

A capable geological structure of the Orkney M5.5 earthquake of 5 August 2014 identified by re-processing seismic reflection data

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Several holes have been successfully drilled into seismogenic zones of M2.0 - M5.5 earthquakes in deep South African gold mines (ICDP DSeis). The last drilling will be completed March or April 2018, as reviewed by Ogasawara et al. (JpGU 2018). The targets include the seismogenic zone of the 2014 Orkney M5.5 earthquake. This event was the largest seismic event (M5.5) to occur in a South African gold mining district. The main and aftershocks were recorded by two strainmeters installed near the bottom of the mine at a depth of about 3 km, 46 in-mine 4.5Hz triaxial sensitive seismometer stations at depths of 2-3 km within a hypocentral radius of 2-3 km, and 17 surface strong motion stations within an epicentral radius of 25 km. The aftershocks are distributed on a nearly vertical plane striking NNW-SSE and are considered to define the “M5.5 fault zone”. The upper edge of this fault is located several hundreds of meters below the deepest level of the mine. The geological structure that hosted the M5.5 earthquake was unknown because the projection of the aftershock plane did not coincide with any capable fault or geological structure on the mining horizon.

In order to locate drilling targets more accurately and identify the responsible geological structure, we re-processed and re-interpreted 2D and 3D seismic reflection data acquired for gold exploration by the mining company in the 1990s and 2000s. A 2D seismic reflection line intersects the M5.5 rupture, defined by the planar distribution of the M5.5 aftershocks; while the 3D seismic reflection cube is located adjacent to the M5.5 rupture. We used the 2D reflection data to identify geological structures that might have hosted the M5.5 event; and the 3D reflection data, together with geological information from exploration boreholes drilled from surface or the mine workings, to calibrate the velocity field. A special effort was made to image geological formations and structures lying below the mining horizons. These structures had not been well-resolved during previous processing as they were not considered to be directly relevant to the assessment of the gold resource.

We were able to identify a steeply-dipping fault zone near the planar distribution of the M5.5 aftershocks below the mining horizon in West Rand Group with multiple seismic reflective layers. Also, we could delineate cross-cutting relationships of the known normal faults that dislocate the gold reef by more than 1 km horizontally and vertically. One of the known normal faults, the De Hoek fault (with shallower dip angle) dislocates the Jersey fault (with steeper dip angle). The southern limit of the planar distribution of the M5.5 aftershock is the lower extension of the Jersey fault that was dislocated by the De Hoek fault. The upper limit of the planar aftershock distribution is below the De Hoek fault.

Stress was measured throughout the hole that got close to the M5.5 fault (Ishida et al. 2018 JpGU). Stress will be measured also throughout the hole that will intersect the M5.5 fault. In addition to these measurements, this work and borehole geophysical logging calibrated the seismic velocity structure, identified the capable geological structure, and delineated its configuration with respect to the known normal faults. These will help us to better understand the termination of the propagation of the M5.5 rupture, which will be discussed in Southern California Center Workshop on Source Inversion Validation.

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