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AE measurements at 1 km depth in a deep South African gold mine and their activities related to two M0 earthquakes

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We have developed a new AE (Acoustic Emission) monitoring array at 1 km depth in the Ezulwini mine in South Africa, which consists of 28 AE sensors (covering 1 - 40 kHz) and 6 tri-axial accelerometers (three of them have a flat frequency response up to 25 kHz, others have up to 10 kHz). Network was almost completed in July 2011, and more than 6,400,000 waveforms at 500 kHz sampling were stored from December 2010 to October 2011. Although many working noise (e.g, vibration with drilling) are contained in these records, more than 1,000,000 waveforms related to AEs are stored.

In this study, we applied the automatic arrival time picking program (Horiuchi et al. 2011, JPGU) to waveforms from August 17 to September 23, 2011, and selected 220,000 hypocenters for which at least 10 P-arrivals were picked and the root mean square residual of arrival time was $<$ 0.2 ms. More than 90% of them were located in front of cavity being made by mining of gold reef, whereas several planar AE distributions were found away from the mining face. Most AEs belonged to either the mining front cluster or such planar clusters, i.e, few AEs occurred away from these clusters. The planar clusters were composed of a few hundred ˜ a few thousand AEs, and their spatial extent were 20 ˜ 100 m. Positions and attitudes of three clusters of them were consistent with geological faults which were identified by our/mine's survey, therefore these AEs must be related to pre-existing weak planes. Other planar clusters may also delineate unknown pre-existing weak planes.

In one of clusters whose strike is consistent with a fault identified by the mine, sudden increasing of AE rate on September 21 and subsequent decay followed Omori's law was found. We estimated Mw for 4645 AEs belonging to this planar cluster by fitting omega-square model to the observed spectrums, and found two relatively-large events (Mw 0.0 event at 6:50 a.m and Mw -0.2 at 7:01 a.m on September 21). Concentration of AEs around rupture initiation point of the first M0 event or accelerated AE rate were not found. Rather, Mw 0.0 seemed to occur in relatively low activity area. While spatial extent of AE activity before Mw 0.0 (2955 events) was 90 m along strike and 60 m along dip, extent of aftershock areas in five minutes after Mw 0.0 and Mw -0.2 were only 10˜15m in diameter, which is consistent with typical M0 rupture size. These two events seem to have ruptured only parts of the region illuminated by AE activity. Initial rupture point of the second M0 event was located at the edge of the aftershock area of the first event. It can be interpreted as the Mw -0.2 was induced by stress concentration at rupture edge of the Mw 0.0. Rubin and Gillard [2000] studied M 0.5 ˜ M 3.5 microearthquakes on San Andreas fault, and suggested the same triggering process from the observation that lower limit of separation between consecutive events were consistent with rupture radius of the first event. We could directly observe this process from the aftershock area indicated by activities of very small AEs.

Keywords: South African gold mines, Acoustic Emission, aftershocks, triggering