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Fracture network and serpentinization at oceanic spreading ridges: in-situ observations and comparison with a fossilized system

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The efficiency of water transport to reactive peridotite is commonly the limiting factor for serpentinization of the lithospheric mantle to happen. This hydration process is typical of the oceanic lithosphere due to its thin crust and active fracturation, continuously creating new pathways for seawater, at ridge axis and subduction zones. Consequently, the extent of serpentinization is closely coupled with the intensity of the tectonic activity.
Our study focuses on two sections of the South West Indian oceanic ridge, an ultra-slow spreading ridge. The very low melt production along this ridge type leads to extreme extensional regimes dominated by either magmatic or tectonic processes; this makes ultra-slow spreading ridges an ideal system to study the impact of magmatic vs tectonic extension on serpentinization along ridge axis. Three extensional regimes have been identified: volcanic, where the melt focuses leading to an up to 8 km thick basaltic crust, magmatic, characterized by a thin basaltic crust and deep seismic activity (down to 30 km depth), and amagmatic, characterized by peridotite covering the seafloor and even deeper seismic activity (down to 35 km depth). Aseismic zones are present at the surface of the magmatic and amagmatic regimes, likely associated with extensive serpentinization and efficient water supply. Based on seismic activity, we estimate that brittle damage can maintain high permeability in the case of the amagmatic and magmatic regimes while it is limited in the case of the volcanic regime. Our results indicate that oceanic ridges with spreading rates slower than 20 millimetres per year store at least 0.10 km3 of water per year in the oceanic mantle due to serpentinization.
We compare these results with observations from serpentinized samples obtained during the 2018 Oman Drilling Project Phase 2. Samples have been drilled down to 400 m deep in the Oman Samail ophiolite and are composed of partially to completely serpentinized lithospheric dunite and harzburgite crosscut by multiple generations of magmatic dykes and serpentine veins. While the story of these rocks is complex, it is still possible to identify early features associated with on axis events. In agreement with our assumption that serpentinization is controlled by seismic damage, early fractures are commonly associated with enhanced serpentinization. We observe the dykes as being supplementary pathways for fluids.