Geophysical Research Abstracts
Vol. 21, EGU2019-6503-2, 2019
EGU General Assembly 2019

An overview of the completed ICDP project, Drilling into Seismogenic zones of M2.0-5.5 earthquakes in South African gold mines (DSeis)

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This talk overviews an ICDP project "Drilling into Seismogenic zones of M2.0-5.5 earthquakes in South African gold mines (DSeis)", which was approved in August 2016. Drilling commenced in June 2017 and was completed in July 2018.

This is an unprecedented endeavor to directly probe seismogenic zones at great depth in various scales to better understand (1) what controls seismogenic processes, (2) how they scale, (3) how fault rock evolves, and (4) whether microbial life is fueled by seismicity.

Highly stressed ground in deep gold mines in South Africa, especially in mining remnants or pillars, often increases the risks posed by normal-faulting earthquakes to mining operations. Some of these seismogenic zones of M=2-3 earthquakes were identified by AE monitoring, allowing us to explore them by drilling BQ holes shorter than several tens of meters in length. We could recover host rock, freshly fractured martials, and fracture systems.

A M5.5 strike-slip earthquake took place in 2014 in metamorphosed 2.9 Ga West Rand Group sedimentary and volcanic rocks. The dense in-mine geophone network and the surface strong motion network elucidated the near-vertical aftershock zone. The deepest mining horizons are at 3 km, and the upper fringe of the aftershock zone several hundreds of meters below them. To probe this seismogenic zone we drilled two NQ holes of 817 and 700 m length from 2.9 km depth (Holes A and B). Hole A deviated from its planned trajectory to run eventually sub-parallel and roughly 100 m from the aftershock zone, traversing the periphery of the M5.5 aftershock zone for a distance of several hundred meters. Hole B and its 100 m long branch hole (Hole C) intersected a zone a few meters in extent where core recovery was poor and loss of drilling water, which is believed to be the structure responsible for the M5.5 event. Kaneki et al (2018 Jpn. Seismol. Soc. Fall Meeting) found talc, biotite, and amorphous material from and around the core loss zone. Drilling was followed by core and downhole geophysical logging, and installation of a packer with water/gas sampling system and downhole pressure/temperature sensor in Hole A which began emitting water and gas 6 months after drilling completion (Rusley et al. AGU 2018; Wiesberg et al. EGU 2019). Hypersaline brine was found, which is compared with fracture water samples in surrounding mining regions in different hydrological conditions. Integration of in-situ stress measurements by both conventional and new methods allowed us to constrain the stress field (Yabe et al. EGU 2019). Legacy 3D seismic reflection data was re-processed to focus on the region below the below mining horizon in an effort to map structures that might have hosted the M5.5 event. The reflection data together with the detailed information on geology and physical properties are being analyzed in more depth.

Our work is financially supported by ICDP, JSPS, South African NRF, US NSF, German DFG, MEXT Japan, ETH Zurich, Ritsumeikan Univ., Witwatersrand Univ., and Tohoku Univ.