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Speed matters - seismicity and spreading processes of ultraslow spreading mid-ocean ridges

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The creation of new ocean lithosphere at mid-ocean ridges is accompanied by characteristic earthquake activity. The analysis of mid-ocean ridge seismicity proved a powerful tool to study submarine accretion of lithosphere and the structure of mid-ocean ridges. During the last decade, the availability of large instrument pools of ocean bottom seismometers enabled surveys of mid-ocean ridge local seismicity that greatly added to our knowledge of active deformation and spreading processes at mid-ocean ridges, capturing magmatic events and mantle exhumation along detachment faults. At the slowest endmember of the global mid-ocean ridge system, however, acquisition of local seismicity data is hindered either by perennial sea-ice in the case of the Arctic Ridge System or by rough seas in the area of the Southwest Indian Ridge. Therefore, our knowledge of active deformation at the magma-poor ultraslow spreading ridges is still limited. Yet, the teleseismic earthquake activity of these ridges shows fundamental differences to any faster spreading ridges, with magma-poor areas being only weakly seismogenic, whereas strong and frequent earthquakes characterize volcanic centres. Long-lasting or repeated earthquake swarms with magnitudes above M>5 appear to precede spreading events, contrary to most faster spreading ridges, where magma intrusion happens unnoticed at land stations.
With a comparative local seismicity study of 3 segments of ultraslow spreading ridges, we gained comprehensive insight into spreading processes and lithospheric structure of ultraslow spreading ridges. Maximum earthquake depths indicate strong variations in along-axis lithospheric thickness that may enable along axis melt flow towards the widely spaced volcanic centres, a concept postulated previously to explain the uneven melt distribution along ultraslow spreading ridges. Amagmatic ridge sections, in contrast, show more than 30 km deep earthquakes indicating a very cold lithosphere. Its upper 15 km are conspicuously aseismic down to depths where serpentinite becomes stable. We suggest that alteration of the mantle peridotite to serpentinite weakens the lithosphere such that it can deform aseismically either along deep reaching well-lubricated shear zones or due to pervasive serpentinisation. A consequence of this concept is that fluid flow must extend far deeper into the lithosphere than previously expected and lead to an enhanced exchange of energy and matter between ocean and lithosphere.

We accidentally witnessed a rare spreading episode at the easternmost Southwest Indian Ridge. It started with teleseismic earthquake swarms 16 years ago. Currently a region of partial melt at about 8 km depth resides under the central volcano of the segment. It potentially fed two dike intrusion events at 35 km along axis distance below a neighbouring subordinate volcanic centre illustrating another aspect of along-axis melt distribution at ultraslow spreading ridges. Interestingly, the intrusions migrated downward and were accompanied by strong tidally modulated seismic tremor that we interpret to result from vigorous hydrothermal circulation fueled by the heat of the dike intrusion.