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DIAMONDS FROM THE SÃO FRANCISCO AND AMAZON CRATONS, BRAZIL

Araújo*DP[1] Silveira FV[2], Weska RK[2], Rachid F[1], Neto FEB[1], Ireland T[4], Holden P[4] and Gobbo L[5]

1. Instituto de Geociências, Universidade de Brasília., Brasília-DF, Brazil. dparaujo@unb.br; 2. Dep. Recursos Minerais, Inst. de Ciências Exatas e da Terra, Universidade Federal do Mato Grosso, Brazil. , 3. Compania de Pesquisa e Recursos Minerais (CPRM), Brasília, Brazil; 4. Research School of Earth Sciences, Australian National University, Canberra, Australia; 5. Rio Tinto Desenvolvimentos Minerais (RTDM), Brasília, Brazil

INTRODUCTION

This work brings preliminary results of a broad diamond study from various locations in Brazil, which will be included in a diamond geology database (*Diamante Brasil*, Silveira et al. this volume) currently carried out by the Geological Survey of Brazil-CPRM (Silveira et al. this volume). The sample collections included in this study are from the São Francisco and Amazon Craton.

Diamond occurrences in Brazil are related to Paleoproterozoic to Cretaceous alluvial deposits, some without known primary source, and to a limited number of diamond-bearing kimberlites. The knowledge of diamond geology in Brazil and most of South America is limited in the scientific literature. In Brazil, one factor that contributed to this is the absence of economic primary diamond mines, which in general promotes fruitful colaboration between industry and academia. We aim with this study to contribute to a better understanding of diamond occurrence in Brazil in relation to tectonic settings and diamond provenance and to add knowledge about the characteristics of the mantle below the South American plate.

METHODS

All diamonds were studied according to their morphology, surface textures and infrared spectroscopy. Selected samples were polished for cathodoluminescence imagery and *in-situ* carbon isotope analyses. Morphology and surface textures of all diamonds were investigated in detail using binocular loupe (50x) and selected samples were polished along dodecahedral planes using a diamond polishing wheel at the University of Brasília. The following methods were done at the Research School of Earth Sciences (RSES) at the Australian National University (ANU). Carbon isotope analyses were carried out with the Sensitive High Mass Resolution Ion MicroProbe (SHRIMP SI-Stable Isotopes). The samples were polished and mounted with the standard in an epoxy mount and coated with ca 10 nm of gold to ensure surface conductivity. Variability in instrumental mass fractionation (IMF) was less than 1‰ during complete day-session analyses. Assessment of this parameter is not straightforward because of the potential variations in standard materials. At this stage we have adopted a conservative approach to determining the uncertainty of an analysis by adding the variance of the standard as measured, the variance of the external mass spectrometric analysis, and the variance of the measured uncertainty of the sample. After correction for IMF, the $\delta^{13}C$ values are calculated using Pee Dee Belemnite (PDB) $^{13}C/^{12}C$ ratio of 0.0112246.

Infrared spectra of diamonds were acquired using a Bruker IFS28 infrared spectrometer equipped with a Bruker A590 infrared microscope. Spectra were collected from 600 to 4000 cm^{-1}, at $2cm^{-1}$ steps, 64 scans and 60 μm spatial resolution.

TECTONIC SETTING AND DIAMOND OCCURRENCE

Major cratonic terrains exposed on South America plate are the Amazon (AM) and São Francisco (SF) cratons, followed by minor exposures as Luis Alves (LA), São Luis (SL) and Rio de La Plata (RP) cratons, as illustrated in Fig. 1. These cratons are separated dominantly by Neoproterozoic terrains (Tocantins (T), Borborema (B) and Mantiqueira (M) Provinces), with occasional Archean blocks, that closed their orogenic cycles to form the Gondwana continent (Cordani and Sato 1999).

São Francisco Craton

Archean and Paleoproterozoic basement rocks, comprising medium and high-grade metamorphic associations and granite-greenstone terrains, are exposed in the northern and southern sectors of the São Francisco Craton (Teixeira *et al*. 2000). The relatively stable geotectonic framework, comprising Paleoproterozoic terrains and Archean nucleii, was partially reworked during the Neoproterozoic orogeny due to the deformation by compression developed in the marginal fold belts (Pereira and Fuck 2005). The geological sketch map of the São Francisco Craton is shown in Fig. 2.

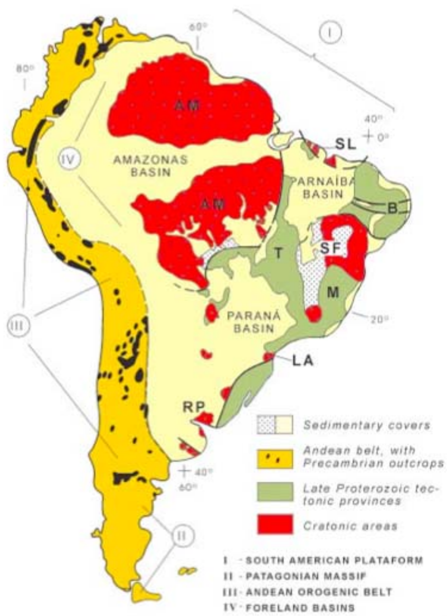


Fig. 1 – Crustal Provinces of South America. See text for abbreviations (Cordani and Sato 1999).

In the SF Craton diamonds occur associated to a vast Meso/Paleoproterozoic sediment unit, the Espinhaço Supergroup, which extends from north to south of the craton (Fig. 3). Kimberlitic diamonds are found in Neoproterozoic kimberlites intruded in Archean blocks (Salvador cluster – 1.15 Ga, Donatti Filho et al. 2009 - and Brauna cluster – 682 ± 20Ma, Pisani et al. 2001), and in Cretaceous kimberlites at the south portion of the Craton (e.g. Maravilhas; Pereira and Fuck 2005). These occurrences will be further referred as 'on-Craton' diamonds.

Adjacent to the Southwertern outcropping limits of the craton, in the Brasilia Fold Belt, occurs the Alto Paranaíba Igneous Province formed by various alkaline rocks as kimberlites, orangeites, kamafugites and carbonatites (Gibson et al. 1997).

These occurrences are within the inferred geophysical limits of the Craton, which extends below the Brasilia Fold Belt (Steenkamp 1998, Pereira e Fuck 2005). In the Alto Paranaíba Province diamonds occur in kimberlites (e.g. Catalão, Três Ranchos, Canastra) and are widespread in

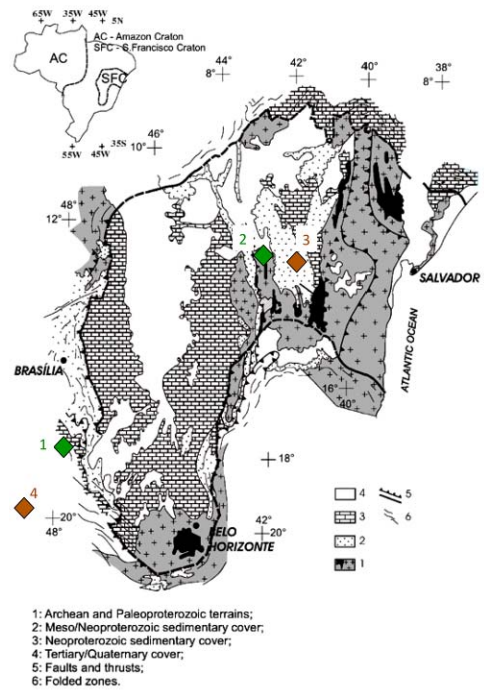


Fig. 2 – Geological sketch map of the São Francisco Craton showing the location of Catalão kimberlite (1), Salvador kimberlite cluster and Barra do Mendes (2), Lençois and Andaraí (3) and Frutal alluvial diamond (4) (adapted from Pimentel and Silva (2003) and Alkimin et al 1993).

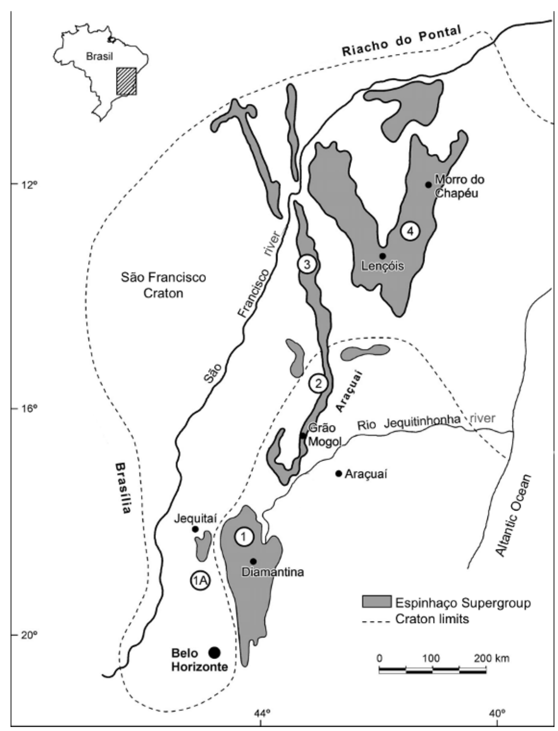


Fig. 3 - Geographic distribution of the Espinhaço Supergroup. 1, Southern Espinhaço; 2, Central Espinhaço; 3, Northern Espinhaço; 4, Chapada Diamantina (Chaves and Brandão 2004)

alluvial deposits. These occurrences will be further referred as ‘border-of-Craton/off-craton’ diamonds.We have studied ‘on-craton’ diamonds from Barra do Mendes (BM) alluvial deposits, which drains the Salvador-1 Kimberlite, and from Andaraí and Lençóis regions, sourced in Mesoproterozoic sediments (Northern Espinhaço Supergroup, Fig. 3). Diamonds on the ‘border-of-craton’ are from the Catalão Kimberlite and ‘Off-craton’ diamonds are from Frutal alluvial deposit (Fig. 3).

Amazon Craton

The Amazon Craton is formed by Archean to Neoproterozoic terrains amalgamated during various orogeny cycles (Tassinari et al. 2000, Fig. 4). It is limited in the east and south by the Tocantins Province (Fig. 1), which includes the Paraguai-Araguaia and Brasília Fold Belts (Almeida et al. 1981).

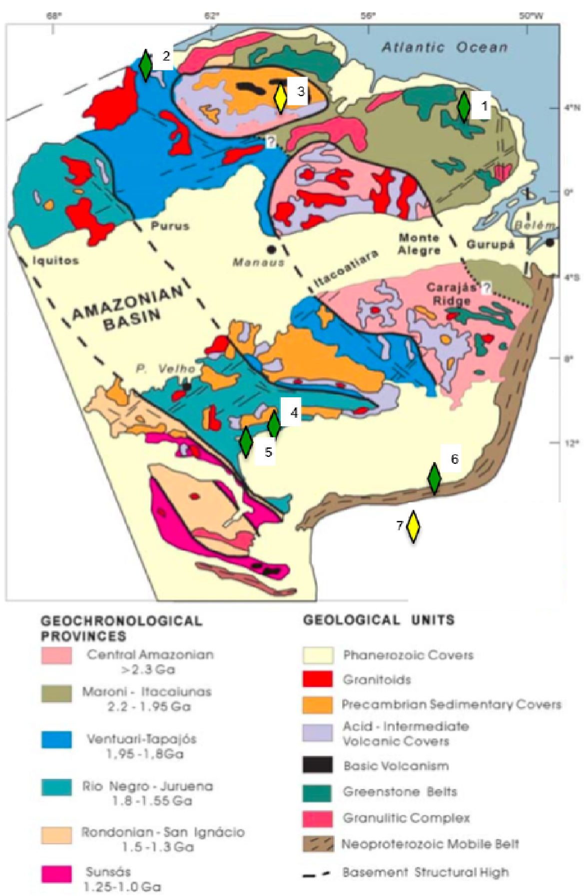


Fig. 4 – Geological Provinces of Amazon Craton (Tassinari et al. 2000) and location of primary (green losangle) and secondary (yellow lasangles) diamond occurrences included in this study. Dachine (1), Guaniamo (2), Roraima Supergroup (3), Juina (4), Pimenta Bueno (5), Paranatinga and Poxoréu (7). See text for references.

Diamond occurrences in the northern Amazon Craton are Dachine in French Guiana (1.9 Ga; Capdevila et al. 1999), Guaniamo in Venezuela (712-730 Ma, Channer et al. 1998) and alluvial diamonds related to the Paleoproterozoic Arai Formation in the Roraima Supergroup (Rodrigues 1991, Santos et al. 2003). The primary source of diamonds in this unit is unknown however paleo-current interpretation suggests a northern provenance (Reis et al. 1990). In the southwestern portion of the Craton there are the Pimenta Bueno Kimberlite Field (232 Ma; Masun et al. 2008; Hunt et al. 2009) and the Juina Kimberlite Field (92-95 Ma; Heaman et al. 1998; Kamisnky et al. 2009), both intruded in Paleoproterozoic terrains of the Rio Negro-Juruena Mobile Belt (Tassinari et al. 2000). Within the Neoproterozoic Paraguai-Araguaia Belt to the south of the craton, there is the Paranatinga Kimberlite Field (127 Ma; Davis 1977). In this region alluvial diamonds (Batovi, Jatobá and Paranatinga rivers) are related both to the nearby kimberlites of the Paranatinga Field and to Cretaceous and Tertiary diamond-bearing sediments. Alluvial deposits to the South of the Paraguai-Araguaia Fold Belt (e.g. Poxoréu, Chapada dos Guimarães) occur over units of the Paraná Basin and are also related to Cretaceous and Tertiary diamond-bearing sediments.

In this study, we included ‘on-craton’ diamonds from the Roraima Supergroup (Tepequém area) and ‘off-craton/border-of-craton’ diamonds from Paranatinga and Poxoréu.

RESULTS

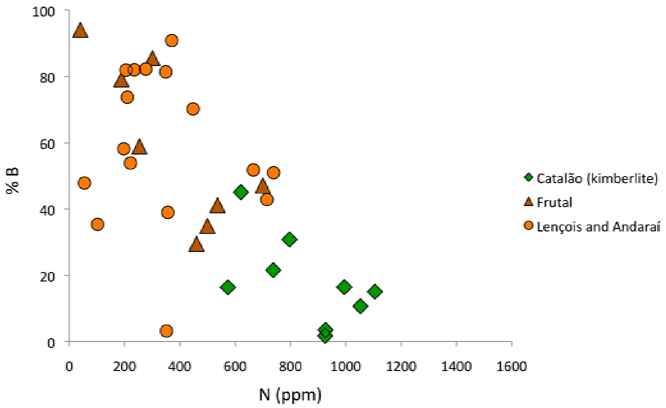
Eighty-eight diamonds were measured for carbon isotope composition and for nitrogen content and aggregation state.

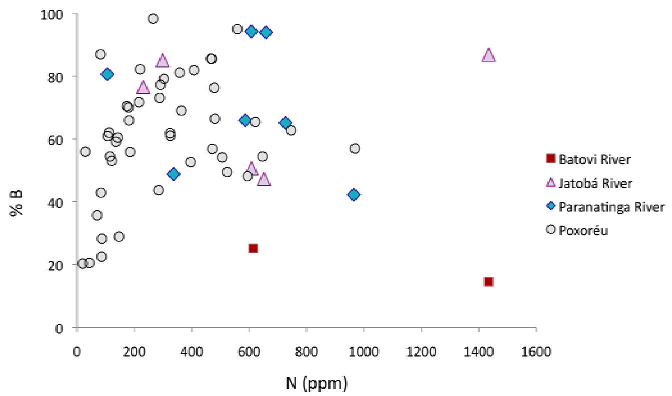
Despite the low number of samples for some locations, different populations could be separated using both techniques.

São Francisco Craton

Andaraí and Lençóis diamonds (n=23) have $\delta^{13}C$ close to mantle values (-6.3 to -1.9‰) while for Barra do Mendes diamonds (n=23) $\delta^{13}C$ varies from -18.1‰ to +2.8‰. Diamonds from the Catalão Kimberlite (n=4) also present mantle-like values and alluvial diamonds from Frutal (n=6) have $\delta^{13}C$ from -9.4 to -2.8‰, and one has a lighter value -20.5‰.

FTIR results separates Catalão kimberlite diamonds, with higher N content and low N aggregation state, from those of Andaraí and Lençóis, with lower N content and medium to high aggregation state (Fig. 5a). Barra do Mendes diamonds were not measured.





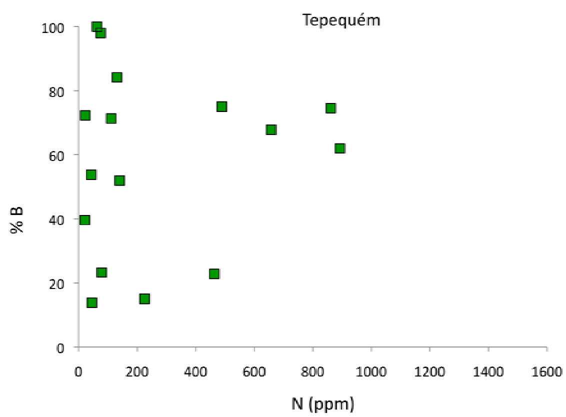


Fig. 5 – N content and percentage of B defect (% of N aggregation state) for diamonds within and adjacent to São Francisco Craton (top diagram) and Amazon Craton (middle and bottom diagram).

Amazon Craton

The range of $\delta^{13}C$ for Tepequem stones (-8.6 to -2.0‰) reproduces the previous results for Boa Vista diamonds (-8.9 to -2.2‰; Tappert et al. 2006), which were sampled to the north of Boa Vista city, close to the Tepequem location.

Most diamonds from Paranatinga area (Jatobá, Batovi and Paranatinga rivers) and Poxoréu region have $\delta^{13}C$ ranging from -6.3 to -3.2‰, except for two samples with -0.6‰ (Jatobá) and -10.2‰ (Paranatinga).

FTIR results show overlap for diamonds from Paranatinga área (Paranatinga and Jatobá Rivers) with N up to 1000 ppm and meddium to high aggregation state. Only two samples from Batovi river, which drain the Paranatinga-Batovi kimberlites, were analysed, and showed distinctive low aggregation of N (Fig. 5b).

Diamonds from Tepequém area hás N up to 900 ppm and low to high N aggregation state (Fig. 5c).

DISCUSSIONS AND CONCLUSIONS

Diamonds from Catalão kimberlite show mantle-like carbon isotope composition and low N aggregation state. The former indicates low temperature and/or low mantle residence time. A cooler mantle is in accordance to its position at the border of the São Francisco Craton. Diamonds from Andaraí and Lençóis also show a restrict $\delta^{13}C$ range (-6.3 to -1.9‰) but lower N content and higher N aggregation compared to Catalão. Likewise, the N data can reflect cooler conditions for diamond formation and storage. Diamonds from Barra do Mendes, on the other hand, show a broader range of $\delta^{13}C$, where the very negative (-18.1‰) and positive (+2.8‰) values lead to interpretation of influence of subducted carbon.

In the northern Amazon Craton, diamonds from Tepequém sourced in Paleoproterozoic sediments show narrow range of $\delta^{13}C$ (-8.9 to -2.2‰) and variable degree of N aggregation, which are comparable to previous results (Tappert et al. 2006). This can reflect diamonds formed at different depths experiencing variable temperature and/or different residence times and/or multiple sources.

Paranatinga diamonds, with the exception of Batovi river diamonds, are similar to Poxoréu ones regarding their $\delta^{13}C$ and FTIR characteristics. The same conclusion was found in a morphological study of more than 4,000 diamonds including samples from Paranatinga, Poxoréu, Chapada dos Guimarães, Diamantino and Alto Paraguai areas (Zolinger et al. 2005), all within the *Rio das Mortes* Rift (Weska 1996) but occuping an extense area (~ 300 km wide). Alluvial diamonds are mostly sourced in Tertiary and Cretaceous diamond-bearing sediments and apart from Paranatinga-Batovi kimberlites, no other primary sources are known. The Batovi river drains the Paranatinga-Batovi kimberlites but more samples need to be invetigated in order to confirm the differences found in N aggregation of the two stones and possibly relate to the diamond kimberlitic population.

The compilation of diamond characteristics, xenocrysts and diamond inclusions chemical composition and geotectonic settings information will allow to better understand the processes involved in diamond formation in these areas.

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