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Seismological in-situ observation of a submarine diking event at the Southwest Indian Ridge associated with tide-modulated tremor

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Spreading events at mid-ocean ridges are rarely observed in-situ. Especially at the slowest spreading mid-ocean ridges, spreading episodes occur seldom and these ridges are situated in remote areas with difficult working conditions precluding for example rapid response missions when a spreading event is detected.

During an ocean bottom seismometer (OBS) experiment at the eastern Southwest Indian Ridge we accidentally recorded two earthquake swarms at a subordinate volcanic segment called Segment 7. The earthquake swarms occurred in January and April 2013 and lasted for few days. They originate at the same location at a depth of about 8 km bsf. In January, seismicity clearly migrated downward during the early hours of the swarm while in April earthquakes immediately spread over the entire area activated by the swarm. With local earthquake tomography, we imaged a region of partial melt beneath the neighbouring Segment 8 volcano extending to about 8 km depth beneath the seafloor. We propose that the earthquake swarms indicate stress release during two dike intrusion events that are potentially fed by the melt reservoir underneath Segment 8 volcano at about 35 km along axis distance.

At the same time, seismic tremor was recorded at the seismic station situated above the intrusion area. Tremor signals already precede the seismic swarm in January and are clearly harmonic with a fundamental frequency of about 0.8 Hz and several harmonics. Spectra of the long lasting tremor throughout late April and May are more complex. Tremor particle motion is almost linear indicating body waves. The direction of the polarisation is pointing to a source SSW of the station. During the main phase of the tremor in April the polarization turns to a more southerly direction and the incidence angle steepens from 65° to about 35° from the vertical, indicating possibly a different tremor excitation area at deeper levels matching the deeper intrusion in April.

Interestingly, the tremor is strongly modulated by the tides with higher fundamental frequencies and higher tremor amplitudes coinciding with low tides. With more than 6 weeks duration, the tremor lasts considerably longer than the swarm activity in April. We thus speculate that the tremor signal is not caused by magma movement during dike intrusion but is generated by vigorous hydrothermal flow in the crust or upper mantle that is fuelled by the heat of the dike intrusions. Semidiurnal variations in tremor frequency and amplitude may result from higher outflow rates in the hydrothermal system during low tides. We assume that or OBS was accidentally located near the conjectured hydrothermal system as the neighbouring stations at about 15 km distance do not record the tremor signal. However, no measurements of hydrothermal plume in the water column exist that would confirm the existence of a hydrothermal vent field.