Chapter VI

FIELD EXCURSION

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DAYS 1 AND 2 - LITHOLOGIES, STRUCTURES AND AGE RELATIONSHIPS IN THE EASTERN PART OF THE JEQUIÉ-MUTUÍPE-MARACÁS DOMAIN OF THE JEQUIÉ-ITABUNA GRANULITIC BELT

FIRST DAY - SEVERAL OUTCROPS ON THE EASTERN PART OF THE JEQUIÉ-MUTUÍPE-MARACÁS DOMAIN AROUND THE TOWNS OF LAJE, MUTUÍPE AND UBAIRA (Fig. VI.1)

From Laje to Jequiriçá (ca. 88 km)
Leaders: Johildo S. F. Barbosa, Moacyr M. Marinho and Pierre Sabaté.

The purpose of this first day of field excursion is to examine the field relations of the enderbitic-charnockitic plutonic rocks of the region as well as a garnet-bearing leucogranite of the ortho- and paraderived domain, close to the town of Ubaira. The tectonic deformations which affected these plutonic rocks will also be examined.

STOP 1-1: Laje outcrop

Large dome-shaped outcrop at the margin of the Jequiriçá river. The dominant structure in this outcrop is given by a parallel arrangement of mesoperthite crystals (0.5-10 cm long) in a planar and undulating banding/foliation. The foliation is not easily seen on fresh surfaces where the rocks are massive-looking and green to dark grey. The rock texture is generally coarse grained but in some parts of the outcrop it is medium to fine grained. The mineralogical banding is marked by alternations of lighter bands, where feldspars predominates, and dark grey bands composed mainly by ferromagnesian minerals, probably originated through accumulation of different mineral phases during the magmatic differentiation and emphasized by the tectonic deformations. In a general way the rock is a charno-enderbite of the low-K calc-alkaline sequence (chap. II), composed by mesoperthite (17%), antiperthitic plagioclase (An25; 43%), quartz (31%) orthopyroxene (5%), clinopyroxene (1%), brown hornblende (1%) and biotite (2%). More details regarding the mineralogy of this rock are given in chapter II, table II.1. Some mafic enclaves, deformed and oriented parallel to the banding, are observed. The folds with low angle axial plane and sub-horizontal S_1 axes are believed to have been formed by the folding episode F_1. The limbs of these folds (banding/foliation S_{n-1}) are sometimes transposed. Some mesoperthite clasts suggest that the movement direction was roughly from ENE to WSW. Quartz and pyroxene pegmatite veins occur in the outcrop: (i) crosscuting the banding and being folded by F_1; (ii) parallel to the banding; and (iii) undeformed and discordant to the banding/foliation. Fluid inclusions in quartz grains of these veins were studied, as well as carbon isotopes in the CO_2 of the inclusions (chap. II). Opx-cpx geothermometry indicates temperatures of about 820°C, considered as the metamorphic re-equilibrium temperature. A Rb-Sr isochron was determined for the outcrop giving an age of 2,850 Ma (Costa and Mascarenhas 1982). On the other hand Wilson (1987) found an age of 3,014 Ma for these rocks through the Sm-Nd method (T_{DM} model ages).

STOP 1-2: Casa de Farinha outcrop

The rock is a finer grained charno-enderbite (chap. II, table II-1). Both the banding and the foliation are more pronounced, and the outcrop has small S_2 folds with steep diping axial plane with N10-20W/30° axes. The axial planes are sometimes transposed in high strain zones. Retrograde minerals such as biotite and hornblende are found in these transposed zones.

STOP 1-3: Mutuípe enderbite outcrop

Outcrop at the eastern entrance of the town of Mutuípe (tall roadcut) showing the characteristic green to grey colour of the regional rocks. The foliation, maybe a S_2 (N20W/90) is easily seen. It is shown by centimeter size alternations of light and dark mineral concentrations, producing a gneissic fabric. The Mutuípe enderbite is composed by: antiperthitic plagioclase An30 (51%), orthopyroxene (4%), clinopyroxene (12%), hornblende (5%), quartz (22%), mesoperthite (4%) and opaque minerals

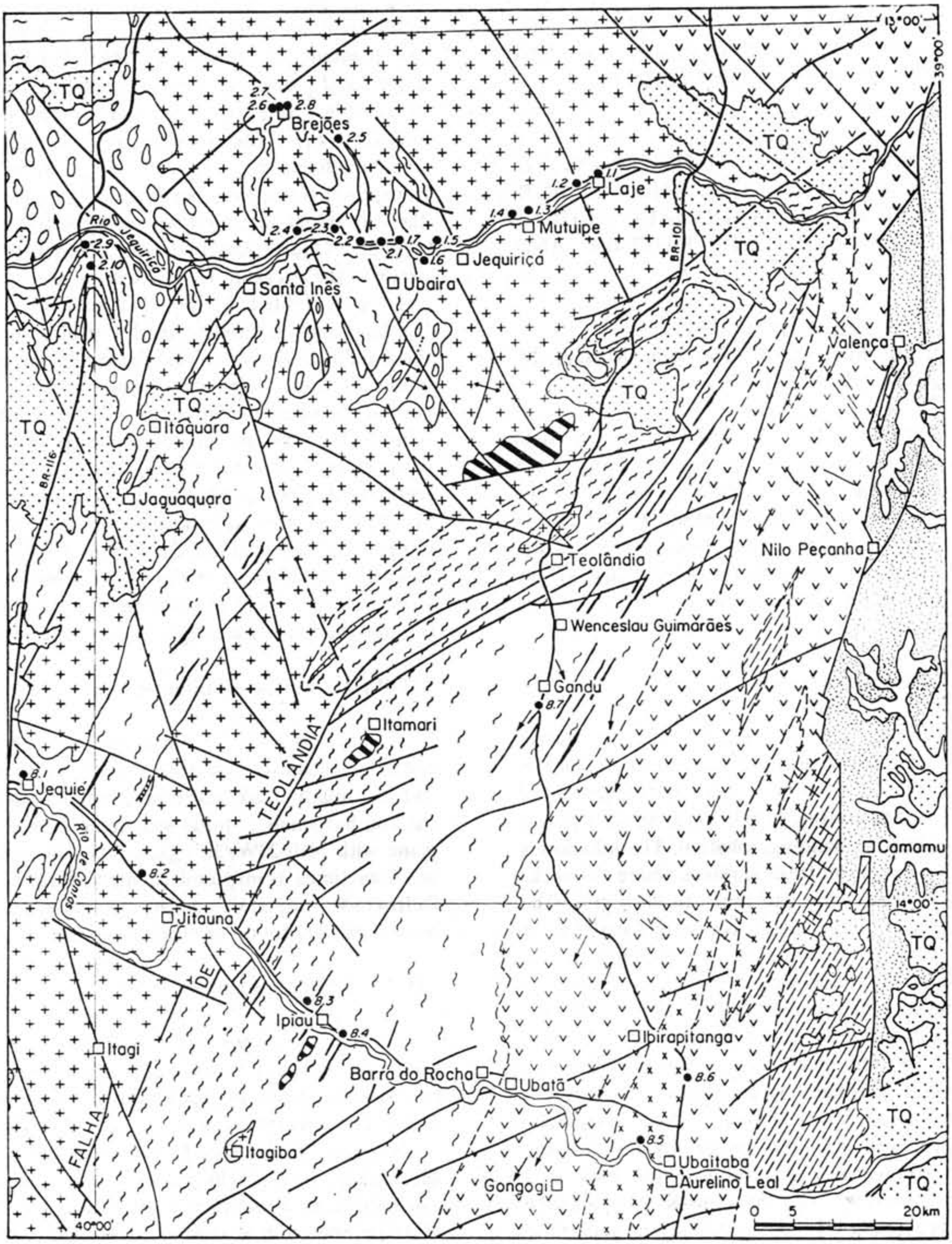

Figure VI.1a - Geological sketch map of the Laje-Jequié region (apud Barbosa, 1991) and location of the outcrops described in the excursion guide.

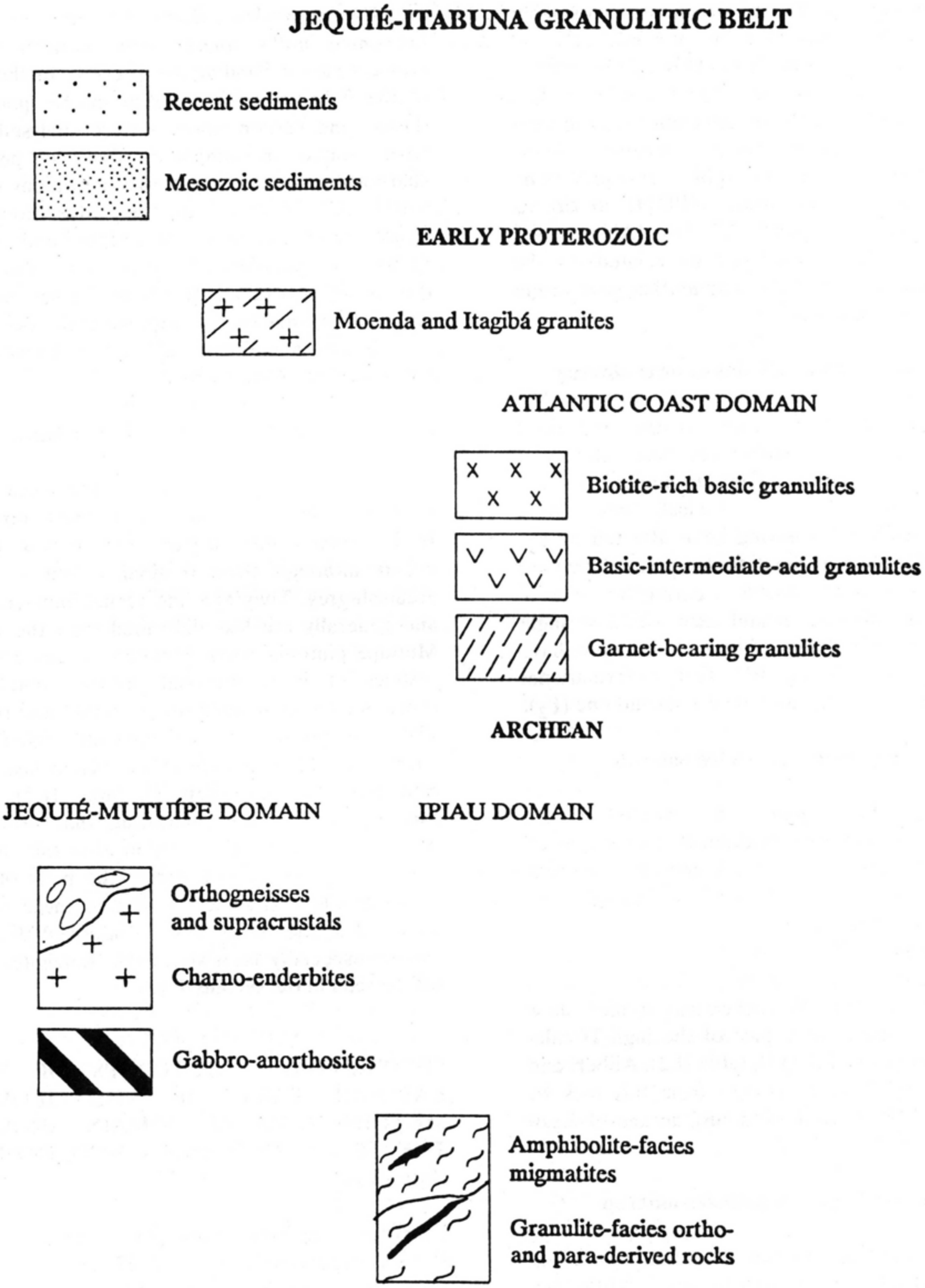

Figure VI.1b - Legend of Figure VI.1a.

(2%). Biotite, apatite and zircon occur in smaller amounts. Retrometamorphic minerals are also found (chap. II, table II.1). This rock is part of the high-Ti calc-alkaline sequence discussed in chapter II. Temperature calculations using opx-cpx pairs yielded values around 820°C, considered as metamorphic re-equilibrium. Recent U/Pb dating using SHRIMP in zircons yielded values around 2.7 Ga (Alibert and Barbosa 1992), considered as related to the crystallization age of the magma that gave origin to these plutonic rocks (chap. IV).

STOP 1-4: Fazenda N. S. das Graças outcrop

Banded rock with centimetre thick intercalations of intermediate, basic and calc-silicatic (?) material. The lithologies, perhaps supracrustal rocks, are tectonically intercalated into the enderbites having been affected by the same deformations. Small folds (about 50 cm) are preserved from the ductile shearing whose axial planes are sub-vertical and axes with low angle northwestward plunge. These folds may have been formed during the first deformational episode (F_1) and refolded by the second one (F_2).

STOP 1-5: Rio Jequiriçá bridge outcrop

In this point a banded/foliated charnockitic rock with medium to coarse grained texture crops out. Its colour is greyish green with pinkish spots of possible surficial hydrothermal origin. The attitude of the banding/foliation is N15W/60SW and is easily seen on the outcrop, unlike the previous outcrops which have a general northeastward dip. Petrochemical studies show that this charnockite is part of the high-Ti calc-alkaline sequence (chap.II, table II.2). Alibert and Barbosa (1992) dated zircons from this rock by the SHRIMP method, obtaining an age of 2,810 Ma (chap. IV).

STOP 1-6: Rio Jequiriçá potholes outcrop

In this outcrop the charnockite presents banding/foliation (S_2?) striking about N10W and dip ranging from 70° to sub-vertical. It shows alternance of coarser and finer grained bands. The mineralogical composition is similar to that of the charnockite from the previous stop. Deformed milky quartz veins parallel to or crosscuting the banding are present. In the CO_2 of the fluid inclusions present in the quartz of these veins, carbon isotopes were analysed. The values found are similar to those of plutonic charnockites from other granulitic regions of the world, and different from the values found in milky quartz present as concordant bands in the ortho- and paraderived rocks to be discussed during day two (chap. II). Note the presence of an enclave, maybe of supracrustal rock that already had a banding before the deformation which affected the host rock.

STOP 1-7: Garnet Leucogranites of Ubaira

The garnetiferous leucogranites occur only in the so called "ortho- and paraderived domain". In the more weathered parts they show a lighter colour although their original colour is light greenish-grey. They are fine to medium grained and generally are less deformed than the Laje-Mutuípe plutonic rocks. Sometimes they contain vestiges of basic material almost completely consumed by the magma that formed these rocks. Their composition is: mesoperthite (60-70%), quartz (10-20%), garnet (5%), plagioclase and orthopyroxene (see chap. II, table II-1). The garnets are euhedral, indicating that probably they finished their crystalization after the end of the ductile deformation, during the peak of the metamorphism. Granites similar to these occur scattered in the ortho- and paraderived domain and are especially associated to the kinzigites that will be seen in the second day.

SECOND DAY - OUTCROPS OF THE EASTERN PART OF THE JEQUIÉ-MUTUÍPE-MARACÁS DOMAIN AROUND THE TOWNS OF UBAIRA AND BREJÕES (Fig. VI.1)

From Jequiriçá to Genipapo (ca. 36 km)
From Genipapo to Brejões (ca. 27 km)
From Brejões to Jequié (ca. 124 km)
Leaders: Johildo S. F. Barbosa, Moacyr M. Marinho and Pierre Sabaté

The general purpose of this second day of excursion is to examine the rocks essentially considered as supracrustals. Orthoderived (or anatectic?) charnockitic rocks, intercalated acid and basic granulites, granulitic migmatites and probable anatexis in the kinzigitic rocks of the region will also be seen.

STOP 2-1: Graphite outcrop

Narrow (centimeter to meter thick) vertical weathered layers of graphite, garnet-bearing kinzigitic material, pegmatites with graphic-like texture, milky quartz layers and serpentinized mafic material. Intercalated with these rocks, there are semi-altered bands of coarse grained charnockitic material (possibly orthoderived), with basic enclaves. Studies of carbon isotopes were performed on the graphites, in the layers of milky quartz and in the quartz crystals of the pegmatites with graphic-like texture. The values found in the graphite suggest an organic, sedimentary origin; the values for the quartz and the pegmatites are different from those of the quartz veins that crosscut the charnockitic rocks of STOP 1-6 (Iyer et al., in print).

STOP 2-2: Patioba outcrop

Here occurs orthoderived charnockitic rocks included in the ortho- and paraderived domain. They are little deformed compared to the plutonic rocks of Laje-Mutuípe. They have almost the same mineralogy as the charnockites of Laje-Mutuípe although they are chemically different (chap. II, table II-2). They present enclaves of basic rock with tholeiitic chemistry similar to the bands of basic granulites that will be examined close to the town of Brejões. Geochronological determinations (Wilson 1987) in these charnockites produced a good Rb-Sr isochron diagram with an age of 2.7 Ga. Sm-Nd model ages are around 3.1 Ga. These charnockitic rocks are considered to be orthoderived, but their chemical similarity with orthopyroxene mobilizates, present in the granulitic migmatites, does not discard the possibility of an anatectic origin (chap. II). Temperature calculations using opx-cpx pairs have yield values around 850°C.

STOP 2-3: Orthopyroxene- bearing garnetiferous quartzites and associated basic rocks

The quartzite is light green coloured and composed by quartz (70-90%), garnet (5-10%), plagioclase (1-5%), orthopyroxene and biotite (chap. II, table II-1). It hardly shows deformational characteristics and present boudins of very fine grained basic rock. Metamorphic pressures estimated for the quartzites reached around 5-6 Kbar. Carbon isotopic studies (chap. II) revealed clearly divergent values from those found for the quartz veins seen in STOP 1-6 and in Laje region.

STOP 2-4: Engenheiro França outcrop

Orthoderived (or anatectic ?) charnockite with mineralogy similar to that of STOP 2-2 (Patioba). Blocks and boudins of basic granulites with variable sizes are scattered throughout the matrix. These are considered restites that were not completely absorbed by the intermediate magma, that formed the charnockitic veins. Quartz-feldspathic veins cut these rocks. These latter and the orthoderived charnockites (or anatectic ?) are not deformed. The charnockite and basic "restite" mineralogy is shown in table II-1, chapter II. These "restites" present tholeiitic chemistry (chap. II) and Sm-Nd age of 3.29 Ga (T_{DM} model age; chap. IV).

STOP 2-5: Kinzigite outcrop (SE of Brejões)

Greenish pink coloured kinzigite bands (N20W/20NE) intercalated with light coloured garnetiferous quartzo-feldspathic material and milky quartz bands. In some parts of the outcrop migmatitic quartzo-feldspathic mobilizates are seen. In the kinzigitic bands can be observed euhedral red garnet and greenish grey, up to 1 cm long, cordierite crystals. Besides these minerals, the kinzigites are composed by quartz, plagioclase, biotite, sillimanite, graphite and rare orthopyroxenes. Temperature calculations performed in these kinzigites shown values around 850°C with pressure estimates of 5-6 Kbar (chap. II, table II-3). The fluid inclusions of the milky quartz bands were studied: the carbon isotopes of CO_2 gave values similar to those found in the milky quartz bands intercalated with the graphite bands of STOP 2-1. The kinzigites are thought to be metapelites, while the milky quartz may correspond to metacherts (chap. II).

STOP 2-6: Brejões outcrop

Flat lying basic granulites and quartzo-feldspathic bands with sharp contacts. The dark basic granulite bands of metric thickness are composed by plagioclase (50%), ortho- and clinopyroxene (30%), hornblende (15%), biotite (5%) and opaque minerals, generally presenting medium grained texture, sometimes polygonal. The light coloured bands, of quartzo-feldspathic material in this outcrop are composed by mesoperthite (40%) and quartz (50%), while plagioclase and opaque minerals occur as accessories. A strong penetrative foliation (N60W/25NE) affects both lithotypes. The petrochemistry shows that the basic granulite bands have the same tholeiitic chemical composition of the "restites" from STOPS 2-2 and 2-4. On the other hand, the protoliths of the quartzo-feldspathic bands may have been aplitic granites, rhyolitic tuffs or even feldspathic arkoses (chap. II).

STOP 2-7: Brejões gravel pit outcrop

Sub-horizontal, centimetre thick milky quartz bands are intercalated with also centimetre thick graphic textured quartzo-feldspathic bands, together with altered banded iron formations and mafic rocks. Carbon isotope studies of the fluid inclusions in the quartz in both the milky quartz and the quartzo-feldspathic material show similar results, suggesting that they have sedimentary origin (chemical-exhalative?). Their isotopic carbon values are similar to those of the STOPS 2-1, 2-3 and 2-5.

STOP 2-8: Kinzigite outcrop (W of Brejões)

Outcrop of kinzigite bands similar to those of STOP 2-5. Abundant granitic material occurs, with euhedral garnet, similar to the garnet leucogranites of Ubaira, being coarser grained and less deformed, showing quartzo-feldspathic pegmatoid mobilizates with mesoperthites up to 5 cm long. Undeformed cordierite-bearing leucogranites of probable anatectic origin are also present. Both the mobilizates and the cordierite leucogranites, seem to have been formed in the peak of the granulitic metamorphism. Recent studies on the kinzigites are stressing the presence of spinel plus quartz, indicating high metamorphic temperatures. The estimated pressures in this outcrop are between 5 and 6 Kbar.

STOP 2-9: Orthopyroxene-bearing garnetiferous quartzite (BR 116)

The most important polyphasic structures (F_1 + F_2) of the region are found in the orthopyroxene-bearing garnetiferous quartzites (Figs. II.1 and VI.1). This one is chemically and mineralogically similar to the quartzite of the STOP 2-3 (chap. II). Carbon isotope studies show similarity between this quartzite and those of the STOPS 2-1, 2-3, 2-5 and 2-7. Geobarometric studies give values around 5 Kbar for the pressures of formation of these rocks (chap. II).

STOP 2-10: Pedrão outcrop

In the outcrop occurs an orthopyroxene-bearing migmatite. It is folded and located inside the previously cited polyphasic structure. The charnockitic dark green material has mineralogy and chemistry similar to the orthoderived charnockites of the STOPS 2-2 (Patioba) and 2-4 (Engenheiro França). It also has chemical composition intermediate between the basic granulite and quartzo-feldspathic bands of STOP 2-3 (Brejões, chap. II). The boudinaged basic granulite bands that form "restites" within the migmatites have mineralogical and chemical composition similar to the "restites" (enclaves) of STOPS 2-2 (Patioba) and 2-4 (Engenheiro França); see chapter II. It is interesting to note that the basic "restites" have dehydrated margins, with an aureole richer in orthopyroxene, owing to the progressive metamorphism. Charnockitic mobilizates with large (5 cm) orthopyroxene crystals, cut the migmatitic banding of the rock. These are not deformed, being considered as formed after the end of the ductile deformations. These granulitic pegmatites have chemical composition similar to the orthoderived charnockites of STOP 2-2 (Patioba) and 2-4 (Engenheiro França).

DAYS 3, 4 AND 5 - LITHOLOGIES, STRUCTURES, AGE RELATIONSHIPS AND METAMORPHISM IN THE WESTERN BORDER OF THE JEQUIÉ-ITABUNA BELT AND CONTENDAS-MIRANTE VOLCANO-SEDIMENTARY SEQUENCE AND RELATED INTRUSIONS

THIRD DAY - SEVERAL OUTCROPS IN THE WESTERN BORDER OF THE JEQUIÉ-ITABUNA BELT AND ONE OUTCROP IN THE PÉ DE SERRA GRANITE (Fig. VI.2)

Jequié to Maracás (ca. 152 km)
Leaders: Moacyr M. Marinho, Pierre Sabaté and Johildo S. F. Barbosa

The general purpose of the third day of the excursion is to investigate the metamorphic zoneography of the western border of the Jequié-Itabuna belt. Such zoneography is characterized by the presence of a westernmost band, retrograded under amphibolite facies conditions in contrast with the typical granulite facies of the central part of the belt. The parageneses of the granulite and amphibolite facies rocks are the following:

Parageneses of the granulite facies

$M_1 + Pl_1 + Q + Opx + Hb_1 \pm Cpx$
$M_1 + Pl_1 + Q + Ol(fayalitic) + Hb_1 \pm Cpx$

M_1 = mesoperthite and perthitic microcline
Pl_1 = An18-24
Hb_1 = Ti-rich greenish brown hastingsite
Opx was never observed in presence of olivine

Paragenesis of the amphibolite facies

$M_2 + Pl_2 + Q + Hb_2 + Bi \pm Cpx$

M_2 = microcline + K-feldspar whose nucleus is mesoperthitic and the edge is microcline or slightly perthitic
Pl_2 = An11-17
Hb_2 = Ti-poor bluish-green hastingsite

Retrograde reactions during the transition from the granulite to the amphibolite facies are:

$Hb_1 \rightarrow Hb_2 + Ilm$
$Pl_1 + M_1 + Opx \rightarrow Bi + Pl_2 + M_2$
(in this second reaction, the mesoperthite supplies the Na for the formation of plagioclase)

These charnockitic lithologies yielded a Pb-Pb isochron age of 2,660±76 Ma (Marinho 1991 and chap. IV).

STOP 3-1: Charnockite pavement in the region of Maracás (km 67.1)

The outcrop is represented by typical greenish brown olivine-bearing charnockitic rock with N-S trending sub-vertical foliation and biotite-rich gneissic rock enclaves. The charnockite is essentially composed of mesoperthite, plagioclase and quartz with smaller proportions of red-brown amphibole (hastingsite), clinopyroxene and fayalite (Fa97), sometimes with interstitial microcline; allanite, zircon, magnetite and ilmenite are present as accessory minerals. The enclave is composed of mesoperthite, quartz, plagioclase, zircon and opaque minerals and still presents orthopyroxene (Fs77, En21, Wo2), reddish biotite and Fe-edenite, but olivine is absent.

This outcrop is an example of the influence of the whole-rock chemical composition on the formation of fayalite and orthopyroxene. The coexistence between the two minerals, controlled by the reaction Fa + Q Opx, depends on the Fe/(Fe + Mg) ratio, pressure and temperature. In the Maracás region, the fayalite is restricted to iron-rich rocks (Fe/(Fe + Mg) ≥ 0.87), while orthopyroxene is present in more magnesian rocks. The role played by the iron content is well illustrated in this outcrop. The charnockite, a plutonic rock with Fe/(Fe+Mg) = 0.95, contains

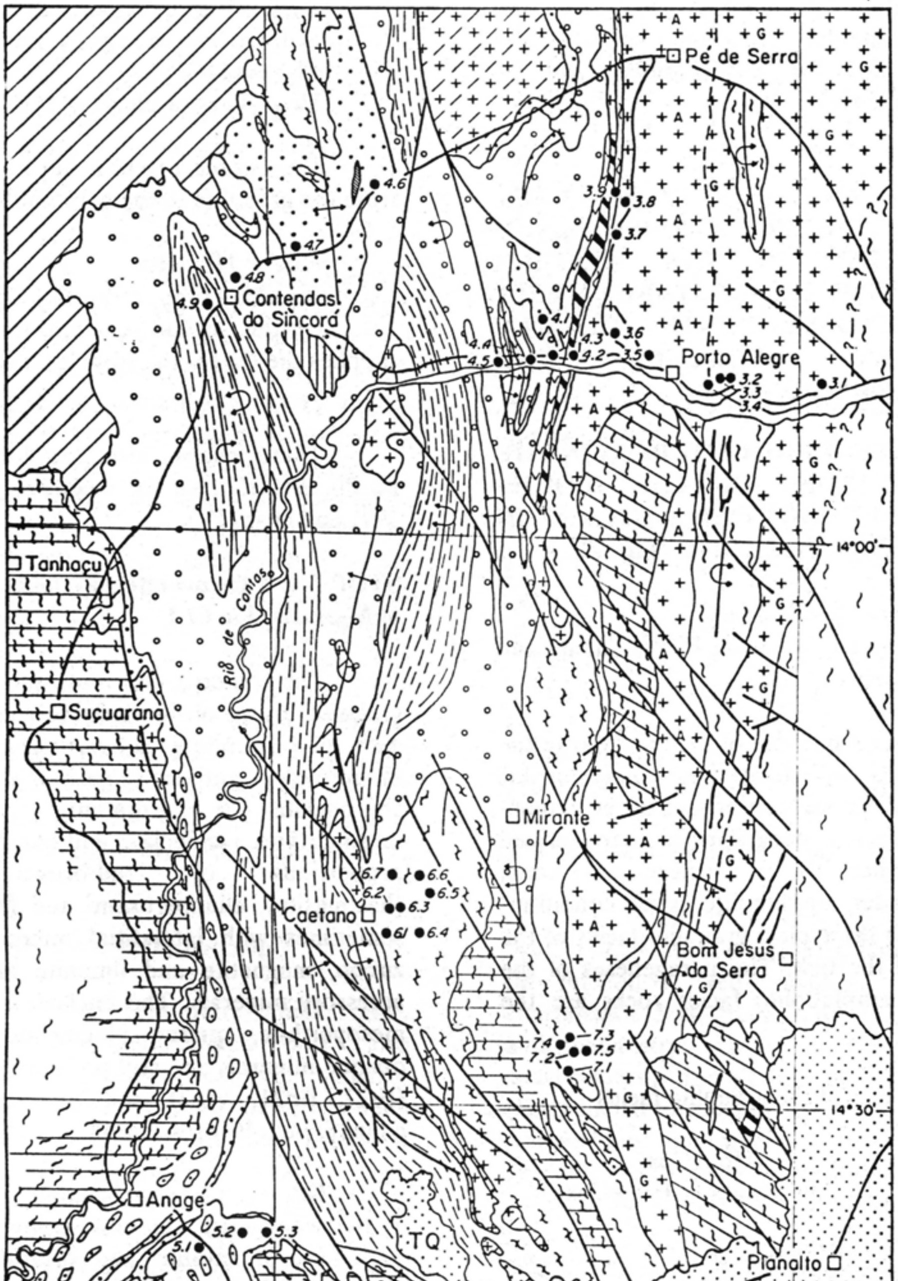

Figure VI.2a - Geological sketch map of the Pé de Serra-Anagé region (apud Barbosa, 1991) and location of the outcrops described in the excursion guide.

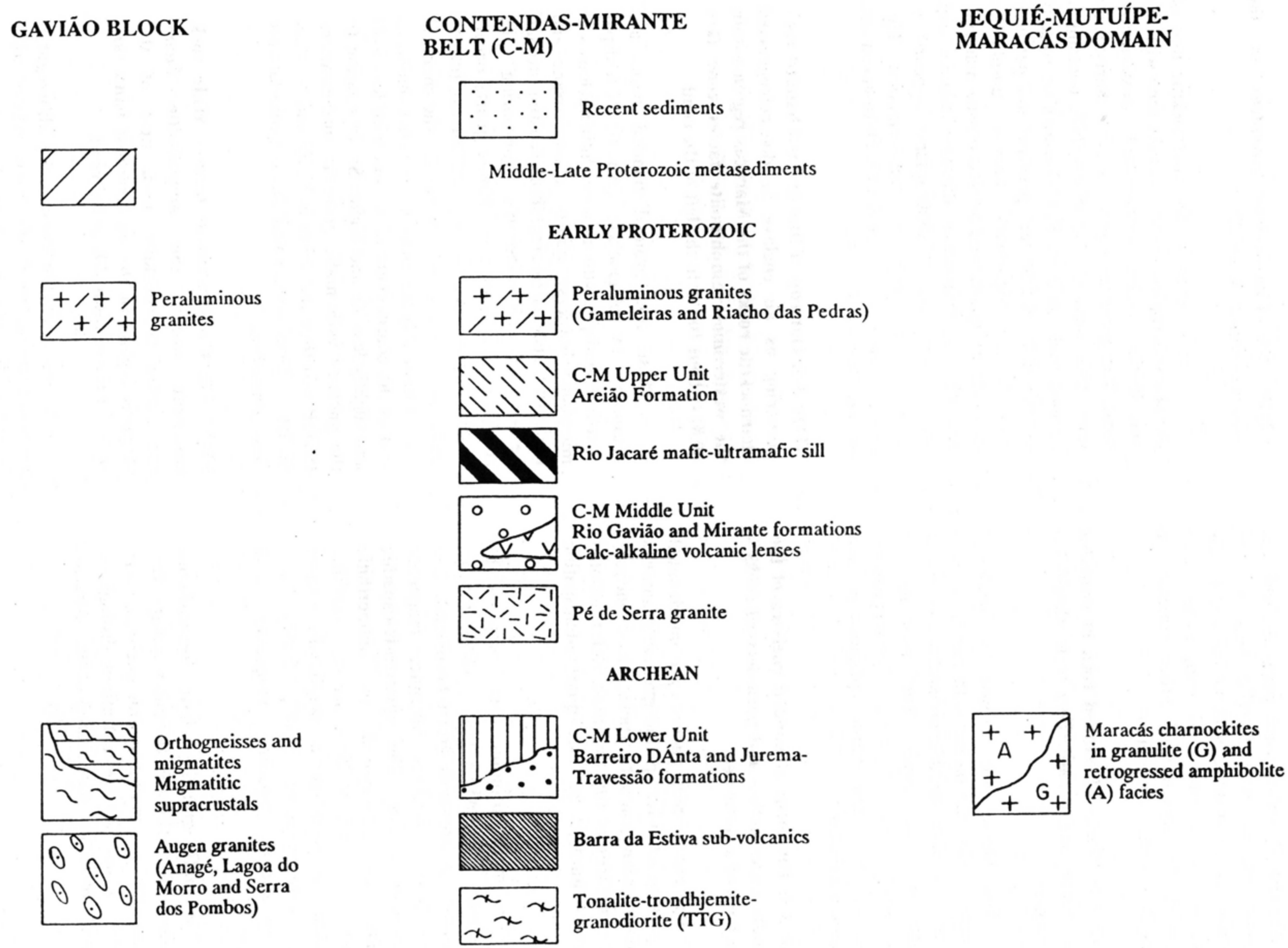

Figure VI.2b - Legend of Figure VI.2a.

fayalite (Fa97) without orthopyroxene, while the gneissic enclave with Fe/(Fe+Mg) = 0.59, contains orthopyroxene without olivine. In this case, where pressure and temperature were identical, the presence of either mineral was controlled by the iron content.

STOP 3-2: Blocks of banded rock in granulite facies ortho- and para-derived rocks (km76.5) - near a gate

The blocks are formed by bands of quartzitic rocks alternating with bands of calc-silicate rocks with variable mineralogical content in the different bands. The minerals are represented by quartz, clinopyroxene, orthopyroxene, antiperthitic plagioclase and perthitic microcline.

STOP 3-3: Pavement of banded gneisses of the granulite facies ortho- and para-derived rocks - at the back of a cattle pen

The outcropping gneisses are interbanded light grey quartzo-feldspathic gneissic granulites and dark green granulitic rocks. These gneisses show structures of the two main deformational episodes truncated by later quartzo-feldspathic veins.

The mafic granulites are composed by plagioclase (An30-35), clinopyroxene, orthopyroxene, brownish green hornblende and reddish biotite, besides ilmenite, magnetite apatite and zircon. The quartzo-feldspathic granulites are composed by antiperthitic plagioclase (An20-25), scarce perthitic microcline, brownish-green amphibole, brown biotite, orthopyroxene (Fs47, En53), and accessory zircon, apatite, magnetite and ilmenite.

The mafic granulites have compositions comparable to back-arc tholeiites (chap. II). Regarding the quartzo-feldspathic gneisses, their lower Nb, Y and Zr concentrations distinghish them easily from the charnockites of the Maracás region.

STOP 3-4: Charnockite pavement in the Maracás region (km 82.7)

This outcrop, in the charnockitic unit of the Maracás region, occurs near the limit with the amphibolite facies retrograded westernmost band. The greenish-brown coloured charnockitic rock, with foliation N30-45W/65NE, contains a gneissic rock enclave. The charnockitic rock is composed by K-feldspar (perthite and perthitic microcline), oligoclase, brown amphibole (hastingsite), quartz and altered olivine material, and accessory magnetite, ilmenite, allanite and zircon. Symplectitic biotite-quartz appears as result of the amphibole transformation. This rock, among others, yielded a Pb-Pb isochron age of 2,660±76 Ma (chap. IV).

STOP 3-5: Outcrop of fine grained banded rock occurring as an enclave in the retrogressed charnockitic rocks of the Maracás region within the westernmost amphibolite facies zone (km 89.8) - about 100 m to the left of the road

These fine grained banded rocks are composed by plagioclase (An17), K-feldspar (perthite, feldspar with mesoperthitic nucleus and microcline borders), quartz, clinopyroxene and green to bluish green amphibole (hastingsite and Fe-hornblende), commonly contouring the clinopyroxene. Symplectitic biotite-quartz occurs around opaque minerals. Apatite, zircon, titanite and allanite are accessory minerals. The chemical composition of these rocks is somewhat similar to that of the charnockitic rocks, but with less K_2O and slightly less Zr and higher Sr. In relation to the gneisses with mafic granulite intercalations (STOP 3-3) they are richer in Y, Zr and Nb than the latter. There are no available isotopic data for these lithologies.

STOP 3-6: Caldeirãozinho farm - Wide rock pavement within the amphibolite facies retrograded charnockitic rock unit of the Maracás region, in the westernmost band (km 91.5) - at the western side of the road

Coarse grained gneissic rock with irregular foliation (general trend N60E/sub-vertical) with rotated mafic and fine grained gneissic rock enclaves. Two generations of granitic dykes crosscut the coarse grained rock: an earlier post-tectonic, and a later one generally orthogonal to the former.

The coarse grained gneiss is composed by K-feldspar (perthite and perthitic microcline), quartz, plagioclase (An11-16) green to bluish green amphibole (hastingsitic hornblende), green to red-brown biotite associated to the amphibole, besides magnetite, allanite, apatite and zircon. The early granitic sill has microcline, plagioclase (An7-10), quartz and pale brown biotite; the accessory minerals are apatite and zircon.

STOP 3-7: Gravel pit at road side in a cataclastic zone which limits the western border of the Jequié-Itabuna granulite belt (km 100.3) - at the eastern side of the road

The lithology in the gravel pit is essentially composed by quartz and microcline fragments permeated by a quartzose mass with crystals of an opaque mineral. It represents a typical tectonic breccia of the western border of the granulitic belt.

STOP 3-8: Pavement of charnockitic rocks of the Maracás region, included in the retrograded westernmost band of amphibolite facies of the Jequié-Itabuna granulitic belt, and containing a banded rock enclave (km 108.0) - about 200 m west of the road

The fine grained banded gneissic rock is similar to that of STOP 3-5. The outcrop gives opportunity to examine the contact between the two lithologies. Notwithstanding the growth of fungi on the surface of the pavement it is evident that the charnockitic rock truncates the banding of the fine grained rock. The two main regional deformational phases are imprinted on the charnockitic rocks.

The charnockitic rock is composed by K-feldspar (microcline - sometimes interstitial - perthitic microcline, feldspar with mesoperthite nucleus and microcline edges), plagioclase (An11-13), quartz, greenish brown to bluish green amphibole (hastingsitic hornblende), brown to pale brown biotite generally associated to amphibole. The common accessory minerals are zircon, magnetite and apatite.

The fine grained gneiss is composed by K-feldspar (microcline and perthite), plagioclase (An10-12), quartz, green to bluish green amphibole (hastingsitic hornblende), diopside with amphibole corona, a rather great amount of titanite, sometimes associated to diopside. The typical accessory minerals are zircon, magnetite and apatite.

STOP 3-9: Ridge of the Pé de Serra granite (km 100.5) - about 500 m west of the road

The rocks are banded. The main foliation, which is parallel to this banding, is deformed by normal folds of the P_R deformational episode that also affects the Contendas-Mirante sequence.

The texture of these rocks is represented by a fine grained mosaic composed by saussuritized plagioclase (An17-20), microcline and quartz, with subhedral bluish green to pale brown amphiboles (magnesium-hastingsitic hornblende), associated to conspicuous titanite crystals. In some samples large, sometimes elongated, plagioclase crystals with Carslbad-albite twinning occur. Among the accessory minerals occur opaque minerals, often with titanite coronas, and zircon.

These lithologies yielded a Pb-Pb errorchron age of 2,559±110 Ma (Marinho 1991 and chap. IV).

Overnight in Maracás (km 152)

FOURTH DAY - THE CONTENDAS-MIRANTE VOLCANO-SEDIMENTARY SEQUENCE, THE PÉ DE SERRA GRANITE AND THE RIO JACARÉ SILL (Fig. VI.2)

Maracás to Tanhaçu (ca. 187 km)
Leaders: Moacyr M. Marinho, Pierre Sabaté and Johildo S. F. Barbosa

The purpose of this fourth day of excursion is to investigate the lithostratigraphy and metamorphism of the Contendas-Mirante sequence. However, an outcrop of the Pé de Serra granite and a section in the Rio Jacaré sill will also be visited.

STOP 4-1: Loose blocks of banded iron formation (km 65.3) - on a dry creek crossing the road

Outcrop of the oxide facies iron formations of the Contendas Mirante sequence. Good outcrops of this lithotype are restricted to the slopes, west of the road, or in drill core samples. In the loose blocks occur alternated quartzose light bands and magnetite-rich dark ones. To these minerals are associated chlorite, epidote and sericite. In this region, included in the cordierite zone, amphiboles of the cummingtonite-grunerite type are also developed.

STOP 4-2: Gentle elevation on the Pé de Serra granite (km 72.1) - about 100 m out of the northern side of the road

The granite presents a gneissic structure with N25E/10SE foliation. Texture and composition similar to those of STOP 3-9.

STOP 4-3: 1.3 km long traverse across gabbros of the Rio Jacaré sill and calc-alkaline andesites and schists of the Contendas-Mirante sequence middle unit (km 72.7) - along both sides of the road

The gabbros are darker or lighter coloured depending on the relative proportion of plagioclase and mafic minerals. Coarse grained types are more common. The general foliation is N25E/75SE.

There are two distinguishable types of texture that are sometimes associated at thin section scale. These textures are due to the different degrees of intensity of the deformation-recrystallization processes. In the less affected rocks the plutonic intersertal texture is still preserved, with saussuritized plagioclase (An40-50) phenocrysts in whose interstices are concentrated opaque minerals and amphiboles (Fe-hornblende type), these latter sometimes containing clinopyroxene nuclei. The increase in the intensity of the deformation-recrystallization leads to typical nematoblastic textures. Helicitic garnet porphyroblasts (Alm = 78, Py = 4, Sp = 4, Gr = 14) were found in drill cores from the northernmost part of the sill.

These gabbroic rocks have a tholeiitic trend close to that of Skaergaard (Marinho 1991). The sill is in the sillimanite-muscovite metamorphic zone, whose temperature obtained through the garnet-hornblende pair ranges between 590-625°C.

These rocks yielded a Pb-Pb errorchron age of 2,472±72 Ma (Marinho 1991 and chap. IV).

The calc-alkaline andesites present a set of folds with axes gently plunging N30E/47°, developping a schistosity and intersection lineation. Folding interference is marked by the presence of recumbent and reclined folds whose axes have variable sense and plunge. Curved axes are also observed. A mineral stretching lineation whose intensity increases to west is weakly delineated.

The andesitic rocks are fine grained having as a characteristic feature the presence of spots with diameter up to 0.2 cm. The texture is granolepidoblastic, formed by amphiboles (compositions on the boundary between Mg-hornblende and Fe-hornblende) and sometimes clinopyroxene, with small quantities of titanite and zircon, within a granoblastic mosaic of plagioclase (An31-37) and quartz.

These andesitic rocks yielded a Pb-Pb isochron age of about 2.5 Ga (Marinho 1991, and chap. IV).

Micaschists of the Mirante formation, containing poikiloblastic late-tectonic nodules of andalusite also occur. The outcrop is within the andalusite zone of the regional metamorphism which affected the Contendas-Mirante sequence. Temperatures between 500° and 580°C and pressures between 2.9 and 3.2 Kbar were determined in samples from a northerly extension of the andalusite zone. The geothermometry was established using different calibrations based in the garnet-biotite and garnet-cordierite pairs; the geobarometry was based in the calibration using the assemblages garnet-plagioclase-biotite, garnet-cordierite and garnet-plagioclase.

STOP 4-4: Nodular micaschist of Mirante formation (km 77.2) - loose block inside a fenced area

Micaschist with cordierite nodules up to 13 cm long. The cordierite is poikiloblastic, post- S_R, comprising quartz, muscovite, chlorite, plagioclase (An32) and small biotite flakes. This latter mineral also appears as poikiloblasts visible even in macroscopic scale.

STOP 4-5: Tectonic slice of Areião formation conglomerates (upper unit of the Contendas-Mirante sequence) within schists of the Mirante formation middle unit (km 80.6) - elevation at about 300 m south of the road

The conglomerate is monomict with stretched pebbles; the matrix is areno-argillaceous, schistose. U-Th-Pb zircon ion microprobe determinations carried out by Nutmann, Cordani and Sabaté (in press) in samples of this conglomerate yielded concordant ages between 2,710 and 2,150 Ma. The ages record the time of the conglomerate deposition between 2,150 and 1,950 Ma, respectively the ages of the younger detrital zircons and of the Transamazonian intrusions that affect the upper unit of the sequence (chap. V).

These zircon ages indicate a discontinuity between the upper and lower units of the Contendas-Mirante sequence.

STOP 4-6: Quarry in the Barra da Estiva Road Junction with sub-volcanic rocks (km 103.6) - the entrance to the (pavement type) quarry lyes at about 700 m east of the road junction, at the northern side of the road

Well foliated (N-S/70E) sometimes cataclastic rock, cut by pegmatitic veins. The rock is rather homogeneous and has a porphyritic rhyolitic composition with millimetric (up to 4.5 mm) plagioclase (An1-7) and quartz phenocrysts. The matrix is a plagioclase and quartz polygonal mosaic with associated biotite and muscovite flakes.

U-Pb zircon determinations carried out by Marinho (1991) by the conventional method, gave an age of about 3.3 Ga for the emplacement of this rock, suggesting that this is the oldest supracrustal dated in Brazil so far. These data however, are in disagreement with the age of 3.0 Ga determined by Wilson (1987) through a Pb-Pb errorchron (chap. IV).

STOP 4-7: Amygdaloidal basalts and flow breccias in the bed of Cinquenta creek (km 117.3) - entrance at the northern side of the road following it up to the bed of the creek

Here amygdaloidal tholeiitic basalts and basaltic breccias of the Contendas-Mirante lower unit crop out. The amygdaloidal basalts present intersertal and amygdaloidal textures. The matrix is very fine grained, composed by plagioclase (An1-5) microliths, actinolite and Mg-hornblende needles, besides small grains of epidote. The amygdules are represented by polygonal aggregates of quartz, chlorite and epidote.

The basaltic breccias are represented by angular fragments of basalt within a fine grained schistose matrix also of basaltic composition. The fragments (millimetric grains to blocks) have porphyritic and intersertal textures, with corroded microphenocrysts of plagioclase within a recrystalized matrix composed by very fine grains of epidote, actinolite needles and plagioclase microliths. The schistose matrix is also composed by plagioclase microliths (An1-8) scattered among small grains of epidote, actinolite and Fe-hornblende needles with associated biotite flakes.

The available isotopic data for these rocks are discussed in chapter IV of this volume. The U-Pb zircon data set a minimum extrusion age for this rock of 3.3 Ga.

STOP 4-8: Phyllites of the Rio Gavião formation (middle unit) in the banks of the Sincorá river (km 128.3) - northern side of the road

The fine grained, chlorite, sericite, quartz and albite-bearing metapelites (chlorite zone) belong to the Rio Gavião formation of the Contendas-Mirante sequence. They have recorded successive episodes of continuous deformation described in chapter III of this volume. It is possible to observe interference patterns of the co-axial folding P_{R-1} and P_R with approximately N-S axes. The effect of the later episodes is recorded by the variations in the plunge of these axes.

Both here and in STOP 4-3 curved axes E-W trending and with flat plunges can be seen, as well as early sheath folds.

The intersection lineation (N10W/15°) is related to S_R. A previous E-W trending stretching lineation is observed locally surrounding the P_R hinges. This lineation is attributed to the tectonic transport related to P_{R-1}.

Contendas do Sincorá (km 131.5)

STOP 4-9: Railroad cut with good exposures of the Areião formation (km 141.5) - northern side of the road

White coloured sandstones with inclined beds, dipping to the west, occur. The beds have oblique stratification. The outcrop is situated on the eastern flank of an approximately N-S synform. The rocks are little deformed. A fine-scale sub-vertical foliation is developped . This corresponds to the S_R foliation seen in all other units. Note the presence of angular pebbles of reddish schists, attibuted to Barreiro d'Anta formation.

The arenaceous formations are intruded by magmatic products which form brecciated pockets or penetrate into fractures and fissures, or even along the bedding. The magmatic material or the associated fluids caused contact metamorphism. The hornfels are strongly enriched in magnetite/ilmenite.

The magmatic material has a microlithic texture tending to porphyritic. It is hypovolcanic, holocrystalline with a criptocrystaline mesostasis. The broken phenocrysts are of sub-automorphic quartz, rounded or corroded, or show undulatory extinction. Untwinned oligoclase can also appear, as well as some opaque minerals, disseminated in the mesostasis. Fine-grained sericite defines a delicate, weakly-developped foliation.

The hornfels shows a granoblastic texture, which is isogranular and locally polygonal. It is composed by quartz, potassic feldspar with Carlsbad twinning, plagioclase and zircon, but the paragenesis is dominated by magnetite/ilmenite (> 60%) formed during the recrystallization. Slight cataclasis can be seen.

Overnight at Tanhaçu (km 187)

FIFTH DAY - THE SERRA DOS POMBOS AND LAGOA DO MORRO GRANITOIDS AND GAVIÃO BLOCK BANDED GNEISSES (Fig. VI.2)

Tanhaçu to Vitória da Conquista (150 km)
Leaders: Moacyr M. Marinho, Pierre Sabaté and Johildo S. F. Barbosa

This fifth day of excursion is reserved to the observation of the Lagoa do Morro granitoid (Lagoa do Morro, s.s. and Serra dos Pombos massifs) besides some exposures of banded gneisses with amphibolite intercalations which occur in the Gavião block.

STOP 5-1: Contact zone between a mega-enclave of banded gneiss of the Gavião block and the augen granitoid massif of the Serra dos Pombos (km 109.0) - roadcut in front of a monument regarding the inauguration of the road

The banded gneisses present tight folds and shearing. The deformation is intense and a N-S/80W foliation is overprinted on the banding. This foliation is correlated to S_R. It reworks a S_{R-1} foliation with general orientation N30E/50NW that follows the banding (S_0?).

Some complex fold interference patterns may be observed.

The transition zone to the granite is recorded by a more intense deformation where the folds repeated in decimetric periodicity are sheared in their limbs and develop a drag dynamics on the shear planes N20E/60NW that work in shear ramps with NE vergence.

In the granite, the stretching and mineral lineations are close to N-S with low angle plunge, expressing the late transcurrent movements. Enclaves of strongly schistose gneisses follow the internal shearings of the granite, where the stretching lineations have atitude N5W/50° very close to the mineral lineations (N10W/55°) found in the gneisses.

The transition from the banded gneisses to the granitoid is marked by a progressive concentration of K-feldspar with the proximity of the granitoid body. This concentration of K-feldspar grows from 0 to 10% in the gneisses and may reach 40% in the granitoid.

The Serra dos Pombos granitoid presents microcline megacrysts up to 3 cm long that include and assimilate saussuritized plagioclase (An13-15) grains. These megacrysts are disposed inside a plagioclase, quartz and microcline mosaic. Reddish to pale-brown biotite associated to muscovite delineates a sharp foliation. The following features distinguish this granitoid from that of Lagoa do Morro:

. absence of quartz segregation in bands, present in the Lagoa do Morro granitoids;
. the reddish to pale-brown biotite instead of green to pale-brown in Lagoa do Morro granitoids;
. the presence of muscovite, which is absent in Lagoa do Morro granitoids; and
. absence of allanite and low abundance of titanite, both of which occur in great amount in the Lagoa do Morro granitoids.

Discrimination between the two massifs was also made by Marinho (1991) in both geochemical and geochronological bases (chapters III and IV).

Concordant U-Pb ages of ca. 2,850 Ma were obtained by Nutman and Cordani (chap. V) in zircons of sample AC-4G. This sample was collected by Marinho et al. (1980) in gneissic-schistose rock (50% biotite, 32% oligoclase, 7% epidote, 5% quartz, titanite, apatite and zircon) in contact with the banded gneisses.

STOP 5-2: Large pavement of the Lagoa do Morro granitoid at "Lajedão do Segredo" (km 117.6) - entrance at the northern side of the road, at a place called Café das Almas

The exposure is essentially represented by a coarse grained granitoid with disordered phenocrysts of K-feldspar. Enclaves of medium-grey fine grained rock also occur. The relations between the lithotypes at the outcrop suggest they represent a coeval intrusion of both magma types.

The granitoid is composed by microcline megacrysts (up to 4 cm) that include plagioclase (An15-17) crystals in a microcline, plagioclase and quartz, fine grained (0.5-1 mm) mosaic. The mosaic also contains oriented green to pale-brown biotite crystals, closely associated to epidote, allanite and titanite crystals. There exists a tendency to segregation of quartz in bands parallel to the foliation delineated by the biotite.

The fine grained rock of the enclave has an equigranular polygonal texture formed by oligoclase (56%) and quartz (30%). A little microcline (7%) also appears in small interstitial grains, besides yellow to dark green biotite (5%) with zircon inclusions. Hematite, apatite, titanite and zircon are the main accessory minerals.

The petrographic and geochemical discrimination between this massif and that of the Serra dos Pombos was already mentioned in the description of the previous stop.

Marinho (1991) indicated an alignement of the granitoid analyses close to 2,850 Ma, on isochronic Pb-Pb and Rb-Sr diagrams. The sample AC-4E of the enclave rock collected by Marinho et al. (1980), was subject to U-Pb determinations by Nutman and Cordani (in press and chap. V) yielding ca. 3.2 Ga. All these data are discussed in chapter IV of this volume.

STOP 5-3: Pavement of the Lagoa do Morro Granitoid in the Lagoa do Morro ranch (km120.0) - next to the farm house

Coarse grained granitoid with general foliation N-S/75E. Two generations of quartz veins, filling joints can be observed: N40E (sinistral) and N40W (dextral). The microscopic features are the same than in the previous stop.

Samples of this outcrop were used by Marinho (1991) for the geochemical and geochronological study discussed in the description of the previous stop (5-2).

STOP 5-4: Blasted roadcut in gneisses of the Gavião block (km 136.8)

The roadcut, with a heterogeneous migmatitic and gneissic unit of the Gavião block, shows biotite gneiss with amphibolite intercalations and a granitic sill, locally discordant. The gneiss is composed of quartz, microcline, oligoclase, biotite with zircon inclusions.

The geometry of the outcrop shows a wide conical anticlinal fold. Its calculated plunge is 30° to NNW and its opening ranges between 20° and 40° to the South. This continuous deformation was applied roughly parallel to S_0 which was developed during a previous folding episode. The resulting folds of this previous phase are of isoclinal style. It is possible to observe several hinges on centimetric to decimetric scale. Stretching and shearing are associated with this older deformational episode.

STOP 5-5: Roadcut in heterogeneous migmatitic gneisses of the Gavião block (km 141.0)

The lithotypes are represented by biotite gneisses with locally interposed granitic bands, and amphibolite intercalations with large masses of biotite associated. The gneisses have a granoblastic texture, fine-grained, polygonal to interlobate, with a few plagioclase porphyroblasts. There is a faint cataclasis. The composition is similar to the gneiss of the previous outcrop. Two biotite generations are present, the first forming thin undulating beds which are cut by the second, noticeably perpendicular.

The geometry of the amphibolites and biotite schists outlines a system of tight similar folds with decametric size. Parasitic folds at smaller scale may be observed. These folds affect a foliation which accompanies the S_0 bedding.

Foliation planes are reworked by later inverse shear movements. The granitic bands are oriented according to the foliation but possess independent porphyroblasts. A mineral stretching lineation N30E/32° is parallel to the C/S intersection lineation developed on the foliation surface.

Overnight at Vitória da Conquista (km 150)

DAYS 6 AND 7 - BASEMENT DOMES: SETE VOLTAS AND BOA VISTA/MATA VERDE (Fig. VI.2)

SIXTH DAY - LITHOLOGIES, STRUCTURES AND AGE RELATIONSHIPS IN THE SETE VOLTAS DOME

From Vitória da Conquista to Caetano (ca. 84 km)
Return to Vitória da Conquista
Leaders: Pierre Sabaté, Moacyr M. Marinho and Johildo S.F.Barbosa

Route: To reach the Sete Voltas region we first go North (in the direction of Jequié and Salvador) along the BR116 main road from Vitória da Conquista to a crossroad (at km 19) with a short (now asphalted) minor road leading, northwestwards, to the village of José Gonçalves (km 24.6). From this village we take a dirt road which leads to the village of Caetano, 59.5 km further on. The road follows a difficult route passing by the following hamlets: Roseira (km

37.8); Lagoa da Pedra farm (km 42.8); Fundo farm (km 47.8); Montes Alto crossroads (km 63); Carrapicho farm (km 69); Campos farm (km 73.3); Marota farm -also called Nova farm- (km 78.3) and finally Caetano (km 59.5). The global directions to be followed are North (From José Gonçalves to Roseira) and Northwest from Roseira to Caetano). The field trip begins at the crossroads of Marota farm which is the 0 km reference point for this part of the trip. From Marota the journey continues northeastwards on the dirt road to Caldeirão, till Lagoa Nova farm. From this farm, we turn southwards along a track to Santa Rosa and Carrapicho farms. The route then turns northwards from Lagoa Nova to Morro Verde, then north and west to the hamlet of Cágados, returning to Caetano by a north-south dirt road which comes from Gabriel farm.

The general purpose of this sixth day of the field excursion is to examine the Tonalite-Trondhjemite-Granodiorite association (TTG) of the Sete Voltas dome. The outcrops are petrographically very monotonous. Some internal or superposed structural features may be observed. Geochemical data and petrogenetic considerations are mostly still unpublished. For these motives, the descriptions given here are very short, allowing open discussion in the field.

Chemically the rocks are similar to the classical known TTG associations. Their typical compositions are indicated below:

TTG_1 (7 samples)

	Range	Average
SiO_2	65.10 - 71.98	68.58
Al_2O_3	15.61 - 17.12	16.27
Fe_2O_3	2.23 - 4.79	3.08
MnO	0.04 - 0.08	0.05
MgO	0.52 - 1.37	0.77
CaO	2.26 - 4.08	2.93
Na_2O	5.41 - 6.01	5.62
K_2O	0.82 - 2.69	1.66
TiO_2	0.19 - 0.50	0.32
P_2O_5	0.08 - 0.22	0.13

TTG_2 (5 samples)

	Range	Average
SiO_2	55.82 - 73.93	69.49
Al_2O_3	14.56 - 18.02	15.45
Fe_2O_3	1.21 - 8.28	3.16
MnO	0.03 - 0.13	0.06
MgO	0.21 - 2,65	0.88
CaO	1.17 - 6.03	2.49
Na_2O	4.66 - 5.93	4.89
K_2O	2.03 - 3.59	2.79
TiO_2	0.11 - 0.94	0.35
P_2O_5	0.03 - 0.43	0.15

TTG_3 (6 samples)

	Range	Average
SiO_2	70.61 - 74.08	72.78
Al_2O_3	14.68 - 15.87	15.16
Fe_2O_3	1.21 - 2.62	1.73
MnO	0.03 - 0.04	0.04
MgO	0.25 - 0.56	0.33
CaO	1.55 - 2.29	1.73
Na_2O	4.92 - 5.62	5.13
K_2O	2.16 - 3.34	2.90
TiO_2	0.14 - 0.28	0.19
P_2O_5	0.04 - 0.09	0.06

LLG (3 samples)

	Range	Average
SiO_2	73.91 - 75.97	74.97
Al_2O_3	13.61 - 14.11	13.94
Fe_2O_3	0.55 - 1.64	1.26
MnO	0.01 - 0.04	0.02
MgO	0.05 - 0.30	0.21
CaO	0.83 - 1.72	1.32
Na_2O	2.49 - 6.46	3.76
K_2O	2.49 - 6.46	4.53
TiO_2	0.03 - 0.17	0.11
P_2O_5	0.02 - 0.05	0.04

sample (2.69%) does not modify the alkalies ratio (K_2O/Na_2O = 0.42) compared with all other TTG_1.

The host rock of these enclaves is an homogeneous fine grained grey gneiss which, however, shows locally a flat layering and is related to TTG_2. It is itself formed by large sub-horizontal sheets (N50W/20SW, N80W/20SW) in the LGG. The TTG_2 also has a trondhjemitic composition (oligoclase, quartz, some biotite and rare microcline). Chemically, it presents a relatively high alkalies ratio (0.71), but within the range of all the regional TTGs.

The late grey granite is quartz-microcline rich and biotite poor. It is the most potassic of the area (6,46%). Both the SV3 (previous outcrop) and SV8 (this outcrop) samples fall on a Rb-Sr reference isochron of 2.64±0.10 Ga with initial $^{87}Sr/^{86}Sr$ ratio of 0.710.

Late pegmatites cut all rock types. They are related to the Transamazonian peraluminous plutonism.

Samples: SV 6 (TTG_2); SV 7 (TTG_1); SV 8 (LGG)
Rb-Sr isochron TTG_2: t= 3.14±0.009 Ga; Sr_i = 0.7017±0.0008
Monozircon (SV 2) TTG_2: t= 3.16±0.002 Ga

OPTIONAL STOP 6-3a

If time permits, in an optional stop, at km 6.3, it will be possible to see two sucessive generations of rocks (TTG_2+LGG) cutting a large mass of older coarse grained banded and migmatized TTG_1. These old TTG comprise more basic components with stretched felsdpar crystals. The N-S trending foliation also affects the late granitic dykes. Aplopegmatite dykes cut the TTG association.

Sample: SV 9 (TTG_1)

STOP 6-4: Homogeneous Sete Voltas trondhjemitic TTG_2 in the south-center of the dome, in Lagoa Nova hamlet (km 8.7)

Several small outcrops are situated on the edge of a pond (dam-reservoir). They are composed of a biotite-poor leucocratic trondhjemite with some dispersed feldspar phenocrysts which mark a possible transition to the porphyritic granodiorite. The proportion of phenocrysts increases to the north. The rock represents a K-richer portion of the TTG_2 group (3.59%) with the higher alkalies ratio of TTG_2 (K_2O/Na_2O = 0.75).

It is possible to observe a complex pattern of a previous preferred orientation underlined by schlieren which are considered to represent the planar magmatic preferred orientation. These discontinuous markers define, at map-scale of the outcrops, an ample dome fold with an E-W trend and south-plunging hinge, the axial plane of which is marked by a penetrative foliation (N40W/sub-vertical). Locally, a non-penetrative incipient foliation (N45E/50SE) may occur.

The outcrops are crosscut by late quartz-pegmatitic veins and tension-gashes. Left-lateral N-S shears and low-dipping faults are time-related to their emplacement.

Sample SV 10 (TTG_2)

OPTIONAL STOP 6-4a

If time permits, another optional stop, at km 10 (that is to say 1.3 km southwards from the last stop, on the road to Santa Rosa farm) will be visited. This outcrop shows a typical homogeneous grey gneiss. It appears foliated or finely banded. Its composition remains in the range of the TTG_2 composition.

Sample SV 25 (TTG_2)

STOP 6-5: Porphyritic granodiorite in the center of the dome (km 13.6) - near houses of the Três Lagoas farm

The outcrop shows the most common rock type of the center part of the dome. This is a granodiorite with phenocrysts of plagioclase and K-feldspar. By comparison with the other TTG_3 of the dome, it is one of the most potassic

(3,12%) and the least sodic (4,92%) but its alkalies ratio (0.63) ranges into the values of the TTG association.

Nearest sample SV 12 (TTG_3)
Rb-Sr isochron TTG_3: t= 3.17±0.16 Ga; Sr_i = 0.7014±0.0011
Monozircon (SV 20) TTG_3: t= 3.24±0.005 Ga

STOP 6-6: Sheared porphyritic granodiorite of the Sete Voltas dome (km 14.0)

The large outcrop is occupied by porphyritic granodiorite related to TTG_3 which suffered strong shearing. This deformation is represented by wide shear bands and mylonitic bands. Gashes in mylonites and rotations of feldspar crystals in the granodiorite indicate a sinistral movement. The N-S trending preferred orientation, is developed under a rheologic regime in transition from viscous to ductile, as marked by undeformed (or weakly deformed) phenocrysts, when away from the shearing bands.

A late grey granite (LGG) dyke cuts the porphyritic granodiorite and shows its own preferred magmatic orientation. This is marked by a fine foliation and by small feldspar crystals (mini-phenocrysts). The preferred orientation is slightly oblique to the walls of the dyke, indicating a sinistral movement along the direction of the dyke during the emplacement. This movement prolongs into sub-solidus to post-solidus conditions as it is shown by the torsion of late N-S discordant quartz and pegmatite veins. The dyke is roughly E-W trending but has suffered the late P_R regional folding responsible for the N-S trending foliation and associated shearing. It is smoothly folded which may indicate a late emplacement relatively to the E-W shortening if we consider the high intensity of this deformation in the other rocks. Consequently, this late grey granite may be younger than the presumed reference age indicated above. It seems to be coeval to the P_R folding episode. The contemporaneous torsion of the pegmatite vein, the emplacement of which is believed to be related to the late peraluminous granitic plutonism, corroborates this interpretation of the evolution. The dominating N-S trend foliation of the outcrop also affects this grey granite dyke. It is particularly visible in the eastern part of the dyke. Late faults with sinistral displacement (N40W/70SW) cut over the dyke and the later quartz-vein.

Samples SV 14 (TTG_3), SV 15 (LGG related)

OPTIONAL STOP 6-6a

If time permits, in another optional stop, at km 15.6, it is possible to examine a large outcrop of a medium grained granodiorite (TTG_3) with large and abundant, well shaped and undeformed phenocrysts. Several of them have a square section and are zoned.

The fabric of these active markers, measured through the (010) planes and the (C) axis of the feldspar "megacrysts" give a good axial distribution showing an unrotational deformation. It corresponds to a sub-horizontal, nearly uniaxial flattening which is related to the magmatic stage of deformation, under viscous regime conditions. Some typical "tuilage" features, like bookshelf sliding, may be observed. They result from the hindered rotation of the geometrically very close crystals during the flattening (near to pure shear). A ductile superimposed deformation is weakly represented in this part of the dome. It is insufficient to induce a strain on these rigid markers.

Morro Verde hamlet (km16.8)

STOP 6-7: Strongly deformed porphyritic granodiorites on the western edge of the Sete Voltas dome (km 23.8)

The granodiorite appears strongly deformed with two anastomosed foliations. The first, defined by phenocrysts, is attributed to the previous magmatic preferred orientation (N15E/60-80NW). The second (N35W/90) corresponds to a superposed deformation. In the latter, small feldspars are recrystallized. Numerous bookshelf sliding features may be observed on vertical surfaces nearly perpendicular to the foliation indicating a strong rotational deformation.

The fabric of the feldspar phenocrysts gives an orthorhombic to monoclinic distribution of (010) planes and a strong compression with rotations of the (C) axis. This is consistent with an uplift of the dome relative to its western host rock.

Return to Caetano (km 31.2), and then Vitória da Conquista

SEVENTH DAY - THE BOA VISTA-MATA VERDE GRANITOID (Age ca. 3.35 Ga) AND ITS "BASEMENT EFFECT" ON THE REGIONAL METAMORPHISM OF THE CONTENDAS-MIRANTE SEQUENCE (Fig. VI.2)

Vitória da Conquista to Jequié (ca. 243 km)
Leaders: Moacyr M. Marinho, Pierre Sabaté and Johildo S. F. Barbosa.

STOP 7-1: Boa Vista Farm. Short traverse on the granitoid along the Poço Creek - beginning at the crossing of the road and the Poço creek

In the intersection between the road and the creek a darker grey coloured rock of tonalitic composition crops out, intruded by a lighter coloured rock richer in K-feldspar, of granitic composition. A S_0/S_{R-1} banding N40W/60SW and a stretching lineation S30E/10° are observed.

The darker rock presents protomylonitic texture characterized by antiperthitic plagioclase (An20-21) phenoclasts up to 0.5 cm long contoured by elongated agglomerates of biotite, epidote, rare muscovite and sometimes polygonal agglomerates of fine grained (0.2-0.3 mm) quartz. The microcline is restricted to small interstitial crystals.

In the lighter rock the microcline is abundant both as small interstitial crystals and also as megacrysts up to 0.5 cm long that include plagioclase. The plagioclases in contact with the microcline show an albitic halo, their nuclei being poorer in anorthite (An15-17). When in contact with the microcline, the biotite presents itself chloritized.

Going 250 m further along the traverse, the amount of microcline is restricted to small interstitial grains and a few bigger crystals (0.12 cm). The hinge of P_{R-1} fold, almost co-axially folded by P_R is observed.

250 m further on, rock of tonalitic composition with very rare interstitial microcline occurs. In this place folds of the deformational episode P_R with incipient S_R foliation (N-S/vertical) associated to a sinistral general movement are seen.

The geochemical data of these and other outcrops of the massif point to the separation of the tonalitic and microcline-rich rocks.

Geochronologic evidence for an old age for this massif were pointed out at first by Marinho et al. (1980) based on the Rb-Sr method, and later on by Cordani et al. (1985) and Wilson (1987) by the Rb-Sr and Pb-Pb methods. The ages were obtained from isochrons with considerable dispersion of points. It is probable that the lithologic dichotomy of the massif, first identified by Marinho (1991), is responsible for the observed dispersions in the isochronic diagrams presented by these authors.

The U-Th-Pb zircon ion-microprobe determinations carried out by Nutman and Cordani (in press and chap. V) in sample AC-1E collected by Marinho et al. (1980) in tonalite of STOP 7-3 finally determined with accuracy the age of this Boa Vista/Mata Verde granitoid massif (see STOP 7-3).

STOP 7-2: Microcline-rich facies of the Boa Vista/Mata Verde granitoid (km 64.5) - about 100 m east of the road

Coarse grained orthogneiss showing N-S sinistral shearing with 5 cm spacing, developed parallel to the vertical axial planes of the P_R folds with sub-horizontal axes. Also seen are open fissures also with sinistral movement.

The rock is K-feldspar rich, highly recrystallized. The plagioclase have a composition close to An17, except when included in microcline, in which case it is zoned whith composition ranging from An2 to An8. This microcline-rich facies of the Boa Vista/Mata Verde granitoid is somewhat similar looking, in macroscopical aspect, to the tonalitic facies.

STOP 7-3: Granitoid outcrop from which sample AC-1E was collected and whose zircons were dated by SHRIMP (Nutman and Cordani, in press, chapt. V) (km 66.5) - about 300 m after the Mata Verde farm house

Tonalitic facies of the Boa Vista/Mata Verde granitoid exhibiting P_R folds with N30W/70NE S_R axial plane. It is cutted by an aplitic dyke. The tonalitic rock is made up by about 70% oligoclase, 20% quartz, 5% biotite, and accessory epidote, apatite, titanite and zircon. The cooling age for this massif was determined in zircons from sample AC-1E which yielded 3,353±5 Ma, interpreted as the time of crystallization of the granitic protolith.

STOP 7-4: Microcline-rich facies of the Boa Vista/Mata Verde granitoid (km 68.3) - next to the old house of Mata Verde farm

K-feldspar rich granitoid with very weak orientation cut by aplitic dyke. Many strongly recrystallized zones. Presence of perthitic microcline megacrysts enclosing plagioclase crystals; microcline also occur interstitially in clear crystals.

STOP 7-5: Sillimanite-K-feldspar zone of the regional metamorphism of the Contendas-Mirante sequence in the eastern border of the Boa Vista/Mata Verde granitoid (km 71.3) - road between the Mata Verde farm and the Coquinho village, near the Poço creek

This is the highest metamorphic grade, at the beginning of the catazone, in the Contendas-Mirante sequence and is restricted to this southernmost part of the belt. This region is characterized by the presence of several TTG-type Archean domes, e.g. Sete Voltas and Boa Vista/Mata Verde. In all other studied regions the sillimanite-muscovite zone represents the highest grade within the metamorphic zoning of the metasediments of the Contendas-Mirante belt (Marinho 1991).

This part of the southernmost Contendas-Mirante belt is characterized in the terrain by the presence of migmatites. These are easily identified by the alternance of mesocratic bands and leucocratic veins. The microscopic study confirms the organization of this rock in bands, as follows:

- the dark bands are biotite-rich and closely associated to sillimanite that delineates a well developed S_R foliation. The cordierite presents two different habits: (i) in globular, generally clear crystals, sometimes contoured by the S_R foliation; (ii) in poikiloblastic porphyroblasts with clear edges and nuclei rich in sillimanite inclusions (needles, rarely prisms), commonly containing the S_R foliation. These dark layers also contain quartz, plagioclase (An25-27) and accessory opaque minerals, zircon and turmaline; and
- the veins are light coloured, essentially quartzo-feldspathic with cordierite and some biotite. Plagioclase is sub-automorphic (An27) and K-feldspar is xenomorphic and generally perthitic. The texture is granular hypidiomorphic, coarse grained (1.2 to 5 mm) and igneous-looking.

The transition from the sillimanite-muscovite to the sillimanite-K-feldspar zone, is marked by the disappearance of muscovite. Generally it follows the classical reaction:

$$Mu + Q \rightarrow Sill + KF + H_2O$$

In the case of the area under discussion the commonest mineral association is the following:

biotite - sillimanite - K-feldspar - cordierite

According to Yardley (1989) this association represents the range of higher temperatures within the zone. He suggests the following continuous reaction for the appearence of this association:

$$Bi + Sill + Q \rightarrow KF + Cd + Liq.$$

The presence of this zone of higher metamorphic grade is restricted to the surroundings of the Archean TTG domes suggesting that these massifs have played the role of conductive zones, allowing an easier elevation of the thermal front according to a mechanism similar to that suggested as "basement effect" by Fonteilles and Guitard (1968).

Finally it should be stressed that the presence of the quartzo-feldspathic melts (neosomes) allowed the dating of the metamorphism of the Contendas-Mirante sequence at 2,012±17 Ma (Marinho 1991) by the whole-rock Rb-Sr isochron method (chap. IV).

Overnight at Jequié (km 243)

EIGHT DAY - GEOLOGICAL TRAVERSE THROUGH THE JEQUIÉ-MUTUÍPE-MARACÁS, IPIAU AND WESTERN SECTOR OF THE ATLANTIC COAST DOMAIN (Fig. VI.1)

Jequié to Gandu (ca. 197 km)
Leaders: Johildo S. F. Barbosa, Moacyr M. Marinho and Pierre Sabaté.

The general purpose of this last day excursion is: (i) to examine the southern extension of the ortho- and para-derived rocks and the plutonic, enderbitic and charnockitic rocks of the Laje and Mutuípe region visited in the first day of excursion; (ii) to analyse the transition amphibolite-granulite facies in Ipiau region; (iii) to see an outcrop of biotite-rich basic granulite, another of intermediate granulite; and (iv) to visit the Gandu quarry, where the folding style of the second tectonic episode, which predominates in the Atlantic Coast Domain, can be clearly seen.

STOP 8-1: Jequié quarry (there are others near by) at the western outskirsts of Jequié town

Outcrop of greenish grey charnockitic granulite of the ortho- and para-derived rocks domain. It displays banding/foliation approximately N-S striking and strongly dipping towards east. A typical sample of this granulite has the following composition: quartz (30%), K-feldspar (mesoperthite and a second generation of microcline: 45%), plagioclase (porphyroclasts and recrystallized grains: 15%), orthopyroxene (10%), traces of red biotite, amphibole and oxides. This rock seems to be intruded by two generations of granitic veins, composed by: microcline (40-50%), amphibole plus biotite (5-10%) and two generations of plagioclase (20-30%). Epidote, chlorite and biotite are common in some samples. Biotitized boudins of basic granulite are sometimes found as enclaves. In samples of this quarry Wilson (1987) found ages of 1,970±136 Ma (Pb/Pb whole-rock) and 2,085±222 Ma (Rb-Sr whole-rock). Nevertheless, Sm-Nd T_{DM} model ages for the same rocks are 2.6 and 2.9 Ga suggesting that their protoliths are much older than 2.0 Ga. This younger age may be one evidence for the main metamorphic episode that affected the region (chap. II).

STOP 8-2: Jitauna charnockite quarry

Quarry of coarse-grained, foliated, sometimes augen charnockite. This rock is part of the low-Ti calc-alkaline sequence that is being studied in the Laje-Mutuípe region, north of this place. Depending on the exploration stage of the quarry, relatively thin bands and lenses of grey gneissic relicts occur intercalated in the dark green charnockitic rocks, indicating the probable role of CO_2 fluids as the charnockitization agent.

STOP 8-3: West of Ipiau

A semi-weathered outcrop with intercalations of amphibolite and quartzo-feldspathic material in the amphibolite-granulite transition zone. The rock foliation is sub-horizontal and is probably connected to the deformational episode F_1. The contact between the mafic and felsic bands is sharp and similar to that seen in Brejões region (STOP 2-6). The amphibolite, coarse to medium grained, with oriented texture, is composed by: plagioclase (An25-30: 45%), hornblende (40%), clinopyroxene (5%), quartz (1-5%) and traces of orthopyroxene. The felsic material is composed by quartz (60%), microcline (35%), plagioclase (5%) and opaque minerals as accessories. The chemistry of the amphibolite is tholeiitic, similar to that of the basic granulite bands (STOP 2-6) and the "restites" of basic granulite (STOPS 2-2, 2-4 and 2-10). The chemistry of the quartzo-feldspathic material is also similar to that of the Brejões outcrop (STOP 2-6). It is worth recording that in the amphibolite-granulite transition zone, the following metamorphic reaction is noticed in the basic bands:

$$Hb + Qz \quad Opx + Cpx + Plag + H_2O$$

and in consequence an increase in the amount of pyroxenes from the Ipiau Domain to the Atlantic Coast Domain, suggesting a progression in the physical conditions of the metamorphism (chap. II). Studies of the relative mobility of the chemical elements have been performed in this zone, showing that there is no great chemical changes during the metamorphic transition (chap. II). Sm-Nd model ages of the amphibolite bands have shown values around 3.1 Ga (Chap. IV).

STOP 8-4: East of Ipiau

Outcrop of vertically banded (S_2) granulite, with the basic bands containing more orthopyroxene than in the previous stop, where a vertical mineral lineation contained on the banding planes is also seen. The charnockitic granulite bands are greyish-green coloured, being composed by quartz (30%), plagioclase (25%), perthitic orthoclase (35%), orthopyroxene (9%) and biotite and opaque minerals as the more common accessories. The basic granulite bands are dark coloured and composed by plagioclase (30-35%), orthopyroxene (2%) and clinopyroxene (18%), with rounded hornblende inclusions, amphibole (30-40%), biotite, opaque and apatite traces. The central part of some of these basic bands, less contaminated by charnockitic granulite country rock, shows a chemical composition similar to that of the amphibolites of the previous outcrop (STOP 8-3). Both are tholeiitic (chap. II). In the outcrop light coloured mobilizates are also seen parallel to or cutting the banding, composed by microcline (50-65%), garnet (0-10%), quartz (20-35%), plagioclase (5%), biotite (1-5%), amphibole (0-2%) and opaque minerals.

STOP 8-5: Biotite-rich basic granulite roadcut outcrop

The rock is dark grey coloured, with medium grained texture and homogeneous aspect. This homogeneity makes it difficult the observation of the rock foliation, although in some places it is possible to determinate its attitude (N15E/80SE) as well as the mineral stretching lineation, contained in the above plane, plunging 10° to SSW. The rock mineralogy includes antiperthitic plagioclase (60%), orthopyroxene (15%), clinopyroxene (15%) and primary metamorphic biotite (5%) in equilibrium with the pyroxenes (see chap. II, table II.1). In some outcrops of this rock type two types of opx-cpx pairs can be found: one coarse- and other fine-grained. The coarser one has indications of plutonic origin (temperature in the grain centers above 900°C) and the fine-grained seems to have been produced by deformation/recrystalization related to the regional granulitic metamorphism (temperatures of the grains estimated in 830°C). The rock can be considered as a monzonite presenting shoshonitic chemistry (chap. II). Unpublished geochronological data suggest an age of 2.4 Ga (Sm-Nd T_{DM} model age; chap. IV).

STOP 8-6: Intermediate granulite outcrop in a BR 101 roadcut

The rock presents dark grey colour, fine to medium grained texture, it is homogeneous and its foliation is poorly visible. Its essential minerals are: plagioclase (An50; 70%), orthopyroxene-clinopyroxene (20-25%). Secondary and accessory minerals are shown in table II-1, chapter II of this volume. Unlike the rocks of the previous stop this one contains only one pair of opx-cpx, that is recrystalized and sometimes is in polygonal contact between each other and plagioclase. The metamorphic temperatures are estimated around 820°C. It has a low-K calc-alkaline andesitic and/or dioritic composition.

STOP 8-7: Gandu quarry

The quarry has banded granulites structured in tight similar folds with axial planes N20E/70-80SE. The structure leads to the inference of a huge crustal shortening during the F_2 episode. The axes of the folds (S20W/20-30°) coincide with the mineral lineation contained into the vertical transposition planes. The black mafic layers (plagioclase, pyroxenes, amphibole and biotite) act as key horizons to show the folding style; they can be remarkably persistent in thickness or been sharply interrupted; in the fold crests and troughs, material flowed in to build a similar folding style. In thin sections cutting the hinges of the folds two biotite generations are noticed: one sub-horizontal cut by another of sub-vertical attitude, both in equillibrium with the orthopyroxene. This indicates that the metamorphic temperatures were maintained after the end of the deformations. The mafic granulites have tholeiitic chemistry similar to the ones already seen in other parts of this Jequié-Itabuna Granulite Belt. The country rock of these basic bands is light grey coloured and of dacitic/tonalitic composition. It was also affected by the deformations previously cited, although it presents undeformed pegmatoid mobilizates. These should have been formed after the end of the deformations, during the peak of the metamorphism. The dacitic/tonalitic rock is composed by: plagioclase (40-50%), quartz (50%), mesoperthite (1-5%), having pyroxenes, garnet, and opaque minerals as the most common accessories. In the mafic granulites a metamorphic temperature around 830°C was obtained. They have ages around 2.6 Ga, estimated by the Sm-Nd method (T_{DM} model ages; chap. IV).