# REPORT

ON

[illegible] MINERAL EXPLORATION

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( [illegible] )

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JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

# REPORT
# ON
# THE COOPERATIVE MINERAL EXPLORATION
# IN
# THE CURRAIS NOVOS AREA
# FEDERATIVE REPUBLIC OF BRAZIL

(PHASE II)



MARCH, 1991

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

## PREFACE

In response to the request of the Government of the Federative Republic of Brazil, the Japanese Government decided to conduct a mineral exploration project in the Currais Novos area and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The JICA and MMAJ sent to the Federative Republic of Brazil a survey team headed by Kazuo Kawakami from August 3 to November 7, 1990.

The team exchanged views with the officials concerned the Government of the Federative Republic of Brazil and conducted a field survey in the Currais Novos area. After the team returned to Japan, further studies were made and the present report has been prepared.

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

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

February, 1991

Kensuke Yanagiya
President
Japan International Cooperation Agency

Gen-ichi Fukuhara
President
Metal Mining Agency of Japan

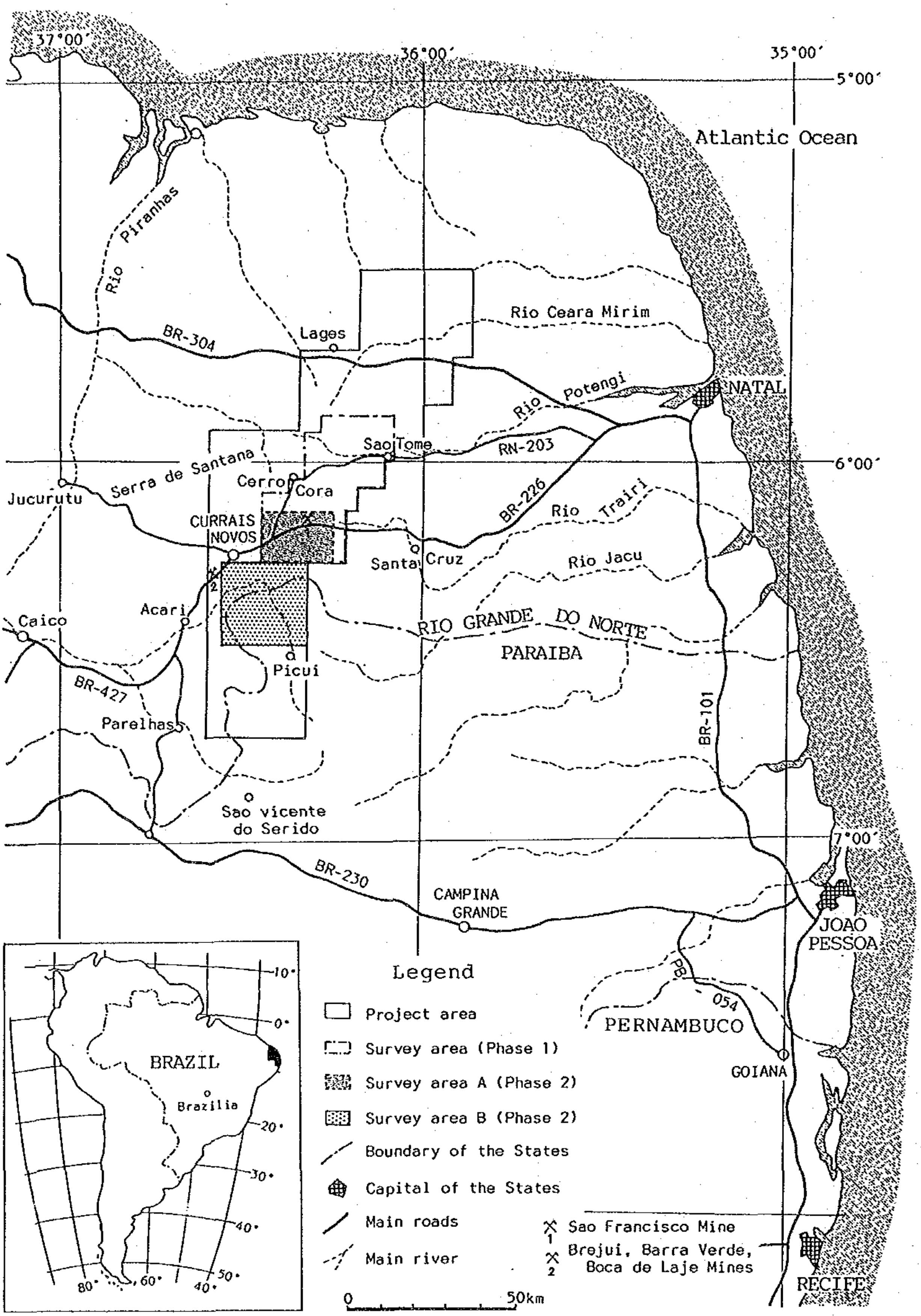



Fig. 1 Location of the survey area

ABSTRACT

In conformity with the Scope of Work agreed between the governments of Federative Republic of Brazil and Japan, the present survey was carried out in the Currais Novos area, state of Rio Grande do Norte, Brazil. The project cover an area of 5,910km$^2$, and the term required for its execution is 3 years. The project was carried out this year as phase II, with members of both Brazilian and Japanese sides taking part in the survey.

The survey of this year was executed in two areas with different methods. In area-A, where was selected as potential area in the phase I survey, soil geochemical and biogeochemical surveys were applied to delineate target areas. In area-B, where is new area neighbouring to the south of phase I survey area, geological and stream sediment geochemical survey were applied to narrow potential area. The survey area of area-A and area-B are 25km$^2$ and 500km$^2$ respectively.

Elements used for tracers in geochemical surveys in area-A are Au, As and Sb for soil survey, Au, As, Sb, Fe and Al for biogeochemical survey. For biogeochemical survey plant leaves were samples. 13 elements, Au, Ag, Fe, Mn, Mo, W, Sn Nb, Ta, Be, Li, As and Sb, were selected for tracers in streamsediment survey in area-B. Gold dust observation in pan concentrates and chemical analyses of them, for Au, Ag, Mo, W, Sn, Ta and Nb, were also executed in some parts of area B and phase I survey area.

The processes and the results of the surveys are as follows.

(1) Area-A

Area-A includes four small target areas, A-I, A-II, A-III and A-IV. In every small target area soil geochemical survey was carried out. In areas A-I and A-II, biogeochemical survey was executed as well. Three elements, Au, As and Sb, do not correlate each other either in soil samples or in

plant samples. Then the correlation of gold mineralization with arsenic and antimony was not pointed out. Correlation between the arsenic contents of soil and that of plant samples was realized. However, Au anomalous areas detected by biogeochemical survey are somewhat related with the Au anomalous areas detected by soil geochemical survey in a topographical point of view. As the result of the surveys described above, the southeastern end of area A-I and eastern part of area A-II were selected for potential areas.

(2) Area B

This area is widely underlain by Precambrian formations. Tertiary formation is distributed in a small area laying on the Precambrian formations. Quarternary alluvium is also distributed. The Precambrian are Archean Caico Complex and Proterozoic Serido Group. The stratigraphy of the Serido Group is composed of Jucurutu Formation, Equador Formation and Serido Formation from the bottom to the top. The Caico Complex, the Jucurutu Formation, the Equador Formation and the Serido Formation are principally composed of granite, gneiss, quartzite and biotite schist respectively. The Caico Complex and the Jucurutu Formation are locally distributed in the southeasternmost part and in the northwestern corner of the area respectively. The Equador Formation is in the western part of the area in a small scale. The Serido Formation occupies wide area in the central part of the area. The shape of ditribution of every formation is elongated, trending north northeast. The Serido Formation was divided into three units from the lithological point of view in phase I. It was further divided into four units in phase II.

In a structural point of view, a number of faults trending north northeast to north and west northwest to east northeast can be traced in the entire area. The faults trending north northeast to north are regional ones and they pass through the survey area. Especially, the fault in the eastern end of this area, which is called Picui Fault, is very important from the regional structural point of view in the northeastern Brazil. The faults trending west northwest to east northeast are in smaller scale than the ones trending north northeast to north and are thought to have acted in younger ages. A folded zone about 3km wide, trending north northeast to north in parallel with regional faults, can also be realized in the central part of the Serido Formation. This folded zone is also regional one.

In a matter of mineralization, a quartz vein accompanied with gold and arsenic is located in the southwestern end of this area. This vein is estimated to be 0.3 to 2 meters wide and about 200 meters long. Chemical assay of sample taken from the vein showed 0.2 ppm of gold and 103 ppm of silver. It is assumed to be hydrothermal quartz vein filled in tentional open fracture from its appearance and characteristics. The geological structure which controlled the location and the appearance of the vein is not disclosed yet. However, the area, where the vein is, is in quite different structure from the surrounding area. That is, though the schistosity of the host schist generally dips more than 30 degrees and the strike of pegmatite dikes is north northeast, the schistosity dips less than 10 degrees and the strike of the pegmatite dikes is west northwest to east northeast in the area where the quartz vein is.

According to the stream sediment survey, Au, As, Fe, Mo and Nb are recognized to form anomalous areas. Correlations can be recognized among the contents of elements, Fe and Mn, Fe and Mo, and Mo and Nb. These pairs of elements can be thought to be related with the composition of rocks in this area. Correlations among elements such as Sn-Be, Fe-Mn-Mo, Ta-Nb, and Li are defined from the factor analysis. Correlations between Sn and Be, and Ta and Nb are supposed to be related with the mineralization in this area. The others are thought to be related with chemical composition of the rocks distributed in the area. Correlation was defined between Au and As in stream sediments in phase I survey. However, no correlation between Au and other elements could be detected in phase II survey.

Gold anomalous areas are dispersed in the area B. Furthermore, points with high gold values are few in the anomalous area and they are not closely centered around. Nearby the upper reaches of the Riacho Pimenta in the southeastern part of the survey area, some points with higher gold values are relatively centered.

From an integral analysis of the obtained results in the phase II survey, further surveys are recommended in the following three areas;

(1) Area A

First, the anomalous area in the southeast of area A-I to realize the gold mineralization.

Second, the anomalous area, where is 500 meters east of the supposed southern extention of the Sao Francisco deposit, also to realize the gold mineralization.

(2) Area B

Third, the area in the Serra do Umburana, where quartz vein with gold mineralization is found, to disclose the gold mineralization.

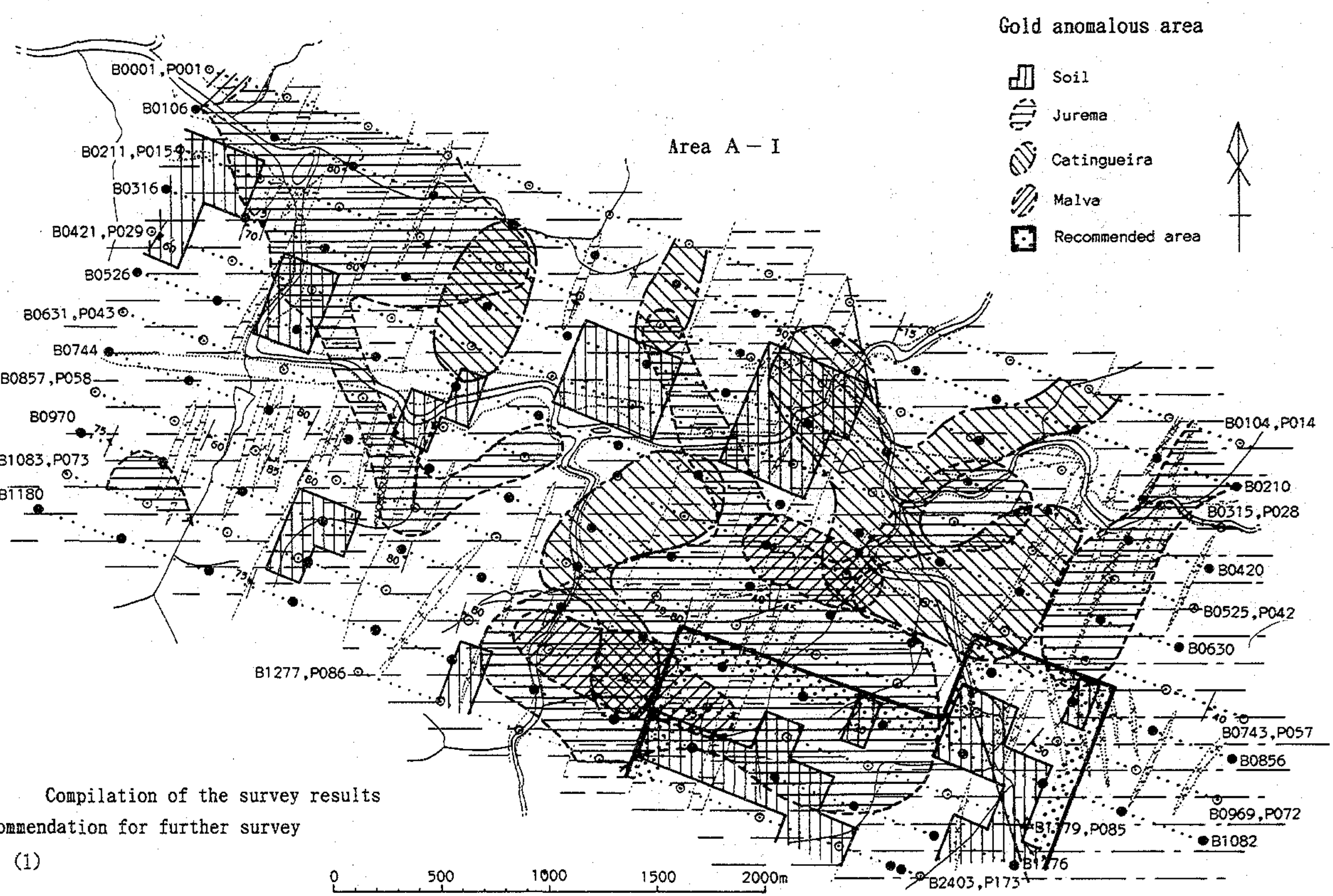



Fig. 2-1　Compilation of the survey results and recommendation for further survey (area A) (1)

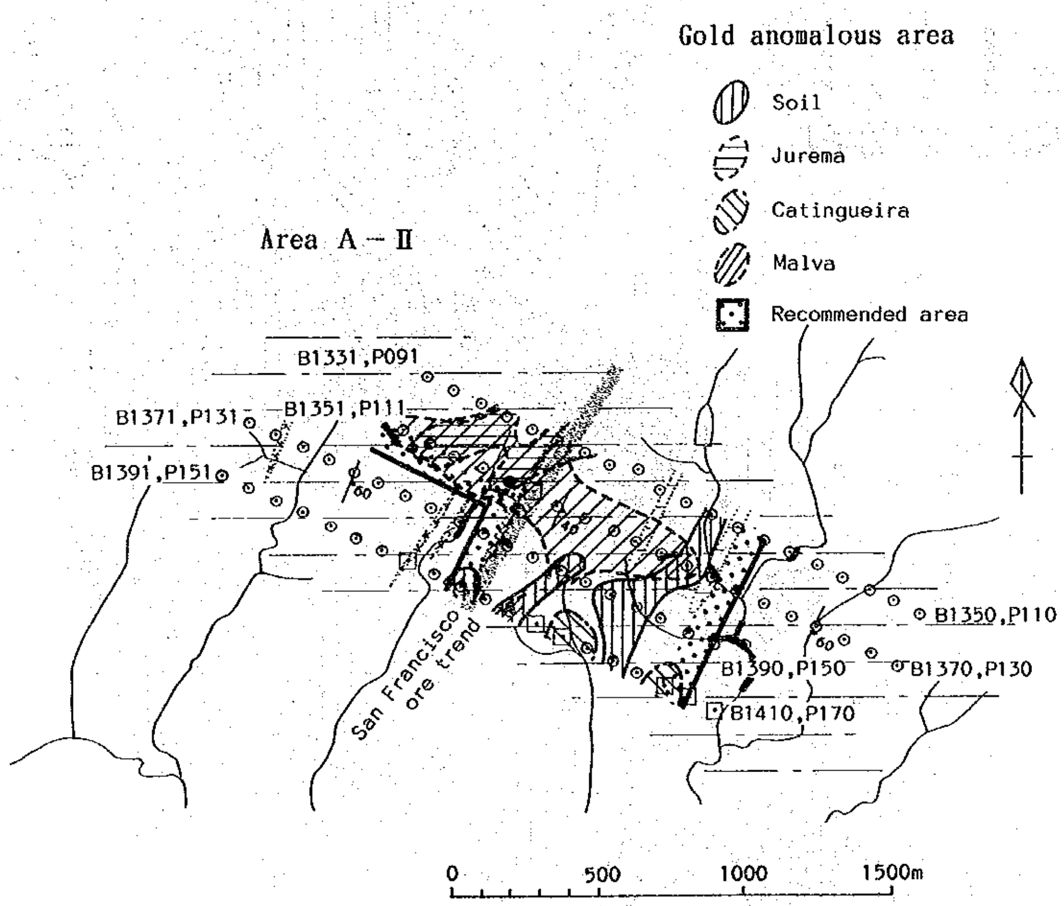



Fig. 2-1　Compilation of the survey results and recommendation for further survey (area A) (2)

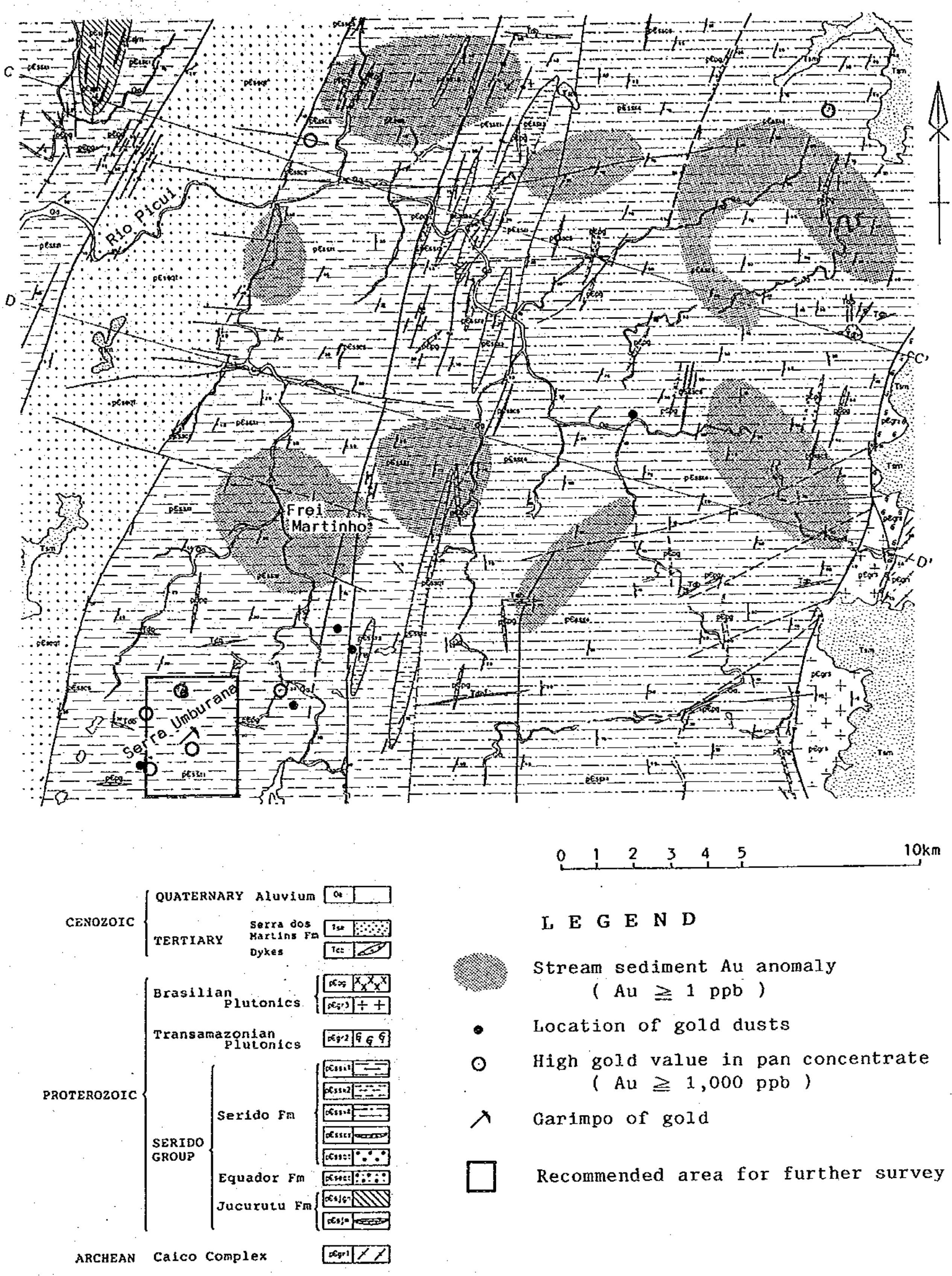



Fig. 2-2 Compilation of the survey results and recommendation for further survey (area B)

CONTENTS

# PART I

# GENERAL

# Chapter 1 - Introduction

## 1-1 Progress of the project

### 1-1-1 Progress of the survey

As stated in the Scope of Work agreed between the governments of the Federative Republic of Brazil and Japan, this survey was carried out in the area of Currais Novos, the state of Rio Grande do Norte, Brazil. The purpose of the project is to disclose geology and gold mineralization in the area. The project covers an area of 5910km$^2$ and it is programmed to be concluded in a period of three years.

This is the second year of the project. The field survey was executed by both Brazilian and Japanese members.

In the phase I surveying, the interpretation of LANDSAT TM image was executed to realize a general geology in the project area. The area for the field survey was reduced into 1000km$^2$ by the study of previous information in order to take up a potential area for the gold mineralization. Geological survey and geochemical sampling were carried out in the area. As the result of those surveys, gold anomalies were detected to the south of the Sao Francisco mine. Detailed survey was recommended in the area with gold anomalies for phase II.

Following to the phase I survey, biogeochemical and soil geochemical survey were executed in the anomalous zones of phase I survey to further reduce the area. Geological survey and stream sediment sampling were also carried out in the area of 500km$^2$ to the south for a new gold mineralization.

### 1-1-2 Results of phase I survey

Two main gold mineralization sites are recognized in the phase I survey area. One is the well known gold deposits of the Sao Francisco mine. The other is the gold occurrence situated 7km west of Sao Tome. The ore in both deposits consists mainly of sulfide-bearing quartz veins, so that the mineralization has been considered as being of hydrothermal type. Mineralized zones in the area are invariably associated to structural zones trending NNE, suggesting that the ore genesis is strongly related with the geologic structure.

Anomalous areas for Au have been disclosed by a stream sediment geochemical survey. These anomalous areas are situated west to southwest and south to southeast of the Sao Francisco mine, and around the mine. The anomalous area in the west-southwest of the mine trends north northeast and is in conformity with the local geologic structure. On the other hand, the anomaly in the south-southeast of the mine do not show, in its distribution, a clear relationship with the geologic structure.

Taking into account these characteristics, the anomalous area in the west-southwest of the San Francisco mine can be pointed out as having higher potential for gold mineralization than that one in the south-southeast of the mine.

Moreover, the west-southwest area extends further to the south outward of the present survey area. Based on the fact that this high potential area is situated in the southernmost part of the survey area, faults trending north-northeast nearly the Sao Francisco deposit possibly extends southwards.

The interpretation of the analyses of pan concentrates of stream sediments revealed that anomalous areas for gold are concentrated in the neighbouhood of the Sao Francisco gold deposit, and also in the area situated 7 to 10km west-northwest of the Sao Francisco mine. The origin of gold in the area west-northwest of Sao Francisco mine is not known. Further detailed studies will allow to shed some light on its origin.

### 1-1-3 Recommendations for phase II survey

Based on the results of phase I survey, following areas recommended for further detailed survey:

1) The area situated west-southwest of Sao Francisco mine, where stream sediment anomalies were concentrated. In this area, detailed surveys to disclose under structures and to delineate possible mineralizations were recommended.

2) The area to the south of phase I area. In this area geological traversing, geochemical survey and geophysical survey were recommended.

3) The anomalous area for gold from pan concentrate situated about 7 to 10km west-northwest of the Sao Francisco mine. In this area, more detailed surveys to disclose under structures and to delineate possible mineralizations were recommended.

4) The anomalous area in the stream sediment survey, situated to the west-southwest of Sao Francisco mine. In this area, detailed surveys were recommended for the same purposes as 1).

## 1-2 Area, purpose and surveying in phase II

The survey area in phase II is devided into two areas, which are called area A and area B. Area A is decreased from the phase I survey area and is situated to the south of the Sao Francisco mine. Area A includes four small areas. They are A-I, A-II, A-III, A-IV. Total area is 25 km$^2$ (Fig.1, FIg.II-1-1). Area B is situated to the south of area A, in between 6°17' and 6°29' south latitude, 36°18' and 36°31' west longitude. The area of survey is 500km$^2$ (Fig.1).

The purpose of the survey in area A is to disclose if the anomalous points detected by streams sediment geochemical survey in phase I forms anomalous zones or not. Soil geochemistry and biogeochemistry were applied for that purpose. Soil sampling points were located to cover valleys where anomalous points were detected. Biogeochemical survey were carried out in order to correlate concentrated elements in soil with those in leaves of plants and to find out a relationship between concentrated elements in plants and underground mineralizations. Three elements of Au, As and Sb were applied as tracers for the soil geochemistry and five elements of Au, As, Sb, Fe and Al were utilized for biogeochemistry as tracers.

The purpose of the survey in area B is to realize geology and disclose geologic and geochemical characteristics of gold mineralization. Geologic survey and stream sediment geochemical survey were executed.

The geologic survey was carried out with a density of traversing, 0.8km/km$^2$, aiming mainly to comprehend and state the relations among the geological units. The geochemical survey was executed with the purpose to know the distribution and the relationship among the 13 selected elements in this area by sampling stream sediments with a density of 1.6 samples/km$^2$.

Pan concentrates were also sampled in places where gold anomalies has been formerly reported, and were detected in this survey. The samples were observed by hand lens if there are any gold dusts or not. The samples were also analysed for 7 elements in order to realize geochemical relation between the area and the concentration of elements.

Field works and laboratory tests in phase II survey were summarized in Table I-1-1.

Table I-1-1 Summary of field works and laboratory tests

Area A

| Field works | | Laboratory tests | |
|---|---|---|---|
| | | Chemical analyses | |
| Survey area | 25km² | Plants (Au, As, Sb, Fe, Al) | 510 |
| Geochemical sampling | | Soils (Au, As, Sb) | 2400 |
| Leaves of plants | | Rocks (SiO2, TiO2, Al2O3, Fe2O3, FeO, MnO, MgO, CaO, Na2O, K2O, P2O5, LOI, Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) | 5 |
| Jurema | 173 | | |
| Catingueira | 172 | | |
| Malva | 165 | Pan concentrates (Au, Ag, Mo, W, Sn, Ta, Nb) | 19 |
| soils | 2400 | Thin section observation | 5 |
| Pan concentrates | 19 | Ore assay (Au, Ag, As, Cu) | 6 |
| | | X-ray diffractometry | 2 |

Area B

| Field works | | Laboraory tests | |
|---|---|---|---|
| | | Chemical analyses | |
| Survey area | 500km² | Stream sediments | 811 |
| Geological traversing | 438km | Rocks (SiO2, TiO2, Al2O3, Fe2O3, FeO, MnO, MgO, CaO, Na2O, K2O, P2O5, LOI, Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) | 25 |
| | | Pan concentrates (Au, Ag, Mo, W, Sn, Ta, Nb) | 62 |
| Geochemical sampling | | Thin section observation | 25 |
| Stream sediments | 811 | Ore assay (Au, Ag, As, Cu) | 6 |
| Pan concentrates | 62 | X-ray diffractometry | 8 |
| | | Fruid inclusion study | 3 |

## 1-3 Organization of the survey team in phase II

The members of the survey in phase II are as follows;

| Japanese side | Brazilian side |
|---|---|
| Kenzo Masuda; MMAJ, Japan | A.A.F. Mont' Alverne, DNPM |
| Hideaki Mukai; MMAJ, Brazil | J.R.A. Dantas, DNPM |
| Kazuo Kawakami; Bishimetal. | R.B. Santos, DNPM |
| Norio Ikeda; Bishimetal. | M.C. Lins, DNPM |
| Masakatu Onodera; Bishimetal. | A.O. Melo Junior, DNPM |
| Mitsutaka Bamba; Bishimetal. | C.A. Ferreira, CPRM |
| | J. Luis da Costa, DNPM |

Bishimetal: Bishimetal Exploration Co. Ltda.

## 1-4 Period of the survey in phase II

The phase II of this project was carried out in the following steps:

- Field surveying; from 03.08.1990 to 07.11.1990
- Preparation of the report; from 08.11.1990 to 20.02.1991

## Chapter 2-Geography of the survey area in phase II

### 2-1 Location and access

The project area is located in the central to southern part of the State of the Rio Grande de Norte, which is situated in the northeastern region of Brazil. This area extends from 5°30' to 6°45' south latitude, and from 35°50' to 36°35' west longitude (Fig.1). The survey area in phase I is located inside the area discribed above, extending from 5°52' to 6°14' south latitude and 36°04' to 36°25' west longitude. The area A in phase II is located inside the southern part of the area in phase I. Area B is located adjoining to the south of the survey area in phase I, extending from 6°17' to 6°29' south latitude and from 36°18' to 36°31' west longitude.

The city of Currais Novos, with population of about 25,000, is situated to the west of area A and northwest of area B. The city of Currais Novos can be accessed by two ways. One way is from Recife, capital of the State of Pernambuco. The journey is of 420km through the route BR-101, PB-054, BR-230 and BR-427. Another way is from Natal, capital of the State of Rio Grande do Norte. The journey is of only 190km following BR-226. There are regular airline services at both Recife and Natal.

The route BR-226 passes through the central part of area A in east-west direction. An unpaved road, crossing in the western part of area B in north-south direction, connects the city of Currais Novos with Frei Martinho and Picui, both of them are in the State of Paraiba.

There are many unpaved roads in area B. However, all of them can not be seen in a topographic map prepared for this project, because the map was based on the aerophotographs taken in 1967.

## 2-2 Topography and hydrography

The project area can be divided into three areas in terms of topographic features. Flat plains dominate in the northern part. An undurating topography with mountains ranging in altitude between 300m and 600m above sea level. And the central western part of the area is occupied by the Serra da Santana with altitude up to 700m above sea level.

The survey area in phase I is dominated by mountains ranging in altitude from 300m to 600m above sea level. Area B in phase II is also occupied by mountains ranging in altitude from 300m to 600m above sea level.

The area B can be further subdivided into three kinds from the viewpoint of the topography. One kind is characterised by the topography of so-called "mesa" with the altitude 600m and 660m. This type of topography can be seen in the western most part, central northern part and eastern-most part of the survey area. The top of the mesa forms peneplain underlain by Tertiary Serra dos Martins Formation. Another kind is remarkable mountin ranges with steep cliffs, 400m to 650m high above sea level. The mountain ranges trend north northeast in the western part of the survey area. This topography corresponds to the distribution of Equador Formation. The rest of the area is characterized by gently undurated mountain ranges with 340m to 500m above sea level. Even in the gently undurated mountain ranges, steep cliffs can be seen to the west of serra Vermelha in the central part of the survey area. This topography was appeared by the difference of resistance against the weathering between siliceous mica schist and pelitic mica schist. Another steep cliffs trending north northeast can be seen 2.5km west of Serra Vermelha. This topography is thought to be manifested by the difference of resistance against weathering because of the existence of fault.

Slightly projected topography few meters wide and few meters to about 10m high, just like corridor, are existed in the entire area. This topography are formed due to the

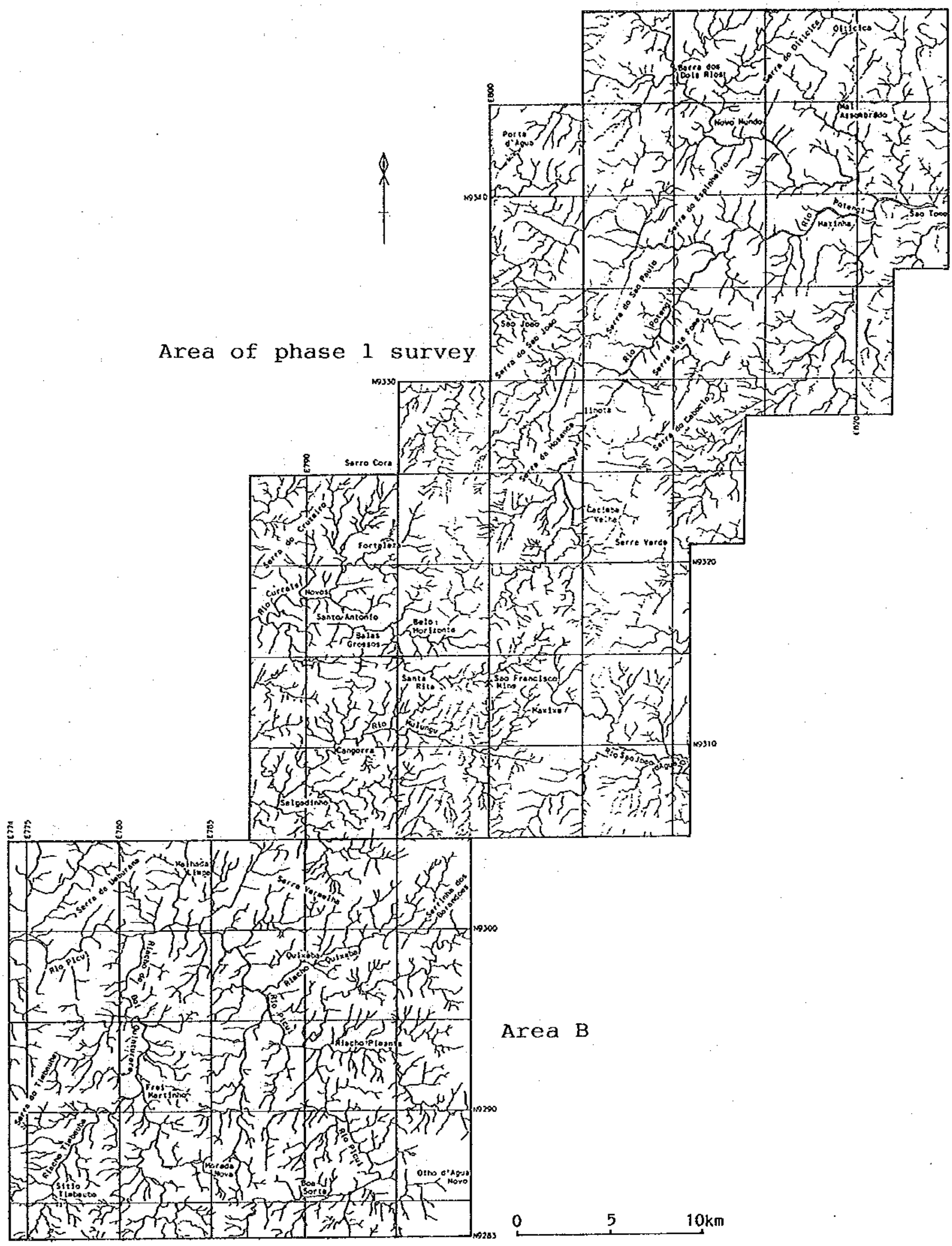



Fig. I-1-1 Drainage system in the survey area (area A and B) existence of pegmatites. Therefore, the topography generaly trend north northeast, with some exceptions of trending northeast and east.

## 2-3 Climate and vegetation

The climate in the project area is semi-arid, according to the climate belt classification, and belongs to the BShs type of the Koppen's climate classification.

The annual climate in this area can be roughly divided into two major seasons. The rainy season lasts from February to May, and the rest of the year is considered to be the dry season. It rains intermittently during the rainy season, and only scarcely in the dry season.

The temperature is almost constant throughout the year, with maximum vlues of 40°C and minimum values of 20°C.

The majority of streams in the project area have water only during the dry season. Accordingly, almost all creeks were dried during the field survey of this year. During the survey period, it rained little in early August, at the end of September and at the beginning of November.

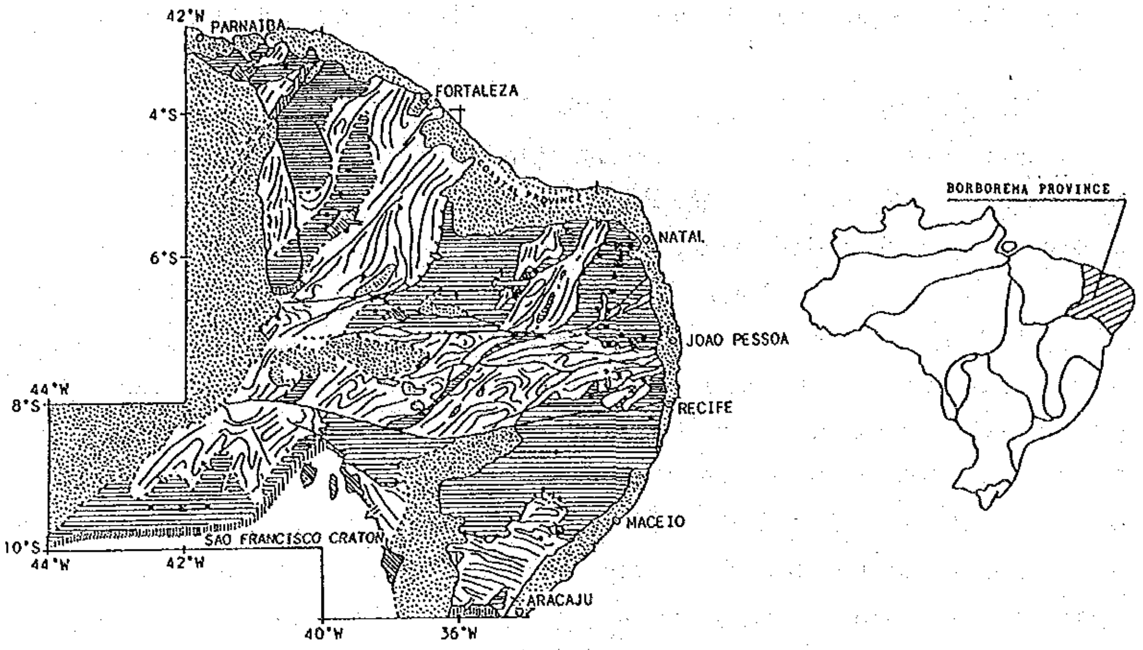
Concerning to the vegetation, this area is included in the so called caatinga district. The district is characteristic of the northeast region of Brazil. Bushes two to four meters tall are typical in the area. Some trees up to ten meters tall grow sparcely along creeks. Principal plant species in the caatinga area are jurema Preta, catingueira, malva, pereiro, marmereiro, morequiduro, xique-xique and so on. Jurema Preta, Catingueira and Malva were applied for botanical geochemistry. Leaves grew rapidly right after the rain, although it was dry season during the field survey.

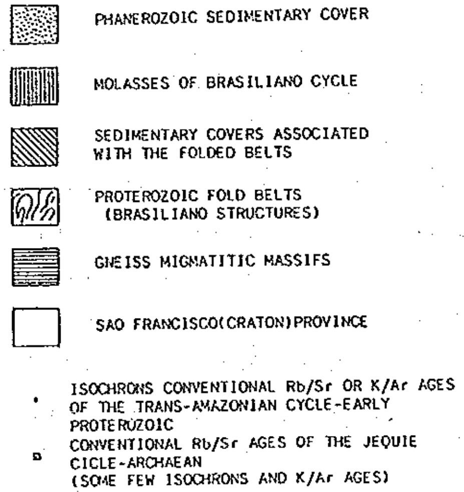
## Chapter 3-Geologic background in the phase II survey area

The phase II survey area is included in one of the regional geotectonic units in the northeastern Brazil. The unit is called Borborema Province (Fig.I-3-1). The Borborema province is divided into blocks and folded belts in view of the Precambrian geology (Brito Neves, 1975, 1983; Almeida et al., 1976). The blocks are composed of gneisses, migmatites and granites. On the other hand, the fold belts are principaly composed of metavolcanics and metasediments. The phase II survey area is situated in the folded belts. Brito Neves (1983) divided the Bolborema province into five geologic domains based on the tightness of fold and metamorphic grade. The survey area is located in the Serido region of the Central domain (Fig.I-3-1).

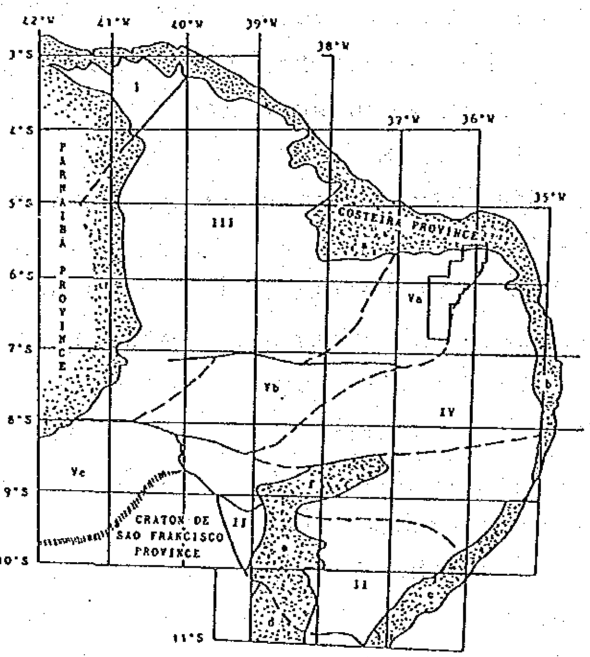
The Precambrian stratigraphy in the Serido region comprises Archean Caico Complex and Proterozoic Serido group (Jardim de Sa & Salim, 1980). The Caico Complex corresponds to the block composed of gneiss, migmatite and granite and the Serido group to the folded belt composed of metavolcanics and metasediments. The stratigraphy of the Serido group is composed of Jucurutu, Equador and Serido Formations from the bottom to the top. Cretaceous Jandaira and Acu Formations, Tertiary Serra dos Martins Formation and Quarternary colluvial sediments and alluviums are layed on the Precambrian formations.

In the entire survey area all the formations except Jandaira Formation are ditributed. The Serido Formation, the Acu Formation and the Serra dos Martins Formations unconformably lie on the Caico Complex, the Serido Formation and the Acu Formation respectively. Three formations in the Serido Group partly contact with each other (Fig.II-2-2). The contacts of them are comformity. The Borborema Province was under the influences of the Jequie Orogenic Cycle (2,900-2,600ma), Transamazonian Orogenic Cycle (2,100-1,800ma) and Brazilian Orogenic Cycle (700-450ma). In the Serido region two steps of Transamazonian tectonism and three steps of




(a)Principal geologic elements, modified by Brito Neves in 1983




| | | | |
|---|---|---|---|
| I - Rio Coreau Domain<br>II - Sergipano Domain<br>V - Central Domain<br>Va - Serido<br>Vb - Pianco-Alto Brigida<br>Vc - Riacho Pontal-Rio Preto | CONVENTIONAL SYSTEMS (OROGENIC BELTS) | SEDIMENTARY BASINS<br>PARNAIBA PROVINCE<br>COSTEIRA PROVINCE<br>a-Apodi<br>b-Pernambuco-Paraiba<br>c-Sergipe-Alagoas<br>d-Tucano Sul<br>e-Tucano Centro<br>f- Jatoba | |
| III - Jaguaribeano Domain<br>IV - Centro-Oriental Domain | VESTIGIAL SYSTEMS and "MASSIFS" | | |

(b)Geologic domains after Brito Neves,1983

Fig. I-3-1 Principal geologic elements,(a); and geologic domain,(b); in the Borborema Province

Brazilian tectonism are realized (Fig.II-2-2). The tectonic movement of the Transamazonian Orogeny is represented by low angle shear and that of the Brazilian Orogeny by high angle shear (Jardim de Sa, et al, 1988). Metamorphic degree of the two tectonism attained to the amphibolite facies.

There exist many intrusive rocks along those sheared zones. Picui fault divides Central domain from Centro-Oriental domain as a tectonic lines in the phase II survey area (Fig.I-3-2).

In the project area, the planer shape of the distribution of geological formations typically extend in the direction of north northeast, the Caico Complex ocupies eastern and western margins of the area and the Serido Formation lies on the central part of it as shown in Fig.II-3-1 and Fig.II-3-2. In the northern half of the project area, the Caico Complex and the Serido Formation distributed side by side trending north northeast (Fig.I-3-2).

The Serido Formation occupies widest area in the project area, then Equador and Jucurutu Formations. The Equador Formation is distributed in the southwestern part of the project area also trending north northeast. The Jucurutu Formation surrounds the Caico Complex and occupies only small area in the southwestern end and the central northern part of the project are (Fig.I-3-2). The Caico Complex is characterized by the lithology composed of gneiss-migmatite-granite, the Jucurutu Formation is characterised by the lithology of gneiss with calc-silicate rocks. The Equador Formation is principally composed of (muscovite) quartzite. The Serido Formation is characterised by biotite schist accompanied with muscovite, cordierite and garnet. Calc silicate thin beds are intercalated in the Serido Formation like in the Jucurutu Formation.

There are scarn type tungsten deposits, vein type gold deposits and pegmatite type columbite-tantalite deposits in the project area (Fig.I-3-2).

The survey area in phase II is shown in Fig.I-3-2. The

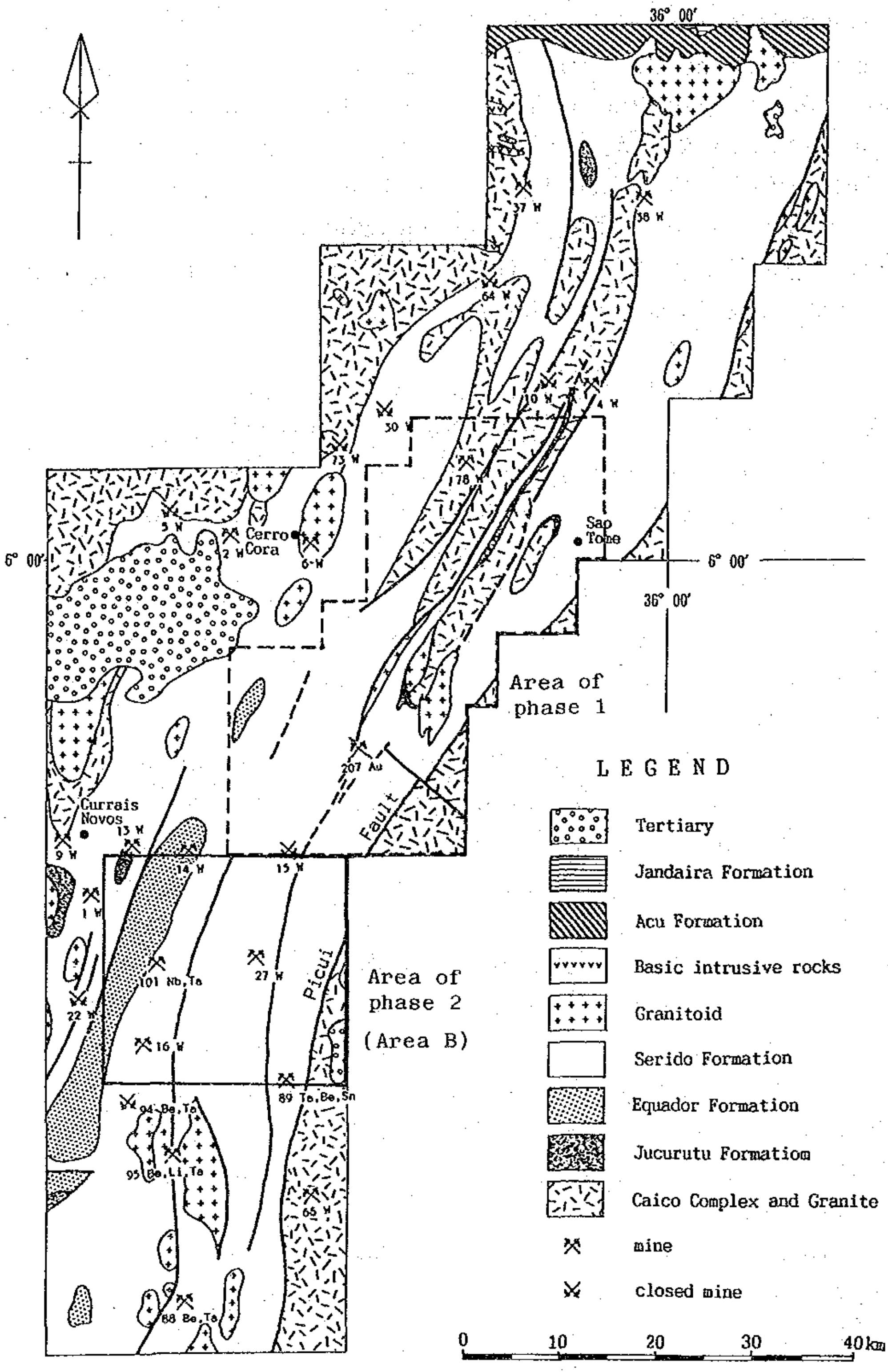



Fig. I -3-2 General geology and known mineral deposits in the project area

area is mainly occupied by the Serido Group with minor area of the Caico Complex. At the eastern end of the survey area, the Picui fault, which trends north northeast to north, devides the Central Domain from the Centro-Oriental Domain.

## Chapter 4-Compilation and discussion of the phase II survey

### 4-1 Geology and structure

The stratigraphy of area B is composed of Archean Caico Complex, Proterozoic Jucurutu, Equador and Serido Formations, Tertiary Serra dos Martins and Quarternary alluvium from the bottom to the top. The Serido Formation occupies wides area in the survey area. The Jucurutu Formation is locally distributed in the northeastern corner of the area. The Equador Formation is also distributed in the western part of the area. The Tertiary Formation occupies the area in the eastern mot part of the survey area to the outside of the survey area. In the western and central northern part of the survey area, the Tertiary Formation is very locally distributed.

The Caico Complex is gneisses biotite granite. The Jucurutu Formation is mainly composed of gneisses accompanied by calc-silicate rock and limestones. The Equador Formation is comprised of muscovite quartzite. The Serido Formation is characterised by biotite schist with muscovite, cordierite and garnet. The Serido Formation is lithologically divided into two principal units to the east and to the west in the central part of the Formation. The western half is mainly composed of biotite schist accompanied by small amount of garnet, muscovite and cordierite. The eastern half is alternations of cordierite-garnet-biotite schist, garnet-biotite schist and biotite schist. In the survey area, Aechean biotite granite gneiss, Proterozoic augengneiss and biotite granite are intruded and Tertiary basalt dikes trending east can be seen in the whole survey area.

Many structural elements trending north northeast to north as well as trending east are recognised in the survey area. The structures trending east are younger than the others.

The shape of distribution of each formation of the

Serido Group distinctively trends north northeast to north. Faults also trend same direction. Picui fault, which is regional tectonic line, runs in the eastern most part of the survey area. The contact between the western end of Equador Formation and the Serido Formation is also fault. In the central part of the Serido Formation fault also exists. The trends of the faults correspond with the strikes of the schistosities and the trend turns from north northeast in the northern part to north-south in the southern part. Folded zone about 3km wide also extends in the same direction as that of faults in the Serido Formation in the central part of the survey area. The folded zone is made by many folds with short wave length, trending in the same direction at that of folded zone. At the western end of the folded belt a fault runs and the eastern end of it corresponds to the lithological contact. In this folded zone, quartzite and silicious schists in a small scale apear trending north.

Many faults trending west northwest to east north east can be recognized in the whole area. The direction corresponds to that of the Tertiary basalt dikes. These faults turn the direction in the central part of the area from west northwest in the western part of the area to east northeast in the eastern part of the area.

## 4-2 Mineralizations and their structural control

There are many quartz veinlets, which form a zone, with mineralization in biotite schist in area A-III. Each veinlet is 1 to 3cm wide. The zone, which is composed of some tens of veinlets, is 5 meter wide. In the zone, some veinlets with copper mineralization exist. The strike of those veinlets are parallel to schistosities of the host rock. Therefore those veinlets were thought to be formed at the same time and/or before the metamorphism. Chemical assay showed the contents of gold to be trace.

Gold mineralization except placer deposits can be seen at three points in B-area. Quartz veins accompanied with copper minerals such as malachite can also be seen in several places. They have possibilities to come with gold mineralization. The quartz vein in the Serido Formation in the Serra do Umburana at the southwestern most part of the survey area is in a large scale. The quartz vein is 0.3 to 2 meters wide and more than 200 meters long. It strikes north 5 degrees east and dips 70 degrees west. On the other hand, the schistosities of the Serido biotite schist strike north-south and dip 5 degrees east. Therefore the quartz vein cuts the schistosities of the host rock by wide angle. The quartz vein is thought to be in a extension fracture in view of the geological circumstances.

Geological structures in the area of the Serra do Umburana is different from the surrounding area. Schistosities of biotite schist generally dip 20 to 30 degrees and more in the surrounding are. However, they dip about 10 degrees and have low-angled wavy structure in this area. And the structure is a monoclinic, generally speaking.

The strike of pegmatite dikes is also characteristic in this area. The pegmatite dikes generally strike parallel to the schistosities of the rocks and across the schistosities by low angle in the surrounded area. However, the dikes strikes east-west, east northwest and northwest. The quartz vein strikes parallel to the schistosities and acrossing the pegmatite dikes.

The direction of streams in this area can be thought to be composed of north northeast to north-south as described in Chapter 2, 2-2 Topography and hydrology.

The quartz vein in the Serra do Umburana is colorless and transparent with druses, accompanied with malachite, hematite and limonite. The quartz vein has 0.2 ppm of gold, 103.8 ppm of silver and 5 ppm of arseny.

Other quartz veins with possible mineralization are at Morada Nova, Salgadinho, Quixaba and northeast of Riacho da Boi Quinturare. These quartz veins are parallel to the schistosities. Therefore, they are thought to be formed before the latest metamorphism or to have been in the original formation. Quartz vein in Peda Serra is a different one. It is pegmatitic and with malachite.

The quartz vein in Morada Nova contain 0.1 ppm of gold, 3.1 ppm of silver and 4 ppm of arsenic. The quartz vein in Pe da Srra contain 0.1 ppm of gold, 9.6 ppm of silver and 4 ppm of arsenic (Fig.I-2-4).

These veins resemble that of San Francisco in view of the rate Au/Ag rather than that of garimpo to the west of Sao Tome. The contents of arsenic against that of gold and silver in these veins is about same as that of San Francisco. The quartz vein in Serra do Umburana resembles the one of San Francisco gold deposit in view of accompanying sulphides such as pyrite and copper mineral.

## 4-3 Geochemistry and its relation with mineralization

Panning and gold dust observation were executed in three small areas in phase II survey area where high arsenic content were detected by stream sediment geochemistry. Gold dust was observed at two points in the drainage of Rio Potengi in the central part of the phase II survey area. In the drainage of Rio Potengi some pan concentrate samples also showed high gold content. In the other drainage to the south of Sao Tome, however, no gold dust was found and point with high gold content was not detected. To assess a correlation between gold and arsenic values in the phase II survey area, the amount of pan concentrate samples may be too little. However, it can be said that gold and arsenic values do not always have a correlation, according to the survey results. Gold and arsenic values may be related to the lithology and/or geological structures separately. Rocks containing rather high gold value are in the Serido Formation, according to the survey in this project. Biotite schist contains 2 to 9 ppb of gold, calc silicate rocks show high gold content at the contact between the Serido Formation and the Equador Formation and near the Picui Fault at the eastern end of the survey area. The calc silicate rock contains maximum of 35 ppb of gold.

On the other hand, high arsenic value is detected only in the part of calc silicate rocks. This fact supports following matter. A zone trending north northeast in the phase III survey area, where high arsenic values were detected in the stream sediment survey coresponds to a zone where a large amount of calc silicate rocks were intercalated. In the soil geochemical survey in phase II, high arsenic values were detected in the part of the Serido Formation where a number of calc silicate rocks were intercalated.

Gold concentration in the quartz veins is about 100 times as much as that in host rocks in the San Francisco deposits, to the west of Sao Tome and in the Serra do Umburana. On the other hand, arsenic content in the veins is about 10 times as much as that of host rocks. Arsenic is rather rich in the host rocks. Accordingly, arsenic concentration with mineralization may not be clearly detected by geochemical survey such as stream sediment survey and soil survey.

From the above mentioned, gold does not occur always with arsenic. Accordingly, gold can not always be detected together with arsenic in the geochemical survey.

High gold values did not follow the southern extention of San Francisco ore trend, they appeared little to the south with same trend. No high gold values also could be detected in the stream sediments around the Serra do Umburana where gold bearing quartz vein is hosted in the biotite schist of the Serido Formation. These dislocation of high gold values can not be clearly explained.

## 4-4 Potential for mineralization

In area A, the southeastern part of area A-I and central eastern part of area A-II were selected for potential areas from the soil survey. From a viewpoint of the size of the anomalous area, the grade of the anomalous gold values and the correlation with geological structures, the area in area A-II has a priority.

In area B, the gold bearing quartz vein in the Serra do Umburana has high potentiality. Regarding to the vein, the relation with some fault can not be pointed out, though the existence of veins of San Francisco deposit and the one to west of Sao Tome were thought to be controlled by some fault. However, the vein in the Serra do Umburana is in the characteristic position from the structural point of view. That is, dip of the host biotite schist and the strike of peegmatite dikes in this area are quite different from the surrounding area. The vein contents 0.3 ppm of gold and 103.8 ppm of silver. Furthermore, gold dusts were observed at the foot of the Serra do Umburana and high gold contents were also detected in pan concentrates at about the same place. The entire picture of the vein is not disclosed yet and there are not any information about this vein, either. As the surface extention is estimated to be as much as about 200m, this is worhty to be surveyed in detail.

In the upper reaches of the Riacho Pimenta in the east of area B, some points with high gold values were located by the stream sediments survey. This area can neither be related to any lithological characteristics nor geological structures. Therefore, this area is concluded to be of no value for further survey.

## Chapter 5-Conclusions and recommendations

### 5-1 Conclusions

(1) Area A

Biogeochemical and soil geochemical surveys were executed in areas A-I and A-II by applying Au, As and Sb elements as tracers. Though every element is not highly concentrated in soil, they delineate anomalous zones separetaly. No correlation were defined among the contents of elements. Therefore, only gold may be usefull as tracer for the gold exploration by soil geochemical survey. In plant also, the three elements are not highly concentrated. However, every element difine some anomalous zones separately. No correlation was not also detected among the contents of each element in plants. A slight correlation can be detected between arsenic content in soil and that in leaves of plants. However, localities of Au anomalous areas detected by plants are somewhat correlated with those of plants in a topographical point of view.

Accordingly, one area in the southeast corner of area A-I and another area extending from the supposed southern extention of the Sao Francisco deposit to the east by 500 meters were defined as potential areas in view of the high gold values and the size of the area with the high gold values in soil.

Soil geochemical survey were carried out in areas A-III and A-IV by applying above three elements as the tracers. Gold contents are very low in the two areas. Furthermore, no correlation was defined between those three elements. These two areas are interpreted not to have any potentiality.

(2) Area B

This area is widely underlain by Precambrian formations. Tertiary formation is distributed in a small area laying on the Precambrian formations. Quarternary alluvium is also ditributed. The Precambrian are Archean Caico

Complex and Proterozoic Serido Group. The stratigraphy of the Serido Group is composed of Jucurutu Formation, Equador Formation and Serido Formation from the bottom to the top. The caico Complex, the Jucurutu Formation, the Equador Formation and the Serido Formation are principally composed of granite, gneiss, quartzite and biotite schist respectively. The Caico Complex and the Jucurutu Formation are locally distributed in the southeasternmost part and in the northwestern corner of the area respectively. The Equador Formation is in the western part of the area in a small scale. The Serido Formation occupies wide area in the central part of the area. The shape of distribution of every formation is elongated, trending north-northeast. The Serido Formation was divided into three units from the lithological point of view in phase I. It was further divided into four units in phase II.

In a structural point of view, a number of faults trending north northeast to north and west northwest to east northeast can be traced in the entire area. The faults trending north northeast to north are regional ones and they pass through the survey area. Especially, the fault in the eastern end of this area, which is called Picui Fault, is very important from the regional structural point of view in the northeastern Brazil. The faults trending west northwest to east northeast are in smaller scale than the ones trending north northeast to north and are thought to have acted in younger ages. A folded zone about 3km wide, trending north northeast to north in parallel with regional faults, can also be recognized in the central part of the Serido Formation. This folded zone is also regional ones.

A quartz vein was excavated in a small scale in Serra do Umburana in the southwestern end of the area B. This vein is estimated to be 0.3 ppm to 2 meters wide and about 200 meters long. Chemical assay of samples taken from the vein showed 0.2 ppm of gold and 103 ppm of silver. It is assumed to be hydrothermal quartz vein filled in tentional open fracture from its appearance and characteristics.

Both the locations of the quartz veins in Sao Francisco deposit and in the west of Sao Tome were thought to be related to the geological structure such as fault. On the other hand, the quartz vein in Serra do Umburana is not related to fault. However, the area where the vein is situated, is in quite different structure from the surrounding area in view of the dips of the schistosity of host rocks and the strike of pegmatite dikes compared to the surrounding area. Accordingly, the geological structure and the conditions regarding to the genesis of the vein is to be realized.

According to the stream sediment survey, Au, As, Fe, Mo and Nb are recognized to make anomalous areas. Correlations can be recognized among the contents of elements, Fe and Mn, Fe and Mo, and Mo and Nb. These pairs of elements can be thought to be related with the composition of rocks in this area. Correlations among elements such as Sn-Be, Fe-Mn-Mo, Ta-Nb, and Li are defined from the factor analysis. Correlations between Sn and Be, and Ta and Nb are supposed to be related with the mineralization in this area. The others are thought to be related with chemical composition of the rocks distributed in the area. Correlation was defined between Au and As in stream sediments in phase I survey. However, no correlation between Au and other elements could be detected in phase II survey.

Gold anomalous areas are dispersed in the area B. Furthermore, points with high gold values are few in the anomalous area and they ae not clearly centered around. Nearby the upper reaches of the Riacho Pimenta in the southeastern part of the survey area, some points with higher gold values are relatively centered. Correlations among the anomalous area and lithology and/or geological structure can not be pointed out.

## 5-2 Recommendations for phase III survey

From the integral analysis of the results of the phase

II survey, following areas are recommended for further detailed survey;

(1) Area A

Firstly, the anomalous area in the southeastern part of area A-I, where soil geochemical anomalies were delineated. In this area, detailed soil- and bio-geochemical methods and geophysical method are suggested.

Secondly, the area to the south of area A-II and the area to the north of Sao Francisco deposit, where supposed southern and northern extensions of the Sao Francisco deposit are detected. In this area, detailed soil- and bio-geochemicl methods and geophysical method are suggested.

(2) Area B

The area in the Serra do Umburana, where quartz vein with gold mineralization is found. In the area, detailed geological and geophysical surveys are suggested to disclose gold mineralization.

# PART II

# GEOLOGIC AND GEOCHEMICAL SURVEYS

## Chapter 1 Geochemical survey in area A

### 1-1 Geology and mineralization in area A

The area A is underlain by the schists of Serido Formation, which are classified into five lithologic units. They are pCssx1, pCssx2, pCssx4, pCsscs and pCssaf. The first one is mainly composed of biotite schist accompanied with garnet and cordierite. The second one is siliceous biotite schist. The third one is alternation of biotite schist, garnet-biotite schist and cordierite-biotite-garnet schist. The fourth one is calc silicate rocks, and the last one is amphibole schist.

The five lithological units are distributed in area A-I, area A-II, area A-III and area A-IV as the following;

In the area A-I, pCssx1 is mainly distributed, and pCssx4 is in the east end of the area. The former intercalates pCssx2, which extends in the direction of NNE-SSW. There are two zones of pCssx2 350m to 450m wide and several zones of them 25m to 100m wide. pCssx4 intercalates thin beds of pCsscs and pCssaf. Many pegmatite dikes, trending north northeast, and basalt dikes, trending west northwest, are intruded in the area.

Area A-II is underlain by pCssx4 and it intercalates thin beds of pCssx2 and pCsscs.

In the area A-III pCssx4 is mainly distributed. pCssx1 is also distributed in the west end of the area. pCssx4 intercalates more than ten beds of thin lenticular pCsscs. Many pegmatite dikes are intruded in the area.

Area A-IV is underlain by pCssx4 and it intercalates pCssx2 trending north northeast, being 300m wide.

Planar schistoshities of schist strike NNE-SSW and dip gently east in the eastern part of area A-I and dip steeply east with the same strike in the rest of the area. Faults and lineaments detected from aerophotographs strike NW-SE and NE-SW.

Quartz veinlets including copper minerals are found in

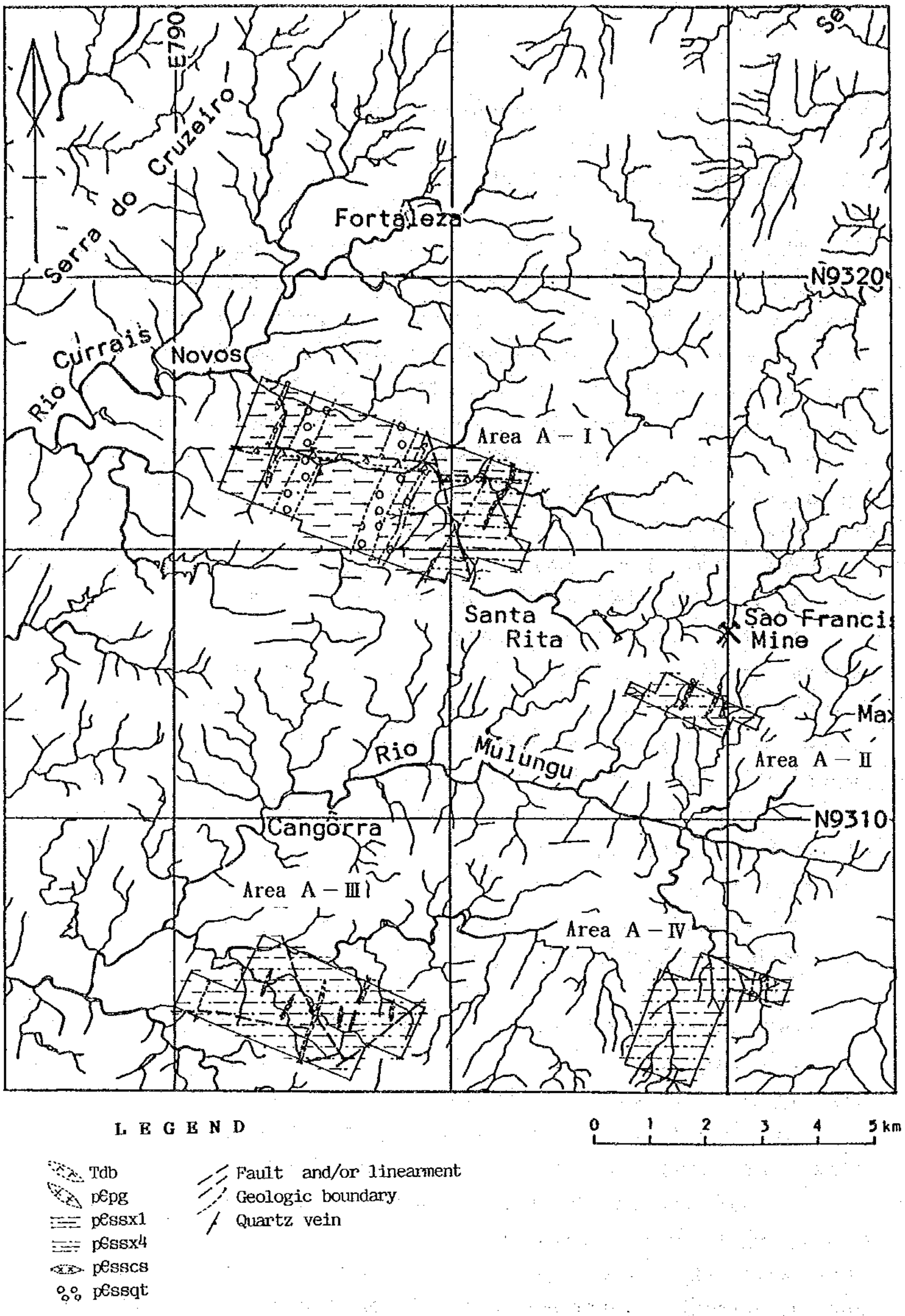



Fig. II-1-1 Geology of area A

the central western part of the area A-I. One garimpo, where placer gold have been mined, is in the eastern part of the area A-I, six in the area A-II and two in the area A-III.

Quartz veinlets including copper minerals are hosted in the biotite schists along the schistosities trending north northeast and dips 80 degrees east. Some tens of veinlets formes a zone. The strike length of the veinlets is about 400m. Each of the veinlet is lm to 5m wide. Three subzones, which are composed of some veinlets accompanied with bornites, are distinguished, being 2cm to 10cm wide (Fig.II-1-2). Copper minerals are bornite and malachite. Gangue minerals ,are quartz chlorite and biotite. The results of ore assay are shown in Table.II-2-4.

## 1-2 Soil geochemical survey

### 1-2-1 Purpose of the survey

Purpose of soil geochemical survey is to narrow down potential areas selected in phase I survey.

### 1-2-2 Procedure of the survey

#### (1) Sampling and sample preparation

Sampling lines were planed in advance, which run across geological structure at right angles in the area. 2,400 soil samples were collected from the four areas. Sampling lines run at intervals of 200m in the areas A-I, A-III and A-IV. Sampling points are located at intervals of 50m along the sampling lines. Sampling lines in area A-II run at intervals of 200m. Sampling points in the area are located at intervals of 100m along the lines. 1,318 samples were collected in the area A-I, 80 samples in the area A-II, 664 samples in the area A-III, 338 samples in the area A-IV.

Soil is not well developed in the area, especially A horizon of soil is hardly recognized. Basements rocks lie at depths of about 20cm under the soil. About 100 grams of soil were taken for each sample from the B horizon of soil. Each

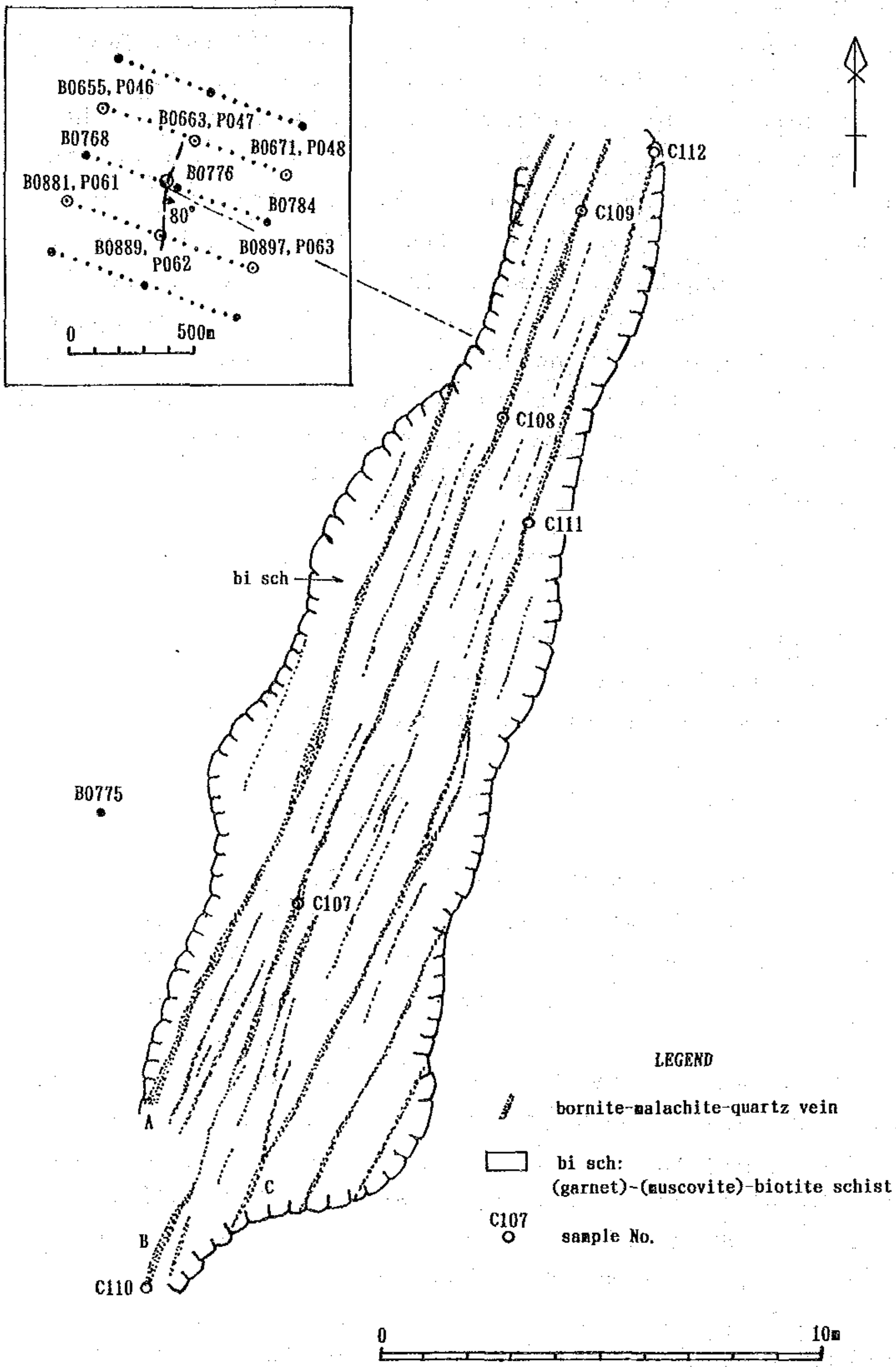



Fig. II-1-2 Sketch of the Copper showing in area A samples was generally taken from the depth ranging 10cm to 15cm in average. In some localities where are thick alluvium or farm land, samples were taken from the deeper part.

Samples were dried without heating at the base camp and sieved out of 80 mesh. 50 grams out of each sample were sent for chemical analyses and the rest of 50 grams were stored in case of need in the future. When each sample was taken, the followings are also described at each sampling point: geology, soil horizon from which the sample was taken, depth where the sample was taken, color of soil, mineral composition, if possible, and grain size of the soil, humidity of the soil, surrounding topography and vegetation.

(2) Chemical analyses of the samples

Samples under 80 meshes were roughly scaled at the base camp, and sent to GEOLOGIA E SONDAGENS LTDA (GEOSOL) for chemical analyses. The analyses were executed for three elements, Au, As and Sb.

The analytical method and the detection limit for each element are listed in Tab.II-1-1. The result of the analyses are presented in the Appendix 1.

(3) Statistical treatment of the analytical data.

The statistical treatment of the analytical data were executed by computer. The value of the half of the detection limit of some elements was applied to be treated for some samples in the statistical calculations. In the samples the elements was not detected because of the detection limit. The analytical data of the samples taken from the four areas were treated as being in a same popuration, because these areas are composed of the same lithology. The results of the statistical treatment of analytical data is shown in Tab. II-1-2.

Correlation coefficients were computed to understand correlation among those elements (Tab.II-1-3).

In order to decide background values of each element, the method of Exploratory Data Analysis (denoted as the EDA

Tab. II-1-1 Methods and detection limits of chemical analyses

| Sample media | Elements | Method | Detection limits |
|---|---|---|---|
| Soil | Au | Emission spectrometry | 0.5 ppm |
| | As | Atomic absorption spectroscopy | 1 ppm |
| | Sb | ditto | 1 ppm |
| Plant | Au | Instrumental neutron activation | 0.2 ppb |
| | As | ditto | 0.01 ppm |
| | Sb | ditto | 0.005 ppm |
| | Fe | Inductively coupled plasma emission spectrometry | 50 ppm |
| | Al | ditto | 50 ppm |
| Stream sediment | Au* | Emission spectrometry | 0.5 ppb |
| | Ag* | ditto | 0.2 ppm |
| | Fe | X-ray fluorescence analysis and wet determination | 10 ppm |
| | Mn | X-ray fluorescence analysis | 5 ppm |
| | Mo* | Emission spectrometry | 1 ppm |
| | W * | X-ray fluorescence analysis | 10 ppm |
| | Sn* | Emission spectrometry | 2 ppm |
| | Nb* | X-ray fluorescence analysis | 10 ppm |
| | Ta* | ditto | 10 ppm |
| | Be | Emission spectrometry | 0.5 ppm |
| | Li | Atomic absorption spectroscopy | 1 ppm |
| | As | ditto | 1 ppm |
| | Sb | ditto | 1 ppm |

* These elements of pan concentrate samples are also analyzed the same method as those of stream sediment samples.
Au of pan concentrate sample is analyzed by atomic absorption spectroscopy when the value is more than 500 ppb.

Tab. II-1-2 Summary of statistical studies of soil and plant analytical data

| Sample media | | Elements | Mean | Variance | Standard deviation | Minimum | Maximum | Below detection limit (%) |
|---|---|---|---|---|---|---|---|---|
| Soil | | Au (ppb) | 0.237 | 0.095 | 0.308 | 0.200 | 208.000 | 93.1 |
| | | As (ppm) | 1.252 | 0.391 | 0.625 | 0.500 | 560.000 | 64.8 |
| | | Sb (ppm) | 0.512 | 0.003 | 0.058 | 0.500 | 2.000 | 96.7 |
| Plant | PA | Au (ppb) | 0.562 | 0.290 | 0.538 | 0.100 | 11.200 | 23.1 |
| | | As (ppm) | 0.015 | 0.489 | 0.699 | 0.005 | 2.410 | 60.7 |
| | | Sb (ppm) | 0.004 | 0.187 | 0.432 | 0.002 | 0.175 | 61.8 |
| | | Fe (ppm) | 101.930 | 0.118 | 0.343 | 25.000 | 1,550.000 | 15.6 |
| | | Al (ppm) | 76.577 | 0.140 | 0.374 | 25.000 | 2,000.000 | 21.3 |
| | PB | Au (ppb) | 0.213 | 0.298 | 0.546 | 0.100 | 907.000 | 64.0 |
| | | As (ppm) | 0.010 | 0.248 | 0.498 | 0.005 | 1.250 | 62.8 |
| | | Sb (ppm) | 0.003 | 0.100 | 0.316 | 0.002 | 0.045 | 80.8 |
| | | Fe (ppm) | 50.793 | 0.025 | 0.159 | 25.000 | 250.000 | 10.5,89.5* |
| | | Al (ppm) | 33.002 | 0.041 | 0.204 | 25.000 | 300.000 | 68.0 |
| | PC | Au (ppb) | 0.874 | 0.258 | 0.508 | 0.100 | 46.000 | 9.1 |
| | | As (ppm) | 0.014 | 0.360 | 0.600 | 0.005 | 5.110 | 47.3 |
| | | Sb (ppm) | 0.004 | 0.202 | 0.449 | 0.002 | 0.055 | 55.8 |
| | | Fe (ppm) | 223.712 | 0.047 | 0.217 | 100.000 | 1,000.000 | none |
| | | Al (ppm) | 184.971 | 0.085 | 0.292 | 50.000 | 1,250.000 | none |

PA:Jurema Preta
PB:Catingueira
PC:Malva
* detection limit or less
Minimum values are half of detection limite except for Fe and Al in PC

Tab. II-1-3 Correlation of three elements in soil geochemical data, and five elements in plant geochemical data

| Sample media | | Elements | Au | As | Sb | Fe | Al |
|---|---|---|---|---|---|---|---|
| Soil | | Au | 1.000 | | | | |
| | | As | 0.032 | 1.000 | | | |
| | | Sb | 0.006 | -0.105 | 1.000 | | |
| Plant | PA | Au | 1.000 | | | | |
| | | As | -0.018 | 1.000 | | | |
| | | Sb | -0.047 | -0.025 | 1.000 | | |
| | | Fe | 0.174 | 0.292 | -0.054 | 1.000 | |
| | | Al | 0.146 | 0.347 | -0.092 | 0.905 | 1.000 |
| | PB | Au | 1.000 | | | | |
| | | As | 0.237 | 1.000 | | | |
| | | Sb | 0.392 | 0.243 | 1.000 | | |
| | | Fe | 0.283 | 0.261 | 0.125 | 1.000 | |
| | | Al | 0.118 | 0.248 | 0.009 | 0.663 | 1.000 |
| | PC | Au | 1.000 | | | | |
| | | As | -0.068 | 1.000 | | | |
| | | Sb | 0.039 | 0.106 | 1.000 | | |
| | | Fe | 0.366 | 0.080 | -0.056 | 1.000 | |
| | | Al | 0.344 | 0.075 | -0.082 | 0.927 | 1.000 |

PA:Jurema Preta, PB:Catingueira, PC:Malva method) was applied (Fig.II-1-3, Tab.II-1-4).

### 1-2-3 Results of the survey

(1) Geochemical anomalies of each element

The analytical value of gold ranges from less than 0.5 ppb up to 208 ppb. Because 93.1% of the number of the samples have the value less than the detection limit, the value of the upper fence is defined 0.5 ppb by EDA method. Consequently, the values higher than the detection limits are to be all anomalous values.

The analytical value of arsenic ranges from less than 1 ppm up to 560 ppm. 64.8% of the number of the samples have the analytical value less than the detection limit. The value of the upper fence is defined 6.750 ppm and the values higher than 6,750 ppm are to be all anomalous values.

The analytical value of antimony ranges from less than 1 ppm up to 2 ppm. Because 97.7% of the number of the samples have the analytical value less than the detection limit, the value of the upper fence is defined to be 0.5 ppm. Consequently the values higher than the detection limits are to be all anomalous values.

The anomalous values of each element are distributed in the area A as follows:

(i) Area A-I

Gold (Au)

Anomalous areas with the analytical values higher than 0.5 ppb are clustered in the southeastern part, in the central part, in the western part and southwest part, as illustrated in Fig.II-1-4(1). The other anomalous areas are studded separately in the other area. Two anomalous areas in the southeastern part are widely clustered, in which twelve points with higher analytical values, including the maximum value of 208 ppb, three points with values higher than 100

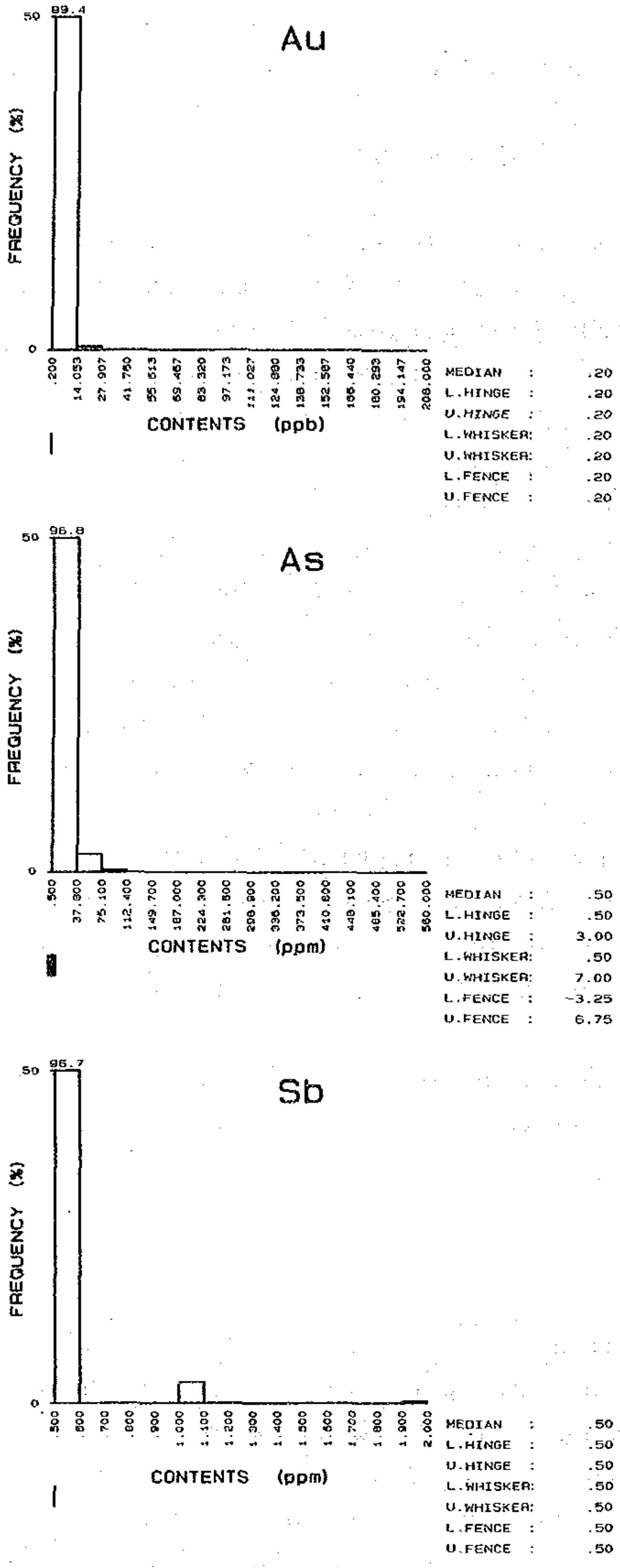



Fig. II-1-3 Histograms and boxplots for the elements in soil

Tab. Ⅱ-1-4 Results of the EDA method analyses of soil and plant samples

| Sample media | | Elements | Median | Lower fence | Lower whisker | Lower hinge | Upper hinge | Upper whisker | Upper fence | Upper fence or more (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Soil | | Au (ppb) | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 6.9 * |
| | | As (ppm) | 0.500 | -3.250 | 0.500 | 0.500 | 3.000 | 7.000 | 6.750 | 19.3 |
| | | Sb (ppm) | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 0.500 | 3.3* |
| Plant | PA | Au (ppb) | 0.600 | - 1.900 | 0.100 | 0.200 | 1.600 | 1.800 | 3.700 | 3.5, 22.5** |
| | | As (ppm) | 0.000 | - 0.060 | 0.000 | 0.000 | 0.040 | 0.070 | 0.100 | 16.8 |
| | | Sb (ppm) | 0.002 | - 0.002 | 0.002 | 0.002 | 0.005 | 0.010 | 0.009 | 21.4 |
| | | Fe (ppm) | 100.000 | 25.000 | 50.000 | 100.000 | 150.000 | 200.000 | 225.000 | 12.1 |
| | | Al (ppm) | 100.000 | - 25.000 | 25.000 | 50.000 | 100.000 | 150.000 | 175.000 | 14.5 |
| | PB | Au (ppb) | 0.100 | - 0.350 | 0.100 | 0.100 | 0.400 | 0.600 | 0.850 | 16.3 |
| | | As (ppm) | 0.000 | - 0.015 | 0.000 | 0.000 | 0.010 | 0.020 | 0.025 | 13.4 |
| | | Sb (ppm) | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 19.2 * |
| | | Fe (ppm) | 50.000 | 50.000 | 50.000 | 50.000 | 50.000 | 50.000 | 50.000 | 10.5 *** |
| | | Al (ppm) | 25.000 | - 12.500 | 25.000 | 25.000 | 50.000 | 50.000 | 87.500 | 5.8 |
| | PC | Au (ppb) | 1.000 | - 1.100 | 0.400 | 0.400 | 1.400 | 2.000 | 2.900 | 12.7 |
| | | As (ppm) | 0.010 | - 0.045 | 0.000 | 0.000 | 0.030 | 0.040 | 0.075 | 11.5 |
| | | Sb (ppm) | 0.002 | - 0.010 | 0.002 | 0.002 | 0.010 | 0.015 | 0.022 | 11.5 |
| | | Fe (ppm) | 200.000 | - 75.000 | 150.000 | 150.000 | 300.000 | 350.000 | 525.000 | 4.8 |
| | | Al (ppm) | 200.000 | -125.000 | 100.000 | 100.000 | 250.000 | 300.000 | 475.000 | 9.1 |

PA: Jurema Preta
PB: Catingueira
PC: Malva

* Detection limit or more
** Upper whisker or more (1.8 ppb<)
*** 100 ppm<

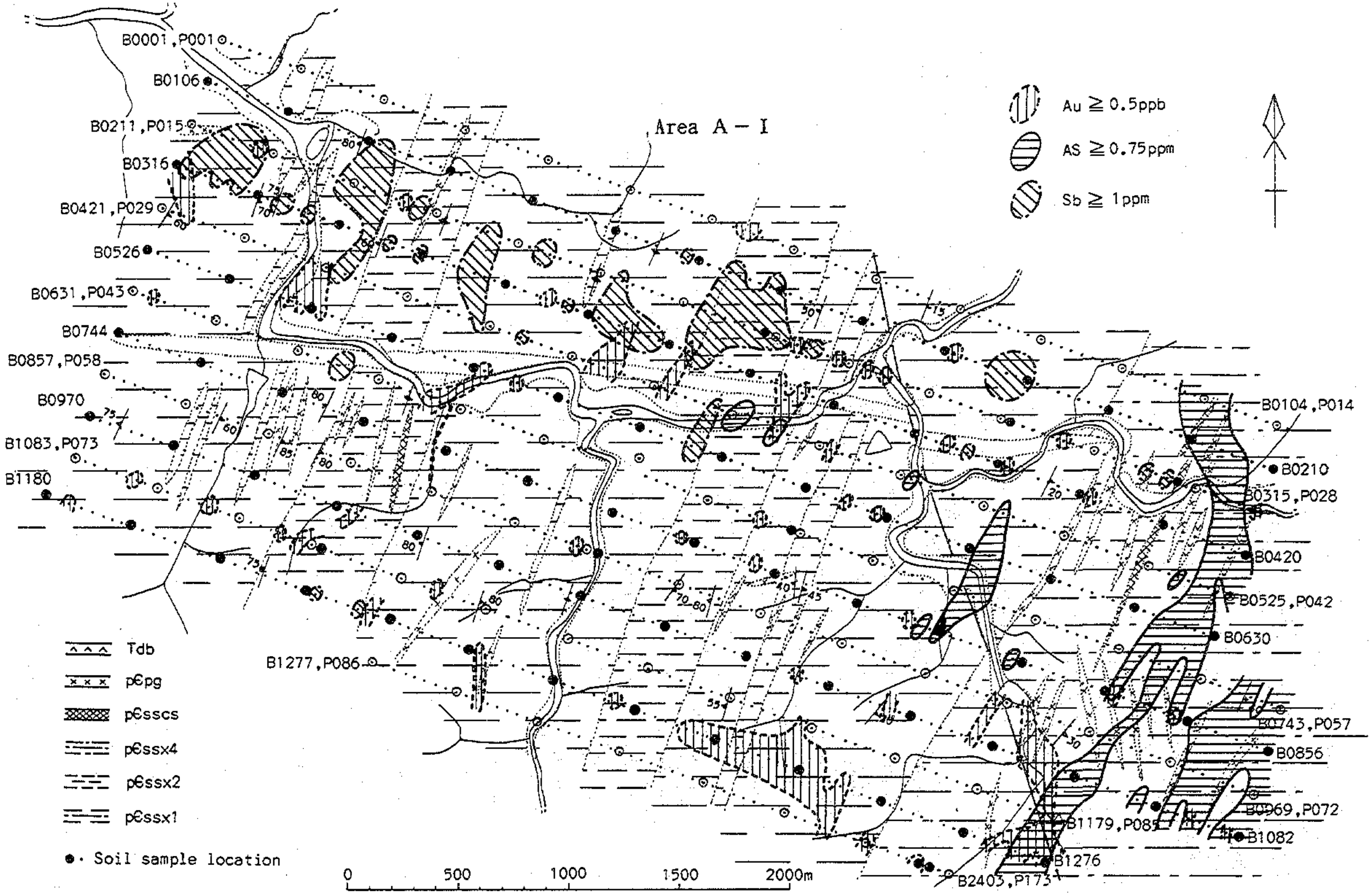



Fig. II-1-4 Au, As and Sb anomalies in soil (1) ppb, two points with the values ranging from 10 ppb to 99 ppb and two points with the values ranging from 5 ppb to 9 ppb.

Arsenic (As)

Anomalous areas with the analytical values higher than 6.75 ppm is in the eastern end zone 1500mm wide, as illustrated in Fig.II-1-4(1), which trends north northeast and is situated in pCssx4 except for some parts. The small anomalous areas, trending north northeast, are also detected in the east end of pCssx1. In the anomalous areas, analytical value of 92 ppm of As was detected. The As anomalous areas scarcely overlay on the above mentioned Au anomalous area except for southeastern end of the area A-I. Here the Au anomalous area trends north northwest and the As anomalous area trends north northeast, which cross the former trend.

Antimony (Sb)

Anomalous areas with the analytical values higher than 1 ppm are illustrated in Fig.II-1-4(1). The analytical values of the anomalous samples are mostly 1 ppm of Sb. Only three points have a value of 2 ppm of Sb. The anomalous areas are sparsely distributed in the area from central north to northwestern part. Each anomalous area trends north northeast in a small scale. They are located side by side trending west northwest. Those areas are mostly situated in pCssx1 and pCssx2 in the northern side of the basalt dike trending west northwest. The Sb anomalous areas do not correspond with the Au and As anomalous areas.

(ii) Area A-II

Gold (Au)

Two anomalous zones with higher analytical value more than 0.5 ppb were detected in the center of the area A-II as illustrated in the Fig.II-1-4(2). One zone is situated about

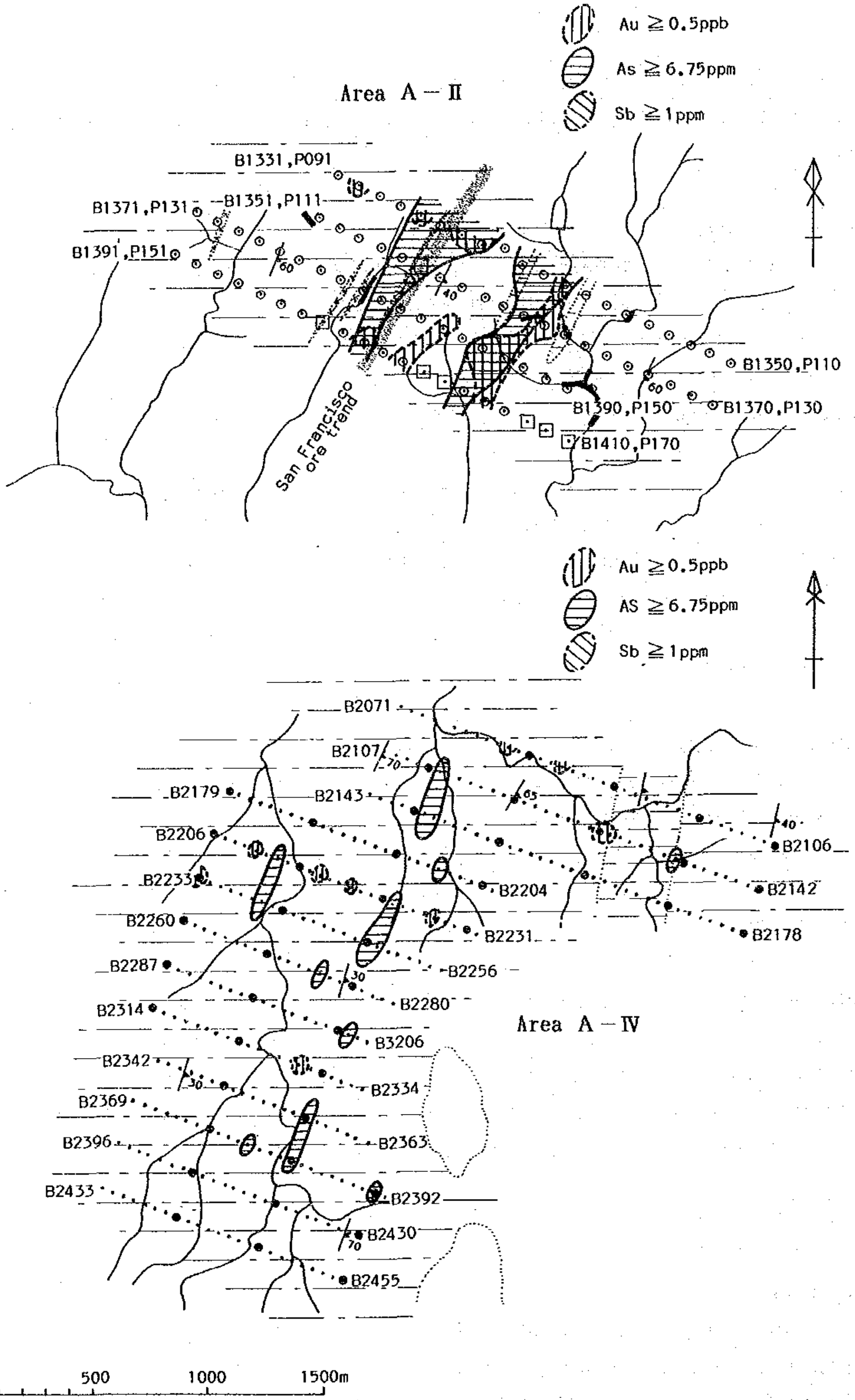



Fig. Ⅱ-1-4 Au, As and Sb anomalies in soil (2)

500m east from the supposed southern extension of the San Francisco gold deposit. The zone is less than 200m wide and trends north northeast. In the zone, analytical values of the samples are characteristically higher such as 14.3 ppb, 19.2 ppb and 20.0 ppb. Another zone is situated about 200m east from the southern extension of the San Francisco gold deposit, which is less than 100m wide and trends north northeast as well. Some more anomalopus points are located at the northern end and southern end of the supposed southern extension of the San Francisco gold deposits.

Arsenic (As)

Two anomalous zones with the analytical values higher than 6.75 ppm are located in the area A-III as illustrated in Fig.II-1-4(2). Both of the two zones are about 50m to 200m wide and trend north northeast. A western zone overlapps the supposed southern extension of the San Francisco gold deposits. In the zone, the analytical values ranging from 54 to 89 ppm of As were detected on some samples. Another zone is located 500m east of the supposed southern extension of the San Francisco gold deposits. This zone mostly overlapps the Au anomalous area mentioned above. The zone include many higher analytical values than 10 ppm of As including 93 ppm. This zone is situated in pCssx4.

Antimony (Sb)

Analytical values were not obtained because the Sb contents of the samples are less than detection limit, 1 ppm. Therefore, no anomalous areas were detected.

(iii) Area A-III

Gold (Au)

Many anomalous areas with the analytical values of 0.5 ppb and more than that are sparsely distributed as illustrated in Fig.II-1-4(3). The areas where some points with anomalous values are clustered and some points with

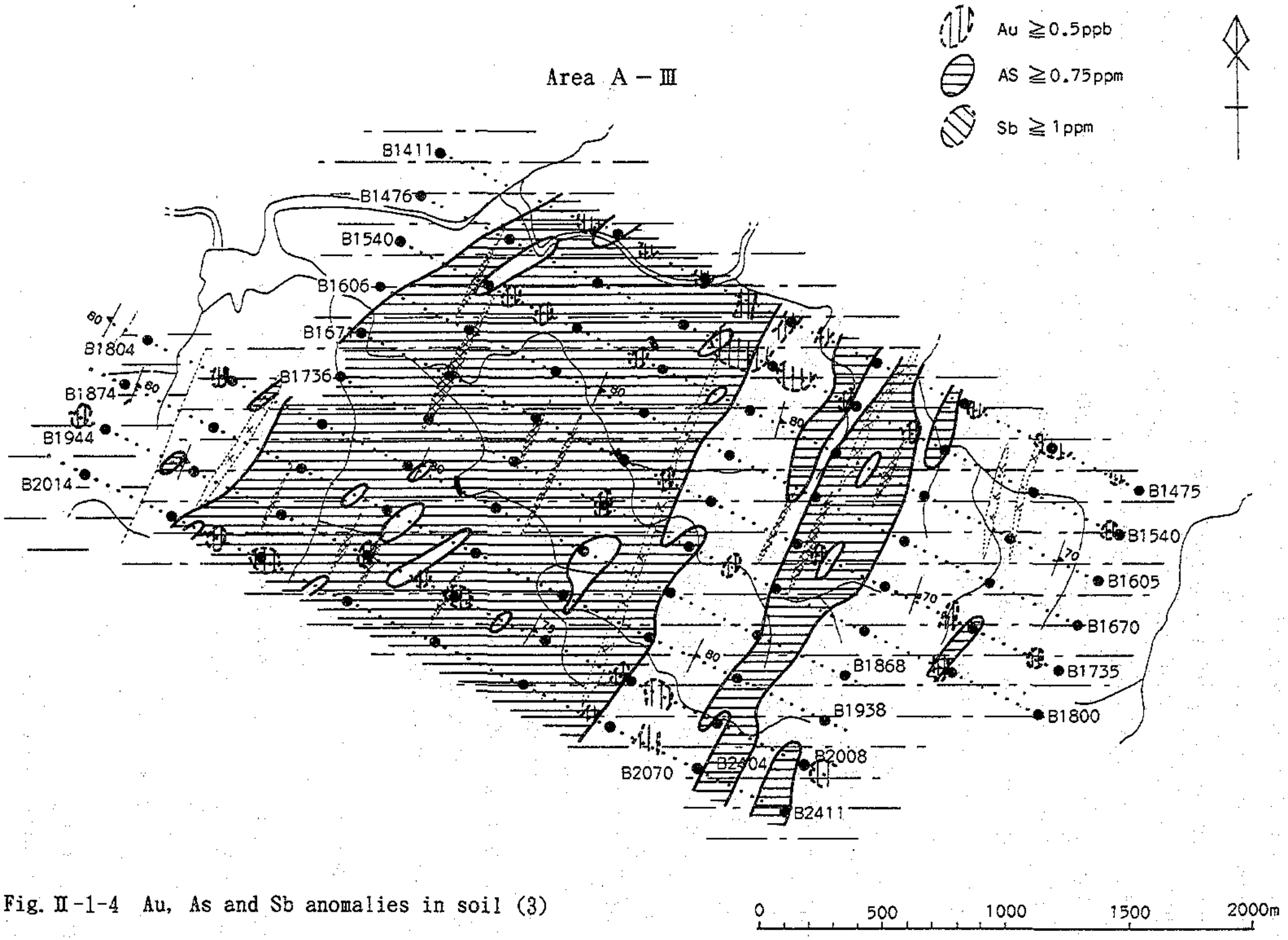



Fig. II-1-4 Au, As and Sb anomalies in soil (3) analytical values of 10 ppb and more than that are in the northern, eastern, southeastern and southwestern part of area A-III.

Arsenic (As)

Two anomalous zones with analytical values of 6.75 ppm and higher than that occupy wide area as illustrated in Fig. II-1-4(3). These zones trends north northeast parallel to each other. Western zone is 1 to 2km wide. In that zone, three points with analytical values of 100 ppm and higher than that including maximum value of 560 ppm, thirty points with analytical values ranging from 50 ppm to 99 ppm were detected. The eastern zone is located about 500m east of the western zone. That zone is 150m to 500m wide. Anomalous points with the values of 242 ppm, 66 ppm and 55 ppm are distributed in the zone.

Both of the zones are in pCssx4, especially in the part alternated with many pCsscs rocks.

Antimony (Sb)

No analytical values were obtained because the Sb content of the samples are below detection limit, 1 ppm. Therefore no anomalous areas were detected.

(iv) Area A-IV

Gold (Au)

Nine anomalous areas with analytical values of 0.5 ppb and higher than that are sparsely distributed in area A-IV as illustrated in Fig.II-1-4(2). In these anomalous areas, only one sample with the analytical value of higher than 10 ppb is located in the northern part.

Arsenic (As)

Anomalous areas with the analytical values of 6.75 ppm and higher than that stand side by side in a direction north northeast in the central zone of area A-IV. The zone is 50 to 100m wide. In that anomalous aras, analytical values are 50 ppm and less than that. The anomalous areas do not correspond with any lithological unit and any anomalous areas of other elements.

Antimony (Sb)

Analytical values were not obtained because Sb content of the samples in the area A-IV are less than detection limit. Therefore no anomalous values were not detected.

## 1-3 Biogeochemical survey

### 1-3-1 Purpose

The purposes of biogeochemical survey are to realize the relationship between concentrations of elements in the plants and mineralization in the area, and to narrow the potential areas selected in the first phase of this project.

### 1-3-2 Procedure

(1) Sampling and sample preparation

A total of 510 pieces of plant samples were collected on some of the lines for soil sampling (PL.II-1-1). In the area A-I, sampling lines run at intervals of 400m and sampling points are located at intervale of 400m on the sampling line. In the area A-II, sampling lines run at intervals of 200m and sampling points located at intervals of 100m along the sampling lines. Plants of three kinds were generally collected at a same sampling point. Sampling point means inside a circle with a radius of 20m. The species of plants were selected with a assistance of Dr. Oswaldo Carneiro de Lira, professor of botany in Recife University.

The selected species of plants are as follows:

| Code | Brazilian Name | Family and Subfamily | Scientific Name |
|---|---|---|---|
| PA | Jurema Preta | Leguminosae, Mimosoideae | Leguminosae Mimosa pula Benth |
| PB | Catinguira | Leguminosae, Caesalpinioideae | Leguminosae Caesapini piramidalis Tul. |
| PC | Malva | Malvaceae | Malva Sida rhombifalia? |

They are broadleaf trees. The trees of Jurema Preta are 6m to 7m high. The trees of Catingueira are 4m to 5m high. The trees of Malva are 1.5m high. The trees of Jurema Preta have sets of slender and narrow leaves like leave of fern. A set of leaves is 5cm to 6cm length. Surfaces of the leaves are somewhat sticky. The trees of Catinguira have the round leaves which are about 2cm diameter and slick. The trees of Malva have the long elliptic leaves. They are 2cm by 5cm in size and are rough and sticky on their surfaces.

Because three kinds of plants do not always grow up together in each sampling point, three kind of plant samples were not always collected in each sampling point. Accordingly the numbers of plant samples taken were 93 samples of Jurema Preta, 92 samples of Catinguira and 92 samples of Malva in the area A-I, and 80 samples of Jurema Preta, 80 samples of Catingueira and 73 samples of Malva in the area A-II.

The leaves of the three kinds of plants were collected with their petides in the both area, A-I and A-II. When plant samples were being collected, the plants changed their old leaves into young ones due to the rain. Plant samples, accordingly, included not only old leaves but also young ones.

The collected plant samples were washed with water and dried without heating. 30g of dried leaves were sent for chemical analyses. The rest of dried leaves were stored in case of need in the future. When samples were collected at each sapling point, the followings were also described: geology of the sampling point, hight of the plants, diameter of the steams of the plants thickness of the soil, inclination of the area, distance to the nearest drainage.

(2) Chemical analyses of the samples

Samples were roughly scaled at the base camp, and sent to the Chemex Labs Ltd. in Canada for chemical analyses. The analyzed elements were five of Au, As, Sb, Fe and Al. The two elements of Fe and Al are used for checking the contamination of the plant samples with dusts.

The analytical method and the detection limit of each element are listed in Tab.II-1-1. The results of the analysi are presented in Appendix 2.

(3) Statistical treatment of the analytical data.

The statistical treatment of the anlytical data were done by computer. The value of the half of the detection limit was used for the samples which have no analytical volues because of the detection limit.

Though the distance between the area A-I and the area A-II is about 3km, lithologyin the two areas are the same. Therefore, the statistical data of the analytical results of the plant samples taken from each area are thought to be in a same population. Then the analytical values were treated all together for statistical analyses.

Summary of statistical results of the analytical data is shown in Tab.II-1-2. Minimum values, average values and maximum values of each element in each plants are as follows:

| | Jurema Preta | | | Catingueira | | | Malva | | |
|---|---|---|---|---|---|---|---|---|---|
| | MIN | AVE | MAX | MIN | AVE | MAX | MIN | AVE | MAX |
| Au | 0.1 | 0.6 | 11.2 | 0.1 | 0.2 | 907.0 | 0.1 | 0.8 | 46.0 |
| As | 0.00 | 0.02 | 2.41 | 0.00 | 0.01 | 1.25 | 0.00 | 0.01 | 5.11 |
| Sb | 0.002 | 0.004 | 0.175 | 0.002 | 0.003 | 0.045 | 0.002 | 0.004 | 0.055 |
| Fe | 25 | 102 | 1,550 | 25 | 51 | 250 | 100 | 224 | 1,000 |
| Al | 25 | 77 | 2,000 | 25 | 33 | 300 | 50 | 185 | 1,250 |

unit: Au=ppb; As, Sb, Fe & Al=ppm

Correlation coefficients were computed to detect the correlation among the elements (Tab.II-1-3, Fig.II-1-5). Correlations between Fe and Al of three kinds of plants are 0.6 and more than that. Correlations between As and Al in Jurema Preta, Au and Fe in Catingueira and, Au and Fe and Au and Al in Malva are 0.3 and lower than that.

In order to decide statistical background of each element, EDA method was applied as well (Fig.II-1-6).

1-3-3 Results of the survey

(1) Jurema Preta

The concentration of gold ranges from less than 0.2 ppb up to 11.2 ppb. 23.1% of the numbers of samples have analytical values less than detection limit. The value of upper whisker definedly EDA method is 1.8 ppb and the values higher than the upper whisker are all to be anomalous values.

The concentration of arsenic ranges from less than 0.01 ppm up to 2.41 ppm. 60.7% of the numbers of the samples have analytical values less than the detection limit. The value of upper fence definedly EDA method is 0.10 ppm and the values higher than the upper fence are all to be anomalous values.

The concentration of antimony ranges from less than 0.005 ppm up to 0.175 ppm. Because 97.7% of the samples have analytical values less than the detection limit, the values of upper fence is 0.009 ppm and the values higher than the upper fence are all to be anomalous values.

The concentrations of iron and aluminum are explained later.

(a) Area A-I

Gold (Au)

The geochemical anomalous areas, as illustrated in the Fig.II-1-7(1), are divided into four areas; southeastern to

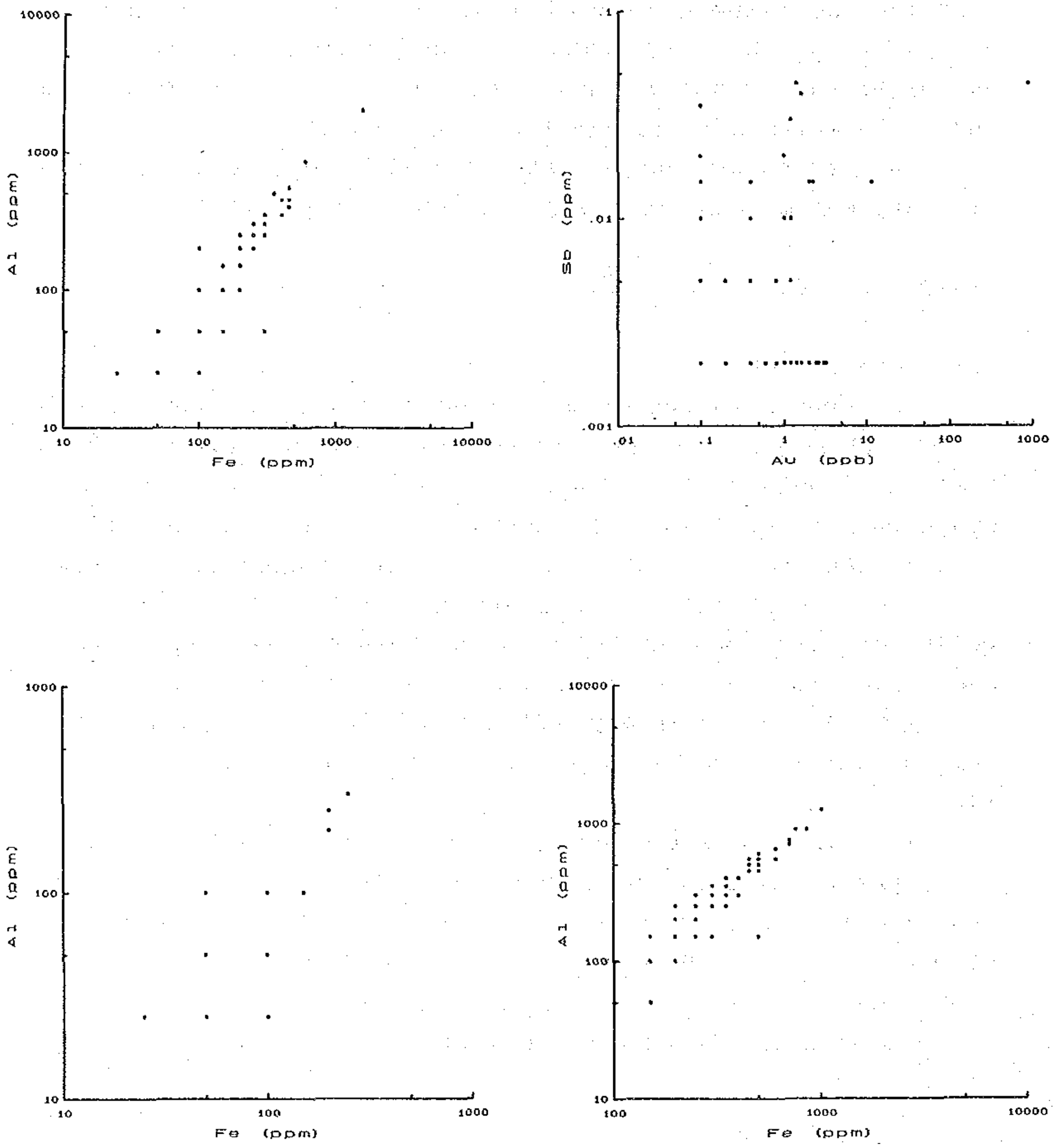



Fig. II-1-5 Diagrams showing correlation between elements concentrated in plants

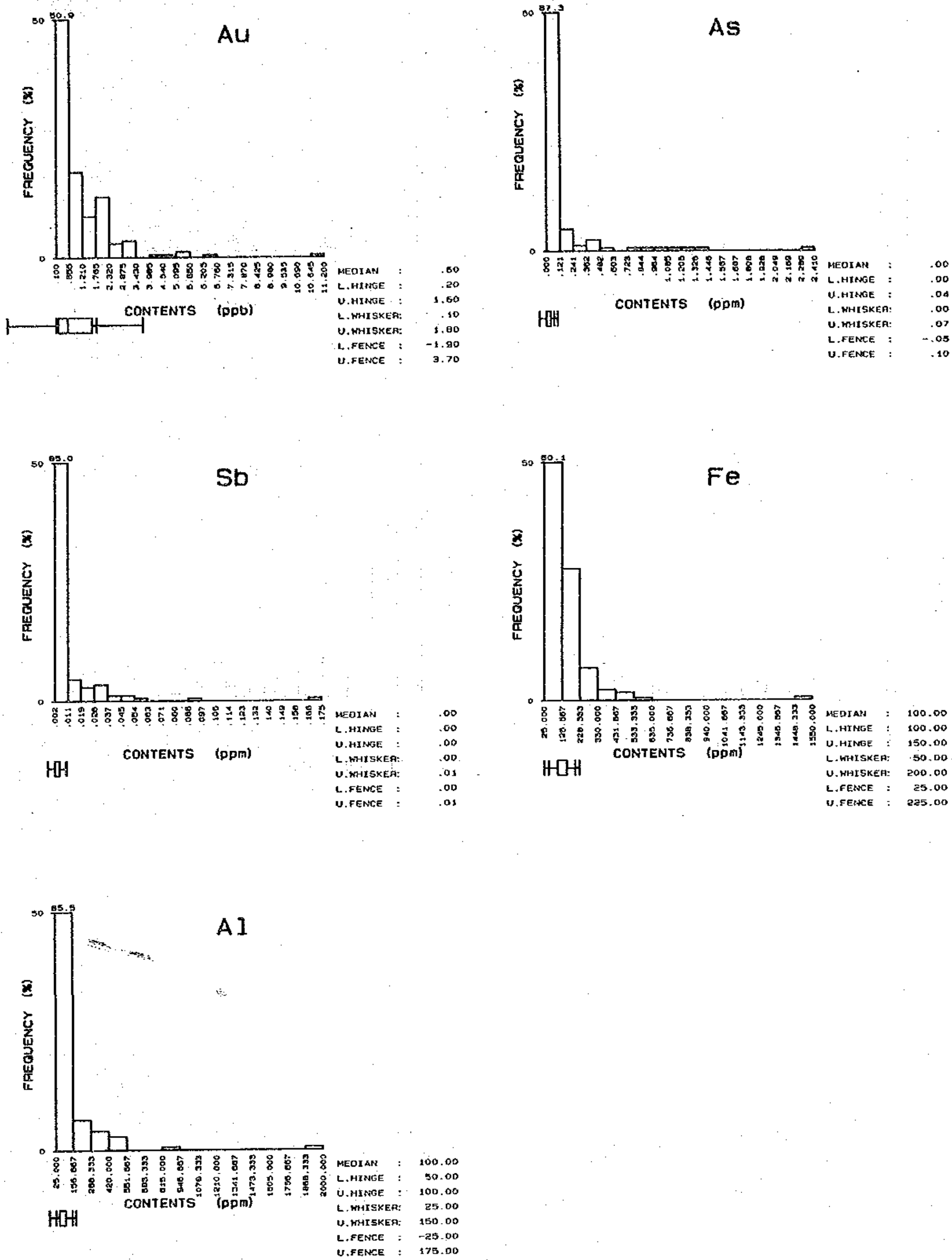



Fig. II-1-6 Histograms and boxplots for Au, As, Sb, Fe and Al in plants (1)

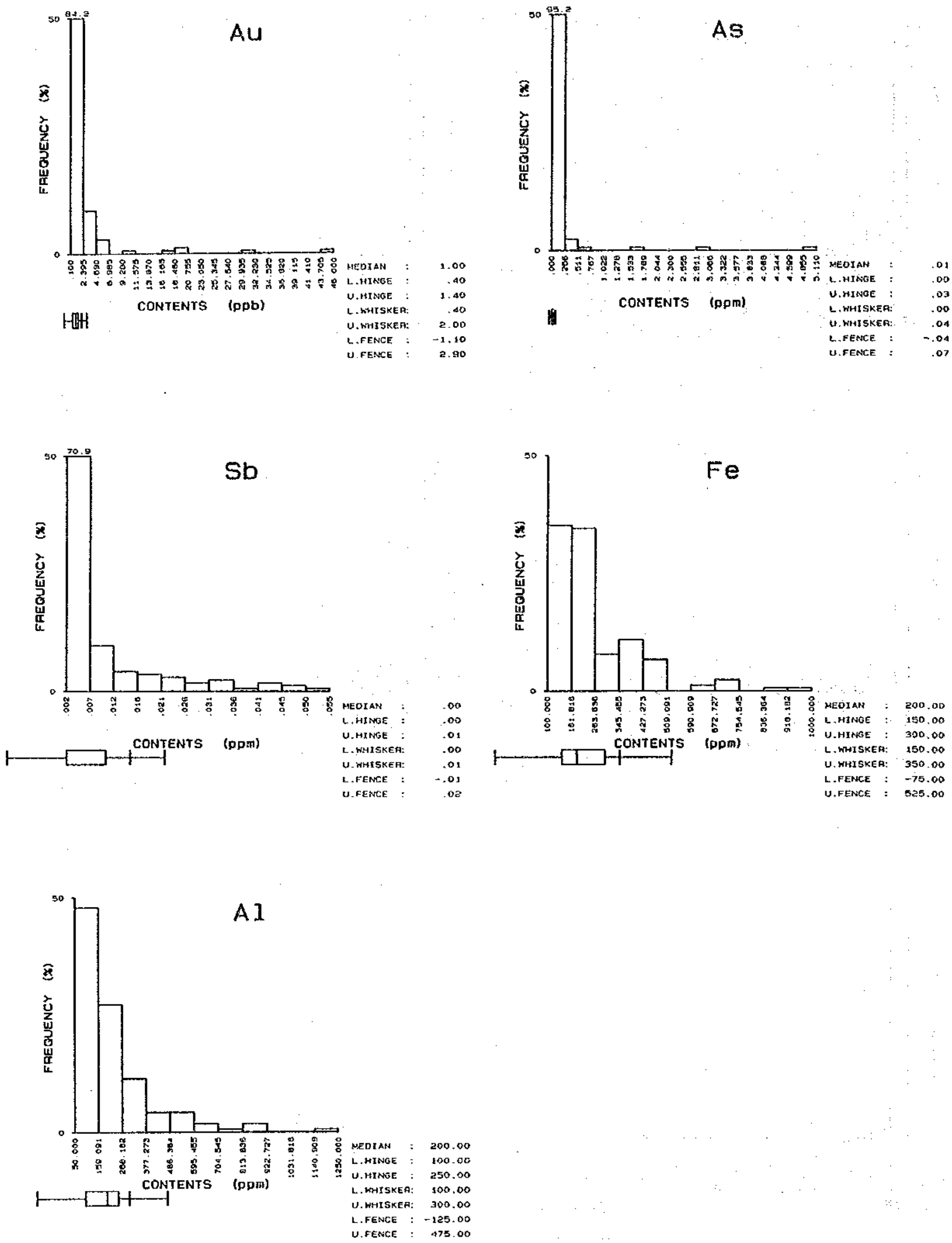



Fig. II-1-6 Histograms and boxplots for Au, As, Sb, Fe and Al in plants (2)

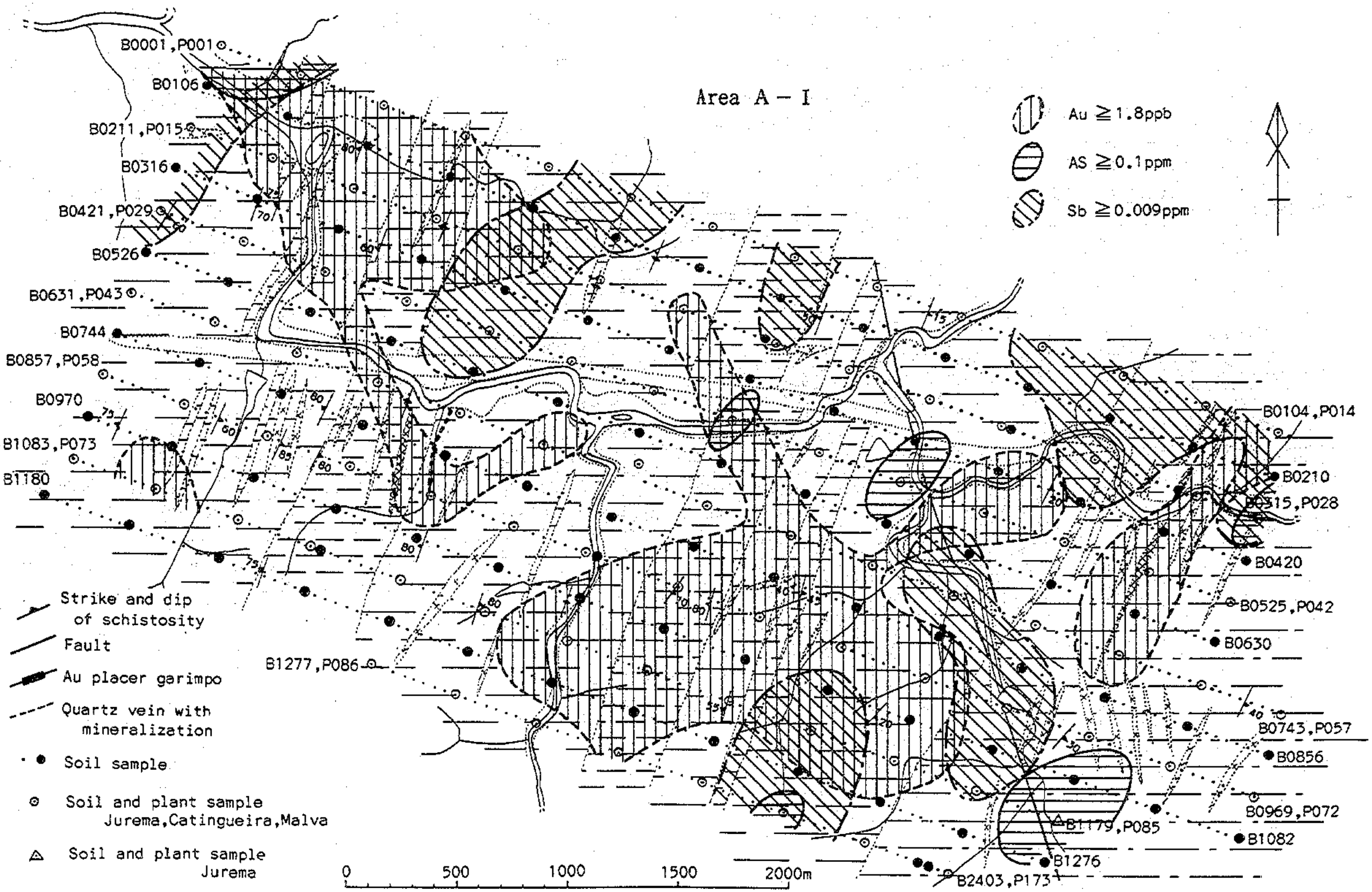



Fig. II-1-7 Au, As, Sb anomalies in three kinds of plants, Jurema (1)

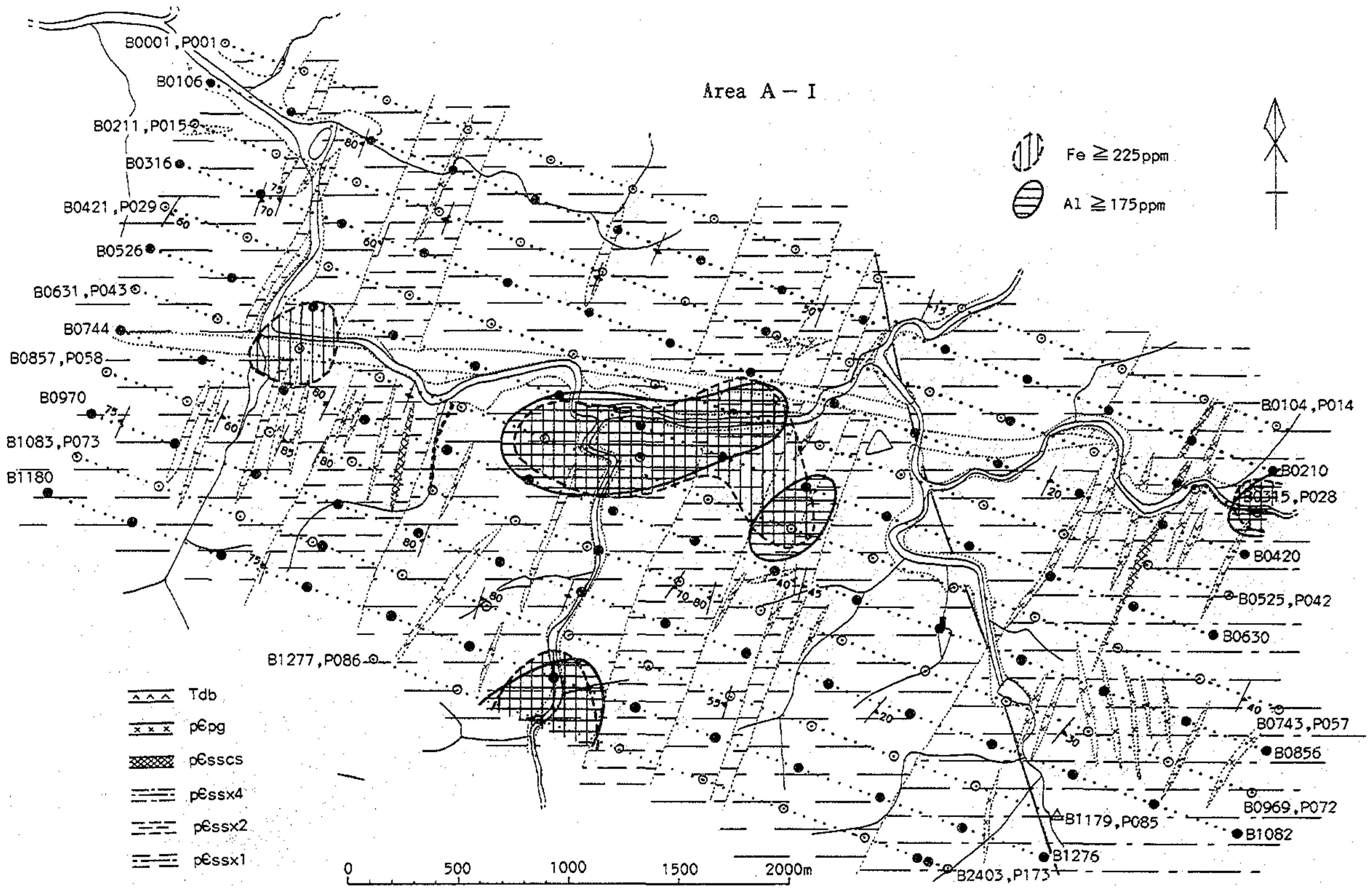



Fig. II-1-7 Fe and Al anomalies in three kinds of plants, Jurema (2) central part, northwestern part, southwestern part and northeastern part. First two anomalous areas occupy wider area. The area, southeastern to central part of the area A-I, has the area of 2km east-west by 1km north-south. In that area the analytical values of Au are ranging from 1.8 ppb to 5.2 ppb. The northwestern part has the area of 1.5km east-west by 1km north-south. In that area the higher analytical value is 4.0 ppb. In the northeastern part, the analytical values are ranging from 2.2 ppb to 6.4 ppb.

Arsenic (As)

Anomalous areas, as illustrated in Fig.II-1-7(1), are composed of six areas. The anomalous areas do not always cover the arsenic anomalous areas. The As anomalous areas are distributed outside of the Au anomalous areas. The highest analytical value, 0.45 ppm, was gained on a sample in the southeastern part of the area. In the central part of the area, a sample with the value of 0.37 ppm of As was located. Other samples have values of the order of 1.0 ppm.

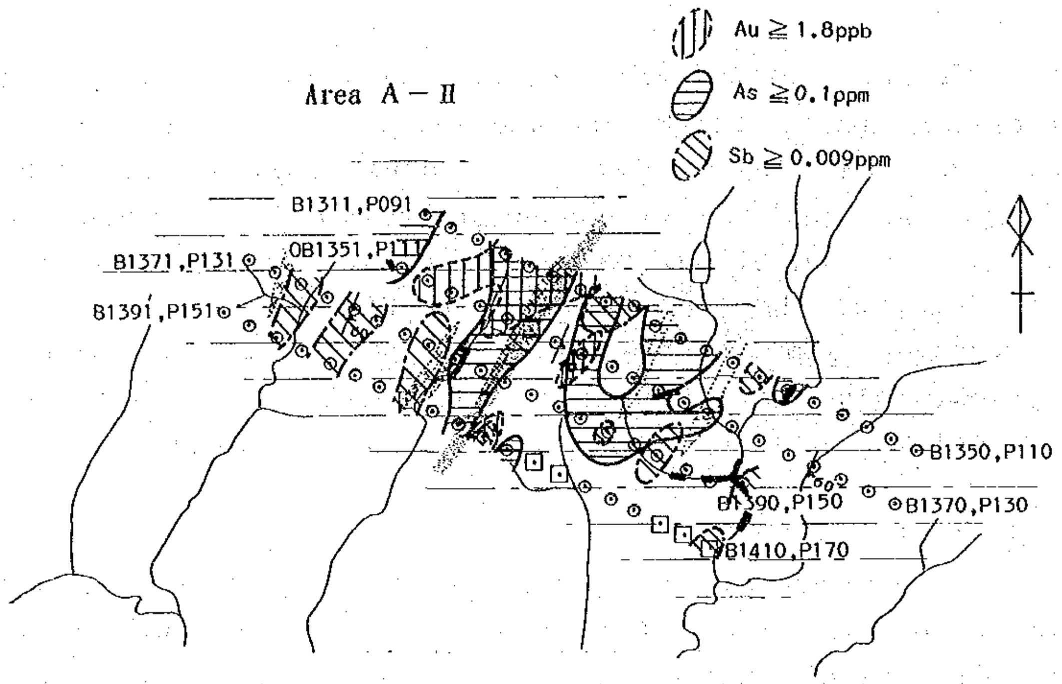
Antimony (Sb)

Anomalous areas, as illustrated in Fig.II-1-7(1), are composed of six areas: two area are located in the northern part and the rests are located one by one in the northwestern, northeastern, eastern and southeastern part of the area. Higher analytical values, 0.06 to 0.175 ppm of As, on samples were detected in the southeastern part. The rest of the analytical values are 0.05 ppm and less than that. Those anomalous areas are not alwlays cover the anomalous areas of Au and As.

(b) Area A-II

Gold (Au)

Anomalous areas are located in the northern part, central part and southern part of the area A-II as illustrated in Fig.II-1-7(3). The northern part occupies



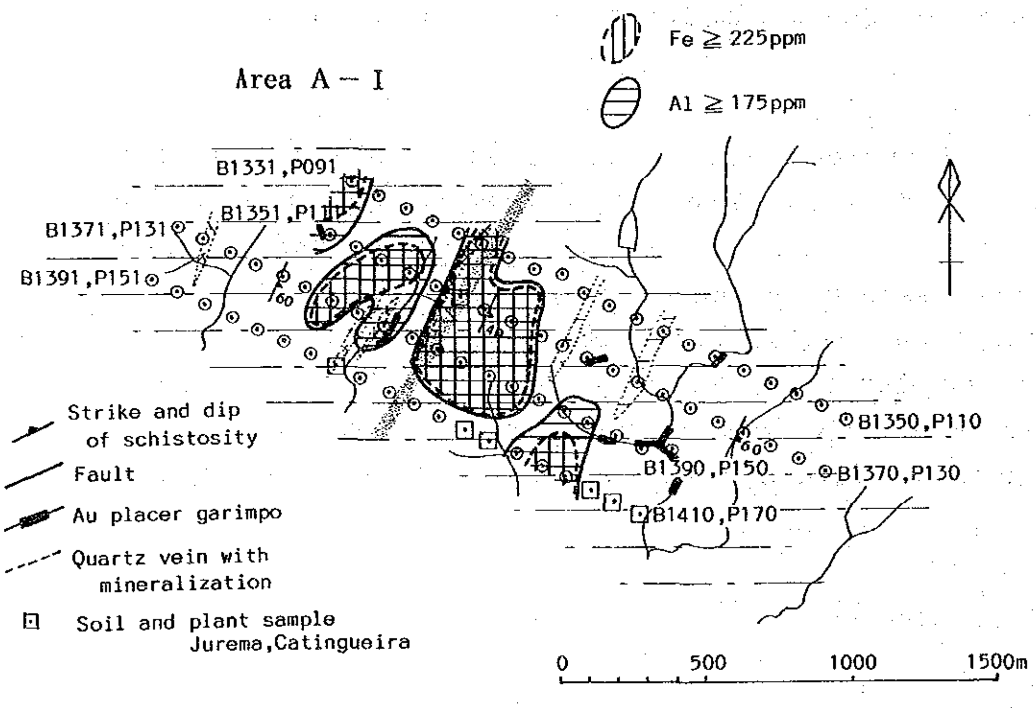




Fig. II-1-7 Au, As, Sb, Fe and Al anomalies in three kinds of plants, Jurema (3) wider area. Those three anomalous areas do not scarecely overlap the Au anomalous areas detected on the soil samples. Analytical values of 1.8 to 4.8 ppb of Au were detected on the northeastern part of the area. On the rest of the samples, 2.2 ppb of Au and less than that of analytical values were detected.

Arsenic (As)

Anomalous areas were delineated in the north to southern part, central and northwestern parts of the area, as illustrated in Fig.II-1-7(3). The anomalous area in the northern part is situated on the supposed southern extension of the Sao Francisco gold deposit. The anomalous area cover almost all the Au anomalous areas in the northern, central and southern parts of the area A-II. Samples taken from the supposed southern extention of the Sao Francisco deposit has higher values of As analytical values, 0.14 to 22.41 ppm. The samples taken from the central part of the area have the values of 0.20 to 1.30 ppm. The samples taken from the northwestern part showed 0.1 to 0.41 ppm of As.

Antimony (Sb)

Ten anomalous areas are located as illustrated in Fig. II-1-7(3). They are composed of six areas in the north to southeastern part and four areas in the southwest to southern part. The anomalous areas do not always correspond with the anomalous areas of Au and As. The values of chemical analyses are 0.02 ppm and less than that.

(ii) Catingueira

The concentration of gold ranges from less than 0.2 ppb to 907.0 ppb. 64.0% of the numbers of samples have analytical values less than the detection limit. The value of the upper fence definedly EDA method is 0.85 ppb and the values higher than the upper fence are all anomalous values.

The concentration of arsenic ranges from less than 0.01 ppm up to 1.25 ppm. 62.8% of the numbers of samples have analytical values less than the detection limit. The value of the upper fence is 0.025 ppm and the values higher than the upper fence are all anomalous values.

The concentration of antimony ranges from less than 0.005 ppm up to 0.045 ppm. 80.8% of the numbers of samples have analytical values less than the detection limit. The value of the upper fence is 0.009 ppm and the values higher than the upper fence are all anomalous values.

The concentrations of iron and aluminum are explained later.

(a) Area A-I

Gold (Au)

Four anomalous areas are detected in the central to northeastern part of the area as illustrated in Fig. II-1-7(4). *The anomalous areas are not always correspond* with the Au anomalous areas of soil. The highest Au value, 907 ppb, was detected on the sample taken from the northwestern end in the northeastern anomalous area. In the same area, on the rest of the samples, 2.2 ppb of gold and less than that were detected. In the central anomalous area, 1.2 to 3.0 ppb of Au were detected on the samples. Other anomalous points are not clustered, having the values of 2.6 ppb and less than that.

Arsenic (As)

Six anomalous areas were detected in the central to northeastern part and western part of the area as illustrated in Fig.II-1-7(4). The northeastern anomalous area is under the gold anomalous area. The samples in the anomalous area have the analytical values of 0.03 to 0.85 ppm of As. The sample with highest value is the same as the one with 907 ppb of Au. The area also corresponds with the anomalous area of Fe and Al. Other anomalous points are dispersed in the area, having the values of 0.03 to 0.06 ppm.

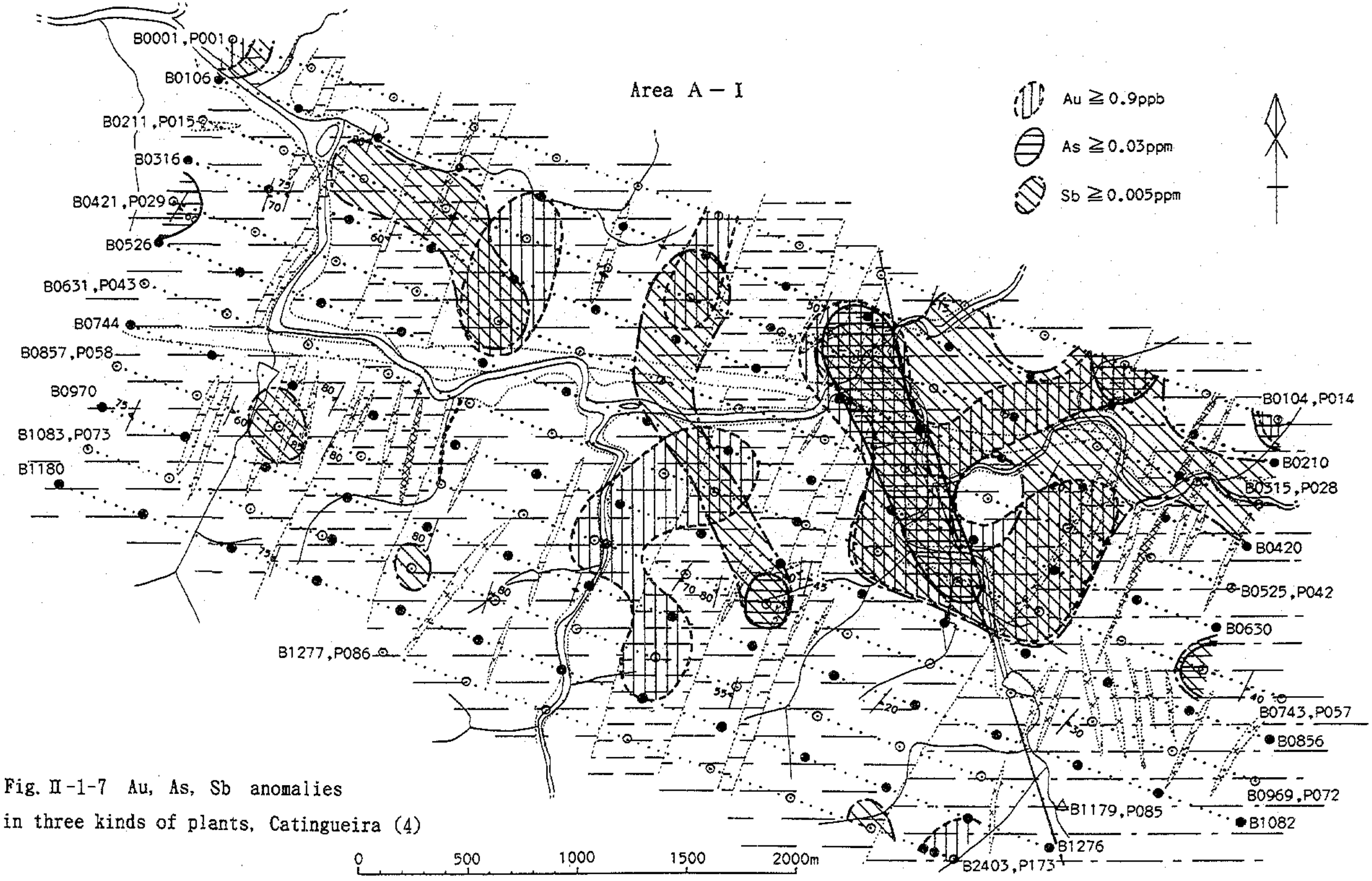



Fig. II-1-7 Au, As, Sb anomalies
in three kinds of plants, Catingueira (4)

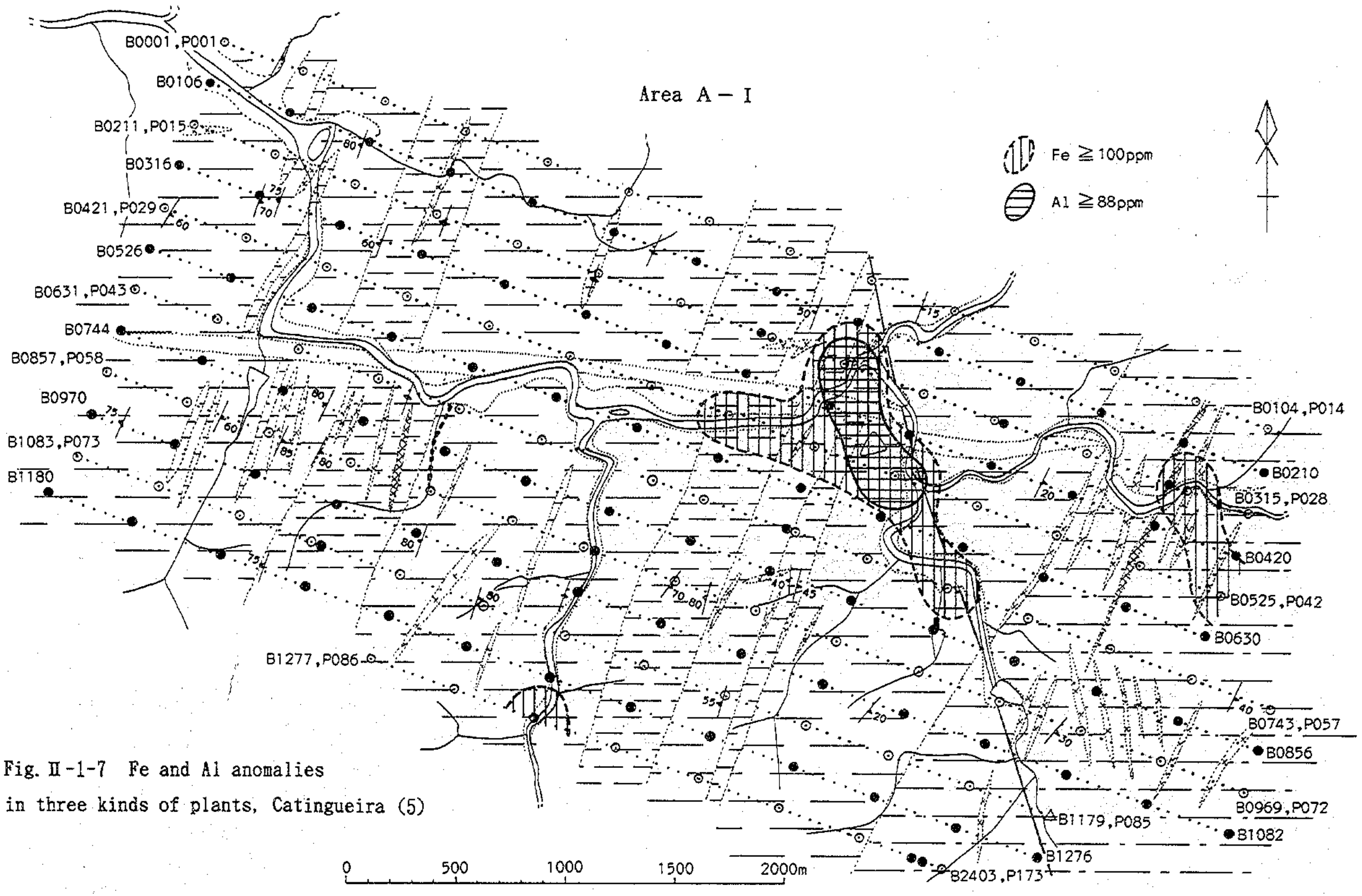



Fig. II-1-7 Fe and Al anomalies in three kinds of plants, Catingueira (5)

Antimony (Sb)

Anomalous areas were detected in the northeastern, central and northwestern part of the area as illustrted in Fig.II-1-6(4). The anomalous areas partly correspond with the Au and As anomalous areas described above. In wide anomalous area in the northeastern part, the analytical values were 0.002 to 0.045 ppm of Sb. The point with maximum value is the same as the one with 907 ppb of Au described above. Other anomalous points are not clustered. Samples with higher analytical values are located on the northern side of the basaltic dike. The distribution of the Sb anomalous areas corresponds with that of soil.

(b) Area A-II

Gold (Au)

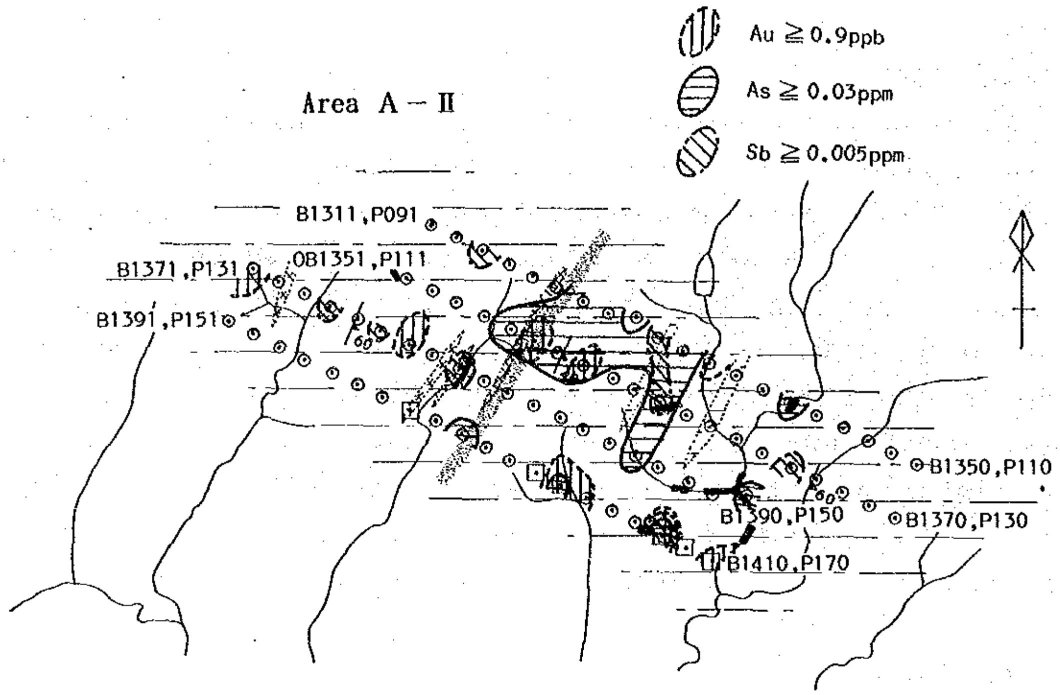
Seven anomalous areas were sparsely located as illustrated in Fig.II-1-7(6). Samples with higher Au values, 2.0 to 11.4 ppb, are distributed in southwestern part. On the supposed southern extention of the Sao Francisco deposite, the value as low as 1.2 ppb of Au was detected.

Arsenic (As)

Six anomalous areas were delineated as illustrated in Fig.II-1-7(6). In them, the anomalous samples in the northern anomalous area are well clustered. The anomalous area comprises the part of Au and Sb anomalous areas. There the analytical value of As of the samples ranges from 0.05 to 1.25 ppm. On the supposed extention of the Sao Francisco deposit, the analytical value was maximum, 1.25 ppm. Other anomalous points have the values ranging from 0.03 to 0.1 ppm of As.

Antimony (Sb)

Six anomalous areas are sparsely detected as illustrated in Fig.II-1-7(6). The areas do not necessarily correspond with the Au and As anomalous areas. Analytical



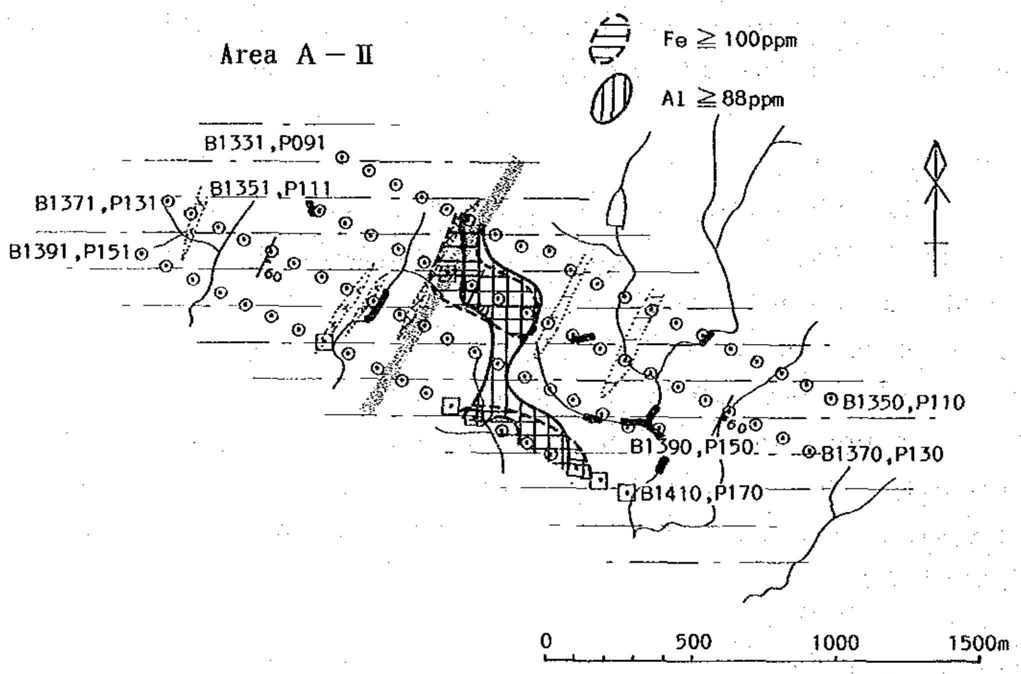




Fig. II-1-7 Au, As, Sb, Fe and Al anomalies in three kinds of plants, Catingueira (6) values are low, 0.005 to 0.02 ppm of Sb.

(iii) Malva

The concentration of gold ranges from less than 0.2 ppb up to 46.0 ppb. 9.1% of the number of samples have analytical values less than the detection limit. The value of the upper fence is 2.9 ppb and the values higher than the upper fence are all anomalous values.

The concentration of arsenic ranges from less than 0.01 ppm up to 5.11 ppm. 47.3% of the numbers of samples have analytical values less than the detection limit. The value of the upper fence is 0.075 ppm and the values higher than the upper fence are all anomalous values.

The concentration of antimony ranges from less than 0.005 ppm up to 0.055 ppm. 55.8% of the numbers of samples have analytical value less than the detection limit. The value of the upper fence is 0.022 ppm and the values higher than the upper fence are all anomalous values.

The concentrations of iron and aluminum are explained later.

(a) Area A-I

Gold (Au)

Two anomalous areas and one anomalous area were detected in the central southeastern part and in the northwestern end of the area respectively, as illustrated in the Fig.II-1-7 (7). Those areas are located inside the Au anomalous area of Jurema. The analytical values are ranging from 3.0 to 4.0 ppm of Au. The anomalous points in the central southeastern part are small clustered.

Arsenic (As)

Eight anomalous areas were detected in the northwest to eastern part of the area as illustrated in Fig.II-1-7(7). They are sparsely located. These anomalous areas are scarcely correspond with the anomalous areas of other elements of soil

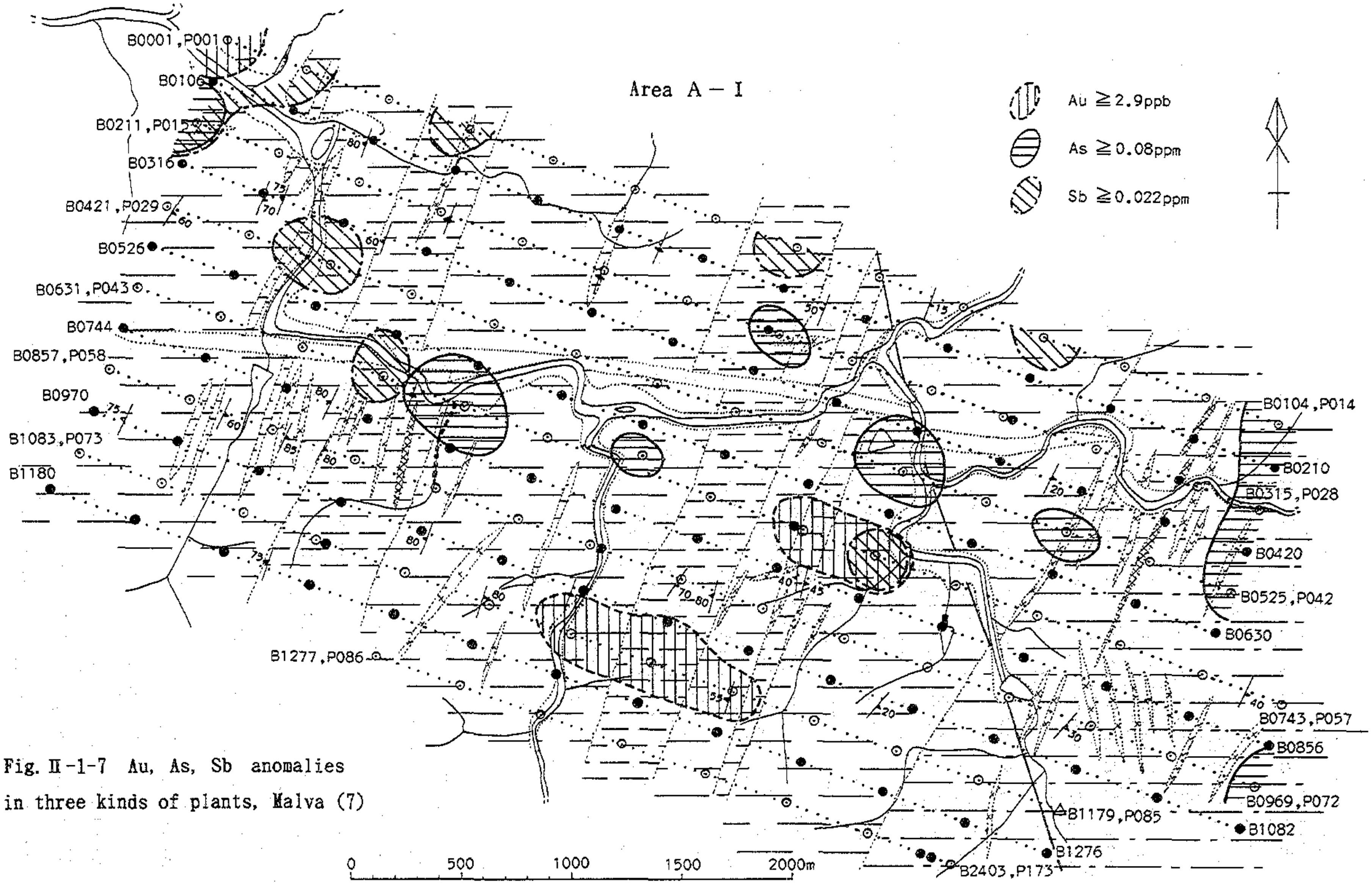



Fig. Ⅱ-1-7 Au, As, Sb anomalies in three kinds of plants, Malva (7)

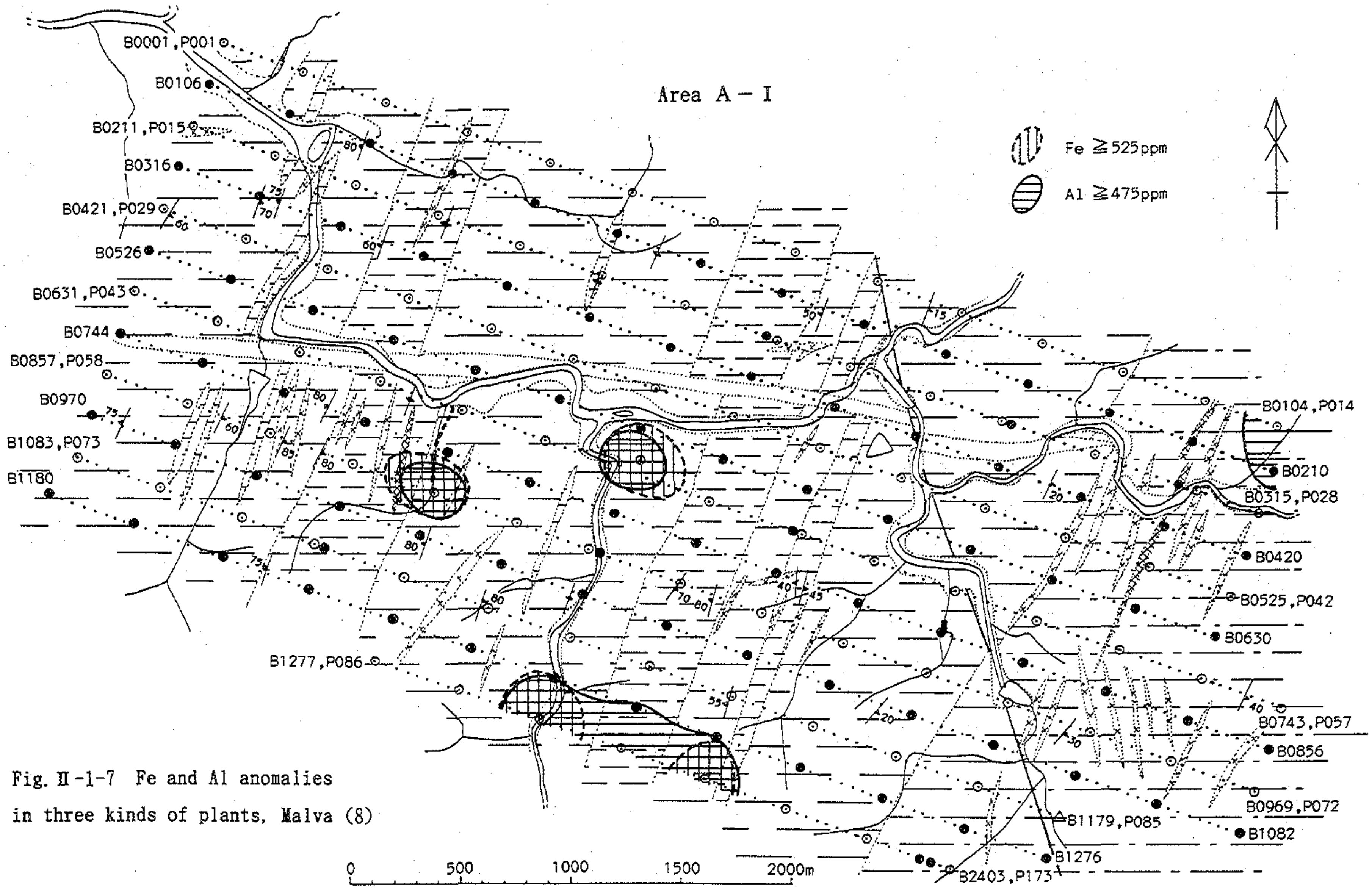



Fig. II-1-7 Fe and Al anomalies in three kinds of plants, Malva (8) and other kind of plants. The higher analytical values, ranging from 1.70 to 5.11 ppm, are detected in the central western part of the area. Analytical values of other samples range from 0.11 to 0.27 ppm.

Antimony (Sb)

Seven anomalous areas were detected in northwest to eastern part of the area as illustrated in Fig.II-1-7(7). The areas do not correspond with the Au and As anomalous areas except for few parts. The analytical values of the samples are ranging from 0.025 to 0.045 ppm of As. The anomalous areas are mainly located in the nothern part of the basaltic dike.

(b) Area A-II

Gold (Au)

Anomalous area trends north northeast in the northwest to central part of the area as illustrated in the Fig. II-1-7(9). This anomalous area is composed of fourteen samples, which have analytical values ranging from 4.0 to 46.0 ppb. Six samples of them have the analytical values of the order of 10 ppb. The anomalous area is partly overlaid on the Au anomalous areas of soil and other kind of plants. The analytical value of 46.0 ppb of Au was detected right on the supposed southern extention of the Sao Francisco deposit.

Arsenic (As)

Six anomalous areas are sparsely distributed as illustrated in Fig.II-1-7(9). The maximum analytical value, 3.00 ppm, is located on the supposed southern extention of the Sao Francisco deposit. Other analytical values are ranging from 0.13 to 0.67 ppm of As.

Antimony (Sb)

Five anomalous areas are sparsely distributed as illustrated in Fig.II-1-7(9). The anomalous areas do not

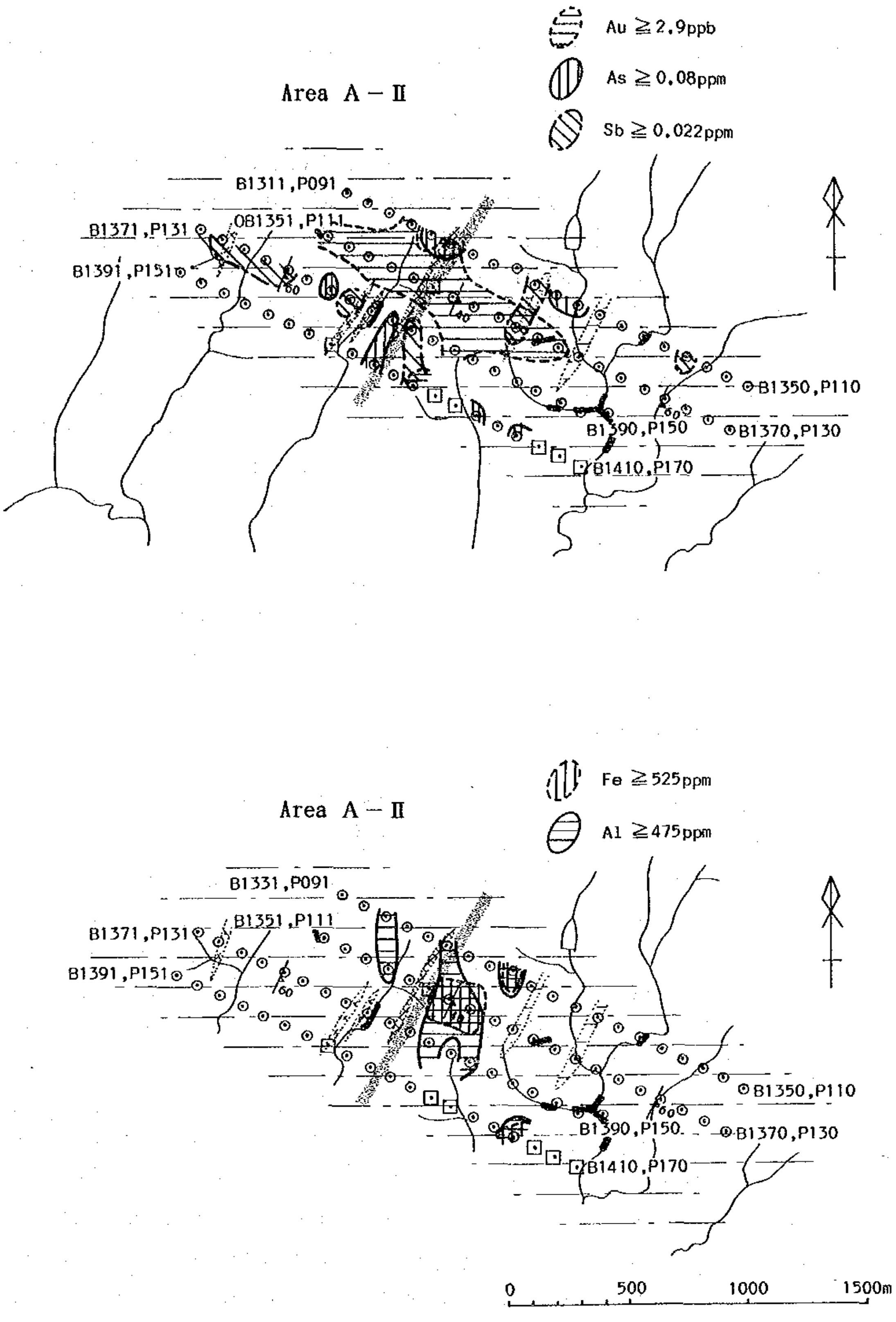



Fig. Ⅱ-1-7 Au, As, Sb, Fe and Al anomalies in three kinds of plants, Malva (9) necessarily overlap with the above-mentioned anomalous areas of Au and As.

Au, As and Sb anomalies in three kinds of plants were mentioned as above. Analytical values of Au are highest in Malva. Anomalous areas of three kinds of plants do not always correspond with each other, except for the central southern and central eastern parts of area A-I and the part right on the supposed southern extension of Sao Francisco deposit in area A-II. Anomalous areas of each kind of plant are overlaid with each other in those areas. Furthermore, Au anomalous area of three kinds of plants overlays As anomalous area of them on the supposed southern extension of Sao Francisco deposit.

Au contents of Jurema and Malva were plotted on a diagram against sampling points in area A-II (Fig.II-1-8). This diagram says that the Au analytical values on each sampling line are higher at the supposed southern extension of Sao Francisco deposit than at the rest of the area.

(iv) Iron and aluminum in three kinds of plants

The concentration of iron in Jurema Pleta ranges from less than 50 ppm up to 1,550 ppm. 15.6% of the number of samples have analytical values less than the detection limit. The concentration of aluminum in the plant ranges from less than 50 ppm up to 2,000 ppm. 21.3% of the numbers of samples have analytical values less than the detection limit.

The concentration of iron in Catingueira ranges from less than 50 ppm up to 250 ppm. 89.5% of the numbers of samples have analytical values less than the detection limit. The concentration of aluminum in the plant ranges from less than 50 ppm up to 300 ppm. 68.0% of the numbers of samples have analytical values less than the detection limit.

The concentration of iron in Malva ranges from less than 50 ppm up to 1,000 ppm. The concentration of aluminum in the plant ranges from less than 50 ppm up to 1,250 ppm.

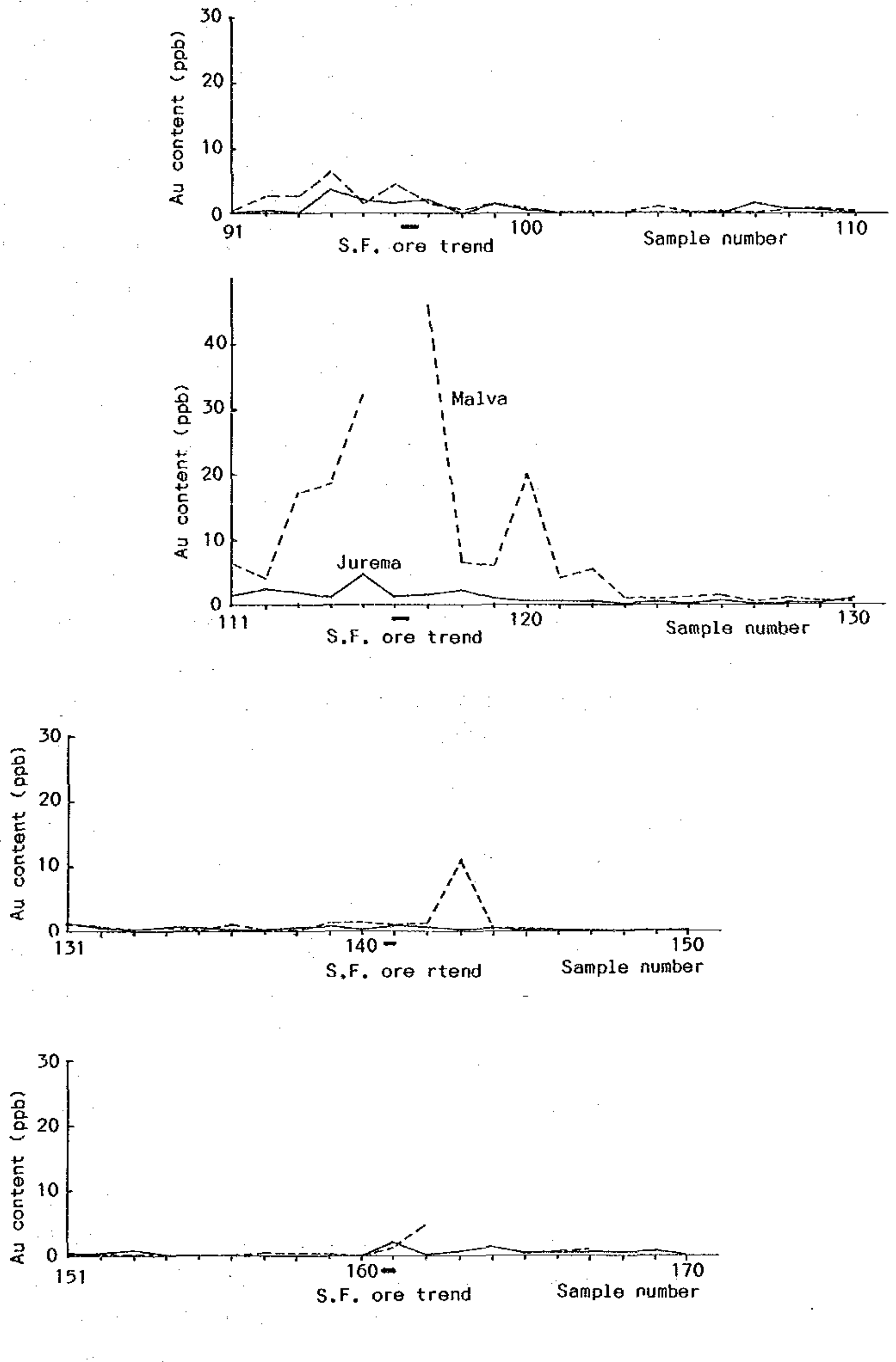



Fig. II-1-8 Diagrams showing Au content in Jurema and Malva along sampling lines

The analytical data of iron and aluminum were treated statistically in a same way of gold, arsenic and antimony. Except for the analytical data of iron of Catingueira, the values higher than the upper fence definedly EDA method are all anomalous values. The values higher than 100 ppm of iron of Catingueira are consequently all anomalous value.

Because the analyzed data of iron and aluminum of each plant have high correlation coefficient, a high concentration areas of iron cover the high concentration areas of aluminum.

In the area A-I, The high concentration areas of Jurema Pleta and Malva overlap each other and the high concentration areas of Catingueira do not cover any concentration areas of other plants. (Fig.II-1-7 (2), (5), (8)). The high concentration areas of Catingueira are in the east part and those of Jurema pleta and malva are in the central part. These areas are not probably related to the geology and lithology in the area A-I. The high concentration areas are situated in riverside and in valleys. The rivers are wide and have no water on the surface. Sand and soil are exposed along the streams. Therefore the high concentration values of iron and aluminum may be influenced by dusts in air and/or movement of underground water to lowland.

In the area A-II, the high concentration areas of three kinds of plants overlap each other perfectly on east side of the supposed extension of the Sao Francisco gold deposit. The high concentration areas of Jurema Preta and Malva overlap each other only partly in the west side of the extension (Fig.II-1-7 (3), (6) (9)). These areas may not be also related probably to the geology and lithology in the area A-II. The high concentration areas is situated in the valleys of east side of the trend of the Sao Francisco gold deposit and on slops continued from the valleys, and in the valleys of west side of the trend. Moreover non-paved roads run in the place where the high concentration areas are situated. Therefore the high concentration values may also be influenced by dusts in air and/or movement of underground water to lowland.

(2) Correlation of elements between plants and soil

Correlation matrix between elements of plant and soil samples is shown in Tab.II-1-5. The concentrations of gold and antimony between plant and soil samples are not related. The concentrations of arsenic between them are somewhat related. Correlation of arsenic concentrations between plant and soil samples are shown in the Fig.II-1-9.

Biological absorption coefficients calculated on each element of plant against that of soil are shown in Appendix 3. Biological absorption coefficient is calculated as the following; Some elemental contents in plants divided by the same elemental contents in soil. The biological absorption coefficients of gold are higher than those of arsenic and antimony. Therefore the plants can somewhat easily absorb gold, then arsenic and antimony. Samples of Jurema Preta and Malva, from the sample number B1334 to B1337 from B1354 to B1357 have high values of the biological absorption coefficient. These samples are located near the trend of the Sao Francisco gold deposit. The area with high biological absorption coefficient covers one of the places where the high concentrations of gold are distributed. Because the gold concent- rations of soil samples are not high, the high biological absorption coefficients of gold may be thought to be of the affection of dusts in the air.

The biological absorption coefficient of Catingueira of sample number PB023 is very high, 4535. The value may not be the biological absorption coefficient itself but may be enrichment of gold brought from outside of the plant.

## 1-4 Discussion

(1) Comparison of soil geochemistry and biogeochemistry

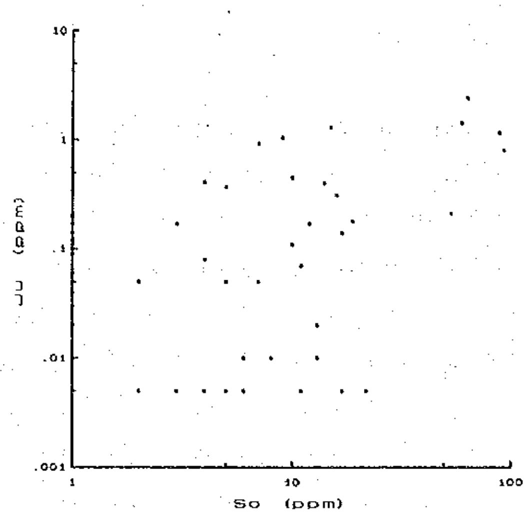
Examples of colculating biological absorption coefficient are few in the world. Some examples of biological absorption coefficient calculated in the Soviet Union are as

So-Ju
SCATTER DIAGRAM

X=So (ppm)
Y=Ju (ppm)

| | So | Ju |
|---|---|---|
| max | 93 | 2.41 |
| min | 1 | .00 |

n= 175
r= .579

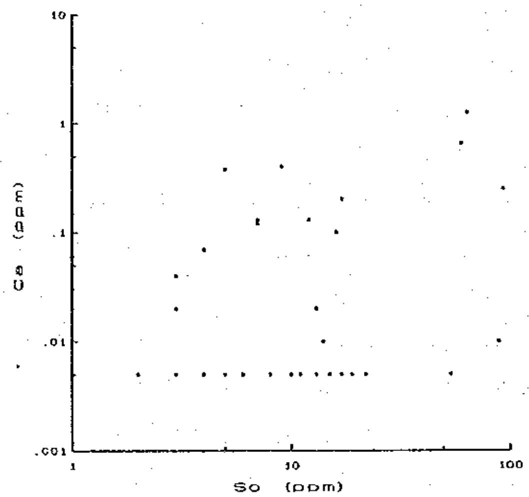



So-Ca
SCATTER DIAGRAM

X=So (ppm)
Y=Ca (ppm)

| | So | Ca |
|---|---|---|
| max | 93 | 1.25 |
| min | 1 | .00 |

n= 175
r= .372




So-Ma
SCATTER DIAGRAM

X=So (ppm)
Y=Ma (ppm)

| | So | Ma |
|---|---|---|
| max | 93 | 5.11 |
| min | 1 | .00 |

n= 175
r= .280

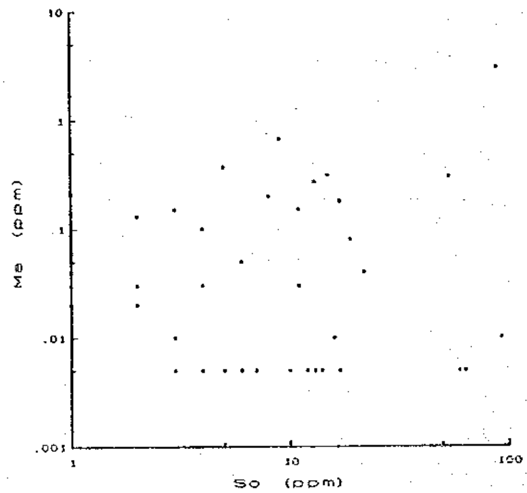



Fig. II-1-9 Diagram showing As correlation between soil and plant

Tab. II-1-5 Elemental correlation between soil and plant samples

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | -0.100 | 1.000 | | |
| 3 | -0.125 | 0.054 | 1.000 | |
| 4 | 0.029 | 0.320 | -0.074 | 1.000 |

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | 0.579 | 1.000 | | |
| 3 | 0.372 | 0.399 | 1.000 | |
| 4 | 0.280 | 0.174 | -0.017 | 1.000 |

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | 0.000 | 1.000 | | |
| 3 | 0.000 | 0.075 | 1.000 | |
| 4 | 0.000 | 0.202 | 0.114 | 1.000 |

1:Soil
2:Jurema
3:Catingueira
4:Malva

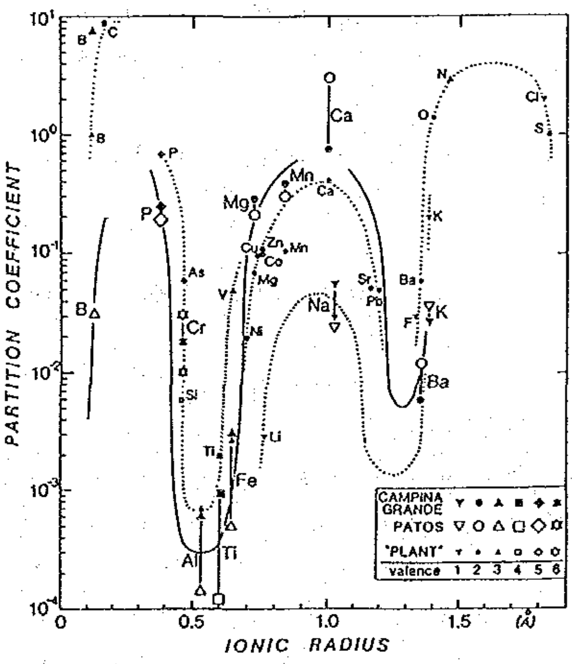



Fig. II-1-10 Partition coefficient -ionic radius diagram for tree and soil system follows: the values of Arsenic are 0.n to n, the values of iron are 0.n and those of Aluminum are 0.n to 0.0n. The values of each plant are also different. Some stems of plants were collected outside of this project area, west of Campina Grande and northwest of Patos in Paraiba and partition coefficients were calculated on them (Masuda, et al, 1989). The partition coefficient has the same meaning as the biological absorption coefficient. According to Masuda, et al, 1989, relationship between the partition coefficient of some element of some plant and ionic radius of that element is explained as cyclic curved line with some amplitude (Fig.II-1-10). In this Figure, the partition coefficient of arsenic can be read 0.n, those of iron and aluminum are 0.00n. The partition coefficient of gold can be ranging from approximately 0.n to n and that of antimony is from 0.0n to 0.n.

In this area, the partition coefficient of gold is calculated 2.37 in Jurema Preta, 0.90 in Catingueira and 3.69 in Malva. The partition coefficient of Arsenic is 0.0048 in Jurema Preta, 0.0032 in Catingueira and 0.002 in Malva. The partition coefficient of Antimony is 0.002 in Jurema Preta, 0.0015 in Catingueira and 0.002 in Malva. The values of arsenic are less in double figures compared to the values of gold and Sd.

Arsenic in the soil in this area may not be in good form to be absorbed by plants.

(2) Relationship among geochemical anomalous areas, geology and mineralization

The geochemical anomalies are compiled on the geologic map, as illustrted in Fig.II-1-11(1).

In the area A-I the anomalous areas of soil and plant don't overlap with each other. Though the concentration of gold in the soil samples are three to fifty times of Clarke's number in southeastern part of the area, the anomalous area of plants, except for a part of the samples of Jurema Preta , do not overlap the anomalous areas of

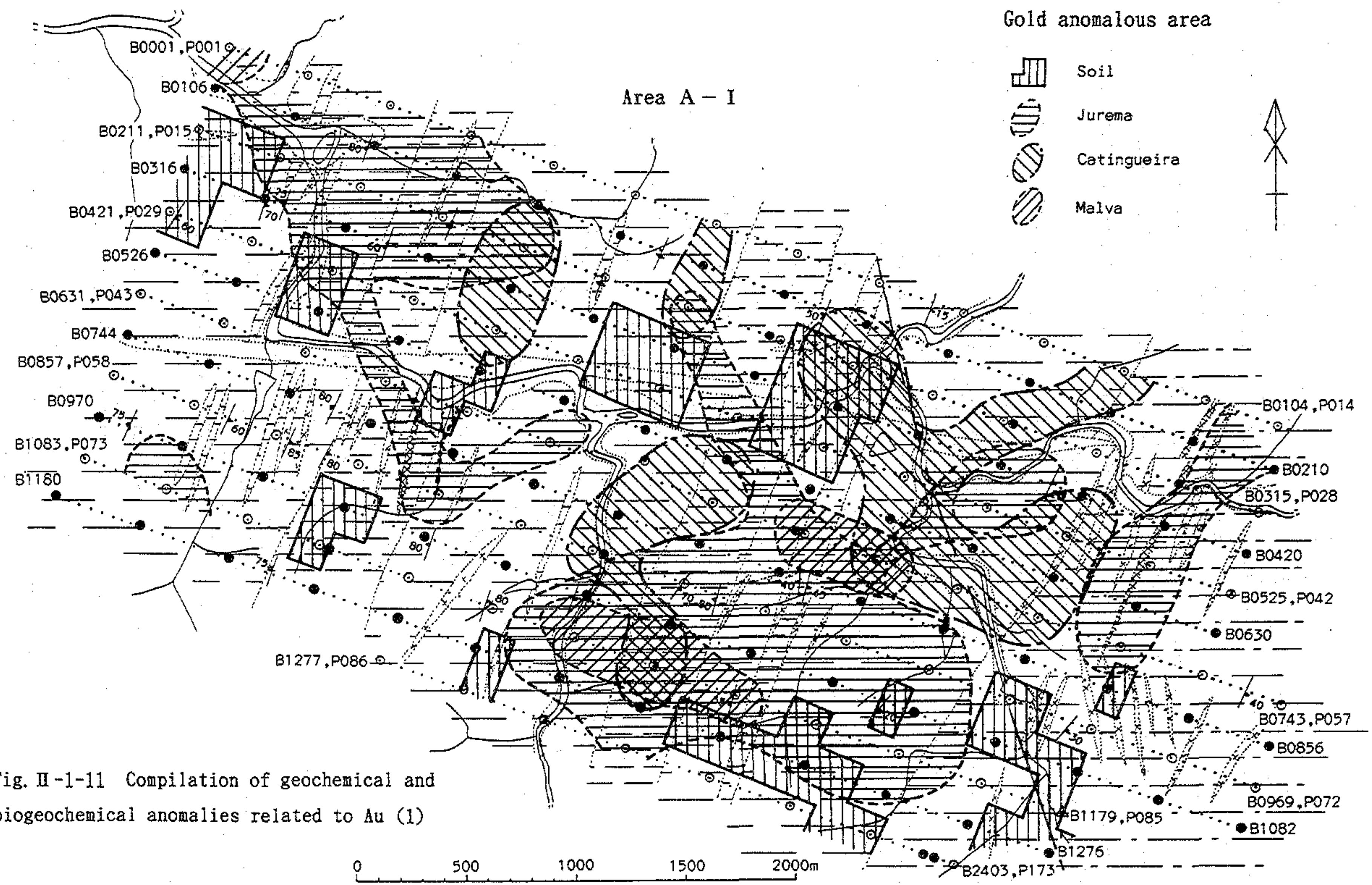



Fig. II-1-11 Compilation of geochemical and biogeochemical anomalies related to Au (1) soil. However, the anomalous areas of the plant can not be assessed properly because no plant samples were taken from the same position as those of soils. The anomalous areas detected by Jurema Preta are located in the lower land and in the lower reaches of a stream compared to the location of the soil anomalies. If the soil anomalies really represent Au mineralization, the location of the Au anomalies detected by Jurema Preta is interpreted to delineate the Au mineralization as wide mineralized area. The same type of relationships can be recognized, with regard to the anomalies of Au and As detected by soil and plants in the northwestern part of the area A-I. The points with Au anomalies detected by three kinds of plants described above may be in the same situation.

Though the concentrations of gold in the plant samples are expected to be the same values as that of soil in view of the values of biological absorption coefficient, the values of the plants are only twice of the Clarke's number. This fact introduces that Au in soil might be in a condition not to be easily absorbed into the plants.

The elements correlated to gold are not detected in soil in the area A-I, but Sb in Catingueira and Fe and Al in Malva have correlation with Au. The concentrations of these three elements in soil, expected from the calculation of the values of the partition coefficient of plant, are same as the values of Clarke's number. Therefore, these three elements are not related to the gold mineralization. It is not still realized whether the amount of As is related to some type of lithology or Au mineralization.

From the reasons mentioned above, to detect the Au dispersion in soil and to narrow a potential area, it is realized that Au contents in Jurema Preta and Malva are effective (Fig.2-1).

In the area A-II, Au anomalous areas of plants do not always correspond with Au anomalous areas of soil (Fig. II-1-11). On the supposed southern extension of Sao Francisco deposit, Au and As anomalous areas detected by every kind of plant overlap with each other. The fact mentions where the deposit is. The location of the deposit also well appears on the diagram, in which Au analytical values were plotted against each sample point. The Au anomalous areas detected by soil geochemical survey has a trend of NNE and the Au anomalous areas detected by biogeochemical survey applying Malva trends WNW in the area A-II. From the fact, it is imagined that the locations of those anomalous areas are controlled by geological structures as the Sao Francisco deposit is. However, general trends controlling Au mineralization in this region may deny the assumption of west northwest tending mineralization.

Gold potential areas in the areas A-I and A-II are shown in Fig.II-1(2).

In the areas A-III and A-IV, soil geochemical survey are executed. Elemental correlations between Au, As and Sb were not detected. Therefore, only Au anomalous areas are delineated on the compiled map (Fig.II-1-11(3), (2)).

Here As anomalous areas of soil were detected in pCssx4, especially in the zone rich in lenticular pCsscs. The analytical values of As reaches at 300 times of Clerk's number. Au and As contents in pCsscs are higher than that of pCssx4. Therefore, the pCsscs is needed to be studied from a view point of Au mineralization in the Serido Formation.

Geochemical and biogeochemical surveys were executed for the first time in this phase in this project. Furthermore, no data regarding to the mineralization was obtained right above the Sao Francisco deposit. Therefore, anomalous zone detected in some places in this phase could not be compared to the anomalous zone to be detected right above the Sao Francisco deposit.

It is concluded that Au in soil and in Jurema Preta and Malva are to be effectively applied to detect the Au mineralization in this area, because those plants absorb the element of Au included in soil and the Au anomalous zones biogeochemically detected by those plants may represent the location of the mineralization. Other tracer elements are

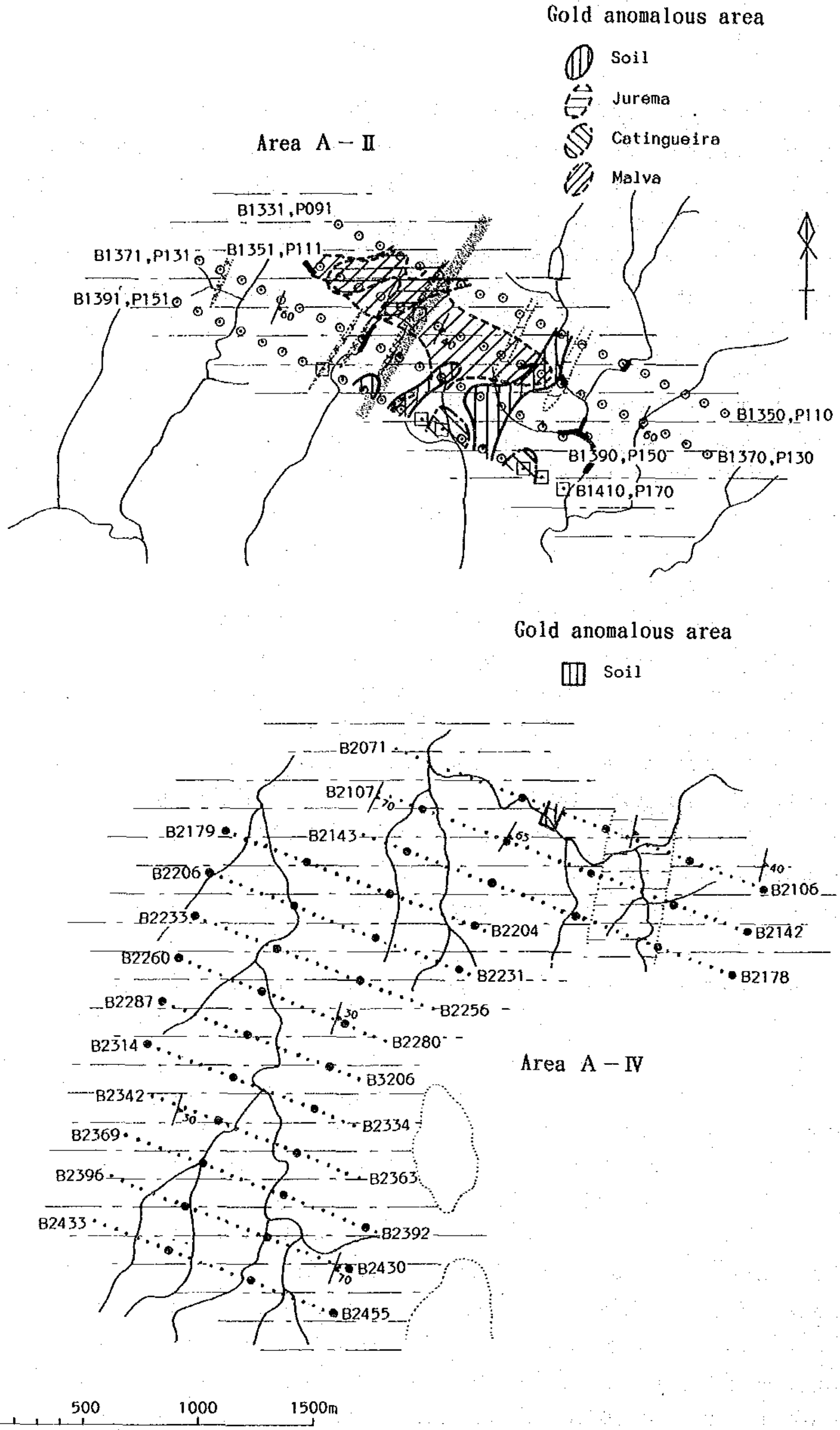



Fig. Ⅱ-1-11 Compilation of geochemical and biogeochemical anomalies related to Au (2)

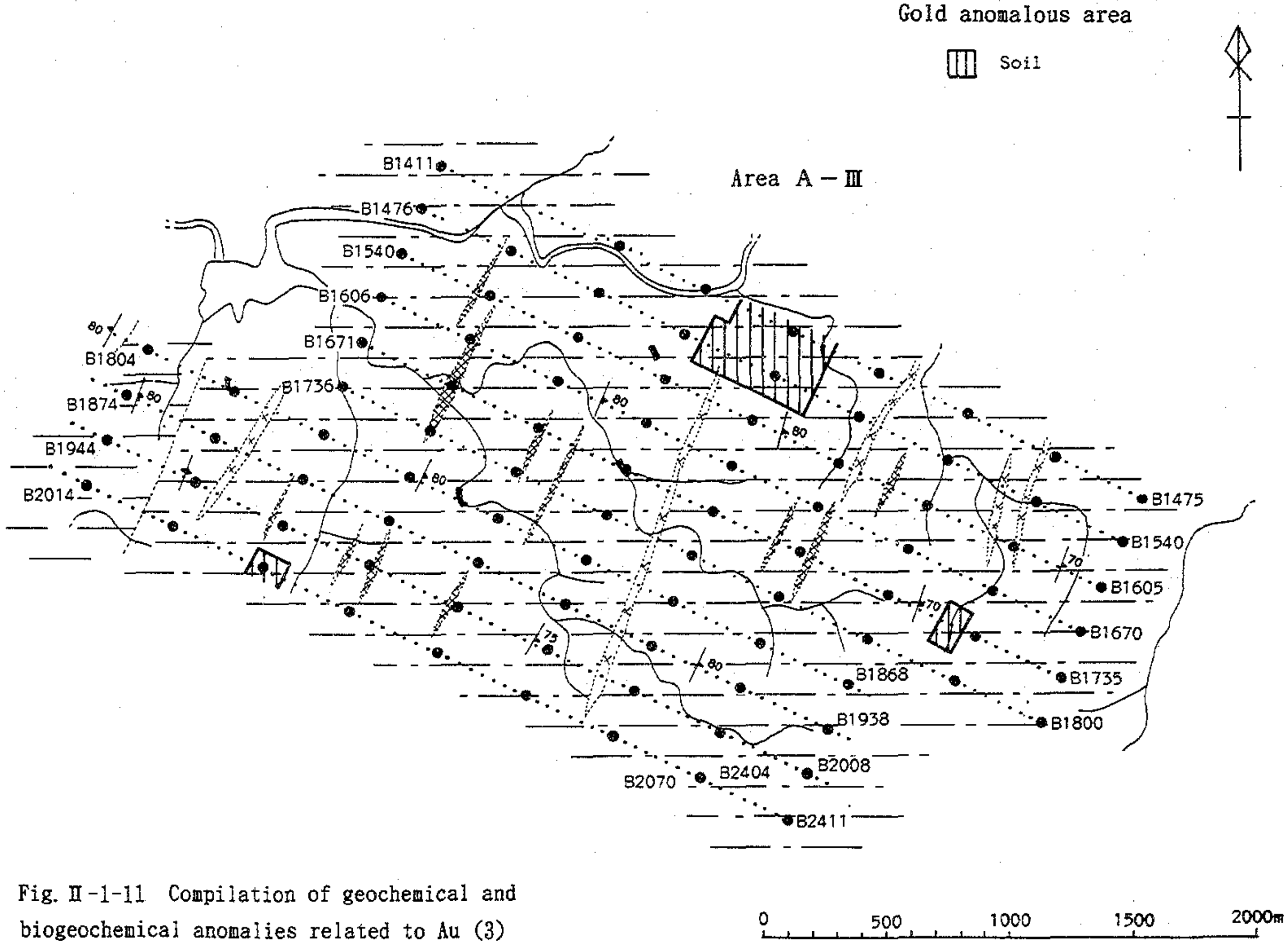



Fig. Ⅱ-1-11 Compilation of geochemical and biogeochemical anomalies related to Au (3) also needed to be studied for the biogeochemical exploration.