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Mantle source characteristics of diamondiferous areas in Brazil revealed from Hf and O isotopes of zircon megacrysts

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Introduction

We investigate the mantle source evolution and possible pathfinders for superdeep diamond exploration, as reflected by new Hf and O isotope data for zircon megacrysts from three kimberlite and diamondiferous areas in Brazil: Juína and Paranatinga in the Amazonian craton and the Alto Paranaíba Igneous Province (APIP) along the southwest São Francisco craton. These areas align with the Azimuth 125° lineament, a NW-SE trend known for its high concentration of carbonatite, kimberlite, kamafugite and alkaline rocks, along with diamond deposits on the South American platform (Fig. 1). One aim was to try to search for mantle geochemical signatures that may be characteristic of kimberlites containing super-deep diamonds such as those in the Juína region (e.g., Cabral-Neto et al. 2023).

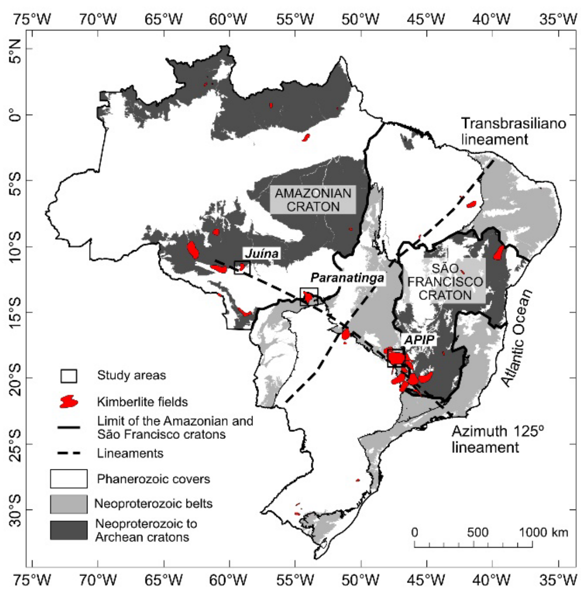

Figure 1: Simplified tectonic map of Brazil with the location of the study areas. Adapted from Bizzi et al. (2003)

Results

A total of 253 mantle zircon grains from kimberlites, diamondiferous streams, and diamond mines were analysed, including a major new dataset from Juína. These zircons typically range from 0.5 to 10.0 mm in length (occasionally up to 20 mm) and 0.2 to 8.0 mm in width, with most aspect ratios ≤1.5. The zircon grains are predominantly rounded, with reabsorption textures and relatively rare inclusions or cracks.

Our U-Pb LA-ICP-MS geochronology for all investigated zircons define four main age peaks for host kimberlite magmatism: approximately 78 and 86 Ma in APIP, around 92 Ma in Juína, and about 122 Ma in Paranatinga. Zircons have initial εHf values that range from +4.2 to +9.3 for Juína, +4.7 to +6.2 for Paranatinga, and -11.0 to 0.0 for APIP (Fig. 2).

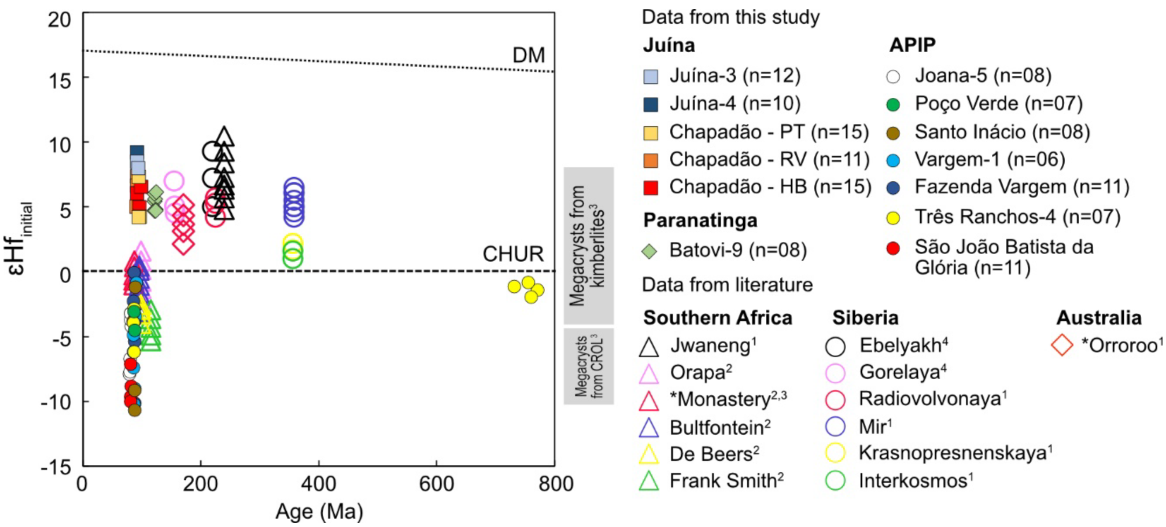

Figure 2: Initial εHf for zircon megacrysts from Juína, Paranatinga, and Alto Paranaíba Igneous Province (APIP). CROL = carbonate-rich olivine lamproite. Data sources: [1]Griffin et al. (2000), [2]Woodhead et al. (2017), [3]Nowell et al. (2004), [4]Sun et al. (2018). *Kimberlites with superdeep diamond occurrences (Shirey et al. 2024)

Intracrystalline variability was assessed through multiple (up to 4) analyses in single zircon grains, revealing no significant intracrystalline heterogeneity in $\delta^{18}O$ values. All analysed zircons fall within the 2SD range of the $\delta^{18}O$ average value for mantle zircons (5.3‰ ± 0.3‰; Valley et al. 1998) (Fig. 3). Zircons from Juína and Paranatinga have very similar average $\delta^{18}O$ values of 5.12 ± 0.02‰ (MSWD = 1.02, n = 77) and 5.07 ± 0.07‰ (MSWD = 0.44, n = 09), respectively. These values are notably lower than those observed in zircons from APIP, with average $\delta^{18}O$ = 5.38 ± 0.03‰ (MSWD = 1.31, n = 37), excluding slightly heterogeneous zircons from the São João Batista da Glória and Santo Inácio sites, with averages of 5.51 ± 0.11‰ (MSWD = 1.80, n = 9) and 5.32 ± 0.12‰ (MSWD = 3.90, n = 14), respectively.

Discussions and conclusions

The contrasting isotope compositions between zircons from the Amazonian craton and APIP indicate divergent magma origins from distinct mantle reservoirs. The Hf isotopic data indicate that zircon megacrysts from the Juína and Paranatinga areas exhibit signatures consistent with, or slightly more depleted than "primitive" kimberlites (Woodhead et al. 2019), pointing to derivation from a relatively homogeneous and pristine depleted deep mantle source with mildly super-chondritic hafnium isotopic compositions. In contrast, APIP zircons display hafnium characteristics typical of "anomalous" kimberlites, suggesting a source from mantle reservoirs "contaminated" by crustal recycling. Furthermore, the contrast in average $\delta^{18}O$ values between the Amazonian and São Francisco cratons suggests either distinct mantle reservoirs or different degrees of interaction with the isotopically heterogeneous subcontinental lithospheric mantle. Our dataset contains no clear discriminator between kimberlites containing abundant superdeep diamonds (e.g., Juína) and those with diamond suites dominated by lithospheric sources, though this is further investigated using zircon trace elements by Hardman et al. (this volume).

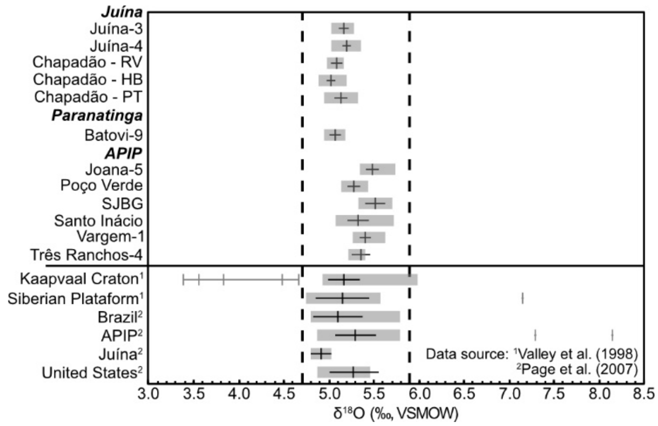

Figure 3: $\delta^{18}O$ values (‰, VSMOW) for zircon megacrysts from Juína, Paranatinga, and Alto Paranaíba Igneous Province (APIP). The black lines represent the average and 1SD, while the grey bars indicate the total range. Individual high and low $\delta^{18}O$ values from the literature are represented by grey lines. Dashed lines denote the 2SD range of the $\delta^{18}O$ average value for kimberlite zircon, which is 5.3‰ according to Valley et al. (1998)

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References

Bizzi LA, Schobbenhaus C, Gonçalves JH et al (2003) Geologia, Tectônica e Recursos Minerais do Brasil: texto, mapas e SIG. CPRM.

Cabral-Neto I, Ruberti E, Pearson DG et al (2023) Diamond sources of the Juína region, Amazonian craton: textural and mineral chemical characteristics of Kimberley-type pyroclastic kimberlites. Min Petrol, 118:1-22.

Griffin WL., Pearson NJ, Belousova E et al (2000) The Hf isotope composition of cratonic mantle: LAM-MC-ICPMS analysis of zircon megacrysts in kimberlites. Geochem Cosmochem Acta 64(1):133–147.

Hardman MF, Pearson DG, DuFrane SA et al (this volume) The origin of kimberlitic zircon and the search for a “fingerprint” for superdeep diamonds: enhanced classification of source rock using zircon trace element compositions and machine learning. 12th Int Kimb Conf: Ext Abstr.

Nowell GM, Pearson, DG, Bell DR et al (2004) Hf isotope systematics of kimberlites and their megacrysts: New constraints on their source regions. J Petrol 45(8):1583–1612.

Page FZ, Fu B, Kita NT et al (2007) Zircons from kimberlite: New insights from oxygen isotopes, trace elements, and Ti in zircon thermometry. Geochem Cosmochem Acta 71(15):3887–3903.

Shirey S, Pearson DG, Stachel T, Walter M (2024) Sublithospheric Diamonds: Plate Tectonics from Earth’s Deepest Mantle Samples. Ann Rev Earth Planet Sci 52.

Sun J, Tappe S, Kostrovitsky SI et al (2018) Mantle sources of kimberlites through time: A U-Pb and Lu-Hf isotope study of zircon megacrysts from the Siberian diamond fields. Chem Geol 479:228–240.

Valley JW, Kinny PD, Schulze DJ, Spicuzza MJ (1998) Zircon megacrysts from kimberlite: Oxygen isotope variability among mantle melts. Contrib Miner Petrol 133(1–2):1–11.

Woodhead J, Hergt J, Giuliani A et al (2017) Tracking continental-scale modification of the Earth’s mantle using zircon megacrysts. Geochem Perspect Lett, 4:1–6.

Woodhead J, Hergt J, Giuliani A et al (2019) Kimberlites reveal 2 billion years of evolution of a deep isolated mantle reservoir. Nat 573:578-581.