

## Investigation into stress field and strength at hypocenters at South African gold mines

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We report on in-situ stress measurements at seven sites at South African gold mines. The depth ranged from 1.0 to 3.4 km (deepest level in the world where mining is in progress). The measured maximum stress ranged from to 146MPa. In the ranges of stress above 100 MPa have not been able to be measured before we introduced a downsized Compact Conical-ended Borehole Overcoring technique (CCBO; ISRM suggested) in South African gold mines, which has several advantages over the methods widely used in South Africa.

The in situ measurements were carried out at the sites with minimal disturbance by mining or geological features at depths of 3.3 and 3.4 km at Tau Tona and Mponeng mines, respectively, both allowing confirmation that the virgin stress assumptions in the mine were acceptable with slight modification. With the modified virgin stress assumptions, the loading conditions for seven seismic events (ML >2.9) over a 9-year period at Tau Tona mine were back-analyzed with an elastic boundary element method that allows non-linear ride and closure on displacement discontinuity elements (Map3D Fault-SlipR), successfully constraining the stress or the strength on the source faults. At the Pink and Green dykes at 116L at Mponeng mine, the rupture plane of a ML2.1 event was finely delineated by the Japanese-German acoustic emission (AE) network with eight AE sensors deployed within several tens of meters from the rupture plane. It was confirmed that, with the virgin stress assumption and the strength, Map3D was able to reproduce an area of ride consistent with the rupture plane delineated by the AE network. A hole of about 90m length was drilled to intersect the ML2.1 rupture plane to constrain stress by analyzing borehole breakout and core discing. The stress thus constrained was consistent with those estimated with Map3D although the former is a little bit larger than the latter. In situ stress measurements were carried out near seismic damage caused by a ML1.5 event, which took place in the area that a Map3D model with simplest geology structure could not predict high stress. The measured stress state was comparable to that evaluated at the above-mentioned seismic sources.

Seismicity is high at a shaft pillar at 1.0 km depth at Ezulwini mine, where BX CCBO stress measurement was carried out. The measured maximum principal stress was significantly higher than the stress at sites at 3.4km depth with no mining activities.

Keywords: SA gold mines, Seismogenic areas, Stress, Strength, In-situ observation