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Drilling into seismogenic zones of M2.0 – M5.5 earthquakes in deep South African gold mines (DSeis)

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Several times a year, mining-induced earthquakes with magnitudes equal to or larger than 2 take place only a few tens of meters away from active workings in South African gold mines at depths of up to 3.4 km. The largest event recorded in mining regions, a M5.5 earthquake, took place near Orkney, South Africa on 5 August 2014, with the upper edge of the activated fault being only some hundred meters below the nearest mine workings (3.0 km depth). This is one of the rare events for which detailed seismological data are available, both from surface and underground seismometers and strainmeters, allowing for a detailed seismological analysis and comparison with in-situ observed data. Therefore, this earthquake calls for drilling to investigate the seismogenic zones before aftershocks diminish. Such a project will have a significantly better spatial coverage (including nuclei of ruptures, strong motion sources, asperities, and rupture edges) than drilling in seismogenic zones of natural large earthquakes and will be possible with a lower risk and at much smaller costs.

In seismogenic zones in a critical state of stress, it is difficult to delineate reliably the local spatial variation in both directions and magnitudes of principal stresses (3D full stress tensor) reliably. However, we have overcome this problem. We are able to numerically model stress better than before, enabling us to orient boreholes so that the chance of stress-induced damage during stress measurement is minimized, and enabling us to measure the full 3D stress tensor successively in a hole within reasonable time even when stresses are as large as those expected in seismogenic zones. Better recovery of cores with less stress-induced damage during drilling is also feasible. These will allow us to address key scientific questions in earthquake science and associated deep biosphere activities which have remained elusive.

We held a 4-day workshop sponsored by ICDP and Ritsumeikan University in October/November 2015, which confirmed the great scientific value as well as technical feasibility, flexibility, and cost-effectiveness of drilling into the targets which have already been well seismologically probed. The value will be maximized if we combine outcomes from a limited number of holes drilled from 3 km depth into the M5.5 seismogenic zones ($\sim$ 4 km depth) with larger number of boreholes from mining horizons into the other targets (M$\sim$2 faults) already extensively exhumed by mining or which will be in future. We could have additional inputs during the 2015 AGU Fall Meeting period. We intend to start drilling before the M5.5 aftershocks diminish or mining around the M2.8 fault starts to alter stress considerably.