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First natural evidence of kinetic Eu anomalies in the Earth's mantle:implications for the interpretation of ghost plagioclase signatures in oceanic basalts

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Positive Eu and Sr anomalies in primitive lavas and melt inclusions are commonly interpreted as reflecting the presence of plagioclase-bearing oceanic crust in their source. These "ghost plagioclase" signatures document the impact of subduction recycling on the heterogeneity of the convective mantle (marble-cake model). Yet, their interpretations rely on the paradigmatic assumption that partial melts are generated in chemical equilibrium with their source, which is questioned by theoretical and experimental considerations. Diffusion rates of trace elements in mantle minerals are relatively slow compared to melt transport rates, suggesting that disequilibrium is the rule rather than the exception during mantle melting. Nonetheless, in the absence of direct field evidence, the paradigm has remained.

Here we report the first natural evidence of Eu anomalies developed kinetically in mantle peridotite clinopyroxene [1]. Extreme REE heterogeneity was observed in high-temperature (up to 1165°C) basalt-hosted xenoliths. Single <1-mm clinopyroxene crystals exhibit strong core-to-rim LREE fractionation accompanied by transient Eu anomalies [$(Eu/Eu^*)_N$ = 0.8-1.8]. Eu anomalies first increase with LREE enrichment and then markedly decreases with further enrichment towards the rims, which cannot be explained by chromatographic re-equilibration and require a kinetic process. Numerical modelling shows that diffusional fractionation between clinopyroxene and melt both devoid of Eu anomalies can generate the observed Eu anomalies without requiring plagioclase. We demonstrate that such anomalies may develop where low-degree, LREE-enriched melts percolate in the presence of small amounts of fast-diffusing Eu^{2+}, which is compatible with temperatures, redox conditions and transport timescales in MORB and OIB sources. We particularly envisage that this is likely to occur in the deep, volatile-induced melting regime beneath mid-ocean ridges. In the absence of converging lines of evidence, ghost plagioclase signatures should not be considered as an unequivocal proxy for the presence of recycled crust in oceanic basalt sources.

[1] Tilhac, R., Hidas, K., Oliveira, B. and Garrido, C.J. 2023. Evidence of ghost plagioclase signature induced by kinetic fractionation of europium in the Earth's mantle. *Nature Communications* (in press).

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