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Osmium isotope evidence for rapid melt migration towards the Moho in the Oman ophiolite

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Melt migration processes in the mantle, particularly beneath mid-oceanic ridges, remain largely debated. Ophiolites are ideal sites for studying these processes and contain dunitic bodies, formed by pyroxene dissolution and olivine precipitation during interaction of the host peridotite with basaltic liquid. This study explores the relationship between dunite distribution and melt transport to the ridge in the mantle section of the southeastern Oman ophiolite.

Structural observations are combined with geochemical data on dunites and their host harzburgites allowing identification of three dunite types: (1) dunites of the Moho Transition Zone (MTZ), a melt storage and reaction zone located immediately below the crust, (2) dunite veins and bands, scattered throughout the main harzburgitic mantle section (MMS), and (3) abundant dunitic bands in the banded unit above the basal thrust of the ophiolite.

Our geochemical work focused on osmium isotopes, particularly suited for tracing melt flow through mantle peridotites. Harzburgites have fairly homogeneous $^{187}Os/^{188}Os$ ratios (0.1131 to 0.1345), similar to abyssal peridotite values, throughout the whole mantle section. In contrast, dunite compositions are strongly correlated with their structural context. Basal dunites have highly residual character (e.g. high Mg#) and Os isotopic compositions (0.1165 to 0.1280) equivalent to those of their host harzburgites, implying formation from these harzburgites by interaction with only small melt fractions. MMS dunites have more radiogenic Os compositions (0.1249 to 0.1330), differing from those of adjacent harzburgites, suggesting more extensive melt interaction. MTZ dunites display low Os concentrations (0.39 to 2.30 ppb) coupled with very high $^{187}Os/^{188}Os$ ratios (0.1319 to 0.1490), close to those of the overlying crust. Their osmium isotope compositions exceed those of MORB and require extensive interaction with melts more radiogenic than MORB and probably derived from a slab. Modeling demonstrates that melt percolation through dunite channels cannot deliver melts with Os compositions equivalent to those of MTZ dunites and Oman lower crust: melt compositions would lose their radiogenic character during percolation due to interaction with Os-rich peridotite. We conclude that melt migration, from the mantle source to the Moho, occurred without equilibration with dunite or harzburgite, and was therefore rapid, or at least chemically isolated.