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Observational studies in South African mines to mitigate seismic risks: implications for mine safety and tectonic earthquakes

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Seismicity poses a significant risk to workers in deep and overstressed mines, such as the gold mines in the Witwatersrand basin of South Africa, as well as inhabitants of earthquake-prone regions such as Japan. A 5-year collaborative project entitled "Observational studies in South African mines to mitigate seismic risks" was launched in 2010 to address these risks, drawing on over a century of South African and Japanese research experience with respect to mining-related and tectonic earthquakes, respectively. The project has three main aims: (1) to learn more about earthquake preparation and triggering mechanisms by deploying arrays of sensitive sensors within rock volumes where mining is likely to induce seismic activity; (2) to learn more about earthquake rupture and rockburst damage phenomena by deploying robust strong ground motion sensors close to potential fault zones and on stope hangingwalls; and (3) to upgrade the South African surface national seismic network in the mining districts.

Research sites have been established at mines operated by Sibanye Gold (Hlanganani Shaft and Cooke #4 Shaft) and Anglogold Ashanti (Moab-Khotsong). More than 70 boreholes (totalling more than 2.8 km in length) have been drilled to locate “capable” faults i.e. faults that are considered likely to become seismically active as a result of mining activity and to deploy sensors. Acoustic emission sensors, strain- and tilt meters, and controlled seismic sources were installed to monitor the deformation of the rock mass, the accumulation of damage during the earthquake preparation phase, and changes in dynamic stress produced by the propagation of the rupture front. These data are being integrated with measurements of rock properties, stope closure, stope strong motion, seismic data recorded by the mine-wide network, and stress modelling.

The mid-point of the 5-year project has passed. New observations of stress and the response of the rock mass to mining have already been made, and many more are expected in the next two years as the mining front sweeps through the monitoring arrays. We will describe examples of technology adaptation and transfer, as well as preliminary research findings. The strain cell and associated tools required for the compact conical-ended borehole overcoring (CCBO) technique, which determines the 3D stress tensor by a single overcoring of a strain cell, have been reduced to the core size used in South African mines. This modified method was tested at three sites, where it was demonstrated that three overcoring measurements can be made within two shifts. A large number of acoustic emission (AE) sensors were installed at Cooke #4 mine. In the period from 30 September to 5 October in 2011 the monitoring system automatically located 40,555 AE, some of which were located by Moriya et al. using the joint hypocenter location method. Moriya et al. applied the multiplet and the double-difference analysis to the selected multiplets, successfully delineating multiple planar structures. Ultimately we hope that this project will produce knowledge and technology that will reduce the risk posed by both mining-induced and tectonic earthquakes