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AGE CONSTRAINTS FOR DEPOSITION AND SEDIMENTARY PROVENANCE OF ESPINHAÇO SUPERGROUP AND BAMBUÍ GROUP IN EASTERN SÃO FRANCISCO CRATON

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Abstract: The São Francisco Craton corresponds to an inner and stable portion of one of the plates involved in the assembly of Gondwanaland in late Neoproterozoic. To the east, the São Francisco Craton is limited by the Araçuaí-West Congo Orogen, which is composed, in its outer part, by the metasedimentary units of the Espinhaço Supergroup and Macaúbas Group. The cratonic adjacent area is mostly covered by the marine neoproterozoic units of the Bambuí Group, with few exposures of the Espinhaço Supergroup rocks. This paper aims to discuss the available geochronolgicl data and to present five new SHRIMP U-Pb dating on detrital zircons from rocks of the Bambuí Group and upper Espinhaço Supergroup at the eastern São Francisco Craton. The available dataset indicate that, within the São Francisco Craton, the upper portion of the Espinhaço Supergroup was deposited in the Pirapora Aulacogen through, in a period constrained between 1280 Ma (younger zircon population) and 933 Ma (age of the intrusive Pedro Lessa Mataigneous Suit). The cratonic basement highs (Sete Lagoas and Januária) seem to have been important source areas to the Mesoproterozoic units. The ages of the zircons found in the Serra de Santa Helena Formation suggest that its sediments may have come both from the Brasília Belt or the Araçuaí Orogen. On the other hand, zircons as young as 580 Ma, found in the Três Marias Formation sandstones indicate contribution from the Araçuaí Orogen. An important part of the sediment supply for the Espinhaço and Bambuí basins in the studied area could have come from older sedimentary units, as suggested by the great overlap in their detrital zircon age spectra. It demonstrates the remarkable polycyclic nature of the sedimentary processes who took place in the São Francisco Craton evolution

Keywords: Geochronology, São Francisco Craton, Pirapora Aulacogen, Bambuí Group, Espinhaço Supergroup

Resumo: PROVENIÊNCIA SEDIMENTAR E BALIZADORES DE IDADE DE DEPOSIÇÃO DAS ROCHAS DO SUPERGRUPO ESPINHAÇO E GRUPO BAMBUÍ NA PORÇÃO LESTE DO CRÁTON DO SÃO FRANCISCO. O Cráton do São Francisco corresponde à porção interna e estável de uma das placas envolvidas na aglutinação do supercontinente Gondwana, no fim do Neoproterozoico. Em sua borda leste o cráton é limitado pelo Orógeno Araçuaí-Congo Ocidental, que é composto, em sua porção externa, por rochas metassedimentares do Supergrupo Espinhaço e do Grupo Macaúbas. A área cratônica adjacente é, em grande parte, coberta por rochas do Grupo Bambuí, à exceção de grandes anticinórios, como o da Serra do Cabral, que exibem, em seu núcleo, rochas do Supergrupo Espinhaço. Este trabalho objetiva apresentar cinco novas datações U-Pb SHRIMP em zircões detríticos de rochas do Supergrupo Espinhaço e do Grupo Bambuí aflorantes na região da Serra do Cabral, integrando-as com os dados existentes. Em conjunto, os dados indicam que, na área cratônica, a porção superior do Supergrupo Espinhaço foi depositada entre 1280 Ma (população mais jovem de zircões detríticos) e 933 Ma (idade de rochas intrusivas básicas). Os altos de Sete Lagoas e Januária parecem ter atuado como importantes áreas-fonte para as unidades mesoproterozoicas. Os zircões encontrados em siltitos da Formação Serra de Santa Helena apresentam fontes possíveis na Faixa Brasília e no Orógeno Araçuaí, enquanto zircões com c.580 Ma, encontrados na Formação Três Marias, devem ter fonte exclusiva no Orógeno Araçuaí. Grande parte dos sedimentos que preencheram as bacias Espinhaço e Bambuí parece ter origem em unidades sedimentares mais antigas, como sugerido pela grande interseção entre seus espectros de idades de zircões detríticos, o que demonstra o notável caráter policíclico dos processos sedimentares.

Palavras-chave: Geocronologia, Cráton do São Francisco, Aulacógeno de Pirapora, Grupo Bambuí, Supergrupo Espinhaço

1. INTRODUCTION

The São Francisco Craton corresponds to an inner and stable portion of one of the plates involved in the assembly of Gondwanaland in late Neoproterozoic (Alkmim, 2004; Alkmim and Martins-Neto, 2012). To the west, the São Francisco Craton is limited by the Araçuaí-West Congo Orogen, which is composed, in its outer part, by the metasedimentary units of the Espinhaço Supergroup and Macaúbas Group. The cratonic adjacent area is mostly covered by the marine neoproterozoic units of the Bambuí Group.

Discussions concerning the depositional age and the geotectonic setting of the Bambuí Group have been constant in the last decades. Babinski *et al*. (2007) obtained a Pb-Pb isochronic age of 740 ± 22 Ma for limestones of the Sete Lagoas Formation, pointing to a cryogenian age. However, in this same formation, zircon populations of c. 610 Ma (Rodrigues, 2008, Pimentel *et al*. 2011) and 550 Ma (Paula-Santos *et al*. 2012, Pimentel *et al*. 2012), as well as the occurrence of *Cloudina sp.* (Warren *et al*. 2014) indicating that the basin history could be more complex than previously thought. The Bambuí Basin has been considered a foreland basin linked to the building of the Brasília Belt (c. 630 Ma, Pimentel *et al*. 2011), which should have constituted its main source area (Martins-Neto *et al*. 2001, Martins-Neto

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and Alkmim 2001, Coelho *et al*. 2008, Kuchenbecker *et al*. 2013). Compounding the tectonic scenario, the collisional stage of the Araçuaí-West Congo orogen (starting at c. 580 Ma, Pedrosa-Soares *et al*. 2007) brings up new potential sources for the basin. This contribution would be recorded only in the upper part of the group (Martins-Neto and Alkmim 2001).

The evolution of the Espinhaço Supergroup has been also matter of debate. Athough is consensual that the Espinhaço basin starts its development in c. 1.75 Ga (Dussin & Dussin 1995, Almeida-Abreu 1995, Knauer 2007) the historically proposed continuous sedimentation was questioned by Chemale Jr. *et al*. (2012): based on detrital zircon ages, the authors suggest a hiatus of c. 500 Ma within the supergroup. The uppermost part of the Espinhaço Supergroup (Conselheiro Mata Gr.) is represented by a shallow marine sequence (with rare dolomite lenses to the top), whose tectonic setting was also contested. Some have considered the unit as a record of a thermal SAG basin (e.g. Knauer 1999, Martins-Neto 1998, 2001), while others have proposed a foredeep context, related to west-vergent compressive tectonics (Almeida-Abreu *et al*. 2001).

In this controversial frame, studies focused on the dating of detrital zircons are becoming increasingly important, since the consolidation of a robust collection of data is crucial step to clarify these issues. With this in mind, this paper aims to discuss the available geochronolgical data and to present five new SHRIMP U-Pb dating on detrital zircons from rocks of the Bambuí Group and upper Espinhaço Supergroup at the eastern São Francisco Craton. The samples were collected in the context of the CPRM-UFMG mapping project, which mapped more than 21000km² in Minas Gerais during 2009/2010.

2. GEOTECTONIC SETTING

The São Francisco Craton (Almeida, 1977) and its african counterpart, the Congo Craton (Trompette, 1994), correspond to the stable parts of a Neoproterozoic palaeocontinent preserved from the Brasiliano-Pan African orogeny (Sial *et al*. 2009). In its southeastern limit, the Araçuaí-West Congo Orogen (AWCO, Fig. 1) represents a confined orogen evolved into an embayment (an inland-sea basin partially floored by oceanic crust) carved into the palaeocontinent (Pedrosa-Soares *et al*. 2001). At least three great aulacogens are recognized within the cratonic area, marking crustal unconformities which played an important role in the orogen evolution (Alkmim *et al*. 2006).

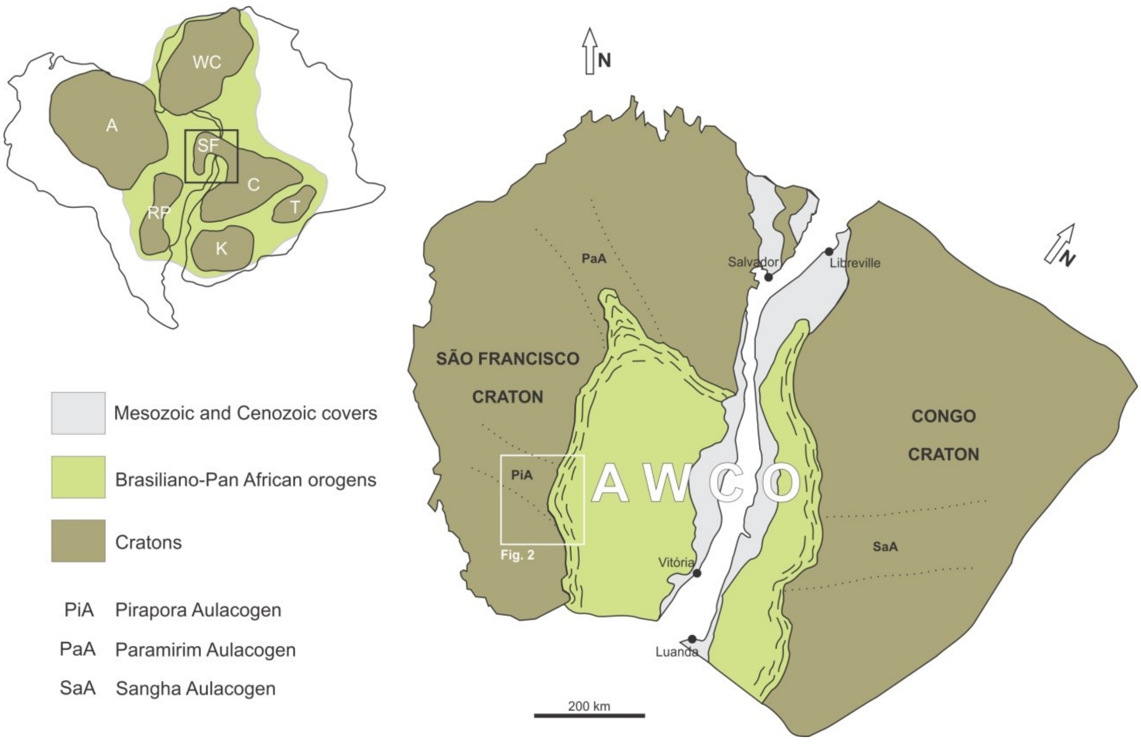

Figure 1. *Geotectonic setting of the São Francisco-Congo Craton and the Araçuaí West Congo Orogen, showing the positions of the aulacogens within the cratons. Based on Pedrosa-Soares et al. (2007).*

3. REGIONAL GEOLOGY

In the outer part of the AO, the Espinhaço Supergroup records the filling of a N–S-trending rift basin, with more than 2000 m thickness (Dussin and Dussin 1995). The rifting process is marked by bimodal magmatism, dated at c. 1.7 Ga (Machado *et al*. 1989, Silva *et al*. 2002, Chemale Jr. *et al*. 2012). The basal units – São João da Chapada and Sopa-Brumadinho formations – are composed by continental quartzites and metaconglomerates (mainly fluvial, fan-deltaic and lacustrine deposits), besides metaigneous hematitic phyllite (Schöll and Fogaça 1979). Both formations are deposited in rift stage, under mechanical subsidence (Martins-Neto 1998). Recently, Chemale Jr. *et al* (2012) report zircons as young as c.1.2 Ga in the Sopa-Brumadinho Formation metaconglomerates, suggesting that most of the supergroup can be substantially younger.The Galho do Miguel Formation is a thick layer of pure quartzite deposited under aeolian influence, which records a quiet tectonic period, and the beginning of thermal subsidence (Martins-Neto 1998). In this phase, marine invasion is recorded in the Conselheiro Mata Group, the topmost unit of Espinhaço Supergroup. The Conselheiro Mata Group includes five formations: Santa Rita (metasiltstone), Córrego dos Borges (quartzite), Córrego da Bandeira (metasiltstone), Córrego Pereira (quartzite) and Rio Pardo Grande (metasiltstone, metadolomite). Both Galho do Miguel Formation and Conselheiro Mata Group occur within the São Francisco Craton, cropping out in anticline cores at the Cabral, Agua Fria and Bicudo ridges (Fig. 2).

The Bambuí Group covers a large part of the SFC domain, and records a foreland basin related to the development of the orogenic Brasília Belt (Martins-Neto *et al.* 2001, Martins-Neto, 2009, Coelho *et al.* 2008). The basin includes basal diamictite-bearing units (Jequitaí and Carrancas formations), deposited under glacial influence (Rocha-Campos & Hasui 1981, Kuchenbecker 2011). The overlain Bambuí Group represents a thick marine pelite-carbonate succession, arranged in three shallowing upward cycles. The group comprises five main units: (i) Sete Lagoas Formation, composed by limestones and dolomites (with local interbeded pelites), whose basal portion is interpreted as a cap carbonate (Vieira *et al* 2007, Babinski *et al*. 2007, Kuchenbecker 2011, Caxito *et al*. 2012, Paula-Santos *et al*. 2015); (ii) Serra de Santa Helena Formation, composed by shales and siltstones with rare interbeded limestones; (iii) Lagoa do Jacaré Formation, that shows reworked and oolitic limestones with pelitic layers; (iv) Serra da Saudade Formation, composed by siltstones an interbeded sandstones, with rares limestone lenses; and (v) Três Marias Formation, composed by arenites, arcoses and siltstones, with local occurrence of conglomerate, only in the east border of the basin.

In its west border, the AO is structured by N-trending folds and thrusts. The main structural array of southern Serra do Espinhaço is controlled by regional thrusts/ductile inverse shear zones, invariably W-vergent (Knauer 2007, Knauer and Ebert 1997, Rolim 1992). To these features are associated a regional N-axis folding system and several mesoscopic structures, such as a regional tectonic foliation, stretching lineation, crenulation cleavage, among others.

The trace of a major emergent thrust delineates the western edge of the AO (Alkmim *et al*. 2006). Along such structure, the Espinhaço Supergroup and Macaúbas Group rocks thrust upon the Bambuí Group rocks, and the deformation propagates inside the cratonic cover for a few kilometers. In the interaction zone between the deformational front and the Pirapora Aulacogen, the cratonic border is marked by the virtual lack of regional thrust zones, and the rocks shows only gentle folds (Fig. 2). Within the aulacogen through, such system is represented by regional sized bivergent folds like the Buenópilos sincline and the Cabral and Bicudo anticlines. Seismic profiles indicated that in depth these folds are related to blind faults that affected the cristaline basement (Reis *et al*. 2012, Hercos *et al*. 2008).

As well as the deformation, metamorphic grade decreases westward within the AO, ranging from granulite facies in the orogenic core, to low-grade metamorphic conditions at its borders.

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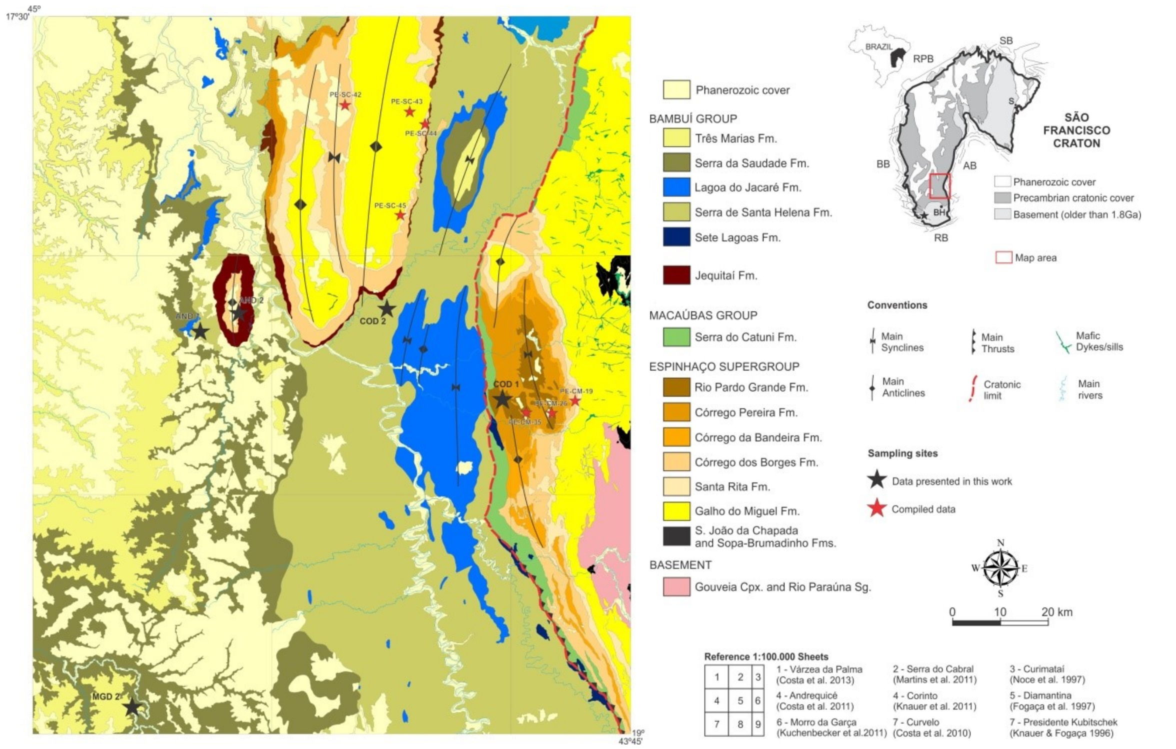

Figure 2. *Simplified geological map from the studied area (see location in the Fig. 1), compiled from the official 1:100.000 sheet maps. Note that the main thrust zone which marks the cratonic limit in the south gives place to a regional fold system to the north, in interaction zone between the orogenic front and the Pirapora Aulacogen through.*

4. AVAILABLE DATA

Seven U-Pb analyses in detrital zircons are available in the literature for the study area, and its results were compiled to improve the interpretation of our new data (Table 1). A brief description of these data is given below.

4.1. Galho do Miguel Formation

Two quartzite samples from Galho do Miguel Formation at the eastern flank of the Cabral ridge was analyzed by Lopes (2012). The samples show very similar main age peaks in 2000-2240 Ma. However, the sample PE-SC-45, collected to the south, has also an important peak in c. 2640-2760 Ma, while the sample PE-SC-43, collected to the north, shows a peak in c. 1500-1700 Ma. This difference was interpreted by the author as the record of distinct sources providing sediments for different parts of the basin. The youngest grain reported has c. 1350 Ma, interpreted as the maximum depositional age of the Galho do Miguel Formation at the Cabral ridge.

4.2. Santa Rita Formation

A quartzite from Santa Rita Formation (sample PE-SC-44) was also collected in the eastern flank of Cabral ridge and analyzed by Lopes (2012). Thirty-five zircons yielded ages ranging from 1480 to 3320 Ma, with main age peaks at c. 1750 Ma, 2100 Ma, 2270 Ma and 2680 Ma, which was interpreted as the ages of the main sources of sediments.

4.3. Córrego dos Borges Fm.

Chemale Jr. *et al*. (2012) report analysis from a quartzite from this unit (sample PE-CM-19), collected in the western border of the Espinhaço ridge (locally known as Mineira ridge). The ages range between 1400 Ma and 3200 Ma, with main peaks at 2080-2240 Ma and 1420-1560 Ma, and secondary peaks at 1720-1800 Ma and 1940-1980 Ma. The youngest zircon was dated at 1395 ± 30 Ma, interpreted as the maximum depositional age of the unit.

Lopes (2012) presents analysis from a quartzite from Córrego dos Borges Formation (sample PE-SC-42) collected in the central portion of the Cabral ridge. The zircons yielded ages ranging 1480-3120 Ma and main peaks at 1750-1800 Ma, 2070-2170 Ma and 2620-2730 Ma. The author remarks the input of the c.1750 Ma zircons on the basin, not reported by the subjacent units. The youngest zircon was dated at c. 1500 Ma.

4.3. Córrego Pereira Formation

Eighty zircon grains recovered from a quartzite of Córrego Pereira Formation (sample PE-CM-26) were dated by Chemale Jr. *et al*. (2012). The ages range between 1300 Ma and 2200 Ma, with a large main peak at 1900-2025 Ma and a secondary peak at 1780-1850 Ma. The youngest zircon was dated at 1329 ± 20.

Table 1. *Summary of the available geochronological data from the Espinhaço Supergroup and Bambuí Group in the study area*

Sample	*Unit*	*Rock*	*nº of grains*	*Range (Ma)*	*Main Peaks (Ma)*	*Younger grain (Ma)*	*Reference*
PE-CM-35	Rio Pardo Grande Fm.	Quartzite	61	1500-2900	1920-2020 (62%)	1514 ± 12	Chemale Jr. *et al*. 2012
PE-CM-26	Córrego Pereira Fm.	Quartzite	80	1300 - 2200	1780-1850 (28%)	1329 ± 20	Chemale Jr. *et al*. 2012
					1900-2025 (67%)		
PE-SC-42	Córrego dos Borges Fm.	Quartzite	69	1480-3120	1750-1800 (29%)	c.1500	Lopes 2012
					2070-2170 (23%)		
					2620-2730 (10%)		
PE-CM-19	Córrego dos Borges Fm.	Quartzite	69	1400-3200	1420-1560 (24%)	1395 ± 30	Chemale Jr. *et al*. 2012
					1720-1800 (15%)		
					1940-1980 (10%)		
					2080-2240 (28%)		
PE-SC-44	Santa Rita Fm.	Quartzite	35	1480-3320	1650-1800 (14%)	1487 ± 40	Lopes 2012
					2040-2300 (40%)		
					2480-2680 (20%)		
PE-SC-43	Galho do Miguel Fm.	Quartzite	74	1550-2950	1500-1700 (18%)	c. 1550	Lopes 2012
					2000-2240 (65%)		
PE-SC-45	Galho do Miguel Fm.	Quartzite	90	1350-3350	2000-2240 (50%)	c.1350	Lopes 2012
					2640-2760 (27%)		

4.4. Rio Pardo Grande Formation

A quartzite (sample PE-SC-35) from Rio Pardo Grande Formation was analyzed by Chemale Jr. *et al*. (2012). Sixty one grains were dated, and yielded ages between 1500 and 2900 Ma, with a large predominant peak at 1920-2020 Ma. The youngest zircon showed an age of 1514 ± 12 Ma.

5. NEW U-PB DATA

5.1. Analitical Procedures

Heavy mineral concentrates were obtained by standard techniques, and zircon grains were hand-picked under a binocular loupe. Zircon grains were mounted in a 2,5cm diameter epoxy disk with standard RSES zircon crystals and sectioned approximately in half. The mount surface was then polished to expose the grain interiors and photographed to obtain cathodo–luminescence (CL) images. One spot was analyzed within each grain, preferably in its rim, and only the analyses that are less than 10% discordant were considered in discussions.

The U–Pb isotopic analyses were performed by using Sensitive High Resolution Ion Microprobe (SHRIMP) equipment of Australian National University according to its conventional routines. Analytical methods and data treatment followed those described by Williams (1998) and Williams & Meyer (1998). Temora (417 Ma; Black *et al*., 2003) standard zircon was used in SHRIMP analytical routines, and data reduction used the SQUID software (Ludwig, 2001), according to the procedures described in Chemale *et al* (2012). The histograms were obtained with the software Isoplot/Ex (Ludwig, 2003).

5.2. Results

Espinhaço Supergroup - Conselheiro Mata Group

Quartzite from Córrego dos Borges Fm. (AND 2 - coordinates 545739^E / 7996784^N)

Located west of the Cabral Range, the Bicudo Range is a north-axis brachyanticline that exposes the Espinhaço Supergroup rocks in its core. The Córrego dos Borges Formation is there represented by a pale, fine- to medium-grained quartzite, often with plane-parallel stratification and riplle marks (Fig. 3A). The sample yielded small zircons, in general rounded and dirty looking. The U-Pb age spectrum obtained in 23 detrital zircon grains range between 1190 and 2125 Ma (Table 2), mainly concentrated in intervals at 1.20-1.35 Ga (19%), 1.5-1.6 Ga (24%), 1.6-1.7 Ga (26%), 1.9-2.1 (19%, Figure 4). A single zircon grain showed an age of 1190±25 Ma, and three grains define the youngest age population at c.1280 Ma, interpreted as the maximum depositional age of the Córrego dos Borges Formation quartzites.

Quartzite from Córrego Pereira Fm. (COD 1 - coordinates 604211^E / 7976060^N)

The sample was collected in the unpaved road that connects Rodeador to Conselheiro Mata. The rock is a grayish fine quartzite, showing rhythmic plane-parallel lamination marked by Fe_2O_3, dipping 30-40° west (Fig. 3B). The rock yielded a lot of subhedral zircon grains, in dirty short prisms. The 33 detrital zircon grains analyzed yielded U–Pb ages ranging from 1150 to 2450 Ma (Table 3), but most of them fall into three age intervals of 1.20-1.30 Ga (18%), 1.35-1.45 Ga (18%) and 1.8-2.0 Ga (30%), suggesting that those were the ages of the most important sources of the sediments (Fig.4). The youngest zircon showed an age of 1150±19 Ma, and the youngest population fits at c.1230 Ma, which could be considered the maximum depositional age of the Córrego Pereira Formation metapelites.

Bambuí Group

Siltstone from Serra de Santa Helena Fm. (AND 1 - coordinates 537147^{E} / 7991897 ^{N} and COD 2 - coordinates 578184^{E} / 7997538^{N})

Two samples from Serra de Santa Helena Formation were collected at the study area: AND 1 is a brownish siltstone, collected west of the Bicudo ridge. The rock shows an outstanding plane-parallel lamination, and displays large amount of detrital mica. Gentle folds indicate weak deformation, consistent with that observed in the Bicudo Anticline (Fig. 3C). The zircons separated from this sample are very small and dirty looking, in subhedral to euhedral short prisms. The 47 zircons grains recovered from this sample yielded U-Pb ages ranging from 620 to 2830 Ma (Table 4), defining a largely predominant peak at 630-670 Ma and secondary peaks at 0.7-0.9 Ga, 1.0-1.2 Ga, 1.8-2.0 Ga and 2.6-2.8 Ga (Fig. 4). The youngest zircon showed an ^{206}Pb/^{238}U age of 622±7 Ma, which is interpreted as the maximum depositional age of this unit.

Sample COD 2 represents a pinkish silty mudstone, collected at the BR135 highway, near Augusto de Lima city. The rock also displays plane-parallel lamination and a large amount of detrital mica. Because of its fine grain size, only 12 zircon grains could be recovered from this sample, all dirty looking and sub-rounded. The zircon grains yielded U–Pb ages ranging from 630 to 2850 Ma (Table 5), showing main peaks at c. 630 Ma e c. 2840 Ma.

Since the results obtained for the two Serra de Santa Helena Formation samples are quite similar, they are plotted together in the diagram (Fig 4.).

Sandstone from Três Marias Fm. (MGD 2 - coordinates 522780^{E} / 7904756^{N})

This sandstone was collected near the Paraopeba River, in the region of Retiro Baixo hydroelectric plant. The rock is a stratified silty sandstone (Fig. 3D), with decimetric layers of fine to medium sandstone, usually with a short amount of feldspar grains. The zircon grains separated from this sample were small, subhedral to euhedral (short prisms) or rounded. Forty-four zircons from this sample were dated and the ages range between 575 and 1920 Ma (Table 6), distributed in a largely predominant peak at c. 650 Ma and secondary peaks at c. 900 Ma, 1500 Ma and 1900 Ma (Fig. 4). The youngest zircon showed an ^{206}Pb/^{238}U age of 575±9 Ma, and we assume it as the maximum depositional age of the unit in this area.

***Table 2.** U-Pb SHRIMP data from detrital zircons of sample AND 2 (Córrego dos Borges Fm.) **Notes:** See Table 5*

Grain Spot	U (ppm)	Th (ppm)	Th/U	^{206}Pb* (ppm)	^{206}Pb^{c} %	Isotope ratios							Age (Ma)						Disc. %	Age (Ma)	±
						^{207}Pb*/^{235}U	± (%)	^{206}Pb*/^{238}U	± (%)	r	^{207}Pb*/^{206}Pb*	± (%)	^{206}Pb/^{238}U	±	^{207}Pb/^{235}U	±	^{207}Pb/^{206}Pb	±			
2,1	250	190	0,78	61,39	0,111	4,175	2,86	0,285	2,02	0,70	0,106	2,03	1618	29	1669	48	1733	37	7	1629	53
3,1	200	236	1,22	51,21	0,185	4,391	3,02	0,297	2,50	0,83	0,107	1,69	1677	37	1711	52	1752	31	4	1721	24
6,1	214	131	0,63	56,30	0,000	4,422	2,50	0,306	1,99	0,80	0,105	1,51	1722	30	1716	43	1709	28	-1	1715	20
8,1	153	198	1,33	45,73	0,000	5,957	3,64	0,347	3,33	0,91	0,124	1,47	1921	55	1970	72	2021	26	5	2004	23
9,1	94	35	0,38	21,25	0,000	3,534	4,28	0,262	2,97	0,69	0,098	3,09	1500	40	1535	66	1583	58	5	1526	33
11,1	246	120	0,51	72,20	0,178	6,150	3,78	0,341	3,39	0,90	0,131	1,67	1892	56	1997	76	2108	29	10	2108	58
12,1	116	54	0,48	28,92	0,000	4,220	3,18	0,290	2,36	0,74	0,106	2,14	1641	34	1678	53	1724	39	5	1676	26
14,1	336	129	0,40	81,19	0,000	3,776	2,16	0,281	1,81	0,84	0,097	1,17	1596	26	1588	34	1576	22	-1	1585	17
15,1	223	120	0,56	68,57	0,098	6,518	2,14	0,358	1,86	0,87	0,132	1,06	1973	32	2048	44	2125	18	7	2125	37
17,1	189	122	0,67	46,71	0,317	4,218	2,72	0,287	1,92	0,71	0,107	1,93	1625	28	1678	46	1744	35	7	1668	22
18,1	90	71	0,82	26,67	0,000	5,242	3,04	0,346	2,59	0,85	0,110	1,60	1914	43	1859	57	1799	29	-6	1836	24
20,1	114	43	0,39	19,94	0,759	2,262	4,24	0,202	2,50	0,59	0,081	3,43	1184	27	1200	51	1230	67	4	1190	25
24,1	262	210	0,83	85,55	0,096	6,569	2,21	0,379	1,96	0,88	0,126	1,03	2073	35	2055	45	2037	18	-2	2045	16
25,1	393	228	0,60	86,32	0,225	3,313	2,71	0,255	2,32	0,86	0,094	1,39	1464	30	1484	40	1513	26	3	1492	20
30,1	277	46	0,17	51,99	0,512	2,509	4,47	0,217	3,24	0,73	0,084	3,08	1266	37	1275	57	1288	60	2	1272	32
33,1	117	103	0,91	29,41	0,000	4,165	3,01	0,293	2,35	0,78	0,103	1,89	1656	34	1667	50	1681	35	1	1668	25
36,1	196	178	0,94	54,61	0,000	4,919	2,71	0,325	2,33	0,86	0,110	1,37	1814	37	1805	49	1795	25	-1	1801	21
37,1	190	96	0,52	40,64	0,323	3,135	2,79	0,249	1,99	0,71	0,091	1,96	1431	25	1441	40	1456	37	2	1439	31
38,1	441	292	0,68	85,22	0,149	2,818	3,28	0,225	2,84	0,87	0,091	1,64	1306	34	1360	45	1446	31	10	1381	23
40,1	115	57	0,51	26,24	0,000	3,561	3,50	0,266	2,64	0,75	0,097	2,30	1519	36	1541	54	1571	43	3	1540	28
41,1	33	32	1,01	8,75	0,000	4,980	4,90	0,308	3,43	0,70	0,117	3,50	1729	52	1816	89	1917	63	10	1800	42
44,1	115	36	0,33	34,21	0,000	5,736	2,78	0,346	2,22	0,80	0,120	1,68	1915	37	1937	54	1960	30	2	1942	23
46,1	206	120	0,60	38,17	0,324	2,539	3,03	0,215	1,91	0,63	0,086	2,35	1255	22	1190	36	1331	45	6	1268	20

Table 3. *U-Pb SHRIMP data from detrital zircons of sample COD 1 (Córrego Pereira Fm.)* ***Notes:*** *See Table 5.*

Grain Spot	U (ppm)	Th (ppm)	Th/U	$^{206}Pb^*$ (ppm)	$^{206}Pb^c$ %	Isotope ratios							Age (Ma)						Disc. %	Age (Ma)	±
						$^{207}Pb^*/^{235}U$	± (%)	$^{206}Pb^*/^{238}U$	± (%)	r	$^{207}Pb^*/^{206}Pb^*$	± (%)	$^{206}Pb/^{238}U$	±	$^{207}Pb/^{235}U$	±	$^{207}Pb/^{206}Pb$	±			
1,1	147	32	0,23	29,13	0,000	2,803	3,06	0,231	2,00	0,65	0,088	2,32	1342	24	1356	42	1379	45	3	1350	21
5,1	265	140	0,54	66,36	0,000	3,990	2,19	0,291	1,65	0,75	0,099	1,43	1646	24	1632	36	1614	27	-2	1632	18
7,1	347	267	0,79	77,85	0,281	3,483	2,70	0,261	1,57	0,58	0,097	2,19	1493	21	1523	41	1566	41	5	1507	19
10,1	64	30	0,48	12,20	0,680	2,679	7,95	0,221	3,98	0,50	0,088	6,88	1289	46	1323	105	1378	132	6	1297	44
11,1	78	44	0,59	26,13	0,000	6,755	3,33	0,392	2,36	0,71	0,125	2,34	2133	43	2080	69	2028	42	-5	2078	30
12,1	360	149	0,43	90,23	0,000	4,043	2,13	0,292	1,58	0,74	0,100	1,43	1651	23	1643	35	1632	27	-1	1643	17
13,1	130	107	0,86	39,03	0,000	5,624	2,86	0,351	1,89	0,66	0,116	2,15	1937	32	1920	55	1901	39	-2	1923	24
14,1	119	76	0,66	39,45	0,000	6,883	2,74	0,386	2,10	0,77	0,129	1,76	2102	38	2096	57	2091	31	-1	2095	24
17,1	370	296	0,83	67,81	0,000	2,443	2,23	0,213	1,58	0,71	0,083	1,57	1247	18	1255	28	1270	31	2	1252	16
19,1	83	126	1,56	32,59	0,000	10,123	4,64	0,455	4,34	0,94	0,161	1,64	2418	87	2446	113	2470	28	2	2465	26
20,1	226	72	0,33	45,18	0,152	2,810	2,92	0,232	1,84	0,63	0,088	2,27	1347	22	2446	72	1377	44	2	1353	20
21,1	322	138	0,44	103,37	0,122	6,732	4,48	0,374	2,67	0,60	0,131	3,60	2047	47	2077	93	2107	63	3	2067	38
22,1	219	156	0,74	60,25	0,000	4,712	1,86	0,321	1,65	0,88	0,107	0,87	1793	26	1769	33	1742	16	-3	1756	14
23,1	185	45	0,25	39,62	0,482	3,134	2,76	0,248	1,77	0,64	0,092	2,11	1427	23	1441	40	1461	40	2	1435	20
24,1	158	107	0,70	49,85	0,000	6,022	2,42	0,366	1,91	0,79	0,119	1,48	2012	33	1979	48	1945	27	-3	1971	21
25,1	422	250	0,61	75,10	0,810	2,358	2,78	0,205	1,66	0,60	0,083	2,23	1204	18	1230	34	1276	44	6	1214	17
26,1	222	177	0,83	58,36	0,201	4,090	2,55	0,306	1,78	0,70	0,097	1,82	1720	27	1652	42	1568	34	-9	1568	67
27,1	151	38	0,26	33,11	0,000	3,157	2,35	0,255	1,83	0,78	0,090	1,47	1464	24	1447	34	1422	28	-3	1446	18
28,1	190	170	0,93	56,12	0,096	5,475	2,37	0,344	1,93	0,81	0,115	1,38	1906	32	1897	45	1887	25	-1	1894	20
29,1	68	65	1,00	17,38	0,000	4,639	2,93	0,298	2,22	0,76	0,113	1,91	1684	33	1756	51	1844	35	10	1844	68
32,1	249	105	0,44	68,70	0,585	5,328	2,29	0,319	1,69	0,74	0,121	1,54	1787	26	1873	43	1970	27	10	1970	54
36,1	269	110	0,42	57,75	0,345	3,092	2,40	0,249	1,75	0,73	0,090	1,64	1435	23	1431	34	1425	31	-1	1431	18
40,1	188	140	0,77	31,64	0,235	2,099	2,85	0,196	1,99	0,70	0,078	2,03	1152	21	1148	33	1142	40	-1	1150	19
43,1	222	130	0,60	56,30	0,134	4,504	2,12	0,295	1,77	0,83	0,111	1,17	1665	26	1732	37	1813	21	9	1813	42
44,1	273	154	0,58	51,73	0,336	2,552	2,53	0,220	1,75	0,69	0,084	1,83	1280	20	1287	33	1299	36	1	1285	18
46,1	134	132	1,01	39,48	0,069	5,411	2,62	0,341	1,89	0,72	0,115	1,81	1894	31	1887	49	1879	33	-1	1887	22
47,1	272	154	0,58	62,07	0,200	3,389	2,51	0,265	1,71	0,68	0,093	1,84	1515	23	1502	38	1484	35	-2	1505	19
49,1	115	88	0,79	33,12	0,168	5,266	2,51	0,335	1,95	0,78	0,114	1,57	1860	32	1863	47	1867	28	0	1864	21
50,1	239	94	0,41	43,17	0,380	2,334	2,99	0,209	1,75	0,59	0,081	2,42	1224	20	1223	37	1219	48	0	1224	18
51,1	175	140	0,82	33,04	0,196	2,663	2,53	0,219	1,84	0,73	0,088	1,73	1276	21	1318	33	1388	33	9	1388	65
56,1	211	74	0,36	38,17	0,398	2,339	3,88	0,209	1,87	0,48	0,081	3,40	1225	21	1224	48	1222	67	0	1225	20
64,1	96	81	0,87	27,73	0,000	5,085	2,56	0,336	2,04	0,80	0,110	1,54	1865	33	1834	47	1798	28	-4	1826	21
66,1	89	52	0,60	26,02	0,108	5,446	2,64	0,341	2,06	0,78	0,116	1,65	1892	34	1892	50	1893	30	0	1892	22

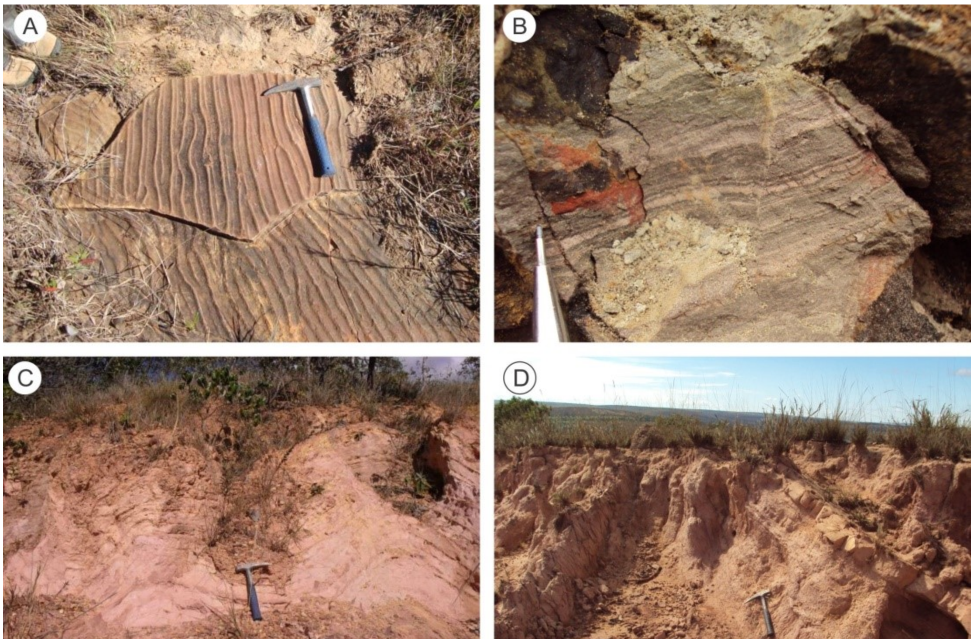

Figure 3. *Field aspects of the studied units. (A) Córrego dos Borges quartzite, showing pronounced ripple marks; (B) Quartzite from Córrego Pereira Formation, with lamination marked by iron oxides; (C) Laminated siltstone from Serra de Santa Helena formation, with metric sized gentle folds; (D) Stratified silty sandstone from the Três Marias Formation, showing a decimetric layer of pure sandstone.*

Table 4. *U-Pb SHRIMP data from detrital zircons of sample AND 1 (Serra de Santa Helena Fm.). -* ***Notes:*** *See Table 5.*

Spot	U (ppm)	Th (ppm)	Th/U	^{206}Pb* (ppm)	^{206}Pbc %	Isotope ratios							Age (Ma)						Disc. %	Age (Ma)	±
						^{207}Pb*/^{235}U	± (%)	^{206}Pb*/^{238}U	± (%)	r	^{207}Pb*/^{206}Pb*	± (%)	^{206}Pb/^{238}U	±	^{207}Pb/^{235}U	±	^{207}Pb/^{206}Pb	±			
1,1	68	169	2,56	13,6	0,591	2,709	3,45	0,231	1,62	0,53	0,085	3,04	1337	20	1331	46	1320	59	-1	1336	19
2,1	331	200	0,62	51,3	0,085	1,830	1,63	0,180	1,18	0,28	0,074	1,13	1069	12	1056	17	1029	23	-4	1062	9
3,1	505	598	1,22	46,7	0,898	0,900	2,82	0,107	1,14	0,60	0,061	2,58	653	7	652	18	648	55	-1	653	7
4,1	822	245	0,31	77,0	1,537	0,930	4,85	0,107	3,98	0,18	0,063	2,77	658	25	668	32	703	59	6	663	19
5,1	637	335	0,54	60,3	0,970	0,925	4,46	0,109	1,13	0,75	0,061	4,31	668	7	665	30	655	93	-2	669	6
6,1	472	277	0,61	41,2	0,432	0,855	2,15	0,101	1,15	0,47	0,061	1,82	622	7	627	13	648	39	4	623	7
8,1	664	444	0,69	58,7	0,105	0,860	1,50	0,103	1,15	0,24	0,061	0,97	631	7	630	9	626	21	-1	631	6
9,1	515	14	0,03	50,7	0,000	0,988	1,52	0,115	1,14	0,25	0,063	1,00	699	8	698	11	693	21	-1	699	6
11,1	297	298	1,04	44,7	0,000	1,781	1,55	0,175	1,19	0,23	0,074	0,99	1040	11	1039	16	1037	20	0	1039	8
12,1	222	199	0,93	24,3	1,149	1,144	5,80	0,126	1,58	0,73	0,066	5,58	765	11	775	45	802	117	5	763	10
15,1	54	59	1,13	5,3	0,112	0,982	3,93	0,114	1,89	0,52	0,062	3,45	697	12	694	27	686	74	-2	697	12
16,1	158	119	0,78	14,3	0,000	0,877	2,45	0,105	1,46	0,41	0,060	1,97	646	9	639	16	615	43	-5	644	8
17,1	93	67	0,75	13,8	0,000	1,753	2,36	0,173	1,52	0,36	0,074	1,80	1027	14	1028	24	1030	36	0	1028	12
20,1	249	121	0,50	22,0	0,177	0,841	2,32	0,102	1,24	0,47	0,060	1,96	628	7	620	14	591	43	-6	626	7
21,1	623	185	0,31	274,4	0,197	14,178	1,19	0,512	1,13	0,05	0,201	0,37	2666	25	2762	33	2833	6	6	2833	52
22,1	195	107	0,57	32,4	0,160	2,130	2,06	0,193	1,35	0,34	0,080	1,55	1137	14	1159	24	1200	31	5	1147	12
26,1	322	177	0,57	31,2	0,158	0,952	2,05	0,113	1,22	0,40	0,061	1,65	688	8	679	14	652	35	-5	685	7
27,1	665	619	0,96	60,9	0,050	0,896	1,47	0,107	1,11	0,24	0,061	0,95	653	7	650	10	637	20	-3	652	6
28,1	102	106	1,08	12,2	0,000	1,300	2,69	0,140	1,56	0,42	0,067	2,18	843	12	846	23	853	45	1	844	11
29,1	189	72	0,39	63,5	0,110	7,157	1,48	0,392	1,28	0,13	0,133	0,73	2130	23	2131	31	2133	13	0	2031	12
30,1	342	246	0,74	99,4	0,497	5,894	1,49	0,337	1,22	0,18	0,127	0,85	1871	20	1960	29	2057	15	9	2057	61
32,1	191	50	0,27	23,2	0,000	1,322	2,12	0,141	1,35	0,36	0,068	1,63	853	11	855	18	861	34	1	854	9
33,1	127	96	0,78	11,4	1,046	0,856	6,23	0,103	1,54	0,75	0,060	6,04	634	9	628	39	607	131	-4	635	8
34,1	217	263	1,25	20,2	0,255	0,917	3,23	0,108	1,34	0,59	0,062	2,94	660	8	661	21	663	63	1	660	8
35,1	676	553	0,85	248,7	0,460	9,819	1,23	0,427	1,10	0,11	0,167	0,56	2290	21	2418	30	2527	9	9	2527	52
36,1	200	240	1,24	25,4	0,178	1,410	1,90	0,147	1,29	0,32	0,069	1,39	886	11	893	17	910	29	3	889	9
37,1	46	52	1,19	13,6	0,326	5,527	2,70	0,346	1,92	0,29	0,116	1,90	1913	32	1905	51	1895	34	-1	1907	21
38,1	586	230	0,41	84,2	0,787	1,746	2,06	0,166	1,17	0,43	0,076	1,70	990	11	1026	21	1104	34	10	1104	74
39,1	525	301	0,59	49,7	0,096	0,939	1,65	0,110	1,21	0,27	0,062	1,12	673	8	672	11	670	24	0	673	6
40,1	255	279	1,13	39,0	0,000	1,825	1,66	0,178	1,24	0,25	0,074	1,10	1055	12	1054	18	1054	22	0	1055	9
41,1	584	263	0,46	54,7	0,071	0,936	1,56	0,109	1,13	0,27	0,062	1,07	666	7	671	10	688	23	3	668	6
42,1	163	62	0,39	14,9	0,105	0,897	2,50	0,106	1,38	0,45	0,061	2,08	651	9	650	16	645	45	-1	651	8
43,1	154	158	1,06	44,7	0,181	5,293	1,71	0,337	1,41	0,18	0,114	0,97	1874	23	1868	32	1861	17	-1	1869	13
45,1	166	154	0,96	46,3	0,153	4,939	1,67	0,324	1,39	0,17	0,110	0,93	1811	22	1809	30	1807	17	0	1809	13
47,1	100	193	2,00	18,5	0,897	2,395	3,87	0,214	1,60	0,59	0,081	3,52	1251	18	1241	48	1223	69	-2	1251	18
49,1	90	101	1,16	15,8	0,309	2,205	2,79	0,204	1,59	0,43	0,078	2,29	1198	17	1183	33	1154	45	-4	1192	15
50,1	192	312	1,67	49,0	0,089	4,655	1,58	0,296	1,28	0,19	0,114	0,93	1671	19	1759	28	1865	17	10	1865	65

Table 5. *U-Pb SHRIMP data from detrital zircons of sample COD 2 (Serra de Santa Helena Fm.)*

Spot	U (ppm)	Th (ppm)	Th/U	^{206}Pb* (ppm)	^{206}Pbc %	Isotope ratios							Age (Ma)						Disc. %	Age (Ma)	±
						^{207}Pb*/^{235}U	± (%)	^{206}Pb*/^{238}U	± (%)	r	^{207}Pb*/^{206}Pb*	± (%)	^{206}Pb/^{238}U	±	^{207}Pb/^{235}U	±	^{207}Pb/^{206}Pb	±			
2,1	246	299	1,25	117,78	0,170	15,474	1,22	0,556	1,16	0,95	0,202	0,39	2850	27	2845	35	2842	6	0	2842	7
3,1	443	200	0,47	58,85	0,535	1,453	1,93	0,154	1,12	0,58	0,069	1,57	921	10	911	18	887	33	-4	918	9
4,1	561	50	0,09	165,53	0,411	5,656	1,20	0,342	1,08	0,90	0,120	0,53	1896	18	1925	23	1956	9	3	1956	19
7,1	178	78	0,45	58,36	0,274	6,819	1,41	0,380	1,21	0,86	0,130	0,72	2075	21	2088	29	2101	13	1	2094	11
8,1	2672	2384	0,92	236,03	0,124	0,875	1,23	0,103	1,04	0,84	0,062	0,66	630	6	638	8	667	14	6	667	28
9,1	1322	812	0,63	116,19	0,115	0,860	1,26	0,102	1,05	0,83	0,061	0,69	627	6	630	8	640	15	2	629	6
11,1	178	60	0,35	19,41	0,498	1,130	2,91	0,126	1,30	0,45	0,065	2,60	767	9	768	22	769	55	0	768	9
13,1	103	62	0,63	45,54	0,145	13,020	1,53	0,515	1,39	0,91	0,183	0,63	2677	31	2681	41	2684	10	0	2683	10
14,1	149	111	0,77	27,44	0,152	2,340	1,91	0,213	1,26	0,66	0,080	1,44	1247	14	1225	23	1185	28	-5	1185	56

Notes (for all data)*: Errors are 1-sigma (1σ); Pbc and Pb* indicate the common and radiogenic portions, respectively.*
Error in Standard calibration was 0.50 and 0.36% (not included in above errors).
(1) Common Pb corrected using measured 204Pb.
Isotopic ratios errors in %.
All Pb in ratios are radiogenic component. Most are corrected for 204Pb and some for 208Pb (metamorphic, Th-poor grains or rims).
disc. = discordance, as 100−100{t[206Pb/238U]/ t[207Pb/206Pb]}.
Uncertainties are 1σ.

Table 6. *U-Pb SHRIMP data from detrital zircons of sample MGD 2 (Três Marias Fm.)* ***Notes:*** *See Table 5.*

Spot	U (ppm)	Th (ppm)	Th/U	^{206}Pb* (ppm)	^{206}Pbc %	Isotope ratios							Age (Ma)						Disc. %	Age (Ma)	±
						^{207}Pb*/^{235}U	± (%)	^{206}Pb*/^{238}U	± (%)	r	^{207}Pb*/^{206}Pb*	± (%)	^{206}Pb/^{238}U	±	^{207}Pb/^{235}U	±	^{207}Pb/^{206}Pb	±			
1,1	50	401	8,37	14,52	0,108	5,446	2,64	0,341	2,06	0,78	0,116	1,65	1892	34	1892	50	1893	30	0	1892	44
3,1	497	298	0,62	66,05	0,017	1,447	3,00	0,155	1,88	0,63	0,068	2,34	928	16	909	27	862	48	-8	921	30
4,1	90	54	0,63	10,25	0,922	1,224	10,08	0,132	2,44	0,24	0,067	9,78	798	18	812	82	849	203	6	798	36
5,1	78	60	0,79	10,74	0,000	1,577	3,77	0,160	2,25	0,60	0,071	3,03	958	20	961	36	970	62	1	959	38
6,1	383	196	0,53	60,91	0,472	1,886	3,03	0,184	1,72	0,57	0,074	2,49	1090	17	1076	33	1048	50	-4	1086	32
7,1	328	336	1,06	34,88	0,220	1,105	3,50	0,124	1,82	0,52	0,065	2,98	752	13	756	26	768	63	2	752	26
8,1	1025	1332	1,34	82,47	0,362	0,763	2,46	0,093	1,55	0,63	0,059	1,91	575	9	576	14	579	42	1	575	17
9,1	607	162	0,28	68,65	0,434	1,167	3,63	0,131	1,80	0,50	0,065	3,15	794	13	785	28	760	66	-4	793	26
11,1	468	128	0,28	117,24	0,000	3,969	2,09	0,292	1,77	0,84	0,099	1,12	1651	26	1628	34	1599	21	-3	1620	33
12,1	123	134	1,13	35,83	0,482	5,680	3,04	0,339	2,05	0,68	0,122	2,24	1881	33	1928	59	1980	40	5	1920	52
13,1	1711	474	0,29	155,02	0,064	0,892	1,79	0,105	1,54	0,86	0,061	0,91	646	9	648	12	653	20	1	647	17
14,1	283	180	0,66	85,26	0,895	5,549	2,81	0,347	1,77	0,63	0,116	2,18	1922	29	1908	54	1893	39	-2	1912	47
15,1	3126	1092	0,36	293,56	0,230	0,923	1,76	0,109	1,50	0,85	0,061	0,93	667	9	664	12	652	20	-2	664	17
18,1	347	159	0,47	31,20	0,327	0,868	2,88	0,104	1,76	0,61	0,060	2,28	639	11	634	18	618	49	-3	638	21
20,1	567	581	1,06	62,07	0,283	1,141	2,65	0,127	1,66	0,63	0,065	2,07	771	12	773	20	778	43	1	771	23
21,1	476	880	1,91	61,22	0,391	1,458	2,87	0,149	1,64	0,57	0,071	2,36	896	14	913	26	956	48	6	900	27
22,1	602	553	0,95	48,44	0,000	0,768	2,25	0,094	1,62	0,72	0,059	1,57	577	9	579	13	585	34	1	578	17
23,1	666	321	0,50	63,22	0,092	0,926	2,40	0,110	1,69	0,71	0,061	1,70	675	11	666	16	633	37	-7	672	21
24,1	512	417	0,84	46,36	0,328	0,875	3,05	0,105	1,66	0,55	0,060	2,56	644	10	638	19	617	55	-4	643	20
25,1	190	116	0,63	28,75	0,000	1,788	2,67	0,176	1,88	0,70	0,074	1,90	1044	18	1041	28	1035	38	-1	1043	33
28,1	207	60	0,30	34,41	0,000	2,034	1,73	0,193	1,26	0,73	0,076	1,18	1140	13	1127	19	1102	24	-3	1131	23
29,1	250	144	0,60	22,76	0,462	0,912	2,48	0,106	1,21	0,49	0,063	2,17	647	7	658	16	696	46	7	648	15
30,1	404	188	0,48	48,73	0,396	1,260	2,25	0,140	1,15	0,51	0,065	1,93	844	9	828	19	785	41	-8	841	18
31,1	473	491	1,07	127,22	0,769	4,988	1,36	0,311	1,10	0,81	0,116	0,80	1743	17	1817	25	1903	14	8	1903	29
33,1	319	475	1,54	29,21	0,172	0,905	1,91	0,106	1,16	0,61	0,062	1,52	652	7	654	13	663	33	2	652	14
35,1	72	44	0,63	6,45	0,241	0,891	3,42	0,104	1,71	0,50	0,062	2,97	636	10	647	22	687	63	7	637	20
36,1	299	78	0,27	41,02	0,045	1,599	1,54	0,159	1,19	0,78	0,073	0,97	954	11	970	15	1006	20	5	1006	39
38,1	3032	1745	0,59	297,70	0,506	0,967	1,33	0,114	1,04	0,78	0,062	0,83	694	7	687	0	663	18	-5	690	13
40,1	311	122	0,40	63,77	0,057	3,112	1,29	0,238	1,13	0,88	0,095	0,61	1378	14	1436	18	1522	12	9	1522	23
41,1	588	315	0,55	79,40	0,667	1,451	1,87	0,156	1,10	0,59	0,067	1,52	935	10	910	17	850	31	-10	850	62
42,1	411	216	0,54	54,72	0,094	1,483	1,45	0,155	1,11	0,77	0,069	0,93	928	10	924	13	912	19	-2	925	17

6. DISCUSSIONS

6.1. Espinhaço Supergroup

The occurrence of Espinhaço Supergroup rocks within the cratonic area is related to a branch of the Espinhaço rift system, named Pirapora Aulacogen (Alkmim & Martins-Neto 2001, Alkmim 2004, Alkmim 2011). The identification of such structure is supported by (i) low values of Bouguer anomaly, showing a NW-trending valley crossing the whole craton (Reis 2011); (ii) remarkable thickening of the paleo/mesoproterozoic units, showed by regional seismic profiles (Coelho *et al*. 2008, Zalán & Romeiro-Silva 2007, Hercos *et al*. 2008); (iii) recently reported transversal seismic profiles showing a deep depression controlled by large scale normal faults (Reis *et al*. 2013).

The Pirapora Aulacogen is limited by two basement highs, named Januária (NE) and Sete Lagoas (SW), which are remarkable features in the Bouger Anomaly maps (Reis 2011). These structures may have exerted a major control in the filling of the basin, and possibly have acted as source-areas for the sediments. The Sete Lagoas High crops out in the southernmost portion of the São Francisco Craton, showing Archean TTG complexes and greenstonebelt sequences, and Palaeproterozoic granitoids and metasedimentary sequences (Romano *et al*. 2013, Teixeira *et al*. 2000, Alkmim 2004). In turn, the Januária High only crops out near to the homonymous city, showing a few exposures of ortogneisses, granites and diorites (Almeida and Uchigasaki 2003, Radambrasil 1982). There is no geochronological constraint for these rocks but a Rb-Sr age of c. 1970 Ma reported in Radambrasil (1982). Nevertheless, an Archean age is considered in the Geological Map of Minas Gerais (COMIG, 2003).

Through paleocurrent measurements and petrographic analysis on the Espinhaço Supergroup units, Lopes (2012) proposed a high-K source-area located northeast of the Cabral ridge. This source-area could have fed the Espinhaço basin at the Pirapora rift branch, but probably fed also the main rift, since the same zircon populations are found at the Mineira ridge. Thus, the zircons older than 1800 Ga, found in both Galho do Miguel Formation and Conselheiro Mata Group, may have come from the basement of the São Francisco Craton at the Januária High, which would be exposed as a topographic high at the time of deposition. It is also considered that other topographic highs with archean/paleoproterozoic rocks could be contributed with sediments (e.g. Sete Lagoas High). For the main rift, at the Espinhaço range, some other basement highs would have acted as source areas (e.g. Porteirinha Block).

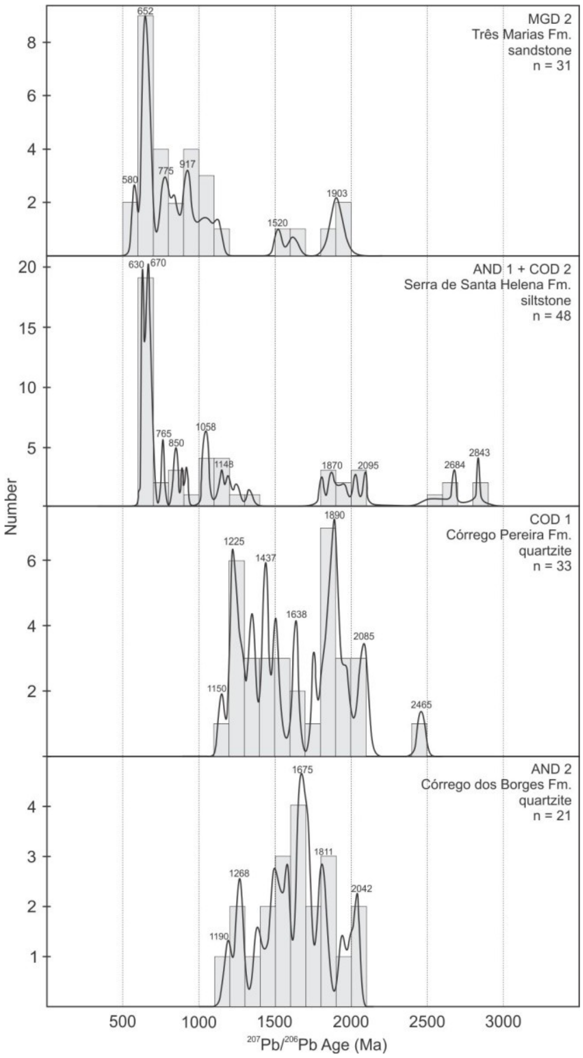

Figure 4. *Frequency histogram and probability curves of zircon ages for the analyzed samples.*

The zircon populations found in samples of the Galho do Miguel Formation vary substantially. In the Cabral ridge (Lopes 2012) as well as in the southern Espinhaço ridge (Chemale Jr. *et al*. 2012), the main population is c. 2000-2200 Ma. In southern Cabral ridge, there is a rise in the Archean contribution, as recorded by a significant peak of c. 2700 Ma (PE-SC-45, Lopes 2012). To the north of the Cabral ridge, the archean contribution decreases considerably, and arises a new and important population of c. 1600 Ma. This pattern suggests some differences in the source-area composition, which could be closely related with the litological differences between the Sete Lagoas and Januária highs.

As pointed out by Kuchenbecker (2014), the sedimentary processes which took place in the evolution of the São Francisco Craton show a remarkable polycyclic nature. In this sense, should be considered that an important part of the sediment supply of the Espinhaço Basin may have come from older sedimentary sequences. The Costa Sena Group (Fogaça *et al*. 1984, Machado *et al*. 1989), the Riacho dos Machados Group (Crocco *et al*. 2006) and the Limoeiro Complex (Penha and Sabóia 1995, Knauer 2007), which occur in the Espinhaço ridge, the Minas and Rio das Velhas supergroups, which occur within the craton, are strong candidates. This possibility is illustrated by the great overlap in the detrital zircon age spectra from all those units (Fig. 5).

At Mineira ridge, the archean contribution in the Conselheiro Mata Group seems to be more expressive in the more basal units, decreasing to the top. This relation suggests changes in the source areas during the basin filling, possibly related to the drowning of the basement highs. In fact, rocks correlated to the upper Espinhaço units directly covering the basement highs have been found in several places, in drillcores (Reis *et al*. 2013) and outcrops (Costa *et al*. 2015), indicating that this unit has covered a wide portion of the craton. This assumption is also confirmed by seismic interpretation (e.g. Reis *et al*. 2013).

The zircon population of c.1750 Ma, found at the study area in samples from Córrego dos Borges, Córrego Pereira and Galho do Miguel formations may come from the Statherian magmatism related to the opening of the Espinhaço Basin, as previously proposed by Lopes (2012). However, the large gap between this magmatic event and the deposition of the Conselheiro Mata Group units, constrained here in c. 1200 Ma, brings up a complex scenario. If the deposition of the Espinhaço Supergroup took place in a continuous evolution (as proposed in some works, e.g. Dussin & Dussin 1995, Martins-Neto 2009, Knauer 2007), at 1200 Ma the such magmatic rocks should be buried under a significant sediment pile, and unlikely would be available to generate sediment. On the other hand, if the Espinhaço Supergroup has evolved in a discontinuous basis, with a significant hiatus between its units (as proposed by some authors, e.g. Chemale Jr. *et al*. 2012, Alkmim and Martins-Neto 2011), the question could be answered by the erosional phase between the two Espinhaço 1st order sequences.

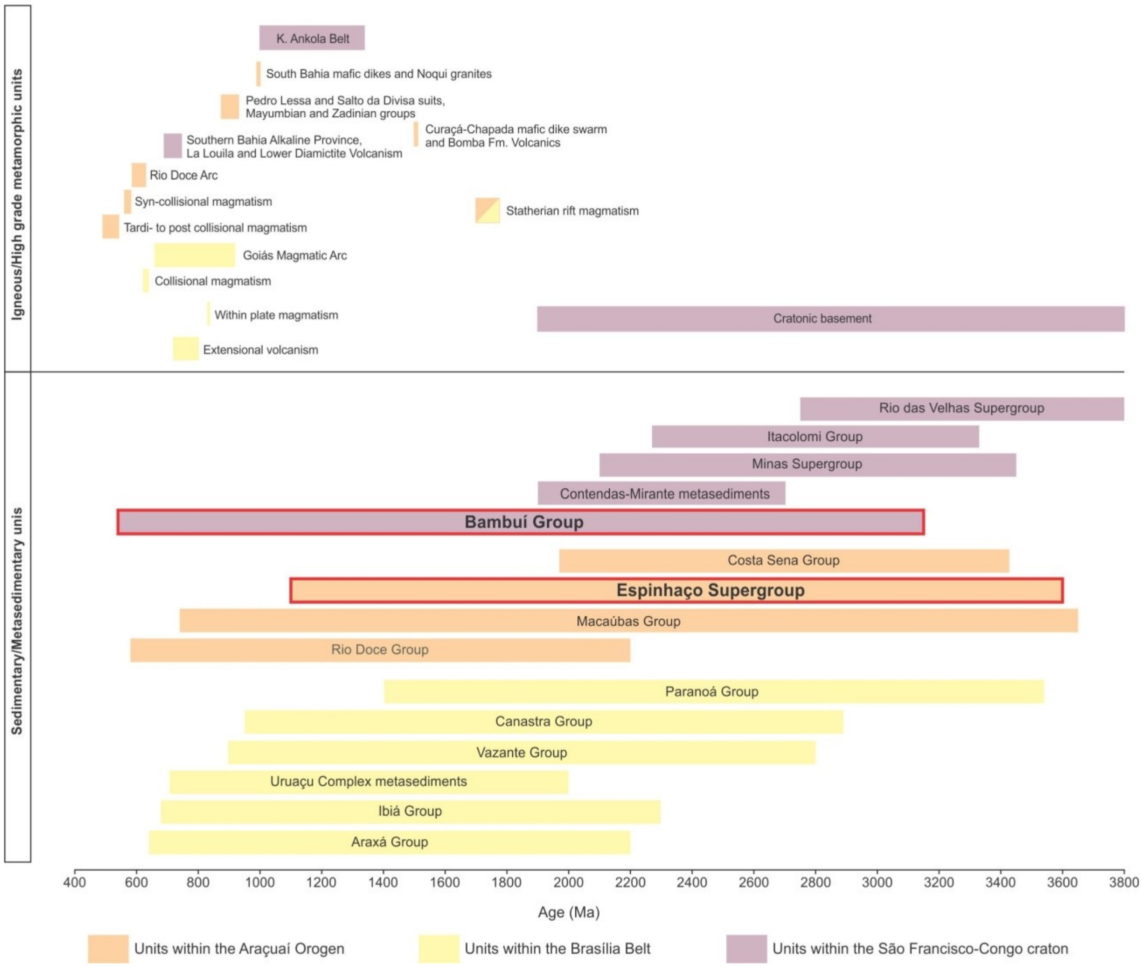

Figure 5. *Provenance sketch illustrating the time spam (for igneous and high grade metamorphic rocks) and detrital zircon ages range (for sedimentary and metasedimentary rocks) of several units in the context of the São Francisco Craton. The studied units are highlighted in red. Source: Kuchenbecker (2014) and references therein.*

The new data constrain considerably the depositional age of the Conselheiro Mata Group. The zircons aging c. 1200 Ma, recovered from Córrego dos Borges and Córrego Pereira formations are the youngest zircons reported by the units and could represent its maximum depositional age. However, the small amount of zircons with such ages requires a more conservative interpretation. The mean age of the youngest representative population of the Córrego dos Borges Formation is 1282 ± 24 Ma, and we assume it as the maximum depositional age of the formation and units above it. Since the whole Conselheiro Mata Group is intruded by mafic dykes of the Pedro Lessa Metaigneous Suíte dated in 933±20 Ma (Dussin and Chemale, 2012), the deposition of the group at the study area is constrained between c. 1280 Ma and 933 Ma.

6.2. Bambuí Group

The geotectonic framework concerning the origin and evolution of Bambuí Basin is very complex, since it lies between two orogenic belts with diachronic evolutionary histories. The link between the early stages of the Bambuí Basin and the uplift of the Brasília Belt is now almost consensual. Evidences of such relation lies on (i) the geometry of the deposits, which define an estward-tapering wedge, ranging from c. 3km thick near to the Brasília Belt to a few hundred meters close to the Araçuaí Orogen, as indicated by regional seismic profiles and borehole data (Reis *et al*. 2013, Romeiro-Silva, 1997); (ii) low values of Bouguer anomaly adjacent and parallel to the Brasília belt, defining a N-trending fosse (Reis 2011, Alkmim 2004); (iii) the tectonic imbrication between older rocks from the Brasília belt and locally-derived rocks from the Bambuí Group (Valeriano 1992, Castro 1997, Martins-Neto *et al*. 2001); (iv) the regional distribution of depositional systems, including conglomeratic units deposited by gravitational flows fed by the Brasília belt orogenic front (Samburá and Lagoa Formosa formations - Uhlein *et al*. 2011, Castro e Dardenne 2000); (v) provenance studies indicating source-areas in the Brasília Belt (Kuchenbecker *et al*. 2013, Castro and Dardenne 2000, Guimarães and Dardenne 1998).

The relation of the Bambuí Basin with the Araçuaí Orogen is not so clear. The Bambuí Group rocks are affected by the regional deformation related to the collisional stages of the orogen (c.

580-530 Ma, Pedrosa Soares *et al*. 2007). If the Araçuaí uplift occurred concurrent to sedimentation, the crustal load and the availability of new source-areas to the east may have greatly influenced the basing filling. According to Martins-Neto and Alkmim (2001), only the topmost units of the Bambuí Group received sediments from the Araçuaí Orogen, which is corroborated by the occurrence of transitional to continental deposits at the eastern border of the basin, related to its clogging stage (Gorutuba Fm. – Kuchenbecker 2014, Costa 2011, Iglesias and Uhlein 2008, Chiavegatto *et al*. 1997). However, the presence of zircons as young as 550 Ma (Paula-Santos *et al*. 2015, Pimentel *et al*. 2012), as well as the Ediacaran guide fossil *Cloudina sp.* (Warren *et al*. 2014), both found in the Sete Lagoas Formation, suggest that the entire Bambuí Group could have received sediment from the Araçuaí Orogen.

The analyses performed in the Serra de Santa Helena Formation are the first ones reported to the eastern portion of the Bambuí Basin. The zircons aging c. 630 Ma are among the youngest ones reported by the formation throughout the basin, and this is interpreted as its maximum depositional age at the study area. Potential source rocks with this age occur in both Araçuaí Orogen and Brasília Belt. In the Araçuaí Orogen, the Rio Doce magmatic arc presents plutonic rocks from 630 Ma to 585 Ma (Pedrosa-Soares *et al*. 2007), while in the Brasília Belt arc magmatism (Pimentel *et al*. 1999), collisional magmatism (Seer and Moraes 2013) and metamorphism are recognized in c. 630 Ma. Due to the pelagic nature of the Serra de Santa Helena Formation rocks, is difficult to decide between these two possible sources from paleocurrent measurements.

For the older age clusters observed in the Serra de Santa Helena Formation (760-900 Ma, 1000 – 1200Ma, 1800-2100 Ma and 2600-2800 Ma) should be considered the potential primary and secondary sources. In both Brasília Belt and Araçuaí Orogen thare are several sedimentary units which contain zircons of the same age of those found in the Bambuí Group (Fig. 5). In this sense, the Canastra, Araxá and Paranoá Groups, from the Brasília Belt side, and the Macaúbas Group and the Espinhaço Supergroup, in the Araçuaí Orogen, are strong candidates.

Primary Archean sources are available in the Brasília Belt (Goiás Massif and other basement inliers) and in the Araçuaí Orogen (Gouveia, Porteirinha and Guanhães complexes), but also in the São Francisco Craton basement. Since the Bambuí Group lies directly on the cristaline basement in several places, it seems to be plausible to assume that the basement highs (Sete Lagoas and Januária) have acted again as source areas. They may have been reactivated by positive epirogeny, in response to the litospheric load of Brasília Belt, to the west, setting the forebulge of the Bambuí foreland basin.

The results obtained for the Três Marias Formation sandstone could contribute to understand the Bambuí Basin evolution in the studied area. The zircons with ages older than 630 Ma have potential source areas in both Brasília Belt and Araçuaí Orogen, as discussed above. However, the presence of zircons as young as 580 Ma is very relevant, and strongly suggests that the Araçuaí Orogen had contributed as a source area. Rocks with this age are widespread distributed in the Araçuaí Orogen, mainly related to magmatism in the syn-collisional stage (Fig. 5).

7. CONCLUSIONS

The U-Pb results here presented were interpreted together with the available data, in order to contribute to the age constraints for deposition and sedimentary provenance study of the Espinhaço Supergroup and Bambuí Group within the São Francisco Craton and its borders. The analysis of all data allows us to list some conclusions:

I. An important part of the sediment supply for the Espinhaço and Bambuí basins in the studied area could have come from older sedimentary units, as suggested by the great overlap in their detrital zircon age spectra. It demonstrates the remarkable polycyclic nature of the sedimentary processes who took place in the São Francisco Craton evolution;

II. The cratonic basement highs (Sete Lagoas and Januária) seem to have been important source areas to the Mesoproterozoic units of the upper Espinhaço Supergroup, feeding the Pirapora Aulacogen. Lithologic differences between the two highs are recorded in the adjoining sedimentary deposits within the aulacogen. Such structures may have also acted as topographic highs during the deposition of the Bambuí Group, after being reactivated by positive epirogeny, in response to the litospheric load of Brasília Belt;

III. Within the São Francisco Craton and at the Mineira ridge, the deposition of the Conselheiro Mata Group could be constrained between 1280 Ma (younger zircon population) and 933 Ma (age of intrusive basic rocks);

IV. The age spectrum of the Serra de Santa Helena Formation zircons suggests that its sediments may have come both from the Brasília Belt and the Araçuaí Belt. On the other hand, zircons as young as 580 Ma, found in the Três Marias

Formation sandstones suggest contribution from the Araçuaí Orogen.

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