Connecting Microseismicity with Faults in Mining Environments

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Mining activities frequently take place through faults or in their proximity. Consequently, understanding fault mechanics and correctly evaluating failure conditions are essential for ensuring safe mining operations. In order to reduce the hazard associated with additionally stressed ground, mining is generally scheduled in engineering practice from relatively difficult to easy rockmass conditions. With microseismic monitoring arrays having become standard nowadays, the amount of observation material available in real-time to the operators is continuously increasing in both size and quality. This allows for an immediate evaluation of the rockmass behaviour in response to the changing stress conditions, and therefore for a safer environment.

While the rapid evaluation of the relative size of a seismic event and its location are of practical interest for any mine application, the extent to which the mine microseismicity can be related to actual faults and other geological structures for fundamental research remains to be determined. Among the questions that need to be addressed are: how much information about the seismic source is contained in the microseismic records, how can this information be extracted, how reliable are the results derived, and what are the limitations of the procedures employed. The scope of the present study is to provide answers to these questions based on analyses of microseismic data recorded at two study sites: Kidd mine in Canada and Darlot mine in Australia.

Kidd mine is a copper-zinc operation using open stope blast hole mining with delayed consolidated rock fill. Mining activity extends to a depth of 2,100 m and is scheduled to go to 3,200 m depth over the next few years. A complex folding process has shaped the orebody as a tight, steeply northeast plunging rod, almost circular in cross-section. An array composed of 11 triaxial and 23 uniaxial accelerometers monitors a rockmass volume of approximately 300 x 300 x 600 m. The analysis focuses on the microseismicity associated with the F North fault, one of the major mined through deep faults at Kidd. Mapped all the way between 1,700 and 2,100 m depth, the fault intersects several minor faults and is seismically very active, generating damaging rockbursts from time to time.

A similar open stope mining technique is employed at Darlot mine for the extraction of gold, with operations extending not deeper than approximately 1,200 m depth. Although the mine does not experience damaging rockbursts, it hosts a complex system of faults that was mapped extensively. Seismic hazard evaluation requires a reliable identification of those faults that are active, as well as their possible extent beyond the mapped limits. A volume of approximately 300 x 200 x 200 m is monitored by an array of 8 triaxial and 8 uniaxial accelerometers. The analysis aims to characterize the mechanism of microseismicity and its association with the geological structures.
The data consists of several tens of microseismic events (M < 0) per study site. Full waveform acquisition was available at 20 kHz sampling rate and manual processing was carried out for the identification of first P- and/or S-arrivals and their polarities, respectively. The methodology used in this investigation includes event location and source mechanism evaluations. The event location analysis is based on a maximum likelihood method that employs direct P- and S-wave first arrivals, and a collapsing technique used to search for best association of microseismicity and faulting. The mechanism evaluation uses a moment tensor approach based on the inversion of low frequency displacements calculated in the time domain with the first P- and S-wave polarities included. Inversions are carried out for data sets that combine rotated triaxial as well as uniaxial recordings of direct body waves. The accuracy of these inversions has been analysed through synthetic testing as a function of the noise level, event location error, and uncertainties in amplitude and polarity readings. The reliability of model inversions is assessed through direct comparisons between the results obtained for alternative models and the results obtained from rotated triaxial and unrotated triaxial used as uniaxial data.

To conclude upon the association of microseismic events to actual faults mapped on site, the disorientation angle between the local structures and possible mechanism solutions is calculated. The analyses show that accurate and reliable event locations and mechanism solutions are critical for the characterization of active faulting. The results obtained outline the increased failure patterns at fault crossings, the significance of local stress changes associated with mining, and the identification of fault activity beyond its mapped trace. It is concluded that the applied collapsing approach and moment tensor inversion are capable and therefore recommended to extracting the necessary information for advanced interpretation.