Ultradeep and oceanic domains of ancient lithospheric blobs: consequences for basalt source regions and geodynamics.

Suzanne Y. O'Reilly[1], William L. Griffin[1,2], Ming Zhang[1] and S. Grand[3]

1. GEMOC, Department of Earth and Planetary Sciences, Macquarie University, NSW 2109, Australia
2. CSIRO Exploration and Mining, North Ryde, NSW 2113, Australia
3. Department of Geological Sciences, University of Texas at Austin, 78712-0254 USA

Xenolith data reveal significant differences in composition and physical properties between Archean and Phanerozoic mantle (Griffin et al., 1999); much intermediate "Proterozoic" mantle may represent reworked Archean material. Although depleted ancient SCLM cannot be recycled through convection due to its low density (eg O'Reilly et al., GSA Today, 2001), truly pristine Archean mantle may be very rare as these buoyant blobs undergo repetitive geochemical transformation to varying degrees. Extensional regimes, including the formation of oceanic lithosphere, will mechanically disrupt ancient low-density lithosphere, forming discrete domains embedded within newly-formed lithospheric mantle.

High-resolution seismic tomography images show low-density regions both in oceanic upper mantle and below the conventional lithosphere-asthenosphere boundary (LAB) beneath continental and especially cratonic regions. These coherent low-density domains appear to persist, in some cases, down to the transition zone beneath some continental cratonic regions.

Large coherent domains with the seismic properties of depleted lithospheric mantle are clearly delineated in high-resolution tomographic images beneath the Atlantic Ocean, to depths greater than 100-150 km (deeper than oceanic lithosphere limits). Such domains can be interpreted as ancient subcontinental lithospheric mantle (SCLM) disrupted during the extension that formed the ocean basin, analogous to the relict domains of Archean mantle identified seismically and geochemically in the younger replacement lithosphere beneath the North China Craton (summary in O'Reilly et al., GSA Today, 2001) and the Proterozoic lithospheric mantle domains identified in the highly extended region of the Taiwan Strait (Wang et al., Geology, 2003).

The possible occurrence of significant volumes of ancient SCLM in oceanic lithosphere (and below) and the ultradeep extensions of deep continental roots have important consequences including:

1). Basaltic magmas in the Atlantic Ocean spatially coincident (at eruption time) with the tomographic domains identified as old SCLM, carry geochemical signatures traditionally attributed to "mantle sources" such as EM1, EM2, HIMU; some have also been shown to have Os-isotope compositions characteristic of ancient lithospheric material (eg Schaefer et al., Nature, 2002). Such signatures have been identified in continental lithosphere (represented by xenoliths; eg Zhang et al., J. Pet., 2001; Choukroun et al., Geology, 2004). Basaltic magmas distant from the low-density domains do not carry such geochemical imprints, suggesting the origin of the "lithospheric" components in some basalts is due to interaction with the deep ancient SCLM remnants.

2). These observations of oceanic blobs and old ultradeep continental root extensions imply that old lithospheric mantle is much more extensive, both laterally and vertically, than previously considered, and suggest greater volumes of lithosphere formed in the Archean than conventionally acknowledged.

3) Ultradeep SCLM domains have important implications for the nature of global convection. Upper-mantle convection may be constrained to upwelling vertical conduits with shallow horizontal flow. The locus of these conduits may be controlled by the geometry of the margins and the coherence of the buoyant lithospheric mantle. The convective plate motions in the upper asthenosphere are "eddies" between these buoyant domains and can be preserved

in the observed plate stress directions and anisotropy (eg Simons and van der Hilst, EPSL, 2003).