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Microruptures concentrating on pre-existing planes at 1 km depth in a South African gold mine and their high b-values

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We deployed an Acoustic Emission (AE) sensor array, which can detect small ruptures down to Mw -5, at 1 km depth in the Cooke 4 shaft (previously known as Ezulwini mine) in South Africa, where up to Mw 3 class earthquakes are indued by mining of a planar gold reef. Naoi et al. [2012; SSJ fall meeting, poster] determined hypocenters by an automatic picking program [Horiuchi et al. 2011] and estimated Mw for 365,237 events. Ninety percent of those were located near mining fronts (hereinafter referred to as stope cluster), whereas most of the remainder belonged to planar clusters apart from the stope-cluster (hereinafter referred to as planar cluster). Naoi et al. [2012] investigated the stope-cluster AEs and showed that they obeyed the GR law with b = 1.3 from Mw -3.7 to 0. The b-value did not depend on time from blasting, even for 0-1min after blasts. Naoi et al. [2012] also confirmed the size distributions of earthquakes detected by mine's seismic network, which were dominated by stope-cluster events, obeyed the GR law with b = 1.3 from Mw -1.2 to 1 (To extract a sufficient number of events, catalogue for longer period and larger volume were used for the mine's seismic network). These suggest that stope-cluster events compose a population obeying the GR law with b = 1.3 between Mw -3.7 and 1.

The present study focus on planar-cluster AEs. We identified 7 planar clusters whose spatial extents were 10 - 80 m, which were located 20 - 70 m away from the mining front and were composed of 314 - 8667 AEs. Position and attitude of one of these clusters was consistent with a large geological fault (named Zebra fault) surrounding which our AE network was deployed. Also, corresponding weak planes (seemed to be joints) were found in tunnel for two other clusters. The remainders are thought to be related to unknown pre-existing weak planes that were not accessible for observation. Because event rates in these planar clusters were nearly constant during the analysis period and because no large earthquake occurred around them whose rupture extent could reach the extents of these clusters since 2009, when mining was started around the AE array, AEs of the planar clusters were judged to be steady activities, not aftershocks of large earthquakes. Relocated hypocenters of these planar clusters by Double Difference method [Waldhauser and Ellsworth, 2000] revealed that their distribution is so sharp that most hypocenters were aggregated within a thickness of 50 cm at the narrowest, sometimes event delineating stepovers and branches. These clusters were unrecognizable unless very small AEs were observed, because the 99.8% of the AEs in these planar clusters were smaller than Mw -2. Particularly, the maximum event in the planar cluster delineating Zebra fault was only Mw -3.0. The size distributions of the planar clusters followed the power law, and their slopes (b-value) were 1.38 to 2.19, which are higher than b-value of stope-cluster (b = 1.3).

Strong planar concentration of planar-cluster AEs observed in the present study is not necessarily consistent with microearthquake activities around active faults (e.g., Liu et al. 2003; Hauksson 2010). In addition, b-values of planar-cluster AEs were significantly different from typically observed b-values for natural earthquakes, whereas b-value of stope-cluster AEs was similar to those of natural earthquakes. This may be interpreted that size distribution of stope-cluster AEs and natural earthquakes reflect size distributions of weak planes in a volume region, whereas planar-cluster AEs are "microruptures" reflecting microscopic irregularities of a macroscopic weak plane (e.g., roughness of a fault); that is, planar-cluster AEs represent a different population from microearthquakes in the usual sense.

Keywords: Acoustic Emission, seismicity, South African deep gold mine