Geophysical Research Abstracts
Vol. 21, EGU2019-12753-1, 2019
EGU General Assembly 2019

Seismological evidence for lithosphere - asthenosphere decoupling beneath the southwestern Indian Ocean

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The extent of mechanical coupling between lithosphere and asthenosphere remains a key question in plate tectonics, particularly in characterizing forces that drive the plates. Oceanic plates are often considered to be coupled to the underlying asthenosphere, the latter being dragged by the overlying plate (Couette flow). But recent modelling (Stotz et al., 2018) proposed a significant component of pressure-induced Poiseuille flow in the asthenosphere beneath the Pacific plate. Advances may reside in mapping and deciphering the deformation of lithosphere and asthenosphere. Seismic anisotropy provides a unique tool to map mantle deformation and to quantify mantle flow at various depth levels within the upper mantle.

To tackle this question in a slow-moving plate environment, we used seismic data from the RHUM-RUM experiment (Réunion Hotspot and Upper Mantle - Réunions Unterer Mantel), that deployed 57 broadband ocean bottom seismometers (OBS) in the Western Indian Ocean around La Réunion and along the neighbouring mid-ocean ridges. We investigated upper mantle structure and flow using data from permanent and temporary seismic stations, by mapping velocity and anisotropy from Rayleigh wave tomography and SKS wave splitting.

Between La Réunion hotspot and the Central Indian Ridge (CIR), Rayleigh-wave tomography and SKS splitting indicate an active, east-west flow of low-velocity asthenosphere, $\sim$1000 km long, $\sim$400 km wide and $\sim$100 km thick, connecting La Réunion hotspot to the CIR. North- and NE of La Réunion, anisotropic Rayleigh wave tomography images an extensive low-velocity body, $\sim$100-150 km thick, beneath the old and cold oceanic lithosphere of the Mascarene Basin. At asthenospheric levels, we observe that azimuthal anisotropy peaks in the middle of the low-velocity layer and tapers to zero at its upper and lower limits, therefore defining a "spindle" shape. This clearly suggests an actively, pressure-driven, Poiseuille-type flow. The fast anisotropic directions trend EW to NW-SE, i.e. towards the CIR and almost perpendicular to the plate motion vector. These observations argue for large flow of hot asthenospheric material towards the spreading ridge and beyond, over lateral distances exceeding 1000 km, likely induced by plume material injection. It also indicates large-scale decoupling of lithosphere and asthenosphere beneath the western Indian Ocean, which may explain - or be caused by - the slow velocity of the Somali plate.