Sr-isotopic evolution of the mantle

K. L. WEAVER AND D. J. DEPAOLO

Department of Earh and Planetary Science, University of California at Berkeley, Berkeley, CA 94720 USA (karrie@eps.berkeley.edu)

The composition of the mantle is dynamic, and has changed greatly over the history of the earth. Extraction of melt from the mantle during crustal formation causes major chemical depletions; input of crustal material at subduction zones introduces enriched material back into the mantle. Both processes generate heterogeneities, and have been active for the last 4 billion years. Sampling of mantle-derived rocks that span much of Earth's history allow us to estimate the composition of the mantle in the past.

Nd, Hf and Sr isotope systems can be used as tracers for processes such as melting and recycling. Measurements of Nd and Hf isotopes in rocks from 0 to 3800 Ma allow us to construct a 'mantle evolution curve' that maps out the isotopic composition of the mantle over time. The data in this curve serve as the main constraint on models of crustal growth and formation and the depletion and composition of the mantle. The relative behaviors of Nd, Hf and Sr in modern mantle-derived rocks are well understood, and it would seem that the Sr-isotopic evolution curve could be used in conjunction with Hf and Nd to provide additional model constraints. Unfortunately the Sr data on ancient rocks are sparse, and often considered unreliable. When available Sr data are considered, they do not behave as expected based on complimentary Nd and Hf data. At 3.8 Ga the Nd isotopic values for mantle-derived rocks depart by as much as 4 epsilon units from the bulk earth value. This indicates a depletion of the mantle with respect to Nd. In contrast, the epsilon Sr of mantle-derived rocks show no record of an early depletion; the mantle epsilon Sr follows the bulk earth value until about 2.7 Ga.

In this study we begin to examine the Sr-isotopic composition of a variety of juvenile rocks. To try and determine the effect of post-emplacement alteration, a variety of mineral phases are analyzed, including low-Rb phases such as apatite. A more comprehensive understanding of the Sr-isotope composition in ancient rocks may allow us to better estimate the relative importance of melting and subduction in the early mantle – the main processes responsible for chemical heterogeneity.

Deep mantle heterogeneity, anisotropy, and thermochemical piles

E.J. GARNERO[1], D.V. HELMBERGER[2] AND A. MCNAMARA[1]

[1]Department of Geological Sciences, Arizona State University, USA (garnero@asu.edu, Allen.McNamara@asu.edu)
[2]Seismological Laboratory, California Institute of Technology USA (helm@gps.caltech.edu)

Seismologists have long characterized Earth's lowermost mantle as far from simple homogeneity. Models based on seismic data include sharp horizontal discontinuities, strong anisotropy, thin ultra-low velocity zones (ULVZ), and sharp vertical boundaries between normal and low velocity mantle. The scales of heterogeneity span several orders of magnitude (a few to 1000's of km). This diversity of structures is beginning to be understood in terms of geodynamics and mineral physics, with dense partial melts causing the ULVZs, a post-perovskite solid-solid phase transition producing regional layering, and the possibility of large-scale variations in chemistry, such as distinct and dense thermo-chemical piles which can guide plume initiation near its boundaries.

Three regions will be highlighted in this presentation: the lower mantle beneath South Africa, the Pacific, and the Caribbean. The first two represent low shear velocities that correlate with surface hot spots, the latter is high velocity and underlies subduction. Seismogram record sections show travel time offsets and waveform complications that require nearly vertical walls separating the anomalously slow structure from normal mantle. Data sampling the African superplume are best fit by ~1200 km wide low velocities extending up to 1000 km above the CMB. The clearest detection of ULVZs may be near the edges of these low velocity structures, consistent with plume genesis there. Many seismic data and modeling examples will be presented.

We also present thermochemical convection calculations with temperature- and depth-dependent rheology, that employ surface boundary conditions consistent with Earth's recent plate history. Initial calculations predict that dense piles develop with remarkable resemblance to the geometry of present day seismic low velocity provinces providing us with first-order thermochemical models that may be used to better understand lower mantle heterogeneity. In addition, we find that the observation of plumes statistically residing at the edges of large, negative seismic anomalies may be geodynamically supported.