Ar, Kr, and Xe composition of the Earth's mantle: Implications for the formation of the atmosphere

S. MUKHOPADHYAY

Dept. of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA; (sujoy@eps.harvard.edu)

Establishing whether the Earth's mantle has solar or planetary heavy noble gases is crucial for planet accretion models and understanding how volatiles were incorporated into the solid Earth. Furthermore, isotopes of Ar, Kr, and Xe that are not produced by radioactive decay, can provide a critical test for models that suggest the Earth's atmosphere was derived from mantle degassing. Here, I report new high-precision Ar, Kr, and Xe in gas-rich basalt glasses from the Atlantic and Pacific Ocean basins that indicate the atmosphere was not primarily derived from outgassing of the mantle.

The noble gases were extracted from fresh basalt glass by step crushing and measured using the Nu multicollector noble gas mass spectrometer at Harvard. Significant improvements in the measurments of heavy noble gases have been made in the Harvard laboratory that allow detection of small isotopic anomalies, of order few per mil, in Ar, Kr, and Xe.

Compared to atmospheric ratios of $^{124,126,128}Xe/^{130}Xe$, a clear excess in these ratios is observed in basalt glasses from both the Atlantic and Pacific basins. The maximum excess in $^{128}Xe/^{130}Xe$ was 18‰ and correlated with excess ^{129}Xe and ^{136}Xe. The $^{124,126,128}Xe/^{130}Xe$ ratios are consistent with mixtures of either air-solar or air-chondritic (Q) xenon. Solar Ar and Kr are significantly different in isotopic composition compared to their chondritic counterparts. Hence, isotopes of Ar and Kr could potentially fingerprint the excess xenon to be either solar or chondritic. The excess in non-radiogenic xenon isotopes is accompanied by air-like non-radiogenic Ar and Kr isotopes. The $^{38}Ar/^{36}Ar$ composition of the atmosphere is indistinguishable from chondritic, and while atmospheric Kr is isotopically heavier than chondritic, it is closer to chondritic than solar composition. It is possible that mantle Ar and Kr in the basalts were overprinted by air-contamination. While this possibility cannot be disproved, based on the excess non-radiogenic xenon isotopes and the high-precision measurements, I argue that Ar, K, Xe composition of the Earth's mantle is closer to chondritic than solar.

A chondritic composition for heavy noble gases in the Earth's mantle implies that degassing of the mantle followed by mass fractionation through hydrodynamic escape cannot generate the atmospheric Ne, Ar, Kr, and Xe isotopic compositions. Delivery of volatiles via late accreting planetesimals may better explain the origin of the terrestrial atmosphere. If the bulk of the present atmosphere was not derived from the mantle degassing, the excess ^{129}Xe in MORBs, compared to the atmosphere, cannot be used to calculate a degassing age for the mantle. Rather the excess ^{129}Xe simply indicates that the mantle and the atmosphere have evolved with different I/Xe ratios.

Hydrogen isotope variations in hydrated volcanic glass as tracers of late Cenozoic precipitation patterns in the western United States

A. MULCH[1,2], A.M. SARNA-WOJCICKI[3], M.E. PERKINS[4] AND C.P. CHAMBERLAIN[2]

[1]Institut für Geologie, Leibniz Universität Hannover, Germany; (mulch@geowi.uni-hannover.de)
[2]Geological and Environmental Sciences, Stanford University, USA; (chamb@pangea.stanford.edu)
[3]U.S. Geol. Survey, Menlo Park, USA; (asarna@usgs.gov)
[4]Geology & Geophysics, University of Utah, USA; (perkins@earth.utah.edu)

Volcanic ash deposits characterize large portions of the Miocene-to-recent sedimentary successions in the western United States. Within thousands of years after deposition at the Earth's surface, volcanic glass in these ashes incorporates relatively large amounts of water (3-5 wt.%). This hydration process provides a hydrogen isotope record that directly reflects paleoclimate and precipitation regimes. Once correctly correlated, widely distributed ashes may then serve as excellent paleoclimate and paleoaltimetry proxies as a) deposition and hydration are almost instantaneous on geologic timescales and can be dated with high temporal resolution and b) the chemical composition of the proxy is constant over large areas (100-100,000 km2) thus eliminating compositional uncertainties related to proxy formation. Here we present, hydrogen isotope data from volcanic glasses across the Basin and Range Province and relate the long-term changes in isotopic composition to changing surface topography and precipitation patterns. Glasses from individual ash layers found in the Central Valley (CA) strongly contrast those in the Northern and Central Basin and Range. Moreover, systematic variations in the dD of volcanic glass at various locations in the Basin and Range Province document the long-term interplay between regional changes in surface elevation, developing topography, and changing precipitation patterns.