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Diverse petrogenesis of Neoarchean TTGs revealed by titanium stable isotopes

DR. LAURA M. SPENCER[1], HUGH SMITHIES[2], HELEN M. WILLIAMS[3], OLIVER NEBEL[4,5], IAN J. PARKINSON[6], JOHAN LISSENBERG[1] AND MARC-ALBAN MILLET[1]

[1]Cardiff University
[2]Geological Survey of Western Australia
[3]University of Cambridge
[4]GEOMAR Helmholtz Centre for Oceanic Research
[5]Monash University
[6]University of Bristol

Tonalite-trondhjemite-granodiorite (TTG) suites are the dominant constituent of Archean continental crust. Their trace element compositions show systematic variations typically interpreted to reflect metabasite partial melting at different pressures, with the low heavy rare earth element concentrations and high La/Yb, Sr/Y and Sr concentrations of some TTGs attributed to high pressure (≥2 GPa) melting. Recent studies challenge this interpretation, and some suggest a subset of "high pressure" (HP) TTGs with very high Sr concentrations and Sr/Y instead formed by hornblende-dominated fractional crystallisation of metasomatised mantle-derived sanukitoid magmas [1]. Titanium (Ti) stable isotopes are fractionated by crystallising Ti-bearing oxides and silicates during magma differentiation and can hence trace this proposed petrogenetic link between high-Sr HP TTGs and sanukitoids.

Here we present the Ti stable isotope compositions (δ^{49}Ti) of Neoarchean (~2650-2700 Ma) TTGs, including high-Sr HP TTGs, from the Eastern Goldfields Superterrane, Yilgarn Craton. They are spatially and temporally associated with the Black Flag Group (BFG) sanukitoids which are proposed to constitute the liquid line of descent linking these high-Sr HP TTGs to mantle-derived magmas [1], and were generated from a mantle source metasomatised by recycled eclogite melts [2]. The high-Sr HP TTGs plot at the evolved end of the δ^{49}Ti differentiation trend and Rayleigh fractionation model for the BFG, providing strong support for formation of high-Sr HP TTGs by amphibole-dominated fractional crystallisation of sanukitoid magmas in the Yilgarn Craton. Conversely, the δ^{49}Ti values of the other TTGs can be explained by the traditional model of partial melting of hydrous metabasite followed by fractional crystallisation. Our results thus reveal the diverse petrogenesis of Neoarchean TTGs. High-Sr HP TTGs are almost ubiquitous in Archean cratons, become abundant and widespread after ~3 Ga, and most are spatially and temporally associated with sanukitoids. These observations imply that high-Sr HP TTG formation by fractional crystallisation of metasomatised mantle-derived sanukitoid magmas was a global phenomenon that emerged in the late Archean due to a geodynamic transition that promoted interaction between recycled metabasite melts and mantle peridotite.

References:
[1] Smithies et al. (2019), Nat Commun 10, 5559
[2] Spencer et al. (2024), Earth & Planet Sci Lett 648, 119067