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Microfracture distributions indicating formation of large-scale cracks in the rock mass ahead of the mining front

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We are monitoring Acoustic Emissions (AEs) down to Mw -4 or less at 1km beneath the ground in the Cooke 4 Mine (previously known as the Ezulwini Mine), where many earthquakes up to Mw 2 are induced by stress concentration due to tabular mining. The network consists of 24 AE sensors and 6 three-component accelerometers. Naoi et al. (2013; Pageoph) made a catalog composed of about 360,000 events by using waveform data obtained for three months, and reported that 90% of them aggregated within 10 m ahead of the mining front at the time.

In this study, we extended the analysis term to 9 months and developed a catalog composed of about one million events. We also applied the double difference algorithm (Waldhauser and Ellsworth, 2000) to them so as to examine spatial distributions of the AEs near the mining front in detail. Travel time differences for relative location were calculated from arrival times automatically read by the program of Horiuchi et al. (2011). To efficiently calculate relative hypocenters for a massive amount of events, we adopted the parallelization method of Hauksson and Shearer (2005), where events in subregions overlapping each other are firstly relocated and then the hypocenters relocated redundantly are averaged to make a single catalog. We succeeded in relocating 96% of the one million events.

The relocated AEs near the mining front exhibited two-dimensional, tabular aggregations with a few tens of meters lateral extent (hereinafter referred to as tabular cluster), rather than a three-dimensional distribution spread more or less uniformly (randomly) over the entire zone of the stope-front activity of 10 m breadth. Each tabular cluster was discernible because they were separated by regions of low AE density. That is, AEs ahead of the mining front basically occur selectively in several discrete tabular zones within a highly stressed volume affected by the mining cavity. The tabular clusters strike parallel to the mining face and dip 60-80^o. This resembles similarly large shear fractures along the plane of maximum shear commonly observed by excavation around the stopes (Gay and Ortlepp, 1979; Adams and Jager, 1980; Adams et al. 1981). Ahead of a panel that advanced by 40 m during the analysis period, 10 such tabular zones formed at intervals of 5 m on average.

By the same AE monitoring network, we also have found extremely aggregated (a few tens of centimeter thickness) planar clusters continuous over the cluster's extent, reminiscent of thoroughgoing fracture surfaces. They often coincide with preexisting geological faults (Naoi et al. 2013; JpGU). In contrast, the AEs of the tabular clusters regularly forming in the mining front were spread over 1-2 m thickness, lacking a dominant aggregation with good continuity. We interpret that the tabular-cluster AEs are microfractures occurring in a formation process of a large-scale shear crack in macroscopically intact rock subjected to high stress ahead of the advancing mining front. Indeed, the activity of tabular clusters gradually increased as the mining front approached and ceased when passed by the front.

Keywords: Acoustic Emission, Induced Earthquake, Rock fracture