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

(PHASE I)

MARCH, 1990

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 September 22 to December 1, 1989.

The team exchanged views with the officials concerned of 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, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

Gen-ichi Fukuhara
President
Metal Mining Agency of Japan

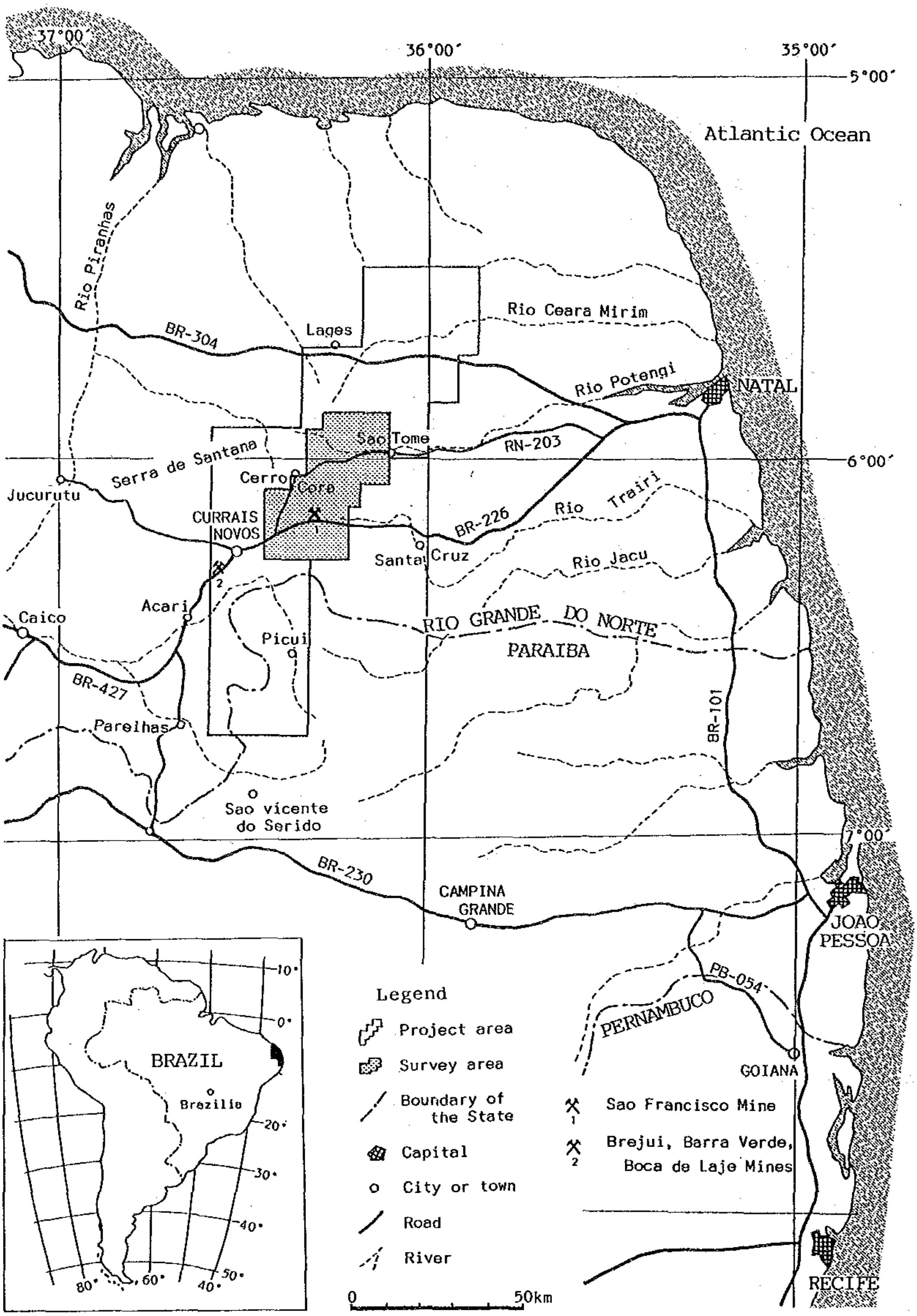

Fig.1 Location of the survey area

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 5910 Km2, and the term required for its execution is 3 years.

The project was started this year with a geologic and geochemical surveying, with members of both Brazilian and Japanese sides taking part in the survey.

The works executed through this first year includes the compilation of existing data, interpretation of LANDSAT TM images, drawing of topographic maps from aerial photographs and field surveying. The 1000 Km2 area for field surveying was selected based on an integrated analyses of the collected data. LANDSAT TM images cover all the project area, and their processing and interpretation were executed concurrently to the field surveying.

The area of field surveying is situated between parallels 5°53' and 6°17' north latitude, and between meridians 36°04' and 36°25' west longitude, in the southern to central part of the state of Rio Grande do Norte. The survey area covers about 1000 Km2.

During the field surveying, geologic traversing and sampling of stream sediments were carried out to understand the geologic and geochemical characteristics of the gold mineralization. Stream sediment samples collected during the geochemical surveying were analyzed for 13 elements including gold. Pan concentrate samples were also collected, and they were observed for the presence of gold dusts as well as analyzed for 7 elements including gold.

The geology of the survey area is dominated by Precambrian units and by small exposures of Tertiary and Quaternary formations. Precambrian units include the Archaean Caico Complex and the Serido Group of Proterozoic age. The Serido Group has been further subdivided, in ascendant stratigraphic order, into Jucurutu Formation, Equador Formation and Serido Formation. The lithology of the Caico Complex, Jucurutu Formation, Equador Formation and Serido Formation can be described as composed mainly of gneiss-migmatite-granites, gneiss, quartzites and biotite-schists, respectively. The northern half of the area is dominated by rocks of the Caico Complex, Jucurutu Formation and Serido Formation, with NNE structural trending. On the other hand, the southern half is characterized by a wide distribution of the Serido Formation.

At the boundaries between the Serido Formation and other units, faults trending north to northeast are frequently observed. These faults cross-cut the entire survey area, and possibly extend outward of the area. In the area underlain by the Serido Formation, there occur faults trending west to southwest, on a small scale. In the Sao Francisco mine, which is the only gold mine in the survey area (fig. 1), ore bodies trend north-northeast.

This may be suggestive of a controlling of the gold mineralization by the NNE trending structures.

Based on interpretation of LANDSAT TM images, it can be said that the area to the north of the Sao Francisco mine is characterized by the presence of extensive faults and lineations trending NNE, while in the area to the south most of the extensive lineations show a WNW trending. It can be expected, therefore, that in the zone of intersection of these two fault systems intensive fracturing and faulting took place.

The Sao Francisco gold deposit seems to be located in this intersection zone of the two fault system, as it is suggested by the interpretation of the LANDSAT TM images. This deposit is situated in the southern part of the area under survey, but other gold occurrences, as that situated to the west of Sao Tome, have been reported in the northeast of the survey area. These deposits consists invariably of gold-bearing quartz veins with pyrite and chalcopyrite.

The Sao Francisco gold deposit has ore reserves of about 590 thousands tons (including indicated reserve), with a grade of 2.5 to 4.3 g/t. The gold occurrence near Sao Tome, however, has not been reported in terms of calculated reserves.

As stressed above, the Sao Francisco gold deposit is located on the intersection of the two fault systems, and the "garimpo" near Sao Tome is located at the bending point of a fault. The mineralization in both deposits seems to be controlled by the fault and fracture systems described above.

In the stream sediment survey, anomalous areas for Nb, Ta, Sn, As and Au have been defined. The anomalous area for Nb nearly overlaps that for Ta. These anomalous areas have elongated forms trending NNE, and cover part of the Caico Complex exposures, which extend approximately 10 Km from Sao Francisco to NNE direction. Anomalous areas for Sn are distributed in the northern half of the survey area, while anomalous areas for Au and As are mainly distributed in the southern half.

These two last anomalous areas do partially overlap each other. Moreover, correlation between Au and As is well defined in the results of factor analysis of 13 elements in stream sediments. Based on this correlation and the distribution of anomalous areas for Au and As, three high-potential areas for gold have been delineated in the area around the Sao Francisco mine. These three areas are situated in the west to southwest area and in the south to southeast area of the mine.

The distribution of high-potential anomalous area for gold in the west to southwest area of the Sao Francisco mine is considered to be related to the geologic structure on the basis of its NNE trend. Due to this evidence of structural control of the gold anomaly, this area was chosen as one for further surveying. This anomalous area probably extends further to the south out of the present survey area. The high-potential area in the east to southeast of the Sao Francisco mine is regarded as less promising than the former one because there are evidences that it may be not related to the geologic structure.

Gold dusts were mainly observed in pan concentrates obtained from sediments of streams originated in the area surrounding the Sao Francisco deposit, and in concentrates from streams situated about 10 Km west of the Sao Francisco mine.

From an integrate analysis of the obtained results, the following four areas are recommended for surveying in the second phase of this project.

First, the stream sediment anomalous area in the west to southwest of the Sao Francisco mine.

Second, the area about 7 to 10 Km north of the Sao Francisco mine, where high gold concentrations were obtained in pan concentrates (Fig. 2).

Third, the anomalous area in the stream sediment survey situated in the south to southeast of the Sao Francisco mine. One of the surveying methods to be adopted in the surveying of the three areas recommended above could be a magnetic survey, in order to disclose faults and fractures related to the gold mineralization. Also, trenching is suggested for geochemical survey.

Finally, the area in the south of the survey area of this first phase, for geologic and geochemical surveying.

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Location map of the project area

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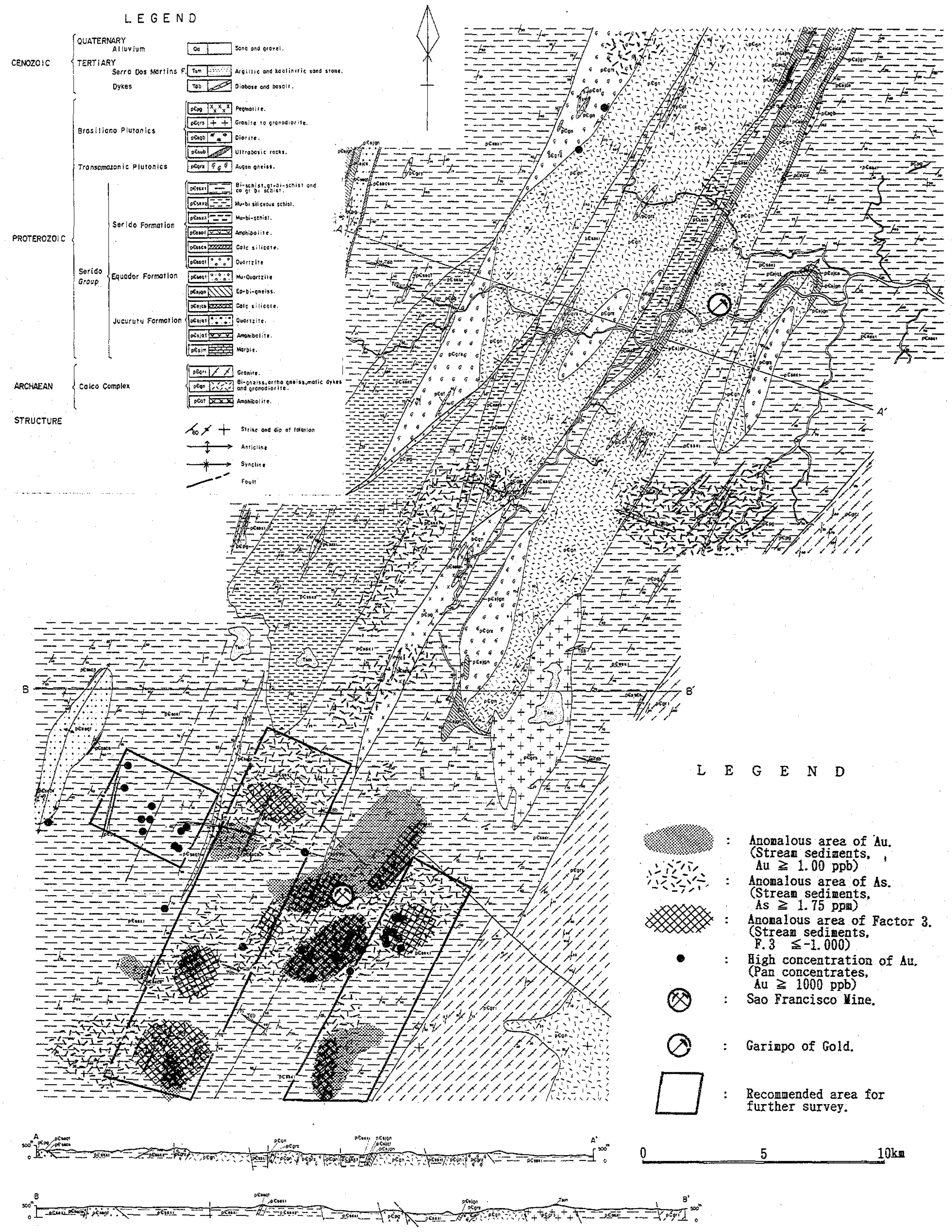


Fig. 2 Compilation of the survey results and the recommendation of further survey.

PART I GENERAL

Chapter 1 - Introduction

1-1 Background and purpose of the project

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, state of Rio Grande do Norte, Brazil. The project covers an area of 5700 Km2, and it is programmed to be concluded in a period of three years. The field surveying was executed by both Brazilian and Japanese members.

The area around Currais Novos has been known as an area of tungsten deposits since the beginning of the 1940's, and this region is considered as containing the largest scheelite reserves in Brazil. Brejui, Barra Verde and Boca de Lage, among others, are some of the mines presently in activity in this region. In addition, some gold occurrences have been reported in the area of this project. These gold occurrences have not been systematically surveyed, but only dug on small scales by the middle of 1970's. In 1977, a mining company called Itapebira Marmores and Granitos Ltda. began a systematic surveying in the area around the Sao Francisco gold mine, whose mining rights was hold by Mineracaó Xapetuba Ltda. Through this survey, the whole reserves of this gold deposit was cubed to about 0.59 million tons, with ore grades between 2.5 to 4.3%. With the decline of scheelite mining activity and the rising prices of gold, the interest for gold in the region has growing continually.

This project is aimed to search for possible mineral deposits in the chosen area, with special attention to gold. In the first phase, from the 5700 Km2 of the project area, a sub-area of 1000 Km2 was selected based on the existing bibliographic information and the analysis of LANDSAT TM images.

1-2 Area, purpose and survey in phase I

The area to be surveyed in this first phase of the project is located in the between parallels 5°53' and 6°17' south latitude, and between meridians 36°04' and 36°25' west longitude. This area is situated in the southern part of the Rio Grande do Norte state, and covers about 1000 Km2.

The objectives of the survey of this first year is to understand the geology of, and to realize the geologic and geochemical characteristics of ore deposits in the survey area.

The geologic survey was carried out with a density of 0.8 Km/Km2, aiming mainly to comprehend and state the relation among the units. The geochemical survey was executed with the purpose to know the distribution of, and the relationship among the 13 selected elements in this area by sampling stream sediments with a density of 1.5 samples/Km2.

A summary of field works as well as the number of chemical analyses and other laboratorial tests are shown in table 1-1-1.

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

Previous data compilation	5,910km^2		
LANDSAT image interpretation	5,910km^2		
Field survey		**Laboratory tests**	
		Chemical analysis & assay	
Survey area	1000km^2	Stream sediments (13 elements)	1500
Geological traversing	900km	Pan concentrates (7 elements)	150
		Rocks (25 elements)	30
Stream sediment samples	1500	Ores (5 elements)	15
Pan concentrates samples		Thin section testing of rocks	30
of stream sediments	150	Polished section testing of ores	7
		X ray powder diffraction	20

1-3 Organization of the survey team in phase I

1-3-1 Project finding

Japanese side		Brasilian side	
Masayuki Morikawa	ANRE, MITI	Elmo Serejo Farias	DNPM
Hideo Hirano	MMAJ	Carlos Oiti Berbert	DNPM
Toshihiko Hayashi	MMAJ	Maria Helena Taira Oguino	DNPM
Hideaki Mukai	MMAJ	Kiomar Oguino	DNPM
(Rio de Janeiro)		Julio de Resende Nesi	DNPM
		Mauro Caldas Mendes	DNPM
		Benedicto Valdir Ramos	DNPM
		Raul Branco	DNPM

ANRE: Agency of Natural Resources and Energy,
MITI: Ministry of International Trade and Industry
MMAJ: Metal Mining Agency of Japan
DNPN: Departamento Nacional da Producao Mineral

1-3-2 Project planning and prior negotiation

Japanese side		Brazilian side	
Masahiro Kawada	ECB, MFA	Elmo Serejo Farias	DNPM
Hajime Ikeda	JICA	Manoel da Redencao e Silva	DNPM
Katsutoki Matsumoto	MMAJ	Carlos Oiti Berbert	DNPM
Hideaki Mukai	MMAJ	Benedicto Waldir Ramos	DNPM
(Rio de Janeiro)		Maria Helena Taira Oguino	DNPM
Tetsuo Suzuki	MMAJ	Augusto Cesar	DNPM
		Alarico Antonio Frota Mont'Alverne	DNPM
		Julio de Resende Nesi	DNPM
		Marinho Alves	DNPM
		Holton Heleri	DNPM
		Carlos Arberte	DNPM
		Joao de Castro	CPRM
		Marinho Arberte	CPRM

ECB: Economic Cooperation Bureau, MFA: Ministry of Foreign Affairs
JICA: Japan International Cooperation Agency
CPRM: Compania de Pesquisa de Recursos Minerais

1-3-3 Field survey

Japanese side		Brazilian side	
Kazuo Kawakami	BEC	Alarico Antonio Frota Mont'Alverne	DNPM
Masakatsu Onodera	BEC	Julio de Resende Nesi	DNPM
Norio Ikeda	BEC	Jose Robinson Alcoforado Dantas	DNPM
Motomu Goto	BEC	Roberto Batista Santos	DNPM
Mitsutaka Bamba	BEC	Mauro Caldas Mendes	DNPM
		Cicero Alves Ferreira	CPRM
		Antonio Jose Barbosa	CPRM
		Jorge Luiz da Costa	DNPM
		Severino do Ramos Souza	DNPM

BEC: Bishimetal Exploration Co., Ltd.

1-4 Period of the survey in phase I

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

- Planning of the field survey: from 1989.7.7 to 1989.7.22;

- Field surveying: from 1989.09.22 to 1989.12.01;

- Preparation of the report: from 1989.12.02 to 1990.02.20.

Chapter 2 - Geography of the survey area in phase I

2-1 Location and access

The project area is located in the central to southern part of the state of Rio Grande do Norte, which is situated in the northeastern region of Brazil. This area extends from 5°30' to 6°45' south latitude, and from 36°50' to 36°55' west longitude. The area selected to be surveyed in this first phase of the project is located inside the area above described, extending from 5°52' to 6°14' south latitude and 36°04' to 36°25' west longitude. The city of Currais Novos, with population of about 25,000, is situated in the middle of the western border of the project area, and about 10 Km west of the survey area of this first phase.

The city of Currais novos can be accessed by air and by roads. There are two regular flight lines, one departing from Recife (capital of the Pernambuco state) and the other from Natal (capital of the Rio Grande do Norte state). This city is also linked to these two capitals by paved roads. Departing from Recife, it is a journey of 420 Km through the route BR-101, PB054 and BR-230. Departing from Natal, the journey is of only 190 Km following BR-226.

Paved roads in the project area are restricted to BR-226 and BR-104, which connects BR-226 and Serro Cora. In addition, there are two major unpaved roads crossing the area. RN-203 connects Serro Cora and Sao Tome, crossing the project area in NNE direction, while the other one departs from Serro Cora and runs northwestwards.

2-2 Topography and hydrography

The project area can be divided into three areas in terms of topographic features. An undulating topography with rounded mountains ranging in altitude between 300m and 600m above the sea level occupies large portions of the area. Flat plains dominate in the northern part while the central western part of the area in occupied by mountains of the Serra da Santana with altitudes up to 700m above the sea level. The area surveyed in this first year is dominated by the undulating topography.

The area surveyed in this year was further subdivided into three areas, based in some topographic distinctions. The northern half of the area exhibit an imbricated topography, resulting from the parallel alignment of highs and lows in the NNE-SSW direction. This topography is very consistent with the distribution of geologic units, which is exhibited by distinct resistance of the rocks to weathering and erosion. The highs are related to exposures of the Caico Complex, while the micaschists of the Serido Formation constitute the lows. Steep cliffs are often observed at the boundaries of these two lithologies. A distinctive topography are found in the central western part of the area, where pegmatite bodies are widely distributed, forming a peculiar relief with flat tops trending NE-SW.

The hydrographic systems in this northern half is comprised by a major NNE-SSw system and by other small systems trending mainly WSW-ESE. These hydrographic systems centralized into the Potenji river, which runs eastwards in the central part of this area.

The southern part of the survey area is comprised by gently undulating mountains with elevations ranging between 400m to 480m above the sea level. The distribution of this topographic unit is identical to that of mica-schists of the Serido Formation, which is weak against weathering and erosion. In some places inside this unit, however, steeply jutted reliefs are observed, related to silicified shear zones.

The hydrographic systems (Fig. I-1-1) in this southern half follow predominantly the NNE-SSW direction, influenced by the presence of shear zones which are strong against erosion. In smaller scale, however, WNW-ESE systems probably related to faults and dikes are frequently observed. Moreover, dendritic systems are present in some areas. All these systems contribute to the stream systems of the Currais Novos and Mulungu rivers, which run westwards.

The topography of the southeastern part of the survey area is dominated by flat plateau with elevations between 500m to 550m above sea level. The distribution of this topographic unit is closely related to the distribution of granites and gneisses of the Caico Complex. The hydrographic system in this area exhibits a dendritic pattern, influenced by exposures of the Caico Complex. This system is tributary of the stream system of the Sao Joao d'Agua river.

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 the dry season (Table I-2-1). It rains intermittently during the rainy season, and only scarcely in the dry season.

The temperature is almost constant throughout the year, with maximum values of 40°C and minimums ranging from 20°C to 30°C.

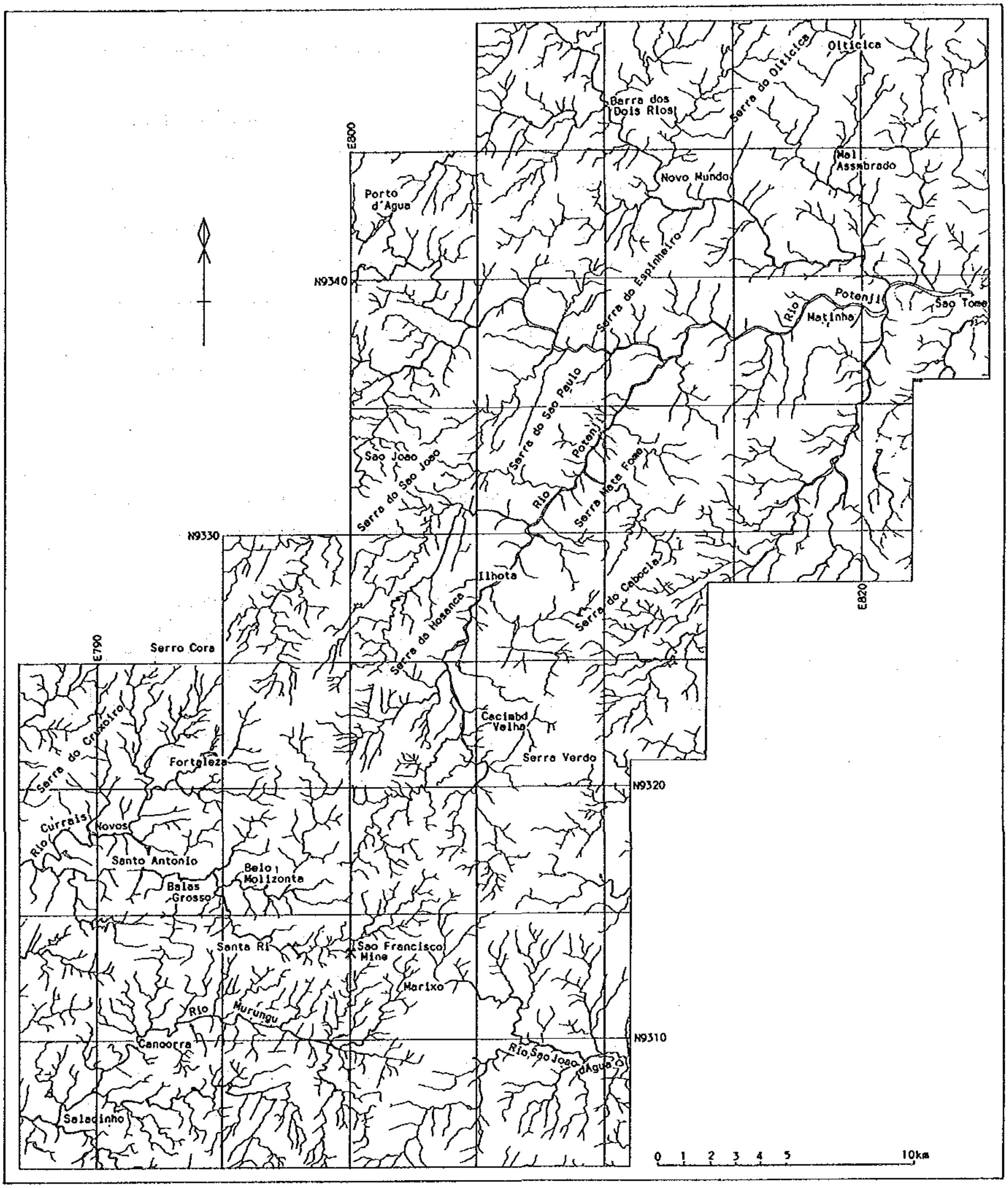


Fig. I-1-1 Drainage system in the survey area

The majority of streams in the project area have water only during the rainy season. Accordingly, almost all creeks were dried during the field survey of this year. During the survey period, there was no rain in October, but in the first nine days of November, it rained at morning.

Concerning to the vegetation, this area is included in the so called forest district of the northeast region of Brazil. Bushes two to three meters tall are typical in the area. These bushes are densely present in the northern half of the survey area. Some trees up to 10m tall grow sparsely along the creeks. The dominant vegetation type is the thorny Caatinga, which includes cactus such as Xique-xique, Cardeiro and Facheiro.

Since the field surveying in this first year was carried out during the dry season, the vegetation did not disturb the survey. Almost all leaves had been fallen, and allowing a clear view of the outcrops. However, in sites with dense vegetation, it took some time to cut the bushes during geologic traversing.

Table I-2-1 Temperature and precipitation change in the survey Area (1980 ~ 1988)
compiled from the data of Secretaria da Agriculutura/RN, 1989

	Monthly presipitation (mm)												Temperature(℃)	
	1	2	3	4	5	6	7	8	9	10	11	12	Max	Min
Currais Novos	35	120	166	135	53	20	25	6	4	0	7	42	33	22
Cerro Cora	74	94	151	210	54	34	27	24	10	0	3	33	33	20
Sao Tome	36	90	174	133	92	35	26	25	11	0	2	10	36	20

Chapter 3 - Previous geologic information on the project area

3-1 Previous surveys

3-1-1 Stratigraphy and structure

The project area belongs to the Borborema Province (Almeida et al., 1981), one of the largest structural units of the northeastern region of Brazil.

The Borborema Province is composed of two basic petrologic units, a gneiss-migmatite-granite unit and an unit consisting mainly of meta-volcanic and meta-sedimentary rocks (Brito Neves, 1975, 1983; Almeida et al., 1976). The survey area is settled inside the Serido Domain, a sub-unit where meta-volcanic and metasedimentary rocks predominate.

The stratigraphy and the structure of the Serido Domain have been investigated by many researchers. Geological maps in scales up to 1:100,000 have been published for some areas. The construction of a regional stratigraphic column has been started by the end of the 1960's to the beginning of the 1970's, and doubts on the positioning of a quartzite bed have long remained.

Jardim de Sa & Salim (1980) proposed a general lithostratigraphy for the Serido Domain and this proposal have been widely accepted, including the positioning of the quartzite bed, presently denominated Equador Formation.

According to Jardim de Sa & Salim (1980), the stratigraphy of the Precambrian in the Serido region is compose, from the bottom to the top, by the Caico Complex and by the Serido Group. This group is, in turn, subdivided into Jucurutu, Equador and Serido Formations. Fanerozoic units consists of the Cretaceous Jandaira and Acu Formations, Tertiary Serra dos Martins, and Quaternary sediments. This report follows this stratigraphy.

The geologic structure of the Borborema Province has been affected by the Jequie (2,900-2600 Ma), Transamazonico (2100-2600 Ma) and Braziliano (450-700 Ma) orogenic cycles. Especially in the Serido region, two stages of tectonic movements during the Transamazonico cycle and three tectonic movements during the Braziliano orogenic cycle have been recognized. The movements related to the Transamazonico orogenic cycle are recorded by low-angle shear zones, while those related to the Braziliano cycle are characterized by high-angle shear zones. Many intrusive rocks are observed along these shear zones.

3-1-2 Mineral deposits

The Serido Domain, in which the project area is inserted, is well known as an area rich in tungsten deposits. Other mineral deposits occurring in the project area are those

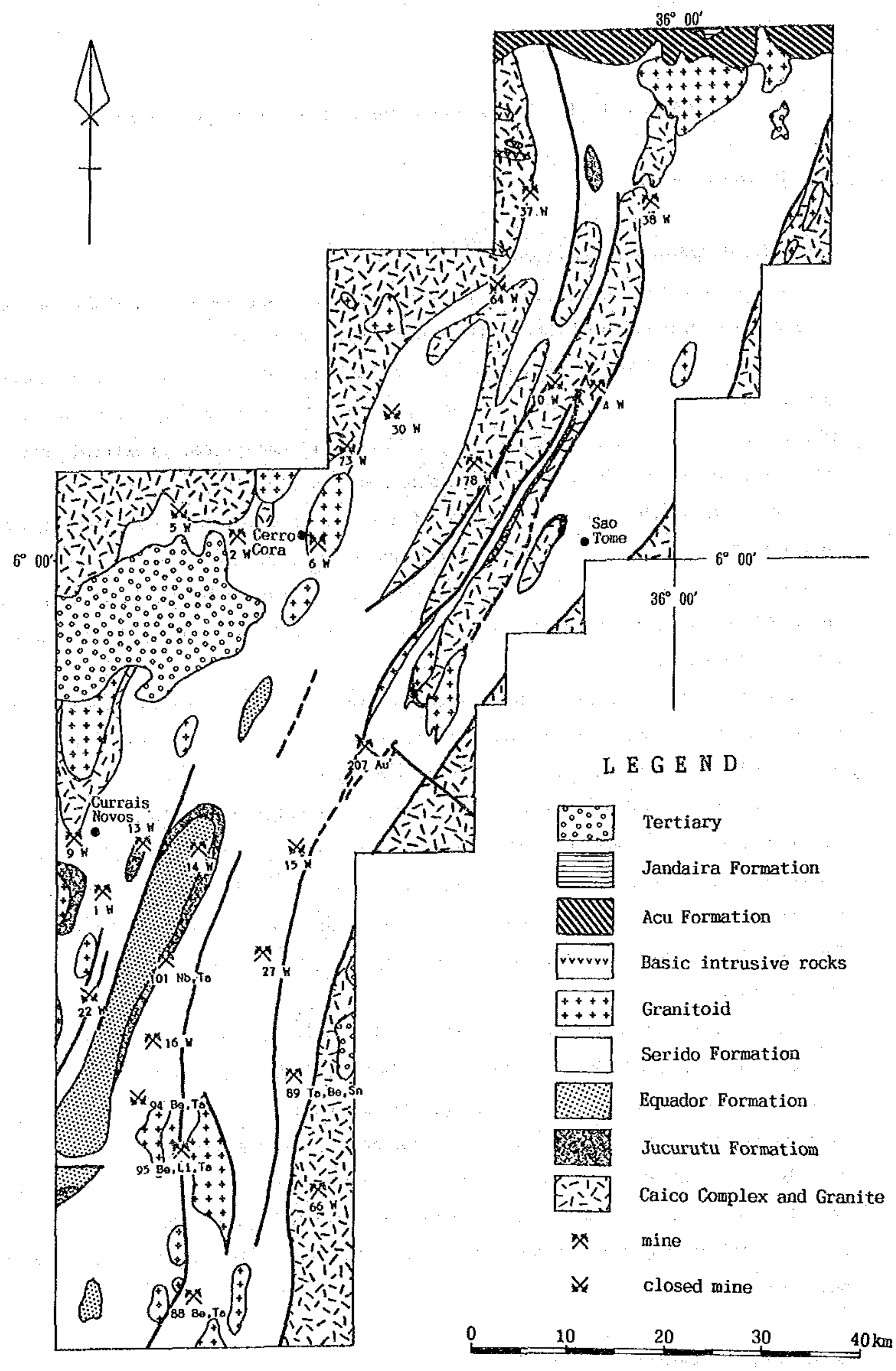


Fig. I-3-1 Knownmineral deposits in the project area derived from Carta Geologia do Brasil, Folha Jaguaribe(SB-24)/Folfa Fortaleza(SA-24) DNPM, 1974

Table I-3-1 Known mineral deposits in the project area

No.	Mineral	State	Locality	Geographic Orientation Lat. S	Long. W	Morphology	Genetic type
1	Scheelite	RN	Currais Novos	6° 19′ 00″	36° 33′ 00″	Stratiform	Hydrothermal
1	Scheelite	RN	Currais Novos	6° 20′ 00″	36° 33′ 00″	Stratiform	Hydrothermal
1	Scheelite	RN	Currais Novos	6° 21′ 00″	36° 33′ 00″	Stratiform	Hydrothermal
2	Scheelite	RN	Santana dos Matos	5° 59′ 00″	36° 25′ 00″	Stratiform	Hydrothermal
4	Scheelite	RN	Sao Tome	5° 51′ 00″	36° 05′ 00″	Stratiform	Hydrothermal
5	Scheelite	RN	Santana Dos Matos	5° 57′ 30″	36° 27′ 00″	Stratiform	Hydrothermal
6	Scheelite	RN	Santana Dos Matos	5° 59′ 00″	36° 20′ 00″	Stratiform	Hydrothermal
6	Scheelite	RN	Santana Dos Matos	5° 58′ 00″	36° 29′ 00″	Stratiform	Hydrothermal
9	Scheelite	RN	Currais Novos	6° 17′ 00″	36° 35′ 30″	Stratiform	Hydrothermal
9	Scheelite	RN	Acari	6° 17′ 30″	36° 38′ 30″	Stratiform	Hydrothermal
9	Scheelite	RN	Currais Novos	6° 16′ 55″	36° 35′ 14″	Stratiform	Hydrothermal
10	Scheelite	RN	Lajes	6° 20′ 20″	36° 07′ 43″	Stratiform	Hydrothermal
13	Scheelite	RN	Currais Novos	6° 17′ 09″	36° 33′ 18″	Stratiform	Hydrothermal
14	Scheelite	RN	Currais Novos	6° 18′ 00″	36° 27′ 00″	Stratiform	Hydrothermal
15	Scheelite	RN	Currais Novos	6° 16′ 00″	36° 21′ 30″	Stratiform	Hydrothermal
16	Scheelite	PB	Frei Martinho	6° 27′ 00″	36° 30′ 30″	Stratiform	Hydrothermal
22	Scheelite	RN	Acari	6° 25′ 00″	36° 33′ 00″	Stratiform	Hydrothermal
27	Scheelite	PB	Frei Martinho	6° 23′ 00″	36° 24′ 00″	Stratiform	Hydrothermal
30	Scheelite	RN	Cerro Cora	5° 53′ 00″	36° 17′ 00″	Stratiform	Hydrothermal
37	Scheelite	RN	Lajes	5° 41′ 00″	36° 08′ 00″	Stratiform	Hydrothermal
38	Scheelite	RN	Caicara do Rio dos Vento	5° 04′ 00″	36° 02′ 00″	Stratiform	Hydrothermal
64	Scheelite	RN	Lajes	5° 44′ 13″	36° 11′ 24″	Stratiform	Hydrothermal
66	Scheelite	RN	Picui	6° 36′ 30″	36° 21′ 30″	Disseminated	Hydrothermal
73	Scheelite	RN	Cerro Cora	5° 53′ 00″	36° 19′ 00″	Vein	Hydrothermal
78	Scheelite	RN	Sao Tome	5° 54′ 30″	36° 11′ 30″	Vein	Hydrothermal
88	Beryl, tantalite	PB	Pedra Lavrada	6° 44′ 00″	36° 28′ 30″	Vein	Pegmatite
89	Tantalite, beryl, cassiterite	PB	Pedra Lavrada	6° 29′ 30″	36° 21′ 30″	Vein	Pegmatite
94	Beryl, tantalite	RN	Carnauba dos Dantas	6° 31′ 00″	36° 30′ 30″	Vein	Pegmatite
95	Beryl, mica, tantalite	RN	Cachoeira da Cruz	6° 34′ 00″	36° 28′ 00″	Vein	Pegmatite
101	Columbite tantalite	PB	Frei Martinho	6° 24′ 30″	36° 29′ 00″	Vein	Pegmatite
207	Gold	RN	Currais Novos	6° 11′ 49″	36° 17′ 00″	Stratiform	Sedimentary

Reference: Carta Geologica do Brasil ao Milionesimo. Folha Jaguaribe (SB-24)/Forha Fortaleza (SA-24) DNPM - 1974.

of niobium-tantalum related to pegmatites, and also those of gold (Fig. I-3-1).

The tungsten deposits in the Serido region have been surveyed by DNPM/CPRM since the beginning of 1970's, and presently the knowledge on this deposits is in a pretty advanced stage. Occurrences of scheelite have been recognized in 216 sites, which amount to some 138,000,000 tons of estimated reserves (average grade of 0.2% WO_3). Brejui, Barra Verde and Boca de Lage are three of the largest mines presently in activity. They are located in the southern part of Currais Novos, and mine the same scheelite deposit. The more advanced the mining works, the more incremented is the knowledge on the structural and petrological features of these deposit.

Concerning to gold occurrences in the project area, there wasn't any detailed exploration survey until the middle of 1970's. In 1977, the occurrence of gold in the area presently known as the Sao Francisco mine was detailed surveyed by the Itapebira Marmores e Granitos Ltda. company. Boring works have been carried out in order to cube the reserves. Moreover, some petrologic as well as structural features have been unraveled, and even refining methods have been proposed. These investigations are summarized in Ferran, A. (1988).

Between 1980 and 1983, the DNPM/CPRM executed surveying works on gold occurrences in the entire state of Rio Grande do Norte. Other informations on gold occurrences in this region is related to works of Souza, Z.S. et al. (1986), who pointed out that the gold mineralization between Sao Tome and Lages, situated to north of the Sao Francisco deposit, is strictly controlled by the geologic structure.

Participants in the Course on Gold Metalogenesis (1989), sponsored by CPRM, investigated the gold mineralization in fracture zones in the area among Serido, Cachoeirinha and Riacho do Pontal, located at the boundary of the Rio Grande do Norte and Paraiba states, and found that the gold mineralization in that area is closely related to a wide shear zone.

3-2 Geology of the surrounding area

The survey area is located inside the Serido region, which is part of the Central Domain of the Borborema Province. In the northern part of the area, exposures are mainly of rocks belonging to the Caico Complex, which consists most of the gneiss-migmatite-granite tripartite. In the rest of the area, rocks of the Serido Group, consisting mainly of meta-volcanic and metasedimentary rocks, are widely distributed. The stratigraphic sequence in this area is composed, from the bottom to the top, by the Archaean Caico Complex, Proterozoic Jucurutu, Equador and Serido Formations, Cretaceous Acu Formation, Tertiary Serra dos Martins Formation and Quaternary sediments.

The survey area has been affected by the Transamazonico and by the Brasiliano orogenic cycles. These two orogenic cycles comprise at least five orogenic and metamorphic stages (Table II-3-1), which have been distinguished based mainly on the types of structural movements. As a general rule, the structures formed during the Transamazonico cycle are characterized by low-angle shear zones, while those related to the Brasiliano orogenic cycle are characterized by high-angle shear zones. In both orogenic cycles, there are evidences that the metamorphic grade reached the amphibolite facies. Along these shear zones, there occurred many intrusions of different types of rocks.

Concerning to major structures, it is worth noting two tectonic lines that cross-cut this area. One is the tectonic line which divides the Central Domain from other structural domains, and the other is the Serido-Cachoeirinha-Riacho do Pontal tectonic line, which prolongs southwards, entering the Paraiba state.

3-3 Mining industry in the project area

In 1942, occurrences of scheelite was discovered in this area for the first time, and soon the mining works were started. The Brejui-Barra Verde deposit that is located in the southwestern part of the survey area was found just after the former discovery and in the period from 1943 to 1954 it was mined only in small scale, in garimpos(*1). By 1955 the mining works became more systematic. From 1942 until 1982, 95% of the scheelite produced in the country was mined in this region. The mines presently in activity are those of Brejui, Barra Verde, Boca de Lage and Zangarelhas.

Gold in this area was discovered in Pago Entupido(*2), in 1942. From 1942 to 1952, it was mined as a placer deposit. In 1976, not only the placer but also the weathered zone and the quartz veins were being mined. However, with the dropping of gold grades, the mine was closed. By this time, this place was already known as Sao Francisco mine.

In 1977, a mining company called Itapebira Marmores e Granitos Ltda. started a systematic exploration survey in the area of the Sao Francisco mine. In November, another mining company (Mineracao Xapetuba Ltda.) restarted the production of this mine by strip mining. According to Ferran, D.A. (1988), the reserves of the Sao Francisco gold deposit amounts to more than 587,000 tons, containing about 1750 Kg of gold.

Table I-3-2 Production and ore reserves of mines in the survey area

Metal	mine	Production: Concentrate (73% WO_3)	Production: ore	Ore reserves	grade
W	Brejui	19,633.3 t	total 5.5×10^6 t	total 10.8×10^6 t (original)	~0.5% (WO_3)
	Barra Verde	14,297.2 t			
	Boca de Lage	2,613.0 t			
	Zangarelhas	--		5.3×10^6 t (remaining)	0.2 ~0.47% (WO_3)
	total	36,543.5 t			
Au	S.Francisco	--	--	587,646 t	2.5 ~4.3(g/t)

from : Brejui/Bova de Lage/Zangarelhas mines ; Maranhao, R. (1986)
S.Francisco Deposit ; Ferran, A. (1988)

(*1) A place where digging in processed manually.

(*2) The old name of the Sao Francisco mine.

Chapter 4 - Compilation and discussion of the phase I survey

4-1 LANDSAT image interpretation

The interpretation of the geology of the project area from LANDSAT TM data were performed based mainly on false color images, principal component analysis images and ratio images.

For composition of false color images, bands 1, 4 and 5 of TM data were assigned to blue, green and red, respectively. Principal component analysis maps and ratio maps were also composed in order to emphasize the color characteristics of different types of rocks and soils.

Color as well as other features like drainage system types and differences in resistance to weathering were examined on the maps, with the aim of delineating geologic units, uncovering major geologic structures, and also disclosing alteration areas which could be related to mineralizations.

In order to identify and delineate geologic units, photogeologic characteristics of the area around the Sao Francisco mine were identified and correlated with features on the LANDSAT images. By correlating features on the images maps with informations from previous geologic maps, it was possible to identify clearly areas of exposures of rocks belonging to the Caico Complex, Equador formation, and Serido Formation. Moreover, granitic, pegmatitic and gabbroic bodies and dykes, Cretaceous sediments, Tertiary sediments and alluvium were also individualized.

Concerning to faults and lineaments, the analysis of image maps revealed that linear structures trending NNE are the most prominent geologic structures in the area under survey. Lineaments trending east were also identified, with similar frequency as those trending NNE. Geologic structures trending east, however, were not clearly identified.

In the area between the Sao Francisco mine and the south of Picui, lineaments trending NNE do not show large extensions. This may be related to the absence, in this area, of great lithologic differences that could emphasize the structural elements.

Extensional faults and lineaments trending NNE are observed especially in the region to the north of the Sao Francisco mine, while extensional structures trending east prevail to the south of the that mine. It is expected, in the intersection of these two structural systems, the development of a strong fracture system, as observed in the neighborhood of the Sao Francisco mine.

The gold mine of Teixeira is part of the gold mineralized zone of the state of Paraiba. In this zone, which is situated along the Serido-Cachoeirinha- Riacho do Pontal shear zone (Fig. I-3-2), faults and fractures intersect the shear zone at high and low angles. The structural setting in the area of the Sao Francisco mine resembles that of the Teixeira mine.

From the above mentioned, the gold mineralizations in the area under survey is pictured as related to the structural context generated by the intersection of two structural systems, namely the NNE-trending and the WNW-trending systems.

Alteration zones related to the mineralizations were not possible to be identified, possibly because of thick vegetation covering and the small size of the mineralization.

4-2 Geology and structure

The stratigraphic section in the survey area is comprised, from the bottom to the top, by the Archaean Caico Complex, the Jucurutu, Equador and Serido Formations belonging to the Proterozoic Serido Group, the Tertiary Serra dos Martins Formation, and by Quaternary sediments. Tertiary and Quaternary units exposures are restricted to small areas. The Archaean and Proterozoic units area widely distributed (Fig. II-3-2). The Caico Complex, composed mainly of the gneiss-migmatite-granite tripartite, is distributed principally in the northern half of the project area, structured in NNE-SSW direction. The biotite-schists of the Serido Formation occupy great part of the southern half of the survey area, and are also distributed throughout the northern half of the area. The boundaries between the Serido Formation and the Caico Complex are preponderantly made by faults and unconformities. The Jucurutu formation, consisting mainly of gneisses, limestone and calc-silicate rocks, are distributed on small areas around exposures of rocks belonging to the Caico Complex. An unit exposed to the north of the Sao Francisco mine, trending NNE-SSW, previously considered as belonging to the Caico complex was, through this survey, identified as part of the Jucuturu Formation.

NNE-SSW faults are present through the entire survey area. As mentioned above, many of them make the boundaries between rocks of the Caico Complex and those belonging to the Serido Formation. Some of these faults, however, extend southwards cutting rocks of the Serido Formation. It is not uncommon the presence of faults in this direction extending for more than 30 Km, even within the survey area.

Faults of smaller scale trending WNW-ESE are observed in the southern half of the survey area. The extension of these faults do not exceed 5 Km.

The Sao Francisco deposit is situated at the intersection of the of the NNE-SSW fault system and the WNW-ESE fault system. The gold occurrence located 7 Km west of Sao Tome is situated in the vicinity of the bending point of the NNE-SSW fault system. At this point, the strike of the faults changes from N30E to N10E.

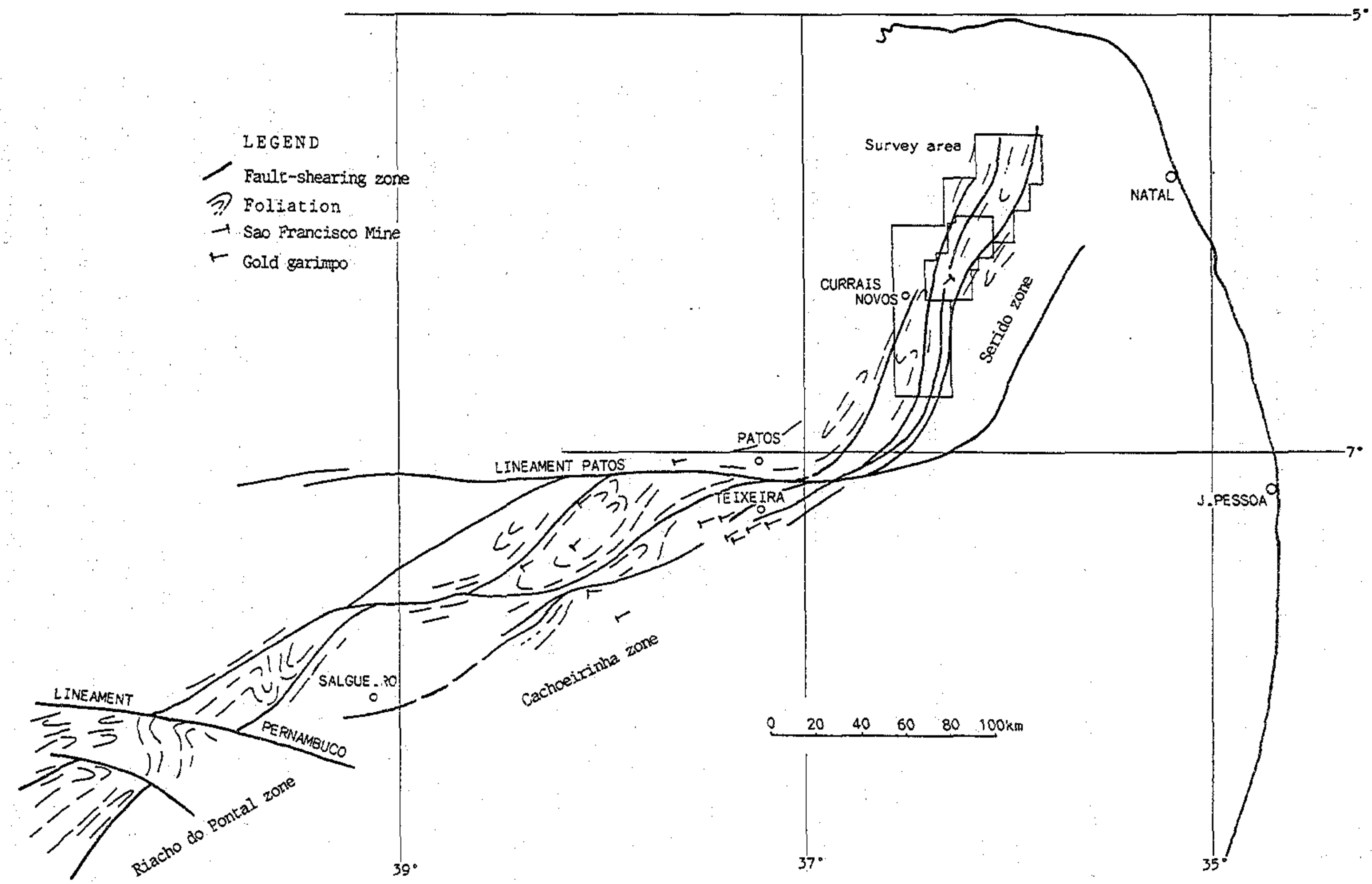


Fig. I -3-2 Location of gold mineralization and main structural lineaments after Barbosa(1989)

The predominant foliation throughout the survey area is in NNE-SSW direction, concordant with the major structures in this region. The main structural disturbance observed in the area is the inflection in the structures at the point of intersection between the two fault systems, which is coincidentally the site of the Sao Francisco gold deposit.

4-3 Mineralization and its structural control

Two main gold mineralization sites are recognized in the survey area. One is the gold occurrence situated 7 Km west of Sao Tome, which is hosted in rocks belonging to the Caico Complex. The other is the well known gold deposit of the Sao Francisco mine. In addition to the gold mineralization that have been reported in previous works, which are invariably hosted by rocks of the Serido and Jucurutu Formations, the existence of gold mineralization hosted by rocks of the Caico Complex were confirmed in this survey. This finding put some doubts on the lithostratigraphic control of the mineralization previously proposed in this area.

The mineralization of the gold occurrence near Sao Tome is located at the site where the NNE-SSW fault system bends slightly northward. This fault system put the rocks or the Serido Formation in contact with those of the Caico Complex. Similarly, the mineralization of the Sao Francisco gold mine took place at the intersection of the two major fault systems occurring in the survey area. Both mineralizations seem structurally controlled, but, besides gold in the quartz veins, mineralization in the country rock was detected only in the samples from the Sao Francisco mine. Other difference between the two gold occurrences above mentioned concerns to the Au/Ag ratio in the analyzed samples. Those from the occurrence near Sao Tome have ratios around two, while in those from the Sao Francisco mine this ratio is lower than 1/8. These differences suggest that the mineralizing fluids in these gold occurrences had not a common origin.

Furthermore, in spite of the presence of sulfides such as pyrite and chalcopyrite in both mineralizations, pyrrhotite is found only in the Sao Francisco deposit. Moreover, secondary minerals like covellite, chalcosite, cuprite, atacamite, melachite, goethite are present only in ores of the Sao Francisco mine.

Alteration minerals such as sericite, kaolinite and chlorite are present in the mineralized zone of the Sao Francisco deposit, but in that of the occurrence near Sao Tome, kaolinite is not present. Sericite are found along the margins of the gold-bearing quartz veins, and is considered to be related to the ore formation. Kaolinite occurs associated with sericite, and is thought to be an oxidation product of sericite. The origin of the chlorite is uncertain.

These mineralization processes are believed to have occurred during the final phase of or after the Brasiliano orogeny. This consideration is based on the given that sericite, which is intimately associated with the gold-bearing quartz veins could never formed or should be unstable during the amphibolite facies metamorphism associated to the Brasiliano orogenic cycle. However, further and more detailed examinations is still required, since the presence of sericite in the mineralized zones seems to have not been truthfully understood.

The fractures, which have provided the depositional spaces for the mineralized quartz veins, are a consequence of the tectonic movements, probably related to the Brasiliano cycle. However, both mineralized and barren quartz veins do exist in the gold occurrences of the survey area. These two types of quartz veins are spatially closely related, but a genetic relatioship seems improbable. Further and more detailed surveys are necessary to comprehend their relationship.

4-4 Geochemistry and its relations with mineralization

Based on factor analysis of analytical data of stream sediments, elements were grouped into pegmatite, tungsten and granite-related ore deposits.

According to the results of factor analysis, As is the element more closely correlated with Au. Since As is also present in gold-bearing quartz veins in the Sao Francisco mine, these two elements are considered to be intimately related each other.

The following 5 areas of Au anomalies were identified from geochemical analyses of stream sediments:

1) The Sao Francisco mine and the area around Santa Ri, a hamlet west of the Sao Francisco mine. These two areas are in the same drainage system.
2) The area located about 2 Km southwest of the Sao Francisco mine. This area is possibly on the southern extension of the Sao Francisco deposit.
3) The area around Marixo, situated about 2 Km southeast of the Sao Francisco mine.
4) The area around Cangorra, in the southwestern limit of the survey area.
5) The area situated nearly 2 Km east of Saladinho, and about 3 Km south to southwest of Cangorra.

The area (1) and (2) are thought to be related to the Sao Francisco deposit, because of they can be considered as standing on a NNE-trending extension of that deposit.

Another interesting feature is related to the distribution of As anomalous areas. In spite of the close relationship found between Au and As, the As anomalous areas overlap all those of Au and extends further for about 20 Km in NNE direction.

From the analytical data of pan concentrates of stream sediments, it was possible to define 2 Au anomalous areas. One of them correspond to the drainage system which includes the areas (1), (2) and (3) above described. The other one extends from Fortaleza to Santo Antonio, and is situated to the west of the zone defined by combining areas (4) and (5).

Gold in placer deposits is mined by "garimpeiros" in the drainage system defined by areas (1), (2) and (3). During the field surveying, gold dust were observed only in pan concentrates obtained inside this drainage system. However, according to the geologist of the Sao Francisco mine, gold is hardly visible in ores of this deposit. Therefore, it seems that the origin of gold in the placers of this area should be further investigated.

According to Bowles, J.F.S. (1988), "... gold taken into solution will be transported by ground water and deposited where conditions change to a regime in which gold is not soluble. ... The gold is deposited to form crystalline or dendritic gold which may be larger in size than the original material. ... This process is applicable to arid laterites and tropical rain forest soils." The gold dust found in drainage systems in the area under survey, especially in the drainage system which includes areas (1), (2) and (3), could be properly explained by the process above quoted, since the drainage systems in which gold dust were found are invariably geographically related to the Sao Francisco deposit.

The anomalous area extending from Fortaleza to Santo Antonio, however, is not directly related to the Sao Francisco deposit, and there is no apparent explanation for the origin of the gold. Further survey seems to be necessary to understand the present distribution of gold in this area.

From the above mentioned, Au anomalies in stream sediments are synthesized into the following four areas except that downstream from the Sao Francisco deposit. First of all, the elongated area trespassing the Sao Francisco deposit, trending NNE. Secondly, a narrow zone trending NNE, situated about 5 Km west to southwest from the Sao Francisco mine. Third, the area located approximately 2 Km southeast of that mine, and lastly, the area situated about 6 Km south of the same mine.

In the area around the "garimpo" located some 7 Km west of Sao Tome, no stream sediment anomaly could be identified. a possible explanation for this absence could be the small size of the occurrence, and so undetectable due to the scale of the present survey.

4-5 Potential for mineralization

In the area of the phase I survey, gold occurrences ("garimpos") of small scales, besides known Au deposits were recognized. Both types of gold mineralizations resemble each other. Their mineralization is thought to have been controlled by structures such as NNE faults rather than by the lithology. In addition, two potential areas for gold occurrences could be defined, which are situated in the areas west to southwest and south to southeast of the Sao Francisco mine. In the former area, there exists a strong relation of the anomaly with the geologic structure, as it can be clearly observed from the NNE trending elongation of the area. Based on this relationship, the former area is thought to be worth for, and recommended for further detailed survey, with priority. Nonetheless, in spite of the small size of geochemical anomaly in the latter potential area, it is also considered to be worth for further surveying.

However, if the area to the south of the present survey area is chosen for further detailed surveying, and additional anomalies were found close to the latter potential area, this area would be extended and become a interesting target for further detailed surveying.

The occurrence located in the area north of Sao Tome is considered as being not worth for further surveying, because of the small size and the lack of important geochemical anomalies in the surrounding area.

Chapter 5 - Conclusions and recommendations for phase II survey

5-1 Conclusions

The survey area is underlaid by Archaean Caico Complex, Proterozoic Jucurutu, Equador and Serido Formations, and by Tertiary and Quaternary Formations. The mineralizations of gold seems to have no stratigraphic control, in spite of the fact that the Serido Formation was found to have higher contents of gold than the rocks of the Caico Complex.

Mining works related to gold in the survey area are restricted to the Sao Francisco mine, a small "garimpo" about 7 Km west of Sao Tome, and mining of some small placers.

Calculated ore reserves of the Sao Francisco deposit amounts to 587,646 tons, containing 1,750 Kg of gold. The reserve of the gold occurrence in the neighborhoods of Sao Tome has not been calculated yet, due to the lack of detailed data. 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 this area are invariably associated to structural (shear) zones trending NNE, suggesting that the ore genesis is strongly related with the geologic structure. The Sao Francisco deposit is situated in an area where faults and fractures trending WNW cross-cut the NNE trending shear zone. On the other hand, the gold occurrence around Sao Tome is located in a bending point of the NNE structural zone.

Anomalous areas for Nb, Ta, Sn, As and Au have been disclosed by a geochemical survey of stream sediments. The anomalous areas for Nb and Ta have both an elongate form trending NNE, and overlap each other. These anomalous areas are situated in an area approximately 10 Km north to northeast of the Sao Francisco mine, and cover partially the exposures of the Caico Complex. The anomalous area for Sn, on the other hand, covers widely the northern half of the area under survey.

Au anomalies in conjunction with As ones were identified in the following three areas: west to southwest (WSW) and south to southeast (SSE) of the Sao Francisco mine, and around this mine. The anomalous area in the WSW of the mine trends NNE and is in conformity with the local geologic structure. This anomaly, therefore, is presumed to be structurally controlled. On the other hand, the anomaly in the SSE of the mine do not show, in its distribution, a clear relationship with the geologic structure.

The mineralization in the Sao Francisco gold deposit is considered to be strongly controlled by the geologic structure. Taking into account this characteristic, the anomalous area in the WSW of the Sao Francisco mine can be pointed out as having higher potential for gold mineralization than that one in the SSE of the mine.

Moreover, the WSW area possibly 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 NNE nearly the Sao Francisco deposit possibly extend southwards. Also, faults trending WNW is typically present in the area of the Sao Francisco deposit, and their extension to the south is suggested by the interpretation of LANDSAT TM images.

The interpretation of analyses of pan concentrates of stream sediments revealed that anomalous areas for gold are concentrated in the neighborhood of the Sao Francisco gold deposit, and also in the area situated 7 to 10 Km WNW of the Sao Francisco mine.
The anomalies found in areas around this deposit are thought to be derived from the deposit. The origin of gold in the other area, however, is not well known, and only further detailed studies will allow to shed some light on its origin.

5-2 Recommendations for phase II survey

Based on the results of the survey in the phases I of this project, the following areas are recommended for further detailed surveying:

1) The area situated WSW of the Sao Francisco mine, where stream sediment anomalies were concentrated. In this area, the following survey methods are suggested:

a) Trenching, following the WNW direction, in order to delineate possible mineralizations;

b) Geophysical survey, in order to uncover underground structures and to identify potential faults and fractures associated with the gold mineralization. One recommended geophysical method is the magnetic survey, since this methodology has been successfully applied, by a Brazilian team, to disclose structural features in the southern area of this project .

2) The area to the south of the phase I area. It is suggested the employment of the following survey methods:

a) Geological traversing and geochemical survey to discover potential areas for gold mineralization;

b) Geophysical survey to define structures such as faults and fractures. It is also recommended to program the surveying to maximize resolution for NNE and WNW structural trends.

3) The anomalous area for gold from pan concentrates situated about 7 to 10 Km WNW of the Sao Francisco mine. The methods recommended to be applied are

a) Geophysical survey to reveal geologic structures that could be associated to the mineralization. The magnetic survey seems to be the most suitable, following the reasoning described above.

b) Trenching in the WNW direction, in order to delineate potential mineralizations.

4) The anomalous area in the stream sediment survey, situated to the WSW of the Sao Francisco mine. The following survey methods are recommended:

a) Geophysical survey to reveal geologic structures that could be associated to the mineralization. The magnetic survey seems to be the most suitable, following the reasoning described above.

b) Trenching in the WNW direction, in order to delineate potential mineralizations.

PART II GEOLOGIC AND GEOCHEMICAL SURVEY

Chapter 1 - Interpretation of the existing information

1-1 Results of previous surveys

1-1-1 Stratigraphy and structure

The present survey is located within one of the largest structural units in northeastern Brazil, known as the Borborema Province (Almeida et al., 1981). This unit is limited to the north by the Sao Luiz Platform, and to the south by the Sao Francisco Platform (Cordani and Brito Neves, 1982). (Fig. II-1-2)

Many geologic mappings have been carried out in the Borborema Province, and there have been some divergences concerning to the stratigraphic positioning of certain units. (Fig. II-1-3)

Brito Neves (1983) and Almeida et al. (1976) have divided the Borborema Province into the following two basic units: a unit consisting mainly of gneisses, migmatites and granites, and another one including mainly meta-volcanic and meta-sedimentary rocks. This last unit has been structurally classified as a fold belt, and has been further subdivided in "inland" and "marginal" types. The "inland" sequence comprises sandy and muddy sedimentary rocks as well as volcanic rocks, while the "marginal" type assembles thick carbonate layers associated with small amounts of terrigenous materials.

Brito Neves (1983) subdivided the Borborema Province in five geologic domains, based on differences in deformation and metamorphic grades (Fig. II-1-4). According to this division, the survey area is situated entirely inside the Serido region of the Central Domain. Santos et al. (1984) has also divided this province into five geological domains similarly to Brito Neves (1983). In this division, the survey area is situated inside the Transnordestino Domain.

In the Serido region, the geology of the Central Domain is dominated by exposures of rocks belonging to the Caico Complex and Serido Group, which comprises the Jucurutu, Equador and Serido Formations, in ascending stratigraphic order. The Archaean Caico Complex represents the basement in this area, and its rocks make up one of the units of the Borborema Province above mentioned. In the same way, the Jucurutu formation should represent the "marginal" sequence and the Serido formation the "inland" sequence.

According to the interpretation of Jardim de Sa et al. (1978), the Jucurutu and Equador Formations consist of pre-orogenic sediments, while the Serido Formation represent flysch-type deposits.

During a series of systematic mapping in the Serido region, Ebert (1969,1970) used the marble layers as the key bed to construct the stratigraphic column. Ferreira and Albuquerque (1969), instead, used the quartzite bed as the key bed during their works in

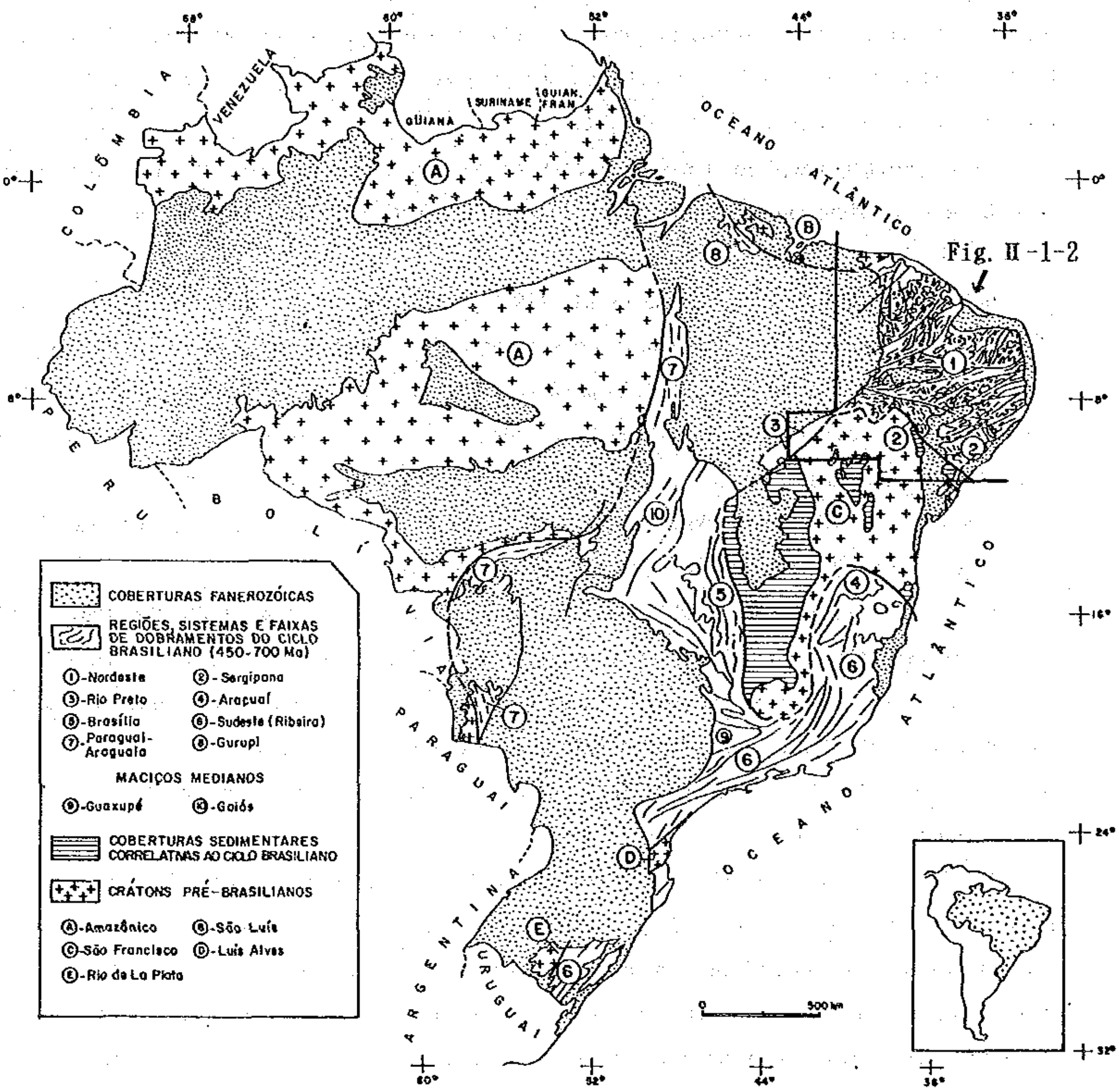


Fig. II-1-1 Folded belts of the Brasiliano cycle and related cratons after Brito Neves, 1975; Almeida et al, 1977; Santos, 1975

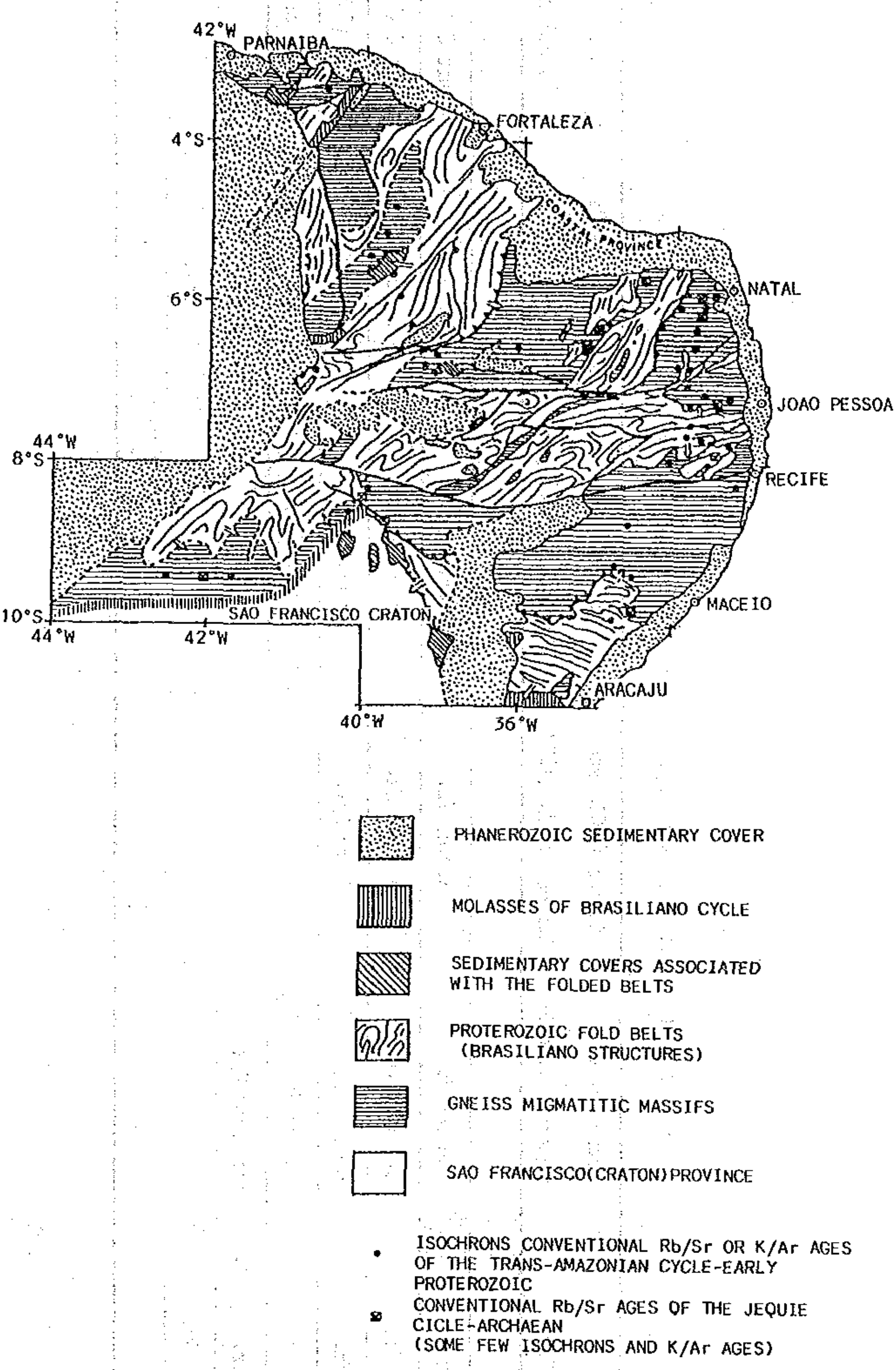


Fig. II-1-2 Principal geologic elements in the Borborema Province

Fig. II-1-3 History of stratigrafic correlation in the Serido region

Ebert (1969, 1970)	Ferreira & Albuquerque (1969)	Santos (1973) and Torres et al. (1973)	Siqueira & Maranhao (1973)	Lima et al. (1980)	Jardim de Sa & Salim (1980)
Serido fm.	Serido fm.	Serido fm.	Serido fm.	Serido Gr.	Unit 3 ("Serido")
Florania fm.	Jucurutu fm.	Jucurutu fm.	Junco fm.	Serido fm.	Unit 2 ("Equador")
Quixaba fm.	Equador fm.	Caico Cpx.	Jucurutu Gr.	Jucurutu fm.	Unit 1 ("Jucurutu")
Parelhas fm.	Caico Gr.		Caico Gr.	Equador fm.	Caico Cox.
Equador fm.	pre-Caico Cpx			Gneissic-migmatitic Cpx.	
Sao Vicente Gr.					

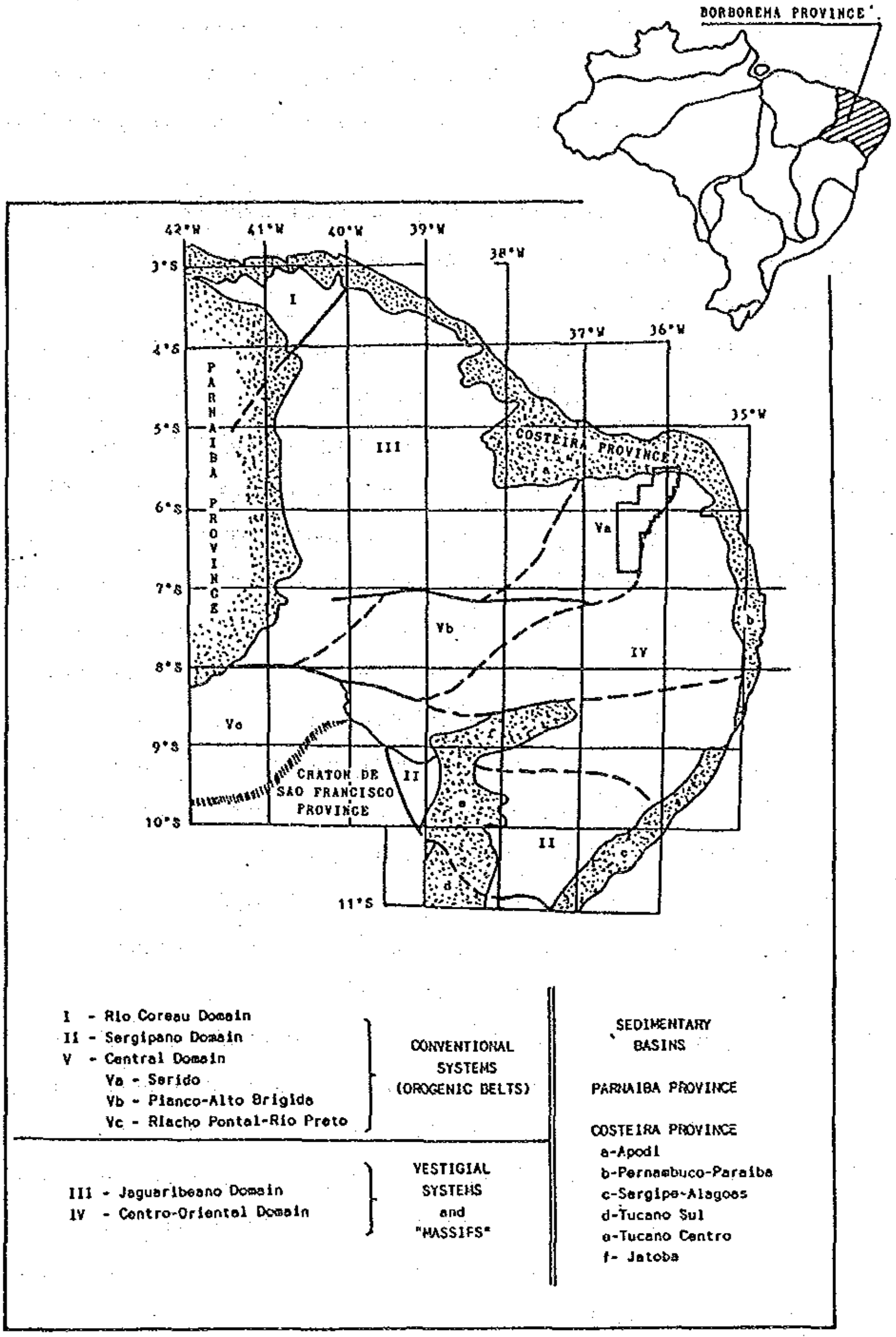


Fig. II-1-4 Geologic domain of the Borborema Province after Brito Neves, 1983 the area. Other important contributions to the knowledge on the stratigraphy of this area are those of Santos (1973) and Torres H.F. et al. (1973) demonstrating that the Caico Complex represents the basement of the Serido Group. Finally, it is worth to mention the contributions of Siqueira and Maranhao (1973), Andritzuky and Busch (1975), and CNEN/CPRM cooperation project.

In the course of the establishment of a widely accepted stratigraphy for the Serido region, one of the major divergences was concerning to the positioning of a quartzite bed presently named as Equador Formation.

Jardim de Sa and Salim (1980) presented convincing arguments to the positioning of the Equador quartzite between the Serido and Jucurutu Formations, based on a detailed study of structural and lithostratigraphic relations among the units cropping out in the Serido region. In this survey, we followed the stratigraphy proposed by these authors.

In addition to the Precambrian units above mentioned, rocks of the Cretaceous Jandaira and Acu Formations, the Tertiary Serra dos Martins Formation and Quaternary sediments also occur in the area. Moreover, plutonic rocks and hypabyssal rocks such as granodiorite and hornblendite are also distributed in the area, but in small scales.

The Serido region is believed to have been affected by three different tectono-thermal events that can be correlated to three main events of continental amplitude occurred in the Brazilian territory. These events are named Jequie (2900 to 2600 Ma.), Transamazonico (2100 to 1800 Ma), and Brasiliano (700 to 400 Ma).

Recently, Jardim de Sa (1984) distinguished and classified five stages of tectonic movements related to the period between the Brasiliano and Transamazonico events, according to their tectono-structural features (Table II-1-1).

Two of these tectonic events (F1 and F2) were recognized as related to the Transamazonico orogenic cycle. They are characterized by low-angle shear zones, with metamorphic grade correspondent to the amphibolite facies. Two other events (F3 and F4) were distinguished as related to the Brasiliano orogenic cycle. The shear zones associated to these two events are featured as high-angle structures. The metamorphic grade also reached the amphibolite facies. The last event (F5) is recognized as associated to a retrogressive phase of the metamorphism.

(2) Deposit

The exploration of deposits in the survey area has been carried out mainly for tungsten and also regionally for gold.

The exploration of tungsten started officially in 1965, in both Rio Grande do Norte and Paraiba states with the "Projeto Tungstenio/Molibdenio" by DNPM/CPRM , and the results

Table II-1-1 Kinematic and metamorphic episodes at the survey area

Structural events		Metamorphic events		Igneous events	Ages
Ph	Events	Ph	Events	Intrutions	
F_1	lower grade/lower strain fabrics F_1 folds appear not developed or are not readily detected.	S_1	green schist to high amphibolite facies, low to intermediate pressure. peak metamorphic conditions was reached during F_2. S_1 foliation was formed in green schist facies. An older tangential deformation comprises an earlier low grade cleavage(S_1), deformed and transposed in a strong schistosity or gneissic banding($S_{1\ 2}$)	G_2 ; syn-F_2 sheet like intrusives along flat lying S surface. Emplacement was trongly controlled by recumbent structures of the F_3 phase. Always intrude the Jucurutu F., mainly close to its basalcontact. In a few cases, these rocks intrude at the level of the Serido F. G_2 cut through the Archean main foliation and structurally conformable with the supracrustals of the Serido G.	2.1 ±0.1 Ga (Rb-Sr WR isochron. during Trans-amazonian Orogeny.
F_2	associated with ductile thrust (flat-lying shear zone)	S_2			
F_3	upright to overturned folds with gently dipping NNE axes having crenulation cleavage or schistosity as axial plane structure, upright - inclined folds were generated during a NNE transcurrent simple shear regime.	S_3	low pressure greenschist to high amphibolite facies.	G_3 occur as minor isolated bodies, or as large composite diapiers. Plutons of granite to granodiorite composition are the most voluminous part, including medium or coarse porphylitic types, as well as equigranular leucogranite. Diorite, gabbro to diorite, quartz diorite to tonalite, hornblendite are alsc included. G_3 *granitoids involve* contributions from deep sources mostly of mafic/ultramafic and/or primi-titive nature, I-type granitoids.	up to 760 Ma (Rb-Sr WR isochron) 660 - 500 Ma during Brasilian age plutonics 650 - 550 Ma is peak of genic conditoin
F_4	shear zones developed slightly later or during another retrogressive phase. coaxial with F_3 folds NNE, more steep axial planes, much less developed crenulation cleavage	S_4			F_4, F_5 events were probably completed up to 500 Ma.
F_5	late kink bands formed by N-S compressive stress	S_5	retrograde phase green schist facies.		

Compiled from Jardim de Sa & Jaziel Martins Sa (1987), Jardim de Sa et al (1987) Jardim de Sa (1988), Jardim de Sa et al (1988) were reported in 1973.

In 1980, the results of the Projeto Scheelita do Serido (Lima, E. de A.M. et al , 1980) were reported.

These explorations played an important role in understanding the stratigraphy of the Serido Domain and for drawing the geologic maps. After that, concerning to tungsten mineralizations, there have been some works detailing specific areas. one example is that of Maranhao, R. et al (1986), who explained in details the geology in the Brejui ,Barra Verde de, Boca de Lage, Zangarelhas mines, which are the most representative deposits within the Serido Domain .

Gold in this region was discovered in the beginning of the 1940's .Gold in placers, in weathered zones and in quartz veins had been mined until 1976. Gold mining gradually slowed down as the grades became lower and lower, and finally stopped.

From the end of the 1970's, CPRM started in this area a series of surveys whose results have been published as 1:1,000,000 and 1:100,000 maps in 1980.

The CPRM's survey for gold in the area was carried out from 1980 to 1983 ,and has been reported as "Projeto Mapas Metalogeneticos e Auriferos, Folhas SB24/SB25, Jaguaribe/Natal", and summarized as the map "Carta Metalogenetico dos Recursos Auriferos, 1:1,000,000".

Almost all gold deposits in the Rio Grande do Norte state, including the project area, are described in the report of this survey. The summary of San Francisco deposit, which are located in the center of the project area is briefly given in this report.

Among the main reports related to gold deposits in the survey area, the following three were chosen to compare general features of different gold deposits occurring in the project area:

(1) Souza, Z.S. et al. (1986)

(2) Ferran, A. (1988)

(3) Barbosa, A.J. (1989)

These reports were distinguished due to the fact that the subject of their surveys accounts for the type of deposits, the formations of the mineralizing fluids, and relation between geologic structure and the mineralizations. Their numbering is just to associate the author with the interpretation in the comparison summarized below.

a) Area of the survey

(1) Lages - Sao Tome

(2) San Francisco mine

(3) Structural zones and faults in Central Domain

b) Type of the deposits

(1) quartz veins and masses of flowing quartz

(2) quartzite (recrystalized chert) and schist of the countryrock; the width of quartzite is about 10-20cm

(3) hydrothermal veins in shear zones, lenticular or spherical veins. The length is smaller than several 10m ,and width is rarely more than 1m.

c) Country rocks

(1) biotite gneiss, mica schist, banded gneiss of the Jucurutu Formation

(2) quartz-biotite-garnet schist of the Serido Formation

(3) mica schist, meta-basite, micaceous phyllite ,non-regular lithofacies

d) Structural control

(1) three generations of quartz veins which reflect related to different tectonic movements

(2) San Francisco and Morro Pelado trends, both NNE-SSW/45"E. The length in the strike direction, for the former, can be measured in Km, and the plunge of the mineralized zone is 12 SW. For the later, narrow layers of chert appear periodically because of folds.

(3) Ore veins are in the low inclined and high inclined shear zones.

e) Ore minerals

(1) gold in the dotted electrum and in the plane shaped electrum, and with pyrite and molybdenite .

(2) gold as native gold and accompanied by pyrite, molybdenite, and galena

(3) gold with pyrite ,chalcopyrite , arsenopyrite and galena in the quartz veins.

f) Occurrence of the deposits

(1) The origin of gold is bimodal volcanic sequence. Moreover, associated to the low metamorphism, the activity of the shear zones remobilizes gold in the migrating solution, and in the higher metamorphic grades, gold is re-solved by high thermal fluids and is dispersed to shallower crustal levels through fractures and joints under reduction conditions.

(2) exhalative-sedimentary deposit

(3) Gold comes from volcanic, plutonic and metamorphic sources.

This gold that have accumulated in shear zones were further concentrated by the activity of dynamic metamorphism related to the tectonic movement .

1-2 Selection of the Survey Area

Based on information on gold deposits in the project area which were briefly summarized above, the four items listed below are considered as necessary conditions for existence of gold deposits in this region, and some promising areas satisfying these items were examined.

(1) Does an appropriate host for the mineralization exist?

(2) Do structures which could be related to gold mineralizations such as shear zones or folds exist ?

(3) Is there any indication of the existence of gold mineralization?

(4) Do features similar to those found in other mineralized areas exist?

Based on these inquiries and in some additional geologic information, the area with 10,000 Km^2 shown in Fig 1 was selected as the area of the first year's survey . The below indicators for the explanation will be presented to the further survey after this from the above mentioned examinations .

(1) The area to be surveyed should comprise both Serido and Jucurutu Formations.

(2) Along stratigraphic and structural directions of the known mineralized chert layers.

(3) The exploration of the shear zones such as Serido-Cachoeirinha-Riacho do Pontal zone.

(4) To pursue known mineralized quartz veins and discover new mineralized zones.

(5) To search for sulfide minerals which are frequently associated to gold mineralizations.

(6) To examine the hydrographic system and find out the source of possible stream sediments anomalies.

(7) The exploration of granitic rock from the general view of the occurrence of the gold deposit

Chapter 2 – LANDSAT image interpretation

2-1 Purpose and procedure

2-1-1 Purpose

The interpretation of the LANDSAT TM images in the project area (about 5910 Km^2) was carried out in order to obtain the information of geologic structure ata large scale, and to disclose the geological structure and the mineralized regions in this area.

2-1-2 Applied data

Data used for interpretation are two scenes of Landsat TM (thematic mapper*), Path 215-Row 64 and Path 215-Row 65. Details of the data are shown in Table II-2-1 and the area covered by these data is shown in Fig. II-2-1.

Table II-2-1 List of LANDSAT data used

Path	Row	Date	ID No.	Cloud Cover	Sun Elevation
215	064	09/MAY/87	58712-91158	0 %	52°
215	065	02/AUG/89	58921-41202	0 %	51°

---

* Band characteristics of LANDSAT TM are as follows;

Band	Wavelength	Band Characteristics
Band 1	0.45~0.52 μm	water body penetration, differentiation soil from vegetation
Band 2	0.52~0.60 μm	useful for vigor assessment of vegetation
Band 3	0.63~0.69 μm	chlorophyll absorption band
Band 4	0.76~0.90 μm	useful for determining biomass content
Band 5	1.55~1.76 μm	indicative of moisture content of vegetation and soil
Band 6	10.40~12.50 μm	thermal infrared band
Band 7	2.08~2.35 μm	discriminating rock types, hydrothermal mapping

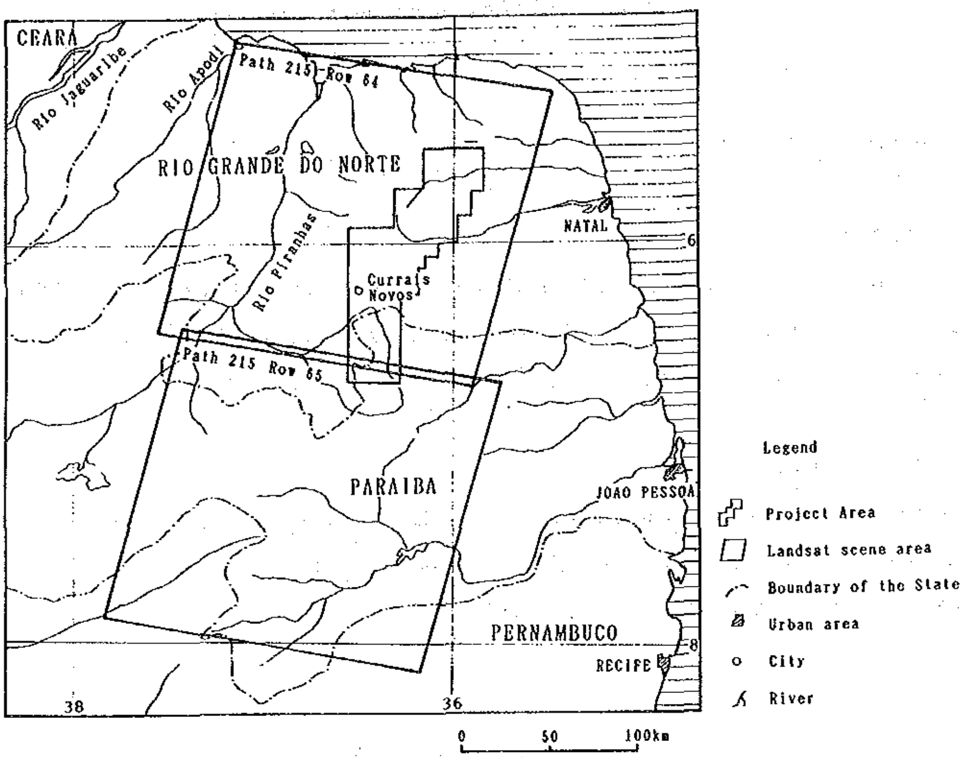


Fig. II-2-1 Index Map of LANDSAT Data.

2-1-3 Procedure

1) Image generation

By using CCT (Computer Compatible Tape) purchased from the Institute of Brazil (INPE), the false color images, principal component color images and ratio images were generated. They are shown in Table II-2-2.

The band 1,4,5 of TM data were selected for the false color images. Band 1.4.5 are assigned to blue, green and red respectively, and they were composed in color after the contrust stretch and edge enhancemwnt. The bands 1,4,5 are used based on the knowledge that these combination is most suitable for the geologic interpretation of the area.

Principal component image was made out in order to empasize the color of rock and soil. Principal component data were calculated by using six bands except band 6 whose resolusion is different from the others, and first, second and third principal component data were selected for color composit.

Table II-2-2 List of LANDSAT TM Images Generated

Type of Image	Path-Row	Sub Scene No.	Scale of Image
False Color Image	215-64	(Full Scene)	1:200,000
False Color Image	215-65	(Full Scene)	1:200,000
False Color Image	215-64	Quadrant 2	1:100,000
False Color Image	215-64	Quadrant 3	1:100,000
False Color Image	215-64	Quadrant 4	1:100,000
False Color Image	215-65	Quadrant 2	1:100,000
Principal Component Image	215-64	Quadrant 2	1:100,000
Principal Component Image	215-64	Quadrant 3	1:100,000
Principal Component Image	215-64	Quadrant 4	1:100,000
Principal Component Image	215-65	Quadrant 2	1:100,000
Ratio Image	215-64	Quadrant 2	1:100,000
Ratio Image	215-64	Quadrant 3	1:100,000
Ratio Image	215-64	Quadrant 4	1:100,000
Ratio Image	215-65	Quadrant 2	1:100,000

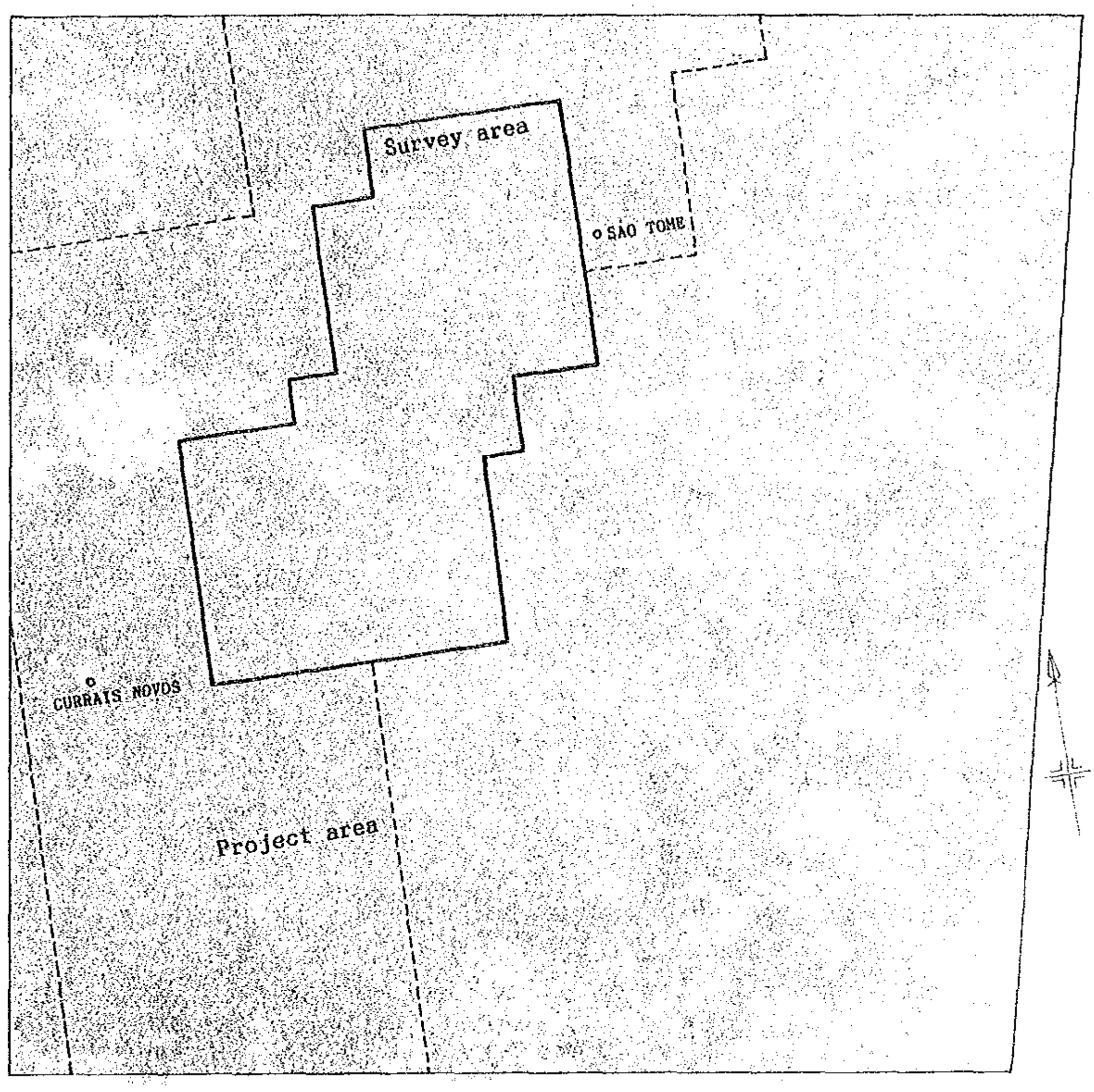
Ratioi images were made out for the same purpose as that of principal component image, using ratio data composed of three combinations, band 5/ band 7, band 4/ band 3 and band 3/ band 2 .

Among them, band 5/ band 7 is effective to defive clay minerales and carbonate rocks. The high value shows the existence of clay and carlenete minerales.

Band 4 / band 3 is effective to disclose densities of vegetation and the types of plants. The high value shows the high vegetation density. The high value of band 3 / band 2 indicates the existence of the ferrous minerals.

2)Geologic Interpretation

In order to classify geological units, interpretate geologic structure and extract of mineralized area, some characteristics on the images were synthetically discussed, such as color, drainage pattern and resistance. In addition, photogeologic characteristics of the region surrouding the mine located near the project area were extracted, and it was compared with that of the area.



LANDSAT [illegible]

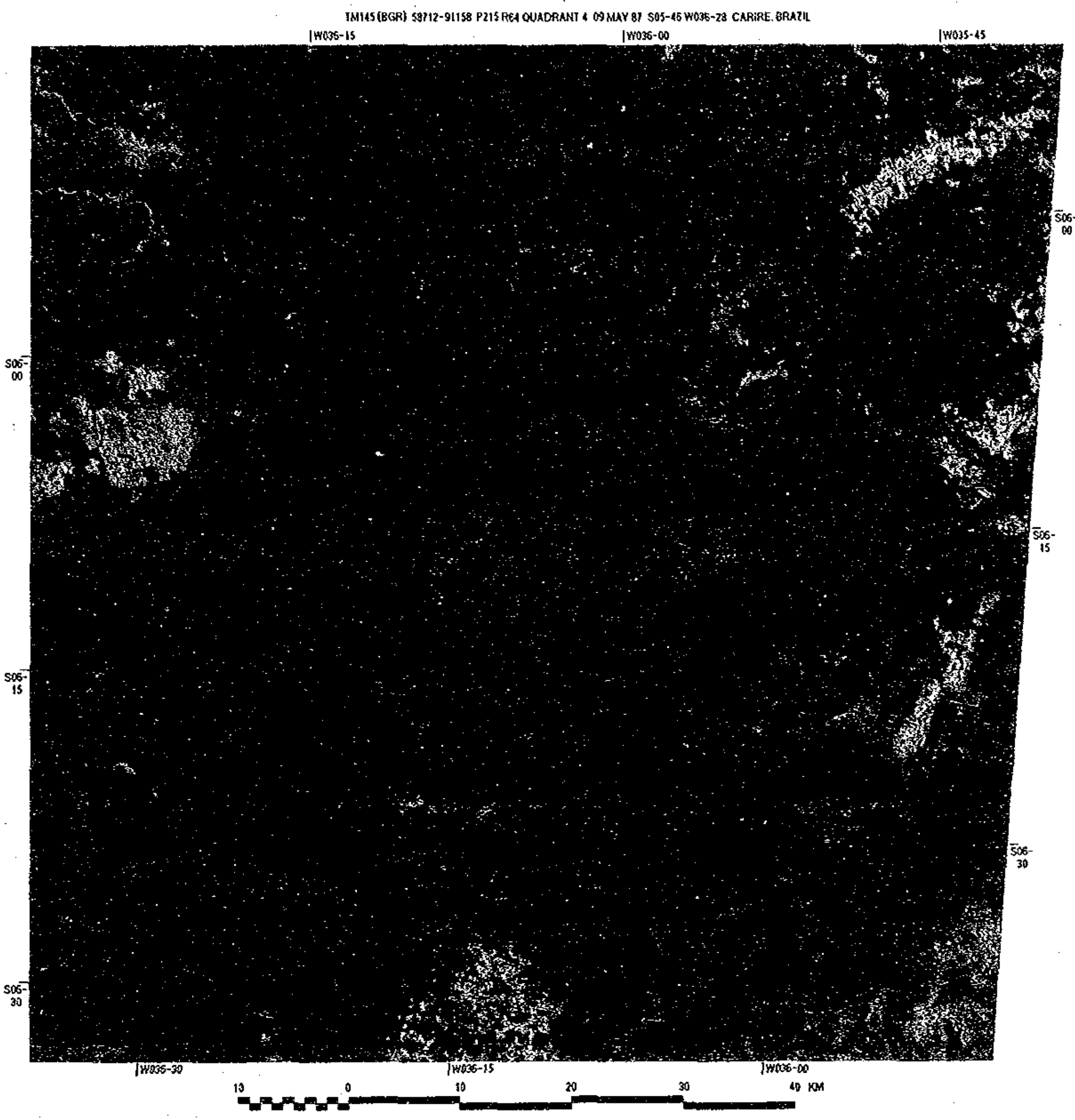
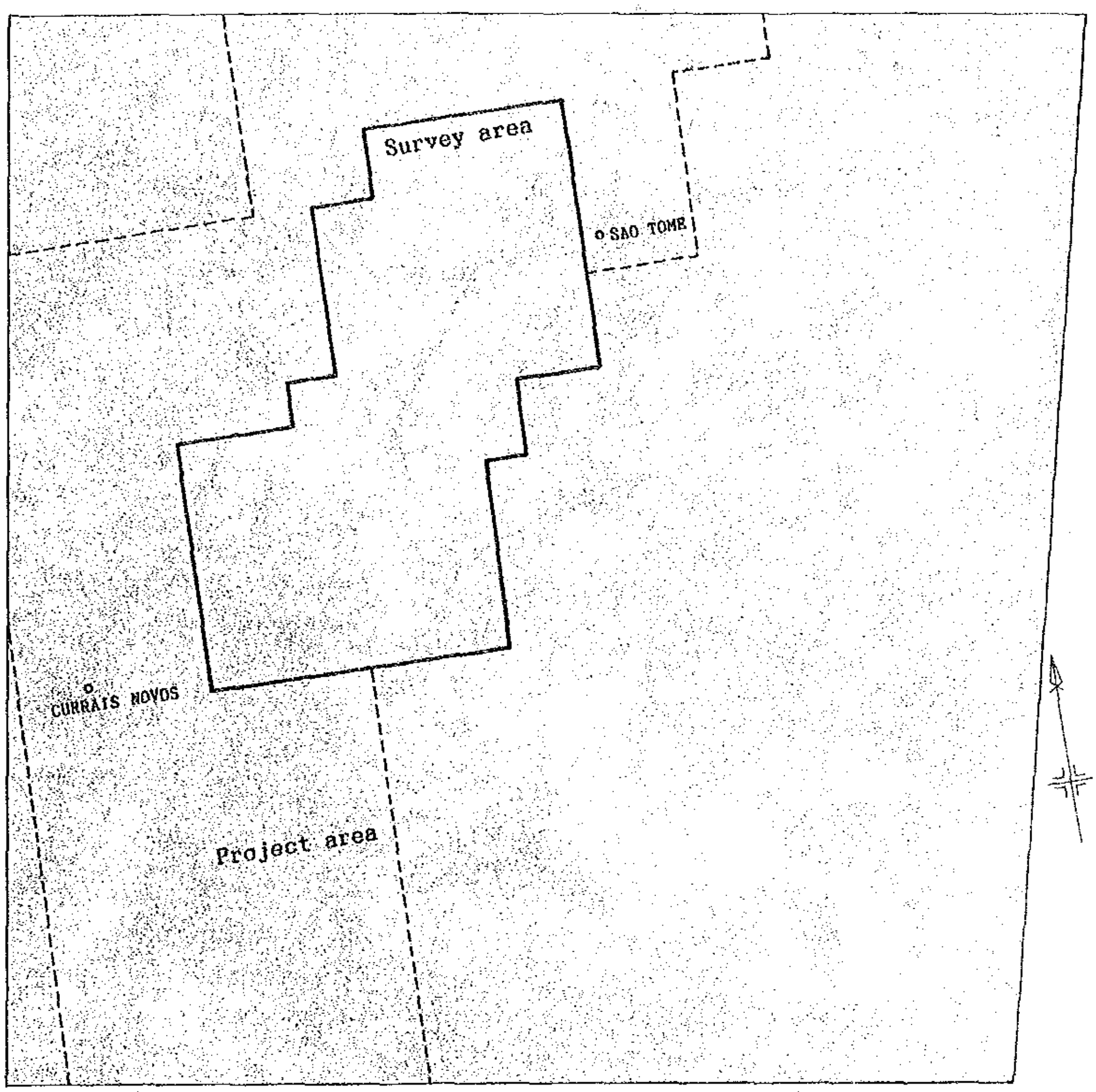


Fig. II–2–2 LANDSAT TM false color image.


Survey area
SAO TOME
CURRAIS NOVOS
Project area

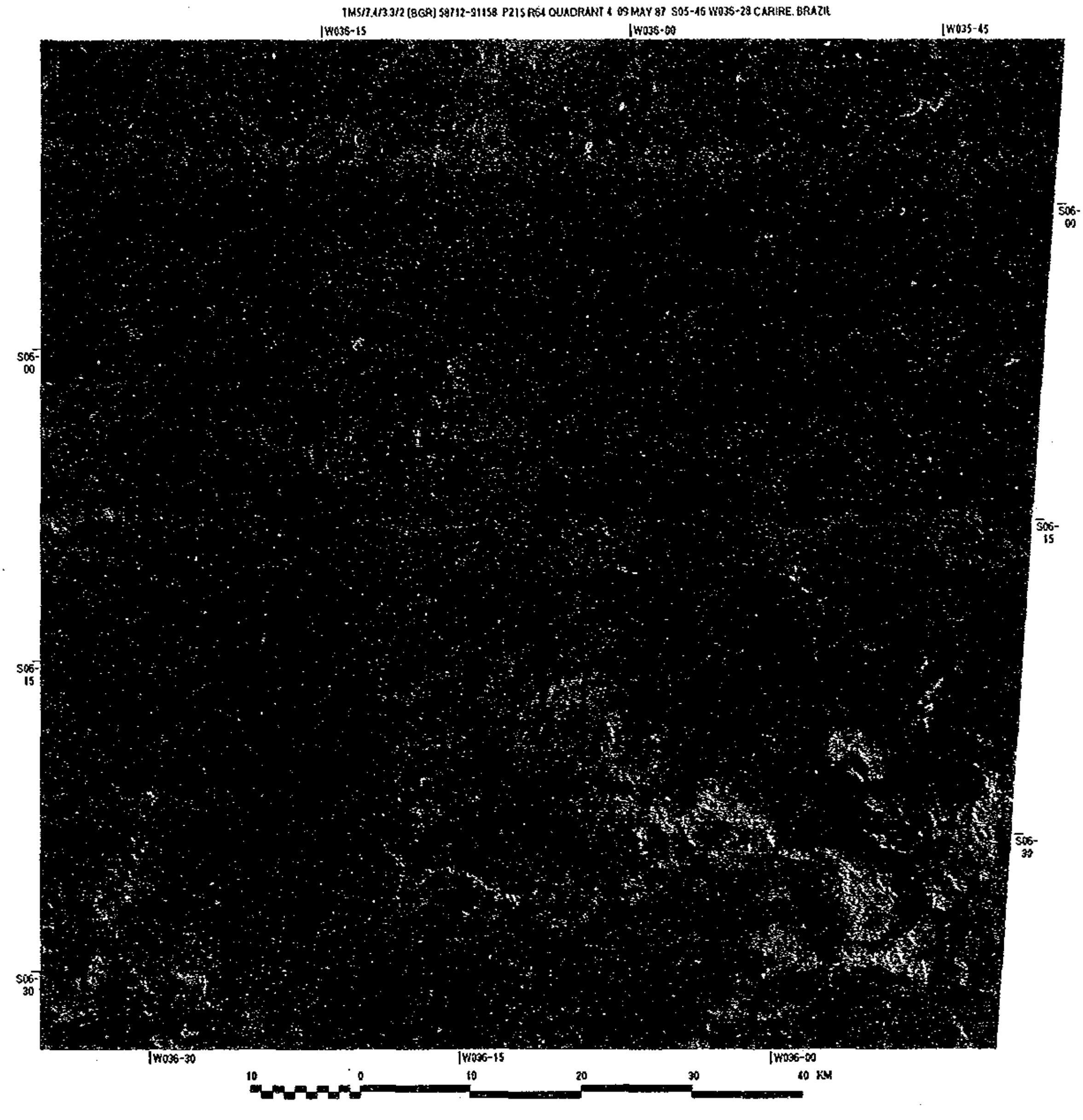
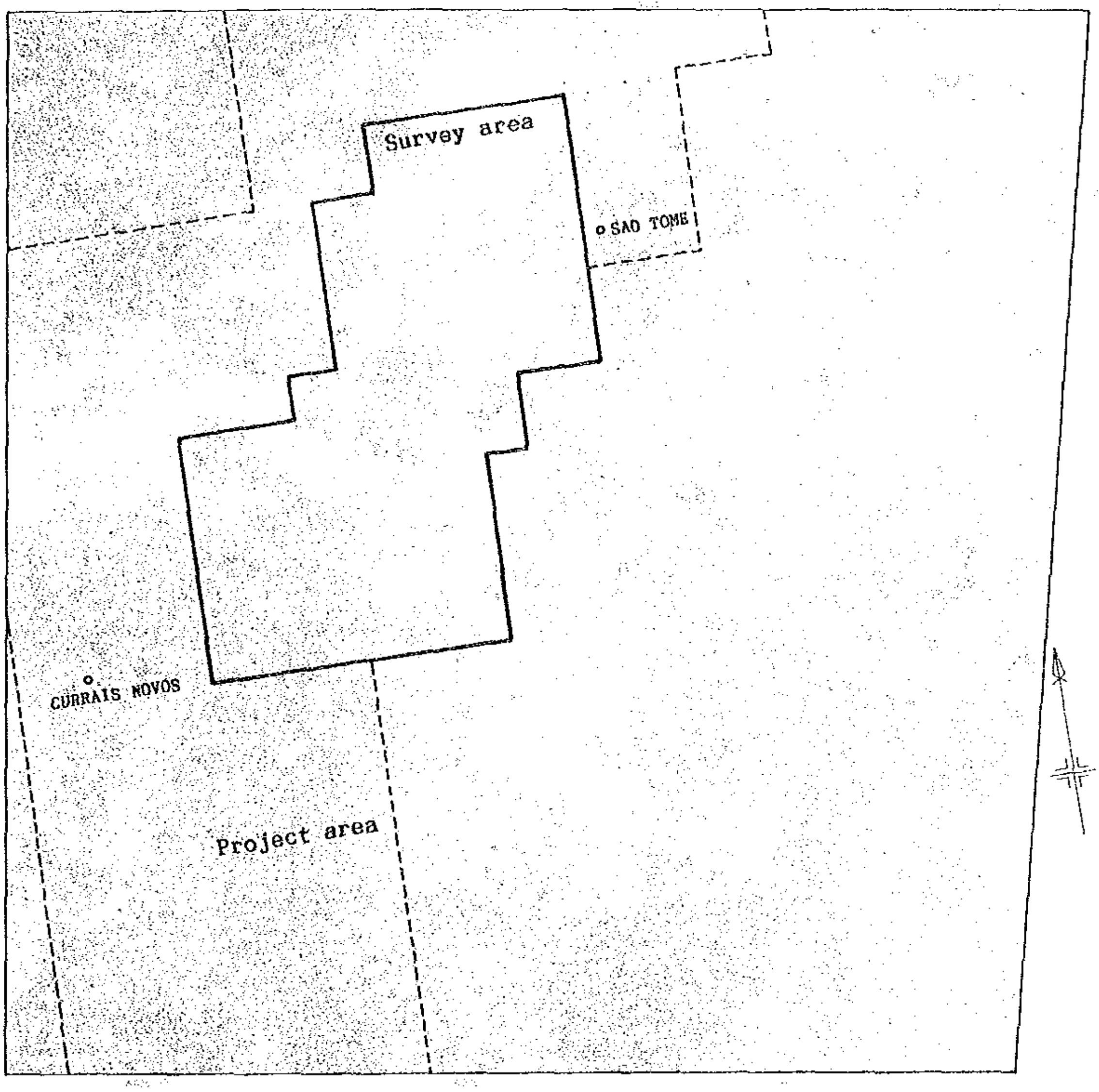


Fig. II–2–3 LANDSAT TM ratio color image.


Survey area
SAO TOME
CURRAIS NOVOS
Project area

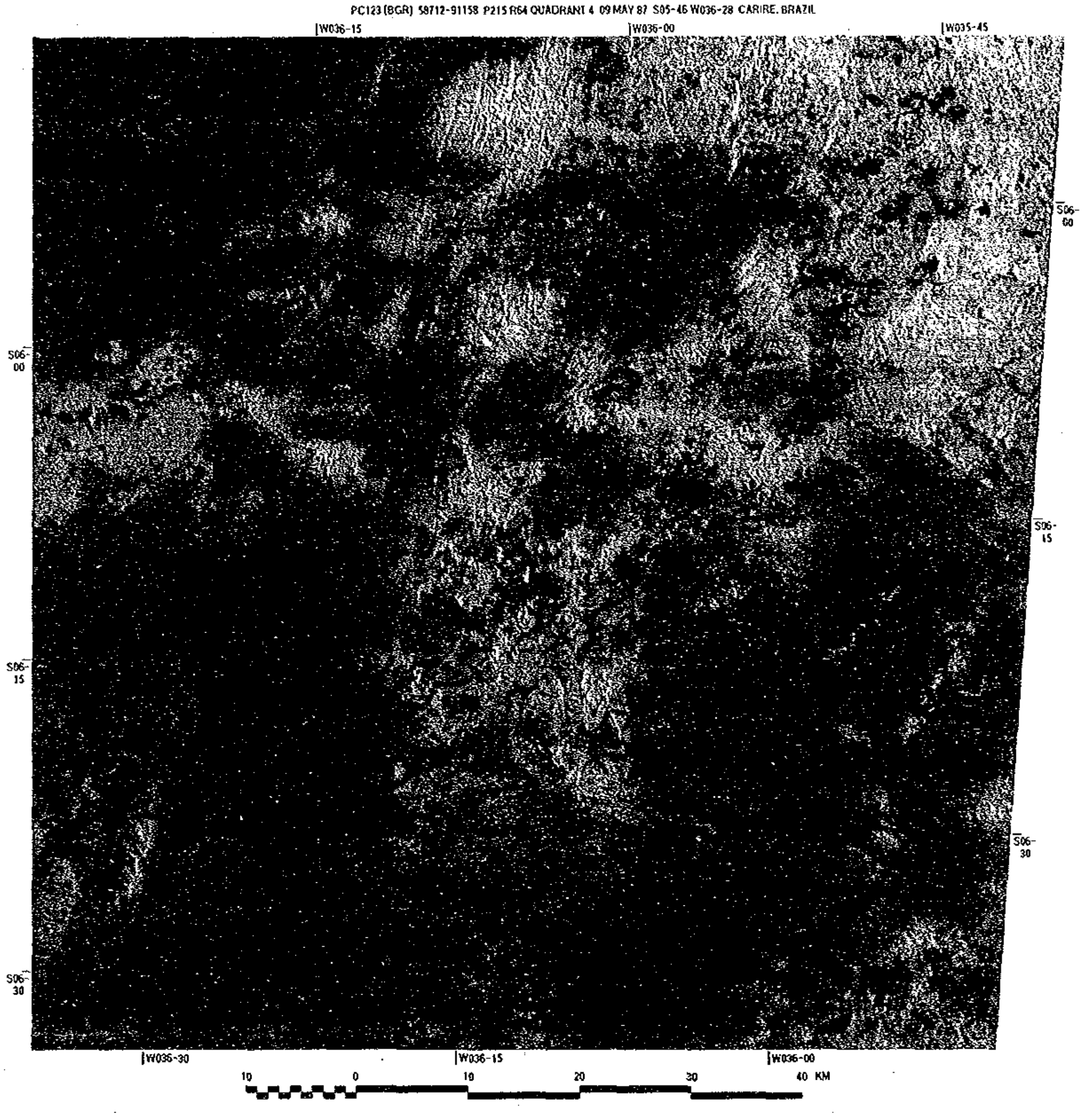


Fig. II–2–4 LANDSAT TM principal color image.

2-2 Interpretation

2-2-1 Lithologic classification

As the result discussed about characteristics on LANDSAT images, 16 units were discriminated as shown in Table II-2-3 and Fig. II-2-5.

Unit p€1a:

This unit is distributed along the eastern margin of the area. It shows characteristically fine and irregular texture, rectangular draninde pattern with high density andrectangular and bedding parallel to the fault.

This unit is corresponding to lithofacies which mainly consists of gneiss in Caico complex (Archean).

Unit p€1b:

This unit is distributed in the northwestern part of the area. This unit has low resistance to weathering and low drainage density.On the Ratio image, it is brown, That could be due to iron oxides on the surface. This unit is also corresponding to the lithofacies which is mainly compassed of gneiss in Caico complex. The bedding is not recognized.

Unit p€1c:

This unit is distributed in the northern part of the area, and it has high resistance and relatively low drainage density. Weel strafication is observed, and lineament, are also recognized. The unit is equivalent to the lithofacies which is mainly composed of gneiss in Caico complex.

Unit p€g1:

This unit is distributed in the southeastern part of Picui. On the false color image it is usually white. The drainage has extremely low density and dendritic pattern. Topography shows flat land. This unit is corresponding to the lithofacies which mainly consists of granite in Caico complex.

Unit p€g2:

This unit is intermillently distributed in the western part of the project area. It has high resistance, and well strafication. Bedding plane could be partialy recognized on the LANDSAT images. This unit mainly correspond to Equador Formation (Proterozoic) which is composed of quartzite.

Unit p€3a:

This unit is extensively distributed from the center to the southen part of the area. The drainage shows high density and fine dendritic pattern, local with rectangular pattern. Stratifation (schistosities) is well observed. This unit correspond to Serid Formation (Proterozoic).

Table II–2–3 Photogeologic interpretation chart.

Units	Drainage Pttern	Morphological Expression						Remarks	Comparison with Existing Data
		Drainage Density	Cross. Sect. of Valley	Cross. Sect. of Ridge	Rock Resistance	Bedding or Schistosity	Lineament Density		
Q	—	low	—	—	low	none	none		Alluvial beds
T	—	low	—	—	high	none	none	flat terrain	Tertiary beds
Kda	—	low	—	—	low	none	none	black color	Creta. diabase
K	dendritic	low	—	—	low	none	none	flat terrain	Cretaceous beds
p€gb	—	—	—	—	low	none	none	purple color	Protero. gabbro
p€pg	parallel	low to med.	∨	∧	high	—	high		Protero. pegmatite
p€g3	—	low	—	—	low	—	low	whitish color	Protero. granitic r.
p€g2	parallel	low	∨	∧	high	—	high	purplish color	Protero. granitic r.
p€3c	parallel	high	∨	∧	high	common	high		Serido Formation
p€3b	dendritic	low	—	—	low	none	low		Serido Formation
p€3a	dendritic, trellis	high	∨	∧	medium	localy common	high		Serido Formation
p€2	parallel	medium	∨	∧	high	common	high		Equador & Jucurutu F.
p€g1	—	low	—	—	med. to low	none	none	whitish color	Caico complex
p€1c	parallel, trellis	low to med.	∨	∧	high	common	high		Caico complex
p€1b	subparallel	medium	∨	⌒	med. to low	none	high		Caico complex
p€1a	trellis	high	∨	∧	high	common	high		Caico complex

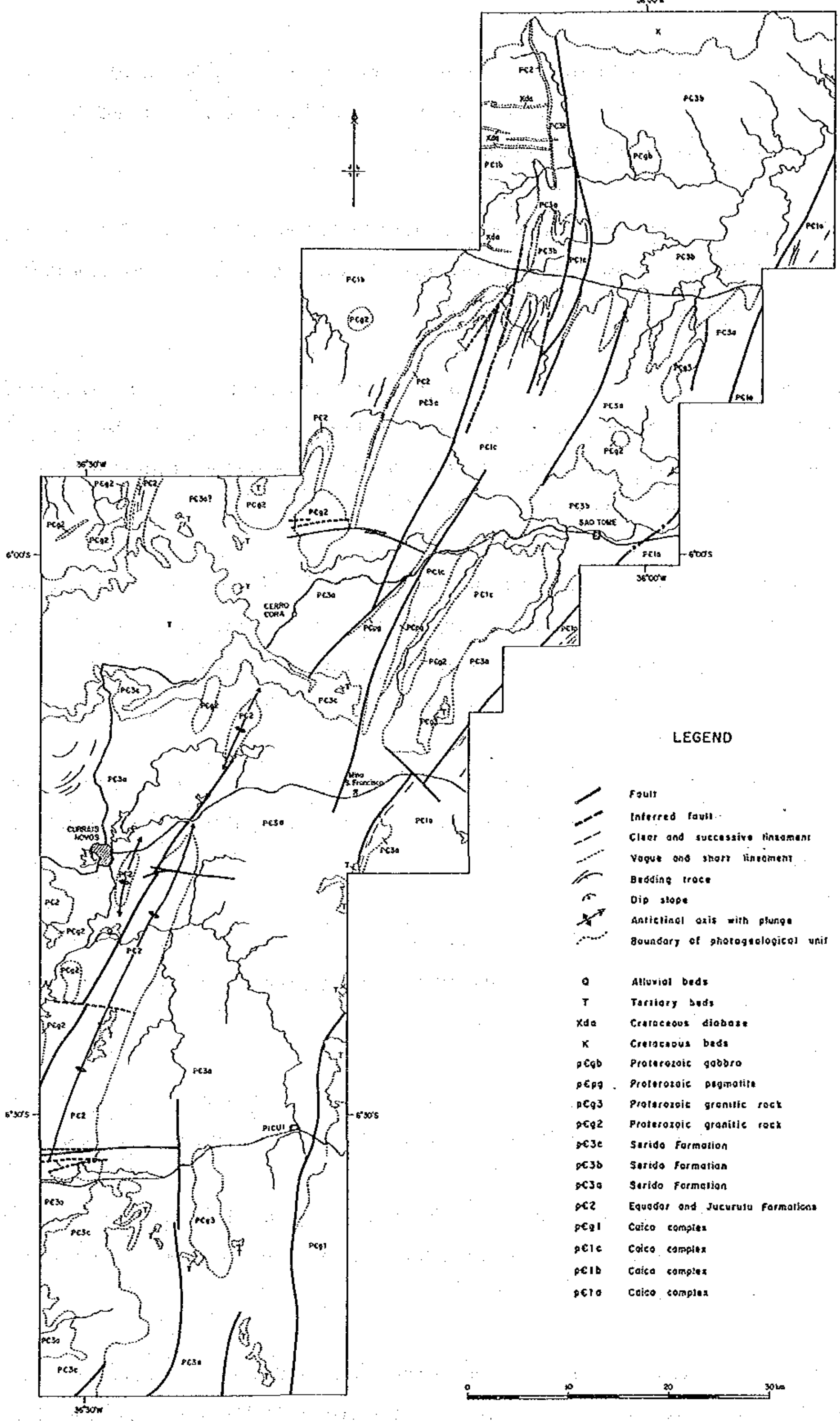


Fig. II–2–5 Geologic interpretation of LANDSAT image in the project area

Unit p€3b:

This unit is distributed in the northen part of the area. Topographically, it is generally flat but localy with low relief. drainage has subdendritic pattern and low density. This unit is also correspond to Serid Formation.

Unit p€3c:

This unit is distribueed in the northen part of San Francisco mine. Its hes high resistance, from the unit p€3a. But about the other characteristics, they are simillar This unit also correspond to Serid Formation.

Unit p€g2:

This unit is distributed along the margin of the projectarea. It has characteristically high resistance, rough texture and well developed lineaments. In some parts, it is bluish purple on the false color imagedue due to sparse vegetation. This unit corresponds to the granitic rock of Proteozoic.

Unit p€g3:

This unit is seen as stock in the southwesten part of Picui, but it is also locally recognized in the northen part of San Tome. It shows flat topography like a p€gl, and in some parts, it generally shows white color due to sparse vegetation on the false color image. This unit also corresponding with the granitic rock of Proteozoic.

Unit p€pg:

This unit is narrowly distributed in the northern part of San Francisco mine. It shows characteristically high resistance and the sharp ridge. This unit is pegmatite dike of Proteozoic.

Unit p€gb:

This unit is distributed inside of unit p€3b which distributed in the northern part of the area. It shows low resistance and purple color on the false color image. This unit is Proterozoic gabbro.

Unit K:

This unit is distributed along the northern margin of the area. It has generally flat, locally shows low relief. This unit consists of Cretaceous sedimentary rocks.

Unit Kda:

This unit is distributed as dikes inside of unit p€lb which distributed in the north margin of the project area, and it exhibits black color. This unit consists of Cretaceous basalt and diabase dikes.

Unit T:

This unit is extensively distributed in the north of Currais Novos, and is also distributed locally several parts of the area. It characteristically shows flat terrain. This unit is corresponding to Tertiary sedimentary rocks.

Unit Q:

This unit is Alluvial beds which is distributed along the rivers.

2-2-2 Structural analysis

Fig. II-2-6 shows the result of analysis of geologic structure. Lineaments were classified into 3 groups, such as (1) the lineaments which are cosidered as the faults by the previous data, (2) the lineaments which are clearly observed and well continuous (except the group (1) and (3) the lineaments which are obscure and less continuous.

Fig. II-2-6 shows that lineaments are predominant in the NNE-SSW trending belt zone locatecd from the northwest of Sao Tome to the southwestern part of the area. Rosediagramm (Fig. II-2-7) about faults and clear lineaments in this area shows that lineaments almost trend NNE-SSW or E-W.

As is discussed in previous chapter, the geologic structure is dominated by NNE-SSW trending in the area. On the LANDSAT image this orientation is also clear and well continuous. E-W trending structure was extracted as well as NNE-SSW on LANDSAT image, however the major E-W trending structure has been hardly known.

NNE-SSW trending structure which consists of faults and continuous lineaments is developing to the north of San Francisco mine and it seems to be continuous to the mine region, mereover E-W trending continuous lineaments is developing from around the San Francisco mine to the southern area.

This fact support the idea that around the San Francisco mine, fractures are well developing as compared with to the other regions.

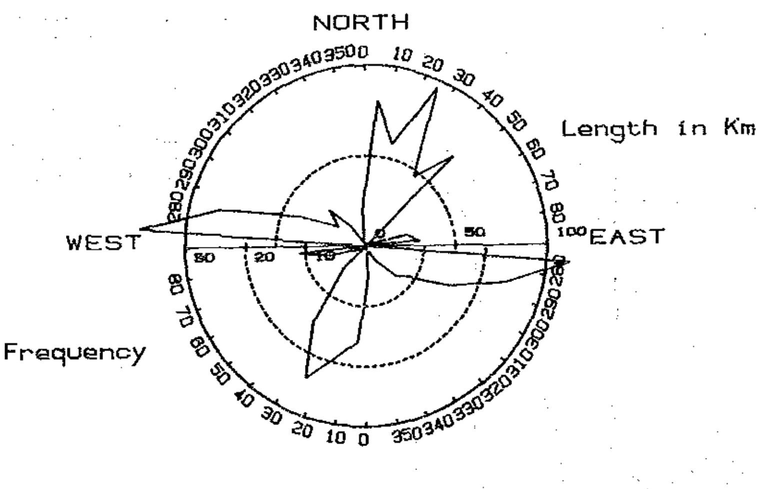


Fig. II-2-7 Rosediagram of Lineaments in the project area

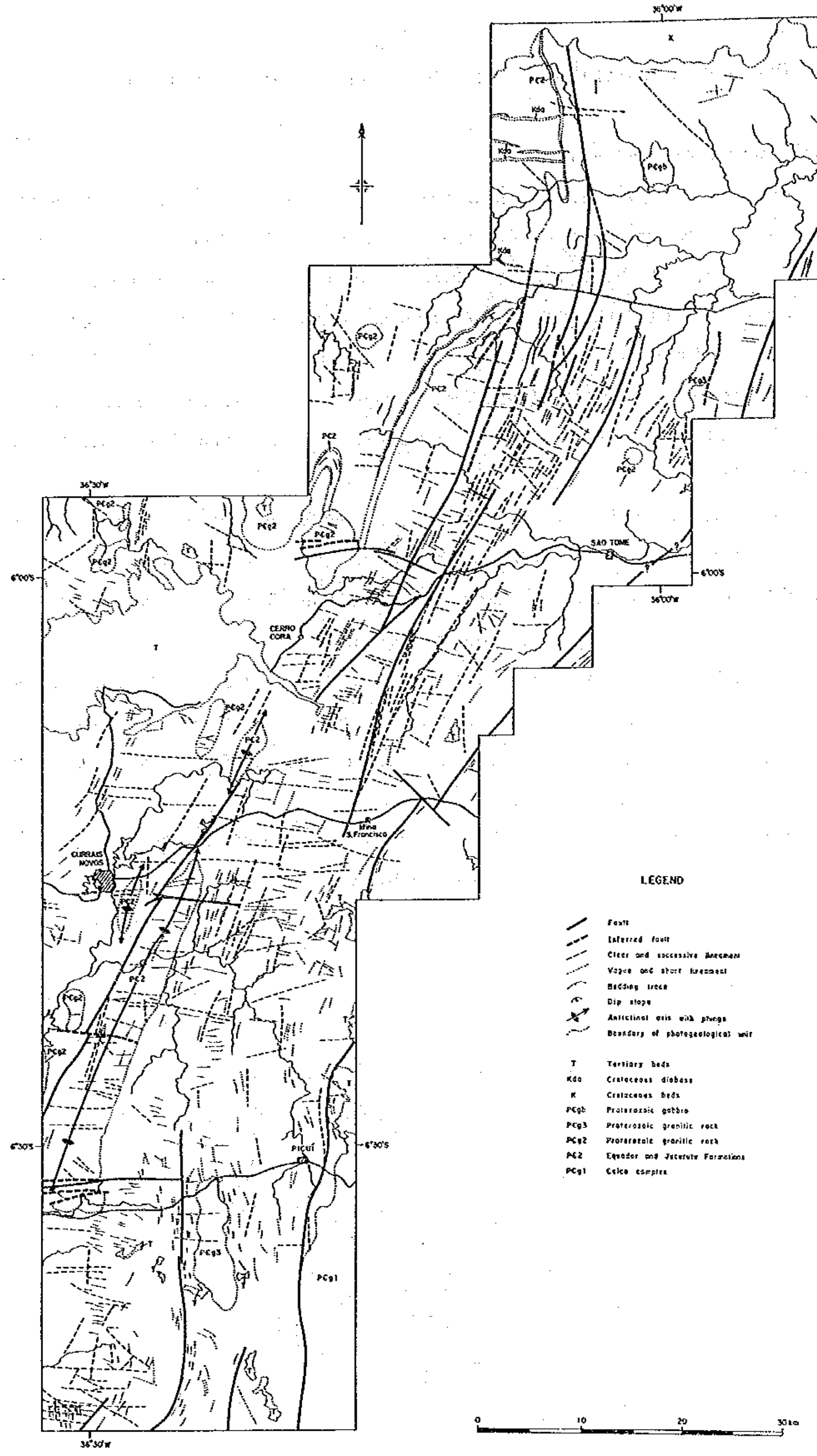


Fig. II–2–6 Lineament interpretation of LANDSAT image in the project area

Among the E-W trending lineaments, the distribution of clear and continuous lineaments are restricted in the apecitic region, furthermore, Tertiary basic dikes found around the San Francisco mine trend E-W. These facts are interested in relation to the mineralizations in this area.

2-3 Discussion

Fig. II-2-8 shows the compillation of Landsat image interpretaion. In this figure, the areas distributing main faults or lineaments are accounted as "Main Lineament Zone", and tonal anomalies are also described.

as mentioned above it is expected that fractures are predominant around the San Francisco mine, because this area is corresponding to an intersection of the NNE-SSW trending faults and continuous lineaments and the E-W trending continuous lineaments. Teixeira located to the southwest of the area is known as gold mineralization zone, were is the district along the Serid-Cachoeirinha-Riacho do Pontal tectonic line, and is located between the major faults. Furthermore, the lineament which perpendicular or diagonal to the faults are developing. It is suggested that this area is highly fractured zone. These facts support the idea that there is high potencial of existence of vein type gold deposit to the north and south of San Francisco mine.

On the Landsat image, because of dense vegetation or narrow range of alteration altered zone could not be extracted. Additionary it is necessary to clarity the relation between the geologic phenomana and the three tonal anomalies by the field check.

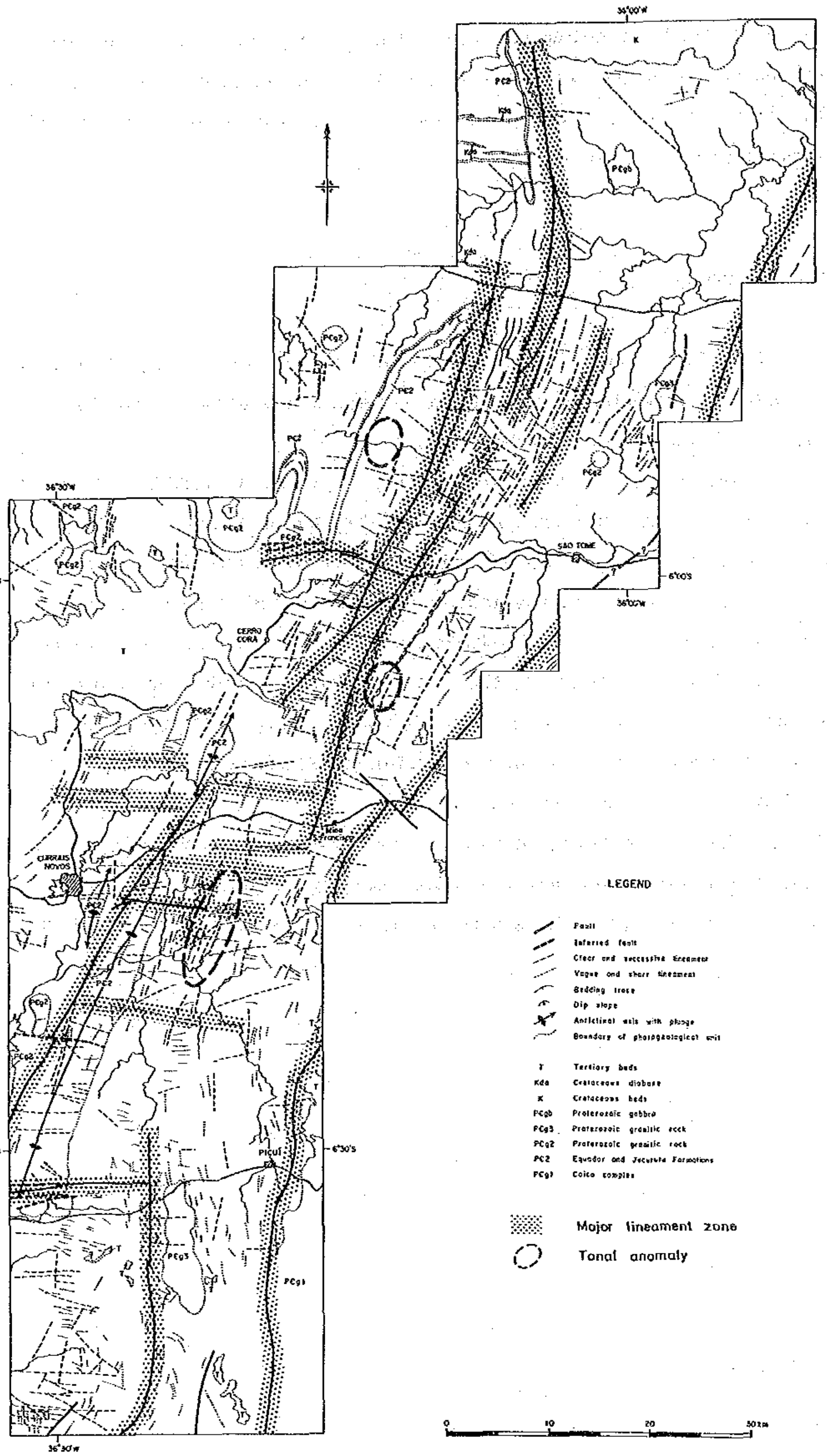


Fig. II–2–8 Compilation of LANDSAT image interpretation in the project area

Chapter 3 - Geologic survey

3-1 Purpose and procedure

3-1-1 Purpose

The purpose of this survey is to comprehend the mode of occurrence of gold deposit though elucidation of geological condition of the surveyed area (1000km2) of this year in the Currais Novos project area.

Survey has been focused on the points as follows, to achieve the above mentioned purpose.

1)Comprehension of the lithologic distribution and confirmation of the stratigraphy of the surveyed area.

2)Comprehension of the characteristics of geological structures.

3)Elucidation of the relationships between the lithology and the known ore deposits.

4)Comprehension and pursuit of the newly discovered gold bearing quartz vein.

5)Comprehension of the relationships between the ore deposits and geological structures in the global point of view.

6)Comprehension of the mineralogical and chemical characteristics of the ore from the known deposits.

3-1-2 Procedure

During the field survey, in convenient, lithologic mapping was carried out successively from south to north with base camp at Currais Novos.

The density of the survey route is more than 0.8km/km2 to cover the all area of the objected area. As mentioned below, stream sediment samples were collected for geochemical survey in parallel with the geological survey.

Before the field survey was started, topographic maps of 1/50,000 scale were prepared in Japan from the aerophotographs of 1/60,000 scale which had been taken in Brazil. The 1/25,000 scale maps were used during the field survey enlarged from 1/50,000 map.

3-2 Details of the survey

3-2-1 Geology

(1)Stratigraphy

Archaean Caico Complex and Proterozoic Serido Group are dominantly distributed in this area. Serido Group is classified into Jucurutu, Equador, and Serido Formations from the bottom of succession (Fig II-3-1).

Although during late 1960s to early 1970s, Equador Formation was supposed to be at the base of the Serido Group, Jardim de Sa and Salim (1978) and Jardim de Sa (1982) located Equador Formation at the middle of Serido Group from the geological detailed survey results. This survey follows the latest stratigraphy (Fig. II-3-2) because no new stratigraphic viewpoint on the basis of geological examination is published from that time on.

Cenozoic, Tertiary Serra do Martins Formation is distributed in the narrow area at the uppermost section of the surveyed area.

(i)Caico Complex

(a)Distribution (Pl. II-3-1 and Fig.II-3-1)

This unit is widely distributed in the northern half and eastern and southeastern part of the surveyed area. Complex body distributed in the northern half of the surveyed area is divided into four individual mass which are parallel each other and elongated trending NNE-SSW. These masses are named No.1, 2, 3, 4 from east to west. No.1 mass extends from Martinha, 5km west of Sao Tome, to SSW. This mass is rather small than other masses, and its width is 2km and its extension is 8km long. No.2 mass extends from Cacimbo in the south through by Serra Mata Fome northward to the east of Oiticica. No.3 mass extends from Ilhota in the south northward through Serra do Sao Paulo, Serra do Espinheiro, and further Novo Mundo up to Serra do Oiticica. No.4 mass extends from Serra do Sao Joao in the south to Barra dos Dois Rios in the south. Width of the No.2, 3, 4 masses are 2 to 4km each and their extension are more than 30km.

Western limit of the mass distributed in the southwestern part of the surveyed area is straight line trending NNE-SSW and the mass extends eastward widely in the east to the outside of the area.

Caico Complex distributed in the northern half of the area topographically appears clearly and forms steep mountains and its ridge. The complex forms flat topography in the southeastern part of the surveyed area.

(b)Lithology

Jardim de Sa(1987) divided the mass into two lithology though stratigraphy and chronology of the mass were not sufficiently known : one is orthogneiss originated from plutonic rocks which are abbreviated as TTG (Tonalite - Trongniemite - Granite) and is associated with migmatite, and the other is metasedimentary rock which is composed mainly of amphibolite - schist - quartzite - ultramafic rock - marble and is called as exogenetic

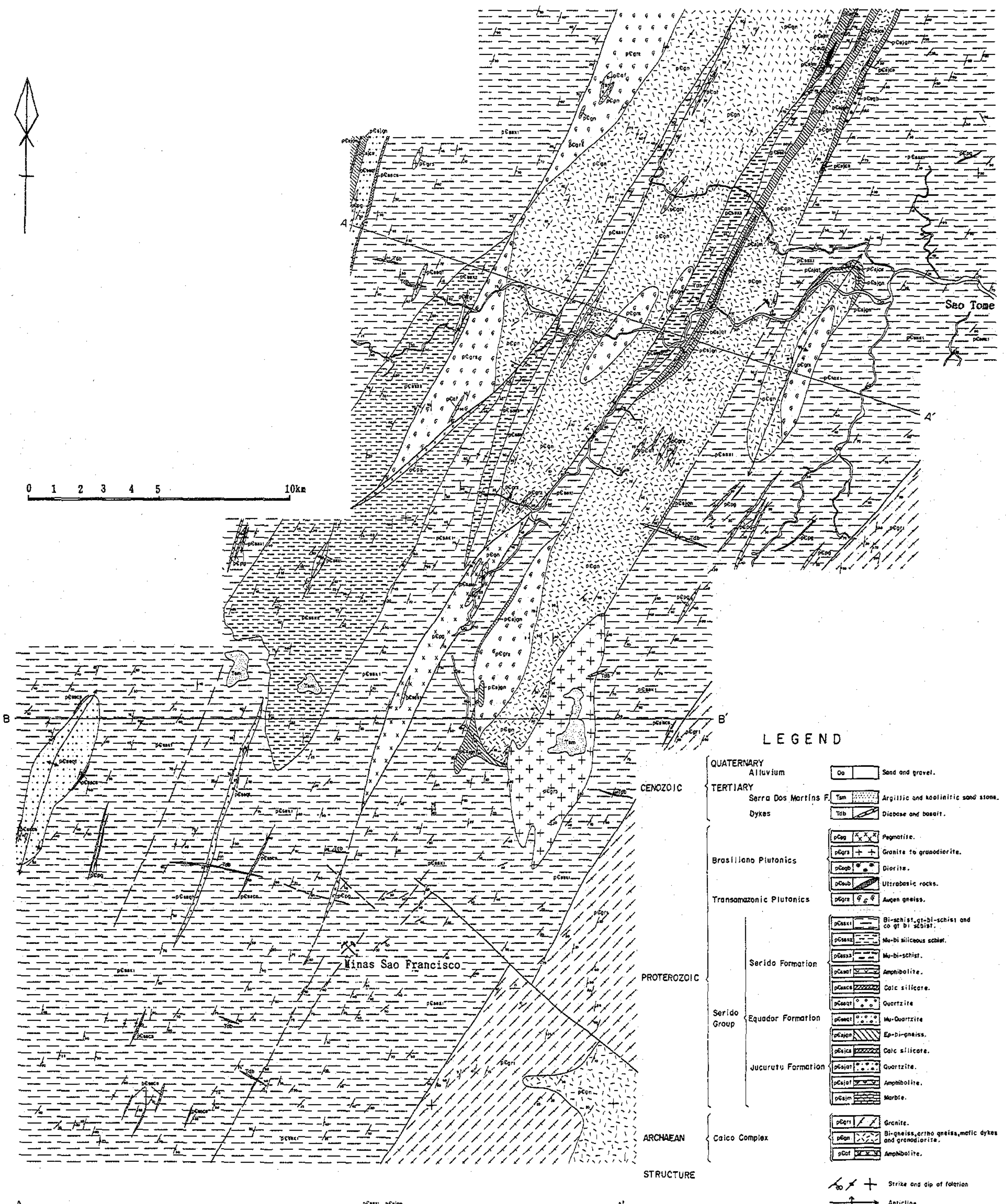


Fig. II-3-1 Geologic map of the survey area

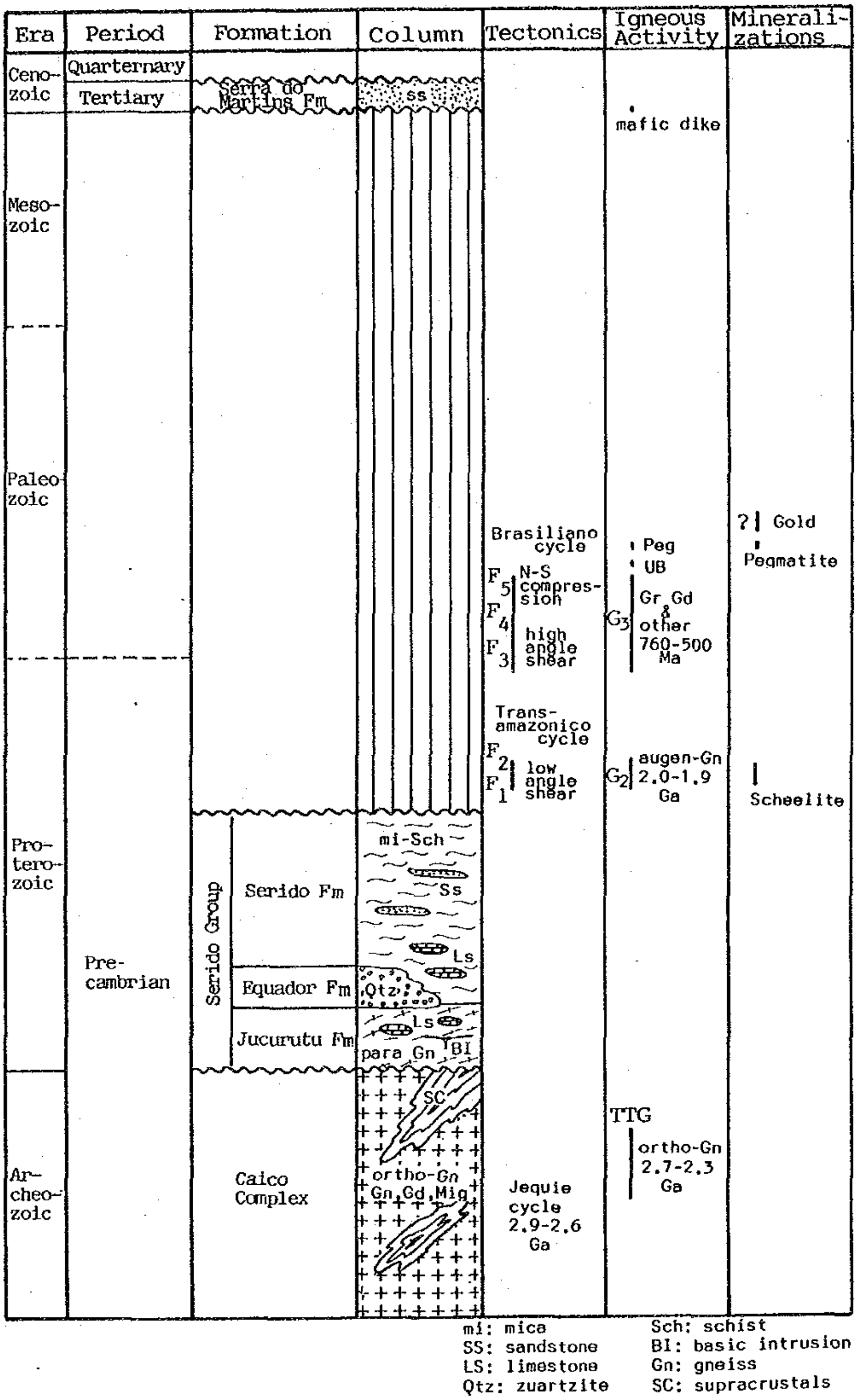


Fig. II-3-2 Generalized columnar section of the survey area rock.

The mass in the southeastern part of the surveyed area is mainly granite (pCgr1) and is correlated with TTG. Biotite bearing paragneiss (pCgr1) is exposed in the mass in the dimension of 3km x 5km and is involved in the exogenetic rock.

Among the complex distributed in the northern half of the surveyed area, the most eastern, the No.1 mass is mainly biotite bearing paragneiss. No.2 and No.3 masses are predominated by biotite bearing paragneiss. They are associated with ortho-gneiss, amphibolite, augen-granite and banded-gneiss, and often show a lithology of injection injection gneiss. Some of biotite-gneiss and amphibolite contain magnetite locally. No.2 and No.3 masses are the gneiss of the exogenetic rock origin because of consisting mainly of paragneiss. Intrusives of G2 granite (pCgr2) and pegmatite (pCpg) intruded in the No.2 and No.3 masses forming the various dimension. No.4 mass is also composed of biotite paragneiss, ortho-gneiss, amphibolite, augen-granite and banded-gneiss and is very rich in amphibolite than No.1, 2, 3 masses.

The southern part of the each mass of No.1, 2, 3, 4 are predominated by biotite paragneiss, whereas ortho-gneiss and amphibolite predominate in the northern part of the each mass. Especially in the northwestern part of the mass, amphibolite is ubiquitous. Biotitite rock, which consist of very coarse grained biotite, is found at the several sites. These biotite rocks are several dozens centimeters thick and up to approximately 50cm. This biotitite is supposed to have been metasomatic origin.

Pegmatitic rocks of various thickness ranging less than 1cm to several meters intruded notably in the all over Caico Complex. Most of these pegmatitic rocks are finer-grained and smaller scale than those distributed in Serido Formation in the south.

Thirteen megascopically distinctive rock samples from the area where Caico Complex is distributed have been collected, and chemical analyses and petrography through microscopic observation on each sample have been carried out (TableII-3-1, Table II-3-2). The samples are labeled as A023, A031, B010, B011, C029, C039, C041, D068, E048, E052, E064, E065, E068 and D047. A023, E064 E068 and D047 are classified as ortho-gneiss, B010, B011, C039, D068, E052 and E65 are as paragneiss, C029 is as augen-granite, and A031, C041 and E048 are amphibolite. Ortho-gneiss and and D047 augen gneiss are supposed to be granite origin. Paragneisses are very much siliceous and are rhyolite in composition if they were igneous rock origin. Sample A031 of amphibolite is rich in MgO and CaO, whereas samples C041 and E048 are rich in Al2O3 and CaO characteristically. The latter might be gabbroic rock origin.

ACF diagram (Fig.II-3-3) constructed from the chemical analyses show that some of paragneiss have a character of "pelitic rock and graywacke" and some of them do of "basic igneous rock" suggestively their original rocks. The chemical analyses result suggests

Table II-3-1 Analytical data of rock samples

Sample	C019	C028	C032	C060	E013	E018	E020	E022A	E022B	E040	E041	E042	E067	A023	A031
Coordinate of location	E 796.70 N 9317.55	800.45 9326.80	805.05 9331.00	800.20 9313.65	801.90 9312.15	798.50 9319.60	797.45 9322.10	803.35 9321.00	803.35 9321.00	796.25 9329.45	795.70 9329.70	795.70 9329.70	817.85 9346.90	805.00 9328.15	811.10 9332.65
Lithology	hb-ep-gt-sa Rock Serido F.	bi Sch Serido F.	bi Sch Serido F.	bi Sch Serido F.	gt-ct-bi Sch Serido F.	gt-mu-bi Sch Serido F.	am Sch Serido F.	gt-ct-bi Sch Serido F.	gt-ct-bi Sch Serido F.	gt-bi Sch Serido F.	hb Sch Serido F.	gt-bi Sch Serido F.	mu-bi Sch Serido F.	mu-bi Gr Caico C.	Amph Caico C.
SiO2 %	58.60	72.50	56.60	63.80	67.70	68.60	65.70	51.80	58.10	65.80	67.00	65.00	63.60	71.80	56.30
TiO2 %	0.81	0.68	1.10	0.95	0.90	0.72	0.78	1.30	1.20	0.96	0.95	0.92	0.55	0.51	0.33
Al2O3 %	17.00	11.40	17.50	15.30	15.50	13.60	14.80	22.40	20.20	14.20	13.60	13.60	15.00	13.30	3.30
Fe2O3 %	1.00	1.60	2.20	L 0.10	0.43	L 0.10	1.10	0.95	1.10	1.00	0.78	0.48	3.40	1.70	2.80
FeO %	4.20	2.50	4.70	6.50	5.10	4.80	3.40	8.50	6.50	5.10	5.10	5.60	2.40	2.20	6.60
MnO %	0.65	0.12	0.17	0.39	0.19	0.18	0.25	0.21	0.22	0.13	0.17	0.15	0.15	0.10	0.27
MgO %	3.40	3.00	4.50	3.70	4.30	2.50	2.20	6.90	4.30	4.00	2.60	4.80	4.90	0.74	15.90
CaO %	12.50	2.00	2.80	2.30	1.10	2.40	9.50	1.40	1.60	2.20	5.90	2.80	2.70	1.50	12.50
Na2O %	0.56	3.30	3.60	3.10	1.80	4.00	0.95	2.20	3.10	2.90	0.90	3.10	2.50	4.40	0.79
K2O %	0.30	2.00	4.30	2.90	1.20	2.20	0.20	2.30	2.00	2.40	1.60	2.60	3.30	3.10	0.11
P2O5 %	0.28	0.18	0.24	0.19	0.28	0.22	0.39	0.30	0.19	0.22	0.28	0.22	0.12	0.14	0.08
LOI %	0.62	0.70	2.25	0.85	1.46	0.69	0.71	1.69	1.39	0.99	1.08	0.71	1.34	0.48	0.96
total %	99.92	99.98	99.96	100.08	99.96	100.01	99.98	99.95	99.90	99.90	99.96	99.98	99.96	99.97	99.94
Au ppb	2	1	3	635	3	9	1	4	3	5	2	L 1	2	2	L 1
Ag ppm	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	0.2	L 0.2	0.2	L 0.2	0.2	L 0.2	L 0.2	L 0.2	L 0.2
Fe %	4.0	3.1	5.2	5.1	4.3	3.7	3.4	7.3	5.8	4.7	4.5	4.7	4.2	2.9	7.1
Mn ppm	5033	908	1363	3020	1505	1406	1978	1670	1714	994	1319	1135	1135	789	2110
Mo ppm	3	2	3	3	1	3	2	4	3	3	3	3	2	L 1	4
W ppm	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Sn ppm	3	L 2	3	L 2	L 2	L 2	L 2	2	2	2	L 2	2	L 2	L 2	L 2
Nb ppm	12	13	15	L 10	L 10	L 10	L 10	L 10	L 10	L 10	10	L 10	L 10	L 10	L 10
Ta ppm	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Be ppm	3	1	1	L 0.5	9	0.5	0.8	4	10	4	L 0.5	0.5	1	0.5	0.5
Li ppm	9	52	69	24	169	38	9	240	127	66	20	41	47	28	4
As ppm	60	L 1	1	1	1	2	1	3	1	L 1	4	1	1	1	L 1
Sb ppm	1	1	1	1	1	2	1	2	1	1	1	1	1	1	L 1

L: lower than

Table Ⅱ-3-1 (continued)

Sample	B010	B011	C029	C039	C041	D068	E048	E052	E064	E065	E068	E066	D047	D022	A062
Coordinate of location E	815.70	815.70	806.95	806.20	809.75	809.80	813.95	810.70	816.05	812.90	811.85	815.70	808.85	807.55	819.70
N	9338.15	9338.15	9330.40	9339.20	9342.90	9346.55	9347.25	9345.80	9341.80	9342.65	9344.80	9341.95	9306.50	9318.85	9346.25
Lithology	mu-bi Gn Caico C.	mu-bi Gn Caico C.	bi Gn Caico C.	bi Gn Caico C.	Amph Caico C.	hb-bi Gn Caico C.	am Sch Caico C.	hb-bi Gn Caico C.	mu-bi Gr Caico C.	bi Gn Caico C.	bi Gn Caico C.	bi Gn JucurutuF.	bi Gr Caico C.	bi Gr (G_2)	sa-hb Sch Intrusion
SiO2 %	71.00	78.10	69.20	70.00	51.00	70.50	52.90	65.40	70.10	70.30	70.30	77.40	71.80	70.40	60.00
TiO2 %	1.00	0.85	0.50	0.46	1.40	0.43	0.85	0.58	0.17	0.95	0.40	0.51	0.31	0.22	0.60
Al2O3 %	12.20	9.60	14.00	13.00	15.40	12.50	12.80	14.20	15.40	10.80	13.60	9.00	14.00	14.90	10.30
Fe2O3 %	1.10	1.30	0.93	1.20	3.80	1.00	2.30	1.60	L 0.10	1.90	1.20	1.10	0.76	0.97	0.82
FeO %	2.30	1.50	2.40	3.10	7.20	3.20	8.60	2.60	1.50	4.10	1.70	1.70	1.30	1.20	3.40
MnO %	0.03	0.02	0.07	0.08	0.19	0.08	0.23	0.07	0.02	0.06	0.03	0.09	0.05	0.10	0.19
MgO %	3.90	2.30	1.90	1.90	5.30	1.70	7.50	3.80	0.83	3.90	2.70	1.40	0.78	0.73	5.90
CaO %	0.73	0.30	2.50	1.50	10.10	1.80	12.00	4.50	1.10	1.00	3.00	2.30	2.40	2.80	13.60
Na2O %	1.70	0.39	3.80	5.20	3.30	4.50	1.30	4.60	5.80	2.50	5.00	2.60	4.40	5.30	1.40
K2O %	4.40	3.90	3.90	2.90	1.20	3.60	0.54	1.80	4.60	3.30	1.30	2.60	3.60	2.60	1.80
P2O5 %	0.34	0.29	0.21	0.12	0.29	0.14	0.27	0.17	0.10	0.38	0.14	0.11	0.16	0.33	1.30
LOI %	1.26	1.40	0.53	0.51	0.79	0.45	0.68	0.58	0.34	0.73	0.59	1.12	0.40	0.39	0.67
total %	99.96	99.95	99.94	99.97	99.97	99.90	99.97	99.90	100.06	99.92	99.96	99.93	99.96	99.94	99.98
Au ppb	2	2	2	4	1	3	1	L 1	L 1	1	1	1	L 1	L 1	L 1
Ag ppm	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	0.2	L 0.2	L 0.2	L 0.2
Fe %	2.6	2.1	2.5	3.2	8.3	3.2	8.3	3.1	1.2	4.5	2.2	2.1	1.5	1.6	3.2
Mn ppm	216	151	530	648	1483	648	1758	519	130	464	259	702	356	800	1450
Mo ppm	1	L 1	1	2	5	1	4	L 1	L 1	1	L 1	L 1	L 1	L 1	2
W ppm	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Sn ppm	14	8	2	L 2	L 2	L 2	L 2	L 2	L 2	19	L 2	L 2	L 2	L 2	L 2
Nb ppm	100	60	15	10	L 10	L 10	L 10	L 10	L 10	81	L 10	L 10	L 10	L 10	L 10
Ta ppm	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Be ppm	3	2	0.6	1	L 0.5	1	L 0.5	0.6	0.5	1	0.5	0.7	L 0.5	L 0.5	0.5
Li ppm	44	35	29	28	16	21	6	21	11	27	12	22	14	16	4
As ppm	1	L 1	L 1	1	3	L 1	1	1	L 1	1	1	1	L 1	2	1
Sb ppm	1	2	L 1	1	1	1	1	2	L 1	1	1	1	L 1	1	1

L: lower than

analysed by GEOSOL Ltda.

Table II-3-2 Mineral assemblages determined by thin section observation

Sample	Rock name determined by thin section testing	Structure	Rock forming minerals															opaque minerals	second minerals	
			quartz	K-feldspar	plagioclase	biotite	muscovite	hornblende	salite	pyralspite	cordierite	sphene	apatite	zircon	chlorite	epidote	calcite			
C019	hb-ep-gt-sa R	Sch	○		○			○	∘	○					○		∘	•	○*	* f.g.mu po cp dissem
C028	bi Sch	Sch	◎		∘	◎							•					•		
C032	bi Sch	Sch	○		∘	◎	•						•		○	∘		∘	○*	* f.g.mu
C060	bi Sch	Sch	∘		○	◎	∘						•	•				○☆	∘*	☆ py * ch
E013	gt-ct-bi Sch	Sch	◎		∘	○	•			○	○		•	•	•			•		pyrite layer
E018	gt-mu-bi Sch	Sch	◎		∘	◎	•			○			•	•				•		
E020	am Sch	Sch	○		○			◎					•			∘				
E22A	gt-ct-bi SCH	Sch	◎		∘	○	•			○	○		•	•	•			•		py cp dissem
E22B	gt-ct-bi Sch	Sch	◎		∘	○	•			○	○		•	•				•		
E040	gt-bi Sch	Sch	◎		∘	○	•			○			•	•				•		
E041	hb Sch	Sch	∘		○			◎☆							∘		∘	•	○*	☆actinolite *f.g.mu,ch
E042	gt-bi Sch	Sch	◎		∘	○				○			•	•				•		
E067	mu-bi Sch	Sch	○		•	○	∘						•		•	∘		∘	○*	* f.g.mu
A023	mu-bi Gr	Gn	○	○	∘	○	•						•	•				∘☆		☆ mag
A031	Amphibolite				∘			◎						•				•		
B010	mu-bi Gn	Gn	◎		○	○	○					•	•	•						
B011	mu-bi Gn	Gn	◎	∘	○	○	○					•	•	•						
C029	bi Gn	auGn	○	○	∘	◎	•					∘	•	•	•			•☆	•*	☆ mag * f.g.mu
C039	bi Gn	Gn	○		○	○						•	•	•	•				•	
C041	Amphibolite		∘		○	∘		◎				•	•		∘	∘			•*	* f.g.mu
D068	hb-bg bi Gn	Gn	○		○	○		∘				•	•		•				•	
E048	am Sch	Sch	∘		○			◎				•	•							
E052	hb-bi Gn	Gn	∘		○	○		○				∘	•	•	•	•		•	•*	* mu
E064	mu-bi Gr	Gn	○	○	∘	○	∘						•	•				•		
E065	bi Gn	Gn	◎		○	○	•					•	•	•						
E068	bi Gn	Gn	○	○	∘	○						•	•	•	•			•☆		☆ mag
E066	bi Gn	Gn	◎	•	○	○	•					•	•	•	•		•		•	
D047	bi Gr	Gn	○	○	∘	○						∘	•	•				•☆	•*	☆mag * f.g.mu
D022	bi Gr	Gn	○	○	○	○						∘	•	•	•			•☆	•*	☆ mag * ep
A062	sa-bg hb Sch	Gn?	○	•	∘			◎	○			∘	•		∘	∘	•			

◎ > ○ > ∘ > •

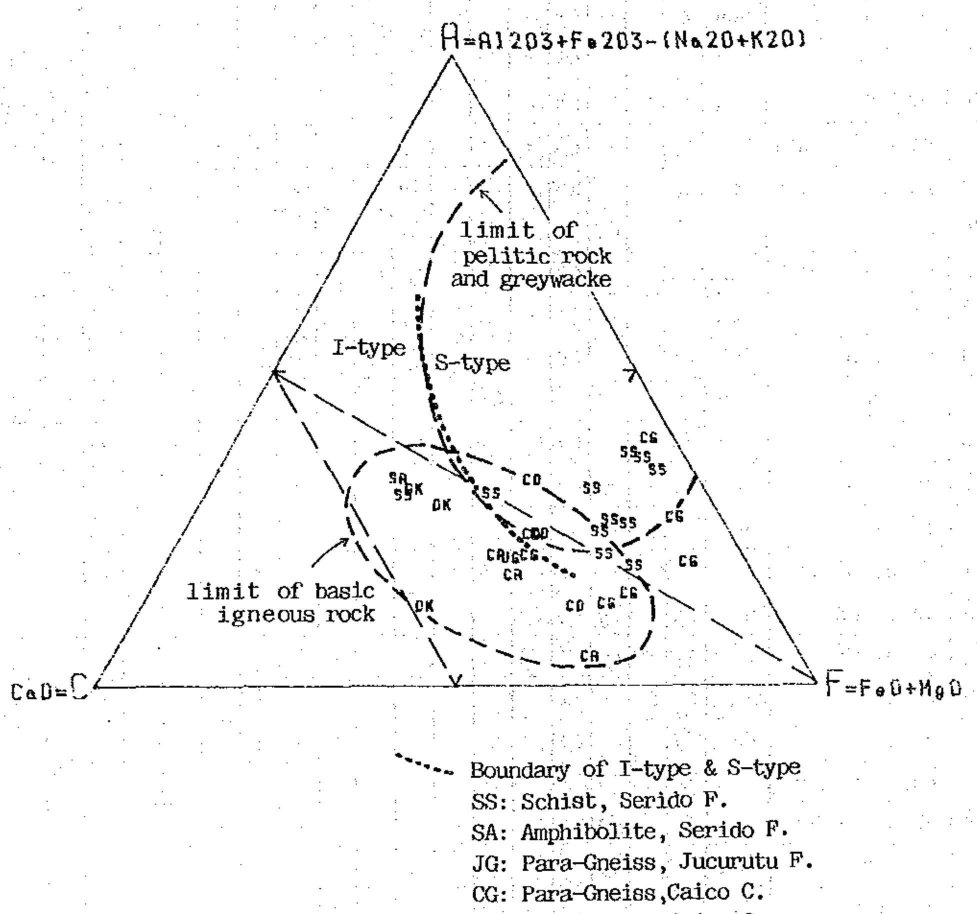


Fig. II-3-3 ACF diagram drawn from the analytical data of rock samples that the sample D047 belongs to the I - type and magnetite - series granitoid (Takahashi et al.,1980).

The samples carried out the chemical analyses are microscopically inspected. The results of observation are listed in TableII-3-2 and summarized as follows:

1) Ortho-gneiss (A023, E064, E068, D047)

Each rock shows gray with pale orange in color, fine - grained and gneisses texture megascopically.

Rock type: Muscovite-biotite-granite, Biotite-gneiss

Texture: Gneissose texture

Constituent minerals: Major; quartz, potassium feldspar, plagioclase, biotite, +muscovite

Minor; apatite, zircon, +titanite,

Accessory; +chlorite

Opaque; magnetite

Secondary; +fine - grained muscovite

2) Paragneiss (B010, B011, C039, D068, E052, E065)

Megascopicallly, B010, B011, C039 and E052 shows mainly gray - colored, but D068 and E065 brown - colored. Each rock is fine to coarse - grained and gneissose texture.

Rock type: Muscovite-biotite-gneiss, biotite-gneiss, amphibolebearing biotite-gneiss, amphibole-biotite-gneiss

Texture: Gneissose texture

Constituent minerals: Major; quartz, plagioclase, biotite, +potassium feldspar, +muscovite amphibole

Minor; titanite, apatite, +zircon, +chlorite, +epidote

Opaque; exist but not identified

Secondary; fine grained muscovite

3) Augen-gneiss (C029)

The rock contains megescopically porphyroblasto of feldspar as augen which is 1cm x 3cm in size and pale orange in color, and the rest of porphyroblast shows gnissose texture consisting of graysish brown colored fine — grained minerals.

Rock type: Biotite gneiss

Texture: (Augen) gneissose

Constituent Minerals: Major; quartz, potassium feldspar, plagioclase, biotite, muscovite

Minor; titanite, apatite, zircon, chlorite

Opaque; magnetite

Secondary; fine grained muscovite

4) Amphibolite (A031, C041, E048)

The sample A031 is dark green in color and fine to medium - grained, and acicular amphibole of about three mm long is distinct. The sample C041 is pale greenish gray, medium - grained and schistose texture. The sample E048 shows dark green and medium - grained, and acicular amphibole of about one to two mm long is remarkable.

Rock type: Amphibolite (E048), amphibole schist (A031, C041)

Texture: Schistose in the amphibole schist

Constituent minerals: Major; plagioclase, amphibole, quartz, +biotite (only plagioclase and amphibole in the sample A031)

Minor; titanite, apatite, chlorite, epidote

Opaque; exist but not identified

Secondary; +fine grained muscovite

(c)Age

According to Santos et al.(1984), the radiometric age of this rock is 2720+135 Ma (Rb-Sr isochron), and supposed to have been influenced by the Transamazonico Orogeny and by the Brazilian Orogeny.

(d)Stratigraphical position

This unit is situated at the bottom of the section of the surveyed area.

(e)Sedimentary environment

Rocks mainly of paragneiss and basic intrusives are classified as supracrustal rock and the those mainly of granitic ortho-gneiss and minor basic rock are as endogenic rock.

(ii)Jucurutu Formation

(a)Distribution (See Pl.II-3-1 and Fig.II-3-1)

This unit is distributed narrowly around Caico Complex, especially around the No.1, 2, and 3 masses. This is narrowly exposed around the northern end and the western side of the No.1 mass. This is distributed in the western side of the No.2 mass elongated 18km long trending NNE-SSW with approximately 500 wide and is expose in a small scale at the northeastern end and at the South Southwestern end of the mass. This is distribute along the northeastern margin of the No.3 mass elongated 350m long and 400m wide. All the distributions mentioned above have a trend concordant with the distribution trend of the Caico Complex.

(b)Thickness

Torres et al.(1973) reported the thickness of the Formation is more than 300m in the central southern part of the Rio Grande do Norte State. However, it is unknown in the surveyed area.

(c)Lithology (Fig.II-3-4)

In the typical rocks millimeter scale banding is observed well. This unit is composed mainly of quartz-feldspathic-gneiss (pCsjgn) associated by minor biotite, muscovite, and epidote in general. Migmatite (pCsjm) occurs locally at the north of Mal Assnbrado. Lenticular shaped marble, calc-silicate rock (skarn), quartzite and mica-schist ranging 2-3m to 5-6m thick are intercalated in the almost of beds. Scheelite occurs in the skarn and was mined as a tungsten deposit in the past.

Chemical composition of the representative rock is shown as sample number E066 in the TableII-3-1. This sample is very much siliceous. Result of petrographic inspection under the microscopy is described as follows (see TableII-3-2):

The sample shows megascopically pale greenish gray colored, fine - grained and gneissose texture.

Rock type: Biotite-schist

Texture: fine grained gneissose

Constituent minerals: Major; quartz, potassium feldspar plagioclase, biotite, muscovite

Minor; titanite, apatite, zircon, chlorite calcite

Secondary; exist but not identified

(d)Age

Radiometric dating and index fossils are not obtained from this unit through the present survey.

(e)Stratigraphic position

Whereas this succession is to be situated above Caico Complex unconformably, the stratigraphic relationships between them is unknown in this area, since the facing of the section was not determined through the textural evidence. However, they are supposed to be faulted at where mylonite is recognized along their boundaries.

Calc-silicate rocks, which is very similar to that in this lithology section, is exist in the northwestern part of the surveyed area. This is justified to be included in Serido Formation since it is judged to be situated above Equador Formation.

(f)Sedimentary environment

The depositional environment of this unit is supposed to be shallow marine (neritic) facies owing to the intercalation of calcareous rock in general.

(iii)Equador Formation

(a)Distribution (Pl. II-3-1, Fig. II-3-1)

This Formation is distributed at the two sites in the surveyed area. The one is situated at southsouthwest of Serro Cola, between Serro Cola and National Way BR-226, and form an oval shape with axis trending NNW-SSW and composes the Serra Crruxoiro. The width of its distribution is 2km across and elongated about 7km long. The other is located at the northwestern edge of the surveyed area, at the west of Porto d'Agua and trending NNE-SSW as the previous one. The width is 600m at most and elongated more than 5.5km and extends outward from the surveyed area.

(b)Thickness

Whereas the thickness of this section was reported as 800m+ in the central southern part of the Rio Grande do Norte state (Ebert,1968), the thickness in this surveyed area is unknown.

(c)Lithology

This unit consists of pure quartzite (pCsegt) and muscovite-quartzite. The amount of muscovite is lesser. This section distributed at the northwestern margin of the surveyed area is composed of the almost pure quartzite and gently to tightly folded with several dozens meters to several meters wave length. The one exposed in the southwestern part of the surveyed area consists almost of muscovite-quartzite.

(d)Age

Whereas the radiometric age and index fossils are not obtained, this unit is supposed to be situated at the lower Proterozoic in terms of the relationships with the other formations.

(f)Sedimentary environment

Deposition of this unit is supposed to be pre date the orogeny.

(iv)Serido Formation

(a)Distribution (see Fig.II-3-1)

This unit occupies the widest area in the surveyed area. This unit covers the almost of the southern half of the surveyed area. At the northern half of the surveyed area, the Formation is widely distributed in the eastern and western part and is furthermore exposed at the rest of Caico Complex and Jucurutu Formation between the eastern and western part. This unit distributed in the rest of Caico Complex and Jucurutu Formation is less than 1km wide, and get wide the width of the distribution southward to meet the widely covering unit. On the north, its narrow distribution area extends northward up to outside the surveyed area.

(b)Thickness

The thickness of this section is reported as much as 300m as an averaged value (Ferran et al.,1973), while it is unknown in the surveyed area.

(c)Lithology

This unit is dominated by mica-schist associated with minor quartzite, marble, amphibolite and calc-silicate rock (skarn).

Mica-schist is megascopically composed of biotite schist, garnet-biotite schist, cordierite-garnet-biotite-schist (above three schists are denoted as pCssx1), muscovite-biotite-bearing siliceous schist (pCssx2), and muscovite-biotite schist (pCssx3).

Since the distribution of the cordierite and garnet bearing biotite schist among the biotite schist in the southern half of the surveyed area is too much complicated to be individually expressed in the 1/50,000 scale map, they are summarized as pCssx1. Trace amount of sillimanite is contained locally in these kind of rocks. Andalusite is also identified from a site. The unit pCssx2 is characteristically recognized in the western part of the surveyed area, and is hard, fine and compact in general, and siliceous with minor association of muscovite and biotite. The unit pCssx3 contains ubiquitous amount of muscovite and biotite and is possibly the product of the retrograde metamorphism. This rock is concordantly distributed among Serido Formation distributed between Caico Complex in the northern half of the surveyed area.

Serido Formation is subdivided into the pelitic unit of pCssx1 and the siliceous unit of pCssx2 globally.

Paragneiss including calc-silicate-rock is situated near the base of this unit and is exposed at the west of Port d'Agua, at the northwestern margin of the surveyed area. The unit of alternation of the calc-silicate rock and biotite schist, whose thickness of each bed is several dozens centimeters and that comprise about 10m alternative unit, is exposed, while its stratigraphic situation is uncertain. This alternation is exposed especially around the southwestern edge of the surveyed area.

Quartzite bed is intercalated in Serido Formation in the southwestern part of the surveyed area. Its width is approximately 200m an elongated about 10km long trending N20°E.

Schistosity is intensively developed through out the Serido Formation, and its texture is intensely lepidoblastic. Tightly folded quartz veins and boudinaged quartz are observed.

Thirteen megascopically distinctive samples were collected from the all area where Serido Formation is distributed and the chemical analyses and petrography under microscopic inspection were carried out. The examined samples are C019, C060, E013, E018, E22A, E22B, E040, E041, and E042 taken from the pCssx1, C028 and E020 from the pCssx2 and C032 and E067 from pCssx3. Number of the mica schist samples are 10 specimen, and one calc-silicate rock, and two amphibolite.

Mica-schist are plotted concentrated near the F end instead of the A end in the ternary ACF diagram (Fig.II-3-3). Thus they are concluded not to be a typical pelitic rock. The analytical results shown in Fig.II-3-1 looks to be scattered considerably and the amount of Al2O3 show the negative correlation with that of SiO2. Rocks rich in Al2O3 is regarded as pelitic while those rich in SiO2 as psamitic.

Simultaneously with the chemical analyses, the above listed samples were petrographycally inspected under microscopic observation. The results are summarized as follows:

1) Mica-schist (pCssx1: C060, E013, E018, E22A, E22B, E040, E042)

Megascopically, The sample E013 is brownish and bluish gray in color, E042 dark gray and the others brownish gray, and shows fine - grained and schistose texture. All of samples without the sample C60 contain porphyroblast of garnet. The sample C060 is accompanied by pyrite veinlet of lesser than one mm width.

Rock type: Garnet-cordierite-biotite schist, garnet-muscovitebiotite schist, garnet-biotite schist

Texture: Schistose

Constituent Minerals: Major; quartz, plagioclase, biotite, pyralspite-garnet, +muscovite +biotite

Minor; apatite, +zircon, +chlorite

Opaque; minor amount but not identified

note; muscovite which occurs cutting the schistosity in the E018 is supposed to be the post the main metamorphic products, pyrite forming veinlets in C060 is supposed to be the post metamorphic products.

2) Mica-schist (pCssx2: C028)

The rock shows megascopically dark gray colored and schistose texture.

Rock type: Biotite-schist

Texture: Schistose

Constituent Minerals: Major; quartz, plagioclase, biotite

Minor; apatite (trace)

Opaque; trace not identified

3) Mica-schist (pCssx3: C032, E067)

Each rock shows greenish gray colored, fine - grained and schistose texture. E067 is characterized by white luster of mica.

Rock type: Muscovite-biotite-schist

Texture: Schistose

Constituent Minerals: Major; quartz, plagioclase, muscovite, biotite

Minor; apatite, chlorite, epidote

Opaque; minor amount but not identified

Secondary; fine grained muscovite

note; chlorite and epidote found in C032is supposed to be products of retrogressive metamorphism due to their mode of occurrences

4) Calc-silicate-rock (pCssxl: C019)

Megascopically, the rock shows greenish gray colored, coarse - grained, hard and compact, and weak schistose texture. The rock contains porphyroblast of garnet.

Rock type: Amphibole-epidote-garnet-salite-rock

Texture: Schistose

Constituent Minerals: Major; quartz, plagioclase, amphibole salite, pyralspite-garnet

Minor; chlorite, calcite

Opaque; trace but not identified. pyrrhotite and chalcopyrite are disseminated.

Secondary; fine grained muscovite

5) Amphibolite (E020, E041)

E020 shows greenish gray in color and coase - grained. E041 shows greenish gray colored, fine - grained and hard, and is associated with white colored quartz vein.

Rock type: Amphibole schist

Texture: Schistose

Constituent Minerals: Major; quartz, plagioclase, amphibole (actinolite in E041?)

Minor; apatite, chlorite(E041), epidote(E020), calcite(E041)

Opaque; trace not identified

Secondary; fine grained muscovite and chlorite(E041)

(d)Age

Late Precambrian. Since this unit had been influenced by the Transamazonico Orogeny, its depositional age should be before 2100ma.

(e)Stratigraphic position

This unit overlays the Equador Formation, whereas it is directly contacted with the Jucurutu Formatiom where the Equador Formation lacks.

(f)Sedimentary environment

This unit has been regarded as flysch sediments and consists of the cyclic sediments of graywacke-argillite turbidite. This is the abyssal sediment.

(v)Tertiary Serra do Martins Formation

(a)Distribution (Pl.II-3-1,Fig.II-3-1)

This unit is distribute in the central part of the surveyed area in the small scale at three cites trending WNW-ESE. At the eastsoutheast of Serro Cola, it is distributed as discrete two exposure east and west. These are the extension of the Serra da Santana widespread in the west, and are distributed as much as 1km across. The other is situated on the summit of the Serra Verdo, and its dimension is 1km (latitudinal) * 2km (longitudinal).

(b)Thickness

Thickness of this section is as much as 40m in the surveyed area.

(c)Lithology

This unit consists of gray coarse-grained sandstone and argillic fine to medium-grained sandstone.

(d)Correlation

This unit is correlated as Cenozoic tertiary.

(e)Stratigraphic position

This unit cover the Precambrian systems unconformably, since the Cretaceous system lacks in the surveyed area, which are exposed near the coastal area in the north of the Borborema district.

(f)Sedimentary environment

According to Bigarella(1975) (in Santos et al.,1984), this unit is subaerial sediments deposited on the pediplane.

(2)Intrusive Rocks

Intrusive rocks in the surveyed area is divides into the intrusive rock related to the Transamazonico-Amazonian cycle Orogeny (G2), intrusive rocks during the Brazilian cycle Orogeny (G3), intrusives after the above mentioned orogenies, and the Tertiary intrusives. The names of the intrusives such as, G2, and G3 follow Jardim de Sa (1981).

(i)G2 granite

(a)Distribution (Pl.II-3-1 and Fig.II-3-1)

Almost of this unit occurs as intrusives in Caico Complex. The only one exception is the intrusion along the boundary between Caico Complex and Jucurutu Formation. All of the intrusives in the Caico Complex are elongated in the same trend as Caico Complex. The dimension of the intrusives varies, and the largest one which intruded into the most western mass of Caico Complex, has dimension of about 2km wide and maximum extension of approximately 10km long. The next largest one, that intruded along the boundary between Caico Complex and Jucurutu Formation, has dimension of about 2km wide and about 8km long. Other intrusives are all small scale and their dimensions are less than 1.5km wide and less than 4km long.

(b)Lithology

This unit is composed of augen-gneiss of granite to granodiorite in composition and fine-grained ortho-gneiss. Whereas this units occurs as a intrusive rocks in Caico Complex, this intrusives are missed to have been distinguished from the ortho-gneiss of Caico Complex, since it has the very similar lithology as the ortho-gneiss of Caico Complex and it is very difficult to distinguish them each other. They are distinguishable since, xenoliths of paregneiss of the Caico Complex are included in the G2 intrusive mass, whereas none of them are found to be included in the ortho-gneiss. Some of the above described ortho-gneiss such as E068 and E064 might belong to the G2 unit.

Sample E068 belongs to the I-type, magnetite-series, whereas E064 shows S-type, ilmenite-series character. The result of the chemical analyses and petrographic inspection under the microscopy on the samples E068 and E064 have been already described above.

(c)Age

Since this unit intruded into the both of Jucurutu Formation and Serido Formation, the age of the intrusion was after the deposition of both of them. G2 is identified due to the structural evidence that this unit intruded into Caico Complex and along the boundary between Jucurutu Formation and Caico Complex.

Radiometric age of 2090Ma was obtained by the Rb-Sr dating (Maced et al.,1984; in Jardim de Sa,1987) and this age determination is in good agreement with the Transamazonico Cycle Orogeny.

(ii)G3 granite

(a)Distribution (see Pl. II-3-1 and Fig.II-3-1)

This unit is exposed at two sites. One is situated at the 7km northeast of the San Francisco mine and elongated trending NNE-SSW. This is centered at the Serra Verdo with the dimension of about 3km wide and about 10km long. The other is located at the about 1km northnortheast of Port d'Agua in the northwestern part of the surveyed area, in a small scale elongated trending NNE-SSW. The width is approximately 200m and its extension is about 1km long.

(b)Lithology

This unit consists of medium-grained gray granodiorite. The chemical analyses and petrographical inspection under the microscopy were carried out on the sample D022. This rock has a characteristics of I-type and magnetite-series granitoids. The result of the microscopic inspection is as follows:

The rock shows megascopically gray with pale orange, fine-grained and schistose texture.

Rock type: Biotite granite

Texture: Gneissose

Constituent Minerals: Major; quartz, potassium feldspar, plagioclase, biotite
Minor; titanite, apatite, zircon, chlorite
Opaque; magnetite
Secondary; epidote

(c)Age

Radiometric dating of 765Ma, and 550Ma and 660Ma (Jardin de Sa et al.,1987) were obtained by the Rb-Sr method. Each of them is interpreted to have been intruded during the Brazilian cycle orogeny.

This unit intruded around the boundary between Caico Complex and Serido Formation, and cut also Jucurutu Formation. Thus this intrusion took place post date of these formations. No direct relationships between the G2 is observed.

(iii)Other intrusive Rocks

(iii-1)Pegmatite(pCpg)

(a)Distribution (see Pl.II-3-1 and Fig.II-3-1)

This type of intrusives are distributed in the all over the surveyed area. They are small scale in general. The largest one is situated around the north of the Sao Francisco mine and occupies the eastern half of the Serra de Hosanca and elongated striking NNE-SSW. Width is approximately 1 km and the extension reaches up to about 13km long. The second largest one is located at the summit of the Serra do Sao Joao, in the central western part of the surveyed area, trending NE-SW. The width is about 100m and the extension is about 7km long. The small scale pegmatites is several meter to several dozens meter wide and the extension reaches up to 4km long at most. They intruded into the all of the country rocks distributed in the surveyed area, and the majority is striking NNE-SSW. However in the west of the second Caico Complex mass, including the northern half of itself, from the west of the surveyed area, the frequency of the pegmatite suddenly decreases.

(b)Lithology

Some of pegmatites intruded into only Caico Complex, whereas another intruded into the all of the country rocks such as Caico Complex, Jucurutu Formation and Serido Formation. Constituent minerals are potassium feldspar, quartz, plagioclase, muscoviteand biotite. The lithology of the pegmatites are not discussed yet in the present survey.

(C) Age

The pegmatite seems to be intruded after sedimentation of Serido Formation because the pegmatite occurs in every Precambrian rock from Caico Complex to Serido Formation.

(iii-2)Amphibole Schist (pCsgb)

(a)Distribution (see Pl.II-3-1 and Fig.II-3-1)

This unit is exposed in small scale trending NNE-SSW at north of Mal Assombrado situated about 8km northnorthwest of Sao Tome. Its width is about 200m and its extension is about 2km long. It intruded along the fault which make the boundary between Serido Formation and Jucurutu Formation.

(b)Lithology

This unit is coarse-grained and the lineation due to the quartz and amphiboles are well developed. The chemical composition and the petrographical result under the microscopy of sample A062 is presented below.

Rock type: Salite-bearing amphibole schist

Texture: Gneissose

Constituent Minerals: Major; quartz, potassium feldspar, plagioclase, amphibole, salite

Minor; titanite, apatite, chlorite, epidote, calcite

(iii-3)Ultramafic Rock (pCsub)

(a)Distribution (see Pl.II-3-1 and Fig.II-3-1)

This unit is distributed at the about 1km southsouthwest of Oiticica, about 10km northnorthwest of Sao Tome, striking NNE-SSW. The width is more than 100m and its extension is about 700m. This intruded into the Jucurutu Formation concordantly with the trend of the Jucurutu Formation.

(b)Lithology

This unit is dark gray in color inside the mass and is gray and dark gray spotted on the surface. It is serpentinized and asbest veinlets are observed. Chemical analyses and petrographical inspection through microscopic observation are not exerted yet.

(C)Age

Since the rock intruded into Jucurutu Formation, the intrusion took place after Jucurutu