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Twin Flames in Deep Earth Volatiles: Heterogeneity from Accretion and Differential Stirring of Mantle Reservoirs

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Volatile elements (H, C, N, and the noble gases) provide crucial insights into the nature of materials accreted to the growing Earth [1-3], and into geodynamical processes that drive chemical exchange among terrestrial reservoirs [4,5] and generation of heterogeneities in Earth's interior [6,7]. High precision noble gas isotopic data have revealed intriguing, distinct sets of signatures in plume-influenced samples compared with samples of the upper mantle [7]. These signatures include early-formed heterogeneities (elemental abundance patterns [8-9] and radiogenic signatures from the I-Pu-Xe system [7,10]), and long-term signatures generated by mantle processing (*i.e.,* volcanic outgassing and regassing of atmospheric volatiles).

Within the current heavy noble gas dataset, the early-formed signatures seem coherently linked to the long-term processing signatures [6,10,11]. This is a curious observation, as totally different processes drive the generation of each set of signatures and there is no a priori reason to expect them to be coupled. If the coherence persists as new samples are measured, a mechanistic link, such as a difference in viscosity or density that dates back to accretion, is required.

To test the robustness of the linkage between early-formed and long-term noble gas signatures, we discuss new high precision data from the East Pacific Rise, Easter Seamount Chain, and Cook-Australs in the context of the global heavy noble gas dataset. To better understand the origin of the linkage, we use forward models of isotopic evolution to identify initial volatile budgets and mantle processing histories that can explain the modern and past compositions of plume-influenced and upper mantle sources. An initially-dry plume mantle best explains He, Ne, Ar and Xe compositions simultaneously.

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