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Seismic structure of nearly amagmatic oceanic lithosphere, Southwest Indian Ridge (64ºE): constraints on tectonic exhumation of mantle-derived peridotites, serpentinization and incipient magmatism

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Ultramafic seafloor at nearly amagmatic corridors of the ultra-slow-spreading Southwest Indian Ridge near 64ºE of longitude compares favourably with magma-poor rifted margins of ocean-continent transition zones in terms of exposure of large tracts of serpentinized peridotites. We focus on one of these nearly amagmatic corridors of the Southwest Indian Ridge where we have the most coverage in terms of mapping, dredging, geological and geophysical constraints; all providing an insight into the tectonic-volcanic setting of the area.

In this corridor, outcrops of mantle-derived serpentinized peridotites were discovered to be widespread over distances of more than 70 km across-axis (Cannat et al., 2006; Sauter et al., 2013). The emplacement of serpentinized peridotites has been explained by slip on successive long-offset detachment faults alternately facing north or south. Sparse magmatism follows the emplacement of the ultramafic basement and is expressed by isolated volcanic edifices on bathymetric maps (Sauter et al., 2013).

Using active-source seismic data acquired during the SISMOSMOOTH 2014 expedition (Leroy et al., 2015), we present the results, on- and off-axis, of the internal structure of the oceanic lithosphere at this nearly amagmatic corridor. We couple our geophysical observations with seafloor geological evidence to examine the tectonic-magmatic conditions here. We discuss serpentinization on the basis of the compressional-wave velocity model in relation with fracturation delineated by the seismic reflectivity structure in the upper 5 km. We interpret the velocity structure in terms of a downward decrease in serpentinization, down to 4-5 km in the basement, probably related to fracturing near the active detachment fault. We compare the velocity model with areas of the mid-ocean ridge documented in terms of exposures of plutonic rocks/serpentinized peridotite on the seafloor, and magma-poor ocean-continent transition zone where exhumation faulting played an important role during the late stages of rifting. Furthermore, we discuss the possible links between the reflectivity structure in our study area and the limited magmatism that follows the tectonic exhumation of the ultramafic basement.

The active axial detachment fault we observed is at an early stage and marked by several strong reflectors that dip 50º (over the upper 5 km of basement that are imaged in our seismic experiments). We interpret these reflectors as primarily caused by damage associated with the fault. Reflectors in the hanging wall of the active detachment fault dip to a maximum of 45º projecting to linear volcanic ridges near axis (<200 m). We interpret these reflectors as short-offset normal faults accommodating part of the extension in the hanging wall and serving as magmatic conduits. Off-axis reflectors which we interpret as a series of fractures associated with an abandoned mature detachment fault system (dipping 25º) also indicate that zones of tectonic damage probably provide sites for serpentinization and also serve as melt pathways feeding volumetrically-small intrusive bodies and volcanic effusives. The combination of these processes (fracturing, serpentinization and incipient magmatism) produces crustal-type velocities. Our conceptual model for the accretion of nearly amagmatic oceanic lithosphere therefore incorporates exhumation, damage zone development, serpentination and sparse magmatism.