# Stress measurement using cores of drilling into seismognic zone of M2.0-M5.5 earthquakes in South African gold mines (ICDP DSeis project)

Akimasa Ishida[1], Bennie Liebeberg[2], Michael Rickenbacher[3], Siyanda Mngadi[4], Harumi Kato[5], Shuhei Abe[6], Yasuo Yabe[6], *Kosuke Sugimura[1], Taku Noda[1], Akio Funato[7], Takatoshi Ito[8], Masao Nakatani[9], Anthony K Ward[10], Raymond J Durrheim[11], Hiroshi Ogasawara[12], Tatsunari Yasutomi[13]

1. Graduate school of science and engineering, Ritsumeikan, 2. Moab Khotsong mine, Anglogold Ashanti, South Africa, 3. ETH Zurich, Switzerland, 4. University of the Witwatersrand, South Africa, 5. 3D Geoscience, Tokyo, Japan, 6. Graduate School of Science, Tohoku University, 7. Fukada Geological Institute, Tokyo, Japan, 8. Fluid Science Institute, Tohoku University, 9. Earthquake Research Institute, the university of tokyo, Japan, 10. Seismogen CC, Carletonville, South Africa, 11. School of Geoscience, University of Witwatersrand, 12. college of Science and Engineer, Ritsumeikan University, 13. Kyoto University

It has been difficult to drill into seismogenic zones and measure stress. However, an ICDP project "Drilling into seismogenic zones of M2.0-5.5 earthquakes in South African gold mines (2016 - on going; Ogasawara et al. 2018 JpGU)" offers us cores with total length > 1.3 km with minimal drilling-induced damage. It was drilled from 2.9km depth at the Moab Khotsong gold mine toward a M5.5 seismogenic zone. Although damage induced by stress or drilling are sometimes very severe, a JST-JICA SATREPS project "Observational studies in South Africa mines to mitigate seismic risks (2010-2015) (hereinafter SATREPS project)" and mine's geology drilling offer us cores drilled out from seismogenic zones of M2-3 earthquakes at the Cooke 4, Mponeng, and Savuka gold mines.

From the above-mentioned drilled-cores, we selected 276 samples with various lithology (e.g., quartzite, siltstone, basaltic lava and intrusive in Archean era; >2.8 Ga), various drilling diameters (AX, BX and NQ), and stored periods (from < 1 month to > 6 years). In order to measure stress we used Diametrical Core Deformation Analysis (Funato and Ito, 2017). This method measures variation in core diameter with roll angle. Maximum differential stress on a plane normal to core axes can be calculated by assuming elastic deformation during drilling.

We measured diametrical variation with roll angle on several sections normal to core axes for each cores. We looked into measurement errors, which included residuals in fitting sinusoidal curves, and differences in sinusoidal curve phases and amplitude (strain). It was found that fitting residuals was not dependent on the lithology, while not the case for the others. We could statistically quantitatively set thresholds to rule out outliers for each lithology.

At the Moab Khotsong mine, an 817m inclined NQ hole was collared at 2.9km depth and drilled obliquely toward the left-lateral M5.5 fault. Differential stress initially decreases with distance from mine working, while turned to increase when drilling reached the depth of upper edge of the M5.5 aftershock zone.

 

At the Savuka mine, differential stress along an AX hole intersecting a M3.5 seismic fault at high angle were compared with an overcoring 3D stress measurements and other stress analysis (DCDA in other hole, DRA, borehole breakout and core discing analysis, numerical stress modeling; Abe 2017).

We could set a threshold to select reliable DCDA results at a highly stressed shaft pillar at the Cooke 4 mine, where Naoi et al. (2013, 2015abc) discussed in detail spatio-temporal evolution of microfracturing activity. The differential stress thus selected were consistent between points close to each other and systematically different in space in association with Zebra fault.

 