On the origin of Coromandel diamonds and the urgent need for new exploration models

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In the Coromandel area, southwestern São Francisco Craton, rich alluvial diamond deposits occur in close spatial association to mantle-derived igneous rocks of the Cretaceous Alto Paranaíba Igneous Province. In this context, diamonds recovered from deposits at the Douradinho, Santo Inácio and Santo Antônio do Bonito rivers, right south to the town of Coromandel, are specially sought after due to the occasional occurrence of sizeable (>100 ct) and pink stones. Decades of exploration in the region, since the 1960's, failed to identify the primary sources of these valuable diamonds. Our study on diamonds and their mineral inclusions from the Douradinho River revealed an unusual diamond population, characterized by low or highly variable nitrogen contents at high aggregation states (up to 100% B-centers). Mineral inclusions in these diamonds indicate that lherzolite is the main diamond source-rock, followed by eclogite and minor harzburgite and websterite. Trace element patterns of eclogitic and websteritic inclusions establish a clear link between subduction processes and diamond formation in the southwestern margin of the São Francisco Craton. A subduction signature is also evident from $\delta^{13}C$ and $\delta^{15}N$ systematics of the host diamonds. Nitrogen isotope data for Douradinho River diamonds are strongly skewed towards positive values (84% of diamonds have $\delta^{15}N > +1.5‰$), while carbon isotope data cluster both at the ^{13}C depleted (< –7‰; 42%) and enriched side (> –3‰; 33%) of the mantle range (–5 ± 2‰). The ^{13}C depleted and enriched portions of the $\delta^{13}C$ distribution are clearly dominated by diamonds of eclogitic/websteritic and lherzolitic paragenesis, respectively. Coupled negative $\delta^{13}C$ and positive $\delta^{15}N$ values observed in a significant number of diamonds provide clear evidence for the involvement of subducted organic material. The limited chemical depletion recorded in lherzolitic inclusions indicates a likely post-Archean age for the lithospheric mantle beneath this part of the São Francisco Craton. The involvement of subducted material and the long mantle residence required to explain the high aggregation state of nitrogen in the studied diamonds point to accretion of subducted material and modification of the mantle roots in the southwestern São Francisco Craton likely during a Paleoproterozoic orogeny (2.2-1.9 Ga). Many years of exploration for the primary sources of diamonds in the Alto Paranaíba region were guided by the paradigm that beneath Archean cratons diamonds are associated with harzburgitic substrates. The outcomes of this study reveal an unconventional setting for diamond exploration. Future exploration efforts should consider new approaches to evaluate lherzolitic and eclogitic diamond potential. Reevaluation of known primary sources considering the outcomes of this study may bring success in finding the primary sources of the Alto Paranaíba diamonds.

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1. Introduction

Diamond exploration techniques are traditionally based on the paradigm that beneath Archean cratons diamonds are associated with harzburgitic substrates (Gurney 1984).

Based on this paradigm, many years of exploration for the valuable diamonds spatially associated with the Cretaceous Alto Paranaíba Igneous Province **(Figure 1)** have failed to identify their primary sources.

Our study on diamonds and their inclusions from the Coromandel area (Carvalho et al. 2022) show a diamond population dominated by lherzolitic and eclogitic inclusions, revealing an unconventional setting for diamond formation and, hence, for diamond exploration.

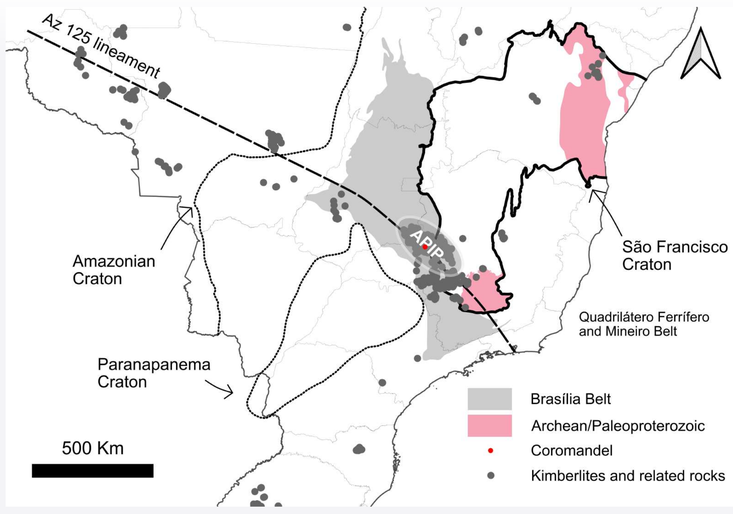

Figure 1: The Alto Paranaíba Igneous Province (APIP) correspond to a set of uncommon alkaline/potassic/ ultramafic rocktypes that occur in western Minas Gerais/eastern Goiás states, structurally oriented following a lineament of azimuth 125°. Intruding the rocks of the Neoproterozoic Brasília mobile belt, the APIP is distributed along the southwestern margin of the São Francisco Craton, where widespread alluvial diamond deposits occur.

2. Results

- Inclusion-bearing diamonds from the Douradinho River (n=10) have lherzolitic (n=4) and eclogitic (n=3) affinity, with additional minor harzburgitic and websteritic diamonds.
- Nitrogen systematics **(Figure 2)** reveal a strong predominance of highly aggregated nitrogen coupled with generally low nitrogen contents. Nitrogen-free (Type II) diamonds also occur.
- Carbon isotope data cluster both at the ^{13}C-depleted and -enriched side of the mantle range **(Figure 3)**. $\delta^{15}N$ data are strongly skewed towards positive values **(Figure 4)**.

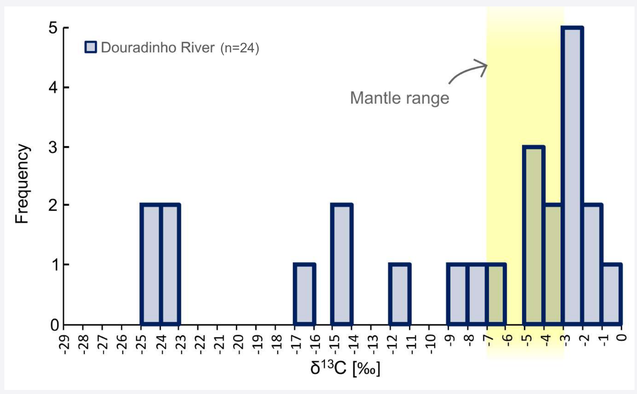

Figure 3: Distribution of diamond C-isotope compositions. For each diamond, median values and range in values are shown.

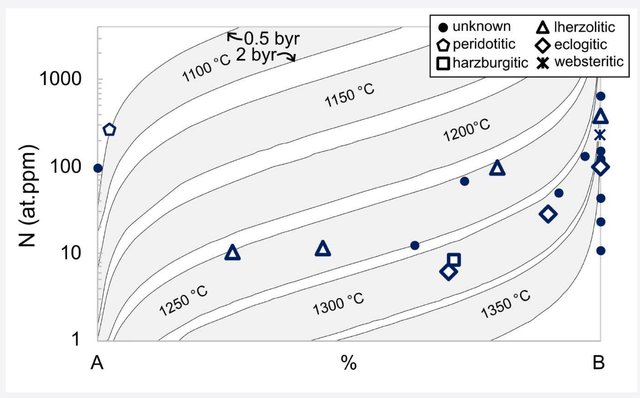

Figure 2: Nitrogen concentration vs. aggregation state (%B=$N_B/(N_A + N_B)$) for diamonds from Douradinho River. Isotherms are calculated for mantle residence times of 0.5 and 2 byr, as indicated.

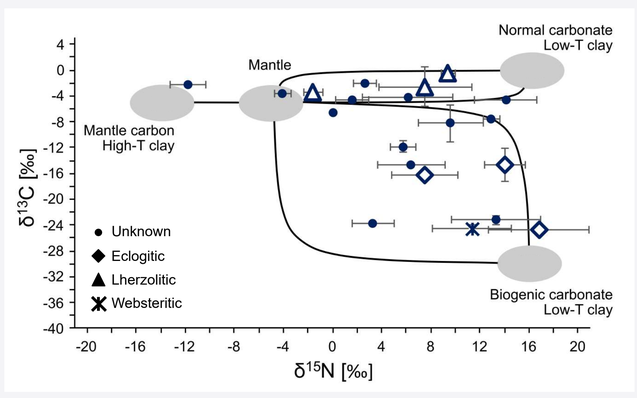

Figure 4: C- vs. N-isotope compositions for diamonds from the Douradinho River. Grey fields are from Li et al. (2019), representing a mantle component and three isotopically distinct reservoirs in altered oceanic crust.

3. Discussion

$\delta^{13}C$ and $\delta^{15}N$ systematics of Douradinho River diamonds are not in agreement with the mode of diamonds worldwide (Stachel et al. 2022). Coupled ^{13}C-depleted and ^{15}N-enriched values **(Figure 4)** provide clear evidence for the involvement of subducted material (Li et al. 2019). Nitrogen systematics document unusually high mantle residence temperatures, consistent with diamonds originating from the base of the lithosphere. Diamond inclusion chemistry records post-Archean signatures, indicating that diamond formation occurred likely during a Paleoproterozoic subduction-driven event **(Figure 5)**.

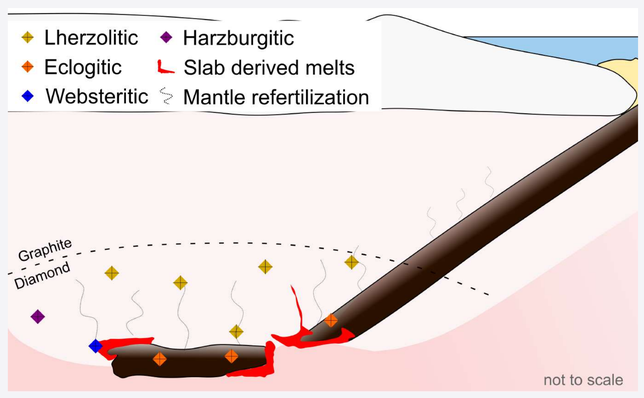

Figure 5: Schematic model illustrating subcretion of a slab fragment beneath the southwestern margin of the São Francisco Craton during an accretionary event and the associated formation of diamonds.

4. Summary and Conclusions

Diamonds recovered from deposits at the Douradinho River, in Coromandel, are different from diamond occurrences worldwide. Prevalence of lherzolitic and eclogitic inclusions points to a post-Archean origin. C- and N-isotope characteristics reveal a clear subduction signature. High abundance of diamonds with highly aggregated nitrogen indicates mantle storage at high temperatures. These characteristics define an unconventional setting for diamond exploration. Future exploration efforts should consider new approaches to evaluate lherzolitic and eclogitic diamond potential. Reevaluation of known primary sources considering the outcomes of this study may bring success in finding the primary sources of Coromandel diamonds.

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