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Basalts as Probes of Global Convection and Regional Geochemical Domains in the Mantle beneath Australia

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The global-scale mantle convection cells in the asthenosphere are not geochemically homogeneous. The heterogeneity is most prominently reflected in the isotopic compositions (Pb-Sr-Nd) of mid-ocean ridge basalts (MORB) that are direct partial melts from the underlying asthenosphere. Of particular relevance to Australia's geodynamic evolution from about 100 million years, is the distinctive geochemical signatures of Pacific Ocean MORB and Indian Ocean MORB). Delineation of the boundary between these two distinct mantle reservoirs and any change in that boundary with time provide information about the patterns of global-scale mantle convection. This information has also allowed us to track large-scale mantle chemical reservoirs such as the distinctive Gondwana lithospheric mantle, and hence better understand the geodynamic evolution of the Australian continent from the time of Gondwana dispersal.

Pb-Sr-Nd isotope data for Cenozoic basalts in eastern Australia (Zhang et al, 1999) show that Pacific-MORB type isotopic signatures characterise the lava-field basalts (55-14 Ma) in southeastern Australia, whereas Indian-MORB type isotopic signatures characterise younger basalts (6-0 Ma) from northeastern Australia. This discovery helps to constrain the changing locus of the major asthenospheric mantle convection cells represented by the Pacific and Indian MORB sources during and following the breakup of the eastern part of Gondwana, and locates, for the first time, the boundary of these convection cells beneath the Australian continent. This extends previous work in the SW Pacific back-arc basins (eg Hickey-Vargas et al., 1995) and the Southern Ocean (Lanyon et al., 1995) that indicates that the I- and P-MORB mantle convection cells have been moving in opposite directions since the early Tertiary. These new data also indicate that the Indian-MORB source is a long-term asthenospheric reservoir beneath most of the Gondwana lithosphere and that the westward migration of the Pacific MORB source may have been associated with the Tasman Sea opening (ca 85-60 Ma) along a broad front southeast of the Australian continent.

Australian basalt provinces also show different regional geochemical fingerprints that reflect lithosphere compositional domains observed in xenoliths from lithospheric mantle. These lithosphere fingerprints are superimposed on the main geochemical signatures inherited from different proportions of sources from the asthenosphere and the Australian plume as the Australian plate has tracked northwards over the last 40 Ma. The geochemical characteristics of each lithospheric domain are the combined imprint of different episodes of anatexis and fluid fluxes (metasomatism) of different origins (including primitive mantle fluids and subduction-derived fluids), related to different mantle tectonic events through time. Each major episode appears to have resulted in distinctive geochemical signatures and a given lithospheric domain may record multiple events.

For example, the New South Wales basalts have lower ε_{Nd} values at given $^{87}Sr/^{86}Sr$, and higher $^{206}Pb/^{204}Pb$ but lower δ 4Pb and δ 6/4Pb values than the North Queensland basalts. These contrasts in Sr-Nd-Pb isotopic trends not only reflect the influence of the Pacific- and Indian-MORB mantle convection cells, but also the principal regional geochemical heterogeneity of the lithospheric mantle domains (EM1 for New South Wales and EM2 for North Queensland).

The Sr-Nd-Pb isotopic trends for younger North Queensland basalts can be explained by mixing of Indian MORB and EM2-type lithospheric mantle sources derived from late Paleozoic regional orogenesis. The HIMU-type incompatible element signatures shown by some highly undersaturated North Queensland basalts (eg low K/Nb of 80-140 and high-μ of 75-172) may have been generated from amphibole- and apatite-bearing lithospheric mantle affected by (N 40 Ma) metasomatism due to the early Tertiary subduction of the Phoenix-Pacific plate. In contrast, the older (44-25 Ma) Mingela basalts have OIB-like smooth incompatible element patterns and Sr-Nd-Pb isotopic signatures requiring contributions from the Australian plume and an EM2-type lithospheric mantle.

Characterising the trace element and isotopic compositions of lithospheric mantle xenoliths and primitive basalts from the same region and integrating with tectonic information allows us to start to unravel this complex of processes and assess their significance for particular lithospheric domains.

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