Strain localization processes at a magma-starved ridge: from micro-scale to macro-scale

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The easternmost part of the Southwest Indian Ridge (SWIR) is characterized by a very low melt-supply. Magma is focused along axis at discrete volcanic centers, leaving large portions of the seafloor where plate divergence is accommodated by large offset normal faults, also called detachment faults. These faults exhumes mantle-derived samples on the seafloor. Microseismicity indicates a brittle lithosphere up to 25 km thick (Schlindwein & Schmid, 2016). These axial detachments require effective localized weakening in the shallow lithosphere to allow for large displacements along the fault and significant flexure of the footwall plate.

Here, we focus on the strain localization processes that operate in the deep axial lithosphere, in the absence of magma and prior to hydrothermal alteration. Using 99 dredged samples of partially serpentinized peridotites, we show that the primary mineralogy records heterogeneous high stress deformation that is detected in all samples to variable degrees. This deformation combines plastic and brittle mechanisms and is characterized by the development of extensively recrystallized anastomosing microshear zones. Estimates of temperature (800-1000°C) and deviatoric stresses (80-270 MPa) during deformation are derived, respectively, from pyroxene thermometry and olivine grain size piezometry. We show that strain localization is initially controlled by stress concentrations due to the contrast in rheology between orthopyroxene (strong, primarily brittle with microfractures, kinks and local dynamic recrystallization) and olivine (weak, primarily plastic with undulose extinction, subgrains, dynamic recrystallization, but also kinks and localized microfractures). We propose that these microstructures reflect the imprint of an episode of lithospheric deformation that formed the root of the axial detachments and that the resulting grain size reduction helps localize strain at the base of the lithosphere. This weakening mechanism plays an essential role in the development of flip-flop detachments in this area (Bickert et al., 2020). It may also operate in other magma-starved contexts such as ocean-continent transitions, where lithospheric deformation occurs without a significant melt supply.

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