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T. Giovanardi*, V. A. V. Girardi, C. T. Correia, S. Sinigoi, C. C. G. Tassinari, and M. Mazzucchelli

U-Pb zircon SHRIMP data from the Cana Brava layered complex: new constraints for the mafic-ultramafic intrusions of Northern Goiás, Brazil

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Abstract: The Cana Brava Complex is the northernmost and least well known layered intrusion of a discontinuous belt of mafic-ultramafic massifs within the Brasilia Belt, which also comprises the Niquelândia and Barro Alto complexes. Available geochronological data from a range of techniques (K/Ar, Ar/Ar, Rb/Sr, Sm/Nd and U/Pb) provide a range of possible ages (time span from 3.9 Ga to 450 Ma), hence a precise and reliable age for the Cana Brava Complex is still lacking. Also, preliminary isotopic and geochemical data of the Cana Brava Complex suggest a significant crustal contamination, which could have affected bulk-rock Sr and Nd systematics resulting in meaningless age determinations. In this paper, we present new U-Pb SHRIMP zircon analyses from four samples of different units of the Cana Brava Complex which suggest that the intrusion occurred during the Neoproterozoic, between 800 and 780 Ma, i.e. at the same age of Niquelândia. Discordant older $^{206}Pb/^{238}U$ ages are provided by inherited zircons, and match the age of the metamorphism of the embedding Palmeirópolis Sequence.

Keywords: Cana Brava; Layered Complex; Geochemistry; Zircon; SHRIMP

***Corresponding Author: T. Giovanardi:** Instituto de Geociências Universidade de São Paulo, Rua do Lago 563, Cidade Universitária, 05508-900 São Paulo, Brazil; Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio, Emilia, Largo S. Eufemia 19, 41121 Modena, Italy E-mail: tommaso.giovanardi@gmail.com

V. A. V. Girardi, C. T. Correia: Instituto de Geociências Universidade de São Paulo, Rua do Lago 563, Cidade Universitária, 05508-900 São Paulo, Brazil

S. Sinigoi: Dipartimento di Geoscienze, Università degli Studi di Trieste, Via E.Weiss 8, 34128 Trieste Italy

1 Introduction

The Cana Brava mafic-ultramafic complex is the northernmost layered intrusion of a discontinuous, belt of mafic-ultramafic massifs which also comprises the Barro Alto Complex in the south and the Niquelândia Complex in the central sector. The mafic-ultramafic belt is oriented North-South, about 300 km long, and considered part of the cental-eastern Brasilia Belt [1, 2]. It is included by Pimentel et al. [3] in the Maciço Mediano de Goiás (i.e. the Goiás Massif).

The Niquelândia mafic-ultramafic complex is relatively well-known [4–10], whereas the others two complexes of the Brasilia Belt (i.e. Cana Brava and Barro Alto) are still poorly studied. Correia et al. [9, 10] and Rivalenti et al. [5] demonstrated that the Niquelândia Complex underwent a strong crustal contamination by a metasedimentary component, which affected the whole rock geochronological data obtained by Rb/Sr, Sm/Nd and K/Ar isotopic systematics (see [11], for the treatment and the significance of whole rock geochronological data in cases of open system: e.g. crustal contamination). Hence, age estimates provided by whole rock Rb/Sr, Sm/Nd, Ar/Ar and K/Ar analyses [1, 2, 12, 13] as well a whole rock + plagioclase + biotite + pyroxene Sm/Nd internal isochrons [2] should be largely disregarded. Correia et al. [2], on the basis of Rb/Sr and Sm/Nd isotope geochemistry, suggested that the Cana Brava Complex underwent extensive crustal contamination, similarly to the Niquelândia Complex.

In this paper, we present new SHRIMP U-Pb zircon analysis with the aim of providing new constraints on the Cana

C. C. G. Tassinari: Instituto de Geociências Universidade de São Paulo, Rua do Lago 563, Cidade Universitária, 05508-900 São Paulo, Brazil

M. Mazzucchelli: Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio, Emilia, Largo S. Eufemia 19, 41121 Modena, Italy

Brava intrusion age, as recently done for the Niquelândia Complex, by Correia et al. [10].

2 Geological setting

The Cana Brava Complex (Figure 1) is about 40 km long and 14 km wide (the widest portion located in the south). The Cana Brava Complex main strike is 10°-20° NNE and dip 30° to 50° NW [14]. The base of the complex is located in the east and the top to the west. The Cana Brava Complex is overthrust to the east on the metasedimentary rocks of the Serra da Mesa Group, while, in the west, it is in magmatic contact with the metasedimentary and metavolcanic rocks of the Palmeirópolis Sequence [2, 14, 15].
The igneous nature of the roof contact is supported by the presence, in the upper units of the complex, of septa and lenses of amphibolites of the Palmeirópolis Sequence [2, 14] and by the absence of mylonites near the contact [14].
According to Correia [14] the Cana Brava mafic-ultramafic Complex is divided, from the base to the top, into 5 units. Correia [14] used the acronym PICB (Proterozoic Inferior Cana Brava) for the all the different units. Here, the units are re-named on the basis of new chronostratigraphic criteria, and to make an easier comparison with the other complexes of the Brasilia Belt. The modified stratigraphic units are:

1. Basal Unit (BU), (corresponding to PICB1 of Correia [14]), which includes intercalated gabbros and epidote-bearing amphibolites with locally mylonitic texture;
2. Ultramafic Unit (UU) (corresponding to PICB2 of Correia [14]), which consists of largely serpentinized peridotite cumulates;
3. Cumulus Websterite Unit (CWU) (corresponding to PICB3 of Correia [14]), constituted by massif websterite with cumulus textures;
4. Lower Layered Gabbro Unit (LLGU) (corresponding to PICB4 of Correia [14]), formed by layered gabbros;
5. Upper Layered Gabbro Unit (ULGU) (corresponding to PICB5 of Correia [14]), which comprises gabbros and more differentiated lithologies approaching the top.

A more detailed description of the rocks of the Cana Brava Complex is reported in Correia [14] and a brief summary of the units names is given in Table 1.
Correia et al. [2] reported the common occurrence of shear zones, faults and deformations in all the units of the Cana Brava Complex. In general, as described in the Niquelândia Complex by Correia et al. [10], these structures are parallel to the primary igneous foliation. The most important shear zone reported by Correia et al. [2] occurs at the transition between the LLGU and ULGU in the southern portion of the complex (Corrego Verde Shear Zone).
Xenoliths of the encasing Palmeirópolis Sequence have been found within both the LLGU and ULGU. According to Correia et al. [2], the xenoliths are schist, quartzite and amphibolite, showing a complex metamorphic foliation, which were incorporated and transposed parallel to the gabbro foliation. Commonly, the xenoliths show reaction rims with the host gabbro, with the appearance of high-grade contact metamorphic assemblages (i.e. orthopyroxene - garnet - rutile; [2]).
Several episodes of recrystallization were inferred in the Cana Brava Complex. Girardi & Kurat [15] proposed three different events: i) a granulite facies metamorphism or a sub-solidus re-equilibration during slow cooling, which took place at about 900°C and 6-7 kbar; ii) next, an event of upper-amphibolite facies metamorphism, responsible for the formation of amphibole at the expense of clinopyroxene; iii) a final low-temperature event which generated serpentinite, rodingite, and talc schist. On the basis of Rb/Sr and Sm/Nd whole-rock ages and a Sm/Nd internal isochron, Correia et al. [2] proposed for the Cana Brava Complex three different events of recrystallization, the first and the last of which are comparable to those inferred by Girardi & Kurat [15] and the intermediates would be related to the Uruaçuano Cycle and the Brasiliano orogeny [16].
The three major intrusions of the Brasilia Belt (i.e., from south to north, Barro Alto, Niquelândia and Cana Brava) shear similar features which are commonly interpreted as fragments of a single continuous structure [3, 17]. According to Pimentel at al. [3], Ferreira Filho et al. [17] and Moraes et al. [18] the tholeiitic-MORB geochemical affinity [1–6] of the three complexes is consistent with a rift environment during the early stages of continental rifting up to the formation of an ocean basin.

3 Previous geochronological data

Two Ar-Ar whole-rock isochrons yielded ages of 1935±110 Ma and 475±15 Ma [12]. Matsui et al. [12] provided also several K-Ar ages which are distributed over a wide time span from 3950 Ma to 480 Ma. Girardi et al. [1] report a Rb-Sr whole-rock isochron age at 1157±150 Ma, obtained on samples of gneiss, schist and calc-silicate rock of the Palmeirópolis Sequence from the western border. At the eastern border the complex is in tectonic contact with

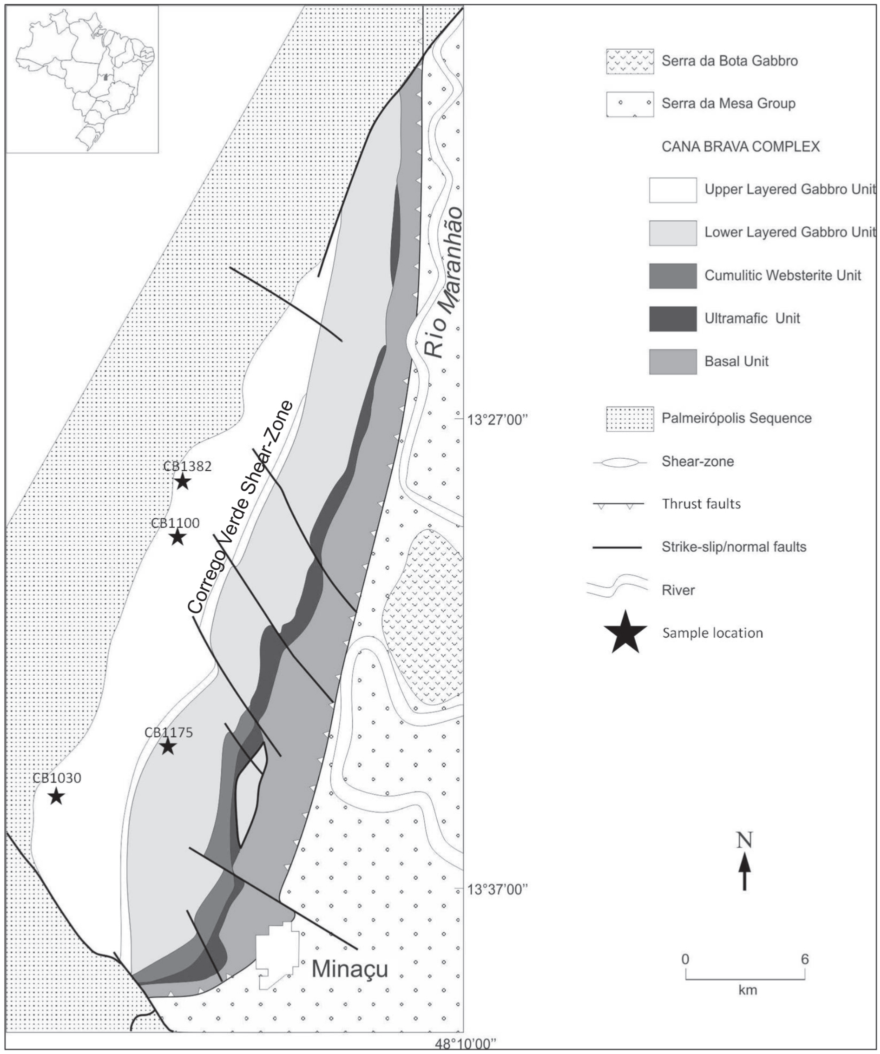

Figure 1: Geological map of the Cana Brava Complex, modified after Correia et al. [2].

Table 1: New names and acronyms of the Cana Brava Complex units and comparison with the old unit names from Correia [14].

Cana Brava Complex Units	
Correia [14]	This study
Proterozoic Inferior Cana Brava 1 (PICB1)	Basal Unit (BU)
Proterozoic Inferior Cana Brava 2 (PICB2)	Ultramafic Unit (UU)
Proterozoic Inferior Cana Brava 3 (PICB3)	Cumulus Websterite Unit (CWU)
Proterozoic Inferior Cana Brava 4 (PICB4)	Lower Layered Gabbro Unit (LLGU)
Proterozoic Inferior Cana Brava 5 (PICB5)	Upper Layered Gabbro Unit (ULGU)

gneisses which yielded a younger whole-rock isochron age of 644±27 Ma. Girardi et al. [1] interpreted the two ages as two different metamorphic peaks which induced the recrystallization of these rocks in amphibolite facies conditions.

Whole rock Sm-Nd isochrons obtained by Fugi [13] for the Cana Brava Complex and the Serra da Bota Gabbro (a smaller gabbro body located close to the eastern contact of Cana Brava within the Serra da Mesa group) yielded ages of 1970±69 Ma and 1088±18 Ma, respectively, which were interpreted as intrusion ages. Whole-rock Rb-Sr determinations and a Sm-Nd internal isochron on whole rock and plagioclase + biotite + pyroxene were performed by Correia et al. [2]. The whole-rock Rb-Sr isochron points to an "age" of 1350±35 Ma while the Sm-Nd internal isochron results in a younger age (770±43 Ma). Correia et al. [2] calculated the regression of the Sr isotopic evolution curve of the Cana Brava Complex, obtaining a minimum age at 2.25 Ga, which was interpreted as the time of the Cana Brava intrusion, whereas the oldest and the youngest ages (i.e. 1350±35 Ma and 770±43 Ma) were attributed to metamorphic events. However, all these data are artefacts of mixing of mantle- and crust- derived components and whole rock data of these hybrid rocks are questionable and should be disregarded. The effects of crustal contamination in the Cana Brava Complex are described by Correia et al. [2] and Ferreira Filho et al. [17].

Ferreira Filho et al. [17] determined U-Pb TIMS zircon ages on two samples from the ULGU and (probably) UU (four and three analyses, respectively). Both samples provide Neoproterozoic ages at 782±3 Ma and 779±1 Ma which are interpreted as intrusion ages of the complex. This is the most reliable age determination as far.

4 Samples and analytical methods

Zircons were separated after crushing, milling, magnetic and heavy liquid separation and hand-picking from 4 samples of the Cana Brava Complex. Out of four samples, one sample (CB1175) is from quartz gabbro at the top of the LLGU while the others (CB1030, CB1100 and CB1382) are representative samples from quartz gabbros of the ULGU [13, 18]. All these rocks show granoblastic texture and zircons occur as accessory phases. The modal composition of the samples, reported by Correia [14], is reported in Table 2.

After the Au-coating, the polished mounts were comprehensively examined with a FEI-QUANTA 250 scanning electron microscope equipped with secondary-electron and cathodoluminescence (CL) detectors at IGc-CPGeo-USP; the most common conditions used in CL analysis were 60 μA emission current, 15.0 kV accelerating voltage, 7 μm beam diameter, 200 μs acquisition time, and a resolution of 1024×884 dpi.

U-Th-Pb isotopic ratios and elemental abundances in ca. 20 μm diameter areas of zircons were determined using the SHRIMP II at the Western Australia Isotope Science Research Centre, Curtin University of Technology, Perth. A 2.0 nA primary ionizing O_2^- beam was employed, and mass resolution set at 5000, resulting in a sensitivity for Pb isotopes of 15 counts per second per Pb ppm per nA. Pb isotope ratios were corrected for common Pb on the basis of the measured $^{204}Pb/^{206}Pb$, typically resulting in a <1% correction to ^{206}Pb. Pb/U isotope ratios were corrected for the interelement discrimination using data currently obtained from the Perth standard zircon CZ3 ($^{206}Pb/^{238}U$ = 0.0914). Ages were calculated using standard decay constants. A more detailed description of the methodology is reported in Correia [19].

3 zircons were analyzed from sample CB1175, 19 zircons from sample CB1100, 12 zircons each from samples CB1030 and CB1382. Analyses are reported in Table 3.

5 Zircon morphology

Zircons separated from sample CB1175 (LLGU) show commonly anhedral-to-subhedral habit. Zircons are colourless and CL images show extremely complex structures (Figure 2A) with complex and chaotic oscillatory zoning and domains, often superimposed by other structures and sometimes partially deleted. Such zoning can indicate deep resorption of the early zircon phase and, possibly, a new zircon growth in a different crystallographic orientation than the substrate zircon [20].

Zircons from ULGU samples show subhedral-to-anhedral habit. Zircons are colourless. CL images commonly show cores with oscillatory zoning or different brightness domains (Figure 2B, C, D). Sometimes the core shows local recrystallization and/or local intermediate resorption. Often the cores are rounded with truncated internal zoning caused by superimposed accretion with different growths of oscillatory zoning (Figure 2B, D). Sometimes the new growth on cores shows domains of variable width and are occasionally resorbed (Figure 2B, D). Some crystals show continuous and simple overgrowth without any accretion structure (Figure 2C).

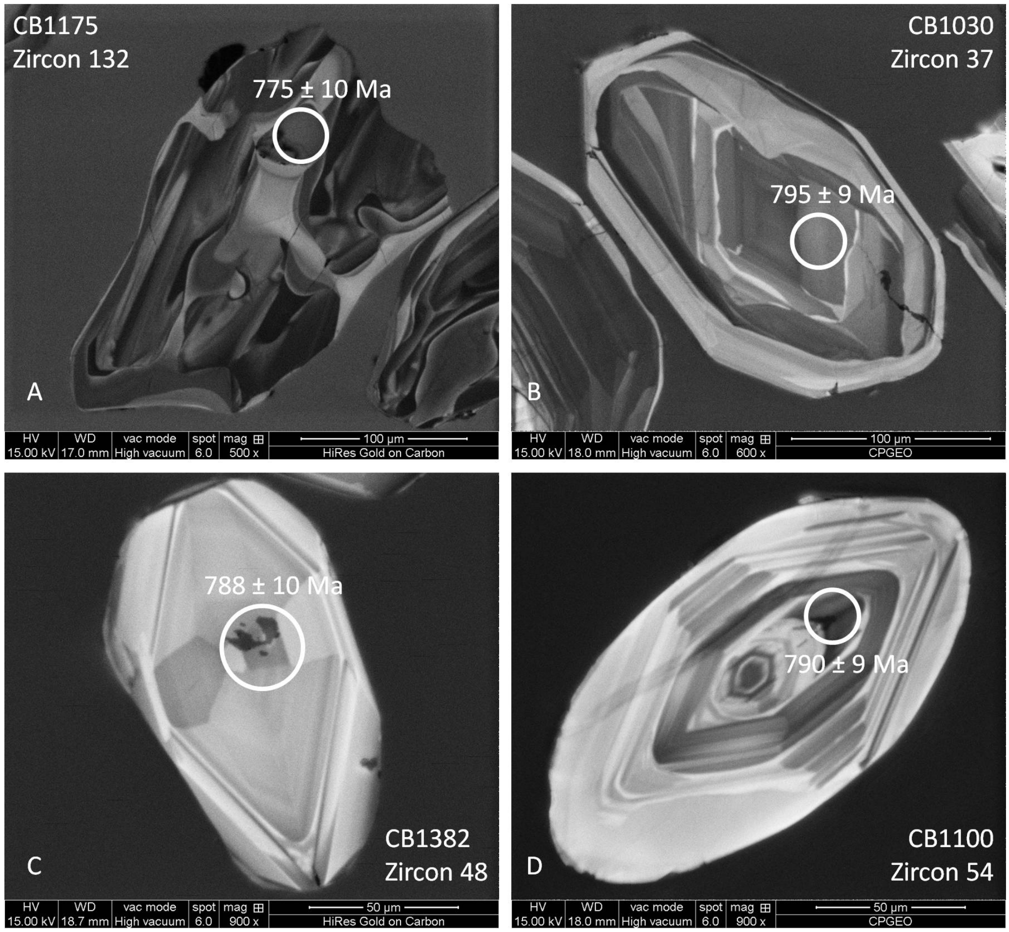

Figure 2: Cathodoluminescence imaging of analyzed zircons from each sample with different structures. In particular, zircon CB1175 (A) shows complex structure; CB1030 (B) shows a magmatic core and two stages of overgrowth rims; CB1382 (C) shows a single zoning growth; CB1100 (D) shows a magmatic core and a single stage of overgrowth rim.

Table 2: Modal composition of rocks from Correia [14].

Sample	CB1175	CB1030	CB1100	CB1382
Unit	LLGU	ULGU	ULGU	ULGU
Orthopyroxene	14.4	12.2	4.1	10.8
Clinopyroxene	33.1	2.0	29.2	19.0
Amphibole	5.1		2.6	2.4
Biotite	0.2	18.0		15.4
Plagioclase	39.1	43.0	51.2	42.3
K-Feldspar	3.0	10.0	5.0	3.6
Quartz	4.2	12.6	3.7	5.2
Spinel	0.7	1.4	4.2	1.3
Classification	Qtz-gabbro	Qtz-gabbro	Qtz-gabbro	Qtz-gabbro

Table 3: U-Pb isotopic data and ratios and $^{206}Pb/^{238}U$ ages (Ma).

Sample	Zircon	U ppm	Th ppm	Th/U	Pb tot	^{206}Pb %	$^{207}Pb/^{206}Pb$	Error (1σ)	$^{206}Pb/^{238}U$	Error (1σ)	$^{207}Pb/^{235}U$	Error (1σ)	$^{206}Pb/^{238}U$ Age (Ma)	Age error (Ma)
CB1100	72	80	38	0.5	26	3.14	0.1161	0.0042	0.2723	0.0079	4.361	0.213	1552.5	±40
CB1100	73	57	20	0.4	9	8.18	0.0657	0.0144	0.1152	0.0037	1.043	0.235	702.9	±21
CB1100	74	264	140	0.5	34	0.53	0.0625	0.0017	0.1198	0.0034	1.032	0.043	729.4	±20
CB1100	75	235	89	0.4	31	2.02	0.0664	0.0032	0.1211	0.0034	1.108	0.065	736.9	±20
CB1100	76	132	30	0.2	24	9.31	0.0642	0.0076	0.1307	0.0038	1.157	0.146	791.9	±22
CB1100	77	66	26	0.4	11	4.31	0.0786	0.0077	0.1401	0.0041	1.518	0.16	845.2	±23
CB1100	84	162	30	0.2	23	1.69	0.0723	0.0031	0.1349	0.0038	1.344	0.074	815.8	±22
CB1100	85	80	31	0.4	12	3.15	0.0749	0.0068	0.1254	0.0037	1.295	0.129	761.6	±21
CB1100	86	193	93	0.5	27	2.57	0.0660	0.0033	0.1248	0.0035	1.136	0.069	758.1	±20
CB1100	50	292	167	0.6	42	1.32	0.0652	0.0015	0.1304	0.0015	1.172	0.032	790.1	±9
CB1100	51	59	23	0.4	10	5.83	0.0618	0.0073	0.1299	0.0021	1.108	0.135	787.3	±12
CB1100	52	223	54	0.2	31	1.54	0.0662	0.0018	0.1331	0.0016	1.214	0.038	805.5	±9
CB1100	53	165	47	0.3	22	0.81	0.0645	0.0018	0.1301	0.0016	1.157	0.038	788.4	±9
CB1100	54	185	93	0.5	27	1.7	0.0631	0.0023	0.1303	0.0016	1.133	0.046	789.6	±9
CB1100	55	117	63	0.5	18	1.57	0.0675	0.0028	0.1325	0.0017	1.233	0.056	802.1	±10
CB1100	56	132	59	0.4	20	2.91	0.0620	0.0033	0.1319	0.0017	1.127	0.063	798.7	±10
CB1100	57	54	22	0.4	9	6.16	0.0701	0.0074	0.1346	0.0023	1.301	0.142	814.1	±13
CB1100	58	98	44	0.4	15	3.02	0.0697	0.0045	0.1337	0.0019	1.285	0.086	808.9	±11
CB1100	59	100	44	0.4	15	2.69	0.0664	0.0039	0.1346	0.0018	1.204	0.075	814.1	±10
CB1030	78	136	61	0.4	18	2.47	0.0559	0.0048	0.1219	0.0035	0.940	0.088	741.5	±20
CB1030	79	493	108	0.2	63	0.98	0.0639	0.0015	0.1279	0.0036	1.126	0.043	775.9	±21
CB1030	80	81	20	0.2	12	4.02	0.0725	0.0070	0.1269	0.0037	1.269	0.132	770.2	±21
CB1030	81	69	21	0.3	10	4.48	0.0602	0.0087	0.1293	0.0038	1.073	0.162	783.9	±22
CB1030	82	1166	473	0.4	149	0.89	0.0634	0.0010	0.1215	0.0034	1.062	0.036	739.2	±20
CB1030	83	237	150	0.6	34	1.03	0.0663	0.0021	0.1260	0.0036	1.153	0.052	765.0	±21
CB1030	34	154	79	0.5	23	3.28	0.0604	0.0035	0.1280	0.0016	1.065	0.065	776.4	±9
CB1030	35	446	35	0.1	56	1.46	0.0646	0.0013	0.1272	0.0014	1.132	0.027	771.9	±8
CB1030	36	81	31	0.4	12	3.24	0.0721	0.0052	0.1319	0.0019	1.312	0.099	798.7	±11
CB1030	37	260	157	0.6	38	1.28	0.0631	0.0017	0.1313	0.0015	1.142	0.035	795.3	±9
CB1030	38	1769	328	0.2	228	0.37	0.0648	0.0004	0.1325	0.0014	1.184	0.015	802.1	±8
CB1030	39	62	27	0.4	11	6.77	0.0688	0.0073	0.1310	0.0021	1.243	0.136	793.6	±12
CB1175	132	225	64	0.3	30	1.33	0.0634	0.0021	0.1278	0.0017	1.118	0.042	775.3	±10
CB1175	133	1473	441	0.3	182	0.16	0.0666	0.0005	0.1223	0.0014	1.124	0.016	743.8	±8
CB1175	134	160	45	0.3	22	1.45	0.0647	0.0029	0.1292	0.0018	1.153	0.057	783.3	±10
CB1382	40	82	79	1.0	15	5.73	0.0658	0.0059	0.1298	0.0019	1.180	0.110	786.7	±11
CB1382	41	66	36	0.5	17	3.56	0.0867	0.0042	0.2125	0.003	2.540	0.130	1242.1	±16
CB1382	42	138	134	1.0	22	2.89	0.0659	0.0033	0.1268	0.0016	1.152	0.062	769.6	±9
CB1382	43	121	96	0.8	18	1.52	0.0639	0.0026	0.1272	0.0016	1.121	0.049	771.9	±9
CB1382	44	180	119	0.7	53	0.91	0.1087	0.0014	0.2606	0.0031	3.906	0.071	1492.9	±16
CB1382	45	108	106	1.0	20	4.9	0.0610	0.0047	0.1340	0.0018	1.127	0.090	810.6	±10
CB1382	46	225	240	1.1	38	2.01	0.0628	0.0021	0.1317	0.0016	1.140	0.043	797.6	±9
CB1382	47	200	244	1.2	33	0.22	0.0672	0.0012	0.1317	0.0016	1.220	0.028	797.6	±9
CB1382	48	135	128	0.9	23	2.94	0.0664	0.0034	0.1300	0.0017	1.191	0.064	787.9	±10
CB1382	70	88	71	0.8	15	5.98	0.0557	0.0057	0.1251	0.0018	0.960	0.100	759.9	±10
CB1382	71	120	101	0.8	21	4.42	0.0662	0.0043	0.1302	0.0017	1.188	0.080	789.0	±10
CB1382	72	165	48	0.3	26	5.41	0.0588	0.0042	0.1305	0.0017	1.057	0.078	790.7	±10

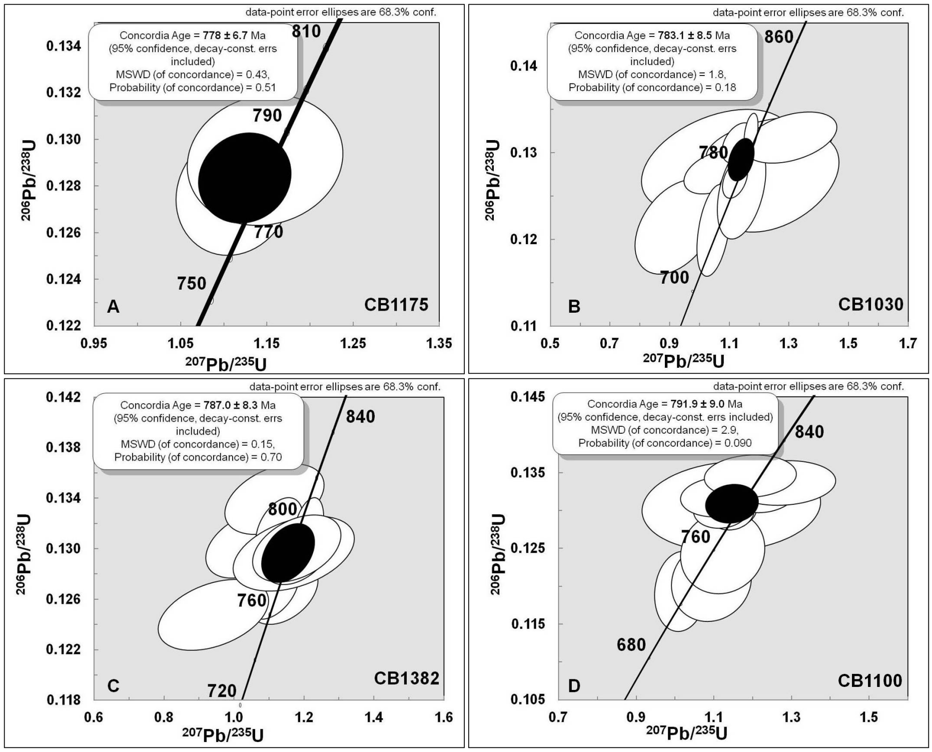

Figure 3: Concordia age calculated with $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ ratios for zircons from each sample. A: sample CB1175; B: sample CB1030; C: sample CB1382; D: sample CB1100.

6 Geochronological U-Pb data

$^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ concordia ages, with 95% of confidence level and 2σ error, are calculated using Isoplot software [21] for all samples (Figure 3A, B, C, D).

Only 3 zircons were analyzed on sample CB1175, and one of them (n. 133) was rejected because high U. The two analyses provide a concordia age of 778.0± 6.7 Ma (Figure 3A), with MSWD = 0.43 and probability of concordance = 0.51. $^{207}Pb/^{206}Pb$ ratio varies from 0.0634 to 0.0647, $^{206}Pb/^{238}U$ from 0.1278 to 0.1292 and $^{207}Pb/^{235}U$ from 1.118 to 1.153 (Table 3).

12 zircons from sample CB1030 show $^{207}Pb/^{206}Pb$ ratio from 0.0559 to 0.0725, $^{206}Pb/^{238}U$ from 0.1219 to 0.1325 and $^{207}Pb/^{235}U$ from 0.940 to 1.312 (Table 3). The calculated concordia age is 783.1±8.5 Ma, with MSWD = 1.8 and probability of concordance = 0.18 (Figure 3B).

12 spot analyses were performed on sample CB1382. Disregarding analyses 41 and 44 because they are clearly inherited cores, providing $^{206}Pb/^{238}U$ ages older than 1.2 Ga, the remaining 10 analyses provide a concordia age of 787.0±8.3 Ma (Figure 3C; MSWD = 0.15 and probability of concordance = 0.70). The CB1382 crystals have $^{207}Pb/^{206}Pb$ ratios

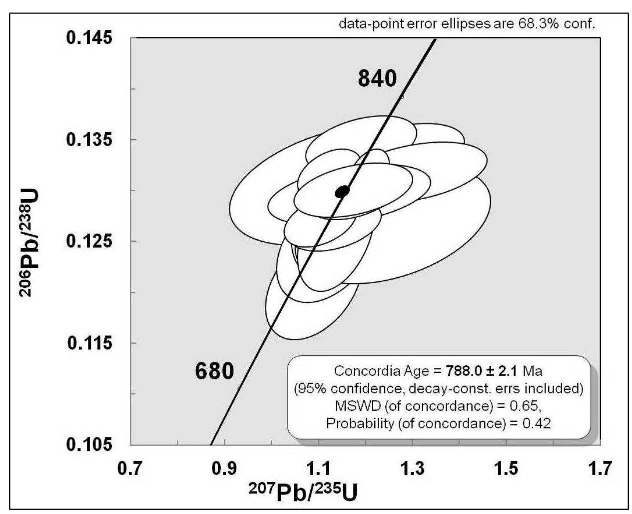

Figure 4: Concordia age calculated with $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ ratios for selected zircons from all samples.

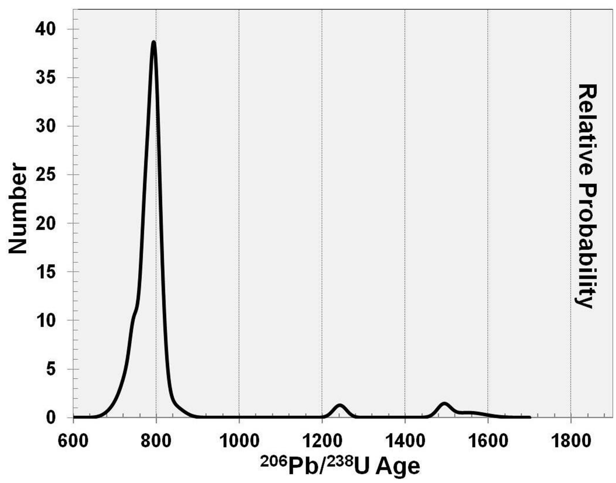

Figure 5: Probability density plot of all the $^{206}Pb/^{238}U$ ages.

from 0.0557 to 0.0672, $^{206}Pb/^{238}U$ from 0.1251 to 0.1340 and $^{207}Pb/^{235}U$ from 0.960 to 1.220 (Table 3).

12 spot analyses from sample CB1100 provide a concordia age of 791.9±9.1 Ma (Figure 3D), with MSWD = 2.9 and probability of concordance = 0.09. The $^{207}Pb/^{206}Pb$ ratio varies from 0.0631 to 0.0701, $^{206}Pb/^{238}U$ from 0.1152 to 0.1346 and $^{207}Pb/^{235}U$ from 1.043 to 1.301 (Table 3). Analysis 72 is excluded because is an inherited zircon which provides a $^{206}Pb/^{238}U$ age of 1552 Ma, analyses 77 and 85 were excluded because largely discordant. Finally, analyses 51, 57, 73 and 74 were excluded because of the low U abundance. Combining all data, excluding those rejected, the results gave a concordia age of 788±2.1 Ma (MSWD = 0.65 and probability of concordance = 0.42, Figure 4). In the probability density distribution of the $^{206}Pb/^{238}U$ ages (Fig. 5), the ages concentrated between 800-780 Ma, with few analyses near 760 Ma.

Notwithstanding that most analyses point to Neoproterozoic ages, a few spot $^{206}Pb/^{238}U$ ages from samples CB1100 (1 analysis) and CB1382 (2 analyses) provided older ages suggesting they are inherited from the host rock. These zircons are discordant, which suggests that they were affected by Pb loss. Calculated $^{206}Pb/^{238}U$ ages provide three peaks at 1552 Ma, 1493 Ma and 1242 Ma (Figure 5). Also, younger $^{206}Pb/^{238}U$ spot ages were found in accretion rims of some crystals in each sample (758-703 Ma), suggesting late stages of Pb-loss or resetting/zircon growth (Figure 5).

7 Discussion

Among the three mafic-ultramafic massifs of the Goiás Massif, the Niquelândia Complex is the most studied. Pimentel et al. [7, 8] proposed that the Niquelândia Complex comprises two separate intrusions on the basis of the presence of deformation structures between the Upper Complex (UC) and the Lower Complex (LC), i.e. the pervasive presence of NS-N10E ductile shear zones with well-developed tectonic foliation within areas where completely or dominantly primary igneous textures are observed [22]. Based on SHRIMP U-Pb zircon ages and a Sm-Nd internal isochrons, these authors attributed to LC and UC crystallization ages of 797±10 Ma and to 1248±23 Ma respectively. However, according to Girardi et al. [6], Correia et al. [9], Rivalenti et al. [5] the two units belong to a single complex, with a gradational contact represented by the Hydrous Zone (HZ) and the differences between the two units are related to the different conditions of the same intrusion. This hypothesis was initially supported by SHRIMP U-Pb zircon ages obtained by Correia et al. [9] from an anorthosite at the top of UC (sample Niq1552) which provided a crystallization age of 833±21 Ma. Recently, Correia et al. [10] demonstrated that LC and UC are part of the same Neoproterozoic intrusion on the basis of a SHRIMP U-Pb age of 780.8±3.7 Ma on zircons from another anorthosite sample (Niq1551) from UC. This age is similar to the intrusion age (within errors) of the LC proposed by Pimentel et al. [7, 8]. Also, the age of 1248±23 Ma interpreted by Pimentel et al. [7, 8] as the intrusion of the UC, was provided by a gabbro affected by significant inheritance, as described by the same authors and discussed by Correia et al. [10]. Moreover, this Mesoproterozoic age is similar to U-Pb and Sm-Nd ages obtained by Moraes et al. [18] for the Juscelândia Sequence and other samples of the volcano-sedimentary country-rocks of Cana Brava and Niquelândia. Furthermore, in the field there is no evidence of a tectonic contact (i.e. milonite or shear zone bands) between LC and UC. Based on these data and observations, Correia et al. [10] concluded that the Niquelândia Complex intruded in the volcano-sedimentary Sequence of Indaianópolis at ca. 790 Ma.

The Barro Alto Complex is less well studied than Niquelândia. Suita et al. [23] reported U-Pb zircon and monazite ages for different rocks from Barro Alto and the associated Juscelândia metavolcanic-metasedimentary Sequence. Obtained ages span from 1730-770 Ma, with peaks at 1.72 Ga, 1.35-1.29 Ga and 820-770 Ma [23]. Suita et al. [23] interpreted that the 1.73-1.72 Ga age is the intrusion time and the others are ages of metamorphic peaks. Correia et al. [24] reported SHRIMP U-Pb ages, from rocks of meta volcano-sedimentary sequence (acid granulite formed by quartz + cordierite + sillimanite + plagioclase + mesopertite near the western contact of the complex) and a high grade metagranite, at 1286±13 Ma and 1302±32 Ma, respectively. Correia et al. [9] reported SHRIMP U-Pb zircon ages between 799-726 Ma for the Barro Alto Complex. They suggested that the Barro Alto intrusion occurred at 733±25 Ma, and that the older ages obtained by Correia et al. [24] are inherited from the country rocks. The U-Pb zircon ages presented in this paper for the Cana Brava Complex provide further evidence for a Neoproterozoic intrusion. In particular, the ages obtained on four samples are undistinguishable within errors (791.9±9.0 Ma, 783.1±8.5 Ma, 787.0±8.3 Ma and 778.0±6.7 Ma for samples CB1100, CB1030, CB1382 and CB1175 respectively). The concordia age obtained pooling together all analyses (beside those rejected) provides an age at 788.0±2.1 Ma. The probability plot (comprising the excluded data, Figure 5) shows a single peak around 800-780 Ma, with three inherited, older zircons and a minor peak shifted towards younger ages, a possible artefact of later resetting/recrystallization event(s). The concordia age around 788.0±2.1 Ma, is close to the age obtained by Ferreira Filho et al. [17] on two samples of the Cana Brava Complex (782±3 Ma and 779±1 Ma), is interpreted as intrusion ages, and is similar to the Sm/Nd internal isochron age of 770±43 Ma [2]. These ages are similar to the U-Pb zircon ages interpreted as dating the intrusion of Barro Alto [24], and Niquelândia [9, 10]. The few older spot-ages are conceivably obtained on zircons inherited from the country rocks. This hypothesis is also supported by the crustal contamination of the Cana Brava Complex as suggested by Correia et al. [2] and Ferreira Filho et al. [17], similarly to that occurring in the Niquelândia Complex [9, 10]. Notwithstanding some U-Pb zircon ages of the Cana Brava Complex are now available (Ferreira Filho et al. [17]; this study), further analyses are required to provide a statistically supported data set for the determination of the Cana Brava intrusion age.

8 Conclusion

The new U-Pb SHRIMP analyses on zircons from samples of the Cana Brava Complex provide a concordia age of 788.0±2.1 Ma. Considering the analyzed samples individually, the $^{206}Pb/^{238}U$ age distribution suggests that the Cana Brava Complex intruded the Palmeirópolis Sequence between 800-780 Ma. This age for the Cana Brava intrusion is similar to those reported in literature for the intrusions of the Niquelândia and Barro Alto complexes [9, 10, 24]. The similarity in the intrusion ages of the three complexes points to a large igneous event in the region during the Neoproterozoic. The presence of older and discordant zircons suggests inheritance from the country rocks in the Cana Brava Complex, as already observed in Niquelândia by Correia et al. [10]. The effects of crustal contamination, well-documented in Niquelândia [5, 10] and inferred for the Cana Brava Complex too, suggest caution in interpreting ages estimated by whole rock K/Ar, Ar/Ar, Sm/Nd and Rb/Sr systematics. Nonetheless, further field work and U-Pb zircon analyses are needed to give a larger statistical support for the Cana Brava intrusion age and related geological events.

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