Microstructural & geochemical evolution of the deep arc lithosphere: implications for seismic discontinuities beneath continents

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Lower crustal and upper mantle xenoliths provide the only direct samples of deep lithosphere, and therefore play an essential role in understanding lithospheric structure. We examine the microstructural and geochemical evolution of peridotite xenoliths from the Sierra Nevada, a Mesozoic continental arc. These xenoliths represent an arc mantle column grading from depleted spinel peridotite characterized by strong orthorhombic olivine LPO to fertile garnet peridotite with weak axial-[010] LPO. In contrast to observed nominally dry axial-[010] LPO, intragranular olivine microstructures indicate deformation under hydrous conditions (in which the (001)[100] system is dominant). However, water contents in olivine are too low to account for E-type fabric. These seemingly contradictory results can be reconciled in the context of the Sierran peridotites’ P-T-t path, which was found to consist of initial lithosphere formation via melt depletion at shallow (<2 GPa) depths followed by thickening, modal metasomatism (involving a hydrous melt), and final equilibration and rapid cooling (~5 My) at deep (>3 GPa) and cold (750 –800 C) conditions. We propose that melt infiltration and associated precipitation of fine-grained pyroxene and garnet facilitated grain-size sensitive creep, localizing deformation in fine-grained regions and resulting in weak, axial-[010] LPOs in the most metasomatized peridotites. So, even though (001)[100] slip may have been the dominant active slip system, E-type fabrics were not produced because the overall LPO was dominated by grain-size sensitive creep promoted by presence of melt. Subsequent cooling resulted in water loss from olivine owing to the drastic lowering of solubility with decreasing temperature. However, final temperatures were too low (750 C) to enable significant deformation –effectively preserving the relict intragranular (001)[100] microstructures. Our study has implications for seismic structure of subduction zones globally. We show that overriding plate lithosphere –an often overlooked aspect of the subduction system –is stratified in terms of composition and fabric. The transition from orthorhombic E-type to weak axial-[010] fabrics results in a significant decrease in Vp anisotropy. Seismic anisotropy in subduction zones is complex, and thus the interplay between compositional gradients and cooling histories of mantle lithosphere need to be considered when interpreting subduction zone structure.

Keywords: subduction, peridotite, xenolith, LPO

