Ikuhiro Hayashi (BEC) Norio Ikeda (BEC)	Homero Lacerda (DNPM) Arpuim Aráujo Pereira (DNPM) Valdemar José de Almeida (DNPM) José Ribamar Constancio da Silva (DNPM) Ivan Wilson Brandão Oliveira (CPRM)
	Geophysical Survey	Aug. 18, 1987 ~ Nov. 1, 1987	Tsuyoshi Suzuki (BEC) Tomio Tanaka (BEC) Keiji Tanaka (BEC)	José dos Anjos Berreto (DNPM)
	Drilling	Oct. 1, 1987 ~ Dec. 20, 1987	Ikuhiro Hayashi (BEC)	Homero Lacerda (DNPM)
	Report Preparation	Oct. 7, 1987 ~ Feb. 20, 1988		
Phase III (1988)	Planning and Negotiation		Kyoichi Koyama (MMAJ) Toshihiko Hayashi (MMAJ) Hideaki Mukai (MMAJ-RIO)	José Belfort dos Santos Bastos (DNPM) Carlos Oiti Berbert (DNPM) Bolivar Gonçalves Siqueira (DNPM) Walter Hugo Schmaltz (DNPM)
	Geophysical Survey	Jun. 5, 1988 ~ July 10, 19	Tomio Tanaka (BEC) Keiji Tanaka(BEC) Kazuto Matsukubo (BEC)	José dos Anjos Barreto (DNPM)
	Drilling	Jun. 4, 1988 ~ Sep. 10, 1988	Kazuo Kawakami (BEC)	Homero Lacerda (BNPM) Ivan Wilson Brandão Oliveira (CPRM)
	Report Preparation	July 11, 1988 ~ Feb. 10, 1989		

(Abbreviation)
DNPM: Departmento Naçional da Producão Mineral
CPRM: Companhia de Pesquisa de Recursos Minerais
MMAJ: Metal Mining Agency of Japan
BEC : Bishimetal Exploration Co., Ltd.

CHAPTER 2 PREVIOUS SURVEY

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 Palmeiropolis" (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 deposists based on the survey results of "Projecto Serra da Mesa". With the progress of study for establishment of stratigraphy of Palmeiropolis volcano-sedimentary rocks, the exploration revealed the presence of a Cu-Pb-Zn sulfide deposit which was previously unkown in the area under discussion. The deposit is called Palmeiropolis are deposit composed of three ore bodies. Ore reserves is reported to be 4 million tons (Cu 0.46~1.25 %; Pb 0.33~1.38%; Zn 4.22~5.85%).

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 (1984) at 1 : 50,000 of "Projeto Palmeiropolis" describes in detail the stratigraphy in the vicinities of ore deposit, especially the stratigraphical division of the Palmeiropolis 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 Palmeiropolis" (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.

CHAPTER 3 GENERAL GEOLOGY OF THE PALMEIROPOLIS AREA

The geology of Brazil is an integral part of the South American Platform from the standpoint of major geologic structures of the South American continent, and its geologic age reaches back to the Archaeozoic Peil.

The Precambrian formations occupy an area of about 4,500 thousand square kilometers, covering more than 50 percent of the whole of Brazil.

The Brazilian orogenic cycle, which took place from late Proterozoic to early Palaeozoic, caused the geologic structure of the Precambrian system 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 the Silurian to Ordovician, and it is distributed at present as three large shields (Guiana, Brasil Central and Atlantico) (Fig. I–3.)

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 also been subjected to other orogenic cycles such 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 cratons by the fold zones (Nordeste, Sergipana, Rio Preto, Araçuai, Brasilia, Sudeste, Paraguai-Araguaia and Grupi) that formed during the Brazilian orogenic cycle (Fig. I–4).

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

The Palmeiropolis area belongs to the Uruaçu zone contemporaneous with 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 the State of Goias including the Palmeiropolis 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 (Palmeiropolis deposit) and Sn-W deposit (Serra da mesa type) in granitic rocks intruding the above rocks.

The stratigraphy of the Palmeiropolis area is roughly divided into 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 rocks [formed in Jequie orogenic cycle (2,500~4,125 my K-Ar and Rb-Sr methods, DNPM, 1984)]: granulite-basic to ultrabasic complex, granite-gneiss-migmatite complex.

Cana Brava asbestos deposit was formed at the same time as the serpentinization of ultrabasic rocks of this age.

(2) Proterozoic

(a) Lower Proterozoic (Formed during the Transamazonian orogenic cycle)

Palmeiropolis volcano-sedimentary sequence: ultrabasic rocks, schist, chert, quartzite, granite.

(b) Middle Proterozoic (formed during the Uruaçuano orogenic cycle)

Serra da Mesa Group: quartzite. schists, limestone~marble, basic rocks, granites.

Rio Maranhão cataclastic zone: quartzite, schists, gneiss

(c) Upper Proterozoic (formed during the Brazilian orogenic cycle)

Paranoa Group: quartzite, dolomite, slate, conglomerate (not distributed is this area)

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

The Palmeiropolis 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 (estern unit). The palmeiropolis ore deposit is located between the intermediate to acidic schistose rocks (hanging wall) and amphibolites (footwall) of Unidade de Central. In addition, it has been determined that similar mineralization exists in the middle part of the acidic schist.

Because this stratigraphy is applied only in the northern part of this area, the classification by DNPM/CPRM (1983) is available for the entire area. They are Pip_1, Pip_2, Pip_3, Pip_4, & Pip_5 from the stratigraphycally lower to the top (Table II-1).

Palmeiropolis ore deposits are hosted between Pip_3 and Pip_4 and in Pip_4.

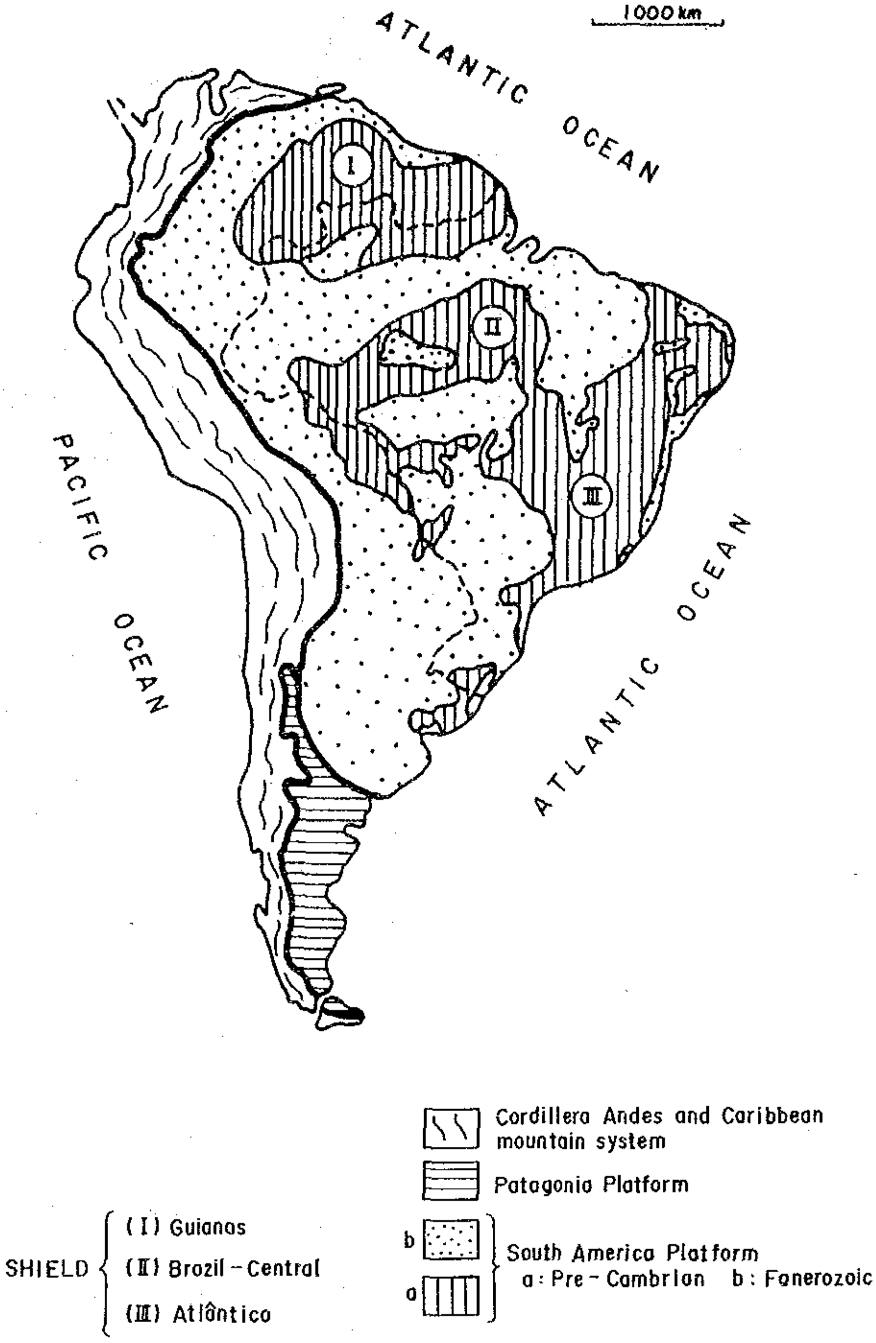
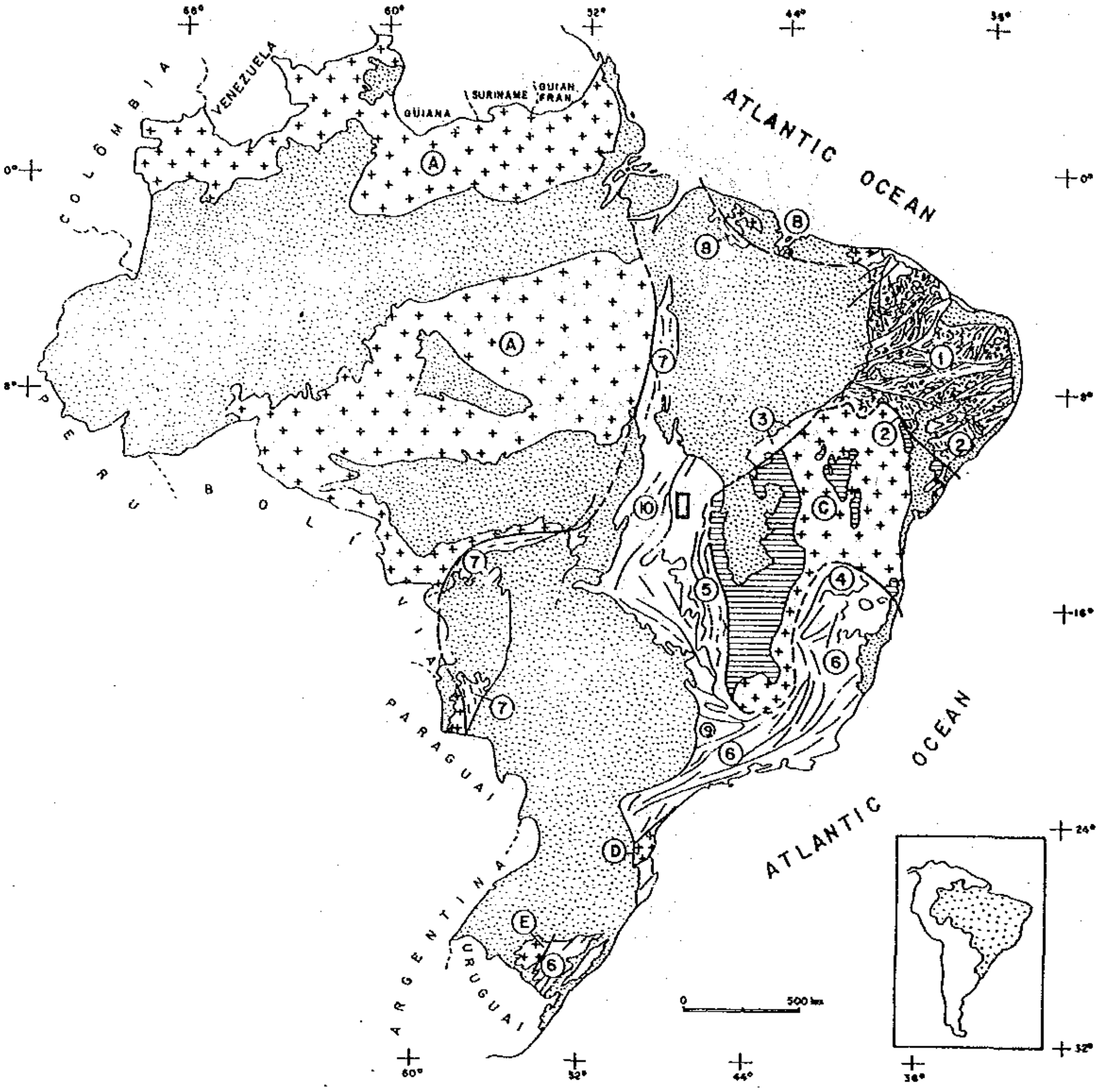


Fig. I-3 Tectonic Division of South America
(Geologia do Brasil, DNPM, 1984)



FANEROZOIC

REGIONS, SYSTEMS AND FOLDING BELTS OF BRAZILIAN CYCLE

① - Nordeste ② - Sergipano
③ - Rio Preto ④ - Araçuai
⑤ - Brazilia ⑥ - Sudeste (Ribeira)
⑦ - Paraguai - Araguaia ⑧ - Gurupi

MEDIAN MASSIF

⑨ - Guaxupe ⑩ - Goias

SEDIMENTS CORRELATED WITH BRAZILIAN CYCLE

PRE - BRAZILIAN CRATONS

Ⓐ - Amazonico Ⓑ - Sao Luis
Ⓒ - Sao Francisco Ⓓ - Luis Alves
Ⓔ - Rio de La Plata

Area of Palmeiropolis Project

Fig. 1-4 Folded Zone of Brazilian Cycle and Cratons
(Geologia do Brasil, DNPM, 1984)

CHAPTER 4 OUTLINE OF THE SURVEY AREA

4–1 Location and Access

The survey area is located in the central part of the State of Goias with Palmeiropolis and Minaçu situated in the north and south respectively. Usually the area can be reached from Goiania, the capital of the State, via Uruaçu and Santa Tereza de Goias and Palmeiropolis through State Highway Go-080, National Highway BR-153 and State Highway GO-142 toward the north, a total distance of 617 kilometers representing about 8 hours of driving time. Rio Dios de Junho area is located 42 km to the south of Palmeiropolis. Morro do Acampamento area is located about 20 km to the east of Palmeiropolis. It takes about one hour to travel to Rio Dois de Junho area and 30 minutes to the Morro do Acampamento Area from Palmeiroposis along unpaved roads.

4–2 Circumstances of the Area

The topography of the area is gererally composed of gentle hills and flat land. Morro Salto is located on an isolated peak (758m) in the northern part and Serra Cana Brava makes a mountain range (810∿900m) in the south. Steep cliffs are formed in the neighbourhood of streams and their branches around Morro do Acampamento.

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

Situated at the southern end of the Amazon zone, this area falls within the tropical humid-type climate characterized by rainy and dry seasons. 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 preipitation
Temperature	Annual mean	23° to 24°C
	Maximum	41°C
	Minimum	15°C

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

CHAPTER 5 CONCLUSIONS AND RECOMENDATIONS

5–1 Conclusions

1. Morro do Acampamento Area

(1) As the result of geochemical survey using stream sediments, anomalous areas of Cu-Pb-Zn are found on Alvo 1P, 2P, 7P, 9P, 10P and 11P. As the result of soil geochemical survey, anomalous areas of Pb-Zn are found in Alvo 7P, 9P, 10P, 13P, and an anomalous area of Cu is found in Alvo 11P. These anomalies are thought to be due to mineralization (Fig. II–7, Fig. III–2).

(2) The drilling executed on the area with IP and geochemical anomalies in Alvo 7P to the northeast of Morro do Acampamento could not delineate the possible mineralization. The target horizon was Pip_4 where Palmeiropolis ore deposits were located (Fig. III–7).

(3) The two drillings carried out no two strong IP anomalous areas in Alvo 9P to the southwest of Morro do Acampamento, confirmed dissemination of sulfide minerals (pyrite and pyrrhotite) in a section spaced 70m to 100m from the core. The maximum amount of sulfide minerals is about 7 wt%. Thin beds of graphite-quartz schist were also found in the same area (Fig. III–7).

(4) The three drillings carried out on three IP anomalous areas to the east of Alvo 10P located in the southwest of Morro do Acampamento, yielded pyrite dissemination with small amounts of chalcopyrite, galena and sphalerite (Fig. III–7).

(5) The disseminated zones are thought to be related to each other because they are present next to each other or very close; the host rocks are all mica schist; sulfide minerals in the host rocks and their occurrences are similar to each other; and geophysical techniques disclosed a continuity in the zones. The Cu-Pb-Zn massive sulfide deposit was simultaneously detected in one of the IP anomalous areas by drilling carried out by CPRM. The massive sulfide deposit was concluded to be continuous into the pyrite dissemination zones.

(6) From the above mentioned, the Morro do Acampamento area, especially to the south of Morro do Acampamento, should be finaly evaluated by further detailed survey which will permit the determination of the scales and the reserves of the ore deposits.

(7) IP and SIP methods wer effective for the detection of the pyrite dissemination. However, they were not able to discriminate Cu-Pb-Zn sulfide minerals in the pyrite dissemination zones neither to localize the Cu-Pb-Zn ore deposit in the dissemination zones. That was thought to be due to the fact that the scale of Cu-Pb-Zn massive sulfide deposit (determined by PM-138-GO) was too small to the pyrite dissemination zone and that the Cu-Pb-Zn sulfide minerals dispersed in the dissemination zones (determined by MBP-4, MBP-5, MBP-6, etc.) were too little compared to the amount of pyrite. IP and SIP methods seemed to have shown a limitation in the determination of the presence and localization of Cu-Pb-Zb sulfide minerals included in a pyrite dissemination on a wide scale.

2. Rio Dois de Junho Area

In the area, geochemical surveys by stream sediments were conducted in Phase I, and a detailed geochemical survey using soil sampling were carried out in Phase II. As the result of the above surveys, geochemical anomalies of Cu, Pb and Zn were found in Pip_4. However, as compared to the size of the Palmeiropolis deposit, the anomalous zones found in these areas are so small that in case of the existence of an ore deposit, it would be rather uneconomically small.

5–2 Recomendations

1. Morro do Acampamento Area

(1) As clarified by Phase II and Phase III of the survey, the stratified Cu-Pb-Zn deposits are present at least at the bottom, middle and top of Pip_4. Geophysical (SIP, IP methods) and drilling surveys are recommended for further exploration in the area of Pip_4, where geochemical anomalies are left unsurveyed.

(2) Carry out detailed geophysical and drilling survey in the areas of southwest of Morro do Acampamento where the IP anomaly zones need of a more detailed study.

(3) A more detailed survey using geophysical and drilling methods is recommended to evaluate the ore reserves, especially to the east, northeast and southwest of the known mineralized area. Since the massive ore deposit was found in the mineralized area in the east of Alvo 10P.

(4) Carry out rock geochemistry to reveal the stratigraphy of the ore hosting field using drilling cores in the Morro do Acampamento area. Carry out inclined drillings directing northwest and arranged in northeast direction, since in this area the shape of the ore deposits are thought to be controlled by the folds with NE trending axis and SE dipping fold axial planes.

2. Rio Dois de Junho Area

Further surveys are not recommended. Because even if ore deposits were found, it would be uneconomical in this area.

PART II PALMEIROPOLIS ENTIRE AREA

CHAPTER 1 GEOLOGY

1-1 General Geology

The geological structure of this area coincides with that of trending north in the Uruacu fols belts developed between Sao Francisco Craton and Amazonico Craton.

This area is composed of the Archaeozoic Cana Brawa basic-ultrabasic massif, the base of the area, Lower Proterozoic Palmeiropolis volcano-sedimentary sequence, Middle Proterozoic Serra da Mesa Group and Rio Maranhão Cataclastic Zone and the Upper Proterozoic Paranoa Group.

Cana Brava basic-ultra basic massif, the basement of this area, is composed of meta-gabbro, serpentinite and pyroxenite. This complex forms the Cana Brava Mountains which trend north in the east and southeast of this area.

The Palmeiropolis volcano-sedimentary sequence is composed of gabroic amphibolite, acidic to intermediate pyroclastics and schists of similar composition occupying 2/3 of the study area and is distributed as belts trending north.

Serra da Mesa Group is composed of garnet-muscovite-quartz schist, biotite-muscovite-quartz schist, chert etc., surrounding the Palmeiropolis volcano-sedimentary sequence in the northwest, west and south of the area.

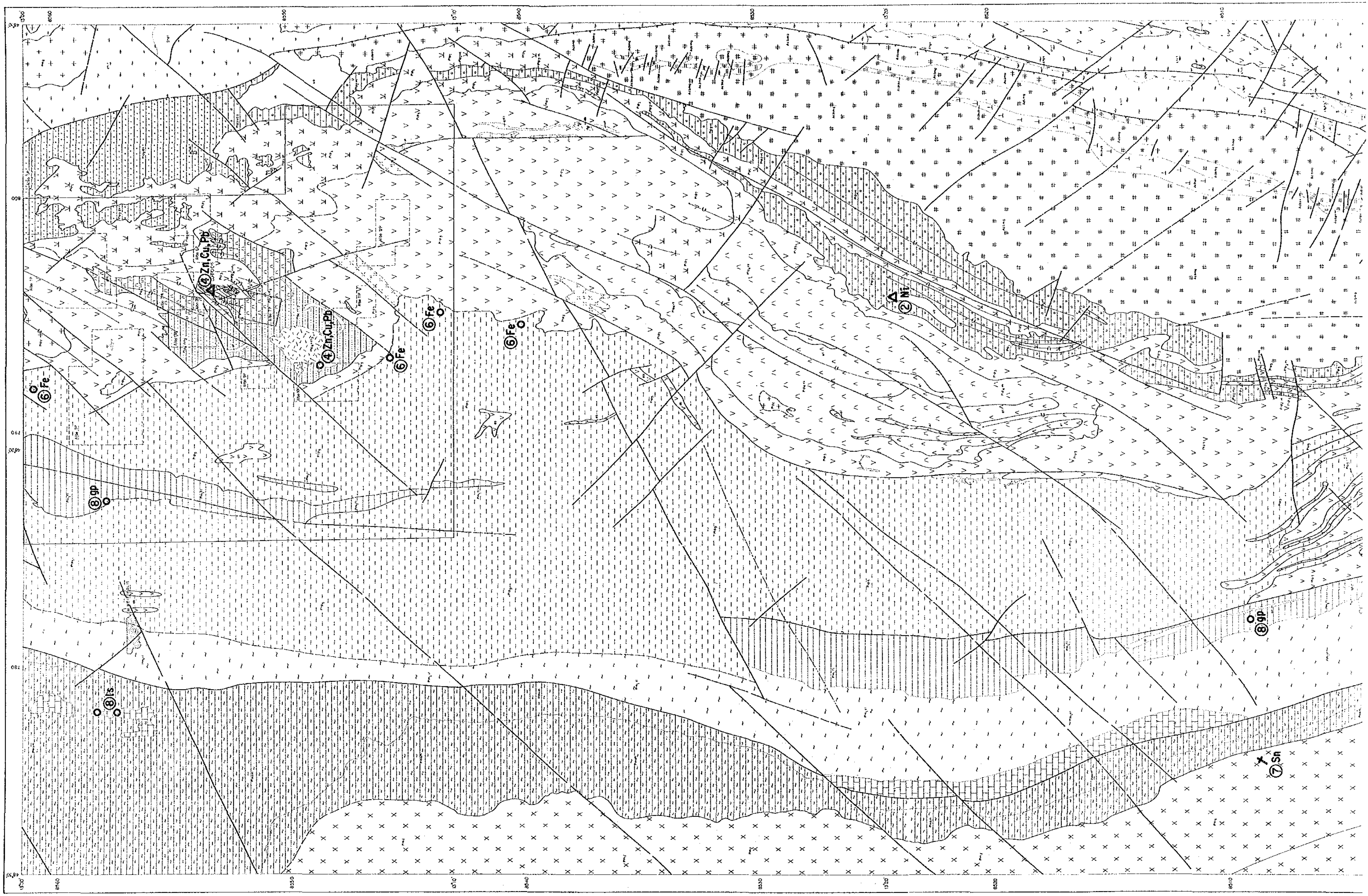
The Rio Maranhao Cataclastic Zone is composed of quartz-muscovite schist, biotite-muscovite schist, calcareous schist-gneiss which have prominent cataclastic texture, being narrowly distributed in a north-south direction in the eastern most part of the area.

Intrusives in this area are granites and basic-ultrabasic complexes.

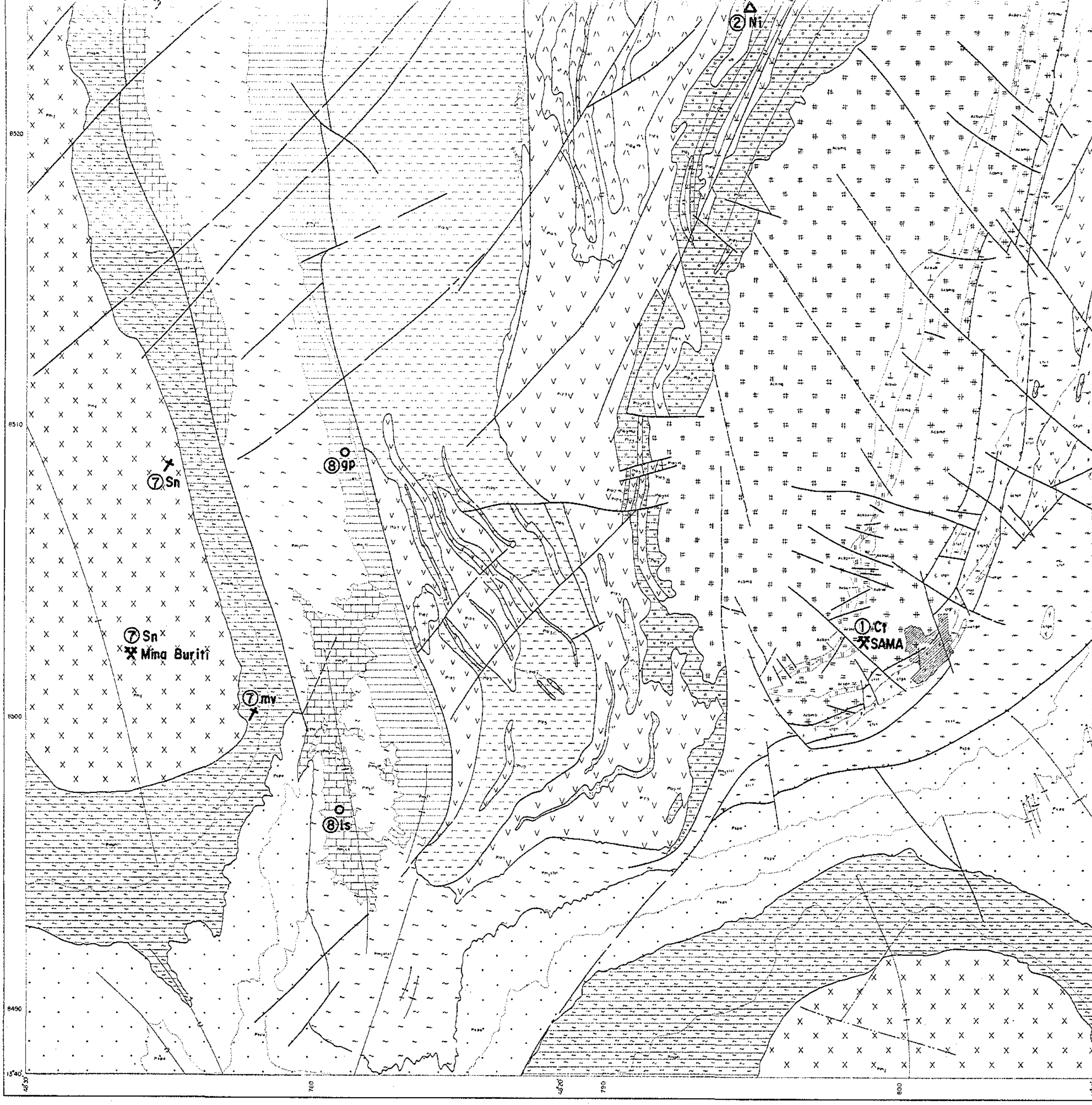
1-2 Detailed Geology

1-2-1 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 Palmeiropolis volcano-sedimentary sequence (Pip), middle Proterozoic Serra da Mesa group (Pmsm, Pm), Rio Maranhão cataclastic zone (ct) and upper Proterozoic Paranoa Group (Pspa)(shown in Figure II–1 and II–2).



④Zn,Cu,Pb
④Zn,Cu,Pb
⑥Fe
⑥Fe
⑥Fe
⑥Fe
②Ni
⑧gp
⑧gp
⑧ls
⑦Sn



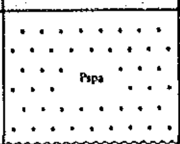
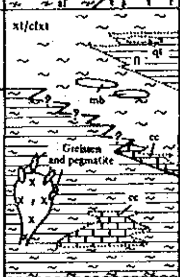
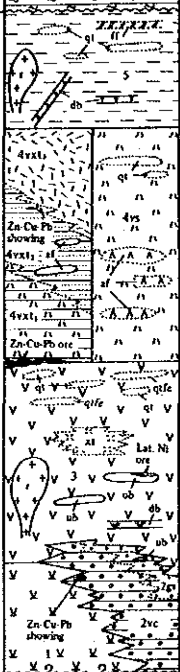
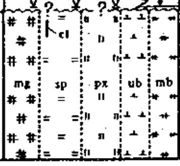
LEGEND

Geological Unit	Symbol	Columnar Section	Lithology
Paranoá Group	Pspa	Pspa	Photo interpretative Unit: quartzite, calcareous and graphytic phyllite, calc-schist, marble and sericite-quartzite
Rio Maranhão Cataclastic Zone	Ct	qt, af, r, gn	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)
Serra da Mesa Group (MARINI, 1976)	Pml	xt/clxt, qt, fl, mb	qt : mg-bearing sc. quartzite fl : 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
	Pmsm	Greisen and pegmatite, r, cc	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
Palmeirópolis Volcano - Sedimentary Sequence (RIBEIRO FILHO and TEIXEIRA, 1981)	Pip	qt, ff, r, 5, db	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)
		4vxt₃, Zn-Cu-Pb showing, 4vxt₂, af, 4vxt₁, Zn-Cu-Pb ore, qt, 4vs	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)
		qt, qtfe, xt, Lat. Ni ore, r, 3, ub, db, 2gv, Zn-Cu-Pb showing, 2vc, 1	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
Cana Brava Basic-Ultrabasic Massif	Acb	ct, mg, sp, px, ub, mb	mg : metagabbro, metanorite and metagabbronorite sp : serpentinite px : pyroxenite ub : serpentinite and pyroxenite mb : basic to ultrabasic rock (post-metamorphism)

Geological boundary
Lithological limit
Fault
Synclinal axis
Anticlinal axis
Synclinorium axis
Anticlinorium axis
17° Bedding plane
25° Schistosity (S_1)
Schistosity (S_2)
→10° Lineation
Lineament
Ct Mines
Sn Mineral showings
Ni Ore deposits
Sn Small Mines ("Garimpo")
①~⑧ : ref. Fig. II-2

Zn - Zinc
Cu - Copper
Pb - Lead
ls - Limestone
mv - Musuvite
Ni - Nickel
Ct - Crisotile asbestos
Sn - Tin
Fe - Iron
gp - Graphite

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

①-⑧: ref. Fig. II-1.

Fig. II - 2 Stratigraphic Columnar Section in the Surveyed Area

(1) **Cana Brava Basic-Ultrabasic Massif**

(i) 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.

(ii) Lithofacies

The massif constitues 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. 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.

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.

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.

(iii) Stratigraphical Relation

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.

(2) **Palmeiropolis Volcano-Sedimentary Sequence**

CPRM (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 Morro do Acampamento 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. The correlation is thought as follows (Table II–1).

Table II - 1 Stratigraphic Correlation of Palmeiropolis Area

<table>
<tr><th>CPRM (1984)</th><th colspan="2">DNPM/CPRM (1983)</th></tr>
<tr><td>$PCPE_1$</td><td colspan="2">ct</td></tr>
<tr><td>$PCPW_1 \sim PCPW_4$</td><td colspan="2">Pip_5</td></tr>
<tr><td>$PCPCxt_3$
$PCPCxt_2$
$PCPCxt_1$</td><td>Pip_4vxt_3
Pip_4vxt_2
Pip_4vxt_1</td><td>Pip_4vs</td></tr>
<tr><td>PCPCaf</td><td colspan="2">Pip_3</td></tr>
<tr><td>$PCPCgb_2$ * *
$PCPCgb_1$ *</td><td>Pip_1 *</td><td>Pip_2 * *</td></tr>
<tr><td>$PCPE_2$ * *</td><td></td><td></td></tr>
</table>

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

$PCPE_2$ and $PCPCgb_2$ are correlated to Pip_2, $PCPCgb_1$ is correlated to Pip_1.

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.

(i) 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.

(ii) 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.

Pip_2 Member: The rocks are distributed intercalated in the Pip_1 member, consisting of acidic to intermediate pyroclastic rocks and schist (Pip_2 vc). 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 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.

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 survey area. This member is subdivided by DNPM/CPRM (1983), from the base upward, into $Pip_4 vxt_1$, $Pip_4 vxt_2$ and $Pip_4 vxt_3$. In the central part of the survey area, however, the rocks are collectively treated as Pip_4 vs.

The lithologic characteristics of each submember is as follows:

$Pip_4 vxt_1$ consists of feldspathic biotite-quartz schist, staurolite-garnet-biotie-quartz schist and biotite-amphibole schist.

$Pip_4 vxt_2$ mainly consists of plagioclase-microcline-biotite-quartz schist and plagioclase-biotite-quartz schist, intercalated with thin layers of amphibolite (af).

$Pip_4 vxt_3$ consists of sericite-microcline-quartz schist.

Pip_4 vs mainly consists of feldspathic garnet-biotite-quartz schist and mica schist which are similar to the schistose rocks found in 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:

Pip_5 member: 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).

(iii) Stratigraphic Relations

This sequence unconformably overlies the Cona Brava basic to altrabasic massif.

(3) Serra da Mesa Group

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

(i) 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.

(ii) 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 schit · banded quartzite (clxt), and is intruded by basic sill (mb).

(iii) **Stratigraphical Relation**

The group unconformably overlies the Palmeiropolis volcano-sedimentary sequence.

(4) **Rio Maranhão Cataclastic Zone (Ct)**

(i) **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.

(ii) **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).

(iii) **Stratigraphical Relation**

The zone is in fault contact with the underlying formations.

(5) **Paranoa Group**

(i) **Distribution**

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

(ii) **Lithofacies**

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

(iii) **Stratigraphical Relation**

The group unconformably overlies the lower formations.

1–2–2 Intrusives

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) Granitic Rocks (γ)

(i) Distribution and Occurrence

The rocks are widely distributed in the western (Serra Dourada) 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.

(ii) 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.

(iii) 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.

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

(i) Distribution and Occurrence

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

(ii) 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.

(iii) Time of Intrusion

Since the age determination 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 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 Palmeiropolis 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 da Mesa Group and the Paranoa 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 (CSAMT 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 Palmeiropolis 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 Palmeiropolis volcano-sedimentary sequence toward the west.

1–4 Metamorphism

Zoning of metamorphic facies was made for the geological units distributed in the survey area, centering mainly on the Palmeiropolis volcano-sedimentary sequence in the semi-detailed survey area. The zoning is based on the results of the field observation, rock analysis (Table II–2) and microscopic observation of thin sections.

Figure II–3 shows the triangular diagrams (ACF diagrams), wherein each apex represents $Al_2O_3 + Fe_2O_3 - (Na_2O + K_2O)$, CaO and FeO + MgO in mol ratio, showing the relation between chemical composition and mineral components of metamorphic rocks.

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).

Based 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_1 fl (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.

A comparative study of Fig. II–4 and Fig. II–5 leads to the assumption that metamorphic facies series of the Palmeiropolis 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 x 10^3 atms respectively.

Table II - 2 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
	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	Pip2vo	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
	Y	59.85 - 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	Pmif2
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

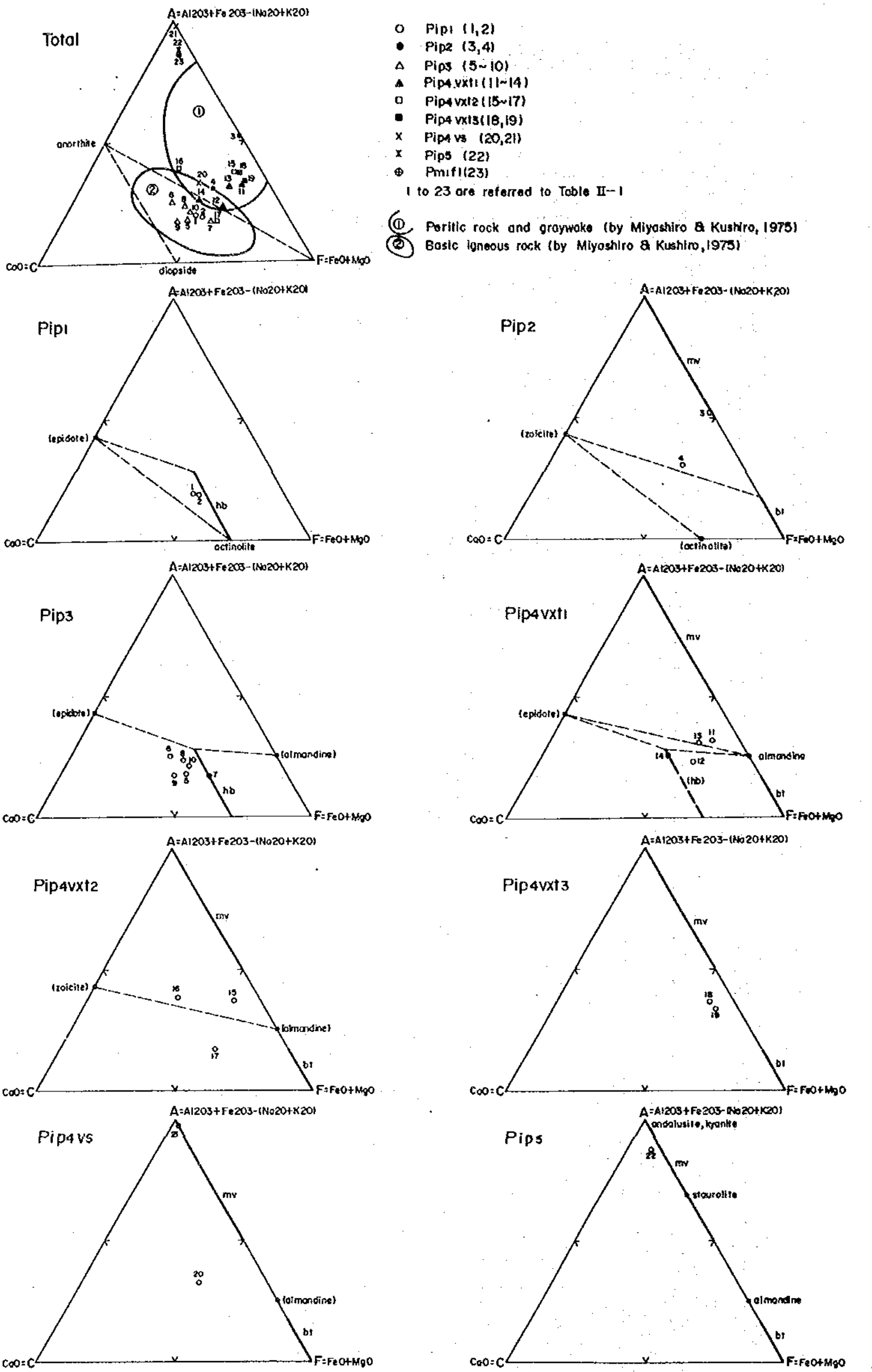


Fig. II - 3 ACF Diagrams of Metamorphic Rocks

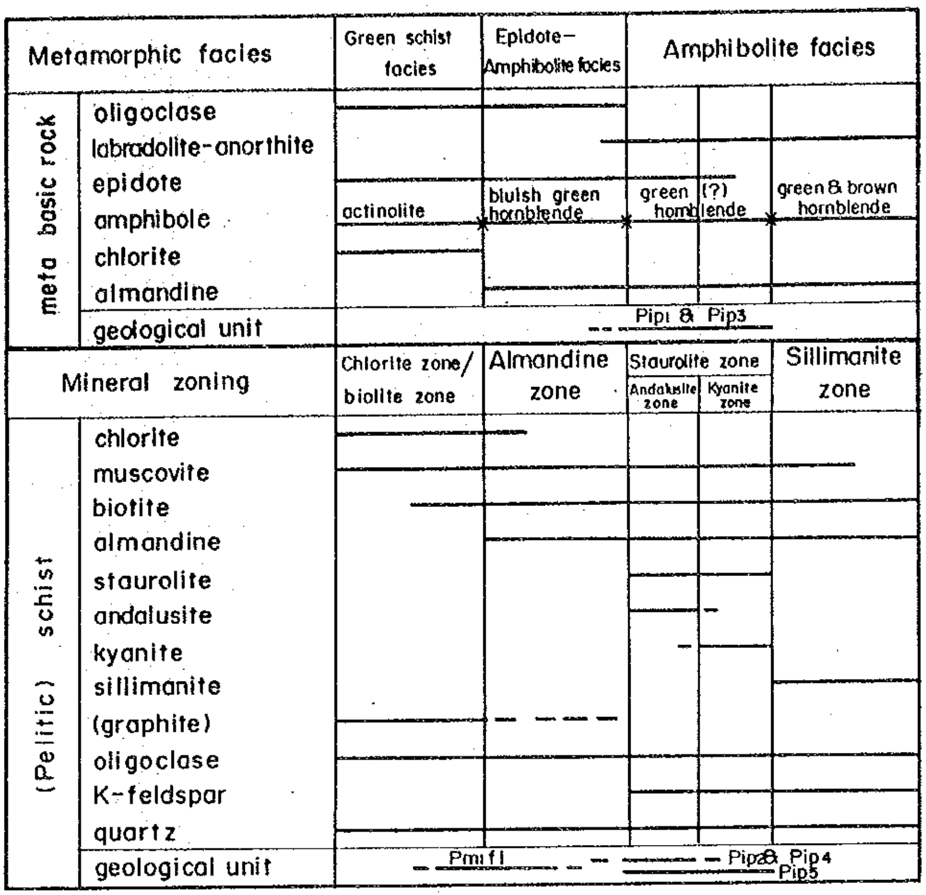
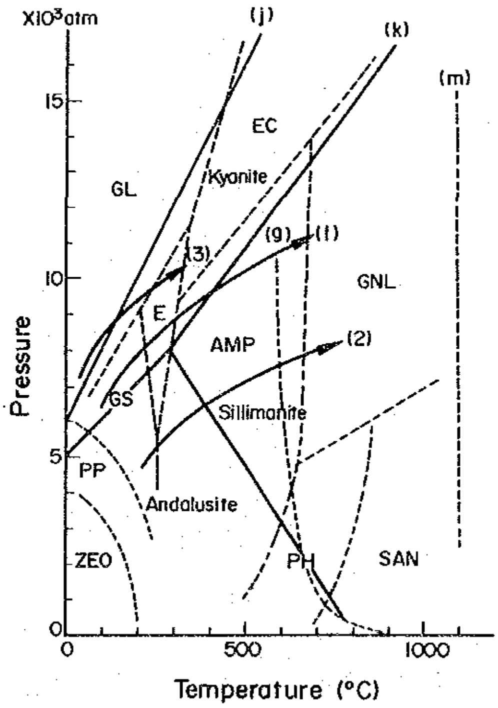


Fig. II-4 Classification of Metamorphic Facies



GL : Glaucophane 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

CHAPTER 2 MINERALIZATION

Although the survey area is populated by deposits of various sizes, (Figures II–1 and II–2), the chief deposits either being surveyed, or under operation at present include the Cana Brava asbestos deposit, the Palmeiropolis Cu-Pb-Zn deposit and the Briti tin deposit.

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 of this report, however, are not available.

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

The deposit is being operated by S.A. Mineraçao de Aminato (SAMA), 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 the low temperature type in brown serpentinite was formed by early stage mineralization, and high grade asbestos of the high temperature type in green serpentinite was formed in later stage mineralization. The ore reserves are 50 million tons (6.7% chrysotile).

The Buriti tin deposit is a deposit consisting of 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 the albitization style alteration forms a small-scale high grade deposit. The Brumadinho's Buriti mine is mainly operated for this type of deposit.

The Palmeiropolis deposit was discovered as a result of the survey by CPRM covering an area of about 30,000 ha (southern half of it is included in Morro do Acampaments area of the current project) as "Project Palmeiropolis" between 1975 and 1984. The Palmeiropolis Cu-Pb-Zn deposit comprises three ore bodies (C–1, C–2, C–3).

The C–1 ore body in the Palmeiropolis is emplaced between the amphibolitic rocks (Pip_3) and schistose rocks (Pip_4), C–2 and C–3 ore bodies are in Pip_4.

The approximate size 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

The main mineral assemblage of the ore consists of sphalerite, pyrrhotite, pyrite, chalcopyrite and galena. Although the content amounts for each mineral are also in the above order, the C-3 ore body contains a lesser amount of lead, thus showing characteristics a little different from the 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 is characterized by more than 50 percent of sulfide (volume percentage) and a brecciated texture.

Disseminated ore: Found in the surrounding part of the former, rarely container more than 20 percent 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 amounts. 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).

An investigation was conducted to find out if 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. It was difficult to qualify the primary hydrothermal alteration minerals by means of X-ray diffraction. And, according to the analysis of alteration intersity using the valve of $(MgO + K_2O)/(Na_2O + K_2O + MgO + CaO) \times 100$ or $K_2O/(Na_2O + K_2O) \times 100$ which are utilized to detect alteration zone from the changes of Na_2O and K_2O contents, it is thought that alteration of country rocks of the area is weak compared to the "Kuroko" and Noranda-type volcanogenic massive sulfide deposits. Because though Kuroko deposits have the values more than 90 % in the former formula and the massive sulfide deposits in Noranda area have the values more than 80 % in the latter formula, the C-1 ore body has the value of 45 to 60 % in the former formula and 50 to 70 % in the latter formula as studied in Phase I.

CHAPTER 3 GEOCHEMICAL SURVEY (STREAM SEDIMENTS)

3–1 Contents of the survey

A geochemical survey of stream sediment was conducted mainly in the area underlain by the Palmeiropolis 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.

Sampling stations were plotted on the survey planning map (drainage map at 1:50,000 was used), making sampling density 2∿3 per km^2. A total of 1031 samples were collected.

Stream sediments were sieved in the water to under 80 mesh and then chemically analyzed for four components such as Cu, Pb, Zn and As by the atomic absorption method.

The assay results of the above four components of the 1031 samples were input into computor and statistically processed using two methods of single component analysis and multivariate analysis.

3–2 Results of the Survey

(1) Single Component Analysis

Histograms and cumulative frequency distribution diagrams were produced for the purpose of extracting anomalous values of each component (*Fig. II–6*).

The histogram for As does not show correct logarithmic normal distribution since 86.4 percent of the values are below the detection limit. On the other hand, the histograms for Pb and Zn show correct logarithmic normal distribution, and Cu is almost the same as the formers.

In cumulative frequency distribution diagrams, each component shows a linear distribution, and no distinct turning point is not observed.

From the above $x + 2\sigma$ the anomalous threshold value of, which occupies about 2.5 per cent of the whole part was adopted (t). This value has also been generally used in geochemical surveys. Meanwhile, the value occupying about five percent of the whole was adopted as a supplementary threshold value (t'). Thus, it was defined that the values higher than (t') and lower than (t) are the lower threshold values and those more than (t) the higher threshold values.

Cumulative frequency distribution diagrams (Lipeltier, 1964) was used for the sake of convenience to determine (t) and (t') of each component, the results of which are shown in Table II–3. Anomalous values almost similar to those of CPRM (1982) were obtained. CPRM determined that the values higher than 98 percent as the anomalous value of the first order and those between 95 to 98 percent as those of the second order.

The correlation of each component is as shown in Table II–4. Although a strong correlation is observed in Cu, Pb and Zn, As is very low in correlation with any other components.

(i) Copper (Cu)

The most sizable geochemical anomalous zone is found in the Pip_1 and Pip_3 formations in the vicinity of the camp site of Billington Metais Ltda. in slightly northeast of the central part of the area. In addition, anomalies on a small scale are distributed at several places including some parts of Alvo 9P, 1P and 6P, as well as in the southwest of 11P in Morro do Acampamento area.

Among these anomalies, those related to Alvo and those scattered in the Pip_4 member in the central part were detected in the drainage system flowing through the boundary between amphibolite of Pip_3 and schist of Pip_4 which corresponds to the C-1 ore horizon. This indicates the relationship with copper mineralization. It is interpreted that the anomalies in the Pip_1 and Pip_3 formations were caused by leaching of copper component contained in the country rock itself, since the background area is underlain by amphibolite derived from the basic rocks.

(ii) Lead (Pb)

The areas which can be extracted as the geochemical anomalous zones are distributed in Alvo 2P and Alvo 7P, Alvo 1P and Pm_1xt formation in the western part of the area. The anomaly at Alvo 2P is that of the high anomalous zone caused by the C-1 deposit, and it is considered possible that the anomalies at Alvo 7P and Alvo 1P are caused by mineralization similar to that of the C-1 deposit. The anomalous zone in the western part is assumed to be in close relation with that of As.

In addition, small anomalies are partially scattered in some parts of Alvo 10P and 9P, in the Pip_3 formation in the northeast of the central part, and in the formations such as Pip_5, Pmsm and Pm_1xt from the northwestern part to the southwestern part of the area. It is interesting that the anomalies at Alvo 10P and 9P are the ones caused by lead mineralization.

(iii) Zinc (Zn)

As the anomalous zones of zinc, a part of Alvo 12P, the Pip_1 and Pip_3 formations at slightly northeast of the central part and the area in the western part, which is overlapped with Pb and As anomalous zones, were extracted. The anomaly at Alvo 12P is found in the schistose rocks, and this area was also extracted as anomalous zone in the soil geochemical survey described later, indicating the possibility of the occurrence of zinc mineralization.

In addition, the anomalies presumably caused by zinc mineralization are also scattered in the southwest of Alvo 2P, Alvo 11P, and in the Pip_4vs formation in the central part. Although anomalies scattered in the Pip_3 and Pip_5 formations have been detected, no showing of ore deposits has been reported.

(iv) Arsenic (As)

A sizable anomalous zone and small anomalies of arsenic are scattered in the Pm_1xt member in the western part of the area and in the vicinity.

The Pm_1xt member in which these anomalies are distributed consists of fine-grained schist derived from pelitic sedimentary rocks, and it cannot be interpreted that As is contained in the country rock itself because the possibility of occurrence of arsenic deposit of sedimentary origin in this horizon has not been reported. On the other hand, since these anomalies are distributed along the fault zone of N-S system, it can be interpreted that these anomalies are associated with the hydrothermal solution ascended along the fault of N-S system.

(2) **Multivariate Analysis**

As the result of analysis by processing data by the varimax method, one of the methods of factor analysis, using computor, the following three factors (Table II–5) were extracted: the first factor being Cu-Zn, the second Pb-As and the third Pb-Zn. Those three facters were examined in relation to geology and mineralization.

(i) **First Factor (Cu-An)**

Based on the definitions that those with factor contributions of not less than 1 (one) are the high factor contribution, and those between 0.5 and 1 (one) the moderate factor contribution, the zones of moderate to high factor contribution were extracted at Alvo 2P, 1P, 6P 9P and 11P to 12P in Morro do Acampamento area. They are almost consistent with the Cu and Zn anomalous zones extracted by single component analysis. Most of these anomalous zones are found in the Pip_1 and Pip_3 formations, in which the geology of the same horizon as that of the known ore deposit or the country rock is contained.

On the other hand, zones of moderate to high factor contributions were extracted in the central part of the area. In particular, the Pip_4vs member which can be correlated to the same horizon as the country rock immediately above the ore deposit is widely distributed. In the zone in the central part of the area. The single component analysis indicates that Cu, Pb and Zn anomalies are also scattered in this formation. Other zones include those concentrated in the Pip_1 and Pip_3 formations in the northeast of the central part of the area (in the vicinity of the Billington Metais camp), those concentrated in the Pip_5 formation in slightly northwest of the central part and those scattered in the Pip_3 formation in the southern part.

As in the above, the first factor is considered to have reflected the characteristic of the country rocks represented by amphibolites such as Pip_1 and Pip_3 derived from basic rock, and it is thought that something to characterize Cu-Zn mineralization would be contained in the terrain underlain by schistose rocks.

(ii) Second Factor (As-Pb)

As the result of factor contribution ranking, as seen in case of the first factor, moderate factor contributions were extracted at Alvo 2P, 9P, 1P and 6P.

Although zones of high factor contribution were extracted in the Pm_1xt and Pmsm formations in the western part of the area, as well as in the Pip_3 and Pip_5 formations in the southern part, no lead mineralized zone was found in both places. These areas as close to the fault and are well consistent with the As anomaly.

On the other hand, no zone of moderate to high factor contribution was extracted in the vicinity of the Pip_4vs formation in the central part of the area, but high factor contribution on a small scale is sparcely scattered in this area.

Thus it is thought that the second factor mainly reflects some hydrothermal alteration ascended along the fault. Although it might be the case that something to characterize the lead mineralization would be contained in the surrounding area of the C-1 deposit, the question whether it is primary or not would have to be left for future investigation.

(iii) Third Factor (Pb-Zn)

As the result of the analysis conducted in the same procedures as in the first and the second factors, moderate to high factor contributions were extracted in all the Alvo areas except for *Alvo 11P in Morro do Acampamento area. These areas included all the lead and zinc anomalies* detected in the single component analysis.

In addition, zones of moderate to high factor contribution were extracted in the zone centering on the Pip_4vs formation in the central part of the area, in the zone centering on the

Pip_5 formation in slightly northwest of the central part and in the Pip_3 and Pip_5 formations in the southern part.

This factor is thought to have mainly reflected the lead and zinc mineralization.

(3) Relation between Geochemical Anomaly and Mineralization

While many geochemically anomalous zones were extracted by single component analysis and multivariate analysis, the investigation of relationship between these anomalous zones and mineralization resulted in extracting the following six important geochemically anomalous areas Fig. II–7).

1 Morro do Acampamento area (Cu-Pb-Zn)

2 Surrounding area of the Pip_4 vs member in Rio Dois de Junho area (Cu-Zn-Pb)

3 In the Pip_1 and Pip_3 formations in the northeast of the central part of the regional survey area (Cu-Zn)

4 In the Pip_5 formation in the northwest of the central part of the regional survey area (Cu-Pb-Zn)

5 In the Pm_1 xt and Pmsm formation in the western part of the regional survey area (As-Pb)

6 In the Pip_3 and Pip_5 formations in the southern part of the regional survey area (As-Pb(-Zn-Cu))

For the above six areas, the following remarks are to be noted:

1 Semi-detailed survey by the soil geochemical method was conducted in Phase I in the survey area, and the detailed survey stage has started.

2 When taking into consideration the distribution of the geology correlated to the same horizon corresponding to the country rock of ore deposit in Morro do Acampamento area, Cu-Pb-Zn mineralization is also expected in this area. This area was examined by semi-detailed soil geochemical survey in Phase II.

3 It is thought that Cu-Zn component contained in the basic rock in the area has been leached and concentrated in some part.

4 Many basic sills accompanied by dissemination of fine-grained sulfide minerals are observed in the Pip_5 formation. The anomalous zones might have been formed in this area under their influence.

5 This is considered to be the anomalous area caused by hydrothermal effect along fault.

6 This is the area overlapped with the Cu-Zn anomalies caused by leaching of Cu and Zn in the basic rocks and As anomalies affected by the hydrothermal effect along fault.

The areas described in the above items 3 to 6 exhibit geochemical anomalies that are different from those being aimed at. Therefore these two areas are not included in the targets of future surveys.

Table II-3 Results of Simplified Statistical Treatment of Geochemical Data of Stream Sediments

Element	Max. (ppm)	Min. (ppm)	Mean (ppm)	t' (5%) (ppm)	t (2.5%) (ppm)
Cu	80	5 (1)	9.748	38.6	46.7
Pb	36	5 (1)	9.783	19.8	21.5
Zn	100	5 (1)	17.776	55.2	62.5
As	63	1 (0.5)	(0.646)	(4.4)	(8.0)

Table II-4 Correlation Matrix of Four Elements of Geochemical Data of Stream Sediments

	Cu	Pb	Zn	As
Cu	1.000			
Pb	0.576	1.000		
Zn	0.741	0.604	1.000	
As	0.261	0.264	0.234	1.000

Table II-5 Results of Factor Analysis of Geochemical Data of Stream Sediments

Factor Loadings (varimax rotation)				Communality
Element \ Factor No.	Factor 1	Factor 2	Factor 3	
Cu	0.705	0.394	0.304	0.7440
Pb	0.345	0.417	0.558	0.6044
Zn	0.684	0.336	0.406	0.7452
As	0.062	0.507	0.056	0.2642
Factor contributions	88.938%	7.815%	3.580%	

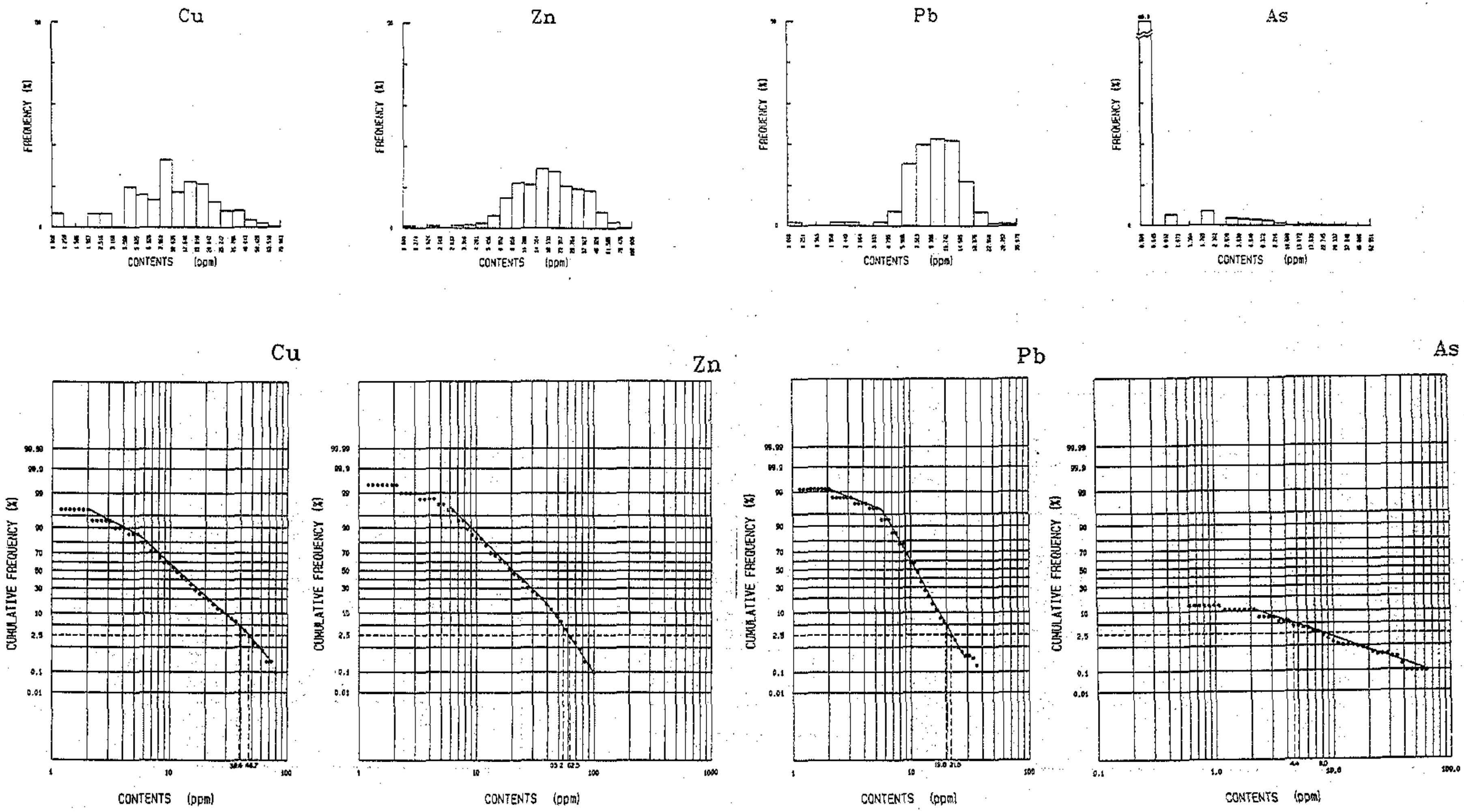
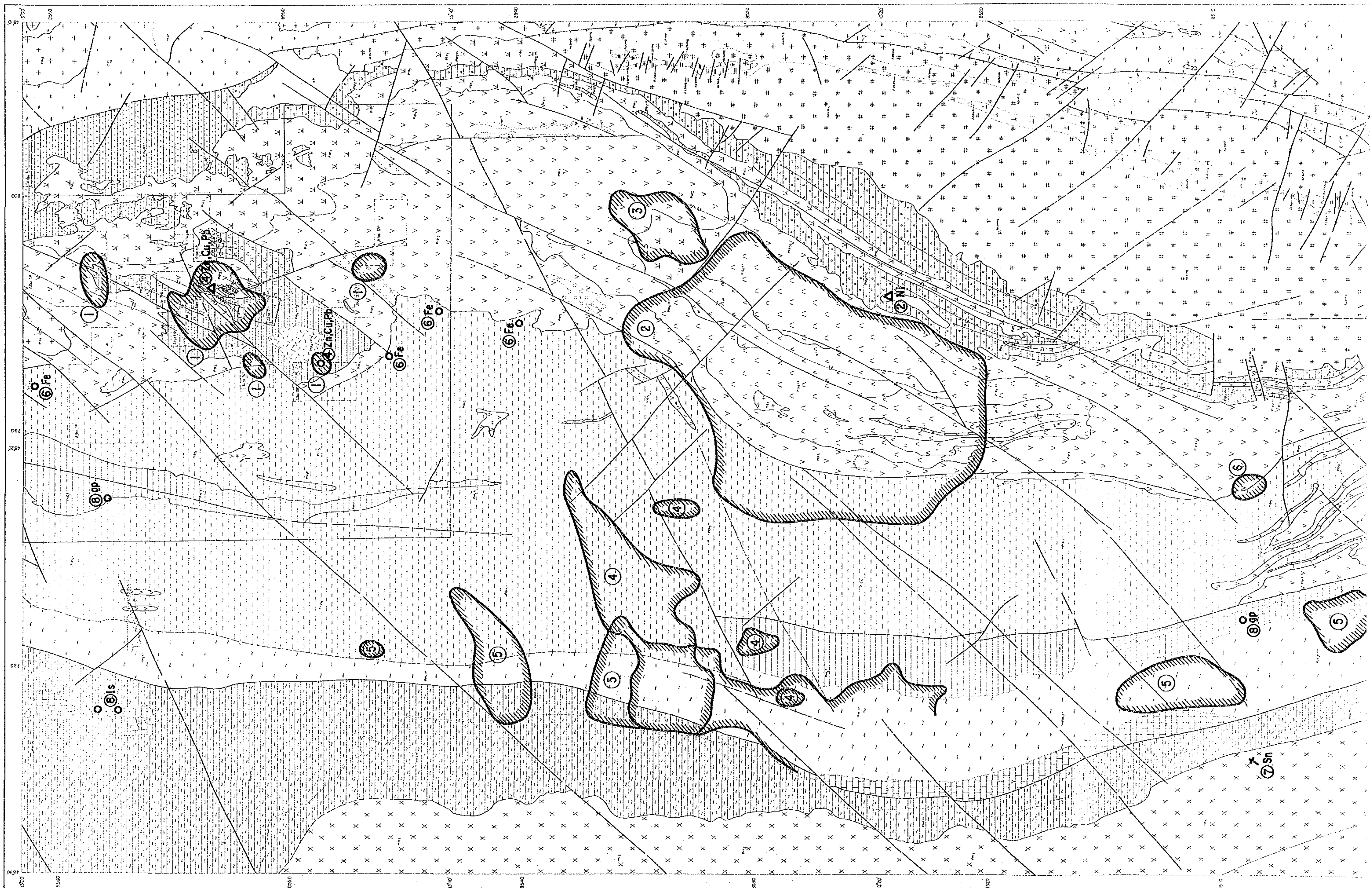
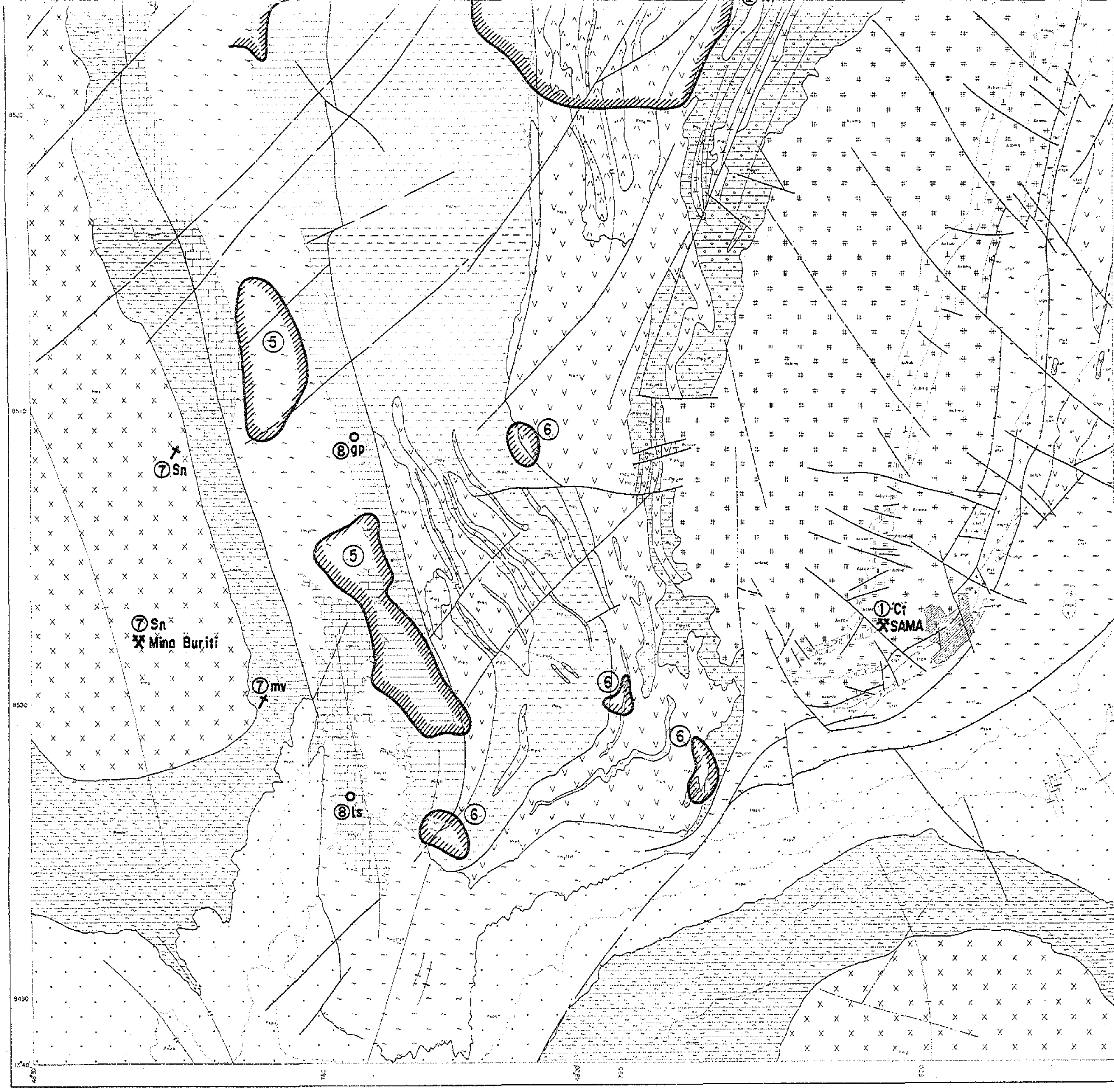


Fig. II - 6 Histogram and Cumulative Frequency Distribution of Cu, Pb, Zn and As of Stream Sediment



Cu,Pb
Zn,Cu,Pb
⑥Fe
⑥Fe
⑥Fe
⑥Fe
②Ni
⑧gp
⑧gp
⑧ls
⑦Sn



LEGEND

Important Geochemical Anomaly Area

① Cu-Pb-Zn (semi-detailed survey area)
② Cu-Pb-Zn (central part)
③ Cu-Zn (Pip1·Pip3)
④ Cu-Pb-Zn (Pip5)
⑤ As-Pb (western part)
⑥ As-Pb(-Cu-Zn) (Pip3·Pip5)

Geological Unit	Symbol	Columnar Section	Lithology
Paranoá Group	Pspa	Pspa	Photo interpretative Unit: quartzite, calcareous and graphytic phyllite, calc-schist, marble and sericite-quartzite
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)
Serra da Mesa Group (MARINI, 1976)	Pml	xt/clxt	qt : mg-bearing sc. quartzite; fl : 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
	Pmsm	Greisen and pegmatite	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

Geological Unit	Symbol	Columnar Section	Lithology
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)
		4vxt3, Zn-Cu-Pb showing, 4vxt2, 4vxt1, Zn-Cu-Pb ore	4vxt3 : sc-mo-qtz sch. (rhyolitic composition); 4vxt2 : pl-mo-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 acidic meta tuff, with quartzite (qt) and amphibolite (af)
		Lat. Ni ore, Zn-Cu-Pb showing	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
Cana Brava Basic-Ultrabasic Massif	Acb	mg, sp, px, ub, mb	mg : metagabbro, metanorite and metagabbronorite; sp : serpentinite; px : pyroxenite; ub : serpentinite and pyroxenite; mb : basic to ultrabasic rock (post-metamorphism)

Geological boundary
Lithological limit
Fault
Synclinal axis
Anticlinal axis
Synclinorium axis
Anticlinorium axis
17° Bedding plane
25° Schistosity (S1)
Schistosity (S2)
10° Lineation
Lineament
$\mathrm{X_{Ct}}$ Mines
$\mathrm{O_{Sn}}$ Mineral showings
Δ_{Ni} Ore deposits
$\mathrm{T_{Sn}}$ Small Mines ("Garimpo")
①~⑧ : ref. Fig. II-2

Zn - Zinc	Ni - Nickel
Cu - Copper	Ct - Crisotile asbestos
Pb - Lead	Sn - Tin
ls - Limestone	Fe - Iron
mv - Musuvite	gp - Graphite

Fig. II - 7 Geochemical Anomaly Map in the Surveyed Area (Stream Sediments)

PART III MORRO DO ACAMPAMENTO AREA

CHAPTER 1 GEOLOGY

1–1 General Geology

The area is situated in the northern part of the Palmeiropolis area, occupying an area of 300km^2. Geological mapping was carried out along with sampling soil at a scale of 1:10,000 enlarged from the drainage map on a scale of 1:50,000 and also aerial photographs at a scale of 1:25,000. Geology was compiled on the 1:20,000 map.

This area is composed of the Lower Proterozoic Palmeiropolis volcano-sedimentary sequence and a part of the Serra da Mesa Group. The former covers most of the area and is subdivided into Pip_1, Pip_2, Pip_3, Pip_4 and Pip_5 formations. Morro Salto granite intrudes them. The latter, Pmlfl, is distributed in a north-south direction in the western part of this area. The formations generally are younger from east to west.

The structure of this area is a complicated due to faults trending northeast and northwest and some folds.

1–2 Detailed Geology

1–2–1 Stratigraphy

Stratigraphy of this area is composed of Pip_1, Pip_2, Pip_3, Pip_4, Pip_5 and Morro Salts granite of the Palmeiropolis volcano-sedimentary sequence and Pmlfl of the Serra da Mesa Group from the lower.

(1) Palmeiropolis volcano-sedimentary sequence

Pip_1: The unit, consisting of dark green gabroic amphibolite, is distributed in the eastern most part of the area in the north northwest-south southwest direction. It unconformably overlies the underlying formations.

Pip_2: The unit mainly consists of acidic to intermediate pyroclastics and schists (Pip_1 vc) of the same components, and changes into meta-greywacke and meta-conglomerate (Pip_2 gv) in the northernmost part. In the North east, this member occurs between Pip_1. Pip_2 and is related to Pip_1 through interfingering.

Pip_3: The unit consists of darkgreen amphibolite and garnet amphibolite with intercalations of thin beds of quartzite (gt), ferruginous quartzite (gtfe) and garnet-biotito-muscovite-quartz schist (Xt).

This member occurs in belts trending north-northwest to the west of Pip_2 in the central part of this area. This member conformably overlies underlying formations and partly contacts with them by fault.

Pip_4: The member is composed of intermediate to acidic schists and is subdivided into $Pip_4\,vxt_1$, $Pip_4\,vxt_2$, $Pip_4\,vxt_3$.

Younger beds crop out from the north to the south in the central part of this area. The member is generally distributed in prolorged shapes trending northeast.

$Pip_4\,vxt_1$ is mainly composed of feldspathic biotite-quartz schist, staurolite-garnet-biotite-quartz schist and biotite-amphibole schist.

$Pip_4\,vxt_2$ is mainly composed of plagioclase-microcline-biotite-quartz schist and plagioclase-biotite-quartz-schist intercalated with amphibolite (af).

$Pip_4\,vxt_3$ is mainly composed of sericite-microcline-quartz schist. The member conformably covers the underlying formations.

Pip_5: The unit is mainly composed of staurolite biotite-muscovite-quartz schist, kyanite-biotite-muscovite-quartz schist, and kyanite-staurolite-muscovite-quartz schist (ff).

The member widely covers the western half of the area and the underlying formations.

Morro Salto Ganite, being small stock, is at the northernmost part of the area. It is a grey to pink-redish brown two mica granite, with a general banded texture. It is thought that it was emplaced in the early Proterozoic.

(2) Serra da Mesa Group

The group is divided into Pmsm and Pml formations from the lower. In this area only Pml occurs.

Pml, consisting of grey phyllite, is distributed in prolonged shape trending north inside the area of Pip_5, in the west of the area.

The stratigraphic relation ship with the underlying formation is one unconformity one.

1–2–2 Structure

Larger geologic structure trending north-northwest is thought to occur because of the general distribution of formations.

The geological structures become very complicated with smaller structures superimposed as different scales of faults and folds. Larger scales of faults and folds are trending northeast and north-northeast with smaller faults scales of trending northwest.

Structures trending northeast and north northeast are prominently developped in the central part of the area. Although most formations are distributed in a band shape trending north-northwest, the distribution of Pip_4 is restrictes by north-northeast trending faults. A number of folds whose axes trend north-northwest develop between faults have the same trend when makes the geology more complicated.

It was determined that the C-I ore body occured in a part of these folds.

CHAPTER 2 MINERALIZATION

Pip_4 member of Palmeiropolis volcano-sedimentary sequence is the principal ore deposit horizon in the area. C-1 ore body situated in the center of the area is a Cu-Pb-Zn ore deposit hosted in Pip_4 right above Pip_3. CPRM determined that C-2 and C-3 ore bodies situated north of the area are also hosted in Pip_4.

Mineralization mainly consisting of pyrite is located in Pip_4 in Alvo 10P in the South, The mineralization was pursued by this survey and was also determined to be in Pip_4. Mineralization on C-1, C-2 and C-3 ore bodies were described.

CHAPTER 3 GEOCHEMICAL SURVEY (SOIL)

3–1 Contents of the Survey

Since the extent of the soil geochemical survey carried out by CPRM in the past was limited within the Alvo area, the threshold values were different in each Alvo.

The current survey was conducted for the purpose of extracting new geochemically anomalous areas by obtaining average anomalous values applicable to a broader extent.

A map at 1:10,000 enlarged from the 1:50,000 scale drainage map was used for sampling, and the air photographs at 1:25,000 were also utilized supplementarily.

Two thousand five hundred and fifty-five soil samples were collected at the average sampling density of eight to nine samples per square kilometer. The sampling was carried out along the main roads and rivers. In addition, offset survey lines were set by clearing in order to make distribution of sampling stations as even as possible through the whole area.

The samples collected were chemically analyzed by the atomic absorption method for the following four target components: Cu, Pb, Zn and As.

The assay data were statistically processed by single component analysis and multivariate analysis.

(1) Single Component Analysis

Histograms and cumulative frequency distribution diagrams were made in order to extract anomalous values of each component (Fig. III–1). These diagrams are classified into the entire samples and respective lithofacies of amphibolites and schistose rocks.

The histogram for As does not show correct logarithmic normal distribution since 77 percent of the values are below the detection limit. On the other hand, the histograms for Cu, Pb and Zn show correct logarithmic normal distribution. Although As shows a linear distribution in the cumulative frequency distribution diagram, distinct turning points were observed in most of the other three components.

Determination of anomalous threshold value was made based on the method used by Lipeltier (1964), as in the case of the stream sediment analysis. Any distict turning points in cumulative frequency distribution curve of entire samples amphiblites and schistose rocks were defined as the threshold values. If a linear distribution was shown, the points at 2.5 percent and five percent were respectivyly defined as the threshold value and the supplementary threshold value. Table III–1 Shows the results.

Table III–2 shows correlation function of each component, in which Cu and Zn show a strong positive correlation, while other components hardly show any correlation.

(2) Multivariate Analysis

Two factors were extracted by factor analysis in the same manner as in the case of the stream sediment analysis (Table III–3). The first factor is Cu-Zn, and the second factor Pb-As.

3–2 Results of the Survey

(1) Single Component Analysis

Because content levels of each component are different according to the lithofacies, the analysis was performed, in addition to the analysis of the entire samples, by dividing the soils into the one derived from basic rocks and the other derived from schistose rocks.

1) Copper (Cu)

The threashold value (t) and the supplementary threshold value (t') of the whole sample are 105 ppm and 95 ppm respectively.

Copper anomaly zones were extracted in the vicinity of the C-1 ore body, as well as at Alvo 1P, 3P, 2PA, 11P, in the southeast of 11P and in the southeast of Morro do Acampamento area.

In the meantime, the analysis by respective lithofacies indicates, that the threshold value of the soil derived from basic rocks is 104.0 ppm, and that of the soil derived from schistose rocks is 71.7 ppm. Compared with the analysis of the entire samples, more anomalous zones were found in the soil derived from schistose rocks.

In the analysis by lithofacies copper anomaly was extracted most widely and strongly immediately above the C-1 ore deposit. In addition, Cu anomalies were extracted in a slightly concentrated manner to the south of Alvo 2PA and Alvo 6P among the extent of distribution of the $Pip_4 vxt_1$ member which is the host rock of the C-1 deposit. These anomalies, however, are not so strong as the one immediately above the C-1 deposit.

Cu anomalies were also extracted in the Pip_5 formation in Alvo 3P, in schist in Alvo 11P and the east of it, and in the Pip_5 formation to the southwest of Alvo 11P. The schist to the east of Alvo 11P and the one in the Pip_5 formation to the southwest of Alvo 11P closely resemble the $Pip_4 vxt_1$ member. Especially because gossan has been confirmed in the Pip_5 formation, it will be necessary to examine the geology in the surrounding areas of these parts.

Besides the above, Cu anomalies were also extracted in the Pip_3 formation in the southeastern part of Morro Solto, in the Pip_3 formation to the east of Alvo 12P and in the surrounding part of the basic sill in the Pip_5 formation in the northeastern part of Morro do Acampamento areas. All of these however are considered to have reflected the characteristic of the country rocks.

2) Lead (Pb)

The threshold value (t) of the whole samples is 35 ppm (8.8%)

The difference of threshold values by lithofacies is not great as compared with the case of copper, and that of the soil derived from basic rocks is 34.9 ppm and that derived from schistose rocks 33.3 ppm.

The largest zone, among other lead anomalous zones, spreads over the area from immediately above the C-1 ore deposit to Alvo 2P, 7P through 13P.

In the Pip_4 formation, additional Pb anomalies were extracted, in Alvo 2PA and the north of it, in Alvo 9P and Alvo 10P and the east of it.

Small anomalies are also scattered in the Pip_2 and Pip_5 formations.

3) Zinc (Zn)

The threshold value (t) and the supplemental threshold value (t') of the whole samples are 114 ppm and 95 ppm respectively.

Copper anomaly zones were extracted in the area immediately above the C-1 ore body, as well as at Alvo 1P, 3P, 2P-13P, 7P, 9P, 10P, 11P-12P and in the southeast of Morro do Acampamento area.

The threshold values vary greatly by lithofacies in the same way as in the case of copper. The values are 125.1 ppm in the soil derived from basic rocks and 90.1 ppm in that derived from schistose rocks.

Compared with the analysis of the whole samples, part of the anomalies has not been found in the soil derived from basic rocks and an additional anomaly zone was detected in the soil derived from schistose rocks.

In the analysis by lithofacies the zinc anomalous zones were extracted at four places in a direction from NE to SW, starting immediately above the C-1 ore deposit to Alvo 7P, through 9P and 10P. Besides these, small anomalies were also detected at Alvo 2PA, 13P, 12P and in the south of 6P, all of which are distributed in the schistose rocks and in amphibolite around the schistose rocks. Small anomalies are also scattered in the Pip_3 formation in the southeastern part of Morro Solto and in other soil derived from basic rocks, but they do not show favorable concentration.

4) Arsenic (As)

The threshold values of arsenic were determined at 5.4 ppm for all the samples while they are 4.2 ppm in the soil derived from basic rocks and 6.0 ppm in that derived from schistose rocks. Since the assay values of arsenic are as small as 12 ppm at the maximum in the soil derived from the basic rocks and 37 ppm at the maximum in the soil derived from schistose rocks, it is appropriate to define these values as high concentration values rather than anomalous values.

The zones of high concentration of arsenic extend continually along the fault of N-S system in the Pip_5 formation and the Pm_1 fl member in the western periphery of Morro do Acampamento area.

Besides the above, additional high concentration values are also scattered mainly in the schistose rocks in the Pip_4 and Pip_5 formations.

(2) Multivariate Analysis

1) First Factor (Zn-Cu)

Moderate to high factor contribution zone obtained in the same manner as that of the stream sediment analysis was extracted extensively on the east of longitude 790 in a concentrated form. The zone includes all the anomalies of copper and zinc obtained by the single component analysis, as well as all the Alvos. It is also consistent with the distribution of the Pip_1 and Pip_3 formations in the eastern part.

Although high factor concentration zones are scattered in the Pip_5 formation in the western part, their distribution is confined to the basic sills and their surroundings.

As mentioned above, the factors are roughly divided into the one characterizing the Cu-Zn mineralization and the other reflecting the characteristic of the country rock.

2) Second Factor (As-Pb)

The largest zone of moderate to high factor contribution was extracted in the same zone as that of arsenic in the western peripheral part of Morro do Acampamento area.

Some moderate to high factor contribution zones were extracted in a concentrated form at Alvo 2P, north of Alvo 2PA, Alvo 9P to 7P through east of 7P, west of 13P and Alvo 10P to east of 10P.

In addition, several zones are also scattered in the Pip_2 formation distributed from the north to the south of the eastern end of the area and in the Pip_3 formation distributed to the northeast and in the southern part of Alvo 12P.

It is thought that the geochemical anomalies which give high factor contribution are the reflection of the hydrothermal effect ascended along the fault.

Since it is unclear whether the anomalies scattered in schistose rocks in Morro do Acampamento area is caused by mineralization of the C-1 deposit type or it is the indication of the characteristic of the schistose rocks, future investigation would have to be required.

(3) Relation between Geochemical Anomaly and Mineralization

While many geochemically anomalous zones were extracted as the result of single component analysis and multivariate analysis, the investigation on the relation between these anomalous zones and mineralization resulted in extracting the geochemically anomalous areas of importance, such as two Cu-Pb-Zn zones, nine Pb-Zn zones, six Cu-Zn zones and four Cu-Pb zones (Fig. III–2) . For these zones, the following remarks are to be noted:

1 Cu-Pb-Zn Zones

The zones were extracted immediately above the C-1 deposit and in Alvo 2PA.

2 Pb-Zn Zones

Some concentrated zones were extracted in each of Alvo 7P, Alvo 9P and Alvo 10P, and others are scattered in the surrounding areas of Alvo 2PA and Alvo 13P. All these are consistent with the distribution of schistose rocks.

3 Cu-Zn Zones

Although the six anomalies extracted are small in scale, five of these are associated with schistose rocks and occurrence of gossan has been confirmed in some of them.

4 Cu-Pb Zones

Each of the two zones was extracted in the Pip_3 and Pip_5 formations respectively.

Among those described above, the Cu-Pb-Zn zones and the Pb-Zn zones, as well as the Cu-Zn zones which are consistent with the distribution of schistose rocks, are considered promising ones to be associated with mineralization.

Table III - 1 Results of Simplified Statistical Treatment of Geochemical Data of Soil (Morro do Acampamento Area)

Element	Lithology	Max. (ppm)	Min. (ppm)	Mean (ppm)	t' (5%) (ppm)	t (2.5%) (ppm)
Cu	Total	2,720	5	33	94.3	104.3
	Amphibolite	2,720	8	49	–	104.0(2.5%)
	Schist	164	5	26	–	71.7(2.5%)
Pb	Total	1,358	5	20	–	34.6(8.8%)
	Amphibolite	1,358	6	20	–	34.9(7.2%)
	Schist	300	5	20	–	33.0(10%)
Zn	Total	1,180	5	25	94.3	113.5
	Amphibolite	1,180	5	42	–	125.1(2.5%)
	Schist	252	5	17	66.1	90.1
As	Total	37	1	–	–	(5.4)
	Amphibolite	12	1	–	–	(4.2)
	Schist	37	1	–	–	(6.0)

Table III - 2 Correlation Matrix of Four Elements of Geochemical Data of Soil (Morro do Acampamento Area)

	Cu	Pb	Zn	As
Cu	1.000			
Pb	0.220	1.000		
Zn	0.697	0.223	1.000	
As	0.011	0.217	−0.047	1.000

Table III - 3 Results of Factor Analysis of Geochemical Data of Soil (Morro do Acampamento Area)

Factor Loadings (varimax rotation)			Communality
Element \ Factor No.	Factor 1	Factor 2	
Cu	0.824	0.121	0.6938
Pb	0.216	0.443	0.2428
Zn	0.837	0.055	0.7035
As	−0.069	0.480	0.2353
Factor contributions	80.326%	21.932%	

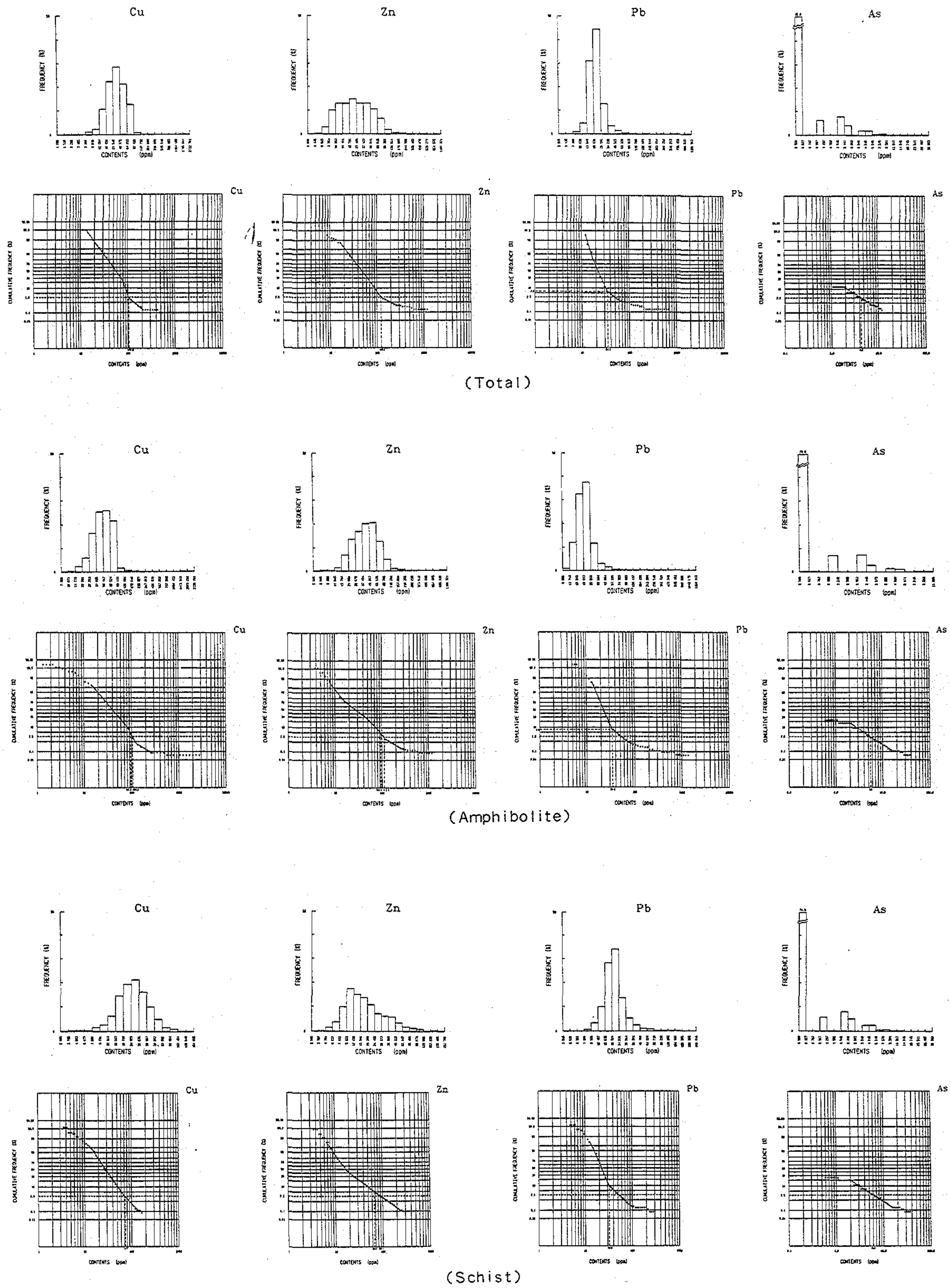


Fig. III - 1 Histogram and Cumulative Frequency Distribution of Cu, Pb, Zn and As of Soil

(Morro do Acampamento Area)

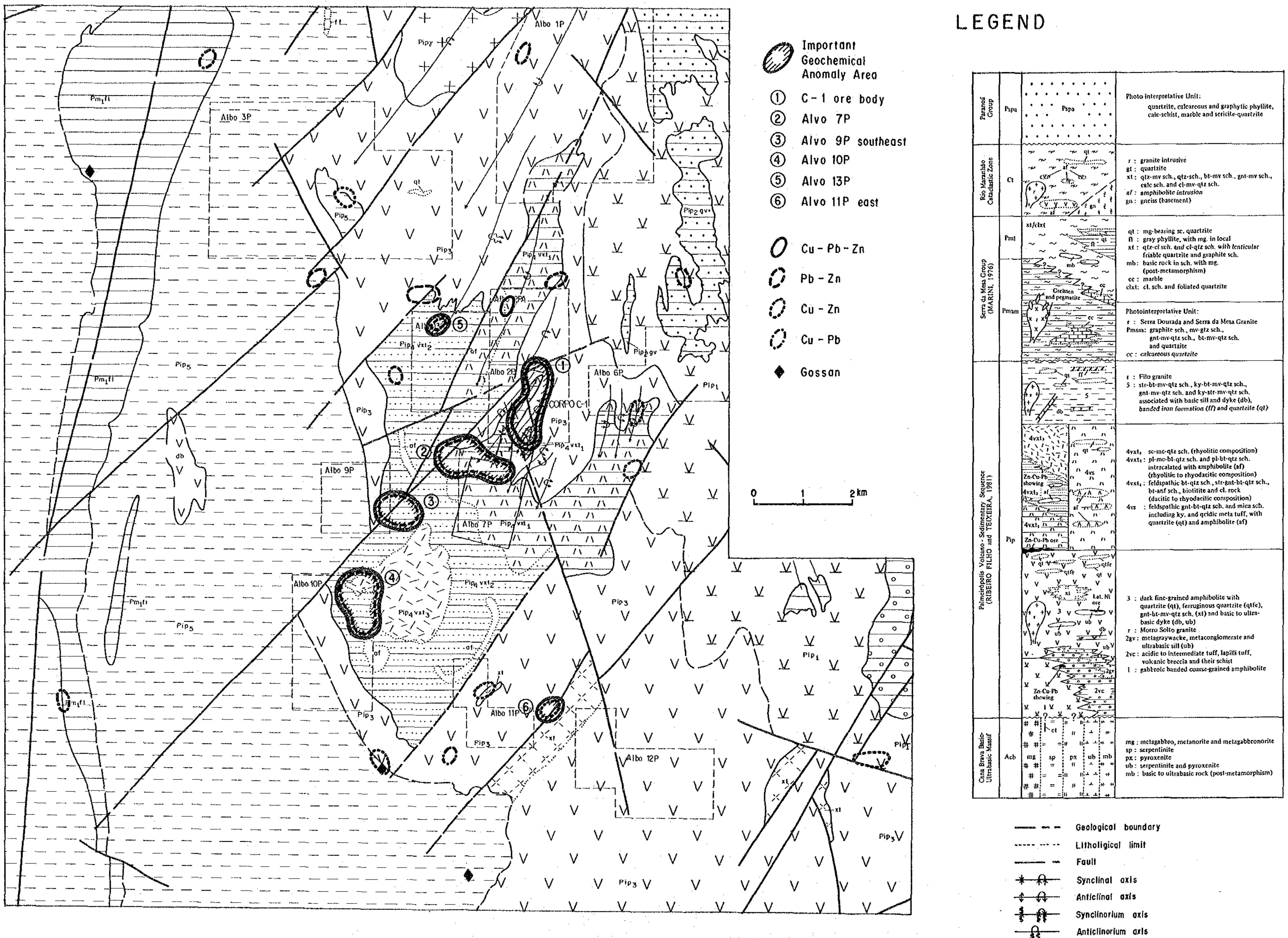


Fig. III - 2 Geochemical Anomaly Map in Morro do Acampamento Area (Soil)