Isotopic Constraints on Archean Mantle Dynamics

SW Parman, Dept. Earth Sciences, Durham University, Science Labs, South Rd., Durham, DH1 3LE, UK, email: stephen.parman@durham.ac.uk

Radiogenic isotopes provide powerful constraints on the evolution of the Earth because they record time. More than any other observational method, geochemistry allows us to ask the question 'When?' This ability has lead to an extremely detailed understanding of how the Earth's crust has evolved physically and chemically, and has allowed us to probe even its earliest beginnings as zircons as old as 4.4 Ga have been identified [1]. One of the primary results of this research has been to quantify the distribution of crustal ages. The fundamental observation is that not all ages are equally represented. In particular, there are four time periods that are grossly overrepresented: 1.2, 1.9, 2.7 and 3.3 Ga [2, 3]. These are the ages of the cratons.

While the observation is clear, its interpretation is not. One possibility is that these peaks in area versus age record pulses of continental crust (CC) growth [4]. Such CC production events would imply large dynamic events in the mantle. However, another interpretation is that erosion destroys most CC, and that the peaks are artifacts of preservation and the cratons just the scraps that have randomly escaped destruction by plate tectonics [5]. In this case, there is no direct evidence about mantle dynamics in the CC age spectrum. At some level, the CC data will always be ambiguous as it is both the data and the means of recording the data. Thus gaps in data can either be real or just when the recording was erased. What is required is an independent record of crust production, preferably one from the mantle itself.

Based upon their trace element composition, it is clear that the CC was extracted from the mantle by melting [6], and so should have left an isotopic fingerprint of its extraction in the mantle. But evidence for such a fingerprint has remained elusive. In general, asking 'When?' has not been very successful in the mantle. Subduction and mixing seems to have been very efficient at erasing the early isotopic record of Earth evolution in standard isotopic systems such as Sr, Nd and Pb. These systems have not yielded very clear answers to the questions about the timing of mantle depletion [7]. However, there are two, relatively new isotopic systems (He and Os) that, due to their distinct chemical behavior, offer hope of unlocking the early melting history of the mantle.

In this talk I will review the He and Os records of mantle melting and how they relate to the early geodynamics of the planet. In particular, both isotopic systems appear to preserve abundance peaks at the same ages as the CC area peaks. There are a number of ways to interpret this correspondence (including random coincidence) and even the data themselves are controversial. However, an attractively simple hypothesis that relates all three data sets is that there were global melting events in the mantle at those times [8]. These events would have produced large volumes of melt (recorded as pulses of CC growth) and proportionally large volumes of melt-depleted mantle (recorded in mantle He and Os isotopes). This hypothesis suggests a very catastrophic (as opposed to uniformitarian) evolution of the Earth, one dominated by a few large events. Given the size of the events, their ultimate cause would have to have been related to mantle dynamics. Geodynamic models of mantle convection have produced such episodic behavior under a range of conditions [9]. Whether or not this idea is eventually confirmed, the He and Os isotopic systems provide fundamental information about early mantle dynamics.

References: **[1]** Wilde, S.A., et al., Nature, 2001. 409: 175-178. **[2]** Condie, K.C., Earth Planet Sci Lett , 1998. 163: 97-108. **[3]** Kemp, A.I.S., et al., Nature, 2006. 439: 580-583. **[4]** Taylor, S.R. and S.M. McLennan, Rev Geophys , 1995. 33: p. 241-265. **[5]** Bowring, S.A. and T. Housh, Science, 1995. 269: p. 1535-1540. **[6]** Hofmann, A.W., Earth Planet Sci Lett, 1988. 90: p. 297-314. **[7]** Zindler, A. and S. Hart,. Ann Rev Earth Planet Sci, 1986. 14: p. 493-571. **[8]** Parman, S.W., Nature, 2007. 446(7138): p. 900-903. **[9]** Davies, G.F., Earth Planet Sci Lett, 1995. 136: p. 363-379.