Chapter 2 Geologic survey in area B

2-1 Purpose and procedure

2-1-1 Purpose of the survey

The purpose of the survey is to realize geology and gold mineralization. The followings are main points in the survey.

1) To realize the distribution of rocks and their stratigrafy.
2) To disclose geological structure.
3) To correlate gold mineralization and the host rocks
4) To locate gold-bearing quartz veins
5) To correlate mineralizations and geological structures in regional point of view.

2-1-2 Procedures of the survey

The density of the survey route is more than 0.8km^2 to cover all of the objected area. As mentioned below, stream sediment and pan concentrate samples were collected for geochemical survey in parallel with the geological survey.

Before the field survey was started, topographic maps of 1/50,000 scale were prepared in Japan for the area of 550km^2 from the aerophotographs of 1/60,000 scale which had been taken in Brazil. The maps in a scale of 1/250,000 were used during the field survey, which are enlarged from the maps in a scale of 1/50,000.

2-2 Detailes of the survey

2-2-1 Geology

Archaean Caico Complex, Proterozoic Serodo Group and

Tertiary Serra dos Martins Formation were dominantly distributed in this area. Proterozoic Serido Group were subdivided into three formations, Jucurutu Formation, Equador Formation and Serido Formation. The stratigraphy constructed by Jardim de Sa and Salim (1978) and Jardim de Sa (1982) is applied in this area (Fig.II-2-2).

(1) Cacico Complex

(i) Distribution

This Complex crops out in the north of Santa Luzia do Picui and the uppermost part of Riacho Saco do Jirau in the southeastern most part of this area (PL.II-2-1, Fig.II-2-1).

(ii) Lithology

According to Jardim de Sa (1987), this Complex is subdivided into two units. One of them is a gneiss which is called TTG (Tonalite-Trondhjemite-Granite) originated from plutonic rocks and is associated with migmatite. The other is meta-sediments which is composed of amphibolites, schists, quartzites, ultra-basic rocks and marbles.

Granite (pCgn1) crops out in this area, which is classified into TTG.

Chemical analysis and thin section observation were made for the rock sample A117 (Table.II-2-1, Table.II-2-2).

Rock name and mineral assemblages are as follows. The sample is pale brown, fine graind, equigranular and has gneissose texture.

Rock name: Gneissose biotite granite

Texture: Gneissose

Rock forming minerals:

Principal minerals; quartz, K-feldspar, biotite, plagioclase

Accesory minerals; chlorite, sphene, apatite, zircon

Opaque minerals; exist

Secondary minerals; fine grained muscovite

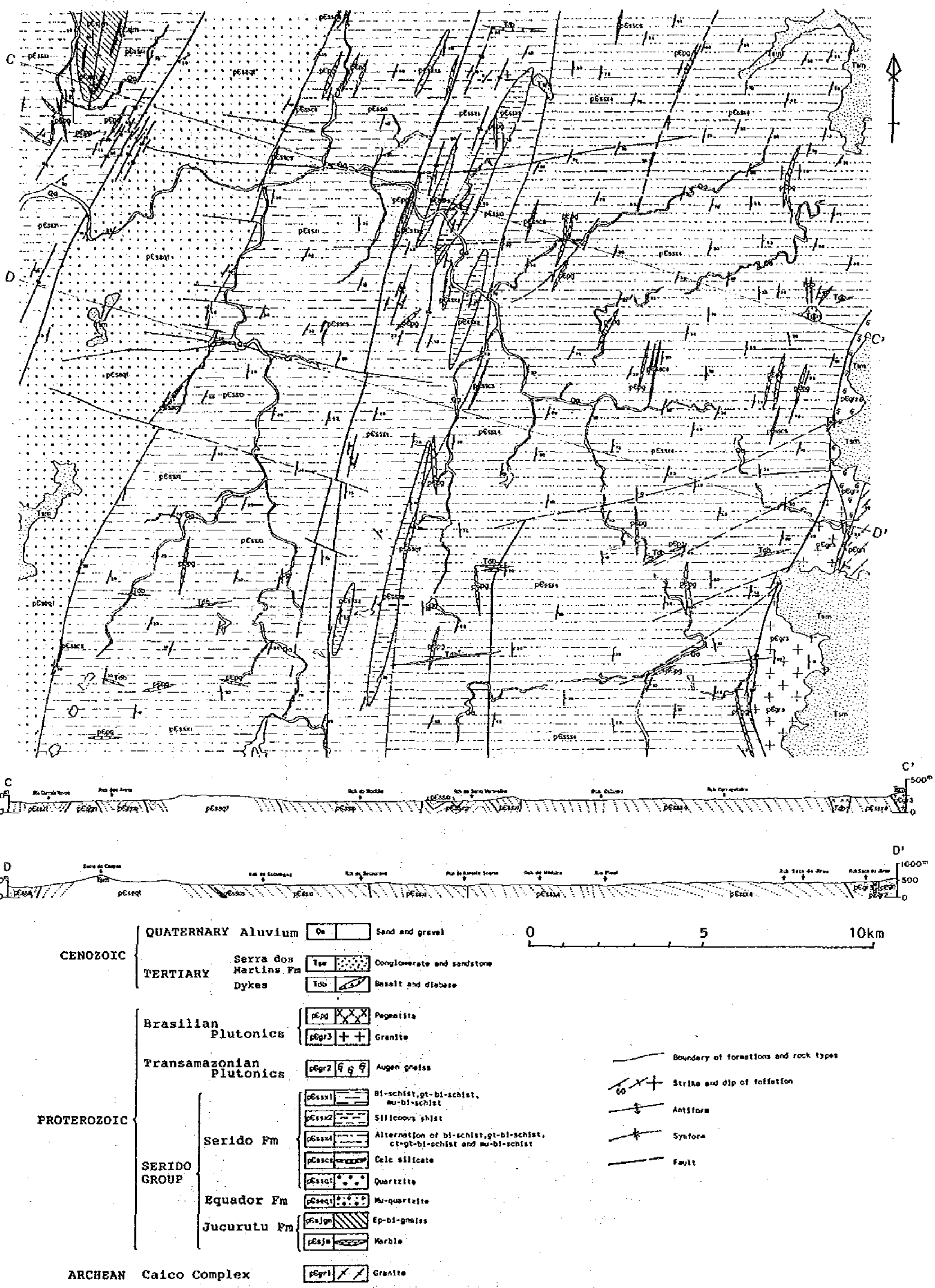
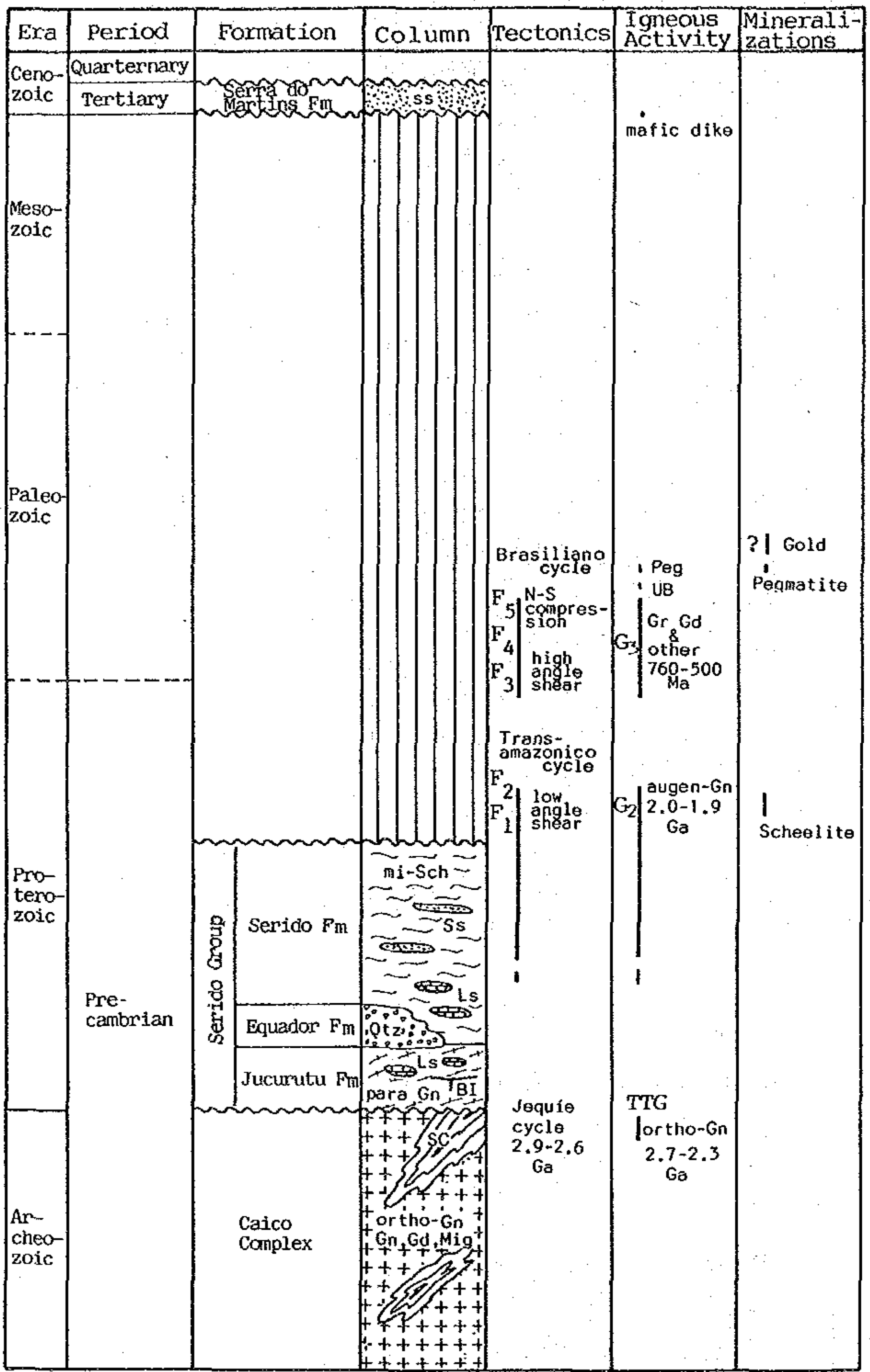


Fig. II-2-1 Geologic map of area B



F_2: Phases of the structural events
TTG: Plutonic rocks in the Caico Complex
G_2: Transamazonian plutonic rocks
G_1: Brazilian plutonic rocks

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

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

Fig. II-2-2 Generalized columnar section of area B

Tab. II-2-1 Analytical data of rock samples from areas A and B

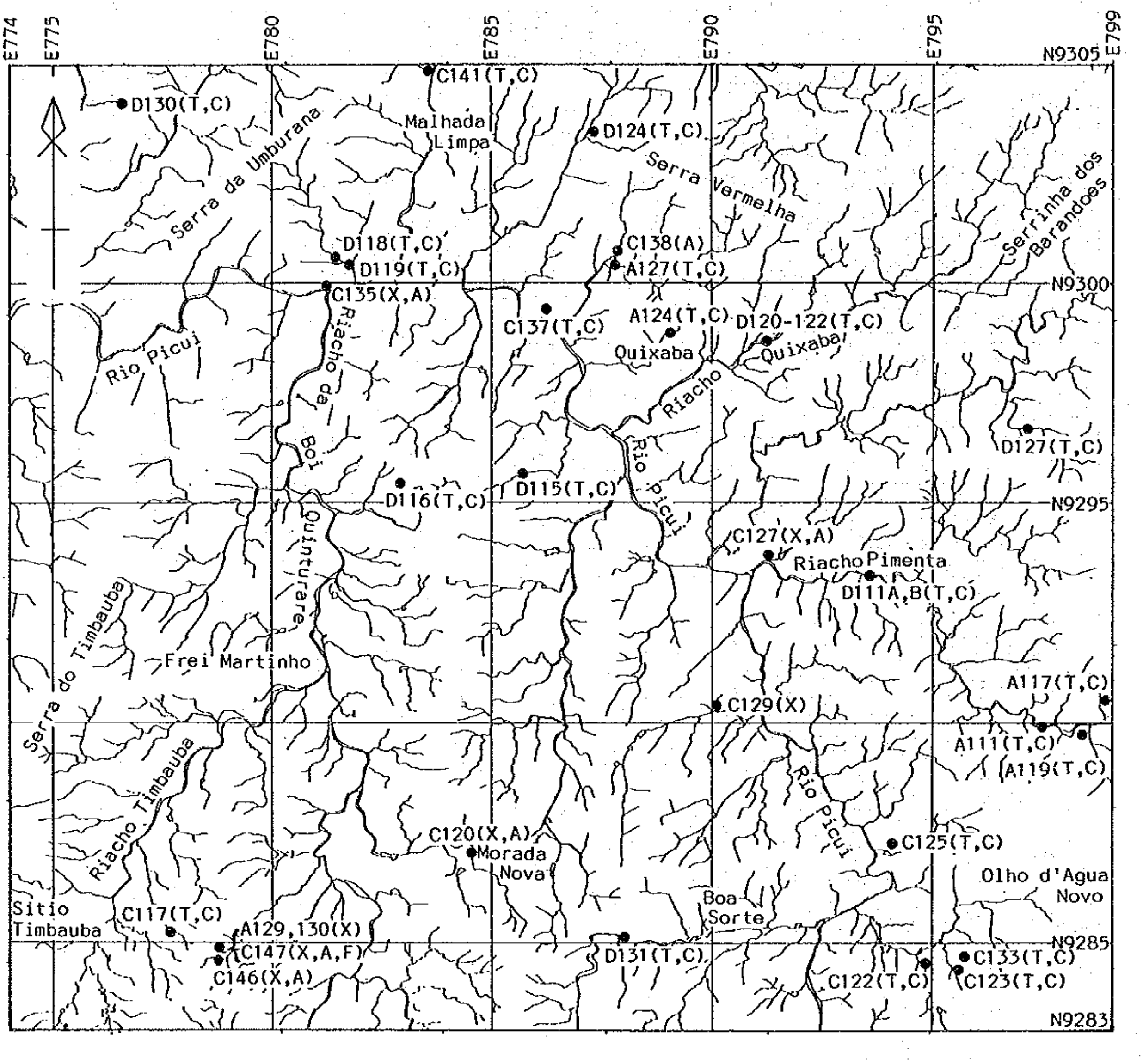
Sample No.	A101	C112	D101	A105	D102	A127	C117	C137	D111A	D111B	D115	D119	D120	D121	D122
Coordinates of location	E793.87 N9316.88	E792.55 N9316.29	E794.02 N9317.05	E792.03 N9306.37	E791.72 N9306.98	E787.75 N9300.55	E777.75 N9285.25	E786.25 N9299.25	E793.65 N9293.35	E793.65 N9293.35	E785.65 N9295.65	E781.75 N9300.45	E791.10 N9298.65	E791.10 N9298.65	E791.10 N9298.65
Lithology	bi-ms-Sch	bi-ms-Sch	hb brg bi-Sch	ep-gt-st Rock	Cataclastic Rock	bi-ms-Sch	gt-bi-Sch	bi-ms-Sch	gt-bi-Sch	ct-bi-Sch	bi-ms-Sch	gt-bi-Sch	bi-ms-Sch	gt-bi-ms-Sch	gt-bi-Sch
SiO2 %	73.60	74.00	72.50	58.50	68.10	71.10	50.40	72.40	68.70	66.40	72.60	67.60	69.30	69.00	69.30
TiO2 %	0.72	0.67	1.00	0.62	0.78	0.85	1.10	0.94	0.77	0.92	0.83	0.81	0.81	0.77	0.79
Al2O3 %	11.20	11.50	10.30	15.60	14.10	12.20	22.80	11.40	14.10	16.70	11.90	14.40	14.50	14.40	14.30
Fe2O3 %	2.80	3.00	2.50	2.90	1.40	2.70	3.40	3.70	1.10	2.60	3.10	1.40	1.10	2.70	1.90
FeO %	1.60	1.10	2.90	2.90	3.50	2.40	6.10	1.80	4.20	4.20	1.80	4.20	4.50	2.70	3.50
MnO %	0.08	0.10	0.12	0.90	0.21	0.10	0.21	0.10	0.11	0.19	0.11	0.09	0.09	0.11	0.21
MgO %	2.50	2.20	2.80	2.90	2.70	3.00	4.70	2.30	2.80	3.90	2.30	3.10	2.60	2.40	2.20
CaO %	2.10	2.70	3.40	14.00	1.10	2.50	2.90	2.80	1.90	1.10	2.80	2.50	1.60	1.80	2.50
Na2O %	2.60	2.60	2.10	0.74	2.10	2.30	3.90	1.90	3.60	1.60	2.00	3.10	2.70	3.40	2.60
K2O %	2.20	1.40	1.70	0.10	3.10	2.20	4.00	1.90	2.00	1.70	1.90	2.20	2.20	2.10	1.70
P2O5 %	0.18	0.12	0.19	0.32	0.23	0.15	0.15	0.17	0.14	0.20	0.14	0.21	0.18	0.05	0.40
LOI %	0.00	0.01	0.00	0.00	2.14	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total %	99.58	99.40	99.51	99.48	99.46	99.50	99.67	99.41	99.43	99.52	99.49	99.62	99.59	99.44	99.41
Au ppb	5.0	33.0	L 0.5	13.0	L 0.5	L 0.5	L 0.5	L 0.5	1.0	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5
Ag ppm	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2
Fe %	3.2	2.9	4.0	4.3	3.7	3.8	7.1	4.0	4.1	5.1	3.6	4.3	4.3	4.0	4.1
Mn ppm	620	770	930	6970	1630	770	1630	770	850	1470	850	700	700	850	1630
Mo ppm	5	2	3	4	L 1.0	1	L 1.0	11	3	3	2	3	2	2	2
W ppm	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Sn ppm	5	L 2	L 2	4	L 2	L 2	L 2	2	L 2	L 2	2	2	2	L 2	2
Nb ppm	24	14	L 10	34	L 10	14	L 10	30	L 10	13	24	24	19	15	20
Ta ppm	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Be ppm	2	1	L 0.5	L 0.5	1	2	2	1	L 0.5	2	2	L 0.5	L 0.5	2	0.5
Li ppm	29	23	11	L 5.0	29	34	46	23	29	97	29	17	11	23	11
As ppm	L 1	L 1	L 1	82	36	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	5	15
Sb ppm	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1

Tab. II-2-1 Analytical data of rock samples from areas A and B (continued)

Sample No.	D124	D131	A124	C122	C125	C141	D116	D118	D130	A111	C123	C133	A119	A117	D127
Coordinates	E787.20	E788.05	E789.10	E794.85	E794.30	E783.65	E783.00	E781.45	E776.75	E797.50	E795.55	E795.60	E798.40	E798.85	E797.15
of location	N9303.40	N9285.10	N9298.90	N9284.50	N9287.30	N9304.85	N9295.50	N9300.60	N9304.20	N9289.90	N9284.40	N9284.75	N9289.80	N9290.45	N9296.70
Lithology	bi-ms-Sch	ct-bi-ms-Sch	gt brg am-Sch	gt brg am-Sch	gt-ep-st Sch	ep-st-Sch	gt brg am Sch	hb-ep-st Rock	hb-bi-Gt	hb-bi Gd	hb-bi Gt	hb-bi Gt	bi Gt	bi-Gt	Basalt
SiO2 %	72.80	61.70	58.20	62.60	60.20	49.10	69.30	51.00	74.60	62.60	66.90	64.70	69.50	69.60	47.30
TiO2 %	0.66	0.92	0.89	0.82	0.72	1.10	0.66	1.60	0.63	0.69	0.32	0.47	0.27	0.23	1.90
Al2O3 %	12.50	17.70	16.80	14.00	13.10	21.60	11.40	7.60	10.70	16.60	16.20	16.30	14.80	15.00	11.00
Fe2O3 %	2.60	2.40	2.50	2.90	1.20	1.20	1.40	1.60	2.50	3.50	1.30	2.60	1.40	1.30	6.60
FeO %	1.60	5.30	4.80	4.20	5.10	1.90	3.80	5.00	1.10	2.40	2.00	2.00	1.40	1.40	4.20
MnO %	0.10	0.14	0.66	1.10	1.10	0.10	0.33	0.22	0.12	0.11	0.12	0.09	0.08	0.08	0.20
MgO %	1.70	3.40	3.20	3.30	2.40	3.80	2.70	9.20	1.20	2.70	0.84	1.40	0.71	0.38	13.10
CaO %	2.20	2.20	11.40	9.20	14.70	19.20	7.30	22.60	3.00	5.60	2.70	3.40	2.20	1.40	10.00
Na2O %	2.60	2.90	0.77	0.91	0.61	1.20	0.71	0.59	3.00	2.80	4.00	4.10	4.10	4.10	3.40
K2O %	2.70	2.70	0.07	0.21	0.10	0.15	1.80	0.08	2.50	2.40	5.10	4.30	4.80	6.00	1.20
P2O5 %	0.13	0.12	0.16	0.29	0.30	0.15	0.19	0.16	0.14	0.21	0.14	0.15	0.16	0.07	0.55
LOI %	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
total %	99.60	99.49	99.45	99.54	99.54	99.51	99.60	99.66	99.50	99.61	99.62	99.51	99.42	99.56	99.46
Au ppb	L 0.5	L 0.5	7.0	35.0	6.0	9.0	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5	2.0
Ag ppm	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2	L 0.2
Fe %	3.1	5.8	5.5	5.3	4.8	2.3	3.9	5.0	2.6	4.3	2.4	3.4	2.1	2.0	7.9
Mn ppm	770	1080	5110	8520	8500	770	2560	1700	930	850	930	700	620	620	1550
Mo ppm	2	2	2	4	5	5	1	5	1	6	4	2	1	1	5
W ppm	L 10	L 10	L 10	700.0	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Sn ppm	2	2	6	23	73	6	2	L 2	L 2	L 2	6.0	6.0	2.0	2.0	8.0
Nb ppm	23	14	11	24	28	17	15	28	12	14	20	20	10	10	21
Ta ppm	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10	L 10
Be ppm	1	L 0.5	L 0.5	10	18	4	1	3	0.5	0.5	2	1	1	1	0.5
Li ppm	23	40	L 5	L 5	L 5	L 5	L 5	L 5	11	L 5	116	60	40	48	8
As ppm	L 1	L 1	L 1	L 1	L 1	L 1	L 1	5	L 1	L 1	L 1	L 1	L 1	L 1	8
Sb ppm	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1

Tab. II-2-2 Mineral assemblages of the rocks taken from areas A and B, determined by thin section observation

Sample	Rock name determined by thin section observation	structure	Rock forming minerals																Opaque minerals	Secondary minerals			Remarks
			Quartz	Potash feldspar	Plagioclase	Biotite	Muscovite	Hornblende	Salite	Pyralspite	Cordierite	Sphene	Apatite	Zircon	Chlorite	Epidote	Calcite	Tourmaline		Fine-grained muscovite	Limonite		
A101	Biotite-muscovite schist	Schistose	◎	∘	·	○	∘							·				·	·				Granular, partly with preferred orientation
A105	Epidote-garnet-salite rock	Granular	○		○				∘	○		·	·	·		○	Cz		·				
A111	Schistose hornhlendse biotite grano diorite	Schistose	◎	∘	∘	○		○					·	·							·		
A117	Gneissose biotite granite	gneisscec	◎	◎	·	○						·	·	·	∘				∘	∘			
A119	Gneissose biotite granite	gneisscec	○	◎	∘	○		∘				∘	·	·	∘	·			∘	∘			
A124	Garnet-bearing amphibolite schist	Schistose	○		○			◎		○			·	·	∘	·			∘				Garnet porphyroblast
A127	Biotite-muscovite schist	Schistose	◎	∘	∘	○	∘					·	·	·				·	∘				
C112	Biotite-muscovite schist	Schistose	◎	∘		○	∘						·	·	·	·			∘	∘			
C117	Garnet-biotite schist	partly Schistose	○	∘	∘	◎	·			○	·		·	·		·	Cz		·				Coarse grained biotite Garnet porphyroblast
C122	Garnet-bearing amphibolite schist	Schistose	◎		○			○		○		·	·			∘	∘			∘	∘		Garnet parphyroblast
C123	Gneissose hornblende-biotite quanite	Granular	◎	○		○		○				∘	·	·	·	·			·				
C125	Garnet-epidote-salite schist	partly Schistose	○		○				∘	○		·	·	·		○	∘		·				
C133	Gneissose hornblende-biotite granite	Granular	◎	○	∘	○		∘				·		·									
C137	Biotite-musvovitc schist	Schistose	○	·		○	∘						·	·	·	·			·	·			
C141	epidote-salite schist	Schistose	∘		◎				∘			∘	·	·		◎	∘						
D101	Hornblende-bearing biotite schist	Schistose	◎		∘	○		∘				·	·	·	∘	∘			·				
D102	Catacl astic rock	Cataclotic	◎		·	·				∘		·	·	·	○	·			·	○			Wavy extinction distict (Q)
D111A	Garnet-biotite schist	Schistose	◎	○		○				○	∘		·	·				·	∘				
D111B	Cordierite-biotite schist	Schistose	◎			○	∘				○		·	·	·			·	·				
D115	Biotite-muscovite schist	Schistose	◎		·	○	∘						·	·	·	·			·	∘			
D116	Garnet-bearing amphibolite schist	Schistose	○		○			◎		○		·	·	·		∘	Cz						
D118	Hornblende-epidote-salite rock	Granular	○		○			○	○			∘		·		◎	Cz ·						Prehnite veinlet ?
D119	Granet-biotite schist	Schistose	◎		○	○				○			·	·	·			·	·				
D120	Biotite-muscovite schist	Schistose	◎	∘		◎	∘			·		·	·	·	·			·	·				
D121	Garnet-biotite-muscovite schist	Schistose	◎	∘		○	∘			∘	·		·	·	·			·	·	∘			
D122	Garnet-biotite schist	Schistose	◎	∘		○	·			○			·	·					·	∘			
D124	Biotite-muscovite schist	Schistose	◎	○	∘	○	∘						·	·	·	·			·	·			
D130	Hornblende-biotite gneiss	Schistose	◎	∘	∘	○		∘				∘	·	·	∘	·	·		·				Hbl-b+ Greiss Grarodiorite
D131	Cordierite-biotite-muscovite schist	Schistose	◎			○	∘				○		·	·	·			·	·				
D127	Basalt	Porphyritic	Phenocryst : augite, olivine groundmass : augite, hyperthene, magnetite, plagioclase, ilmenite. Secondary, minerals : chlorite, quartz, clinozoisite																				



C117; Sample number
T; Thin section observation
C; Chemical analyses for whole rock
X; X-ray difractometry
A; Ore assay
F; Fluid inclusion study

Fig. II-2-3 Location of samples for laboratory tests

(iii) Age

There are not any evidence to show geologic time in this area. Therefore, this unit was correlated to Caico Complex because of the lithology.

(iv) Stratigraphic position

This unit is situated in the lowermost position in this area.

(2) Jucurutu Formation

(i) Distribution

This unit crops out from Sao Sebastiao in the north-western-most part of this area to nothern Currais Novos (Pl.II-2-1, Fig.II-2-1). The area of distribution forms elliptical shape. Its width is about 2km and its length is about 8km.

(ii) Thickness of the unit

According to Torres et al. (1973), the thickness of the unit is more than 300m in the central southern part of the State of Rio Grande do Norte. However, in this area the thickness is not known because only the upper unit is exposed.

(iii) Lithology

According to Lima (1986), this unit is mainly composed of biotite gneiss associated with biotite schist, amphibolite, hornfels, quartzite and calc-silicate. In this area, this unit is composed of quartzo-feldspathic gneiss (pCsjgn) including biotite, hornblende and epidote. One marble unit two to three meters wide intecalates in it.

Chemical analysis and thin section observation were executed for one rock sample D130. Chemical composition and mineral assemblages of the sample are shown in Table.II-2-1 and Table.II-2-2 respectively. This sample is mottled light grey, fine to coarse grained and has schistosity. Spotted epidote can be seen by hand lense.

Rock name: Hornblende-biotite gneiss

Texture: gneissose

Rock forming minerals:

Principal minerals; quartz, biotite, K-feldspar, plagioclase, hornblende

Accesory minerals; chlorite, sphane, apatite, zircon, epidote

Opaque minerals; exist

Secondary minerals; calcite

(iv) Ages

According to Lima (1986), the unit is correlated to early Proterozoic. No informations concerning radiogenic dating and fossils were available in this survey.

(v) Stratigraphic position

Jucurutu Formation does not contact with Caico Complex in this area. Therefore, the relation between these two is not known in this area. Furthermore, the Jucurutu Formation does not contact with stratigraphically upper Equador Formation, but with biotite schist of Serido Formation. At the contact between the Jucurutu and the Serido, any faults can not be traced even in stractural point of view. The unit crops out along to the axis of anticline trending north and plunging to the south, and the unit extends under the biotite schist of the Serido Formation.

The Jucurutu Formation, which was supposed to be distributed on the north and east edge of the Equador Formation in the west of the survey area in the previous survey (DNPM/CPRM, 1980), could not be followed in the phase II survey.

Scheelite deposites associated with tactite such as those of Malhada Limpa and Sitio Timbauba were thought to be hosted in the Jucurutu Formation. However, those deposits were identified in the phase II survey to be hosted in the biotite schist of the Serido Formation and at the contact between the Jucurutu Formation and the Serido Formation.

(vi) Sedimentary environment

The Jucurutu Formation is supposed to be shallow marine sediments because of the lithology such as being with limestone.

(3) Equador Formation

(i) Distribution

The Equador Formation is distributed trending north northeast in the western part of the survey area (PL.II-2-1, Fig.II-2-1). The distribution area is about 5km wide, and extends from the northern outside to the southern outside of the area. The unit forms deeply cut mountains 600m high due to the characteristic lithology and structure described later. There are Serra do Umburana, Serra do Chapeu and Serra do Timbauba from the north to the south.

(ii) Thickness of the unit

According to Ebert (1968), the thickness is more than 800m in the central southern part of the State of Rio Grande do Norte. In this area, the thickness of the formation is not disclosed because the formation contacts with the upper Serido Formation, but not with the lower formation.

(iii) Lithology

The formation is composed of quartzite, muscovite quartzite and muscovite feldspathic quartzite. Biotite can locally be seen. The rock of the formation is harder than biotite schist of the Serido Formation and bears against weathering. The rocks are easily broken into thin plates few cenntimeters thick along bedding plane and schistosities. Many folds with short wave length are well developped in the western most part of the area. Their axes trend north-northeast. Some folds in a very small scale with few to tens of centimaters of wave length can be seen.

(iv) Ages

The formation is in lower Proterozoic.

(v) Stratigraphic position

This formation conformably overlies the Jucurutu Formation. Their contact can not be seen in this area.

(vi) Sedimentary environment

It is side to be pre-orogenic sediments.

(4) Serido Formation

(i) Distribution

This area is widely underlain by the Serido Formation (PL.II-2-1, Fig.II-2-1). It is distributed in the west of north northeast trending line connecting Sitio Areias and Aba da Serra and in the east of north northeast trending line connecting Malhada Limpa, Pe da Serra and Sitio Tinbauba until the eastern most part of the area. The area is about 20km wide in the east-west direction. The formation trends north northeast in most of the area.

(ii) Thickness of the unit

According to Ferran et al. (1973), the average thickness of the formation is the order of 300m. It could not be measured in phase II survey.

(iii) Lithology

The unit is principally composed of mica schist associated with silicious schist, calc-silicate and small amount of quartzite in this area.

The mica schist was subdivided into three subunits in this survey area. They are pCssx1, pCssx2 and pCssx4. This pCssx1 is not the one of phase I. It is divided into pCssx1 and pCssx4 from the lithological point of view. pCssx2 is defined just as the one of phase I. The unit in the western half, which is named pCssx1 in phase II, is principally composed of biotite schist accompanied by small amount of garnet-biotite schist and cordierite-biotite schist. In the eastern margin of pCssx1, muscovite-biotite schist exists in the zone, 3km wide, trending north northeast. The muscovites are of small amount and larger than principal rock forming minerals like quartz and biotite. The muscovites does not always extend in parallel with the other minerals. The muscovites may be the products of retrograde metamorphism.

In the zone of the eastern margin of pCssx1 described above, a number of siliceous biotite schists, which is called pCssx2, crop out in a small scale. They extend also trending north northeast. The zone is a fold zone. The axes of folds trend north northeast, and their wave length are some hundreds of meters. pCssx2 occurs as inliers. pCssx2 is siliceous and has less biotite. It is more compact and harder than pCssx1. The west end of the zone, which is identified by fault trending north northeast, goes through Mochila, Serra da Sucuarana and Varzea Verde from the north to the south. The east end of the zone, which trends north northeast along its contact with pCssx4, goes through Serra Vermelha, Cauacu de Baixo and east of Morada Nova.

The unit in the western half of the area is identified by the alternation of following lithological unit, which is named pCssx4. The lithological units are mainly composed of biotite schist, garnet-biotite schist, cordierite-garnet-biotite schist. The thickness of each lithological unit are about 10cm to 2m. A lot of garnet are not always included, but a large amount of cordierite is always included. The contact between pCssx1 and pCssx4 can be traced easily.

Quartzite unit, pCssx2, crops out inside the area of pCssx1 to the south of Cauasu de Sima.

Calc-silicate rocks, pCsscs, are disparsed in a small scale all over the Serido Formation. The outcrops are some tens of centi-meters in width and few to some ten of meters in length. Many outcrops of pCsscs can be seen in the zone trending north northeast with the width of 4km from the east of Serra Vermelha to Quixaba in central northern part of the survey area. To the north of this zone, in the phase II survey area, a lot of outcrops of pCsscs can be seen.

Some beds of pCsscs are sometimes accompanied by scheelite deposit. Scheelite deposits are mostly localized at the contact between the Serido Forqmation and the Equador Formation. Ore deposits of Malhada Limpa, Pe da Serra and Sitio Timbauba sliging from the north to the south are the famous ones. At Cauacu in the central part of the Serido Formation scheelite was also reported to have been mined.

Schistosities are well developed in the Serido Formation. Biotite schist is partly milonitized along the folds trending north northeast at the central part and at the eastern most part of the survey area. Furthermore garnet porphylobrasts of biotite schist are broken into small fragments along the folds at the easternmost part of the survey area.

Chemical analyses and thin section observation were executed for 23 rock samples taken from the Serido Formation.

5 samples were taken from pCssx1, 4 samples from pCssx2, 7 samples from pCssx4 and 7 samples from pCsscs.

The results of the chemical analyses are as follows (Table.II-2-1). Location of 16 samples of the Serido Formation in ACF diagrams are inside the limit of pelitic rock-greywacke except for 7 samples of pCsscs (Fig.II-2-4). The location of those 16 samples are shifted toward the A-C line from the vertex F inside the limit compared to the location of samples taken in phase I area. That is, the amount of (Feo+MgO+MnO) is lesser than that of the samples in phase I. The location of the samples, taken in phase I area, in ACF diagram were nearer to the vertex F than that of phase II area. Au content of the 16 samples is less than 5 ppb, leser than that of phase II survey area. Li content of the Serido Formation is more than that of calc-silicates. This might be because of the amount of mica schist. Mn is supposed to be included in garnets. Mn abounds in the mica schists of the Serido Formation.

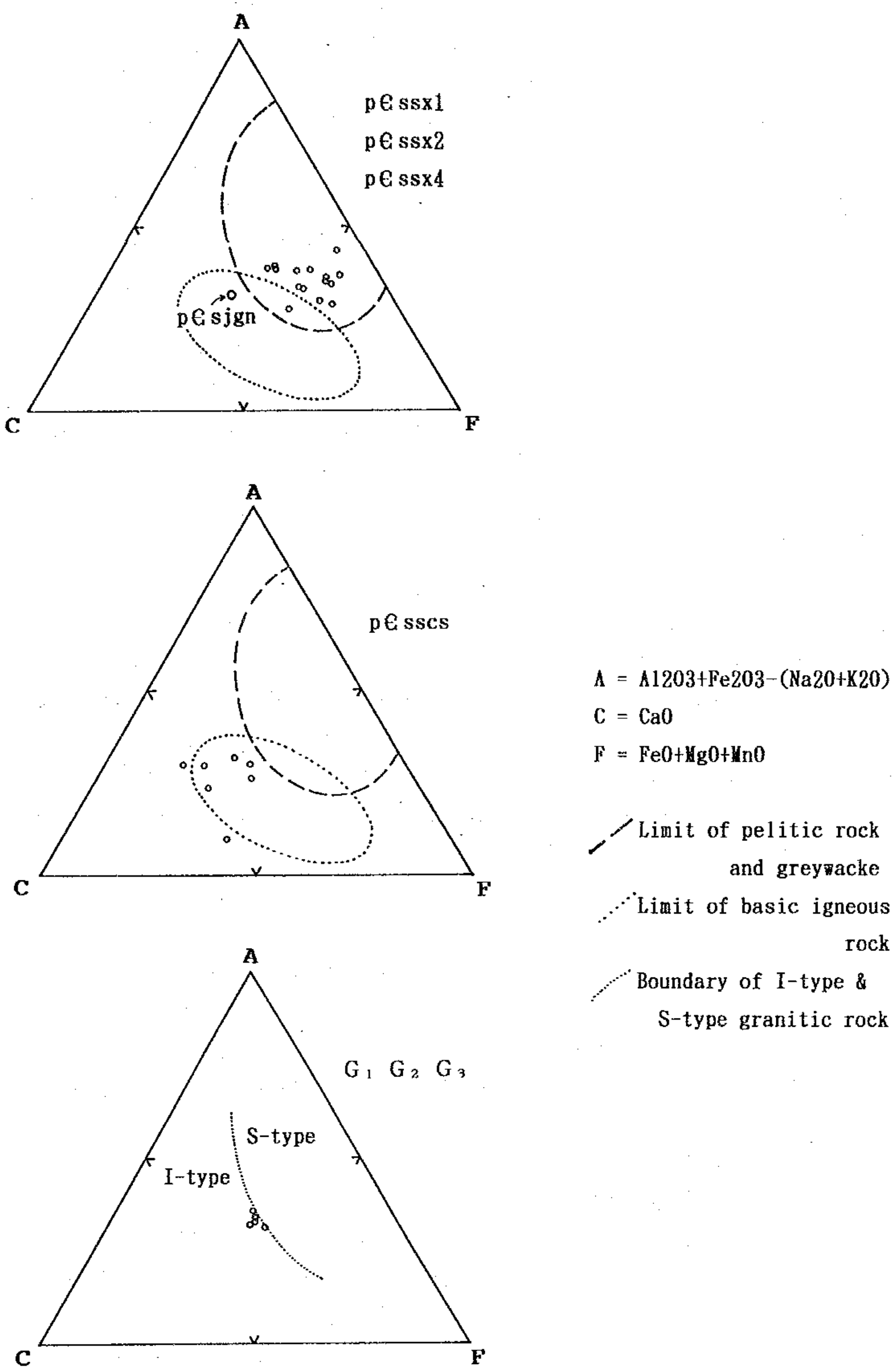


Fig. II-2-4 ACF diagrams drawn from the analytical data of rock samples, area B

The samples of pCsscs is located inside the limit of basic igneous rock in the ACF diagram except two samples (Fig.II-2-3). The two samples are C141 and D118. C141 is plotted upper left outside the limit of basic igneous rosk of the ACF diagram, the other is plotted lower left outside the limit of it. Both of the two samples were taken from the boundary between the Serido Formation and the Equador Formation. Sample C141 was sampled from Malhada Limpa, sample C118 was taken from Pe da Serra. The contents of CaO in the samples C141 and C118 are 19.2% and 22.6% respectively. The contents are more than that of other rocks of pCsscs. Both of them are assumed to be originated from calcaleous rocks. The rocks of pCsscs inside the limit of basic igneous rocks are possibly originated from basic rocks, even if they were called calc silicate rocks, pCsscs, as a field name. The rock forming minerals resemble those of basic rocks. The rocks of that kind are to be more sampled and studied by chemical analyses. Samples A105, C122 and C125, which are called pCsscs, are added As, Mo, Sn, Be and Au. They are thought to be mineralized by the fluid originated from granitic rocks and they are called tactites.

The results of thin section observation are as Table. II-2-2 and compiled as follows.

1) Mica schist of pCssxl:

The samples are grey to dark grey, medium to coarse grained and has schistosity. Prophyroblasts of garnet and muscovite are included in some of the samples.

Rock name: biotite-muscovite schist, garnet-biotite schist

Texture: schistose

Rock forming minerals:

Principal minerals; quartz, biotite, (K-feldspar), (plagioclase), (muscovite), (cordierite)

accesory minerals; apatite, zircon, (chlorite), (clinozoisite), (tourmaline)

opaque minerals; exist
secondary minerals; (fine grained muscovite)
Minerals in parenthesis are partly lacking.

2) Mica schist of pCssx2

The samples are grey, fine to medium grained and has schistosity. The rocks are compact and harder than the rocks of pCssx1 and has black and white banded structure. Some samples have small amount of muscovite.

Rock name: biotite-muscovite schist
Texture: schistose
Rock forming minerals:
principal minerals; quartz, biotite, (plagioclase), (K-feldspar), (muscovite)
accesory minerals; apatite, (sphene), (zircon), (clinozoisite), (tourmaline)
opaque minerals; exist
secondary minerals; (fine grained muscovite)

3) Mica schist of pCssx4

The samples are grey to brownish grey, meedium to coarse grained and has schistosities. Some samples are mottled like salt and pepper. Garnet porphyroblasts smaller than 2mm diameter are included in the samples D102, D111A, D121 and D122. Cordierite porphyroblasts can be seen in the samples D111B and D131. Black and white banded texture are well developed in the samples D120 and D121.

Rock name: garnet-biotite schist, cordierite-biotite schist, biotite-muscovite schist, garnet-biotite-muscovite schist, cordierite-biotite-muscovite schist and cataclastic rock (D102)
Texture: schistose
Rock forming minerals:
principal minerals; quartz, biotite, (K-feldspar), (muscovite), (garnet), (cordierite), (plagioclase)
accesory minerals; zircon, (apatite), (tourmaline),

(plagioclase)
opaque minerals; exist
secondary minerals; (fine grained muscovite),
(chlorite)

4) Calc-silicate rocks of pCsscs

The samples are greenish grey, fine to medium grained and grano-nematoblastic. Garnets can be seen in all of the samples except for C141.

Rock name: epidote-garnet-salite rock, garnet-bearing amphibole schist, epidote-salite schist, amphibole-epidote-salite schist

Texture: granular, schistose

Rock forming minerals:

principal minerals; quartz, plagioclase, (amphibole), (garnet), (clinozoisite)
accesory minerals; (sphene), (apatite), (zircon), (chlorite), (calcite)
opaque minerals; exist
secondary minerals; (fine grained muscovite)

(iv) Ages

The unit is of Pre Cambrian age, because it suffers from Transamazonian tectonics (2200 to 1800 Ma, Brito Neves).

(v) Stratigraphic relation

The unit conformably overlies the Equador Formation. The Serido Formation has an interfinger relations with the lower Equador Formation in the west of Pe da Serra in the western part of the area. Calc-silicate rocks sometimes occur at the contact between the Serido Formation and the Equador Formation. The contact of the Serido Formation with the Jucurutu Formation in the northwestern most part of the area can not directly be seen. However, the Serido Formation structurely conformably contacts with the Jucurutu Formation.

(vi) Sedimentary environment

It is thought to be flysh and deep ocean sediments composed of cyclic greywacke and argillite-terbidite.

(5) Tertiary Serra dos Martins Formation

(i) Distribution

The rocks of the unit crop out on mesas 600m and 620m high in the easternmost part and in the western part of the area respectively (PL.II-2-1, Fig.II-2-1). The rock also crops out on the top of Serra Vermelha 600m high in the central part of the area.

(ii) Thickness of the unit

The unit is 30m thick in this area. However, it is acturely more than that because the top of the unit was eroded out.

(iii) Lithology

The unit is principally composed of conglomerates, sandstones and argillitic shales.

(iv) Ages

This unit is correlated to Tertiary from the lithological point of view. Fossils do not occur in this area.

(v) Stratigraphic relation

The unit unconfromably overlies Archaean and Proterozoic formations in this area.

(vi) Sedimentary environment

According to Bigarella (1975) in Santos et al. (1984), the unit is of continental sediments which was deposited on pediplane.

(6) Intrusive rocks

Intrusive rocks in this area are classified into four groups. They are the ones of Transamazonian orogenic age, the ones of Brazilian orogenic age, the ones of Proterozoic to Palaeozoic age and the ones of Tertiary age. Jardim de Sa (1981) called the intrusives of Transamazonian orogenic age G2 and the intrusives of Brzilian orogenic age G3.

(i) G2 intrusive rocks

This intrusives crop out trending north at the upper most part of the Riacho Saco do Jirau to the north of Santa Luzia do Picui in the southeastern most part of the survey area (PL.II-2-1, Fig.II-2-1). This intrusive contacts with Serido Formation and G3 intrusives on the west side and with Caico Complex on the east side. The contact between the G2 rocks and the Serido Formation follows along the Picui Fault. The Picui Fault is the first order of tectonic line which divides Central Domain and Centro-Oriental Domain described before. The rock is augen gneiss with granitic composition. Xenolith of micaschist and aplite dike can be seen in the augen gneiss. The xenolith is 5cm by 50cm and the aplite is 50cm wide.

Radiogenic age was not taken in this area. The lithology of the rock is the one of typical G2. The rock was intruded after the deposition of the Serido Formation.

Chemical analyses and thin section observation were executed for the rock sample A119 (Table.II-2-1, Fig.II-2-2).

The location of the samples are shown in Fig.II-2-3. According to the chemical analysis, the sample has a same composition as the one of granite.

The result of the thin section observation is as follows.

This sample is seen to be pale brown, coarse grained augen gneiss with K-feldspar ougens.

Rock name: gneissose biotie granite

Texture: gneissose

Rock forming minerals:

principal minerals; quartz, K-feldspar, biotite, plagioclase, amphibole

accesory minerals; sphene, apatite, zircon, chlorite, clinozoisite

opaque minerals; exist

secondary minerals; fine grained muscovite

(ii) G3 intrusive rocks

The G3 intrusives are distributed from Riacho Saco do Jirau and Riacho Olho d'Agua to Saco do Umburana in the southwestern most part of the survey area.

The G3 contacts with G2 on the east side and with *Serido Formation on the west side and it is covered by* Tertiary Serra dos Martins Formation. G3 is in fault contact with the Serido Formation. The foult is the Picui Fault. A number of pegmatites were intruded along the Picui Fault.

The G3 is grey to pale brown, fine to coarse grained and equigranular granodiorite. In the greyish part of the G3, lenticular leucoclatic parts are observed as if they are welded parts of welded tuff.

Radiogenic age was not taken in this area. The lighology is the one of typical G3.

Chemical analyses and thin section observation were executed for the samples A111, C123, C133 (Table.II-2-1, Table.II-2-2).

The rocks of G3 are grey or pale brown, medium to coarse grained and has schistosity. Sample A111 is compact and hard, which resembles siliceous biotite schist.

Rock name: hornblende-biotite granodiorite

Texture: gneissose or schistose

Rock forming minerals:

principal minerals; quartz, K-feldspar, biotite, hornblende, (plagioclase)

accesory minerals; zircon, sphene, (apatite), (chlorite), (epidote)

opaque minerals; (exist)

secondary minerals; (limonite ?)

(iii) Pegmatite

A number of pegmatites are densely ditributed in all over the survey area. They are few cm to about 10m wide and are presumed to be of maximum of 2km long. The pegmatites in general trend north northeast in the northern half of the area and north in the southern half of the area just like the trends of schistosities. However, they trend east northeast in the southeast of the survey area, this may show that weak tectonic lines of this trend existed in the area. The pegmatites in the area from Quinturare to Serra do Umburana in the southwestern part of the survey area mostly trend east northeast, northwest and east. Their trends are different from those in the rest of the area. This shows that this area suffered from different tectonic activity when the pegmatites were intruded. The pegmatites mostly steeply dip with some exceptions.

The pegmatites were intruded into all of the rocks except Tertiary Formation. However, they are neither seen in G2 nor in Jucurutu Formation in this area.

Pegmatite forming minerals are principaly K-feldspar, quartz, plagioclase, muscovite, biotite and tourmaline. Beryl, colombite-tantalite are partly included as accesory minerals. Muscovite, beryl, colombite-tantalite are mined in some places in a small scale.

The age of the pegmatite intrusion is after Serido Formation was deposited.

(iv) Tertiary basalt

Tertiary basalts mostly occurrs as dikes. They trend west northwest, east and east northeast and dip steeply. They are few tens of cm to 1m wide, and sometimes composed of several dikes. They all occur in the Serido Formation, especially in the south of the survey area. Stock intrusives with the diameter of 500m and radially arranged dikes of basalt around the stock occur at Saco do Inferninho in the easternmost part of the survey area.

Chemical analysis and thin section observation were executed for the sample, D127, taken from the radially arranged dike (Table.II-2-1, Table.II-2-2). The sample is black and fine grained and has olivine phenocrysts 1cm diameter.

Thin section observation is as follows.

Rock name: basalt

Texture: porphyritic and intergranular in matrix

Rock forming minerals:

phenocryst; augite, olivine

matrix; augite, hypersthene, magnetite, plagioclase, ilmenite

secondary minerals; chlorite, quartz, clinozoisite

2-2-2 Structure

(1) Characteristics of the structure

Regional stractural position was described in the report of phase I survey and in Chapter 3 of Part I in this report.

Structural trend strongly appears in the distribution of each formation and pegmatite, in the extention of faults and schistosites. The direction of the trend is north northeast in the northern half of the survey area and north in the southern half of the survey area.

Picui Fault, which divies the Central Domain from the Centro-Oriental Domain, is situated along the boundary between the Serido Formation and G2-G3 intrusives in the eastern edge of the survey area. It is steeply inclined to the east. Fault can also be seen at the boundary between the west end of Equador Formation and the Serido Formation. It is presumed to incline to the west from the point of the structural relation. Fairly large scale of fault extends in pCssxl in the central part of the Serido Formation. It has same trend as the other faults. Another same trending fault in a small scale passes through Carnauba in the northeastern part of the area. This fault is the same as the one extending from the San Francisco Mine to the south southwest which was recognized in phase I survey. In the central southern part of the survey area, north-trending fault passes from Divisao to the south.

Other faults trending west northwest and east northeast can be seen in the whole area. The faults trending west northwest can be recognized in the western half of the area, and the faults trending east northeast can be recognized in the eastern half of the area. These faults trend almost same as the Tertiary basalt dikes do. However, inferred faults trending east northeast in the southeastern part of the area are presumed to have acted when the pegmatites were intruded because some pegmatites are parallel to those faults. The faults are presumed to have been acted before the west northwest trending faults. In the area around Serra da Umburana, the pegmatite trend west northwest to east northeast. The trend is different from those of the rest of the area. That means that this area had been acting differently from the area when the pegmatites were intruded.

The strike of schistosities is parallel to general structure and the schistosities generally dip east by more than 30 degrees except folded zone. However, near Umburana in the southwestern part of the area, the schistosities dip by less than 10 degrees. These evidences regarding strikes of pegmatites and dips of schistosities show that this area was situated on the structurally unique position. Gold bearing quartz vein which will be discribed later is situated at this place.

The folded zone 3km wide extends north northeast to north in the eastern margine of pCssxl of the Serido Formation. The direction is also the same as the ones of general structure. Some antiforms and synforms with the wave length of some hundreds of meters are well developed in the zone. Their axes trend north northeast. Around the boundary between the Serido Formation and the west end of the Equador Formation, there also appears folded belt with some antiforms and synforms trending north northeast. These folded belts extend in to the north in the phase I survey area. The rocks of pCssx2 mainly occur in the folded zone in pCssx1. The Jucurutu Formation occurrs along the axis of antiform trending north in the northwest end of the survey area.

(2) Relationship of mineralization with the structures

The Sao Francisco deposit is located at the crossing point of two directions of faults trending north-northeast and west-northwest in the Serido Formation. Fault trending north-northeast is principal in this area and the one trending weat-northwest is minor one. In the area to the north of the Sao Francisco Mine, schistosities of the rocks of the Serido Formation strike east-northeast. The direction is also different from the one in general. Therefore, the general structure around the mine was presumed to have been disordered during tectonic activity. The gold mineralization of the Sao Francisco deposit was assumed to be related to the structural diturbance occurred by fault activities. On the other hand, gold bearing quartz vein in Serra da Umburana in the phae II survey area is hosted in biotite schist of pCssx1. The quartz vein trends north and steeply dips west. The strike of the quartz vein is different from the one of pegmatites and the dip of it is different from biotite schist. Tectonic activities in the Serra da Umburana, where gold bearing quartz vein occur, may also be different from the ones in general around this area. However, the relationship of the mineralization with the structure is not realized.

There occur some sulphide bearing quartz veins in this area. They are in very small scale. Some of them are gold bearing and may be gold bearing. They are generally parallel with the schistosities of mica schist. Therefore, they are thought to have been made during the tectonics caused at the metamorphism.

Pegmatites did not bring gold in general. However, pegmatitic quartz vein occurred in the Equador Formation to the west of Pe da Serra brought minor gold with copper sulphide.

2-2-3 Mineralization and alteration

(1) Mineralization in area B

There occur scheelite deposits related to tactites, columbite-tantalite deposits related to pegmatites, gold bearing quartz veins and their placer deposits. The deposits are shown in Table.II-2-3 and Fig.II-2-4.

Here glod in host rock and placer is described. Gold in placer was surveyed where gold was produced at garimpos. The garimpos are all in small scale and mostly located around Serra da Umburana and west of Cabeco Perada in the southwest of the survey area. Some in less scale are located east of Frei Martinho, at Salgadinho in the central part and at some other places in the northeastern part of the area. In each garimpo very small amount of gold was produced so far.

Quartz veins in biotite schist were mainly surveyed as gold mineralization in host rocks. Quartz veins are associated with iron sulphide such as pyrite, copper minerals such as malachite and some other oxides. The reason why quartz veins associated with sulphides and copper minerals were targeted is that because the Sao Francisco deposit in this area is associated with pyrite and chalcopyrite, same type of deposite as the Sao Francisco will be expected in the same area in a geologically point of view.

There are three types of mineralized quartz veins in the area B. First type is the one at the Serra da Umburana, second type is the one in pegmatite intruded in the Equador Formation and the third one is the one in biotite schist parallel to schistosity (Fig.II-2-4, Table.II-2-3).

The quartz vein in Serra da Umburana is in larger size than the others. It was surveyed and made a sketch (Fig.

Tab. II-2-3 Mines and mineral showings in area B

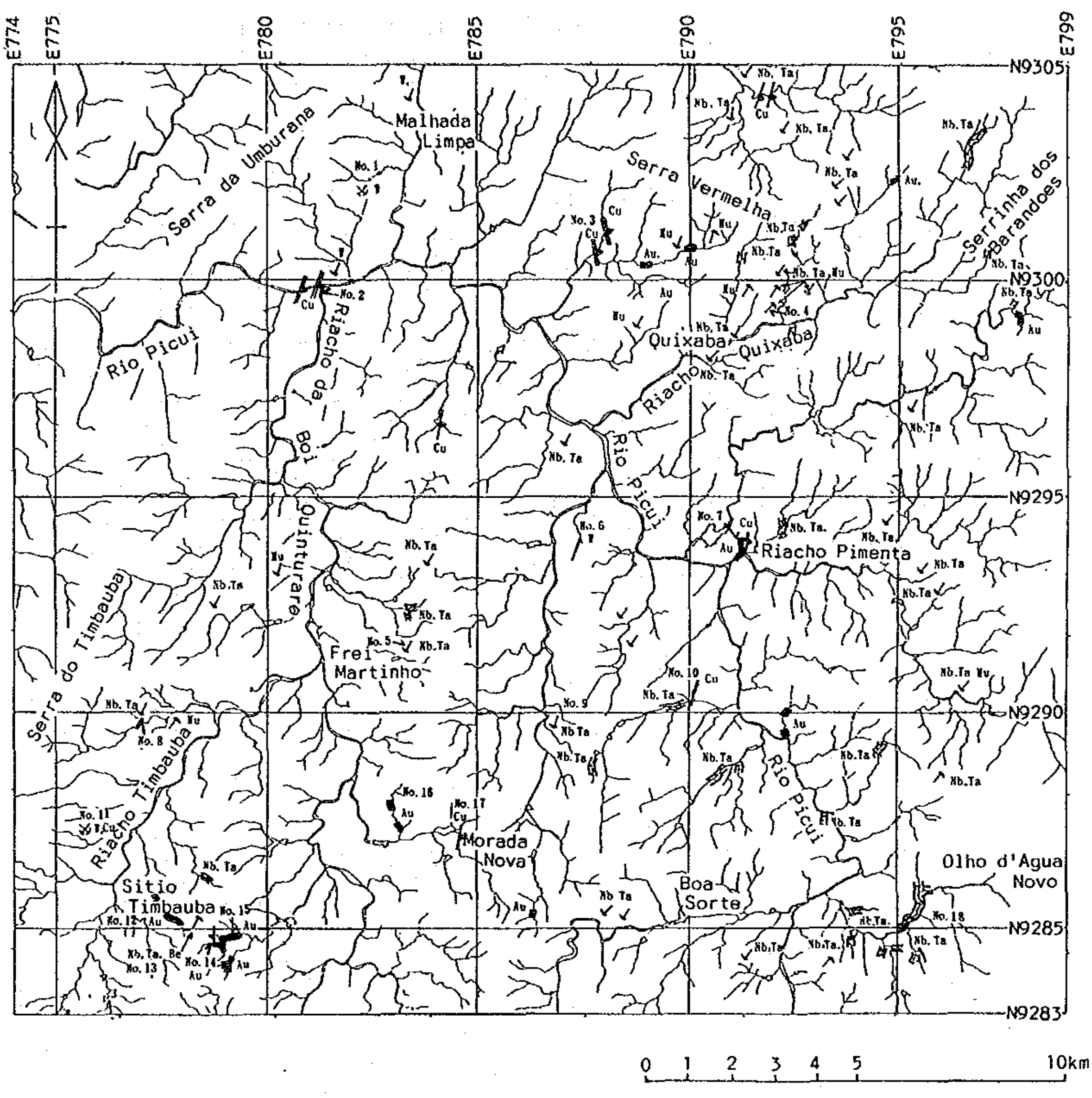
No.	Name of mineral showing	Coordinate		Host rock	Description				
		E	N		Occurrence	Size	Type	Alteration	Remarks
1	Malhada Limpa	782.20	9302.20	Calc-silicate rock (*)	sh-gt-ep-dp-carbonates spots	5mx50m	W skarn	carbonitization silicification	
2	-	781.15	9299.90	mu-qt schist(Ecuador Fm.)	mal-py qt v	2 veins of w : 2	Au-Ag-Cu bearing qt v	-	C135
3	-	787.80	9300.70	siliceous bi Schist (*)	mal qt v	do.	Cu bearing qt v	-	C138
4	-	791.70	9299.35	Pegmatite	cl in pegmatite	-	ta-cl	-	
5	-	783.35	9291.55	do.	do.	-	do.	-	
6	-	787.40	9293.85	Calc-silicate rock (*)	sh-gt-ep-carbonates spots	-	W skarn	carbonitization silicification	
7		791.20	9293.80	ct-gt-bi Schist(*)	- / mal-lm-q v	400m along river, / W:2~5cm, L:10m+	Au placer, / cu bg qt v	-	C127, paning ;10g Au/week
8	-	777.35	9290.05	Pegmatite	cl in pegmatite	-	Nb-Ta vein	-	
9	-	786.80	9289.95	do.	do.	-	do.	-	
10	-	790.10	9290.35	ct-bi Schist (*)	mal-py-lm qt v	W=10cm	Cu bg q v	-	C129
11	Mina Timbauba	775.70	9287.20	Calc-silicate rock (*)	sh-mal-az-ep-carbonates-spots	3mx50m	W-Cu skarn	carbonitization silicification	
12	-	777.75	9285.25	-	-	900m along river	Au placer	-	C117
13	Morro do Garrapato	778.20	9285.05	Pegmatite	up:by in Pegmatite low:ta-cl in Pegmatite	W:5m, L:100m, D:30m	Cl-ta-by Nb-Ta-Be v	-	
14	Garimpo do Boqueirao	778.75	9284.85	bi Schict(*)	mal-py qt v	W:2m, L:350m+	Au-Ag-Cu bg q v	-	A129 130, C146 147
15	-	779.00	9284.75	-	-	700m & 200m along river	Au placer	-	
16	-	783.15	9287.25	-	-	200m & 200m along river	do.	-	
17	-	784.60	9287.05	bi-qt Schict(*)	mal-py qt v	W:10cm, L:5m+	Au-Ag-Cu bg q v	-	C120
18	-	795.50	9285.50	-	-	1.2km along river	Nb-Ta placer	-	

II-2-5). The vein is 0.3 to two meters wide and more than 200 meters long. It strikes N 5°E, dips 70°W. On the other hand, The schistosity of host rocks strikes north-south and dips 5°E. Accordingly, the dip of schistosity and the dip of the quartz vein are crossing each other by high angle. The quartz vein is thought to be filled in an open fracture in view of its appearance. It is colorless and transparent with druses, accompanying pyrite, malachite, hematite and limonite. A sample was taken from the vein and analysed. It contains 0.2 ppm of gold, 103 ppm of silver, 3.76% of copper and 5 ppm of arsenic.

Another type of quartz veins can be seen at Morrada Nova, southwest of Serra Vermelha and at Salgadinho. They are accompanied with malachite, pyrite and limonite. Every quartz vein is parallel with the schistosity of host rock. Therefore, They are thought to have been formed before the latest metamorphism or to have been in the original formation. The quartz vein at Morada Nova is composed of two thin veins, one is 2 to 5cm wide and 10 meters long, and the other is 10cm wide and 5 meters long. The quartz vein of Salgadinho comprises several thin veinlets, which are 2 to 5cm wide and 10 meters long. Three samples were taken from these veinlets and analysed. The quartz vein at Morada Nova contains 0.1 ppm of gold and 3.1 ppm of silver (Tab. II-2-4).

Last type of quartz vein is pegmatitic one. This type of vein can be seen in the Equador Formation close to the Serido Formation at Pe da Serra. It is accompanied with malachite and pyrite. It is composed of two veinlets 2 to 5cm wide and 10 meters long. The sample taken from the vein contains 0.1 ppm of gold and 9.6 ppm of silver.

Those quartz veins are all in small scale, except the one at Serra da Umburana. However, the characteristics of them resembles the one of Sao Francisco in view of the contents of gold, silver and arsenic, the rate of gold content per silver content and accompanying minerals such as sulphides, pyrite and copper mineral. Quartz veins in the area of phase II are different from the one in the Caico



L E G E N D

:Closed mine
:Garimpo of Au(placer)
:Garimpo of Nb & Ta(placer)
:Operating garimpo
:Closed garimpo
:Malachite-(pyrite)-quartz vein
:Malachite-pegmatitic quartz vein

Au:Gold
Cu:Copper
W:Tungsten
Ta:Tantalum
Be:Beryllium
Mu:Muscovite

Fig. II-2-5 Location of mines and mineral showings in area B

Tab. II-2-4 Assay data of ore samples taken from areas A and B

Sample No.	Location		Au (ppm)	Ag (ppm)	As (ppm)	Cu (%)	Remarks	
	E	N						
C107	792.55	9316.29	Tr	Tr	5	0.50	Bn-mal-qtz v	Area A
C108	〃	〃	Tr	Tr	3	0.09	do.	
C109	〃	〃	Tr	Tr	8	0.06	do.	
C110	〃	〃	Tr	Tr	7	0.13	do.	
C111	〃	〃	Tr	Tr	3	0.04	do.	
C112	〃	〃	Tr	Tr	3	0.10	do.	
C120	784.60	9287.05	0.1	3.1	4	0.13	py-mal-qtz v	Area B
C127	791.20	9293.80	Tr	Tr	6	0.06	mal-qtz v from Au showing	
C135	781.15	9299.90	0.1	9.6	4	0.86	mal-peg qtz v in Ecuador Fm.	
C138	787.80	9300.70	Tr	Tr	8	0.03	mal-peg qtz v in Serido Fm.	
C146	778.75	9284.65	Tr	Tr	2	0.01	qtz v from Au showing	
C147	778.75	9284.85	0.2	103.8	5	3.76	py-mal-qtz v from Au showing	

Tab. II-2-5 Mineral assemblages of samples taken from areas A and B, determined by X-ray diffraction

Sample No.	Coordinates of sample location		Description	RFM								clay minerals				OAM	Fe minerals			Cu minerals			Remarks
	E	N		gt	pg	Kf	bi	pre	sps	dr	fap	Kl	sc	mm	ch	nja	py	ht	mt	cp	bn	at	
C107	792.55	9316.29	bn-mal-qtz v	◎	◎			?	○		•	•	○		•						•		Area A-I
C108	792.55	9316.29	bn-mal-qtz v	◎	○			?			•	•	•								•		〃
C146	778.75	9284.65		◎	•	•				•			•		•								Garimpo do Boqueirao
C147	778.75	9284.85		◎						○			•			•							〃
A129	778.75	9284.85	clay(H.W.)	◎	○	•				◦		◦	○	◦								?	〃
A130	778.75	9284.85	clay(F.W.)	◎	◦	◦		?		•		◦	◦	◦									〃
C120	784.60	9287.05	py-mal-qtz v	◎		•							•				•	•	•	?			Area B
C127	791.20	9293.80	mal-qtz v	◎	○	•	○								•		•						Au showing, Area B
C129	790.10	9290.35	py-mal-qtz v	◎	○		○								•		•						Area B
C135	781.15	9299.90		◎	○	○				•			◦										Equador Fm.

H.W. : hanging wall of py-qtz vein
F.W. : foot wall of py-qtz vein
B.M. : black mineral
R F M : rock forming minerals
OAM : other altered minerals

qt : quartz
pg : plagioclase
Kf : K-feldspar
bi : biotite
kl : kaolinite
Sc : sericite
mm : montmorillonite
ch : chlorite

nja : natrojarosite
pre : prehnite
sps : spessartine
dr : dravite
fap : fruorapatite
py : pyrite
ht : hematite
mt : magnetite
cp : chalcopyrite
bn : bornite
at : atacamite

Complex west of Sao Tome in the same point of view as described above.

Those quartz veins and clay attached at the side of those veins were also tested by X-ray diffractometry to realize the characteristics of their alterlation of mineralization (Tab.II-2-5). Sericite, kaolinite and montmorillonite occur in the vein and in the clay. These clay minerals should dissapear at the temperature 600°C which was attained at the metamorphism of amphibolite facies in this region (Lima, E, S., 1987). Therefore, these minerals should be thought to have formed after the metamorphism. These clay minerals are usually formed by hydrothermal alteration. Therefore, the quartz vein says that it was made by hydrothermal activation.

Determination of homogenized temperature was executed on the samples taken from the Sao Francisco deposite and the quartz vein in Serra da Umburana to understand the mineralization. Fluid inclusions in one quartz vein sample taken from the Sao Francisco deposite are in the size of 0.001mm. Primary inclusions are rich in CO_2. These inclusions were not available to determine the temperature because of the size. Fluid inclu- sions in another sample also taken from the Sao Francisco deposite are less than 0.01mm in size. They are also rich in CO_2. They were not available to determine the temperature because of the same reason. In the sample taken from the quartz vein in Serra da Umburana, fluid inclusions are 0.005 to 0.015mm in size. The inclusions are mostly secondary ones and large. Primary inclusions are rare and small. Temperature determination was executed on the primary fluid inclusions. The temperature is 130 to 140°C. However, the temperature is considered to be too low for the gold deposi- tion. Therefore, the fluid inclusions are thought to have been formed in secondary quartz after gold mineralization.

(2) Tonal anomaly detected on the LANDSAT images

Color anomaly occurred with possible argillization was detected on the LANDSAT images in phase I survey. The anomaly means more pale and blueish on the faulse color.

On the anomalous area in area B, there exists lighter white compact siliceous rock on the ground, the schistosity of the rock dips slightly, alteration related with mineralization is not occurred. Furthermore, the outcrops of the rocks described above occupy wide area, and plants sparsely grows on the hillside compared to valley side. The kinds of plants are not different from the ones in the other area except for local part. Therefore, the tonal anomaly is assumed not to be occurred with mineralization but to be related with plant density and geology.

On the anomalous area in area A, the area is widely occupied by pegmatite and is slightly reddish. As can be seen on the images, plants are very sparse. Then, the tonal anomary on this area is also assumed to be derived from the plant density and geology.

(3) Trace elements in rock samples

Trace elements same as the ones applied for geochemical survey were analysed for rock samples. The values of Ta, Sn and Ag are below detection limit. The values of W are also below detection limit except one sample C122 (Tab.II-2-1). 2.0 to 5.8% of Fe is contained in the samples except for the sample from the Tertiary basalt. The contents of Fe can not be related with lithological types except for the basalt, which content is 7.9%. The sample C122, which was taken from pCsscs in the southeast of the survey area, is determined to be garnet bearing amphibole schist by thin section observation. It has higher values of Sn, Be and Au than those of other samples, that is, it may be mineralized.

Some characteristics on the trace elements in rock samples are described below.

Gold (Au)

Gold contents of the samples taken from the Serido Formation are mostly below detection limit, 0.5 ppb, except for some samples taken from pCsscs, A101 and C112. Samples taken from muscovite-biotite schist and pCsscs in area A-I contain more gold, 5.0 to 35 ppb. Sample A101 taken from pCssx2 contains 5.0 ppb, sample C112 taken from pCssx1 contains 33.0 ppb of gold. Sample C112, which is the host rock of quartz veinlets accompanied with malachite in area A-I, may be mineralized. However, in the quartz vein in the host rock gold mineralization could not be detected. The reason may be because of the higher detection limit, 0.1 ppm. According to the analytical data on the samples taken from the Serido Formation in phase I, the samples has 1 to 9 ppb of gold except for 635 ppb on the host rock of the Sao Francisco deposit. The gold content of sample A101 is not high. Samples, A105, A124, C122, C125 and C141, taken from pCsscs has 6 to 35 ppb of gold, higher than those of biotite schist. Sample C122, having 35 ppb of gold, may be mineralized as described above.

Manganess (Mn)

High content of Mn can be detected on the samples taken from the Serido Formation, especially on the samples from pCsscs. Samples, A124, C122, C125 and C141 taken from pCsscs might be mineralized, because of higher contents of Sn, Be and Au besides Mn than other samples. Higher Mn content can be explained from the mineral composition of the Serido Formation. Because a lot of garnets, pyralspites, are included in the formation.

Molybdenum (Mo)

Mica schists of the Serido Formation in area B contains 1 to 3 ppm of Mo on an average. The sample A101 and some samples from area A have higher contents with maximum of 5 ppm. The content may not be related to mineralization.

Tin (Sn)

Samples taken from pCsscs have higher contents of Sn. Samples, C122 and C125, taken in the southeast of the survey area have especially higher content. They are possively mineralized. Sample A101 taken from pCsscs in area A is with higher content.

Beryllium (Be)

Beryllium content in the rocks is generally low, 2 ppm on the average. Samples, C122, C125 and C141 taken from area B, have higher values ranging from 4 to 18 ppm. They might be mineralized as described above.

Lithium (Li)

Lithium contents of samples taken from pCsscs are all below detection limit, 5 ppm. Rocks of the Serido Formation have 11 to 97 ppm of Li. Granites have 11 to 116 ppm of Li. The rocks containing a lot of micas can be explained to be with a lot of Lithium, because Lithium is usually contained in micas in rocks. Sample C123 taken from the granite G3 has the highest value of 116 ppm in this phase. One sample of mica schist taken from the Serido Formation in phase I had a highest value of 240 ppm of Li.

Sample taken from the Tertiary basalt has a low value.

Arsenic (As)

As is generally contained below 1 ppm. Samples A105 of pCsscs from area A, D118 of pCsscs from area B, D102 of pCssx4 from area A, D121 and D122 of pCssx4 from area B and D127 of Tertiary basalt content more As. That is, the higher As values are centered around the area trending north northeast, where is in the western margin of pCssx4 and where pCsscs is densely distributed. The correlation of the contents with mineralization is not disclosed.

2-3 Discussion

(1) Geology and structure

pCssx1 of the Serido Formation, defined in phase I, was subdivided into two units, pCssx1 and pCssx4, in phase II. The boundary between them is rather distinct. Both zones 3km wide on each side of the boundary are characteristic of their lithology and structure. That is, on the western side of the boundary, where pCssx1 is distributed, folds with north northeast-trending axes are well developed in a small scale, and a number of pCssx2 thin beds are distributed. Schistosities of rocks in this zone generally incline gently except local parts. At the western side of the zone, fault runs trending north northeast. On the other hand, on the eastern side of the boundary, rocks of pCsscs are densely distributed, especially on the northern part. No faults can be observed. On the east of the zone, a fault can be traced to the north to the Sao Francisco deposit.

Faults trending north northeast to north can be seen in the entire area, and other faults trending west northwest and east northeast can be traced in the western part of the area and in the eastern part of the area, respectively. The faults trending north northeast to north are older than those trending west northwest, because the former ones are dislocated by the latter ones. The time relation between the faults trending east northeast and the others is not known. However, Picui Fault, which is trending north northeast to north in the east of the area, is assumed to have been acted from the oldest time because it is in a regional tectonic line.

The faults in area B described above are not intruded by any intrusive rocks except those trending west northwest. The fauls trending west northwest are partly intruded by Tertiary basalt dikes.

In the samples taken from the Serido Formation in the phase I survey area, gold is contained by 1 to 9 ppm.

However, the samples, taken from the Serido Formation in area B, scarcely contain gold. A large part of the rocks defined as pCsscs are assumed to be originated from basic rocks rather than calc silicate rocks. Moreover, some of them include more gold and arsenic than other rocks in the Serido Formation. Therefore, the zone containing more pCsscs overlaps the zone where As and Au anomalies were detected in phase I survey to north northeast.

(2) Mineralization

Gold mineralization is divided into three types in area B. One type is quartz vein, which crosses the schistosities of the host rock, in Serra do Umburana in the southwest of the survey area. Second type is pegmatitic quartz vein in the Equador Formation in the northwest of the area. Third type is also quartz vein parallel to the schistosity of the host in the Serido Formation in the entire survey area. The latter two types are in a small scale. Only the first type is described here. The quartz vein, 0.3 to 2 meters wide, strikes N5°E and dips 70°W. It cuts the schistosity of the host rock as described above. The quartz vein is accompanied by pyrite, malachite and iron oxides. A sample taken from the vein contains 0.2 ppm of gold, 103 ppm of silver, 3.6% of copper and 5 ppm of arsenic. It resembles the Sao Francisco deposite in view of the contained ore minerals such as pyrite and copper mineral and the rate of Au content per Ag content. It is assusmed to be fracture filled hydrothermal deposit from the appearance and including minerals.

Sericite occurs in the quartz vein, and sericite, kaolinite and montmorillonite occur in the clay attached by the quartz vein at the Boqueirao garimpo in Serra da Umburana (Fig.II-2-6). These altered minerals are considered to have been formed after the metamorphism of the Brazilian orogeny, because they should ot be formed during the metamorphism of amphibolite facies. Sericite could not be

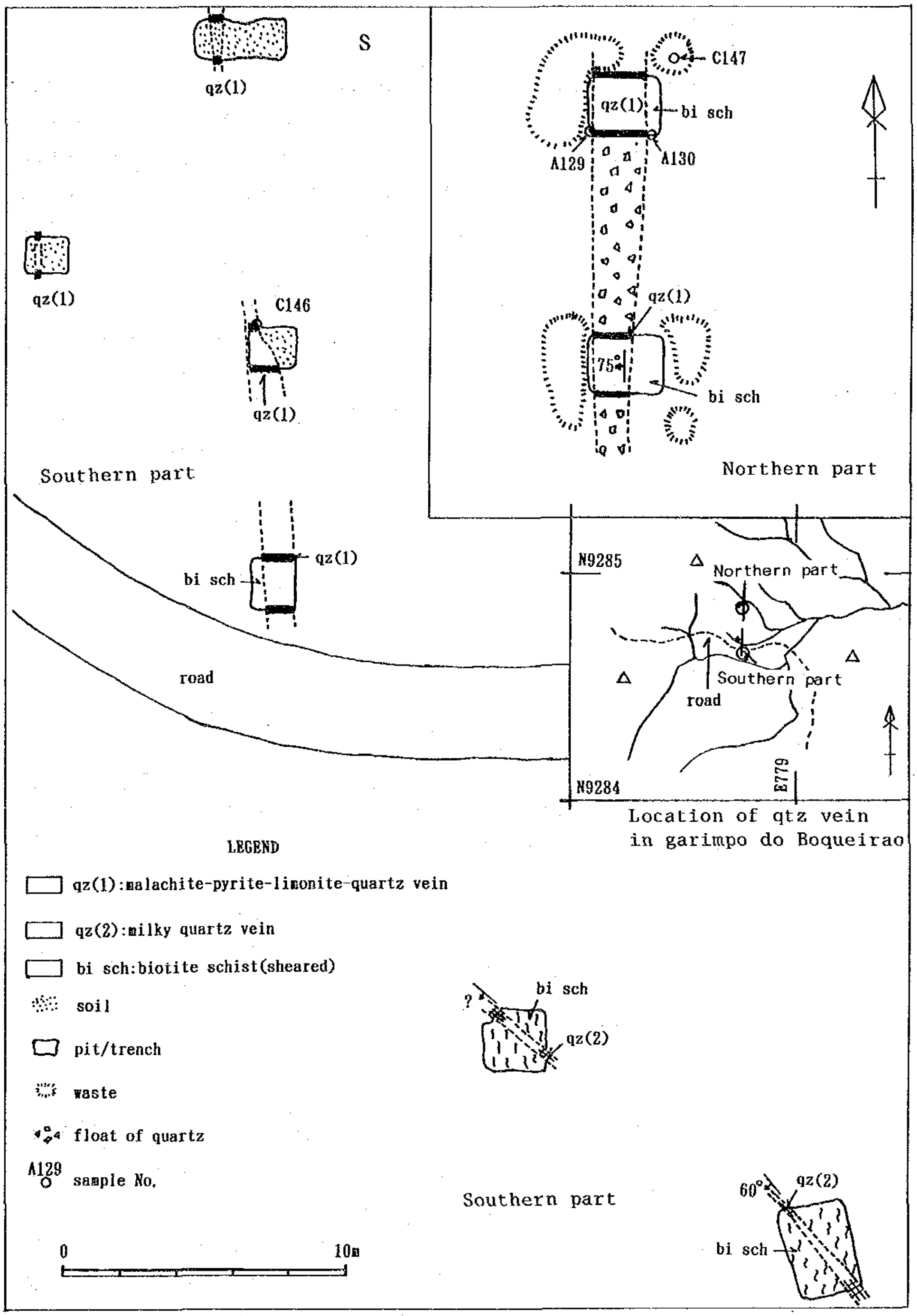


Fig. II-2-6 Exploration pits and quartz veins in Au showing in Serra do Umburana, Garimpo do Boqueirao seen in the host rocks. Furthermore, in the sample taken from the biotite schist about 1km to the northwest apart from the garimpo, sericite could not be observed even by the microscope. Accordingly, those altered minerals are supposed to be hydrothermal products rather than metamorphic products.

From the above mentioned, the quartz vein in the Boqueirao garimpo is thought to be mineralized in the fracture after the tectonics of the Brazilian orogeny. However, any igneous rock contributing heat for the hydrothermal ore fluid can not be defined, though some pegmatites and basaltic dikes exist in that area. The basaltic dikes is about 2km to the west northwest of the site of the vein, and it trends west northwest. If it extends east southeast, it goes through the site of the vein. However, the dike is not known if it took part in the mineralization, because the ages of the mineralization is not known.

The origin of gold is still not known. In phase I survey, biotite schists in the Serido Formation was supposed to give gold to the mineralization. However, biotite schists of the Serido Formation in the phase II survey area include less gold than that in phase I survey area. The nearest rock, with high gold content, to the quartz vein is calc silicate rock, pCsscs, which is about 4km west of the vein and at the boundary between the Equador Formation and the Serido Formation.

(3) Geology and mineralization

Mineralization in phase I survey area was soppoSed to have been related with the tectonics which formed faults, because the mineralization is very close to a fault and the strikes and dips of the schistosities of the rock near the mineralization are abnormal. On the other hand, any fault can not be recognized at the Serra do Umburana, either on the ground or on the aerial photographs. However, in the area 3km by 5km around the quartz vein, strikes and dips of the schistosities of the host rocks and the strikes of pegmatite dikes are quite different from those in the surrounding area. The tectonics which formed the vein fracture can not be realized from these structures described above.

The supposed fault related with the mineralization of the Sao Francisco deposits extends into the phase II survey area to the south about 5km. No mineralization is observed along the supposed fault.

(4) Exploration guides

Gold bearing quartz veins are classified into two types in the area including phase I and II survey areas. One is formed by tectonics related with fault and the other is related with some other tectonics. Therefore, areas influenced by the other tectonics than faults, which have been acted during long geologic time, should be the target to be surveyed.

Chapter 3 Geochemical Survey in Area B

3-1 Stream sediment Survey

3-1-1 Objectives

Geochemical survey of stream sediments was conducted in the Area B (500km^2), which is located in the southern extension of the Phase I area, aiming at studying geochemical behavior of the certain elements during mineralization. This, eventually, enable us to evaluate the potentiality for ore deposits, especially that of gold, in the area.

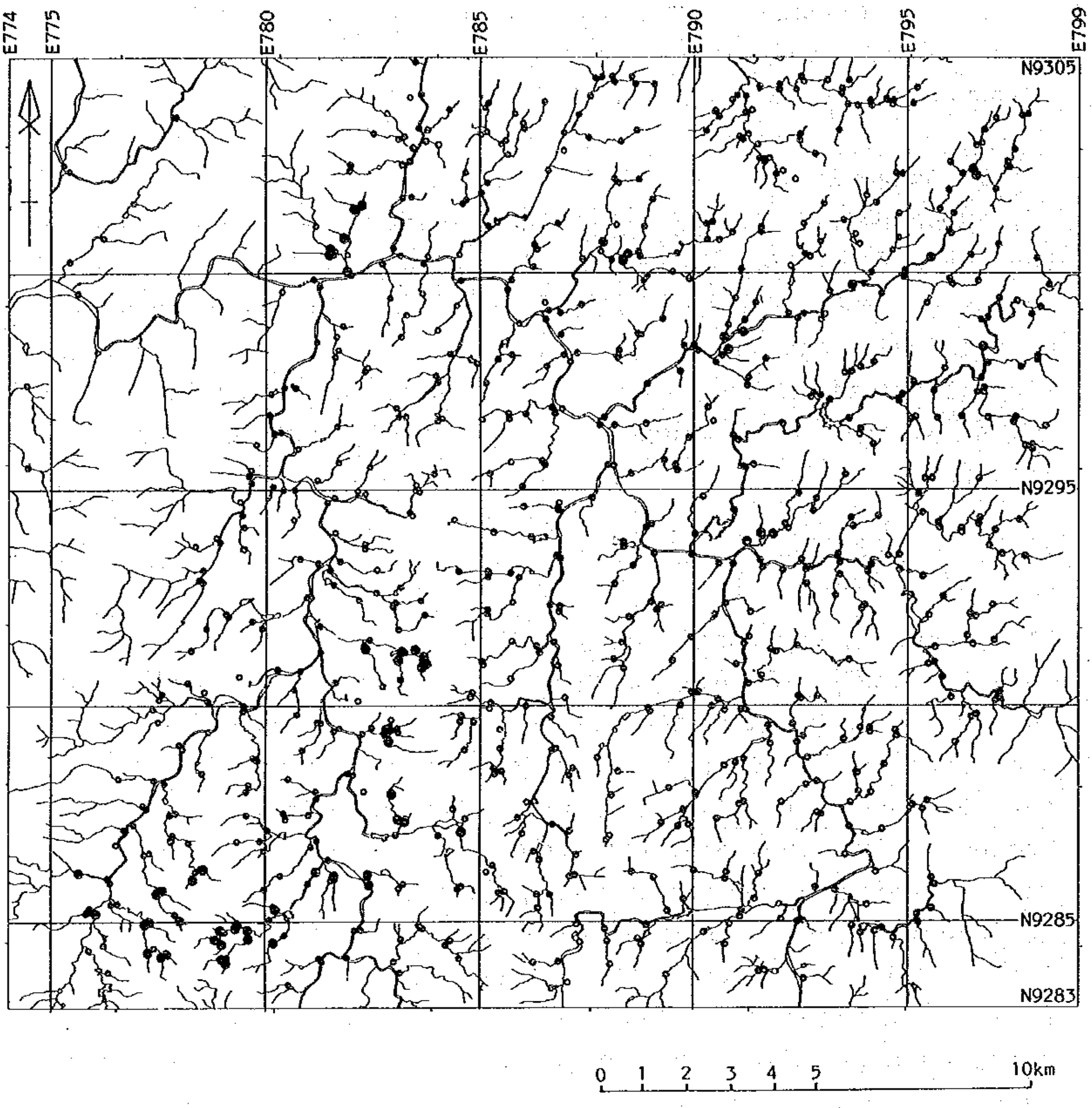
3-1-2 Methods

(1) Sampling and sample preparation

A total of 811 samples of stream sediments was collected at an average density of 1.6 samples/km^2. The sampling was conducted at a slightly higher density in northern part of the area where Au anomalous zones were suggested by the previous report. For avoiding a mixed stream sediments of two streams, sampling sites were located at upper stream keeping some distances from junctions. Stream sediments were collected from a surface to 10cm deep at each sampling site and they were, simultaneously, sieved using 80 mesh sieve. The collected samples of -80 mesh were, further, splitted into four portions and a 50g sample was sent for chemical analyses and another 50g sample were kept as a spare sample. Information such as geology, depth and width of the stream, grain size of the stream sediments was recorded at each sampling site.

(2) Chemical analyses of the samples

After rough weighing at the camp site, the samples were dispatched to GEOSOL, Brazil, same as soil samples, for chemical analyses of 13 elements (Au, Ag, Fe, Mn, Mo, W, Sn, Nb, Ta, Be, Li, As and Sb). Analytical methods and detection



o Stream sediment sampling point

● Pan concentrate sampling point

Fig. II-3-1 Location of stream sediment and pan concentrate samples in area B limits for each element and analytical result are, respectively, shown at Table.II-3-1 and in Appendix 3.

(3) Statistical treatment of analytical date

(i) Univariate analysis

For a purpose of using a computer for various calculations, the value half of detection limit was taken for the samples giving a value less than a detection limit. Statistical figures are shown at Table.II-3-2.

For understanding relations between elements, correlation matrix and correlation diagram are shown at Table.II-3-2 and in Fig.II-3-2, respectively. Farely good relations with correlation coefficient more than 0.5 exist between Fe-Mn, Fe-Mo and Mo-Nb.

The EDA method, previously mentioned, was used for determination of threshould values which define anomalies. Histograms showing concentration of elements and boxplots are given in Fig.II-3-3 on each element basis. Upper fence and upper whisker were taken, respectively, for threshould and sub-threshould values (Fig.II-3-3).

(ii) Multivariate analysis

Factor analysis was employed for understanding of possible lithological control of bedrock to the dispertion of elements in the stream sediments and relations between elements and mineralization.

The elements such as Ag, W, Sb were excluded from the consideration because of low concentration of these elements, many samples showing analytical value close to nil. As shown on Table.II-3-4, the barimax method of factor analysis calculated by computer gives four factors, Factor 1: Sn-Be-(Nb)-(Mo), Factor 2: Fe-Mn-Mo, Factor 3: Li and Factor 4: Ta-Nb.

The concentrations of each element in a particular sample are effectively reflected by factor scores how much these factors contributed for each samples. The result of

Tab. II-3-1 Summary of statistical studies of stream sediment analytical data

Elements	Mean	Variance	Standard deviation	Minimum	Maximum	Below detection limit (%)
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

Minimum values are half of detection limite except for Fe, Mn and Li

Tab. Ⅱ-3-2 Correlation of thirteen elements in stream sediment geochemical data

Elements	Au	Ag	Fe	Mn	Mo	W	Sn	Nb	Ta	Be	Li	As	Sb
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	0.296	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

Tab. II-3-3 Results of the EDA method analyses of stream sediment samples

Elements	Median	Lower fence	Lower whisker	Lower hinge	Upper hinge	Upper whisker	Upper fence	Upper fence or more (%)
Au (ppb)	0.200	0.200	0.200	0.200	0.200	0.200	0.200	15.8 *
Ag (ppm)	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.1 *
Fe (%)	4.800	-0.500	3.400	3.700	6.500	7.100	10.700	7.2
Mn (ppm)	1040.000	-320.000	680.000	760.000	1480.000	1610.000	2560.000	6.2
Mo (ppm)	2.000	-2.000	0.500	1.000	3.000	4.000	6.000	10.1
W (ppm)	5.000	5.000	5.000	5.000	5.000	5.000	5.000	--
Sn (ppm)	1.000	-3.500	1.000	1.000	4.000	5.000	8.500	6.0
Nb (ppm)	28.000	-34.000	11.000	14.000	46.000	55.000	94.000	6.8
Ta (ppm)	5.000	5.000	5.000	5.000	5.000	5.000	5.000	2.8 *
Be (ppm)	1.000	-1.750	0.500	0.500	2.000	2.000	4.250	2.8
Li (ppm)	16.000	-7.000	11.000	11.000	23.000	26.000	41.000	2.8
As (ppm)	0.500	0.500	0.500	0.500	0.500	0.500	0.500	11.8 *
Sb (ppm)	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.6 *

Tab. II-3-4 Results of factor analyses in stream sediment samples

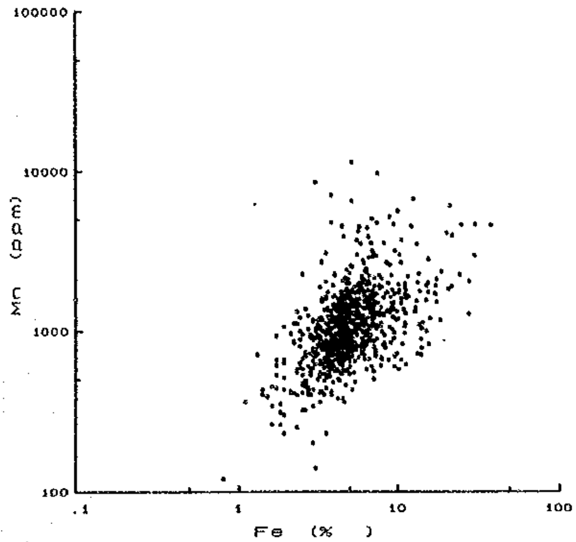
Elements	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Au	-0.005	0.098	-0.126	-0.008	0.0256
Fe	0.096	0.741	-0.072	0.096	0.5731
Mn	0.076	0.687	0.148	0.256	0.5652
Mo	0.373	0.425	-0.514	0.187	0.6184
Sn	0.527	-0.112	0.130	0.066	0.3112
Nb	0.386	0.281	-0.339	0.500	0.5928
Ta	0.049	0.076	-0.043	0.572	0.3370
Be	0.519	0.138	-0.021	0.047	0.2916
Li	0.112	0.098	0.487	-0.098	0.2686
As	0.016	-0.144	0.087	0.004	0.0284
Contributions	24.0%	37.6%	19.0%	19.5%	

Fe–Mn
SCATTER DIAGRAM

X=Fe (%)
Y=Mn (ppm)

	Fe	Mn
max	38.9	11390
min	.8	120

n= 811
r= .542

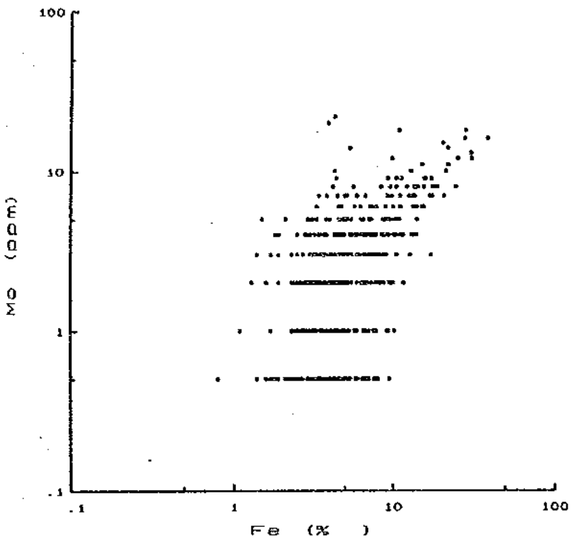


Fe–Mo
SCATTER DIAGRAM

X=Fe (%)
Y=Mo (ppm)

	Fe	Mo
max	38.9	22.0
min	.8	.5

n= 811
r= .454



Mo–Nb
SCATTER DIAGRAM

X=Mo (ppm)
Y=Nb (ppm)

	Mo	Nb
max	22.0	395
min	.5	5

n= 811
r= .568

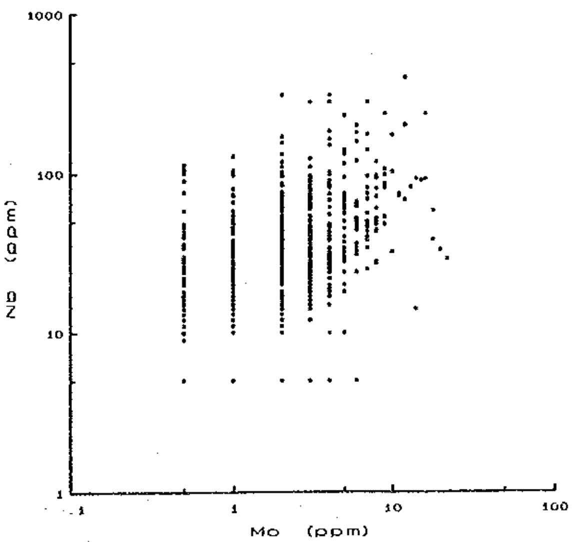


Fig. II-3-2 Diagram showing correlation between elements concentrated in stream sediments

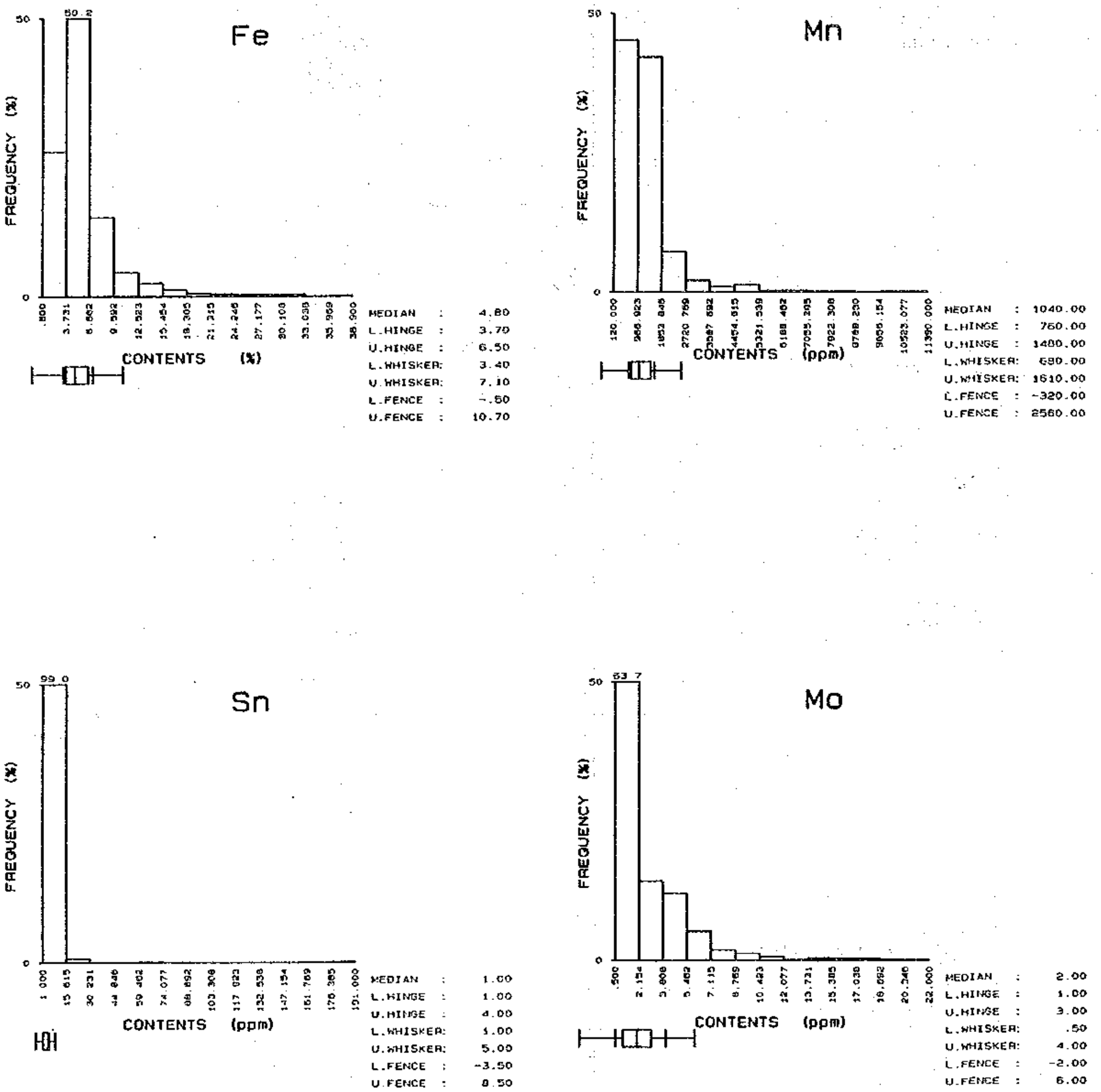
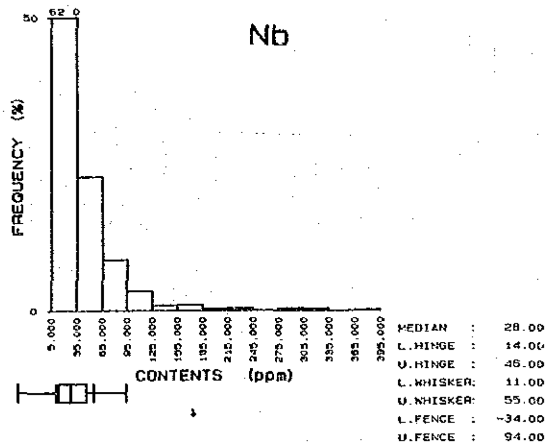
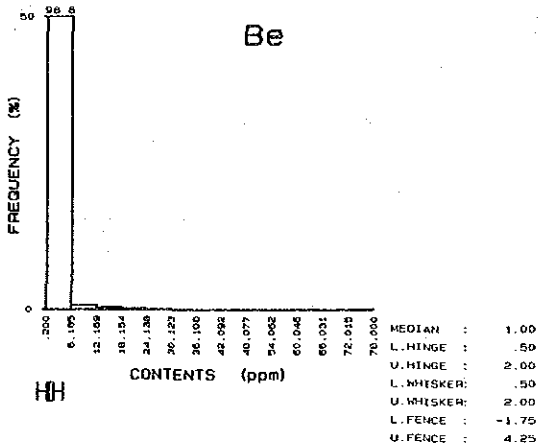


Fig. II-3-3 Histograms and boxplots for 10 elements in stream sediments (1)





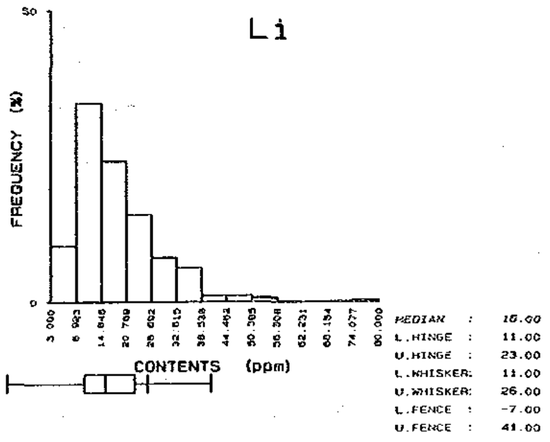
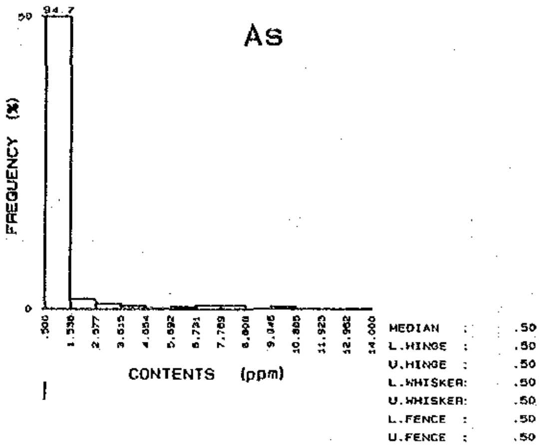
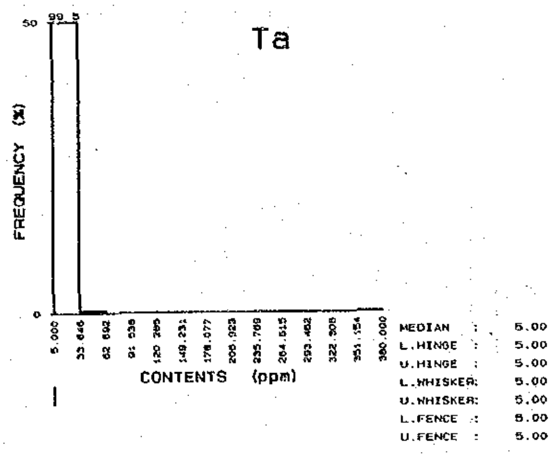


Fig. II-3-3 Histograms and boxplots for 10 elements in stream sediments (2)





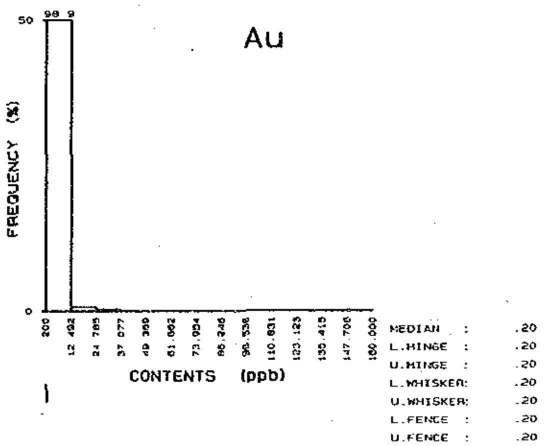


Fig. II-3-3 Histograms and boxplots for 10 elements in stream sediments (3)

factor analysis was considered by picking up the factor scores greater than one for evaluating the possible relation of certain elements to mineralization.

3-1-3 Results of the Survey

(1) Geochemical anomalies of each element

Geochemical anomaly map were constructed for 10 elements except Ag, W and Sb (Fig.II-3-4 to -8).

Gold (Au): The concentration of Au ranges from less than 0.5 ppb (detection limit) to maximum value of 160 ppb. The value of less than detection limit was obtained from 84.2% of a whole samples. The threshould value was conventionally decided as 0.5 ppb.

Followig anomalous zone were obtained (Fig.II-3-4).

1) Surounding area of Malhada Limpa in the northern part of the area
2) Au Garimpo area, south of Serra Vermelha in nouth-eastern part of the area
3) Middlestream of Rio Quixaba and its southeastern vicinity in northeastern part of the area
4) Middlestream of Riacho Pimenta and its western vicinity in eastern part of the area
5) Surounding area of Boa Sorte and its northern extension in southern part of the area
6) Surounding area of Frei Martinho and its eastern extention in southwestern part of the area
7) Lower stream of Riacho do Boi Quinturare in north-western part of the area.

Other than above, two isolated samples show the value greater than threshould value. Sample S2349 in northwestern part of the area gives maximum value of 160 ppb. Another one is sample S2179 with 19.5 ppb collected at the lower stream of garimpo.

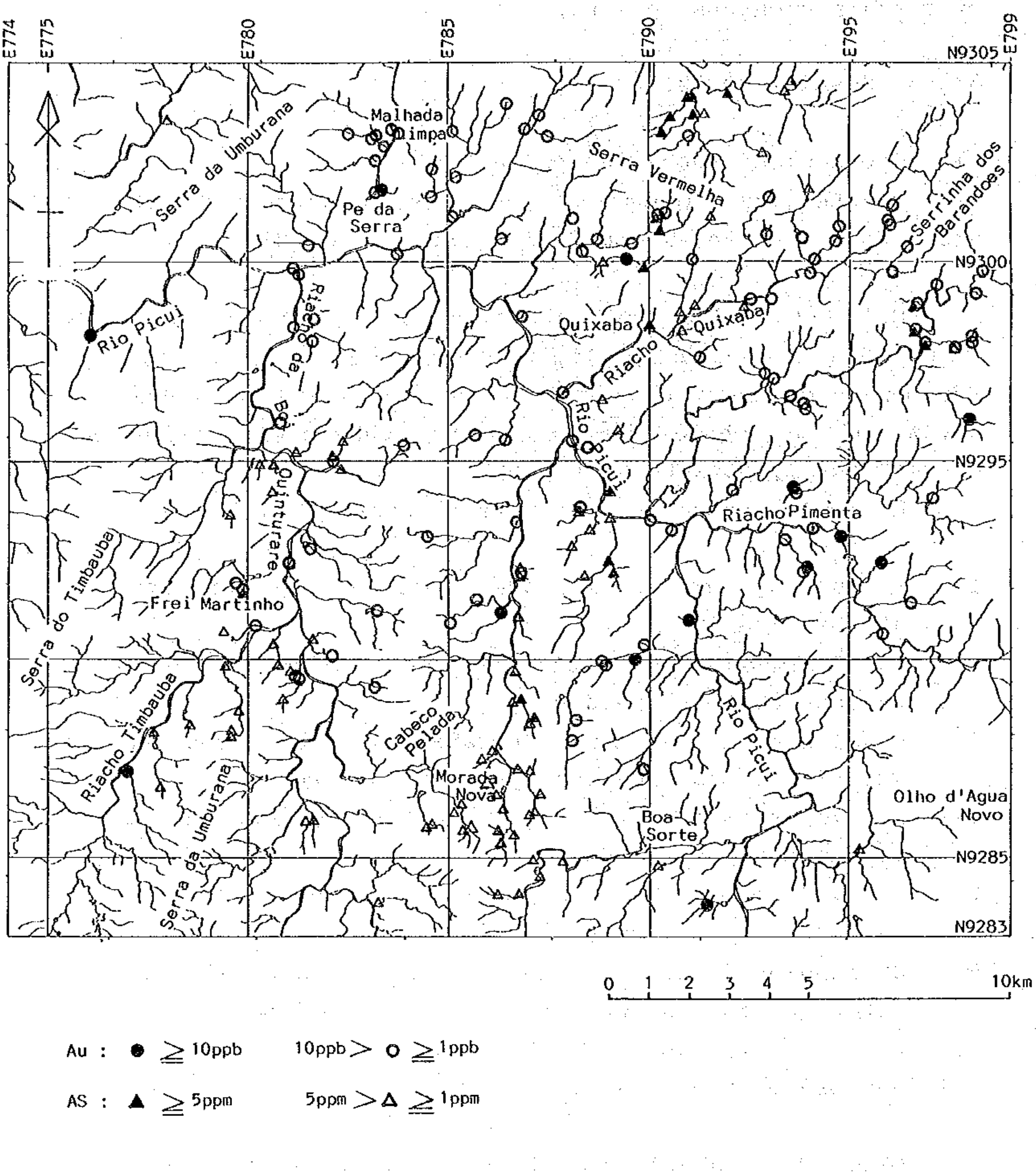
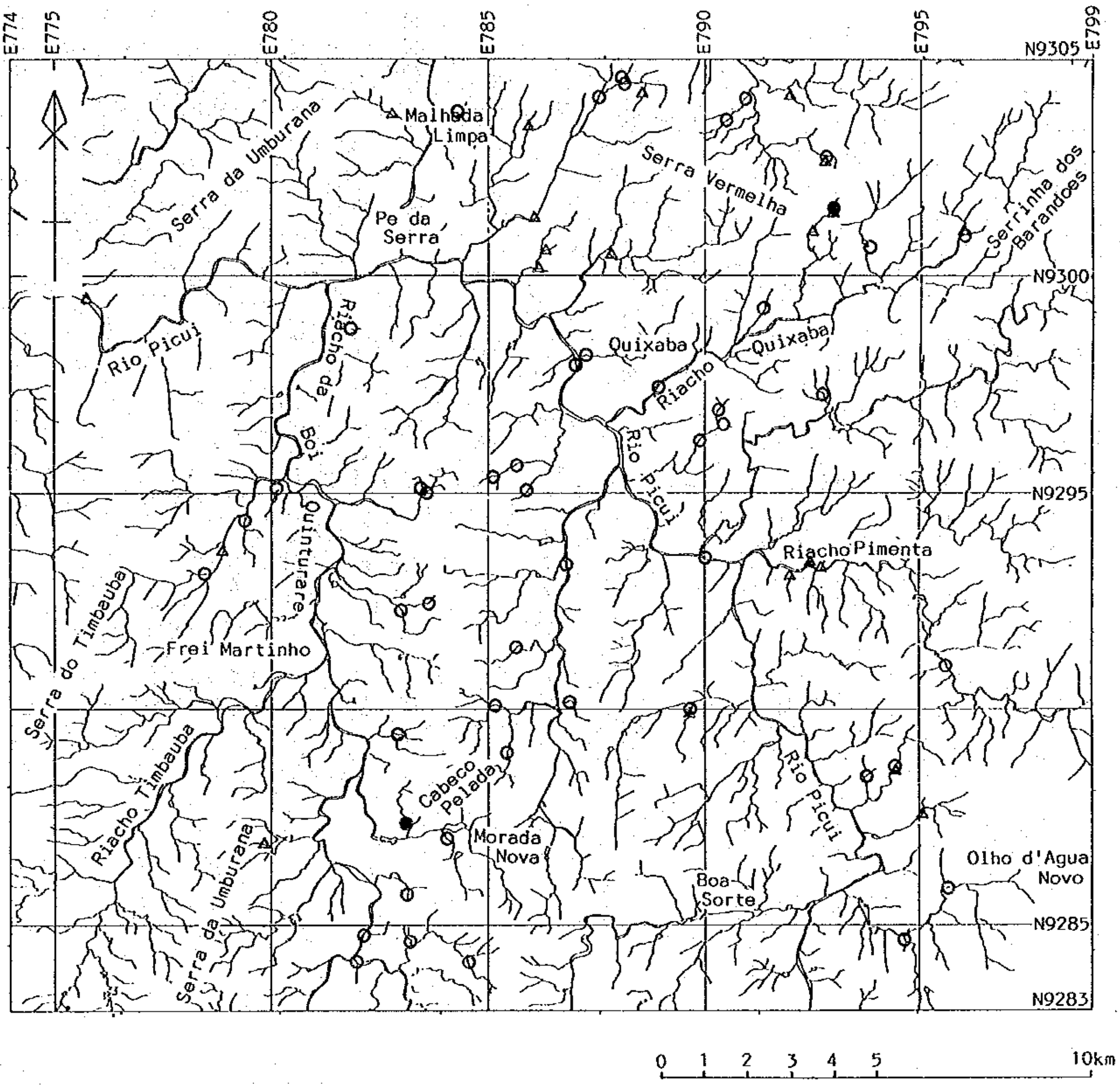


Fig. II-3-4 Au and As anomalies in stream sediments.



Sn : ● ≧ 20ppm 20ppm > ○ ≧ 8.5ppm

Be : ▲ ≧ 40ppm 40ppm > △ ≧ 4.25ppm

Fig. II-3-5 Sn and Be anomalies in stream sediments.

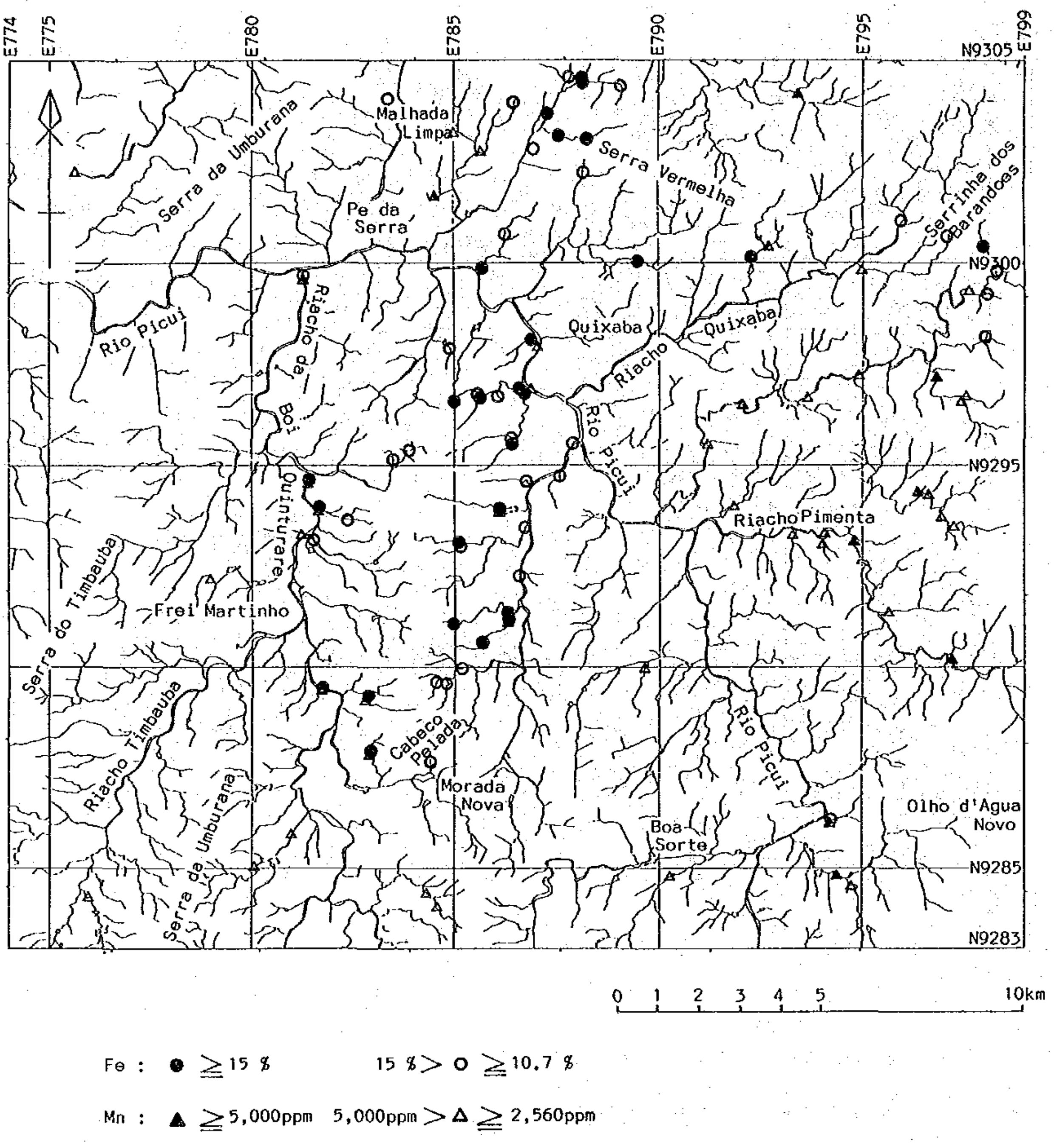


Fig. II-3-6 Fe and Mn anomalies in stream sediments.

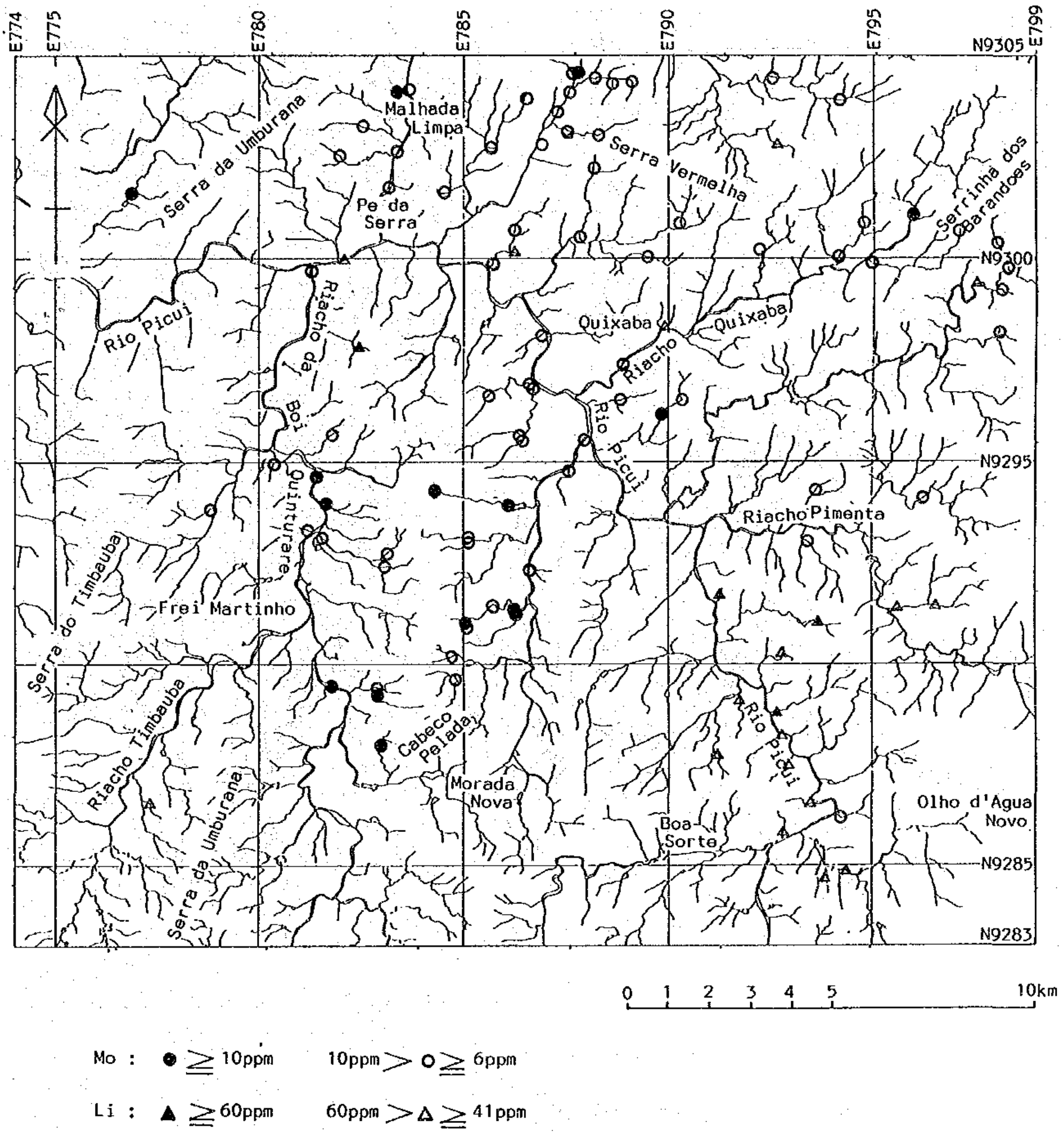


Fig. II-3-7 Mo and Li anomalies in stream sediments.

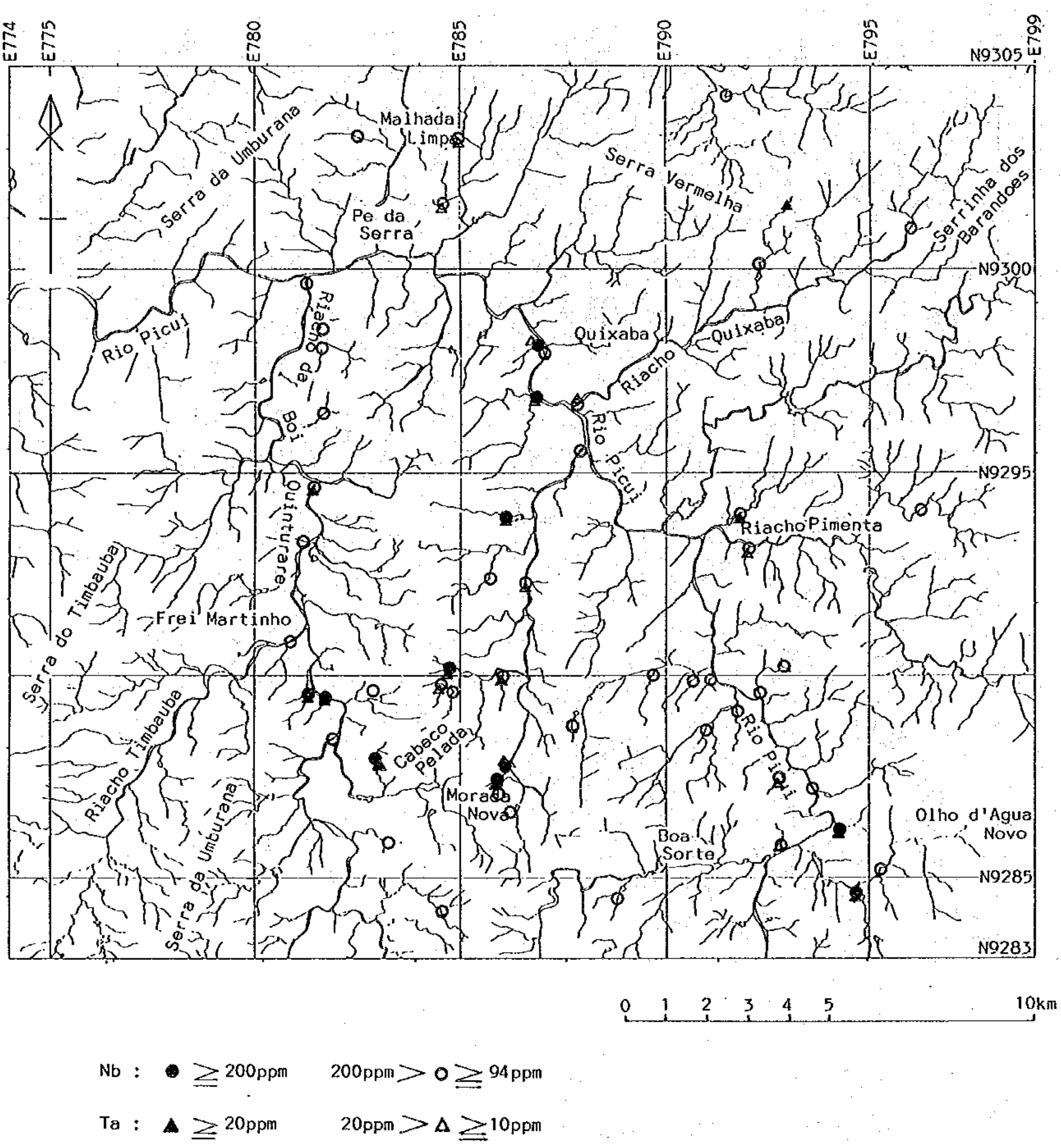


Fig. II-3-8 Nb and Ta anomalies in stream sediments.

Among above anomalous zones, zone 4) is represented by Au values of nealy 10 ppb, while zone 5) in Boa Sorte is dominated by samples with less than 1 ppb.

The distribution of anomalous zone dose not show a good correlation with a distribution of garimpos. Only anomalous zone 2) is distributed overlapping garimpos. Other than this, only one isolated sample (S1923) with anomalous value was found around Au garimpo in the southwestern part of the area.

Iron (Fe): A concentration of Fe ranges from the minimum value of 0.8% to the maximum value of 38.9%. The upper fence was obtained at 10.7%. Fig.II-3-6 shows an intremittent aliement of seven anomalous zones of Fe in SSW direction from south- western part of Serra Vermelha to southern part of Frei Martinho.

Manganese (Mn): Mn ranges from 120 ppm to 11,390 ppm with upper fence at 2,560 ppm. Anomalous zones are mainly distributed in eastern part of the area and they are summarized in following five locations in a whole area (Fig.II-3-6).

1) In the area of northern tributary of Riacho Pimenta in the eastern part of the sarea.
2) Three locations in the upper to middle stream of Riacho Pimenta in the eastern part of the area.
3) Three locations in southeastern part of the area.
4) Three locations in southwestern part of the area.
5) One location at Frei Martinho in northern part of the area.

Among the above, 1) and 2) have the widest distribution.

Molybdenum (Mo): Mo ranges from minimum value of less than 1 ppm (detection limit) to maximum value of 22 ppm. The number of samples with concentration less 1 ppm reaches 36.7%

of a whole samples and upper fence was obtained at 6 ppm. Fig. II-3-7 shows main locations of Mo anomalous zones in the two areas.

1) Surrounding area of Malhada Limpa.
2) Seven scattered locations being aligned in SSW direction from the stream in western part of Serra Vermelha to the south of Frei Martinho.

Mo anomalous zones of 2) overlap Fe anomalous zones.

Tin (Sn): Sn ranges from minimum value of less than 2 ppm (detection limit) to maximum value of 191 ppm. The number of samples with concentration less 2 ppm reaches 64.9% of a whole samples and upper fence was obtained at 8.5 ppm. Sn anomalous zones does not show any particular areas for their distribution (Fig.II-3-5), however, they tend to be located in same catchment areas of southern and central part of the area.

Niobiun (Nb): A concentration of Nb ranges from minimum value of less than 10 ppm (detection limit) to maximum value of 395 ppm. The value less than detection limit was obtained from the 17.4% of a whole samples and upper fence was obtained at 94 ppm. Anomalous zones of Nb mainly occur in the following four areas.

1) The area between Frei Martinho and Morada Nova.
2) Central part of the area.
3) Upper stream of Rio Picui in the southeastern part of the area.
4) Along Riacho do Boi Quinturare which flows northward from Frei Martinho.

These anomalous zones, except ones in northeastern and southwestern part of the area, are distributed overlapping primary and placer Nb and Ta deposits. The samples in anomalous zones 1) to 3) give a concentration of more than

200 ppm.

Tantalum (Ta): A concetration of Ta ranges from minimum value of less than 10 ppm (detection limit) to maximum value of 380 ppm. A number of samples with concentration less than detection limit reaches as high as 97.2% of a whole samples and 10 ppm was taken for the threshould value. Ta anomalous zones closely overlap that of Nb (Fig.II-3-8).

Beryllium (Be): A concentration of Be ranges from minimum value of less than 0.5 ppm (detection limit) to maximum value of 78 ppm. 35.9% of a whole samples gives concentration less than detection limit and upper fence is 4.25 ppm. Anomalous samples scatterd in the northern part of the area, however, thier distribution is not restricted in a particular catchment area (Fig.II-3-5). Other than this, three anomalous zone, one of which includes maximum value of 78 ppm, are found in southwestern part of the area.

Lithium (Li): A concentration of Li ranges from 3 ppm to 80 ppm with upper fence at 41 ppm. Anomalous zones tend to be located in southeastern part of the area (Fig.II-3-7).

Arsenic (As): A concentration of As ranges from minimum value of less 1 ppm (detection limit) to maximum value of 14 ppm. The value less than 14 ppm was obtained from 88.2% of a whole samples and 1 ppm was, arbitrary, taken for threshould value. Anomalous zones are mainly located in two areas (Fig.II-3-4).

1) Five locations being aligned in SSW direction from Serra Vermelha to Morada Nova.
2) *Southwestern and northern part of the Frei Martinho.*

Anomalous zones of 1) are distributed along the western end of pCssx4 (Serido Formation) and have widespreding catchment area around Morada Nova. Samples in the anomalous zone of northern part of the area tend to show a higher value of close to 10 ppm.

On the contrary to the results of last year, As and Au do not show a good correlation, probably because of a low concenration of As in this survey, giving the value of less than detection limit for many samples. The result of last year, same as this year, show a distribution of As anomalous zones along the western end of pCssx4 (Serido Formation) where intercalation of lens-shape pCsscs occurs.

Mn gives the second highest concentration next to Fe among analyzed elements. This relatively high concentration of Mn in stream sediments probably due to lithological control of bedrock in catchment area. A common occurrence of garnet, which contains considerable amount of Mn, in Serido Formation is probably responsible for this. Some of the samples show relatively high values in Nb and Ta, the maximum value of which are the highest among the trace elements, and these elements show a relatively uniform value all over the area. This is atributed to a common occurrence of columbite-tantalite bearing pegmatite in the area. Collection of stream sediments only from superficial layer, as done in this survey, may not be adequate for exploration of these ore deposits, since a high specific density of Nb-, Ta-, and Sn- minerals force them to rest on a deeper horizon in the stream sediments and, this, also, considered to be one of the reason for many samples showing Ta and Sn value less than detection limit. A scarce occurrence of granitic rocks in the area is, also, respossible to a occurrence of many low Sn samples. Main Be-minerals, in the area, occur in pegmatite. A scattered occurrenece of pegmatite in the area result in distribution of only small anomalous zones, because of a dilution of this element in the stream sediments.

Li is, generally, contained in micas. High concentration zone of Li occurs in the area of Serido Formation. Since bulk rock analyses show high Li content in granitic rocks in southeastern part of the area, high Li concentration zones in southeastern part of the area may well be reflected by the occurrence of granite.

A concentration of Mo is lowest next to Au and As. The Mo high concentration zone located around Malhada Limpa can be atributted to the occurrence of mineralization of skarn type (tactite) in the area. Although the source of Mo high concentration zones aligned in NNE-SSW direction in the west of Serra Vermelha is not precisely known, the occurrence of a fold zone and faults with a same trend in the area could be a cause of these. Mo, probably Fe too, was concentrated in the area transported upward through the fractures and faults associated with the folding in the area.

(2) Factor analyses

The result of factor analysis was shown on the map, plotting samples with high factor score (more than 1.00) for each factor (Fig.II-3-9 to II-3-12).

(i) Factor 1: Se-Be-(Nb)-(Mo)

Zones of high factor score are mainly distributed in three locations except for small scattered zones (Fig. II-3-9).

1) Lower stream of Riacho Quixaba to Riacho Pimenta
2) Northwestern part of the area
3) Northwest of Frei Martinho

Zone 1) is the most widespread among them.

The distribution of high factor score zone of Factor 1 in the area of calcsilicate rocks in the western margine of the Serido Formation and around pegmatite suggest that Factor 1 reflects mineralization of skarn type couppled with pegmatite deposit.

(ii) Factor 2: Fe-Mn-(Mo)

The distribution of high factor score zones overlaps

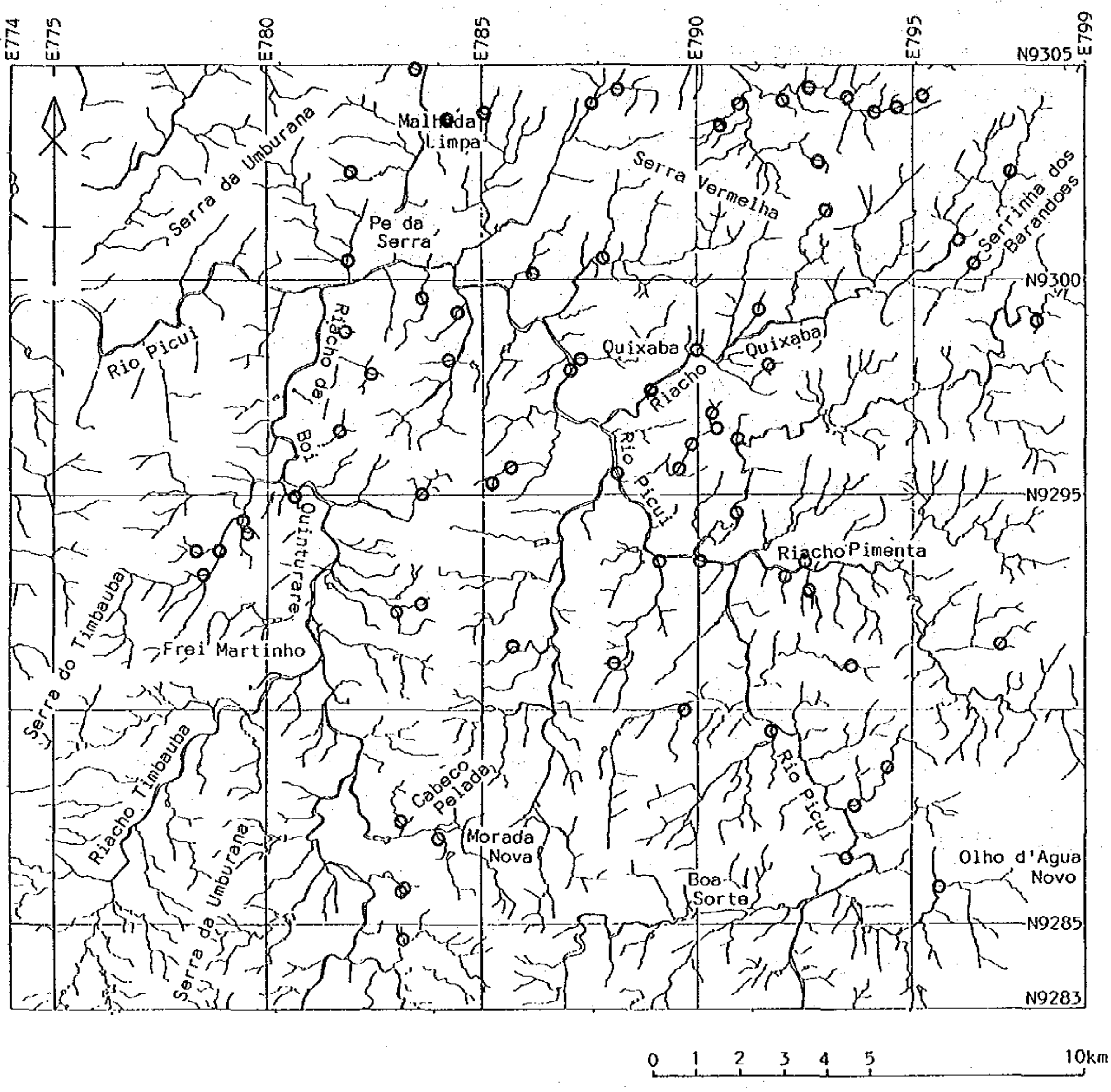


Fig. II-3-9 High factor scores from factor analysis in stream sediments:
Factor 1 ; Sn - Be

high concentration zones of Fe and Mo in the area from west of Serra Vermelha to the south of Frei Martinho in NNE-SSW direction and high concentration zones of Mn in eastern part, south eastern part and southwestern part of the area (Fig. II-3-10). Fe and Mn have a higher factor loading compared with that of Mo and they are most preferably contained in garnet. This suggest that Factor 2 is contoroled by lithology of bedrock, in another word, abundance of garnet.

(iii) Factor 3: Li

High factor score zones occupy one third of eastern part of the area (Fig.II-3-11). This factor probably reflects abundant micas in pCssx4 of Serido Formation and the intrusion of granite in the eastern part of the area.

(vi) Factor 4: Ta-Nb

This factor, most plobably, reflects pegmatite deposit (Fig.II-3-12).

3-2 Pan concentrate geochemical survey

3-2-1 Purpose of the survey

The purpose of the pan concentrate geochemical survey is as follows.

1) To verify the correlations between Au and As in the central part of the phase I survey area, where As anomalous areas were defined there and As is correlated with Au by stream sediment geochemical survey in the phase I survey area. (area A)

2) To survey the extension of gold bearing rocks and stream sediments around those rocks and stream sediments which were formerly reported to contain gold by DNPM and CPRM. (area B)

3) To realize the extension of the mineralization on the

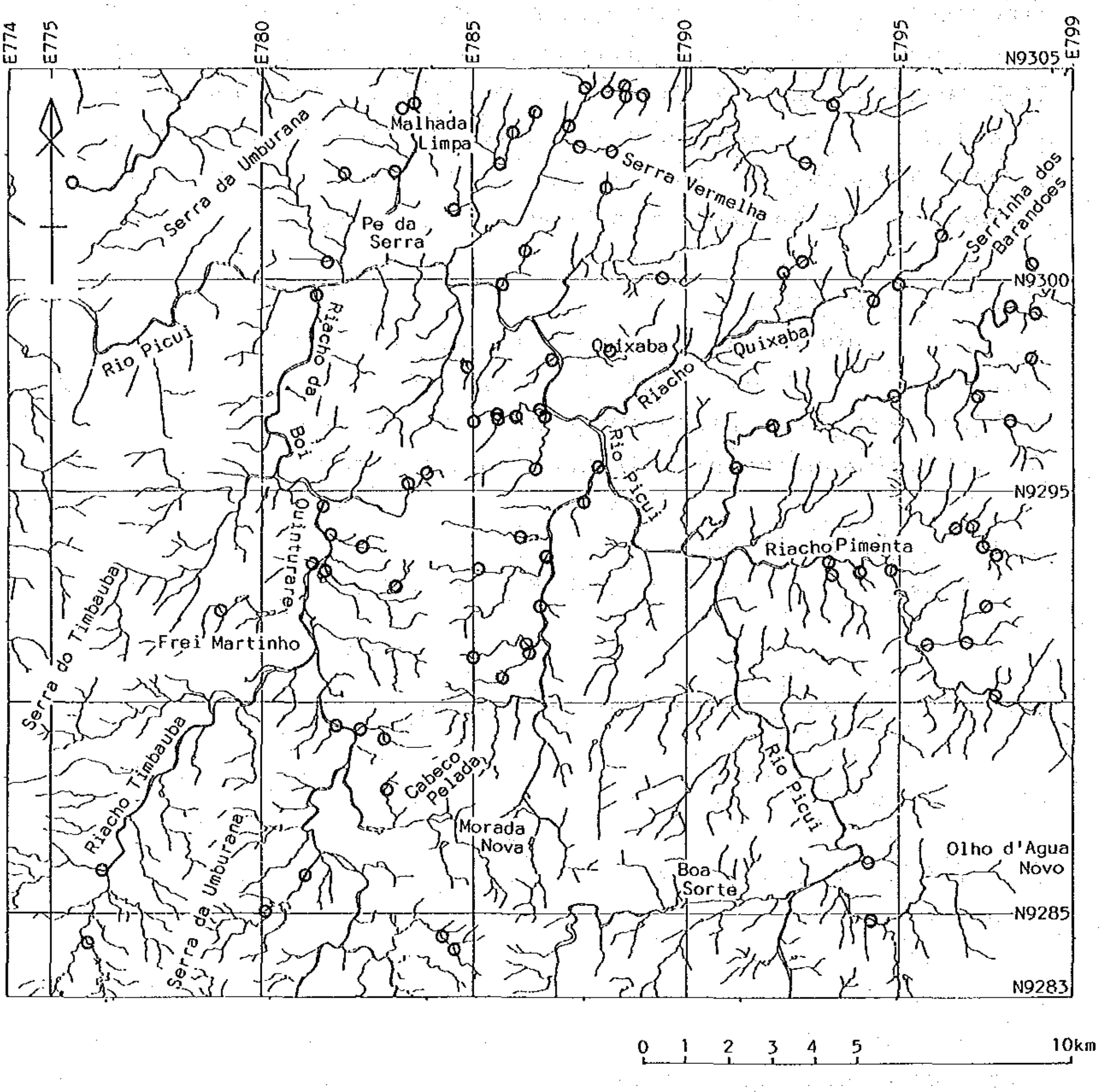


Fig. II-3-10 High factor scores from factor analysis in stream sediments:
Factor 2 ; Fe - Mn - Mo

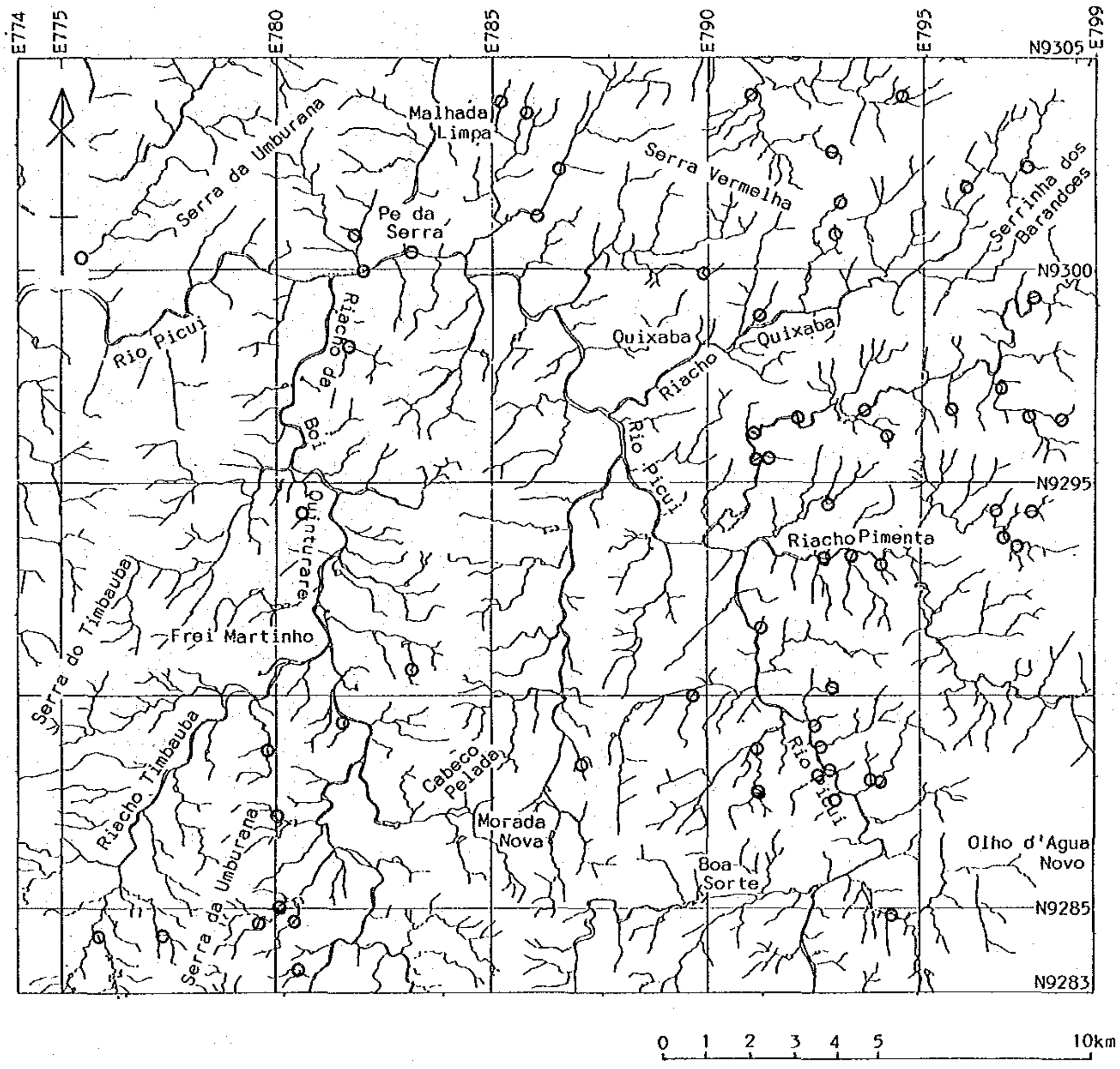


Fig. II-3-11 High factor scores from factor analysis in stream sediments:
Factor 3 ; Li

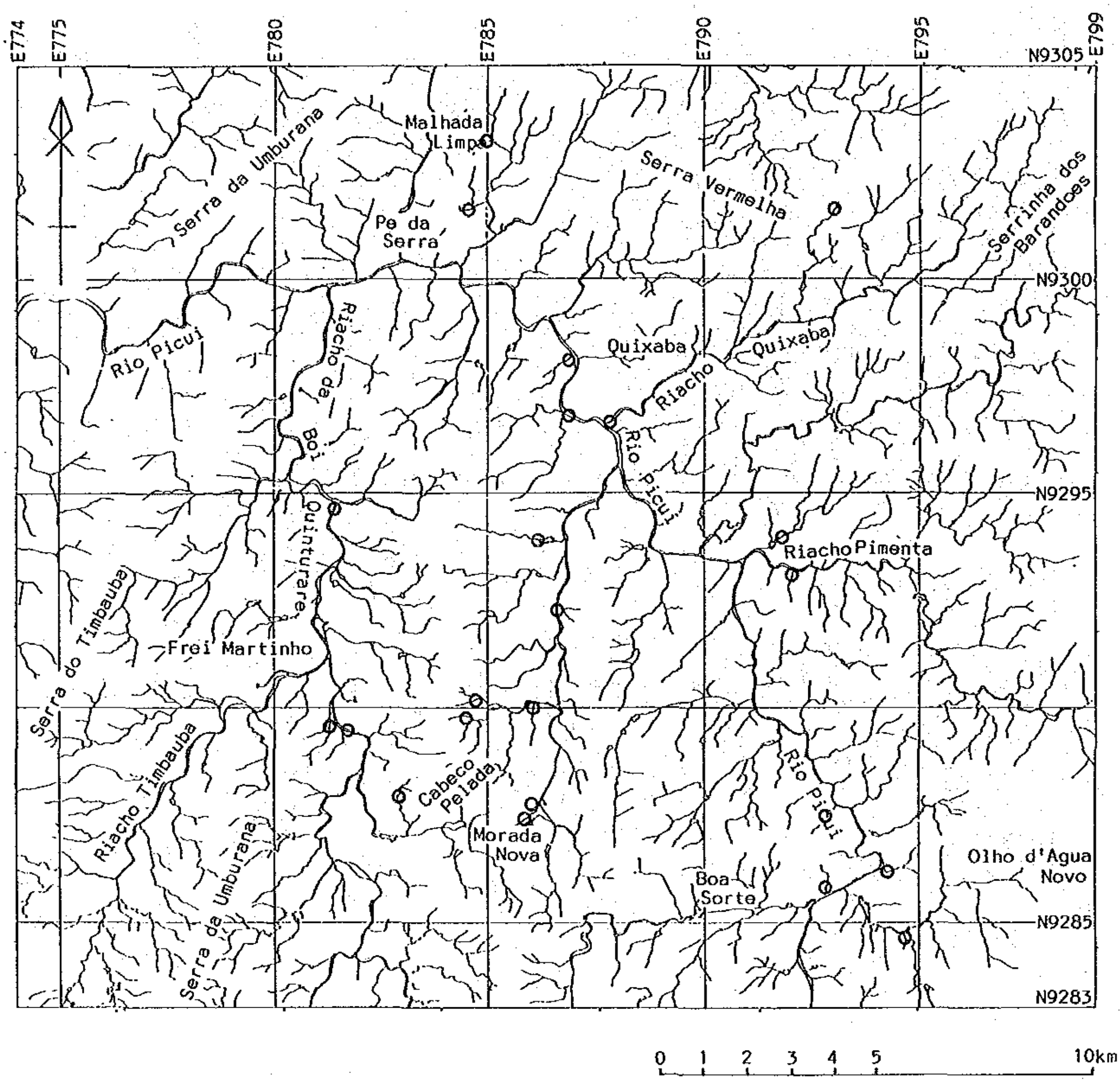


Fig. II-3-12 High factor scores from factor analysis in stream sediments:
Factor 4 ; Ta - Nb

drainage system when gold bearing quartz vein and/or gold dusts were detected during the phase II survey.

3-2-2 Procedures of the survey

(1) Sampling

The sampling points were planed in advanceon the topographic map in a scale of 1:25,000. Then the points were tested in the field if it is good or not for the sampling. The points are decided in view of the style of transportation of sediments. The points are for instance on the inside of the curved stream and behind the large block on the straight stream. The samples were taken from the bottom of the sediment or from the middle of the sediments where heavy minerals were concentrated (Appendix 7). The procedure of the sampling is as follows. Sand and gravel about 40 to 50kg are sieved and decreased the weight and size into 20kg and less than 4mm diameter respectively. Then the sand are panned. The panning was executed to observe gold dusts. Therefore, the samples took for the purpose are sometimes very little.

(2) Chemical analyses of the samples

The samples were analysed for Au, Ag, Mo, W, Sn, Ta and Nb. The methods and the detection limits of the chemical analyses are described before. The analyses were executed by Geosol-Geologia e Sondagens Ltda. The data of the analyses are shown in Appendix 6.

(3) Data of the analyses

The statistical analyses of the data do not have meaning. Because the procedures of collecting samples were differents on each sample, that is, the samples were collected only from the heaviest part of the sediments and they are very little. Then, the data were treated for only relative amount of each element.

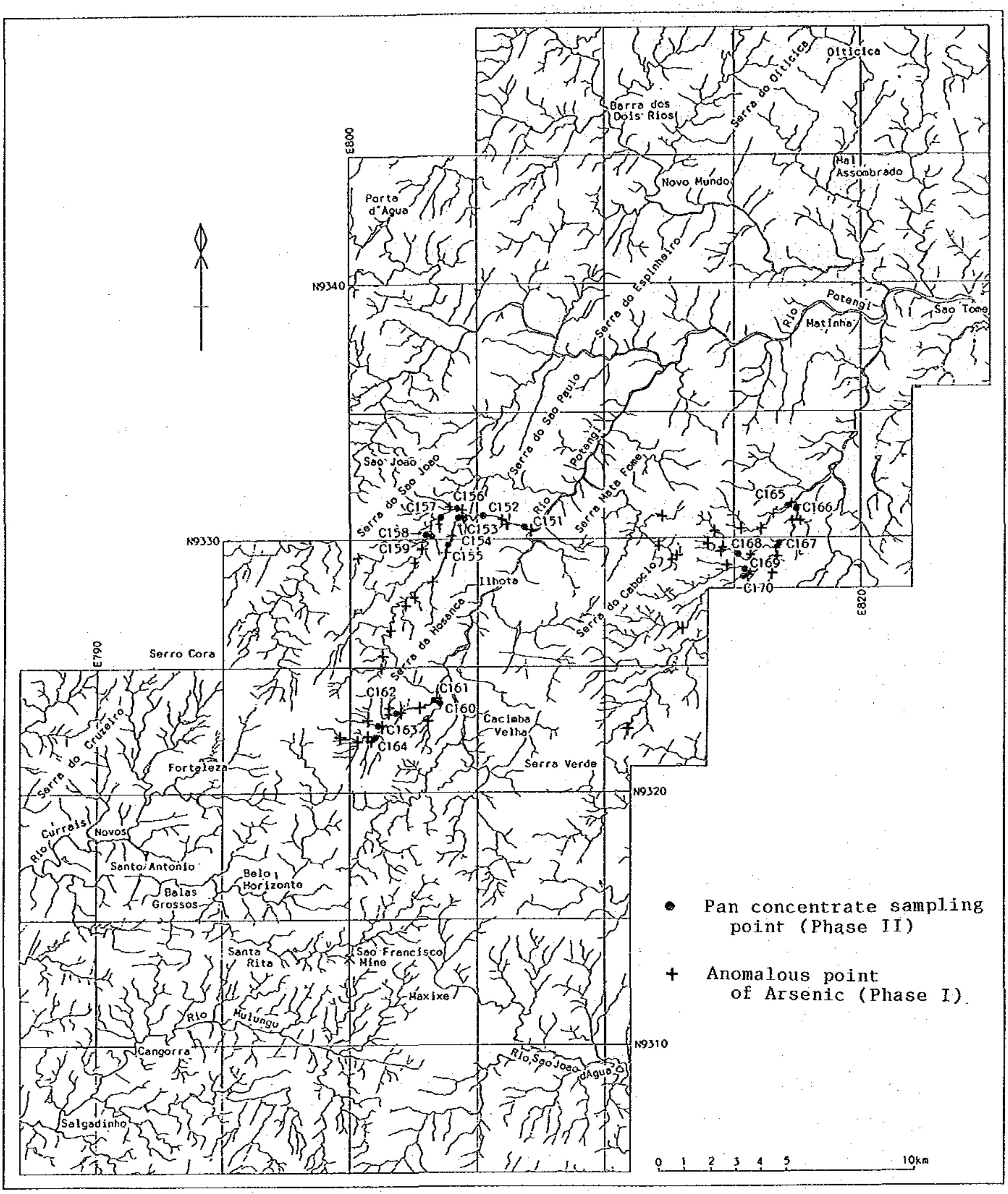


Fig. II-3-13 Location of pan concentrate samples in phase I survey area

3-2-3 Result of the survey

(1) Observation of the pan concentrate samples

Samples were observed by a hand lense of 20 magnifications to find out gold dusts and to identify other heavy minerals. Gold dusts were found at two points in phase I survey area, and six points in area B. The size of those gold dusts are 0.5mm long except one of them (Appendix 8). The two points in phase I area are located in the Rio Potengi drainage system (Fig.II-3-14). One of them, C156, is at the southern end of the Serra do Sao Paulo, another, C164, is at the southern end of the Serra Do Hosanca.

In area B, gold dust was observed in the sample, C128, taken from Salgadinho east central part of the survey area. Other samples with gold dusts were all taken from the southwestern part of the area (Fig.II-3-14). Three samples, C186, C188, C192, are from the west of Cabeco Pelada, two samples, C205, C212, are from west of Serra do Umburana.

Magnetite, columbite-tantalite and scheelite were also identified. Columbite-tantalites are released from pegmatites and scheelites are originated from tactites.

(2) Concentration of elements

Gold (Au)

Locations of gold dusts and the samples which have more than 1,000 ppb of gold content were shown on the map (Fig. II-3-14). The values of chemical assays are classified into more than 1,000 ppb and more than 10,000 ppb. The samples with 10,000 ppb and more than that of gold are C201 and C205. The samples in which gold dust was identified did not always give high values of gold. Same result happened in phase I survey. This may be because the gold dust did not get in the powder to be analysed when the sample was analysed. The sample with the value of 1,000 ppb and more than that and less than 10,000 ppb of gold are C155, C159 and C184 in the phase I area and C171, C193, C208, C213 and

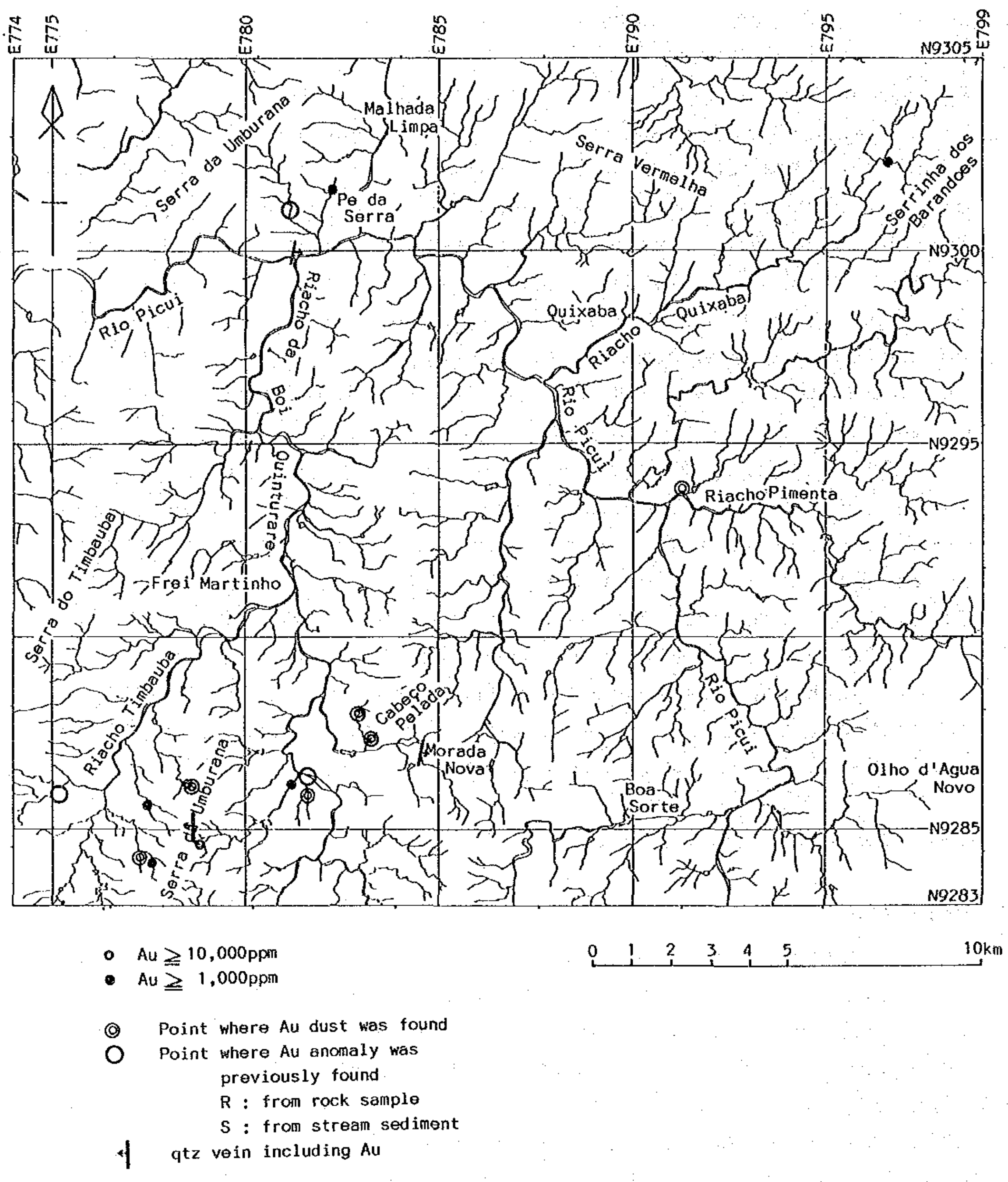


Fig. II-3-14 Au concentration in pan concentrates

C229 in the phase II survey area. The samples in the phase I survey area are all in the Rio Potengi drainage system, where is located at the western end of the pCsxx4. The samples in the phase II survey area are located around Serra do Umburana except C171. The sample C171 is from Pe da Serra south of Malhada Limpa. In the Serra do Umburana, gold bearing quartz vein occurrs as described above.

Either gold dusts nor high gold values were detected in the drainage system south of Sao Tome. Therefore, here Au is not geochemically correlated with As.

Silver (Ag)

Silver was not detected on all samples because of detection limite.

Molybdenum (Mo)

Contents of Mo are generally very low. Locations of samples containing 10 ppm and more than that of Mo are shown on the map (Fig.II-3-15). The samples are C171, C172, C180, C215 and C232 and are all located on area B. They are distributed in Pe da Serra, Frei Martinho and Sitio Timbauba. Samples, C171 and C215, containing 100 ppm of Mo were taken at Pe da Serra and Sitio Timbauba respectively. They are all located on the small drainages extended from the area where Equador Formation and tactites are distributed. Therefore, the higher Mo content in the samples may be related to some mineralization.

Tungsten (W)

As can be seen in Appendix 6, scheelite was observed at many locations (Fig.II-3-15). Then, it is natural that scheelite is observed in a lot of samples. Samples in the drainage of Rio Potenge in phase I survey area are especially rich in scheelite. However, no high value of scheelite can be detected in the samples in the drainage south of Sao Tome. The drainage of the Rio Potengi, where scheelite high values were detected, is in the zone of

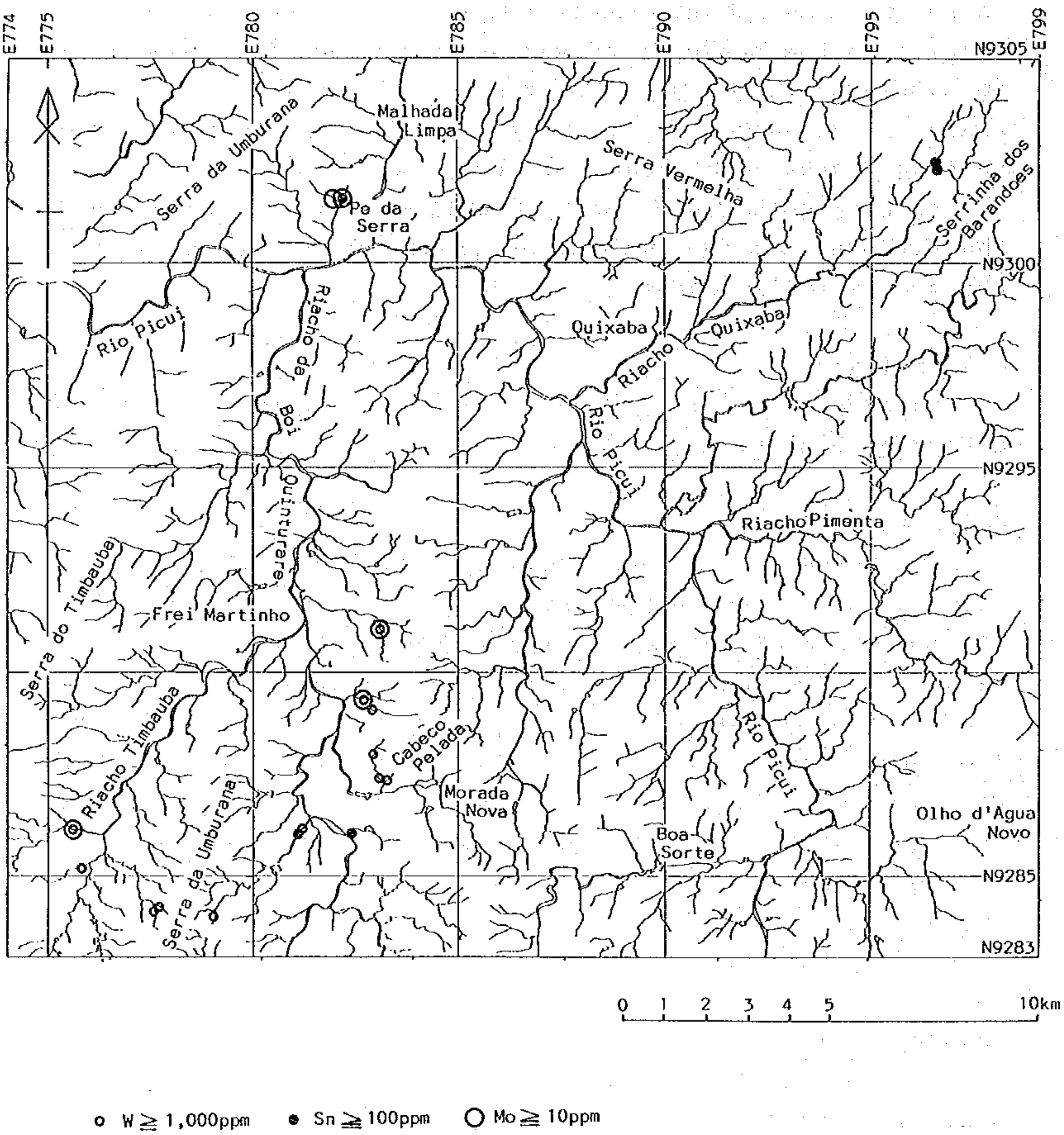


Fig. II-3-15 W, Sn and Mo concentration in pan concentrates pCssx4, trending north northeast to the west of the Caico Complex. The zone is rich in pCsscs. Samples with values higher than 10,000 ppm of W are C159 and C164 in phase I survey area. Values of 1,000 ppm and higher than that and less than 10,000 ppm are detected at 6 points in phase I survey area and at 13 points in phase II survey area. They are all in the Serido Formation. In phase II area, they are at Pe da Serra, in the south of Frei Martinho, in the west of Cabeco Pelada and Serra do Umburana. The samples C171, at Pe da Serra, C193, west of Cabeco Pelada. C213, west of Serra do Umburana, with high values of W have also high values of Au. Nearby the upper reaches of the samples C171 and C193, scheelite deposits was mined out in a small scale.

Tin (Sn)

The analytical values are generally low. The maximum value is 280 ppm. The points with values of 100 ppm and more than that are all in are B. They are samples C190, C193, C228 and C229. The former two samples are taken from the southwest of Cabeco Pelada and the latter two samples are taken from the northeastern end of the survey aea (Fig. II-3-15). They are all in the Serido Formation. Granitic rocks supposed to be related with mineralization could not be find in the upper reaches or around any sampling point. Therefore, the correlation between the high values of Tin and some mineralization can not be defined.

Tantalum (Ta)

Ta occurrs with Nb as minerals of columbite-tantalite in pegmatites. It is natural that this area is rich in Ta because in this area pegmatited rich in colombite-tantalite are widely distributed, and the minerals stay to the last as the result of panning. Points with values more than 10,000 ppm are shown on the map (Fig.II-3-16). The samples with high Ta values are centered on the drainage of the Rio Potengi in the phase I survey area as the samples with high tungusten values. In the drainages south of Sao Tome, any

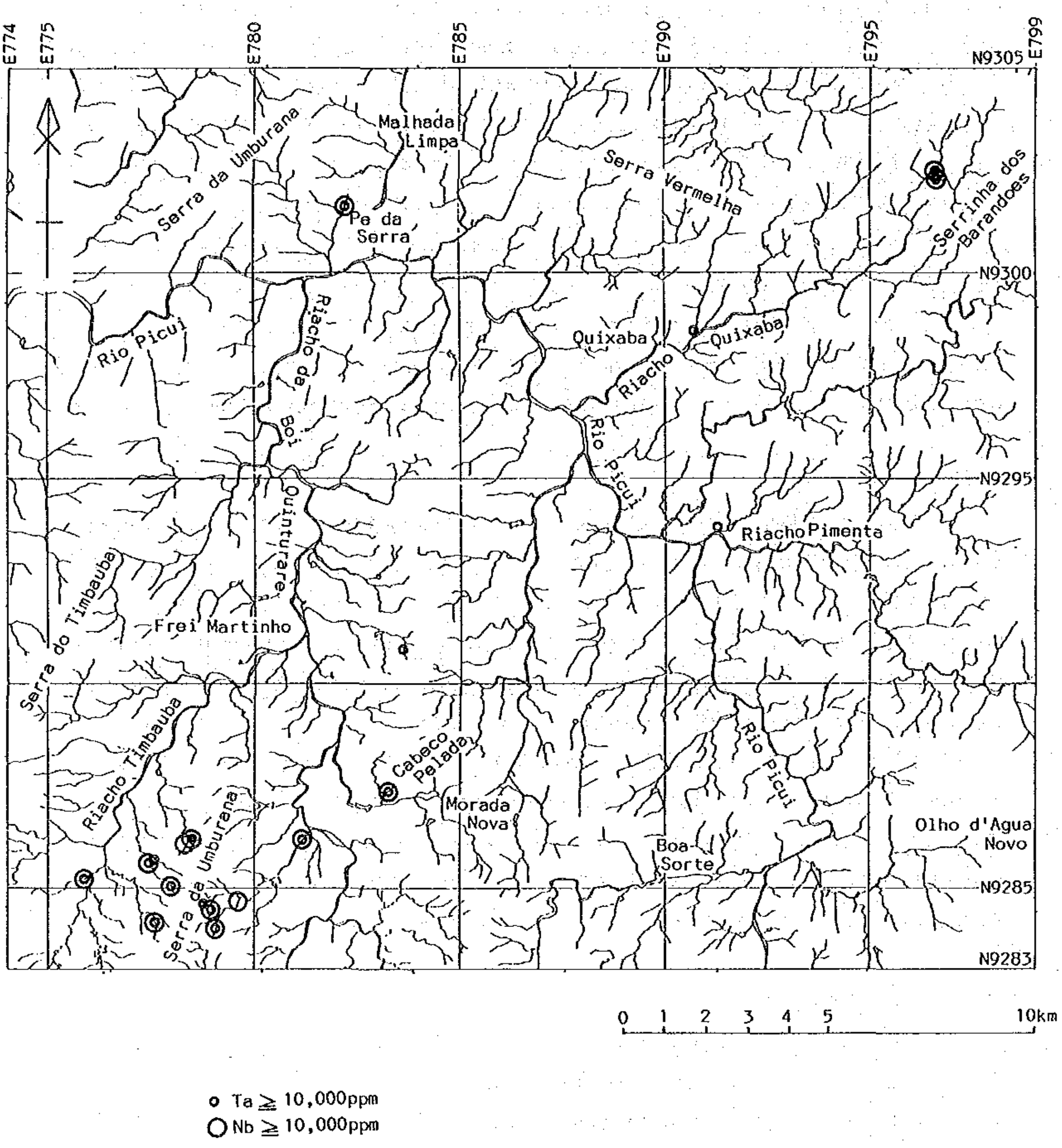


Fig. II-3-16 Ta and Nb concentration in pan concentrates samples with more than 10,000 ppm of Ta are not detected. In area B, samples, C201-218, are centered on around Serra do Umburana and west of Cabeco Pelada.

Niobium (Nb)

Location of samples with more than 10,000 ppm of Nb are shown on the map (Fig.II-3-16). The area with high values of Nb is distributed as same as that of Ta.

3-3 Discussions

Gold anomalous areas with small clusters of samples of higher gold values detected by stream sediment geochemical survey are ditributed in the entire survey area. The anomalous areas are not correlated to the geology. The gold anomalous areas detected in phase I survey are widely distributed to the west of the San Francisco ore deposit. The anomalous areas detected in phae II survey are also widely distributed. Following 7 areas were selected for gold anomalous areas as the result of statistical treatment of analytical data (Fig.II-3-17).

1) Around Malhada Limp on the northern part of the survey area
2) Gold garimpo area in the south of the Serra Vermelha
3) In the middle of Riacho Quixaba and southeast of there
4) In the middle o the Riacho Pimenta and west of there
5) In the north of Boa Sorte
6) Around Frei Mratinho and east of there
7) In the lower reaches of Riacho do Boi Quinturale

Stream sediment samples with higher gold values are centered on in the area 4). Four samples with gold values more than 10 ppb are in the same drainages. In the anomalous area, especially around Serra do Umburana, where gold bearing quartz vein occurs, no anomalies were detected on the stream sediments. The reason why stream sediment

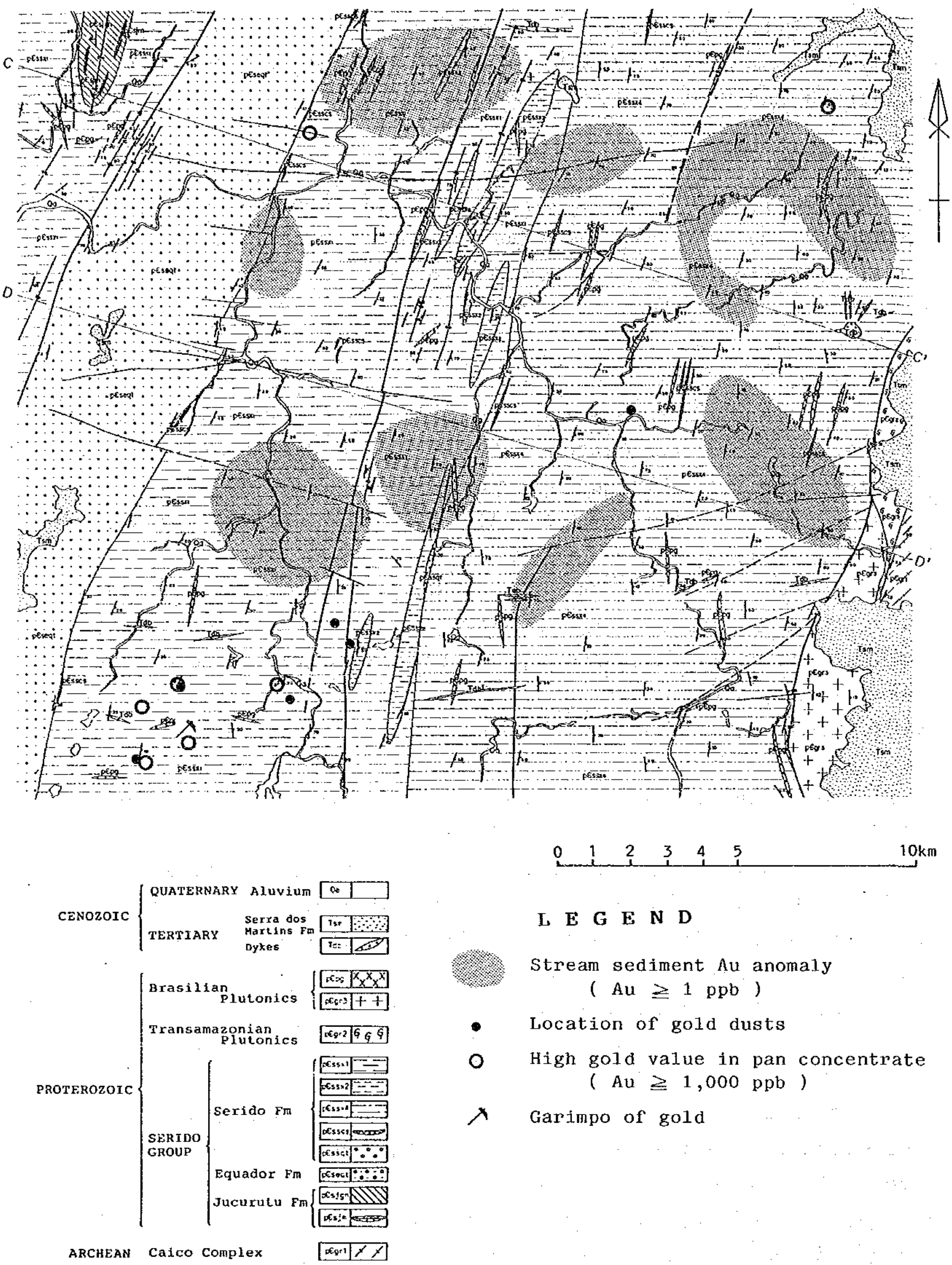


Fig. II-3-17 Compilation of the survey results in area B anomalies were not detected is not realized yet. However, when it is realized that there are a lot of and higher gold anomalous points in the drainage near Sao Francisco in Serra do Umburana is in small scale. Though the gold bearing quartz vein west of Sao Tome in the phase I survey area showed higher gold content, no stream sediment anomalies were detected in the surrounding drainages.

Slight correlation between Au and As was detected as the result of factor analysis of analytical data of the stream sediments. However, it is not detected on the samples taken in phase II survey area. The reason why the correlation is not detected may be because the samples with As values below detection limit are too many. As anomalies were distributed in the zone west end of the pCssx4 in the Serido Formation, where rocks of pCsscs were condensely distributed. In this zone, the Au anomalies were also detected. However, those Au anomalies do not have higher values of Au and the anomalies were not centered on, either. The relation of Au mineralization with pCsscs should be further studied.

Pan concentrate samples with higher Au values are distributed around Serra do Umburana, especially from the east of the Serra do Umburana to Cabeco Pelada 3km to the northeast of the Serra, gold dusts were observed and higher Au values were also detected.

According to the multi-element analysis of the analytical data of the stream sediment samples, factors related to the lithological characteristics of the metamorphic rocks and other mineralization than that of gold were defined.

PART III

CONCLUSIONS AND RECOMMENDATIONS

Chapter 1 Conclusions

(1) Area A

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

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

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

(2) Area B

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

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

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

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

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

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

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

Chapter 2 Recommendations for phase III survey

From the integral analysis of the results of the phase II survey, following areas are recommended for further detailed survey;

(1) Area A

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

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

(2) Area B

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

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3. DATA

Listagem das ocorrencias minerais
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FIGURES

TABLES

PLATES

APPENDICES

Appendix 4 Analytical data of stream sediment samples.
Appendix 5 Analytical data of pan concentrate samples.
Appendix 6 Observations of pan concentrates.