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# SYMPOSIUM ON RAPAKIVI GRANITES AND RELATED ROCKS

## EXCURSION GUIDE:

## THE RAPAKIVI GRANITES OF THE RONDONIA TIN PROVINCE AND ASSOCIATED MINERALIZATION

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# OVERVIEW OF THE RAPAKIVI GRANITES OF THE RONDÔNIA TIN PROVINCE (RTP)

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## INTRODUCTION

The rapakivi granites of the Rondônia Tin Province (RTP) and related mineralization occurred within the time interval of 1.57 to 0.90 Ga and four age groups can be distinguished respectively at 1.57; 1.40-1.38; 1.30-1.25 and 1.05-0.90 Ga (U/Pb zircon ages, unpublished preliminary data).

These rapakivi rocks comprise four igneous suites composed of rocks of different ages, petrology and geochemistry (Fig. 2 and Table 2). Their intrusion was contemporaneous with tectono-magmatic activity in the Rio Negro-Juruena (1750-1550 Ma), Rondonian/San Ignácio (1500-1300 Ma) and Sunsás/Aguapei (1300-1100 Ma) orogenic events (Litherland et al., 1986; Teixeira et al., 1989; Bettencourt and Dall'Agnol, 1987; Bettencourt, 1992) at the southwestern margin of the Amazonian Craton (Fig. 2).

The massifs are principally subalkaline to slightly peraluminous and exhibit characteristics of A-type and within-plate granites. Epizonal subalkaline rapakivi monzogranites to syenogranites are the principal rocks. Contemporaneous mafic rocks (poorly known) charnockite/mangerite suites, anorthosite (rare), and tholeitic basaltic dykes are spatially associated with them (Isotta et al., 1978; Leal et al., 1978; Bettencourt and Dall'Agnol, 1987; Leite Jr., 1992; Teixeira et al., 1990). Plutons intrude medium to high grade metamorphic basement terranes of the Early Proterozoic Rio Negro-Juruena Province (1.75-1.55 Ga) and Middle Proterozoic Rondonian Province (1.5-1.3 Ga) orogenic crust (Fig. 2).

The 1.30-0.90 Ga rapakivi granites and associated tin mineralization are an important part of the RTP, now known world-wide. After the discovery of the Bom Futuro "Garimpo" in 1987 its international economic and scientific importance became more evident. The RTP has collectively accumulated a production of almost 215,000 tons of Sn during the last 36 years, mainly from placer deposits, and has injected about US$2 billion into the nation's economy.

The particular focus of this short overview is to briefly summarize the main features of some of the rapakivi granite complexes of the RTP. The Serra da Providência Batholith, Santo Antônio Massif and Teotônio Intrusive Suite as well as the Younger Granites of Rondônia (Massangana Complex, São Carlos and Caritianas massifs, and Santa Bárbara Complex) which will be visited during the excursion will be presented (Fig. 2).

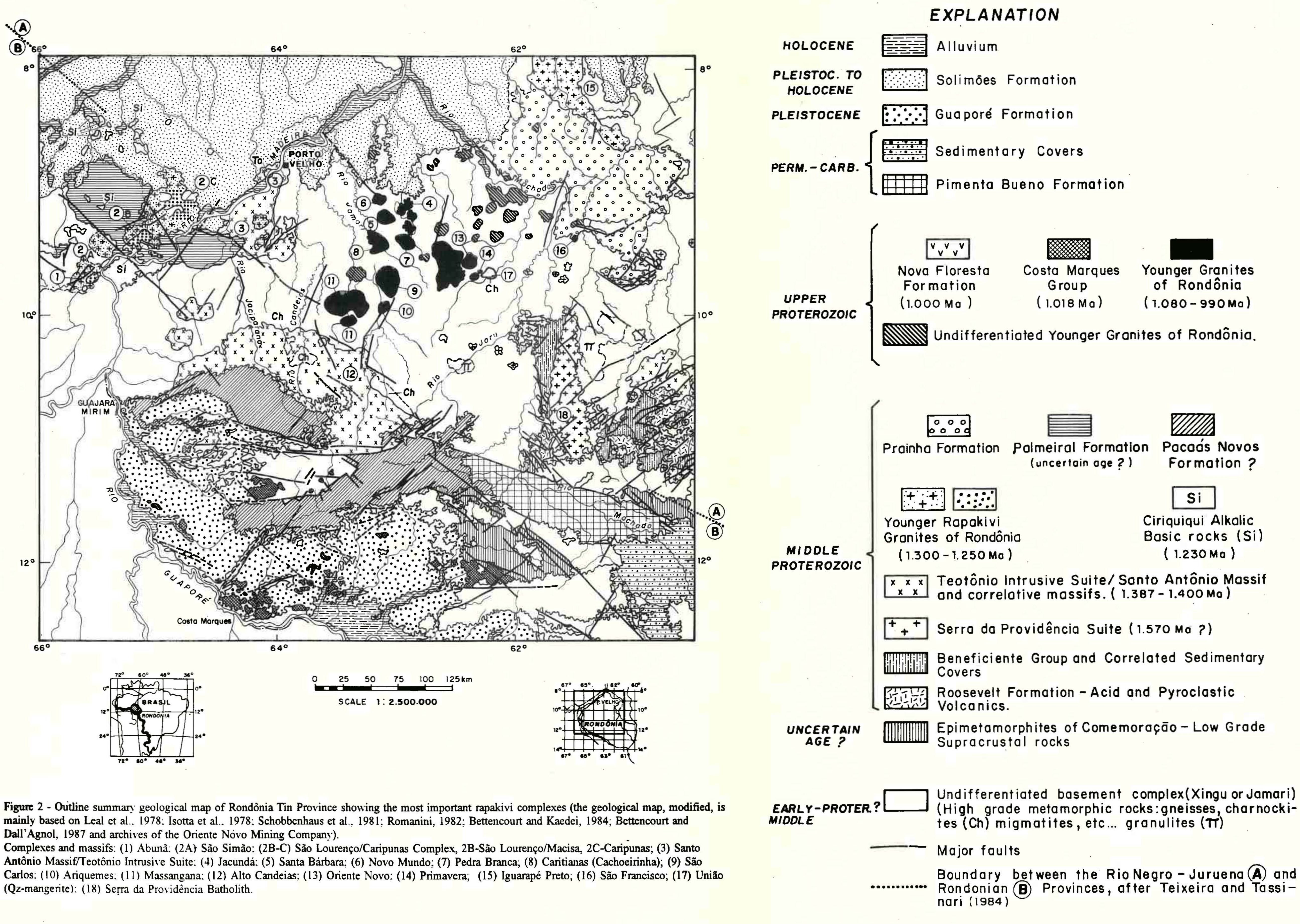


**Figure 2** - Outline summary geological map of Rondônia Tin Province showing the most important rapakivi complexes (the geological map, modified, is mainly based on Leal et al., 1978; Isotta et al., 1978; Schobbenhaus et al., 1981; Romanini, 1982; Bettencourt and Kaedei, 1984; Bettencourt and Dall'Agnol, 1987 and archives of the Oriente Nóvo Mining Company).
Complexes and massifs: (1) Abunã; (2A) São Simão; (2B-C) São Lourenço/Caripunas Complex, 2B-São Lourenço/Macisa, 2C-Caripunas; (3) Santo Antônio Massif/Teotônio Intrusive Suite; (4) Jacundá; (5) Santa Bárbara; (6) Novo Mundo; (7) Pedra Branca; (8) Caritianas (Cachoeirinha); (9) São Carlos; (10) Ariquemes; (11) Massangana; (12) Alto Candeias; (13) Oriente Novo; (14) Primavera; (15) Iguarapé Preto; (16) São Francisco; (17) União (Qz-mangerite); (18) Serra da Providência Batholith.

| Main rapakivi suite | Group/Complex/Massif | Rb/Sr Age (Ma) | 87Sr/86Sr | U/Pb zircon (Ma) | Associated rocks | Rb/Sr Age (Ma) | $^{87}Sr/^{86}Sr$ | U/Pb zircon (Ma) | K/Ar (Ma) |
|---|---|---|---|---|---|---|---|---|---|
| Serra da Providência (2) | Serra da Providência Complex | 1400±57 (2) | 0.713±0.005 | ≈1570 | Roosevelt acid to intermediate | 1.582±32 (1) | 0.7032±0.0007 | ----- | ----- |
| | | | | 1566±3 (6) | volcanics (1) | | | | |
| | | | | 1573±15 (6) | Ouro Preto charnockite (8) | ----- | ----- | ≈1560 (8) | ----- |
| | Alto Candeias Complex (3) | 1384±74 (3) | 0.703±0.009 | ----- | Alkaline complexes | | | | |
| | | | | | -Acari | ≈1450 | ----- | ----- | ----- |
| | | | | | -Arinos | ≈1400-1200 | | | |
| | Santo Antônio Massif | ----- | ----- | 1406±32 (6) | | | | | |
| Teotônio Intrusive Suite (6) | ----- | ----- | ----- | 1387±16 (6) | Charnockite Jaru (4) | ----- | ----- | 1351±8 (4) | ----- |
| | | | | | Teotônio (5) | ≈1250 (5) | | | |
| Younger Rapakivi granites (3) (6) | Caripunas/São Lourenço Complex: | 1268±15 (3) | 0.7071±0.0024 | | -Ciriquiqui/Curuquete (5) Gabbro-Anorthosite Suite | ≈1230 (5) | | | |
| | S.Lourenço (6) | ----- | | 1312±3 (6) | -Alkaline Complexes | | | | |
| | Caripunas | ----- | | 1309±24 (6) | Guariba (5) | 1260±56 (5) | 0.708 | | |
| | | | | | Canamã (5) | 1216±32 (5) | 0.704 | | |
| | | | | | Teotônio (5) | ≈1250 (5) | ----- | | ≈1150 |
| | Igarapé Preto | 1195±50 | 0.7090±0.0026 | | Rio Branco | ≈1130 | ≈0.708 | | |
| Younger Granites of Rondônia (3) (7) (6) | Massifs: | | | | Caripunas Acid Volcanics (1) | 1040±44 | 0.7193±0.003 | ----- | ----- |
| | Oriente Novo | | | 1080±27 (6) | Quartz-Mangerite (3) (6) | 1420±280 | 0.706 | 1048±8 (6) | |
| | Santa Clara | 1052±21 (3) | 0.710±0.0008 | 1081±50 (6) | | | | | |
| | São Carlos/Caritianas | 960±6 (7) | 0.707±0.0004 | ----- | -Nova Floresta Basaltic Dyke | ----- | ----- | | 1100-970 |
| | Pedra Branca | 954±20 (7) | 0.709± 0.016 | 998±5 (6) | Swarms and Flows (5) | | | | |
| | Massangana: | | | | -Younger Alkali Mafic Dykes | ----- | ----- | | |
| | S.Domingos | 960±27 (3) | 0.714±0.014 | | -Acid volcanics | ----- | ----- | | |
| | Facies Bom Jardim | | | 991±14 (6) | | | | | |
| | Massangana | | | | | | | | |
| | Costa Marques Group (2) | 1018±76 | 0.704 | ------ | | | | | |

Table 2 - Summary of the rapakivi granites of Rondônia and associated rocks (age and isotopic data).
Age references: (1) Leal et al., 1978; (2) Tassinari et al., 1984a; (3) Priem et al., 1989; (4) Olszewski et al., 1989; (5) Teixeira et al., 1990; (6) Our unpublished on going preliminary U/Pb zircon ages (analyses by Tosdal R. - USGS - USA); (7) Bettencourt, J.S., unpublished Rb/Sr isochrons Z.W.O.. Lab., Voor. Isot. Geol. - Amsterdam; (8) Van Schmus and Tassinari, verbal communication, 1995. Isotopic analyses were performed at the: Geochronological Research Center of the University of São Paulo (Brazil), Z.W.O. Laboratorium Voor Isotope Geologie of Amsterdam (Netherlands) and United States Geological Survey - USA (Geochron Laboratory) - Menlo Park - California - USA.

# THE GRANITOIDS RELATED TO THE RIO NEGRO-JURUENA OROGENY

## THE SERRA DA PROVIDÊNCIA INTRUSIVE SUITE

### Age and Distribution Patterns

Under this designation are considered: 1) the elongated, oval shaped Serra da Providência Batholith (140x40 km) and 2) approximately 40 stocks and isolated small bodies, varying from 3x3 km and 30x20 km in size, predominantly circular or oval in shape as reported by Leal et al. (1978) (Fig. 2).

They are epizonal in nature and clearly cut the Xingu Complex (Silva et al., 1974) of the Rio Negro-Juruena Province (1.75-1.55 Ga; Teixeira et al., 1989) although their contact relationships with the overlaying sedimentary cover are controversial (Leal et al., 1978; Soeiro et al., 1977; Romanini, 1982).

All the available ages for the Serra da Providência Batholith obtained by Rb/Sr whole rock, show values ranging from 1.5 to 1.2 Ma which rise much controversy. More recently a Rb/Sr reference isochron of 1360±30 Ma ($(^{87}Sr/^{86}Sr)_i$=0.71448 was obtained by Tassinari (verbal communication, 1995) (Table 2).

Analyses of two U/Pb zircon fractions of the normal rapakivi granites and rapakivi porphyries of the Serra da Providência Batholith yielded an age of 1573±15 Ma (our preliminary unpublished data) which is regarded as an estimate of the igneous crystallization age of the rapakivi porphyries and which shows that Rb/Sr ages might be too young (Table 2).

### Petrographic and geochemical characteristics

More recently Rizzotto et al. (1995; abstract, this symposium) have studied the southern portion of the Serra da Providência Batholith where four granitic facies showing gradational contacts have been recognized: pyterlites with subordinate wiborgite (PR), pink-grey porphyritic granites (PGPG), porphyry granites (PG) and equigranular pink graphic syenogranites (EGS). Associated with the normal rapakivi granites, gabbros, diabases, rhyolites, rhyolite-porphyries, quartz-porphyry and dykes of andesites are also observed at the Serra da Providência and Rio Roosevelt (Leal et al., 1978). Mafic rocks coeval with the charnockite/mangerite rapakivi suite are found in close spatial association, and some of their ages are reported in Table 2.

According to Rizzotto et al. (op.cit.) the main petrographic features of these rapakivi granites are as follows: PR are pinkish to whitish hornblende-biotite monzogranites, which show tabular to ovoid (up to 5 cm diameter) feldspars, and typical normal hornblende-biotite monzogranites. Microgranular enclaves of granite to quartz-dioritic composition occur.

PGPG are biotite monzogranites with ovoid K-feldspar phenocrysts. Biotite and hornblende are the main mafic minerals. Quartz-dioritic microgranular autholiths are widespread. Aplitic dykes are also seen.

PG are predominantly monzogranites, sometimes transitional to EGS syenogranites. They are red-grey color, and occasionally show rapakivi texture. Epidote, green biotite, carbonates and chlorite are hydrothermal products.

The EGS are pink medium-grained biotite rapakivi syenogranites. Perthitic K-feldspar microcline to epidote and sericite and biotite altered to chlorite are the major constituents. Zircon, fluorite and minor apatite are the typical accessory minerals.

More details about the petrography are provided in the outcrop descriptions.

### Geochemical characteristics

A rough idea about the major chemistry of the rocks was presented by the preliminary survey made by Leal et al. (1978) and, more information is given, at present, by Rizzotto et al. (1995; this symposium). The preliminary geochemical data indicated that the surveyed rocks have relatively high $SiO_2$ (68 to 72%), K/Na, Fe/Mg, K/Rb (100 to 300), Rb/Sr (1 to 10) ratios and low $Al_2O_3$, MgO and CaO.

The rocks have metaluminous to slightly peraluminous character, alkali affinities and characteristics akin to intra-plate A-type granites. Based on 8 samples, Leal et al. (op.cit.)

demonstrated that the average chemical composition of the rapakivi rocks of the Batholith is quite similar to the equivalent rapakivi rocks of Finland (Vorma, 1976). In addition, the normative means Q, Or, Ab of these rocks are similar to the average standard rapakivi of Sahama (1945).

## THE GRANITOIDS RELATED TO RONDONIAN/SAN IGNÁCIO OROGENY

## THE SANTO ANTÔNIO MASSIF AND TEOTÔNIO INTRUSIVE SUITE

### Age and distribution

The Santo Antônio Massif and the Teotônio Intrusive Suite, and U-Pb zircon age of 1406±32 Ma and 1387±16 Ma respectively (Tosdal and Bettencourt, 1994 and unpublished U/Pb zircon ages), are part of a poorly exposed batholithic occurrence of granitoid rocks which occurs in the northwest Rondônia (Fig. 2, Table 2) which have been investigated recently by Adamy and Romanini (1990) and Payolla (1994). They cut the ortho- and paragneisses of the high to medium grade basement (Jamari Complex; Isotta et al., 1978) of the Rio Negro-Juruena Province (1.75 to 1.55 Ga; Teixeira et al., 1989). They characterize a spatial and temporal association of subalkaline and alkaline plutonic rocks.

### Santo Antônio Massif

The Santo Antônio Massif (Payolla, 1994) is composed of three granitoid varieties, with the following emplacement sequence: 1) coarse-grained seriate to locally porphyritic monzogranite and syenogranite with sparse anti-rapakivi and rapakivi textures and interstitial drop quartz, 2) fine-grained equigranular quartz monzonite, and 3) medium-grained equigranular monzogranite. Hybrid rocks dykes, as well as minor synplutonic diabase dykes emplaced in partially molten host granitoids, provide evidence for bimodal magmatism.

The granitoids are subalkaline and slightly peraluminous rocks showing high Fe/Mg, K, F, Rb, Ga, Nb, Zr and REE, as well as low Ca, Mg, P and Sr, being similar to Phanerozoic within-plate and A-type ($A_2$ group) granites. The diabases show geochemical features comparable to continental tholeiites (high Fe/Mg and deep Nb, Ta and Sr troughs in spiderdiagrams), although contaminated with silicic components.

The hybrid rocks vary from rather heterogeneous porphyritic and breccia-like intermediate rocks with compositions from monzogranite to quartz-monzonite through quartz-monzodiorite to homogeneous porphyritic monzogranite. The occurrence of quartz ocelli, mantled feldspar and mafic microgranular enclaves, and the linear distribution of the major elements confirm the hybrid origin for these rocks.

### Teotônio Intrusive Suite

In the Teotônio cataract Teotônio Intrusive Suite is composed of three main rock types: 1) massive coarse-grained alkali feldspar granite, 2) banded medium-grained alkali feldspar granite, and 3) pink coarse- to medium-grained (quartz) alkali feldspar syenite and syenogranite. The alkali feldspar granites are cut by NE dipping, up to 2 meters wide, dykes of fayalite-bearing, grey to greenish fine and medium-grained clinopyroxene (quartz) alkali feldspar syenites, as well as synplutonic dykes of intermediate rocks (diorite, monzodiorite and monzonite). The parallel arrangement of the dykes defines a large scale banding in the outcrops. Late pink fine-grained monzogranites occurs as SW dipping cutting through the above rock types.

The anhydrous, high temperature mineralogy of syenitic and granitic hypersolvus rocks was partially altered to hydrous phases. Alkali feldspar show coarse exsolution textures (ribbon, braid and patch perthites). Fayalite is partially to completely altered to grunerite+opaque oxide and iddingsite. Clinopyroxene is altered to green amphibole showing crude symplectitic intergrowths with quartz. The alteration is more intense in the pink coarse- to medium grained syenites and granites.

The rocks define a alkaline silica-oversaturated series with high (Fe/Fe+Mg=0.81 to 0.99). The syenites and granites are metaluminous rocks with chemical characteristics of Phanerozoic within-plate and A-type ($A_1$ group) granites.

## THE YOUNGER RAPAKIVI GRANITES OF RONDÔNIA (YRGR)

### Distribution and age pattern

The YRGR and related plutons are well represented by the rapakivi granites of the S.Lourenço/Caripunas Complex (Fig. 2 - Tab. 2). These granites were first described in São Lourenço region by Kloosterman (1967a, b; 1970) and later on the Caripunas region by Bettencourt and Kaedei (1984). The rocks were all included in the YRGR (1.30-1.25 Ga), named by Bettencourt and Dall'Agnol (1987).
Several stocks (Fig. 2) such as Abunã, São Sebastião, Igarapé Preto might be of the same age.
The 90x40 km complex trends in a north-easterly direction along the left band of the Madeira River (Fig. 2). The long axis coincides with the dominant N50-60E strike direction of the Madeira-Tapajós lineament.
This is a epizonal polyphase batholith composed of various plutonic rapakivi phases, subvolcanic quartz-feldspar porphyry dykes, silicic fissural volcanics (rhyolites-rhyolite ignimbrites) and associated mafic rock (poorly known), which transect the 1.75-1.55 Rio Negro-Juruena orogenic crust.
In the S.Lourenço region the rapakivi granites cut graben sediments of the Palmeiral Formation which underwent contact metamorphism and intrusion of scattered cassiterite bearing quartz veins mineralization.

### Petrography

The granites of the S.Lourenço/Caripunas Complex exhibit mineralogical and chemical features not very different from the classic rapakivi suites of Fennoscandia (Vorma, 1976; Rämö, 1991; Haapala and Rämö, 1992; Rämö and Haapala, 1995). Normal rapakivi ovoidal textures are well developed in Caripunas region but true wiborgites occur only in small amounts.
The plutons are made up of granites "sensu stricto" (Streckeisen, 1976) and the modal compositions vary from quartz-syenite, syenogranite, subordinate monzogranite, alkali feldspar granite, with variable texture, mineralogy, chemical composition and differences in the proportion of amphiboles and micas.
The earlier rapakivi varieties are represented by pyterlites and wiborgites (this in small amount in Caripunas region) and porphyritic types. Dark colored even-grained fayalite-ferrohastingsite, ferrohastingsite-biotite quartz syenites and alkali-feldspar granites are met with.
The more evolved facies occur in S.Lourenço and are represented by biotite-syenogranites and even-grained biotite alkali feldspar granites. Porphyritic varieties are dominant.
Among the earliest rapakivi varieties even-grained fayalite alkali-feldspar granites of Caripunas are "hypersolvus" granites whereas in S.Lourenço the alkali-feldspar granites are "subsolvus" in character and intensely affected by late to post-magmatic alteration processes, to which tin mineralization is associated.
For the normal and porphyritic rapakivi types, besides the characteristic texture, K-feldspar (typical micro-perthitic orthoclase) and plagioclase (andesine or oligoclase), the main mafic silicates are iron-titaniferous hornblende (hastingsite) and biotite. The important accessories are zircon, ilmenite, magnetite and titanite. The fayalite granites contain abundant perthitic K-feldspar, little or no plagioclase, and quartz, fayalite, diopsidic augite, red biotite and amphibole of the pargasite-ferrohastingsite series are the main mafic silicates. The red, even-grained biotite and hornblende granites are rich in K-feldspar (perthitic orthoclase) besides plagioclase (oligoclase or albite). The dominant mafic minerals are hornblende (hastingsite, sometimes forming reaction coronas around augite and diopside), red biotite and pseudomorphs of olivine. Fluorite is always present.
The rapakivi granites are predominantly

metaluminous to slightly peraluminous ilmenite-type or magnetite-type granites whereas some of the alkali-feldspar varieties of Caripunas are peralkaline in nature.

### Geochemical characteristics

The normal and porphyritic rapakivi varieties of the complex and one sample of rhyolite porphyry of S.Lourenço show higher contents of CaO, MgO, $Al_2O_3$ and low contents, of $SiO_2$ in relation to the latest even-grained granites. Combined, the average element concentrations of the rapakivi granites are of the order of: $SiO_2$ (72.3%), $Al_2O_3$ (12.5%), MgO (0.19%), CaO (0.87%), $Na_2O$ (3.7%), $K_2O$ (5.4%), F (2528 ppm), Rb (385 ppm), and Zr (243 ppm). These values are not very different from those of the Laitila Massif as presented by Vorma (1976).

The earlier normal, porphyritic and fayalite rapakivi granites show high content of REE varying from 360 to 589 ppm. They are strongly enriched in LREE relative to HREE, $[La/Yb]_N$= 5.5 to 8.5 and negative Eu/Eu* anomaly of about 0.5.

Late biotite subsolvus granites of S.Lourenço exhibit lower concentration of REE=364 ppm. The content of LREE decreases and that of HREE increases, which indicate a strong fractionation of LREE, $[La/Yb]_N$=8.0. The deep Eu anomaly Eu/Eu*=0.16, and HREE enrichment patterns in the subsolvus biotite tin granites might be related to the late to post-magmatic processes of alteration and mineralizing fluids enriched in F and/or Cl (Bowden et al., 1984; Harris and Marriner, 1980).

The chemical discriminant diagrams show the geochemical characteristics of A-type and within-plate granites. Also the initial $^{87}Sr/^{86}Sr$ ratios (Caripunas, 0.710; S.Lourenço, 0.706; Priem et al., 1988), and the relatively low Y/Nb ratio indicate involvement of Early Proterozoic crustal components in the magma genesis. All this features are reinforced by our preliminary Pb's isotopic data.

### Mineralization

The important Sn and related rare metal elements mineralization seen in S.Lourenço region show a closer spatial relationship with the latest subsolvus lithium or fluorine rich siderophyllite-bearing syenogranites and alkali-feldspar granites of rapakivi affinities. Cassiterite bearing greisens and cassiterite quartz veins are abundant but little is known about their distribution, morphology and composition.

## THE GRANITES RELATED TO SUNSÁS OROGENY

## THE YOUNGER GRANITES OF RONDÔNIA

### Distribution and age pattern

The Younger Granites of Rondônia (YGR) occur as epizonal multiphase batholiths and stocks notably along a north-south trend in the Jamari Uplift (Romanini, 1982; Bettencourt et al., 1987; Payolla et al., 1991; Leite Jr., 1992; Pinho, 1987) (Fig. 3). They consist of several kinds of plutons, circular of elliptical in shape, ranging in diameter from 2 to 25 km. They sometimes form small sheeted bodies, "stocks" and batholithic masses. They are typically cratogenic, subvolcanic in character and probably were intruded in "dilational jogs" (Sibson, 1986) into medium- to high-grade metamorphic terranes of the Rio Negro-Juruena (1.75-1.55 Ga) and Rondonian (1.5-1.3 Ga) provinces (Bettencourt, 1992).

The contacts, when observed, are irregular, abrupt, sometimes with breccia and enclaves. Subvolcanic and volcanic structures like ring dykes, cone-sheets and probably cauldron-subsidence are recognized in some plutons.

The (YGR) comprise two contrasting chrono-groups which have been dated to be 1081 Ma age (Older Group) and 991 Ma age (Younger Group) (U-Pb from zircon; our unpublished data from ongoing research). These ages are respectively about 29 Ma and 44 Ma older than the Rb/Sr ages obtained by Priem et al. (1989).

## Petrography

Among the (YGR) two distinct suites are identified, a dominant one with a subsolvus and subalkaline character, and the other more restricted in area with hypersolvus and alkaline to peralkaline nature. They are observed in close association in some batholiths or stocks, e.g., Oriente Novo Massif (Leite, 1992), Massangana (Romanini, 1982).

The subalkaline suite consists of three distinct intrusive phases. Early intrusive bodies are mainly magnetite-type, coarse-grained porphyritic biotite (±hastingsite) monzogranites and syenogranites, with local pyterlite rapakivi texture; typical accessory minerals are zircon, apatite, allanite, sphene, magnetite, ilmenite and fluorite. Intermediate intrusive phase involved ilmenite-type porphyritic to equigranular biotite syenogranites and alkali-feldspar granites with zircon, monazite, ilmenite and fluorite as common accessory minerals. The latest intrusive phase comprises Li-protolithionite-albite leucogranites, the most differentiated rocks, with "snowball" texture, consisting of lathshaped albite surrounding and enclosed by larger anhedral crystals of untwinned microcline and unstrained quartz as seen in Oriente Novo Massif and described by Leite Jr. (1992) and Leite Jr. and Bettencourt (1992).

The subalkaline granites are metaluminous to slightly peraluminous, except for albite granites that show an alkaline character. The majority of the granites was crystallized from water-deficient magmas, which were mainly formed from a parent magma of crustal origin ($Sr_i$= 0.717± 0.0026), by crystal fractionation processes. Thermogravitational and convective fractionation of a halogen-rich residual granitic melt are thought to be additional petrogenetic processes related to the formation of Li-mica albite leucogranites. The Q-Ab-Or normative composition of albite granites are close to pseudoternary minimum at 1 kbar with 1 wt% added fluorine in the haplo-granite-$H_2O$-F system.

The minor alkaline suite is represented by alkali-feldspar microsyenites, trachytes, granites and rhyolites as seen in the Oriente Novo and São Carlos massifs, the Massangana complex and Bom Futuro Hill. They comprise a sodic-alkaline series in the modal Q-A-P diagram and they show a metaluminous to peralkaline character. Some petrographic features (e.g. presence of microgranular enclaves of probable basalt to quartz trachyte composition in the granites and rhyolites) and the variation of standard indices (e.g. K/Rb, Rb/Sr) indicate the involvement of magma mixing and crystal fractionation processes in the genesis of magmas.

## Chemical characteristics

The monzogranites, syenogranites and alkali-feldspar granites have distinct petrography and geochemical trends. The changing composition and/or abundance of plagioclase defines the petrographic trend. The geochemical trend, based on Harker diagrams, also shows a regular and marked change. Another important geochemical trend is the change from metaluminous to slightly peraluminous character. The monzogranites, syenogranites and alkali-feldspar granites also have high $K_2O$+$Na_2O$, FeO/MgO, Ga/Al, Zr, Y, Nb, Rb, F and REE, such as occur in subalkaline A-type granites and intra-plate granites. The Li-mica albite leucogranite, the most differentiated rock, fits the petrographic trend well, but not the geochemical trend, because of its very high values of Rb, Li and Sn.

The rapakivi granites have high total REE (277 to 2539 rpm), are enriched in LREE ($La_N/Yb_N$ = 2.2 to 24.0) and exhibit deep negative Eu anomaly ($Eu/Eu_N$ = 0.1 to 0.6). The 0.99 Ga Sn-bearing granites have REE patterns as follow: REE = 520 ppm, low LREE fractionation $(La/Yb)_N$ = 5.7 and a distinct deep negative Eu anomaly $(Eu/Eu)_N$ = 0.19. The REE patterns are typical of rapakivi granites and are comparable to those referred by Vorma (1976).

The granites of both suites are characterized by high Fe/(Fe+Mg) and K/(K+Na) ratios as well as by high Ga, Rb, Zr, Y, F and REE contents. They have the geochemical characteristics of subalkaline A-type granites and within-plate granites.

## Mineralization

Several types of late to post-magmatic processes occurred in the subalkaline suite. K-feld-

spathization and Na-feldspathization represent pervasive alterations restricted to granites of the intermediate intrusive phase, while greisenization, silicification and argilization constitute widespread fissural alteration.
The primary mineralization of tin, tungsten, niobium, tantalum, beryllium, fluorine and sulfide is spatially associated mainly with the latest intrusive phases of the subalkaline suite and occur mostly as: pegmatite with topaz and beryl; Li-mica albite leucogranite with cassiterite and columbite-tantalite; topaz protolithionite albite rhyolites with cassiterite; greisen bodies with cassiterite composed mainly of quartz, Li-mica and topaz, in various proportions, and quartz veins with cassiterite, wolframite, beryl and Cu-Pb-Zn-Fe sulfides.

## TECTONIC SETTING

A possible link between Amazônia and Laurentia has been object of much discussion, more recently by Hoffman (1991), Moores (1991), Dalziel (1992a and b) and Sadowski and Bettencourt (1995). The lateral geometrical fit of Grenvillia and Amazônia proposed by Dalziel (1992 a and b) and the implication of such correlation during Proterozoic time (Sadowski and Bettencourt, op.cit.) offer a good opportunity to constrain the origin and tectonic setting of the rapakivi plutons and associated mafic rocks of the south-southwestern sector of the Amazonian Craton which must be visualized within the framework of such a possible lateral palaeogeographic link.
Taking this in consideration we consider that the Serra da Providência Suite (1573±15 Ma) could be correlated to the final post-tectonic stages of evolution of the Rio Negro-Juruena belt at 1.55-1.5 Ga or might also represent a extensional cratonic magmatism preceding the Rondonian Orogenic Cycle, but this hypothesis needs further confirmation.
The cratonic igneous event represented by Santo Antônio Massif, Teotônio Intrusive Suite and related complexes might be correlated to widespread rifting and major continental extension which preceded the opening of the Grenville ocean at around 1,4-1.3 Ga (Sadowski and Bettencourt, op.cit.) and at the start or preceding the Rondonian/San Ignácio Orogenic Cycle. The extension was also accompanied by emplacement of charnockite-mangerite suites and mafic intrusive rocks which are poorly known (Table 2).
The Younger Rapakivi granites, best represented by the S.Lourenço/Caripunas rapakivi granites (1.3-1 25 Ga) can be related to a distensional period at the end of the Rondonian/San Ignacio Orogenic Cycle (Sadowski and Bettencourt, op. cit.).
The start of Sunsás/Aguapei Cycle was characterized by an important continental distension followed by a cratonic magmatic episode which is represented by the Younger Granites of Rondônia (1.08-0.90 Ga). The plutons are directly linked to a transtensional regime and extensive strike-slip faults initially with a left-lateral component. These structures are a response to collision at the end of the Grenvillian/Sunsás Cycle along the Grenville/Sunsás front as envisaged by Sadowski and Bettencourt (op.cit.). According to Bettencourt (1992) the massifs occur as epizonal multiphase batholiths and stocks notably along a north-south trend and are intruded probably in structures like dilational jogs (Sibson, 1986). These structures act as preferential pathways for fluid infiltration and flow of fluids and are favorable sites of development of tin mineralized breccia pipes and vein systems. However this hypotheses needs further research field work.

## ISOTOPIC CONSTRAINTS ON THE ORIGIN OF RAPAKIVI GRANITES OF RONDÔNIA

Sr isotopic data of the rapakivi granite suites of Rondônia comprise approximately 100 samples which were Rb/Sr whole rock investigated (Priem et al., 1986; Teixeira et al., 1989). The bulk of the strontium initial ratios which range from 0.707 to 0.712 favors a crustal origin for the rapakivi and related massifs.
Model whole rock Pb isotopic compositions ~~using Rb/Sr ages~~ for 36 samples from 6 massifs, and the youngest associated alkaline intrusives indicate a derivation of Pb from crustal sources (Tosdal et al., 1995; this symposium). The crustal origin suggested by the Pb isotopic data is

consistent with the elevated $^{87}Sr/^{86}Sr$ values (>0.707) reported from the granite massifs. All Pb isotopic compositions lie adjacent to, or above extensions of the average crustal growth curve, and lie generally at lower $^{207}Pb/^{204}Pb$ for a given value of $^{206}Pb/^{204}Pb$ than do Early Proterozoic gneissic rocks of Rio Negro/Juruena belt (Tassinari, 1984). Where the U-Pb ages of the massifs are known, the Pb model ages are older by about 50 to 100 m.y. Intersuite differences in Pb isotopic compositions and time-averaged Th/U are based on age and geographic location. One group includes the Caripunas, São Lourenço and Santo Antônio massifs that are >1250 Ma whereas the second group comprises the Younger Granites of Rondônia with ages <1100 Ma. The older massifs are characterized by elevated $^{206}Pb/^{204}Pb$ (20.2-30.1) and low $^{208}Pb/^{204}Pb$ (40-45) indicative of high m character and time-averaged Th/U<4. In contrast, the younger massifs have lower $^{206}Pb/^{204}Pb$ (17.6-20.6) and $^{208}Pb/^{204}Pb$ (37.3-43.2) lying adjacent to or above the average crustal growth curve, indicating time-average Th/U>4. The 1387±17 Ma Teotônio Intrusive Complex has characteristics of both age groups, with the high $^{208}Pb/^{204}Pb$ (43.1-55.5) isotopic compositions and geographic location of the younger group, but with the high $^{206}Pb/^{204}Pb$ (21.5-22.9) and age of the older group.

From the initial Pb results it is clear that there was an involvement of Early Proterozoic crust in the genesis of the granite massifs and evidently different crustal-lithospheric types played large roles in the genesis of the massifs and their associated Sn deposits. This latter hypothesis need further studies.

A few Sm-Nd $T_{DM}$ model ages of the Rio Negro-Juruena Province basement rocks of about 2.0 Ga were obtained by Sato et al. (in preparation, apud Tassinari et al., 1995, this symposium). These data also indicate the same authors, an Early to Middle Proterozoic continental crust as the main magmatic source for the rapakivi granites.

## MINERALIZATION

The important Sn, W, Nb, Ta, F, REE, .fluorite and topaz mineralization are principally bound to the Younger Rapakivi granites of Rondônia (YRGR: 1.3-1.25 Ga) and to the Younger Granites of Rondônia (YGR: 1.08-1.0 Ga). They show a closer spatial relationship with the latest subsolvus lithium or fluorine rich siderophyllite-bearing syenogranites and alkali feldspars granites of the YRGR and to the latest intrusive phases of the subalkaline suite of the YGR as represented mostly by Li-protolithionite-albite leucogranites, as well as to topaz siderophyllite albite rhyolites (the most differentiated rocks in the Province).

Different styles of mineralization have been described and most of the Sn, mainly occur as: cassiterite dissemination in the Li-mica leucogranite, as in Oriente Novo Massif (Leite Jr., 1992) as well as in greisen bodies, stockworks of veinlets associated with greisen and quartz veins, quartz vein swarms and breccias whereas W occurs most of the time as wolframite in quartz veins.

The greisens are of variable composition sometimes composed mainly of quartz Li-mica and topaz in various proportions (Oriente Novo, Caritianas and Santa Bárbara massifs) together with zircon, cassiterite and opaque minerals as accessories, or made up of quartz, galena, fluorite, topaz, zinnwaldite, as reported in Palanqueta Granite-Bom Futuro (Silva et al., 1995; this symposium). The tin bearing quartz-veins may show a simple mineralogy or may be complex veins made up of quartz, adularia, zinnwaldite, siderophyllite and cassiterite, besides zircon, monazite, manganese oxides, ilmenite and wolframite (seen in Bom Futuro Mine, Villanova and Franke, 1995; this symposium) and Caritianas massif (Pinho, 1987). Pegmatites bearing topaz and beryl are also common.

The disseminated mineralization as observed in the Li-mica albite leucogranites (Leite Jr., op.cit.), suggests that Sn and related metals are derived from magmatic sources.

# GENERAL OUTLINE OF THE EXCURSION AND DAILY ROUTES

A general outline and location of the areas and mining districts that will be visited are shown in Figures 3 and 4.

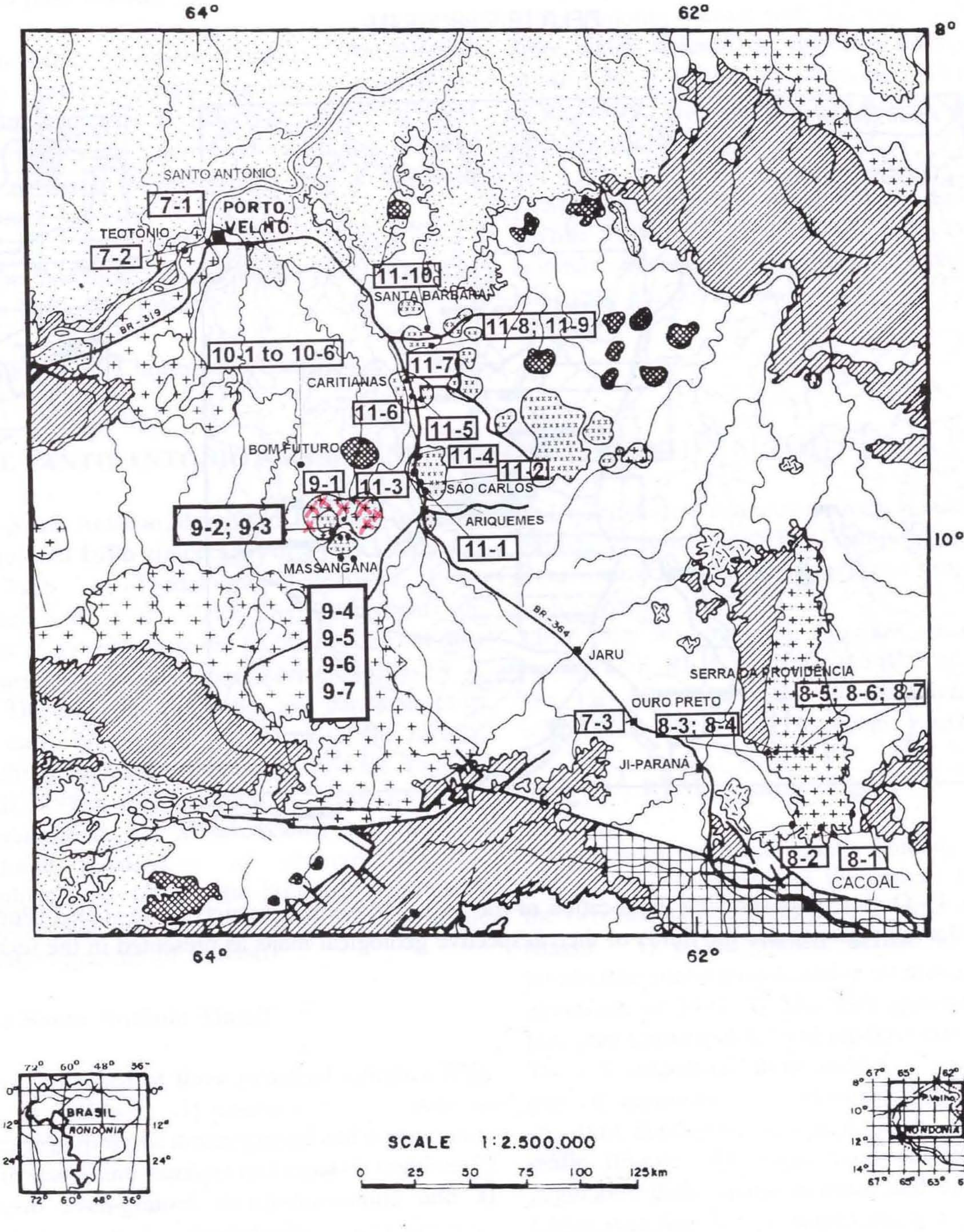


Figure 3 - IGCP-Project 315 (Field Trip, August 7-12, 1995) route map for the excursion. Number in squares indicate the day and number of the stop on that day.

# FIELD TRIP PROGRAM

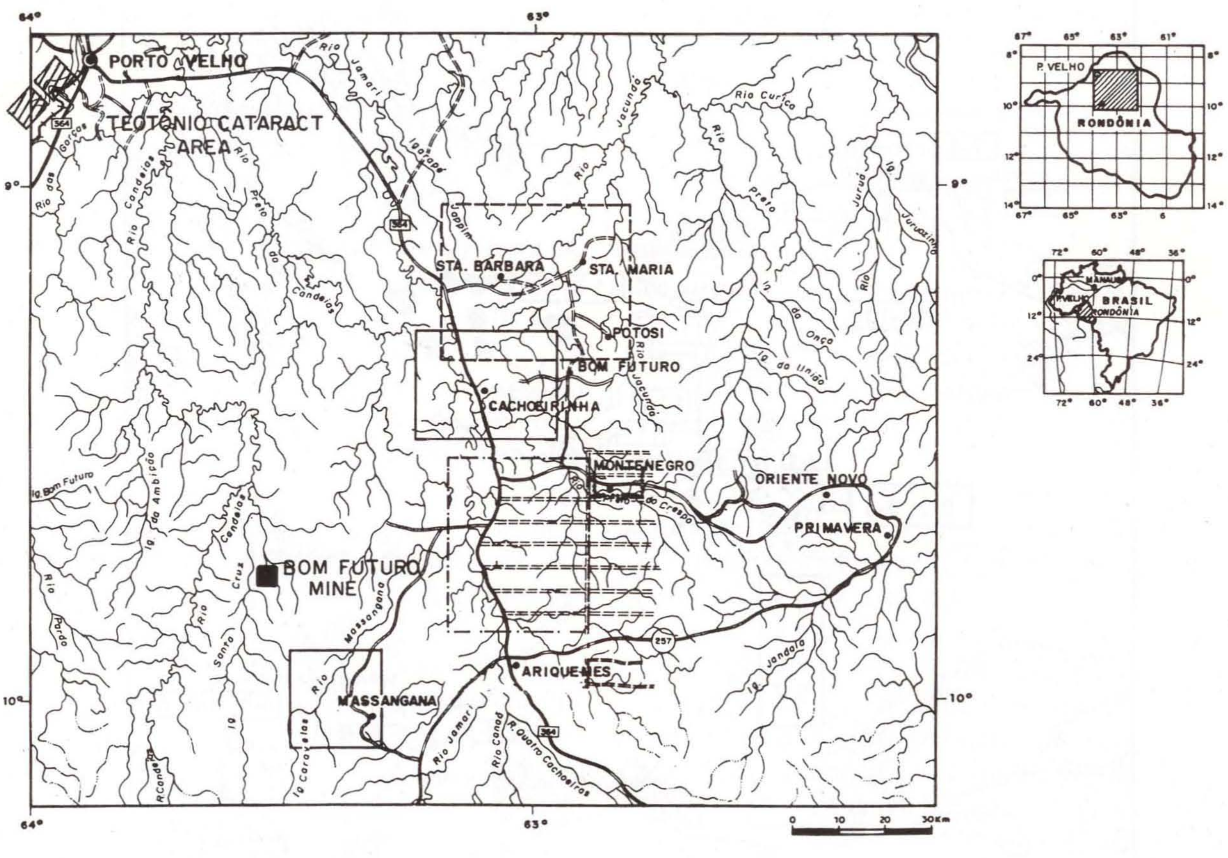


Figure 4 - Outline map showing the location of the areas and mining districts to be visited (Porto Velho/Jamari regions) and the limits of their respective geological maps as presented in the text.