Evolution of deep mantle sources as inferred from Os-Nd isotope systematics of Archean komatiites

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We present ^{190}Pt-^{186}Os and ^{187}Re-^{187}Os isotopic and highly siderophile element (HSE) abundance data for eight well preserved komatiite systems from around the globe, including 3.6 Ga Schapenburg, 3.5 Ga Komati, 3.3 Ga Weltevreden, 2.9 Ga Kamennoozero, 2.8 Ga Kostomuksha, 2.7 Ga Belingwe, 2.7 Ga Abitibi, and 2.5 Ga Vetreny. These data provide important insights to the evolution of absolute and relative HSE abundances in the deep mantle throughout the Archean. Based on precise initial $^{186}Os/^{188}Os$ and $^{187}Os/^{188}Os$, models for the komatiite sources suggest long-term evolution to the times of melting with $^{190}Pt/^{188}Os$ and $^{187}Re/^{188}Os$ of 0.00183±15 and 0.412±8, respectively ($2\sigma_{mean}$). These source parameters are remarkably uniform and fall well within the range of those measured in chondritic meteorites. The evolution of the komatiite sources over >1 Ga generally shows no shifts in trajectory that would reflect major changes in Pt/Os or Re/Os, as might occur due to progressive melt extraction or crustal recycling. Over the same time interval, absolute HSE abundances in the komatiite sources increase. The trend, however, is far from linear; e.g. Pt abundances in the sources increase from 2 ppb to 6 ppb between 3.6 and 3.3 Ga and then level at 6 ppb through the rest of the Archean. In contrast, the komatiite sources were characterized by strong depletions in highly incompatible lithophile trace elements, as compared with chondrites. Sm-Nd isotopic data indicate evolution with time-integrated $^{147}Sm/^{144}Nd$ averaged at 0.214±3 and 0.209±1 for the early and late Archean systems, respectively. The collective Os-Nd results indicate that during the period of time examined, processes acting on the mantle sources affected Sm/Nd, yet did not substantially modify Re/Os or Pt/Os. These characteristics are consistent with mixing between two mantle reservoirs. The Sm-Nd constraints on the earliest reservoir are similar to the hypothesized Early Depleted Reservoir of Boyet and Carlson (2006). This could represent either a primitive early crust, or a reservoir created during magma ocean crystallization. The lower HSE, yet chondritic Re/Os and Pt/Os, would be consistent with the establishment of this reservoir by late accretion, but prior to accumulating a full complement of HSE. The second reservoir would potentially be representative of the upper mantle.

Chondritic-like xenon in the Archean atmosphere

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Xenon in the present-day atmospheric is depleted compared to lighter atmospheric noble gases and isotopically fractionated (i.e. enriched in heavy isotopes) by 3-4 % par amu related to condritic or solar Xe. Because it is the heaviest noble gas, any mass dependent process such as atmospheric escape would have resulted in the reverse situation, that is, bettter retention of Xe and lower isotopic fractionation of Xe compared to e.g. Kr. This observation, known as the xenon paradox is one of the most intersting problems in geochemistry. It has resisted decades of modeling efforts.

We have reported in [1] the analyses of xenon and other noble gases in meso-Archean sedimentary rocks (baryte and fluid inclusions in hydrothermal quartz) from North Pole (Pilbara, Australia), which show that Xe alone is isotopically fractionated and intermediate between chondritic and modern atmospheric compositions. This observation suggests that Xe isotopic fractionation, and, by inference, Xe depletion in the atmosphere was still ongoing 1 Ga after Earth's formation and was not limited to the Earth's building period as previously thought. In laboratory experiments, the only processes able to fractionate Xe isotopes at the percent level require ionization (e.g. [2]), suggesting that the fractionation of atmospheric Xe was related to the solar UV light during the first half of Earth's history. Independent evidence for deep UV penetration in the atmosphere stems from mass independent fractionation of sulfur isotopes trapped in Archean sedimentary rocks [3]. A delayed loss of atmospheric xenon has implications for the early evolution of Earth. The age of the Earth computed from retention of ^{129}Xe produced by the decay of ^{129}I ($T_{1/2}$ = 16 Ma) becomes ~50 Ma instead of ~110 Ma computed previously with the present-day inventory of atmospheric Xe. The depletion in the mantle and atmosphere of Xe isotopes produced by extinct ^{244}Pu ($T_{1/2}$ = 82 Ma) is more understandable if Xe loss continued well after the decay of plutonium-244.

[1] Pujol *et al.* (in press) *Earth Planet. Sci. Lett.* [2] Frick *et al.* (1979) *Proc. Lunar Planet. Sci. Conf. 10th,* 1961. [3] Farquhar *et al.* (2000) *Science* **289**, 756.