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Chemical gradients and progressive veining in a partly serpentinized harzburgite

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Serpentinized ultramafic rocks constitute a major part of the oceanic lithosphere. They form when water interacts with olivine and pyroxene to produce a dense network of veins comprised of secondary minerals: Serpentine + brucite ± magnetite veins occur in olivine, Al-rich serpentine + talc veins occur in orthopyroxene, and Al-rich serpentine ± talc ± brucite veins occur at the boundary between orthopyroxene and olivine. Here, we present a detailed study on a harzburgite from the Santa Elena Ophiolite in Costa Rica that is ~30% serpentinized in order to provide new constraints on the effect of variable water (H_2O) and silica (SiO_2) activities on vein formation in peridotites.

The studied sample records 1) mineralogical and chemical zonations in olivine-hosted veins that show a distinct pattern with increasing width of the veins (consumption of olivine), 2) varying brucite composition depending on whether or not it is associated with magnetite, and 3) chemical gradients in Si, Al, Cr, and Ca at the boundary between orthopyroxene- and olivine-hosted veins. These observed chemical variations suggest fluid mediated mass transport within and between orthopyroxene- and olivine-hosted veins. We use thermodynamic models to show that an increase in vein width and progressive evolution of olivine-hosted veins is accompanied by an increase in water-rock ratios. This is associated with the development of chemical gradients (e.g. gradients in water and silica activity) between the fluid-rich center of serpentine veins and the olivine grain boundaries as typically expressed by the abundance of brucite in the vein center and a dominance of serpentine at the boundary with olivine. The increase in water-rock ratios within the vein center also leads to the formation of magnetite from Fe-rich brucite ± Fe-rich serpentine. Mass transfer between vein core and vein rim may exist on the submicron-scale along grain boundaries of the finely intergrown serpentine-brucite mixture. We imply that local chemical equilibria exist within olivine-hosted veins and that chemical gradients control the mineral assemblages during hydration of ultramafic rock. Thus, these chemical gradients may have major implications on the petrophysical evolution of the oceanic lithosphere.