REPORT ON GEOLOGICAL SURVEY

REPORT ON GEOLOGICAL SURVEY

OF

ANTA GORDA

BRAZIL

PHASE II

MAY 1982

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 3 July and 22 October, 1981, Metal Mining Agency of Japan dispatched a survey team headed by Dr. Sadao Maruyama to conduct geological survey and geophysical survey of the Phase II 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 II, 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.

March 1982

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

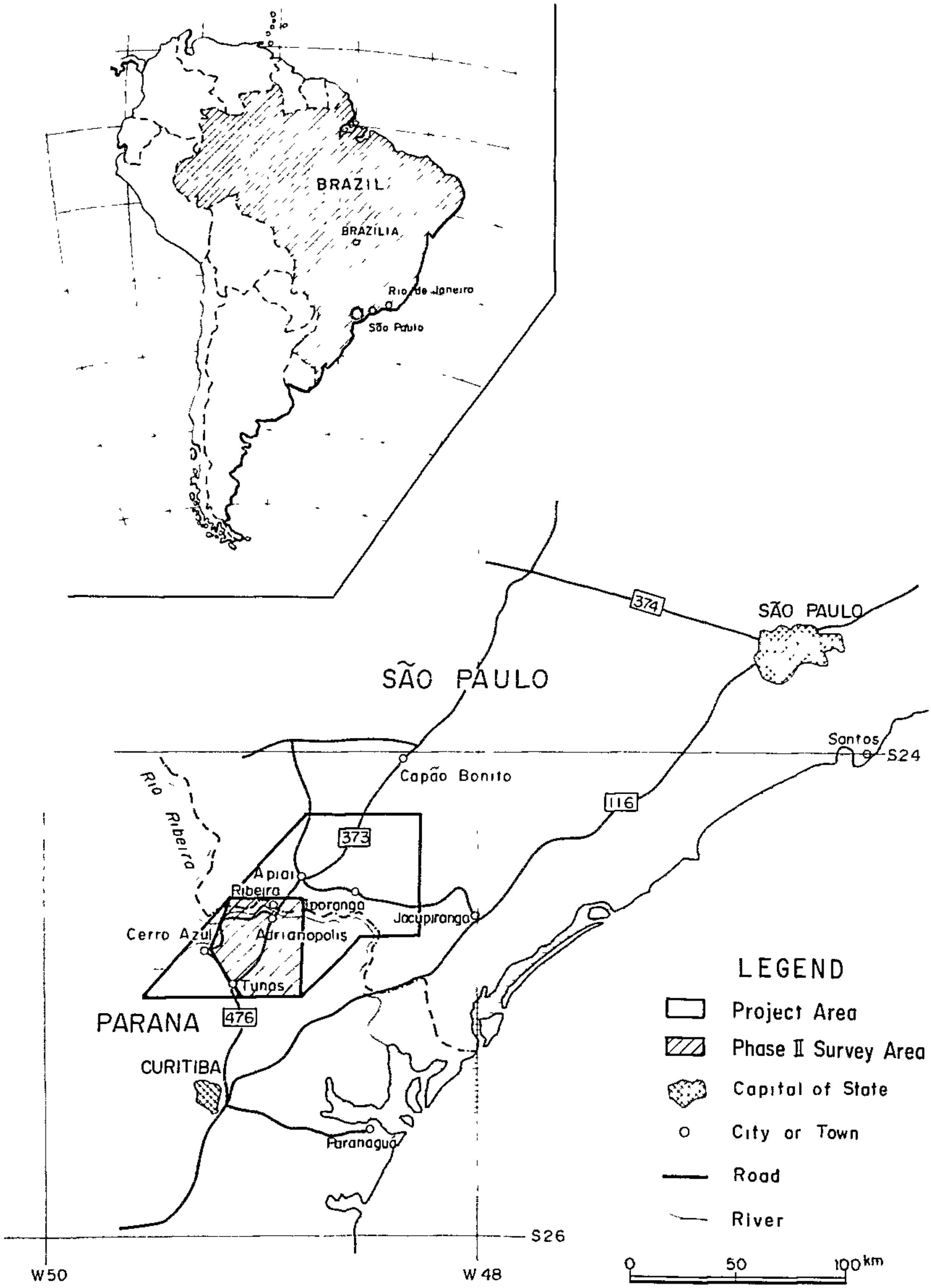

Fig. 1. Location Map of Survey Area

ABSTRACT

In the survey of the second year in the Anta Gorda area of the Federative Republic of BRAZIL, geological survey and geophisical survey were carried out to establish the useful guide for future exploration by detailed studies of the stratigraphy, geological structure, igneous activity and mineralization of the area as well as the mutual relation between them.

The semi-detail geological exploration, underground survey of the Perau mine and the Rocha mine, the geochemical survey and the geophisical survey (IP and spectral IP methods, gravity survey) were carried out during the period.

As the result of the geological survey, it was clarified that geology and stratigraphy are composed of Pre-Cambrian Setuva formation and Açungui group showing conformable relationship.

Açungui formation III, uppermost horizone of the Açungui group, were divided to three members. It was also clarified that the present working mines such as the Rocha mine, the Barrinha mine and the Panelas mine are located in limestone and dolomite of the Middle Member of the Açungui formation III.

The Perau deposit is a strata form deposit which has been formed during early stage of sedimentation of the Açungui formation I, and ore shoots were formed by folding structure of host rock

As the results of the geological survey and geophisical survey, IP and spectral IP, the existence of the other ore shoots in the deeper portion can be expected, and the major geological structure were confirmed by the gravity survey.

As results of the geochemical survey of soil in the Perau horizon, it was clarified that the best portion of Cu-Pb-Zn correlation is coincide with the portion of the ore deposit. The Rocha mine is the vein type deposit which was formed by geotectonic movement in the end of Pre-Cambrian age The host rock near the ore deposits is containing high value of Ag, and this fact is expected to be useful guide for exploration of same type ore deposits.

As for future exploration, the drilling exploration for deeper portion of the Perau ore horizon and the electric survey for southern area of the Perau mine are expected.

It is also expected that to be studied a possibility of a blind ore deposit at the Barrinha mine by the electric survey.

Also geological exploration in the northern half of the area of the Anta Gorda Project has to be carried out.

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GENERAL REMARKS

CHAPTER 1. INTRODUCTION

1–1 Purpose and Scope of the Survey

At the request of the Japan International Cooperation Agency (JICA), the Metal Mining Agency of Japan (MMAJ) begain this cooperative mineral exploration in the Republic of Brazil from April, 1980. In October of 1980, the MMAJ agreed to the scope of the work for this project with the Brazilian Departmento Nacional da Produção Mineral (DNPM).

Many small lead ore deposits have been found in the states of Parana and São Paulo of southeastern Brazil, numerous studies have been conducted in the past, but as yet there is still no widespread accepted agreement about the relationships between geological structures, igneous activity, and mineralization, as well as the origins of these ore deposits

In accordance with the agreed schedule, the first year was spent conducting multiple investigations of the geological conditions of the 5800 km² area, which contain lead deposits, establishing a geological stratigraphy, clarifying the geological structures, and evaluating the existing ore deposits in geologically.

The present survey, which was conducted in the second year, attempted to clarify details of the geological structures and stratigraphy, by carrying out a semi-detailed geological survey within the 1200 km² area situated in the state of Parana, south of Rio Ribeira. From the results of the first year survey it was thought that this area had good prospects. The present survey also attempted to further clarify the geological setting of these ore deposits, and to obtain some useful direction for futher mineral exploration.

1–2 Substance of the Survey

The second year survey attempted to carry out a semi-detailed geological investigation of the 1200 km² area, as well as a detailed geological study, a geochemical exploration, an underground survey, and a geophysical exploration of the Perau area. A detailed geological investigation and an underground survey of the Rocha area were also conducted.

From this semi-detailed geological survey, a geologic map on a scale (1/25,000) using aerial photographic interpretation was produced. For the geological survey of the Perau area, a newly produced scale (1/10,000) topographic map was used, and a detailed investigation was carried out. The geochemical soil exploration was conducted at the IP survey lines throughout the area of distribution of the Perau horizon.

For the underground survey, ore deposits were studied on a scale of 1/500 as a general rule, and at times a sketch of 1/100 was used. Also the drilling cores which had been previously carried out in the Perau mine area were studied, and used those samples of ores for learning about the geology and geological structure

For the geological survey of the Rocha area, a scale 1/10,000 detailed geological survey has been carried out and tracing the extent of the horizon of ore deposits has been done. For the underground survey, an investigation of the veins, and a scale 1/1,000 geological survey was carried out, and for a part of it a 1/100 scale sketch has been carried out and the underground geological map was made. Also the Rocha mine area drilling cores were studied as much as possible, and that information was used to clarify the distribution of ore deposits, and the underground geology.

Existing geological data related to the area being surveyed included a geological map (1/100,000) compiled by the Companhia de Pesquesa de Recursos Minerals (CPRM) of Brazil in 1977 Also, geological map (1/25,000) of the Perau and Rocha area was included in the unpublished report of the Projecto Chumbão. This data became a good reference source for the present study.

The present investigation, i e. the geological survey, the geolchemical exploration and the geophysical exploration, were carried out by ten technical engineers from Japan, and five technical engineers from Brazil.

In arranging and finishing this report many advices were given from Dr. Akira Sasaki of the Geological Survey of Japan, for the Pb radiometric age determinations, from Dr. Toshio Igarashi, of the Geological Survey of Japan, on limestone. Also many useful suggestion were given from Professor Sukune Takenouchi of Tokyo University on ore minerals, and from Associate Professor Takahiko Maruyama of Akita Unversity on metamorphic rocks.

The authors wish to express many thanks and gratitude to them from heart.

1–3 Organization of Survey Team

The members of the survey team who participated in the design negotiation, and the actual field investigation for this year's study are listed below. The geological and geophysical engineers from CPRM who requested this work from the Republic of Brazil contributed to this project.

1–3–1 Survey Planning and Negotiation

1) Japan Side Planning and Negotiation

Nobuhisa Nakajima .... MMAJ

Katsumi Yokokawa .... MMAJ

Takafumi Tsujimoto .... MMAJ

2) Brazilian Side Planning and Negotiation

Antonio Carlos Giordan Marcondes de Godoy .... DNPM

Luis Eraldo Matoz .... DNPM

Fernando Batolla, Jr. .... CPRM

1–3–2 Actual Location Survey

1) Survey Members . Japan.

Sadao Maruyama (Team leader, geologist) .... BEC.

Tsuyoshi Suzuki (subleader, geologist) .... 〃

Kiyohisa Shibata (geologist) .... 〃

Haruo Watanabe (geologist) .... 〃

Hiroshi Takahashi (geologist) .... 〃

Susumu Sasaki (geophysist) .... 〃

Akira Egawa (geophysist) .... 〃

Tomio Tanaka (geophysist) .... 〃

Naoyoshi Takahashi (geophysist) .... 〃

Masatane Kato (geophysist) .... 〃

2) Survey Members . Brazil

Elias Carneiro Daitx (Team leader, geologist) .... CPRM

Cid Chiodi Filho (geologist) .... 〃

Cassio Roberto da Silva (geologist) .... 〃

Jose Carlos Garcia Ferreira (geologist) .... 〃

Frederico Augusto Verejão Marinho (geophysist) ..... 〃

1–4 Previous Surveys

The geology of the area under study has been investigated by many people, and it is apparent that Pre-Cambrian age rocks, a principle part of the area, are well distributed throughout the area.

Cordani et.al. (1967) have obtained calibrated results of radiometric age as 3,000 – 450 m.y., and described that orogenic movements took place several times in the period.

For the petrological and stratigraphical studies, Bigarella et al. (1956), Marini et al. (1967), Fuck et al. (1971), Ebert (1971), Continho (1971), and Kaefen (1972), have all attempted to define the geological stratigraphy.

For the studies of mineral deposits, Melcher (1968), has reported on the ore deposits in the limestone of the Açungui group.

Leonardos et al. (1956), thought that the origins of the ore deposits of the area have to do with hypogene deposits, which are related to granite. However, Melcher (1968) and others have proposed differing viewpoints from their studies on the Pb radiometric age and the grades of Pb.

For the regional geological map of the survey area and its surrounds, the DNPM's compiled map in scale (1/1,000,000) Curitiba (1974), the CPRM Produced 1/100,000 geological map for Projeto Leste do Parana and the CPRM produced 1/50,000 geological map for Projeto Sudelpa in the province of San Paulo in 1974 were widely used. As for surveys done in recent years, Projeto Chumbao, which was carried out between 1978-1979 by the CPRM on a request by the DNPM, studied the geology and ore deposits of the Perau and Rocha areas. In 1980, their report, including a 1/25,000 geologic map, was published (this was not for general publication). Also, the MMAJ carried out the first year survey of the collaborative meneral exploration of the Anta Gorda area form January to April 1980, on a request by the JICA. In their report, the classification of the geologic stratigraphy followed basically the 1/1,000,000 Curitiba maps (1974), dividing the Açungui group into three formations as Açunqui Formation I, II and III. According to the same report, the lead ore deposits of the area are classified to the bedded ore deposits of Perau type and in the fissure filling deposits of Rocha type. It also describes that the Perau type is distributed in Açungui Formation I, while Rocha type is distributed in the limestone of Açungui Formation III.

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CHAPTER 2 SUMMARY OF THE SURVEY AREA

2–1 Location and Transportation

The area of the present survey is located to the southwest of São Paulo the largest city in Brazil, and is located to the south of the Rio Ribeira in the state of Parana (Fig I–1.) The state highway route 476 runs almost through the center of the survey area, with Adrianopolis being base camp of the present survey, about 360 km. away from São Paulo, a six hour drive by automobile. The survey area is also about 130 km. away from Curitiba, the provincial capital of Parana, which can be reached in about three hours by car. Closer towns, such as Apiai, which was the base for the survey of the first year, is about 36 km. away. Tunas, on the southern boundary of the survey area, is about 56 km. away. On the eastern side of the survey area, a main state highway, route 116, runs from São Paulo to Curitiba. Buses run regularly several times a day to the cities of São Paulo and Curitiba from Ribeira. Also, there are several domestic flights a day between São Paulo and Curitiba.

2–2 Topography and Drainage System

The topography of the area of the present study is mainly controlled by geological structures of the Pre-Cambrian system, with mountain systems mostly running NE-SW Limestone is found in many places from the northern part of the survey area to the north-eastern part. In this area, very steep topography and karst topography are characteristically developed, and doline is frequently seen. In the midwestern and southeastern parts of the area, low grade metamorphosed phyllite are developed. These areas have a relatively gentle sloping topography, however, deep valleys are developed well.

From about the center of the area to the south, gneiss, schist, and quartzite are distributed in a dome-shaped, while anticline and syncline structures are developed. The NE-SW mountain systems, which are largely dominated by these folded structures and very steep topography is often seen. In the northern and also the western areas, large intrusive rocks of granite are distributed, and in these areas relatively gently sloping topography is seen. There are also places which show very steep topography at the boundaries of granites.

For the drainage system, the Rio Ribeira is a quite large river running from the western side of the area towards the north, then flowing towards the northeast. The drainage system of the neighboring areas are all branches of Rio Ribeira which is about 100 meters above sea

level. Neighboring mountain tops are over 1,000 meters above sea level.

In the limestone zone, a karst topographical plateau with V-shaped valley are formed and a dendritic drainage pattern forms At places where doline develops, the water system is halted locally.

In areas where metamorphic rocks have been formed, the system is controlled by structural lines, and lattice-like and parallel-like water systems have developed Gently sloping topography and deep dendritic drainage patterns are characteristic of these granite areas

In the Perau area, the main drainage systems generally show a N-S and NNE flow, these systems include the Ribeirão Grande, Ribeirão Canoas, and the Rio San Sebastian In the Rocha area, the Ribeirão do Rocha, Ribeirão das Onças and the Ribeirão de Carumbe show a NW-SE direction, and flow into the Rio Ribeira

2–3 Weather and Vegetation

The weather in the survey area is characteristic of the region, with much sub-tropical rains, the differences in the four seasons are relatively well-defined. The average annual rainfall is between 1200–1300 mm, the bulk of which falls between the months of October–February The average annual temperature is between 16–19 degrees C., but it is not rare for the daily highs in the summer (January–March) to exceed 35 degrees C. Sometimes the temperature falls nearly to 0 degrees C. in the winter (July–September)

The vegetation in the area is thickly wooded, with pines, oaks and miscellaneous trees, although large parts of the area have been cleared to the neighboring mountaintops and are used as fields and pastureland. Other than the previously mentioned trees, small shrubs and ferns grow densely. Some ferns, (Samambaias), grow especially thickly in areas where granite and metamorphic rock are distributed. However, they usually do not grow where limestone is distributed

CHAPTER 3. GENERAL DISCUSSION

Many basic data were obtained as the results of this year's survey, such as the stratigraphy inside the area, metamorphism, the age of geological ore deposits, geological structures, and ore deposits.

The following are separate discussions of the significant, individual results from the examinations of the data.

3–1 Geological Survey and Geochemical Exploration

3–1–1 Stratigraphy

The main geological stratigraphy of the area is divided from lower part to upper part in the following manner.

The geology that belongs to the Pre-Cambrian system consists of metamorphic rock of the Setuva formation and Açungui group, and also granite and gabbro which intruded in these metamorphic rocks.

The geology that belongs to the Mesozoic is formed from the intrusive rocks of syenite and basic rocks.

The Setuva formation is composed mainly of gneiss, mica schist, and quartzite, and the formation constitute the lowest portion of the geology of the area.

The Açungui group, which is composed mainly of pelitic-psammitic schists, phylite, limestone, and amphibolite-amphibole schists, it is divided into three formations such as the Açungui formation I, II and III, according to the results of the first year's study. The Açungui formation III, according to the present study, has been further divided into three parts such as Upper, Middle and Lower Members

The stratigraphic relationship between the Setuva formation and the Açungui group has been previously discussed by many people. There have been various ways of thinking about this problem. One example of viewpoint is that the Setuva formation constitute the lowest portion of the Açungui group, (Bigarella, 1956), the other is that from the facts that the difference of metamorphic grade between the Setuva formation and the Açungui group, and also a part of the gneiss of the Setuva formation is mixed with milonite, a structural unconformity exists between the two (Projeto Chumao Report, 1981).

However, these viewpoints utilize the same rock facies which are standard in dividing both formations. Also, there is agreement in regards to the thought that the Setuva forma-

tion is lower than the Açungui group. Consequently, theories differ on two points:

Whether or not an unconformable relationship exists between the two,

And whether or not the degree of metamorphism and the age of metamorphism different between the two.

According to the present study, the unconformable relationship between the Setuva formation and the Açungui group could not be recognized. Also, the results of microscopic examination could not detect large differences, as the metamorphic facies, both are belong to green schist facies to epidote-amphibolite facies.

It is also thought that the metamorphic rocks were subjected to the metamorphism in the Brazilian cycle, and it is difficult to presume that an unconformable relationship exists between the Setuva formation and the Açungui group.

3–1–2 Metamorphism of the Pre-Cambrian System

The metamorphic rocks of the Setuva formation and Açungui group distribute in the survey area are composed mainly of gneiss, schist and phyllite, originated of psamitic and pelitic sediments, and amphibolites originated of basic volcanic rocks and it's effusives.

On the mineral assemblage of the basic metamorphic rocks, the Setuva formation consists of hornblend-epidote-bitite, and also the Açungui formation consists of hornblend-actinolite-epidote.

These mineral assemblages show characteristic of green schist facies and epidote-amphibolite facies, and also show that the metamorphic facies of the basic metamorphic rocks of the Setuva formation and Açungui formation have not much difference.

On the psamitic-pelitic metamorphic rocks, other than contain quartz and feldspar, the Setuva formation consists of mineral assemblage of biotite-muscovite.

The other hand, the Açungui formation consists of three group of mineral assemblage as follows;

① biotite-muscovite-garnet

② biotite muscovite

③ muscovite (sericite) -graphite

These mineral assemblage show a characteristic of green schist facies or epidote-amphibolite facies in generally.

The assemblage of ① is recognized in the neighboring area of the Itaoca granite mass, and it is considerable that forming of a large quantity of garnet was influenced by the

granite intrustion.

The assemblage of ② is recognized in the eastern area of the N-S line, Ribeira-Tunas, and the ③ is observed in the western area. The assemblage ③ , particularly, dominated in the upper part of Açungui formation I and Açungui formation II at the northern area of Tunas.

At the neighboring area of the Perau mine, difference of the metamorphic facies between Setuva formation and Açungui formation I could not be recognized.

As results above mentioned, the metamorphic facies in the survey area are belong to green schist facies to epidote-amphibolite facies. And the metamorphic facies of the Setuva formation and the Açungui formation have not much difference.

3-1-3 The Perau Area

The Perau ore deposit is a strata bound lead ore deposit conformed in the calc-silicate rock of the lower section of the Açungui formation I This calc-silicate rock, the host rock of the ore deposit, sits on top of the quartzite which forms the lowest section of the Açungui formation I, and it is distributed in a lenticular shape The horizon of this Perau ore deposit is thought of as the same as the horizon of the Agua Clara ore deposit (Pb, Ba) in the southern part of the survey area, and the Pretinho ore horizon of the eastern section. Surrounding the Perau mine, it can be seen in a scale of 4 km long, and a maximum thickness of 150 meters.

The host rocks of the ore deposit that can be seen underground, are composed mainly of calc-silicate rock, and alternation of banded-massive limestone, dolomite, pelitic-siliceaus schists and quartz thin lenses. Immediately under the ore deposit, a graphite schists thin layer (13 meters at the widest) is found, and directly above the ore deposits, barite which accompanied local lead mineralization, is abundantly aggregated in a lenticular-bedded form. Moreover, 3 ~ 10 meters magnetite zone is widely found in the 5 ~ 10 meters hanging wall. As for the regional exploration of horizon of ore deposits, the quartzite of the lowest part of Açungui formation I becomes a good key bed. In the Perau area, graphite schist and magnetite zones become a good key bed for distinguishing the hanging and foot walls of the ore deposit.

The main ore body of the Perau mine have a length of about 350 meters, and a dip length of about 120 meters. It is composed of some ore beds, and is divided into some ore shoots, being congruent with the direction of small folding structures or lineations, showing S45–70°W, 20–35°S direction, depending on the swelling and shrinking of the ore beds.

The line uniting the bottom edge of the ore shoots, is roughly parallel with the surface of the earth, and the upper half of the main ore body can be thought of as having been erroded out.

The mineral assemblage consists mainly of galena and pyrite, and other than small amounts of chalcopyrite and sphalerite, accompanied by very small amounts of pyrrhotite, marcasite, and tetrahedrite. These ore minerals were subjected to remobilization according to the influence of the folding of the host rocks, and galena and chalcopyrite especially show a characteristic for easy remobilized. Pyrite shows a conformable banded structure in the bedding, and from microscopic observation, concentric structures remain in sphalerite and marcasite. The Perau ore deposits can be thought of as ore minerals were crystallized in low temperature, and that have sedimented syngenetically in the host rock.

The grade of lead ore shows that many samples having around 10% of Pb, and seem to be no difference between enlarged areas of the ore bed and other areas. The grade of silver seems to be high, but any silver mineral cannot be found and it is thought that it accompanies galena and tetrahedrite.

The workable part in the Perau ore deposit is enlarged part (ore shoot) as geological structure.

According to the geochemical soil survey, covering the Perau horizon, the anomaly zones of Pb, Zn, and Cu are consistent with the "Perau Horizon" The mutual relation of Pb-Zn-Cu, is especially well shown in the envirous of the main ore deposit, and a Cu anomaly can be observed in the south.

From the results of electric survey (IP, SIP) which were carried out in the area around the Perau ore deposits, the Perau horizon has been detected clearly, and its continuity into the lower part can be expected.

From a gravity survey the figure of granite and the fault structures were confirmed.

As for scope of future exploration of the Perau ore deposits, there is a necessity for confirming the possible existence of new ore deposits in the deeper portion by drilling. It is also necessary to carry out electrical survey and geochemical survey in the southern area of the Perau showing copper ore indication

3–1–4 The Rocha Area

The geology of the Rocha area consists mainly of the Lower Member and Middle Member of the Açungui formation III, with metabasite and diabase dykes.

The Rocha ore deposit is vein type lead ore deposit in the limestone ($AIIIL_2$) horizon of the Middle Member of Açungui formation III.

According to the underground survey, the lithology of the limestone ($AIIIL_2$) which forms the host rock of the ore deposit, are divided into a limestone dominant part (L), a limestone-dolomite alternation (A), and a dolomite dominant part (D), and veins are developed in the dolomite.

The Rocha mine is situated in the western wing of the Rocha syncline. Its geological structure indicates a monoclinal structure with a strike generally trending NE–SW with a dip to SE. In the underground, a complex folding structure which is principally drag fold, can be observed. The folding structure is well developed in the area of alternating limestone and dolomite (A), and shows a weakening toward the limestone (L) and bedded dolomite (D_1) In the massive dolomite (D_2), where the veined fissure patterns develop, folding structures cannot be observed. From the results of observations of these folding structures, the competency of the appearance of limestone-dolomite becomes massive dolomite (D_2)> bedded dolomite (D_1) > limestone (L) > alternating limestone-dolomite (A).

The fissures, containing the veins, develop in the massive dolomite (D_2) and a part of it indicates the characteristic of a faulting structure.

The fault fissure pattern indicates a strike of N–S, while the vein fissure pattern show a NNW–SSE trend.

The veins, in generally, develop in areas of massive and thick dolomite (D_2), and undergo degradation in other host rocks.

As for the ore shoots of veins, in general, is not enlarged one vein, but in formed with many small veins aggregated in a parallel fashion.

As for the mineral assemblage, galena and pyrite can be observed with the naked eye, while tetrahedrite, arsenopyrite, marcasite, and pyrrhotite are observed under the microscope. These ore minerals are aggregated and crystallized in the fissure of the host rock, galena was moving until a late period.

In regards to the limestone-dolomite which forms the host rock of the ore deposit of the Rocha mine, analysis of the base metal components (Au, Ag, Cu, Pb, Zn) and analysis of lithochemical components (CaO, SiO_2, Al_2O_3, FeO, MgO) were carried out using X-ray diffraction analysis, and an atomic absorpsion analysis. The results indicated a strong trend for Ag with limestone, a weak trend for Ag with dolomite, and the opposite trend for Pb, Zn.

The amount of Ag contained in the Rocha mining area shows an extremely high value compared to general carbonate rock, and it can be thought of as a major characteristic showing the host rock of the ore deposit in the regional exploration.

As for the future exploration in the Rocha area, it is necessary to regard the dolomite area and exploration in the areas between the known ore deposits, as well as the lower portions of known veins.

3–1–5 Results of Lead Isotope Measurements

The lead ore deposit of the present area can be divided into two types such as the bedded ore deposit of the Perau type and the veined ore deposit of the Rocha type.

Plotting the measured value of the lead isotope of galena obtained from these ore deposits on the ore lead growth curve of Cumming and Richards (1975), the samples of the Perau type and the Rocha type, constitute clearly different groups. The former converges in the neighborhood of 1400 m y., and the latter indicates a trend of convergence in the neighborhood of about 1200 m.y.

These values, as stated by Melcher (1968), are older than the intrusion peirod (550 m.y.) of the granite of this area, and contradicts the argument that mineralization was related to intrusion of granite. Conversely, the Perau type ore deposits were sedimented syngenetically with the host rock in the Açungui formation I, and the thought that the Rocha type ore deposit was formed as base metal which depositted in the host rock (Açungui formation III) were abundantly concentrated in the fissure of the host rock.

3–1–6 The Geochemical Survey

A geochemical survey of the soil was carried out covering the Perau horizon.

The 113 samples of B-horizon soil were collected with 50 meters interval, (100 meters at some samples) along the IP survey lines.

The obtained data, according to analysis of atomic absorbsion, analyzed Cu, Pb, Zn, Ni, Co, and Mn. From these data a factor analysis of multivariate calculation was carried out.

According to these results, the anomaly zones of the components Cu, Pb, and Zn are well correlated with the Perau Horizon. The mutual relation of Cu-Pb-Zn is especially well shown in the environs of the Perau ore deposits.

The mutual relation of Mu-Co-Ni-Zn is shown along the distribution of amphibolite (AIam) and the Perau horizon (AIIs).

The Cu component is found in the Perau Horizon to the south of the area, and is well in agreement with geological surveys at the surface.

In the case of future exploration of the Perau Horizon, the good area of mutual relation of Cu-Pb-Zn can be regarded as promissable.

3–2 Geophysical Survey

3–2–1 Gravity Survey

Gravity survey was conducted in the vicinity of Perau mine with an area of 100 km^2 and total number of 274 points.

1) A more apparent feature of gravity map is a northeast-trending gravity contours which is consistent with the main geological structure with a NE trend in the survey area.

2) Setuva formation considered as basement rock and Açungui I formation of Pre-Cambrian are delineated. Setuva formation exposed at Serra do Cadeado, being northeast striking anticlinal structure, dip gently to its both wings. To Northwest, it increases its depth gradually, repeating a minor folding towards a major northeast-striking fault from Epitacio Pessoa through Praia Grande to Quilo Metro Quarenta, with a downthrown of 1,500 m on northwest.

3) At the northwest side of this fault, Setuva formation has its depth of 2,500 m and dips to northwest gently. The thickness of Açungui I formation is larger than 2,500 m.

4) At the southeast side of this major fault, intrusive rocks considered as gabbro is assumed along this fault.

5) Granitic rock are delineated at the northwestern corner of the survey area.

3–2–2 Induced Polarization Method

IP electrical survey was carried out near Perau mine, setting 12 survey lines with total line length of 30.2 km.

1) Three IP anomalous zones of over 3.0% FE are detected at the northern part (A anomalous zone), the central part (B anomalous zone) and the southwestern part (C anomalous zone) in the IP electrical survey area.

2) A anomalous zone is caused by graphite schist and the possibility of ore deposit is very little.

3) B anomalous zone is distributed in the vicinity of Perau mine and consisted of two anomalous zones. One is located at the northeast of Perau mine and might be caused by amphibolite associated with sulfide. Another one is detected near Perau mine and might reflect the Perau ore horizon. Its anomalous source with westward dipping is consistent of the geological survey results. And it may extend to the south and southeast. The possibility of ore deposit at the south and at the souteast of Perau mine and at depth is large.

4) C anomalous zone has a similar tendency with A anomalous zone. And this anomaous zone has a diffrent feature with B anomalous zone. Therefore, anomalous sources is seemed not to be the Cu-Zn-Pb ore deposit casing B anomalous zone and to be mainly graphite schist associated with sulfide. But there is a possibility to be caused by the same ore deposits with Perau mine at depth because of the existence of the extension of B anomalous zone.

3–2–3 Spectral IP Method

Spectral IP method was conducted on two IP survey lines (Lines G and K, line length 5 km), where interesting results were observed on conventional IP method.

1) As spectral IP was conducted over the same survey lines of Lines K and G and the same anomalies were detected with the conventional IP, the same naming are used for the anomalies.

2) Anomaly A detected in the western side of line K is reflecting the graphite schist.

3) Anomaly B locates in the middle of Line G at Perau mine area indicating the west dipping Perau ore horizon.

4) Anomaly C seen in the west of Line G has a quite different pattern with that of anomaly B, which would not suggest the causative sulfide mineralization of copper, lead and zinc. Although some anomaly looks like a pattern of anomaly A, IP effect is stronger than A due to graphite schist with stronger pyritization. There is, however, another possibility of different type of mineralization.

3–2–4 Aeromagnetic Interpretation

Aeromagnetic interpretation work was performed for the northeastern area (B-area, 3,250 km^2) of the survey area,

1) The direction of geotectonic lines indicated in the geomagnetic residual map is mainly NE–SW and is consistent with the geological lineament in the survey area.

2) Intrusive Rocks such as granite, gabbro, diabase and syenite are delineated. The distribution of gabbro and diabase is controlled by the above-mentioned geotectonic lines.

3) The mines in the survey area locate apparently near the forementioned intrusive rocks, but it is considered that there are no relations between the mines and intrusive rocks.

4) These mines locate within the magnetic bodies of class D (psammitic rock, pelitic rock and limestone).

CHAPTER 4 CONCLUSION AND RECOMMENDATION

In order to obtain a useful guide for the future exploration and to study mutual relation between the ore forming portion and the geological structure, sub-detail geological survey has been conducted. And also detail geological survey on the Perau mine and the Rocha mine, especially on the Perau mine, the geochemical survey and geophisical survey (IP, SIP electorical survey, gravimetory survey) have been carried out.

The conclusions as the results of these survey are follows;

1. Geology of the present area consists mainly of metamorphic rocks of Setuva formation and Açungui group of Pre-cambrian system, and igneous rocks intrude these metamorphic rocks. According to the first year survey, Açungui group was divided into three formations, and furthermore, in the present survey Açungui formation III which is the uppermost of Açungui group was also divided into three Members such as Lower Member, Middle Member and Upper Member.
2. Metamorphic rocks are belong to a green schist facies or epidote-amphibolite facies, and metamorphic facies of Setuva formation and Açungui group can not be observed much difference.
3. The Rocha deposit, Barrinha deposit and Panelas deposit are situated in the limestone and dolomite of the Middle Member of Açungui formation III as same horizon.
4. The Perau deposit is bedded lead ore deposit (strata bound deposit) which was formed syngenetically in the host rocks in the early stage of the Açungui formation I (1400–1300 m.y).
5. As the results of geochemical survey coverring Perau horizon, the mutual relation of Cu-Pb-Zn is well shown in the environ of the ore deposit, and Cu anomaly is distributed along the Perau horizon towards the southern portion of the Perau mine.
6. As the results of IP and spectral IP erectrical survey, an possibility of continuity of the Perau horizon towards lower portion, and an anomaly zone has been detected at the lower portion of the Perau ore deposit, present working, along the Perau horizon.
7. As the results of gravity survey, the structures of Anta Gorda anticline, Agua Clara anticline, Riberirao Grande fault and Varginha granite mass were confirmed.
8. The Rocha deposit is vein type deposit which was formed by a geotectonic movement of Brazilian Cycle in the end of Pre-Cambrian age. Vein fissures are developed especially in the massive dolomite.

Ag content in the limestone, neighboring the ore deposit, shows higher value than general carbonate roks, it can be thought of as a major characteristic that indicate the host rock of ore deposit for future exploration.

9. Consequently, many fundamental data have been obtained from present survey, and furthermore following survey can be expected.

9–1 The IP anomaly zone which was detected in the lower portion along the Perau horizon, can be thought of as possible to relate with the Mineralization.
Drilling exploration should be conducted to confirm it.

9–2 Semi-detail geological survey in the northern half area of Anta Gorda project should be conducted in order to clarify the mutual relation between the ore deposits and geological structure.

9–3 In order to clarify the possibility of existence of ore deposits, electrical survey and geochemical survey should be carried out in the southern area of the Perau mine.

9–4 Barrinha deposit is vein type, and is located on a crest of the Barrinha anticline as blind deposit in limestone and calc-schist which is same horizon as the Rocha mine. The electrical survey should be carried out in the surrounding area of the known deposit to clarify a possibility of another blind ore deposit.

PARTICULARS

PART I GEOLOGICAL SURVEY

CHAPTER I GEOLOGY

1–1 Summary of Geology

It is known that the geology of the present survey area and its surrounds consist of the Setuva formation and the Açungui group of Pre-Cambrian age. It is also known that many lead ore deposits in the Açungui group.

The Setuva formation which forms the lowest part of the geology of the present survey area and is composed mainly of geniesses. The Açungui group is divided into three groups, as the Açungui formation I, II, and III, which are composed of schist phyllite, amphibolite, and limestone.

The geology, in general, is folded and faulted, and it is difficult to clearly understand the structural and stratigraphical relationships between the Setuva formation and the Açungui group. Many theories have been proposed, but according to this survey, they are thought of as a concordant relationship.

Igneous rocks which are found in the above metamorphic rock, were formed later in the period. Metabasic rock subjected to a weak metamorphism, granite which was intruded in the end of the Pre-Cambrian period, syenite and diabase which were intruded in the Cretaceous Period, are all found.

The major metamorphism of these metamorphic rocks of the Pre-Cambrian age took place toward the Brazilian Cycle.

According to metamorphic mineral assemblage of amphibolite and mica schist, metamorphic facies of Setuva formation and Açungui group are belong to green schist facies to epidote-amphibolite facies, and can not be recognized much difference between them.

Geological structure in the present survey area is predominantly shown NE-SW direction.

Ribeira fault, passing through the central part of the area, divide the geological structure into two parts.

In the southeastern area of the fault, NE-SW trend folding structures which consist of Setuva formation, Açungui formation I and II, are arranged from north to south and Setuva formation expose at the core of anticlines.

In the northwestern area of the fault, Açungui formation III distribute widespread with NE-SW strike, and show more complicate structure with folding and fauting than Açungui formation I and II.

The ore deposits in the area are divided into the Perau type ore deposit as bedded deposit in Açungui formation I, and the Rocha type ore deposit as vein type in the limestone of the Açungui formation III.

A geological map of the area is shown in Fig. I–1, and a generalized columnar section is shown in Fig. I–2, and a stratigraphic correlation is shown in Fig. I–3.

1–2 Stratigraphy

The geology of the area is composed of gneiss of the Setuva formation, and schist, ausphibolite, phyllite, and limestone of the Açungui group.

1–2–1 Setuva Formation

The Setuva formation forms the lowest portion of the geology of the area, and consists mainly of gneiss, which includes some quartzite in partially.

Distribution and Thickness.

The Setuva Formation is exposed as the core of the anticlinal structure of the Anta Gorda and Perau anticlines, which have a folding axis of NE-SW, in the southwestern portion of the area and in the southeastern edge of the area.

The anticlinal structures are arranged north to south, while showing a NE-SW trend. The distribution of this formation is also exposed sat the axis part being repetitious with these folds Areas of Setuva formation indicating a wider distribution in the Anta Gorda anticline area and indicating smaller distributions the Perau anticline area. In the Anta Gorda anticline area, quartzite is distributed in the center portion of the anticline axis. This quartzite indicates apparantly the lowest part, but in the Agua Clara anticline, it is not exposed, consequently it is regarded an intercalation locally in the gneiss.

Lithology

The main lithology are composed of muscovite-biotite gneiss, amphibolite-biotite gneiss, augen gneiss, and quartzite.

The gneisses are shown massive and dark grey to dark green colour, in generally, and muscovite, biotite, quartz and feldspar are observed. Clear banded structures gneissose structures is composed of muscovite and biotite prefominated part and in quartz and feldspar predominant part can be observed.

The rock forming minerals generally appear with a coarse to fine grained from the lower to the upper part. In the coarse grained areas include the porphyroblast of the potash feldspar.

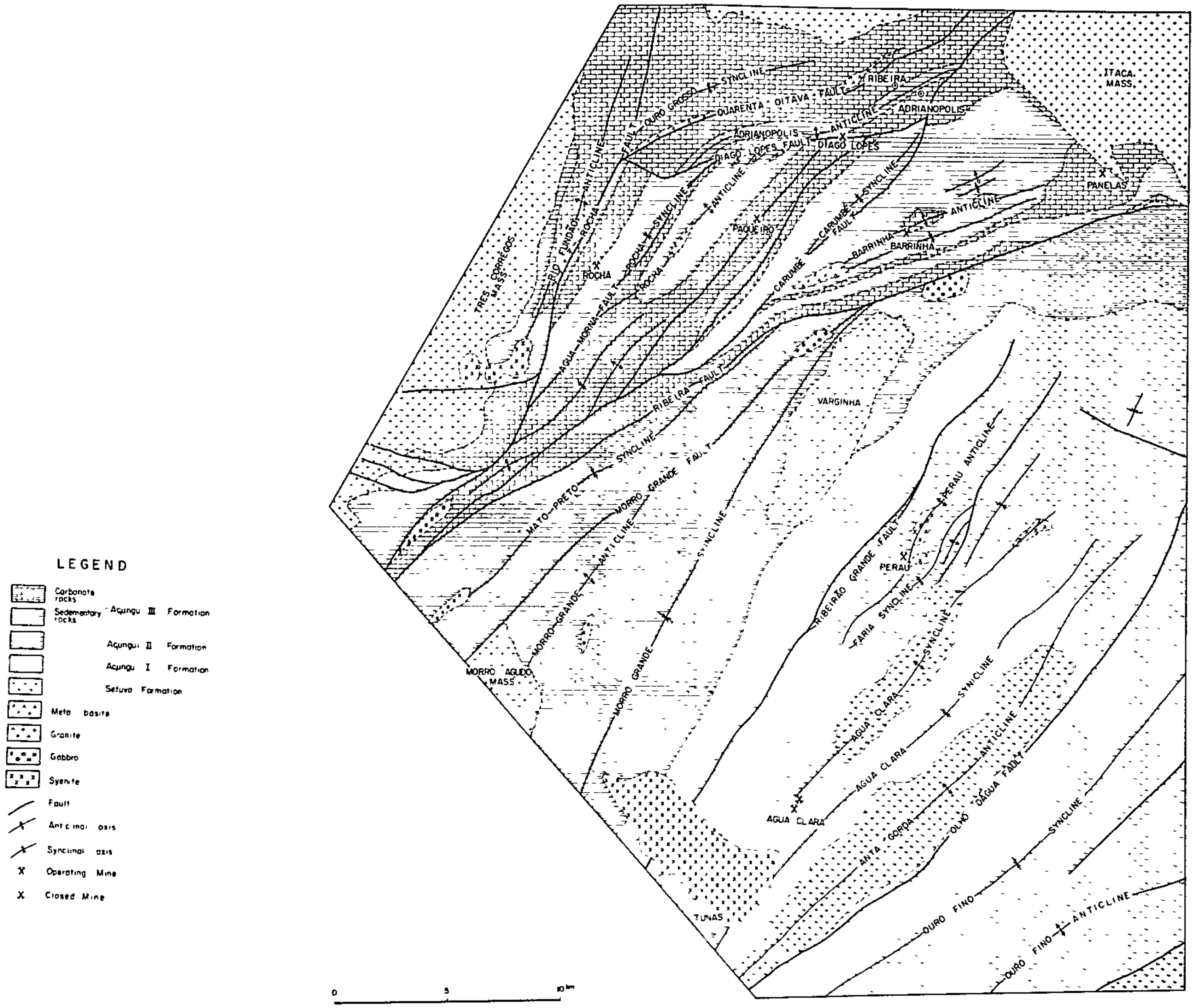

Fig. I-1 Geological Map of Survey Area

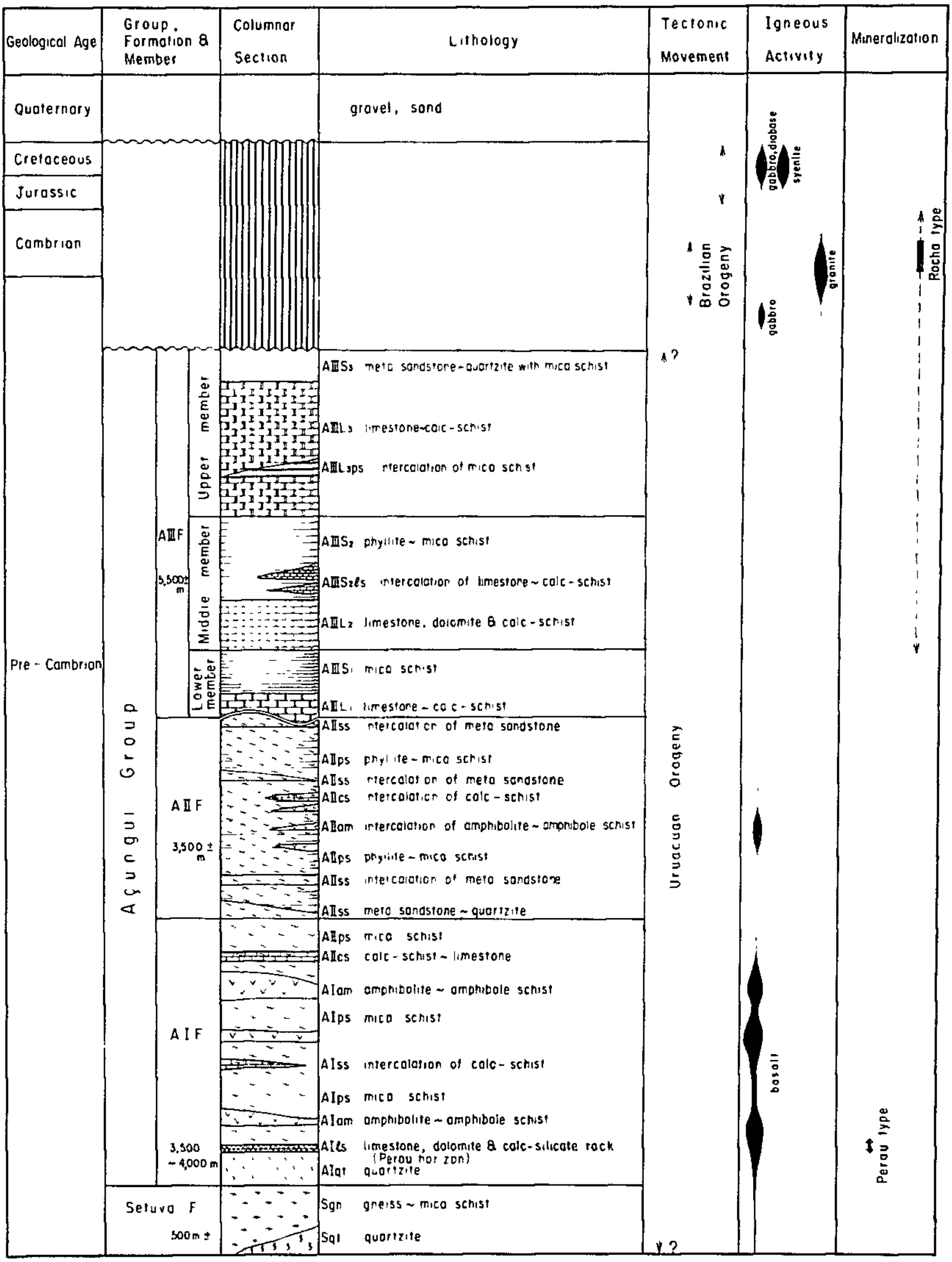

Fig. Ⅰ-2 Generalized Stratigraphic Columnar Section in Survey Area

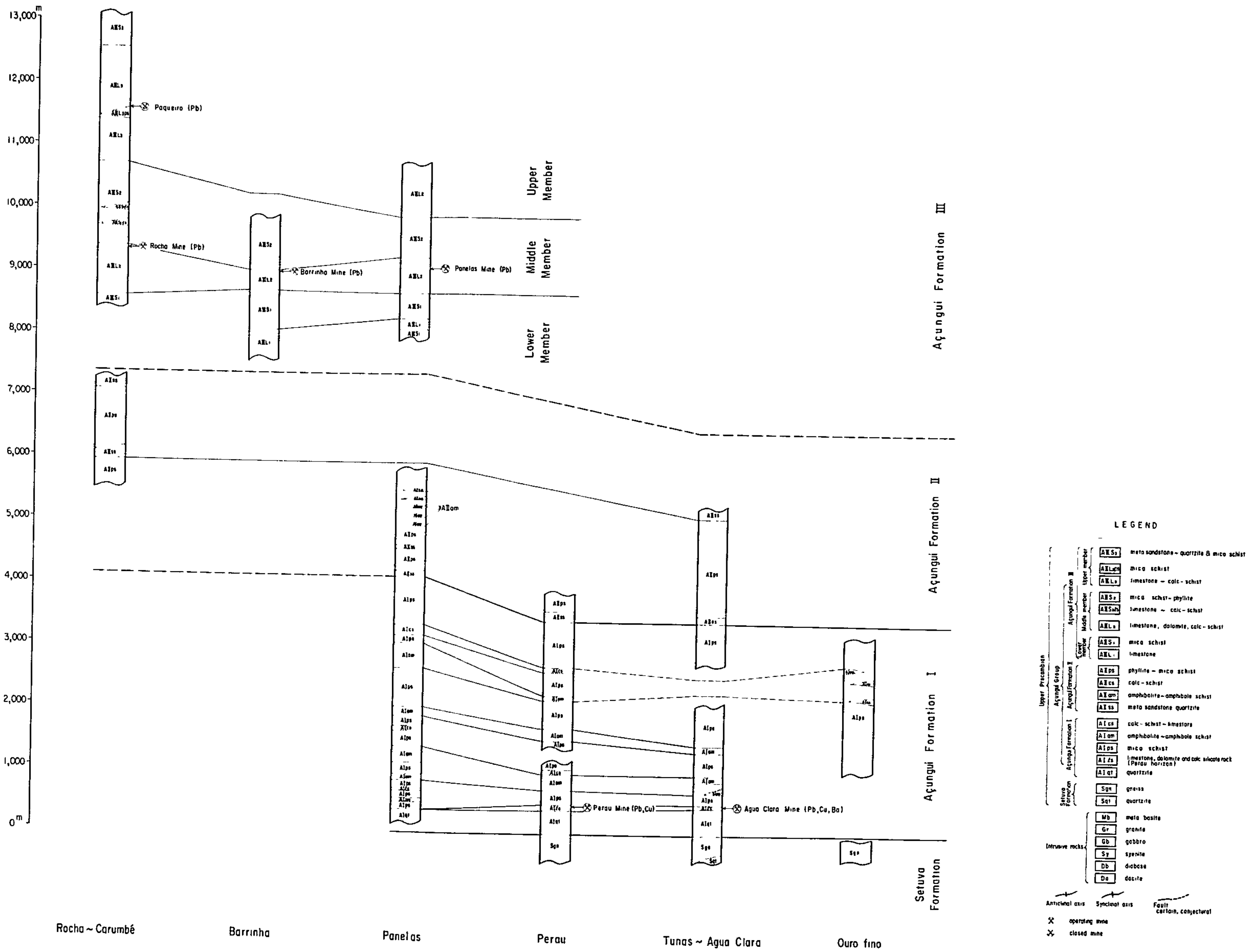

Fig. I-3 Geological Columnar Section and Stratigraphic Correlation in Survey Area

The augen gneiss, which contains many accumulations of large porphyroblasts of potash feldspar and quartz crystals, is exposed in many places and representative samples can be best seen in the northeastern portion of the Anta Gorda village, and upstream of the Ribeirão do Perau in the area of the Agua Clara anticline. Large crystals of potash feldspar can be best seen upstream of the Ribeirão de Perau.

Under the microscope, the mineral assemblage of the gneiss consist generally of quartz, feldspar, biotite, muscovite, hornblende, and epidote and also small amounts of zircon, garnet, and apatite are associated. Lepidoblastic-nematoblastic structure are characteristic in generally, and porphyroblastic structure can be seen in the augen gneiss. Quartz and feldspar are small grained crystals, which are directionally arranged associating with smaller flakes of biotite and muscovite.

Larger crystals of potash feldspar and aggregation of quartz crystals are contained porphyritically in the augen gneiss, and small grains of quartz, potash feldspar, biotite amphibolite are distributed in a banded structure filling up those large crystals.

Quartzite can be observed upstream from the Rio de Veado on the Anta Gorda anticline, it is white to grey in color small-grained and schistosity has clearly developed.

From the fact that muscovite and biotite are contained in large amounts, the gneiss shows a characteristic of peritic sedimentary rock origin. Moreover, from the fact that quartz and feldspar are also present in large amounts, the psammitic sedimentary rock origin characteristics of gneiss are also present. The quartzite can especially be regarded as a predominantly sedimentary rock from a psammitic mineral origin.

Stratigraphical relationship and age

The lower part of the present stratigraphy are unclear because it can be not possible to be checked in the survey area.

1–2–2 Açungui group

The Açungui group were divided from the bottom into the Açungui formation I, II, and III according to the JICA report of 1981.

From the present survey, the Açungui formation III was further divided into three beds such as the Lower, Middle Member and the Upper Member.

(1) Acungui Formation I

The lowest portion of this formation consists mainly of Quartzite, which covers the Setuva formation. The main part of the formation consist of mica schist and phyllite. Calc-silicate rock is intercalated in the space between quartzite and mica schist, and there is also

intercalation of much amphibolite in the mica schist.

The upper most portion of Açungui formation is up to the bottom of quartzite-sandstone bed, which is the lowest part of the Açungui formation II that developes near the Serra do Veute e Sete.

Distribution and Thickness

This formation surrounds the Setuva formation. The quartzite at the lowest part of this formation is located only on the Setuva formation which forms the core of the Anta Gorda anticline, the Agua Clara anticline, and the Perau anticline. The top of the formation passes from the northern side of the village of Cricima, through Serra do Vente e Sete, and up to 5 Km northwest of the Tunas village.

The thickness of the formation is inferred to be about 3,500 – 4,000 meters, and in the northeastern area of each of the anticline structures, the thickness of the formation becomes much thicker interbedding thick amphibolites.

Lithology

The main rock facies of the formation is composed mainly of quartzite, limestone-calc-silicate rock, biotite and amphibolite.

(a) Quartzite (A I qt)

It appears white to yellowish grey and is massive. In partially it has a schistose structure.

The main constituent minerals are fine-grained quartz and associate small amounts of feldspar. The film of muscovite is included, especially in the Agua Clara region, the muscovite content is high and schistosity develops.

A gradually changing relationship toward limestone, calc-silicate rock, and mica schist which are upper portion of quartzite can be observed, and in the neighboring boundary it alternates with their layers of the above mentioned limestone or mica schists. also can be seen.

The limestone and calc-silicate which are host rock of Perau ore deposit is formed a lenticular shape and situate directly above the quartite, consequently it becomes an useful key bed as lithologically characteristic horizon for regional exploration. In the region around the Perau area, the thickness is 300 meters, but in the Anta Gorda region it becomes less than 100 meters thick.

(b) Limestone ∿ calc-silicate rock (A I ℓs)

Limestone and calc-silicate rock is distributed in a lenticular shape directly above the quartzite. In the part of these rocks, the Perau, the Agua Clara, and the Pretinho ore deposits are interbedded.

Areas where the exposure of the horizon of limestone-calc-silicate rock which was

confirmed in the past, are the region of around the Perau, the Corrego Volta Grande, the Agua Clara, and the Pretinho areas. In the region of the Perau mine area a much thicker and wider distribution is seen, being four kilometers long by 150 kilometers thick.

In this area, rock facies of calc-silicate rock show a light grey to green appearance, and have banded structures, which are formed from flakes of biotite in large amounts of quartz, calcite, muscovite, and tremolite.

The ore deposit host rocks of the Perau mine area are complex of calc-silicate and peritic-siliceous schists.

(c) Mica schist (A I ps)

The rock facies of the mica schist is remarkable change, however, the fundamental rock facies is grey to dark grey, small to medium grains have developed schistosity.

The main constituent minerals of the mica schist consist of quartz, biotite, muscovite, and sericite. Also, plagioclase, garnet, amphibolite, and tremolite are associated in these.

According to assemblage of the above constituent minerals, rock facies of biotite-muscovite-biotite schists and muscovite-sericite-muscovite schists are seen. The former shows a trend of development from near the Perau area to the north, while the latter show a trend from the southern area of the Perau to near the Ouro Fino area in the southeastern of the survey area, and in the region of Tunas The former shows a clear schistosity, contains many flakes of biotite, and often includes coarse grains of garnet.

Under the microscope, the lepidoblastic structure according to the above minerals is characteristic, and rarely includes staurolite.

Directly above the ore deposit horizon of the Perau mine, a large accumulation of magnetite can be seen.

The latter includes large amounts of muscovite, and being smaller grained, the schistosity is weaker than the former. Often show the alternating distribution with quartz-muscovite-biotite schists, however, the rock facies of phyllite are seen near Ouro Fino and the northern part of Tunas.

Under the microscope, lepidoblastic structures formed by sericite, muscovite, quartz, and small amounts of biotite can be seen, but in the areas that show the phyllite these minerals are very fine grain size, and the lepidoblastic structures become unclear.

The mica schist intercalate the amphibolite bed and the limestone bed, and appear to be about 3,700 meters thick.

(d) Amphibolite (A I am)

Appears dark green, with a fine to coarse grained, and massive-banded heterogenous rock types.

Being included in the above mica schists*, it is continuously long and slender, concordant to the bedding of the mica schists. The amphibolite bed, the width of which differs from several meters to 100 meters, is widely distributed. It is especially well developed in the northern part of the Perau anticline, showing a maximum width of 400 meters.

From the results of microscopic observation, the main constituent mineral is composed of amphibolite, plagioclase, and actinolite, including small amounts of garnet, epidote, biotite, and tourmaline. Other than that, the inclusion of magnetite and pyrite also exists. In the massive section, the porphyroblastic structures are characteristic of amphibolite. These rocks often include thin layers of mica schists, often coexisting with lime schists, and is well conformable with the schists of sedimentary rock origin in the regional area.

Concerning the origin of these rocks, some ideas have been proposed in the past that basaltic igneous rock was intruded before the formation of the schists (CPRM, 1981), and that there is a possibility these rocks were formed by either tuff, or inpure calcareous or dolomitic sedimentary rocks, or from mixture of both rocks (JICA, 1981).

According to the results of this survey, by the reason that it is distributed conformally in as basic lava and tuff blended with a part of peritic sedimentary rock.
amphibolite are plotted on the basic igneous region in the ACF diagram (Fig. I–4), the origin of these rocks can be thought of as having been formed as basic lava and tuff blended with a part of peritic sedimentary rock.

(e) Limestone Calc-schist (A I cs)

In the surrounded area of the Perau mine, limestone ∿ calc-schist beds are intercalated with mica schist (A I ps). In this area, rock facies of calc-schist have a fine alternative structure of limestone and schist which is composed of biotite, muscovite and tremolite..

In the Rio San Sebastião of eastern area, limestone thin layer is distributed as lateral. And a limestone bed distributing continually from the Cricima Village to western area of

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* The main samples of this rock are located in the mica schists of the Açungui formation I, but other than that, similar rock facies are located in the mica gneiss of the upper section of the Setuva formation in a smaller scale, also in the quartzite of the Açungui formation I, and some thin layers are found partially in the Açungui formation II.

Ribeirão Grande shows massive limestone at northern area of Cricıma and shows predominantly calc-schist from crossing point of Ribeirão Grande to the south.

Also other small beds are mainly calc-schist.

Stratigraphical relationship and age

The stratigraphical relationship with lower Setuva formation was thought of as being an tectonic unconformity (CPRM, 1981), but accordıng to the present survey, it can be regarded as a concordant structure from the following reasons.

The gneiss of the Setuva formation, in coarse-grained rock forming minerals are rse-abundantly developed in the lower part, and towards the upper part it changes to a fine-grained muscovite-biotite gneiss, being covered by the quartzite of the lowest horizon of the Açungui formation I.

According to the CPRM report of 1981, the Rb/Sr age of the gneiss of the Setuva formation was gıven as about 1400 m.y., while the age of both this and the Açungui formatıon I, havıng 1330 m.y., are quite close together, and can be thought of as beıng sedimented continually.

According to the DNPM's Projeto do Parana's 1/1,000,000 map (1977), the results of a K/Ar age measurement of the biotite of the gneiss was shown as about 783 – 782 m.y., and this shows that age of metamorphism is in accordance with the Brazilian cycle.

(2) Acungui formation II

This formation is composed of mica schists and phyllite, and often intercalation of quartzite-psammitic schists is a characteristic. The quartzite of the neighboring Serra do Vente e Sete makes up the lowest levels, concordantly covering the Açungui formation I. The upper levels are cut by the Ribeira fault.

Distribution and Thickness

The Açungui formation II passes through the center portion from the southwestern parts of the survey area showing strike NE-SW, and to the northeastern areas showing E-W, as a distribution of belted form.

Quartzıte ~ metasandstone is located in the central-northeastern area, as well as in the central to southern areas. Amphibolite is located on a small scale ın the northeastern area.

It is dıfficult to confirm thickness of the formation because of poor distrıbution of key beds in the area, however, infered thickness is calculated over 3,000 meters.

Lithology

The rock facies consists of mica schist and phyllite (A II ps), and includes small amounts of quartzite meta sandstone (A II ss), amphibolite (A II am), and limestone ∿

calc-schist (A II cs).

The rock facies of the mica schists are located predominantly from the center sections of the area to the north eastern sections. The rock types of phyllite show a predominant trend from the center to the southwestern areas.

Mica schists appear grey, dark grey and black, with a small to medium grain size. Biotite-quartz and muscovite schists, the main rock types, which contain a lot of biotite are similar to the mica schists of the Açungui formation I. In the field, however, psammitic areas are generally more abundant, compared to the Açungui formation I, in these psammitic areas, quartz grains are more frequent than sericite.

A large amount of biotite is seen in the northeastern part of the area. Coarse grained biotite and magnetite are abundantly accumulated locally, especially in the southern part of the Panelas mine biotite can be observed developing cross the schistosity.

Near the Itaoca granite, biotite becomes coarse-grained, and the development cross schistosity can be observed. This is due to the thermal influence of the Itaoca granite.

In the area of Cacador village in the central area, biotite schists and phyllite, which often contains graphite, are found in an alternating pattern, and in areas intruded by the Varginha granite, strongly subjected to silicification occurs.

Phyllite appears light grey to dark grey, and weathered rock is very soft.

Under microscope, muscovite, biotite, quartz and plagioclase are mainly observed associate with small amount of garnet and tourmaline, and showing a lepidoblastic structure.

There are many samples of peritic origin which have as the main rock-forming mineral, quartz-graphite-muscovite. Rock types which can be thought of as tuffacious origin.

(b) Quartzite-metasandstone

The quartzite and metasandstone are massive, greyish white and show a weak schistosed structure. The quartzite which forms the lowest part of the Açungui formation II developes at Serra de Vente e Sete in the central part of the area, and becomes continuous towards the northeast, forming a ridge topographically. This quartzite gradually changes into layers of metasandstone and psammitic schists towards the southwest, and then the exposure often discontinuous.

This rock facies is a good key bed to separate the lower limit of the Açungui formation II and the upper limit of the Açungui formation I in the central sections to the northeastern sections. In the southern sections, however, it becomes unclear, and the separation of both is difficult.

The rock facies found near the village of Cacador in the central part of the survey area

and in the middle of the Rio Mato Preto in the southwestern part, are medium to coarse-grained metasandstone-conglomerates, including quartzite.

The rock facies under the microscope is shown as follws:

Quartzite and metasandstone show a granoblastic structure which contains small amounts of muscovite and plagioclase. Quartz grains are the main forming minerals.

Stratigraphical relationship

It covers concordantly the lower level of the Açungui formation I, and the upper part is cut by the Ribeira fault.

(3) Acungui Formation III

This formation is composed mainly of peritic-psammitic schists, sandstone and limestone, it also includes igneous rock and metamorphic rock. It is widely distributed in the northern-northwestern parts of the area, and appears to be a complicated structure, being influenced by folding and faulting.

In the past, it was thought that limestone was distributed in the lower sections, and peritic-psammitic schists or sandstone distributed in the upper sections. It was also thought that the limestone of the lower sections were constantly repeating and being exposed by the complicated folding, according to the detailed study on these rocks on the present survey, however, it was clarified that the limestone beds divided into three beds (A III L_1, A III L_2, and A III L_3) became clear. These beds are belonged into three members as the Lower Member, Middle Member and Upper Member combined with peritic-psammitic schist and sandstone (A III S_1, A III S_2, and A III $S_2$2).

(a) The Lower Member

This Member is divided into limestone of the lower part (A III L_1) and the mica schists of the upper part (A III S_1).

Distribution and Thickness

It is distributed long and narrow along the north side of the Ribeira fault from the Rio Bocanha in the southwestern part of the area to Tio Caraca Grande in the northeastern part. It is also found in small amounts in the Rocha area in the west. The thickness of the total is inferred to be over 1,200 meters, and of the limestone (A III L_1) is over 600 meters, and the mica schists are about (A III S_1) 600 meters

Lithology

The limestone (A III L_1) appears dark grey to black in color, with fine to middle-sized grains of massive, fine or saccharoidal structures, and bedding is clear. Other than the frequent intercalation of dolomite in the central to the southwestern portion of the area,

fluorite is found in the northern part of the Cacador village in the central sections, as appearing in a veined structure, massive and brecciated. The mica schist is composed mainly of quartz-biotite- muscovite schists, medium to coarse grain, grey to dark grey, and small folding structures are noticeable.

Under the microscope, muscovite and quartz are abundant, and lepisoblastic structures including small amounts of biotite, plagioclase, and garnet are seen.

Granoblastic structure can be observed in the limestone is mainly formed from calcite and also granoblastic structure that show in dolomite (doloslone) is mainly compose of dolomite.

(b) The Middle Member

This Member consists of the limestone, calc-schist (A III L_2) of the lower part and the mica schists, psamitic schists (A III S_2) of the upper part.

Distribution and Thickness

In the eastern part of the Cerra do Carumbé fault, a general strike of NEE-SWW is seen, and it is all dipping to the north showing gentle folding. In the region of the Rocha area, a strike of NE-SW is seen, and it is distributed on the axis of the Rocha anticline and on the wing of the Rocha syncline, and is found showing a complex structure with many faults.

Lead ore deposits of the Rocha, the Barrinha, and the Panelas mines situated in this limestone (A III L_2). The thickness is presumed to be 1200 – 2000 meters, and within that, the limestone (A III L_2) is the largest in the Rocha area (900 meters), it is 300 meters in the area of the Barrinha area, and is seen as being about 500 meters in the region of the Panelas area. In the neighborhood of the Cerra do Carumbé fault, it becomes about 100 meters.

The mica schist (A III S_2) in the region of the Rocha mining areas is the thickest as 1,000 meters, while in the region of Panelas is presumed to be about 850 meters.

Lithology

Limestone (A III L_2) appears greyish white to dark grey, and changes from small finely grained to coarse grained saccharoidal structures. It often has dolomite and calc-schists.

Light grey to dark grey, fine to medium sized grained limestone develops in the neighborhood of the Rocha mine. In the lower part of the limestone appears white to light grey, and alternates with a well bedded limestone. In the upper part, massive grey to dark grey dolomite is intercalated.

Because limestone ∿ dolomite are the main ore deposit host rocks of the Rocha mining

areas, the rock types were finely divided in the present underground survey, and a detailed survey was carried out.

In the Barrinha mine area grey to dark grey limestone and calc-schists are found in an alternating pattern. The allmost limestone change to calc-schist at the middle of the Rio Carumbé.

In the calc-schists, bedding is developed and a characteristic pattern of alternating bands of dark grey biotite and muscovite part (2–5 cm. wide) and white carbonate rock part (5–10 cm, wide) can be seen. Also, large amount of coarse-grained tremolite can be seen near the Secrisa ore deposits in the Barrinha mine.

Limestone is developed near the Panelas area, and it is divided into black limestone and white limestone on the geological map of the area.

In the present survey, both rock types were compiled together and mapped. Remarkable flow fold can be observed often in this limestone. Also, coarse grained saccharoidal structures can be observed near the granite regions.

The mica schist (A III S_2) is grey to light green grey color, and fine to medium grained. Rock facies of quartz-biotite-muscovite schist, chlorite-quartz-muscovite schists, and quartz-graphite-muscovite schists are seen. Those containing a lot of quartz grains appear as psammitic schist.

In the lower parts of this member in the Rocha area, the proportion of fine grained biotite-muscovite schists is large, and it changes into muscovite-quartz schists in the upper part. Limestone-calc-schist (A III $S_2 \ell s$) are often intercalated in this bed (A III S_2), and a continuous a large amount of tremolite zone in the boundary with calc-schist can be observed. These rock types can be seen in the northern part of the Diago Lopez fault, also large tremolite crystals develop in the northwestern part of Colleto village.

In the axis of the Rocha anticline structure, grey to greyish tan fine-grained muscovite-quartz-schists are widely found. In the upper parts, conglomerates consists of elongated quartz granules (3–7 mm) are interbedded. In the lower parts, limestone and calc-schist thin layers are included.

Muscovite-biotite schist are widely found in the Barrinha-Panelas area, and coarse grained biotite develops, obliquely in the bedding, in the surround area of the Itaoca granite. Garnet is often abundantly associated in these rocks. The characteristics of these rocks under the microscope are similar to the limestone and calc-schists of the lower sections.

(c) The Upper Member

The Member consists of the limestone (A III L_3) of the lower sections, and the sandstone-quartzite conglomerate alternating bands (A III S_3) of the upper levels. The limestone intercalates the mica schists (A III L_3 ps).

Distribution and Thickness

In the area uniting Adrianopolis – Serrado Carumbi – Rio Mato Preto, a general strike of NE-SW is seen, and is found long and narrow. The thickness is not confirmed in the upper sections of the area, thus it is unclear, but the width of the whole body is presumed to be over 2,500 meters. Of this, the limestone (A III L_3) is presumed to be 11,400 – 1,800 meters in the Serra do Carumbé area. In the northern area of the Rio Ribeira, it is thought to be thicker than this The mica schists included in the limestone (A III L_3 ps) is cut by the faults, thus the actual width is unclear, but a 100 meter order is inferred. As for the metasandstone-quartzite and metaconglomerate alternating bands (A III S_3), therefore the upper portion is cut by faults and actual width is unclear, it is presumed to be over 500 meters.

Lithology

Limestone (A III L_3) beds consist of greyish white to dark grey colour, fine to medium sized granules of massive limestone and alternation of mica schist and calc-schist.

Near the Paqueiro mine area, grey fine-grained massive-banded limestone is developing in the lower parts, and dark grey finely grained mica schists in the middle part, and also alternation of limestone and calc-schist are developed.

In the northern sections of Rio Ribeira, massive or banded crystalline limestone of grey to greyish white color, medium to coarse grained, is the main rock facies. Often alternation of limestone, mica schist and calc-schist is developed, and there are cases where biotite aggregate in large amounts. Banded or massive crystalline limestone is developed from the Rio Ribeira to the Itaoca granite area and appears as a marble, containing coarse biotite flakes, in the northern portion of the Ribeira town.

Mica schist (A III L_3 ps) is found in a long and narrow area along the Quarenta Oitava fault. The rock facies consists of staurolite-muscovite-biotite schists, and coarse grained biotite can be seen in large amounts by the naked eye, while staurolite can only be observed under the microscope.

The meta sandstone, quartzite, conglomerate alternation (A III S_3) show NE-SW strike and is distributed in a long and narrow area in the Serra do Carumbé. The meta sand-

stone, quartzite show a rhythmical sedimentary structure, and intercalate conglomerate layers (0.5 – 5 meters thick) in the upper portion.

Quartzite-sandstone are white to light yellow, fine to medium grained, showing a weak bedding. Metaconglomerates consist of pebbles of quartz or siliceous rock (2 – 4 mm) and the psammitic matrix.

1–3 Intrusive Rocks

The intrusive rocks found in the survey area include metabasite, granite, gabbro, syenite, and diabase. The metabasite and granite are regarded as intrusives formed during the Brazilian orogeny. Gabbro, syenite, and diabase are thought to have been formed by the Perana basic igneous activity, which started its activity from Jurassic to Cretaceous Periods, and the maximal activity is estimated between 130 and 120 m.y

1–3–1 Metabasite

It is distributed in the area of Açungui formation III showing sheet form and partly stock form. This rock intruded after sedimentation of Açungui group and is metamorphosed as well as the rocks of Açungui group.

Distribution

The intrusive body which is distributed along Quarenta Oitava Fault with long and narrow zone shows interfinger relation with mica shicst (A III L_3 ps) in the northwestern part of the town of Riberia

Those found exposed in the Rio Carumbé and the axial part of the Rocha anticline shows sheet form or stock shape. Also, an intrusive body along the fault is seen in the Quarenta Oitava fault area and the Rocha fault area. The intrusive bodies are interpreted as the transsected body by the fault which originally intruded concordantly in the formation.

Lithology

Dark grey to dark green, fine to medium grained. Various rock facies are seen, such as metagabbro, meta-diabase, and metabasalt. According to the report of the JICA of 1981, these rocks were classified as the metagabbro which will be described in the later section, however this year's survey result showed that though thic rock is metamorphosed, gabbro is not subjected to any metamorphism, based upon these rocks were classified into two different rocks.

The characteristics of microscopic observation of the representative rocks are as follows:

Hornblend–actinolite–metametagabbro (D–015).

Location· Intrusive body along the Quarenta Oitava fault, southern section of Riberia.

Structure: Poikiloblastic structure

Rock forming minerals· actinolite > hornblende > plagioclase >> quartz > biotite > sphene, iron oxide (partly hematite), apatite >> zircon.

Actinolite is a subhedral-euhedral crystal with a size of 0.7 x 1.5 mm, and is contained in large amounts with hornblende. Hornblende shows a subhedral-euhedral crystal with a size of 0.5 x 1.9 mm.

Actinolite and hornblende poikilitically contains coarse-grained crystals of plagioclase and quartz.

Plagioclase shows subhedral crystals (0.4 mm) and shows finely grained structures (0 2 – 0.5 mm).

Quartz and biotite are contained in small amounts.

Age of intrusion

It intrudes the Açungui formation III but from the fact that these rocks also were metamorphosed, it is presumed that the intrusion proceeded to the major activity of granite during the Brazilian orogeny which is thought to have brought the regional metamorphism to the area.

1–3–2 Granite

Granites are distributed in the Açungui group as a batholith or stock, in each of the central and northern parts of the survey area.

Distribution

A part of the Trés Córregos batholith body is exposed from the southern part of the survey area to the northern part. A part of the Varginha body, in the northeastern area, a part of Itaoca body in the central area, and Morro Agudo body in the southwestern parts are distributed respectively showing as stock shape.

Lithology

Greyish white to light red, medium to coarse-grained massive granite to granodiorite. In the vicinity of Olho Dágua in the eastern area, grey to dark grey altered dacite distributes locally as dykes which is estimated to be a part of granite.

The crystals are generally equigranular and shows pinkish color if there contains large amounts of potash feldspar. In the Itaoca or the Trés Córregos rock body, megacrasts of potash feldspar of over 5 cm are characteristic.

There is no orientation in the arrangement of the minerals, but in one portion of the Trés Córregos body of the southern area mylonitized rock facies are found in places where faults develop. The characteristics of representative rocks observes under the microscope are as follows:

Microcline-hornblende-biotite-granodiorite (A–001)

Location: Itaoca rock body of the northeastern part of Panelas.

Texture: Holocrystalline, porphyritic texture

Rock forming minerals. Plagioclase > quartz, microcline > biotite hornblende, sphene, iron oxide, apatite.

As for the plagioclase, it is albite to oligoclase, euhedral to subhedral and with a size of 1.5 x 2.0 mm. An albite twin can be readily observed.

Quartz shows a coarse structure (anhedral), with a size of about 1.0 x 1.2 mm, it interstices other minerals.

Potash feldspar appears porphyritic and euhedral with a size of about 5 x 6 mm (including large crystals). It also fills up the spaces of other minerals. Generally microcline twins are remarkable, and perthite structures also develop.

Biotite is euhedral to subhedral, and is partly section or wholly chloritized. It is associated with hornblende.

Hornblende appears euhedral to subhedral, with a size of about 0.5 x 1.0 mm.

Age of intrusion

From the K/Ar dating using biotite, according to Cordani et al. (1967), the Trés Córregos rock body indicates 510 ± 15 m.y. The Itaoca granite body indicates 500 ± m.y., both cases correspond to the early Cambrian.

According to Cordani et al., the ages of intrusion of granite of the Brazilian orogenic period are divided into the following groups:

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

(2) 600 – 590 m.y. ––– intrusion during later stage of the orogenic movement.

(3) 590 – 500 m.y. ––– intrusion of the last stage of the orogenic movement.

Consequently, the granite of the area is thought of as the intrusion of the last stage of the orogenic movement of (3).

1–3–3 Metagabbro

It intrudes in the vicinity of Ribeira fault or other fault or folding axis as small stock.

Distribution

There are two small bodies found in the vicinity of the Ribeira fault in the central part of the area. There are also small rock bodies intruded in the fold axis in the south-western part of the area.

Lithology

The main rock types are black medium-grained small holo-crystalline and leucocratic metagabbro, but the rock found in the southern part of the Barrinha mine area, quartz diorite is the main rock type.

These rocks were not metamorphosed, and compared to metabasite, the different between them by the naked eye and under the microscope, are clear.

The characteristics under the microscope of representative rocks. are as follows:

1 Rock name. amphibole metagabbro (A–018)

Location lowside of the Ribeira river 4 Km west of Panelas

Structure: ophitic structure

Constituent minerals: Plagioclase > augite >> common hornblende, hypersthene. Plagioclase, shows a size of about 1.2 x 0.3 mm, and is euhedral to subhedral. Hypersthene is subhedral. Average grain size 0.4 x 0.3 mm. Common hornblende shows needle shape and is subhedral to anhedral. The average grain size is 0.3 x 0.11 mm.

2. Rock name: Quartz diorite (C–023)

Location: Three km south of the Barrinha mine areas.

Structure: Subhedral. equigranular structure

Constituent minerals. Plagioclase >> biotite > clinopyroxine. quartz > amphibolite, iron oxideral. apatite.

Plagioclase is both euhedral (1–2 mm) and anhedral (2–3 mm) As for the former, albite twins are well developed. and clear zoning structures can be seen. and the latter, unclear albite twins and zoning structures can rarely be seen. It is crystallized in such a way as to fill up the spaces of other ore minerals.

Biotite is euhedral-subhedral, light to drak yellow. showing a size of about 0.5 – 0.1 mm. and is partly strongly chloritized.

Accompanied with large amounts of iron ore minerals, it contains quartz and fine-grained euhedral plagioclase poikilitically.

Orthopyroxine is indicated as subhedral, with an average grain size of 0.4 x 1.2 mm. It is distributed heterogeneously.

Quartz is anhedral and fills up the spaces of other ore minerals and is partly granular.

Hornblende is contained in small amounts, and a large parts are altered to chlorite or some other unclear ore mineral.

Age of Intrusion

A metagabbro is intruded through the Açungui II formation and the Açungui III formation as small stock form.

According to the results of K/Ar dating of the same types of intrusive rocks by Cordani (1966) and G. Amaral (1976), the former showed 108.4 m.y., while the latter obtained about 147 – 117 m.y. These ages suggest the intrusion period to be from Jurassic to the Cretaceous.

1–3–4 Syenite

Other than the rocks intruding in a stock form in the north of Tunas, small amounts of rock are known in the area of Mato Preto in the western part of the area.

Distribution

The rocks from the northern part of Tunas show a Northwest to Southeast intrusive trend, and ore found in an area of about 20 km^2. The rock bodies in the neighborhood of Mato Preto is found, showing small stock of less than one kilometer in diameter.

Lithology

These are grey to dark grey, medium to coarse-grained holocrystalline, massive rocks, they contain small amounts of colored ore minerals of short columnar form in the new plagioclase and the potash feldspar.

The characteristics of representative rocks under the microscope are as follows:

Rock name: Common hornblende-clinopyroxine-biotite syenite (C–073)

Location: four kilometers north of Tunas.

Structure subhedral and eiquigranular structure.

Constituent minerals· potash feldspar > plagioclase > biotite, clinopyroxine, augite. Potash feldspar is a subhedral perthite, with average grain of 4.0 x 1.2 mm. Carlsbad twins can be seen often.

Plagioclase is subhedral, with an average grain size of 2.5 x 1.0 mm and the An content is 10%.

Biotite is euhedral to subhedral, with an average grain size of 0.3 mm, the largest being 1.5 mm.

Hornblende is anhedral to subhedral, with an average grain size of 0.3 mm.

Clinopyroxine is euhedral to subhedral, with an average grain size of 0.4 mm.

Age of Intrusion

According to Cordani (1968), the K/Ar age of the biotite of the rock north of Tunas is 111.5 ± 15.6 m.y., which corresponds to the middle of Cretaceous.

1–3–5 Diabase

This intrudes into the Setuva formation, the Açungui groups, and the granite as dykes.

Distribution

It is widely found in the whole survey area as NW-SE trending dykes.

Generally the width of the dyke is some tens of centimeters to several meters, but in the northern part of the Rocha mine area, the width sometimes exceeds 30 meters. The strike extention ranges from several meters to several kilometers.

Lithology

Dark grey to black diabase, and basalt are the main rock types.

In these same dykes, the central part appear as coarse-grained holocrystalline diabase or coarse grained basalt rock types. Marginal types look like basalt as do smaller dykes also.

The characteristics of representative rocks under the microscope are as follows:

Rock name: Olivine basalt (D–113)

Location: One kilometer north of Cricima village

Structure: porphyritic, intergranular structure.

Constituent minerals: plagioclase, clinopyroxine, hypersthene, olivine.

Plagioclase indicates euhedral crystals in the grand mass, with an average grain size of 0.8 x 0.3 mm.

Clinopyroxine is a euhedral crystal, indicating an average grain size of 1.0 x 0.5 mm. A zonal texture can be seen in the interference color.

Hypersthene is euhedral, with an average grain size of 1.0 x 0.5 mm.

Olivine is euhedral, indicating the largest size of about 4.0 x 3.0 mm.

Iron oxide is abundant.

1–4 Metamorphism

The rocks composing the Setuva formation and the Açungui group found in the survey area, are metamorphic rocks of the Pre-Cambrian age.

These metamorphic rocks are composed of gneiss and phyllite of psammitic and pelitic sediments origin and of amphibolite and amphibole schist of basic volcanics origin.

There are many discussions and opinions regarding these metamorphic facies but the majority believes that these rocks belong the metamorphic facies between green schist facies and amphibolite facies

The Açungui group belongs to the green schist facies, while the Setuva formation belongs to the amphibolite facies showing different degree of metamorphism.

Fig. I–6 indicates the distribution of the ACF diagram of the combination of metamorphic minerals in the representative sample of metamorphic rock obtained in the present survey.

As for the basic metamorphic rocks, the assemblage of amphibolite-epidote-biotite is seen in the Setuva formation, and of amphibolite-actinolite-garnet epidote is seen in the Açungui group.

The characteristic of these mineral assemblages show from green schist facies to epidote-amphibolite facies. A large difference cannot be seen between the basic metamorphic facies of the Setuva formation and the Açungui group.

The metamorphic rocks of the psammitic-peritic origin, the biotite-muscovite combination is characteristic in the Setuva formation. However, those in the Açungui group can be divided into the following three groups:

① biotite-muscovite-garnet

② biotite-muscovite

③ muscovite-graphite-sericite

These are characteristical mineral assemblages of the green schist facies, but ③ shows a low degree of metamorphism.

The combination of ① is found characteristically in the surround area of the Itaoca granite near Adrianopolis-Barrinha-Cricima. As for the forming of large amounts of garnet, there is also the possibility that it was influenced by the intrusion of granite.

The combination of ② can be seen in the eastern side of the north-south line connecting Ribeira-Tunas, while the combination of ③ can often be seen in the opposite side. There is especially a lot of ③ from upper part of the Açungui formation I to the Açungui

Table I-1 Chemical Components of Rock Samples

	Sample No	AO18	AO31	AO39	AO80	AO81	AO92	AO95	AO93	CO47	DO23B
	Location	Rio Ribeira	Curmbe	Curmbe	Perau	Perau	Perau	Perau	Perau	Vargina	Rio Ribeira
	Rock Name	Gabbro	Gabbro	Meta diabase	hb Schist	bt Schist	bt-mus Schist	hb-bt Gneiss	ep-hb Schist	act-Schist	act-Schist
Chemical Composition	SiO_2	48.97	50.74	49.97	64.54	51.73	62.26	63.98	46.49	49.78	49.38
	TiO_2	0.86	2.29	0.77	1.34	0.74	0.57	0.67	2.19	1.37	1.61
	Al_2O_3	11.38	14.07	11.39	11.70	15.06	15.77	15.37	15.66	13.57	17.43
	Fe_2O_3	1.28	3.15	3.79	5.03	3.64	1.35	1.88	4.94	2.71	3.00
	FeO	10.06	11.82	7.65	6.79	8.95	4.96	2.98	10.24	10.85	9.59
	MnO	0.29	0.18	0.20	0.27	0.34	0.05	0.06	0.25	0.26	0.21
	MgO	10.14	3.90	9.52	0.73	6.70	4.76	1.72	5.37	7.19	4.49
	CaO	14.09	8.23	12.82	3.20	7.18	0.91	3.41	10.54	9.42	8.69
	Na_2O	1.60	2.72	1.33	4.75	3.60	4.10	3.53	1.30	2.52	2.76
	K_2O	0.09	1.21	0.26	0.05	0.11	3.70	4.16	1.25	0.19	0.40
	P_2O_5	0.06	0.36	0.04	0.29	0.09	0.24	0.30	0.11	0.13	0.14
	CO_2	0.09	-	-	0.66	0.04	-	0.85	0.37	0.07	-
	$+H_2O$	0.40	0.91	1.72	0.43	0.86	1.03	0.65	0.85	0.92	1.66
	$-H_2O$	0.24	0.24	0.12	0.14	0.12	0.04	0.16	0.20	0.38	0.32
	Total	99.55	99.82	99.58	99.92	99.16	99.74	99.72	99.76	99.36	99.68

CIPW Normative Mineral	Q		0.00	4.15	3.55	28.24	1.70	12.63	19.30	3.02	1.18	2.79
	C		0.00	0.00	0.00	0.11	0.00	3.94	1.38	0.00	0.00	0.00
	or		0.53	7.15	1.54	0.30	0.65	21.87	24.58	7.39	1.12	2.36
	ab		13.54	23.02	11.25	40.19	30.46	34.69	29.87	11.00	21.32	23.35
	an		23.60	22.61	24.34	10.16	24.61	2.95	10.03	33.20	25.15	33.99
	di	wo	18.95	6.63	16.28	0.00	4.26	0.00	0.00	6.77	8.49	3.43
		en	10.93	2.57	10.65	0.00	2.32	0.00	0.00	3.53	4.38	1.58
		fs	7.16	4.15	4.50	0.00	1.78	0.00	0.00	3.05	3.89	1.82
	hy	en	6.91	7.14	13.06	1.82	14.37	11.86	4.28	9.84	13.53	9.60
		fs	4.52	11.51	5.52	6.60	11.05	7.14	2.92	8.52	12.02	11.05
	ol	fo	5.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		fa	3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	mt		1.86	4.57	5.50	7.29	5.28	1.96	2.73	7.16	3.93	4.35
	il		1.63	4.35	1.46	2.54	1.41	1.08	1.27	4.16	2.60	3.06
	ap		0.14	0.83	0.09	0.67	0.21	0.56	0.70	0.25	0.30	0.32
	cc		0.20	0.00	0.00	1.43	0.09	0.00	1.84	0.80	0.15	0.00
	Total		98.91	98.67	97.74	99.35	98.18	98.67	98.91	98.71	98.06	97.70
	Q+or+ab		14.07	34.32	16.34	68.73	32.82	69.19	73.75	21.41	23.62	28.51
	D.I.		14.23	34.78	16.72	69.17	33.42	70.12	74.56	21.69	24.09	29.18

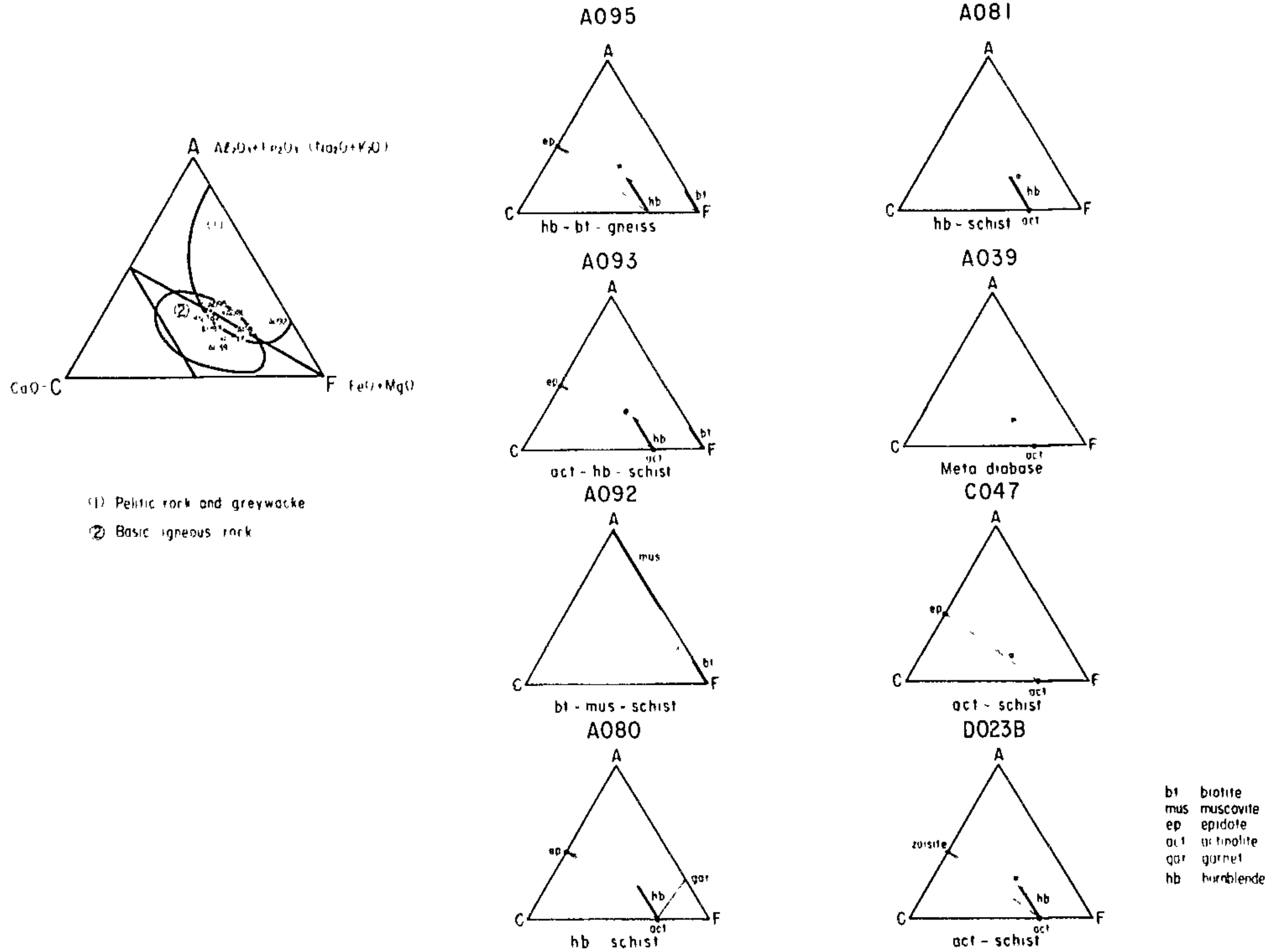
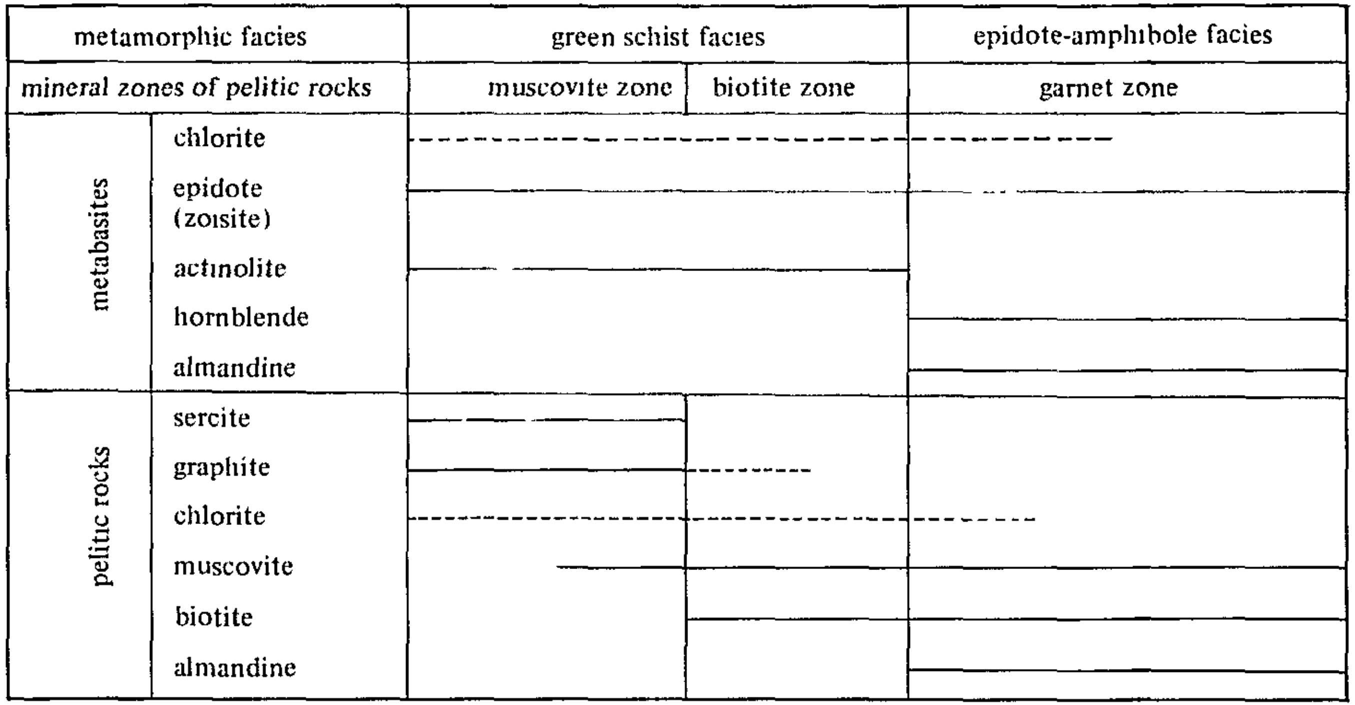


Fig. I-4 ACF Diagrams of Chemical Analized Samples



(medified from Miyashiro 1979)

Fig. I -5　Mineral Assemblages of Metamorphic Rocks in Survey Area

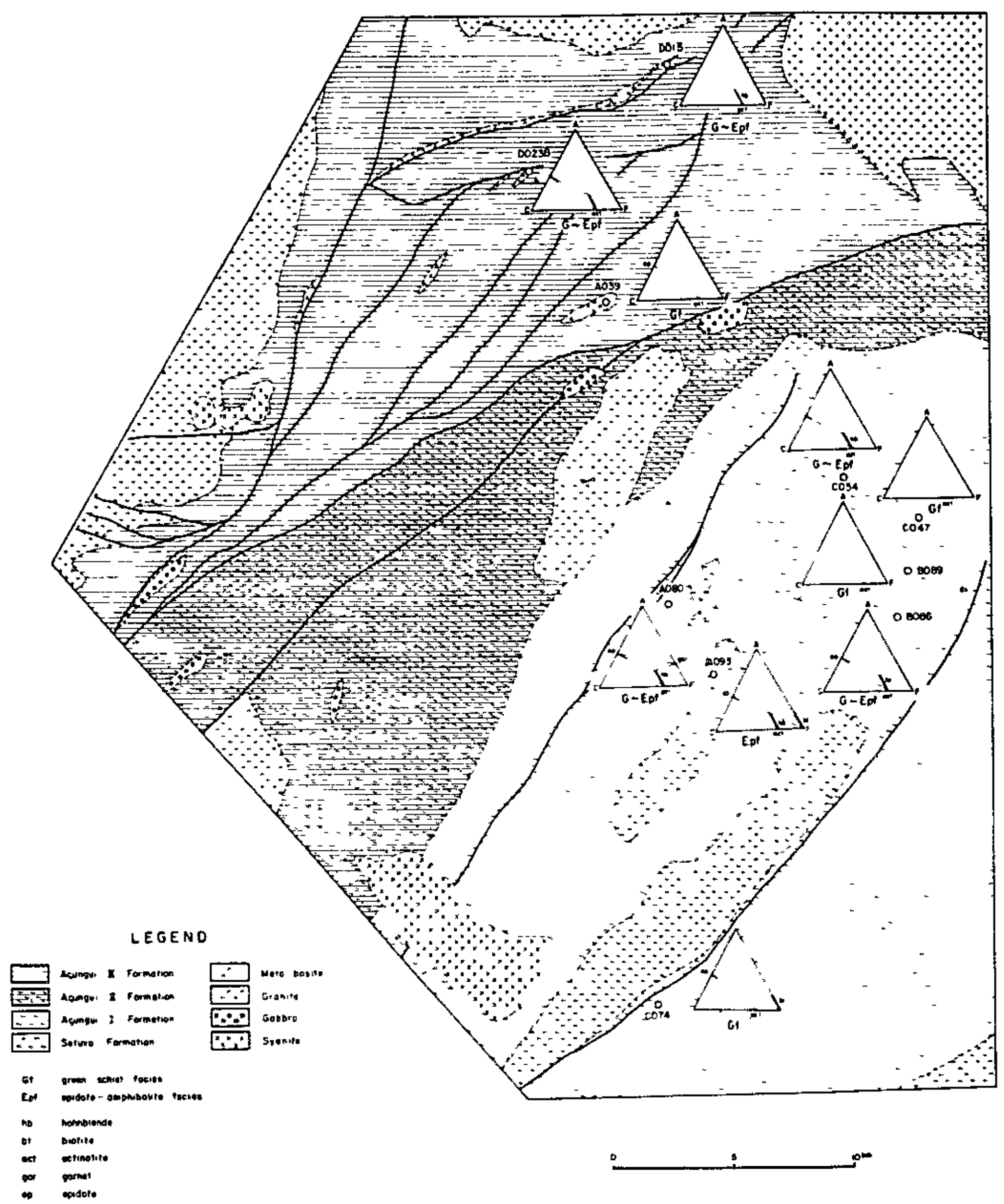


Fig. I-6-1 Metamorphic Facies Map

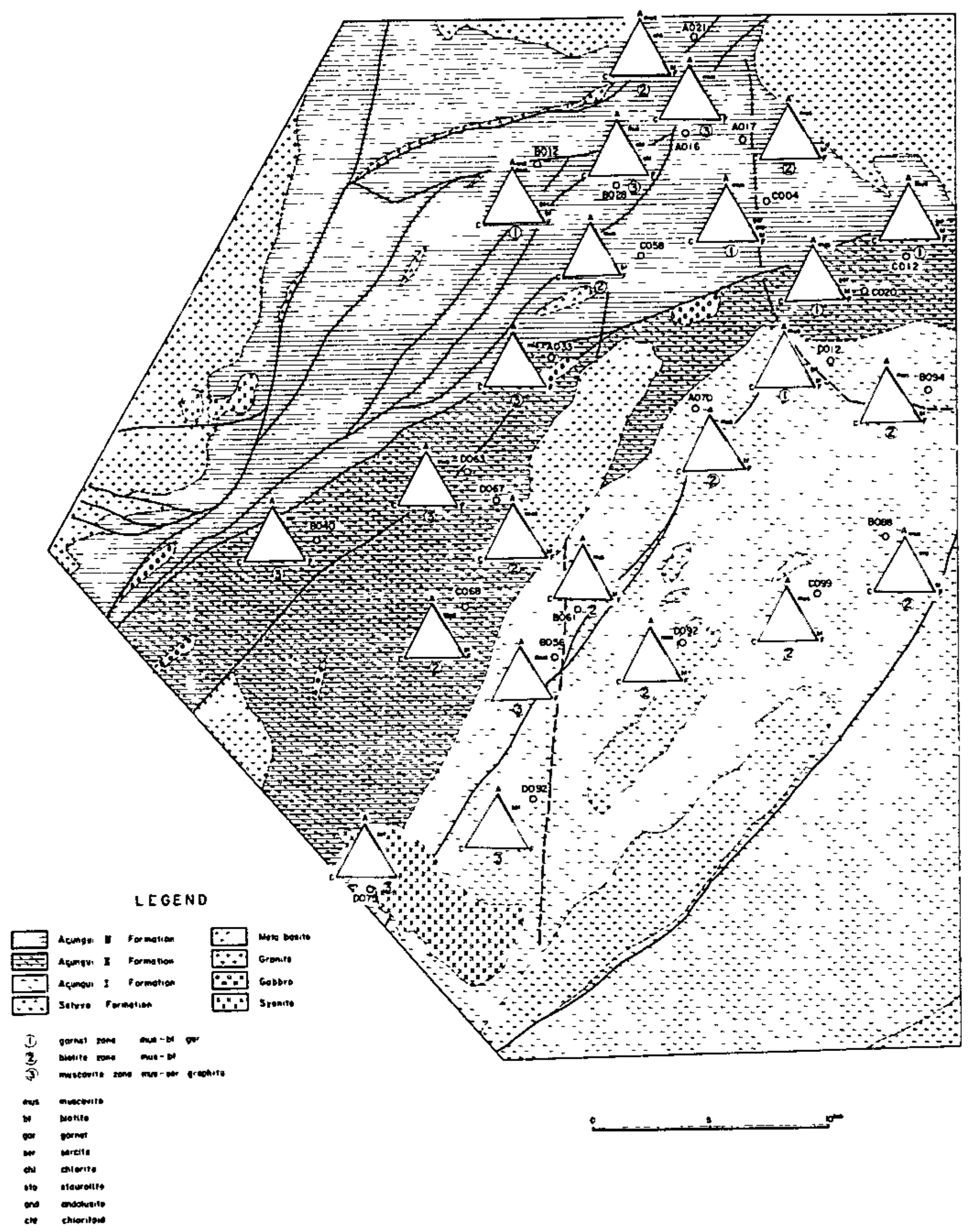


Fig. I-6-2 Metamorphic Mineral Zones Map of Pelitic Rocks

formation II in the northwestern area of Tunas.

In the Perau area, a difference cannot be seen in either the metamorphic rock facies of the Setuva formation or in the metamorphic rock facies of the Açungui formation I.

According to the results of Rb/Sr age measurement of the metamorphic rocks of the survey area, about 1400 – 1700 m.y. (Batolla, Jr., 1977; CPRM, 1981) is known. On the other hand, a value of 582 ± 31 m.y. (Cordani, 1967) was obtained by the results of K/Ar age measurement of the biotite in the gneiss of the Setuva formation. The age of the biotite, according to this K/Ar measurement is thought to reflect the age of metamorphism of this area. This metamorphic period is in agreement with the Brazilian orogeny (750 – 500 m.y.).

1–5 Geological Structure and Geological History

1–5–1 Geological Structure

The main geological structures of the survey area show that a NE-SW structure pattern is predominant. Fig. I–1 shows the distribution of each formations, intrusive rocks, the main geological lineaments in the survey area. Also, certain of the names of the faults and folds which are used here have been given a new provisional designation.

The Setuva formation, which forms the basement of the present survey area is exposed, repeating itself at an order of 3 – 5 km wavelength in the core of the NE-SW trend anticline structures such as, the Perau anticline, the Agua Clara anticline, and the Anta Gorda anticline, which are arranged north to south.

The Açungui formation I, and II are found surrounding the Setuva formation. The Açungui formation II and the Açungui formation III are cut and adjoined by the Ribeira fault, which passes through the central portion of the area showing NE-SW direction. The Açungui formation III is widely distributed showing a NE-SW strike, in the northern side of the fault, and it is shown a more complex structure than both the Açungui formation I and the Açungui formation II, this is probably because of its many faults and folds.

The main characteristics of the folding structures and the fault structures which control the geological structure of the present area are as follows:

(1) Folding Structures

Folding structures (NE-SW pattern) developing in Setuva formation - Açungui formation I.

Perau anticline: axis length 13 kilometers, plunging in the north and south. The Perau area is located in the southern wing of the anticline

Faria syncline: axis length 7 kilometers, plunging in the south, and cut by fault in the north.

Agua Clara anticline: axis length 17 kilometers, plunging in the north and in the south.

Agua Clara syncline: same as the above Agua Clara anticline.

Anta Gorda anticline: axis length over 20 kilometers, plunging in the north and south.

Folding structure (NE-SW pattern) developing in the Açungui formation II.

Mato Preto syncline: axis length 20 kilometers, cut in the north by the Ribeira fault.

Morro Grande anticline: axis length 13 kilometers, cut in the north by fault, and intruded in the south by the Agudo granite.

Morro Grande syncline; axis length 17 kilometers, intruded by the Varginha granite in the north

Each of these folds are parallel, showing a NE-SW strike, in about a three kilometer interval.

Folding structure (NE-SW pattern and NEE-SWW pattern) which develop in the Açungui formation III.

Barrinha anticline: NEE-SWW, axis length 10 kilometers The Barrinha mine area is situated in the axis part of the fold

Adrianopolis anticline: NE-SW pattern, axis length 8 kilometers, cut by fault in the north and south.

Rocha syncline: NE-SW pattern, axis length 3 kilometers, cut by fault in the north and south. The Rocha mine area is situated in the western wing.

(2) Fault Structures

The largest faults bisecting the geological structures of the present area are the Ribeira faults of a NE-SW pattern.

As for this Ribeira fault, a block of the northern side drops about 2,000 meters. The pattern of fault and folding structures are a little different in the north and south sides of the fault.

In the south side of the Ribeira fault, a NE-SW pattern strike fault is developing.

Olho Dágua fault. Parallel to the Anta Gorda anticline, a block of the southeastern

side drops. The throw is about 2,000 meters.

Ribeirão Grande fault Parallel to the Perau anticline, the block of the northwestern side drops about 600 meters.

Morro Grande fault: Diverging from the Ribeira fault, it develops as a strike fault in the Açungui formation I.

Other than this, NW-SE pattern small scale faults can be seen in the neighborhood of the Cricima village in the eastern portion of the area. These faults also show a characteristic of the strike faults.

In the northern side of the Ribeira fault, a NE-SW pattern strike fault and NEE-SWW or E-W pattern fault are distributed.

NE-SW Pattern Faults

Cerra do Carumbé fault· Cuts the A III S_3 of the uppermost of the Açungui formation III. A block of the northwestern side drops about 1,000 meters.

Agua Morua fault: Passing through the between the Rocha anticline and syncline, it continues into the Diago Lopés fault in the north, and is connected to the Rocha fault in the south. Southeastern side block drops about 800 meters.

Rocha fault: It is parallel to the strike of the stratigraphy in the western portion of the Rocha mine, but is at an oblique strike in the northern and southern sections. A western side block drops about 1,000 meters.

These NE-SW strikes intend to convergent with the Ribeira fault at the southwestern edge of the survey area.

NEE-SWW or East to West Pattern Faults

portion of the Itaoca granite, and comes out of the northern area. A

A northern side block drops, but the throw is unclear.

drops, but the throw is unclear.

Diago Lopés ore deposit, a vein type lead ore deposit, is located in this fault.

Diago Lopes ore deposit, a vein type lead ore deposit, is located in this fault.

Other than that, E-W pattern faults, cut the Trés Corregos granite, derive from the Rocha fault in the south of the Mato Preto, and milonitized a part of the granite bodies.

1–5–2 Geological History

There are especially a lot of theories concerning the stratigraphical relationship of the Setuva formation and the Açungui group, but there is still no widespread agreement. Here,

the geological history of the area shall be examined from the data obtained from the results of age measurement of the Setuva formation and the Açungui group and from the data obtained in the present study.

As for the Pre-Cambrian basement rocks along the eastern shore of Brazil, the mountain range of Paraiba do Sul zone which consists of gneiss-migmatite, is the oldest and thought to have been formed in the Trans Amazon period (2200 – 1800 m.y.).

The survey area is situated in the western side of this Paraiba do Sul zone.

The age of original rocks of the Setuva formation and the Açungui group in the survey area, is known as 1400 – 1170 m.y. by Rb/Sr age, and thought have been formed by the geo-synclinal sediments of the Uruaçuan orogeny which took place in the eastern side of Brazil.

The sediments of the Setuva formation are composed of predominant psammitic-pelitic mixed sediments and transfer to the Açungui group sediments.

The sediments of the Açungui group is predominantly composed of psammitic sediments in the lower part, and while gradually shifting to pelitic sediments toward upper part. While preserving the shallow sea environment until the sedimentation of limestone and psammitic rock of the Açungui formation III, these sedimentations are regarded as having been formed continuously. Basic volcanic activity occurs in the periods of the Setuva formation to the Açungui formation I and the Açungui formation II. It is especially active in the Açungui formation I, and supplies lava and its pyroclastics.

Just before the basic volcanic activity of the Açungui formation I, the limestone, dolomite and silicate material accumulated, and the sulfide deposit of the Perau type ore was deposited in a stagnent condition.

The Pb/Pb age of the lead ore of the Perau shows 1400 – 1300 m.y., and also shows that it was supplied from the magma at that time. However, the age of the lead ore of the Rocha indicates 1200 – 1100 m.y., and is congruent with the age of the accumulating period of the Açungui formation III. It is conversely older than the period which formed the vein fissure pattern. To explain this contradiction, it is concerned that the sulfide minerals (mainly galena) which accumulated in the lime-dolomite of the Açungui formation III and after that having been abundantly concentrated in the vein fissure which is formed by the later orogenic movements.

In the ending period of the Pre-Cambarian age, a tectonic movement, breakdown and reconjuction of old plateaus, took place in the whole area of Brazil, and the metamorphic rocks of the area were formed at this period.

It is thought that also have been subjected to burial metamorphism before the Brazilian orogeny, but the major metamorphic rocks which presently can be seen, were formed at this period.

The 582 ± 31 m.y. K/Ar age of the gneiss of the Setuva formation shows metamorphism at this period.

Also, the major folding and the following fault structures were formed in this period, and formed the vein fissure pattern of the Rocha type ore deposit.

This tectonic movement brought about the intrusion of metagabbro, and the end period of the tectonic movement brought about the intrusion of granite.

From the Jurassic to the Cretaceous period, a large scale effusion of Parana basalt and other igneous rocks (at the most 130 – 120 m.y.) took place in the southern region of Brazil. The basic rock and syenite of the area intruded in this period.

CHAPTER 2 ORE DEPOSITS

2–1 Introduction

In the present survey area, diverse lead ore deposits and mineral occurrences exist in the Açungui group, as shown in PL I–4 The ore deposits can be roughly divided into two types, the Perau type and the Rocha type.

The Perau type ore deposits originate in a stratiform in the limestone ~ calc-silicate rock, distributed as a lens directly above the quartzite of the base of the Açungui formation I. The Perau deposit (Pb, Ag, Cu, Zn), presently in operation, the Agua Clara deposit (Pb, Cu, Ba), now not working, and the Pretuiho deposti (Ba), which is in preparation for development, are belong to strata bound ore deposit

The rocha type ore deposits however, originate in a vein type in the A III L_2 and A III L_3 layers of the Açungui III limestone bed. The Rocha deposit, Barrinha deposit, and Panelas deposit are representative mines in operation, all of which are located in the A III L_2 limestone layer. Other mines not in operation, include the diago Lopes Mine, Bueno Mine and Paqueiro Mine, all of which are located in the A III L_3 limestone. Other than these, there are other many mineral occurrences which are located in the A III L_2 and A III L_3 limestone.

For the present survey, the Perau mine and Rocha mine were selected as representative mines for these ore deposits

The survey of the Perau mine were carried out using various techniques, including a 1/10,000 surface geological survey, 1/500 ~ 1/100 underground survey, a core logging survey, a geochemical survey of the ore deposit horizon, and a geophysical exploration (using IP, SIP, and gravity methods)

The surveys for the Rocha mine were carried out with a 1/10,000 surface geological survey, both 1/100 and 1/1,000 underground geological ore deposit surveys, and a core logging survey.

2–2 Geology and Ore Deposits of the Perau Area

2–2–1 Summary of the Perau Mine

The Perau mine is located 25 kms. south of Adrianopolis. The mine office of Eletro sao Marco Ltda., and the underground entrance are located 1.5 kms. upstream from the Ribeirão do Perau, a tributary of the Ribeirão Grande.

The Perau deposits are strata bound lead ore deposits which originate syngenetically in the limestone ~ calc-silicate rock, distributed as a lens above the quartzite forming base of the Açungui formation I. Outcrops of the ore deposit can be seen in the area, about 500 meters above sea level.

The development of this mine have been commenced with an open pit at the oxidized copper ore part of the outcrop as the target. With the appearance of lead ore deposits, the pit has been changed into underground mining methods, and presently has extended into several main levels. These levels include the G-1 level at 460 meters above sea level, the G-2 level at 419 meters, the G-3 level at 438 meters, and the G-4 level at 374 meters. Also there are seven sublevels developed between these, at a spacing of about 10 meters.

At present there are 90 workers, with a monthly production of 1500 tons of Crude ore, content is 7–10% of Pb, with 80–120 g/ton of Ag. The whole quantity is sold to the Plumbum S.A. Company, which has a smelter plant at the Panelas mine.

2–2–2 Geology

The geology of the Perau mine areas and the surround is composed of the Setuva formation base of the area, and of the Açungui formation I (Fig. I–7 and I–8).

The present survey area is situated in the northern part of the Agua Clara anticline which has a NE-SW direction axis, and is influenced by fold structures of the Perau anticline and Faria syncline.

(1) Setuva Formation

Distribution

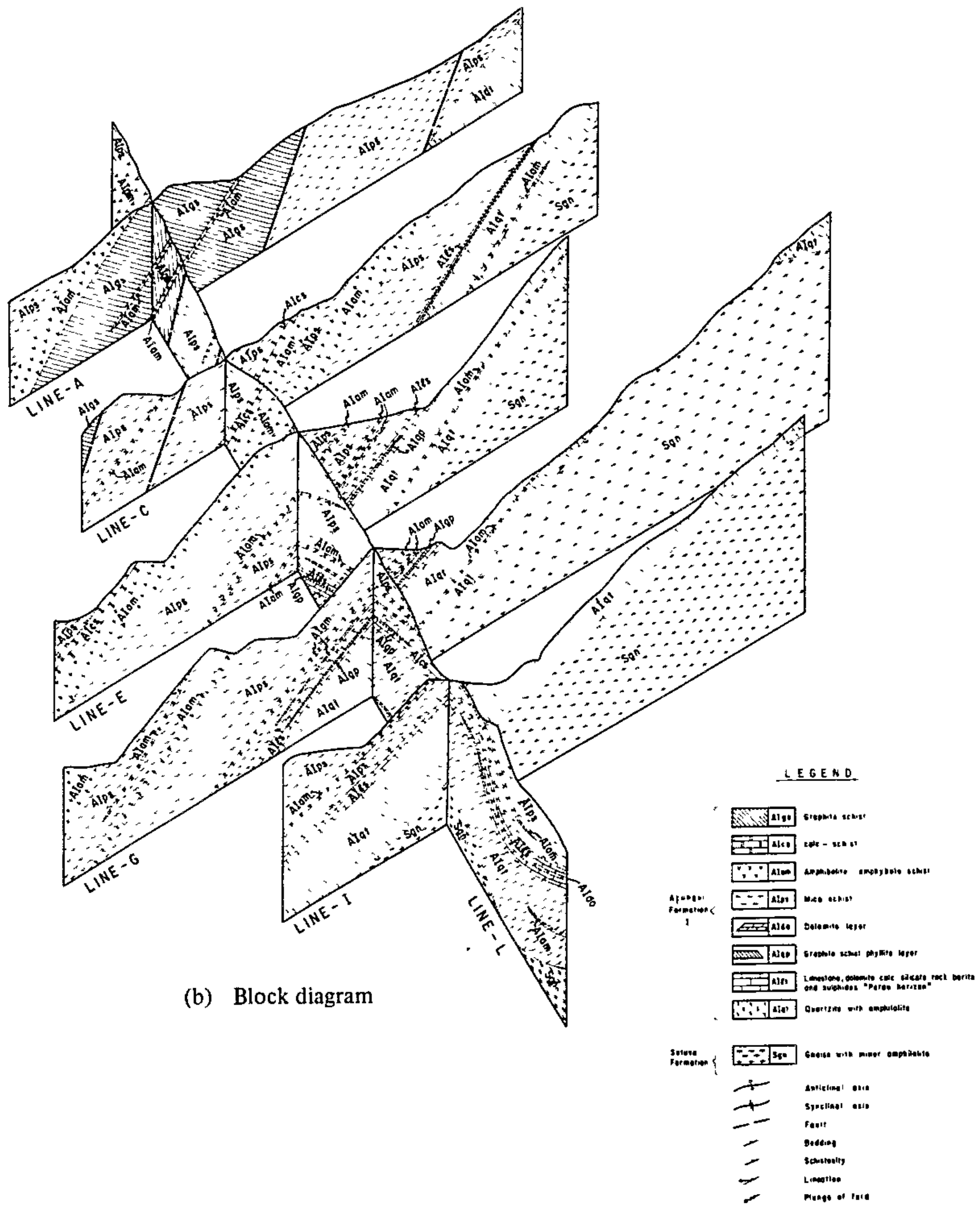
The Setuva formation is widely distributed, showing general strike of N20–40°E, and dip of 20 – 35°NW, forming part of the axis of the Agua Clara anticline at the upstream of the Ribeirão do Perau. It also forms part of the axis of the Perau anticline with a NE-SW strike in the eastern and northeastern parts of the Perau mine area.

Lithology

The main lithology include gneisses (Sgn) consists of muscovite-biotite gneiss, amphibolite-biotite gneiss and augen gneiss, and intercalated biotite-epidote-amphbolite gneiss.

The changing appearance of these lithofacies are best observed at the Ribeirão do Perau. The main lithology as seen from downstream to upstream are biotite schist, muscovite-biotite gneiss and amphibolite-biotite gneiss, include thin layers (under 5 meters)

(a) Plane



(b) Block diagram

Fig. I-7 Geological Map of Perau Area

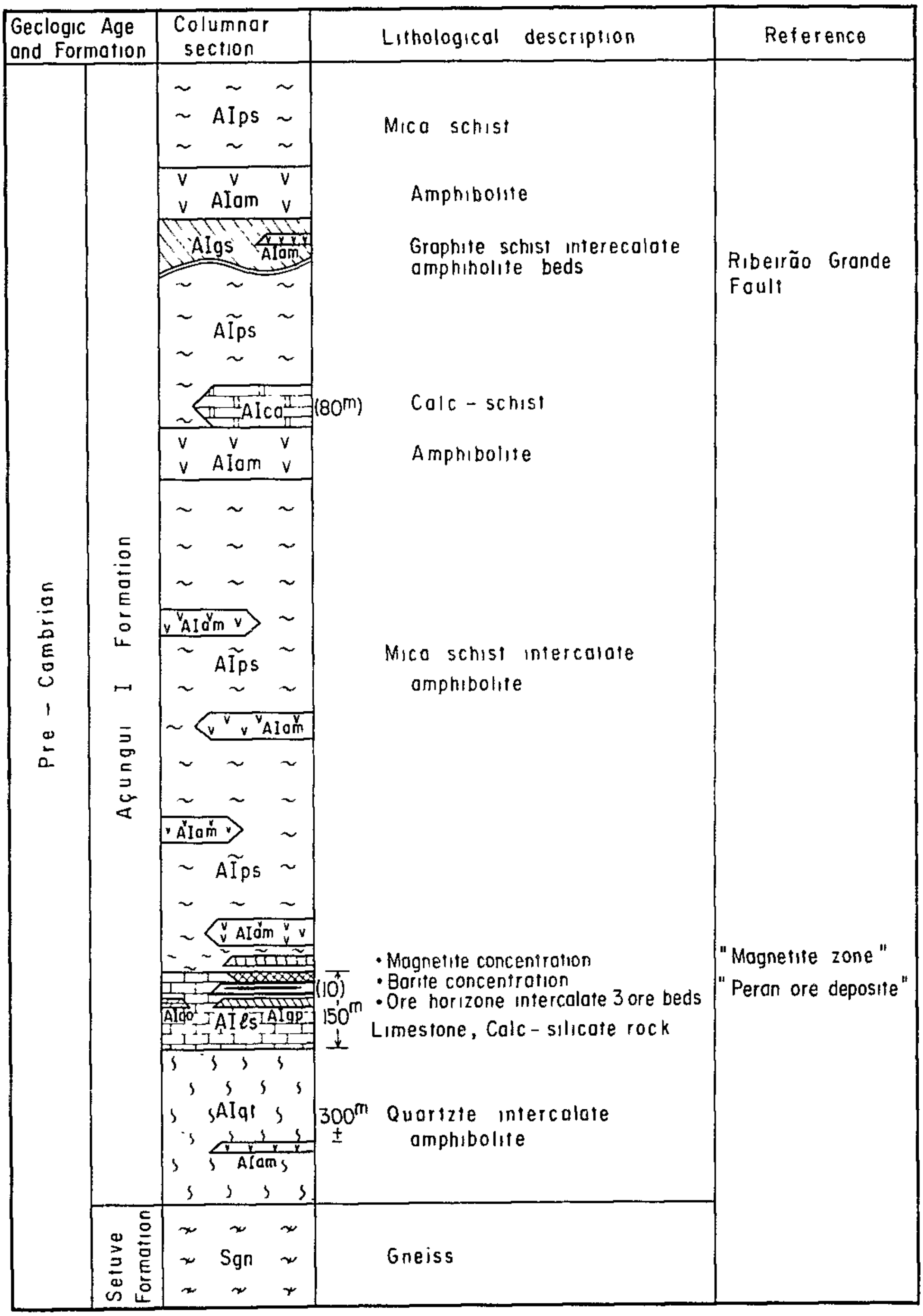


Fig. I-8 Geological Columnar in Perau Area

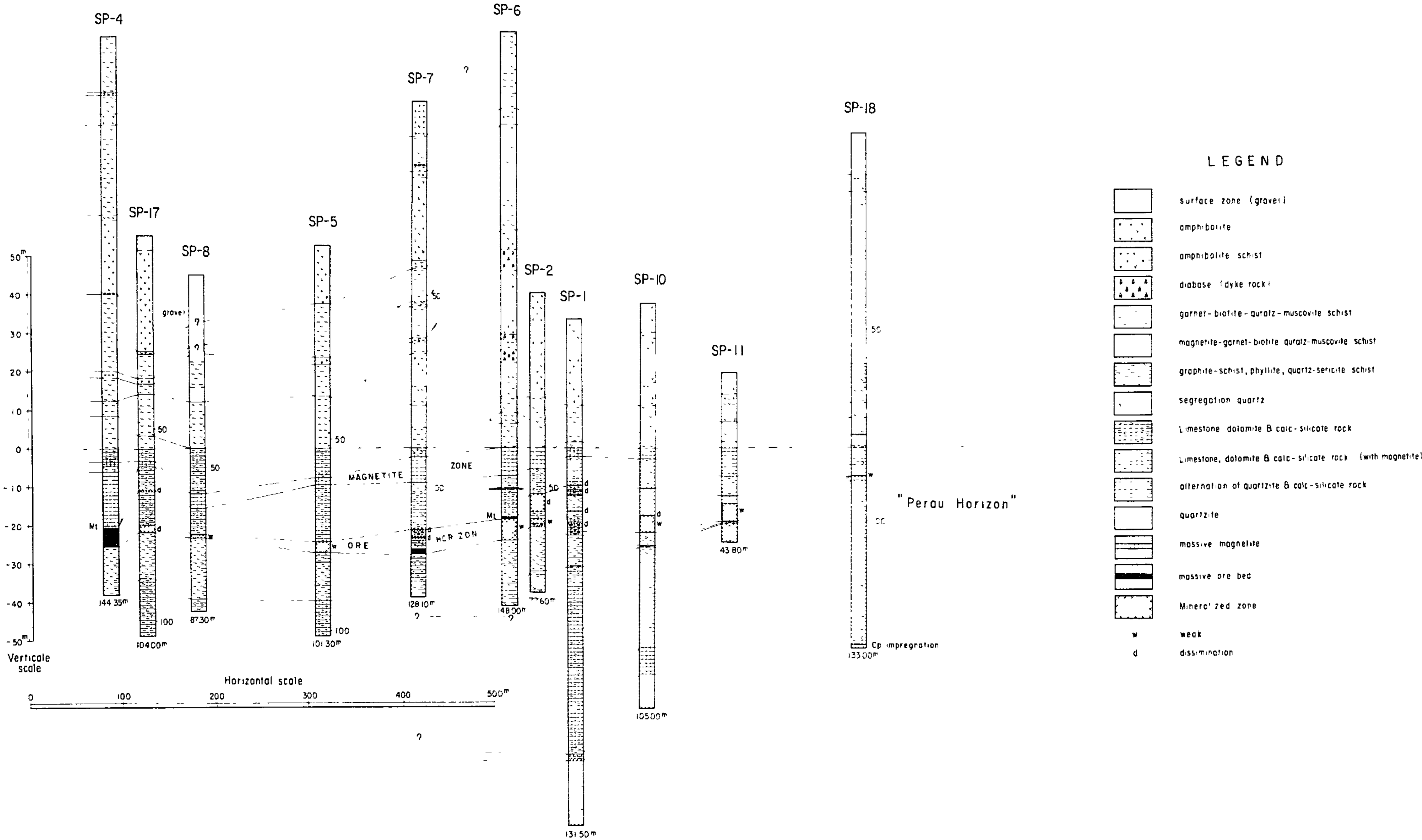


Fig. I-9 Correlative Section of Core Logs in Perau Mine

of biotite-epidote-amphibolite gneiss, and also area where the augen gneiss has developed with characteristics of porphyroblast of feldspar, and area where biotite gneiss are developing can be observed. However, the Setuva formation of the eastern and northeastern parts of the Perau mine consists mainly of biotite schists.

(2) Açungui Formation I

Distribution

This formation is the lowest member of the Açungui group, and is widely distributed concordantly above the Setuva formation.

Quartzite is widely distributed in the eastern half of the survey area. In the central part a limestone ~ calc-silicate rock which intercalated Perau ore deposit. is distributed in the N-S direction, in the western part mica schist, amphibolite-amphibole schist, calc-schists and graphite are distributed.

Lithology

The lithology consists of as follows, from the bottom quartzite, limestone ~ calc-silicate rocks (including Perau ore deposits, graphite schist layer and dolomite layer), and mica schists (including amphibolite, calc-schists, and graphite schists).

(a) Quartzite (AIqt)

The quartzite appears white, fine, and massive, and has a layer about 300 meters thick

The middle portion of this horizon includes amphibolite schist, biotite-amphibolite schist thin layer (less than 10 meters). In the neighboring boundaries of the limestone-calc-silicate rock, it changes gradually into calc-silicate rock, passing through a transition zone containing both rocks with a thickness of about 10 meters.

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

This rock facies can be best observed near the Perau mine road, the Perau mine underground, and drilling cores, and AIls distributes 4 kms length and 150 meters thick in maximum.

The main rock facies are alternating bands of strata which changing between limestone and calc-silicate and pelitic ~ silicious schists. The Perau ore deposits is intercalated in these host rocks as a strata bound.

At the Perau mine area, there is a graphits schist layer (AIgp) at the foot wall side of the ore deposit (13 meters thick at its largest layer), which disapppears toward the south. In the south there is a thin layer of dolomite (AIdo) less than 10 meters thick, at this horizon. In the hanging wall of the ore deposit, locally densely grouped lenses and layered barite can

be seen. The distribution of 3–10 meter thick magnetite zone at the 5–10 meter hanging wall of the ore deposits can be observed at surface outcrops, at the entrance of underground level G-2, and in drilling core.

From the results of X-ray diffraction analyses and through chemical analyses, of host rock samples obtained from the underground, the calc-silicate rocks and the pelitic-siliceous schists were identified as being formed from the following combination of rocks;

Calc-silicate rocks (well vessicated by HCI acid)

biotite - tremolite - calcite shcist

quartz - biotite - calcite schist

sericite - tremolite - dolomite - calcite schist

Pelitic ~ siliceous schist

quartz - muscovite schist

biotite - quartz - muscovite schist

tremolite - quartz - muscovite schist

As can be seen in the 1/100 underground sketch (PL I–8), the host rocks of the hanging and foot walls of the ore deposits show a complex structure of alternating strata of calc-silicate rock, banded-massive limestone, dolomite, pelitic ~ siliceous schists, and a small quartz lenses with the amount of dolomite being small.

(c) Mica schist (Alps)

These lithofacies consists mainly of schists which well schistosed and granules which appear gray to dark grey color. The main constituent minerals which comprise the mica schist are composed mainly of quartz, biotite, muscovite, sericite, and accompanying plagioclase, garnet, amphibolite, and tremolite.

In these rocks, a few centimeters to a few meters thick vein of quartz is distributed concordantly in the schistosed plane, and often shows a boundin-like structure.

According to the mineral assemblage of the above minerals, it is classified in to the quartz-biotite-muscovite rock facies and quartz-muscovite-sericite rock facies. The former is distributed from the western side of the Perau mine area to the northern side, and contains much garnet, and in the drilling cores from the Perau area a large amount of magnetite can be seen. The latter is situated upper portion of the former, and the garnet and magnetite components are few.

(d) Amphibolite ~ amphibolite schist (Alam)

This is found in great amounts concordantly in the mica schists.

The rock facies are medium sized granules appearing dark grey - dark green, and show both homogeneous or heterogeneous massive rock with a banded structure.

The distribution of these rocks is from 15–10 meters above the calc-silicate horizon. The thickness of these strata vary from a few meters to over 200 meters at its thickest point. These rocks are especially predominant in the Açungui formation I and from the fact that it is concordant with the mica schists, the original rocks can be thought of as basic lavas and extruded materials.

Under the microscopic observation the nematoblastic-porphyroblastic texture is characteristic, the main constituent minerals are plagioclase, actinolite, epidote, amphibolite, and a little quartz.

At the western end and northwestern portions of the Perau area those are alternating with calc-schist and graphite schists.

(e) Limestone ~ Calc-schist (AIcs)

These rock facies appear as dark grey to greenish-grey medium granule sized, a schistosed plane has developed, and is well vessicated by Hydrochloric acid. Along the right bank of the Ribeirão Grande, on the western side of the Perau area, it is distributed a strike continuation of about 3 kms, the widest layers beeing about 80 meters. The upper most portion is cut by the Ribeirão Grande fault.

The constituent minerals are composed mainly of quartz, plagioclase, calcite, biotite, small amounts of muscovite, garnet, actinolite and tremolite. From this mineral assemblage, it indicates a rock facies resembling calc-silicate rocks of the "Perau horizon", but the proportion of quartz and limestone is small, and by being a rock facies close to mica schist, mineralization cannot be observed.

(f) Graphite schist (AIgs)

These rock facies appear as dark grey to black granules, and schitosity has been developed. Along the fault on the left bank of the Ribeirão Grande, (the hanging wall fault of the Ribeirão Grande fault), a strike continuation about 3 kms. is found, showing the widest layer to be of about 230 meters wide. The constituent minerals are composed mainly of quartz, graphite, and muscovite, and often includes thin layers of psammitic schists, amphibolite schists, and calc-schists. The infiltration of oxidized copper ore can be observed in the fissure zone of these rocks.

2–2–3 Geological Structure

The main geological structure of the present area is a NE-SW system of folding, lineation and faulting structures can also be observed. In the central portion of the area, the Perau anticline is located while south of that the Faria syncline is located. In the northwestern portion the Ribeirao Grande fault and its hanging wall branch fault are located.

(1) Fold

The Perau anticline and the Faria syncline are roughly parallel, having an axis direction of about N30–50°E. The folding axis plunges in a SW direction. At the northwestern moderating at areas near the anticline axis, and becoming steeper at neighboring faults. lessening at areas near the anticline axis, and becoming steeper at neighboring faults.

Because of the influence of the Perau anticline and the Faria syncline, the "Perau horizon" and each strata of the hanging and foot walls are distributed with forming into an "S" shape.

In the underground of the Perau mine, the open folds have wave length of about 50m , and appear as "undulations" of the ore deposits, as can be seen in the 1/500 underground geological map (PL I–7). The line bringing together the crest of this open fold at the upper and lower underground levels is consistent with the direction of the Perau anticline axis. This folding structure can be thought of as being closely related to forming ore shoot, but confirming the existence of this order of folding through field observations is difficult.

Other than the folds mentioned above, smaller folded structures on the order of several centimeters to tens of centimeters can be observed in the biotite gneiss of the upper part of the Setuva formation upstream from the Ribeirao do Perau, in the "Perau horizon" of the Açungui formation I and in the mica schist above that. Its folding axis is consistent with the Perau anticline axis, and indicates a pitch direction of S30–45°W, 20°S.

Other than that, local intrafolial folds can be observed in the underground, and these folds are thought to have been formed by strike faults. This fault structure does not continue obliquely in the hanging and foot walls of ore body, but develop parallel in the upper and lower portion of ore body, and form local ore shoots.

(2) Lineation

Lineation has developed on the bedding schistocity of the gneiss of the Setuva formation, and the quartzite, calc-silicate rock, graphite schist and mica schist of the Açungui formation I. The direction of these lineations is a S30–50°W, indication a pitch of 10–25°, and is consistent with the direction of each of the above mentioned folding axes.

Underground at the G-3 level, it indicates locally a S20–40°E, 10–20° pitch, and is consistent with the direction of lineation that can be observed in the field.

(3) Fault

In the field along the Ribeirão Grande, the Ribeirão Grande fault and its hanging wall branch fault are parallel. These are infered faults, and can be thought of as a normal fault where the northwestern block has fallen.

From the results of the geophysical exploration (Gravity), the existence of faulting structures in this neighborhood is presumed, and also that the northwestern block has fallen several hundred meters is also presumed.

In the results of the underground survey in the Perau mine, it is became clear that much strike faulting has developed in the hanging and foot walls of the ore bodies, and oblique faults against to ore bodies are also widely distributed.

The strike faults in general do not have argillized or brecciated zones, and it is difficult to distinct between the bedding plane and a schistosed plane in many cases This strike fault is originated from a slip plane which is parallel to a plane of bedding or schistosity, and developed in the hanging and foot walls of the ore deposit parallel to the direction of the inclination of the bed, and sometimes roughly obliquely.

In the that scale of strike fault is large and parallel to the bed, and the fault plane contact directly with the ore deposit, the upper and lower facies of the ore deposits are scraped off by the fault and changes the thickness of ore deposit or removes it

On the contrary, sometimes the ore deposit and the host rocks are subjected to intrafolial folding structure between strike faults of the hanging and foot walls of the ore deposits, and there are cases were limited parts of the ore deposit are enriched Examples of these are the "b" and "f" ore shoots (Fig. I–10).

The other hand, the strike fault which is slightly oblique to the bedding also removes the ore deposit, at example of this can be observed in the rise between the G-2+20 level and the G-2 level, here the fault is steeper than the bedding, and dislocates largely the ore deposits in the G-2+20 level.

In the case, the ore deposit comes in contact with the strike fault, it shows appearance of compact and fine grained, and includes fragments of the host rock, can be observed.

The oblique faults are distributed obliquely to the strike of the host rocks, and show the general strike as N30–60°E, dip 45–90°NW.

This type of faults has characteristics as follows;

The almost are normal faults, and cut the strike faults and ore deposits.

The distance of dislocation is small less than 1 meter and 2–3 meters as the maximum.

The width of the fault measures from several cms. to about 20 cms , and fault clay cannot be observed, but it is often filled up by secondary calcite.

The strike of the fault is consistent with the direction of the Ribeirão Grande fault and the folding axis.

Within the faults, located underground, the strike fault can be thought of as having been originated in the folding movement of the present area, and formed as the development of the "slip plane" in the bedding or schistosity plane.

In the case of the oblique faults, small fault systems are formed by tension stress in generally, and from the fact that the strike of the fault is associate with the direction of the folding axis, it can be thought that it was formed by a tention stress in the same direction of the folding axis, after the release of the NW-SE main stress of the folding movement.

2–2–4 Ore Deposits

(1) Summary of the Ore Deposits

The Perau ore deposit is a strata bound lead ore deposit associated with the calc-silicate rock (AIls) of the Açungui formation I. In detailed observations, the calc-silicate host rock of the ore deposits shows complex rock facies combination, as stated in Section 2–2–2, (2), (b). According to the results of underground survey and drilling core logging, the distribution of mineralized zone ranges about 800 meters in the strike side and about 120 meters in the slip side was confirmed.

On the surface outcrops, in the cutting face of a trail towards the south of the Perau mine, the calc-silicate rocks of the "Perau horizon", including much folia of quartz, exposed. In these outcrops, small scale pyrite and chalcopyrite impregnation and banded or lens shapes can be observed. And chalcopyrite are mostly changed into oxidized copper ore. In the southern area, distribute dolomite, underground prospecting of Mina Azurita where tens of meters have been carried out in the past, unfortunately the promissing results were not found.

In the mineralized zone, being confirmed by the above mentioned underground and drill

prospecting, the "main ore body" is the mining target and show a strike elongation of about 350 meters and a dip elongation of about 120 meters, and the subterranean G-1 to G-3 levels are developed.

This main ore deposit is divided into many ore shoots, called "Bonanza", according to the swelling and shrinkage of the ore beds. The lowest line which unites the lowest level of these Bonanzas is roughly parallel to the surface of the surface. The G-4 level mineralized zone, about 500 meters north of the main ore deposits, shows a possibility of existence of another Bonanza. The mineral assemblage is composed mainly of galena accompanied by pyrite, chalcopyrite, and sphalerite, and occasionally pyrrhotite, marcasite, or tetrahedrite. Galena and chalcopyrite are remobilized, and fill up the space of host rock (gangue) which has been brecciated.

(2) The Shape and Scale of the Ore Deposits

The main ore body of the Perau is composed of many ore beds* having a thickness of several tens of cms. to several meters in the mineralized zone which is shown several meters to 10 meters thickness.

These ore beds repeat a growth and shrinkage, being subjected to the folding of the host rocks, some one show an exceedingly good continuity, and several one are very continuous.

Within the main ore deposits, if the ore beds are enlarged and having thicknesses of over 0.5, meters four ore shoots** (Bonanza I, II, III, and IV) are formed (Fig. 1–10). Moreover, ore bed is enlarged to over 1.0 meters, three ore pockets (a, b, and c) are formed in the Bonanza II and three ore pockets (d, e, and f.) are formed in the Bonanza III.

Bonanza II indicates a scale of 50 meters x 100 meters at the largest, and the others indicate a scale of about 30 meters x 100 meters.

The scale of the ore pockets show various scale, the largest one is found in "a", and shows a scale of 30 meters x 100 meters.

The direction of these ore shoots, "Bonanza", and the pitch, generally show as S45–70°W, 20–35°, and is consistently distributed with the folding structures of the host rocks and lineation. The direction and Pitch of the ore pockets are especially well congruent with the direction and pitch of the lineation of the host rock.

The main ore body consists of, are 2–3 ore beds, and the ore shoots are made of these

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* In areas where massive, impregnated, or banded galena-pyrite aggregated, six ore beds intercalate with gangue rocks can be observed and are generally arranged in 2–3 beds.

** Ore beds are enlarged at crests by the folds of secondary order, and there is a tendency for reduction at the wing.

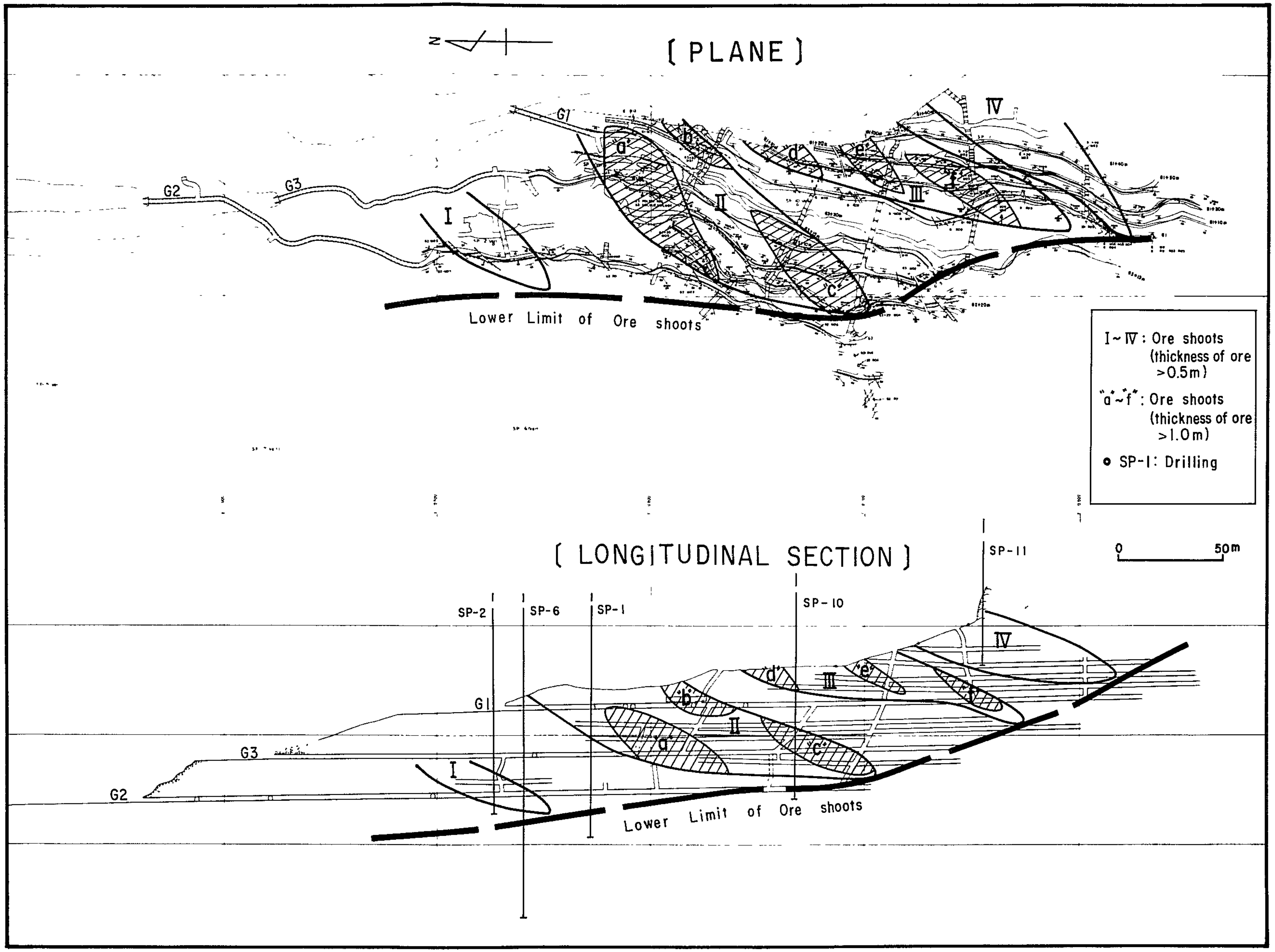

Fig. I-10 Distribution Map of Ore Shoots in Perau Mine

enlarged ore beds.

It is confirmed that Bonanza I consists of two ore beds by the G-2 level, G-3+10 level, and the SP-2 drilling data.

The ore bed which is at present observed at the G-2 level and G-2+10 level, can be thought of as part of the lowest foot wall side. According to the data on the SP-2 drilling, another ore bed is also observed in the hanging wall side, and it is necessary to carry out underground prospection for it in the future.

Bonanza II is comfirmed that consists of three beds, by the G-1 level, G-3 level, G-3 level, G-2+20 level, an rise and drilling (SP-1 and SP-10) data. Of these ore pockets, "a" corresponds to the upper most ore bed, while "b" and "c" correspond to the middle ore beds.

At the G-2 level, bottom of Bonanza II, three thin ore beds are distributed as echelon shape, but the existence of ore shoots is not confirmed. From the data of the cross cut, directly under the ore pockets "a" and "c", it is thought of that the lower parts of Bananza II does not reach G-2 level.

The SP-10 drilling passed through a portion between Bonanza II and III, where the quality of ore had worsened, while SP-1 reached part of the last edge of ore pocket "a", these show that the circumstances of the ore deposit are not good.

Bonanza III and IV are confirmed that each one consists of two ore beds, by the data of the G-1 level and of sub-levels, and also from SP-11 drilling data. In either case, III and IV correspond to ore beds of the foot wall. At one part of the G-2 level and G-3 level, barite is distributed in the hanging walls of these ore beds. In this, fine-grained galena is shown impregnation as a clound-like fashion, but quality of the ore deposit is poor.

(3) The Mineral Assemblage

The ore minerals, mainly galena and pyrite, along with small amounts of chalcopyrite and sphalerite, can be observed by the naked eye, and furthermore under the microscopic observation, pyrrhotite, marcasite, and tetrahedrite can be observed in extremely small amounts.

Pyrite shows as a fine-graned, banded structure, and is arranged syngenetically in the host rocks, form a small folding and Boudin, and is filled up by galena (photo G3+20).

Galena appears as medium to coarse sized and as a whole, are arranged concordantly in the bedding of the host rock.

Generally, even shows a massive and homogeneous appearance, the fragments of brecciated or pebbled host rocks and pyrite can be seen in the polished section. In especially areas where small folding structures have developed or in ore shoots, the inclusion

of these rock fregments are appear frequently.

The Galena is remobilized and fills up the fractures of the host rock and pyrite, cutting through structure of the ore bed and it's host rocks, and the phenomenon of the "Hanekomi-spur", of coarse grained galna, can be seen.

Sphalerite distributed in small amounts accompanying galena throughout the whole area of the main ore body, and it is enriched locally (in the southern part of G-1, G-4, and the SP-4 drillings) in some places.

The characteristics of each type of ore mineral which can be observed under the microscope are as follows:

GALENA: In the portion of massive appearance by naked eye, there are aggregation of coarse grained crystals have developed cleavages (photo of G-3 MO1), and it includes other ore minerals, (pyrite, sphalerite, and pyrrhotite), and corrodes them (photo of G-3 MOl, G-2 MO4). Often remobilized and fills up fractures and the original structure of the host rocks (photo of G-3 MO4, G-3+20 MO1). In the portion of impregnation, distribution of fine grained pellet like galena is controled by the primary structure of the host rocks (Photo of G-2 MO5).

PYRITE: Subhedral to anhedral crystals crystals, including small amounts of euhedral crystals, are aggregate in a mosaic texture. (photo of G-3 MO3), and accompany small amounts of galena and sphalerite. Some pyrite are included in galena show subhedral to anhedral, and margin of the crystals are corroded by galena.

SPHALERITE: Associate with galena, pyrite, and chalcopyrite. Filled with galena, and it fills fractures of pyrite. In the crystals, fine grained chalcopyrites are observed (photo of G-1 MO8). In the portion where sphalerite has abundantly concentrated at the G-4 level, aggregation of fine grained sphalerite-pyrite are observed (photo of G-4 MO1). In that portion, concentric structures which can be thought of primary structures of sediments are observed (photo of G-4 MO2).

CHALCOPYRITE: Coexist with the above mentioned ore minerals and also marcasite. It It can be observed that enclosed by galena, indicating anhedral shape (photo of G-3 MO4), filling up fractures of pyrite and marcasite (photo of G-1 MO4), and can also be observed small round grains in the sphalerite.

MARCASITE: A small amount of it occurs with pyrite, chalcopyrite, and sphalerite. It can be thought of as crystallized in the earliest period, and it can be observed as rims and cleavages of the mineral are replaced by pyrite or chalcopyrite (photo of G-4 MO2).

Concentric structures, which can be thought of the primary structure as the above mentioned sphalerite, can be observed at the G-4 level (photo of G-4 MO2).

PYRRHOTITE: Small grains are occured in the galena (photo of G-2 MO3) and rims and cleavages of grain are replaced by pyrite (photo of G-2 MO3), and can be thought of as the ore minerals are crystallized at an early period with marcasite.

TETRAHEDRITE: In sections that come in contact with galena and pyrite, small amounts can be observed, indicating an irregular shape (photo of G-1 MO5). It can be thought to have crystallized at closely the same time with galena.

As for the relationships of quantity among the above mentioned minerals, galena and pyrite are the most abundant and secondly small amounts of sphalerite and chalcopyrite are contained. These three minerals can be observed by the naked eye, while marcasite, pycrhotite, and tetrahedrite can only be observed under the microscope.

These minerals are subject to remobilization influenced by folding structures of the host rocks, and moved from the original site of crystallization. Galena and chalcopyrite, especially, show a characteristic of easy remobilization. The mineral assemblage indicates characteristics of polymetallic ores consist mainly of pyrite and galena in principal. Also, from the fact that concentric structures (can be thought regarded as one part of colloform structure) in sphalerite and marcasite, crystallization from lower temperature solutions can be presumed. Also, the banded structure of pyrite indicates an exceedingly concordant accumulation in the bedding of the host rock.

(4) Results of Ore Analyses

The Perau mine produce Pb and Ag ore with a monthly production of 1500 tons, Pb 7–10%, Ag 80–120 g/ton of crude ore. Concerning the distribution of Pb and Ag grades, it is difficult to explaine assay distribution, because there is no data on the systematic sampling and analyses of mining area. But according to results of the analyses of chip samples from many points of the ore deposit in the present survey, it could be concerned as follows;

In usually, grades of chip sample analysis are higher than crude ore grade but it is possible to estimate the such tendency in the whole ore body.

The results of analysis of 30 ore samples obtained from the Perau ore deposits are shown in Table A–5. Many of Pb grades show near a 10%, and the difference of those assays in the enlarged part and thin part cannot be observed. This can be thought of as the

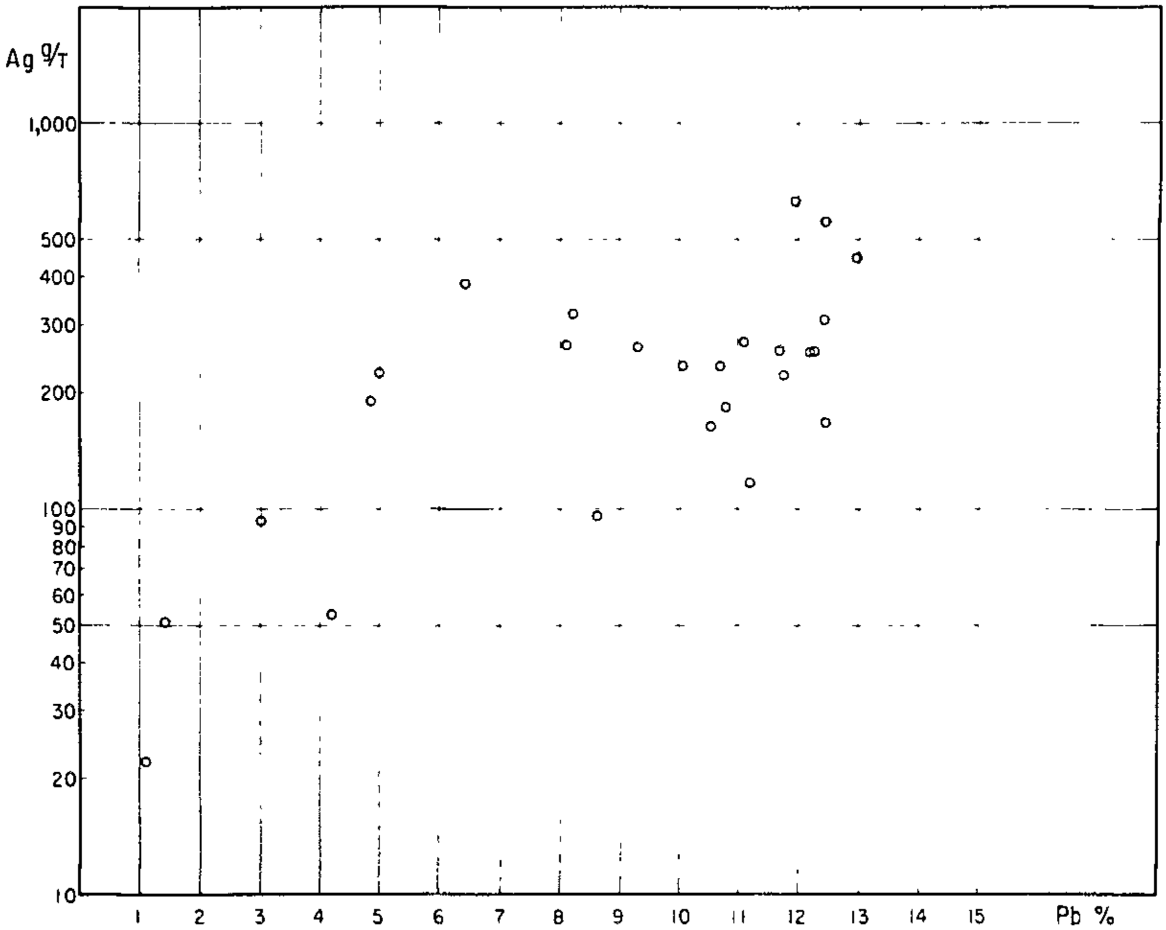

Fig. I-11 Correlation Diagram between Pb and Ag in Perau Mine

result of galena is subjected to remobilization, and fill up roughly homogeneously the insides of the ore bed. Consequently, even though the galena looks like a massive, homogenous, high grade ore by the naked eye, it contains small fragments of the host rock, it does not become a very high grade.

As for the grade of zinc, there are many samples which show a low grade of less than 1%. However, but is found throughout the whole ore body, and there are some samples that show a high grade in the locally (4–10% zn.), especially samples from areas where sphalerite has abundantly aggregated (southern portion of G-1 level, and G-4 level).

The grade of copper shows an exceedingly low of less than 1%, many places being less that 0.1%, and shows that it is contained throughout the whole ore body as like as zinc.

Silver indicates the highest value, at 629.3 g/ton, and there are many samples higher than 200 g/ton. According to the results of microscope observation, the existence of silver mineral cannot be observed, but small amounts of tetrahedrite accompany with galena.

Ingenerally, the polymetallic deposits consist of lead, zinc, and copper, as principle mining objects, and silver mainly exists in the sulfide minerals such as tetrahedrite, galena, and bornite as an isomorphous mixture. The silver of this ore deposit can also be thought of as being contained in galena and tetrahedrite. Over half of the samples of gold were below the limits of measurement of analysis. Even in samples containing gold, the highest value is only 1.5 g/ton and most were lower than 0.5 g/ton.

As for the results of analysis of chip samples of the Perau ore deposit, the objective ore for production are Pb-Ag ores, and there is not enough Cu, Zn, and Au for the object of production.

Concerning on the regularity of distribution of assay in vertical and lateral directions, there are many unclear points since there is not mich data, but it is recognized that the grade of Pb-Ag show roughly the same value even at the ore shoots and other points.

Consequently, a producible ore of the Perau ore deposits is the enlarged part of the ore bed under the geological structural condition.

2–2–5 Relation of the Geochemical Exploration and Ore Deposit

The geochemical exploration (soil) has been carried out in the Perau horizon distributed area.

Six elements of Cu, Pb, Zn, Ni, Co and Mn were anylized.

The anomalous value of these elementsare shown as over the 10 $\bar{x}+\sigma$ of histgram of them.

Pb and Zn anomaly zone are coincide directly with upper portion of ore deposit, and Cu anomaly zone distribute from the position of the ore deposit to southern area of it.

As for results of factor analysis by multivate analysis, a factor which is characterized with Cu-Pb-Zn, is concievable to reflect the mineralization, and high score zone of factor is extremely coincide with distribution of ore deposit.

The other hand, a factor of Ni-Co-Mn-Zn is concievable to reflect the characteristic of lithology such as calc-silicate rocks (Alls) and amphibolite(Alam) and high score zones of it's factor are associated with distribution of those rocks.

2–2–6 Relation of the Geophisical Exploration and Ore Deposit

The geophisical survey, gravimetry and electric (IP and SIP methode) has been carried out in the Perau area.

The gravity survey was carried out intend to obtain an information of underground structure, and the existence of the fault structure along Ribeirão Greande in the north-western area of Perau mine was detected.

Electric survey was carried out mainly IP methode and Subordinary SIP methode.

As for results of electric survey, some anomaly zone were obtained around the Perau area as follows,

(1) An anomaly zone coincide the distribution of graphite schist in the northwestern area.

(2) An anomaly zone coincide with weak pyrite dissemination and graphite in the mica schist above the Perau horizone.

(3) An anomaly zone Coincide with Perau horizone.

(4) An anomaly zone indicating amphibolite layer which is intercalated in the quartzite under the Perau horizone.

These anomaly zones have different characteristics of FE anomaly and appearance resistivity individually.

The continuity of the anomaly zone (3), being considered as responced to the Perau ore horizone, was obtained at the deep portion.

The direction of the arrengement of these anomaly zone and pitch show S or SSW.

These facts are agreed with geological evidences of the Perau ore deposits that the ore shoots show S or SSW direction of pitch as same as folding structure of host rock, and that the ore shoots, present working, show lower limit at the G-2 level (not meaning lower limit of the mineralization) and it is expected that the ore shoots appear in the deeper portion.

Also it is expected to carry out exploration toward the deeper portion along the Perau horizon.

2–2–7 Scope of Future Exploration

As a result of synthetic disscussion about geological and geophisical survey, the expective exploration in the Perau mine and surround in the future are as follows;

(1) The ore shoots in the Perau main ore body is limitted bottom at the G-2 level, however, the drilling data SP-6 indicate a possibility of existence of another ore shoot under the G-2 level, consequently it is expected to be carried out underground exploration at G-4 level in the future.

(2) The drilling exploration at the G-H line area to be expected because of the IP anomaly zone has been detected under the G-H line area.

(3) The Perau ore deposit is located at the northwestern wing of the Perau anticline, and the ore shoots have been formed under the influence of folding structure, consequently the opposit side of the anticline or at the wing of the Faria syncline, have same geological conditions, are expected to be carried out the electric survey and geochemical exploration.

2–3 The Geology and Ore Deposits of the Rocha Area

2–3–1 Summary of the Rocha Mine

The Rocha area is located about 24 km. southwest of Adrianopolis. The mine office of Rocha Exploração e Comercio de Minerio Ltda. is situated in a upstream from the Ribeirão do Rocha about 230 meters above sea level hidden by steep mountain sides, in a tributary of Rio Ribeira.

The present main working areas are Sub-levels of the 308 and the 403 meter levels, and older levels at the 227 meter level is progressing to re-open.

There are 150 workers, and the monthly production of crude ore is about 3,000 tons containing 5–7% of Pb and 100–130 g/ton of Ag. The Lead ore is graded up to 35%, and all of it is sold to the S.A. Plumbum company refinery in Panelas.

2–3–2 Geology

The geology of the Rocha area consist of the Lower and Middle Member of the Açungui formation III (A III) and also dykes of diabase and altered meta-basic rock are distributed in them (PL I–10 and Fig. I–12).

The general strike is seen as a NNE-SSW trend. The Lower Member is distributed long and narrow in the western part of the area, while the Middle Member is widely distributed over most of the area.

The Rocha fault on the western edge of the area, and the Agua Morna fault on the eastern edge are both strike faults have a NNE-SSW trend.

Near the western side of the Agua Morna fault, there is the Rocha syncline, which is cut by the fault. The present survey area is situated on the western wing of this syncline, and the geology show a monoclinal structure with an easterly dip.

(1) The Lower Member

Distribution

About one km. to the west of the Rocha mine, with a strike of N20–35°E, and a dip of 35–50°SE can be seen. That part of the area is cut by the Rocha fault with a NNE-SSW trend.

Lithology

The lithology is mainly composed of a grey or dark grey fine grained muscovite (sericite) schists which is developing schistosity that include many beds of psammite schists containing abundant of quartz grains.

(2) The Middle Member

This Member is divided into limestone (A III L_2) of the lower section and mica schists (A III S_2) of the upper section in the 1/25,000 geologic map. It is found over a large portion of the present survey area.

(a) Limestone (A III L_2)

Distribution

It has a general strike of N20–40°E with a dip of 50–80°SE. It is found over the western half of the area. The dolomite (L_2 dol) forms the best ore deposit host rock, and a strike elongation of 5 km. and the thickest width of 200 meters has been confirmed.

Lithology

From the bottom to the top, it is comprised of calc-schist (L_2 cs), limestone (L_2 ls) and dolomite (L_2 dol).

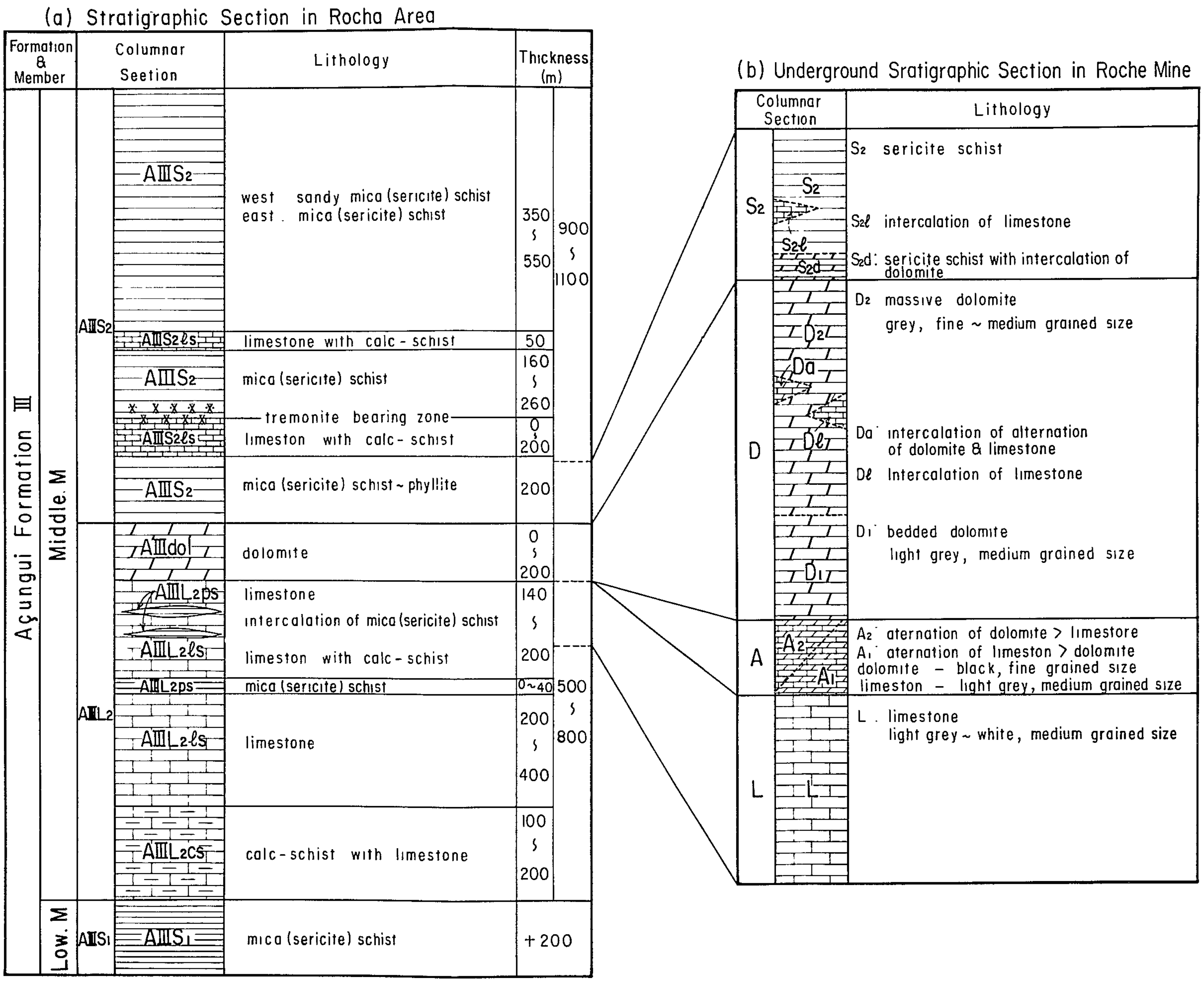

Fig. I-12 Geological Columnar Section in Rocha Mine

The calc-schists (L_2 cs) are white to light grey muscovite (sericite)-calcite schists, and intercalates thin layers of muscovite (sericite) schists (5~10 cm). In general, clear bedding and schistosity can be observed, but they become less clear to the north.

The limestone (L_2 ls) effervesces strongly with HCl. and it is fine-medium grained a light - dark grey color, and the bedding is clear. In the upper portion, rock facies resembling calc-schists are shown, and include lenticular layers of muscovite (sericite) schists. The most upper portion become massive and pass through part of alternation of limestone and dolomite, and then change to dolomite.

Dolomite (L_2 dol) does not react very strongly to HCl. A fine grained dark grey - light grey massive rock facies is seen.

The different reactions of limestone and dolomite to a 10% solution of Hydrochloric acid (HCl) provide a simple and quick field test to differentiate between them. The following four rock types were defined,

① Limestone effervesced strongly, large size bubbles collect, and the time of effervescence is long.

② Dolomitic limestone: effervesced relatively strongly, but the size of the bubbles are small.

③ Calcareous dolomite: effervesced weakly, and disappears quickly.

④ Dolomite: generally does not effervesce.

From the results of X-ray diffraction and chemical analysis of the rock samples (Table A-4), a part of the above mentioned limestone (L_2 ls) and also dolomite (L_2 dol) are widely found in underground of the Rocha mine, and the lead ore veins are found in the dolomite dominant part.

Before the studies of the underground survey and drill core logging, limestone and dolomite were classified in to the limestone dominant part (L), limestone and dolomite alternation (A) and dolomite dominant part (D) as the result of the 1/100 sketch of the side wall at the Nova Esperanza cross cut of 308 meter level (Fig. I-13), accordingly classification method on limestone and dolomite above mentioned. The geological maps (PL I-7 and I-10) of the 308 meter level and 403 meter level have been mapped according this classification. The limestone and dolomite alternation (A) has been observed in the northwestern portion in an adit along the Basseti fault, drill core I-125 and I-95 at the 403 meter level.

At the 308 meter level, it also can be observed in the western cross cut, the Nova Esperanca cross cut, drill core I-125 and I-139. In this rock, ①, ② and ④ appear as like

as alternation of 0.3–1.0 thickness of each other. Appearance with naked eye of the section ① and ② are shown as medium grained and pale gray colour, and the section ④ is fine grained and black colour bearing pyrite crystals.

The dolomite dominant part (D), at the 403 meter level, can be observed in the western cross cut, drill core I–125 and I–95. At the 308 meter level, also can be observed in the western cross cut, the Nova Esperanza cross cut, drill core I–124, I–139, I–112 and I–141. In this rock, the ④ is shown predominantly and intercalate with ② thin layers. Appearance with naked eye of the section ④ is shown fine to medium grained, pale gray to dark gray colour with pyrite dissemination. And the ② is shown medium grained and white colour.

(b) Mica schist (A III S2)

Distribution

The mica schist distribute widely in the eastern half of the ore showing the general strike of N20–40°E, dip 35–75°E. The eastern margin of the area is cut by the Agua Morna fault, and a part of the Rocha syncline can be seen in the northeastern marginal area.

Lithology

The main rock facies is composed of muscovite (sericite) schist with gray to dark gray colour. Graphitic muscovite (sericite) schist or phyllite are developing at the lower portion, and psamitic schists are intercalated abundantly in the mica schist.

This tendency is especially strong in the northern area, and the bedding becomes unclear. A characteristic of these rocks can be observed with the naked eye, such as the bandded structure consists of blcak parts containing abundant graphite and white parts which without graphite.

Limestone-dolomite schist (S_2 ls) appears grey - dark grey, and shows alternating bands of 20–50 cm. thickness. Those of the lowest part are distribute widely, and from top of the plane to bottom of the sericite schists of the hanging wall, large prism or needle like tremolite crystals are well formed. This tremolite zone is very continuous, and is an important key bed in this area. Tremolite cannot be observed in other limestone-dolomite schists.

(3) Metabasite

Distribution

It is distributed in a long and narrow area along the Rocha fault in the western edge of the survey area. Though it is difficult to clearly identify the distribution because of poor outcrops, it is thought to be an intrusive a sheet-like configuration.

Lithology

Fresh samples could not be obtained from the weathered floats, but it generally appears as dark green with a medium grain size, and show magnetic nature as weakly.

(4) Diabase Dyke

Distribution

Numerous dykes striking NW-SE can be seen at the underground and on the surface in the Rocha area. These dykes cut through each of the above mentioned beds and generally have a width of 1–2 meters, but reach up to 30 meters at their widest in the northeastern section of the survey area.

Lithology

The rock appears black to dark grey, a fine to medium grain size, and massive. As a characteristics, the center part of the dyke shows a diabase rock facies which have a porphyritic texture, where phenocryst of pyroxene can be observed, and marginal part of the dyke or the small dykes have a basaltic texture.

2–3–3 Geological Structure

(1) The Geologic Structure of the Rocha Area

The Lower and Middle Member of the Açungui formation III which shows a general strike of N25–40°E, and most of the dips are to the SE, as a monoclinal structure.

A synclinal structure can be observed on the eastern edge of the area, and a large part of the present survey area is situated on the western wing of this syncline.

Fault structures are distributed with a NNE-SSW trend and also a NNW-SSE trend. The Rocha fault on the western edge of the area and the Agua Morna fault on the eastern edge are NNE-SSW trend faults. As the NNW-SSE trend faults, the Bassetti and Esperanza faults and vein fissure patterns can be seen in the Rocha underground. The Rocha fault is a normal fault, with 1000 meter drop of the eastern block being inferred. The Agua Morna fault is also a normal fault, with 800 meter drop on the eastern side likewise being inferred.

(2) The Geological Structure in the Rocha Mine

The general strike of the underground geology shows a NE-SW trend which is roughly the same as the general strike which can be seen at the surface. The dip, however, becomes northwesterly at a part of the limestone and dolomite, and is not in accordance with the general dip direction of the surrounds on the surface. This is explained by the fact that the

Rocha mining areas are situated on the western wing of the Rocha syncline, and drag fold has developed in the limestone ~ dolomite area.

The fault structures and vein fissures have developed together in the dolomite, and show a NNW-SSE trend.

(a) Folding Structures

In the underground of the Rocha mine, from area where developing limestone (L) through alternating area of limestone and dolomite (A), the transition area, to dolomite developing area (D), various types of folding structures can be observed.

Fig. I–13 is a sketch (the scale is 1/100) of the folds which can be observed in the side wall of the Nova Esperanza cross cut at the 308 meter level. At this cross cut, an open fold can be seen in the limestone toward the center, and a tight fold is developing in close to (A).

In the (A) alternating part, tight folds and isoclinal folds are noticeably developing. In the dolomite (D), folding structures cannot be seen, and if there were any, these would only be a few.

In the massive dolomite (D_2), apart from folded area, where folding structures do not develop, but vein fissures can be observed.

Fig. I–14 is a sketch of the appearance of the folds which can be seen in the alternating section (A), in the western cross cut at the 403 meter level. The black layer of the dolomite alternating with the limestone, show a drag fold configuration, and is interpreted that the alternating part (A) forms a more larger order drag fold according to the stress of the direction of the arrow.

From the results of observations of the measured strike, dip, and small folding structures at each point of the underground, folding structures as the schematic cross-section maps of Fig. I–15 and Fig. I–16 are interpreted as developing in transitional sections of limestone and dolomite.

This fold is formed by the same stresses which formed the Rocha syncline, and shows a drag fold configuration. In the foot walls of the "enveloping surface of folds" which unite the fold crests of the dolomite side, bedded dolomite (D_1) flows into the synclinal area and the limestone (L) flows into the anticlinal area, and the alternating part (A) is much easier to flow and is incompetent. The reason why folds generally do not develop in the massive dolomite (D_2) at the hanging wall side of the enveloping surface of folds, is that a slip plane is formed between the dolomite and the mica schist of

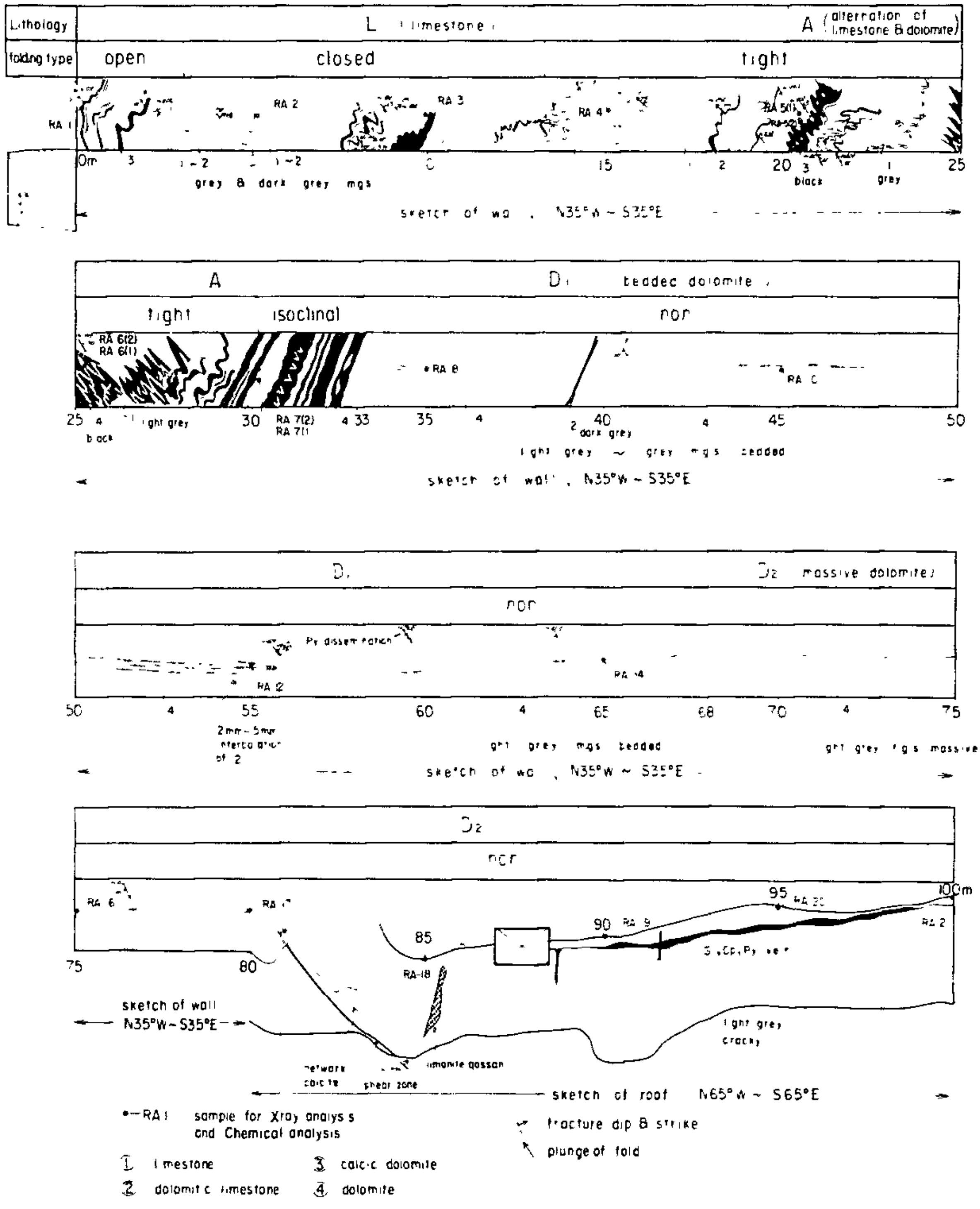

Fig. I-13 Geological Sketch of Nova Esperança (308 m Level) Cross-Cut in Rocha Mine

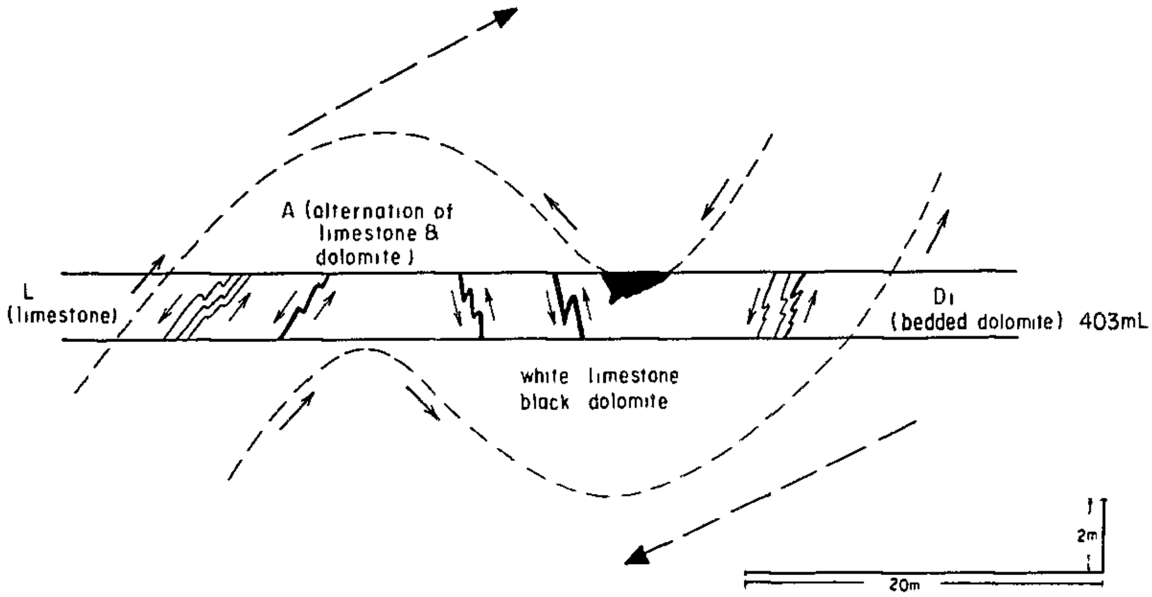

Fig. I -14 Sketch Showing Folding at 403 m Level in Rocha Mine

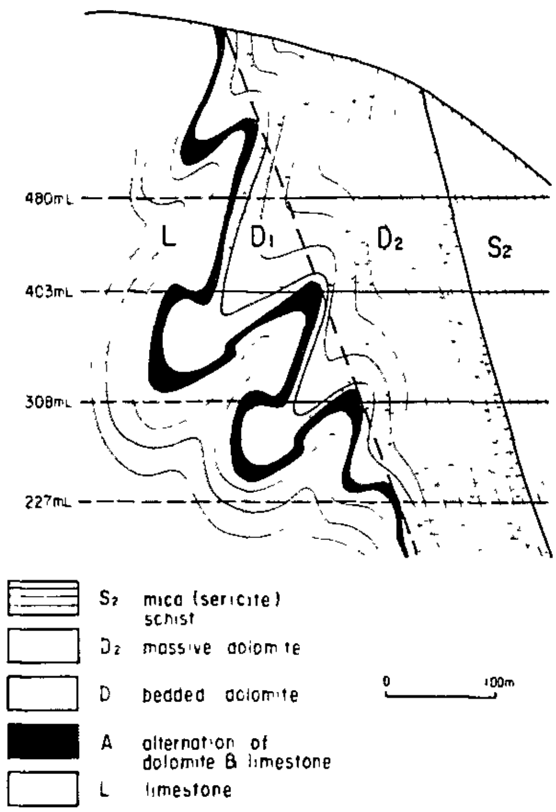

Fig. I -15 Geological Profile near Basseti in Rocha Mine

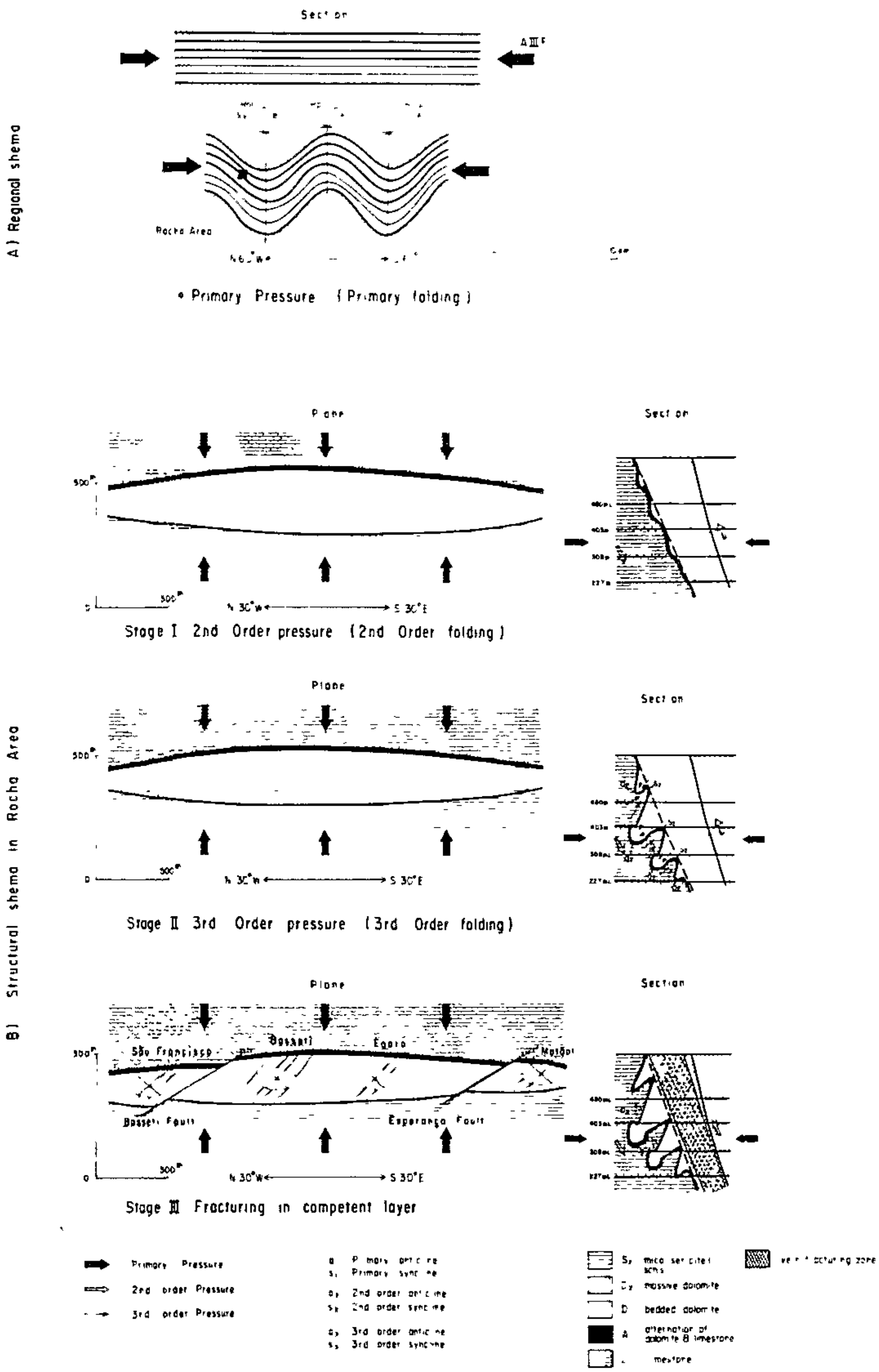

Fig. I-16 Relation of Stress against Folding and Fracturing

the hanging wall, and the inner stress of the dolomite (D_2) was released into that plane, dolomite (D_2) can therefore be thought of as relatively competent against to (L), (A), and (D_1) units.

From the results of observation of these folding structures, the order of competency of the limestone and dolomite units becomes $D_2 > D_1 > L > A$

(b) Faults and Vein Fissure Patterns

The faults seen underground are confirmed as the Bassetti fault and the Esperanza fault.

The strike of the Bassetti fault is roughly N-S, a dip of 70°E. It is distributed from the mica schists (S_2) to the limestone (L), and is well developed in the dolomite. This fault is a characteristic left lateral fault, and deslocated a 60–80 meters horizontaly. The Esperanza fault shows a strike of NNW-SSE, and a dip of 60°E. Similar to the Bassetti fault, it is a left lateral fault, and also makes a 60–80 meter deslocation.

As well as these faults, vein fissure patterns develop in the dolomite, and especially in the massive dolomite (D_2). These fissure patterns are divided into the following three systems:

① N20–30°W dipping 60–70°NE.

② N20–30°W dipping 60–70°SW.

③ N60°W, 90 degrees

Up until the present, tens of veins have been confirmed.

These faults and vein fissure patterns are thought to have formed in the relatively competent dolomite (D_2) by the same directional stress which caused the last stages of folding activity of the Rocha area.

2–3–4 Ore Deposits

The ore deposits of the Rocha mine are seen as a vein-type lead ore deposit developing in the dolomite (D_2) which is a part of the limestone (L_2) of the Açungui formation III.

The veins are divided into the type 1 showing a NNW-SSE pattern, and the type 2 showing N-S pattern fault (Fig. I–17, Table I–2).

(1) The veins of type 1

The veins belonging to this type are divided into four vein groups, from south to north such as the São Francisco, the Bassetti, the Egara, and the Matão vein groups.

(a) The São Francisco Vein Group

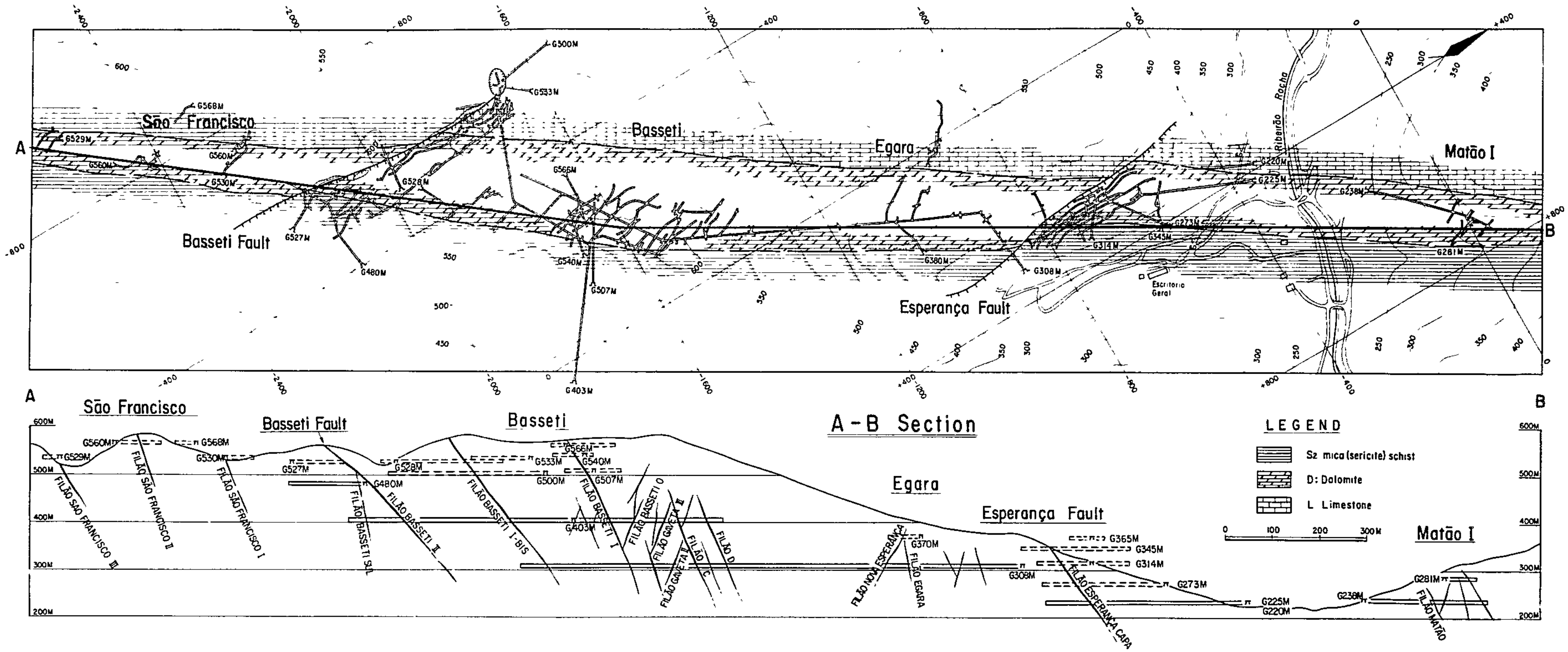

Fig. I-17 Distribution Map of Ore Veins in Rocha Mine

Table I-2 List of Ore Veins in Rocha Mine

type & group		Vein Name	Strike of vein	Dip of vein	length of vein (m)	mean wide of vein (cm)
TYPE I	São Francisco	São Francisco III	N 20°W	55°E	30	30
		São Francisco II	N 20°W	74°E	100	20
		São Francisco I	N 10°W	60°E	50	10
	Basseti	Basseti II - sul	N - S	68°E	100	20
		Basseti I - Bis	N 15°W	60°E	100	20
		Basseti I	N 20°W	65°E	120	50
		Basseti 0	N5°W-20°W	65°W	180	60
		Gaveta III	N 20°W	70°W	160	30
		Gaveta II	N 15°W	60°W	80	5
		C	N 25°W	68°E	110	30
		D	N 25°W	70°E	70	15
	Egara	Nova Esperança	N 65°W	60°SW	40	20
		Egara	N 40°W	80°NE	70	20
	Matão	Matão I	N 10°W N 35°W	75°E 80°W	70 40	5 50
		Matão II	N 75°W	50°N	40	1
TYPE 2		Basseti II	N - S	74°E	400	30
		Esperança	N - S	58°E	200	50

Situated in the southern area of the Rocha ore deposit, it is formed from the three veins of the São Francisco I, II, and III., from 520 meters – 560 meters above sea level, there are outcrops and entrance, but the entrance is unaccessible due to collapse. The general strike is N20°W, with a dip of 60°E. The scale of the vein is presumed to be, a strike elongation of 30–100 meters, with a width of 10–30 cm. based upon the distribution of outcrop.

(b) The Bassetti Vein Group

It is situated in the dolomite area is abundant in the central portion of the Rocha ore deposit. This group consists of eight veins closely spaced each other. The Bassetti - sul, I - Bis, I, C, and D, with a strike of N20°W, dip 60–74°E, and the Bassetti O, Gaveta II and III, with a strike of N20°W and a dip of 60–70°W.

The scale of the vein is superior compared to other vein groups. The length along the strike of the vein is 80–180 meters, and the vein width is 5–60 cm. While the enlarging and shrinking are notable, the width tends to enlarge in the area center of the massive dolomite (D_2). Fig. I–18 which is a sketch of the roof of the ore shoot, presently being mined, that can be seen in the sublevel of 55 meters above the 308 meter level of the Gaveta III vein. In areas forming the ore shoot, it is not one vein enlarged, but rather 5–6 smaller veins of 20–30 cm width aggregate in parallel can be observed. High grade Lead ore is shown in the enlarged part and massive galena has aggregate (RP–6, 7, 8), and also in the areas of fine grained galena have been disseminated (RP–4, 5). Towards the end of the ore shoot, small veins are decreasing, and the massive galena disappears. Passing through the weak impregnation of the fine-grained galena-pyrite (RP–1, 2) and at the end of the section, they become small veins of dolomite and calcite.

These vein groups develop in the massive dolomite (D_2) of the host rock. In other host rocks, the veins get worse, or not formed. As for the Gaveta IV vein at the 308 meter level (which is similar to the Bassetti I of 408 meter level), from the massive dolomite (D_2), to the limestone and dolomite alternating section (A) the vein gradually worsens, and the phenomenon of the vein disappearing as a horse tail can be observed.

(c) The Egara Vein Group

It is situated a little north of the center of the Rocha ore deposit. At the 308 meter level, the Nova Esperanza and Egara veins and two or three smaller veins can be observed. The Nova Esperanza vein shows a strike direction of N65°W, and a dip of 60°SW. The vein shows a length along the strike of 40 meters, and a vein width of 20 cm. The Egara vein

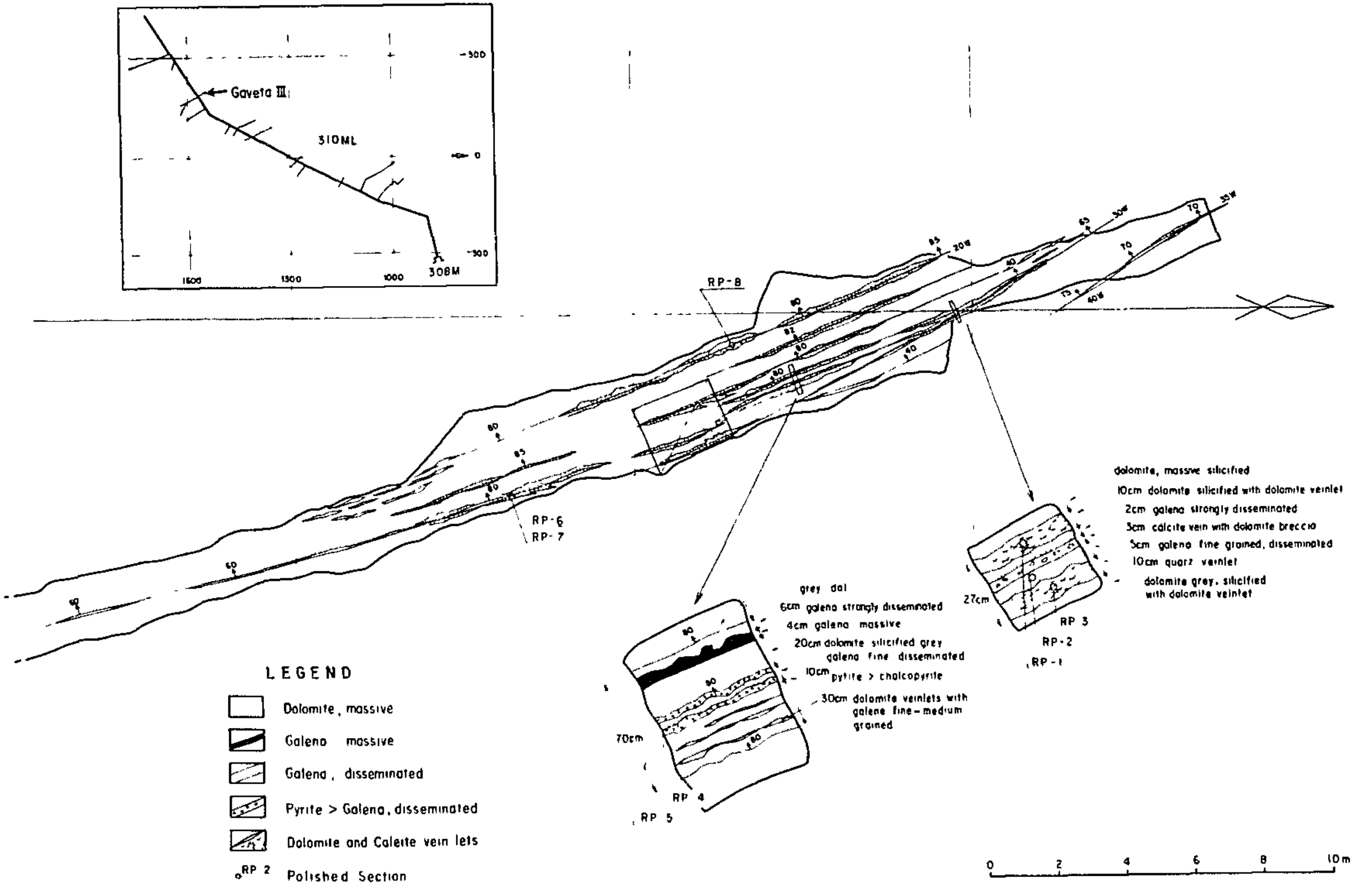

Fig. I-18 Sketch of Ore Shoot of Gaveta III in Rocha Mine

shows a strike of N40°W, and a dip of 80°NE. The scale of the vein is 50 meters along its length, with a width of 1–10 cm, it is a small vein.

The other than these principal veins, several smaller veins with a NW-SE trend can be observed, in the northwestern area of the Egara vein, and bedded veins also can be observed in the bedding plane, which have a different strike direction than general trend in the limestone and dolomite alternation (A). These veins have a strike direction of N35°E, with a dip of 70°NE, and have a length of 20 meters and a width of 60 cm.

(d) The Matão Vein Group

Located 1 kilometer north of the Egara ore deposit group, the Matão I, II veins are found. The Matão I vein intercepts two veins, one in the western section of the area at the 238 meter level, and one in the eastern section. The western vein has a strike of N35°W, and a dip of 80°, the length along strike is 10 meters, and a lenticular form, with a width of 30–40 cm. The Eastern vein has a strike of N10°W, and a dip of 70°E, the width is 5–10 cm. The Matão II vein is intercepted near the 281 meter level, it is a small vein with strike direction of N75°E, and a dip of 50°N, it's width is 1–2 cm.

The above mentioned type 1 veins are formed continuous only in (D_2), and while in (D_2) thick area, the continuity is good and the density of the vein is high, and the vein width is relatively large.

(2) The Veins of Type 2

The veins belonging to this type, include veins originating in the Bassetti II fault, as well as veins originating in the Esperanza fault.

(a) The Bassetti Fault Vein

Situated a little south of the center of the Rocha ore deposit, it has a strike of N-S, and a dip of 54°E, it horizontally deslocates limestone, dolomite, and muscovite schists left laterally about 60 meters. At the 403 meter level, a sheared zone of width 20–50 cm with fault clay possibly trace about 400 meters. Galena and pyrite are intermittent in either lenticular or smaller vein form, with the length being 20–30 meters, and the width 5–30 cm, they originate in this sheared zone.

(b) Esperanza Fault Vein

Situated a little north of the center of the Rocha ore deposits, it can be observed at the 308 meter and 313 meter level. This fault has a N-S strike, with a dip of 58°E, showing a left lateral deslocation about 80 meters of limestone, dolomite, and muscovite schist, and

being traced 200 meters by the strike elongation. There is mineralization in the sheared zone, and veins of pyrite lens form and galena (scale elongation 50 meters, largest width 3 meters, average 50 cm) are intermittent.

(3) The Mineral Assembrage

The main ore minerals forming the veins of the Rocha ore deposits are composed mainly of galena, pyrite, and small amounts of chaclopyrite and sphalerite, all of which can be observed with the naked eye. Under the microscope however, tetrahedrite, arsenopyrite, marcasite and pyrrhotite can be observed and also associate chalcocite and covellite as secondary minerals. Gangue minerals are mainly dolomite and calcite, and include small amounts of quartz.

Microscopic analysis of the main ore samples are as follows:

PR–2

galena > pyrite >> chalcopyrite > tetrahedrite

Galena fill up the opening of the gangue, is distributed in an irregular shape, and thus is found in smaller vein structures. Pyrite is corroded and cut as the vein structure by the galena. Small grains of chalcopyrite can be seen in the pyrite and gangue, and tetrahedrite can be observed in the contact of chalcopyrite and pyrite.

RP–4

galena > pyrite >> tetrahedrite > chalcopyrite > sphalerite

secondary minerals: chalcocite

Galena exists irregular in smaller veins and in gangue. Pyrite is replaced with galena. Galena is assembrage with chalcopyrite, tetrahedrite, and sphalerite. The rims of chalcopyrite and galena are replaced with chalcocite.

PR–7

galena >> pyrite >> chalcopyrite > tetrahedrite >> sphalerite

Galena includes pyrite, chalcopyrite, tetrahedrite and sphalerite. Pyrite is being corroded by galena. Chalcopyrite is aggregate with sphalerite and tetrahedrite.

PR–9

galena >> chalcopyrite > sphalerite, pyrite, pyrrhotite, tetrahedrite, marcasite

Chalcopyrite includes dot of pyrrhotite, tetrahedrite, and sphalerite. Pyrrhotite is associate with chalcopyrite.

PR–14

galena > pyrite = tetrahedrite >> chalcopyrite >> arsenopyrite