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3.3 Ga SHRIMP U–Pb zircon age of a felsic metavolcanic rock from the Mundo Novo greenstone belt in the São Francisco craton, Bahia (NE Brazil)

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Abstract

Felsic metavolcanics associated with supracrustal rocks provide U–Pb zircon and Sm–Nd T_{DM} ages of approximately 3.3 Ga, which establish an Archean age of the Mundo Novo greenstone belt. A granodioritic gneiss from the Mairi complex, located on the eastern boundary of the Mundo Novo greenstone belt, exhibits a zircon evaporation minimum age of 3.04 Ga and a Nd model age of 3.2 Ga. These results constrain the occurrence of at least three major geological units in this area: the Archean Mundo Novo greenstone belt, the Archean Mairi gneisses, and the adjoining Paleoproterozoic (<2.1 Ga) Jacobina sedimentary basin. The Jacobina basin follows the same trend as the Archean structure, extending southward to the Contendas–Mirante belt, in which a similar Archean–Paleoproterozoic association appears. We postulate that during the Paleoproterozoic in the eastern margin of the Gavião block, these Archean greenstone belts constituted a zone of weakness along which a late-stage orogenic sedimentary basin developed. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Zircon age; Metavolcanic rock; Mundo Novo greenstone belt

1. Introduction

Archean and Paleoproterozoic supracrustal associations (greenstone belts) are described in the northeastern part of the São Francisco craton (SFC) in Bahia (Fig. 1). The age of such rock types is often difficult to constrain using geochronological methodologies because of (1) the weak fractionation of isotopic systems studied in mafic and ultramafic rocks and (2) the possible resetting of whole-rock systems during metamorphic processes in both mafic and felsic rocks. In this part of the SFC, high-grade events were developed during the Trans-Amazonian orogeny (ca. 2.1 Ga), which makes it difficult to interpret the whole-rock geochronology. Inherited zircons from metasediments of the SFC provide indirect evidence for an early Paleoproterozoic deposition age (2.15–1.95 Ga) of the upper part of the Contendas–Mirante and Jacobina sedimentary belts (Nutman et al., 1994; Mougeot et al., 1995). However, the best way to date such volcano sedimentary complexes more precisely is to use felsic metavolcanic rocks, which are often associated with mafic rocks and generally contain magmatic zircons. This paper provides TIMS $^{207}Pb/^{206}Pb$ evaporation and SHRIMP U–Pb zircon ages, as well as some Nd model ages from a metadacite and surrounding rocks of the Mundo Novo greenstone belt, which is geographically associated with the Jacobina supracrustals.

2. Geological setting

In Bahia State, the SFC is represented as a juxtaposition of four Archean continental blocks brought together during convergent and collisional processes at approximately

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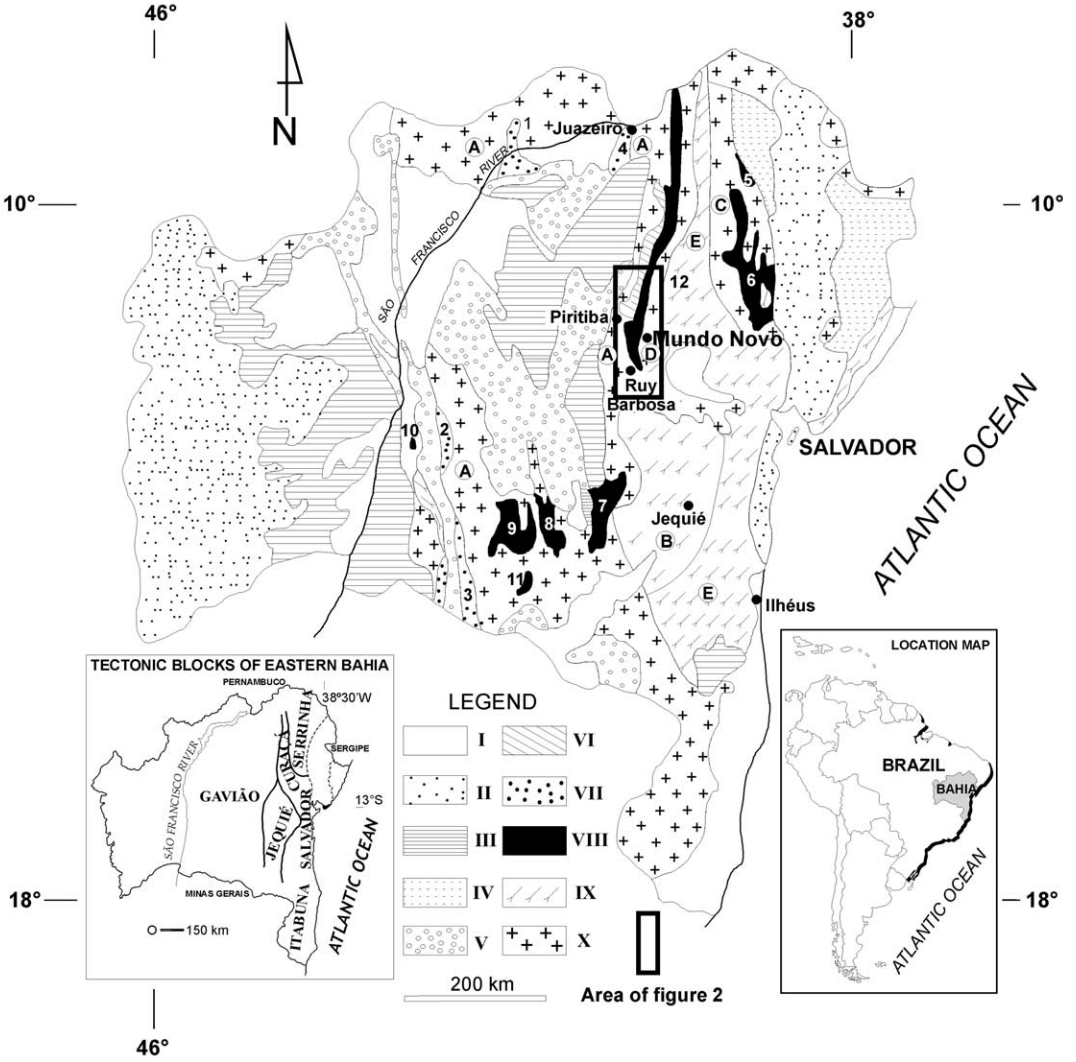

Fig. 1. Geological map of Bahia showing the location of the Mundo Novo greenstone belt (Mascarenhas, 1976). I: Cenozoic cover. II: Mesozoic basins. Neo-Proterozoic: III: São Francisco supergroup. IV: Sergipano fold belt. Meso-Proterozoic: V: Espinhaço supergroup. Paleoproterozoic to Archean: VI: Jacobina group. VII: Volcano sedimentary sequences (1) Barreiro-Colomi, (2) Boquira, (3) Urandi-Licinio de Almeida, and (4) Rio Salitre. VIII: Greenstone belts (5) Rio Capim, (6) Rio Itapicuru (Serrinha), (7) Contendas–Mirante, (8) Umburanas, (9) Brumado, (10) Riacho de Santana, (11) Guajeru, and (12) Mundo Novo. Archean: IX: Granulitic complex. X: Granitic gneiss terrains (A) Gavião block, (B) Jequié block, (C) Serrinha block, (D) Mairi complex, (E) Itabuna–Salvador–Curaçá belt.

2.1 Ga during the Trans-Amazonian orogeny (Barbosa and Sabaté, 2002): the Gavião block, the granulitic Jequié block, the granulitic Itabuna–Salvador–Curaçá belt, and the Serrinha block (Fig. 1).

The Serrinha block in the northeast is considered similar to the Gavião block because of similarities in the rock types observed, even though the oldest Archean terrains (3.4 Ga) found in the Gavião block are not recognized (Sampaio, 1992; Sabaté et al., 1994a,b). The basement is made up of tonalitic, granodioritic, and granitic gneisses yielding Rb–Sr whole-rock isochron ages of 3.1, 3.0, 2.7, and 2.1 Ga (Mascarenhas and Garcia, 1989; Bastos Leal, 1992); a U–Pb zircon age of 2.9 Ga (upper intercept) is indicated by Gaal et al. (1987). The Rio Itapicuru greenstone belt is Paleoproterozoic. It is composed of tholeiitic basalts with pillow lavas in the lower part, then felsic volcanics with andesites, tuffs and dacites, and clastic sediments at the top (Davison et al., 1988; Silva, 1992). All ages obtained are around 2.2–2.1 Ga, with the tholeiitic basalts providing Sm–Nd and Pb–Pb ages of 2.2 Ga (Silva, 1992). The andesites are dated by U–Pb zircon at 2178 ± 23 Ma (Gaal et al., 1987), in relative agreement with a previous Rb–Sr whole-rock isochron age of 2080 ± 90 Ma (Brito Neves et al., 1980). These ages are also in agreement with Nd and Pb–Pb ages around 2.1 Ga (Silva, 1992).

To the west, the Gavião block (Fig. 1) contains the oldest Archean relics known in South America (Martin et al., 1991, 1997; Nutman and Cordani, 1993; Mougeot, 1996; Santos Pinto et al., 1998; Bastos Leal et al., 1998; Teixeira et al., 2000). It is composed of medium-grade Archean primitive continental crust (TTG), dated by zircon in the range of 3.2–3.4 Ga, and 2.7 Ga recycled granitoids. Several supracrustal

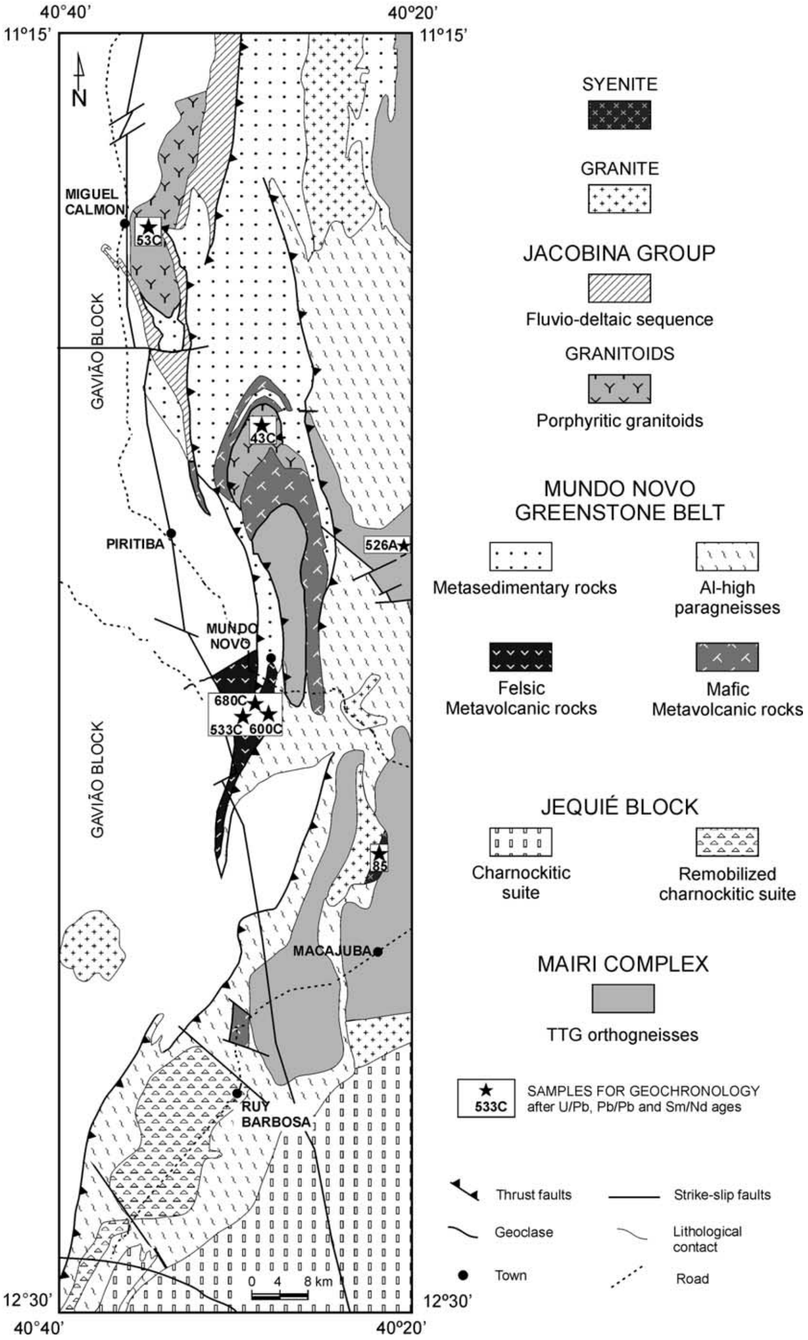

Fig. 2. Geological map of the southern part of the Mundo Novo greenstone belt (from Souza, in prep.).

belts in the Gavião block were described by the Companhia Baiana de Pesquisa Mineral (CBPM) programs as greenstone belts of possible Archean or Paleoproterozoic age; they make up the belts of Brumado, Umburanas, Contendas–Mirante, and Riacho de Santana (Cunha and Froes, 1994; Cunha et al., 1996; Peixoto et al., 1996). These supracrustal belts are dated by zircon, Pb–Pb whole-rock, and Sm–Nd methods as 3.3–2.5 Ga (Wilson, 1987; Wilson et al., 1988; Marinho, 1991; Marinho et al., 1994; Bastos Leal et al., 1998). The greenstone belts are composed of metamorphosed mafic and ultramafic metavolcanic rocks, including komatiites with spinifex texture and tholeiitic basalts in the lower part, felsic metavolcanics and pyroclastic flows interbedded with scarce metasediments in the middle part, and iron-rich (BIF) and calcareous sediments at the top (Cunha and Froes, 1994). During the early Paleoproterozoic, the Gavião block underwent intensive migmatization, and related anatectic granites were emplaced at around 2.1–2.0 Ga. They indicate major crustal thickening at that time (Santos Pinto et al., 1998; Bastos Leal et al., 2000). The Gavião block and the eastern granulitic terrains are separated by a linear tectonic structure

600 km long (Contendas–Jacobina lineament, Sabaté et al., 1990). The Jacobina–Mundo Novo and Contendas–Mirante supracrustal belts follow this boundary in the eastern part of the Gavião block (Marinho, 1991; Sabaté et al., 1990, 1994a,b).

The Jequié block (B in Fig. 1) and the Itabuna–Salvador–Curaçá belt (E in Fig. 1) are made up of charnockites with Archean and Paleoproterozoic magmatic protoliths dated by U–Pb zircon at 2.8, 2.6, and 2.1 Ga (Barbosa, 1990; Alibert and Barbosa, 1992; Marinho et al., 1994; Sabaté et al., 1994a,b; Ledru et al., 1994). Granulitic supracrustals, tectonically mixed with the charnockites, are also recognized. Granulite facies metamorphism is dated at approximately 2.1 Ga, and a previous high-grade event is suggested (Wilson, 1987; Wilson et al., 1988; Barbosa, 1990, 1996; Marinho et al., 1994; Ledru et al., 1994; Sabaté et al., 1994a,b).

The Mundo Novo greenstone belt and the Jacobina group (Figs. 1 and 2) are often interpreted as a single Paleoproterozoic basin known as the Jacobina basin (Couto et al., 1978; Ledru et al., 1997). The two units are bounded to the west by the 3.4 Ga Gavião basement of TTG affinity (Mougeot, 1996) and to the east by the Mairi gneissic complex. The latter is a TTG/tholeiitic bimodal suite dated at ca. 3.0 Ga by Rb–Sr (Brito Neves et al., 1980) and is considered part of the Gavião block (Sabaté, 1996; Barbosa and Sabaté, 2002). The Mundo Novo supracrustal belt (Fig. 2) is one of the most complete volcano sedimentary belts in the adjoining Gavião block (Mascarenhas and Silva, 1994). It crops out from the south of Mundo Novo City to Juazeiro City in the northernmost part of Bahia. From the base to the top, it is mainly composed of the following (Souza et al., 1996; Fig. 2):

1. Mafic metavolcanics formed mainly of basalts with pillow-lava structures (Roig et al., 1992), andesitic metabasalts, cherts, BIF, calcsilicate rocks, and graphitic schists; ultramafic tectonic slices intercalated within the Jacobina group are interpreted to belong to the greenstone belt. Metamorphism is of medium-grade and associated with sillimanite-bearing granites.
2. Felsic metavolcanics of dacitic and rhyodacitic composition with variolitic texture (cf. sample SSR 680c in this geochronological study), associated with pyroclastic metasediments, south of Mundo Novo.
3. Clastic to chemical metasedimentary rocks, including the Bananeiras Formation (iron- and manganese-rich pelitic schists and quartzite, Leo et al., 1964; Mascarenhas, 1969); the Agua Branca Formation (quartzite, quartziferous schists, phyllites, BIF, and associated Mn mineralization, Griffon, 1967); part of the Itapicuru complex (chemical and volcano sedimentary deposits, Loureiro and Santos, 1991); the Brejo dos Paulos Formation (ferriferous quartzites, gondites, calcsilicate, and mafic and ultramafic rocks, Arcanjo and Couto, 1978); and the Cruz das Almas Formation (conglomerates, quartzites, metasiltstones, and Fe–Mn–rich metapelites), which is alternatively interpreted as a lateral equivalent of the Bananeiras Formation (Leo et al., 1964; Couto et al., 1978) or correspondent to the top of the Jacobina group (Cox, 1967; Mascarenhas et al., 1992).
4. To the east of the Mundo Novo greenstone belt, Al-rich gneisses (kinzigites and cordierite–sillimanite-bearing gneisses) in close association with peraluminous granites. Such an association has recently been interpreted as a tectonic slice (originating in the Itabuna–Salvador–Curaçá belt) that contains the products of dehydration melting processes of the Trans-Amazonian orogeny, namely, restitic residues (Al-rich gneisses) and anatectic liquids (peraluminous granites) (Leite, in prep.).

To the west of the greenstone belt, according to the interpretation of Mascarenhas and Silva (1994), the metasedimentary fluvio-deltaic and marine units of the Jacobina group (Leo et al., 1964) are restricted from the base to the top to the following: (1) the Serra do Corrego conglomeratic and quartzitic formations containing economic gold deposits that appear to be derived from the greenstone belt, (2) the Rio do Ouro quartzites with intercalations of conglomerates and aluminous schists, and (3) the metapelites and quartzites of Cruz das Almas and quartzites and phyllites of the Serra da Paciência (Mascarenhas et al., 1992).

The Mundo Novo greenstone belt and the Jacobina group show amphibolite facies paragenesis related to two phases of metamorphism: the first is of Barrovian type (medium pressure/temperature) with garnet-, staurolite-, and epidote-bearing assemblages, and the second is of low pressure and high-temperature type (LP/HT) with andalusite- and sillimanite-bearing assemblages. This metamorphic history is related to crustal thickening and the intrusion of peraluminous magmas during the Trans-Amazonian orogeny around 2.1–2.0 Ga (Leite, in prep.). Local variations in metamorphic conditions are related to shearing, as in zones with kyanite-bearing (higher pressures) or garnet (spessartite type) paragenesis. The muscovite- and chlorite-bearing zones imply hydration reactions under green schist facies conditions. The Al-high paragneiss are metamorphosed in the upper amphibolite/lower granulite facies (garnet-, sillimanite-, and cordierite-bearing assemblages).

The Mundo Novo greenstone belt and the Jacobina group are both included in tectonic slices related to a major east-to-west overthrusting associated with sinistral wrenching linked to Paleoproterozoic collisional processes (Leo et al, 1964; Griffon, 1967; Mascarenhas, 1969; Sabaté, 1996; Ledru et al., 1994, 1997). Mascarenhas and Silva (1994) describe interference folding in the greenstone belt that is not recognized in the Jacobina group. These authors suggest that the Mundo Novo greenstone belt could be older than the Jacobina sequence, possibly Archean. Ledru et al. (1994, 1997) also describe an even more complex tectonic evolution in some formations of the greenstone belt (Bananeiras and Cruz das Almas) where early foliation is preserved. However, these authors do not support the existence of units of significantly different ages.

A surrounding migmatitic gneissic basement to the west of the Jacobina sequence has been dated at 3.4 Ga (Mougeot et al., 1995; Mougeot, 1996), in agreement with the age obtained for the early stages of continental crust formation in the Gavião block (Martin et al., 1991, 1997; Nutman and Cordani, 1993). Some Rb–Sr ages at 3.0 Ga, from the same gneissic basement, also support an Archean age, even if the systems were partially opened during Trans-Amazonian events (Couto et al., 1978; Mascarenhas and Garcia, 1989).

A Rb–Sr isochron age of 1.86 Ga was obtained by Melo (1991) for the metadacites from the Mundo Novo greenstone belt, which is interpreted as the crystallization age. However, because the Rb–Sr system in felsic volcanics is commonly reset and the age defined is in the same range or younger than the late granites, it may have been modified during Trans-Amazonian events, as was observed, for example, for the Contendas–Mirante felsic metavolcanics (Wilson, 1987; Marinho, 1991).

In the Jacobina group, Rb–Sr whole-rock ages of 2.5 and 2.7 Ga have been obtained for kyanite-bearing quartzites of the Serra do Corrego and phyllites of the Itapicuru complex (Mascarenhas, 1976). These isochron ages and the high initial ratios observed suggest an Archean protolith involved in the source of the sedimentary rocks. This interpretation is in agreement with the ages of detrital zircons from a conglomerate member of the Rio do Ouro Formation, in that 85% of the population is close to 3.4 Ga and the rest yields mainly 2.15 Ga (Mougeot et al., 1995). The youngest age obtained by Mougeot (1996) is 2086 ± 43 Ma. This result provides a good estimate for sedimentation of the Jacobina group between 2086 ± 43 and 1969 ± 29 Ma, the Rb–Sr age of the Campo Formoso granite that cuts the Jacobina group (Sabaté et al., 1990). The ^{40}Ar/^{39}Ar mica ages of 1.91 and 1.94 Ga are interpreted as minimum cooling ages of the major deformation observed in the Jacobina group (Ledru et al., 1997).

Ledru et al. (1997) interpret the Jacobina group, including the Mundo Novo greenstone belt, as a foreland basin developed during the Trans-Amazonian collision and corresponding to the overthrusting of the eastern Jequié-type granulitic terrain over the western lower-grade terrains. Mascarenhas and Silva (1994) interpret the Jacobina group as a graben related to rifting located around a greenstone belt of Archean or Paleoproterozoic age.

Three hypotheses may be forwarded about the age of the felsic volcanism of Mundo Novo. It may be related to crustal melting during Trans-Amazonian collisional processes and have an age close to 2.1 Ga, which is the hypothesis of a single-stage evolution of the Jacobina basin (Ledru et al., 1997). It may be related to an early stage of the Trans-Amazonian orogeny (rifting), with an age of ca. 2.2 Ga, as observed in the oldest volcanism of the Paleoproterozoic Rio Itapicuru greenstone belt farther east (Silva, 1992). Finally, it may be even older and related to Archean tectono-metamorphic evolution.

3. Methodology

U–Pb zircon analyses were made using SHRIMP I (Canberra ANU), and each analysis consisted of six scans through the mass range. The data have been reduced in a manner similar to that described by Williams (1998). The Pb/U ratios have been normalized relative to a value of 0.1859 for the ^{206}Pb/^{238}U ratio of the AS3 reference zircons, equivalent to an age of 1099 Ma (Paces and Miller, 1993). Uncertainties for individual analyses (ratios and ages) are at the one σ level, but the uncertainties in calculated weighted mean ages are reported as 95% confidence limits. Weighted mean ^{207}Pb/^{206}Pb ages were carried out using ISOPLOT/EX (Ludwig, 1999). ^{207}Pb/^{206}Pb zircon evaporation (Kober, 1986) TIMS analyses were performed on a Finnigan Mat 262 mass spectrometer at Géosciences Rennes—CNRS following classical procedures (Peucat et al., 1999). Replicate analyses for NBS 983 are as follows: $^{206}\text{Pb}/^{204}\text{Pb} = 2763 \pm 2$ and $^{207}\text{Pb}/^{206}\text{Pb} = 0.071247 \pm 3$. Nd and Sr analyses were performed in the Clermont Ferrand laboratory on a VG mass spectrometer using methods described by Martin et al. (1997). Nd model ages were calculated using ϵ_{Nd} values of +8 for the present-day depleted mantle and $^{147}\text{Sm}/^{144}\text{Nd} = 0.2137$, following a radiogenic linear growth for the mantle starting at 4.54 Ga, in agreement with Nägler and Kramers's (1998) model. For ^{207}Pb/^{206}Pb zircon evaporation ages, common lead for correction was assumed to have the composition calculated from the two-stage model of Stacey and Kramers (1975). Errors on ^{207}Pb/^{206}Pb ages are the weighted average at the 2σ level of ages and errors obtained on independent runs of 20 ratios, using the Isoplot programme of Ludwig (1999). Each grain was analyzed at different temperature steps (low, high, and very high) corresponding, respectively, to currents of 2.6, 3.0, and 3.3 A (approximatively to 1480, 1540, and 1610 ± 10 °C). All ages were calculated using the decay constants and isotopes abundances listed by Steiger and Jäger (1977).

4. Geochronological results

Sr and Nd whole-rock analyses were carried out on seven samples (Table 1). Zircon dating was performed by the evaporation method and SHRIMP (Tables 2 and 3) on felsic volcanites and on one enclosing gneiss by the evaporation method (Table 2).

Sample SSR 526A is a granodioritic gneiss from the Mairi complex (Fig. 2) located between the Mundo Novo greenstone belt and granulitic terrains of the Jequié block. It is contained within a TTG gneiss suite similar to that observed in the Gavião block. The Nd T_{DM} age of 3.21 Ga

Table 1
Sm–Nd and Rb–Sr isotopic data for whole-rocks

Samples	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	Error $\times 10^{-6}$	ϵ Nd_0 at: 0 Ga	T_{DM} ($\epsilon_0 = 8$) in Ga	ϵ Nd_0 at:			Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Error $\times 10^{-6}$	I_0Sr at:		
								3.3 Ga	3.1 Ga	2.1 Ga						3.3 Ga	3.1 Ga	2.1 Ga
Gneiss of the Mairi complex:																		
SSR 526A	2.16	15.0	0.0869	0.510357	11	−45	3.21	–	−2	–	92	350	0.761	0.736043	18	–	0.703	
Metadacites of the Mundo Novo greenstone belt:																		
SSR 600	10.0	49.3	0.1231	0.511044	7	−31	3.35	0	–	–	44	45	2.82	0.832663	15	0.698	–	–
SSR 533C	13.9	69.3	0.1216	0.510992	7	−32	3.38	0	–	–	123	18	19.8	1.716713	7	0.768	–	–
SSR 680C	9.70	48.0	0.1223	0.511005	11	−32	3.38	0	–	–	52	61	2.47	0.837013	14	0.719	–	–
Miguel Calmon granite:																		
SSR 53C	2.83	22.7	0.0753	0.509978	8	−52	3.36	–	–	−19	92	519	0.513	0.730017	13	–	–	0.714
Areia Branca orthogneiss:																		
SSR 43C	7.42	57.6	0.0780	0.510884	10	−34	2.42	–	–	−2	184	137	3.88	0.885286	8	–	–	0.768
Syenite:																		
SSR 85	16.4	130	0.0763	0.510560	6	−41	2.75	–	–	−8	193	1026	0.545	0.719618	19	–	–	0.703

Table 2
Summary of TIMS Pb evaporation zircon isotopic data

Samples	Step intensity in ampere	n ratios measured	$^{206}Pb/^{204}Pb$ measured	$^{207}Pb/^{206}Pb$ measured	Error 2 $\sigma m \times 10^{-4}$	$^{207}Pb/^{206}Pb$ corrected	$^{207}Pb/^{206}Pb$ age (Ma)	Weighted 2 σ error ± (in Ma)
Mairi gneiss (SSR 526 A)								
9 Euhedral gra	3.0	100[a]	1827	0.2318	5	0.2261	3025	22
	3.0	100	1890	0.2343	5	0.2288	3043	25
	3.3	40[a]	1922	0.2332	6	0.2278	3040	15
		240	1869	0.2331		Average:	3040	15
Metadacite (SSR 680 C)								
7 Euhedral gra	2.6	120	2920	0.2595	3.7	0.2558	3220	6
6 Euhedral gra	2.6	100	7498	0.2625	1.6	0.2611	3254	2

All runs have been recorded using an ion counting process.
[a] Low intensity run (<5000 counts on ^{206}Pb).

(Table 1) represents the maximum age of extraction of the protolith from the mantle, unless it results from mixing processes involving components of various ages. Zircon dating was performed by the evaporation method, but we were unsuccessful for single grains and had to use several grains during the lead ionization procedure. We obtained a range of $^{207}Pb/^{206}Pb$ ages between 3025 ± 22 and 3040 ± 15 Ma (Table 2). We interpret the zircon age of 3040 ± 15 Ma as the minimum age of crystallization, in accordance with the Nd evidence of an Archean protolith. This age is in agreement with the Rb–Sr whole-rocks ages of ca 3.0 Ga by Couto et al. (1978) and Mascarenhas and Garcia (1989). The negative ϵ_{Nd} ratio (−2) and high 87Sr/86SSr (0.703) (Table 1) at 3.04 Ga (zircon age) suggest either crustal reworking or an older age for crystallization of the granodioritic magmas.

Sample SSR 680C, typical of the felsic volcanic rocks of the Mundo Novo greenstone belt, is a porphyritic metadacite with a microporphyritic texture. Phenocrysts are ca. 1–2 mm in size and composed of round quartz, subeuhedral to slightly deformed plagioclase (fusiform structures), and altered green biotite. The quartzo-feldspatic (quartz, plagioclase, microcline) ground mass is fine grained and slightly foliated. Amygdals of quartz are also observed. The metadacitic samples SSR 600, SSR 533C, and SSR 680C have similar Nd signatures, thus yielding model ages of ca. 3.4 Ga (Table 1). The Sr isotope compositions calculated are heterogeneous and clearly disturbed, with values either lower than 0.700 or very high (up to 0.768). Zircon dating was performed on sample SSR 680C by the evaporation method and SHRIMP. Zircons are euhedral and of high-temperature type (S25-J5 of Pupin (1980)) without any evidence of inherited cores (Fig. 3). They are relatively large but have abundant gas vapor trails, which are diagnostic of rapid cooling. Whereas the cathodoluminescence shows simple magmatic zoning, the transmitted light photomicrographs show abundant cavities consistent with a volcanic to subvolcanic paragenesis. Here again, we used several grains to obtain a significant amount of radiogenic lead during the evaporation procedure. The first set of data provides a $^{207}Pb/^{206}Pb$ age of 3220 ± 6 Ma; another set yields 3254 ± 2 Ma. This result suggests an Archean age of the zircons, but the range of ages observed (30 Ma) suggests some further lead loss. The oldest age is interpreted as a minimum age for the magmatic crystallization. To define this age more precisely, we performed U–Pb dating by ion microprobe (SHRIMP). The data from the 17 analyzed grains are subconcordant in the Concordia diagram (Fig. 3) and define an average $^{207}Pb/^{206}Pb$ age of 3305 ± 9 Ma, which is the age of the felsic volcanic metadacite event. It is also similar to the Nd model ages obtained for the same rocks and suggests that felsic volcanism is related to a stage of accretion of juvenile continental crust.

Sample SSR 53C corresponds to the Miguel Calmon granite, which is a Paleoproterozoic pluton emplaced within the Archean Gavião basement and the Jacobina group on the western side of the greenstone belt (Fig. 2). The Nd model age of 3.36 Ga indicates that this granite is mainly derived from an Archean source, probably corresponding to the 3.4 Ga Gavião basement, which is also suggested by the high Sr (0.714, Table 1) initial ratio calculated at 2.10 Ga.

Sample SSR 43C corresponds to the Areia Branca orthogneiss. Its Nd model age of 2.42 Ga indicates a different source from the previous granite and suggests that the protolith may have resulted from the mixing between Archean and Proterozoic components. As such, it is a maximum age for the magmatic stage and probably related to the Trans-Amazonian orogeny at approximately 2.1 Ga. The Sr initial ratio at 2.1 Ga is very high (0.768, Table 1), which indicates the Rb–Sr system was disturbed.

Sample SSR 85 is a syenite that probably corresponds to the late Trans-Amazonian alkaline magmatism in the SFC that has been dated at 2004 ± 32 Ma (Conceição et al., 1997) and 2030 ± 6 Ma (Peucat et al., unpublished) by evaporation on zircons ($^{207}Pb/^{206}Pb$ ages) from the Itiüba batholith. Taking into account this age, the Nd isotopic system with a T_{DM} model age of 2.75 Ga and negative ϵ_{Nd} ratio at 2.03 Ga (−8) obtained for sample SSR 85 (Table 1) suggest an Archean component mixed with the alkaline Proterozoic source. The Sr initial ratio of 0.703 at 2.03 Ga

Table 3
Summary of SHRIMP U–Pb zircon results for sample SSR680c

Grain spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	$^{204}Pb/^{206}Pb$	f_{206} (%)	Radiogenic ratios						Ages (in Ma)						Conc (%)
							$^{206}Pb/^{238}U$	±	$^{207}Pb/^{235}U$	±	$^{207}Pb/^{206}Pb$	±	$^{206}Pb/^{238}U$	±	$^{207}Pb/^{235}U$	±	$^{207}Pb/^{206}Pb$	±	
1.1	112	62	0.55	35	0.000714	0.88	0.6789	0.0158	25.13	0.72	0.2684	0.0037	3340	61	3313	28	3297	22	101
2.1	119	72	0.61	37	0.001493	1.83	0.6645	0.0168	24.28	0.74	0.2650	0.0037	3285	66	3280	30	3277	22	100
3.1	158	88	0.56	47	0.001003	1.23	0.6497	0.0137	24.06	0.64	0.2686	0.0036	3227	54	3271	26	3298	21	98
4.1	112	54	0.48	34	0.002141	2.63	0.6806	0.0251	24.74	1.10	0.2636	0.0054	3347	97	3298	44	3268	33	102
5.1	154	98	0.64	47	0.000930	1.14	0.6556	0.0197	24.38	0.85	0.2697	0.0038	3250	77	3284	34	3304	22	98
6.1	158	103	0.65	49	0.001029	1.26	0.6596	0.0203	24.74	0.89	0.2721	0.0040	3266	79	3298	36	3318	23	98
7.1	104	42	0.40	28	0.001746	2.14	0.6002	0.0203	22.15	0.90	0.2676	0.0051	3031	82	3190	40	3292	30	92
8.1	166	113	0.68	53	0.001499	1.84	0.6811	0.0176	25.27	0.73	0.2690	0.0027	3349	68	3319	29	3300	16	102
9.1	128	66	0.52	38	0.001716	2.11	0.6664	0.0232	24.80	0.99	0.2699	0.0041	3292	90	3300	40	3305	24	100
10.1	84	38	0.45	24	0.002638	3.24	0.6328	0.0198	23.45	0.91	0.2688	0.0053	3161	78	3246	39	3299	31	96
11.1	164	99	0.60	49	0.001974	2.42	0.6501	0.0156	23.88	0.68	0.2664	0.0035	3229	61	3263	28	3285	20	98
12.1	115	61	0.53	35	0.002202	2.70	0.6523	0.0190	24.84	0.85	0.2761	0.0040	3237	75	3302	34	3341	23	97
13.1	166	110	0.66	51	0.000777	0.96	0.6600	0.0213	24.56	0.87	0.2699	0.0029	3267	83	3291	35	3306	17	99
14.1	141	71	0.51	44	0.001743	2.14	0.6814	0.0190	25.40	0.85	0.2704	0.0041	3350	73	3324	33	3308	24	101
15.1	129	81	0.63	41	0.000276	0.34	0.6858	0.0144	25.72	0.59	0.2720	0.0019	3367	55	3336	23	3318	11	102
16.1	76	34	0.45	24	0.000202	0.25	0.6929	0.0145	26.01	0.62	0.2722	0.0025	3394	56	3347	24	3319	14	102
17.1	116	72	0.62	37	0.000405	0.50	0.6935	0.0170	25.57	0.71	0.2675	0.0029	3396	65	3330	28	3291	17	103

Uncertainties given at the one σ level. f_{206}% denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the $^{204}Pb/^{206}Pb$ ratio. Conc. (100%) denotes a concordant analysis.

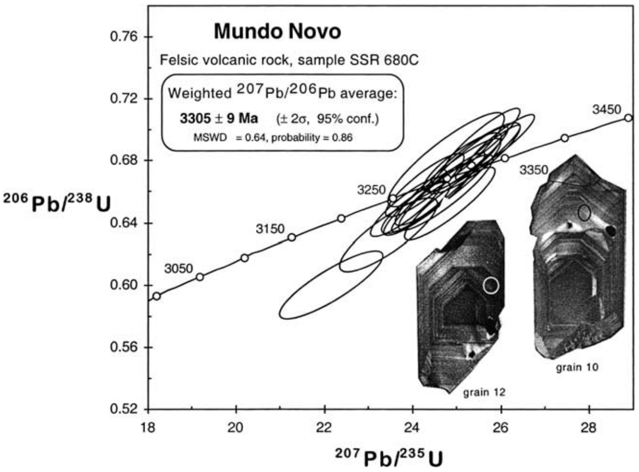

Fig. 3. U–Pb concordia plot of the SHRIMP ion probe data for the Mundo Novo felsic volcanic rock, sample SSR 680C, and cathodoluminescence images of two analyzed SHRIMP grains. Magmatic zoning and large development of the (101) pyramid are clear, as are the SHRIMP pits (30 μm in diameter).

(Table 1) would indicate a mantle-derived component of the syenitic magmatic stage. Alternatively, the syenite could be derived from a REE-enriched mantle source at 2.03 Ga with the T_{DM} Nd model age not significant, but the ϵ_{Nd} of (−8) is probably a stronger negative value at 2.03 Ga, in support of this hypothesis.

5. Discussion and conclusion

The U–Pb zircon SHRIMP age of 3305 ± 9 Ma obtained for the felsic metavolcanic rock of Mundo Novo greenstone belt is interpreted as recording a juvenile magmatic stage. This age probably defines the formation of the Mundo Novo greenstone belt and is assumed to be in the same range as the associated metabasalts, BIF, cherts, and other rocks. The economic gold deposit of the Jacobina basin is considered derived from the greenstone belt (Mascarenhas and Silva, 1994), and consequently, its source is Archean. To the east of the greenstone belt, a granodioritic gneiss belonging to the Mairi complex yields an Archean age that is slightly younger than the Mundo Novo felsic volcanism. These Mairi gneisses are similar in age to some gneisses of the Gavião block farther west (Santos Pinto et al., 1998). From a geochronological point of view, this establishes the existence of three major units in the Jacobina region: the 3.3 Ga greenstone belt, the 3.0–3.2 Ga eastern Mairi gneisses, and the 2.1 Ga Jacobina sedimentary basin.

The second set of conclusions pertains to similarities that can be established for the southern Contendas–Mirante belt (Fig. 1). This belt is made up of several units of different ages (Marinho, 1991; Marinho et al., 1994). The lower unit is very similar to the Mundo Novo greenstone belt, with basaltic and felsic metavolcanic rocks, metacherts, BIF, marble, calc-schists, and detrital metasediments. The felsic metavolcanics yield a U–Pb zircon age of 3304 ± 31 Ma and Nd crustal residence ages of 3.3–3.4 Ga (Marinho et al., 1994), in the range of the results obtained for the Mundo Novo metadacites. The upper unit is a detrital sedimentary formation (Areião Formation), mainly fluvio-deltaic, similar to the Paleoproterozoic Jacobina basin. A conglomerate from the upper unit (Nutman et al., 1994) has yielded detrital zircon ages at ca 2.7 Ga (Jequié type) and 2.15 Ga. The oldest inherited zircons differ from those found in the Jacobina sequence (Mougeot, 1996), which are mainly 3.4 Ga (Gavião type). This indicates that different Archean sources were involved in the ca. 2.1 Ga sedimentary basin, probably according to the proximity of the corresponding basements.

The last conclusion implies that the Paleoproterozoic basin follows the trend of ancient Archean greenstone belts over a distance of ca. 600 km. According to the model of Ledru et al. (1997), a flexure of the lithosphere would have occurred to the west of a thickened lithosphere during the Trans-Amazonian collision, leading to the development of foreland basins in which the Jacobina group and Areião Formation were accumulated. We postulate that this flexure was developed along a zone of weakness that corresponds to the occurrence of the Archean greenstone belts. These probably induced rheological contrasts in the continental crust at the eastern margin of the Gavião block. The zone of tectonic weakness would correspond with the so-called Contendas–Jacobina lineament of Sabaté et al. (1990, 1996), which would have reused an old Archean structure.

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