REPORT ON GEOLOGICAL SURVEY

OF

ANTA GORDA

BRAZIL

CONSOLIDATED REPORT

MAY 1984

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 Anta Gorda region located in the southern part of that country, 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 four years from fiscal 1980 to 1983 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 Producão 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 four 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.

March 1984

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

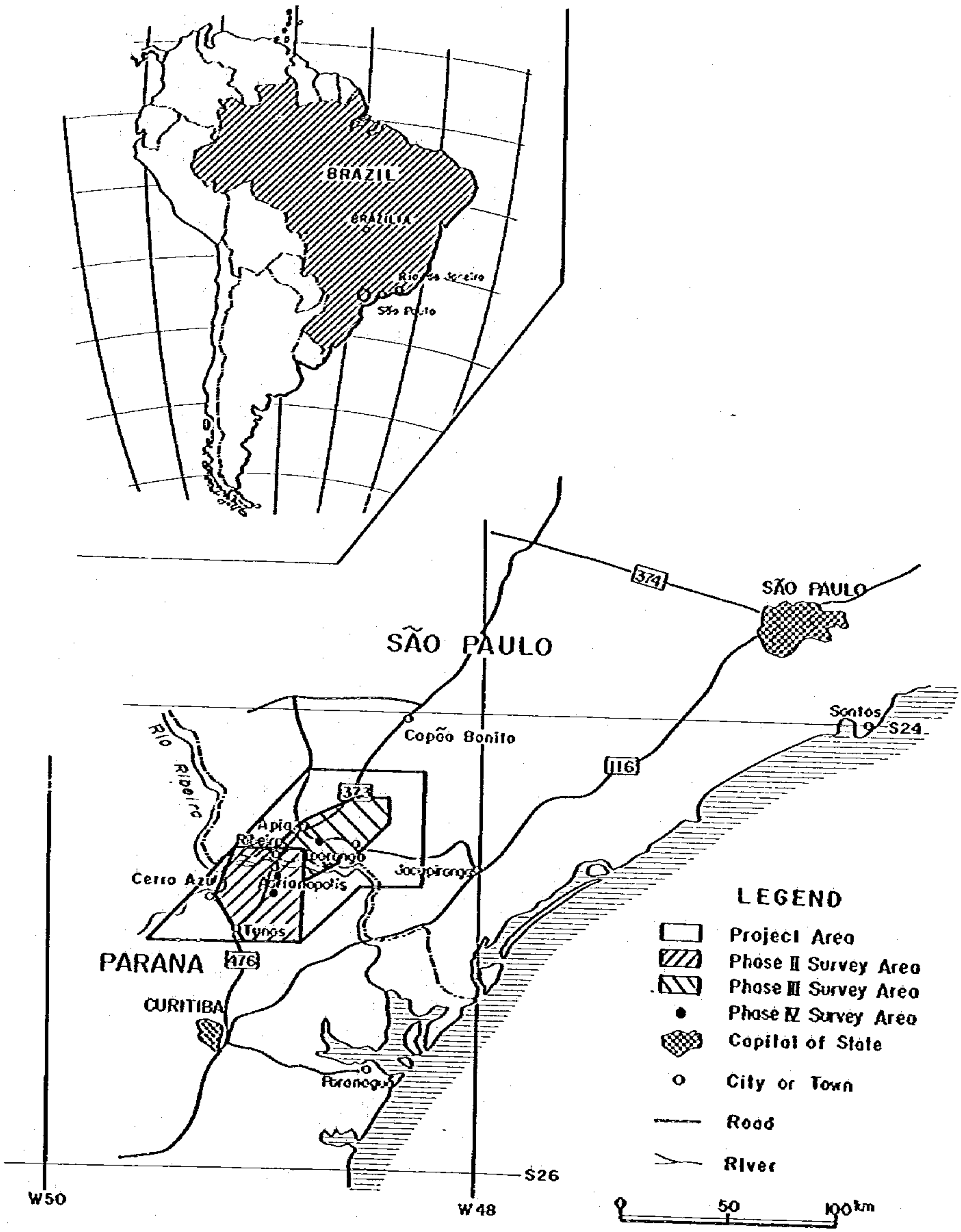

Fig. 1 Location Map of the Project Area

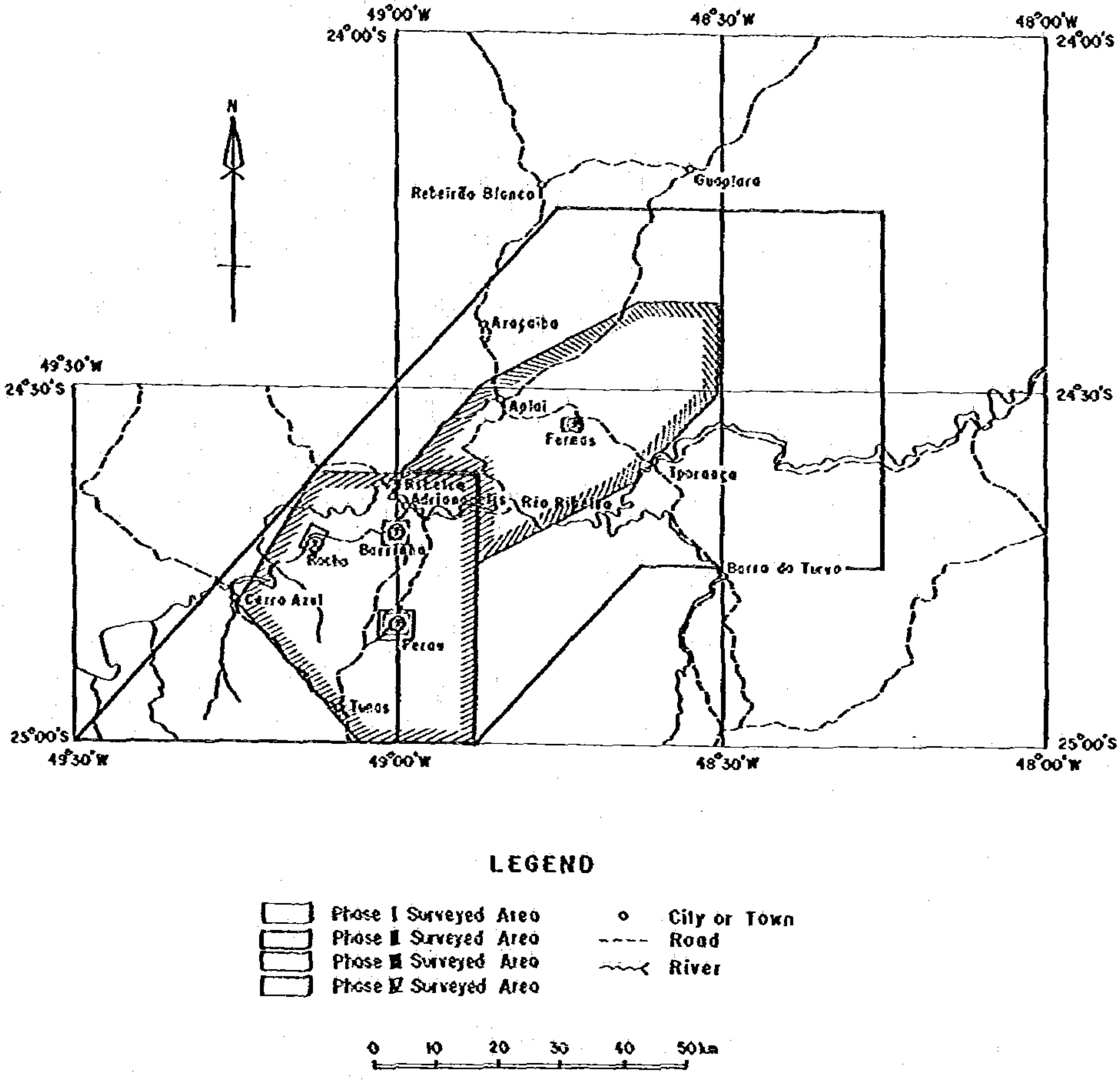

Fig. 2 Location Map of the Surveyed Area

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ABSTRACT

The report is a compilation of the result of the collaborative basic survey for natural resources development conducted in the Anta Gorda region in Federative Republic of Brazil for four years from 1980 to 1983.

The purpose of the survey is to make clear the geologic structure and mineralizaiton, and the relationship between them to obtain a useful guidance for the next stage of the exploration and mine development.

The Federative Republic of Brazil had been putting emphasis upon the development of lead deposits distributed in the basin of Rio Ribeira in the Anta Gorda region as a link of the nonferrous metals industry development, and requested the survey of geology and ore deposit of the region to the Government of Japan. The Government of Japan, in response to the request, despatched Mr. Kyuzo Tadokoro and his mission in October 1980, and made an agreement of the Scope of Work.

In the survey of the Phase I preliminary geological survey (1:50,000 in scale) and photogeological interpretation were conducted for the area of 5,800 square kilometers, and furthermore, reanalysis of the data on geochemical survey of stream sediments and aeromagnetic interpretation in the southern area were made among the existing survey data.

As the result of comprehensive studies of these data, the stratigraphy and the geologic structure were made clear, and especially the Açungui group was subdivided into three formations such as AI, AII and AIII.

The known deposits were roughly classified into the Perau-type stratabound lead deposits and the Rocha-type, vein-type to irregular massive lead deposits.

The ore-bearing horizon and the distribution of each type became clear, and some promising areas were expected beside the known deposits. As the result, geological survey (semi-detailed survey) for the area of 2,200 square kilometers and detailed geological survey, geochemical survey and geophysical survey for the Perau deposit and the Rocha deposit were proposed to be conducted survey for the second year.

In the survey of the Phase II, semi-detailed survey (1,200 km^2, 1:25,000) in the southern part of the area, detailed geological survey, geochemical survey, geophysical survey (IP, SIP, and gravity) and underground survey in the Perau area, and detailed geological survey and underground survey in the Rocha area were conducted in accordance with the proposal mentioned above, and furthermore, the existing data of aeromagnetic survey in the northern part of the area was analyzed.

The comprehensive analysis of these data resulted in subdivision of the Açungui III formation, having led to make clear that the Rocha deposit was emplaced in the AIIIL$_2$ member among those subdivided members and that the Barrinha deposit was also emplaced in the same horizon. In the Perau area, although the lower limit of the deposit which was being operated was made clear, IP and SIP anomalies were detected in the same ore horizon, and emplacement of ore deposit was expected. In the Rocha area, the ore bearing horizon, the characteristics of veins, and properties of Ag-Pb in the country rocks were made clear, but it was also proved that the room for future exploration remained only in the deeper part because the lateral distribution of ore-bearing horizon was limited. Thus the survey of the area was stopped by the end of Phase II.

As the result of these survey, the detailed geological survey and electric survey (IP, SIP) in the Barrinha area and detailed geological survey electric survey (IP) and drill survey in the Perau area were proposed for the survey of the Phase III.

In the survey of Phase III, semi-detailed geological survey (1,000 km², 1:25,000) and rock geochemical survey in the northern area, detailed geological survey and electric survey (IP, SIP) in the Barrinha area, and detailed geological survey, electric survey (IP) and drill survey (three holes) were conducted in accordance with the proposal mentioned above.

The comprehensive studies of these survey data resulted in to subdivide the Açungui III formation in the northern area of semi-detailed survey in the same manner as in the southern area, and the rock geochemical survey led to detect a promising anomaly in the Furnas area. Three IP anomaly zones and three SIP spectrum-type anomalies were detected in the Barrinha area. Among these, the IP anomalies in the northeastern part of the area and the SIP anomaly to the southeast of the Quatro deposit were thought to be promising. In the Perau area, a strata-bound lead and zinc deposit accompanied by barite was newly discovered as the result of the drill survey in the west of the Perau mine. It was also made clear that the IP anomalous zone extensively distributed in the surrounding area of Perau did not continue to the southern part.

As the result of the survey in the above, the following items were proposed for the room for exploration in future: detailed geological survey and electric survey in the Furnas area, drill survey in the Barrinha area, and in addition, drill survey for investigation of the shape of ore deposit and the extent of distribution.

In the survey of the Anta Gorda region, a great fruit was obtained by discovering the new ore deposit, and promising rooms for exploration were extracted as the result of survey in Phase III. Therefore, the period of survey was extended further for one year to conduct the survey of Phase IV.

In the survey of Phase IV, detailed geological survey and electric survey (IP, SIP) in the Furnas area, drill survey (two holes) in the Barrinha area and drill survey (three holes) in the Perau area were conducted in accordance with the proposal in the above.

As the result of comprehensive analysis of these data, a detailed stratigraphy of the Furnas area, and ore-bearing horizon was clarified. As the result of electric survey, in the Furnas area it was proved that there occur the strata showing a strong IP anomaly in the hanging wall and foot-wall of the ore-bearing horizon, which led to make difficult of detecting the IP anomaly in the ore-bearing horizon. The survey and exploration using a new technique should be desired in future. The drill survey in the Perau area resulted in to make clear the scale and the shape of the Perau new deposit. The drill survey in the Barrinha area resulted in to make clear the existence of complicated fold structure and the cause of the anomaly such as the IP anomalies in the northeastern part of the area and the SIP anomaly to the southeast of the Quatro deposit, having led to make clear the room for future exploration.

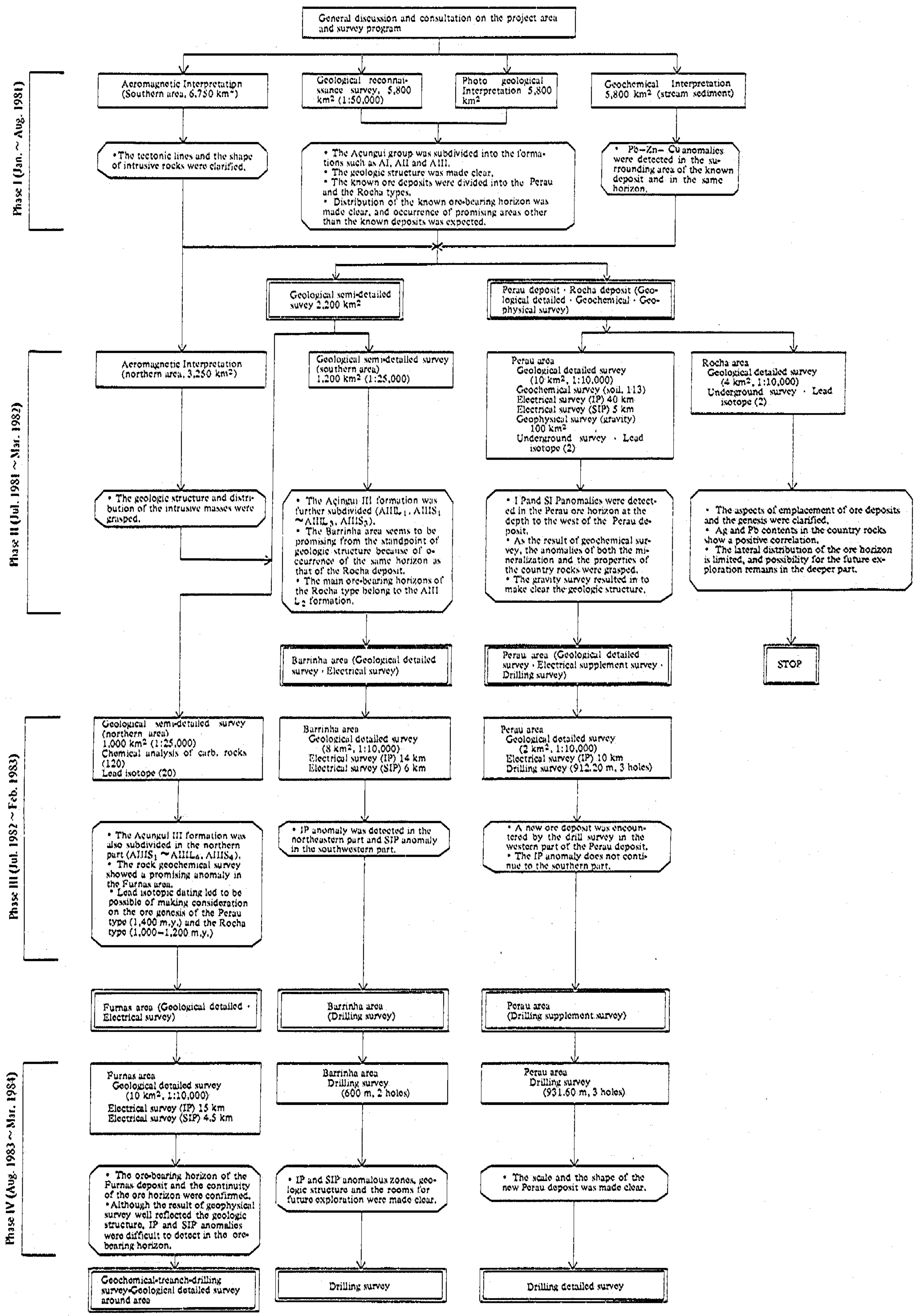
Based on the comprehensive investigation of the result of survey mentioned above, the following items are recommended for the room to be explored in future.

(1) In the Perau area, it is desirable to carry out drill survey in the northern to the northeastern part of the new deposit to confirm whole aspect of the deposit. Fill-in drilling for evaluation of the deposit is also recommended.

(2) In the Barrinha area, it is recommended to conduct drill survey on the southern side of the E–W system fault in the north of the survey area, and on the south of the Quatro deposit.

(3) In the Furnas area, it is desirable to trace the ore-bearing horizon by carrying out detailed geological survey. A detailed geochemical survey of soil and rock along the ore-bearing horizon is also desired.

(4) In the Rocha area, the exploration toward the lower part is desired to be conducted by making a detailed investigation on the vein fracture system, although the lateral extension of the ore-bearing horizon might not be expected.


General discussion and consultation on the project area and survey program
Phase I (Jan. ~ Aug. 1981)
Aeromagnetic Interpretation (Southern area, 6,750 km²)
Geological reconnaissance survey, 5,800 km² (1:50,000)
Photo geological Interpretation 5,800 km²
Geochemical Interpretation 5,800 km² (stream sediment)
• The tectonic lines and the shape of intrusive rocks were clarified.
• The Acungui group was subdivided into the formations such as AI, AII and AIII. • The geologic structure was made clear. • The known ore deposits were divided into the Perau and the Rocha types. • Distribution of the known ore-bearing horizon was made clear, and occurrence of promising areas other than the known deposits was expected.
• Pb–Zn– Cu anomalies were detected in the surrounding area of the known deposit and in the same horizon.
Geological semi-detailed survey 2,200 km²
Perau deposit · Rocha deposit (Geological detailed · Geochemical · Geophysical survey)
Phase II (Jul. 1981 ~ Mar. 1982)
Aeromagnetic Interpretation (northern area, 3,250 km²)
Geological semi-detailed survey (southern area) 1,200 km² (1:25,000)
Perau area Geological detailed survey (10 km², 1:10,000) Geochemical survey (soil, 113) Electrical survey (IP) 40 km Electrical survey (SIP) 5 km Geophysical survey (gravity) 100 km² Underground survey · Lead isotope (2)
Rocha area Geological detailed survey (4 km², 1:10,000) Underground survey · Lead isotope (2)
• The geologic structure and distribution of the intrusive masses were grasped.
• The Acingui III formation was further subdivided (AIIIL₁, AIIIS₁ ~AIIIL₃, AIIIS₃). • The Barrinha area seems to be promising from the standpoint of geologic structure because of occurrence of the same horizon as that of the Rocha deposit. • The main ore-bearing horizons of the Rocha type belong to the AIII L₂ formation.
• I P and SI P anomalies were detected in the Perau ore horizon at the depth to the west of the Perau deposit. • As the result of geochemical survey, the anomalies of both the mineralization and the properties of the country rocks were grasped. • The gravity survey resulted in to make clear the geologic structure.
• The aspects of emplacement of ore deposits and the genesis were clarified. • Ag and Pb contents in the country rocks show a positive correlation. • The lateral distribution of the ore horizon is limited, and possibility for the future exploration remains in the deeper part.
Barrinha area (Geological detailed survey · Electrical survey)
Perau area (Geological detailed survey · Electrical supplement survey · Drilling survey)
STOP
Phase III (Jul. 1982 ~ Feb. 1983)
Geological semi-detailed survey (northern area) 1,000 km² (1:25,000) Chemical analysis of carb. rocks (120) Lead isotope (20)
Barrinha area Geological detailed survey (8 km², 1:10,000) Electrical survey (IP) 14 km Electrical survey (SIP) 6 km
Perau area Geological detailed survey (2 km², 1:10,000) Electrical survey (IP) 10 km Drilling survey (912.20 m, 3 holes)
• The Acungui III formation was also subdivided in the northern part (AIIIS₁ ~AIIIL₄, AIIIS₄). • The rock geochemical survey showed a promising anomaly in the Furnas area. • Lead isotopic dating led to be possible of making consideration on the ore genesis of the Perau type (1,400 m.y.) and the Rocha type (1,000–1,200 m.y.)
• IP anomaly was detected in the northeastern part and SIP anomaly in the southwestern part.
• A new ore deposit was encountered by the drill survey in the western part of the Perau deposit. • The IP anomaly does not continue to the southern part.
Furnas area (Geological detailed · Electrical survey)
Barrinha area (Drilling survey)
Perau area (Drilling supplement survey)
Phase IV (Aug. 1983 ~ Mar. 1984)
Furnas area Geological detailed survey (10 km², 1:10,000) Electrical survey (IP) 15 km Electrical survey (SIP) 4.5 km
Barrinha area Drilling survey (600 m, 2 holes)
Perau area Drilling survey (931.60 m, 3 holes)
• The ore-bearing horizon of the Furnas deposit and the continuity of the ore horizon were confirmed. • Although the result of geophysical survey well reflected the geologic structure, IP and SIP anomalies were difficult to detect in the ore-bearing horizon.
• IP and SIP anomalous zones, geologic structure and the rooms for future exploration were made clear.
• The scale and the shape of the new Perau deposit was made clear.
Geochemical-treanch-drilling survey-Geological detailed survey around area
Drilling survey
Drilling detailed survey

Ⅰ. INTRODUCTION

CHAPTER 1 OUTLINE OF THE SURVEY

1–1 Purpose and Scope of the Survey

Federative Republic of Brasil have made National Nonferrous Metal Industrial Developing Plan to establish a self-sufficiency system for nonferrous metal, and putting force onto develope lead ore deposits in the Vale do Ribeira where located in Sao Paulo and Parana states.

The government of Brazil requested the governmnet of Japan to conduct exploration in the area, and the government of Japan responced to the request and sent Mr. Kyuzo Tadokoro and his mission to Brazil on 10 October 1980.

The mission discussed with Departamento Nacional da Produção Mineral (DNPM), and made an agreement of the Scope of Work on the project area and substances of exploration after preliminary survey on the proposed project area.

There is still no widespread and various studies about the relation between mineralization and geologic structure or igneous activity as well as ore genesis in the area.

The purpose of the survey was to extract the promising areas of occurrence of lead and zinc deposits and to make useful suggestions for future exploration by clarification of the geologic structure and studying of emplacement of deposits.

The preliminary survey was commenced in Phase I and the accuracy of survey was improved successively having resulted in to discover stratabound Pb–Zn–Ba deposit on the western side of the Perau mine in Phase III.

The electric surveys (IP method and SIP method) were conducted in the surveyed area and demonstrated to be very effective for the survey of lead and zinc deposit, and especially the SIP method greatly contributed to the discovery of new ore deposit in the Perau area.

1–2 Substance of the Survey

For the purpose mentioned above, the survey was conducted for four years from fiscal 1980 to 1983 in the area of 5,800 square kilometers as shown in Fig. 1.

The method of survey was to narrow down successively the area, having resulted in to select the promising area. Geological survey, geochemical survey, geophysical survey and drill survey were carried out in line with each stage of the surveys (Table 1–1, Fig. 2).

The progress and substances of the survey are as follows.

1–2–1 Survey in Phase I

In the survey of Phase I, geological survey and photogeological survey as well as reanalysis

Table I-1 Outline of the Field Survey and Laboratory Work in Phase I～IV

Items		Phase I (1980)	Phase II (1981)	Phase III (1982)	Phase IV (1983)
Period		Jan. 12～Apr. 4, 1981	Jul. 3～Oct. 22, 1981	Jul. 2～Oct. 21, 1982	Aug. 26, 1983～ Feb. 7, 1984
Geological Survey (km^2)					
	Reconnaissance Survey	5,800	–	–	–
	Semi-detailed Survey	–	1,200 (Southern Part)	1,000 (Northern Part)	–
	Detailed Survey	–	10 (Peras) 4 (Rocha)	2 (Peras) 8 (Barrinha)	10 (Furnas)
Photo-interpretation (km^2)		5,800	–	–	–
Topographic Mapping (km^2)		–	1,200 (1 : 25,000) 100 (1 : 10,000)	1,000 (1 : 25,000)	–
Geochemical Survey					
	Interpretation of Existing Data	5,800 km^2	–	–	–
	Detailed Survey	–	On the Peras ore Horizon	–	–
Geophysical Survey					
	Aeromagnetic Interpretation	6,750 km^2	3,250 km^2	–	–
	Gravity Survey	–	100 km^2	–	–
	IP Method	–	30.2 km (Peras)	10 km (Peras) 14 km (Barrinha)	12 km (Furnas)
	Spectral IP Method	–	5 km (Peras)	6 km (Barrinha)	4.5 km (Furnas)
Drilling		–	–	912.20m (3 holes)	931.6m (3 holes in Peras) 600m (2 holes in Barrinha)
Laboratory Work	Thin Section	61	100	90	26
	Polished Section	51	50	53	32
	Assay (ore)	108	52	81 (37)*	44 (22)*
	do. (rock)	12	51	120	– –
	X-ray	54	56	–	–
	Soil	–	113	–	–
	Pb Isotopic Analysis	–	4	20	–
	Fossil	11	–	–	–
	Physical Property Measurement	Magnetic susceptibility 56	Density 58 PFE, Resistivity 30	PFE, Resistivity 49	–

* Samples from Drilling

of the existing data of geochemical survey and aeromagnetic survey were performed for the purpose of obtaining useful guidance for the survey of ore deposit in future by establishing stratigraphy, analyzing geologic structure and positioning the existing ore deposits.

In the geological survey, route maps (1/20,000) were produced for four routes acrossing the general geologic structure, and survey of the representative ore deposits was made, which were compiled to the geological maps in the scales such as 1/50,000 and 1/100,000 with reference to the existing data.

Interpretation of aerial photo and Landsat images were deciphered the macrostructure before geological survey and the microstructure after finishing the survey.

In connection with reanalysis of geochemical data, since the data were available from the result of regional geochemical survey on stream sediment conducted by DNPM (CPRM) as Projeto Geoquimica no Vale do Ribeira reanalysis was made for three components of copper, lead and zinc selecting the sampling points which showed a sample pattern as homogeneous as possible.

In reinterpretation of the data of aeromagnetic survey, the magnetic structure map was produced for the Parana state which is the southern part of the survey area because magnetic variation map had been prepared only for that area.

As the result, the area of 2,200 km² which is likely to have potentiality of occurrence of lead deposit was selected for the area of semi-detailed geological survey.

Especially the Perau deposit and the Rocha deposit were considered to be the typical types of ore deposits such as strata-bound deposit and vein-type deposit, having suggested the necessity of detailed geological survey, geochemical survey and geophysical survey.

1–2–2 Survey in Phase II

In the survey of Phase II, semi-detailed geological survey of the southern area (the area belonging to the Parana state, south of Ribeira River, covering a space of 1,200 km²), detailed geological survey of the Perau area and the Rocha area, and geochemical survey and geophysical survey of gravity survey and electric surveys (IP method and SIP method) were conducted among the promising areas extracted as the result of the survey of the Phase I. Interpretation of aeromagnetic survey of the São Paulo State area was also carried out.

In semi-detailed geological survey, the route maps were produced using the newly prepared topographic map (1/25,000), and the geological maps (1/25,000 and 1/50,000) were compiled in combination with the aerial photo of 1/25,000 in scale.

In detailed geological survey, geological survey and underground survey were carried out, having resulted in to compile geological map of 1/10,000 in scale using the core-drilling sections up to that time. Geochemical survey of soil (B-horizon) along the IP-survey line was conducted in the Perau area, which was applied for interpretation of the ore deposit.

Gravity survey and electric survey of IP method and spectral IP method were performed in the Perau area, and sufficient information of the subsurface geologic structure and ore deposit.

In connection with aeromagnetic survey, interpretation was made for the area of São Paulo state side and magnetic structure maps (1/100,000 and 1/250,000) were also produced.

As the result of survey, possibility of new ore deposit was expected in the Perau area, and drilling and electric survey were recommended. In the Barrinha area, electric survey (IP method and SIP method) and detailed geological survey were recommended because of promising areas for exploration were left in the area. On the other hand, necessity of semi-detailed survey was suggested for the northern part (1,000 km²).

1–2–3 Survey in Phase III

In the survey of Phase III, semi-detailed geological survey of the northern area (north of Ribeira river belonging to the São Paulo state, 1,000 km²) was carried out among the areas selected on the result of survey of the Phase I. Beside it, detailed geological survey of the Perau area and the Barrinha area, IP survey and drill survey in the Perau area and electric survey (IP, SIP) in the Barrinha area were performed.

In semi-detailed geological survey, geological survey, geochemical survey to estimate sedimentary environment and age determination of the lead ore deposit by Pb isotopic analysis were carried out.

In detailed geological survey of the Barrinha area, emphasis was laid upon surface geological survey and analysis of fold structure.

In terms of electric survey, IP survey was conducted at the eastern wing of the Perau anticline and IP survey and SIP survey in the Barrinha area. In particular, SIP method was applied to the surrounding area of the known ore deposit, having resulted in to get hold of the characteristic of ore deposit.

Drill survey was directed to the anomalous zone of electric survey detected in the vicinity of G-Line in the Perau area, which lead to confirm the occurrence of strata-bound Pb–Zn–Ag–Ba ore deposit.

As the result of the surveys mentioned above, following surveys were recommended for the next stage: continued drilling in the Perau area, drilling survey for the anomalous zone detected by IP and SIP in the Barrinha area, and in addition, detailed geological survey and electric survey (IP, SIP) in the Furnas area within the northern area.

1–2–4 Survey in Phase IV

In the survey of Phase IV, the geological survey (detailed survey) and geophysical survey (IP, SIP) in the Furnas area, the drilling survey in the two areas of Perau and Barrinha were conducted.

1–3 Members of the Survey

The members engaged in the planning and negotiation for the project, field survey, and analysis in Japan are as shown in Table I–2.

Geologists and geophysical engineers from CPRM and IPT (Instituto de Pesquisas Tecnologicas do Estado de São Paulo) entrusted by the Federative Republic of Brazil participated in the field survey.

Table I-2 Member List of the Survey Team in Phase I ~ IV

Items		Phase I (1980)	Phase II (1981)	Phase III (1982)	Phase IV (1983)
Japanese Member	Planning and Organization	Nobuhisa Nakajima	Nobuhisa Nakajima Katsumi Yokokawa Takafumi Tsujimoto	Nobuhisa Nakajima Yoshitake Hosoi Takafumi Tsujimoto	Toru Miura Kisou Tsuruoka Ken Nakayama Tsunekazu Ajiki Hideyuki Ueda
	Team Leader (Geologist)	Sadao Maruyama	Sadao Maruyama	Tsuyoshi Suzuki	Tsuyoshi Suzuki
	Geologist	Hiroshi Fuchimoto Kiyohisa Shibata Masakazu Kawai Hiroshi Takahashi	Tsuyoshi Suzuki Kiyohisa Shibata Haruo Watanabe Hiroshi Takahashi	Kiyohisa Shibata Akira Takigawa Norio Ikeda Hiroshi Takahashi	Norio Ikeda
	Photo Geologist	Yoshiaki Shibata (in Japan)	-	-	-
	Geophysicist	Asahi Hattori (in Japan) Susumu Sasaki (in Japan) Kazato Matsukubo (in Japan)	Susumu Sasaki Akira Egawa Tomio Tanaka Naoyoshi Takahashi Masatane Kato	Tomio Tanaka Akira Egawa Matsuo Kondo	Tomio Tanaka Toshimasa Tajima Masatane Kato
Brazil Member	Planning and organization	Kiomar Oguino Roberto M. Akinaga Luiz Eraldo de Mattos José Peres Algarte	Antonio C. G. M. Godoy Kiomar Oguino Roberto M. Akinaga Luiz Eraldo de Mattos Fernando Batolla Jr.	Carlos Oiti Berbert Luiz Eraldo de Mattos Fernando Batolla Junior	Carlos Oiti Berbert Kiomar Oguino Luiz Eraldo de Mattos Fernando Batolla Junior
	Team Leader (Geologist)	Fernando Batolla Junior	Elias Carneiro Daitx	Elias Carneiro Daitx	Elias Carneiro Daitx
	Geologist	Elias Carneiro Daitx Armando Teruo Takahashi Cassio Roberto da Silva José Carlos Garcia Ferreira Osamu Maeyama Paulo de Tarso Perose	Cid Chiodi Filho Cassio Roberto da Silva José Carlos Garcia Ferreira	Armando Teruo Takahashi Cassio Roberto da Silva José Carlos Garcia Ferreira Osamu Maeyama	José Carlos Garcia Ferreira
	Geophysicist	-	Frederico Augusto Varejão Marinho	Frederico Augusto Varejão Marinho	Francisco J.F. Ferreira Fernando A.R. de Oliveira

CHAPTER 2 OUTLINE OF THE SURVEY AREA

2–1 Situation and Access

The survey area is situated about 200 km to the southwest of São Paulo (approximately 10 million in population), the largest city in Brazil, and spread over the two states of São Paulo and Paraná putting Ribeira river between them (Fig. 1 and 2).

The state highways (São Paulo State Highway 373 and Paraná State Highway 476) run almost through the center of the survey area. Apiaí city (8,000 in population) is the largest city in the survey area, where the base camp for semi-detailed geological survey in Phase III and that for detailed geological survey and geophysical survey in Phase IV were set up. It is apart about 320 km from São Paulo and takes five hours by car to drive between these cities. From Curitiba city (1,000,000 in population), the capital city of Paraná State to Apiaí through Tunas, it takes four hours by car for a distance of 170 km. Adrianópolis where the base camp for geological survey and drilling in Phase III, and drilling in Phase IV, was set up, is apart about 40 km from Apiaí mentioned above and it is one hour drive by car. The road between Adrianópolis and Curitiba is unpaved.

A trunk road (Federal Highway 116) connecting São Paulo city and Curitiba city extends on the east of the survey area. Jacupiranga situated midway of the highway and Apiai are connected by an unpaved road which passes through Iporanga, and it takes three hours to drive along it (115 km).

Several services of regular bus are operated every day to São Paulo and Curitiba from Ribeira which is situated along the border between the two states of São Paulo and Paraná. Several air services are also operated every day between São Paulo and Curitiba.

2–2 Topography and Drainage System

A trend of geologic structure in parallel with the eastern coast line of Brazil predominates in the Precambrian shield in the eastern part of the country. The structure of NE–SW system is notable in the neighborhood of the survey area, which is well reflected to the topography.

Both the Mar mountain range (Coast Range) 1,000 to 1,500 m in altitude extending on the east of the survey area and the Paranapiacaba range on the west are composed of granitic rocks which have intruded under the control of geologic structure of NE–SW system.

The survey area forms a basin-like mountain mass (600 to 1,000 m. above sea level) surrounded by these two ranges showing a tendency of sltitude higher in the west and becoming lower toward the east.

All the drainage systems belong to the Ribeira River, and the main stream flows eastward showing marked meandering. Since the altitude of the river bed of the main stream is between 100 and 200 m above sea level, the relative height of the highland reaches 500 to 1,000 m.

In the granite zone (eastern margin of the Paranapiacaba range) distributed at the western end of the survey area, topography is relatively gentle with dendritic drainage system, whilst the limestone zone on the east of it forms a plateau with karst topography characterized by deep V-shaped valleys. In the phyllite-schist zone further east of the above, valleys of trellis to parallel pattern formed in relation to the geologic structure are dominantly observed, and in the area of the southeastern part distributed by quartzite, mountain ranges formed by folding run in parallel with a characteristic feature.

2–3 Climate and Vegetation

The climate of the area is subtropical to temperate rainy type, and the changes of the four seasons are relatively distinct.

Annual precipitation is 1,200 to 1,300 mm, most of which is concentrated in the period from October to February.

The mean temperature of the year is 16°C to 19°C, and it often exceeds 35°C in the day time during summer (January to March). It falls nearly to 0°C in winter (July to September).

Vegetation is generally thick, and the mountains are covered with thickly wooded conifers and miscellaneous trees. In greater part of the area, however, the trees have been cut down nearly to the hill tops, and the cutovers are utilized as plowed firld and ranch. Beside these conifers and miscellaneous trees, shrubs and samambaias are thickly wooded. Among these, samambaia grows thick in the terrains of granite and metamorphic rocks, while it does not grow in the limestone terrain.

II. GEOLOGICAL SURVEY AND GEOCHEMICAL SURVEY

CHAPTER 1 GENERAL REMARKS

Geology of the survey area and its surrounding part consists of the Setuva formation and the Açungui formation of Precambrian System, and it has been known that numerous lead ore deposits are emplaced in the Açungui formation. Although the geology and ore deposit of the area have been studied by many persons, the main works are those described in the following.

Cordani and Bittencourt (1967) mentioned, having obtained the isotopic age of 3,000 ~ 450 m.y. as the result of study of radiometric dating, that several times of Orogeny took place in the region.

Petrographic and stratigraphic studies were performed by Bigarella and Sallumani (1956), Marini and others (1967), Fuck and others (1971), Ebert (1971) and Kaefer and Algarte (1972), and stratigraphic classification was attempted.

In connection with the study of ore deposit, Melcher (1968) reported on the ore deposits in carbonate rocks of the Açungui formation. Although Barbosa (1956) and others thought that these were hypogene deposit associated with granite distributed in the surrounding area, Melcher (1968) and others have different opinions on the basis of the studies of Pb isotopic dating and lead grade of the host rocks. Thus no definite theory has been established up to present time.

As to the regional geological map of the surveyed area and its surroundings, the following maps are widely used: Curitiba (1:1,000,000, 1974) compiled by DNPM, a map (1:100,000, 1977) compiled by CPRM in Projeto Leste do Parana entrusted by DNPM and a map (1:50,000, 1974) produced by CPRM in Projeto Sudelpa in São Paulo State.

In recent years, CPRM investigated for DNPM the geology and ore deposit of the Ribeira Valley area as Projeto Integração e Detalhe Geológico no Vale do Ribeira from 1978 to 1979 and published a report including geological maps 1:100,000, 1:25,000 and 1:5,000 in scale.

MMAJ conducted the natural resources development collaborative basic survey in the Anta Gorda region in compliance with the request of JICA for four years from fiscal 1980 to 1983 (JICA and MMAJ, 1981, 1982, 1983 and 1984). These reports (JICA and MMAJ) provide plenty data on stratigraphic classification of the area, geologic structure, characteristics and times of the volcanic activity, zoning of metamorphism and classification of the lead ore deposits. Especially the lead ore deposits were divided broadly into two categories such as the strata-bound deposit of Perau type and the fracture-filling deposit of Rocha type, and also the ore horizons of each type have been made clear.

CHAPTER 2 GEOLOGY

The Precambrian is assumed to occupy two-third of the area of Brazil. As shown in Fig. II–1, it can be divided broadly into three regions of Guianas, Brazil Central and Atlantico, and the survey area belongs to the southern mountain mass in Atlantico.

2–1 Stratigraphy

Geology of the surveyed area is composed of the precambrian metamorphic rocks of the Setuva formation and the Açungui formation from the base upward, into which basic rocks and granitic rocks of Brazilian Orogeny (750 ~ 500 m.y.) and dykes of Cretaceous diabasic rocks have intruded.

Although the names of strata and stratigraphical classification in the surveyed area followed basically the geological map of Curitiba (1:1,000,000, 1974), the Açungui formation which had been discussed lumped together were divided on the basis of the result of route mapping and aerial photo interpretation into the three formations of Açungui I, II and III.

Fig. II–2 shows the geology of the reconnaissance survey area, Fig. II–3 the generalized stratigraphic columnar section and Table II–1 the characteristics of the photogeological units.

The Açungui III formation was further divided, in the stage of semi-detailed geological survey, into the groups or rock facies units. Plate 1 of Fig. II–4 shows the geological map of the semi-detailed survey area, and Fig. II–5 the generalized stratigraphic columnar section of the above area.

2–1–1 Setuva Formation

The Setuva formation constitutes the lowermost part of the geology of the area and consists mainly of gneissose rocks (Sgn) partly interbedded with quartzite (Sqt).

<u>Distribution and Thickness</u>

The formation is exposed in the southern part of the area as the cores of the Anta Gorda anticline and the Perau anticline which have the anticlinal axes of NE–SW system, and at the southern end in addition.

The anticlines in the above are arranged in the direction of north to south showing a trend of NE–SW system, and the formation is repeatedly exposed at their axial parts because of occurrence of folds in a series.

The most extensive occurrence is found in the Anta Gorda anticline, while on a smallest scale in the Perau anticline. Quartzite is found at the central part of the anticlinal axis of the Anta Gorda anticline. Although it seems to show the lowermost part of the formation, it is

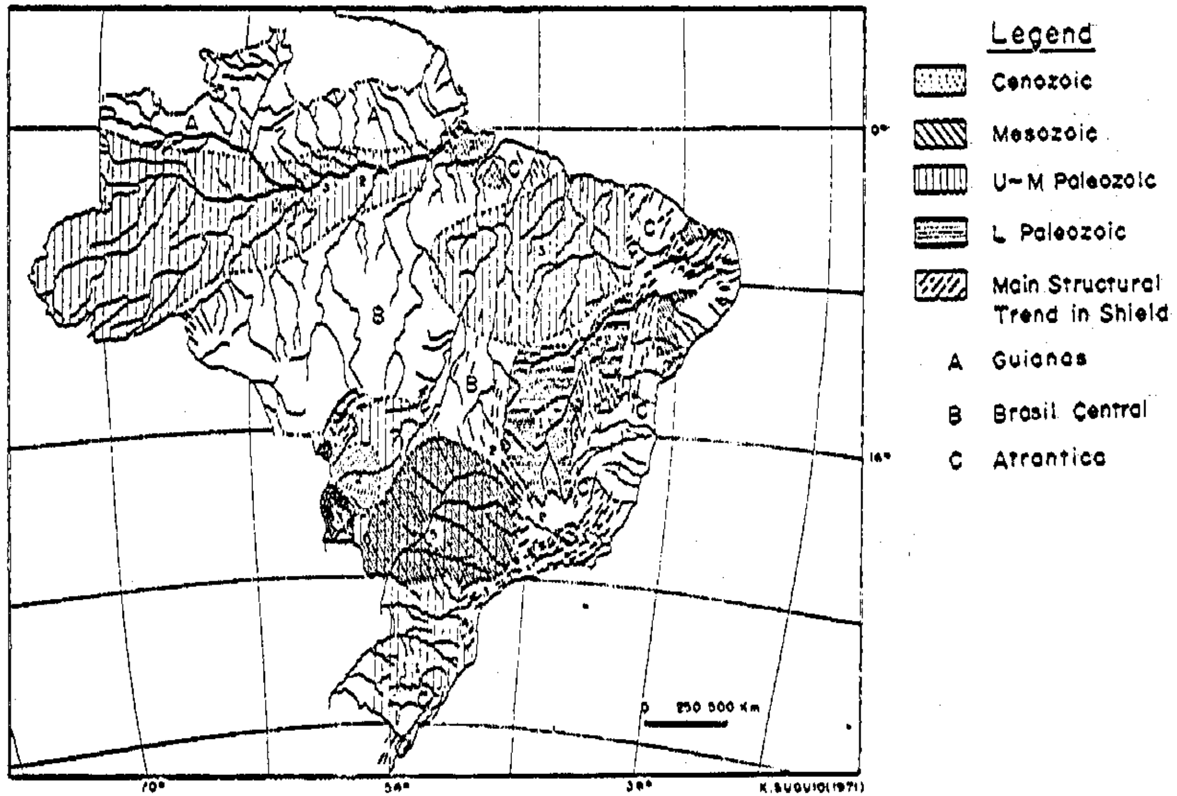


Fig. II-1 Main Tectonic Map in Brazil

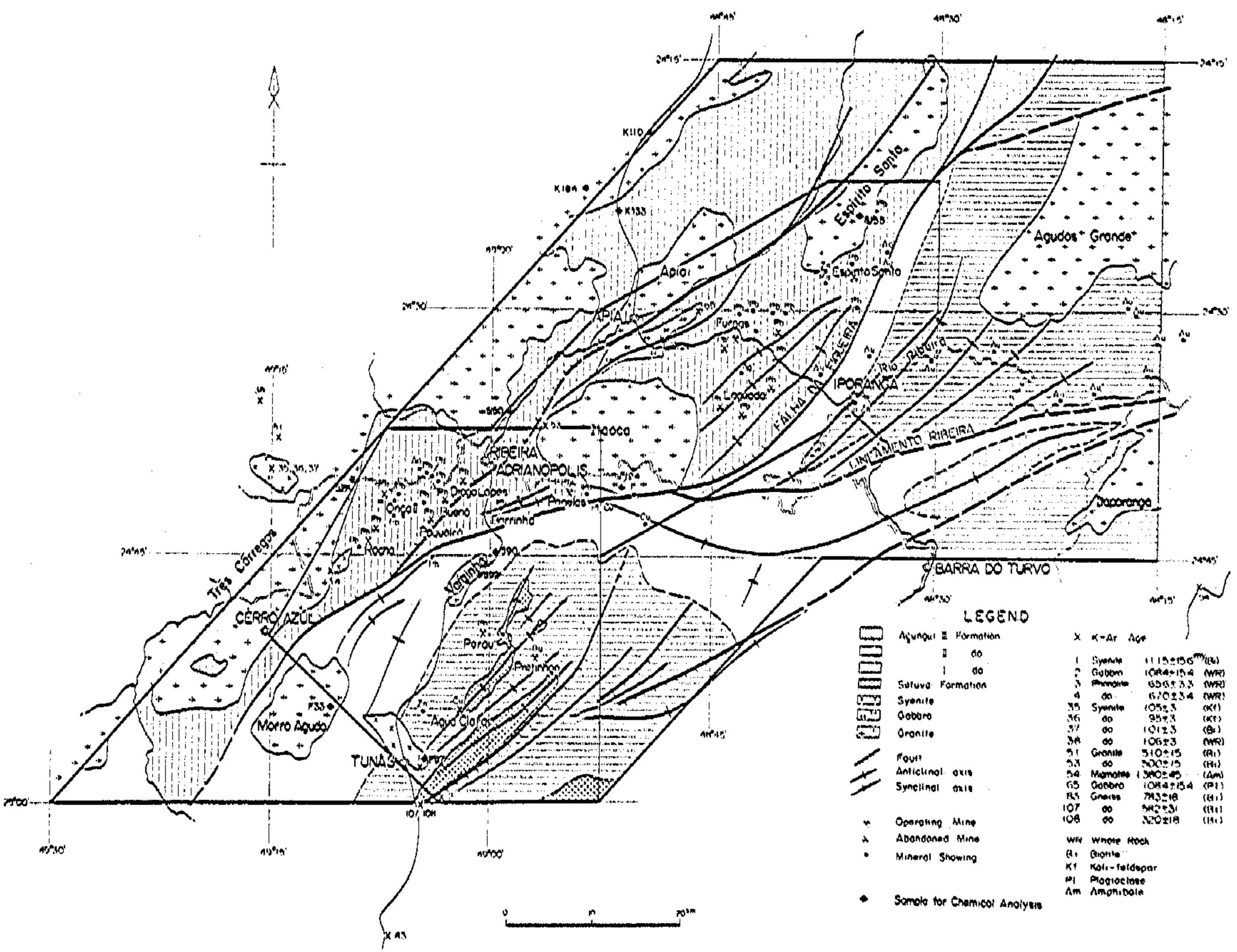


Fig. II-2 Geological Map of the Reconnaissance Survey Area

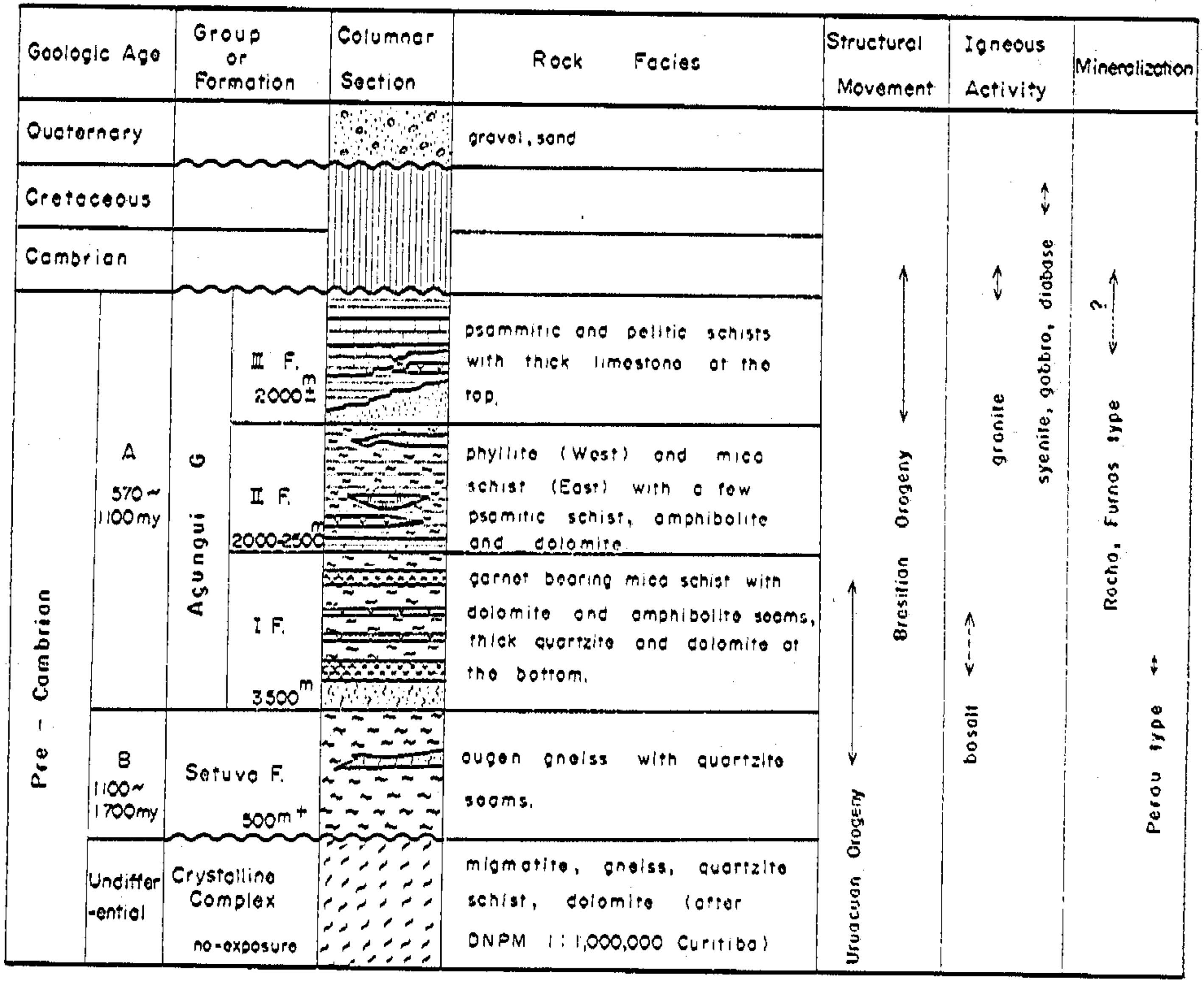


Fig. II-3 Generalized Stratigraphic Columnar Section in the Reconnaissance Survey Area

Table II-1 Characteristics of Photogeological Units

Characteristics / Units	Photo - characteristics		Morphological expression							Remarks	Lithology		
			DRAINAGE			ROCK PROPERTIES							
	Tone	Texture	Pattern	Density	Cross sect. of valley or gully	Resistance	Bedding (schistosity)	Jointing	Boundaries				
A (Q)	light	fine, smooth	—	—	—	very low	—	—	—	loose material	The Quaternary		
B1 (AIIIps)	medium grey	fine, uneven	dendritic	high	gentle V-form	low	none	low density	relatively sharp		pelitic schist, phyllite	Formation III	Aoungui Group
B2 (AIIIls)	medium grey	fine, uneven	— (internal drainage)		—	low	none	medium density	sharp	showing karst topography	limestone, dolomite		
B3 (AIIIcs)	medium grey	fine, smooth	subdendritic	low	gentle V-form	low to moderate	none	none	vague	showing karst topography (only doline)	pelitic limestone		
B4 (AIIIam)	medium grey	coarse, rough	—	low	—	low	none	none	vague	thin bed	amphibolite to amphibole schist		
B5 (AIIIss)	light to medium grey	fine, uneven	parallel	high to medium	sharp V-form	high	well bedded	high density	sharp		psammitic schist with pelitic schist		
C1 (AIIps)	light to medium grey	fine, uneven	trellis, dendritic	high	gentle V-form	moderate	none	relatively high density	sharp		pelitic schist, phyllite	Formation II	
C2 (AIIls)	medium grey	fine, uneven	—	—	—	low to moderate	none	—	relatively sharp	small exposure, karst topography	limestone		
C3 (AIIam)	medium grey	coarse, rough	subdendritic	low	U-form	low	none	none	sharp	thin bed	amphibolite to amphibole schist		
C4 (AIIss)	medium grey	fine, uneven	parallel	low	sharp V-form	high	massive	medium density	sharp		psammitic schist		
D1 (AIps)	medium grey	fine, uneven	dendritic, trellis	high	gentle V-form	moderate	massive	medium density	partly vague		pelitic schist, phyllite	Formation I	
D2 (AIam)	medium grey	coarse, rough	subdendritic	low	U-form	low	none	none	sharp	thin bed	amphibolite to amphibole schist		
D3 (AIls)	medium grey	fine	—	—	—	moderate	—	—	vague	thin bed, showing karst topography	limestone, dolomite, calc silicate rock		
D4 (AIqt)	light to medium grey	fine, uneven	parallel	medium	sharp V-form	high	very well bedded	medium density	sharp		quartzite		
E1 (Sgn)	medium grey	coarse	parallel	medium to low	gentle V-form	moderate to low	none	low density	sharp		gneiss	Setuva Formation	
E2 (Sqt)	medium grey	fine, uneven	parallel	medium to low	sharp V-form	high	well bedded	medium density	sharp		quartzite		
F1 (Gr)	light	fine	parallel	very high	gentle V-form	low	—	medium density	sharp		granite	Intrusive rocks	
F2 (Gr)	medium grey	coarse, rough	parallel, trellis	high to medium	sharp V-form	high to moderate	—	high density	sharp		granite		
G (Gb)	medium grey	coarse, rough	—	low	—	moderate to low	—	none	vague		gabbro		
H (Sy)	medium grey	fine, smooth	—	low	—	moderate to low	—	none	sharp		syenite		
I1 (Db)	medium grey	—	—	—	—	low	—	—	relatively sharp	dyke	diabase		
I2 (Db)	medium grey	—	—	—	—	moderate	—	—	sharp	dyke	diabase		

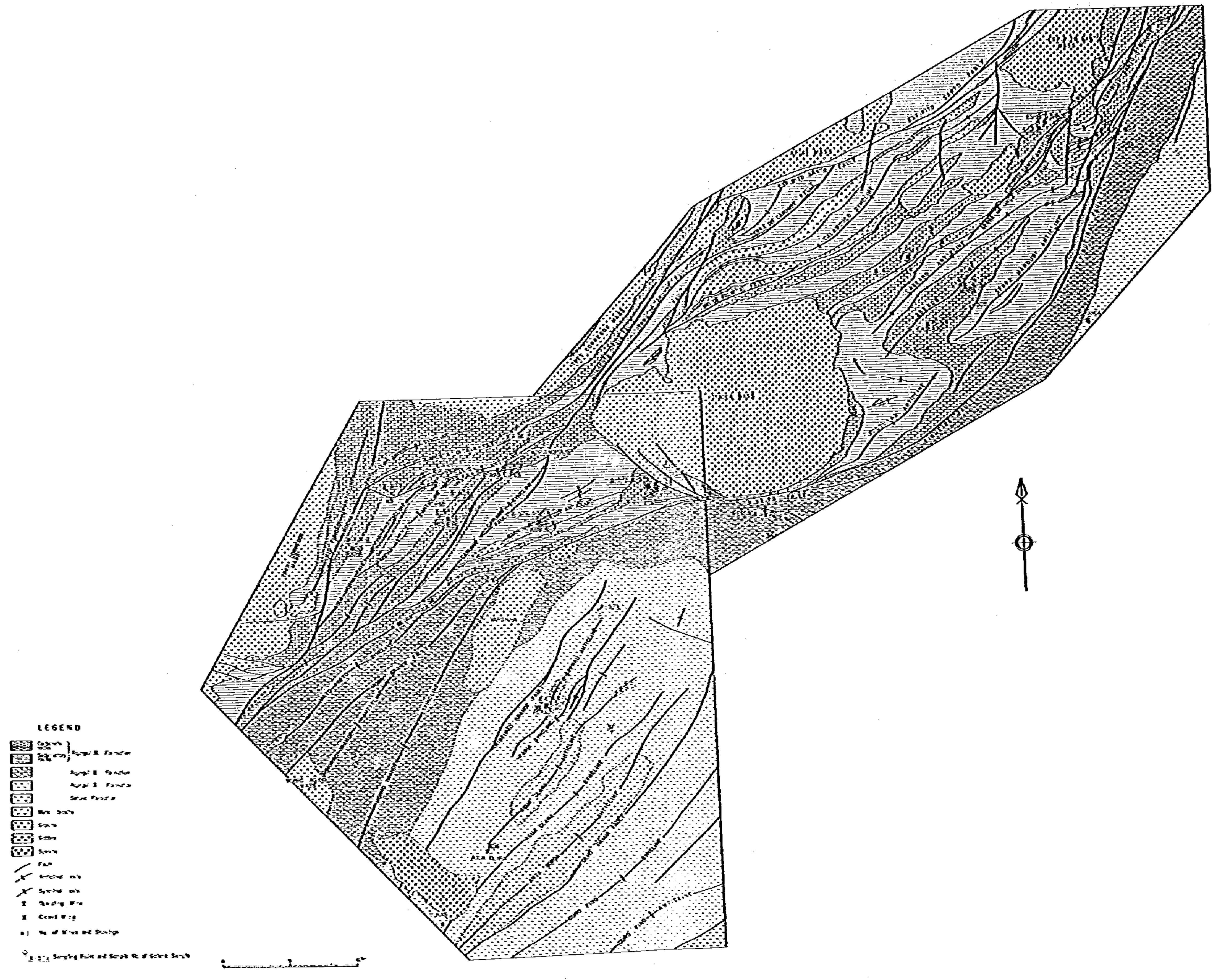


Fig. II-4 Geological Map of the Semi-detailed Survey Area

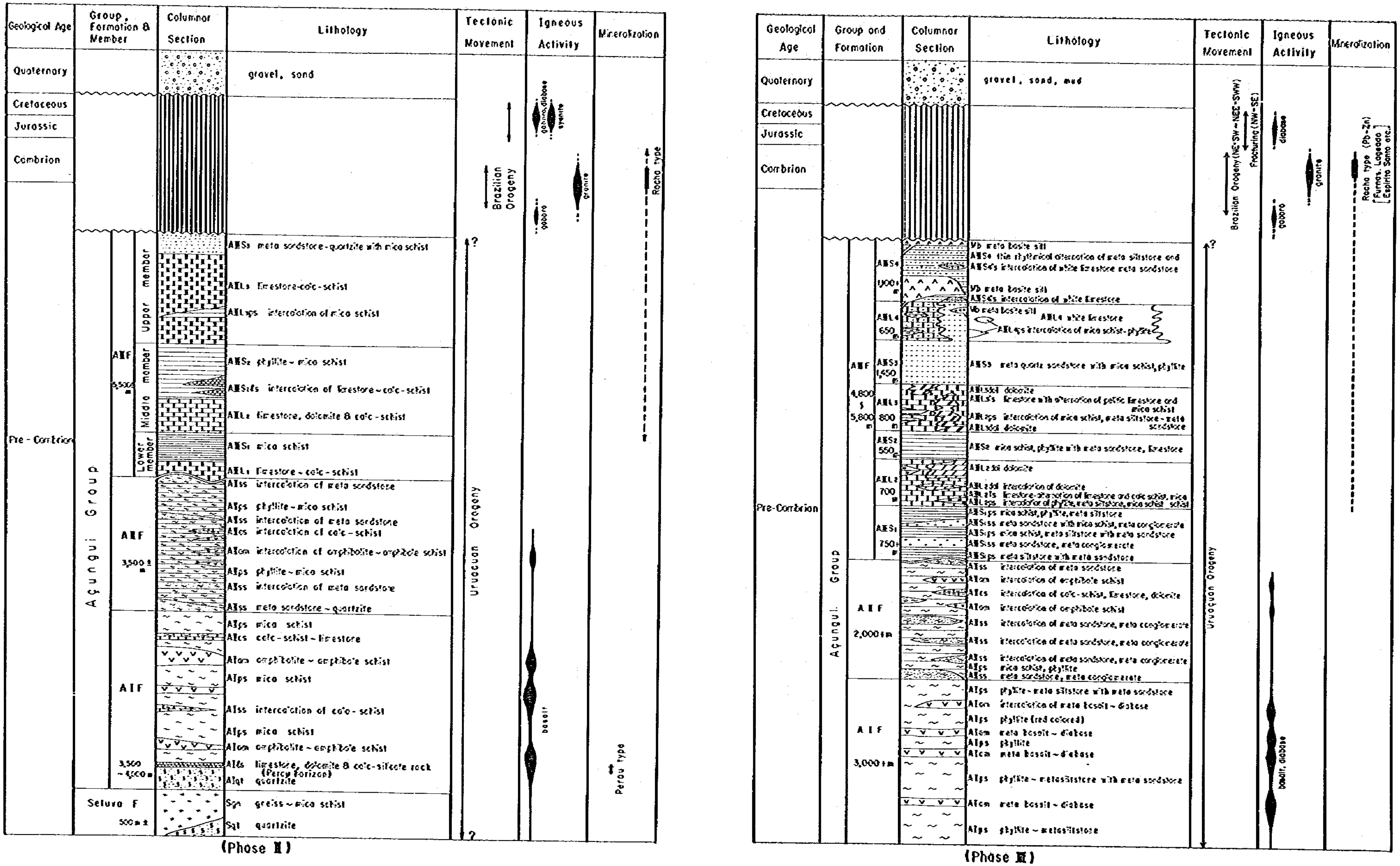


Fig. II-5 Generalized Stratigraphic Columnar Section in the Semi-detailed Survey Area

thought to be a partially intercalated bed since no exposure of the rock has been found in the Agua Clara anticline.

It is difficult to assume the thickness of the formation because no exposure of the lower limit has been observed.

Rock Facies

The main rock facies are composed of muscovite-biotite gneiss, hornblende biotite geniss, augen gneiss and quartzite.

Gneissose rocks are generally dark gray to dark green and massive, in which muscovite, biotite, quartz and feldspar are commonly observed, showing distinct compositional banding (gneissose texture) consisting of alternating bands with portions rich in muscovite and biotite and those of abundant quartz and feldspar.

The rocks show a tendency in general that grain size of the constituent minerals become fine from the lower upward, and porphyroblasts of K-feldspar are often observed in the coarse-grained portion. It is sometimes interbedded with thin layers of amphibolite in the upper reaches of Perau river.

Augen gneiss containing coarse porphyroblasts of K-feldspar and aggregate of quartz crystals is exposed everywhere. The typical one is well observed on the northeast of the Anta Gorda settlement and in the upper reaches of Perau river in the Agua Clara anticline, where coarse crystals of K-feldspar more than two centimeter across are sometimes found.

Quartzite is observed in the uppermost reaches of Veados river in the Anta Gorda anticline. It is white to pale gray, fine-grained quartzite with distinct schistosity.

Under the microscope, the rocks show a characteristic to have been derived from arenaceous to pelitic sedimentary rocks, especially quartzite seems to have been derived from sedimentary rocks with dominant sandy materials.

Characteristics of Photogeological Units

Quartzite in the formation shows a parallel drainage pattern with medium to low density of drainage system, and is high in resistance and well bedded. The ridges are angular and the valleys are narrow V shaped. The drainage system in gneiss shows similar density and pattern to quartzite, but resistance is low. The rock is massive with no bedding. The ridges are round and the valleys are open V shaped. They are therefore readily distinguished by the difference of resistance.

Relation with Underlying Strata and Time

Since the lower limit of the formation is not distributed in the surveyed area, the relation with the underlying strata can not be made clear. According to Batolla et al. (1977 and 1981)

Rb/Sr dating of gneiss in the formation shows 1,400 m.y.

2–1–2 Açungui Formation

The Açungui formation is further divided into three formations such as the Açungui I, II and III on the southern area of Itaoca granite mass from the base upward. Furthermore, the Açungui III formation is divided into 4m on the north.

(1) Açungui I Formation

The formation consists mainly of mica schist to phyllite and is characteristically interbedded with amphibolites and carbonate rocks. The lowermost bed is quartzite overlying the Setuva formation and the upper limit is a quartzite to metasandstone, the lowermost bed of the Açungui II formation.

Distribution and Thickness

In the southern part, the formation is distributed in the Perau area and in the neighboring areas of the Tunas and Anta Gorda settlements in a form surrounding the Setuva formation. In the northeastern part, it is found on the north of Iporanga striking north-northeast.

The thickness is assumed to be 3,500 to 4,000 m in the southern part, and more than 3,000 m in the northeastern part, although the true thicness is not clear because of absence of the underlying formation.

Rock Facies

The main rock facies of the formation are composed of quartzite (AIqt), limestone to calc-silicate rock (AIls), mica schist to phyllite (AIps), amphibolite to metabasalt (AIam) and limestone or limestone schist (AIcs).

(a) Quartzite (AIqt)

The rock is white to pale yellowish gray and massive partly showing schistose structure.

The main constituent mineral of the rock is fine to minute-grained quartz accompanied by a small amount of feldspar. It is often intercalated with film-like thin layers of muscovite. Muscovite is found in abundance and schistosity is distinct in the vicinity of Agua Clara.

The rock grades into limestone or calc-silicate rocks, or into mica schist of the upper sequences, and it alternates with the limestone and thin layers of the mica schist.

Since, directly above the rock, limestone to calc-silicate rocks, the host rock of the Perau-type ore deposit are distributed, the rock becomes an effective key bed for investigation of the ore horizon from the characteristics of rock facies.

The bed is 300 m thick in the surrounding area of the Perau mine, which decreases to less than 100 m in the vicinity of Anta Gorda.

(b) Limestone ~ Calc-silicate Rocks (AIls)

Limestone to calc-silicate rocks and dolomite are distributed directly above the quartzite, and the strata-bound deposits such as the Perau deposit (Pb–Zn–Ag–Ba), the Agua Clara (Ba, Cu, Pb) deposit, Canoas deposit (Pb–Zn–Ag–Ba) and the Pretinhos (Ba, Cu) deposit are emplaced in some part of them.

The areas in which the exposures of limestone to calc-silicate rock of this horizon have been found in the surrounding area of the Perau mine, at Volta Grande Creek, in the vicinity of the Agua Clara mine and in the neighboring area of the Pretinhos mine, showing the widest distribution (approximately 4 km in lateral extension and 150 m in maximum thickness) in the surrounding area of the Perau mine.

The host rock of the Perau deposit consists of complicated alternating beds of calc-silicate rocks and pelitic to siliceous schist.

(c) Mica schist to Phyllite (Alps)

The rock facies varies markedly. The rock facies found in the southern part is basically medium to fine-grained mica schist gray to dark gray in color, while the rocks distributed on the east of Iporanga are mainly composed of pale brown or purplish gray to grayish green, fine-grained phyllite.

The main constituent minerals of mica schist are quartz, biotite, muscovite and sericite, accompanied with plagioclase, garnet, hornblende and tremolite. Mica schist is divided into muscovite-biotite schist found on the north of the Perau mine and graphite- muscovite- sericite schist developed on the south according to assemblage of the constituent minerals. Muscovite-biotite schist shows a distinct schistosity containing abundant flakes of biotite, often accompanied by coarse garnet. Under the microscope, lepidoblastic texture consisting of these minerals is found characteristically and staurolite is rarely observed. Concentration of magnetite is found in muscovite-biotite schist directly above the ore horizon of the Perau mine. Graphite-muscovite-sericite schist contains muscovite in abundance, and is fine-grained with weak schistosity as compared with muscovite-biotite schist, partly showing rock facies similar to phyllite. Under the microscopic observation, lepidoblastic texture, composed of sericite, muscovite and quartz with small amount of biotite is observed.

The main constituent minerals of phyllite in the northern part consist of muscovite and quartz, and in addition, graphite, hematite and chlorite are sometimes observed. Red phyllite containing hematite is found as a key bed in the eastern part of Serra do Monte Negro. Phyllite is partly interbedded with metasiltstone or metasandstone to metaconglomerate with indistinct schistosity. Under the microscopic observation, lepidoblastic texture consisting of quartz, muscovite, hematite, chlorite and actinolite are observed.

(d) Amphibolite-metabasalt Lava (Alam)

Difference of facies of the rocks is found between the north-eastern part and the southern part, being composed of fine to medium-grained dark green, massive metabasalt in the north-eastern part and schistose to massive, heterogeneous amphibolite, dark green and fine to coarse-grained, in the southern part.

Metabasalt and amphibolite are frequently intercalated with phyllite to mica-schist above mentioned in harmonious with the bedding. The thickness varies from several meters to 100 m showing a maximum of 400 m to the north of the Perau anticline.

The constituent minerals of metabasalt consist of plagioclase, pyroxene and actinolite.

As to the origin of the rock, the presence of green phyllite between two closely lying meta-basalt, which is likely to have been derived from tuff, seems to demonstrate the basaltic lava origin.

Microscopic observation shows that the main constituent minerals of amphibolite consist of hornblende, plagioclase and actinolite accompanied with a small amount of garnet, epidote, biotite and tourmaline, sometimes with magnetite and pyrite.

The rock, which is essentially an amphibolite characterized by porphyroblastic texture in the massive part, is often interbedded with thin layers of mica schist, and also shows an occurrence to exist together with calc-schist, being very harmonious with schistose rocks in the surrounding areas which are obviously sedimentary in origin.

In terms of the origin of the rock, a conception is that basaltic igneous rock intruded into the sedimentary rocks before formation of schist (CPRM 1981), and the other is that there is a possibility that tuff has been derived from the impure calcareous or dolomitic sedimentary rocks, or from the mixture of the two (JICA, MMAJ 1981). Because the assay values of amphibolites are plotted in the domain of basic igneous rock on the ACF diagram, because occurrence of the rock is found to be quite harmonious with the schistose rocks as the result of the survey, and because igneous texture is shown in the massive part, it is thought that the origin of the rock is mainly from basic extrusive rock, lava and tuff of the same source and partly from pelitic sedimentary rocks occurred together with the formers.

(e) Limestone, calc-schist (Alcs)

Beside limestone and cla-silicate rock, the formation is interbedded with several beds of limestone to calc schist in the middle to upper part in the surrounding area of the Perau mine. The calc-schists described in this clause are a fine alternation of schist consisting of limestone, biotite-muscovite schist and tremolite schist.

Thin layers of limestone are distributed almost in horizontal attitude in the basin of São

Sebastião River in the eastern part of the survey area.

A limestone bed distributed continuously from the Criciúma settlement to the western side of Grande River is predominated with massive limestone in the vicinity of the Criciúma settlement in the northern part, while calc-schist becomes dominant toward the south from the intersection with Grande River. Beside it, the rock distributed in a lenticular form on a small scale consists mainly of rock facies of calc schist.

Characteristics of Photogeological Units

Quartzite is very high in resistance, forming notably angular ridges, and well bedded. Mica schist to phyllite are characterized by the occurrence of very fine drainage system, showing dendritic or trellis pattern. Resistance is medium and bedding is almost none. Amphibolite or amphibole schist is small in resistance as compared with other units. Erosion has not been advanced with poor development of drainage system, and it is readily distinguished by rough texture. Although the calcareous rock is distinguishable by the presence of doline on a small scale, the boundaries are indistinct making difficult to trace the bed. It is easy to distinguish quartzite from amphibolite to amphibole schist because of difference of resistance, leading to be able to understand the structures such as folds and faults by tracing those rocks.

Stratigraphical Relation and Time

Although there has been a conception that the stratigraphical relation with the underlying Setuva formation was a tectonic unconformity (CPRM 1981), the relation of conformity was made clear as the result of the survey.

(2) Açungui II Formation

The Açungui II formation is mainly composed of mica schist to phyllite, interbedded with quartzite and/or metasandstone to metaconglomerate in the lower part in general, being accompanied by a small amount of amphibolite and thin layers of limestone in the middle part. Among the formations which had been classified as the Açungui I formation in the northeastern part, the phyllitic rocks interbedded in abundance with metasandstone to metaconglomerate, being distributed between Iporanga west and the Figueira Fault, was redefined as the Açungui II formation as the result of the survey in Phase III.

Distribution and Thickness

The formation is distributed in zones striking northeast to east on the southern side of the Ribeira fault, while it is found in a small and narrow zone in the eastern part of the Figueira fault on the northern side of the Ribeira fault as mentioned in the above.

Thickness is assumed to be up to more than 3,500 m in the southern part, and more than 2,000 m in the northeastern part.

Rock Facies

The formation consists mainly of mica schist to phyllite (AIIps) interbedded with small amount of quartzite and/or metasandstone to metaconglomerate (AIIss), amphibolite (AIIam) and calcareous rocks (AIIcs).

(a) Mica Schist to Phyllite

Mica schist predominates in the central part and phyllite is distributed in the southwestern part and the northeastern part.

Mica schist is gray to dark gray being partly pale green to yellowish green, and is composed of fine to medium-grained muscovite-biotite schist and sericite-chlorite schist. It tends to be abundant in content of biotite in the central part, especially being concentrated coarse-grained biotite, garnet and magnetite on the south of the Panelas mine where can be observed that the occurrence of biotite often developed crossing the schistosity at right angle. Because, in this part, biotite becomes coarser and the crystals are found to have crossed the schistosity obliquely or at right angles as getting nearer to the Itaoca granite, it is possible that the metamorphic rocks of the area might be subjected to the effect of the Itaoca granite. While, in the surrounding area of the Caçador settlement, alternating beds of biotite schist and phyllite which often contains graphite are found, the both rocks have been highly silicified at the part penetrated by the Varginha granite.

Phyllite is pale brown to red or pale green, and no macroscopic difference can be recognized from that of the Açungui I formation. In the northeastern part, red phyllite is broadly distributed in a zone 700 to 800 m to the west of the boundary with the Açungui I formation.

Under the microscope, these rock facies includes many of those of pelitic origin consisting of very fine-grained quartz, sericite, graphite and muscovite, whilst mica schist is composed mainly of muscovite, biotite, quartz and plagioclase, showing lepidoblastic texture accompanied by very small amount of garnet and tourmaline. Phyllite also displays lepidoblastic texture composed of muscovite, sericite and graphite, which is very fine-grained.

(b) Quartzite to Metasandstone and/or metaconglomerate (AIIss)

Quartzite to metasandstone are gray to brown medium to coarse-grained massive rocks sometimes showing a weak schistose textue.

Among the rocks which constitute the lowermost part of the Açungui II formation, quartzite (key bed) is dominant in the surrounding area of Serra de Vinte e Sete in the central part of the area, extending to the northeastern part, which grades into a thin bed of metasandstone in the southwestern part. The upper horizon above that of dominant metaconglomerate was classified as the Açungui II formation. Metaconglomerate is found along the mountain path leading to the television pylon and along Ribeira River to the southwest of the former lying directly above the Açungui I formation. The gravels consists of phyllite, quartzite and metasandstone, partly containing gravels likely to be granite and gneiss. They are 5 mm to 5 cm in diameter sometimes reaching up to 20 cm, and shows a lenticular form. Sorting and grading are generally poor. Matrix is composed of lithic sandstone showing weak schistosity. Metasandstone found at Taquaruvira to the southwest of Iporanga partly contains biotite, in which massive lithic part is observed.

Under the microscope, metasandstone displays granoblastic texture consisting mainly of quartz grain accompanied by a small amount of muscovite and plagioclase.

Metaconglomerate is composed of muscovite, quartz and plagioclase, and a small amount of actinolite, chlorite and graphite, showing lepidoblastic texture.

(c) Amphibolite (AIIam)

Amphibolite is distributed in the center of the survey area as 3 to 4 sheets of thin beds in the middle of the formation. It is pale green to dark green and medium to coarse-grained showing massive to schistose texture. In the surrounding areas of occurrence of amphibolite, a tendency is observed that the facies varies from amphibolite through chlorite-sericite schist to mica schist.

(d) Calcareous Rocks (AIIcs)

Calcareous rocks consist of limestone, dolomite and calcareous phyllite, and are distributed on the northern side of Pescaria River in the northeastern part of the area and to the west of Ressaca in the central part. The rocks have a tendency to be found in the area close to amphibolite (AIIam).

The rocks are white to dark gray, which are rather bright as compared with calcareous rocks of the Açungui III formation. According to Projeto Leste do Paraná (1977, CPRM), showings of copper, lead and zinc are described in calc-schist on a small scale to the west and south of Ressaca, but they could not be confirmed in the survey of this time.

Characteristics of Photogeological Units

The characteristics are almost similar to those described in the clause of the Açungui I formation. That is, metasandstone has a high resistance similar to quartzite, fine dendritic drainage system is found in mica schist to phyllite, and amphibolite and amphibole schist show rough texture and low resistance. Karst topography is partly observed in calcareous rock.

Stratigraphical relation

Although in the survey of Phase I, the rocks on the eastern side of the Figueira fault was classified as the Açungui I formation having been made into a bundle, which was divided into two formation, the lower formation was named the Açungui I formation and the upper the Açungui II formation, in the survey of Phase III. The boundary was setted at the bottom of metasandstone to metaconglomerate (AIIss) distributed from the vicinity of Ribeira river in the eastern part of the area to the vicinity of Serra do Monte Negro.

Although the Açungui II formation conformably overlies the Açungui I formation, it is in fault contact with the upper Açungui III formation having been cut by the Figueira fault and Ribeira fault.

(3) Açungui III Formation

The formation is mainly composed of mica schist, phyllite, metasandstone and calcareous rocks, and are extensively distributed from the northern part to the southwestern part of the area on the western side of the Figueira fault and the Ribeira fault. It occurs on a small scale at Caverna do Diabo in the southeastern part of the area.

In the survey of Phase I, the formation had been divided from the base upward into mica schist, calcareous rocks and metasandstone or mica schist, and it had been considered that calcareous rocks of the middle part were repeatedly exposed due to a complicated fold structure. In the survey of Phase II, it was divided based on combination of calcareous rocks and meta-sedimentary rocks into 3 m such as the lower member ($AIIIL_1$, $AIIIS_1$), the middle member ($AIIIL_2$, $AIIIS_2$) and the upper member ($AIIIL_3$, $AIIIS_3$). In the survey of Phase III, it became clear as the result of careful traces of each member that calcareous rocks ($AIIIL_4$) and meta-sedimentary rocks ($AIIIS_4$) were present further in the upper sequence, and that 4 members were present eventually. Each formation was, however, classified into each rock facies in the survey of Phase III keeping out of classification into members, because distribution of $AIIIL_4$ was limited and because the member shows interfingering relationships stratigraphically with the upper part of $AIIIS_3$.

Therefore, in this report, the classification of the rocks in the semi-detailed survey area was described on the basis of that of Phase III.

(a) $AIIIL_1$ Member

Distribution and Thickness

It is distributed in a narrow zone along the northern side of the Ribeira fault from the vicinity of Bocanha in the southwestern part of the area to the south of Panelas in the central part.

Rock Facies

Limestone ($AIIIL_1$) is dark gray to black, fine-grained to medium-grained, massive and compact or saccharoidal, showing distinct bedding. It is often interbedded with dolomite in the southwestern part of the area. In addition, fluorite occurs on the north of the Caçador settlement in the form of vein, mass and breccia. It forms alternating beds with psammitic mica schist in the southern part of Panelas Mine.

Under the microscope, limestone displays granoblastic texture consisting mainly of calcite, and dolomite shows the same texture consisting of dolomite.

(b) $AIIS_1$ Member

Distribution and Thickness

It is distributed from the south of the Barrinha deposit in the western part through the southern part of the Panelas mine to the vicinity of the Monjolinho deposit in the northeastern part forming the cores of the Serra Manduri anticline and the Lageado anticline. Beside it, it occurs in the western part of the Rocha mine on a small scale. The thickness of the member is about 600 m in the southwestern part and more than 750 m in the notheastern part.

Rock Facies

The main rocks are mica schist to phyllite and metasiltstone ($AIIS_1$ps) interbedded with metasandstone and metaconglomerate ($AIIS_1$ss) in the northeastern part.

In the southwestern part, the dominant rock is gray to dark gray and medium to coarse-grained biotite-muscovite schist showing notable micro-foldings. Toward the northeast, it varies to purplish gray to reddish and fine to medium-grained sericite-chlorite schist to phyllite, and massive metasiltstone predominates in the surrounding areas of Betari River to Morro do Manduri. Metasandstone to metaconglomerate display reddish gray color, which contain only the poor sorted pebbles of quartzite (4 ~ 15 mm across). Chloritoid is partly observed in the $AIIS_1$ member in the northeastern part.

Under the microscope, mica schist shows lepidoblastic texture consisting of quartz and small amount of biotite, plagioclase and garnet. Metaconglomerate displays granoblastic texture consisting of quartz, K-feldspar, muscovite and chlorite accompanied by a small amount of hematite, opaque minerals and zircon.

(c) $AIIL_2$ Member

Distribution and Thickness

It is distributed in a zone extending from Barrinha through Panelas, Pavão and Lageado to Iporanga River and in another zone from Rocha through the Apiaí-Ribeira road to the west of Apiaí.

The lead ore deposits such as Rocha, Barrinha, Panelas and Lageado, and fluorite deposit of Sete Barras are emplaced in this member.

The thickness of the member is estimated to be 200 to 300 m in the surrounding area of the Barrinha mine, 500 m in the surrounding area of the Panelas mine, 500 to 750 m in the neighboring area of Lageado, 650 m at Iporanga river, 900 m in the surrounding area of the Rocha mine and about 800 m along the Apiaí-Ribeira road.

Rock Facies

The main rocks are limestone ($AIIL_2ls$) and dolomite ($AIIL_2dol$).

Limestone is grayish white to dark gray, showing the rock facies of fine-grained, compact to coarse-grained, saccharoidal or pelitic. Dolomite are found only in the Rocha mine area in the western part, but dark gray, fine-grained, massive and compact dolomite is dominant at Lageado and eastward.

A brief description for each area follows: in the surrounding area of the Barrinha mine, alternating beds of gray to dark gray limestone and calc-schist are distributed; in the surrounding area of the Panelas mine, the rocks are black limestone and white limestone; in the vicinity of Lageado and eastward, pelitic limestone intercalated with phyllite ($AIIL_2ps$) and thin layers of dolomite are found, becoming dominant with dolomite toward the upper part; in the neighboring area of the Rocha mine, pale gray to dark gray and fine to medium-grained limestone predominates, which is interbedded with white to pale gray limestone in the lower part, while it is accompanied by gray to dark gray and massive dolomite in the upper part; along the Apiaí-Ribeira road, calc-silicate rock subjected to thermal metamorphism by the intrusion of Três Córregos granite is distributed.

(d) $AIIS_2$ Member

Distribution and Thickness

Beside the occurrence similar to the $AIIL_2$ member, it is distributed on the northern side of the Espirito Santo fault and the Serra do Carumbé fault.

The thickness varies from place to place, such as 850 m in the Barrinha-Panelas area, 350 m at Betari river, 700 m on the northeast of it, 1,000 m in the surrounding area of the Rocha mine and more than 700 m in the eastern part of Apiaí.

Rock Facies

Mica schist predominates in the western part, while mica schist to phyllite and metasiltstone prevails in the northeastern part.

Mica schist is gray to pale greenish gray and fine to medium-grained, showing rock facies such as biotite-sericite schist, chlorite-sericite schist and graphite-sericite schist with distinct schistosity. The rocks are sandy and rich in manganese as compared with $AIIS_1$ member. Biotite and garnet are concentrated in the surrounding part of Itaoca granite.

Metasiltstone shows a rock facies red to purplish gray in color and fine-grained. It is found on the northern side of the Espírito Santo fault, intercalated with white to red and fine to coarse-grained metasandstone.

In the surrounding area of the Rocha mine and at Iporanga River, the rock is intercalated with thin layers of carbonate rocks (AIIS$_2$ls).

(e) AIIL$_3$ Member

Distribution and Thickness

It is distributed in a long and narrow zone from Mato Preto River in the western part of the area toward the northeast through Paqueiro and Adrianópolis to Apiaí. It is also distributed in long and narrow zones in the northeastern part of the area as well as in the area connecting Boa Vista, Furnas and Espirito Santo, showing a general strike of NE--SW.

The lead ore deposits such as Paqueiro, Bueno, Diogo Lopes, Furnas and Espirito Santo are emplaced in this member.

The thickness is great in the vicinity of Serra do Carumbé such as shown by 1,400 to 1,800 m, while it is 800 to 1,100 m in the surrounding area of Furnas and about 1,000 m at Espirito Santo.

Rock Facies

The member consists mainly of limestone (AIIL$_3$ls) often accompanied by dolomite (AIIL$_3$dol). It is partly intercalated with meta sandstone and mica schist (AIIL$_3$ps).

Limestone (AIIL$_3$ls) is gray to dark gray and fine to medium grained, varying in rock facies from massive and compact to coarse grained.

In the surrounding area of the Paqueiro mine, gray, fine-grained and massive to bandded limestone is found in the lower part, being intercalated with dark gray and fine-grained mica schist (AIIL$_2$ps) about 100 m thick, and alternation beds of limestone and calc-schist are developed in the upper part.

In the northern part of the Ribeira River area, gray to grayish white, medium to coarse grained and bandded or massive crystalline limestone constitutes the main rock facies. Alternating beds of limestone, mica schist and calc-schist are often found, sometimes concentrated by biotite. Bandded or masive crystalline limestone dominantly occurs from the valley of the Ribeira River to the surrounding part of Itaoca granite, sometimes containing biotite.

In the surrounding Furnas area, carbonate rocks (AIIL$_3$ls) is separated into three parts such as lower, middle and upper by two intertrappean layers of metasedimentary rocks (AIIL$_3$ ps) which extend relatively continuously. No difference in rock facies can be observed between those parts, in which the rock is relatively well bedded limestone, gray to dark gray and fine to medium-grained. It is partly intercalated with thin layers of mica schist and meta-quartz sandstone. Carbonate rocks of the lower part forms the host rock of the Furnas deposit.

Dolomite predominates in the surrounding area of Espirito Santo and the southwest of its while limestone occurs dominantly in the northeastern area. Bedding is generally distinct with well bedded structure in which the width of each band is 5 to 30 cm. Pyrite dissemination is often observed.

In the vicinity of Apiaí, the rock is mainly composed of dark gray, medium to coarse-grained pelitic limestone, finely interbedded with thin layers (20 ~ 50 cm) of metasandstone and metasiltstone. Limestone in the surrounding part of Apiaí granite has undergone contact metamorphism to form massive crystalline limestone, accompanied by epidote and garnet.

At the limestone mine of Camargo Correia, the rock show a facies gray to dark gray in color, medium to coarse-grained and massive. At the close contact to Itaoca granite, it shows coarse facies having been altered to marble, and abundant coarse biotite flakes have been concentrated.

Dolomite ($AIIIL_3dol$) is gray to purplish gray or pale green and fine to coarse-grained massive dolomite accompanied by calcite veins and dolomite veins. Roughly three horizons are recognized in the surrounding area of Furnas. The lower part forms the important host rock of the ore deposit consisting of bandded dolomite and dark gray and fine-grained pelitic dolomite.

The middle part is also composed of pelitic dolomite, in which only pyrite dessemination is observed. The upper part is gray and coarse-grained, partly accompanied with network veins of calcite to dolomite in dark gray brecciated dolomite.

A clear zebra structure is observed along the São Paulo State Highway 373, where a stripped pattern consisting of fine-grained, dark gray part and pale gray part is shown.

Dolomite shows gray, fine-grained, massive and compact facies in the surrounding area of Espirito Santo and in the southwestern part of it, and cross-laminae are often observed.

Meta-sedimentary rocks ($AIIIL_3ps$) consist of mica schist, metasandstone and metasiltstone, which are found as intercalated beds in limestone and dolomite.

(f) $AIIIS_3$ Member

Distribution and Thickness

In the area of Phase II, it is distributed in zones along the Serra da Bocanha fault and the Serra do Carumbé fault at the western end. In the area of Phase III, it is distributed in long and narrow zones at the southern limb and northern limb of the Calabouço syncline. It is also exposed at the axial part of the Espírito Santo syncline on a small scale.

The thickness is more than 500 m in the Serra do Carumbé area and 900 m in the Serra da Boa Vista reaching up to 1,500 m in the vicinity of Serra da Vargem Grande in the northeastern part of it.

Rock Facies

The member is composed of rhythmical alternating beds of quartite and metasandstone white to yellowish and fine to medium grained, intercalated with quartzite or thin layers of metaconglomerate containing round pebbles of quartz (2 ~ 4 mm across) in the upper part. In the area of Phase III, they vary to meta-quartz sandstone, which is grayish white to purplish gray or reddish brown and fine to medium-grained, showing distinct bedding. Pyrite dissemination is locally found.

Sericite and chiastolite and observed at the contact with Espirito Santo granite, and garnet is found in the surrounding part of Itaoca granite.

(g) $AIIIL_4$ Member

The member consists mainly of limestone, intercalated with mica schist to phyllite.

Distribution and Thickness

It shows a long and narrow distribution along the southern limb of the Calabouço syncline from Gurutuva through Passa Vinte Creek and the upper reaches of Betari River to the southeastern part of Bairro da Cachimba.

The thickness is 530 to 750 m in the vicinities from Palmital River to Betari River, which decreases toward the northeast. It is 70 m in the southeaster part of Bairro da Cachimba.

Rock Facies

It is a characteristic of the rock facies of the limestone ($AIIIL_4$) that it shows relatively distinct bedding and that it is white to pale gray and fine-grained to coarse-grained, which leads to be able readily to discriminate it with the naked eye from the $AIIIL_2$ member and the $AIIIL_3$ member which show dark gray color.

At Palmital River, it is intercalated with two thin layers of brown sericite schist to phyllite.

The intercalated layers of meta-quartz sandstone ($AIIIS_3$) in limestone increase toward the northeast in the upper reaches of Betari River, which grade into meta-quartz sandstone. On the other hand, the limestone is not distributed at the northern limb of the Calabouço syncline, where meta-quartz sandstone is found in the same horizon as this member, which leads to the assumption that they grade into each other in a form of interfingering relationship within the syncline.

(h) $AIIIS_4$ Member

The $AIIIS_4$ member constitutes the uppermost part of the Açungui Formation distributed in the survey area. The main rocks are thin alternating beds of metasiltstone, metasandstone and carbonate rocks in which metasiltstone is dominant, intercalated with thin layers of limestone.

Distribution and Thickness

It is distributed in a zone in the vicinity of the axial part of the Calabouço syncline from Gumutuva west through Palmital to Bairro da Cachimba east.

The AIIS$_4$ member has been separated into two parts by basic rocks (described later) intruded into it in a form of sheet. The thickness underneath the basic rocks is 50 to 320 m and 80 to 780 m above it.

Rock Facies

The characteristic of the rock facies is shown by thin, quite regularly alternating beds (each bed is five to 10 cm thick) consisting mainly of gray to pale green or brown metasiltstone accompanied by metasandstone and carbonate rocks. They are locally intercalated with siliceous facies.

Under the microscope, the rock shows lepidoblastic texture consisting of muscovite, quartz and chlorite, with accessory amount of opaque minerals, sphene, andalusite and chloritoid.

Characteristics of Photogeological Units

Metasandstone is high in resistance, showing narrow V-shape valley and angular ridges. The drainage system is low in density and parallel. It is also well bedded. Mica schist and phyllite show smooth texture with dendritic drainage system of high density, and are low in resistance. Limestone of the member is widely distributed, which shows a marked karst topography. The drainage system is low in density, and resistance is low to medium. Bedding is none. The boundary between metasandstone and limestone is quite distinct due to the difference of resistance, and together with presence of bedding in metasandstone leads to be able to analyze the structures such as folds and faults.

Stratigraphical Relation and Time

Although the formation conformably overlies the underlying Açungui II formation in the vicinity of Barra do Turvo in the eastern part, it is in fault contact with the Açungui II formation in other areas by the Ribeira fault and Figueira fault. The time is assumed to be upper Precambrian because it has been intruded by the granitic rocks of 510 m.y.

2–2 Intrusive Rocks

The intrusive rocks distributed in the survey area are meta-basic rocks, granitic rocks, gabbro, syenite and diabasic rocks. The former two are considered to be the products of the Brazilian Orogeny took place from late Precambrian to Cambrian and the rest are considered to have been formed as a part of the Paraná basic volcanic activity associated with the reactivity of the South

American Plateau from Jurassic to Cretaceous.

2–2–1 Metabasic Rocks (Mb)

Distribution and Occurrence

The main body intruded into the $AIHS_4$ member in a form of sheet and is distributed in long and narrow zones in the direction of NEE–SWW along the axis of the Calabouço synchline for 28 km. Beside these, the rock intruded at the axial part of the antlelines such as Rocha and Barrinha in the forms of sheet or stock, and the others are found seemingly to have intruded along the Rocha fault and the Quarenta Oitavo fault in a form of sheet.

Rock Facies

The rock displays various rock facies such as metagabbro, metadiabase and metabasalt dark gray to dark green, fine to coarse-grained and massive. Macroscopically, the constituent minerals are plagioclase, pyroxene and actionalite, and accessory minerals are chlorite, epidote and magnetite. Chlorite veins and veins of white minerals are locally found. Under the microscope, ophitic texture and poikiloblastic texture are shown, and plagioclase, augite, hypersthene and actinolite, and a small amount of quartz, biotite, magnetite and chlorite, are observed. The rocks were classified as gabbroic rocks described later having made into a bundle in the survey of Phase I, but these rocks were classified after Phase II because there would be a great difference according to whether or not the rocks have undergone metamorphism.

Characteristics of Photogeological Units

Since the rocks show coarse texture, the density of drainage is low and the resistance is middle to low, the boundary is indistinct within the carbonate rocks.

Time of Intrusion

Although the rock cut the Açungui III formation, the time of intrusion is though to be the early stage of the Brazilian Orogeny or before it, since they have been subjected to folding and metamorphism together with the Açungui formations.

2–2–2 Granitic Rocks

Distribution and Occurrence

The rocks intruded on the western side of the survey area as the Trés Corregos mass in the direction of NE–SW with a width of 30 km. In the central part, the rock masses such as Espfrito Santo, Apiaf, Itaoca, Varginha and Morro Agudo and distributed from the northeastern part to the southwestern part as batholith or stock. Furthermore, on the eastern side, the Agudos Grande mass and Itaporanga mass are distributed as batholith. Beside these, small intrusive bodies of a form of dyke are locally found.

Rock Facies

The rocks are grayish white to pink and composed of fine to coarse-grained and massive biotite granite to granodiorite. It is a characteristic that K-feldspar 0.5 to 2 cm long is contained as phenocryst, and the phenocrysts of K-feldspar more than 5 cm long are contained in the Itaoca mass and Tres Corregos mass. Beside it, plagioclase, quartz and biotite and small amount of hornblende and magnetite are observed. Hornblende is, however, scarce in the Espirito Santo mass as compared with other masses.

Mylonite texture is found in a part of the Apiaí mass and Tres Corregos mass.

Under the microscope, the rocks show holocrystalline and porphyritic textures consisting of K-feldspar, plagioclase, quartz and biotite, with small amount of hornblende, zircon, sphene and apatite. Plagioclase is sericitized and biotite is chloritized.

Characteristics of Photogeological Units

The rocks are divided into two units of F_1 and F_2 according to the difference of resistance and drainage system. The masses such as Itaoca, Três Corregos, Espirito Santo and Apiaí are contained in the former, and those such as Morro Agudo, Agudos Grande, and Varginha in the latter. The formers are low in resistance and erosion in advanced. The density of drainage system is very high, showing fine parallel pattern. The latters are high in resistance, forming hills. Texture is coarse, and density of drainage system is high to medium, showing parallel or trellis pattern of drainage system.

Time of Intrusion

The time of intrusion is thought to be before or after the faulting after metamorphism in the Brazilian Orogeny.

According to Cordani & Bittencourt (1967), K/Ar dating of biotite showed 500 ± 15 M.a. in the Tres Corregos mass and 500 ± 15 M.a. in the Itaoca mass, indicating that the both correspond to early Precambrian.

According to Cordani and Kawashita (1971), the time of intrusion of the granitic rocks in the Brazilian Orogeny is classified as follows:

(1) 650 ~ 600 m.y. intrusion during the orogenic movement

(2) 600 ~ 590 m.y. intrusion in the later stage of the orogenic movement

(3) 590 ~ 500 m.y. intrusion at the end of the orogenic movement

Therefore, the time of intrusion of the granitic rocks of the area has been considered to belong to (3) intrusion at the end of the orogenic movement.

2–2–3 Gabbroic Rocks (Gb)

Distribution

In the area of Phase II, two stock-like small masses along the Ribeira fault and a stock-like small body to the southwest of the above are found.

Rock Facies

Melanocratic, medium-grained, compact and holocrystalline gabbroic rocks are the main rock facies. Rock facies of quartz diorite is observed in a part of the Jose Fernandes mass in the southern part of Barrinha. Since these rocks have not undergone metamorphism, the macroscopic and microscopic characteristics are obviously different from meta-basic rocks already mentioned.

Under the microscope, the rocks show ophitic texture, in which plagioclase, augite, and small amount of hornblende and hypersthene are observed.

Time of Intrusion

As the result of K/Ar dating of the intrusive rocks of the same kind by Amaral et al. (1967) ages between 147 ~ 117 m.y. showing late Jurassic to Cretaceous were obtained.

2–2–4 Syenite

Distribution

The rock is distributed as a stock to the north of Tunas intruded in the direction of NW–SE showing an area of 20 km^2, and another small body is found in the western part of the area.

Rock Facies

It is gray to dark gray, medium to coarse-grained, holocrystalline and massive rock, and a small amount of short prismatic mafic minerals are contained among fresh plagioclase and K-feldspar. Under the microscope, it shows subhedral equigranular texture and contains K-feldspar, plagioclase, and small amount of biotite, monoclinic pyroxene and augite.

Time of Intrusion

According to Amaral et al. (1967), K/Ar age of the Tunas mass is shown to be 111.5 ± 15.6 m.y., indicating middle Cretaceous.

2–2–5 Diabasic Rocks

Distribution

The rocks intrude the Açungui formation and the granitic rocks in the whole surveyed area as dykes of NW–SE system. The width of dykes is from several tens centimeters to several meters in general, showing a maximum width of 75 m. They vary in lateral extension reaching up to 15 km.

Rock Facies

The rocks are dark gray to black and consist of medium to fine-grained diabase or gabbro. Megascopically, the rocks are composed mainly of plagioclase and pyroxene with accessory amount of biotite and magnetite. Chlorite and pyrite are partly observed. Under the microscope, the rocks shows ophitic texture, and consist of augite and plagioclase with very small amount of actinolite, biotite, chlorite and magnetite.

Characteristics of Photogeological Units

The rocks are divided into two units from the difference of resistance. Most of those (unit I_1) are low in resistance and are always can be traced as depressed lineament. Those distributed in the Tres Corregos mass in the western part of the survey area and the Espirito Santo mass (unit I_2) are higher in resistance than granite, and are distinguished as protoruded lineaments.

Time of Intrusion

The intrusion of the rocks is considered a part of basic igneous activity associated with reactivity of the South America Plateau commenced in Jurassic, and it is assumed to have intruded from Jurassic to Cretaceous.

2–2–6 Chemical Composition of Intrusive Rocks

Chemical analysis on 11 samples of igneous rocks mainly of granitic rocks was carried out in Phase I. Table II-2 shows the analytical values and the weight percentage of index minerals calculated from the analytical values. These results of analysis show that the granitic rocks distributed in the area belong to granite to granodiorite of alkali rock series, which is according with the result of microscopic observation.

2–3 Metamorphism

The rocks which constitute the Setuva formation and the Açungui formation consist of the metamorphic rocks of Precambrian System.

These metamorphic rocks consist of gneiss, schist and phyllite derived from psammitic and pelitic sedimentary materials as well as amphibolite and amphibole schist derived from basic igneous rocks and tuff of the same source.

Although many geologists have mentioned the opinions on the metamorphic facies of these rocks, many are of the opinion that they belong to metamorphic facies of green schist facies to amphibolite facies.

In this survey, as the result of zoning of metamorphic facies of the Setuva formation and the Açungui formation on the basis of field observation, chemical analysis of rocks and microscopic

Table II-2 Chemical Analysis and Normative Compotion of Igneous Rocks

			I-33	I-87	I-124	S-28	S-50	S-90	S-92	S-135	K-110	K-133	K-151
Location			Morro Agudo	Tenas	Bravo	Tres Corregos	Tres Corregos	Vicente Sete	Virginia	Espirito Santo	Ribeirão Branco	Araçaiba	Araçaiba
Rock Name			Granite	Syenite	Quartz monzonite	Granite	Granodiorite	Monzodiorite	Granite	Granodiorite	Granodiorite	Amphibolite	Granite
Chemical composition	SiO_2		66.50	61.74	64.70	54.53	67.95	52.48	68.02	71.58	65.17	46.95	69.69
	TiO_2		0.72	0.39	0.71	0.78	0.52	1.85	0.21	0.30	0.61	1.76	0.35
	Al_2O_3		14.67	18.91	15.46	15.42	14.45	17.43	15.17	13.94	15.65	17.43	15.43
	Fe_2O_3		0.32	1.16	1.12	1.92	1.32	1.75	1.98	0.23	0.76	1.37	0.55
	FeO		4.81	3.77	3.23	4.13	2.98	7.15	2.54	3.34	2.59	8.52	1.95
	MnO		0.05	0.13	0.64	0.13	0.08	0.15	0.08	0.07	0.54	0.30	0.03
	MgO		0.87	0.22	1.83	2.42	1.59	3.13	1.35	0.79	0.93	5.98	0.57
	CaO		2.37	1.33	3.63	5.02	2.79	6.42	2.97	1.68	2.11	8.48	1.65
	Na_2O		3.99	6.28	3.52	2.53	3.69	3.31	2.95	3.69	4.47	2.59	3.85
	K_2O		4.32	5.23	4.57	3.56	3.31	3.69	4.09	2.94	3.59	2.62	4.43
	P_2O_5		0.23	0.76	0.32	0.31	0.25	0.45	0.14	0.14	0.19	0.56	0.11
	CO_2		–	0.47	0.13	5.59	-	0.76	–	–	0.11	-	–
	$H_2O(+)$		0.51	0.25	0.11	1.71	0.57	0.56	0.64	0.55	0.13	2.65	0.41
	$H_2O(-)$		0.41	0.28	0.12	0.14	0.18	0.18	0.22	0.06	0.32	0.22	0.17
	Total		99.21	99.32	99.27	99.25	99.83	99.65	99.55	99.31	99.38	99.37	99.42
CIPW norm	Q		22.84	0.57	15.94		25.03	0.42	25.22	31.93	22.61	0.00	24.53
	C		1.15	0.74	0.00		0.47	0.00	0.75	1.97	0.76	0.00	1.21
	or		25.53	30.91	26.78		19.56	21.81	24.17	17.37	20.65	15.58	26.18
	ab		26.15	53.14	29.79		30.65	27.15	25.22	31.22	37.82	20.13	32.58
	an		10.26	3.45	12.06		12.21	22.25	13.92	7.42	9.59	28.65	8.61
	di	wo	0.00	0.00	0.05		0.00	1.33	0.00	0.00	0.00	4.30	0.00
		en	0.00	0.00	0.54		0.93	0.81	0.00	0.00	0.00	2.31	0.00
		fs	0.00	0.00	0.54		0.00	0.76	0.00	0.00	0.00	1.85	0.00
	hy	en	2.17	0.55	4.52		0.50	7.18	3.36	1.97	2.32	0.00	1.42
		fs	7.53	5.56	3.87		3.67	8.22	4.53	5.69	3.53	0.00	2.33
	ol	fo	0.00	0.00	0.00		0.00	0.30	0.00	0.00	0.00	5.73	0.00
		fa	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
	mt		0.46	1.68	1.62		1.91	2.54	1.57	0.29	1.19	2.68	0.83
	il		1.37	0.74	1.35		0.99	3.43	0.51	0.57	0.78	3.34	0.59
	ap		0.53	0.14	0.74		0.58	1.07	0.32	0.32	0.44	1.30	0.25
	cc		0.00	1.09	0.28		0.00	1.65	0.00	0.00	0.24	0.00	0.00
	Total		97.98	95.53	99.54		99.54	95.43	98.99	98.67	98.93	95.97	98.89
	Q+or+ab		74.51	84.92	74.55		75.05	49.59	74.65	83.53	81.18	35.71	83.29
	D.I.		74.65	85.92	75.22		75.93	53.27	75.36	81.61	82.06	28.30	84.22

observation, these metamorphism are classified into regional metamorphism and contact metamorphism. Table II-3 shows the classification of metamorphic facies and Fig. II-6 shows a map of metamorphic zoning.

2-3-1 Regional Metamorphism

The structure of metamorphic rocks shows the direction of NE-SW system, and they were formed in association with the Brazilian Orogeny (JICA and MMAJ, 1981, 1982 and 1983). It has been confirmed that the result of Rb/Sr dating of the source rock of the metamorphic rocks showed 1,400 ~ 1,170 m.y. (Batolla Jr et al. 1977 and 1981). On the other hand, the result of K/Ar dating of biotite in gneiss of the Setuva formation showed 582 ± 31 m.y. (Cordani and Bittencourt 1967). The age of biotite by K/Ar dating seems to show that the time of metamorphism is consistent with the Brazilian Orogeney's (750 ~ 500 m.y.).

The rocks derived from psammitic and pelitic rocks are classified into (1) biotite zone and (2) muscovite zone according to mineral assemblage.

(1) biotite zone .... muscovite – biotite

(2) muscovite zone .... graphite – sericite – muscovite

The biotite zone is found on the eastern side of the approximately north-south line passing through the Agua Clara mine in the area distributed by the Açungui I and II formations south of the Ribeira fault. The muscovite zone is observed from the upper part of the Açungui I formation on the northwest of Tunas to the Açungui II formation and the whole area of the Açungui III formation north of the Ribeira fault. No difference of metamorphic facies between the Setuva formation and the Açungui I formation can be recognized in the surrounding area of the Perau mine.

The meta-basic rocks generally belong to green schist facies to epidote amphibolite facies showing a correspondence to the mineral zone of metamorphic rocks derived from psammitic and pelitic rocks as in the following.

Mineral assemblage of epidote-hornblende-biotite is shown in the Setuva formation and that of actinolite-epidote to garne-epidote-hornblende in the Açungui I and II formation. These belong to green schist facies to epidote amphibolite facies, and correspond to (1) biotite zone derived from psammitic and pelitic rocks showing no great difference.

The mineral assemblages of meta-basic rocks intruded into the Açungui III formation north of the Ribeira fault are chlorite-epidote of green schist facies in the southern part and actinolite-epidote of green schist facies in the northern part, showing a little higher metamorphic grade in the northern part. These mineral assemblages correspond to (2) muscovite zone derived from

Table II-3 Classification of Metamorphic Facies of the Surveyed Area

<table>
<tr><th>type of metamorphism</th><th>origin rock</th><th colspan="4">low ← metamorphic grade → height</th></tr>
<tr><td rowspan="4">regional metamorphism</td><td rowspan="2">pelitic rock</td><td colspan="2">muscovite (sericite) zone</td><td colspan="2">biotite zone</td></tr>
<tr><td colspan="2">graphite-sericite -muscovite-Assem.</td><td colspan="2">muscovite-biotite -Assem.</td></tr>
<tr><td rowspan="2">basic rock</td><td colspan="3">green rock facies</td><td>epidote-amphibolite facies</td></tr>
<tr><td>chlorite-epidote -Assem.</td><td colspan="2">actinolite-epidote -Assem.</td><td>(garnet)-epidote-amphibole-Assem.</td></tr>
<tr><td rowspan="2">contact metamorphism</td><td>pelitic rock</td><td colspan="2">biotite hornfels</td><td colspan="2">biotite-garnet hornfels</td></tr>
<tr><td>carbonate rock</td><td colspan="4">marble</td></tr>
</table>

Assem. : Assemblage

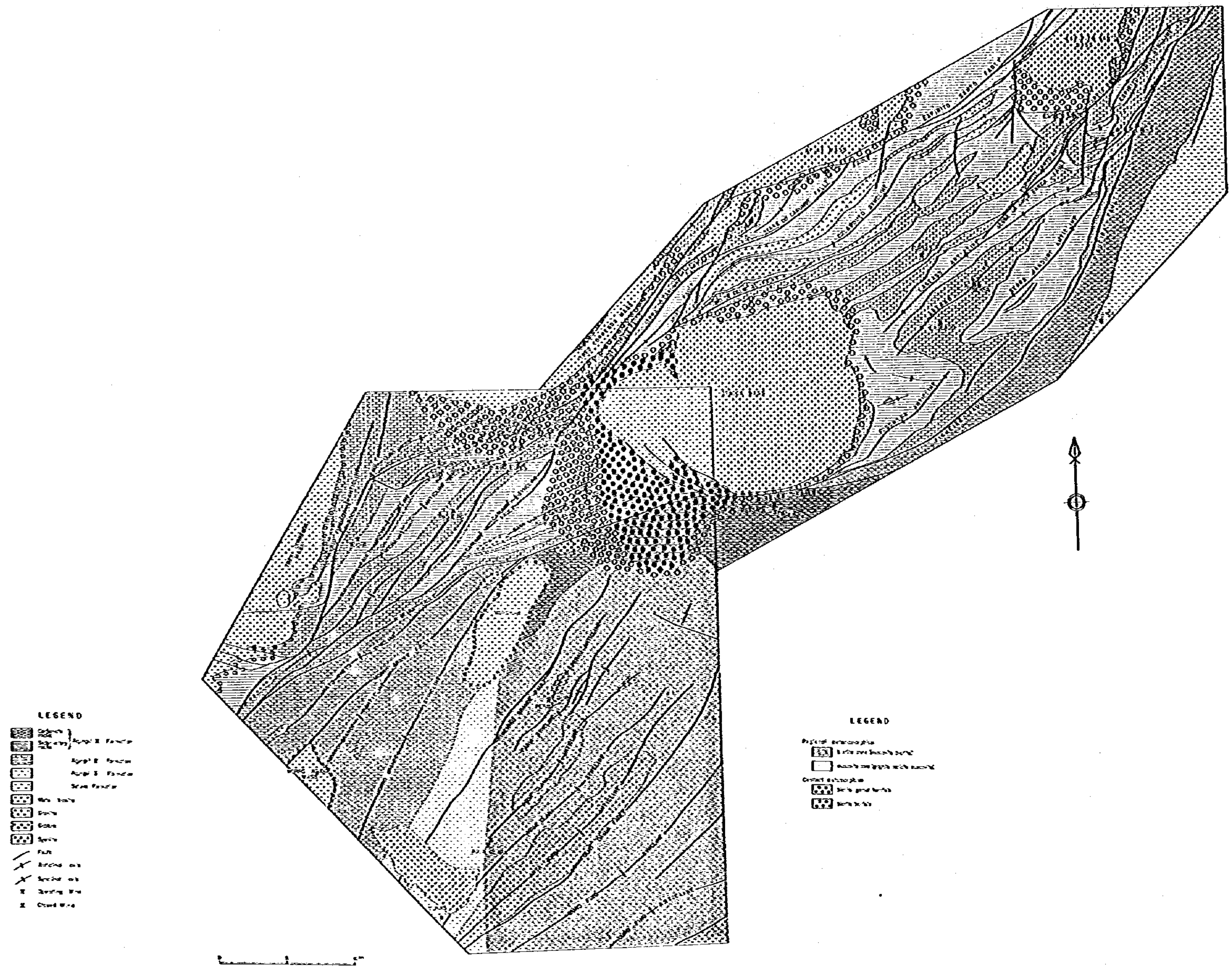


Fig. II-6 Metamorphic Facies Map in the Surveyed Area

psammitic and pelitic rocks.

2–3–2 Contact Metamorphism

In the survey area, biotite hornbels containing prophyroblasts of biotite has been formed in the surrounding part of the granite masses such as Trés Corregos, Apiaf, Itaoca and Espirito Santo. Garnet hornfels has been formed dominantly in the western part of the Itaoca mass, and biotite honfels has been formed in the outer zone of it. Alteration to marble or skarnization is clearly observed in a part of carbonate rocks in close contact with the granite masses.

2–4 Geologic Structure and Geotectonic History

2–4–1 Geologic Structure

The area is positioned in the Apiaf fold zone of the Mantiqueira Tectonic Province in the tectonic division of Brazil (Almeida, F.F.M, 1981). A coast range called Paraiba do Sal runs to the east of the area, which is composed of crystalline complex (genissose rocks to migmatitic rocks) considered to have formed in the Transamazonian Orogeney (2,200 ~ 1,800 m.y.) .

The direction which controls the geologic structure of the area to a considerable degree is the systems such as NE–SW to NEE–SWW. These directions are considered to have been formed during the Brazilian Orogeny (750 ~ 500 m.y.). Moreover, a fold structure of NNW–SSE system which is thought to have been formed by tectonic movement of the older time is observed to have remained. Cutting the geologic structures mentioned above, intrusive rocks of NW–SE system and fault structures of N–S system are found. These directions are considered to be the newest geologic structure in the area. The Setuva formation which forms the basement of the area is repeatedly exposed as the cores of anticlines of NE–SW system in the order of wave length of 3 to 5 km. The trend of their arrangement is north to south.

The Açungui I formation is distributed in the southern part in a form to surround the Setuva formation, which is distributed in the northeastern part being put between the Figueira fault and the Ribeira fault. Although in the western part of the Perau mine, the isoclinal structure dipping 30° to 70° west is observed, repetition of the same horizon is observed on the eastern side of the Perau mine and in the northeastern due to the structure of NE–SW system.

The Açungui II formation conformably overlies the Açungui I formation and is distributed in the direction of NE–SW to E–W on the southern side of the Ribeira fault. In addition, it is distributed in a long and narrow zone on the eastern part of the Figueira fault. The anticlinal structures are found in the central part of the formation on the southern side of the Riverira fault. Although the bedding is not clear on the eastern side of the Figueira fault, it is assumed that the strata become younger toward the west.

The Açungui III formation is distributed on the northwestern side of the Ribeira fault and the Figueira fault, in which distinct geologic structures of NE–SW system to NEE–SWW system are dominant due to thick alternating beds of carbonate rocks and meta-sedimentary rocks.

(1) Fold Structure

(a) Fold Structure in Setuva Formation to Açungui I Formation

The fold structures of NE–SW system represented by the anticlines such as Perau, Agua Clara and Anta Gorda and the synclines occurring between the aboves such as Faria and Agua Clara are found in the Setuva formation and the Açungui I formation. The length of axes and wave length of these structures are in the order of 10 to 20 km and 3 to 5 km respectively.

(b) Fold Structure in Açungui II Formation

The structures of NE–SW system such as the Mato Preto syncline, the Morro Grande anticline and the Morro Grande syncline are found to the northwest of Tunas. The axial length and wave length of these are in the order of 15 to 20 km and 5 to 8 km respectively similar to those in the Setuva formation and the Açungui I formation in the above.

The Ressaca syncline extending approximately eastward in the central part has an axial length of 60 km.

(c) Fold Structure in Açungui III Formation

The fold structures found in the Açungui III formation distributed on the northwestern side of the Ribeira fault and the Figueira fault are dominant in the systems such as NE–SW and NEE–SWW. These are cut, in many cases, by the faults on the western side of the Itaoca granite mass, the axial length is, therefore, shorter than those of the eastern side in general. These folds are classified into the orders from the first to the fourth according to the length of fold axis.

The folds which belong to the first order are the Calabouço synchline (DNPM, 1977) and the Serra Manduri – Forquilha anticline which is more than 35 km in axial length, and the Carumbé syncline is continuous to the former and the Barrinha anticline to the latter.

The vein fracture systems of the Furnas deposit and the Barrinha deposit were formed in close association with these foldings.

The folds which belong to the second order are represented by the Lageado anticline and the Lageado syncline having an axial length of about 20 km, which are concerned in the formation of the vein fractures of the Lageado deposit.

The Rocha anticline and syncline, and the Espirito Santo anticline and syncline, which are approximately 10 km in axial length, belong to the third order, and are related to the formation of the vein fractures of the Rocha deposit and the Espirito Santo deposit.

The folds of the fourth order are five and less kilometers in axial length and are found in the surrounding areas of the Monjolinho deposit and other places.

The 1/2 wave length of the first order is 12 km in maximum, that of the second order are 1 to 3 km and that of the third order 1 to 2 km.

The fold structure of NNW–SSE system are found in the surrounding area of Lageado, and the similar structure is found at the place where the fold structure of NE–SW system changes its plunge, which is worth notice as a remain of the old structure.

(2) Fault Structure

The directions of NE–SW to NEE–SWW systems are dominant in the faults which greatly control the geologic structure of the area. The main ones among those are the Figueira fault (DNPM, 1972), the Ribeira fault (DNPM, 1972), the Espirito Santo fault (DNPM, 1972), the Serra do Carumbé fault and the Olho D'ágna fault, showing more than 2,000 m in the amount of dislocation. Especially the former two are the important faults that divide the geology of the area into two. The faults that are about 1,000 m the amount of dislocation are those such as the Quarenta Oitava fault, the Rocha fault, the Agua Morna fault, the Morro Grande fault and the Riberirao Grande fault. Beside these, the faults on a small scale showing the trends such as NW–SE and N–S are also found.

(3) Other Structures

Among the intrusive rocks mentioned above, the intrusive direction of syenite and diabasic rocks show the system of NW–SE. The microstructures such as schistosity, drug fold and vein fracture are also found.

2–4–2 Geotectonic History

Compilation of the geotectonic history is considered to be important for discussion of the ore genesis.

The Uruaçuan Orogeny (1,400 ~ 1,100 m.y.) and the Brazilian Orogeny (750 ~ 500 m.y.) seem to belong to one orogeny in a broad sense. The geotectonic history of the area is described in the following by dividing it into four stages. Fig. II–7 shows the two dimensional diagram, in which the Furnas deposit and the Lageado deposit are projected along the line A–A' of the geological section (Plate 1).

Stage I (Uruaçuan Orogeny)

It has been known that the age of source rock of meta-sedimentary rocks distributed in the area was 1,400 ~ 1,100 m.y. (Batolla Jr, 1977, CPRM, 1981) from the result of Rb/Sr dating, and it is considered that the time of sedimentation was during the Uruaçuan Orogeny. In Stage I, it has been considered that sedimentation took place in the stage of geosyncline and that the deposition of lead minerals took place in this time (JICA and MMAJ, 1982) on the basid of the

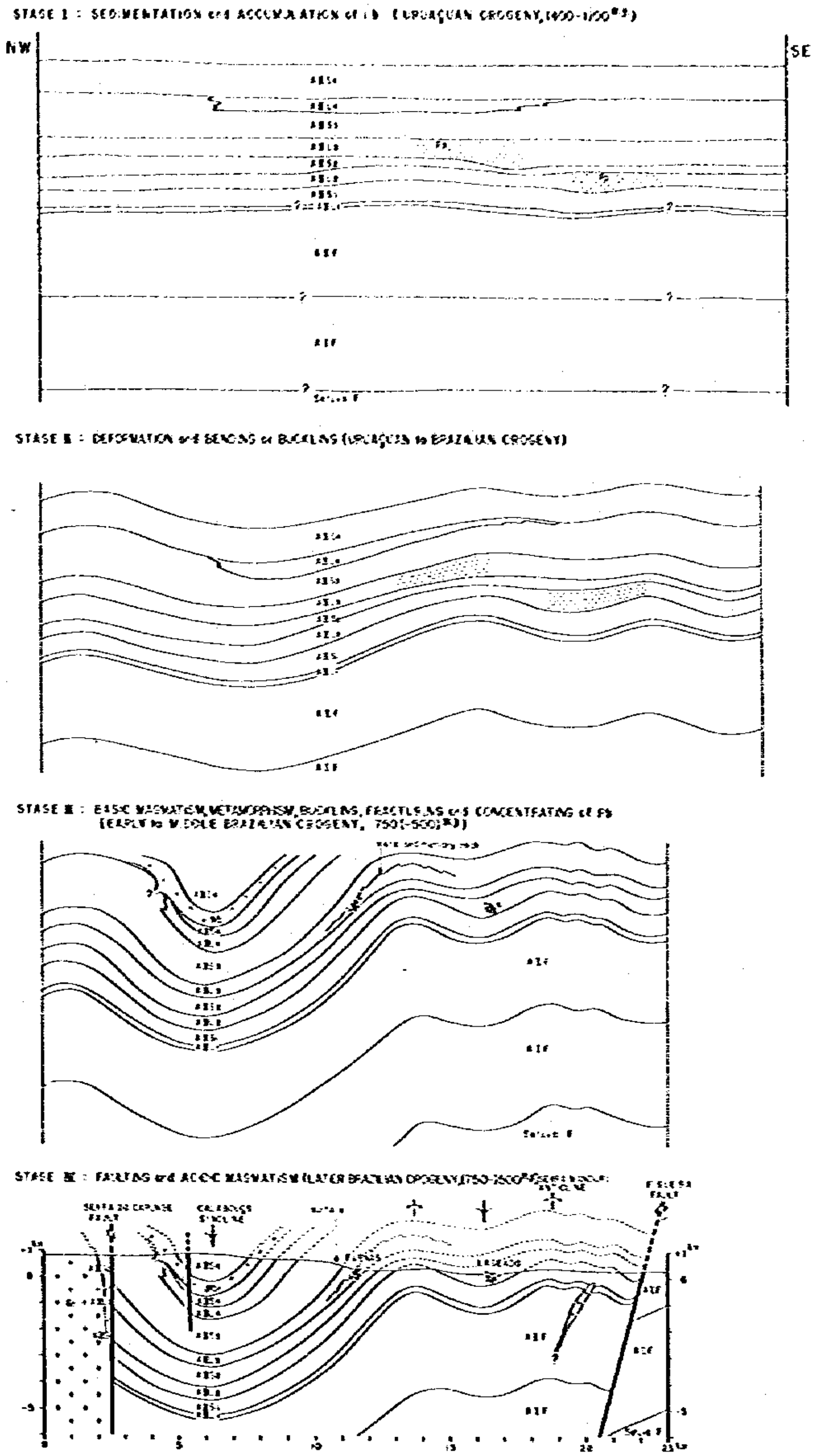


Fig. II-7 Geotectonic History of the Surveyed Area

data of lead isotopic age determination. Especially, in the Açungui I formation, it seems that calcareous to dolomitic rocks was deposited immediately before the vigorous basic volcanic activity and that the Perau deposit was syngenetically formed in a part of these rocks under a reducing environment.

Stage II (Uruaçuan Orogeny to Brazilian Orogeny)

Because the schistosity of NW–SE system is cut by that of NE–SW system, it is not contradictory to assume that the initial deformation took place after the Uruaçuan Orogeny and before the Brazilian Orogeny. Heterogeneous load pressure, upheaval and subsidence of the basement or lateral pressure of NE–SW system are considered as the cause of deformation.

Stage III (Initial to middle Brazilian Orogeny)

In this stage, basic volcanic activity and deformation and metamorphism which characterize the schistosity of NE–SW system took place and stratigraphical and regional difference of metamorphism was brought about by the temperature-pressure conditions. At the same time, buckle folding by lateral pressure in the direction of NW–SE took place, resulting in to form fold structure of approximately NE–SW system, high-angle fractures and small fractures including fissility along bedding plane. As the result, it seems that the vein-type lead ore deposit was concentrated in this small fracture system.

As shown in Fig. II–7, the Furnas deposit is positioned in a part of limb where the thickness of bed decreases abruptly from the axial part running in the southern part, and the Lageado deposit is found at the axial part of syncline where the thickness of bed becomes maximum.

Stage IV (Late Brazilian Orogeny)

It is thought that the fold structure of NE–SW system represented by Figueira fault and, at the same time, acidic igneous activity took place, which includes intrusion of the granitic masses such as Itaoca, Três Córregos, Apiai and Espírito Santo.

Further in the later stage, fulting of left hand-side dislocation in the direction of north to south and activity of intrusion of diabasic dykes in Jurassic to Cretaceous took place as a movement of the post Brazilian orogenic cycle, although these are not shown in the figure.

CHAPTER 3 ORE DEPOSIT

3–1 Outline of Ore Deposit

Many lead ore deposits and showings are found in the Açungui formation in the survey area as shown in Fig. II–2, Fig. II–4 and PL–1. The types of these deposits are roughly classified into the Perau type and the Rocha type.

The Perau type deposit is a stratiform deposit emplaced in limestone to calc-silicate rock interbedded in the lower part of the Açungui I formation showing a lenticular form. The mines belong to this type are shown as follows; the new ore deposit (Pb–An–Ag–Ba) in the western part of the Perau mine was encountered by drilling this time, the Perau mine (Pb–Ag) in operation, the Agua Clara mine (Pb–Cu–Ba) in which the operation is suspended at present, the Pretinho mine (Ba–Cu) which is under preparation for development and the Canoas mine (Pb–Zn–Ag–Ba) which is being explored.

The Rocha type deposit is vein-type to irregular massive deposit emplaced in calcareous rocks in the Açungui III formation. The representative operating mines include the Rocha mine, the Barrinha mine, the Furnas mine and the Panelas mine, and in addition, the mines in which the operation is suspended at present such as the Lageado to Serra deposits, the Espirito Santo mine, the Paqueiro mine, the Bueno mine and the Diago Lopas mine and many other showings are known in the area.

It was made clear as the result of survey that the main ore deposits and showings are concentratedly emplaced in $AIIIL_2$ and $AIIIL_3$ among the calcareous rocks in the Açungui III formation (Table II–4).

As to the genesis of ore deposit, the Perau deposit is considered that the sulphide minerals was syngenetically deposited from low-temperature solution associated with the basic igenous activity in the calc-silicate rock of the Açungui I formation, and in the Rocha type deposit it seems that the sulphide minerals which had been deposited in the calcareous rocks of the Açungui III formation was removed to and concentrated in the vein fracture system which was formed by the later Brazilian Orogeny.

3–2 Perau-type Deposit

3–2–1 Perau Deposit

(1) Outline of the Perau Mine

The Perau mine is situated about 25 km to the south of Adrianópolis, and the mine office of São Marco S.A. is located at 1.5 km upstream from the confluence of Grande River and Perau

Table II-4 List of Mines and Showings in the Surveyed Area

(1)

No.	Name of Mine & Showing	Kind of Ore	Type	Status	Location	Host Rock	Ore Deposits: Strike & dip	Ore Deposits: Lateral Extension	Ore Deposits: Longitudinal Extension	Ore Deposits: Average Width	Grade: Au g/t	Grade: Ag g/t	Grade: Cu %	Grade: Pb %	Grade: Zn %	Ore Mineral	Remarks
1	Braço da Pesqueira	Pb	Vein	closed	Areia Branca	Açungui III F L_3 limestone	-	-	-	-	-	-	-	-	-	Gn	
2	Agua da Limeira	Pb	do	do	East of Espirito Santo	Açungui III F L_3 limestone	N40°~60°W, 30°~70°SW	1,200m	-	0,005 ~0,20m	0,4	334,0	0,06	12,09	0,00	Gn, Cp, Py, Ce, Cv	
3	Monjolinho de Sebastião	Pb	do	do	do	Açungui III F L_3 dolomite	N40°E, 80°SE	10	-	network 0,03~0,10	0,8	204,0	0,00	7,70	0,00	Gn, Py, Cp	production several tons
4	Espirito Santo	Pb	do	do	Espirito Santo	Açungui III F L_3 limestone	N50°E, 80°NW	250	100	0,30	0,0	85,9	0,05	8,57	0,66	Gn, Hm, Cer, Py, Cv	production several hundred tons
5	Figueira	Pb	do	do	Southwest of Espirito Santo	do	N50°E, 55°NW	-	-	0,15~0,20	-	-	-	-	-	Sp, Ga, Py, Cp	production several hundred kilograms
6	Pacienela	Zn, Pb	do	do	do	do	N60°E, 50°NE	-	-	0,80~1,50	-	-	-	-	-	Gn, Sp, Py, Cp	production Galena 200 kg
7	Furnas	Pb, Ag, Zn	Vein and pipelike	operating	Furnas	do	N60°W, 80°SW N40°E, 45°NW	800	100	-	0,2	2586,0	0,11	12,60	3,82	Gn, Sp, Py, Tt, Cer	production (1981), 500 T/M Pb: 7%, Ag: 3,000 g/T
8	Gruta de Santana	Pb	Vein	closed	East of Furnas	Açungui III F L_3 limestone	-	-	-	network 0,01~0,05	0,0	7,9	0,02	5,92	2,79	Gn, Sp	production 10 tons
9	Agua Suja	(Pb)	(Vein)	do	Northeast of Furnas	Açungui III F L_3 limestone	-	-	-	(0,02~0,04)	11,8	2,0	0,01	0,12	0,01	Hm, Gt	
10	Ocorrencia de Cobre	Cu, Zn	Vein	do	Lageado	Açungui III F L_3 dolomite	N55°E, 50°SE	1,5	30	network 0,02	1,5	100,7	1,33	0,50	11,50	Gn, Cv, Py, Hm, Cer	
11	Lourenço Velho (São Lourenço)	Pb	do	do	do	Açungui III F L_3 limestone	N45°E, 75°NE	20~30	-	1,00	-	-	-	-	-	Gn, Cer	production 10 tons
12	Santana Velha	Pb	do	do	do	do	N75°E, 70°NE	5	250	0,50	-	-	-	-	-	Gn, Sp	production 1,000 tons
13	Porco ou Porco do Mato	Pb, Zn	do	do	do	do	N70°E, 70°NE	-	-	0,60~0,80	-	-	-	-	-	Gn, Sp, Py	production Gn, 2 tons
14	Mamangava	Pb	do	do	do	do	N65°E, 70°NE	500	100	0,80	0	215	0,0	11,1	0,01	Gn, Sp, Py, Cer	by JICA (1981), production several thousand tons
15	Santana Nova	Pb, Ag	do	do	do	do	N50°E, 75°NE	600	200	0,30	0,3	1874,0	0,08	12,24	0,01	Gn, Py, Cer, Cv	production several thousand tons Pb; 5~50%
16	Santana F	Pb	do	do	do	do	N50°E, 60°NE	-	100+	1,00~2,00	-	-	-	-	-	Gn, Py, Cer	production Gn; 20~30 tons
17	Nova Esperança	Pb, Ag	do	do	do	do	N80°E, 70°NE	20	80+	0,50	0,5	1891,0	0,08	12,04	0,01	Gn, Cer, Py, Cp, Cv	production 40 tons Pb; 40%
18	São Vicente	Pb	do	do	do	do	N50°E, 50°NE	-	50	0,60	0,5	496,0	0,08	12,04	0,22	Gn, Hm, Cer	production 40 tons
19	Coqueiro	Pb	do	do	do	do	N60°E, 80°NE	-	6+	0,20	-	-	-	-	-	Gn, Py, Cer	production 5 tons
20	Rugios	Pb	do	do	do	do	N50°E, 70°NE	-	150	0,30	-	-	-	-	-	Gn, Py	production 500 tons
21	Jardim I-II	Pb, Ag	do	do	do	do	N50°~60°E, 60°NE	20	250	0,70	0,4	2150,0	0,58	12,14	0,08	Gn, Py, Hm, Cer	production 1,000 tons (I), 80 tons Pb; 50% (II)
22	São Rafael I-II-III	Pb	do	do	do	do	N70°E, 60°NE	-	150+	1,00	-	-	-	-	-	Gn, Py	by Sudelpa, production 500~1,000 tons
23	Boa Ventura	Pb	do	do	do	do	N70°E, 60°NE	5~10	80m (by-vein; 1,000m)	1,00~1,50	0,1	1073,0	0,05	11,84	0,27	Gn, Py, Hm, Cer	production 85 tons
24	Macaquinho	Pb	do	do	do	do	E-W, 65°S	-	-	0,10	-	-	-	-	-	Gn, Sp, Hm, Cer	production several hundred tons
25	Jaguatirica	Pb, Zn	do	do	do	do	N50°E, 65°NE	-	30+	0,10~0,50	0,1	835,0	0,16	10,56	5,37	Gn, Cer, Sp, Py, Mt, Hm, Cv	production 80 tons
26	Sete Alqueires	Pb	do	do	do	do	N70°E, 75°NE	-	-	?	-	-	-	-	-	Gn, Hm	
27	Horta Funda I-II-III-IV	Pb	do	do	do	do	N30°E, 40°NE	-	-	0,20~0,30	-	-	-	-	-	Gn, Sp	
28	Alto do Bento (Desvanso I-II)	Pb	do	do	do	do	N70°E, 70°NE	-	-	0,30~0,40	-	-	-	-	-	Gn, Sp, Py	by Sudelpa, production Gn; 15 tons
29	Casa Velha	Pb	do	do	do	do	N60°E, 80°NE	-	200	0,10~0,40	tr	265	-	9,48	nd	Gn, Sp, Py, Hm, Cer	by Sudelpa
30	Sitio Novo	Pb	do	do	do	do	N80°E, 60°NE	-	-	0,20~0,30	-	-	-	-	-	Gn	
31	Horta do Leão	Pb, Ag	do	do	do	do	N45°E, 60°NE	-	60	0,20~0,30	0,0	1131,0	0,01	12,86	0,27	Gn, Sp, Py	
32	Santo Antonio do Pavão	Pb	do	do	Pavão	do	N60°W, 30°~80°NE	300	130+	0,15	0,0	31,9	0,00	4,29	0,06	Py, Gn	by Sudelpa, production 20 tons
33	Fluorita de Sete Barras	F	do	do	do	do	N80°E	50+	20	0,50	nd	(F) 24,6	nd	nd	nd	F	
34	Mater Empresa de Mineração	Cu	strata form	do	do	Açungui II F calcsilicate rock	N80°W, 35°N	60	60	0,50	1,0	10	0,4	0,2	0,7	Cp, Py, (Gu)	

(2)

Ser. No.	Name of Mine & Showing	Kind of Ores	Type	Status Quo	Location	Host Rock	Ore Deposits				Grade					Ore-Mineral	Remarks
							Strike & Dip	Lateral Extention	Longitudinal Extention	Average Width	Au g/t	Ag g/t	Cu(%)	Pb (%)	Zn (%)		
35	Perau	Pb, Ag	stratiform	operating do	Estado Paraná Município Adrianopolis	Açungui I F calcsilicate rock	N10E 30W	300+	200	0,50	0	120	0,2	18,7	2,0	Ga, Sp, Cp, Py	production (1981) 1,500 T/M Pb:8,5% Ag:100 g/T
36	Agua Clara	Cu, Pb Ba	do	closed	do	Açungui I F dolomite	E-W 40S	10	50	0,20	0	8	0,8	0,0	0,0	Ga, Cp, Ba	
37	Pretinho	Ba	do	operating	do	Açungui I F calcsilicate rock	N40E 35S	1,000	100+	1,50	($BaSO_4$) 85	(S) 0,5	ppm 400	ppm 50	ppm 60	Ba	production (1980) 140T/Y
38	Panelas	Pb	bedded vein & vein	operating	do	Açungui III F L_3 limestone	N40E 50N	900	200	0,30	0	130	0,3	24,0	0,0	Ga, Sp, Py, Po	total production 1,200,000 T Pb: 7.0% production (1981) 2,500T/M Pb:5,8% Ag:100g/T
39	Laranjal	Pb	bedded vein do	closed	do	do	N70E 60N	-	-	0,50	1	223	0,6	17,4	0,1	Ga	
40	Cearina	Pb	do	do	do	Açungui III F L_3 calcareous shale	E-W 60N	-	-	0,10~0,50	0	187	0,1	7,9	0,0	Ga, Cer	
41	Barrinha	Pb, Ag	do	under Exploration	do	Açungui III F L_3 limestone & calcareous shale	N50~70E 40~80N	50~70	70~200	0,50~14,00	1	150	0,1	30,6	0,0	Ga, Sp, Cp, Py Cer, Pyro	
42	Diogo Lopes	Pb, Ag	do	closed	do	Açungui III F L_3 limestone	N75~85E 50~70S	10	50	0,80	1	221	0,1	16,1	0,4	Ga, Py	total production 144T Pb: 9,72%
43	Bueno	Pb, Ag	do	do	do	do	N35E 50S	15	20	1,50	1	70	0,2	23,1	0,0	Ga, Py	total production 66T Pb:10,6%
44	Paqueiro	Pb, Ag	bedded vein & vein	do	do	do	N50~60E 80N~80S	1~70	40	0,20~1,20	1	214	0,5	9,6	0,0	Ga, Sp, Cp, Py	total production 16,300T Pb:9%
45	Carumbe	Pb, Cu	vein	do	do	Açungui III F L_1 limestone	-	-	-	-	-	-	-	-	-	Ga, Py, Cp, F	
46	Bras	F	do	do	do	do	-	-	-	-	-	-	-	-	-	F, Ga, Py, Cp	
47	Quarenta Oitava	Pb	do	do	do	Açungui III F S_3fs limestone	N10E, 90	-	-	-	-	-	-	-	-	Ga, Lim, Py, Sp, Tt	
48	Onça I	Pb	do	do	do	do	-	-	-	0,30	-	-	-	-	-	Ga	
49	Onça II	Pb	do	do	do	Açungui III F L_3 limestone	N10E, 85NW	-	-	-	3,0	904,	1,04	7,40	0,03	Ga, Lim, Py, Tt, Cp, Sp	
50	Rocha	Pb, Ag	do	operating	do	Açungui III F L_3 dolomite	N10~30W 60N, 60S	180~400	150~300	0,10~2,00	1	130	0,5	18,0	0,4	Ga, Sp, Cp, Py	production (1981) 2,800T/M Pb:6,5% Ag:130g/T

Ga : Galena Cer : Cerussite Py : Pyrite Ba : Barite
Sp : Sphalerite Pyro : Pyromorphite Lim : Limonite Tt : Tetrahedrite
Cp : Chalcopyrite Po : Pyrrhotite F : Fluorite

Creek a tributary of the former.

The Perau deposit which is currently in operation is a stratiform lead ore deposit emplaced in carbonate rock of the Açungui I formation. At present, the main adits are developed on the levels from G_1 to G_4, and seven sublevels have been excavated at a vertical distance of about 10 m between the main levels.

The mine workers are 90 at present, producing 850 tons of crude ore every month at the grades of 5.63% Pb and 80 g/t Ag, which is sold to the smelter (Panelas Mine) of Plumbun S.A.

(2) Geology

Geology of the surrounding area of the Perau mine consists of the Setuva formation and the Açungui I formation from the base upward (Fig. II–8 and II–9). The Setuva formation is composed of gneissose rocks and is distributed at the axial parts of the Perau anticline and the Agua Clara anticline.

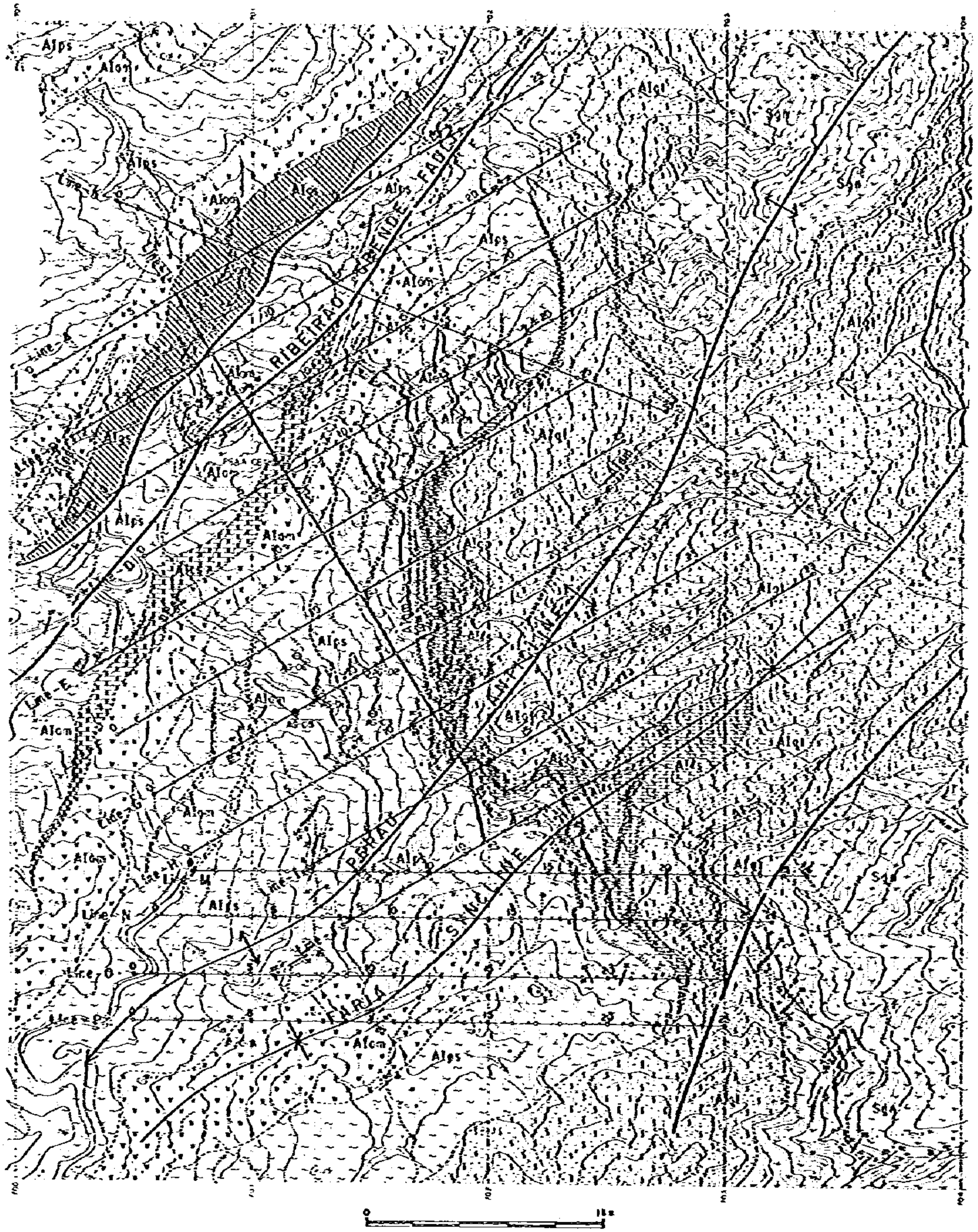
The Açungui I formtion conformably overlies the Setuva formation and consists of quartzite (AIqt), limestone and dolomite to carbonate schist (AIls), intercalated with the Perau deposit, thin layers of graphite schist (AIgp) and thin layers of dolomite (AIdo), mica schist (AIps), amphibolite to amphibole schist (AIam), calc-schist (AIcs) and graphite schist (AIgs) from the base upward. Among these, limestone and dolomite to carbonate schist in which the Perau deposit is emplaced are distributed in a form of "S" shape with the Perau mine as the center. The thin bed of graphite schist in the footwall of the ore deposit and the "magnetite zone" in the hanging wall form the effective key beds of the ore horizon (Fig. II–9).

The main geologic structure of the surroundings of the Perau mine is controlled by the Perau anticline and the Faria syncline of NE–SW system. As the fault structure, the existence of the Ribeirao Grande fault to the northeast of the Perau mine has been known.

The Perau anticline and the Faria syncline are distributed almost in parallel with the axes in the direction of N30° ~ 50°E, and the axes plunge toward the southwest. The Perau ore horizon (AIls) and the beds in the hanging wall and footwall are distributed in a form of "S", and the Perau ore horizon thinning out to the south of the mine.

The Perau mine is situated in the northwestern limb of the Perau anticline, and microstructure and crenulation is observed in the underground. It is also known that the ore shoot of the deposit and the direction of the plunge of the microfolding axes are consistent with each other.

The microfolding or crenulation is often observed in the drill cores which consist of mica schist and carbonate rocks. From the cross section of the drill holes, however, the Perau ore horizon is distributed showing almost homoclinal structure, in which disturbance of geology is not observed.



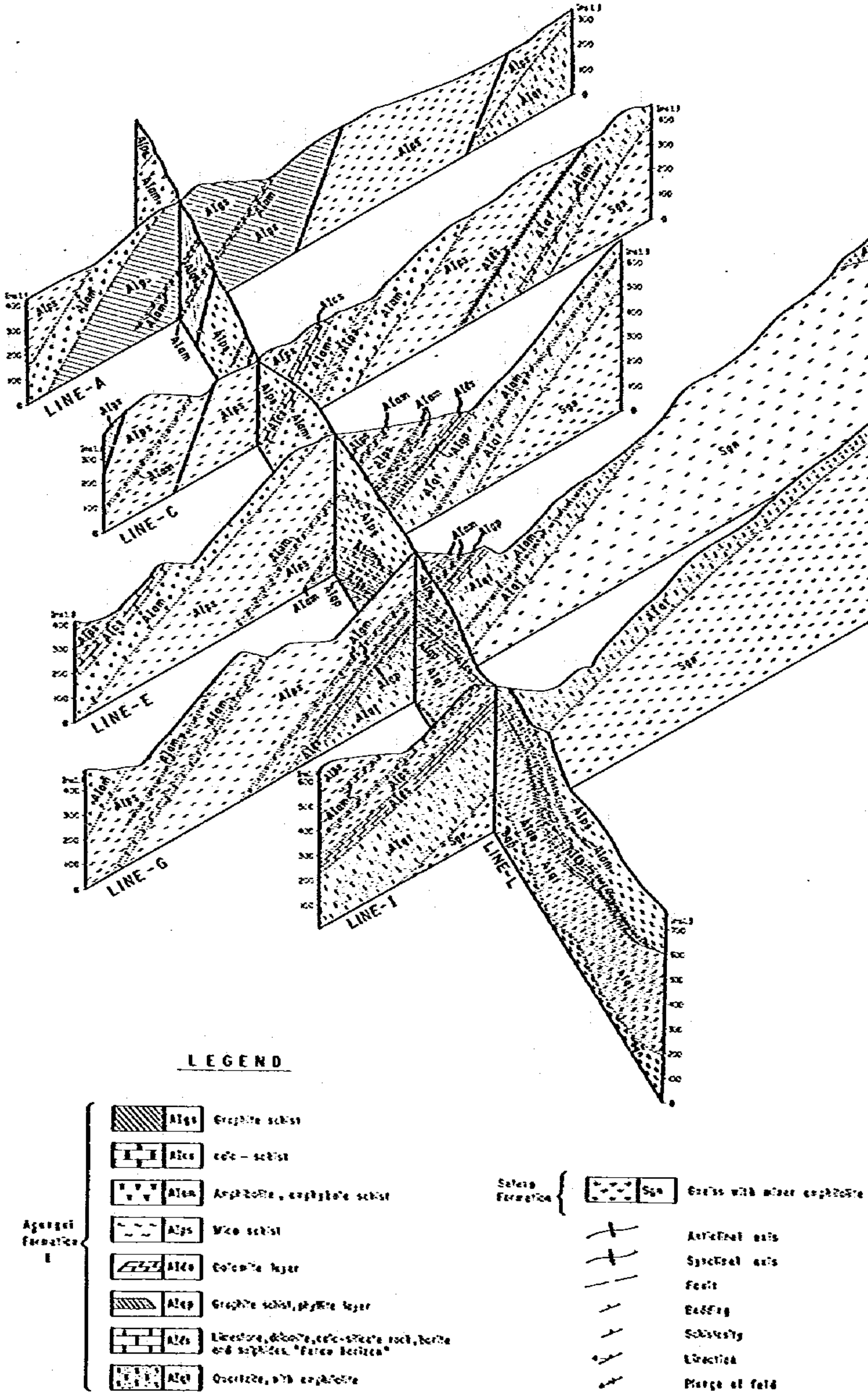


Fig. II-8 Geological Map and Geological Profile of Perau Area

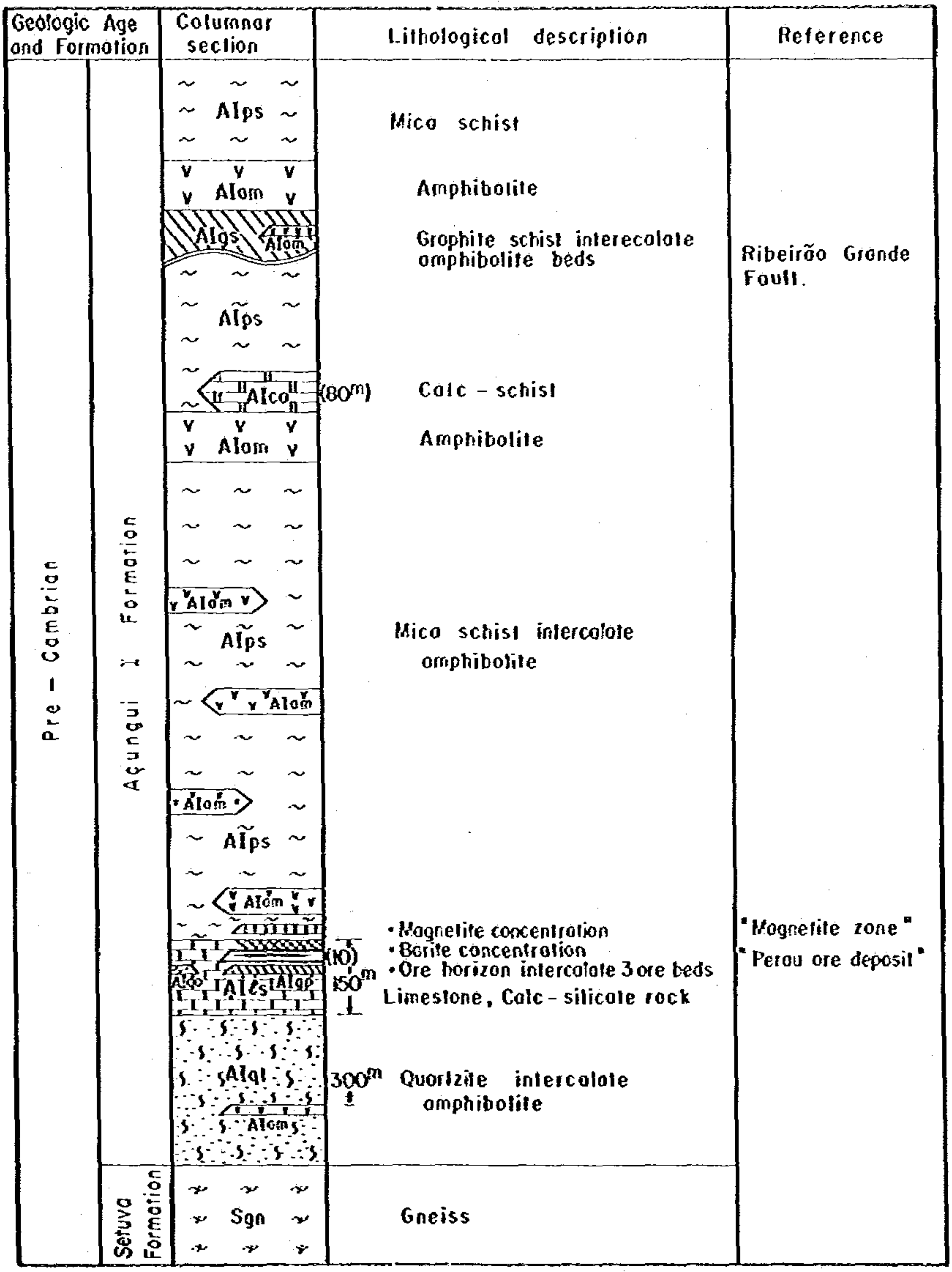


Fig. II-9 Generalized Stratigraphic Columnar Section in Perau Area

(3) Ore Deposit

(a) Outline of Ore Deposit

The Perau deposit is a lead ore deposit emplaced harmoniously in limestone and dolomite to carbonate schist (AIIs) of the Açungui I formation showing a stratiform.

An extent of mineralization about 800 m in lateral extension and about 120 m in length along the dip has been known by tunneling and exploration by drilling. The "main ore body" is found between the G_1 level and the G_2 level showing a size of about 350 m in lateral extension and about 120 m in length along the dip. In the "main ore body" several ore shoots are found being separated by swelling and pinching of the vein, and the lower limit is in the vicinity of the G_2 level about 120 m below the surface (Fig. II–10).

In the new ore deposit on the western side of the Perau mine, the ore reserves were calculated as shown in the following as the result of exploration by drilling six holes.

Ore reserves 1,000,000 tons, 4.0% Pb, 2.0% Zn, 85 g/t Ag, 14.0% BaO

(b) Mineral Assemblage of Ore Minerals

The characteristic of the ore mineral assemblage of the Perau deposit currently in operation is the existence of the main ore minerals such as galena and pyrite and subordinate chalcopyrite and sphlerite by the observation with the naked eye, and in addition, those such as pyrrhotite, marcasite and tetrahedrite observed under the microscope.

While galena and pyrite are arranged harmoniously with the bedding of the country rock showing a strate-bound form, galena show a phenomenon that it has filled the cracks in the wall rock and pyrite as a mobile fluid sometimes forming the "hanekomi, meaning plunging into" which consists of coarse galena cutting the structures of ore bed and wall rock.

The ore mineral assemblage of the barite-sulphide zone encountered by the drill survey of this time shows basically no great difference from that of the Perau deposit. However, some different characteristics are shown, such as association of barite, abundance of sphalerite and concentration of mineral grains in a certain horizon in a form of dissemination without showing any notable phenomenon of mobile fluidity.

The mineral assemblage of both the Perau deposit and the barite-sulphide zone observed in the drill core shows a characteristic of polymetallic deposit composed of galena, sphalerite, pyrite and chalcopyrite as the main constituent minerals. Especially the minerals of the Perau deposit are considered to have crystallized from the solution of low temperature and harmoniously deposited with the bedding of the wall rock.

Although the stratigraphical position of the mineralized zone can be regarded as a whole to

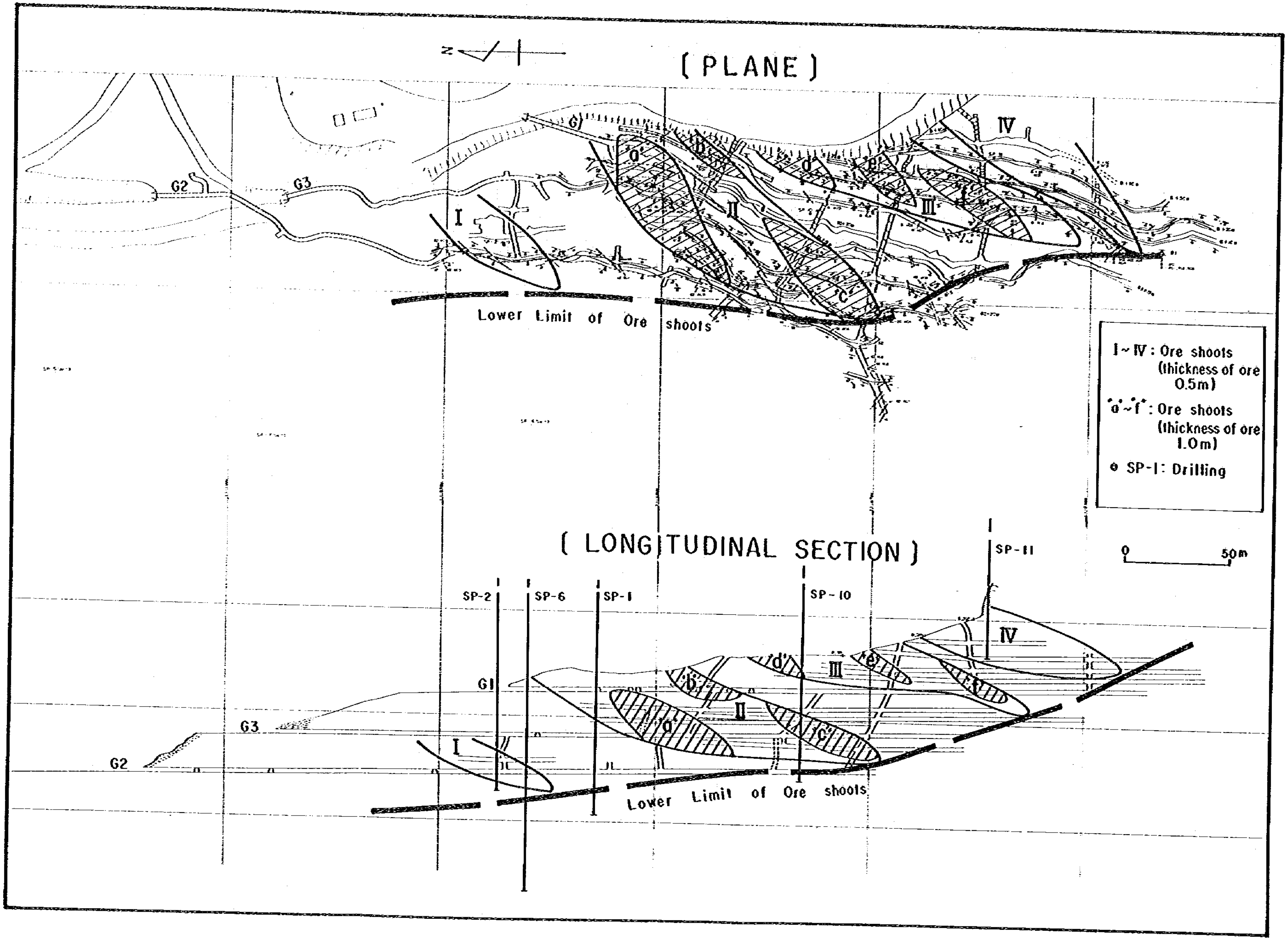


Fig. II-10 Distribution Map of Ore Shoots in Perau Mine be the same as that of the Perau deposit, it is considered that the time of mineralization of the barite-sulphide zone is a little later than that of the Perau deposit and positioned in a little upper horizon, because a mineralized zone of the Perau type was encountered in the hole AG−01 immediately below the barite-sulphide zone and because a barite-galena zone has been found in the underground of the Perau mine on the hanging wall side of the Perau deposit several meters upward from the ore horizon.

(c) Result of Assay of Ore

While it was made clear that there is a difference in the ratio of content of the main ore minerals between the Perau deposit currently in operation and the barite-sulphide zone discovered by the drill survey, such relation is well proved by the assay result.

As the result of assay of the ore samples obtained from the Perau deposit (35 samples, Table II−5), many samples showed about 10 percent in lead grade, and no difference was found between the thick part and other part of the ore bed.

The zinc grade was generally low showing those less than one percent. However, the assay grade showed that zinc was contained throughout the ore body.

Although the copper grade was shown to be very low since all the sample showed less than one percent (less than 0.1 % was shown in many samples), it was indicated that copper was contained throughout the ore body as in the case of zinc.

The maximum value of silver was 629.3 g/t among many samples which showed the grade more than 200 g/t. Although the presence of silver minerals could not be confirmed microscopically, it is considered that silver is present in galena and tetrahedrite in a form of solid solution, because galena is observed in abundance microscopically accompanied with a small amount of tetrahedrite.

As to the grade of gold, more than a half of the samples showed the values below the limit of detection. Even in the samples which showed the gold content, most of them showed very low values less than 0.5 g/t, among which 1.5 g/t was the maximum.

As shown in the above, the economically workable ore is the leadsilver ore, and copper, zinc and gold are not contained to an extent to be economically recovered judging from the assay result of chip samples obtained from every place of the deposit.

Although the regularity of grade in the directions of vertical and horizontal can not be made clear because of scarcity of data, the grade of lead and silver is almost proportional in each place, and the difference between those in ore shoot and other parts can not be recognized.

Therefore, the economically workable part in the Perau deposit is the part of the bed to have been swollen on account of geologic structure.

Table II-5 Assay Results of Ores of Perau Mine

No.	Sample No.	Location	Occurrence	Au g/t	Ag g/t	Cu %	Pb %	Zn %
1	G1-M01	Perau Mine G1L	galena impregnation W:10	0.3	270.9	0.003	11.14	0.42
2	M02	do do	sphalerite, galena impregnation W:30	0.0	267.4	0.015	9.34	4.23
3	M03	do do	galena, banded ore W:20	0.0	177.1	0.037	11.86	1.19
4	M04	do do	pyrite rich massive ore W:30	0.4	51.9	0.887	1.42	0.44
5	M05	do do	fine banded galena W:60	0.0	97.1	0.065	8.62	0.01
6	M06	do do	massive galena W:40	1.3	320.0	0.026	8.26	0.56
7	M07	do do	do W:10	0.6	453.2	0.160	12.93	0.85
8	M08	do do	massive galena vein, cutting schistosity of wall rock W:10	0.1	316.6	0.051	12.46	0.61
9	M09	do do	massive galena W:20	0.5	226.3	0.374	11.86	1.21
10	M10	do do	massive galena-pyrite W:170	0.1	193.1	0.179	4.55	0.50
11	M11	do do	galena impregnation W:70	0.1	264.0	0.013	12.28	0.06
12	M12	do do	galena impregnation W:30	0.0	116.3	0.156	4.33	0.79
13	G1+10 M03	do G1+10mL	do W:30	0.3	268.5	0.155	8.13	0.02
14	G1+20 M02	do G1+20mL	galena impregnation (clasted ore) W:50	0.0	238.0	0.023	10.47	0.59
15	G1+30 M03	do G1+30mL	massive galena W:20	0.0	629.3	0.023	11.93	0.17
16	G1+30 M05	do do	galena impregnation W:50	0.3	164.1	0.065	10.58	0.01
17	G1+40 M03	do G1+40mL	massive galena-pyrite W:10	0.1	254.3	0.687	12.22	0.03
18	G2-M03	do G2L	massive galena-sphalerite W:10	0.0	560.9	0.005	12.40	1.24
19	M04	do G2L	massive galena W:20	0.0	250.4	0.018	10.70	0.38
20	M05	do G2L	galena impregnation in Barite Zone W:30	0.0	53.1	0.018	4.21	0.03
21	M06	do G2L	galena fine impregnation W:10	0.0	165.5	0.003	12.47	2.29
22	G2+20 M4	do G2+20mL	galena impregnation W:20	0.5	359.1	0.002	6.40	0.61
23	G3-M01	do G3L	banded galena-pyrite W:40	0.0	94.6	0.030	3.00	0.01
24	M02	do do	banded galena W:20	0.2	259.8	0.008	11.74	0.04
25	G3-M03	do do	massive pyrite with galena W:10	0.0	22.2	0.014	1.11	0.01
26	M04	do do	banded pyrite-galena W:40	0.4	226.1	0.301	5.06	0.41
27	M08	do do	galena impregnation W:10	0.0	61.8	0.059	9.55	0.62
28	G3+20 M01	Perau Mining G3+20mL	galena impregnation W:110	0.0	167.4	0.001	10.84	0.01
29	G4-M01	do G4L	sphalerite-galena impregnation W:10	0.0	93.5	0.019	1.47	6.59
30	M02	do G4L	pyrite-sphalerite-galena impregnation W:20	0.0	116.3	0.007	3.82	9.99
31	A-574	do G2+8-S	galena and sphalerite in barite zone W:150	0.0	53.0	0.074	5.50	0.12
32	A-575	do G2+8-N	do W:170	0.0	52.0	0.010	5.40	0.40
33	F-685	Perau Mine	galena in barite zone	0.0	53.0	0.076	4.60	0.15
34	F-686	do	do	0.0	40.0	0.11	3.40	0.13
35	F-687	do	do	0.0	52.0	0.01	5.3	0.90

On the other hand, the result of anlysis of the drill cores obtained in this survey is as shown in Table II–6.

In the hole AG–01, the section between 255.95 m and 263.45 m was barite-sulphide zone, in which the grade of BaO was 15 to 27 %, and the values of metallic elements were about four percent in lead, about three percent in zinc, about 100 g/t in silver and 100 to 500 ppm in copper.

In the mineralized zone (263.45 ~ 269.90 m) which is absent in barite in the footwall of the barite-sulphide zone, lead grade is 2.3 to 5.0 % in this part, copper is very low in content. The silver grade is 60 to 100 g/t, showing a similar pattern as the Perau deposit.

In the hole AG–02, the barite-sulphide zone is found in two beds such as the section from 242.85 m to 247.85 m and from 251.40 m to 253.60 m. In the upper mineralized zone, lead grade is 5%, whilst zinc grade is low, showing less than 1%. Silver grade is about 90 g/t, and copper grade is of great variety showing 45 to 480 ppm. Copper is higher in grade in the carbonate rock in the upper part, locally showing 1.2% Cu. Lead grade and zinc grade show almost the same value in the mineralized zone between 251.40 m and 253.60 m, indicating that zinc is higher in grade than in the upper mineralized zone.

In the hole AG–03, the mineralized zone becomes poor, showing an appearance of the termination of the ore deposit. Zinc grade and BaO grade are low, and the grade of SiO_2 becomes high. The pattern of the mineralized zone resembles to that of the Perau deposit.

In the hole AG–04, the mineralized zone is much poor than the hole AG–03, was intersected 196.95 m to 197.15 m, 199.80 m to 199.90 m and 200.65 m to 200.75 m. The first one is the barite-sulphide zone and the two latter are the dissemination with only galena.

In the hole AG–05, the barite-sulphide zone was intersected between 354.65 m and 358.35 m. The high-grade part in this mineralized zone are 354.65 m to 355.65 m and 357.85 m to 358.35 m, which are small in thickness of mineralized part as compared with those of AG–01 and AG–02, showing an aspect to be approaching the marginal part of the ore deposit.

In the hole AG–06, the barite-sulphide zone was intersected between 327.55 m and 329.40 m. Pyrrhotite contained in abundance in this hole in comparison with another holes. This mineralized zone is conspicuously inferior to those of AG–01 and AG–02 in grade as well as thickness, and seems to be the tail end of the ore deposit.

As described in the above, the result of assay of the drilling cores shows that the barite-sulphide mineralized zone are dominant in the AG–01 and AG–02, showing the tendency decreasing the grade and thickness toward another holes.

Table II-6 Assay Results of Drilling Core of Perau Area

(1)

No.	Sample No.	Depth (m)	Width (m)	Rock Type	Pb (%)	Zn (%)	Cu (ppm)	Ag (ppm)	CaO (%)	MgO (%)	SiO2 (%)	BaO (%)
AG-01		254.95										
1	F-563	~255.95	1.00	cab-sch	0.07	0.03	90	3	11.8	6.0	39.8	2.1
2	F-564	~256.95	1.00	ore	2.1	3.3	120	100	7.7	6.6	8.0	26.1
3	F-565	~257.95	1.00	ore	1.2	3.8	70	50	11.9	9.4	5.5	17.8
4	F-566	~258.95	1.00	ore	3.3	3.5	170	110	11.9	9.4	6.7	16.1
5	F-567	~259.95	1.00	ore	5.3	3.8	110	75	12.6	9.4	4.9	15.4
6	F-568	~260.95	1.00	ore	8.9	2.2	290	150	8.4	6.9	3.4	27.1
7	F-569	~261.95	1.00	ore	3.6	0.68	590	80	18.2	13.8	4.6	7.5
8	F-570	~262.95	1.00	ore	7.5	2.6	330	130	11.2	8.6	4.0	18.1
9	F-571	~263.45	0.50	ore	1.7	4.7	50	35	6.6	5.5	10.3	27.1
10	F-572	~264.45	1.00	ore	0.19	0.84	280	12	14.0	9.4	23.0	10.9
11	F-573	~265.45	1.00	ore	5.0	0.36	250	100	14.0	9.9	34.6	0.05
12	F-574	~265.90	0.45	ore	2.3	0.41	110	60	3.4	5.3	52.3	0.05
AG-02		231.05										
13	F-629	~232.05	1.00	cab-sch	0.02	0.01	230	1	11.8	5.8	41.9	0.45
14	F-630	~233.05	1.00	cab-sch	0.32	0.02	1.2%	44	22.7	10.2	16.6	0.08
15	F-631	~234.05	1.00	cab-sch	0.08	0.01	4200	13	24.4	8.5	16.6	0.37
16	F-632	~235.05	1.00	cab-sch	0.02	0.01	960	5	24.0	12.0	14.0	0.3
17	F-633	~236.05	1.00	cab-sch	0.01	0.04	1200	5.5	18.2	6.6	24.4	0.49
18	F-634	~237.05	1.00	cab-sch	0.06	0.03	2000	11	17.4	7.7	31.7	0.71
19	F-635	~237.80	1.00	cab-sch	0.01	0.01	2400	7.5	24.0	8.3	21.1	0.15
20	F-650	241.85 ~242.85	1.00	cab-sch	0.03	0.02	75	2	12.6	7.3	38.6	0.94
21	F-637	~243.85	1.00	ore	4.9	1.7	140	76	12.3	5.8	5.4	17.9
22	F-638	~244.85	1.00	ore	6.3	0.32	480	98	13.2	6.6	6.3	22.3
23	F-639	~245.85	1.00	ore	6.4	0.16	45	98	14.3	7.7	7.5	17.9
24	F-640	~246.85	1.00	ore	6.0	0.09	70	86	11.2	5.6	10.2	22.3
25	F-641	~247.85	1.00	ore	2.4	0.29	75	76	12.3	5.6	15.6	22.3
26	F-642	~248.85	1.00	cab-sch	0.14	0.27	80	5.5	14.0	7.5	43.8	2.7
27	F-643	~249.85	1.00	cab-sch	0.02	L	40	1.5	10.4	6.0	2.8	2.2
28	F-644	~250.85	1.00	cab-sch	0.07	0.01	150	3.5	15.1	7.5	28.5	2.7
29	F-645	~251.40	0.55	cab-sch	0.25	0.03	90	8.0	15.1	6.6	33.4	1.3
30	F-646	~252.50	1.10	ore	6.0	4.5	60	68	12.2	7.5	4.3	17.9
31	F-647	~253.35	0.85	cab-sch	0.21	0.09	70	7.0	11.8	6.4	17.5	13.4
32	F-648	~253.60	0.25	ore	6.4	5.6	40	114	13.2	6.9	7.6	12.3
33	F-649	~254.60	1.00	cab-sch	0.65	0.38	160	10	11.9	5.2	32.9	4.0
AG-03		188.30										
34	F-673	~189.50	1.20	cab-sch	0.02	0.01	1200	3	9.7	4.8	53.0	1.6
35	F-674	~190.70	1.20	cab-sch	0.24	0.03	880	5	17.0	6.0	39.6	0.89
36	F-675	194.30 ~195.30	1.00	ore	3.3	0.39	350	38	9.5	3.7	35.0	8.5
37	F-676	~196.20	0.90	ore	2.0	1.6	230	35	7.0	2.5	46.5	0.67

No.	Sample No.	Depth (m)	Width (m)	Rock Type	Pb (%)	Zn (%)	Cu (ppm)	Ag (ppm)
AG-04		195.15						
38	TS-21	~196.95	1.8	amph-se-q-sch, carb-sch	0.03	0.01	190	3.5
39	TS-20	~197.15	0.2	gl.-zb. in barite	1.60	0.46	330	26
40	TS-19	~198.15	1.0	carb-sch	2.30	0.20	75	34
41	TS-18	~199.80	1.65	carb-sch	0.07	0.03	410	2.5
42	TS-17	~199.90	0.1	gl. ore	8.00	0.03	18	200
43	TS-16	~200.65	0.75	carb-sch	0.50	0.02	45	4.5
44	TS-15	~200.75	0.1	gl. ore	4.50	1.60	30	100
45	TS-14	~201.75	1.0	carb-sch	0.03	0.01	50	2
AG-05		353.65						
46	ED-124	~354.65	1.0	carb-sch	0.008	0.014	28	1
47	ED-125	~355.65	1.0	gl.-zb. in barite	2.5	2.9	100	75
48	ED-126	~356.65	1.0	do.	0.19	0.056	35	14
49	ED-127	~357.85	1.2	do.	0.06	0.07	55	8
50	ED-128	~358.35	0.5	do.	4.9	2.8	160	185
51	ED-129	~359.50	1.15	carb-sch	0.006	0.006	60	0.8
52	ED-130	~360.50	1.0	grph-sch	0.015	0.0035	40	0.8
AG-06		326.55						
53	ED-65	~327.55	1.0	carb-sch	0.04	0.01	25	1
54	ED-66	~328.05	0.5	gl.-zb. in barite	2.20	0.04	22	38
55	ED-67	~328.60	0.55	gl.-zb. poor ore	0.04	0.04	20	3
56	ED-68	~329.40	0.8	gl.-zb. ore	1.80	4.40	70	38
57	ED-69	~330.15	0.75	graph-sch	0.19	0.18	23	6
58	ED-70	~330.60	0.45	gl.-zb. ore	1.30	1.10	30	38
59	ED-71	~331.60	1.0	grph-sch	0.07	0.04	25	1

(d) Relationship between the Result of Geochemical Survey and Ore Deposit

The result of soil geochemical survey in the surrounding area of the Perau ore horizon (AIls) (analyzed elements are Cu, Pb, Zn, Ni, Co and Mn) shows that the anomalous zones of lead and zinc are consistent with the position directly above the ore deposit and that that of copper is distributed from the part directly above the ore deposit toward the south.

As the result of factor analysis by the method of multi-variate interpretation, it is considered that the factors characterized by Cu–Pb–Zn reflect the mineralization and that the zones high in the factor marks are well consistent with the distribution of ore deposit. Also it is considered that the factors characterized by Ni–Co–Mn–Zn reflect the properties of rocks such as amphibolite (AIam) in addition to limestone and dolomite to carbonate schist (AIls) which is the ore-bearing horizon and that the zones high in the factor marks are consistent with the distribution of those rocks.

(e) Relationship between the Result of Geophysical Survey and Ore Deposit

In connection with geophycial survey in the surrounding area of the Perau mine, gravity survey and electric survey (IP method and SIP method) were conducted in 1981 (Phase II), and successively IP survey was carried out in the southern part of Perau in Phase III. Among these, the new ore deposit mentioned above was discovered as the result of drill survey performed on the basis of the result of analysis of electric survey conducted in 1981.

The anomalous zones obtained in the surrounding area of the Perau mine are classified into the following four patterns:

(1) the anomalous zone consistent with the distribution of graphite schist,
(2) the anomalous zone in mica schist intercalated with pyrite-dessemination zone in the hanging wall of the Perau ore horizon and graphite schist,
(3) the anomalous zone consistent with the Perau ore horizon, and
(4) the anomalous zone consistent with the amphibolite horizon intercalated in quartzite on the footwall side of the Perau ore horizon.

Among these, the anomalous zone of (3) is the important target of the survey.

The anomalous zones of (2) and (3) are present in the area where the drill survey was carried out this time, and especially that of (2) is dominant. The result of the drill survey is consistent very well with the result of analysis of the electric survey, and graphite schist is found in mica schist in the anomalous zone of (2). In this zone, pyrite occurs along the schistosity plane in a form of film, which forms the anomaly source of the electric survey.

In the anomalous zone of (3), barite-sulphide zone, which is the new mineralized zone, is present. It is also possible that the "magnetite zone" in the hanging wall of the mineralized zone was a cause of the anomaly.

As the result of IP survey in the southern part of Perau, a part of the anomalous zone of (2) was detected, but that of (3) was not detected. Therefore, it is not likely that the mineralized zone of the Perau horizon exteds up to the southern part.

3–2–2 Agua Clara Deposit

(1) Outline of the Mine

The Agua Clara mine is situated at 6 km to the northeast of Tunas, and apart 10 km to the south-southwest from the Perau mine. Prospecting by three tunnels for copper was carried out during January 1974 and January 1976, and prospecting for barite was conducted during February 1976 and August 1977, having produced 180 tons of ore. All the operation, however, is suspended at present.

(2) Geology in the Surrounding Area of the Deposit

Quartzite (Alqt) which froms the bottom of the Açungui I formation, dolomite (50 m in thickness), calcareous schist (20 m in thickness) (Alls), and mica schist (Alps) are distributed.

Three structures trending northeast including two anticlines and a syncline are present in the neighboring area, all of which plunge toward the southwest. Thus the strike and dip of strate are inconstant.

(3) Ore Deposit

The ore deposit consists of chalcopyrite-quartz vein, in which the quartz veins, the remains of weathering have been embossed in a form of skeleton. Chalcopyrite contained as dissemination has been altered to azurite and bornite.

The assay result of the sample taken at the outcrop on the northern slope of Morro do Zinco is shown in the following.

Sample No.	Width	Au	Ag	Cu	Pb	Zn
F–81	0.20 m	0.0 g/t	8.4 g/t	0.81%	0.01%	0.01%

The deposit of barite is found in mica schist 800 m to the southwest of the copper deposit, which have been explored by the two tunnels such as Taboa and Paiol. The horizon of barite is not contained in the calcareous schist, different from the Perau deposit, but is found one meter above the boundary with that rock, being one meter in the width of ore bed. The bed contains very small amount of chalcopyrite and pyrite. The banded magnetite layers several centimeters wide are found along the walls of barite bed in both hanging wall and footwall.

3–2–3 Pretinho Deposit

(1) Outline of the Deposit

The Pretinho deposit is situated about 5 km to the east of the Perau mine and is operated as a branch mine of the Perau mine and at present, is closed. The annual production in 1980 was