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

(CONSOLIDATED REPORT)

MARCH 1992

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

PREFACE

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

This project was carried out over a period of three years from 1989 to 1992 and completed on schedule with the inestimable collaboration of the concerned governmental agencies of the Federative Republic of Brazil, especially the Departamento Nacional da Producao Mineral (DNPM) and Companhia de Pesquisa de Recursos Minerais (CPRM). This report is a summary of relevant survey results of these three years.

In closing, we wish to express our sincere appreciation to the officials concerned of the Government of the Federative Republic of Brazil for their always friendly cooperation extended to the Japanese survey teams.

March, 1992

Kensuke Yanagiya

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ABSTRACT

In conformity with the Scope of Work agreed between the governments of the Federative Republic of Brazil and Japan in July 11th, 1989, the present survey was carried out in the Currais Novos area (Figure 1, Figure 2), the state of Rio Grande do Norte, Federative Republic of Brazil. The project was executed over three years from 1989 to 1991 with following results.

(1) Geology and Structure

LANDSAT TM images of the project area were geologically and structurally interpreted covering 5,910 km^2 in the first phase. 16 geologic units were identified from the characteristics of the images, correlating reasonably well with known geologic units. A number of lineaments striking NNE-SSW and E-W could also be clearly defined in the images. Some geologic structures seem to correlate with those associated with gold mineralization.

Geologic mapping covering 2,000 km^2 were carried out during three phases. The project area is widely underlain by Precambrian rocks. They are represented by the Archean Caico Complex, and the Proterozoic Serido Group. The Serido Group is constituted of Jucurutu Formation, Equador Formation and Serido Formation, in ascending order. The Caico Complex comprises gneisses, migmatites and granites. The Jucurutu and Equador Formations are composed of gneisses and quartzites respectively. The Serido Formation consists mainly of biotite schist. Tertiary continental sediments as well as Quarternary alluvial and colluvial sediments lie directly on the Precambrian Formations.

NNE-SSW to N-S trending structures are prominent in the entire survey area. The trending NNE-SSW Picui fault divides the Serido Formation from the Caico Complex in the east end of the survey area. Major faults trending NNE-SSW to N-S cross through the central and the western parts of the area. A 3 Km wide fold zone do extend across the area in N-S direction. On the other hand, faults and basaltic dikes extending in WNW-ESE ~ ENE-WSW direction intersect those faults and the fold zone above described.

Based on an overall interpretation of the obtained results, the following relevant observations can be made concerning to the geology and structures of the survey area. Rocks previously thought to belong to the Jucurutu Formation were partially included in the Caico Complex or Serido Formation, based on their lithologic features and/or stratigraphic position. Rocks belonging to the Serido Formation were subdivided into four units based on their lithologic characteristics. It was confirmed that a 3 Km wide fold zone crosses through the central part of the survey area in NNE-SSW direction. The control of gold mineralization in this area seems to be mainly structural rather than stratigraphic.

(2) Stream Sediment Geochemical Survey

Stream sediment geochemical survey was executed concomitantly with the geological mapping

during all three phases.

Au in stream sediment indicated anomalies in the area surrounding the Sao Francisco gold deposit. Au anomalies were also disclosed in areas to the north and south of Frei Martinho and to the west of Picui. In areas surrounding small auriferous quartz veins, Au anomalies were detected only sporadically. Chemical analyses of up to 13 elements, namely Au, Ag, Fe, Mn, Mo, W, Sn. Nb, Ta, Be, Li, As, and Sb have shown that Au is the only reliable tracer in prospecting for gold in this area, because of no trustworthy correlation have been observed between Au and any other element.

Gold dust were observed in pan concentrates at some points. They are very occasional and fine except nearby the Sao Francisco deposit, where they occur more frequently. Gold dust were also found in the surroundings of a small mineralization, but they are quite scarce. These results together with those of stream sediment geochemical survey indicate that there exist very few possibility of finding a large gold mineralization within the project area. It seems therefore reasonable to concluded that, apart from that being mined at the Sao Francisco mine, another large gold deposit does not exist within the limits of the project area.

(3) Soil Geochemical Survey

Soil geochemical survey was carried out in areas A and B in Phase II and Phase III, respectively. Four sub-areas, A-I, A-II, A-III, A-IV of area A and one sub-area B-I of area B were prospected by soil geochemical survey, by analyzing Au, As and Sb. These areas have been recommended for further detailed survey as results of previous reconnaissance surveys indicated them as promising for gold.

Au anomalies occur concentrated in the southeast part of the area A-I and in the central part of the area A-II. On the other hand, they occur rather scattered as spots in area B-I. In the surroundings of quartz veins known as auriferous, gold anomalies were not always distinguishably detected. Furthermore, the spatial correspondence between gold anomalies in soil and mineralization were found to be almost absent, except for some portions of area A-II. Gold anomalies did overlap that of arsenic right on the Sao Francisco deposit, which includes gold and arsenic in the ore minerals. However, since these three elements are only badly correlated in the other areas Au was considered as the only effective element for prospecting this area by soil geochemical survey.

Soil geochemical survey yielded results that could not be confirmed by underground prospecting methods like trenching. This absent of correlation can be related to the poor development of soils in the area, and to the pluvial regime, which tends to wash over the soils during the rainy season by torrential rains. Soil geochemical survey seems, therefore, to be an inadequate geochemical prospecting method of areas with similar hydrologic and climatic conditions.

(4) Biogeochemical Survey

Biogeochemical survey was carried out in areas A-I and A-II during Phase II by way of experiment. Leaves were chosen as sampling material and were collected from three different vegetation (Jurema Preta, Caatingueira and Malva) at the same points.

Results have shown that Jurema Preta and Malva do effectively absorb Au from soil. Judging from the relationship between the location of biogeochemical anomalies and known mineralizations, Jurema Preta was considered to be the more effective for regional Au exploration than other plants.

(5) Geophysical Survey

IP was the geophysical method utilized to map underground structures in area A-II, in order to locate the trenches and gather information on anomalies associated with such a kind of vein-type gold mineralization. The IP method has been chosen because of its inherent advantages in prospecting for sulfide-bearing mineralizations. The area A-II has been recommended for detailed prospecting from results of surveys carried out in Phase II.

Three anomalous zones were delineated based on the distribution of high percent frequency effect (HPFE). These zones are located in the western, central and eastern portions of the area. The NNE-trending central anomalous zone, lays on the southern extension of the Sao Francisco gold deposit. The other two zones are oriented in a different direction, intersecting the trend of the central anomalous zone. Based on these geophysical results and previously mentioned geochemical results, trenching survey has been carried out aiming at attest the existence of underground mineralization.

Rocks within the Sao Francisco gold deposit contain relatively high contents of sulfides, which has been described as concentrated along a NNE-trending fault zone. This seems to be a highly valuable information to be taken into account in interpreting the obtained geophysical results. High PFE zones continuous at depth have been obtained on the central anomalous zone, indicating that it may contain sulfide in somewhat high concentration. Moreover, a NNE-trending fault zone has been inferred within this central anomalous zone. All these features are quite similar to those obtained on the Sao Francisco deposit, suggesting that a similar mineralization may exist below this central zone. On the other hand, the other two anomalous zones did not show the characteristics of the ore deposit mentioned above. Moreover, in these two anomalous zones, the relationship between the HPFE and mineralization in underground rocks has not been clarified by trenching survey. Further works seems therefore necessary for understanding the actual potential of these zones.

An integrated analysis of these geophysical results indicate that the IP method can be very useful in locating mineralized zones such as that being mined at the Sao Francisco mine.

(6) Trenching Survey

Trenching survey were carried out in areas A-I and A-II during the Phase II. The locations of trenches have been set based on previous surveys executed in Phases I, II and III.

Only very low gold contents (17 ppb) has been detected from samples collected in trenches dug within area A-I, although gold contents as high as 208ppb has been observed in soils overlying the trenches. Moreover, the sampling points where gold has been detected were only sparsely distributed in the trenches. It can be concluded that the gold anomalies observed in soils do not reflect the gold contents of the underlying rocks, and that the gold contents of rocks in the trenches are not due to any kind of mineralizing process.

On the other hand, Au contents ranging between 0.6 to 19 ppb has been continuously observed in a 60m interval within a trench located to the east of, and parallel to the ore body of the Sao Francisco deposit. Geochemical as well as geophysical anomalies have also been conspicuously observed nearby this trench, so that the detected gold seems to be related to a mineralizing process rather than to be an original feature of these rocks.

(7) Mineralization

Results of surveys carried out over these three years of this project have shown that, apart from the Sao Francisco deposit, only two small gold mineralizations exist within the project area. These two small gold mineralizations are located approximately 30 Km to the north and south of the Sao Francisco mine, and comprise mainly auriferous quartz veins, being both too small to be economically developed. Within area A, where some promising potential areas have been recommended for further prospecting, there may not exist any economical ore reserves except that being mined at the Sao Francisco mine. In areas B and C, though occurrences of gold have not been well understood, it seems doubtful that any economical ore reserves do exist, judging from results of stream sediment geochemical survey. Gold mineralization in this area seems to be better pictured as being of epithermal type, and to have formed through fracture-filling by ore solutions during the late- and post-metamorphic period. Gold is believed to have been leached from the country rocks such as Serido Formation and Caico Complex, as the ore fluids passed through. Although the present survey results did disclose some important features about the gold mineralization in the project area, it seem that some important, if not essential, information on the mineralization control(s) remain still not clearly understood. Maybe a more detailed study of the Sao Francisco deposit could provide helpful clues on gold mineralization in this area, which will be worthwhile not only to further prospecting of this area, but also for searching of gold in geologically similar regions.

(8)Survey Method

In the course of the project, geologic reconnaissance survey, mine survey, stream sediment geochemical survey, soil geochemical survey, IP survey and trench survey were consecutively carried out aiming at the selection of promising areas for gold mineralization. As a result, two small mineralization constituted of auriferous quartz veins were recognized to the south and north of the Sao Francisco mine. These two small mineralization were clearly defined only during geologic traversing, while that of being exploited at the Sao Francisco mine has been detected by all survey methods described above.

Results of reconnaissance surveys have allowed the selection of area A, located to the south of the Sao Francisco mine, and the area B-I, located in the southwestern portion of area B, as the targets of detailed prospecting. The efficiency of the applied survey methods during the project are summarized below.

Stream sediment geochemical survey proved to be effective for reconnaissance gold exploration since gold anomalies were clearly detected in the surroundings of the Sao Francisco deposit. However, this method failed to detect small mineralizations related to auriferous quartz veins, meaning that under the prevailing climate conditions, it is not always effective.

Soil geochemical survey in this area seems to still require some basic studies for its application. Soils are not well developed in the area and gold concentrations in soils are poorly correlated with gold contents in the subsurface rocks.

Biogeochemical survey yielded results that can be considered somewhat effective in a reconnaissance survey since gold contents of some plants' leaves did reflect the gold contents of soils.

IP survey proved to be effective in delineating the mineralization of the Sao Francisco ore deposit. IP can be therefore considered an useful tool in prospecting for similar sulfide-bearing gold mineralization, given that the mineralization has a reasonable size. When targeting at small ore deposits such as those related to small auriferous quartz veins, the interpretation of geophysical anomalies seems to be still dubious.

From the above mentioned, the project area can be defined as not having potentiality for new economic ore deposits, apart from the Sao Francisco deposit. Nevertheless, considering the whole set of information obtained over these three years of this project, the investigation of those auriferous quartz veins observed in area B by indirect but powerful methods such as the geophysical survey, from structural and morphological points of views seem to be worth of consideration, foreseeing the event of an exploration survey of an area with similar geologic conditions.

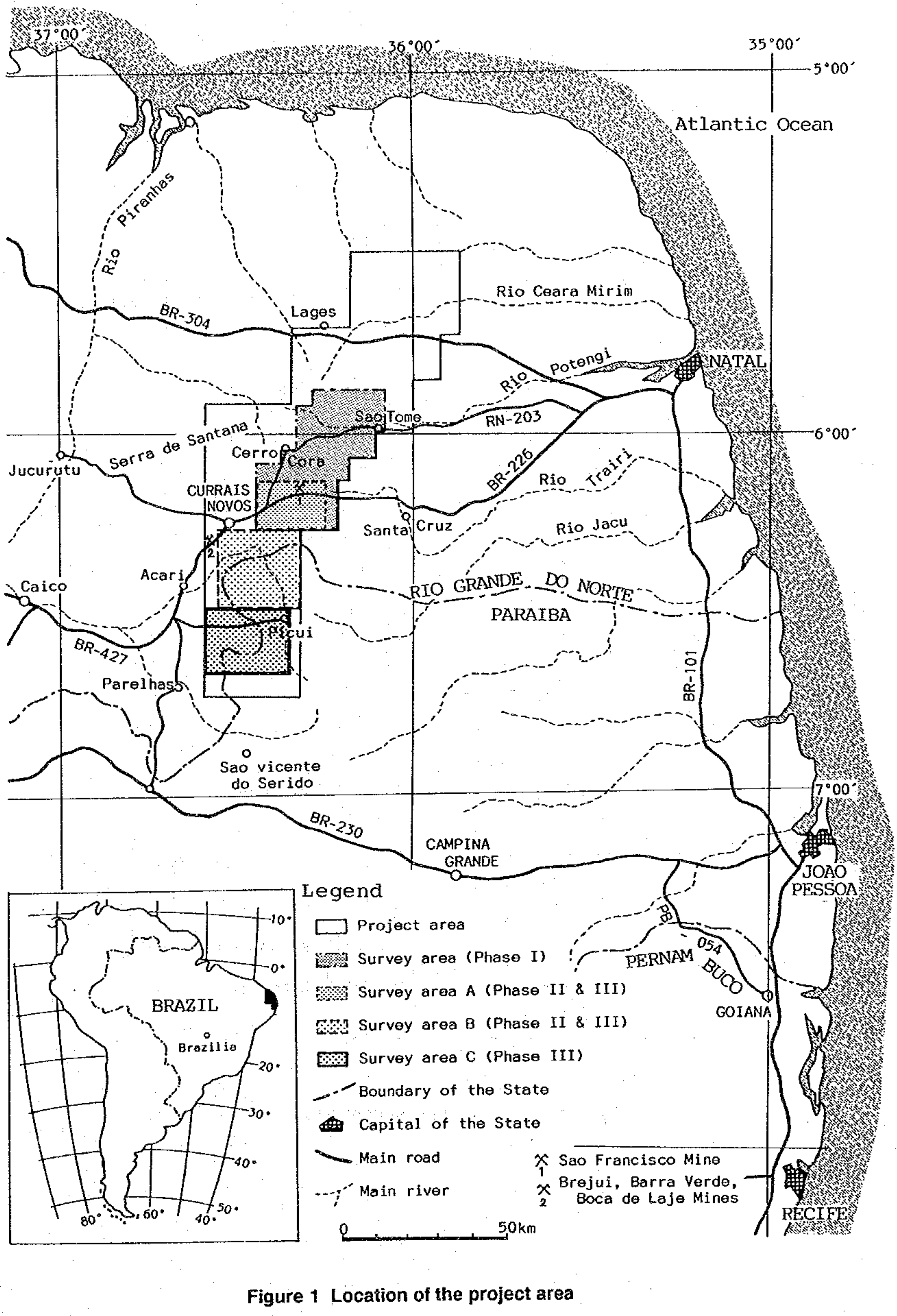

Figure 1 Location of the project area

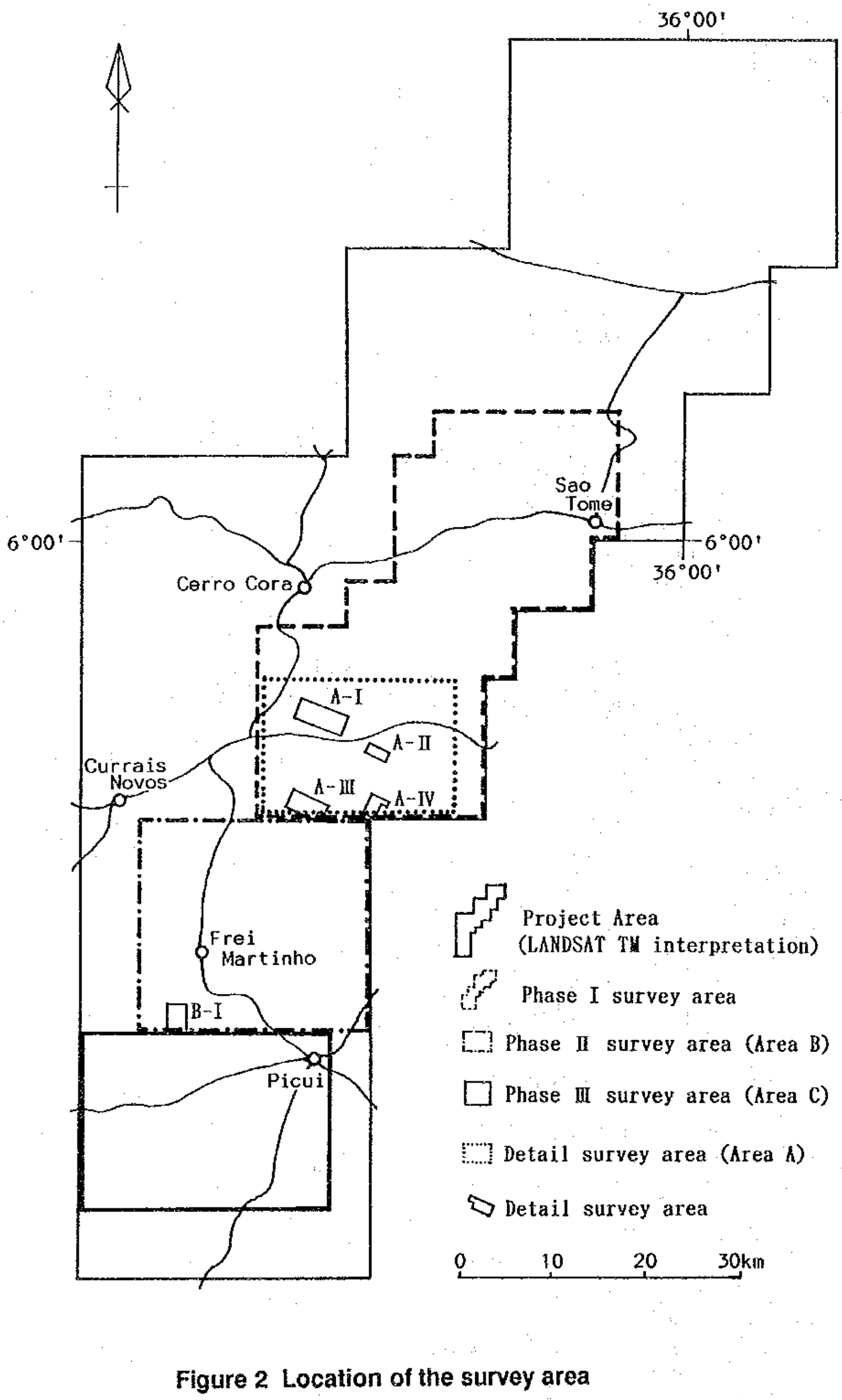

Figure 2 Location of the survey area

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PART I

GENERAL REMARKS

Chapter 1 Outline of the survey

1-1 SURVEY AREAS and OBJECTIVES

The area to have been surveyed is located in between 5° 30' and 6°45' south latitude, and in between 35°50' and 36° 35' west longitude. This area is situated in the south central part of the state of Rio Grande do Norte through the north central part of the state of Paraiba, covering 5,910km^2.

The objective of the survey was to define the potential areas for the existence of auriferous deposit, then to confirm the presence of the deposits by means of geological mapping, geochemical survey, geophysical survey and finally trenching.

1-2 SURVEY METHODS and COVERAGE

Variable survey methods was applied for this gold exploration project. Survey methods and their amounts are listed in Figure I-1-1 and Table I-1-1.

1-3 SURVEY and PERSONNEL

The duration and the survey members are listed in Table I-1-2 for each survey method.

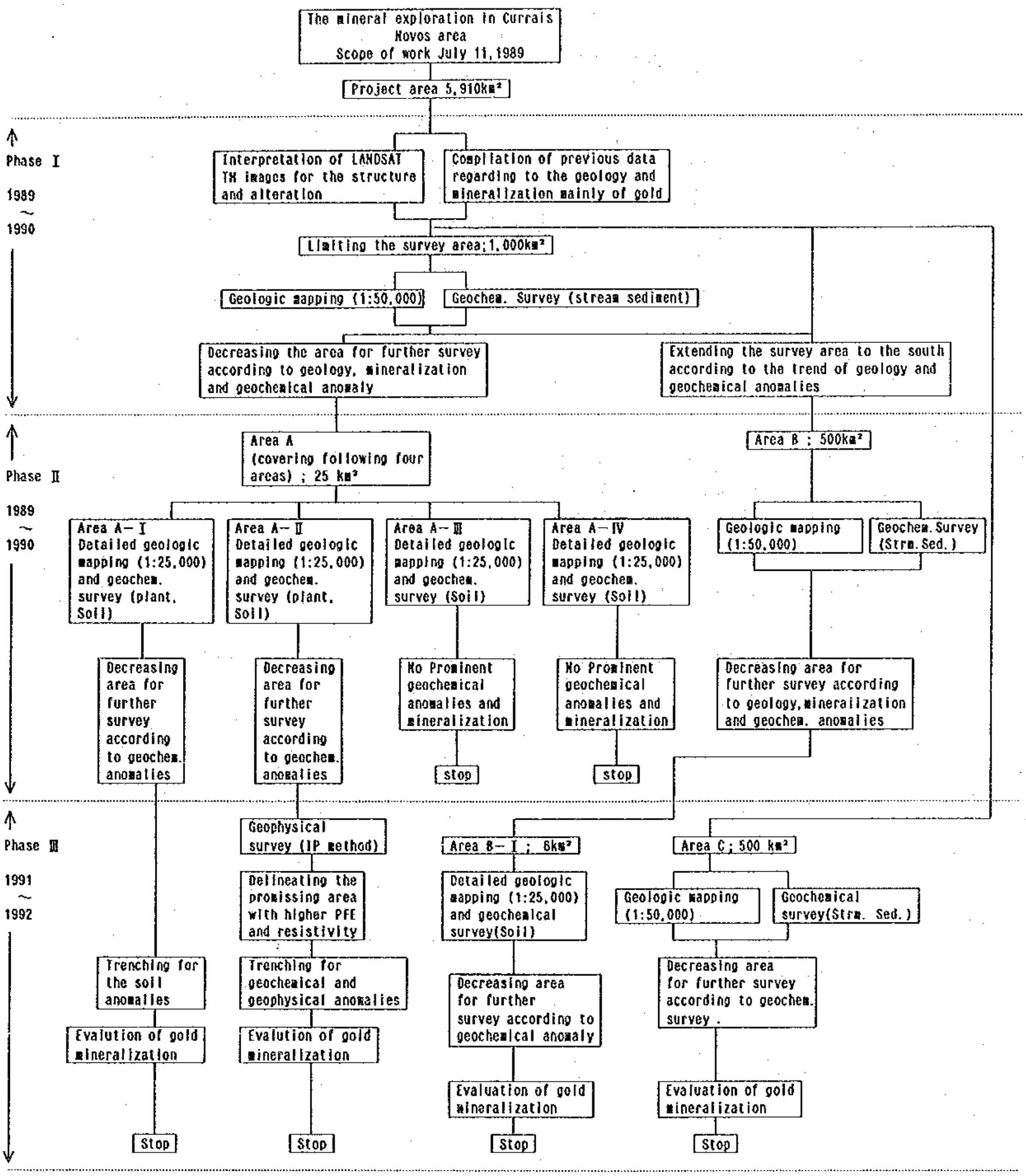


Figure I-1-1 Flow of the project

Table I-1-1 Amounts of surveys

Phase	Compil. previous data	Interpret. LANDSAT TM images	Geologic mapping (1:50,000)		Geochemical survey		Geophysical survey		Trenching	
Phase I	5,910 km^2	6,910 km^2 14 TM images scale 1:200,000 1:100,000	Area	1,000 km^2	Area	1,000 km^2				
			Geologic traversing	900 km (using map of 1:25,000)	Sample and chemical analyses	Stream sediment (Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) : 1,500 Pan concentrate (Au, Ag, Mo, W, Sn, Nb, Ta) : 150				
			Chemical analyses	Whole rock and trace element analyses (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, LOI, Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) : 30						
			Lab. tests	Thin section observation of rocks : 30 Polished section observation of ores : 7 Xray powder diffraction : 20						
Phase II			Area	Area A ; 25 km^2 Area B ; 500 km^2	Area	Area A ; 25 km^2 (soil) Area B ; 500 km^2 (str. sed)				
			Geologic traversing	Area B ; 438 km (using map of 1:25,000)	Sample and chemical analyses	Stream sediment (Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) : 811 Pan concentrate (Au, Ag, Mo, W, Sn, Nb, Ta) : 81 Soil (Au, As, Sb) : 2,400 Plant leaves : Jurema (Au, As, Sb, Fe, Al) : 173 Catingueira (Au, As, Sb, Fe, Al) : 172 Malva (Au, As, Sb, Fe, Al) : 165				
			Chemical analyses	Whole rock and trace element analyses (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, LOI, Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) : 30 Ores (Au, Ag, As, Cu) : 12						
			Lab. tests	Thin section observation of rocks : 30 Xray powder diffraction : 10 Fruid inclusion study : 3						
Phase III			Area	Area B-1 ; 25 km^2 Area C ; 500 km^2	Area	Area B-1 ; 25 km^2 (soil) Area C ; 500 km^2 (str. sed)	Area	Area A-II; 2km^2	Area and trenches	Area A-I : 6 trenches total : 209 m Area A-II : 4 trenches total 200m
							Method	IP method		
			Geologic traversing	Area C ; 498 km (using map of 1:25,000)	Sample and chemical analyses	Stream sediment (Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) : 807 Pan concentrate (Au, Ag, Mo, W, Sn, Nb, Ta) : 83 Soil (Au, As, Sb) : 660	Suvey lines	5 lines total 10 km		
			Chemical analyses	Whole rock and trace element analyses (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, LOI, Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As, Sb) : 30 Ores (Au, Ag,) : 4			Measuremede	556 times		
							Lab. tests	Resistivity measurenents : 20 Polarization measurements : 20	Chemical analyses	Chonnel rock sample (Au, Ag, W) : 501
			Lab. tests	Thin section observation of rocks : 30 Xray powder diffraction : 1			Chemical analysis	Rock (S) : 20	Lab. tests	Xray powder diffraction : 9

Table I-1-2 Period and member of surveys

Phase	Works	Period	Members	
			Japanese side	Brazilian side
Phase I	Project planning	July 7 ~ July 22, 1989	Masahiro Kawada ECB, MFA Hajime Ikeda JICA Katsutoki Matsumoto MMAJ Hideaki Mukai MMAJ Tetsuo Suzuki MMAJ	Elmo Serejo Farias DNPM Manoel da Redenção e Silva DNPM Carlos Oiti Berbert DNPM Benedicto Waldir Ramos DNPM Maria Helena Taira Oguino DNPM 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 DNPM Marinho Arberte DNPM
	Geological and geochemical survey	September 22 ~ December 1, 1989	Kazuo Kawakami BEC Masakatsu Onodera BEC Norio Ikeda BEC Motomu Goto BEC Mitsutaka Bamba BEC Yoshiaki Shibata BEC (LANDSAT image interpretation)	Alarico Antonio Frota Mont'Alverne DNPM Julio de Resende Nesi DNPM Jose Robinson Alcoforado Dantas DNPM Roberto Batista Santos DNPM Mauro Caldas Mendes DNPM Cicero Alves Ferreira CPRM Antonio Jose Barbosa CPRM Jorge Luiz da Costa DNPM Severino do Ramos Souza DNPM
	Report Preparation	December 2, 1989 ~ February 20, 1990		
Phase II	Geological and geochemical survey	August 3 ~ November 7, 1990	Kenzo Masuta MMAJ Hideaki Mukai MMAJ Kazuo Kawakami BEC Norio Ikeda BEC Masakatsu Onodera BEC Mitsutaka Bamba BEC	Alarico Antonio Frota Mont'Alverne DNPM Jose Robinson Alcoforado Dantas DNPM Roberto Batista Santos DNPM Mauro Caldas Mendes DNPM Antonio Honorio de Melo Junior DNPM Cicero Alves Ferreira CPRM Jorge Luiz da Costa DNPM
	Report Preparation	November 8, 1990 ~ February 20, 1991		
Phase III	Geological and geochemical survey, Trenching	July 6, ~ September 25, 1991	Kazuo Kawakami BEC Masakatsu Onodera BEC Motomu Goto BEC	Alarico Antonio Frota Mont'Alverne DNPM Jose Robinson Alcoforado Dantas DNPM Mauro Caldas Mendes DNPM Antonio Honorio de Melo Junior DNPM Cicero Alves Ferreira CPRM Jorge Luiz da Costa DNPM
	Geophysical survey	July 8, ~ August 28, 1991	Tomio Tanaka BEC Kazuto Matsukubo BEC	Luis Barbosa Barros DNPM Roberto Batista Santos DNPM
	Report Preparation	August 29, ~ January 31, 1992		

ECB : Economic Cooperation Bureau
MFA : Ministry of Foreign Affairs
JICA : Japan International Cooperation Agency
MMAJ : Metal Mining Agency of Japan
DNPM : Departamento Nacional da Produção Mineral
CPRM : Companhia de Pesquisa de Recursos Minerais
BEC : Bishimetal Exploration Co., Ltd.

Chapter 2 Previous Works

2-1 STRATIGRAPHY and STRUCTURE

The survey area 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). Brito Neves (1983) have subdivided the Boborema Province into five geologic domains, based on the differences of their deformation and metamorphic grades (Figure I-2-1). According to this division, the survey area is situated entirely inside the Serido region of the Central Domain.

According to Jardim de Sa & Salim (1980), the Serido Region is stratigraphically principally composed of Archean Caico Complex and Proterozoic Serido Group, which comprises the Jucururu, Equador and Serido Formations in ascending order. 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 represents flysch-type deposits.

In addition to the Precambrian units, rocks of Cretaceous Jandaira and Acu Formations, the Tertiary Serra dos Martins Formation and Guarternary sediments are also occur in the area. Moreover, plutonic and hypabyssal rocks such as granite, granodiorite and hornblendite are also distributed in the area in variable scales. In this survey, the stratigraphy proposed by Jardim de Sa was followed.

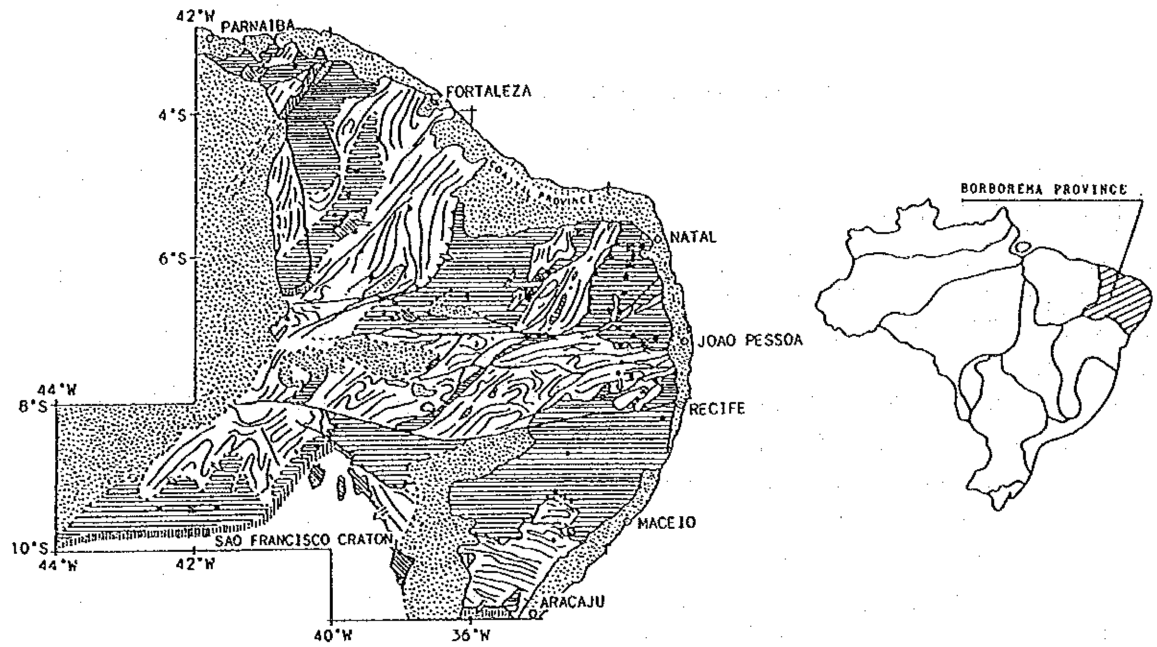
The Serido region is believed to have been affected by three different tectonothermal events that can be correlated to three main events of continental amplitude occurred in the Brazilian territory. These events are named Jequie (2,900 to 2,600 Ma), Transamazonian (2,100 to 1,800 Ma) and Brazilian (700 to 400 Ma). Recently, Jardim de Sa (1984) compiled and classified five stages of tectonic movements in the period between the Transamazonian and Brazilian events from their tectono-structural features.

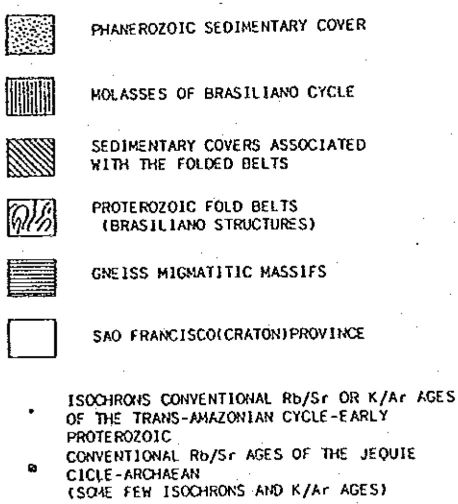
2-2 MINERALIZATION

The exploration of ore 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 the states of Rio Grande do Norte and Paraiba with the " Projeto Tungstenio / Molibdenio " by DNPM/CPRM, and the results were reported in 1973. In 1980, the results of the " Projeto Scheelita do Serido " (Lima, E. de A. M. et al,1980) were also reported.

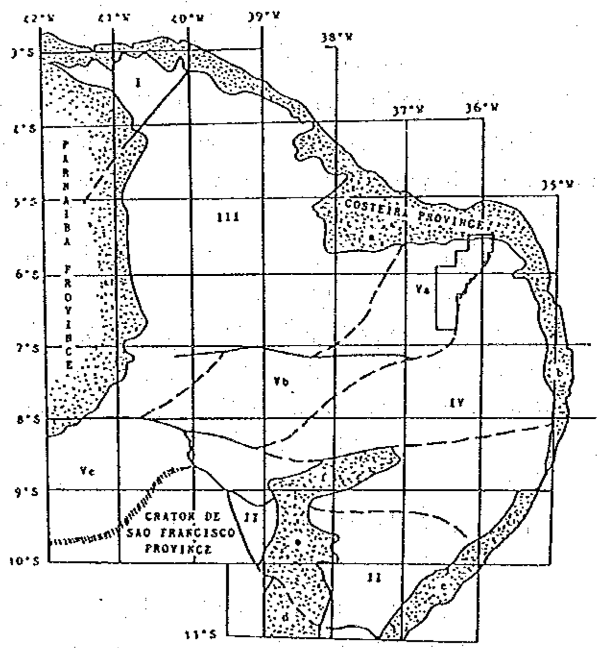
These exploration played an important role in understanding the stratigraphy of the Serido region and in geologic mappings. After that, concerning to tungsten mineralization, there have been many works detailing specific areas. One example is that of Maranhao, R. et al (1986), who explained in detail the geology of Brejui, Barra Verde, Boca de Lage and Zangarelhas mines, which are the most representative deposits in the Serido region.

Gold in the region was discovered in the beginning of the 1940's. Gold has been mined in





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



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

(b)Geologic domains after Brito Neves,1983

Figure I-2-1 Principal geologic elements (a) and geologic domains (b) in the Borborema Province

placer deposit, weathered zone and in quartz veins until 1976. Then gold mining gradually slowed down as the grade became lower, and finally stopped. From the end of the 1970's, CPRM started a series of geological surveys in this area, whose results have been published as maps on the scales of 1:1,000,000 and 1:100,000 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 Metalogeneticos dos Recursos Auriferos, 1:1,000,000 ".

Almost all gold deposits in the state of Rio Grande do Norte including the project area are described in the report of this survey. The summary of Sao Francisco deposit, which are located in the center of the project area, is briefly given in this. According to the above references, gold of this area principally occurs in quartz veins and the location of those quartz veins are controlled by structure or metamorphism or stratigraphic position. The strutural position was said to be in the Jucurutu Formation or Serido Formation. Recently Barbosa (1989) reported that the location of gold deposit was controled by the major tectonic lines (Figure I-2-2).

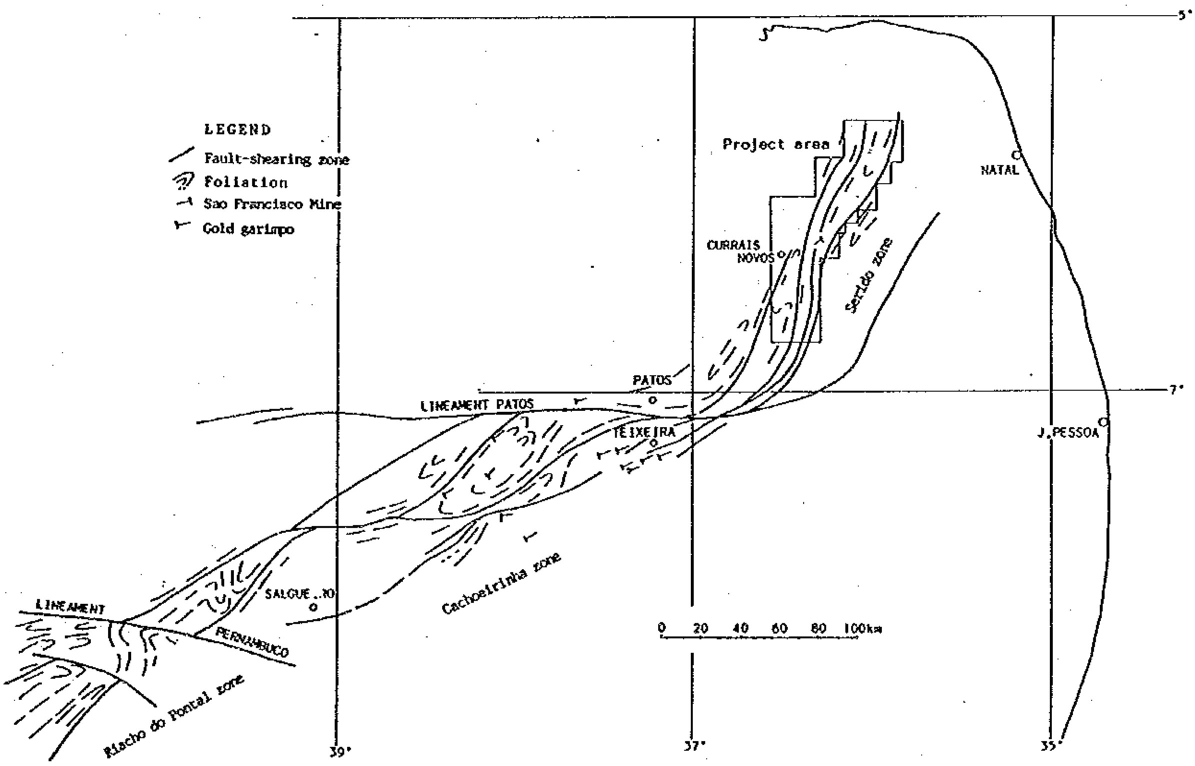


Figure I-2-2 Location of gold mineralization and structural lineaments; after Barbosa (1989)

Chapter 3 General geology

3-1 STRATIGRAPHY

The project area is situated in the Serido region of the Central Domain in the Borborema Province. The stratigraphy in the survey area comprises the Archean Caico Complex, Proterozoic Jucurutu, Equador and Serido Formations belonging to the Serido Group, Cretaceous Acu Formation, Tertiary Serra dos Martins Formation and Quarternary sediments in ascending order (Figure I-3-1).

The Caico Complex, principally composed of gneiss-migmatite-granite tripartite, is distributed mainly in the northwestern, eastern and central parts of the survey area. The Serido Formation, comprising metasediments, occupies great part of in the central part of the survey area. The Jucurutu Formation composed of gneisses is at the western boundary between the Serido Formation and the Caico Complex. The Equador Formation, which mainly includes quartzite, crops out in the west side of the area where Serido Formation occupies. Cretaceous Acu Formation distributed in the northern most part of the survey area. Tertiary Serra dos Martins Formation lies on the Serra do Santana to the northwest of the survey area and is sparsely distributed with a very small area in the southern half of the survey area.

The survey area has been affected by the Transamazonian and Brazilian orogenic cycles. These two orogenic cycles comprise five structural and metamorphic events, which have been distinguished mainly on the types of metamorphism.

It is noteworthy that there are a great number of faults. The Picui Fault is the largest, running between the Caico Complex and the Serido Formation in the east end of the survey area. It divides furthermore the Central Domain from the Centro-oriental Domain at the larger scale. There exist many faults parallel to the Picui Fault in the entire survey area. A number of new faults crossing by a high angle to the former faults are also traceable in the survey area.

3-2 MINERALIZATION

Mineral deposits occurring in the project area are those of tungsten related to scarn, niobium-tantalum with pegmatite and also those of vein type gold (Figure I-3-1, Table I-3-1).

The scarn type tungsten deposits were formed by metasomatism of calcareous rocks of the Jucurutu and the Serido Formation. Major tungsten deposits, connecting Brejui, Barra Verde, Boca de Lage and Zangerelhas mines, occurs in the Jucurutu Formation to the south of Currais Novos. Some minor tungsten deposits in the Jucurutu Formation have also been found to the northwest of Sao Tome. Tungsten deposits in the Serido Formation are all small. In those tungsten deposits, a small amount of copper, molybdenum and gold are included.

Auriferous quartz veins are represented by the sao Francisco deposit in the central part of the survey area. It occurs in the Serido Formation, with a lateral extension of few kilometers. Two other

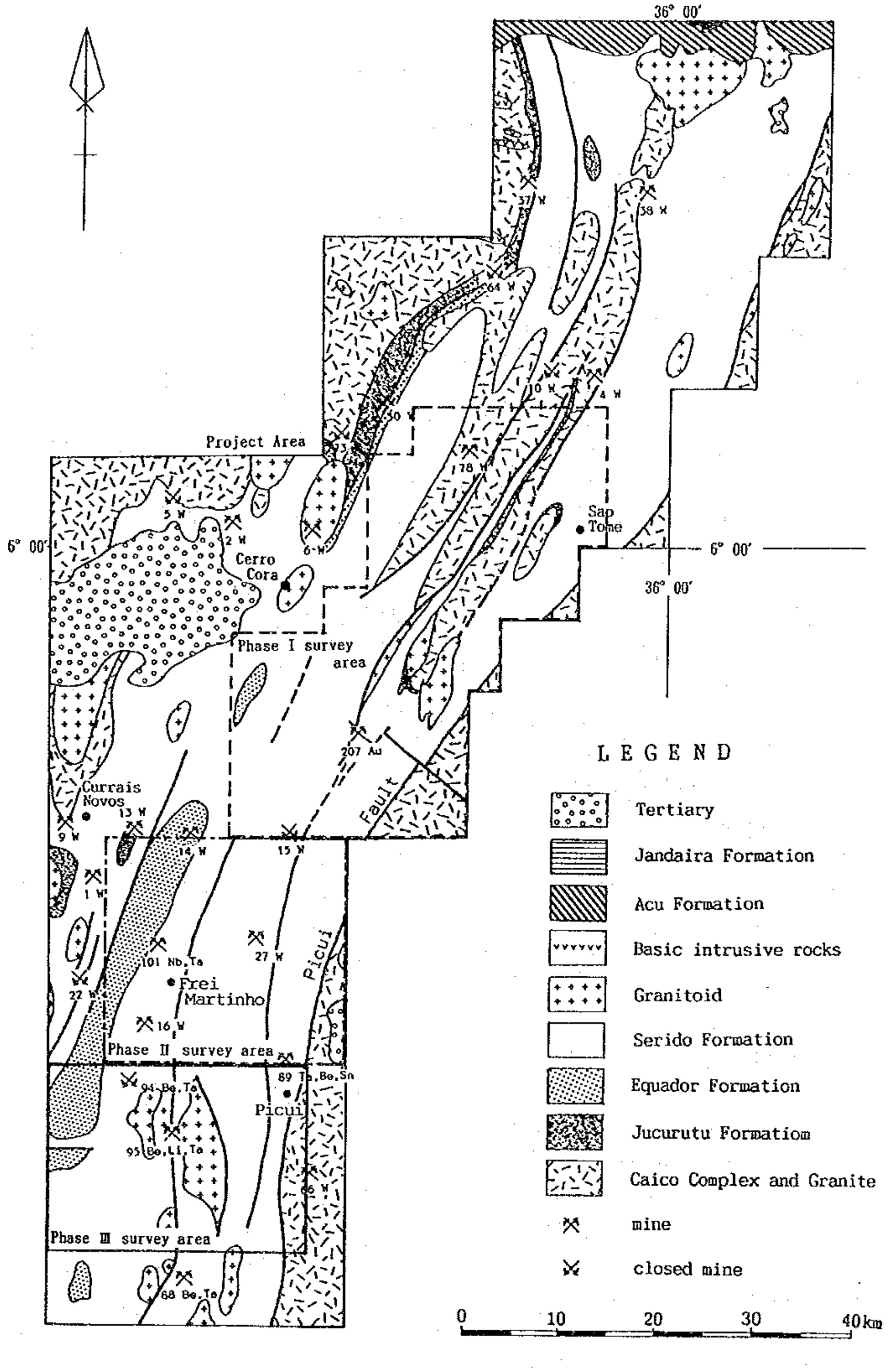


Figure I-3-1 General geology and known mineral deposits in the project area; revised from Carta Geologia do Brasil, Folha Jaguaribe (SB-24)/Folha Fortaleza (SA-24), DNPM, 1974.

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.

minor auriferous quartz veins are also found in the survey area, one of which is in the Caico Complex and the other occurs in the Serido Formation. Any of these auriferous quartz veins are controlled by the structures such as faults and fractures in terms of their occurrence.

3-3 MINING ACTIVITIES

In 1942, scheelite was discovered in this area for the first time, and soon mining works were started. The Brejui - Barra Verde deposit that is located in the west central 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. By 1955 the mining works became more systematic. From 1942 to 1982, 95% of the scheelite was produced in this region. The mines activated in recent years are those of Brejui, Barra Verde, Boca de Lage and Zangarelhas (Table I-3-2).

Gold in this area was discovered in present Sao Francisco area in 1942. From 1942 to 1952 it was mined as a placer deposit. In 1976, not only the placer but also weathered zone and quartz veins were being mined. However, with the drops 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 systematic exploration survey in the same area. In November, 1987, another mining company (Mineracao Xapetuba Ltda.) restarted the production by strip mining. According to Ferran,D.A.(1988), the reserves of the Sao Francisco deposit amounts to more than 587,000 tons, containing about 1,750kg of gold (Table I-3-2).

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

Metal	mine	Production		Ore reserves	grade
		Concentrate (73% WO3)	ore		
W	Brejui	19,633.3 t	total 5.5×106 t	total 10.8×106 t (original)	~0.5% (WO3)
	Barra Verde	14,297.2 t			
	Boca de Lage	2,613.0 t			
	Zangarelhas	--		5.3×106 t (remaining)	0.2 ~0.47% (WO3)
	total	36,543.5 t			
Au	S.Francisco	--	--	587,646 t	av. 2.5~4.3(g/t)

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

Chapter 4 Physiography

4-1 LOCATION and ACESS

The project area is located in the central southern part of the state of Rio Grande do Norte and in the central northern part of the state of Paraiba. This area extends from 5°30' to 6°45' south latitude, and from 35°50' to 36°35' west longitude. The area selected to be surveyed in the three phases of the project is as shown in Figure 1.

The city of Currais Novos, with population of about 25,000, is situated in the middle of western border of the project area. The city can be accessed by air and by roads. There are two regular flight lines, one departing from Recife (capital of the state of Pernambuco) and the other from Natal (capital of the state of Rio Grande do Norte). Currais Novos is also linked to these two capitals by paved roads. Departing from Recife, it is a journey of 420km through the routs BR-101, PB-054 and BR-230, via Campina Grande in the state of Paraiba. Departing from Natal, the journey is of only 190km following BR-226.

4-2 TOPOGRAPHY and DRAINAGE

The project area can be divided into thee areas in terms of large topographic features. An undulating topography with rounded mountains ranging in altitude between 300m and 600m above sea level occupies large portion of the area. Flat plains dominate in the northern most part, while the central western part of the area is occupied by mountains of the Serra da Santana with altitudes up to 700m above sea level. The topographic features o f the survey area are further classified due to a scale and relations to geology.

The northern most part of the area surveyed in the first phase exhibits an imbricated topography, resulting from the parallel alignment of highs and lows in the NNE-SSW direction with altitude between 300m and 600m. This topography is very consistent with the distribution of geologic units. The highs are related to exposures of the Caico Complex, while the micaschists of the Serido Formation constitute the lows.

The central part of the survey area comprises gently undulating mountains with elevations ranging from 340m to 500m above sea level. The distribution of the topographic units is identical to that of mica schists of the Serido Formation, which is weaker against weathering and erosion.

The east to southeast portion of the survey area forms gentle plains 500m to 550m high above sea level. The plains are principally occupied by granites and gneisses of the Caico Complex.

In the west to southern part and in the central east part of the survey area, peneplains, with altitude between 600m to 700m, can be distinguished as mesas. The Serra dos Martins Formation lies on the mesas.

Prominent mountain ranges, trending NNE with the width of 3 to 5km and with steep cliffs 400m to 650m high above sea level, rise and extend from the southwest of Serro Cora to the southwestern corner of the survey area. This topography corresponds to the Equador Formation.

The drainages in the northern part of the survey area reflect the topography, comprising NNE trending principal drainages and minor drainages with other directions. These drainages come together into Rio Potenji, flowing toward east via Sao Tome.

The drainages in the central portion of the survey area are basically composed of those trending NNE and WNW. They are tributaries of the Rio Currais Novos, flowing westward, and of Rio Picui and Rio Murungu, flowing northward into the Rio Currais Novos. All of the drainages are finally connected to the Rio Piranhas, being to the west of the survey area and flows into the Atlantic Ocean.

The drainages in the eastern side of the survey area has a pattern of sub-dendritic, which reflect the geology of granite of the Caico Complex. These are the tributaries of the Rio Sao Joao d'Agua, flowing toward east.

4-3 CLIMATE and VEGETATION

The climate in the project area is semi-arid 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 the dry season. It rains intermittently during the rainy season and only scarcely in the dry season.

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

Referring to the vegetation, this area is called Caatinga, specializing the dry region of the northeastern Brazil. Bushes two to three meters tall are typical and densely present in the northern half of the survey area. Some trees up to up to 10m tall grow sparsely along drainages. Dominant vegetation types are Jurema, Catingueira, Malva, Pereiro, Marmereiro, Xique xique and so on.

Chapter 5 Results

5-1 PHASE I RESULTS

The survey area in phase I is shown in Figure 2. In the area geologic reconnaissance survey and stream sediment geochemical survey were executed.

The survey area is underlain by Archean Caico Complex, Proterozoic Jucurutu, Equador and Serido Formations, and by Tertiary and Quarternary sediments. The Caico Complex, Jucurutu Formation and Equador Formation are lithologically represented by granite-gneiss, gneiss and quartzite respectively. The Serido Formation comprises mainly of biotite gneiss. Every formation is extended in the same direction of NNE-SSW (Figure I-3-1, Figure II-2-2). As the result of the survey, Jucurutu Formation in the north of the survey area was partly corrected to Caico omplex.

Faults trending north northeast to north and west northwest to east northeast dominate in the survey area. Faults trending north northeast to north are principal in the regional area including the survey area, passing through the entire survey area from the north to the south. The fault in the east side of the survey area, called Picui Fault, is an important one in terms of the regional tectonic division of the northeastern Brazil. Faults trending west northwest to east northeast are also distributed in the entire survey area. They are younger and smaller than the north northeast to north trending faults. Folded zone about 3km wide also passes through in the central part of the entire survey area from the north to the south in parallel with the principal faults (Figure II-2-2).

Auriferous mineralization in the survey area are restricted to the Sao Francisco deposit and a small deposit about 7km west of Sao Tome. Gold is in quartz veins with sulfide minerals such as pyrite and chalcopyrite (Figure II-2-2). The Sao Francisco quartz veins were formed in the structural zone trending north northeast, which crosses the other faults trending west northwest. The quartz vein west of Sao Tome occurs also in the structural zone, where faults with supposed mineralization slightly bend.

Gold anomalies, 1ppb - 450ppb, were detected in the west to southwest and in the southeast of the Sao Francisco mine by stream sediment geochemical survey (Figure II-2-3). Among those anomalies, those in the west to southwest of the Sao Francisco mine, which are also located at the southern end of the phase I survey area, are interpreted to be potential. They were supposed to extend to further south.

From the above,

1) an area to the west to southwest of the Sao Francisco mine, where geochemical gold anomalies were detected, was recommended for further detail survey with geophysical survey and trenching, and

2) a new area to the south of the phase I survey area was recommended for geological and geochemical survey.

5-2 PHASE II RESULTS

In the phase II survey, an area including the area 1), mentioned above, is called area A and an area 2), also mentioned above, was called area B.

(1) Area A

Four areas, A-I, A-II, A-III and A-IV shown in Figure 2, were outlined for soil geochemical and biogeochemical surveys. Areas A-I and A-II were for both of the surveys and areas A-III and A-IV were only for soil geochemical survey. Three elements of Au, As and Sb were utilized as tracer elements. The contents of those three elements in either soil or plant are not correlated with each other.

According to gold contents of soil, 0.5 to 208ppb, and plant leaves, 0.9ppb to 907ppb, the southeast portion of area A-I and around the central portion of area A-II were recommended for further survey. Areas A-III and A-IV were dropped because of lack of gold anomalies.

(2) Area B

Stratigraphy and geologic structures of the area B, shown in Figure 2, are basically same as those of the phase I survey area.

An auriferous quartz vein was excavated at a small scale in the southeastern corner of the area B. The vein is 0.3 to 2m wide, 200m long. This vein is considered to be epithermal from the evidences of the occurrence and ore mineral composition and so on. The occurrence of the vein is not controlled by any faults.

Stream sediment geochemical survey with 13 tracer elements revealed that gold itself was the effective element for the gold exploration because those elements were not correlated with each other. Gold anomalous areas were sparsely distributed and moreover, do not include a lot of higher gold values in the area. The anomalous gold values are 0.5ppb to 160ppb. Higher anomalous points somewhat concentrate along Rio Pimenta in the east of the area B, without any relations to lithology and/or structure.

From the above mentioned, the followings are recommended for further survey,

1) Southeastern part of the area A-I, and areas to the south of area A-II and to the north of the Sao Francisco mine with the methods of soil- and bio-geochemical survey. Geophysical survey was also thought to be effective for the area A-II.

2) Area with auriferous quartz vein at the southwestern corner of the area B with the methods of detail geological traversing and geophysical survey.

5-3 PHASE III RESULTS

Detailed surveys were carried out in the area A-I, A -II and B-I of the area B, according to the results and recommendations of the phase II surveys. New area called C, situated in the southern neighbor of the area B as shown in Figure 2, was also a survey area.

(1) area A

Trenching survey was carried out at the location where gold anomalies were detected by the soil geochemical survey in area A-I. No significant gold, 0.5ppb to 17ppb, were detected and the points where gold was detected were sparcely distributed in the trenches. Therefore, no further survey were recommended in the area A-I.

In area A-II, gold, supposed to be derived from mineralization, was detected at the location about 200m east of the Sao Francisco ore trend, where geophysical anomaly overlaps geochemical anomalies. The points, where 0.6 - 19ppb of gold was detected, were stretched in a interval of 60m. According to the geophysical survey, the possible mineralization further extends to the deep.

The IP survey was effective to delineate the Sao Francisco ore deposit. Therefore, as far as an auriferous quartz vein has a reasonable size, the IP method should be effective. While, the soil geochemical survey was demonstrated not to be effective in this area as far as the survey method was followed in the same manner.

(2) area B

Soil geochemical survey was carried out in the area B-I (Figure 2), using elements of Au, As and Sb as tracer elements. These three elements were not correlated with each other.

Gold anomalous points are sparsely distributed in the area B-I. Near the anomalous points detected at the northeastern corner, there might occur auriferous quartz veins. Because two suilfide quartz veins trending NNE were found both on the west and east slopes of the Serra da Umburana with the distances of about 300m and one of them on the western slope containing gold. Furthermore, the gold anomalous points are in the extension of the sulfide quartz vein.

(3) area C

Stratigraphy, lithologies and geologic structures are basically similar to the areas surveyed in phases I and II. However, the Jucurutu Formation does not crop out, in the area C. And pegmatite characteristically occupies a large portion in the center of the area.

Concerning to the mineralization, Niobium-Tantalum mineralization related to pegmatite dikes and Tungsten mineralization occur in this area. No other identical mineralization was found.

Stream sediment geochemical survey revealed that gold was not correlated with any other elements among 13 elements applied as tracer elements, and gold anomalies are very few and sparsely distributed. However, some gold anomalous points are somewhat concentrated between Riacho Ermo and Riacho Casado in northwest part of the area C.

If some more surveys were executed, following areas and methods are recommended,

1) The northern extension of the San Francisco deposit should be surveyed by the IP method, because the state of the mineralization is not well understood. The survey result is utilized for the future exploration for the same type of gold mineralization.

2) The area with sulfide quartz vein in the area B-I, by the methods of detailed geologic and geophysical survey, to understand the gold mineralization in the area.

Chapter 6 Conclusions and recommendations

6-1 CONCLUSIONS

Whole Project Area

Results of the surveys carried out over the last three years have shown that, apart from some evidences for existence of a satellite mineralization of the Sao Francisco deposit, and a small occurrence of auriferous quartz veins observed in area B, no other evidence of new mineralizations are present within the survey area. It seems, therefore, that there exist only few possibilities to a new, economic gold deposit be found within the limits of the project area, except for some potential left in the neighborhoods of the auriferous veins above mentioned.

Area A

The geophysical (IP) survey carried out around the Sao Francisco deposit proved to be able to clearly delineate the ore body, providing important insights as for interpretation of similar data obtained in other areas of this project. Results of geophysical surveys indicated the existence of a satellite mineralization in the surroundings of the Sao Francisco deposit, suggesting that there remains some possibilities of lateral expansions of the presently known reserves. Moreover, geophysical results indicated that the mineralization at the Sao Francisco deposit is continuous even to levels deeper than presently prospected.

Area B

Sulfide-bearing quartz veins, some of them auriferous, were observed in the areas east and west of the Umburana Range. These veins have not been detailed explored, and there are some evidences suggesting the existence of hidden veins in the neighboring. A detailed investigation of this area could therefore lead important findings and obtention of valuable information concerning to the mineralization processes that have occurred in the region. It should be emphasized, however, that the sizes of the observed veins are rather small, indicating that even if they are associted to a gold mineralization, it will be hardly economic.

Exploration Methods

Geologic traversing and stream sediment geochemical survey proved themselves to be very effective tools for prospecting and delineating gold anomalous zones in the project area.

On the other hand, soil geochemical survey yielded results that could not be confirmed by underground prospecting methods like trenching. This absent of correlation can be related to the poor development of soils in the area, and to the pluvial regime, which tends to wash over the soils during the rainy season by torrential rains. Soil geochemical survey seems, therefore, to be an inadequate geochemical prospecting method of areas with similar hydrologic and climatic conditions.

Biogeochemical prospecting yielde some interesting results, reflecting quite well the subsurface anomalies.

Geophysical survey by the IP method proved itself to be effective in delineating large mineralization as that of the Sao Francisco deposit, but yielded dubious results in detecting small vein-type occurrences.

6-2 RECOMMENDATIONS

(1) It is recommended that a known mineralization such as the Sao Francisco deposit and auriferous quartz veins occurrences like that to the south ~ southwest of Frei Martinho are investigated from a genetic point of view. The results will, without doubts, be helpful for selecting more effective methods and for providing valuable interpretation clues to explore for gold in similar areas.

(2) The area around the Umburana range is recommend to be investigated by geophysical (IP) survey and detailed geological mapping, in order to understand the actual distribution of the occurrence as well as the mineralizing process that lead to the formation of sulfide-bearing (sometimes auriferous) quartz veins observed in the foothills of this mountain range.

(3) Based on results accumulated over the three years of this project, the following steps are recommended for the exploration of epithermal gold mineralization similar to the Sao Francisco deposit. At first, regional geological and stream sediment geochemical surveys, followed by detailed geological mapping aimed at localization of mineralizing evidences and by geophysical (IP) survey to delineate the underground mineralization. The mineralization should be finally confirmed by trenching and/or drilling surveys.

PART II

DETAILED DESCRIPTION

Chapter 1 LANDSAT Images Interpretation

1-1 APPLIED DATA and INTERPRETATION PROCEDURES

1-1-1 Applied Data

Data utilized for the interpretation are LANDSAT TM (Thematic Mapper) taken from the earth resources satellite, LANDSAT 5, launched by NASA in 1984 (Table II-1-1).

1-1-2 Interpretation Procedures

(1) Image generation

Thee type of images, false color images, principal component analysis images and ratio images, were generated from Compute Compatible Tapes (Table II-1-2, Figure II-1-1, Figure II-1-2, Figure II-1-3). CCT was purchased from the Institute Nacional de Pesquisa Espaco in Brazil.

The bands 1, 4, 5 of TM data were selected to generate the false color images. Bands 1, 4, 5, which are assigned to blue, green and red respectively, were composed in color after the contrast stretch and edge enhancement.

Principal component analysis images were generated in order to emphasize the color of rocks and soil. The data of the images were calculated with six bands except band 6, whose resolution is different from the others. The first, second and third principal components were combined and composed in color for the optimum geologic interpretation.

Ratio images were generated with the same purpose as that of principal component images. Data to generate the images were the ratio of the bands, Band5/band7, band4/band3 and band3/band2.

(2) Geologic Interpretation

Classification of the geologic units and interpretation of the structures were executed based on the color and geographical features such as drainage patterns and erosion susceptibility on the images.

1-2 INTERPRETATION

1-2-1 Lithologic Classification

Sixteen geologic units were discriminated on the images, being correlated to known geologic formations and lithologic units (Figure II-1-4).

(1) pC1a

This unit occupies the eastern margin of the project area, corresponding to the lithologies dominated by the gneiss of the Caico Complex. Dense trellis drainage pattern and stratified structure parallel to faults are characteristic in the area.

(2) pC1b

This unit is distributed in the northwest, corresponding to the lithologies represented by the gneiss of the Caico Complex. Stratified structure was not developed.

(3) pC1c

This unit is in the north of the project area, also correlated to the lithologies of the gneiss of the Caico Complex. High resistance against erosion and lower density of drainages are distinguished.

(4) pCgl

This unit occurs in the southeast of Picui, correlated to the granite of the Caico Complex. White portions are widely distributed in this unit on the false color images. Wide spaced dendritic drainage pattern and flat plain are also characteristic.

(5) pC2

This unit occurs intermittently on the west side of the project area, corresponding to the quartzite of the Equador formation. High resistance is kept against erosion and stratified structure is prominent.

(6) pC3a

This unit occupies the central and southern portion of the project area, being correlated to the Serido Formation. Drainages are densely distributed with fine dendritic and trellis patterns. Stratified structures are easily discriminated.

(7) pC3b

This unit can be seen in the north of the project area, corresponding to the Serido Formation. Flat plain and sparse dendritic drainages are characteristic.

(8) pC3c

This unit occupies a small area to the north of the Sao Francisco deposit, corresponding to the Serido Formation. This has higher resistance than pC3b against erosion.

(9) pCg2

This unit is distributed at the margin of the project area, being correlated to the Proterozoic granites. This unit is rough with higher resistance against erosion. Leneaments are prominently developed.

(10) pCg3

This unit occurs as stocks to the southwest of Picui and to the north of Sao Tome, correspond-

Table II-1-1 LANDSAT data

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°

Table II-1-2 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

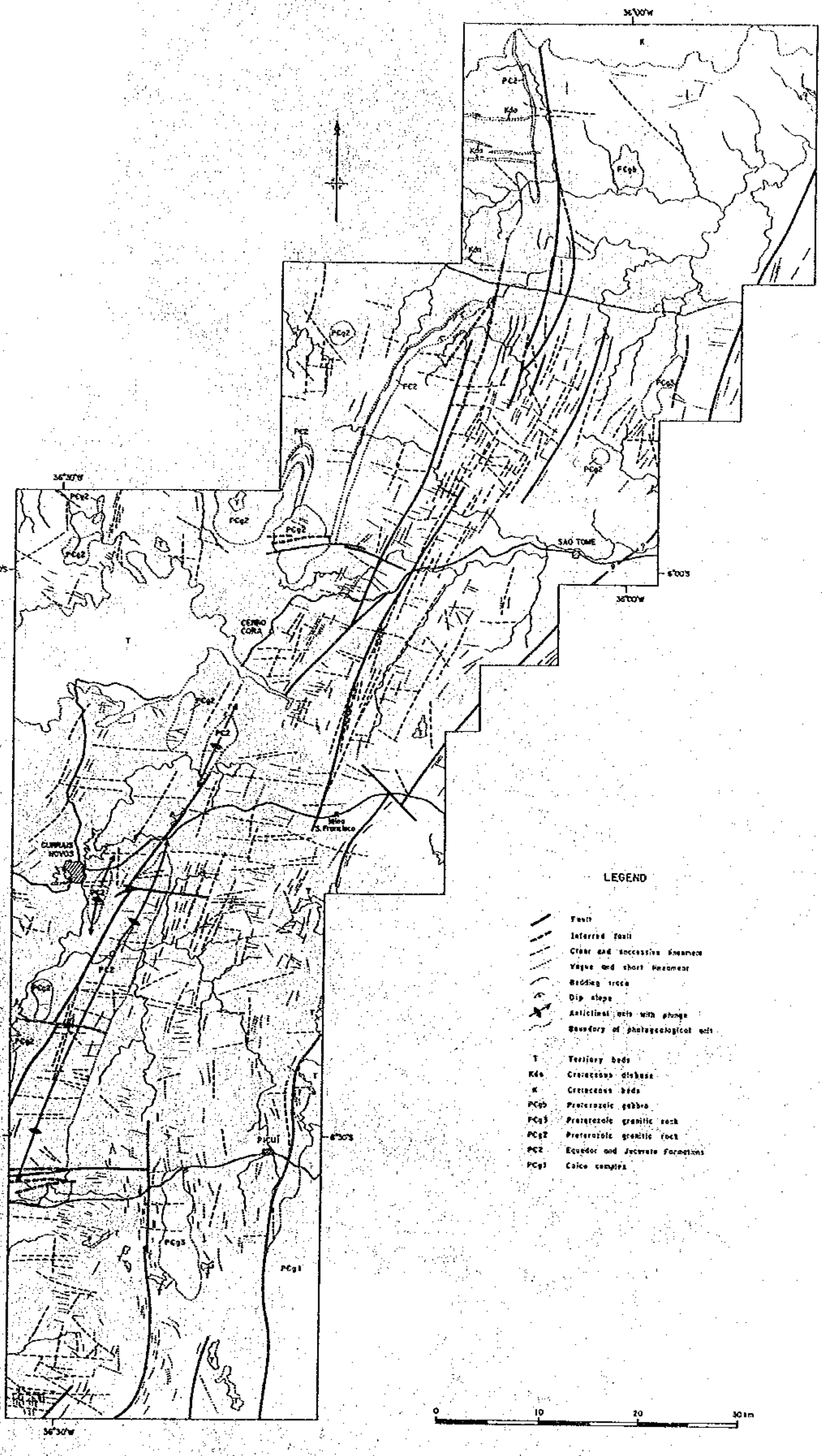

36°00'W
36°30'W
6°00'S
6°30'S
CERRO CORA
SAO TOME
CURRAIS NOVOS
PICUI
LEGEND
Fault
Inferred fault
Clear and successive lineament
Vague and short lineament
Bedding trace
Dip slope
Anticlinal axis with plunge
Boundary of photogeological unit
T Tertiary beds
Kdb Cretaceous diabase
K Cretaceous beds
PCgb Proterozoic gabbro
PCg3 Proterozoic granitic rock
PCg2 Proterozoic granitic rock
PC2 Equador and Jucurutu Formations
PCg1 Caico complex
0
10
20
30 km

Figure II [illegible]

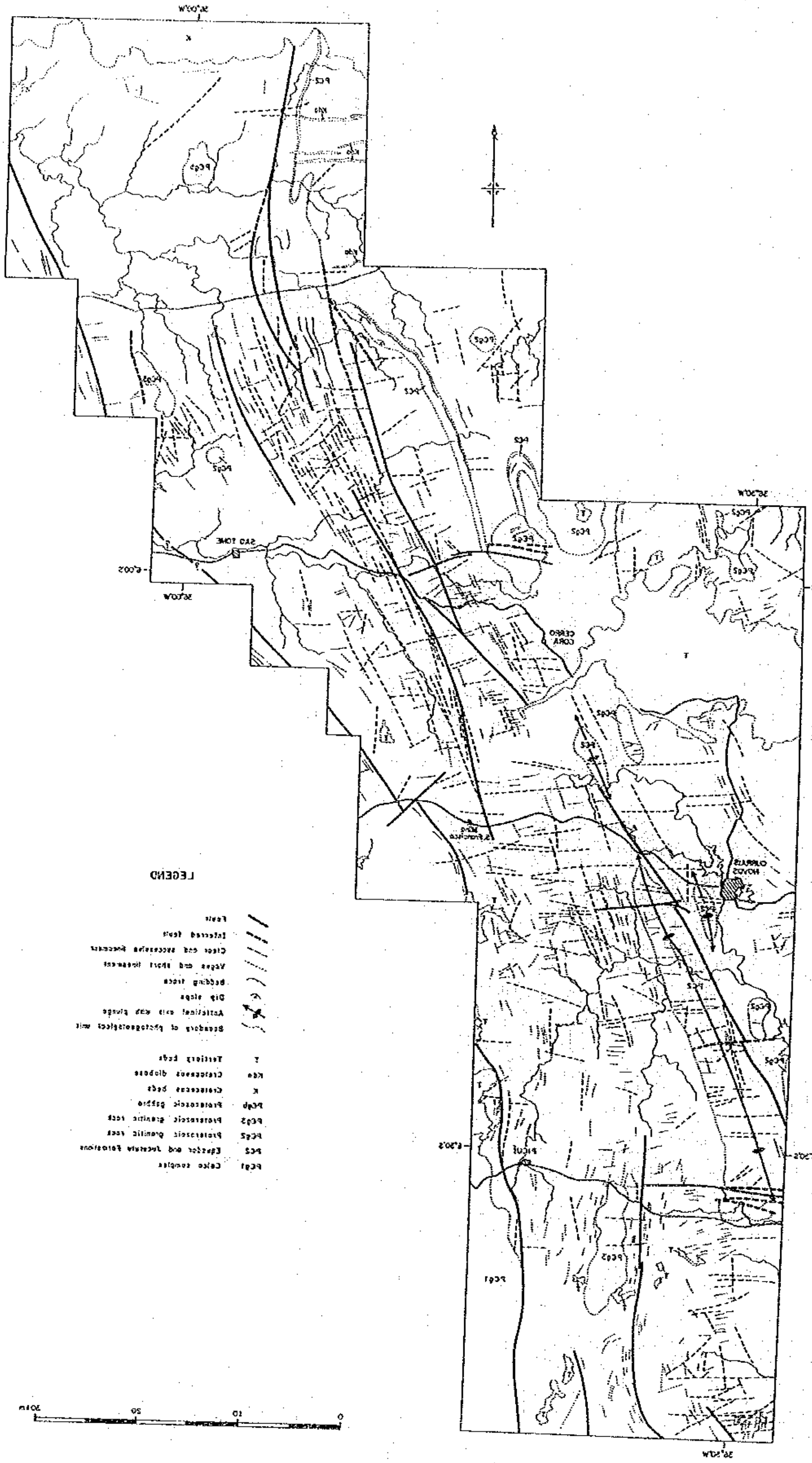
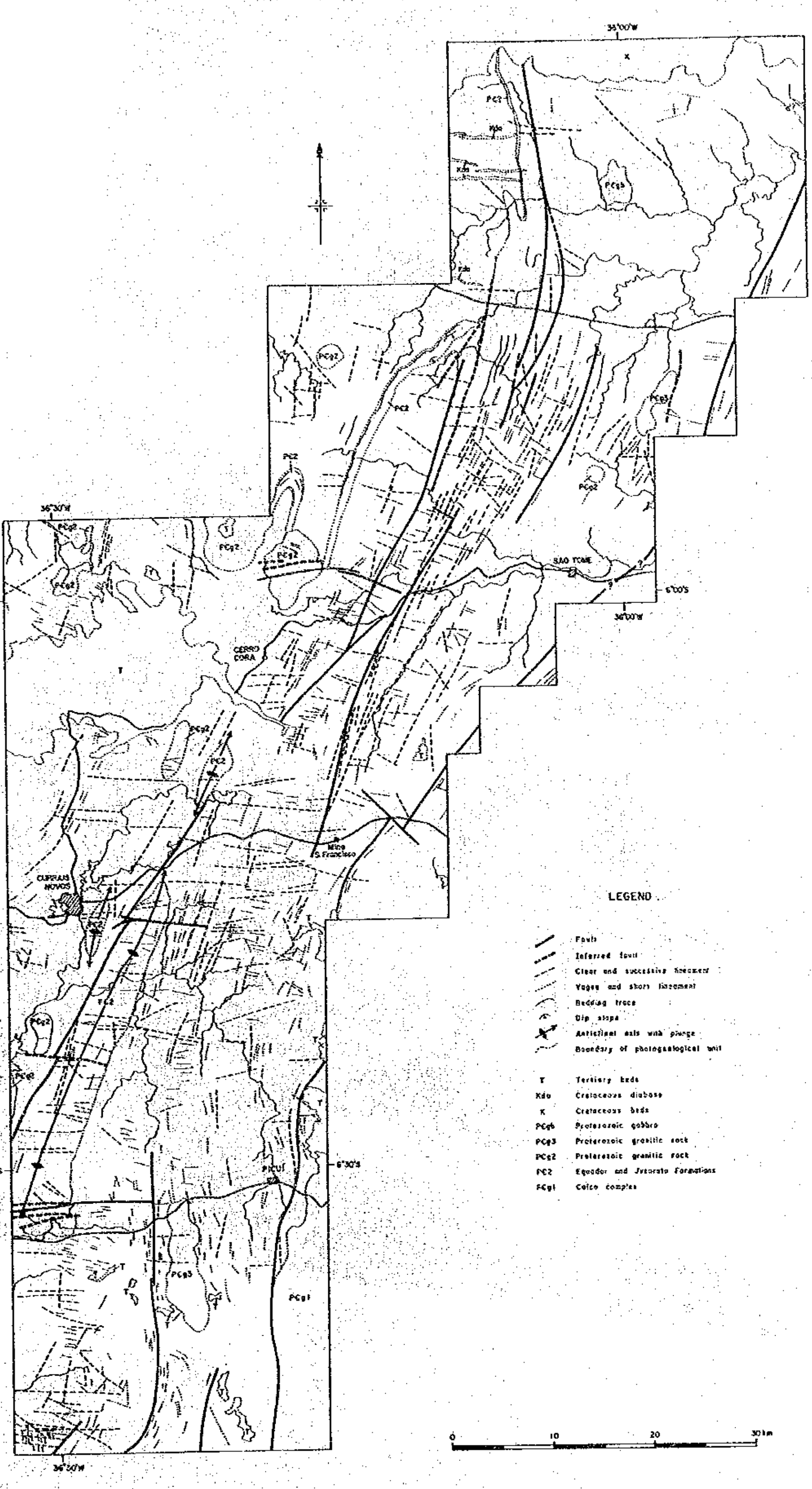
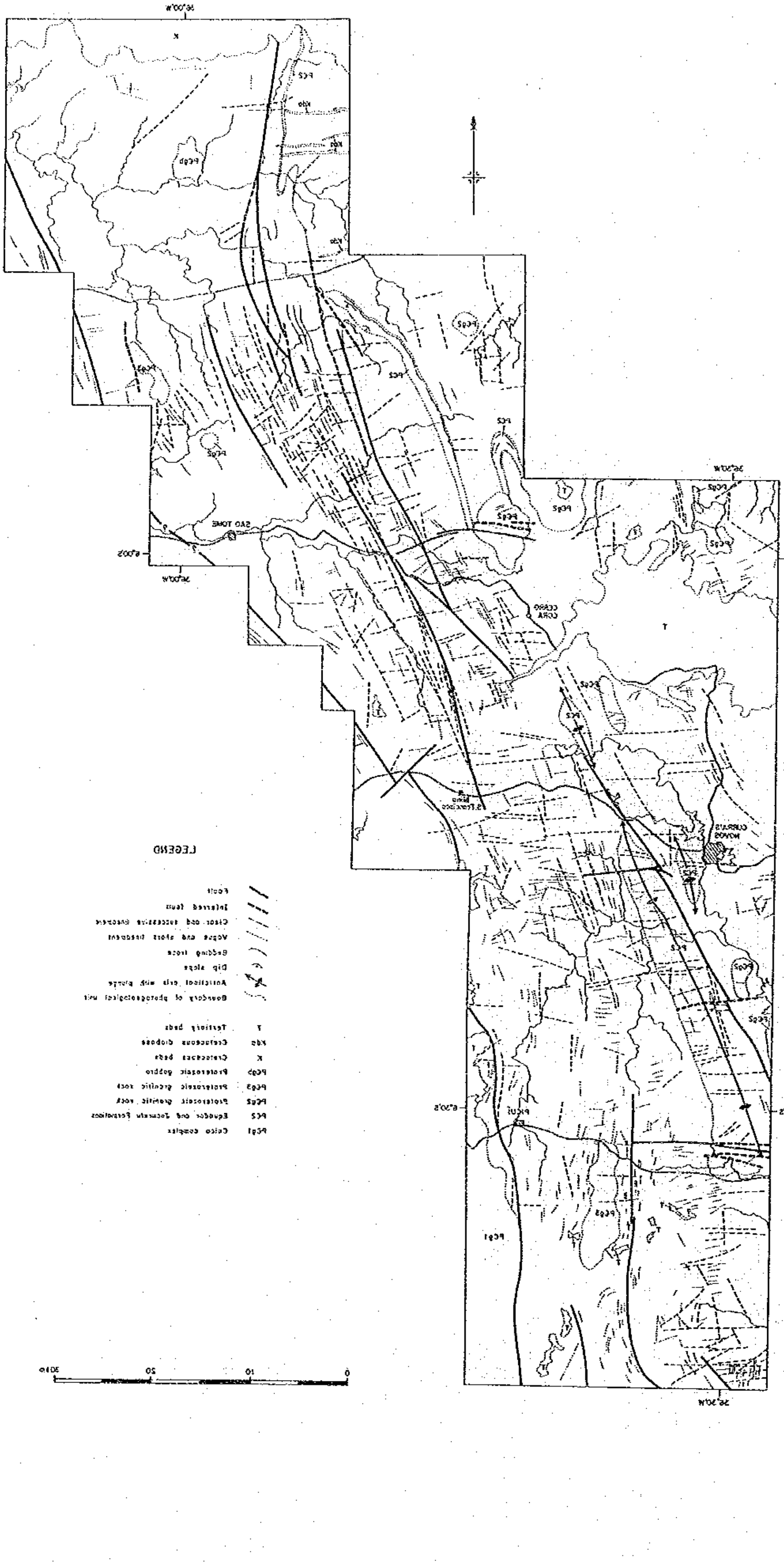

LEGEND
Fault
Inferred fault
Clear and successive lineament
Vague and short lineament
Bedding trace
Dip slope
Anticlinal axis with plunge
Boundary of photogeological unit
T Tertiary beds
Kdb Cretaceous diabase
K Cretaceous beds
PЄgb Proterozoic gabbro
PЄg3 Proterozoic granitic rock
PЄg2 Proterozoic granitic rock
PЄ2 Equador and Jucurutu Formations
PЄg1 Caico complex
SAO TOME
CERRO CORA
CURRAIS NOVOS
PICUI
36°00'W
36°30'W
6°00'S
6°30'S
0 10 20 30 Km

Figure II-1-1 LANDSAT TM false color image



35°00'W
36°30'W
6°00'S
36°00'W
6°30'S
CERRO CORA
CURRAIS NOVOS
SAO TOME
Mina S.Francisco
PICUI
LEGEND.
Fault
Inferred fault
Clear and successive lineament
Vague and short lineament
Bedding trace
Dip slope
Anticlinal axis with plunge
Boundary of photogeological unit
T Tertiary beds
Kdo Cretaceous diabase
K Cretaceous beds
PCgb Proterozoic gabbro
PCg3 Proterozoic granitic rock
PCg2 Proterozoic granitic rock
PC2 Equador and Jucurutu Formations
PCg1 Caico complex
0 10 20 30 km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T Tertiary beds
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PЄ2 Equador and Jucurutu Formations
PЄg1 Caicó complex
SAO TOME
CERRO CORA
CURRAIS NOVOS
36°00'W
36°30'W
6°00'S
6°30'S
0 10 20 30 km

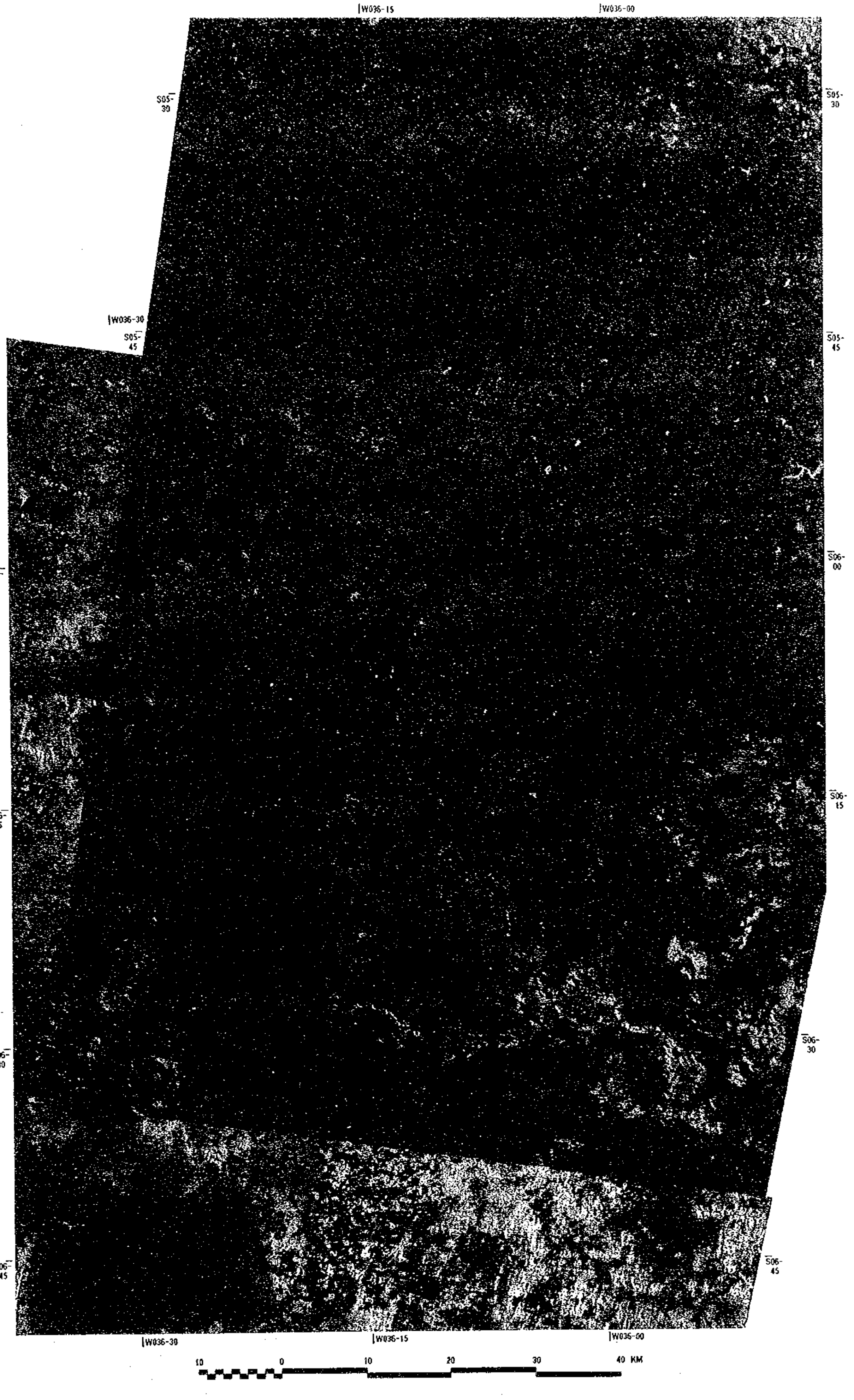
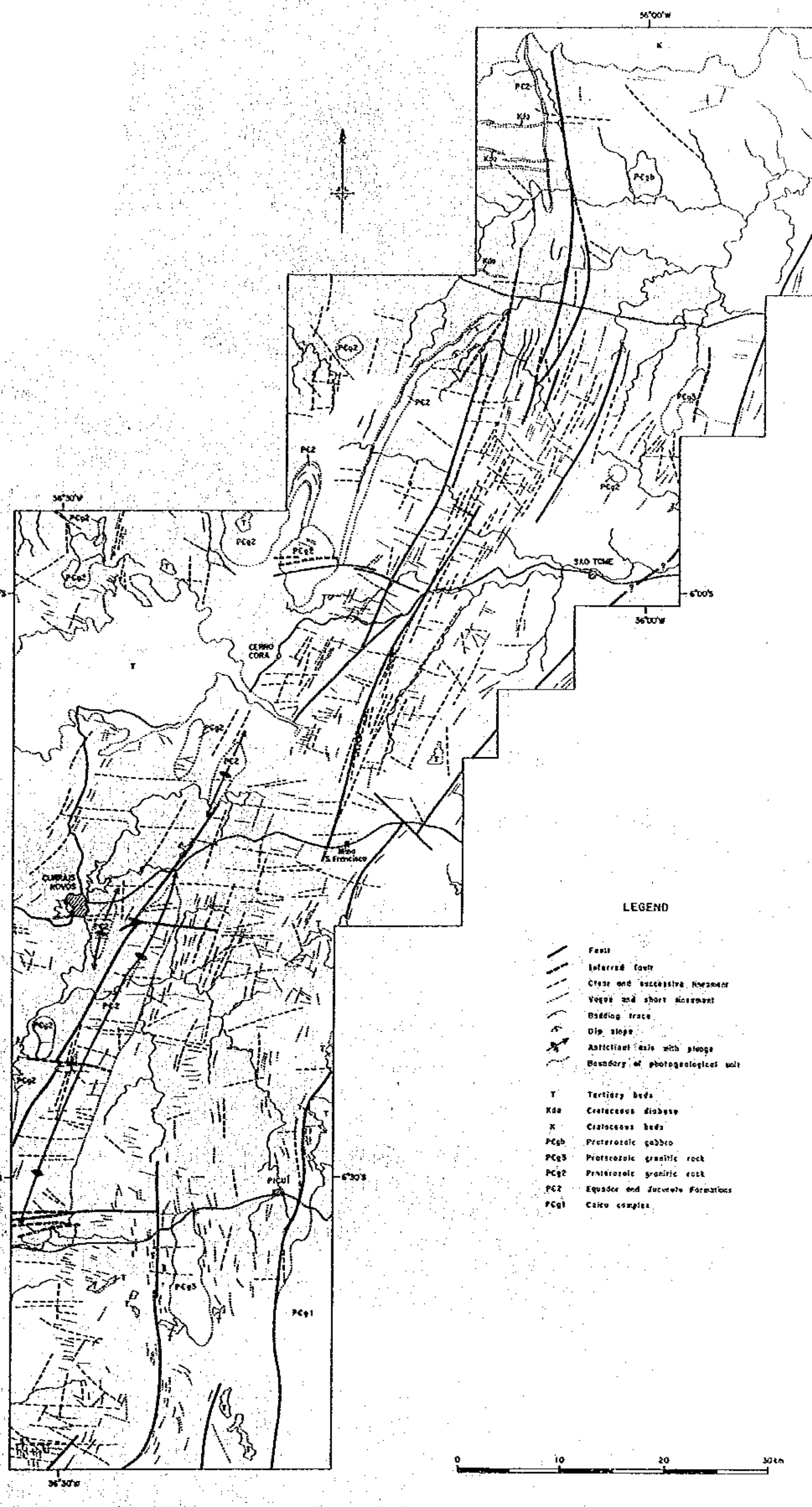


Figure II-1-2 LANDSAT TM ratio color image



36°00'W
36°30'W
6°00'S
6°30'S
CERRO CORA
SAO TOME
CURRAIS NOVOS
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PICUI
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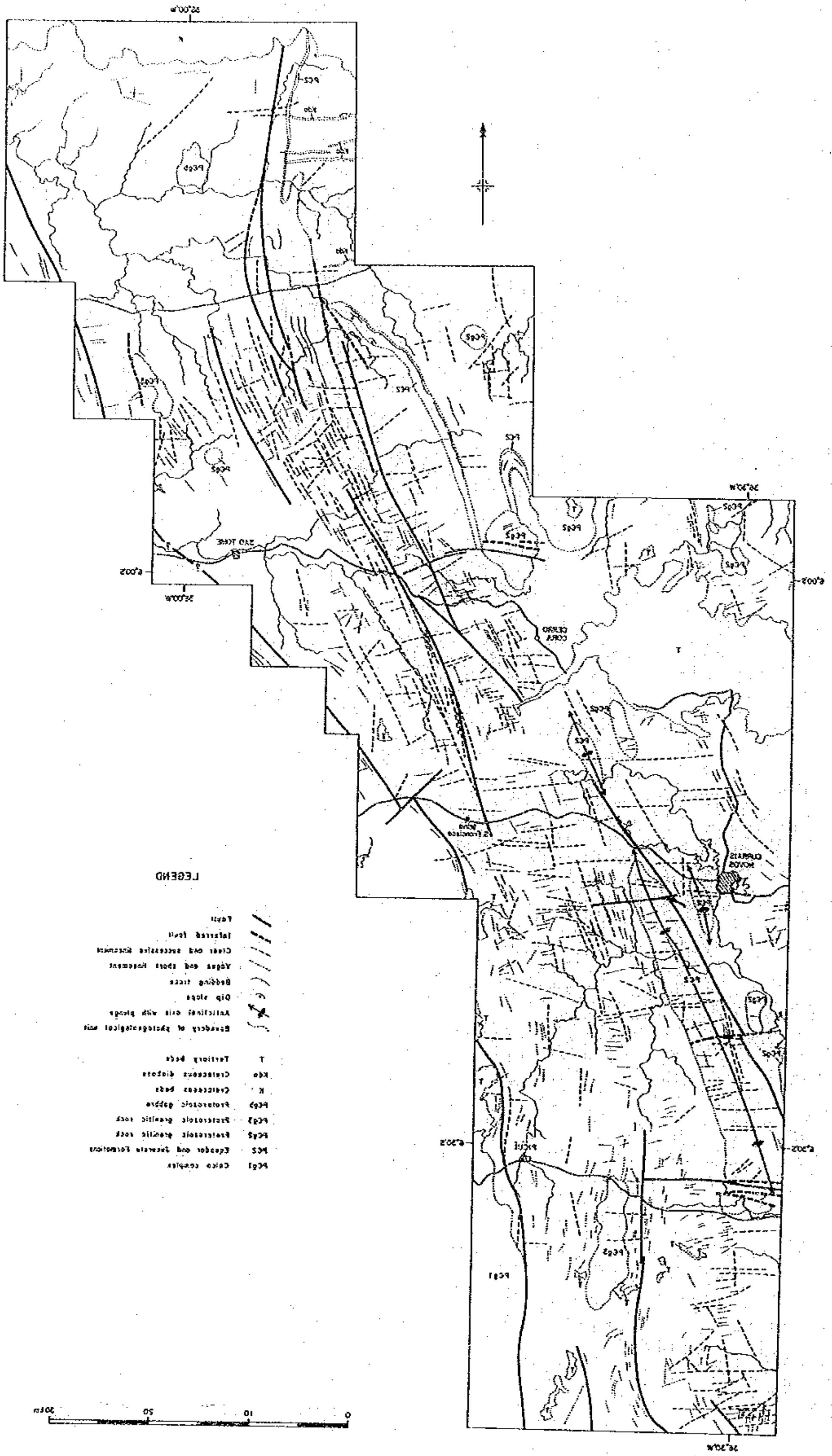
LEGEND
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PC2 Equador and Jucurutu Formations
PCg1 Caico complex
0 10 20 30km
36°00'W
36°30'W
6°00'S
6°30'S
SÃO TOMÉ
CERRO CORÁ
CURRAIS NOVOS
PICUÍ

Figure II-1-3 LANDSAT TM principal component color image

ing to the Proterozoic granite. The area is flat as same as pCg1. The land seems white without vegetation on the false color images.

(11) pCpg

This unit elongates to the north of the Sao Francisco mine, corresponding to Proterozoic pegmatite. Higher resistance and sharp ridges are characteristic.

(12) pCgb

This unit occurs in the unit pC3b in the north of the project area, corresponding to the Proterozoic gabro. Not only lower resistance but also the color of purple are characteristic on the images.

(13) K

The unit occupies the northern edges of the project area, being correlated to the Cretaceous sediments. It has somewhat flat topography with slight undulation.

(14) Kda

This unit form the shape of dike in the unit pC1b along the northern margin of the project area. They are black, corresponding to the Cretaceous basalt and/or diabase dikes.

(15) T

This unit dominates to the north of Currais Novos and sparsely distributed in other places. This is Tertiary sediments, forming distinct flat plateau.

(16) Q

This unit corresponds to alluvial sediments along drainages.

1-2-2 Structure

A number of lineaments are extracted in the zone trending NNE from the northwest of Sao Tome through the southwest of the project area (FigureII-1-5). The lineaments are composed of those trending north northeast and east. Lineaments trending two directions are extracted with same frequency.

Faults and well continuous lineaments dominate in the area to the north of the Sao Francisco deposit, which is situated in the southern extension of those lineaments. On the other hand, lineaments trending east are continuously traced in the area to the south of the Sao Francisco deposit.

1-2-3 Geology, Structure and Mineralization

False color images were effective for the geographical and strutural interpretation. Principal component analysis and ratio images were not effective for the extraction of alteration zone generated by mineralization, because tones representing a difference of vegetation dencity were emphasized.

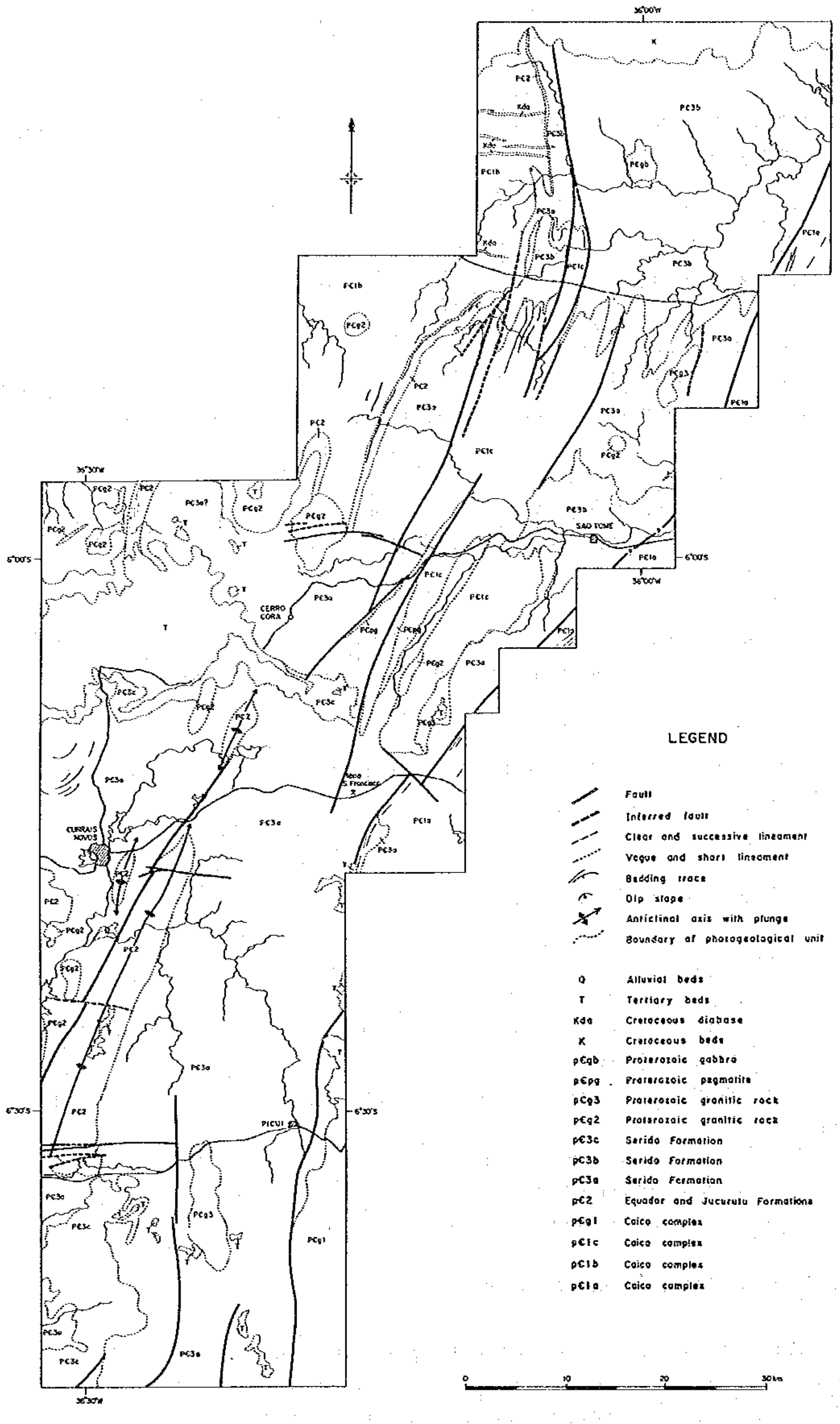


Figure II-1-4 Geologic interpretation of LANDSAT images

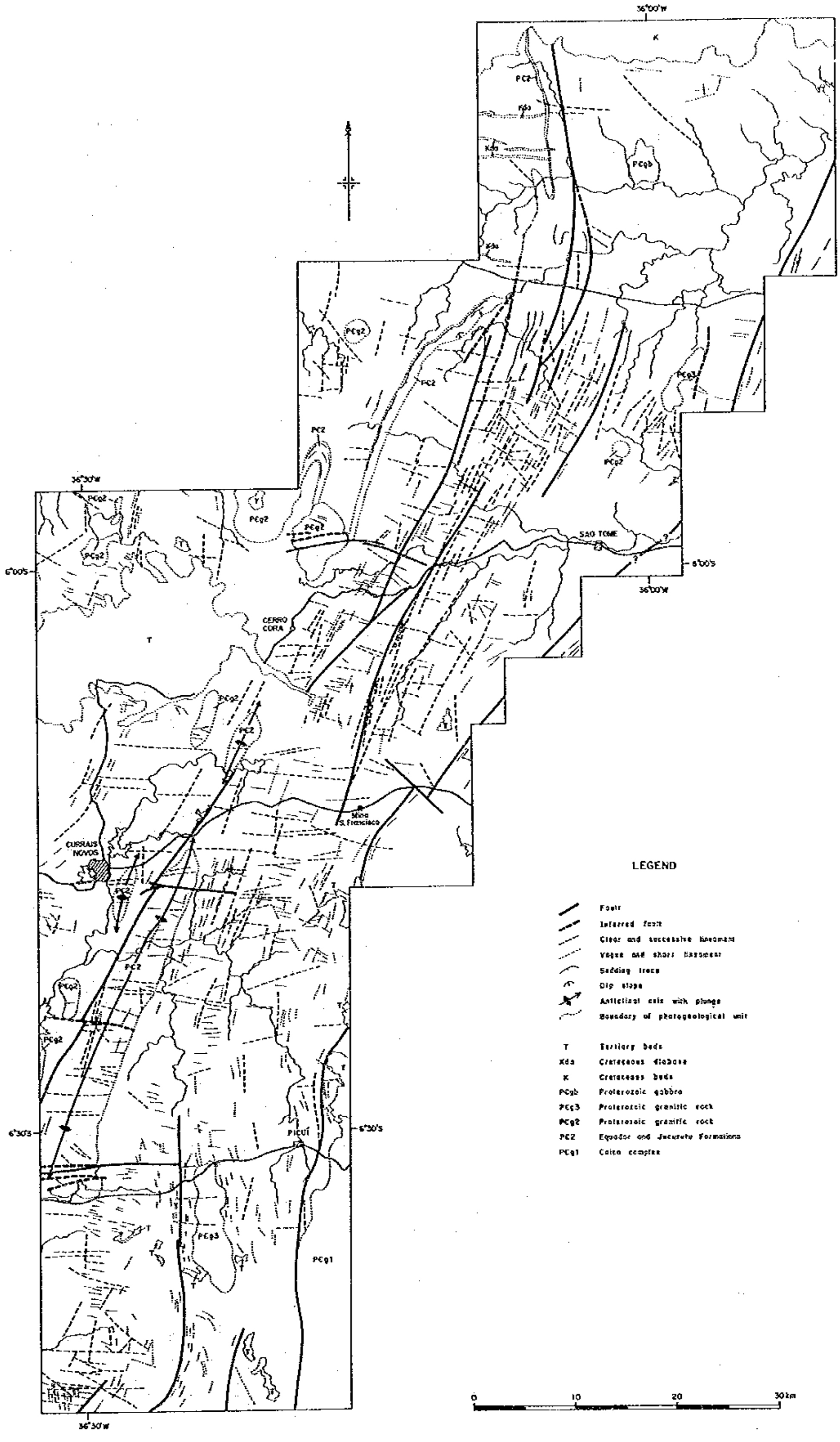


Figure II-1-5 Lineament interpretation of LANDSAT images

Teixeira, which is situated in the center of the state of Paraiba and is known as gold district, is in between faults in the region along the tectonic zone in the Serido Formation (Figure I-2-2). Furthermore, a number of lineaments crossing those faults by higher angles are extracted on the images. Therefore, the area surrounding Teixeira is in the sheared zone with well developed faults. The geologic situation in the area surrounding the Sao Francisco deposit is as same as that of the Teixeira. That is, lineaments with two directions, NNE-SSW and E-W, are crossing each other in that region.

Chapter 2 Reconnaissance Survey

2-1 GEOLOGY

According to Jardim de Sa and Salim (1978) and Jardim de Sa (1982), the survey area is underlain by Archean Caico Complex, Proterozoic Serido Group and Tertiary Serra dos Martins Formation (Figure II-2-1). Proterozoic Serido Group is subdivided into Jucurutu Formation, Equador Formation and Serido Formation in ascending order. The survey was carried out following their stratigraphy.

2-1-1 Precambrian Units

(1) Caico Complex

Caico Complex is distributed in the area west of Sao Tome and east of the survey area (Figure II-2-2). The Complex west of Sao Tome crops out to the north from the point 7km to the north of Sao Francisco mine. The area is 14km in east west and 30km in north south.

The Complex in the east of the survey area occupies the eastern margin of the area. The Complex is divided by Picui fault from the other on the western end, while it extends further to the east outside of the survey area. The Complex forms slight undulating hills.

According to Jardim de Sa (1987), the Complex is principally divided into two types of lithologies. One is represented by gneisses with migmatite, which is originated from plutonics and is called Tonalite-Trogniemite-Granite (TTG). The other is metasedimentary rocks composed of amphibolite, schist, quartzite, ultrabasic rocks, marble and so on, which is also called exogenetic rocks.

The Complex which crops out on the northeastern margin of the survey area belongs to the category of TTG composed mainly of granites. It is named pCgr1 on the map.

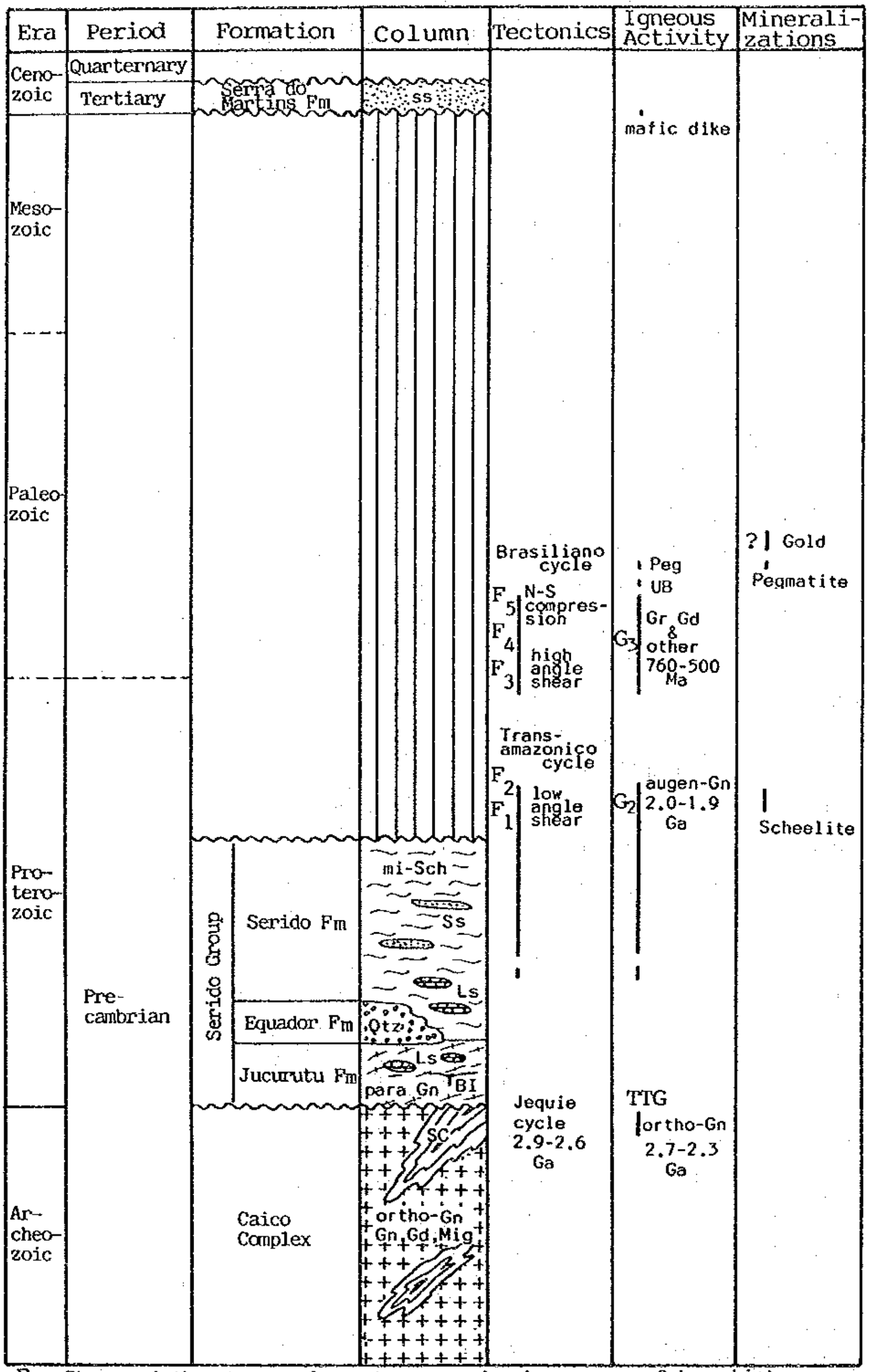
The Complex in the north of the survey area comes into the category of the exogenetic rocks. They are principally composed of paragneiss, accompanied with orthogneiss, amphibolite, augen gneiss, banded gneiss, injection gneiss and so on, characterized by pCgn on the map. The Complex is intruded by G_2 granite (pCgr2) and pegmatite (pCpg) at various scales.

The Complex in the north of Picui comprises largely of biotite gneiss (pCgn), while the Complex in the south of Picui is composed of complex biotite gneiss, biotite granite and amphibolite and so on. The gneiss has augens of feldspars in some places.

According to Santos et al.(1984), the radioactive age of the Complex is 2,720 +135 Ma (Rb-Sr isochron), which indicates Archean age. The Complex is affected by two orogenic events, Transamazonian and Brazilian.

The Complex is the basement of the area.

Rocks composed mainly of paragneiss and basic intrusives fall under the category of exogenetic rocks.



F2: Phases of the structural events
TTG: Plutonic rocks in the Caico Complex
G2: Transamazonian plutonic rocks
G1: Brazilian plutonic rocks

mi: mica
SS: sandstone
LS: limestone
Qtz: zuartzite

Sch: schist
BI: basic intrusion
Gn: gneiss
SC: supracrustals

Figure II-2-1 Generalized columnar section of the project area

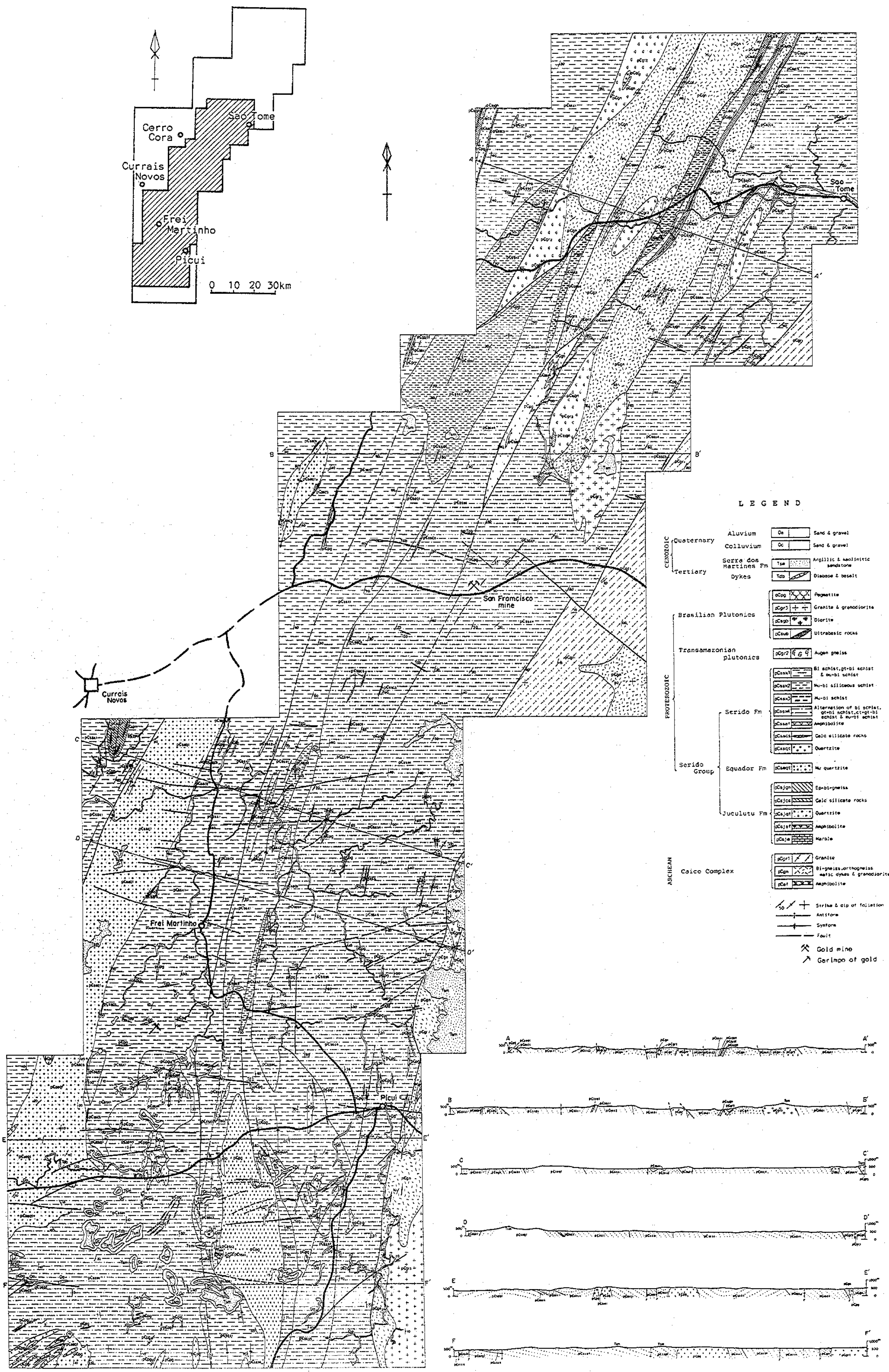


Figure II-2-2 Geologic map of the survey area

(2) Jucurutu Formation

The formation occupies the margins of the Caico Complexes, trending NNE, in the northern portion of the survey area. It can be seen to the east of Currais Novos on a small scale (Figure II-2-2).

According to Torres et al.(1973), it is more than 300m thick in the area of Florania, northwest of Currais Novos. It could not be measured in the survey area.

The formation is principally composed of quartzo feldspathic gneiss, named as pCsjgn, accompanied with minor biotite, muscovite and epidote. Banded structure in the order of millimeters is discriminated in a typical rock. Migmatite, named as pCsjm, can also be recognized in the northern most part of the distribution. The formation characteristically comprises marbles, calc-silicate rocks, quartzites and mica schists in a lenticular shape 2 to 6 meters wide. In skarn as calc-silicate rocks, scheelite occurrs and was formerly produced as tungten deposit in various locations in the survey area.

Radioactive dating was not carried out on the rocks in the area. According to Lima 81986), the formation is correlated to early Proterozoic of age.

The formation uncomformably lies on the caico Complex.

The Jucurutu Formation, which were located at the northern and eastern margins of the Equador Formation by former mapping (such as DNPM/CPRM,1980), was eliminated by this survey. Therefore host rocks of tungsten deposits such as Malhada Limpa and Sitio Timbauba, which were thought to be in the Jucurutu Formation there in the past, was correlated to the Serido Formation.

It is thought to be deposited in a shallow marine environment from the evidences such as intercalation of limestone.

(3) Equador Formation

The formation is distributed intermittently in NNE-SSW direction in the west to southwest portion of the survey area (Figure II-2-2). The formation forms deeply carved mountain ranges with the elevation around 600m in the northern part. However, in the southern most part of the distribution, the mountain decreases the elevation forming slightly undulating topography.

It is thought to be more than 800m thick in the south central part of the state of Rio Grande do Norte (Ebert, 1968). The thickness was not measured in this region.

It comprises quartzite, muscovite quartzite and muscovite feldspathic quartzite, partly accompanied with biotite. Biotite schist is also intercalated in some area. The formation is folded in open and closed sense with the axes trending NNE. However, the dips of the foliation decrease to 10 degrees and the strikes are also changed into ENE-WSW to WNW-ESE at the southern end of the distribution.

The Formation lies conformably on the Jucurutu Formation. The contact can be seen at the northwestern corner of the survey area.

The formation is correlated to the lower Proterozoic. However, there are no data concerning to dating or fossils.

It is thought to be pre-orogenic sediments.

(4) Serido Formation

The Formation occupies wide area in the central portion of the survey area (Figure II-2-2). It extends in the direction of NE-SW in the northern part and NNE-SSW in the southern part of the survey area.

According to Torres et al.(1973), the thickness of the formation is in the order of 300m in the area of Florania. It was not measured in this region.

The formation is principally composed of mica schist accompanied with calc-silicate rocks, named as pCsscs, quartzite, named as pCssqt, and amphibolite. The mica schist can be divided into four types, pCssx1, pCssx2, pCssx3 and pCssx4.

pCssx1 is mainly composed of biotite schist with local intercalations of garnet-biotite schist and cordierite-biotite schist. Minor silimanite and andalusite are also observed.

pCssx2 is hard compact siliceous schist, accompanied with minor muscovite and biotite.

pCssx3 represents muscovite-biotite schist. Chlorite is locally observed. The rocks are rich in muscovite and biotite. Muscovites are possibly the products of retrogressive metamorphism.

pCssx4 is the alternating beds of biotite schist, garnet-biotite schist and cordierite-garnet-biotite schist. Each bed is 10cm to 2m thick. Cordierite characteristically occurs as great numbers of poikiloblastic porphyroblasts few centimeters to more than ten centimeters in diameter in one bed.

pCsscs was called calc-silicate beds, comprising skarn rocks, amphibolites, amphibole schists and epidote-garnet-salite schists and so on. They widely occur in the Serido Formation except in the southern part. Those beds are few tens of centimeters wide and laterally extend few meters to few tens of meters. In skarn rocks occurring around the contact between the Serido and the Equador Formations, scheelite is locally accompanied.

pCssqt is a thin bed of white fine quartzite, occurring 6km northwest of the Sao Francisco mine inside the pCssx4.

Amphibole schist occurs at a small scale inside the pCssx2 to the eat and southeast of Serro Cora.

Foliations are prominently developed in the entire Formation.

Those biotite schists have a chemical composition of pelitic rocks and graywacke. The rocks of the formation is richer in gold than the other rocks in the north of the survey area.

The formation is thought to be formed in the early Proterozoic due to the subjection of the Transamazonian orogeny.

The Formation conformably lies on the Equador Formation. At the western end of the distribution of the Serido Formation, the Equador Formation changes into the Serido Formation with interfinger relation.

The Formation is considered as deep marine flysch sediment, having the deposition cycle of greywacke to argillite and turbidite.

2-1-2 Tertiary Formation

(1) Serra dos Martins Formation

The Formation is distributed around Serra Cora in the north west of the area (Figure II-2-2), on the area higher than 600m in the central eastern portion, on the places higher than 620m in the area where the Equador Formation occupies and on mesas in the southern part of the survey area.

The Formation is 30 to 40m thick in this area. However, the top of the Formation is somewhat eroded.

It comprises conglomerate, mainly composed of quartzite, sandstone and argillic shale. It became characteristically reddish by oxidation.

The formation is correlated to the Tertiary sediments near the survey area. Fossils were not found.

The Formation lies directly on the Archean and Proterozoic formations.

According to the Bigarela (1975), in Santos et al.,1984, it is terrestrial sediment deposited on the pediplain.

2-1-3 Intrusives

Intrusive rocks in this area are classified into four as follows, G_2 of the Transamazonian orogeny, G_3 of the Brazilian orogeny, Proterozoic to Paleozoic intrusives and Tertiary intrusives. G_2 and G_3 are used by Jardim de Sa (1981).

(1) G_2 and G_3 Rocks

This occurs as intrusives on variable scales in the Caico Complex in the north of the survey area. The lithologies of the rocks comprises augen gneiss of granite and/or granodiorite composition and fine grained orthogneiss.

The intrusive age of the rocks is considered to be after the deposition of the Serido Formation, because the rocks intruded into the Jucurutu and the Serido Formations. The radioactive age decided by Rb-Sr method on the rocks is 2,090 Ma (Macedo et al., 1984; in Jardim de Sa,1987), corresponding to the Transamazonian orogeny.

This rock also occurs about 10km north of Picui. It extends in the direction of N-S. It is also augen gneiss with the composition of granite, being considered to be formed after the deposition of the Serido Formation.

Three localities of the rocks were confirmed in the north of the survey area. One of those is situated 7km to the northeast of the Sao Francisco mine, extending in the direction of NNE. It intrudes into the boundary between the Caico Complex and the Serido Formation, cutting the Jucurutu Formation. No relationships with G_2 were found. The rocks are gray to pale brown, fine to coarse grained, equigranular granodiorite. Radioactive ages of the intrusion of 550 Ma and 660 Ma were gained by Rb-Sr method (Macedo et al.,1984; in Jardim de sa, 1987). This age corresponds to the age of the Brazilian orogeny.

The rock occurs in the eastern margin of the survey area. It is gray, fine to medium grained biotite granite. No data of the intrusion age was available.

The rock crops out at a small scale in the northwestern end of the survey area. The outcrop extends in the direction of NNE. It is gray medium grained biotite gneiss. There is no data on the intrusive age.

(2) Pegmatite

Pegmatite dikes are densely distributed in the entire survey area (Figure II-2-2). They are small in general. Pegmatite 4km wide and 17km long is the largest, occurring in the southern end of the survey area.

Pegmatite dikes are generally few meters to few tens of meters wide and few hundred meters long with the maximum length of about 4km. The direction of the pegmatites generally corresponds to the direction of that of foliation of the schist. However, it sometimes cross cut the foliation. In the southwestern portion of the survey area, the pegmatite generally trends NE. In the area about 5km south of Frei Martinho, there are many pegmatite trending east, WNW and ENE.

The pegmatite described above intruded into all of the formations except Tertiary rocks. In the Caico Complex in the northern part of the survey area, pegmatites intruded in the Complex in several phases.

Pegmatites are principally composed of potash feldspar, quartz, plagioclase, muscovite, biotite and tourmaline with minor beryl, columbite and tantalite. Muscovite, beryl and columbite-tantalite are in some places mined at a small scale.

The age of the pegmatite intrusion is after the intrusion of G_3, except those in the Caico complex in the north of the survey area.

(3) Basalts

Basalts intrusions are widely distributed as dikes in the entire area except the northern part of the survey area. The dikes occur along faults trending WNW and ENE. The dikes are 10cm to 2m wide, dipping steeply. Stock of basalt about 500m in diameter and radial dikes surrounding the stock occur in the southeast of the survey area. It is dark, fine, massive, having olivin phenocrysts 1cm in diameter.

(4) Other intrusives

Amphibole schist crops out about 8km north northwest of Sao Tome. It is about 200m wide and 2km long, extending in the direction of NNE-SSW. It intruded into the boundary between the Serido and the Jucurutu Formations.

It is coarse grained with prominent dark green linear structures.

Ultrabasic rock occurs about 10km north northwest of Sao Tome, extending in the direction of NNE-SSW. It is about 100m wide and 700m long. It intruded into the Jucurutu Formation in the same direction as the one of Jucurutu Formation.

2-2 STRUCTURE

(1) Structure

Structural trends, represented by major faults and folded zone, predominate in the surveyed area because of the suffering from the Precambrian tectonics. Those tends are NNE-SSW to NE-SW to NS.

Picui fault, which is of the major tectonic line dividing the Central Domain from the Centro-oriental Domain, is running from north to south in the eastern side of the survey area. There are major faults passing through the area from north to south in the central portion of the survey area as well. Folded zone about 3km wide runs parallel to those faults. Faults trending WNW to ENE, crosscutting the direction described above, are also developed in the entire area. Tertiary basalt dikes occur along these faults.

Foliations strike subparallel to the major structures and dip generally eastward by more than 30 , except in the area about 7 to 10 km south southwest of Frei Martinho, where they dip east or west by less than 10 .

In the folded zone, antiforms and synforms with the same direction as that of the zone and wave length few hundred meters long are developed. pCssx2 in general occurs in this zone.

(2) Relations between Structure and Mineralization

The Sao Francisco deposit occurs in the area where two types of faults, trending NNE and ENE, come together in the Serido Formation. In the north of the deposit, foliations of the biotite schist strike differently ENE, suggesting the disturbance of the structure during tectonism.

The auriferous quartz vein west of Sao Tome is situated at the location where fault changes its direction from N30 E to N10 E in the Caico Complex.

The area including Serra da Umburana, where auriferous quartz vein occurs, is structurally different from the surrounding area in terms of the directions of pegmatites and inclination of the foliations of the biotite schists.

From the above mentioned, auriferous quartz veins can be understood to be localized at the location where the structure is disordered against the surrounding area.

2-3 MINERALIZATION

Three gold mineralizations are known in this area. They are Sao Francisco deposit, auriferous quartz vein 7km west of Sao tome and also auriferous quartz vein 7km south southwest of Frei Martinho (Figure II-2-2).

In the area surrounding the Sao Francisco mine, placer gold is mined on a small scale.

(1) Sao Francisco Deposit

(a) Type of Deposit

According to Ferran, A.(1988) and Cassedane, J.P. (1973), followings are discussed about the mineralization. There are two mineralization zones parallel to each other, named as Sao Francisco trend and Morro Pelado trend. They extend in the direction NNE-SSW. Mineralization is principally found in quartz vein and in recrystallized meta-chert both in those trends. Minor mineralization is also found in the host schist. Each quartz vein and meta-chert are 10 to 20cm thick with the maximum thickness of 50cm. Mineralized zone is more than 50m wide 3km long as a whole. Average grade in the mineralization of the Sao Francisco trend is 6.6 g/t, locally reaches at 100 g/t. The grade in the Morro Pelado trend is 3 g/t. 2,745 kg of gold is included in the whole deposit.

Ferran, A. (1988) regarded the deposit as a exhalative sedimentary deposit and Cassedane, J.P. (1988) supposed the deposit to be a deposit in the metamorphic rock without relations to plutonic rocks.

According to this survey, the Sao Francisco deposit was considered to be a epithermal deposit from the evidences regarding structural control, ore forming minerals, alteration minerals in the quartz veins and so on.

Ore host rock of the Sao Francisco deposit is garnet-(muscovite)-biotite schist of the Serido Formation.

According to Ferran, A.(1988), both of the Morro Pelado and the Sao Francisco trends are mineralized meta-chert. The Sao Francisco trend, comprising two meta-chert beds, strikes NNE-SSW and dips southeastward by 45 . The mineralized part is parallel to lineation of the host rock, plunging south southwestward by 12 degrees along bedding planes of the meta-chert. At the Morro Pelado trend, thin chert beds repeatedly appear on the ground. The trend is 50m wide on the ground. Their strike and dip are as same as those of the Sao Francisco trend.

According to this survey in the mining pit, gold mineralization is found both in quartz veins and in host rock in the Morro Pelado trend. And the quartz veins are hosted in sheared zone with milonite and in tension fractures. Strikes and dips of the auriferous quartz veins in the sheared zone are similar to those of foliation of the schist. However, quartz veins in the tension fractures partly crosscut the foliations.

(b) Ore and alteration minerals

Gold occurs as free gold and associated with sulfide minerals such as pyrite, pyrrhotite, galena and molybdenite in the sao Francisco trend. In the Morro Pelado trend, gold occurs in the same manner without galena and molybdenite (Ferran, A., 1988). Cassedane, J.P. et al. (1973) reported melnikovite-pyrite, marcasite, arsenopyrite, chalcopyrite, bornite, covellite, chalcocite, sphalerite, hematite, manganese oxide, limonite, iron and magnesium sulfate, angelellite, scorodite, sulfur, anglesite and cerussite as ore minerals other than gold and calcite and dolomite as gangue minerals.

This survey confirmed pyrite, chalcopyrite, pyrrhotite, chalcocite, covellite, cuprite, limonite, malachite and atacamite as ore minerals and quartz and carbonate mineral as gangue minerals.

Ore minerals including sulfides and oxides do not keep any traces either of thermal metamorphism or of dynamic metamorphism.

Native gold occurring in this deposit are very small. No gold was determined microscopic observation in this survey.

Quartz vein sample taken from the mining pit had 0.1 to 3.7 ppm of gold, 0.8 to 57.3 ppm of silver and 2 to 23 ppm of arsenic. A sample with highest arsenic values has also highest gold and silver values. That suggests these elements are brought together with the mineralization. The ratio of gold to silver, Au/Ag, is less than one eighth. On the other hand, the host rock next to the vein had 635 ppb of gold, while biotite schist generally has 1 to 9 ppb of gold. That suggests the schist next to the vein is mineralized.

Sericite and kaolinite were found in the mineralized quartz vein and in clay attached to the vein, suggesting that the veins are originated from hydrothermal activity.

Fluid inclusions are too small, 0.001mm to 0.01 mm in diameter, to determine the temperature and primary fluid inclusions in the mineralized veins are rich in carbon dioxide.

(c) Ore genesis

Cassedane, J. P.(1973) considered that the deposit was a one formed in the metamorphic rocks without relations to the plutonic rocks and with possible reworking from the older one.

Ferran, A. (1988) concluded this deposit to be an exhalative sedimentary one from the evidences of the extension of the chert and paragenesis with sulfides.

This present survey suppose the deposit to be epithermal fracture filling type with the evidences that the veins are either in sheared zone or in tension fractures with alteration minerals such as sericite. Furthermore, the deposit supposed to be formed after the latest Brazilian tectonics because no evidences on the metamorphism were kept in the ore minerals and sericite still remains in the mineralized vein.

(2) Auriferous Quartz Veins West of Sao Tome

(a) Type of deposit

Mineralization principally occurs in quartz veins. Auriferous quartz veins are less than 10cm wide and about 60m long. Gold contents of two samples taken from the vein is 5.1ppm and 9.1ppm, which are higher than those of the Sao Francisco deposit. Silver contents of the same samples are 2.8ppm and 4.5ppm. The ratios of gold to silver, Au/Ag, are about 2, which are larger than those of the Sao Francisco deposit. The contents of arsenic are less than 1ppm. That suggests the ore forming fluid to be different from the one of the Sao Francisco deposit.

The quartz veins are formed in the biotite gneiss of the Caico Complex.

The auriferous quartz veins strike N30 E and dip 50 E. At the northern end of the auriferous quartz veins, other quartz veins without mineralization and with different strikes and dips interrupt the extension of the auriferous quartz veins.

The auriferous quartz veins occurs in regional sense at the place where major fault, running through the boundary between the Serido Formation and the Caico Complex, changes its direction from N30 E on the north to N10 E on the south. The veins might have occurred at the opening formed by lateral movement of the fault.

This present survey confirmed pyrite, chalcopyrite, chalcocite and covelline as a microscopic observation of polished sections and sericite as a alteration mineral and chlorite by X-ray diffraction.

(b) Ore genesis

The auriferous quartz veins are regarded as epithermal fissure filling type from the evidences of the location, ore mineral composition and alteration minerals. However, the ore fluid is different from the Sao Francisco deposit in terms of the ratio of gold to silver, Au/Ag, and the arsenic contents.

(3) Auriferous Quartz Vein S ~ SW of Frei Martinho

(a) Type of deposit

The deposit is fissure filling quartz vein in the Serido Formation. The quartz vein is 0.3 to 2m wide and 200m long. The sample of the quartz vein had 0.2ppm Au, 103ppm Ag, 3.76% Cu and 5ppm As.

The locality of the auriferous quartz vein was not controlled by major fault but local tectonic movement.

Pyrite, malachite, hematite and limonite are identified. Sericite, kaolinite and montmorillonite occur in the auriferous quartz vein and the clay next to it.

(b) Ore genesis

The deposit is considered to be epithermal vein type deposit from the occurrences of ore and alteration minerals. The ratio of gold contents to silver contents, which is less than one hundredth, and the content of arsenic indicates that the ore fluid is different from those of Sao Francisco deposit and of west of Sao tome.

2-4 GEOCHEMICAL SURVEY

2-4-1 Method

Geochemical survey was carried out with stream sediments in the entire survey area, 2,000km^2 during three years.

Surface stream sediments were sampled from the entire survey area with the sampling density of about 1.6/km^2. Heavy sediment samples were also taken by panning from the area where gold occurrences had been reported and were found in this survey. Following elements were analyzed for geochemical interpretation; Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As and Sb for surface stream sediments and Au, Ag, Mo, W, Sn, Nb and Ta for panned samples.

Exploratory Data Analysis method (EDA method, by H, Kurtz, 1988) were applied for the extraction of geochemical anomalies from the surface sediment (Table II-2-3).

Panned samples were taken mainly for the identification of gold particles.

2-4-2 Stream Sediment Survey

(1)Sampling

Samples were taken from the interval from the surface to the depth of about 10cm. The samples total 3,128.

(2) Statistical treatment of analytical values (Table II-2-1)

Elements, Ag, W, Ta and Sb, were not detected on the surface stream sediments because of the detection limits. Furthermore, those elements were not detected on the rock samples, either.

Mean values of Fe, Mn, Mo, Sn, Nb and Li are similar to those of rock samples. That is, those values were interpreted to reflect the chemical composition of rocks, the Caico Complex in the north and the Serido Formation in the south.

The element Be may reflect the composition of pegmatite. The element As has higher values in the south of the survey area. The maximum analytical values of those elements reaches to few to ten times of those of the rock samples. Therefore, those higher values may represent not only the composition of the rocks but also some mineralization.

The element Au was not detected because of its detection limit as well.

(3) Correlation among the elements (Table II-2-2)

Correlation coefficient between Fe and Mn is 0.542 to 0.740. They slightly correlate. These elements are thought to represent the composition of rocks.

Correlation coefficient between Mo and Nb is 0.591 and 0.568 in the north and in the central of the survey area, and -0.001 in the south of the survey area.

The correlations between Sn and Nb and between Sn and Ta are 0.587 and 0.592 in the north of the survey area respectively. Those correlations are thought to represent the composition of rocks.

Elements Nb and Ta are principally accompanied with pegmatites. However, the correlation coefficient between those elements is 0.535 and 0.567 in the north and in the south of the survey area, though pegmatites are distributed in the entire area.

(4) Concentration of elements

(a) Gold

For a large number of samples, gold was not detected because of the detection limit, 1ppb for the first phase and 0.5ppb for the second phase. The analytical values obtained, therefore, were all accepted as anomalous values. The analytical values are widely distributed in the area to the south 5km north of the Sao Francisco deposit, especially in the south central portion of the area. Higher values and clusters of anomalous values can be seen in the following areas (Figure II-2-3);

1) area surrounding the Sao Francisco mine, 7km east to west and 10km north to south,
2) area 15km northeast of Frei Martinho,
3) area 13km east of Frei Martinho,
4) area 15km west of Picui.

(b) Iron

The area with higher concentration of iron extends from the area about 10km west of the Sao Francisco mine to south to southwest ward as a zone 3km wide. In the area 15km north of the Sao

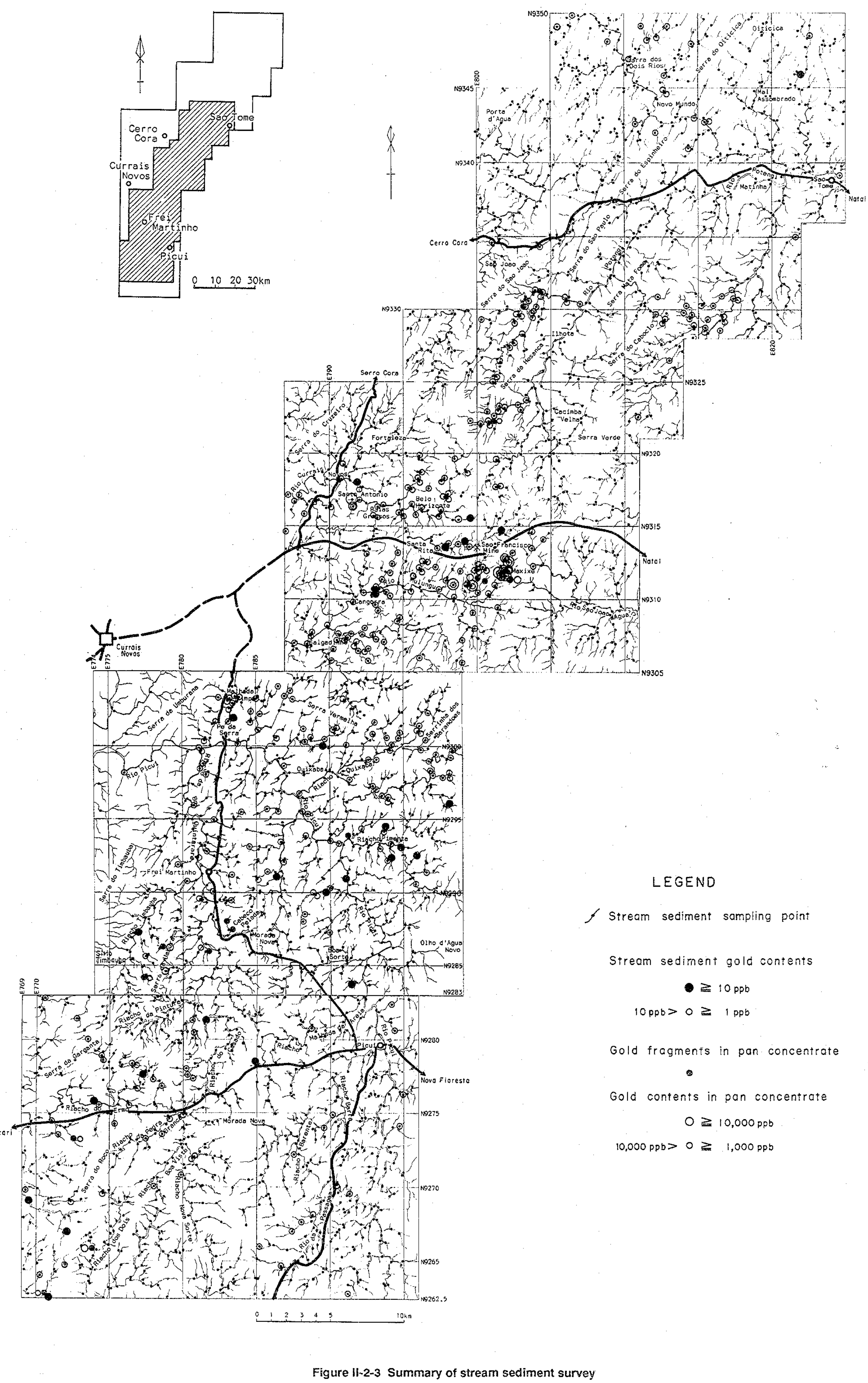


Figure II-2-3 Summary of stream sediment survey

Francisco mine, higher concentration of iron were detected. The area is a extension of the zone same as one described above. The zone with higher concentration of iron corresponds to the folded zone running from north to south in the central portion of the survey area. Therefore, the concentration of iron is probably related to the folded zone.

(c) Manganese

All samples include more than 5ppm of manganese. Higher analytical values were detected in the following areas,

1) area extending along the boundary between the Caico Complex and the Serido Formation.
2) southern most part of the survey area, where is 13km east west and 15km north south, in pCssx4 of the Serido Formation. No mineralization were found.

(d) Molybdenum

An area with higher molybdenum concentration as a whole overlie the area with higher iron concentration in the northern half of the survey area. The area extends as a zone 3km wide from 10km west of Sao Francisco mine toward south to south southwestward until 5km southeast of Frei Martinho.

(e) Tin

Tin is concentrated in the following areas;

1) In the northernmost part, higher tin concentration overlies on the Caico Complex. In the area where the Serido Formation is distributed, the higher concentration can be seen west of the Sao Francisco mine.
2) In the central area where the Serido Formation is distributed.
3) In the area 10km southwest of Picui, where large pegmatite occurs. Therefore, the tin concentration is possibly correlated with the pegmatite.

(f) Niobium

Niobium is concentrated in the following areas;

1) In the northern most part, where the Caico Complex predominates.
2) A zone 2 to 3km wide and 15km long in the direction of north south, and other zone parallel to it 5km distant to the east. The niobium concentration may be correlated with pegmatite dikes.

(g) Arsenic

Arsenic anomalous areas are summarized as follows;

1) Around the Sao Francisco deposit, 7km east west by 3km north south,
2) 13km west of Sao tome, 6km east west by 3km north south,
3) Zone, 3km wide and 45km long trending southwest, starting from 10km north of the Sao Francisco deposit. This zone is situated in the west side of pCssx4 and to the east of the folded

zone. In this zone, a large number of pCsscs beds occur and they include higher Arsenic. Therefore, the higher Arsenic anomalies in this area indicate possible composition of the rocks.

4) Another zone, 3km wide trending NNE, passing through Malhada Limpa. This zone is situated in the west end of the Serido Formation, being intercalated with pCsscs beds. This zone may also reflect the composition of the rocks.

On the other elements, Ag, W, Ta, Be, Li and Sb, no characteristic anomalies were detected.

(5) Factor analysis

Factor analysis on the stream sediment samples collected in each phase were carried out (Table II-2-4). Sample locations with higher factor score were examined with respect to geology and mineralization on each factor obtained by the analysis.

(a) Factor represented by Fe-Mn-(Mo)-Nb)

This factor was extracted in each phase survey area. Contribution, indicated by percentages, are 29.8% to 37.6%. The factor are principally represented by Fe-Mn. Mo-Nb are added to it in the north to central parts of the survey area. In the southern part, factor loadings of Mo and Nb are lower, and these elements were not understood to correlate to Fe-Mn.

Points with higher score are distributed on the Caico Complex in the northern most part of the survey area and on the Serido Formation, especially on the folded zone passing through the central portion of the area. The factor is considered to reflect the composition of the rocks, because these elements are principal in the rocks such as of the Caico Complex and the Serido Formation.

(b) Factor represented by Ta-Nb

Factor loadings of Ta and Nb are 0.572 and 0.500 in the central part of the survey area, 0.809 and 0.729 in the southern p@art of the survey area. Contribution of the factor, represented by percentages, is 19.5% in the central part and 35.4% in the southern part of the survey area. Points with higher factor scores are distributed on the entire Serido Formation. The factor is considered to be correlated to the mineralization of pegmatitc because columbite-tantalite minerals frequently occur in pegmatites in the central to southern part of the survey area.

(c) Factors related to Sn, represented by Sn-Mo-Nb, Sn-Be and Be-(Li)-(Sn)

The contribution of those factors, indicated by percentages, is about 20%. The factor loadings of those elements are about 0.5 as well.

The factor, Sn-Mo-Nb, is considered to be related to mineralization, because the distribution of the points with higher factor scores are similar to that of factor Ta-Nb described above.

The factor, Sn-Be, is extracted in the central part in the second phase. The factor may be related to the mineralization such as skarnization and pegmatization in terms of the relations of the distribution of the higher factor scores to the lithology and mineralization.

The factor, Be-(Li)-(Sn), is thought to be related to pegmatites because the distribution of

Table II-2-1 Statistical studies of stream sediment analytical data

	Elements	Mean	Variance	Standard deviation	Minimum	Maximum	Below detection limit(%)
Phase I	Au(ppb)	0.545	0.037	0.192	0.500	450.000	94.3
	Ag(ppm)	0.102	0.006	0.076	0.100	1.000	98.0
	Fe(%)	3.316	0.054	0.232	0.500	10.300	none
	Mn(ppm)	886.703	0.042	0.204	100.000	12305.000	none
	Mo(ppm)	1.562	0.108	0.329	0.500	101.000	21.8
	W (ppm)	5.073	0.006	0.076	5.000	125.000	99.0
	Sn(ppm)	1.672	0.150	0.387	1.000	68.000	68.1
	Nb(ppm)	23.853	0.200	0.447	5.000	660.000	14.8
	Ta(ppm)	5.394	0.023	0.151	5.000	89.000	94.9
	Be(ppm)	1.849	0.121	0.348	0.200	74.000	5.4
	Li(ppm)	4.053	0.068	0.261	0.500	20.000	1.5
	As(ppm)	0.771	0.081	2.285	0.500	25.000	59.2
	Sb(ppm)	0.721	0.025	0.157	0.500	5.000	48.3
Phase II	Au(ppb)	0.309	0.211	0.459	0.200	160.000	84.2
	Ag(ppm)	0.100	0.000	0.021	0.100	0.400	99.9
	Fe(%)	5.010	0.047	0.218	0.800	38.900	none
	Mn(ppm)	1068.634	0.060	0.245	120.000	11390.003	none
	Mo(ppm)	1.769	0.150	0.388	0.500	22.000	36.7
	W (ppm)	5.000	0.000	0.000	5.000	5.000	all
	Sn(ppm)	1.945	0.132	0.363	1.000	191.000	64.9
	Nb(ppm)	25.173	0.161	0.401	5.000	395.000	17.4
	Ta(ppm)	5.224	0.015	0.123	5.000	380.000	97.2
	Be(ppm)	0.962	0.178	0.421	0.200	78.000	35.9
	Li(ppm)	16.099	0.050	0.225	3.000	80.000	none
	As(ppm)	0.584	0.048	0.220	0.500	14.000	88.2
	Sb(ppm)	0.502	0.001	0.024	0.500	1.000	99.4
Phase III	Au(ppb)	0.246	0.119	0.344	0.200	63.000	93.1
	Ag(ppm)	0.100	0.000	0.021	0.100	0.400	99.9
	Fe(%)	3.279	0.030	0.173	0.510	18.580	none
	Mn(ppm)	1036.945	0.057	0.239	89.000	7386.010	none
	Mo(ppm)	0.578	0.026	0.162	0.500	4.000	84.8
	W (ppm)	5.246	0.016	0.125	5.000	268.000	96.5
	Sn(ppm)	2.149	0.090	0.299	1.000	19.000	40.6
	Nb(ppm)	23.147	0.140	0.374	5.000	680.000	11.8
	Ta(ppm)	5.799	0.051	0.226	5.000	270.000	90.8
	Be(ppm)	22.837	0.032	0.180	6.900	372.900	none
	Li(ppm)	26.369	0.041	0.201	5.000	86.000	none
	As(ppm)	1.381	0.054	0.233	0.500	4.000	15.5
	Sb(ppm)	0.500	0.000	0.011	0.500	1.000	99.9

Table II-2-2 Correlation among thirteen elements of stream sediments

	Elements	Au	Ag	Fe	Mn	Mo	W	Sn	Nb	Ta	Be	Li	As	Sb
Phase I	Au	1.000												
	Ag	-0.026	1.000											
	Fe	-0.014	0.097	1.000										
	Mn	0.049	0.052	0.629	1.000									
	Mo	-0.023	0.089	0.425	0.304	1.000								
	W	0.032	0.040	0.091	0.061	0.058	1.000							
	Sn	-0.069	0.138	0.297	0.111	0.404	0.160	1.000						
	Nb	-0.041	0.127	0.446	0.505	0.591	0.150	0.587	1.000					
	Ta	-0.005	0.121	0.221	0.141	0.262	0.218	0.592	0.535	1.000				
	Be	0.004	0.023	0.242	0.107	0.179	0.055	0.134	0.234	0.091	1.000			
	Li	0.008	-0.009	0.332	0.216	-0.070	-0.035	-0.155	-0.187	-0.139	0.045	1.000		
	As	0.018	0.022	0.016	0.090	-0.013	-0.003	-0.054	-0.088	-0.021	-0.054	0.142	1.000	
	Sb	-0.039	0.043	0.167	0.021	0.185	0.057	0.229	0.022	0.152	0.032	-0.036	-0.030	1.000
Phase II	Au	1.000												
	Ag	0.078	1.000											
	Fe	0.087	-0.023	1.000										
	Mn	0.066	-0.001	0.542	1.000									
	Mo	0.080	-0.050	0.454	0.267	1.000								
	W	0.000	0.000	0.000	0.000	0.000	1.000							
	Sn	-0.013	-0.028	-0.040	-0.025	0.092	0.000	1.000						
	Nb	0.009	-0.032	0.286	0.327	0.568	0.000	0.177	1.000					
	Ta	0.041	-0.005	0.130	0.193	0.161	0.000	0.055	0.340	1.000				
	Be	0.057	0.041	0.141	0.164	0.283	0.000	0.278	0.246	0.073	1.000			
	Li	-0.102	-0.020	0.068	0.139	-0.209	0.000	0.140	-0.151	-0.076	0.050	1.000		
	As	-0.013	0.182	-0.105	-0.100	-0.072	0.000	0.011	-0.065	-0.004	-0.012	0.057	1.000	
	Sb	-0.032	-0.003	-0.046	-0.072	0.018	0.000	0.095	0.018	-0.012	0.026	-0.031	0.019	1.000
Phase III	Au	1.000												
	Ag	-0.009	1.000											
	Fe	0.030	0.035	1.000										
	Mn	0.072	0.107	0.740	1.000									
	Mo	0.026	-0.014	-0.178	-0.159	1.000								
	W	0.044	-0.006	0.086	0.076	0.023	1.000							
	Sn	-0.005	-0.039	0.085	-0.033	0.049	0.101	1.000						
	Nb	0.052	-0.024	0.358	0.488	-0.001	0.162	0.198	1.000					
	Ta	0.092	-0.010	0.209	0.313	-0.008	0.129	0.107	0.567	1.000				
	Be	0.021	-0.032	0.097	0.012	0.066	0.127	0.316	0.318	0.233	1.000			
	Li	0.024	0.024	0.443	0.220	-0.104	0.005	0.104	0.037	0.015	0.360	1.000		
	As	0.018	0.024	-0.007	-0.033	-0.102	-0.093	-0.089	-0.104	-0.008	0.043	-0.029	1.000	
	Sb	-0.009	-0.001	-0.018	0.001	0.052	-0.006	-0.039	0.000	-0.010	-0.010	0.007	-0.067	1.000

Table II-2-3 EDA analyses for stream sediment analytical data

	Elements	Median	Lower fence	Lower wisker	Lower hinge	Upper hinge	Upper wisker	Upper fence	Upper fence or more(%)
Phase I	Au(ppb)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5.7
	Ag(ppm)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.0
	Fe(%)	3.40	-1.45	1.90	2.30	4.80	5.40	8.55	3.7
	Mn(ppm)	880	-65	620	670	1160	1270	1895	4.9
	Mo(ppm)	2.0	-2.0	0.5	1.0	3.0	3.0	5.0	5.2
	W (ppm)	5	5	5	5	5	5	5	1.0
	Sn(ppm)	1.0	-0.5	1.0	1.0	2.0	4.0	3.5	17.7
	Nb(ppm)	23	-29	10	13	41	54	83	11.6
	Ta(ppm)	5	5	5	5	5	5	5	5.1
	Be(ppm)	2.00	-2.00	1.00	1.00	3.0	3.0	6.0	2.1
	Li(ppm)	4.0	-1.5	2.0	3.0	6.0	7.0	10.5	2.2
	As(ppm)	0.50	-0.25	0.50	0.50	1.00	1.00	1.75	13.1
	Sb(ppm)	1.00	-0.25	0.50	0.50	1.00	1.00	1.75	0.9
Phase II	Au(ppb)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	15.8 *
	Ag(ppm)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1 *
	Fe(%)	4.8	-0.5	3.4	3.7	6.5	7.1	10.7	7.2
	Mn(ppm)	1040	-320	680	760	1480	1610	2560	6.2
	Mo(ppm)	2.0	-2.0	0.5	1.0	3.0	4.0	6.0	10.1
	W (ppm)	5	5	5	5	5	5	5	--
	Sn(ppm)	1.0	-3.5	1.0	1.0	4.0	5.0	8.5	6.0
	Nb(ppm)	28	-34	11	14	46	55	94	6.8
	Ta(ppm)	5	5	5	5	5	5	5	2.8 *
	Be(ppm)	1.00	-1.75	0.50	0.50	2.00	2.00	4.25	2.8
	Li(ppm)	16	-7	11	11	23	26	41	2.8
	As(ppm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	11.8 *
	Sb(ppm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6 *
Phase III	Au(ppb)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	6.9
	Ag(ppm)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
	Fe(%)	3.35	0.39	2.46	2.67	4.19	4.54	6.47	2.7
	Mn(ppm)	1025	-307.5	669	735	1430	1598	2472.5	5.7
	Mo(ppm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	15.2
	W (ppm)	5	5	5	5	5	5	5	3.5
	Sn(ppm)	3	-3.5	1	1	4	4	8.5	1.2
	Nb(ppm)	22	-18	13	15	37	45	70	10.0
	Ta(ppm)	5	5	5	5	5	5	5	9.2
	Be(ppm)	22.5	-2.05	15.8	17	29.7	32.5	48.75	2.6
	Li(ppm)	27	-5.5	18	20	37	40	62.5	1.9
	As(ppm)	2	-0.5	1	1	2	2	3.5	0.01
	Sb(ppm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0