REPORT ON GEOLOGICAL SURVEY

OF

ANTA GORDA

BRAZIL

PHASE I

AUGUST 1981

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

The government of Japan, in response to the request of the Government of the Federative Republic of Brazil, decided to conduct collaborative mineral exploration in Anta Gorda areas in southern Brazil and entrusted its execution to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ).

Between 12 January and 4 April, 1981, Metal Mining Agency of Japan dispatched a survey team headed by Dr. Sadao Maruyama to conduct geological survey the Phase I of the project.

The survey had been accomplished under close cooperation with the Government of the Federative Republic of Brazil and its various authorities.

This report is a compilation of the survey of the Phase I, and after the completion of the project the consolidated report will be submitted to the Government of the Federative Republic of Brazil.

We wish to express our appreciation to all of the organizations and members who bore the responsibility for the project; the Government of the Federative Republic of Brazil Departmento Nacional da Produção Mineral, and other authorities and the Embassy of Japan in Brazil.

August 1981

Keisuka Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

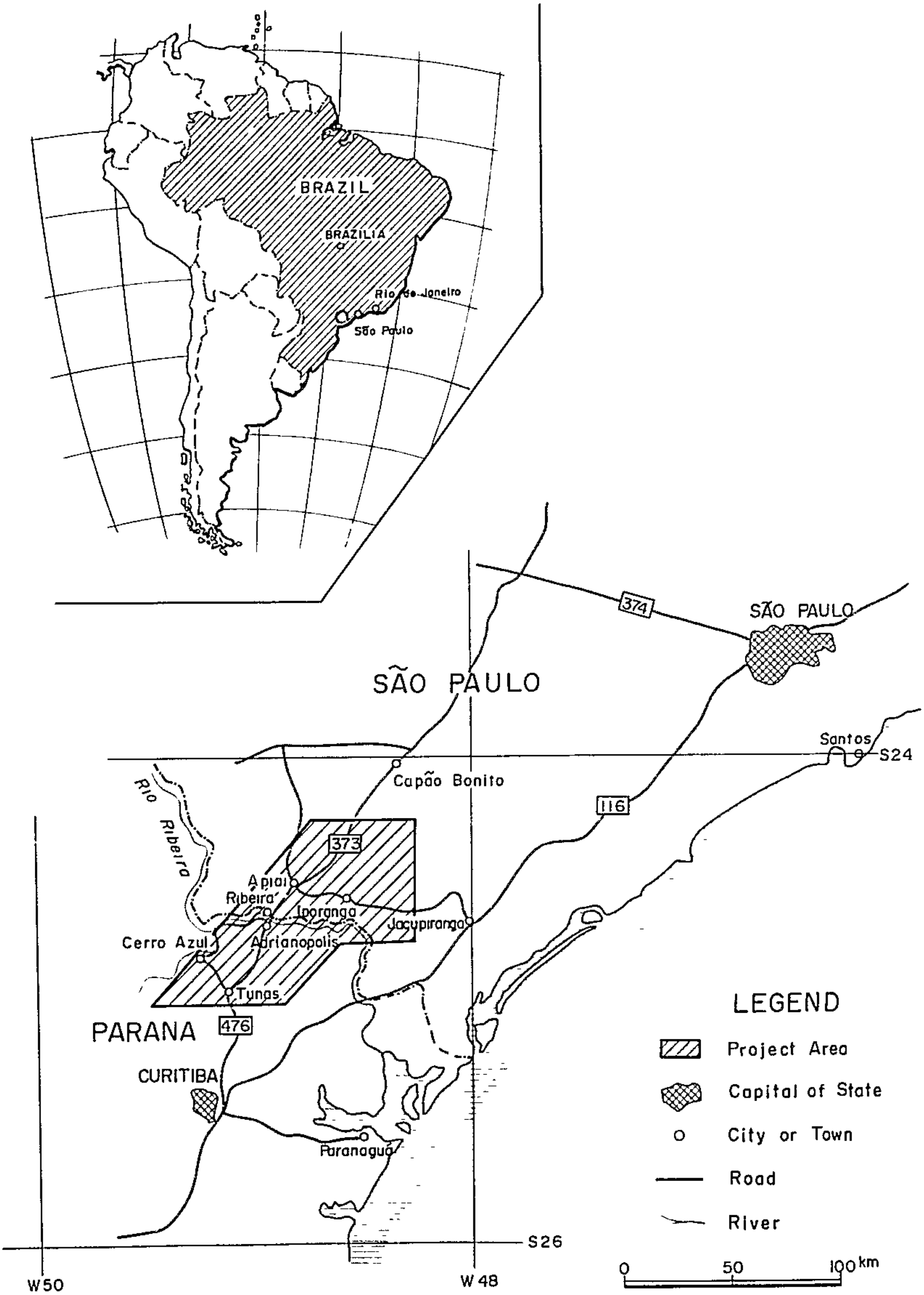
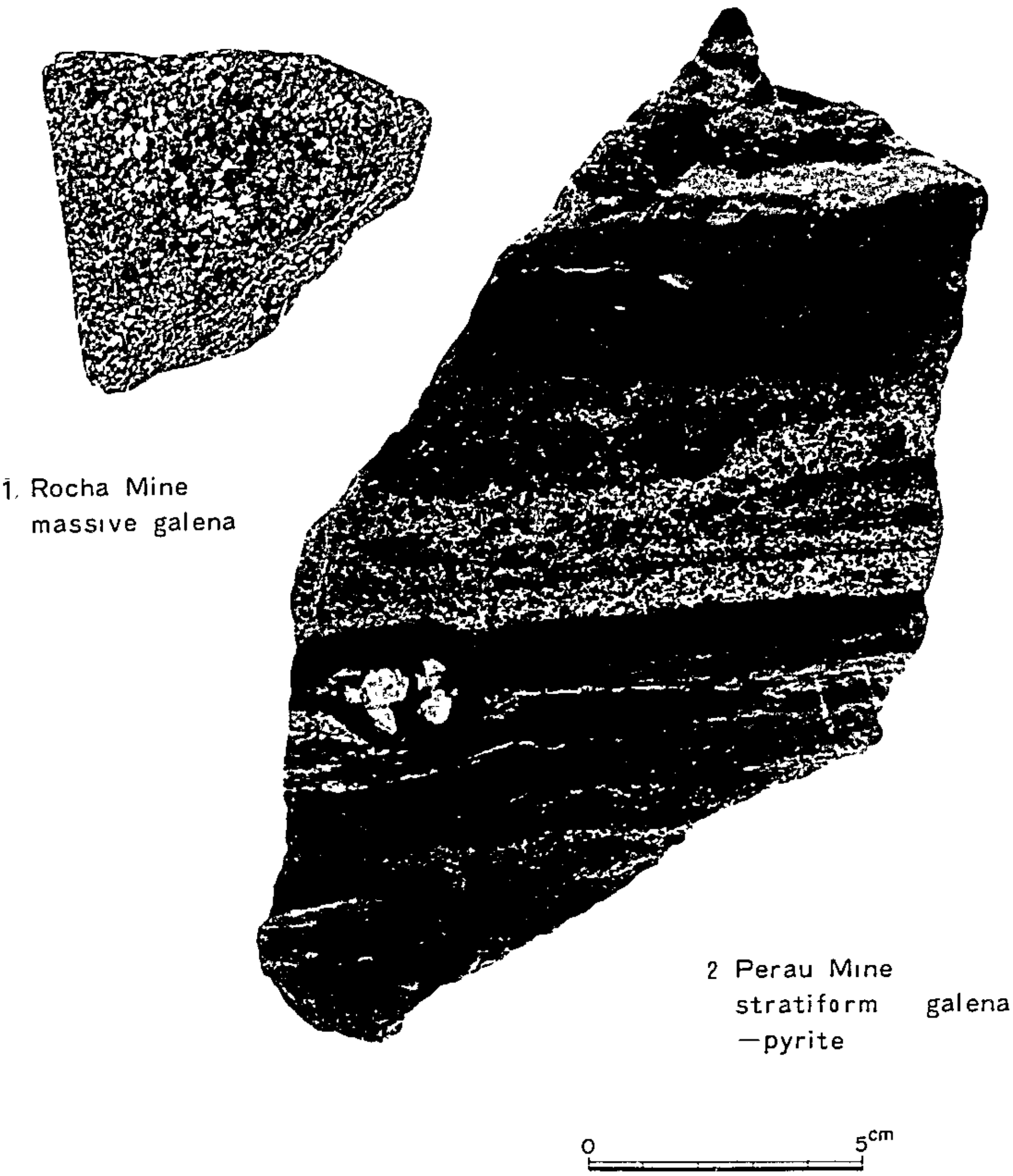


Fig. 1. Location Map of the Project Area

Landsat Image of Anta Gorda Area



Typical Ores of Rocha & Perau Mines

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ABSTRACT

Photogeological and geological survey of the Anta Gorda area in the Federative Republic of Brazil was conducted during the first year of the Project. Interpretation of existing geochemical and aeromagnetic survey data was also done to obtain a useful guide for future exploration of known silver bearing lead deposits as well as to delineate the promising areas.

Interpretation of aerial photo and geological surveys along main routes were done in order to check the correctness of the existing geological maps. As a result, the pelitic schists and calcareous rocks, which was originally grouped as the Upper Pre-Cambrian Açungui was divided into three different formations namely, Açungui I, II, and III, with distinct lithology and structure.

The silver bearing lead deposits, classified as stratiform Perau type occurs in the lower part of the dolomitic rocks, while the Rocha vein type deposits are observed in the upper portion. The former deposit is found specifically in the Açungui I formation. Since the ore - bearing strata is repeatedly exposed by folding, the high potential area for ore deposits has enlarged. On the other hand, the latter deposit could be divided into two categories namely the deposits which developed only within the dolomite and the fissure filling deposits which developed at the axial part of the folded limestone bed. Both of which, are controlled by the lithology and structure of the country rock. A more detailed survey is necessary in the future exploration of the Anta Gorda Area.

Geochemical survey data were interpreted on the data processing for their copper, lead, and zinc contents. As a result, three more anomalous zones of copper were indentified in places which are believed to be lying in the same horizon as that of the Perau type deposits. Therefore the potential of ore mineralization in the area has increased, though the highly anomalous zones were the same to those of the past data.

By interpretation of the aeromagnetic survey data, a magnetic structure map was produced on the southern half of the surveyed area since the existing data of magnetic variation map was available only for this area. As a result, occurrence of the tectonic lines and the shape of intrusive rocks were made clear. For some parts, only magnetic variation maps were produced because of a shortage of detailed data making it impossible to interpret fully the distribution of weakly magnetic rocks bodies wherein lead deposit might be present. In view hereof, it is necessary to interpret the aeromagnetic survey data over the whole area to make a detailed interpretation of the geological structures in the area.

GENERAL REMARKS

CHAPTER I INTRODUCTION

1–1 Purpose and Scope of the Survey

The purpose of this survey is to establish the geology and stratigraphy of the area which is very useful for exploration and delineation of ore deposits present in the area. A total of 5,800km^2 were covered during the survey.

Many small lead deposits has been known in the surrounding area of the Ribeira valley bordering the two states of São Paulo and Parana. Some of which are in operation and others are under development.

Although many studies have been conducted on these deposits, no definite theory has been established as to the paragenesis of the ore mineralization.

1–2 Details of the Survey

During the first phase of the survey, photogeological and preliminary geological survey including interpretation of existing data on geochemical and aeromagnetic surveys conducted by D N P M (Departamento Nacional Produção Mineral) was carried out.

Among the surveyed area, a geological map with a scale of 1:50,000 was prepared in 1974 by Projeto Sudelpa of C P R M (Companhia de Pesquisa de Recursos Minerais = Mineral Resources Investigation Corporation) on the side of São Paulo which is located on the northern part of the area. C P R M is now making a geological map of the southern part of the area under the Projeto Chumbõn (Lead Project).

In addition, C P R M also compiled in 1974, a geological map with a scale of 1:100,000 from existing data of private organization named as Projeto Leste do Parana (Eastern Parana Project), which covers about 70% of the surveyed area.

The geological survey team is composed of five Japanese engineers and six Brazilian engineers. Mapping was carried out along four routes which are perpendicular to the geological structures. Maps mentioned were effectively used to consider both stratigraphy and geological structures.

Landsat analysis including photo interpretation was made in Japan. These studies and interpretation of major structure were made prior to the field survey. Interpretation of detailed structures were made after the survey.

Interpretation of the Cu, Pb and Zn values of selected geochemical samples previously collected by D N P M (C P R M) in connection with the Projeto Geoquimica no Vale do

Riveira was done. These samples were selected so as to obtain a homogenous sample pattern.

By interpreting the data on aeromagnetic survey, a magnetic structural map was produced in order to analyze its geological structures. In this case, however, only a magnetic structural map on the southern part of the sruveyed area was made since no data was available for the northern part.

The schedule in detail of the geological survey of the project area for the first year is shown in Table I.

Table 1. Outline of Field Survey in Phase I

	Period	Length of Survey Route
Preparatory Work	Jan. 12, ~ Jan. 29, 1981	――
Route Survey	Jan. 30, ~ Mar. 4, 1981 Mar. 12, ~ Mar. 24, 1981	Route Survey 313 Km (1:10,000) Check Survey 58 Km (1:25,000)
Mine Survey	Mar. 5, ~ Mar. 11, 1981	――
Compilation	Mar. 25, ~ April 4, 1981	――

The authors wish to express their thanks and gratitude to the Geological Survey of Japan especially to Dr. Akira Sasaki for radiometric dating, Dr. Toshio Igarashi and Dr. Tadashi Fujinuki for some instructions about limestone which are very important in the preparation of this report. Honorary professor Hajime Yoshizawa of Kyoto University and Dr. Mitsuo Hashimoto of National Museum are likewise acknowledge for their useful advices and petrographic indentification of rock samples.

1–3 Organization of the Survey Team

Geologists of C P R M and I P T (Instituto de Pesquisa Tecnologica do Estado de São Paulo) commissioned by D N P M jointly participated in the field survey. Participation of the members of the survey team both on the field and in the interpretation and analysis of results in Japan is as follows:

Japan Side Planning and Negotiation

Nobuhisa Nakajima	Metal Mining Agency of Japan

Brazil Side Planning and Negotiation

Luis Eraldo	Departmento Nacional da Produção Mineral
Fernando Batolla Júnior	Companhia de Pesquisa de Recursos Minerals

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	Kiyohisa Shibata	do
	Masakazu Kawai	do
	Hiroshi Takahashi	do
Photointerpretation (in Japan)	Yoshiaki Shibata	do
Aeromagnetic Interpretation (in Japan)	Asahi Hattori	do
	Susumu Sasaki	do
	Toshio Tajima	do

Brazilian Survey Team

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	Jose Carlos Garcia Ferreira	do
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	Paulo de Tarso Peroso	do

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CHAPTER 2. OUTLINE OF THE SURVEYED AREA

2–1 Location and Accessibility

The surveyed area extends in both states of São Paulo and Parana. São Paulo, the largest city in Brazil with a population of 10 million (1975) is about 200km to the notheast of the area. São Paulo State Highway No. 373 and Parana State Highway No. 476 pass through the center of the surveyed area. Apiai, the largest town in the area with a population of 8,000 and 320km from São Paulo City was the base during the survey. Apiai can be reached five hours by car from São Paulo city and four hours by car from Curitiba (170km.), the capital city of Parana, with a population of 1 million (1975). On the eastern portion of the surveyed area, State Highway No. 116 (a main highway) runs from São Paulo to Curitiba. A 115 kilometer road connects Apiai to the towns of Jacupiranga via Iporanga which takes about 3 hours drive.

Regular bus services ply from Ribeira, located as the border of the states, to São Paulo and Curitiba several times everyday. Air service is not available within the area.

2–2 Topography

A geomorphologic structure parallel to the eastern coast of Brazil predominates in Pre-Cambrian shield (Suguio K. 1971). A NE–SW structure system is well observed in the surveyed area and its vicinity. This is well manifested in the topography: Mar Range with 1,000 – 1,500m in elevation on the eastern side of the area and Paranapiacaba Range on the west. Both ranges are composed of granitic rocks which is controlled by the NE–SW trending geological structures in the area.

The surveyed area ranges in elevation from 600 to 1000 meters above sea level. A basin is formed by the two mountain ranges and is found in the center of the area. The west side is higher in elevation.

The area is being drained mainly by the Ribeira river which flows eastward and meanders in the center of the area. Dendritic drainage system is developed in comparatively gently rolling areas and is underlain by granitic rocks, particularly on the eastern margin of the Paranapiacaba range. Deep V- shaped valleys with Karst topography are manifested in the limestone area. On the eastern most part of the area which is underlain by phyllites and schist, trellis or parallel valleys are developed which is believed to be related to tectonic line. On the other hand, the southeastern portion of the area which is underlain by quartzite, a

NE–SW folded mountain ranges is present, thus giving emphasis to the geologic structure in the area.

2–3 Climate and Vegetation

The climate of the surveyed area belong to the type of temperate zone and the change of four seasons is relatively defined. Summer time is from January to March and it is common that the maximum temperature rises above 35°C. On the contrary, winter is from July to September and temperature often goes down to almost 0°C.

Virgin vegetation is scarse because the land is agriculturally developed and/or used as pasturage for animals almost up to the top of the mountains. Second growth trees often grow closely along the valleys. Pinheiro or Brazilian pine are often planted along the road.

CHAPTER 3. GENERAL DISCUSSION

During this phase, field survey and interpretation of the existing data were carried out in order to obtain knowledge necessary for the planning of the survey exploration to be done in the next phase. A number of new facts and problems to be solved were encountered during the survey. Problems related to the ore deposit will be discussed in this chapter.

3–1 Ore Bearing Horizon of Perau Type Deposits

The stratigraphy of the area consists of Upper Pre-Cambrian rocks such as the Setuva Formation and the Açungui I, II, and III formations. The Perau deposit is a stratiform silver bearing lead - (copper - zinc) ore deposit which occurs in the calc-silicate rock on the lower portion of the Açungui I formation and is associated with thin layers of barite and magnetite immediately on the upper side of the ore.

The outcrop of the calc-silicate rock which is the host rock of the ore deposit continues for more than 10 kilometers up to the Aqua Clara deposit on the south along the Setuva formation which appears to be the core of the anticline located on the east side of the Perau deposit. Sometimes calc-silicate rocks grades into dolomitic beds.

The Pretinhoe mine is located on the eastern side of the Setuva formation (the eastern wing of the anticline) wherein a thick bed of barite (1–2m. in thickness) occurs in calc-silicate rock and a thin layer of magnetite in a biotite schist is also found to be similar to the Perau deposit. In this barite bed, several stringers of chalcopyrite that are less than 1mm. are present which are parallel to the bedding plane and is associated with a very small amount of lead and zinc (54 ppm Pb, 61 ppm Zn). Since the stratigraphy of the Pretinhoe deposit and the Perau deposit are almost the same, continuation of the calcareous rock beds might also be present on the eastern side of the Setuva formation. Since Setuva formation is repeatedly exposed more on the eastern side due to folding and is observed on the southeastern portion of the surveyed area, therefore, it is also possible that the ore bearing horizon of the Perau deposit might have also been repeatedly exposed.

3–2 Structural Control of the Rocha Type Deposits

The Rocha type deposit is a vein type deposit present in limestone of the Açungui III formation. This type of deposit is closely related to the lithology and folding structures in the area.

In the Rocha mine, a thick bed of calcareous rock is divided into limestone (300m in width) and dolomite (150m in width). By means of underground geological survey and examining the drill core, it was found out that the ore vein occurs only within the dolomite bed. Development of fissures in the dolomite rock is an evidence that it is different from that of the properties of the limestone, however, a detailed survey for fact finding will be necessary in the future. Because of difficulty of macroscopical differentiation of dolomite from limestone in the area, it is desirable to elucidate the mechanism of structures controlling the lead deposits occurring in number in the surrounding area of the Rocha mine by means of making the most of field tests by using inorganic or organic reagents.

On the other hand, the Furnas deposit and the Lageado deposit occurring in limestone on the areas are the vein type deposit which is parallel to the axis of a large synclinal structure or the stratiform or the echelon type of deposit in a certain horizon of this limestone bed. The detailed mechanism of the structural control in the area will be made clear by investigating carefully the detailed structures in the limestone.

3–3 Genesis of Lead Ore Deposits

Years ago, various discussions have been made on the genesis of the lead deposits present in the limestone ~ dolomitic rocks in the area and many believed that it is magmatic in origin.

Oliveira A. I. (1937) discussed the genetic relation between the ore deposit and granite occurred near the deposit. Borbosa A.F. (1955) concluded from the survey of the Furnas deposit that the genesis of ore deposit was related to the granite exposed in the area from the following facts:

1) mineralization took place in two stages.
2) no colloform structure had been found and the crystals of galena grew toward the inside from the boundary of the ore and the country rock.
3) silification and sericitization were observed.

On the other hand, Damasceno E.C. (1966) identified the time of formation of lead deposit of the area to be 1,130 m.y. from the measurement of lead isotope in galena and described that the deposit was older than the intrusive granite which was showed by the K-Ar dating and is 550 m.y.

Melcher G.C. (1968) suggested the possibility of a lead bearing hydrothermal solution which existed in the older sediments than the Açungui formation because the lead content of the formation as well as granite is relatively low.

Table 2 Pb Isotope Ages of Galena, Ribeira Valley Region

Jazida	Relacões isotópicas		Idade aparente (m.a.)	
	Pb_{207}/Pb_{204}	Pb_{206}/Pb_{204}	Holmes-Houtermans	Russel-Farquhar
Esperanca	15,65	17,01	1040 ± 100	1140 ± 100
Basseti	15,59	16,92	1040 ± 100	1140 ± 100
Paqueiro F1	15,51	16,82	1030 ± 100	1110 ± 100
Paqueiro F1	15,59	16,90	1060 ± 100	1120 ± 100
Paqueiro bis	15,59	16,78	1170 ± 100	1200 ± 100
Paqueiro bis	15,65	16,83	1170 ± 100	1220 ± 100
Panelas	15,54	16,66	1190 ± 100	1260 ± 100
Furnas	15,54	16,97	950 ± 100	1040 ± 100
Lageado	15,61	17,00	1030 ± 100	960 ± 100
Itapirapuã	15,73	17,98	400 ± 40	480 ± 50

Odan Y. (1978) considered the dark colored bed several centimeter wide with lead content of 0.1–0.5% intercalated in limestone in the Panelas deposit and its surroundings to be an evidence of sedimentary origin.

The result of the survey, it was confirmed that the Perau deposit is a stratiform type of deposit (Cu, Pb) in calc-silicate rock associated with thin layers of barite and magnetite in the immediate upper part of the host rock and that, in the Agua Clara deposit on the southern extension of Panelas and in the Pretinhoe deposit (barite) on the eastern extension, the beds such as chalcopyrite–(galena), barite and magnetite occurred in the same stratigraphical position. Therefore, it is highly possible that the deposits of this type were formed concurrently and syngenetically.

In addition, it is desirable to make further investigation on the relation between the formation of the Perau deposit and igneous activity of amphibolite because (1) calc-silicate rock or dolomitic rock which form the country rocks of the deposits often coexist with amphibolite and because (2) dissemination of chalcopyrite is observed in amphibolite.

On the other hand, the Rocha or Furnas type deposit emplaced in limestone ~ dolomite of the Açungui III formation in the form of vein and has an epigenetic character. As to the origin of this type, the following processes are considered:

(1) the deposit syngenetically formed with the surrounding country rocks was melted by tectonic movement and brought to the present position.

(2) ore solution was separated in relation to the granitic intrustion and filled the fissure. In the case of (2), there is a conflict of evidence that the age of lead isotope is older than that of granite. However, since the modified model of the Holmes-Houtermans and Russel – Farquhar models are generally used at present because these models are at variance with the real conditions, it is desirable to make remeasurement of the age of lead isotope.

3–4 Metamorphism

Because the route of field survey was limited to some main routes, confirmation of the continuation of key beds and elucidation of geological structure were made by making the most of the result of air photo interpretation. As a result, the Açungui group was able to be divided into three formations and the existence of synclinal structure which runs approximately through the center of the Açungui II formation was established, which resulted into a well-defined geological structure.

In connection with the study of metamorphism, however, some problems remained unsolved: the Açungui I formation mainly consists of crystalline schist and the Açungi II consists of phyllite showing higher metamorphic grade in the lower formation, while on the contrary, the result of survey in the northeastern part between Iporanga and Barra do Turvo revealed that the metamorphic grade of the Açungui I is lower than that of the Açungui II. Therefore, it is considered to be important to make further study on metamorphism to make more clear the structural development of the area.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

To obtain a useful guide in the survey and exploration of ore deposits in the further, it is important to define clearly the geological environment and character of the deposits and their distribution in the Ribeira River Basin. Photogeologic study and geological survey along the main routes including analysis of data on geochemical prospecting and aeromagnetic survey were carried out. In view of the above, the following conclusions and recommendations are summarized:

1. The surveyed area is consists of Upper Pre-Cambrian rocks in which the Açungui group was divided into three different formations namely Açungui I, II, and III with distinct lithology and structure.
2. A NE–SW structure system prodominates in the surveyed area. This fault system and a number of monor folding of the calcareous and granitic intrusiton are possibly due to the Brazilian Orogeny (650 – 450 m.y.)
3. The silver bearing lead deposits, classified as stratiform Perau type occurs in the lower part of the dolomitic rocks, while the Rocha vein type deposits are observed in upper portion.

   The Perau type of deposits are found emplaced in the same horizon where the Agua Clara and the Pretinhoe deposit occur. In both deposits, barite and magnetite are found associated on the hanging wall whose presence perhaps tends to suggest syngenetic origin. Similarly, amphibolite considered to have been originated from volcanic activity that is frequently exposed in the area also suggests the genetic relation with the ore formation.

   Deposits such as Rocha, Furnas, Lageado, Panelas are included in the Rocha type deposit. These deposits are emplaced in fissures caused by folding. The Rocha deposit shows a remarkable control of the country rock, that is, it occurs only in the dolomitic beds.
4. Results of analysis of geochemical data indicated copper anomalies in the same horizon where the Perau deposit occurs. This situation is recommended to be verified and checked in the future.
5. Analysis of the aeromagnetic survey data that was carried out on the southern half of the surveyed area and the study of the magnetic structural map showed clearly

the distribution of the intrusive rocks.

A detailed study as to the relationship between the distribution of the weak magnetic bed in which the lead deposit occurs and the intrusive rocks is recommended.

6. As mentioned above, to supplement the data gathered during the first year of the survey, the following follow-up investigations are recommended.

6–1. In order to clearly define the relationship between geologic structure and ore deposition, a semi-detailed to detailed geological investigation of potential areas where occurrence of lead deposits has been pinpointed should be conducted.

6–2. To understand further the loci of ore deposition and the characteristics of the ore deposit, a detailed geological and geochemical mapping including a geophysical survey (gravity, IP etc.) on the Perau deposit and the Rocha deposit should be carried out. The survey may be used as a model to promote the survey and exploration of stratiform and vein type deposits in the future.

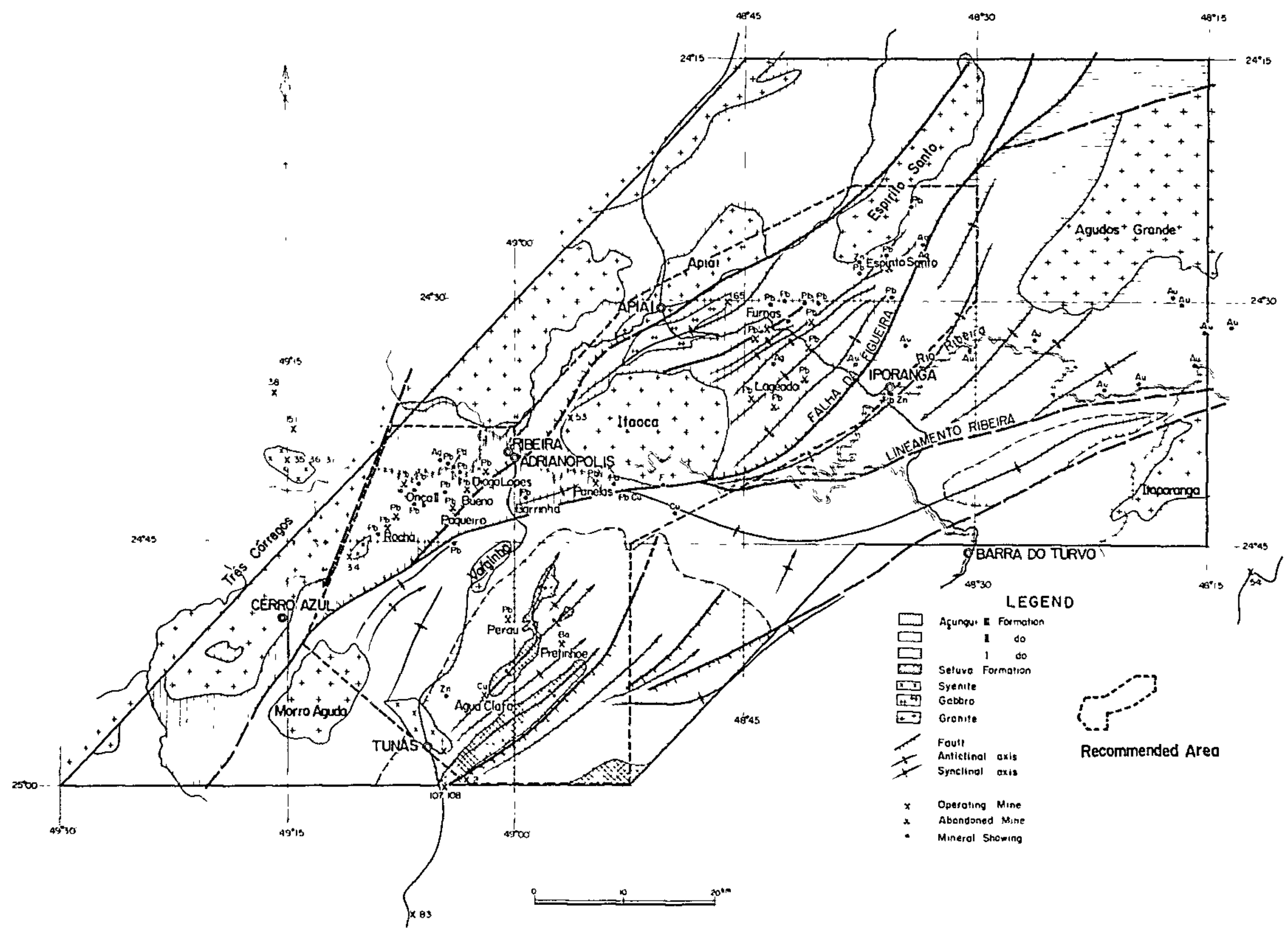


Fig. 2. Recommended Area to be covered in next Phase

PART I GEOLOGICAL SURVEY

CHAPTER 1 GEOLOGY

1–1 Previous Works

It is estimated that the Precambrian System overlies about two third of the whole land of Brazil. The distribution is generally divided into three regions such as Guianas, Brasil Central and Atlantico (Fig. I–1). The project area belongs to the southern massif of

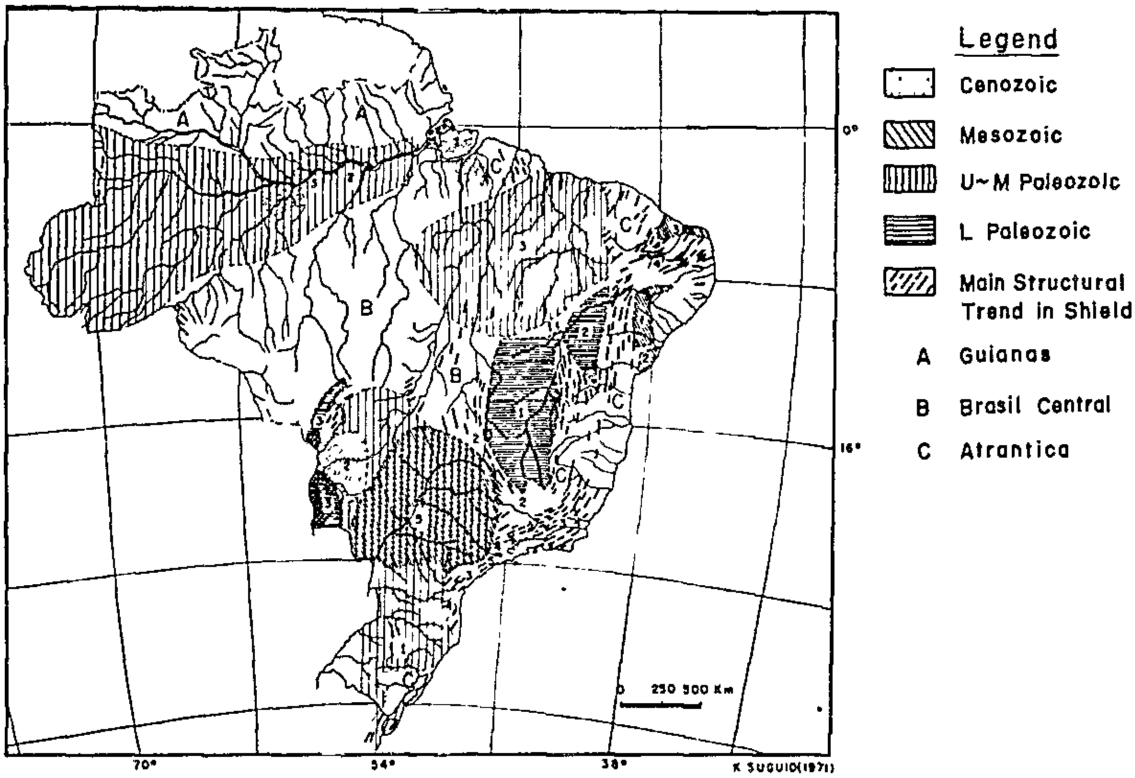


Fig. 1–1 Main Tectonic Map in Brazil

Atlantico. More than 1,500 radiometric datings were made on Precambrian rocks of Brazil by Cordani and others. According to them, Imatacan Orogeny, 3,000–2,700 m.y., Trans-amazonian Orogeny, 2,000–1,800 m.y. and Uruaçuan Orogeny, 1,400–900 m.y. took place. After these, further broad Brazilian Orogeny occurred in the range of 650–450 m.y.

The geology of the surveyed area and its surroundings was compiled in the geological map of Curitiba (1:1,000,000, 1974) by DNPM. According to the explanatory note of the map, most of the radiometric ages of the rocks belong to 500–600 m.y., among which no data indicates the age before Transamazonian Orogeny.

Kaefer L.Q. et al. (1972) considered that the crystalline complex which forms the basement of the area mainly consists of highly-crystalline migmatite and that it was produced as the result of metamorphism in the mesozone or katazone. Fuck R.A. et al. (1971) considered that the complex belonged to the older orogeny than Brazilian Orogeny because its metamorphic grade was clearly different from that of the overlying Açungui group and the radiometric age was also older.

The Setuva formation which consists of various kind of crystalline schists. It was formerly considered to be the base of the Açungui group (Bigarella J.J. et al. (1956) but was separated from the Açungui group by Mariri O.J. et al. (1967). Although Fuck R.A. et al. (1971) and H. (1971) observed the unconformity between them, Coutinho H.M.V. (1971) has been skeptical about the existence of unconformity because the Setuva formation would have been correlated to the crystalline complex from lithology, structure and metamorphic grade. Kaefer L.Q. et al. (1972) consider that the metamorphic grade of the formation corresponds to albite-epidote-amphibolite ~ amphibolite facies and that the time of sedimentation was Precambrian as mentioned above, and claim that K-Ar ages would contain controversial problems. The thickness of the Setuva formation was estimated by Marini O.J. et al. (1967) to be 3,500m.

The Açungui group was at first called São Roque series in São Paulo state and considered to be Silurian. However, in 1943, Oliveira et al. gave the group the name of São Roque & Açungui series and correlated it to the Minas series (absolute age, 1,650 – 1,340 m.y.) of Algonkian Group. Almeida F.F.M. (1967) discussed the origin and development of the Brazilian shield and concluded that the group represented the sedimentation of ortho-geosyncline of the Baikalian cycle (the latest stage of Precambrian).

Table 1–1 shows the stratigraphical classification in the geological map of Critiba, 1:1000,000 (mentioned above), and it is adopted in this report.

The Açungui group mainly consists of fine-grained metasediments and chemical sediments. The thickness measured by Maack R. et al. (1947) is 5,000 – 7,000m. Melcher G.C. et al. consider that the rocks have undergone metamorphism corresponding to green schist facies.

Cordani U.G. et al. (1967) discussed the development of geological structure of the Açungui group. According to him, the main orogenic stage was 600–650 m.y. ago followed by various kinds of orogenic movements until 500 m.y. ago, which accelerated granitic intrusion.

Table 1–1. Pre-Gondwana Unit in the Northeast of Curitiba

Era/Período	Grupo/Sub-Grupo	Formação
Devoniano	Campos Gerais	Ponta Grossa
		Furnas
Cambro-Ordoviciano	Castro	Guaratubinha
Cambriano		Camarinha
Pré-Cambriano A	Açungui	Granitos intrusivos Metassedimentos
Pré-Cambriano B		Setuva
Pré-Cambriano Indiviso	Complexo Cristalino	

Pré-Cambriano A (570–1,000 my), Pré-Cambriano B (1,100–1,700 my)

In terms of the ore deposits, the lead deposits in limestone and dolomite of the Açungui group have been known since old time. According to the detailed study of Melcher G.C. (1968), the type of the ore deposits can be divided into the fissure filling type (Panelas, Rocha) and the pocket type (Furnas, Lageado).

Although Leonardos O.H. (1956) and others considered that the deposits belonged to a typical hypogene deposit, and has a genetic relationship with the granite exposed in the surrounding area. Damasceno E.C. claimed that Pb-isotop dating of galena showed older age than that of the intrusive granitic rocks, and Melcher G.C. considers that the deposits were concentrated to the present locations by remobilization from his study on Pb contents in metasediments of the Açungui group.

1–2 Outline of Geology

The Setuva formation and the Açungui group are widly distributed in the surveyed area. According to the time classification used in Brazil, it is considered that the former belongs to B (1,100–1,700 m.y.) and the latter to A (570–1,100 m.y.). The Setuva formation consists of gneissose rocks and the Açungui group, crystalline schits and phyllite because especially the Açungui group generally shows a remarkable folding with poor existence of key-bed and because of the absence of fossil, the exact thickness of the formation can not be measured and the geological structure is difficult to understand. However, as the result of the

route survey and airphoto-interpretation of this time, zoning of the geology developed with amphibolite and limestone was made tentatively dividing it into three zones such as I, II and III in an ascending order.

As the igneous rocks, granite of late Cambrian having been intruded the metamorphic rocks mentioned above as well as syenite, gabbro and diabase belonging to Cretaceous are distributed, all showing a northeast trend.

The outline of geology of the area is shown in Fig. 1–2 and the generalized geological section is shown in Table 1–2.

1–3 Stratigraphy

Some consideration will be made refering the geological results obtained from the main routes, photo-interpretation map and existing geological maps.

1–3–1 Setuva Formation

The Setuva formation is the oldest beds in the surveyed area and mainly consists of augen gneiss.

Distribution and thickness:

The formation is exposed as the core of anticlinal structure along the road from Tunas to Anta Gorda village at the southern corner of the surveyed area, where the repeated exposure of the formation can be observed. It is difficult to estimate the whole thickness of the formation because the bottom of the formation is not exposed there, it measured 500m within the limit of exposure.

Rock facies:

The rock is considered to be originally pelitic. It mainly consists of augen gneiss intercalating quartzite. The gneiss is dark green and massive rock which includes pinkish red felspar in a form of augen structure. In some places, a banding structure, viz. alternation of felspar-rick part and mica-and epidote-rich part, is observed. Schistosity is not so developed. The augen gneiss exposed along the route from Tunas to Anta Gorda village is intercalated by white and a little coarse grained quartzite (200m. in thickness). The upper section of the augen gneisses (150m. in thickness) is similar to biotite schist, but fine grained felspar (1–2 mm.) is partly included in the spotted form.

The mineral assemblage of gneiss of the area generally consists of biotite hornblende,

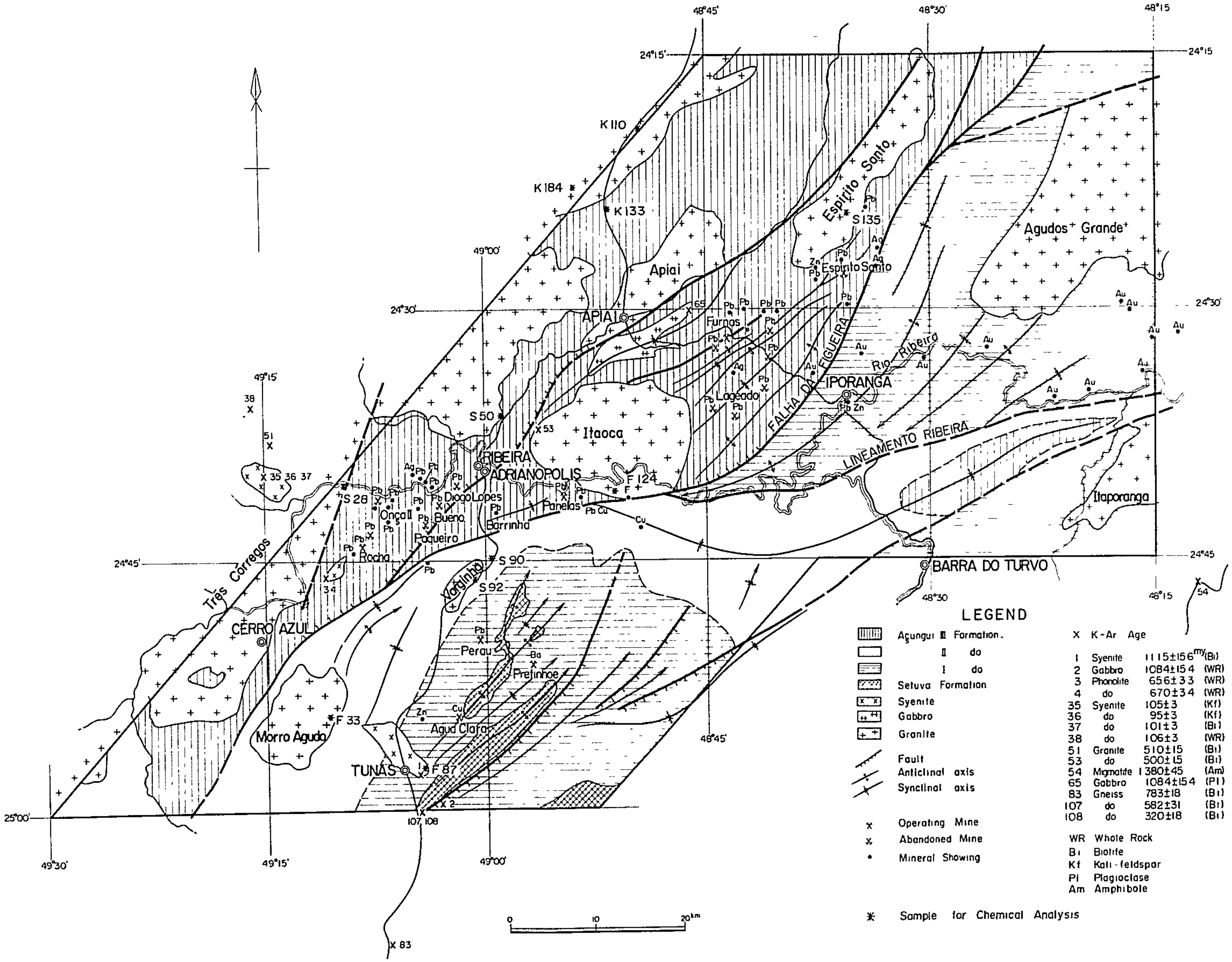


Fig. 1–2 Geological Map of the Project Area

Table I–2 Generalized Stratigraphic Section in the Project Area

Geologic Age		Group or Formation		Columnar Section	Rock Facies	Structural Movement	Igneous Activity	Mineralization
Quaternary					gravel, sand			
Cretaceous							syenite, gabbro, diabase	
Cambrian						Brasilian Orogeny	granite	? Rocha, Furnas type
Pre - Cambrian	A 570 ~ 1100my	Agungui G	III F 2000m±		psammitic and pelitic schists with thick limestone at the top			
			II F. 2000-2500m		phyllite (West) and mica schist (East) with a few psamitic schist, amphibolite and dolomite			
			I F 3500m		garnet bearing mica schist with dolomite and amphibolite seams, thick quartzite and dolomite at the bottom.	Uruacuan Orogeny	basalt	Perau type
	B 1100~ 1700my	Setuva F 500m+			augen gneiss with quartzite seams.			
	Undiffer-ential	Crystalline Complex no-exposure			migmatite, gneiss, quartzite schist, dolomite (after DNPM 1 1,000,000 Curitiba)			

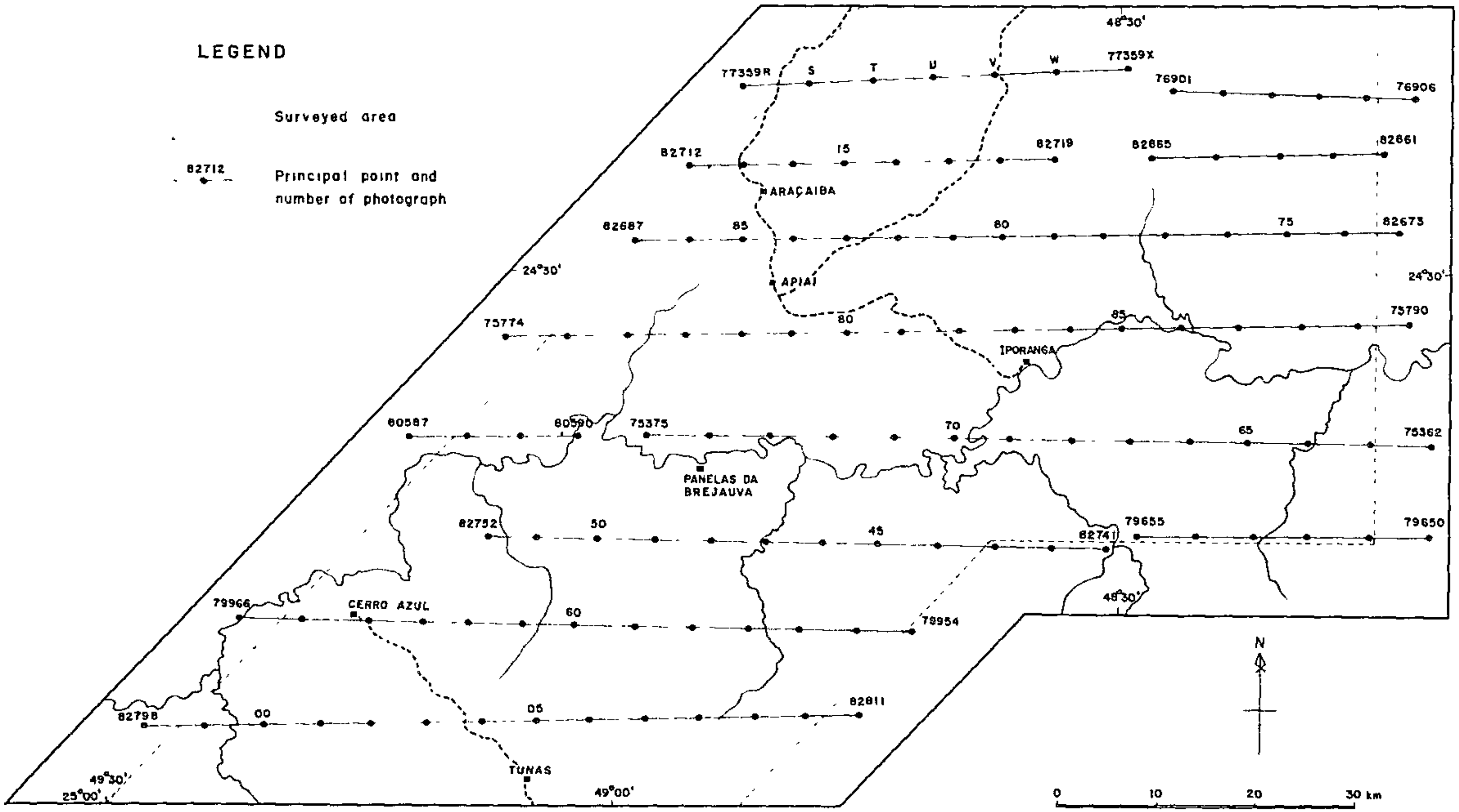
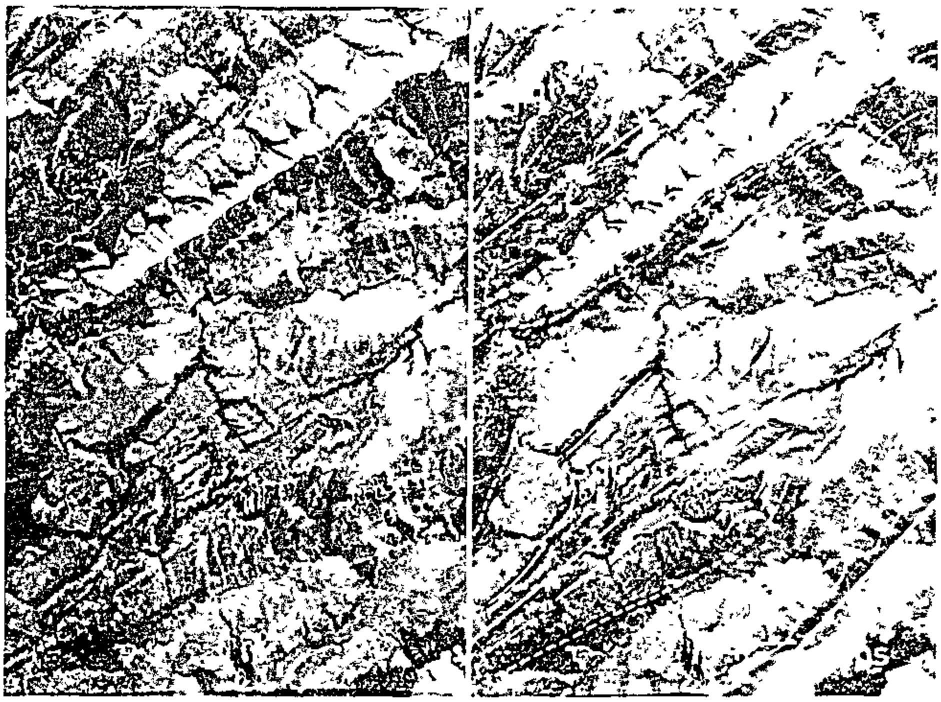


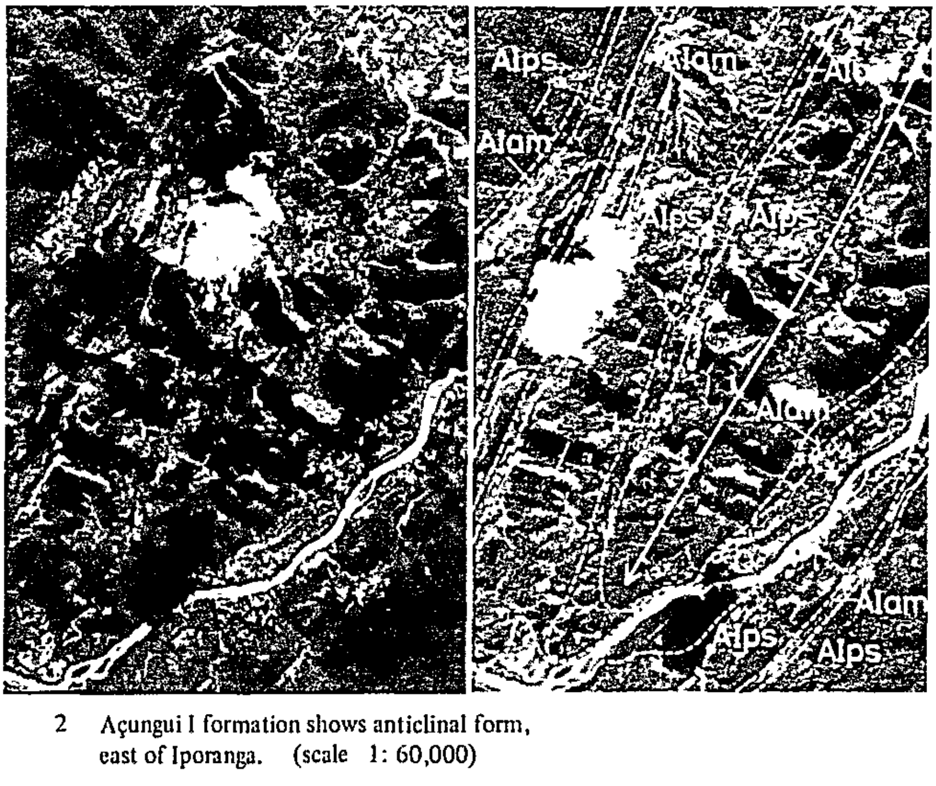
Fig. I–3 Index Map of Aerial Photographs

Table I–3 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		
B_1 (AIIIps)	medium grey	fine, uneven	dendritic	high	gentle V-form	low	none	low density	relatively sharp		pelitic schist, phyllite	Formation III	Acungu Group
B_2 (AIIIls)	medium grey	fine, uneven	——	(internal drainage)	— —	low	none	medium density	sharp	showing karst topography	limestone, dolomite	Formation III	Acungu Group
B_3 (AIIIcs)	medium grey	fine, smooth	subdendritic	low	gentle V-form	low to moderate	none	none	vague	showing karst topography (only doline)	pelitic limestone	Formation III	Acungu Group
B_4 (AIIIam)	medium grey	coarse, rough	——	low	——	low	none	none	vague	thin bed	amphibolite to amphibole schist	Formation III	Acungu Group
B_5 (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	Formation III	Acungu Group
C_1 (AIIps)	light to medium grey	fine, uneven	trellis, dendritic	high	gentle V-form	moderate	none	relatively high density	sharp		pelitic schist, phyllite	Formation II	Acungu Group
C_2 (AIIls)	medium grey	fine, uneven	——	——	——	low to moderate	none	——	relatively sharp	small exposure, karst topography	limestone	Formation II	Acungu Group
C_3 (AIIam)	medium grey	coarse, rough	subdendritic	low	U-form	low	none	none	sharp	thin bed	amphibolite to amphibole schist	Formation II	Acungu Group
C_4 (AIIss)	medium grey	fine, uneven	parallel	low	sharp V-form	high	massive	medium density	sharp		psammitic schist	Formation II	Acungu Group
D_1 (AIps)	medium grey	fine, uneven	dendritic, trellis	high	gentle V-form	moderate	massive	medium density	partly vague		pelitic schist, phyllite	Formation I	Acungu Group
D_2 (AIam)	medium grey	coarse, rough	subdendritic	low	U-form	low	none	none	sharp	thin bed	amphibolite to amphibole schist	Formation I	Acungu Group
D_3 (AIls)	medium grey	fine	——	——	——	moderate	——	— —	vague	thin bed, showing karst topography	limestone, dolomite, calc silicate rock	Formation I	Acungu Group
D_4 (AIqt)	light to medium grey	fine, uneven	parallel	medium	sharp V-form	high	very well bedded	medium density	sharp		quartzite	Formation I	Acungu Group
E_1 (Sgn)	medium grey	coarse	parallel	medium to low	gentle V-form	moderate to low	none	low density	sharp		gneiss	Setuva Formation	
E_2 (Sqt)	medium grey	fine, uneven	parallel	medium to low	sharp V-form	high	well bedded	medium density	sharp		quartzite	Setuva Formation	
F_1 (Gr)	light	fine	parallel	very high	gentle V-form	low	——	medium density	sharp		granite	Intrusive rocks	
F_2 (Gr)	medium grey	coarse, rough	parallel, trellis	high to medium	sharp V-form	high to moderate	——	high density	sharp		granite	Intrusive rocks	
G (Gb)	medium grey	coarse, rough	——	low	——	moderate to low	——	none	vague		gabbro	Intrusive rocks	
H (Sy)	medium grey	fine, smooth	——	low	——	moderate to low	——	none	sharp		syenite	Intrusive rocks	
I_1 (Db)	medium grey	——	——	——	——	low	— —	— —	relatively sharp	dyke	diabase	Intrusive rocks	
I_2 (Db)	medium grey	——	——	——	——	moderate	— —	— —	sharp	dyke	diabase	Intrusive rocks	

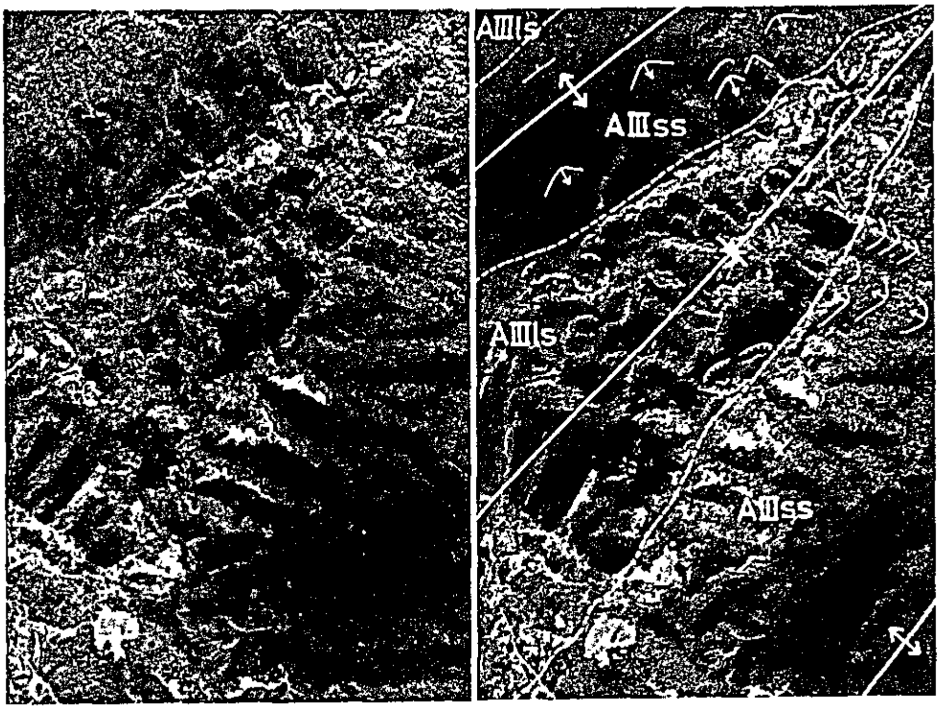


1 Setuva formation and Açungui I formation show folded structure, east of Tunas. (scale 1: 60,000)



2 Açungui I formation shows anticlinal form, east of Iporanga. (scale 1: 60,000)

Fig. I–4A Geological Interpretation of Aerial Photographs



3 Açungui III formation shows folded structure, west of Iporanga. (scale 1: 60,000)

4 Granite (Itaoka body) intrudes into Açungui III formation, south of Apiaí. (scale 1: 60,000)

Fig. I–4B Geological Interpretation of Aerial Photographs

plagioclase, alkali-felspar, epidote and titanite, which corresponds to amphibolite facies of Eskola P. (1929).

Under the microscope, the gneiss (F105, 106), exposed to the north of Anta Gorda, contains porphyroblasts of K-feldspar (4mm in size), plagioclase and quartz (all of which are embeded in crushed and fine grained quartz and K-feldspar) showing a banding structure with biotite and hornblende bands. A large amount of epidote are also present. In the gneiss* (F290) to the south of Barra do Turbo, irregularly tabular potash felspar (pinkish red in color) is contained in dark green part which consists of coarse crystals of hornblende with a nematoblastic texture.

Photo-characteristics:

On aerial photographs quarzite shows medium to low drainage density, parallel drainage pattern and high resistance. It is well bedded. It forms angular ridges and sharp V-formed valley. Gneiss exhibits the same density and pattern of drainage as quarzite, however it does low resistance and none bedding. It tends to exhibit subdued relief.

Therefore, it is easy to classify them because of the difference of resistance.

Stratigraphic relation and age:

The formation is overlain unconformably by the Açungui group. The K-Ar age of biotite in the gneiss south of Tunas at the southern limit of the surveyed area was reported to be 582 ± 31 m.y. and 783 ± 18 m.y. (Cordani et al. (1967), Ebert (1971)), both of which correspond to Precambrian A (570–1,000 m.y.). However, it is considered that the time of sedimentation is a little bit older like Precambrian B (1,100–1,700 m.y.).

1–3–2 Açungui Group

The group mainly consists of pelitic to psammitic and calcareous metamorphic rocks and covers the most part of the surveyed area. The group can be divided into the following

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* The sample was taken from the place where the rock was defined as migmatite in crystaltine complex in the geological sheet "Projeto SUDESTE do Estado de São Paulo" 1:250,000, DNPM–CPRM (1972). K-Ar age of amphibole in migmatite 30km east from here was measured 1,380 m.y. and three samples in the same migmatite zone 35km northeast of Curitiba were 521 ~ 568 ± 26 ~ 28 m.y. in age, which suggests the existence of different aged migmatites.

three formations*.

(1) Açungui I formation

The Açungui I formation is mainly composed of metamorphic rocks originated from pelitic rock, characteristically containing abundant amphibolite. A quartzite bed on the Setuva formation is the bottom of this formation, and the upper limit is the top of a zone wherein amphibolite is predominant. The upper limit of the formation can be found at the exposure of amphibolite bed about 12km. south of Adrianopolis along the road from Adrianopolis to Perau mine.

Distribution and thickness:

The formation is distributed in the southeastern of the surveyed area which includes the Perau mine, Tunas and Anta Gorda village as well as in the northeastern part in the southwest of which Iporanga is located.

Rock facies:

The rocks mainly consist of pelitic schist in the southern part and phyllite in the northeastern part, intercating quartzite, amphibolite, chlorite schist, limestone and conglomerate. The general mineral assemblage of these schists consists of muscovite, biotite, plagioclase, tremolite, garnet and carbonates, which corresponds to green schist facies ~ epidote-amphibolite facies of Eskola P.

The pelitic schist is a black banded schistose rock with a well developed microfolding structure. Porphyroblasts of garnet (4–5mm. in grain size) are often observed. Under the microscope, fine grained quartz fills the space between the black bands composed of two micas and ore (magnetite), showing a nematoblastic texture. Garnet shows a euhedral crystal form crossing the schistose texture (F115, S37, S41).

Phyllite is a pelitic rock black or reddish brown in color with poor schistosity. Under the microscope, it is an aggregate of microcrystals of quartz and sericite (0.01–0.02mm. in size), and the metamorphic grade is almost the same as that of schists. Quartzite is distributed only in the southeastern part as the bottom of the Açungui I formation as shown in Fig. I–5. It is a yellowish white, massive rock with weak schistosity. The thickness is 90–100m. and the bed is easily traceable on an aerial photo.

Under the microscope, the quartzite mainly consists of equigranular quartz (0.4mm

* Fuck et al. (1971) divided the Açungui group into four formations, but the correlation could not be done this time because the literature was not available.

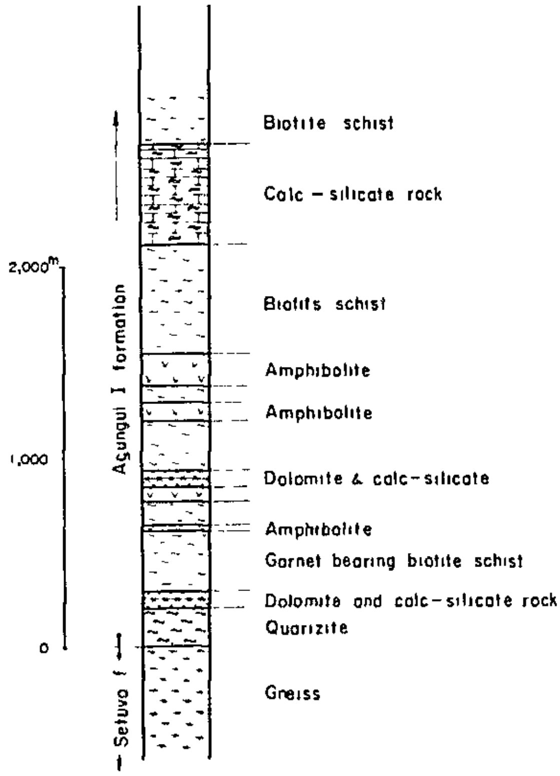


Fig. I–5 Geological Columnar Section in Perau Mine

across in grain size) showing a granoblastic texture. A weak trend is observed in the arrangement of sericite flakes which are contained in very small amount (F–1, F67).

The carbonate rock on the quartzite is 50–70m. in thickness, and is the host rock of Cu, Pb and Zn deposits of Perau type. It is chiefly consists of a white and massive dolomitic rock. However, it varies to a compact and pale greenish gray calc-silicate rock at the Perau mine area. Under the microscope, the biotite bands with a considerable amount of fine grained tourmaline are found in the aggregate of muscovite, quartz and tremolite including considerable amount of calcite which fills their interstices (F–278).

Amphibolite is a dark green, medium grained ~ fine grained massive rock and thinlyextends conformably in crystalline schist and phyllite. The thickness of the bed varies from several meters to 200m. showing a schistose structure very often at the contact with other rocks, though the center part is massive.

The amphibolite tend to coexist with carbonate rocks. Under the microscope, bluish green hornblende occurs abundantly with interstitial quartz and plagioclase (labradorite), all of which had been suffered fracturing. Abundant magnetite is observed as an accessory mineral (F–7). A decisive evidence on origin of the amphibolite could not be obtained in this survey.

However, it is highly possible from the following reasons that the rock was derived either from impure calcareous rock or dolomitic sedimentary rock, or from mixture of both rocks, and is not a basic igneous sill.

(1) Thin beds of amphibolite continue for several kilometers,

(2) It tends to coexist with calc-silicate rocks,

(3) Almandine, epidote and biotite could not be found in the rock.

Green schist is a pale greenish massive rock being widely distributed in a layer. Under the microscope, much tremollite can be observed generally chloritized (T–173).

Conglomerate is distributed in the surrounding area of Iporanga. It is divided into two types: (1) conglomerate containing angular pebbles of fine to medium grain (2–30mm. in size) in a matrix of very fine grained quartz. This type can be observed along the highway at about six kilometers downstream from Iporanga, where it is intercalated in pelitic phyllite with the thickness of about 50m. (2) poorly sorted conglomerate exposed along the road extending northward from Iporanga, containing breccias of mica schist, quartzite and phyllite (3–10mm. in diameter) with a pelitic matrix. Reverse grading is observed in this rock. The grade of consolidation is considerably low compared with the former type. The conglomerate has a thickness of about 400m. Rounded pebbles with the size of about 50mm. are contained at the place near Iporanga (the upper section), which seems to be younger. Although the pebbles of granite were found by the previous survey of CPRM, they could not be found in this survey.

Photo-characteristics:

On aerial photographs quarzite could be discriminated as a high resistant unit. It shows pronounced relief with prominent dip slopes and clear stratification. Pelitic schist and phyllite shows very fine drainage pattern which is dendritic or trellis, moderate resistance and massive bedding. Amphibolite and amphibole schist exhibit rough texture, low drainage density and lower resistance than other units. Calcarious rock could be differenciated by the karst topography of doline, but it is difficult to follow the unit because of thin bed and vague boundary.

By the difference of resistance, it is very easy to discriminate quartzite and amphibolite ~ amphibole schist, therefore, the geological structure such as fold and fault could be clarified.

Stratigraphic relation and age:

This formation overlies the Setuva formation conformably. As the conglomerate located north of Iporanga is clearly conformable with pelitic phyllite, no subdivision was made on this rock, considering it as a member of the Açungui I formation. However, Leonardos O.H. (1934, 1941) and Barbosa O. (1948) considered it to be a more younger rock and called it Ribeira system because they thought it lay on the lower formation unconformably. A detailed investigation will be required in the future.

(2) Açungui II formation

The Açungui II formation is distributed in a zone in the middle part of the surveyed area

overlying the Açungui I formation, having been cut the upper limit by the Figueira fault.

Distribution and thickness:

The formation is typically exposed along the roads between tunas and Cerro Azul and Iporanga and Barra do Turvo, being distributed in a zone of 10km width trending ENE–WSW.

Very few key bed and repetition of a large folding with minor foldings observed by field survey and photointerpretation make it difficult to measure the accurate thickness of the formation. It is, however, possibly to be 2,000–2,500m. by rough estimation.

Rock facies:

The Açungui II formation mainly consists of pelitic phyllite and pelitic ~ psammitic schist, and a small amount of sandstone, amphibolite and limestone. Pelitic phyllite is distributed in the southwestern part. It is dark grey to black in color. Due to the existence of iron, reddish brown ~ purplish parts are often observed. Pelitic ~ psammitic schist is distributed in the southeastern part, and is also dark grey, reddish brown and sometimes pale green in color.

So far as observed in the field, the bedding plane is not always distinct. However, it is sometimes discernible because of the difference of color tone and local intercalation of sandy part. As a result of field observation, schistosity almost coincides with bedding plane.

The schist contained in the formation is substantially quite same to that of the Açungui I formation. The schist to the north of Barra do Turvo is a pelitic schist with bands of green and red parts in a unit of several milimeters. Under the microscope, sericite–biotite flakes and fine grained quartz (0.01 ~ 0.02mm in size) aggregates are alternatively arrenged. Narrow bands of chlorite and sericite are also present in the latter (T–10).

As mentioned above, the Açungui I formation mainly consists of schist, while the Açungui II formation mainly consists of phyllite. However, the boundary between two formations is transitional, therefore, the boundary of metamorphic zoning does not always coincide with that of the formations.

Photo-characteristics:

Each unit has almost same characteristics as the unit of Formation I. Psammitic schist shows high resistance as quartzite of Formation I, pelitic schist and phyllite do fine dendritic drinage pattern. Amphibolite ~ amphibole schist does coarse texture and low resistance. Moreover, limestone exhibits karst topography.

Unit C, (map symbol AIIps) in the east of the areas is more resistant than the unit in

the southwest, coresponding that the former consists of pelitic schist with intercalation of psammitic schist and the latter does mainly of phyllite.

Stratigraphic relation and age:

It overlies the lower Açungui I formation conformably and contacts with the upper Açungui III formation by the Figueira fault. K-Ar (the whole rock) age of 560 ± 20 m.y. was reported on phyllite sample taken at the point 40km. northwest of Curitiba which is considered to be the southern extension of the II formation (Cordani et al. (1967)).

(3) *Açungui III formation*

The formation mainly consists of pelitic ~ psammitic metamorphic rocks and calcareous rocks associated with metavolcanic rocks. The formation is much characterized by the wide distribution of thick limestone bed (600m. in thickness) and the existence of the lead deposits such as Furnas, Lageado and Rocha.

Distribution and thickness:

The formation is distributed in the western part of the Figueira fault which extends in the direction of NE–SW in the central part of the surveyed area. In the northern part, it contacts with the Açungui I formation by the fault, while in northern part, it contacts with the lower Açungui II formation in the same way. The Açungui III formation is locally distributed in the vicinity of Caverra do Diabo overlying conformably the Açungui II formation. Some part of the formation is lacking by faulting, the thickness can not exactly be known, but it is assumed to be about 2,000m.

Rock facies:

The formation is divided into five facies such as psammitic schist, pelitic schist, pelitic limestone, calcareous rock and peritic ~ psammitic schist in an ascending order. They are intercalated by amphibolite and green schist. In the northern part, the uppermost section of pelitic ~ psammitic schist is absent, while in southern part, psammitic schist and pelitic schist of the lowermost part is lacking.

Psammitic schist mainly consists of sericite-quartz schist intercalating pelitic sericite-schist and metaconglomerate. Sericite-quartz schist consists of quartz grains (0.05–0.1mm. in size) in a matrix of more fine grained quartz and sericite, often showing an obscure bedding plane. In some part of this schist, coarse grained (0.1–0.15mm.) metasandstone with several meters thickness and pelitic sericite schist are alternatively intercalated.

Metaconglomerate consists of fine ~ medium pebbles of quartoze rocks, granitic rocks and sandy matrix, intervening in psammitic schist.

Pelitic schist consists of pelitic ~ silty sericite-schist intercalating psammitic schist mentioned above. Schistosity is considerably distinct.

Pelitic limestone is found at the transitional part between pelitic schist and limestone and consists of the alternation of pelitic schist, calcareous schist and limestone. It is dark grey in color with increasing amount of calcareous rocks toward the upper section. It is distributed in the area between Apiai and Araçaiba and in the southern part, but does not occur in the Furnas-Lageodo area.

Calcareous rock is white ~ grey ~ dark grey, massive rock, which mainly consists of limestone, dolomite and calcareous schist. Limestone consists of mosaic aggregate of calcite with a size of 0.2–0.3mm which is considered to have been recrystallized. Dolomite generally consists of very fine grained (0.05mm.) dolomite, equigranular quartz and sericite. Macroscopically it is difficult to discriminate these rocks so that it will be necessary to use an acid foaming or chromopholia tests. Lead deposits are found in this calcareous rock.

Calcareous rock shows a characteristic banding of dark grey thin layer consisting of biotite and dolomite (2 ~ 5cm. in thickness) and white thin layer consisting of carbonate rock (5 ~ 10cm. in thickness). The thickness of calcareous rock is estimated to be about 500m.

Amphibolite ~ amphibole schist are intercalated in pelitic schist and distributed to the north and at about 1.5km. to the south of Araçaiba. Amphibolite is a green massive and compact rock. Under the microscope, plagioclase 4mm. in size (altered to chlorite and epidote), green hornblende of the almost same size (altered to an aggregate of quartz and carbonate) and abundant opaque minerals are observed (S–48).

Photo-characteristics:

Psammitic schist is a resistant unit, and the valley or gulley exhibits sharp V-form and the ridge is angular. The drainage shows low density and parallel pattern. Moreover Psammitic schist is well bedded. Pelitic schist and phyllite shows fine texture, high drainage density, dendritic drainage pattern and low resistance. Limestone of the formation widely crops out with forming clear karst topography. Pelitic limestone exhibits smooth texture and it forms even hills and scattered dolines. The drainage is low dense and the bedding is not apparent. Amphibolite and amphibole schist shows rough texture and low resistance.

The boundary between psammitic schist and limestone is very clear because of the

difference of resistance and psammitic schist is well bedded. Therefore it is possible to interpretate the structure, fault and folding.

Stratigraphic relation and age:

The Açungui III formation overlies on the II formation conformably. The relation between the III formation and upper formations are not clear because the Três Córregos granite intruded into the upper section of III formation. The sedimentation time is older than 510 m.y. (= Três Córregos granite)

1–4 Intrusive Rocks

The igneous rocks intruded in the surveyed area are granitic rocks, syenite, gabbro and diabase.

1–4–1 Granitic rocks

Granitic rocks were intruded the Açungui group everywhere in the surveyed area as batholith or stock.

Distribution:

It is intruded along the western periphery of the surveyed area in NE–SW direction as a batholith (Três Corrégos body) with about 30km. width. Besides, several bodies such as, from the north, Espirito Santo, Apiai, Itaoca, Varginha, and Morro Agudo (20–150km^2 of an area of exposure) are distributed. Further to the east, bathliths such as Agudos Grande and Itaporanga are distributed.

Moreover, dykes and stocks of granite porphyry are exposed to the north of Apiai and along the road east of Iporanga in a small scale.

Rock facies:

Granitic rocks are leucocratic, medium ~ coarse grained, massive rocks. Crystals are generally equigranular. As they include always potash feldspar, they are pinkish to pale reddish in color. Crystals of potash felspar are coarse, reaching sometimes up to 5cm. in length. Although there is generally no clear orientation of rock forming minerals, some gneissose or migmatitic texture is observed in Três Corrégos body at the contact with sedimentary rocks. Granite porphyry is yellowish white, fine grained compact rock. These granitic rocks were intruded into the Açungui group but there are almost no chilled margin nor contact metamorphism of the group.

In some batholiths, the Açungui formation is found as a roof pendant.

A microscopic observation of a typical granite is as follows:

Biotite granite (F 57)   Três Corrêgos body

Texture: Holocrystalline, porphyritic

Mineral composition:

Orthoclase, microcline, quartz > plagioclase > biotite

Potash felspar is subhedral and perthitic texture is observed in microcline.

Quartz is anhedral with remarkable wave extinction.

Crystals are fractured.

Plagioclase is oligoclase and small in amount.

Biotite flakes are foliated.

Alteration minerals:

Chlorite, sericite and opaque minerals.

The values of chemical analysis of samples taken from each bodies are plotted in the field of granite ~ granodiorite as shown in Fig. I–6. However, under the microscope, texture and mineral composition of these rocks are not so different from the rock mentioned above (F–57). Only slight differences exist in compositional ratio of minerals and in presence or absence of hornblende.

Photo-characteristics:

It is devided into two units, F_1,and F_2, on the basis of the difference of resistance and drainage pattern. Unit F_1, shows low resistance, high drainage density and fine parallel drainage pattern. It is corresponding with the bodies such as Itaoca, Três Côrregas, Espirito Santo, Apiai. Unit F_2 shows high resistance, rough texture, low to mideum drainage density and parallel or trellis drainage pattern with forming hills.

Intruding age:

According to Cordani et al. (1967), K-Ar ages of biotite were 510 ± 15 m.y. in the Três Côrregos body and 510 ± 15 m.y. in the Itaoca body, both of which correspond to early Cambrian.

1–4–2 Syenite

Syenite is exposed as stock intruded into the Açungui group.

Distribution:

It is distributed to the north of Tunas with the area of about $20km^2$ extending in NW–SE direction.

Rock facies:

It is yellowish green ~ dark grey, medium ~ coarse grained massive rock, with a holocrystalline and an equigranular textures. A small amount of short prismatic mafic minerals are contained.

Characters under the microscope are as follows:

Aegirine syenite (F 87) Along the road between Tunas and Agua Clara

Texture: Equigranular, holocrystalline.

Mineral composition:

Orthoclase, microcline ≫ aegirine > plagioclase > hornblende > opaque minerals > biotite

Orthoclase displays subhedral crystal form with the size of about 4mm. in length, showing a perthitic texture with microcline.

Aegirine is a greenish granular crystal showing strong pleochroism.

Plagioclase shows albite twinning, which corresponds to 20–30 % An.

Hornblende is subhedral, brown or green in color.

Biotite is contained in a small amount together with opaque minerals

Alteration minerals:

Opaque minerals and sericite.

Intruding age:

According to Cordani et al. (1968), K-ar age of biotite in the Tunas intrusive showed 111.5 ± 15.6 m.y., which shows middle Cretaceous.

1–4–3 Gabbro and Diabase

Gabbro is intruded into the Açungui group and granite as a stock or a dyke.

Distribution:

Gabbro and diabase are distributed as dykes perpendicular (NW–SE) to the general geological structure. Besides, a sill-like dyke of gabbro extending for about 7km. is found 1km. south of Apiai along a tectonic line of NE–SW direction. A small elliptical body 2km

in length of major axis (Jose Fernandes Intrusive) is also exposed near the top of the Vinte e Sete Range. The sample (S–90) taken from this body was chemically and microscopically monzo-diorite. It may be expected that there are some changes in rock facies.

Rock facies:

Gabbro is a melanocratic (C.I. = 60 ~ 70), medium grained compact rock. Diabase is also melanocratic and is more fine grained. Both rocks are locally greenish grey in color.

An outline of microscopic observation of typical rocks is as follows:

Biotite-augite gabbro (F–38) Morro Grande intrusive

Texture: Equigranular, holocrystalline

Mineral composition:

augite > plagioclase ≫ biotite

Augite is prismatic or granular with the general size of 2mm. in length occupying about 60 % of the whole field.

Plagioclase is subhedral with the size of 2–3mm. in length.

Albite twinning is well observed, corresponding to An 60 (labradorite)

A small amount of biotite in a foliated form is contained.

Alteration minerals:

Chlorite and opaque minerals.

Biotite-augite diabase (F–9) Perau mine

Texture: Doleritic texture

Mineral composition:

augite > plagioclase ≫ biotite

Anhedral crystals of augite, fills the interstices between the prismatic crystals of plagioclase which have the size of 0.5–1.0mm. in length.

Biotite is contained in small amount.

The diabase is different from the above mentioned gabbro only in texture, but mineral composition is the same.

Alteration minerals:

Chlorite, serpentinite, opaque minerals and carbonate minerals.

Photo-characteristics:

Gabbro exhibits rough texture, low drainage density and moderate to low resistance. Therefore it is difficult to differenciate gabbro intruded into limestone.

Diabase is classified into two units, I_1 and I_2, based on the difference of resistance. But they are mostly included in Unit I_1 which shows low resistance. Unit I_1 is traceable as the concave lineament. Whereas, Unit I_2 is more resistant than Unite I_1 and traceable in granitic rocks as the convex lineaments. It crops out in Três Córregos body in the southwest of the area and in Espirito Santo body in the north of the area.

Intruding age:

K-Ar age of plagioclase in gabbro southeast of Tunas measured by Cordani et al. (1968) was 73.8 ± 3.7 m.y. (108.4 m.y. on the whole rock) and age of the rock at Apiai measured by Amaral et al (1966) was 123.5 ± 4.3 m.y., both of which correspond to middle ~ late Cretaceous.

As the ages and trend of intrusion of these basic rocks are almost same as syenite, intrusion of all these basic rocks are considered to have been controlled by the same geological structure.

1–5 Chemical Composition of Igneous Rocks

The result of chemical analysis carried out on 11 samples of igneous rocks distributed in the surveyed area is as shown in the following.

Samples for analysis are mainly granitic rocks, the localities of which are shown in Fig. I–2. Analytical values and weight percentage of normative minerals calculated from the analytical values are shown in Table I–3.

Fig. I–4 shows the relation between the weight percentage of each oxide and the differentiation index (D.I.), which shows the characteristics of calc-alkaline rock series that, with the progress of magmatic differentiation (D.I. increases), SiO_2 increases and FeO decreases. Also in M–F–A diagram (Fig. I–5) showing MgO : (FeO + Fe_2O_3) : (Na_2O + K_2O), the all values can be plotted in the field of calc-alkaline rock series except for K–133.

Fig. I–6 shows the result of plotting normative constituents of each rock sample "quartz-plagioclase-alkali felspar diagram" proposed by IUGS Subcommission 1973. According to the subcommission, alkali felspar includes albite (0–5% An), while plagioclase must exclude albite. As is evident from the diagram, the granite samples in the surveyed area have the characters of those distributed near the boundary between granite and granodiorite, and "syenite" of Tunas falls within the field of monzonite.

The names of intrusive rocks mentioned in the previous section was given as the result of

Table I–4 Chemical Analysis and Normative Composition of Igneous Rocks

Sample No.		I-33	I-87	I-124	S-28	S-50	S-90	S-92	S-135	K-110	K-133	K-184
Location		Morro Agudo	Tunas	Itaoca	Tres Corregos	Tres Corregos	Vinte e Sete	Verganha	Espirito Santo	Ribeirão Branco	Araçaiba	Araçaiba
Rock Name		Granite	Syenite	Quartz monzonite	Granite	Granodiorite	Manzo-diorite	Granite	Granodiorite	Granodiorite	Amphibolite	Granite
Chemical composition	SiO_2	66.50	61.78	64.78	54.51	67.95	52.44	68.02	71.58	68.77	46.95	69.69
	TiO_2	0.72	0.39	0.71	0.78	0.52	1.85	0.27	0.30	0.41	1.76	0.31
	Al_2O_3	14.67	18.01	15.46	15.42	14.45	17.43	15.17	13.94	15.05	17.43	15.49
	Fe_2O_3	0.32	1.16	1.12	1.92	1.32	1.75	1.08	0.20	0.76	1.37	0.55
	FeO	4.81	3.77	3.23	4.13	2.98	7.15	2.84	3.34	2.59	8.52	1.98
	MnO	0.08	0.13	0.04	0.13	0.08	0.15	0.08	0.07	0.04	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	3.03	5.82	2.79	6.62	2.97	1.68	2.11	8.48	1.88
	Na_2O	3.09	6.28	3.52	2.83	3.60	3.21	2.98	3.69	4.47	2.50	3.85
	K_2O	4.32	5.23	4.87	3.56	3.31	3.69	4.09	2.94	3.50	2.62	4.43
	P_2O_5	0.23	0.06	0.32	0.31	0.25	0.46	0.14	0.14	0.19	0.56	0.11
	CO_2		0.47	0.13	5.50		0.76	-		0.11	-	
	$H_2O(+)$	0.81	0.25	0.11	1.71	0.57	0.86	0.64	0.58	0.13	2.68	0.41
	$H_2O(-)$	0.42	0.24	0.12	0.14	0.08	0.18	0.22	0.06	0.32	0.22	0.12
	Total	99.21	99.32	99.27	99.20	99.49	99.68	99.85	99.31	99.38	99.37	99.42

CIPW norm	Q		22.84	0.87	15.94		25.03	0.62	25.22	31.93	22.67	0.00	24.53
	C		1.15	0.74	0.00		0.47	0.00	0.78	1.97	0.76	0.00	1.21
	or		25.53	30.91	28.78		19.56	21.81	24.17	17.37	20.68	15.58	26.18
	ab		26.15	53.14	29.79		30.46	27.16	25.22	31.22	37.82	20.13	32.58
	an		10.26	3.48	12.00		12.21	22.25	13.82	7.42	8.59	28.65	8.61
	di	wo	0.00	0.00	0.08		0.00	1.33	0.00	0.00	0.00	4.30	0.00
		en	0.00	0.00	0.04		0.00	0.61	0.00	0.00	0.00	2.31	0.00
		fs	0.00	0.00	0.04		0.00	0.70	0.00	0.00	0.00	1.85	0.00
	hy	en	2.17	0.55	4.52		0.00	7.18	3.36	1.97	2.32	0.00	1.42
		fs	7.53	5.56	3.87		3.67	8.22	4.03	5.60	3.53	0.00	2.73
	ol	fo	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	8.79	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	1.10	2.08	0.80
	il		1.37	0.74	1.35		0.99	3.49	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	1.02	0.28		0.00	1.65	0.00	0.00	0.24	0.00	0.00
	Total		97.98	98.83	99.04		99.84	98.63	98.99	98.67	98.93	95.97	98.89
	Q + or + ab		74.51	84.92	74.50		75.05	49.59	74.60	80.53	81.18	35.71	83.29
	D.I.		76.05	85.92	75.22		75.93	50.27	75.36	81.61	82.06	28.30	84.22

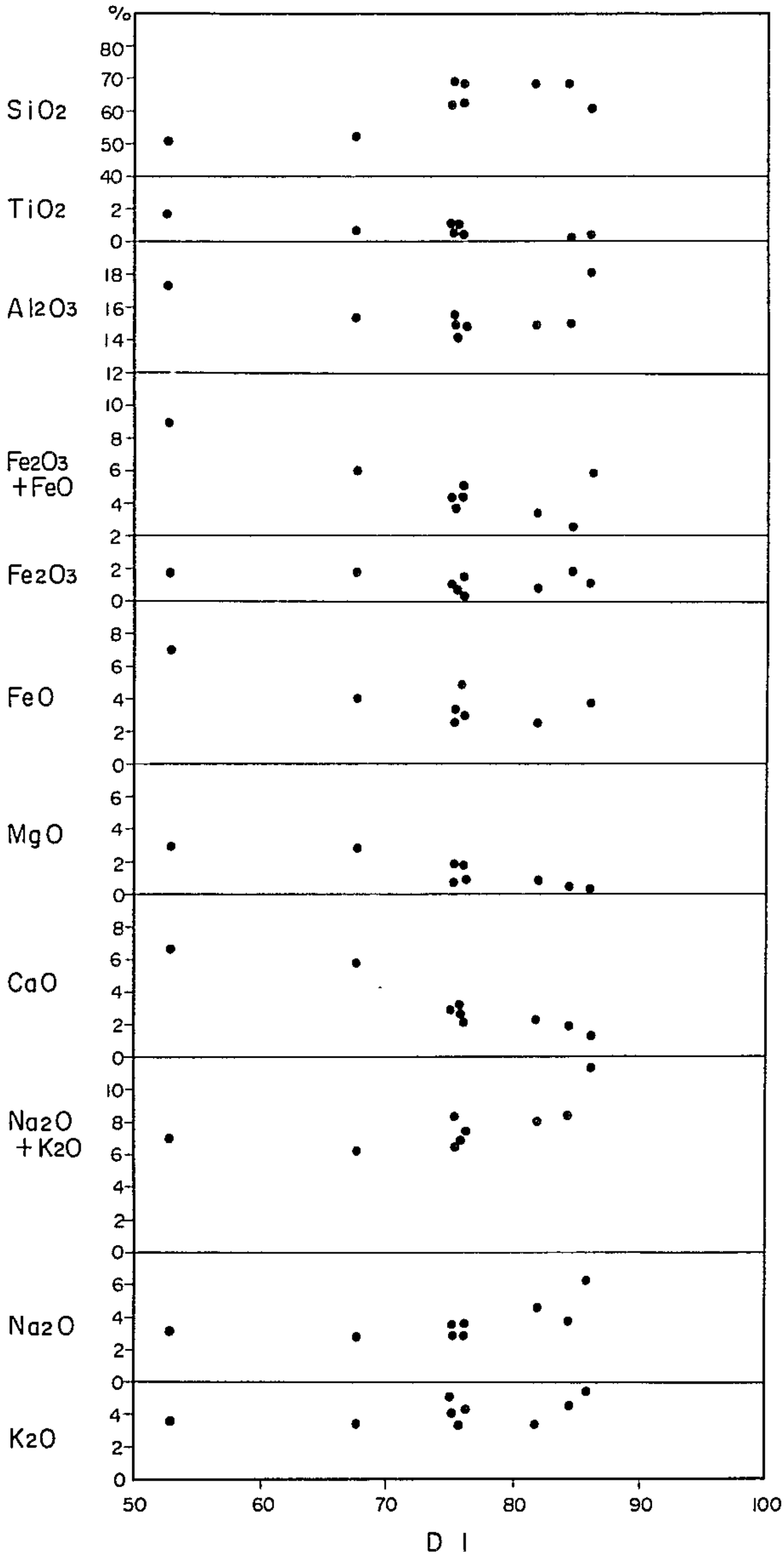


Fig. I–6 Variation Diagram of Intrusive Rocks

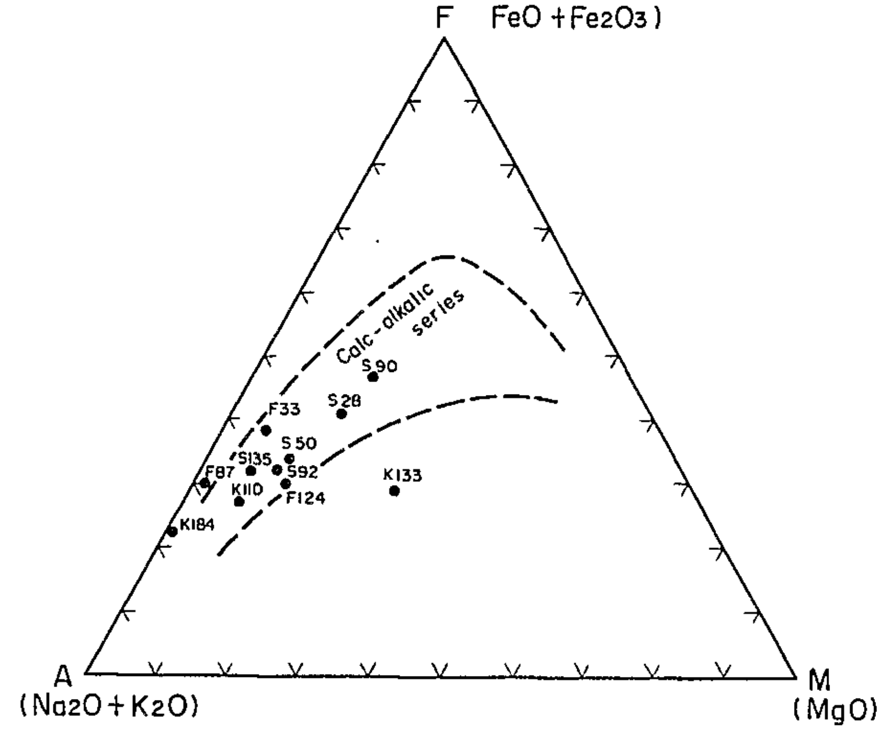


Fig. I–7 MFA Diagram of Intrusive Rocks

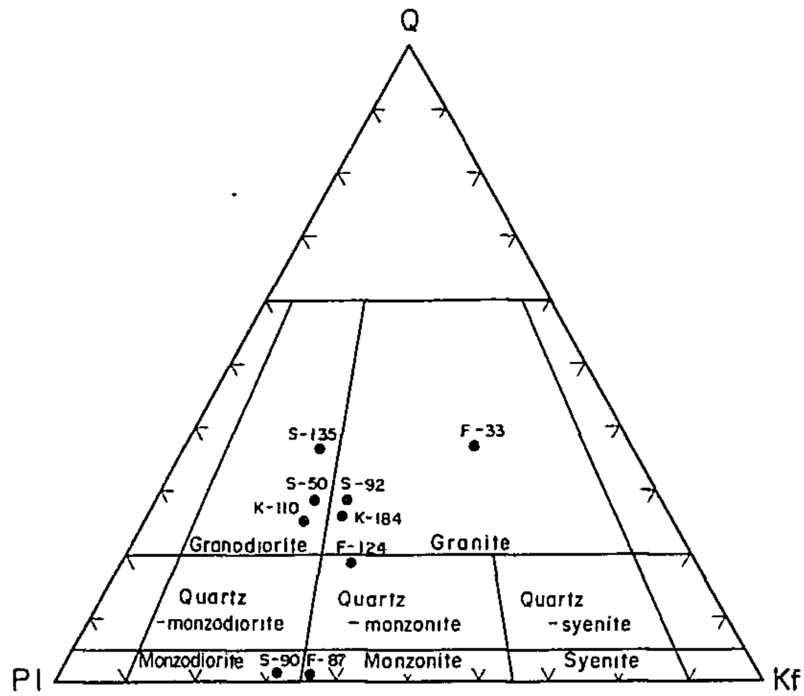


Fig. I–8 Q–PL–Kf Diagram of Intrusive Rocks

microscopic observation, which almost agreed with the results of analysis. But under the microscope, the Tunas intrusive (F 87) mainly consists of orthoclase and microcline containing small amount of plagioclase of An 30%.

Recalculation of norm, using the value of (orthoclase + microcline) : plagioclase (An30) = 86 : 14, shows that the rock falls in the field of syenite rather than monzonite. Therefore, "syenite" is suitable for the intrusive.

1–6 Geological Structure and Geological History

1–6–1 Geological Structure

A geological structure parallel to the coastline is known in the Precambrian schield (Atlantico Massif) distributed along the eastern coast of Brazil, in which it is indicated that the ages of formations become younger from the coast toward interior.

In the surveyed area and its surroundings, structures of NE–SW system which are parallel to the coastline predominate, and the old rocks such as Precambrian (undifferentiated) crystalline complex, Setuva Formation of Precambrian B (1,100–1,700 m.y.) and Açungui Group of Precambrian A (570–1,100 m.y.) are zonally distributed in a NE–SW direction. Further to the west, Devonian and the younger sedimentary rocks which form the Parana basin are widely distributed overlying the Precambrian rocks mentioned above.

Fig. I–2 shows the distribution of each formation, main structural lines and distribution of granitic rocks, though it is a little modified.

As is clear from the figure, the Setuva formation, which is the basement of the surveyed area, is distributed from the Perau mine to Anta Gorda in a form of belt trending NE–SW. Such distribution is due to an anticlinal structure with an axis of the same direction, and is repeatedly exposed by the synclinal structure with 3 ~ 5km. wave lengths. Each anticlinal and synclinal axis, undulating gently in the direction of axes, finally plunges to the northeast and to the southwest.

The Açungui I formation is distributed in the southern part, surrounding the Setuva formation and, in the norhern part, in a form of wedge enclosed by the two faults such as the Figueira fault and the Ribeira fault (Lineamento Ribeira).

In the western area from the Perau mine, a monoclinal structure dipping 30° ~ 70°W is evident, while on the east and north sides, folding structures with an axis of NE–SW system are developed, in which a repetition of the same bed is observed. Especially, the thickness of the Açungui I formation exposed for more than 40km. from Iporanga to the east along the

Ribeira River, became clear to be only about 3,500m. from the aerial photointerpretation.

The Açungui II formation conformably overlies the Açungui I formation and is distributed , trending NE–SW to E–W in the central part of the surveyed area. And the northern side of the formation is cut by the two faults such as Figueira and Ribeira. According to the photointerpretation, a synclinal axis runs through the center of the Açungui II formation. Consequently, the Açungui I formation is separated by the Açungui II formation, resulting in the separation of the Açungui I formation; on the north and south. Since the microfolding structure is often observed at the outcrops, it is considered that a large scale synclinal structure is formed with repetition of microfolding.

The Açungui III formation mainly consists of limestone, in which relatively smaller foldings extend in NE–SW direction with the wave length of 0.5–1.0km. However, in the surrounding area of Furnas and Lageado in the northern part, psammitic schist in the lower sequence of limestone shows gentle folding with relatively long wave length of about 5km. Therefore, it is considered that the short wave folding of the upper sequence was caused by the parasitic folding in the competent limesonte against the folding of the lower incompetent sandstone.

The fault system of NE–SW direction predominates in the area. The east and west sides of the areas of the Açungui I formation, which is a uplift zone, tends to have falled down by the fault. The down throw of the western block due to the Figueira fault which is the largest structural line in the surveyed area is estimated to be about 100m. in the southern part and about 2,500m. in the northern part.

Granitic rocks were intruded into the Açungui group, controlled by the general geological structure of NE–SW system.

Syenite and considerable numbers of basic rocks of Cretaceous were also intruded the Açungui group along the tension cracks of NW–SE system.

1–6–2 Geological History

A number of studies have been done on Precambrian basement rocks which are distributed along the eastern coast of Brazil from Bahia State to Uruguai. According to them, the coastal range called Paraiba do Sul zone runs through the most outer zone. It consists of crystalline complex (gneissose ~ migmatitic rocks), which is considered to have been formed during the Transamazonic Cycle (1,800–2,000 m.y.).

It is considered that the Ribeira folding zone including the Açungui group proposed by

Almeida F.F.M. et al. (1973) is located in the inner side of Para do Sul and consists of geosynclinal sediments deposited during the Brazilian Cycle (450–650 m.y.). And it is believed that the Açungui group was deposited intrinsically in the environment of continental shelf, the basement of which is something like granitic rocks.

Although crystalline complex is not exposed in the surveyed area as mentioned before, it is considered that the complex formed the basement of the surveyed area and the Setuva formation of Precambrian B was deposited on it.

In the time of Precambrian A, the Açungui I formation began its deposition with quartzite at the bottom, then followed by dolomitic rocks and mudstone successively. A basic volcanic activity took place during the time and erupted lava and tuff. A basic volcanic activity also took place during the time of deposition of dolomitic rocks, which would have led to the emplacement of Perau type ore deposit. Since cross lamina can be observed in sandstone in the I formation, it is assumed that the sedimentary environment was generally shallow. After that sedimentation of the Açungui II formation mainly composed of mudstone followed. Volcanic activity was almost dormant at that time.

At the end of Precambrian, a upheaval movement of basement took place. After deposition of conglomerate and sandstone, thick beds (up to 600m) of limestone and dolomite of the Açungui III formation were deposited. Existence of ripple mark and cross lamina suggests that sedimentation was in neritic environment.

The main metamorphism and tectonic movement occurred at the end of the deposition of the Açungui group (650 ~ 600 m.y. ago) : sedimentary rocks underwent regional metamorphism of green schist facies ~ amphibolite facies; the east and west of neighboring areas were unheaved in NE–SW direction passing Tunas and Espirito Santo, resulting in a remarkable folding within the Açungui II and III formations. On the contrary, in the Açungui I formation, only a relatively long waved folding was formed. The reason for this would be attributed to the existence of quartzite bed in the formation with the thickness of up to 100m.

Granitic rocks (500 m.y.) were intruded along with this upheaval movement, and the faults including the Figuera fault were formed during the time.

Lead deposits occurred in limestone of the Açungui III formation is considered to have been formed in close relation to this orogenic movement.

After that, although sedimentation of clastic rocks followed in Parana Basin on the west during the time from Palaeozoic to Mesozoic, the surveyed area stayed quiet and stable. Alkaline rocks and basic rocks were intruded in the Cretaceous time as stocks and dykes along the fissures of NW–SE system which is perpendicular to the general geological structure.

CHAPTER 2 ORE DEPOSIT

2–1. Outline of Ore Deposits

A number of lead deposits occurring in the Açungui formations of the surveyed area can be divided, as shown in Fig. I–2, into the north zone and the south zone.

In the southern mineralized zone, the ore deposits are found in limestone ~ calcareous schist distributed about 20km. southwest of Ribeira in a form of bed, which includes recently developed Perau mine, Agua Clara which is under suspension of operation and Pretinhoe (Ba) Mine which is under preparation for development. The northern mineralised zone is located in the area of 20km. x 70km including Apiai and Ribeira, in which operating mines such as Furnas, Panelas and Rocha and other many deposits such as Espirito Santo, Lageado and Paqueiro are known. These deposits are emplaced in a form of vein in strongly disturbed limestone ~ dolomite.

Ore minerals in both zones mainly consist of galena associated with a very small amount of chalcopyrite, sphalerite and pyrite. The gangue minerals are scarcely observed.

As to origin of the ore deposits, it is the most prevailing discussion on those in the northern zone that the deposit was formed by remobilization as the result of tectonic movement or granite intrusion. In connection with the stratiform deposits in the southern zone, many geologists consider them to be syngenetic, though no definite opinion has been published.

2–2. Description on Each Ore Deposit

The outline of the main ore deposits investigated this time is described in the following.

2–2–1 Perau Area

The deposits in this area are stratiform ore deposits occurred in limestone ~ dolomite developed in the lower part of the Açungui I formation, and some deposits such as Perau (Pb), Agua Clara (Cu, Pb) and Pretinhoe (Ba) have been known.

(A) Perau Deposit

1) Outline of the mine

The Perau mine is situated in the mountain about 25km. south of Adrianopolis. The mine office of Eletro São Marco Ltda is located on the southern bank of River Perau, a tributary of Rio Grande, about 1.5km. upstream from the confluence.

The outcrop of ore deposit is found at 500m above the sea level, and exploration

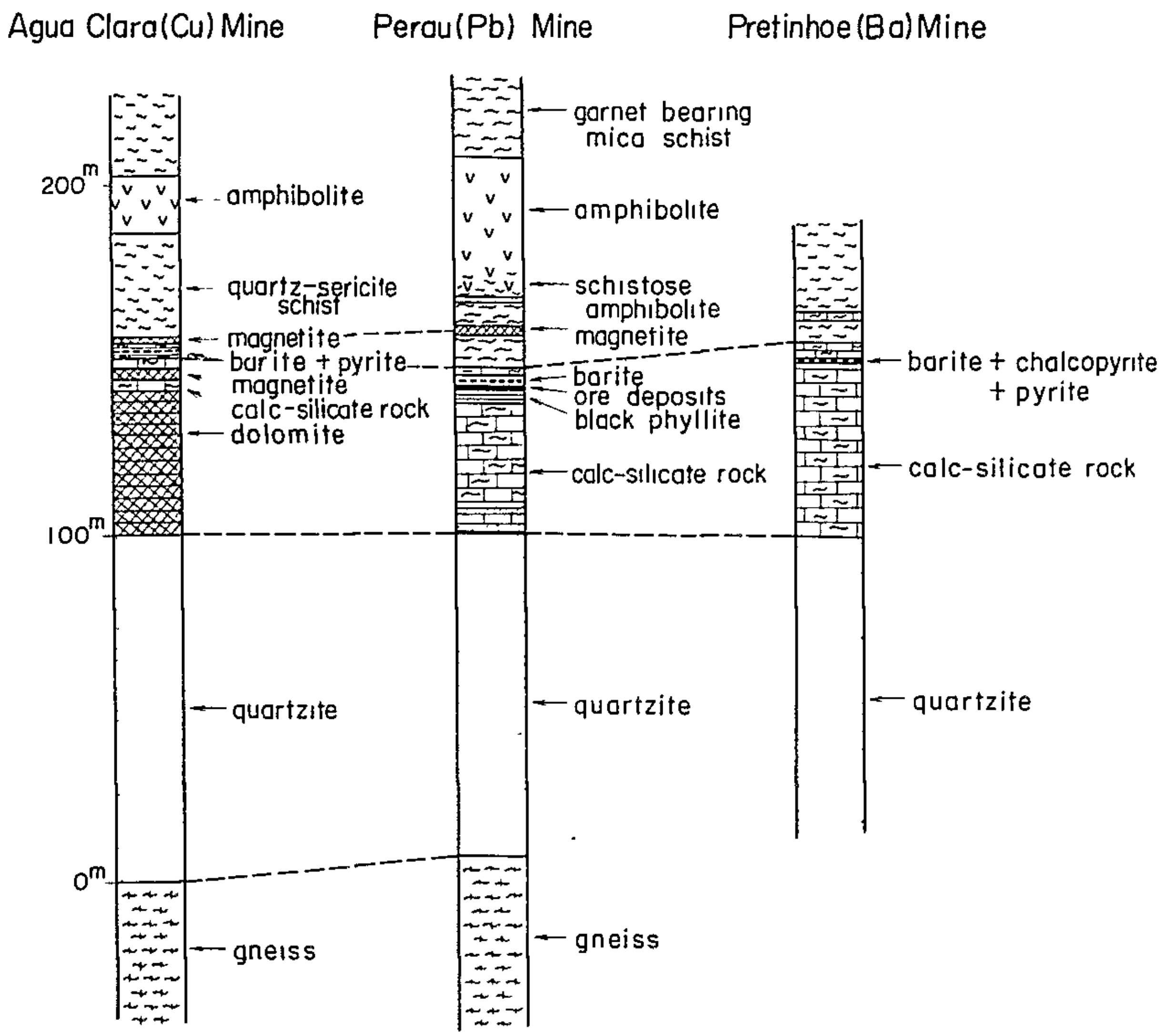
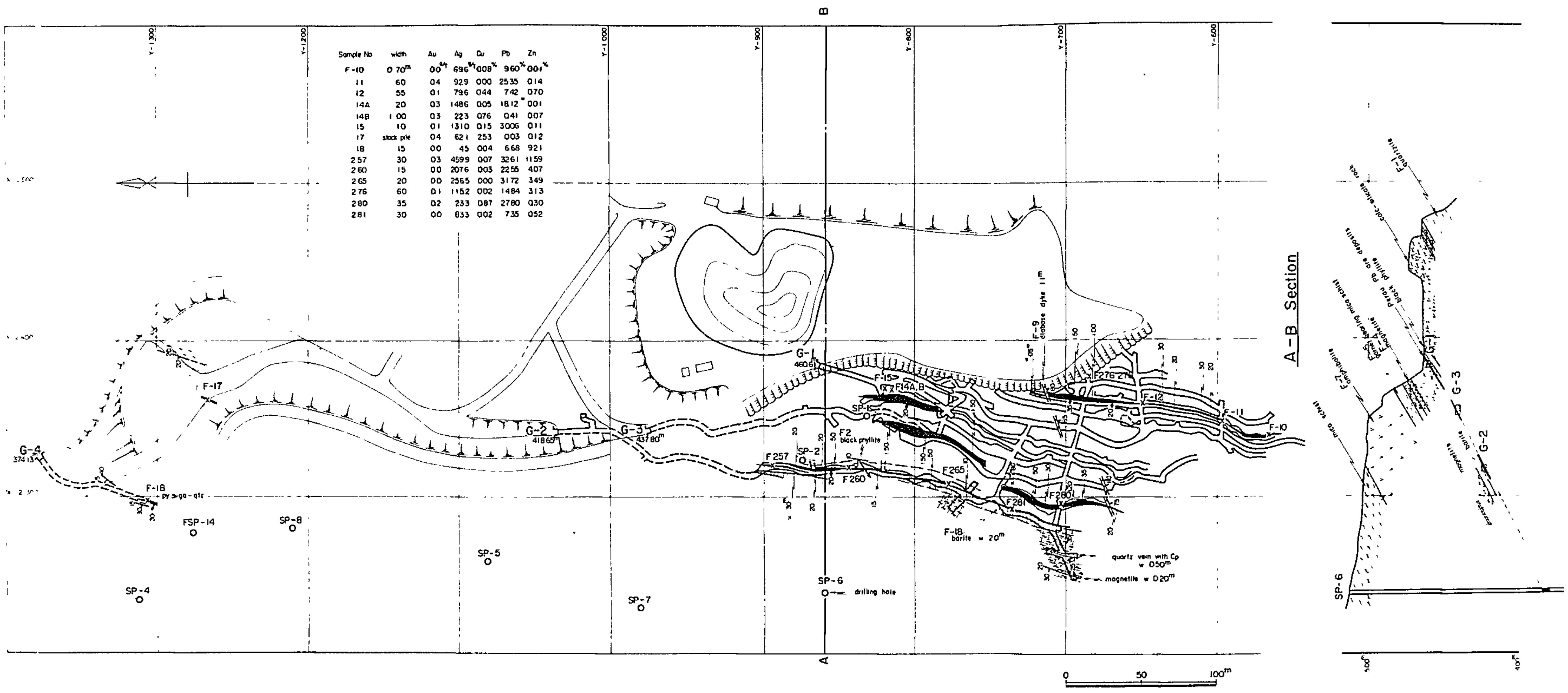


Fig. I–9 Stratigraphic Correlation among Three Mines



Sample No	width	Au	Ag	Cu	Pb	Zn
F-10	0 70m	00 g/t	696 g/t	008 %	960 %	001 %
11	60	04	929	000	2535	014
12	55	01	796	044	742	070
14A	20	03	1486	005	1812 *	001
14B	1 00	03	223	076	041	007
15	10	01	1310	015	3006	011
17	stock pile	04	621	253	003	012
18	15	00	45	004	668	921
257	30	03	4599	007	3261	1159
260	15	00	2076	003	2255	407
265	20	00	2565	000	3172	349
276	60	01	1152	002	1484	313
280	35	02	233	087	2780	030
281	30	00	833	002	735	052

Fig. I–10 Geological Map of Perau Mine

has been carried out on the four levels below the outcrop such as 460m., 438m, 419m and 374m. At present 90 workers are working. Monthly production of 1,500 tons (Pb 7 ~ 10 %, Ag 80 ~ 120 g/T) of crude ore is sold to Panelas Smeltery.

2) Geology of the surrounding area

In the surrounding area of the mine, quartzite, calc-silicate rock, pelitic schist and amphibolite of the lower Açungui I formation are distributed. Quartzite of the lowermost part is white in color, massive and compact with a thickness of 90 ~ 100m. At the contact with calc-silicate rock of the upper sequence, an alternation zone (10m. in thickness) of the two rocks intervenes and grades into the calc-silicate rock, decreasing intercalation of quartzite (0.2 ~ 1m.) toward the upper.

Calc-silicate rock is a pale greenish grey schist having a thickness of about 50m. The Perau deposit is found near the upper boundary of the rock.

On the calc-silicate rock is garnet bearing biotite-muscovite schist in which a magnetite bed (2m. thick) is intercalated.

Although the strike and dip of the Açungui formation in the surrounding area of the Perau mine does not show regular directions because of the existence of axes of anticline and syncline, a monoclinal structure of N–S and 30W is shown in the proximity of the ore deposit. Lineament of S40–60W is developed on the schistosity plane.

A few igneous rock are found in the area. An exposure of granite is found about 7km. apart from the mine, and several dykes of diabase are intruded into the Açungui formation and the deposit with a trend of NW–SE.

3) Ore Deposit

As shown in Fig. I–10, the Perau deposit is a stratiform lead deposit, which is developed by the drifts of 300–400m length on the main levels (G–1, G–3 and G–2 from the upper) excavated every 20m. vertical intervals. Also an ore deposit, which is estimated to correspond to the same horizon with the main ore body, has been drifted to the south for 80m. on the G–4 level which is 300m. apart from G–2 adit horizontally, with 40m below in height.

Existence of a black phyllite bed intercalated about 1–2m. below the ore body and a magnetite bed (0.5–2.0m. in thickness) found at 15m. above has been a powerful guide for the exploration in the area.

The ore beds observed in the drifts, as shown in Fig. I–11, consist of massive galena and galena impregnation. Thickness of the bed is 0.10–1.50m. or more (0.50m. in average)

and ore grade is estimated to be about 6 %. According to the results of drilling from the surface, several ore beds composed of massive ore or impregnation (each thickness is 0.50 – 1.00m). with gangue rocks seem to continue laterally with repetition of swell and pinch. The thickest ore zone consists of six beds (each 0.5m thick) in nine meters length.

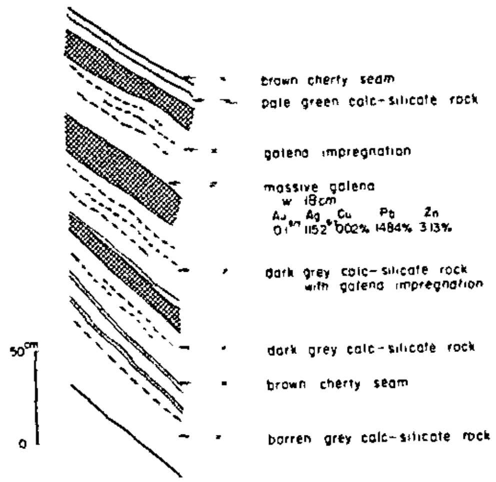


Fig. I–11 Sketch showing Ore Occurrence at G–1 Raise, Perau Mine

Ore minerals mainly consist of galena and pyrite with very small amount of chalcopyrite and sphalerite. Gangue minerals are absolutely absent or, a small amount of quartz or barite can be partially observed. Fig. I–12 (A) and (B) show the typical occurrence of the ore.

Pyrite is generally fine grained and has a banded structure which is completely harmonious to the bedding of country rocks and entirely resembles to the bedded cupriferous pyritie ore (Kieslager).

Galena is coarse grained and generally harmonious to the bedding, but in some part, it includes breccias of country rocks and rounded pebbles of pyrite and some spurs of galena are observed along the crack of country rock. These evidences show that pyrite has kept the original texture, while galena has moved to fill the cracks of the ore and country rocks.

The characters of typical ore are as follows.

Galena–pyrite ore (F–11): G–1 Sublevel

Macroscopic characteristics–

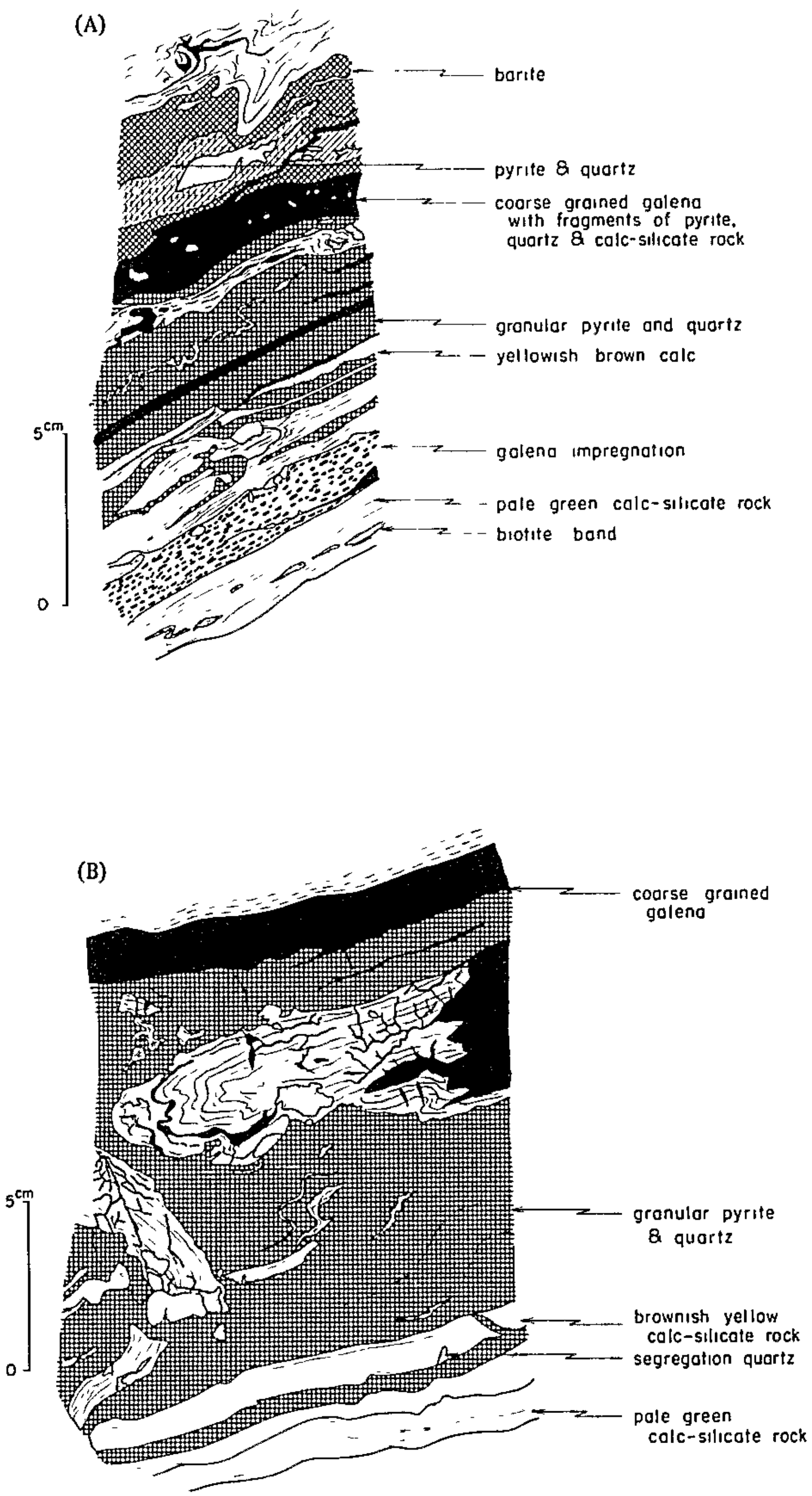


Fig. I–12 Typical Occurrence of Perau Ore

Pyrite banding is observed along the boundary with the country rock, and galena in the center part is coarse grained, filling the cracks of gangue rock and pyrite.

Microscopic characteristics–

The ore consists of abundant coarse grained pyrite and stringer of galena which is partly massive. Galena fills the cracks of pyrite and is scattered in it as spots. A small amount of minute crystals of sphalerite and chalcopyrite are observed. The sequence of crystallization of these minerals is, from the earlier, pyrite → galena → sphalerite → chalcopyrite.

The result of chemical analysis is as follows;

Sample No.	Width	Au	Ag	Cu	Pb	Zn
F–11	0.60m.	0.4g/T	92.9g/T	0.00 %	25.35 %	0.14 %

The vertical relation between galena and banded pyrite is not always certain. However, barite always occurs above the ore.

4) Ore Shoot

Ore shoot of the Perau ore deposit has not yet been known well. According to the orientated map used in the mine, the 'bonanzas' in both adits of G–1 and G–3 are found near Y–800, where the thickness of each ore bed reaches up to 1.00m. ~ 3.00m. showing the apparent direction of ore shoot to be in a N90W direction. However, no special rich part of the ore could be found in the prospecting drift of G–2 level, which is 20m. below the G–3 adit, showing a thickness of 0.10 ~ 0.30m. therefore, a sudden downward pinching would be indicated.

The mine staffs consider the direction of ore shoot to be N25W, taking the drill intersection (SP–2, W=3.5m, 5.43 % Pb) at about 10m. above the G–2 level into consideration. However, the ore shoot of the Perau deposit seems to extend in a form of narrow rectangulars or bamboo leaves and lineation measured on schistosity plane of black phyllite shows a trend of S40 – 50W, therefore, the direction of the ore shoot may coincide with that of the lineation. More detailed survey in underground would be recommended.

The ore bed in the G–4 level, 300m. north of the entrance of G–2 adit, is in the same horizon with the main ore body, occurring above the black phyllite. The ore bed with the thickness of 0.10 ~ 0.20m. consists of galena, sphalerite, pyrite and small amount of quartz, containing abundant breccias of limestone of the country rock.

The result of chemical analysis is as follows;

Sample No.	Width	Au	Ag	Cu	Pb	Zn
F−18	0.20m	0.1g/T	4.5g/T	0.04 %	6.68 %	9.21 %

On the south of the Perau ore deposit, an ore bed (0.01 – 0.05m. thick) which is in the same horizon with the Perau deposit consisting of chalcopyrite, pyrite and quartz extends intermittently for about 1.7km. to Galeria da Azurita. At Galeria da Azurita, an ore bed (0.10m. thick) of azurite in dolomite has been drifted for about 30m. The ore contains round grains of transparent quartz and druses in abundance. Galena and sphalerite are almost absent.

The result of chmical analysis is as follows;

Sample No.	Width	Au	Ag	Cu	Pb	Zn
F−269	0.10m.	0.3g/T	116.2g/T	29.90 %	0.04 %	0.09 %

(B) Agua Clara Deposit

1) Outline of the mine

The Agua Clara mine is located at 6km. to the notheast of Tunas and apart about 10km. from the Perau mine to the south-southwest.

During the period from January 1974 to January 1976, prospecting for copper was conducted by drifting at three points. From February to August 1977, exploration on barite was carried out, shipping 180 tons of ore. After that all works have been suspended.

2) Geology of the surrounding area

Quartzite and dolomite (50m. in thickness) composed of the bottom of the Açungui I formation, calcareous schist (20m. in thickness) and quartz-sericite schist are distributed. As there are six anticlines and synclines plunging to SW in the area, the strike and dip of the strata are irregular.

3) Ore deposit

The ore deposit is a vein developed in pale yellowish brown dolomite, and weather-resistant quartz protrudes as a skeleton. Impregrated chalcopyrite is altered to azurite and bornite. The result of analysis of the sample taken from an outcrop on the northern slope of Morro do Zinco is as follows:

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

Barite deposit occurs in quartz-sericite schist 800m. southwest of the copper deposit, which was prospected by two drifts such as Taboa and Paiol. Different from the Perau

deposit, the barite is not found in calcareous schist, but it is located 1m. above the boundary of the schist. The thickness of barite is 1 meter. The bed contains a small amount of chalcopyrite and pyrite, and banded magnetite beds, several centimeters in width, are found on both sides of the barite bed.

(C) Pretinhoe Deposit

1) Outline of the mine

The Pretinhoe mine is located about 5km. east of the Perau mine, and is it's branch mine. The deposit was recently discovered by CPRM, where preparatory and some mining works are being carried out. Annual production in 1980 was 140 tons of crude ore.

2) Geology of the surrounding area

In the vicinity of the mine, quartzite and calc-silicate rock of the bottom of the Açungui I formation and biotite-quartz schist are distributed. Entirely the same rock facies as those of the Perau mine is repeated here due to an anticlinal structure extending from Agua Clara in NE–SW direction (cf. Fig. I–9). Strike and dip of the strata are N40E and 30 ~ 40S.

Biotite-quartz schist shows dark green in color by chloritization and contains a considerable amount of porphyroblast of garnet. Impregnation zone of magnetite and thin layers of pelitic limestone are intercalated in the schist.

3) Ore deposit

The bed of barite is found in calcareous schist with a thickness of 0.80 ~ 1.50m. The barite bed can be said to be entirely in the same horizon as that of the Perau mine, since it is located 50m. apart from the lower quartzite and 5m. to the upper biotite schist. A narrow band of chalcopyrite and galena with several milimeters in width is locally included in the barite bed.

The result of chemical analysis is as follows;

Sample No.	Width	$BaSO_4$	S	Cu	Pb	Zn
F–113	0.80m.	85.48 %	0.51 %	812ppm	54ppm	61ppm

The lateral extension of the ore bed is as the result of stripping of overburden, up to more than 1,000m.

2–2–2 Rocha Area

The ore deposits and the showings located in the area are found in three zones of limestone belonging to the Açungui III formation, extending in the directions of NE–SW ~ ENE–WSW. In the extension of 5km., more than 50 silver bearing lead deposits and show-

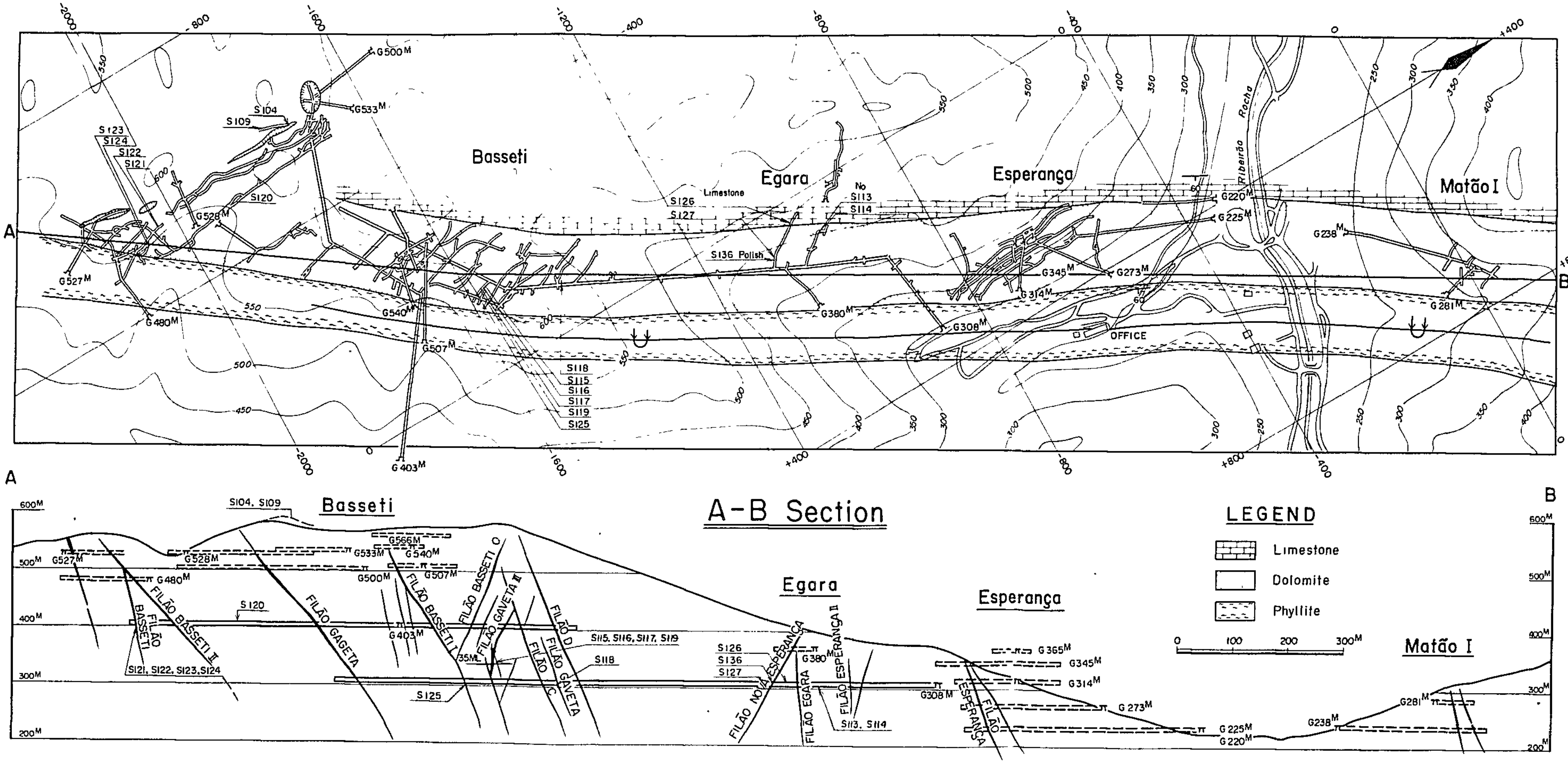


Fig. I–13 Geological Map of Rocha Mine

ings have been known. Among these the main ore deposits are as follows:

1. The western limestone zone .... Rocha, Onça II, Quarenta Oito.
2. The central limestone zone .... Paqueiro, Bueno, Diogo Lopes.
3. The eastern limeston zone .... Barrinha, Cecrisa Laranjal, Braz, Carumbe.

These limestone zones are a repetition of the same zone as the result of folding. The deposits are veins and stratiform deposits emplaced at the axes of anticlines.

(A) Rocha Deposit

1) Outline of the mine

The Rocha mine is situated 14km. west-southwest of Adrianopolis. The mine road extends westward about 20km. from the junction on the highway (state road No.476), running from Adrianopolis to Tunas, at about 4km. south of Adrianopolis. Several openings have been excavated at places in the height of 200–600m. above sea level along the upstream of Rocha River, a branch of the Ribeira River.

The mine was opened in 1956 and has been operated by the present owner, Mineração Rocha, SA. since 1979. Underground mining are mainly conducted at 310m. and 403m. levels. The prospection at 220m. level is under way. Open pit mining is also being carried out at 600m level.

The crude ore is handpicked at the mine site, and the concentrate is sold to Panelas Smelter which is 40km. apart from the mine. Monthly production of concentrate is 2,500 tons with the grades of 6.5 % Pb and 130g/T Ag.

2) Geology of the surrounding area

The rocks found in the surroundings of the mine consist of the Açungui III formation composed of calcareous rocks and pelitic rocks, in which a number of diabase dykes of Cretaceous have intruded. Anticlinal and synclinal structures in the Açungui formation are repeated with steep dips such as 70°S ~ 70°N, and a general strike of NE–SW.

The sequence of rocks around the mine consists of limestone (more than 300m. in thickness), dolomite (about 150m.) and phyllite (50m.) in an ascerding order.

3) Ore Deposit

Occurrence of the Rocha deposit is limited, as shown in Fig. I–13, within dolomite which extends in NE–SW direction. It is the vein type deposit filling the fissures of three systems such as (a) N20°–30°W, 60°–70°NE, (b) N20°-30°W, 60°–70°SW, (c) N60°W, 90°.

So far ten-odd veins have been found, which are arranged in a form of ladder. The scale of vein is 350m in maximum extension, the average being 150m. with width of 0.05–

2.00m. The veins take a lenticular form with remarkable pinch and swell.

Fissures are better developed in dolomite (which is the country rock of the ore) than in limestone, although both rocks are massive and have the same appearance. At the northwestward drift on the 308m. level of the Egara vein, microfolding is developed only within limestone, and a regularly extending vein in dolomite thins out in a form of horse tail in limestone. This fact indicates that limestone was more incompetent against the deformation, which resulted in causing flowage at the time of folding as in phyllitic rocks, and no notable fissure was formed in the rock. (cf. Fig. I–14)

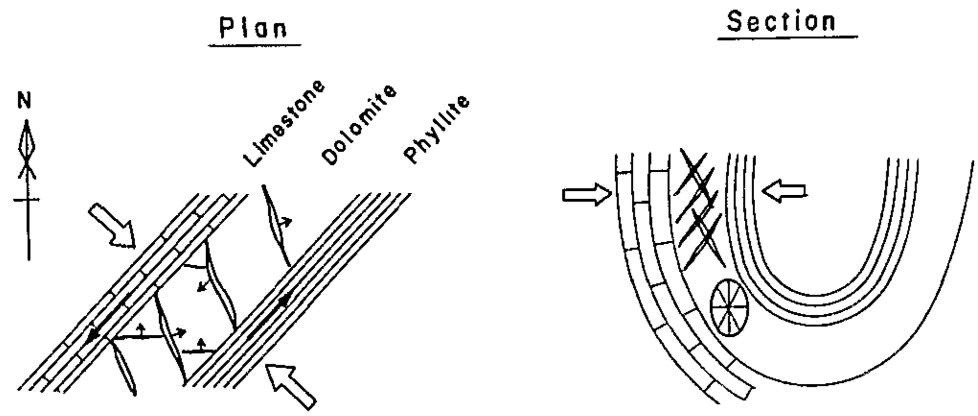


Fig. 1–14 Relation between Stress and Veins, Rocha Mine

Since the folding structure of the whole area belongs to NE–SW system, it is clear that the area suffered the compressive force of NW–SE direction which is perpendicular to the system. Therefore, the following consideration would reasonably be made on the mechanism of formation of three fissure systems observed in the Rocha mine.

(1) Compressive force in NW–SE direction caused lateral displacement (NE–SW system) along the strata together with folding of the strata.

(2) Tension cracks (N30°W, 70°N, N30°W, 70°S) were formed by the above movement.

(3) A weak secondary shear fractures were generated along with the tension crack. A regular distance of every 300m or its multiples is observed in the arrengement of the tension cracks, which are the main fissures in this mine.

The characteristics of typical limestone and dolomite of the Rocha mine are as follows.

Table I–5 Characteristics of Limestone & Dolomite, Rocha Mine

Location	Magascopic Feature	Chemical Analysis					X-Ray Analysis				Microscopic I eature
		CaO	MgO	Al_2O_3	$I e_2O_3$	SiO_2	M	Q	Cc	D	
Lmestone S126 308 mL Egara ore body	grey, massive	% 41.29	% 2.32	% 0.09	% 0 67	% 19 84	△	○	◎	○	aggregate of mosaic calcite grains (0.2mm in diameter) a few anhedral quartz and muscovite are present.
Dolomite S127 308 mL Egara Ore body	grey, massive	25.13	16 72	0.44	1.32	16 56	•	○		◎	aggregate of dolomite (0 05 ~ 0 1mm) and quartz (0 1 mm) a few muscovite is present, with clear schistosity

M . Mica, Q · Quartz, Cc : Calcite, D Dolomite
• . very rare, △ rare, ○ . common, ◎ · abundant

The assemlage of ore minerals is simple and no zonal distribution has been known. The ore mainly consists of galena with a few amount of argentite, chalcopyrite, sphalerite and pyrite. Gangue minerals consist of calcite and quartz, which are very few amount.

Microscopic observation of the typical ore shows that early crystals of pyrite are broken to pieces and sphalerite ≪ galena fill the cracks. Dots of chalcopyrite are observed in sphalerite, and a small amount of argentite is enclosed in galena.

The sequence of crystallization is pyrite → sphalerite → chalcopyrite → argentite → galena. (S–119).

An example of grades of the ore vein is as follows:

310mL Fillão Egara vein (S–113)

Sample No.	Width	Au	Ag	Cu	Pb	Zn
S–113	0.80m	1.8g/T	470g/T	0.49 %	26.95 %	0.02 %

(B) Barrinha Deposit (Fig. 1–15)

1) Outline of the mine

The mine is situated 10km. south of Adrianopolis. There are several old pits and outcrops at the altitude of 500 ~ 600m. Open pit mining is being carried out at the Quatro outcrop of the main deposit, and preparation for mining is under way at the outcrops such as Oito and São Joaquim.

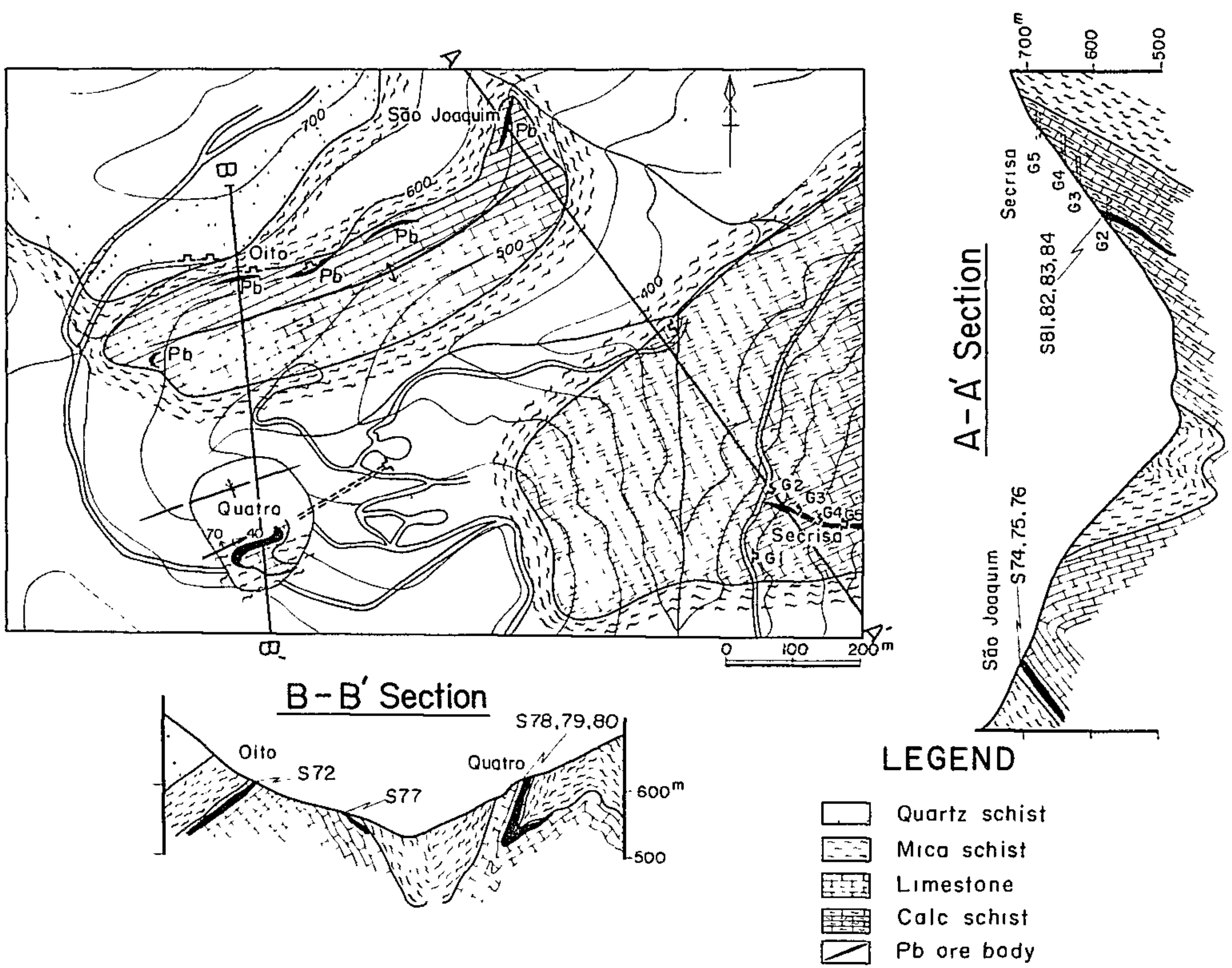


Fig. I–15 Geological Map of Barrinha Mine

2) Geology in the surrounding area

Limestone, calcareous schist, phyllite and sericite schist of the Açungui III formation are distributed, in which dolerite dykes of Cretaceous are intruded.

Country rocks of the ore deposits are limestone and calcareous schist, which show a general strike of N70°E, dipping 40°N in the west area and 70°S in the east area. The general structure of the area is the combination of anticline and syncline with axes of ENE–WSW direction, which gently plunge toward the east or west.

3) Ore deposits

The deposits are stratiformly emplaced in the upper part of limestone; the Quatro deposit in the center, Oito and São Joaquim in the west, and Searisa and Larajal in the east.

(i) Quatro deposit

The ore bed dips at 40° toward ENE direction, controlled by the folding structure. The lateral extension is 70m. with a thickness of 10 ~ 14m. Ore minerals are galena, chalcopyrite and pyrite associated with secondary oxide minerals such as cerussite, pyromorphite and limonite.

The result of chemical analysis is as follows;

Smaple No.	Ag	Ag	Cu	Pb	Zn
S–78	0.0 g/T	15.33 g/T	0.08 %	30.61 %	0.04 %

(ii) Oito ~ São Joaquim Deposit

Strike and dip are N70°W and 40N. The ore bed extends laterally 200m. in the direction of strike with a thickness of 0.4 ~ 1.0m. Ore mineral is galena associated with quartz and calcite.

The result of chemical analisis of the outcrops are

Location	Sample No.	Width	Au	Ag	Cu	Pb	Zn
Oito	S–72	0.50 m	0.7 g/T	199.5 g/T	0.26 %	15.20 %	0.05 %
São Joaquim	S–75	0.50	3.9	164.3	0.10	8.30	2.98

(iii) Secrisa ~ Laranjel Deposit

Underground prospecting was carried out at four places of upper and lower levels, but the details are not known.

Laranjel is a stratiform deposit in calcareous schist with strike of 70°E and dip of 60°N.

The result of chemical analysis is as follows;

Location	Sample No.	Width	Au	Ag	Cu	Pb	Zn
Laranjel	S–85	0.40^{m}	$0.8^{g/T}$	$222.9^{g/T}$	0.58 %	17.38 %	0.06 %
Secrisa G–2	S–82	Stockpile	0.1	187.1	0.09	7.86	0.01

(C) Paqueiro Deposit (Fig. I–16)

1) Outline of the mine

The Paqueiro mine is situated at almost the middle point between Adrianapolis and the Rocha mine.

The mine was opened in 1953 and operated by Plumbum SA from 1957 to 1971. The operation is suspended at present. The total amount of ore produced is 16,300 T, 9 % Pb.

2) Geology of the surrounding area

Limestone and sericite schist are repeatedly exposed by the folding with an axis of NE–SW system and are distributed in a form of narrow belt. Strike faults are developed.

3) Ore deposits

Vein type deposits filling the fissures are developed near the boundary between limestone and sericite schist or in limestone. There are four ore bodies such as A, B, C and D, among which the largest ore body D sinks in water.

The ore minerals are galena and pyrite associated with gangue minerals such as quartz and calcite.

The scale and grade of the ore deposits are as follows:

Ore Body	Scale	Sample No.	Au	Ag	Cu	Pb	Zn
A	L=6, $W=0.3^{m}$	S–63 ($w=0.2^{m}$)	$0.1^{g/T}$	$6.4^{g/T}$	0.01 %	1.61 %	0.45 %
B	Lens ($0.2x0.05^{m}$)	S–65 ($w=0.2^{m}$)	0.1	84.5	0.06	5.95	0.01
C	$L=700^{m}$ echelon	S–62 ($w=1.2^{m}$)	2.5	110.0	0.03	8.91	0.01
D	$L=200^{m}$ echelon	S–59 ($w=0.2^{m}$)	0.4	656.5	0.09	21.83	0.01

(D) Bueno Deposit (Fig. I–17)

1) Outline of the mine

The mine is located 2km. northeast of the Pequeiro mine. Prospecting was carried out at three levels such as 550m, 572m, and 600m. The time of opening of the mine is not known. The operation has been suspended since 1971. The amount of ore produced is 66T, 10.6 % Pb.

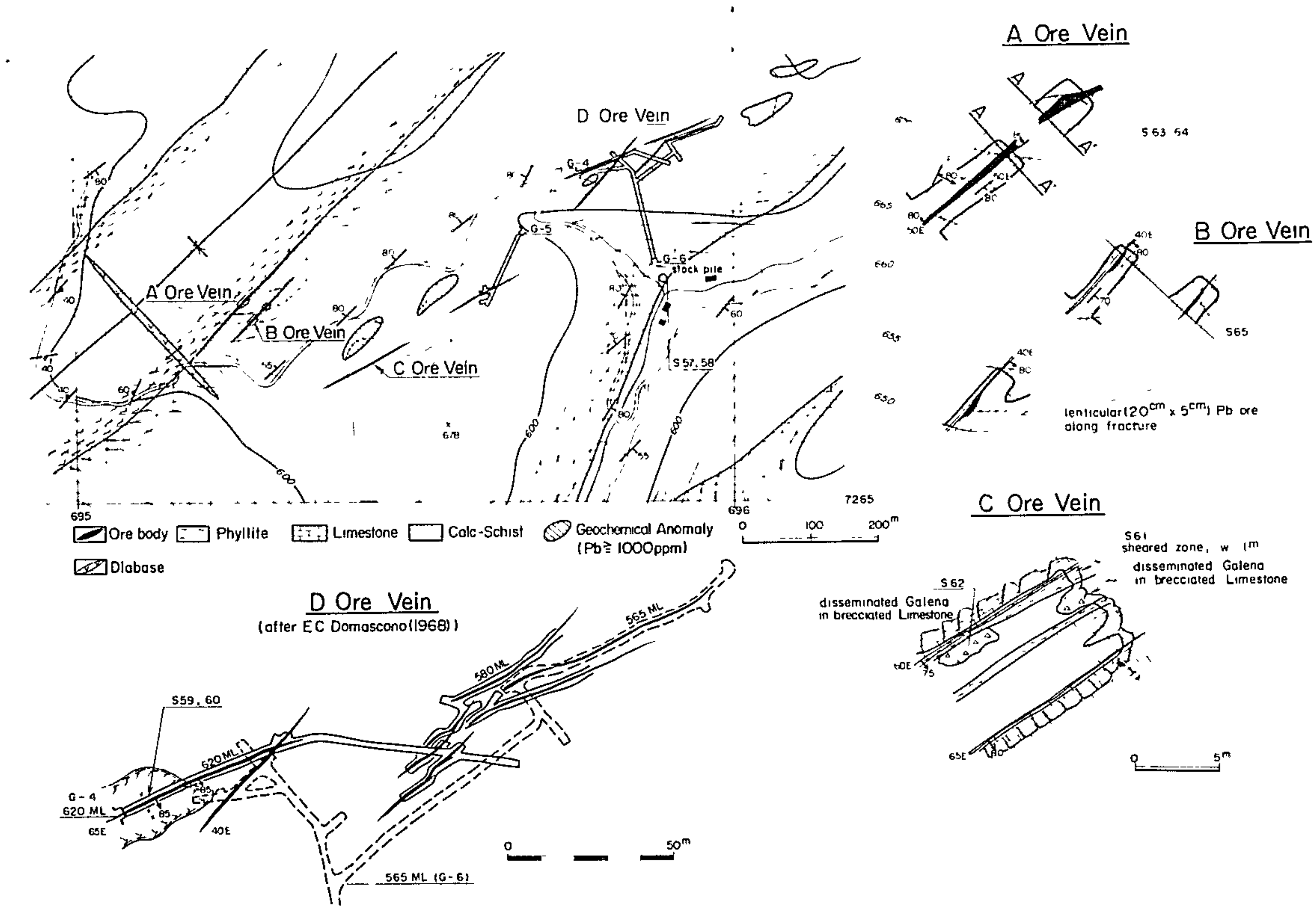


Fig. I–16 Geological Map of Paqueiro Mine

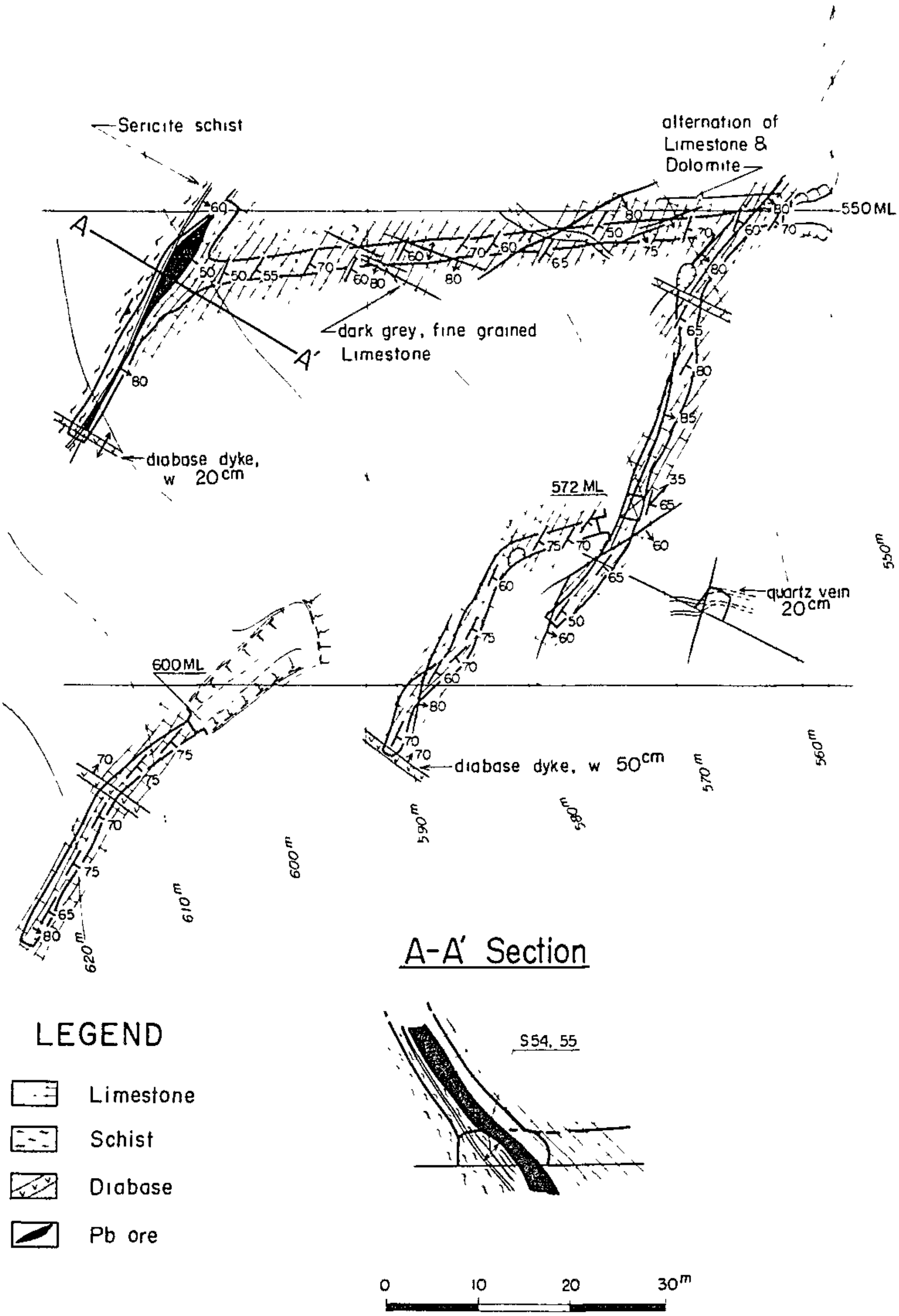


Fig. I–17 Geological Map of Bueno Mine

2) Geology of the surrounding area

The mine is on the northeastern extension of the Pequeiro mine, and limestone, sericite schist and dykes of diabase are distributed. The foldings with an axis of NE–SW direction are repeated.

3) Ore Deposit

It is a vein-type deposit found along the fault developed near the contact between limestone and sericite schist, and shows a lenticular form with a lateral extension of 15m. and width of 1.5m.

Ore minerals are galena and pyrite associated with gangue minerals such as quartz and calcite. Under the microscope, chalcopyrite and galena penetrate pyrite as veinlets (S–54).

Grades of ore of stockpile are as follows:

Sample No.	Au	Ag	Cu	Pb	Zn
S–55	0.5g/T	70.2g/T	0.18 %	23.05 %	0.01 %

(E) Diogo Lopes Mine (Fig. I–18)

1) Outline of the mine

The mine is situated 2km. west-southwest of Adrianopolis. Prospecting galleries are located at 445m., 468m., and 470m above sea level. The opening time of the mine is not known. The operation has been suspended since 1975. The total amount of ore produced is 144T, 9.72 % Pb.

2) Geology in the surrounding area

Geology is almost similar to those of the Pequeiro and Bueno mines. Regionally, the mine is situated at the turning point of the geological structure from NE–SW system to E–W trend. Two fault systems such as E–W and NW–SE are found, among which the former is considered to be a shear fault.

3) Ore Deposit

The deposits of the mine are classified into two types. One is a vein type found along the fissures developed at the contact of limestone with sericite schist and in limestone. The other is a stratiform type in limestone.

Vein type deposit

This type is found at 468m. and 445m. levels. The former shows notable pinch and swell with lateral extension of 50m. and the width of 0.1–0.5m., while the latter shows a lenticular form with lateral extension of 50m. and the width of 0.1–0.3m.

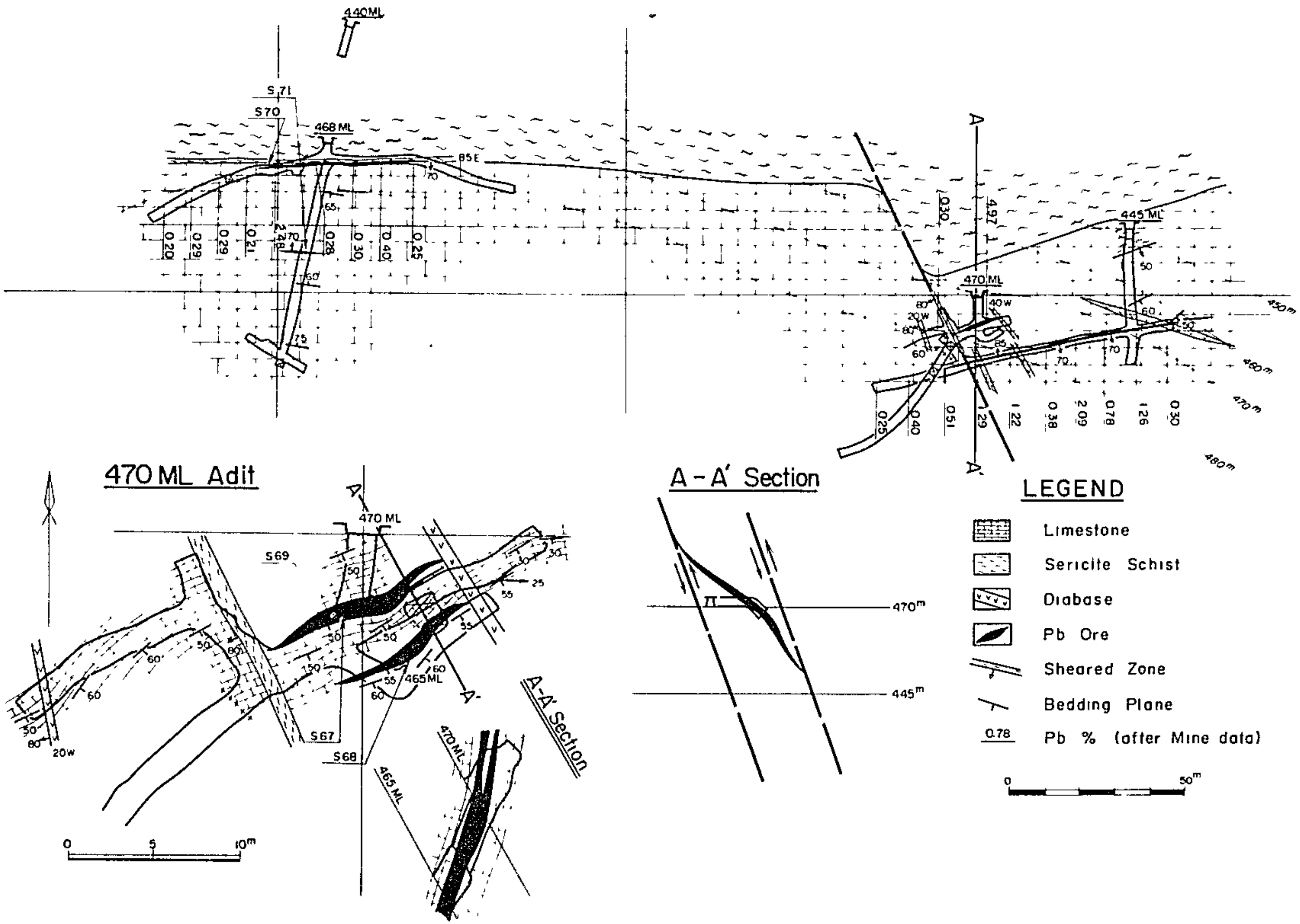


Fig. I–18 Geological Map of Diogo Lopes Mine

Stratiform type deposit

This is observed in 470m. level and shows a lenticular form with lateral extension of 10m. and the width of 0.1–1.0m.

Ore minerals in both types are quite similar, consisting of galena and pyrite being associated with calcite and quartz.

Representative grades of ores from both 470mL and 468mL are as follows:

	Sample No.	Width	Au	Ag	Cu	Pb	Zn
470 mL	S–68	0.50^{m}	$0.9^{g/T}$	$424.9^{g/T}$	$0.07^{\%}$	$31.83^{\%}$	$0.38^{\%}$
468 mL	S–71	0.40	0.0	18.0	0.07	0.41	0.01

2–2–3 Panelas Area

The occurrence of the deposits in the area are limited within limestone of the Açungui III formation. The Panelas lead deposit which is the largest ore deposit in the surveyed area is included in this area and also a fluorite deposit occurs as a different type of deposit.

(A) Panelas Deposit

1) Outline of the mine

Panelas is a lead mine situated about 14km. east of Adrianopolis and operated by Plumbum SA. Industria Brasileira de Mineração, which operates a smelter at the mine site. The deposit was discoverd in 1936, and the mill plant was constructed in 1954. The amount of ore mined up to date is 1,200 thousand tons and lead production reached 84.5 thousand tons. The main part of the deposit has been mined out. Monthly production is maintained at the level of 2,500 tons (Pb 5.8 %, Ag 100 g/T). Among the total 380 laborers, 150 work for mining and 130 work for milling and smelting.

At the mill plant, 7,000 tons of ore are treated a month including the ore purchased from the mine of the surrounding area. The breakdown is as follows:

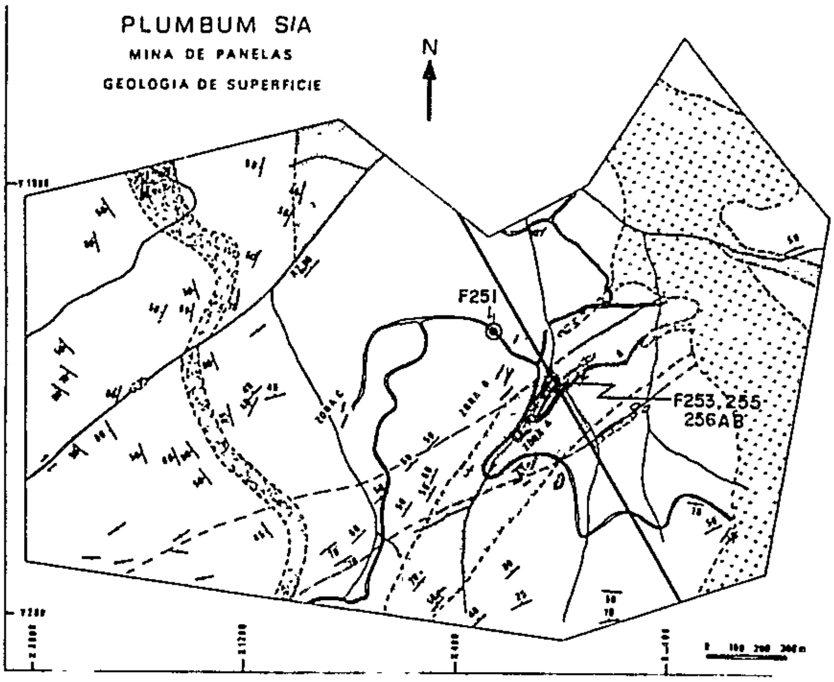
Panelas mine	2,500 T/M	5.8 % Pb
Rocha mine	2,500 T/M	6.5 % Pb
Perau mine	1,500 T/M	8.5 % Pb
Total	6,500 T/M	

The smelter has the capacity of 1,800 T/M of lead, which also treats the imported ore.

2) Geology of the surrounding area

The rocks distributed in the surrounding areas of the mine consist of limestone and mica schist of the Açungui III formation and the Itaoca granite which intruds into the above

rocks. Although the general strike and dip of the area are NE–SW and 50°N, they are NW–SE and 50°S in the west.



CC : calcário claro,

CN : calcario negro,

MX : micaxisto,

G : granito,

P : parfiro,

D : diabase

◎ : sampling site

Fig. I–19 Geological Map of Panelas Mine Area (After Odan Y.)

Limestone in the mine area can be divided into black limestone (CN) and grey limestone (CC), which shows sometimes remarkable flow folding.

Fig. I–20 Flow Folding of Limestone, Panelas Mine

3) Ore Deposit

The Panelas mine is an old mine in which the total extension of the underground level reaches as long as 80km. Because of the concrete seals of the passage to the old mined out areas, the observation in the underground is limited to a few places.

According to Odan Y. (1978), there are 90 ore bodies in the Panelas deposits, the occurrence of which can be divided into three zones such as A, B, and C. A zone consists of black limestone which includes 68 ore bodies showing a remarkable contrast to B zone of grey limestone (including 20 ore bodies) and C zone (including 2 ore bodies).

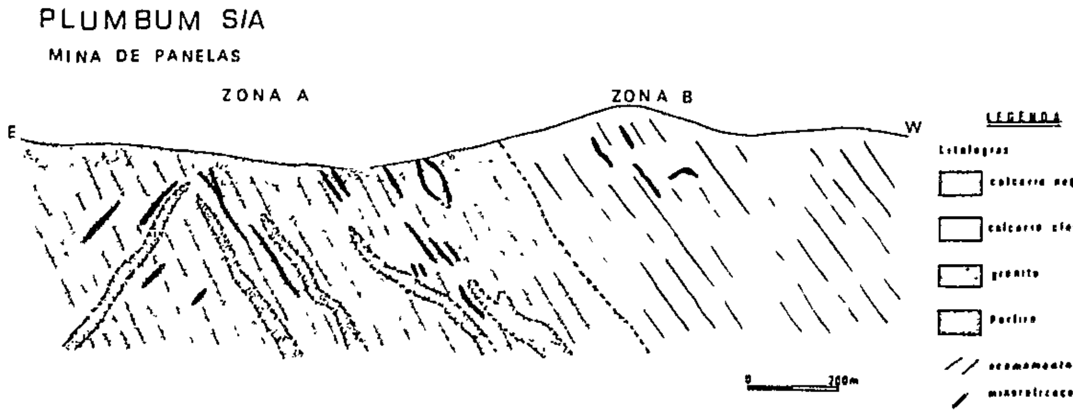


Fig. I–21 Schematic Profile of Panelas Mine (After Odan Y.)

A unit ore body is narrow rectangular in shape, trending to continue along the shoote. The average width is 0.30m. although the ore bodies are generally conformable to the surrounding strata, sometimes it is clearly oblique to the bedding.

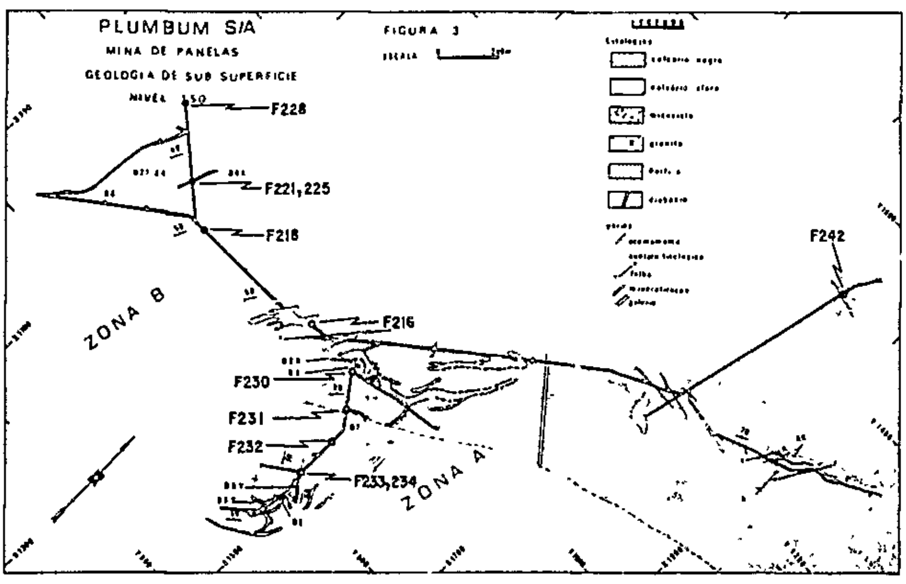


Fig. I–22 Location Map of Rock Samples (150 mL), Panelas Mine

According to Odan Y., black limestone (A zone) is rich in graphite, and assemblage of ore minerals mainly consists of galena and pyrrhotite, while in greyish white limestone (B zone), galena-pyrite predominates.

In order to investigate the relation between the ore deposit and country rock, various tests were made this time on samples of limestone taken from the cross cut on the 150mL and limestone with black bandes taken on the surface 200m. west of the mine office (cf. Figs. I–19, I–22). The result are shown in the following table.

Table I–6 Chemical & X-Ray Analysis of Panelas Limestone

150 mL

	Megascopic Observation	Chemical Analysis							X Ray Analysis				
		CaO	MgO	Al_2O_3	Fe_2O_3	C	CO_2	IR	M	Tr	Q	Cc	D
I 216	fine black	38 39	3.36	0 21	1 07		-	22 58	•				
218	fine grey	15 39	5 27	0 48	1 76		-	58 52					•
225	coarse, grey	44 40	8 85	0 02	0 14	-		1 06	• ?		• ?		
228	fine, black	42 92	2 96	0 17	0 61	-		15 62		•			
230	coarse, black	52 41	9 66	0 06	0 29	-		3 30			•		
231	fine, black	45 16	1 21	0 08	0.56	0 76	30.20	15 22		•	•		
232	coarse, white	31 76	4 34	0 56	2 70	-		29 76	'				
234	coarse, white	52 00	1 15	0 06	0 66	0 01	34 09	3 76		. ?			
Surface													
I 256A	fine, black	45 11	0 96	0 12	1 19	0 02	13 84	14 44	•				
256B	coarse, white	50 67	0 76	0 08	0 94	0 03	21 05	4 84	•		• ?		

Chemical Analysis - no data
X Ray Analysis M Mica (phlogopite) Tr Tremolite Q Quartz Cc Calcite
D Dolomite, • very rare rare common abundant

Galena-pyrrhotite ores are located at the points of F–225, F–230 and F–234 in the cross cut.

Under the microscope, the rocks consist of crystals of calcite except for F218, tending to become coarse grained (1x0.5mm.) near the ore bodies showing a mosaic texture, and to become fine grained (0.5x0.2mm.) at a distance away from the ore bodies showing distinct schistosity. This evidence indicates that recrystallization is more advanced near the ore deposit. In black limestone, abundant very fine grained black spots (carbonaceous matter?) are scattered without exception. As the result of chemical analysis, there is a distinct difference in the content of carbnaceous matter, viz, black limestone has 0.76 % while greyish white limestone, 0.01 %. As indicated by Odan Y., it is considered that there is a high possibility that the presence of carbonaceous matter has given an influence on the deposition of ore minerals.

As for the ore minerals, most of pyrite grains are replaced by pyrrhotite, which is considered to have been caused by contact metamorphism of the Itaoca granite because the country rock has suffered thermal metamorphyism (Melcher G.C. 1968).

The sequence of crystallization of ore minerals is pyrite → pyrrhotite → chalcopyrite → tetrahedrite → galena.

Examples of analysis of ore minerals in A and B zones are as follows:

	Location	Width	Au	Ag	Cu	Pb	Zn
Zone A	219 ml G–27 (F–207)	0.10m	0.0g/T	0.9g/T	0.20 %	24.46 %	0.04 %
Zone B	150 ml B4L (F–221)	0.10	0.4	270.	0.80	28.85	0.02

(B) Fluorita de Sete Barras Deposit

1) Outline of the mine

The fluorite mine is situated about 10km. east of the Panelas mine. Network veins of fluorite are found at the contact of limestone of the Agungui III formation with granite. Prospecting was carried out by excavating two shafts (18–20m. deep) at altitudes of 370m and 395m above sea level.

2) Ore Deposit

Fluorite ore does not expose in the vicinity of the old shafts, and as the crude ore from the bottom of the shaft has very fine grained fluorite, it is difficult to discern it.

The continuation of the vein for about 2km. along the contact of granite in the direction of N80°E had been confirmed by CPRM. At the trench yellowish brown fluorite networks filling the cracks of the country rock.

Typical value of analysis is as follows:

Sample No.	Sampling width	F
F–123	0.50m	24.64 %

2–2–4 Furnas–Lageado Area

The deposits in the area are vein type lead deposits occurring in limestone of the Açungui III formation, in which a number of showings are arranged regularly. Among these, only the Furnas mine is in operation at present.

(A) Furnas Deposit

1) Outline of the mine

The mine is situated at 17km. from Apiai along Highway 165 which runs from Apiai to Iporanga.

It was opened in 1920 by Sociedade Mineração Furnas Ltda., and suspension and reopen were repeated since then. It has been operated by Cia Argentifera Furnas Mineração Inchistria e Comerero Ltda. since 1978.

Ore production is 500T/M with average grades of crude ore of 7 % Pb and 3000 g/T. As most of ore is oxidized, the crude ore is concentrated to about 20 % Pb by means of gravity separation and shipped by track to the Panelas Smelter which is 70km. apart.

2) Geology of the surrounding area

Psammitic and pelitic schits of the Acungui III formation are distributed between Apiai and Iporanga, where repetition of anticline and syncline of NE–SW system is observed. At the apex of anticline, psammitic and pelitic schists of the lower sequences are exposed as the result of erosion of the upper limestone, while, at the synclinal part, the limestone is widely distributed. The Furnas deposit is found in limestone distributed at the a general strike

Limestone of the surrounding area shows an overfolding structure with a general strike of NE–SW system and a dip of 60–70°N.

An attempt was made in this survey to determine the vertical succession of the strata from the relation between bedding plane and schistosity plane (cleavage). It was found, as the result, that there is a strong possibility of overturn of the limestone, which is the country rock of the Furnas ore deposit. As shown in Fig. I–23, it is assumed that a small scale parasitic fold would be developed in the interior, although the limestone which includes the Furnas deposit shows a considerably large scale syncline structure.

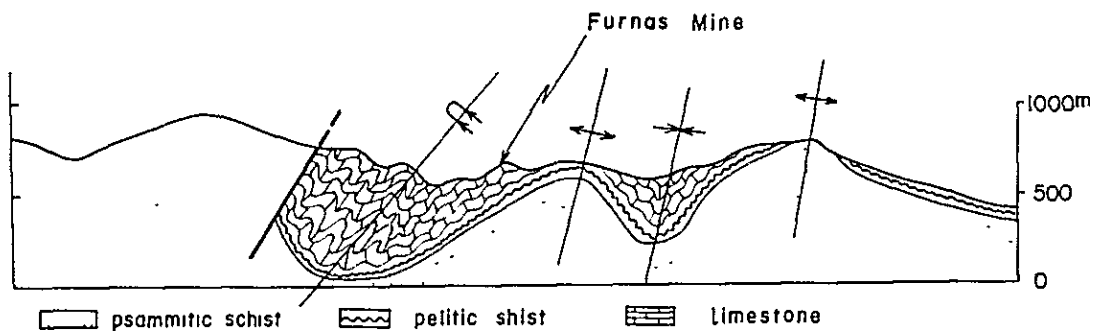
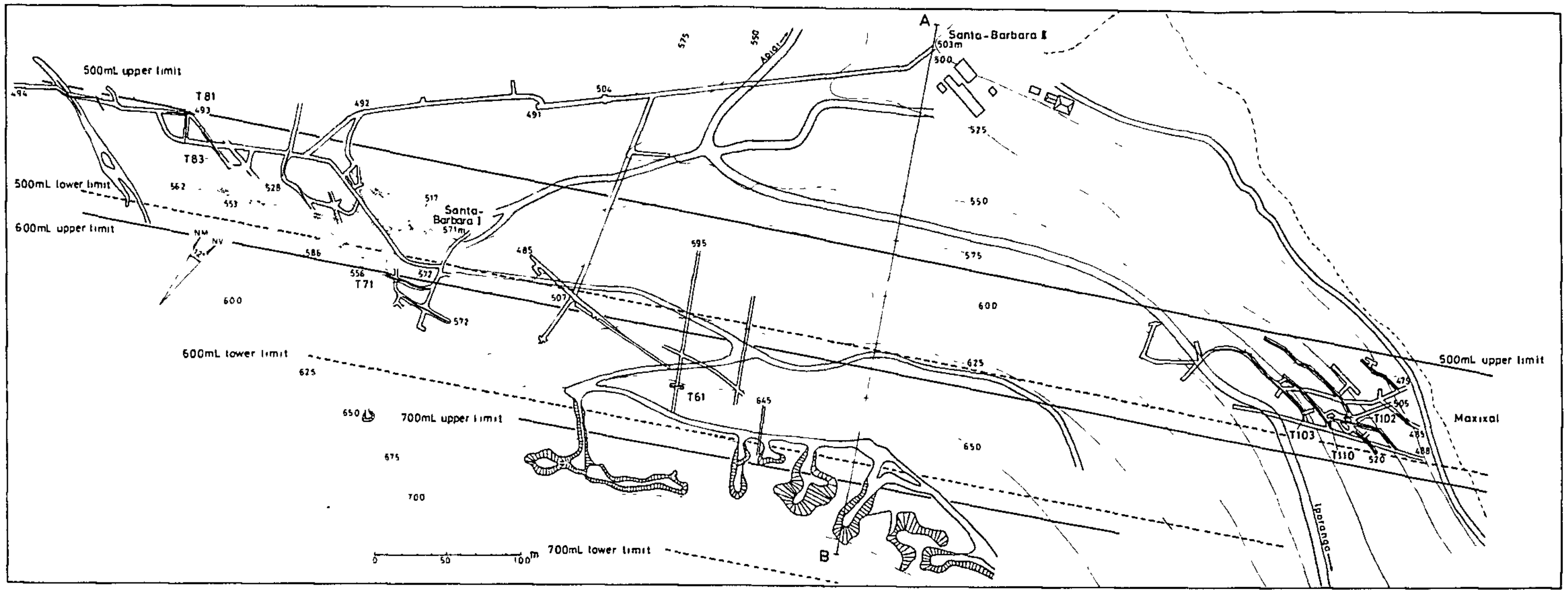


Fig. I–23 Cross Section (NW–SE) of Furnas Mine Area

As shown in Fig. I–24, two types of the deposit are found in the Furnas deposit such as (1) the deposits occurring along the bedding plane of limestone (N50 ~ 60°E, 50 ~ 60°N) and (2) the vein type deposits bearing N70° ~ E–W, and 80°S which cut the bedding plane.



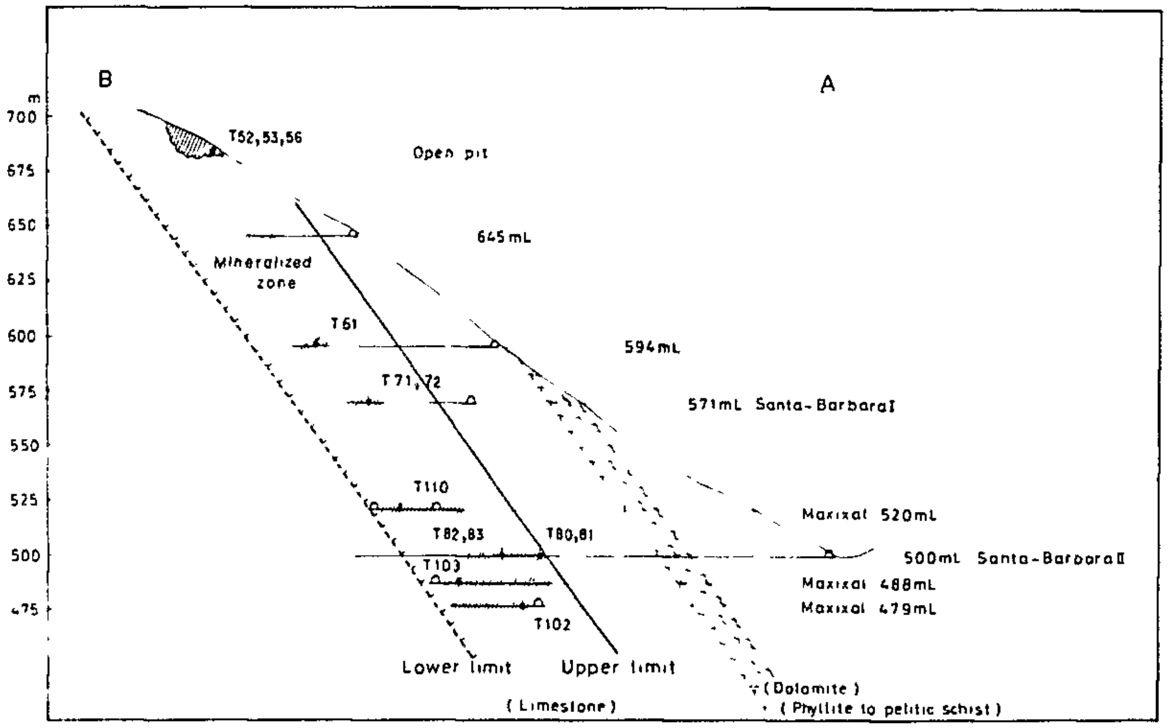


Fig. I–24 Geologic Plan and Section of Furnas Mine

Bonanzas are often formed at the junction of the two types. The both deposits show remarkable pinch and swell with the maximum width of 2.00m (average 0.20m) and lateral extension of up to 100m.

It becomes clear by the survey of this time that the mineralized zone is limited in the limestone at the distance between 50 and 100m. from the upper boundary of the pelitic schist.

Ore minerals mainly consist of galena, sphalerite and pyrite being associated with argentite. Secondary minerals are cerussite, smithsonite and limonite. Quartz and calcite are gangue minerals.

Microscopic observation of the typical ore (T–83) at 500mL of Santa Barbara II showed that euhedral pyrite and granular sphalerite are penetrated by argentite and galena in the forms of stringer or dot. The sequence of crystallization is pyrite → sphalerite → argentite → galena.

The result of analysis is as follows:

Sample No.	Width	Au	Ag	Cu	Pb	Zn
T–83	0.2^{m}	$0.0^{g/T}$	$311.9^{g/T}$	0.07 %	17.26 %	27.31 %

(B) Lageado Deposit

1) *Outline of the deposit*

The Lageado deposit is located at 5km. southeast of the Furnas mine. 16 deposits and showings are known within the area of 1.5km. wide by 4km. long. All of them are small in scale. They were prospected by person or company, but the operations are now all suspended.

2) Geology of the surrounding area

Although limestone of the Açungui III formation of the area shows a synclinal structure like that of the Furnas deposit, it is considered that the more small-scale folding would exist in the interior.

3) Ore deposit

As shown in Fig. I–25, the deposits are arranged in the NE–SW direction which is parallel to the axis of synclinal structure. According to Melcher G.C. (1968), the deposit shows two types of shape such as vein and pocket, and six parallel vein fissures are present. They are described from the north to the south as follows:

i. N50°E, 80°S — lateral extension is 20 ~ 30m., Lourenço Velho vein, average width 0.30m.

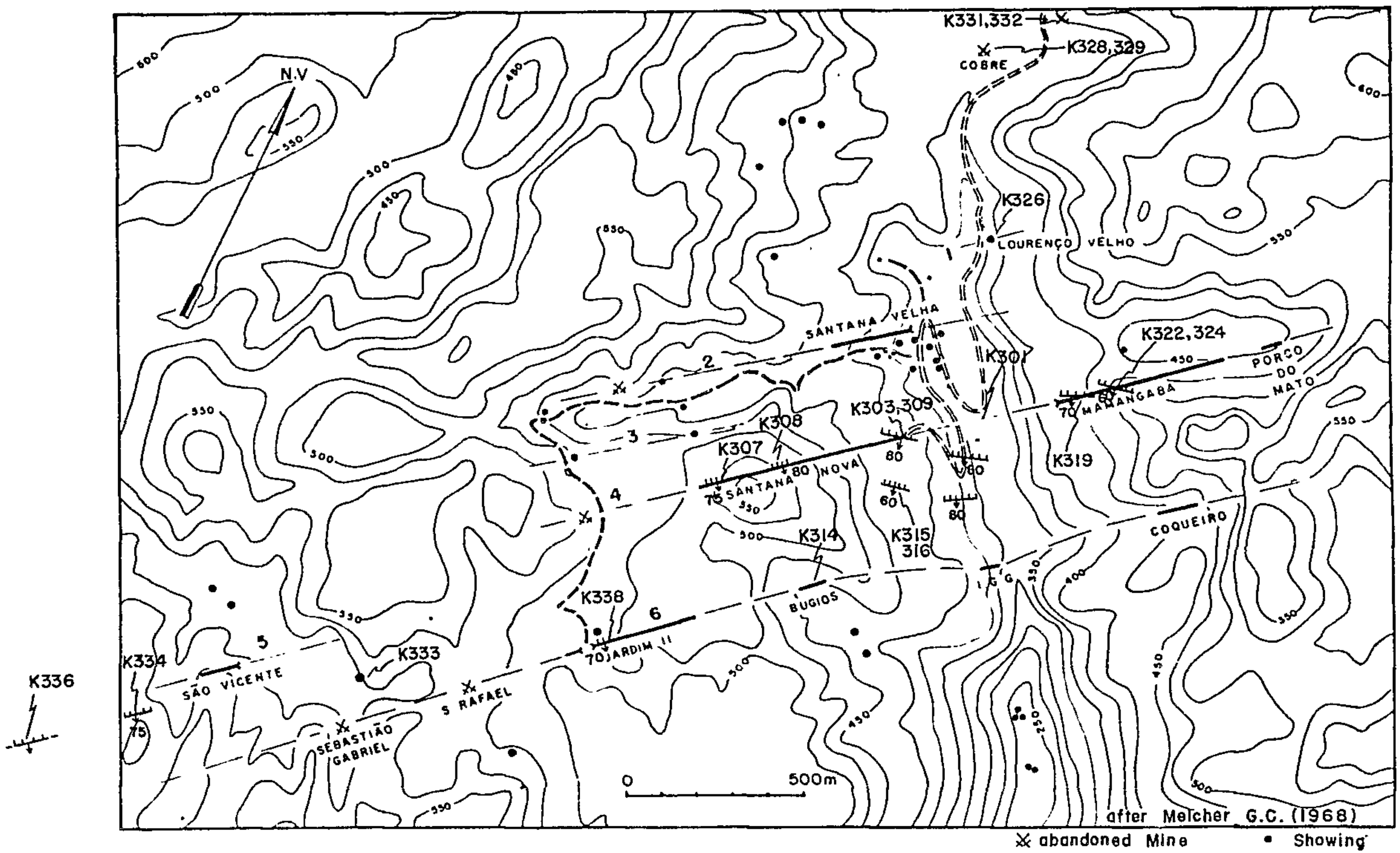


Fig. I–25 Mineralized Fractures and Deposits in Lageado Region

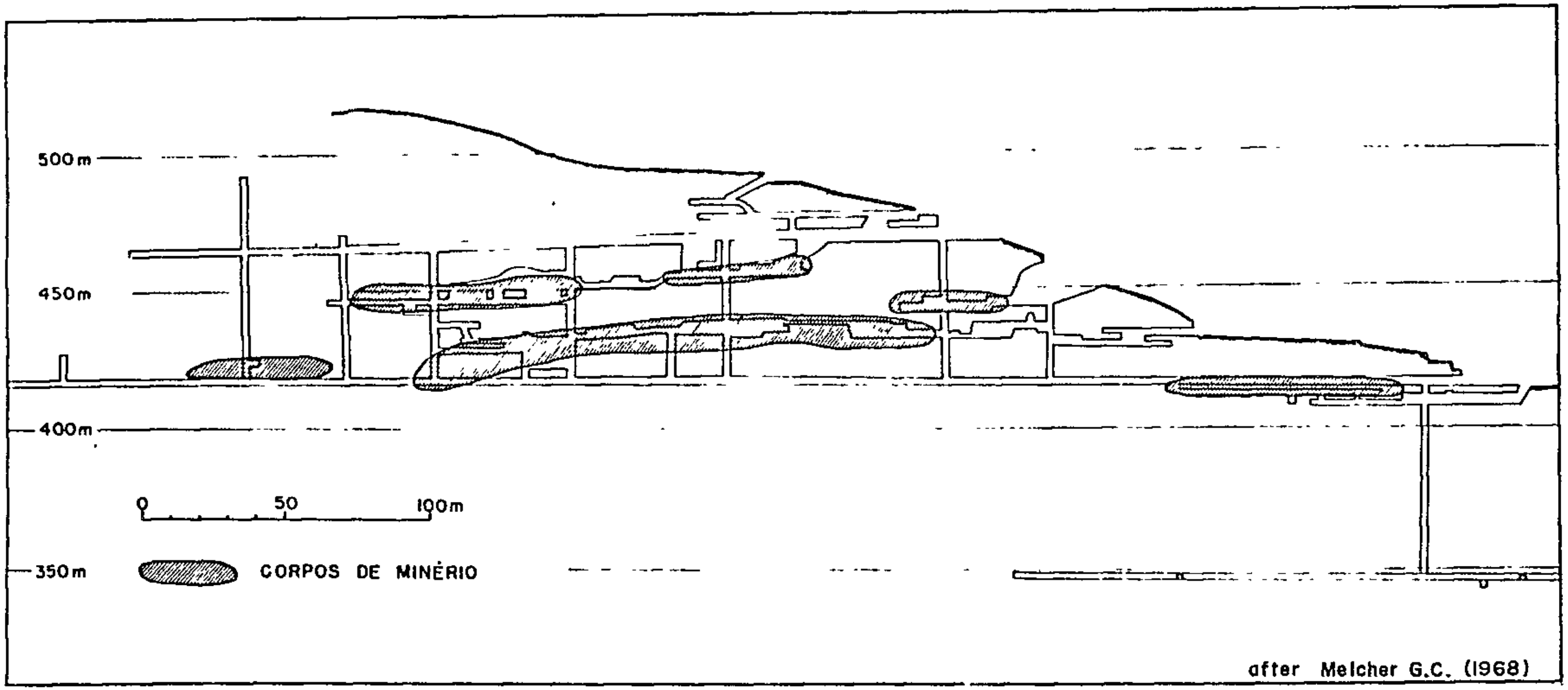


Fig. I–26 Longitudinal Projection of Santana Nova Mine, Lageado

ii.	N55°E, 75°S	lateral extension is 800m., Santa Velho and other small outcrops, width 0.30 ~ 1.00m.
iii.	N55°E,	two small outcrops in small scale
iv.	N50°E, 50°S	largest scale in the area, Santana Nova, Mamangaba, Porco do Mato
v.	N40°E, 80°S	São Vicente deposit, width 0.25 ~ 0.30m.
vi.	N40° ~ 45°E, 60° ~ 80°S	Sao Rafael, Jardin II, Bugios, Coqueiro, width 0.20 ~ 2.00m.

The Santa Nova deposit (iv) produced most of the ore production of the Lageado deposit for years. It has been confirmed that the deposit extends more than 600m. along the strike and continued about 200m. toward depth. The strike and dip of limestone, the country rock of the ore, is N50 E and 5 ~ 20N. The bonanzas show a form of pocket as shown in Fig. I–27, and six pockets were mined. The dimension of the pockets is up to 18m in lateral and 2m. in vertical with average width of 0.20m. showing a peculiar shape. It is probable that the bed of calcareous schist intercalated in the limestone played the role of the cap rock.

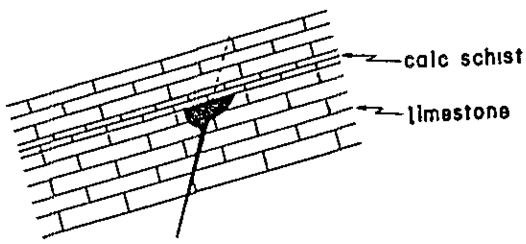


Fig. I–27 Ore Pocket in Lageado Deposits

PART Ⅱ GEOCHEMICAL INTERPRETATION

CHAPTER 1 DETAILS OF GEOCHEMICAL SURVEYS CARRIED OUT IN ANTA GORDA AND ITS SURROUNDING AREAS

Geochemical survey by soil sampling was carried out in this area and its surroundings by G. C. Melcher in 1960. In addition, geochemical studies on the rocks of the Açungui group and granite were made by many researchers.

A systematic regional geochemical survey was carried out by the Government of Brazil as Projeto Sudelpa (1975). After that, Projeto Geoquimica no Vale do Ribeira (1978) was conducted over a partly overlapping area with that of Projeto Sudelpa. Although the Anta Gorda area is included in the surveyed area of Projeto Geoquimica no Vale do Ribeira and its data are the main object for interpretation this time, the outline of the both projects including Sudelpa will be described in the following because a part of its data are quoted in the work.

1–1 The Outline of Geochemical Survey in Projeto Sudelpa

This is the project of the São Paulo State Southern Part Development Agency (SUDELPA) and conducted by CPRM.

In order to cover an area of 17,000km^2 in the southwestern part of São Paulo State, samples of 841 of stream sediment, 17 of soil, 4 of pan concentrate and 3 of rock were taken. Density of stream sediment sampling was 20km^2/sample.

These samples were semi-quantitatively analysed by emission spectroscopic analysis for 30 elements, the results were statistically processed by computor. The results of analysis of the data revealed that highly anomalous zones of the following metals occurred in the areas of the Açungui group; copper, lead, iron, titanium, manganese, cobalt, chromium, nickel and vanadium.

a) Interesting anomalous zones such as copper and lead in limestone of the Açungui group, and copper in metasediments of the same formation were extracted.

b) Copper can be an indicator element for lead mainly in limestone zone.

c) The relation between lead and copper in metasediments of the Açungui group suggests the hydrothermal mineralization.

d) The background values of lead are high in granite and in the Açungui formation in the southwestern part of the area.

e) In the granite of Três, Córregos, Itaóca, Agudos, Grandes and Guaram, the values

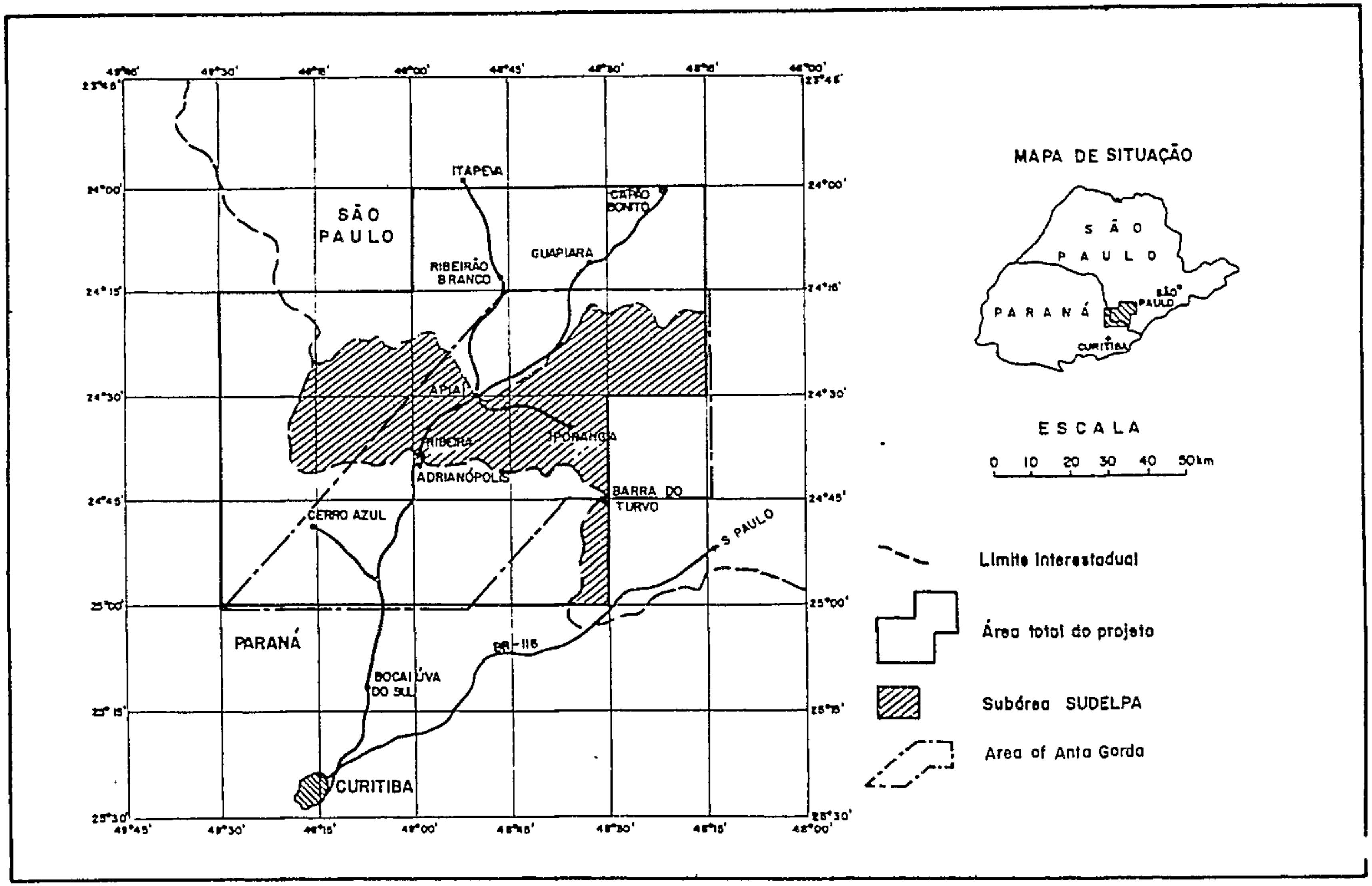


Fig. II–1 Location Map of Project Areas

of barium are unusually high.

f) Strontium is concentrated in granite.

g) Geochemical prospecting and emission spectroscopic analysis are effective for the stream sediment survey in this area. Zone of the existing ore deposits was reconfirmed as the area of anomaly, and new anomalous zones were obtained.

h) Gold, silver, zinc, arsenic and molybdenum could not be confirmed by this analytical method. It is necessary to consider other method of analysis for these elements.

1–2 Outline of Geochemical Prospecting by Projeto Geoquimica no Vale do Ribeira

The project was planned by DNPM and conducted by CPRM.

1–2–1 The Area Surveyed

At first, a regional geochemical prospecting was planned for the area of 7,900km^2 excluding the overlapping part with Projeto Sudelpa from the whole project area of 11,200km^2. Afterwards, it became clear that Projeto Sudelpa covered only 50 % of the planned area of 3,300km^2, so additional 900km^2 were sampled supplementarily. Therefore, the actual area sampled in this project was 8,800km^2.

1–2–2 Sampling Density (Plan and the Result)

Allocation of the sampling points was planned beforehand on the topographical map of 1/50,000 scale to take a sample in every 5km^2 in the area of metasediments of the Açungui formation and 5–10km^2 in other area. Sampling of pan concentrate was planned to take a sample in every 50km^2 which is the average area of a unit drainage in the area. However, the drainage area of the Ribeira de Iguape, Pardo, Açungui, Piedade and Apiai-Guaqu Rivers are more than 200km^2. In these cases, it was determined to take a composite sample. For this purpose, 2–4 samples, each of which represents a drainage area of less than 3km^2, were combined together to make one sample for analysis.

As the result of sampling based on the plan, a sampling density of the stream sediment was 6.96km^2 per one sample for the area of 8,102km^2. When the area of Projeto Sudelpa is added to it, the total becomes 9,750km^2, which covers 87% of the whole planned area. The distribution of samples by drainage area is as shown in the following table.

The average sampling density of stream sediment in the area of Projeto Sudelpa is 6.44 km^2/sample.

Table II–1. Area of Drainage and Number of Samples

Type of Sampling	Area of Drainage (Km^2)	Number of Samples	Percentage %
Stream Sediments	< 5	467	40
	5 – 10	344	30
	10 – 20	203	17
	20 – 40	114	10
	> 40	36	3
Total	6 96	1,164	100
Pan Concentrats	< 50	38	21
	50 – 100	67	37
	100 – 200	56	31
	> 200	22	12
Total		183	100

1–2–3 Chemical Analysis

Samples were analyzed after sieving with 80-mesh screen.

Samples of stream sediment were analyzed by atomic absorption spectroscopic analysis (AA analysis) for silver, copper, lead, zinc, iron, manganese, cobalt and nickel, and those of pan concentrate, by AA analysis for gold, copper, lead and zinc; the latters were semi-quantitatively analyzed by emission spectroscopic analysis for 30 elements. In addtion, the samples of stream sediment of Projeto Sudelpa were reanalyzed by AA method for copper, lead and zinc.

1–2–4 Interpretation of the Analytical Results

257 samples of stream sediment taken from the area of 1,648km² of Sudelpa and 1,288 samples from the area of 8,102km² of this project were statistically processed separately, and parameters for each were calculated as shown in the attached tables.
(Appendices A–8)

1–2–5 Extraction of Geochemically Anomalous Areas

The sampling areas of this project (8,102km²) and the Sudelpa project (1,648km²) were separately examined.

a) The Sudelpa area

According to the report, the distribution and the relation of coexistence of elements such as copper, lead and zinc were discussed and the anomalous areas were extracted by classifying the 257 samples into the six lithological units as shown in the Fig. II–1. Copper anomalies are observed in the area of clastic sediments of the Açungui group, the average value of which is 40 ppm. As the result, seven anomalous zones were extracted in this area. Two anomalous zones were also extracted in the area of chemical sediments of the Açungui group. Among these, geologically the most important zones are JR–440 and 450, which show high anomalies of lead and zinc and they may be caused by sulphide mineralization. Lead shows high anomalies in the areas of clastic sediments of the Açungui group, the average value of which is 24 ppm. Lead anomalies are associated with copper and zinc anomalies which correspond well to the existing ore deposits. Zinc also tends to show anomalies in the areas of clastic sediments of the Açungui group.

The anomalous values are found in the northeastern part of the APIAI map and in the southwestern part of the CAPÃO BONITO map.

b) The area of Geoquimica Regional (Sampling area of this project)

Of the 1,288 samples, parameters were calculated for each class classified by the size of drainage areas represented by each sample such as $< 5km^2$, $5-10km^2$ and $10-20km^2$ according to the 10 geological units shown in Fig. II–3.

As a result, copper shows high anomalies in the lower formation of the Açungui group and in the Setuva formation, the values of which is 26 ppm. These anomalies generally coexist with those of zinc, but the correlation coefficient with lead is a little lower.

Distribution of the 37 samples which showed copper anomaly is as follows: 6 in the lower formation of the Açungui group and the Setuva formation, 11 in the clastic sediments, 4 in the limestone and 13 in the granite zone. The Setuva formation consists of amphibolite, hornblende schit and quartzite and it area is generally rich in copper, showing the value as high as 50–100 ppm. It is considered that this fact is caused by the occurrence of amphibolite or the Perau-type mineralization. The anomalous zones observed in the clastic rocks in the Açungui group are associated with high values of zinc, iron, cobalt, nickel and manganese, which suggests the existence of basic rocks.

Lead showd the highest value in the chemical sediments in the Açungui group, showing the average value of 19 ppm. The number of lead anomalies accampanied with zinc are 5 in the lower formation of the Açungui group, 22 in the clastic sediments in the Açungui

group and 9 in the chemical sediments. The lead anomalies in the clastic sediments and the chemical sediments in the Açungui group are generally associated with copper and zinc, well suggesting the existence of the ore deposit. Although zinc tends to show high anomalies in the areas of the lower formation of the Açungui group and the Setuva formation, it is not so clearer than the other elements 27 anomalous areas are extracted, most of which are associated with lead and zinc.

1–3 Some Problems in "Projeto Geoquimica no Vale do Ribeira"

A detailed examination has been made in the report and no problem is found in procedure of the analysis. However, in the geochemical prospecting, it is considered that there would be some problems in considerations on the selection of sampling sites and determination of the drainage area represented by the sample, all of which are the basic problems.

1–3–1 The Sampling Sites of Stream Sediment and their Densities

The sampling sites was planned beforehand on the topographical maps of 1/50,000 scale to get the density of $5km^2$ per sample in the area of the Açungui group and $5-10km^2$ in other area. It is likely, as a result, that, as described in the paragraph 1–2–2, 70 % of the whole samples have met the standard of the drainage area. However, as will be mentioned later, the samples in the tributaries of the same river system are included duplicately. So, if these are omitted, the number of samples which meet the standard will more decrease. In the Sudelpa area, such consideration on the standard has not been given.

1–3–2 Data Processing

Statistical processing has been carried out on both data of the project and Sudelpa together. It would be possible to process these data in a bundle if a supplemental work was made beforehand in the Sudelpa area in order to get a homogeneous pattern.

The statistical values are calculated by the rank of drainage area, which makes it very complicated to select anomalous values, though it is the final purpose. And this is doubtful how much significance the results thus gained would have had.

At present, there seems no proper theoretical basis for processing different dimensions of the drainage area.

In geochemical prospecting in the stage of regional survey, it is experimentally desirable

that the area of drainage represented by each sample is less than $10km^2$ from the standpoint of geology and ore deposit. The sampling density should be homogeneous as much as possible in order to fit the statistical data processing.

1–3–3 Survey Area

According to the report of the project, it is claimed that the geochemical survey has covered the area of $9,750km^2$. However, it is recommended that an effective area for geochemical sampling would be reexamined taking the items mentioned above into account.

CHAPTER 2 INTERPRETATION OF THE DATA OF GEOCHEMICAL SURVEY IN THE ANTA GORDA AREA

A regional geochemical survey of the area was carried out, as mentioned above, by DNPM (and CPRM) from 1976 to 1977 as Projeto Geoquimica no Vale do Ribeira and the final report was published in June 1978.

In this project, it was aimed at interpretation of the data to contribute to clarification of mineralization in the area.

Although a generally detailed examination has been made in the report of DNPM–CPRM, there are some problems in the selection of sampling sites of stream sediment, and it is necessary to reexamine the samples at the effective sampling sites.

2–1 The Area for Interpretation

The area for interpretation is, as shown in Fig. II–1, totaling about 7,600km^2 including the whole areas of the topographical map sheets of 1/100,000 of APIAI and CERRO AZUL, and a part of GUAPIARA and CAPÃO BONITO.

2–2 Selection of Stream Sediment Samples

It was determined to extract available samples covered the area of drainage less than 10km^2 by the reasons mentioned below.

2–2–1 Considerations on the Area of Drainage and the Sampling Density

The purpose of geochemical survey in Projeto Geoquimica no Vale do Ribeira is the regional prospecting.

The sampling density of stream sediment in this stage of survey should be determined taking the topography, access and geological unit etc. into consideration. For example, in the case of the survey conducted by UNDP in an area of Central America, 1km^2 per sample was employed.

In Brazil, "Projeto Geoquimica Regional no Centro-Oeste do Brazil (PGRC) was carried out from 1974 to 1978 with technological cooperation of Canada, and it has been evaluated as a very significant project. It was a very large-scale, regional geochemical survey for stream sediment conducted in an area of 216,700km^2. In the area of about 60,000km^2 in the southern part, sampling densities of 10–20km^2 resulted in effective and successful extraction

of anomalous areas of the elements.

By using these results a rough isocounter map can be made for each element, by which anomalous values can be extracted and, at the same time, the relation with geological formations as well as the character of distribution of element can be easily read, which led to planning the follow up survey in the surrounding areas. In this case, of course, threshold values are also determined by statistical procedure. However, further mathematical discussion seems to have little significance in this stage from the original purpose of the regional geochemical survey. It is rather more important for the survey to indicate the anormaly on geological map and to interprete anomalies accurately.

On the basis of the result of PGRC, "Um Novo Enforque da Programação da Prospecção de Mincrios 1979" was submitted by the Japanese mission, which recommended that a regional geochmical survey by stream sediment, was at first to be carried out in order to evaluate the potential of natural resources in the whole Brazil as promptly as possible.

If sampling density is larger than these, the interpretation of the survey results would not sufficiently be pursued, as was in the northern part of the project area (25–40 km^2/ sample). As an additional sampling or resampling is needed, it is uneconomical as a whole with increase of survey expenses.

In the case of the Ribeira area, it is desirable that the sampling density is 3–5 km^2/ sample when taking into consideration that the expected ore deposits are mainly lead and zinc deposits associated, if any, with copper, that many surveys has been carried out on this area and that the geological unit is relatively small.

However, as the standard of selection, the maximum sampling density was set at 10 km^2/sample because sampling in the project finished already. As the result of selection of proper samples based on this standard, the following distribution of samples was obtained. The reason why 37 samples reprenting more than 10km^2 were included is that the area of survey would become small if the limit of 10km^2 is strictly observed. Therefore, some of those against the standard were adopted.

2–2–2 Treatment of the Composite Sample (Multipula)

Two to four samples collected from closely spaced creeks were mixed together and analyzed. Although no special note is given in the list of analytical results attached in the report, it is jedged that the sample with M at the tail of number might correspond to it. The composite sample was considered to represent the total area of each drainage represented

Table II–2 Sample Numbers approved for Interpretation

Drainage Area (km^2)	Sample Numbers (pcs)
1 – 5	435
6 – 10	271
11 15	35
16 -	2
Total	743

by the original separate sample. However, some composite samples which had been combined with the samples taken from both banks of the river in the places where more than three creeks were spaced, were omitted.

2–2–3 Example of Duplicate Sample and Its Treatment

A number of samples had been taken in the same tributary system (Fig. II–2). As these can not be considered to be independent samples, only one sample which represents drainage area of less than $10km^2$ was selected among those samples.

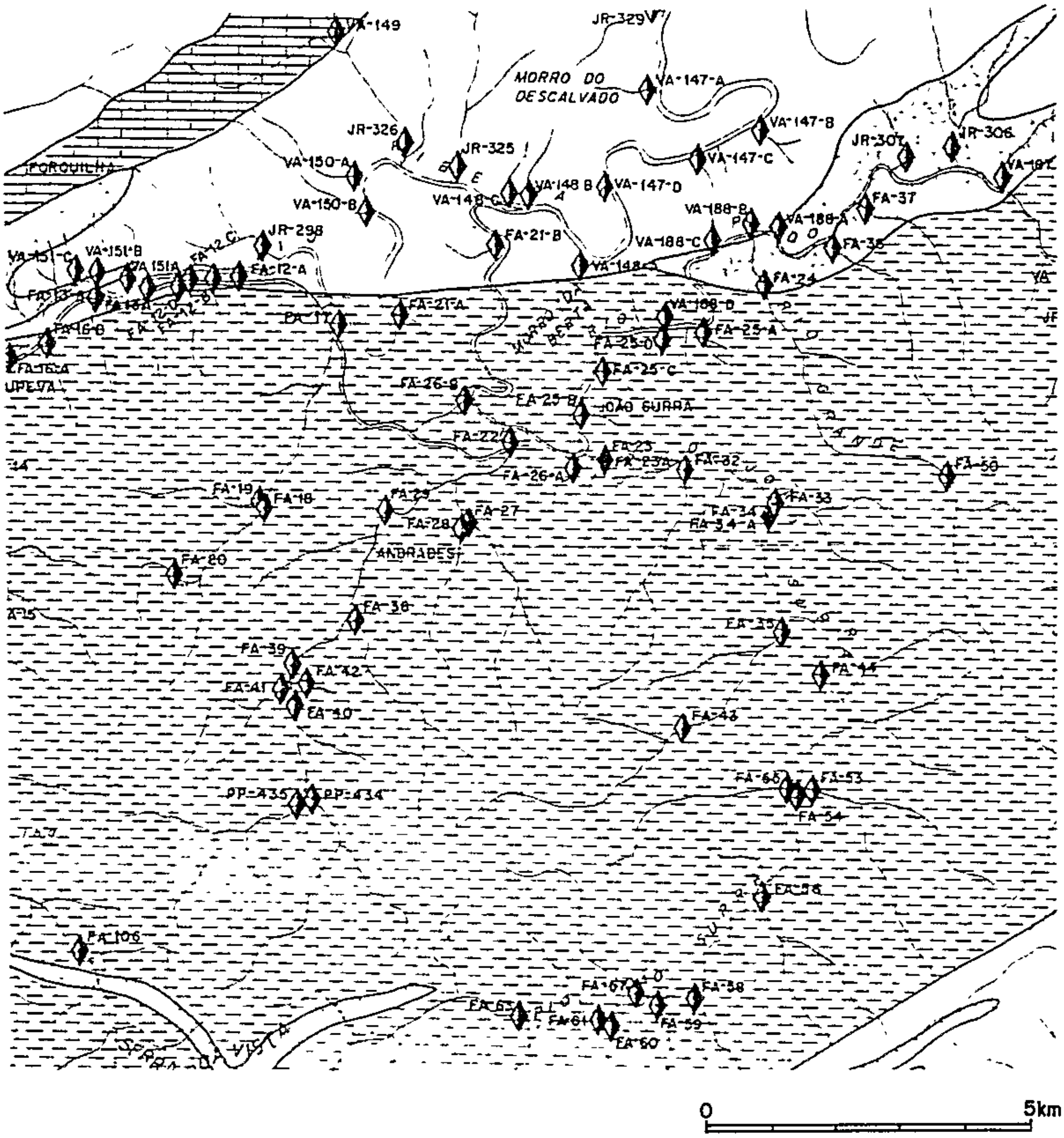
2–2–4 Geological Units

As shown in Fig. II–3, in the Projeto Geoquimica no Vale do Ribeira, the formations were divided into the following geological units in the ascending order, and the data were statistically processed by the unit:

gneiss-migmatite complex (10), the Setuva formation (9), quartzite (8), the Açungui group composed of metabasite and amphibolite (7), the Açungui group composed of schist and amphibolite (6), the middle Açungui group composed of clastic rocks (5), the upper Açungui group composed of clastic rocks (4), the Açungui group composed of chemical sediments (3), granitic rocks (2) and basic complex (1).

As the result of geological survey of this time, it was found that (9) and (10) are cognate, and two units such as limestone (3) and others (4 + 5 + 6 + 7 + 8) are enough for the Açungui group to interprete and subdivision of the complex rocks was not necessary.

After a careful examination, these groups were divided into four units such as granite (2), limestone (3) of the Açungui group (the Açungui III formation of this time), schist and phyllite of the Açungui group (the Açungui I + II formations) and the Setuva formation. The statistical processing was carried out by such classification.



JR-326
◇ sampling site and sample No.

Fig. II–2 Sampling Pattern in Ribeira Project

Projeto Anta Gorda	Projeto Geoquimica no Vale do Ribeira	
		Diques de rochas básicas, geralmente diabásio
	1	COMPLEXOS BÁSICOS (Apiai, Bairro da Cruz e José Fernandes).
1	2	Rochas graniticas sin a pós tectônicas
2	3	GRUPO AÇUNGUI-SEQUENCIA QUÍMICA Representado por epicalcários calcíticos e dolomiticos, passando à mármores quando mais evoluida metamorficamente, SEQUÊNCIA CLASTO-QUÍMICA Metassedimentos síltico-argilosos com intercalações de rochas carbonáticas, calca-filitos e calca-xistos
3	4	GRUPO AÇUNGUI - SEQUÊNCIA CLÁSTICA DE BAIXO GRAU Metassedrmentos siltico-argilosos incluindo metassiltitos, ardósias, filitos, metaritmitos e subordinadamente metaconglomerados e epiquartzitos.
	5	GRUPO AÇUNGUI - SEQUÊNCIA CLÁSTICA DE MÉDIO GRAU Quartzo-sericita-xistos, quartzo-xistos, xistos à biotita e/ou muscovita, eventualmente à granada e estaurolita.
	6	GRUPO AÇUNGUI - XISTOS E ANFIBOLITOS: Sequencia formada por quartzo-sericita-xistos e xistos micáceos associadas com anfibolitos, anfibólio-xistas, calca-anfibolio-xistos, magnetita-anfibólio-xistos, filita-grafitosos, calcossilicatadas e calca-xistas e possivelmente metavulcanitos.
	7	GRUPO AÇUNGUI - Metabasitos e anfibolitos
	8	Corpos geralmente lenticulares de epiquartzitos, quartzitos e/ou sericita-quartzitos associados às Rochas Açungui e/ou Formação Setuva.
4	9	FORMAÇÃO SETUVA Biotita-xistos, biotita-muscovita-xistos e quartzo-xistos.
		FORMAÇÃO SETUVA Anfibolitos anfibólio-xistos é calco-anfibólio-xistos.
		FORMAÇÃO SETUVA - Paragnaisses, anfibólio-xistos, leotinitos, muscovita-biotita-gnaisses, quartzo-xistos
		FORMAÇÃO SETUVA - Orto e/ou paragnaisses porfiroblásticos.
	10	COMPLEXO GNAÍSSICO-MIGMATÍTICO Migmatitos embrechíticos e epibolíticos e, subordinadamente, gnaisses, quartzitos e xistos

Fig. II–3 Lithological Units