ICDP DSeis: an altered lamprophyre dike identified at the M5.5 seismogenic zone by the analyses of the 3D reflection data and drilled core at Kochi Core Center.

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Only in-situ investigation of geo-mechano-hydro-bio-chemical interaction at seismogenic zones could address outstanding questions in the science of earthquakes and deep-life. However, seismogenic zone drilling remained one of the most significant challenges (e.g., the ICDP Science Plan 2014-2019).

The ICDP DSeis project accomplished the drilling into the upper fringe of the aftershock zones of the 2014 M5.5 Orkney earthquake (the ICDP Annual Report 2018). The DSeis team collared three holes from 2.9 km depth at the Moab Khotsong gold mine, South Africa. The formations the drilling penetrated included the Archean meta-sedimental and volcanic rocks (mafic flooded lava, sills, and dikes). The DSeis designed the direction to minimize drilling-induced damage. A 3 m double-tube and a 1.5 m triple-tube for the most critical section could maximize the recovery of the fault material even from the intersection of the upper fringe of the aftershock zone. Yabe et al. (this session) analyzed the core, successfully delineating spatial variation of stress. Hirono et al. (this session) conducted petrological and geochemical analyses, finding minerals typical for an altered lamprophyre dike, including talc as well as foliated fault materials. However, due to borehole closure at the intersection, the DSeis team couldn't accomplish downhole geophysical logging at and beyond the intersection.

Therefore, we conducted MSCL and X-ray CT scans for the most critical sections of the core at the Kochi Core Center (KCC). The MSCL density and magnetic susceptibility were consistent with those in the formations above the aftershock zone intersection where the down-hole geophysical logging was conducted, but significantly higher at the altered lamprophyre dike than those for the other mafic rock formations. The X-ray CT scan supplemented the structural characteristics of the dike.

The 2D reflection seismic profile across the aftershock zone showed that the M5.5 Orkney earthquake aftershocks spread over the West Rand Group (2.9 Ga; Ogasawara et al., 2018 AGU). However, the 2D data couldn’t provide the detailed structural architecture of the seismogenic zone. Linzer et al. (JSS 2018) and Manzi et al. (JSS 2018) found the 1996 3D seismic reflection survey that covers a 15 km x 9 km area with 25 m x 25 m bin size and includes the southern part of the aftershock zone. Noda (2020) calibrated the velocity field for the time-to-depth conversion of the cube by tying up with some surface exploration geological drilling. The depth-converted 3D seismic reflection cube elucidated some of the SE-dipping planes with strong reflection in the West Rand Group, some of which corresponded to the dolerite sills that the DSeis holes and the mine tunnels intersected.

The notable characteristics in the 3D seismic cube include
(1) A near-vertical disruption zone truncates the SE-dipping reflectors both in horizontal and vertical

slices in the West Rand Group.
(2) The Die Hoek and associated normal faults crosscut and displace the less reflective formations overlying the strong reflections in the West Rand Group, apparently bounding the sharp, south-dipping upper fringe of the aftershock zone.
(3) A near-vertical, straight disruption zone crosscuts the strata from the West Rand Group up to the base of the Karoo sediments, thus constraining its timing of activity to the Gondwana supercontinent break-up.
(4) The location of the disruption zone coincides with the aftershock zone.

In a proposed ICDP post-drilling workshop at KCC, we plan to discuss geo-mechano-hydro-bio-chemical interaction at the seismogenic zone in more depth together with the dense surface and underground seismic monitoring data, the dense geology data mapped on the mining horizons, the non-meteoric hypersaline brine and abiogenic gas sampled from the DSeis holes.

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