Sr, Nd, Pb and Hf evidence for two-plume mixing beneath the East African Rift System

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The complexities of the East African Rift System revolve around two areas of mantle upwelling presently located beneath Afar (NE Ethiopia) and the Tanzania craton and their interaction with the overlying lithosphere. Over the past 40 million years, the thermal upwellings or plumes produced chemically distinct lavas in NE Ethiopia and Turkana (N Kenya) respectively, implying separate source regions. Prior to this study, there was no compelling evidence indicating any interaction between the two plumes. However, new Sr, Nd, Pb, and Hf isotopic data from three areas on the eastern Ethiopian plateau between Turkana and Afar suggesting the HIMU-like Turkana source contributed to 24-26 Ma magmatism in central Ethiopia, and its influence decreased from southwest to northeast Ethiopia. [1]

The origin and relationship between the two plumes are not straight forward. Based on its eruptive style and high $^3He/^4He$ ratios (R/Ra $\leq$ 19) the Afar plume likely originated as a classic deep-mantle thermal plume. [2] The HIMU signature manifest in 40-26 Ma Turkana lavas and 26-23 Ma Ethiopian lavas could be derived from either deep mantle recycling of oceanic crust or lithospheric melting. However, the presence of high-Ni olivine in both HIMU-like lavas in Turkana and Ethiopia suggest derivation from a pyroxenite source (recycled oceanic crust) instead of mantle peridotite. [3, 4] Lavas unequivocally associated with Afar do not contain high-Ni olivine. [5].

There are two plausible explanations for the mixing trends recorded in Ethiopian lavas: (1) the Turkana source experienced northward flow between 23 and 26 Ma, mixing with the Afar plume to produce the observed geochemical signatures, or (2) the Afar plume is more heterogenous than previously recognized, and the trends are mixtures of those heterogeneities. Spatial and temporal geochemical data appear to support the northward flow model.

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Refining sources and sinks in the global Molybdenum cycle

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Molybdenum (Mo) is the most abundant trace metal in the ocean and plays an important role in the nitrogen metabolism of planktonic organisms. Recently Mo isotope fractionation became more and more important as a new proxy for the oxygenation history of the oceans and atmosphere. In this context, it is important to establish the sinks and sources of the oceanic Mo cycle. In oxygenic water Mo exists as the molybdate MoO_4^{2-}. Mean Ocean Molybdenum (MOMO) has a concentration of 105nM and a heavy isotopic composition of $\delta^{98/95}Mo = 2.3‰$ relative to our standard [1].

The Black Sea is the archetype sink for anoxic and euxinic sedimentation. A detailed profile from the NW shelf to the deep Black Sea shows that Mo removal into surface sediments is related to the amount of free H_2S_{aq}. Complete fixation requires a critical H_2S_{aq} concentration (>11μM, [2]). Below this concentration, unreactive molybdate coexist with thiomolybdate, which causes isotope fractionation between sediments and bottom water.

Regarding Mo sources, the average Mo river influx to the oceans is less well established. Based on silicate rocks [1] and molybdenites [3] the Mo isotopic composition is assumed to be between -0.4 and +0.6‰. Our river results show variable $\delta^{98/95}Mo$, between 0 and 1.8‰. The range is similar to [4]; however, the variations we observe in both, $\delta^{98/95}Mo$ and Mo concentration, clearly indicate that several different processes are operating, suggesting that the modelling of [4] significantly underestimates the complexities of the riverine Mo system and thus global continental runoff. Further, in view of the heavy industrial use of Mo, it is essential to exclude anthropogenic effects to discriminate natural and anthropogenic Mo.

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