MIS32-14 Room:304 Time:May 24 12:30-12:45

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

OGASAWARA, Hiroshi[1*] ; YABE, Yasuo[2] ; ITO, Takatoshi[2] ; VAN ASWEGEN, Gerrie[3] ; CICHOWICZ, Artur[4] ; DURRHEIM, Raymond[5] ; PARTICIPANTS, Related meeting[6]

[1]Ritsumeikan Univ., [2]Tohoku Univ., [3]Inst. Mine Seismology, South Africa, [4]Council for Geoscience, South Africa, [5]CSIR / Witwatersrand Univ., South Africa, [6]Participants of J-DESC SATREPS WS and related meetings

Several fault-zone drilling projects have been carried out around the world (e.g. the Nojima, San Andreas, Chelungpu, Wenchuan, and Alpine faults, Gulf of Corinth, Nankai Trough, Japan Trench, and Costa Rica). Building on these, the 2013 ICDP Science Conference (Mori and Ellsworth, 2013) proposed that in the next decade ICDP focuses on fault drilling topics such as:

- How do earthquakes nucleate and propagate? Why do they stop?
- What controls the frequency and size of earthquakes?
- How does fault permeability and fluid pressure vary during earthquakes?
- How does stress vary during the earthquake cycle?

However, necessary near-field borehole observations have always been difficult where earthquakes nucleate.

Mining-induced earthquakes with magnitudes $\geqq$ 2 take place only a few tens of meters away from active workings in South African (SA) gold mines at depths of up to 3.4 km, where recent work (e.g. Ogasawara et al. 2014) yielded unique results. The largest event recorded around SA mining region, a M5.5 earthquake, took place near Orkney 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 (Figure). We also have some additional sites where M$\simeq$2 hypocenters are located within several tens of meters. So, drilling is possible with a significantly better spatial coverage (including nuclei of ruptures, strong motion sources, asperities, and rupture edges) and a lower risk and at much smaller costs.

In seismogenic zones in a critical state of stress, difficult is to measure 3D absolute stress reliably. However, we have overcome this problem. Better recovery of cores with less stress-induced damage is also feasible. These will allow us the following work:

(1) DIRECT MEASUREMENT of 3D ABSOLUTE STRESS.

(2) INTEGRATED STRESS ANALYSIS of hydro-fracturing and stress damage in boreholes and cores, compared with the 3D absolute stress.

(3) ANALYSIS of AVAILABLE SEISMIC DATA to delineate co- and post-seismic rupture processes, strong motion sources, stress inversion, spatio-temporal variation of stress drop, Coulomb failure stress, b-value, and pore pressure to compare with the results of drilling and measurements.

(4) TESTING of HYOPOTHETICAL M5.5 SOURCE MECHANISMS: the Orkney M5.5 was significantly deeper than the mining horizon with a strike-slip faulting mechanism, being different from nearby mining induced events typically on mining horizons with normal faulting mechanisms. The stress in-situ measured at ˜3km depth just above the M5.5 fault didn′ t account for strike-slip faulting, suggesting the fault was weak or stress abruptly changes somewhere.

(5) INSTALLATION of SENSORS CLOSE to the M5.5 FAULT to monitor seismicity, and spatio-temporal changes in strain, pore pressure, and velocity structure, enabling investigation into background loading, fault-healing, and stress perturbation sources.

Our potential future work reported here was built on the outcome by the researchers from Ritsumeikan, Tokyo, Tohoku, Kyoto, Kagoshima, and Hokkaido universities, AIST, TRIES, NIED, CSIR, Wits University, and Council for Geoscience, and the engineers at gold mines and associated companies (Angogold, Sibanye, Goldfields, GoldOne, First Uranium, Seismogen, OHMS, Groundwork, 3D Geoscience, Akema Boring, Homeseismo, Techno Sugaya), and funded by SATREPS, JSPS (No. 21224012, 21246134), Obs. Res. Prog. Prediction Earthq. Volc. Erupt., Ritsumeikan Univ., Tohoku Univ. COE, SA DST, and SA Research Chairs initiative.

Figure Caption: Main and aftershocks of the Orkney M5.5 (green circles), surface strong motion stations (light blue triangles), strainmeters and stress measurement site at ˜3km depth (a pink square), and a tunnel at 3km depth for potential drilling (white thin rectangle).

MIS32-14 Room:304 Time:May 24 12:30-12:45

Keywords: Drilling into seismogenic zones, Deep South African gold mines, Physics of earthquakes, Stress and Strength, Comparison with seismological analyses