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Mantle compositional architecture and diamond potential for the Alto Paranaíba Igneous Province, Brazil: compositional signatures from garnet xenocrysts in kimberlites

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Introduction

The Alto Paranaíba Igneous Province (APIP), SW São Francisco Craton, Brazil, hosts important kimberlitic fields that are associated with historical alluvial diamond occurrences in the region. Diamond studies reveal the prevalence of lherzolitic and eclogitic diamond substrates, indicating that traditional exploration models, which focus on the presence of subcalcic garnets, may not be effective in this province. To better characterize the composition of the lithospheric mantle underlying the APIP and understand the implications for evaluating its diamond potential, we present results for mantle garnet xenocrysts from APIP kimberlites.

Materials and Methods

We present new data on garnet xenocrysts for major and minor elements, via EPMA, and trace elements, via LA-ICP-MS, from seven intrusions (Catalão-1a, -1b, Ilicínea, Pântano, Forca-01, Paraíso, and Romaria). We combine this with an extensive compilation of previously published and unpublished data on APIP garnet from 30 main intrusions (>3000 garnet analyses). The intrusions were grouped according to geographical proximity, being divided into five different fields: Três Ranchos, Pântano, Canastra, Ilicínea, and Divinópolis (**Figure 1**).

Mineral Chemistry

Most garnets are classified (using Grütter et al. 2004) as lherzolitic (G9; 81%), with subordinate harzburgitic (G10; 10%, mainly Canastra Field), pyroxenitic (G4), eclogitic (G3) and wehrlitic (G12) (**Figure 1**). The Ca-intercept values of APIP garnets (modes at 4.2 to 5%) are comparable to peridotitic garnets of cratonic and pericratonic settings, with the Canastra Field showing higher values, and the Três Ranchos field the lower ones.

Based on chondrite-normalized REE (McDonough and Sun 1995) distribution patterns, the APIP garnets were divided into three main subgroups:
(1) the main "normal" patterns, characterized by positive light-REE slopes coupled with flat to slightly positive slopes for the medium-REE and heavy-REE ($[Nd/Er]_N<0.4$; $[Er/Lu]_N\geq0.3$); this group has low to moderate Cr_2O_3 (0.01-7.8 mass%) and low $[Ti/Eu]_N$ ratios (0.2-1.4);
(2) “sinusoidal” REE patterns, with high $[Nd/Er]_N$ (1.0-7.3) and low $[Er/Lu]_N$ (0.1-0.4) ratios; this group has high Cr_2O_3 (6.0-10.4 mass%) and sub-chondritic $[Ti/Eu]_N$ values (0.6-2.7);
(3) mildly sinusoidal patterns, with $[Er/Lu]_N$ ratios (0.3-0.7) partially overlapping those of garnets with sinusoidal signatures but having lower $[Nd/Er]_N$ values (up to 1.3). These garnets show moderate to high Cr_2O_3 (4.1-9.3 mass%) and widely varying $[Ti/Eu]_N$ ratios range (0.1 to 2.9).

The Y (0.25 to 81.32 ppm), Zr (0.34 to 1367 ppm), and Ti (> 63.80 ppm) values and the $(Sm/Er)_N$ (0.02 to 4.84 ppm) and Ti/Eu (> 239.62) ratios of garnet xenocrysts indicate a depleted mantle source, influenced, to varying degrees, by silicate, carbonate and high-temperature metasomatism. Application of Ni-in-garnet thermometry (Nimis et al. 2024 and Stachel et al. 2022) indicates temperatures from 715°C to 1430°C. Projection of such temperatures onto a cold cratonic geotherm of ~39mW/m^2 (based on geothermobarometry on APIP pyroxene inclusions in diamonds) (Carvalho et al. 2022) (**Figure 2**) places the APIP garnets in a wide depth range of 85 to 215 km depth, partially overlapping the inclusion-based P-T range for APIP diamonds (Carvalho et al. 2022). Seven percent (11 of 157 peridotitic garnets) of the garnets are derived from the diamond stability field, indicating relatively inefficient sampling of the deep lithosphere.

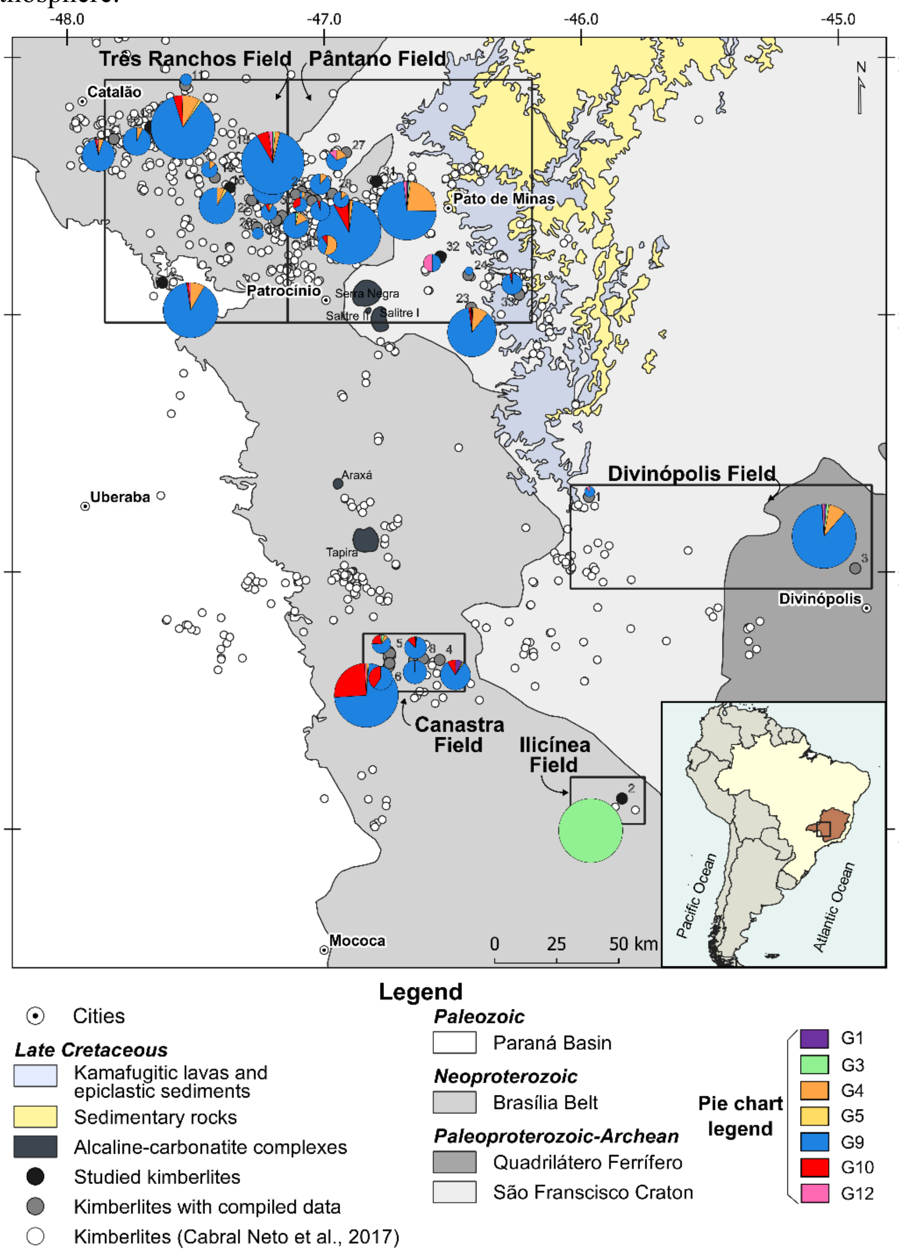

Figure 1: APIP simplified geological map (adapted from Cabral Neto et al. 2017). Pie charts indicate the proportion of different garnet types (Grütter et al. 2004) and their sizes proportionally reflect the data between kimberlites. Black dots indicate studied kimberlites, grey spots indicate kimberlites with compiled data and white dots indicate kimberlitic bodies. The five fields were divided based on the geographical proximity of the kimberlites. 1: Cana Verde; 2: Ilicínea; 3: Junco; 4: Canastra-1; 5: Canastra-18; 6: Canastra-3; 7: Canastra-35; 8: Canastra-5; 9: Canastra-8; 10: Abadia; 11: Boqueirão; 12: Catalão; 13: Catalão-1A; 14: Catalão-1B; 15: Forca; 16: Grota do Cedro; 17: Grotão; 18: Poço Verde; 19: Romaria; 20: Tamborete 1; 21: Três Ranchos-IV; 22: Santa Clara 23: Abel Régis; 24: Babilônia; 25: Canastrel; 26: Charneca; 27: Fosfértil; 28: Galeria; 29: Morungá; 30: Oswaldo França; 31: Pântano; 32: Paraíso; 33: Ponte Funda; 34: Rodrigues; 35: Vargem-1; 36: Vargem-2.

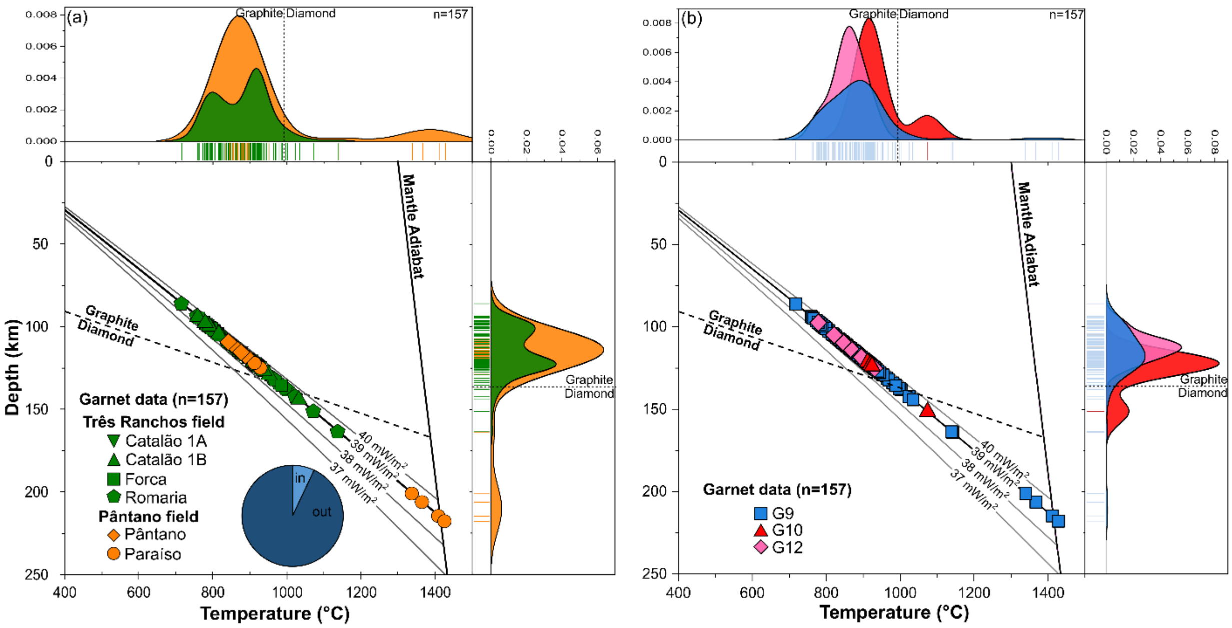

Figure 2: Projection of Ni-in garnet temperatures (Nimis et al. 2024) onto a typical cold cratonic geotherm (39 mW/m^2), according to (a) kimberlite and its respective field and (b) garnet type (Grütter et al. 2004). The pie chart (Figure 2-a) represents the data inside and outside the diamond stability field.

Implications for Diamond Exploration

Our new garnet compositions from the Catalão-1a, -1b, Ilicínea, Pântano, Forca-01, Paraíso, and Romaria kimberlites confirm the predominance of lherzolites in the mantle section underpinning the APIP, with subordinate metasomatized units and other mantle lithologies such as eclogite (5%). Recognizing the relationship of REE_N patterns observed in garnet xenocrysts and comparing them with diamond garnet inclusions will contribute to the development of an improved diamond exploration model for the APIP.

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References

Cabral Neto I., Nannini F, Silveira FV, Cunha LM (2017). Áreas kimberlíticas e diamantíferas do estado de Minas Gerais e regiões adjacentes: CPRM. Informe de Recursos minerais - Série Pedras Preciosas, n10, Projeto Diamante Brasil, Brasília.

Carvalho LDV, Stachel T, Pearson DG, Fuck RA, Jalowitzki T, Timmerman S, et al. (2022). Diamond formation beneath the Coromandel area, southwestern São Francisco Craton–The role of re-fertilization and subduction. Lithos 430:106856.

Grütter HS, Gurney JJ, Menzies AH, Winter F (2004). An updated classification scheme for mantle-derived garnet, for use by diamond explorers. Lithos 77(1-4):841-857.

McDonough WF, Sun SS (1995). The composition of the Earth. Chemical Geology, 120(3-4), 223-253.

Nimis P, Zanetti A, Franz L (2024). A revision of the Ni-in-garnet geothermometer with special regard to its pressure dependence. Lithos 468:107513.

Stachel T (2022). PTEXL - Geothermobarometry of Mantle Rocks. Borealis, V1. https://doi.org/10.5683/SP3/IMYNCL.