Degassing history of the Earth

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The degassing history of the Earth is investigated through consideration of rare gas isotope abundances. Although the Earth is a highly degassed body, depleted in rare gases by many orders of magnitude relative to their solar abundances, it is at the present-day losing primordial rare gases which were trapped at the time of accretion.

The loss of rare gases from the Earth's mantle is directly related to mantle melting and the degassing of these melts at the surface. The present-day relationship between melting and degassing may be assessed given that the rare gases appear to behave as incompatible elements upon melting. It may eventually prove possible to relate evidence for higher loss rates of rare gases earlier in Earth history to amounts of mantle melting.

It is difficult to reconcile the differences in the Ne and Ar isotope composition between basalts erupted at ridges and at plume sites with anything but a convectively layered mantle structure, and one that has been so for most of Earth history. The small amount of ^{3}He and other primordial isotopes of Ne and Ar in the present-day upper mantle are accounted for by entrainment from the lower mantle. In the latter case entrainment of only ~1% of the lower mantle mass per Ga is able to provide the ^{3}He inventory in the upper mantle. The residence time of He in this reservoir is estimated at ~1 Ga [1] which is very similar to earlier estimates for the highly incompatible lithophile elements, U, Th, Pb [2]. However, the amount of these lithophile elements that accompany the introduction of ^{3}He into the upper mantle is too small to sustain their steady-state abundances. The continental lithosphere appears to be the major source of these lithophile elements.

The degassing of the Earth during accretion is constrained by Pu-U-I-Xe systematics. Degassing was much more efficient during the first 100-200 Ma than subsequently, and it was more complete for Xe than for the lighter gases [3]. More than 90% of the degassed Xe escaped from the atmosphere during this period. The combination of fractional degassing of melts [4] and rare gas escape from the atmosphere [5] is able to explain the deficit of terrestrial Xe as a simple consequence of this early degassing history.

By the time Xe was quantitatively retained in the atmosphere, the abundances of Kr and the lighter gases in the Earth's interior were similar to or higher than the present-day atmospheric abundances. Subsequent transfer of these lighter rare gases into the atmosphere requires a high rate of post-accretion degassing and melt produciton. Considerations of Pu-U-Xe systematics suggest that relatively rapid post-accretion degassing was continued to ca. 4.1–4.2 Ga.

References

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