5.1.14

Xe, mantle degassing, and atmospheric closure

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The extent of mantle degassing to form the atmosphere has been widely debated. Here the budgets of Xe isotopes produced early in Earth history from short-lived nuclides, ^{136*}Xe from ^{244}Pu ($t_{1/2}$=80Ma) and ^{129*}Xe from ^{129}I ($t_{1/2}$=16Ma), are examined. The budgets of Xe isotopes have been significantly altered by early losses to space, and the present budgets are used to constrain both the extent of mantle degassing and timing of these planetary losses.

Consideration of the terrestrial ^{244}Pu-derived fissiogenic Xe budget indicates only ~40% of the Earth's Xe has been degassed from the solid Earth. This value is consistent with the ^{40}Ar budget and requires that a large fraction of the mantle has remained inefficiently degassed. Using plausible alternatives to commonly used values for bulk Earth U and I concentrations, the Pu/U ratio, and atmospheric daughter Xe do not qualitatively change these conclusions. The extent of mantle depletion is largely dependent upon the Pu content, and a greater extent of mantle depletion is obtained if the initial Pu/U ratio is reduced proportionately; however, it remains substantially less than the total mantle for any reasonable Pu/U ratio. Also, any change in the initial Pu/U ratio must be accompanied by a similar change in the K/U ratio to keep the ^{40}K-^{40}Ar budget in line. Because of parameter independence, obtaining a much greater level of mantle degassing, and in particular achieving a high level of degassing throughout most of the mantle, is highly unlikely.

The atmospheric ^{129*}Xe/^{136*}Xe ratio corresponds to a model atmosphere closure age of 10^8 yrs. This is significantly after Moon formation, and it cannot be shortened by plausible changes in relevant parameters. Closure times are increased with decreased Pu/U ratio. While model closure ages assume efficient early loss followed by complete retention after instantaneous closure, more complicated loss histories would require extended loss and an even later time of final closure.

A consideration of all constraints strongly indicates that Xe was lost from Earth long after Moon formation, requiring another mechanism for atmosphere loss, and subsequently retained within a substantial fraction of the mantle. Changing these conclusions would require abandoning the commonly accepted, independently derived values for several parameters together, as well as regarding the consistency of the calculations using the commonly accepted values as fortuitous. Also, changes that allow for an increase in volume of degassed mantle extend atmosphere closure time, linking theories of these two Earth characteristics.

5.1.15

Contrasting origins of the upper mantle MORB source revealed by Hf and Pb isotopes from the Australian-Antarctic Discordance

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The Australian-Antarctic Discordance is the location of a geochemical and tectonic boundary between Indian and Pacific upper mantle domains. New Hf and Pb isotope results for mid-ocean ridge basalt (MORB) glasses from each domain define crossing mixing arrays that, when considered in light of Hf and Pb isotope data for other MORBs, ocean island basalts (OIBs), and lower crustal granulites (LCG), indicate that the upper mantle MORB source may be regionally polluted by different mechanisms. The Indian upper mantle in the AAD region is affected by delamination and/or entrainment of garnet facies continental material during rifting, while the Pacific upper mantle is dominantly affected by subduction-related processes.