He, Ar and N isotopes in the sub-continental mantle as deduced from the ultramafic xenoliths of Southeastern Australia

Takuya Matsumoto [1], Daniele L. Pinti [2], Jun-ichi Matsuda [3], Akihiro Seta [1], Susumu Umino [4]

[1] Earth and Space Sci., Osaka Univ, [2] Groupe Geochimie des Gaz Rares Universite' Paris SUD XI, [3] Earth and Space Sci., Osaka Univ., [4] Dept. Bio. and Geosci., Shizuoka Univ.

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Elemental and isotopic compositions of helium, argon and nitrogen were determined for ultramafic xenoliths from Southeastern Australia. We found a correlation between the N2/36Ar and the 40Ar/36Ar ratios with one end-member being the present-day atmosphere and a second having elevated N2/36Ar and 40Ar/36Ar ratios, higher than the atmospheric ratios. Being this second component required to explain the N2/36Ar composition observed in MORBs, it may represent a global characteristic of the upper mantle and may record an elemental fractionation process during the early history of the earth. However, in order to explain slightly heavier nitrogen isotopic compositions in the xenoliths, we may need to have a recycled sedimentary component in addition to the MORB-like component.

The elemental and isotopic compositions of noble gases in mantle-derived samples have provided unique constraints on the evolution of the earth's geochemical reservoirs. Although equally important, the geochemistry of terrestrial nitrogen is still not well understood. The few existing studies on mantle nitrogen suggests the presence of a lighter N component having a delta 15N ranging from -5 permil (vs air) (observed in MORBs [1]) and -30 permil (observed in peridotitic diamonds [2]). This component may represent the N meteoritic precursor, fractionated by processes of degassing [1] or by recycling [3].

Here we attempt to characterize the mantle nitrogen by using mantle-derived xenoliths from the Australian subcontinental lithosphere. The samples belong to the Plio-Pleistocene Newer Volcanics in southeastern Australia. They are equivalent to the anhydrous lherzolites of [4] (or component A of [5]) which show a pure upper mantle He, Ne, Ar and Xe isotopic compositions. Based on those results, the noble gases in the continental lithosphere are interpreted as of metasomatic origin and derived directly from the underlying and well-mixed upper mantle reservoir. Therefore, it is expected that the xenoliths can be an alternative class of samples than diamonds, which could provide precise information on the mantle nitrogen beneath the continents.

Nitrogen and argon were extracted from olivine separates by vacuum crushing and analyzed by using a quadrupole mass spectrometer. Helium and argon isotopic ratios were also determined by using a noble gas mass spectrometer VG5400, after gas extraction by stepped pyrolysis. Preliminary results show a helium isotopic signature equal to that observed in MORBs (7-8 Ra) and 40Ar/36Ar ratios, higher than the atmospheric ratio (~4000). The 40Ar/36Ar ratios measured by crushing and stepheating are in agreement each other, indicating that the mantle-derived gases are mainly trapped in fluid inclusions. Thus, overall isotopic characteristics of noble gases in the present samples are consistent with the notion that the noble gases had been metasomatically transferred from the convective upper mantle to the shallower continental lithosphere [4].

In terms of elemental composition of nitrogen and argon, we found a correlation between the N2/36Ar and the 40Ar/36Ar ratios with one end-member being the present-day atmosphere and a second having elevated N2/36Ar and 40Ar/36Ar ratios, higher than the atmospheric ratios. This second end-member is likely to characterize the degassed upper mantle beneath the continental lithosphere. Being this component required to explain the N2/36Ar composition observed in MORBs [6], it may represent a global characteristic of the upper mantle and may record an elemental fractionation process during the early history of the earth.

In spite of the above elemental characteristics, supporting a presence of a convective mantle component in the continental lithosphere, the xenoliths do not show a pure nitrogen isotopic signature, as observed in MORBs. Xenoliths from Southeastern Australia show positive delta 15N values, which suggest the possible contribution of surface-related materials like sediments. If so, we might have observed a relict of an ancient sedimentary component recycled during Paleozoic, when the marginal arcs had accumulated to form the Australian continent. The argon and nitrogen isotopic compositions in xenoliths can be explained if 20-30 % of total N2 now found in the samples had been derived from a recycled sedimentary component.

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