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The Role of Lithospheric Mantle in Continent Stability: Re-Os Isotopic Mapping of the Upper Mantle in Southwestern USA

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Compared to interplate deformation, the factors that govern where intra-continental deformation occurs are not well known. For example, in the Cordilleran orogeny of western North America some regions, such as Mojavia in southeastern California, suffered extensive crustal reworking, whereas other regions, such as the Colorado Plateau, remained tectonically stable, despite being an island of stability within the orogenic belt. One possibility for the variable behavior is a difference in the thickness and viscosity of the mantle lithosphere underlying these provinces. Using thermobarometry and Re-Os isotopic systematics of peridotite xenoliths erupted in Miocene lavas, we find that reworked Mojavia block is underlain by ~20 km of ~2.3-2.5 Ga lithospheric mantle (LM), and that the stable Colorado Plateau is underlain by ~100 km of ~1.8 Ga mantle (Fig. 1), indicating that Archean lithosphere is not necessarily more stable than post-Archean lithosphere, as commonly believed. Instead the LM beneath Mojavia is more Fe-rich, and hence denser, relative to that beneath the Colorado Plateau and stable Archean cratons (Fig. 2). If the LM meets the isopycnic condition (Jordan, 1988), that is the negative buoyancy imposed by its colder thermal state is compensated by an intrinsic buoyancy due to compositional differences, then LM poorer in Fe allows for the stabilization of a thicker, stronger thermal boundary layer (TBL), as shown in Fig. 2. In addition, the partial melting required for making Fe-poor mantle also results in dehydration, which further strengthens the mantle by increasing its intrinsic viscosity (Pollack, 1986; Hirth and Kohlstedt, 1996). Thus, the presently thin and Fe-rich Mojavian LM may have initially been thinner and weaker than that beneath the Fe-poor Colorado Plateau, explaining why the former was more extensively reworked. Alternatively, the thin nature of Mojavian lithosphere may result from convective disruption associated with the Cordilleran orogeny, but even so, its susceptibility to disruption may have ultimately depended on its more Fe-rich character. We conclude that intra-continental deformation is intimately linked to the composition (and nature) of the underlying LM. A corollary of our observations is that ancient LM persists even in highly tectonized regions, although delamination of LM may still occur on the edges of continents, as recently shown by Kay and Kay (1993) and Lee et al. (2000).

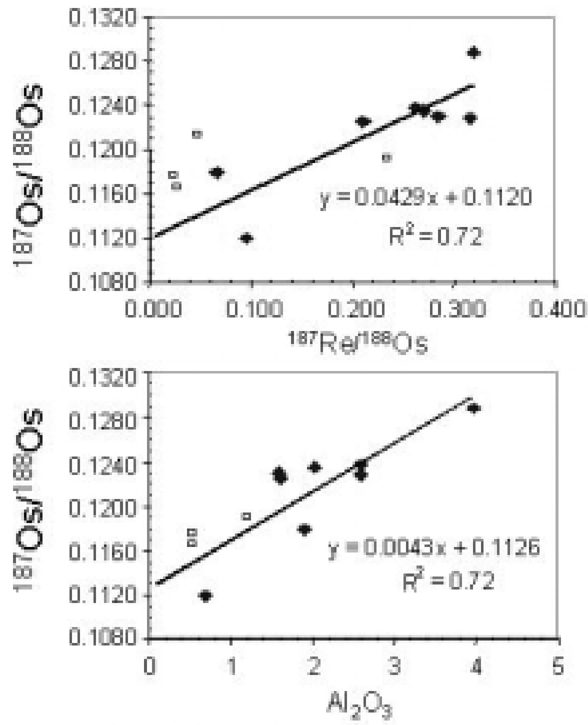

Fig. 1. $^{187}Os/^{188}Os$ versus Al_2O_3 and $^{187}Re/^{188}Os$ for xenoliths from Mojavia (filled diamonds) and the Colorado Plateau (open squares). Line is regressed through Cima data only.

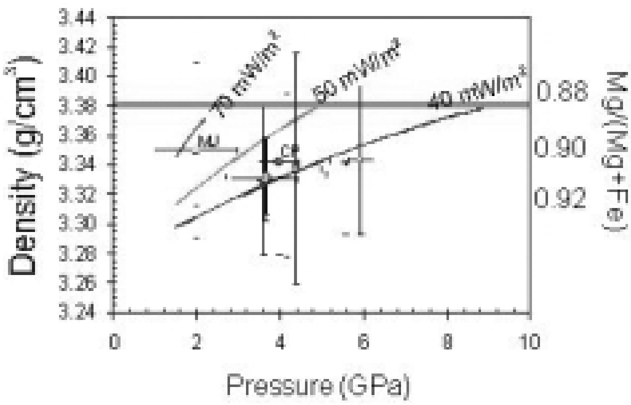

Fig. 2. Isopycnic curves for LM that is neutrally buoyant in the asthenosphere. Curves are for different thermal states of the lithosphere (e.g., different TBLs), assuming asthenosphere with 1300 °C potential adiabat. Densities are at STP conditions using linear combinations of mineral densities, end-members, and mineral modes. Thick horizontal line = density of pyrolite. Data are for Archean cratons except for MJ=Mojavia, CP=Colorado Plateau.

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