Emergence and disappearance of repeating earthquakes on a geological fault in a deep gold mine in South Africa

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We deployed an Acoustic Emission (AE) monitoring network consisting of 30 very sensitive AE sensors and 7 accelerometers at 1-km depth in the Cooke 4 gold mine in South Africa, where many earthquakes up to ~M 3 are induced by stress buildup by mining. Naoi et al. [2015] analyzed data obtained by the AE network during 2 months, and they found very small repeating earthquakes of $-5.1 \leq Mw \leq -3.6$ which occurred on a geological fault. In this study, we extended the analysis period to 14 months, investigating a time variation of the repeating earthquakes during longer periods.

Firstly, we relocated 5869 events that occurred along the geological fault during the 14 months (from 7 April 2011 to 30 may 2012) by using the double-difference method [Waldhauser and Ellsworth, 2000] with the cross-correlation travel-time reading technique. Of the relocated AEs, we chose 3735 events within 3 m from an approximation plane of the two-dimensional distribution of the AEs, which delineates the fault. We then cross-correlated waveforms of all event pairs whose interevent distances D were less than 2 m. We chose event pairs whose seismograms had cross-correlation coefficient greater than 0.90 at 20 percent or more working stations at the time and their rupture areas evaluated from a circular crack model overlapped significantly. We finally assembled them into “repeater groups” whose event pairs shared one event or more.Out of the 3735 events (35.6%), 1328 events belonging to 308 groups were identified as repeaters. The number of recurrence reached 45 times for the largest repeater group.

Activities of some groups continues for the whole 14 months (Type A), but we also found groups that newly emerged (Type B) or disappeared (Type C) in the analysis period. We also found areas of ~10-m scale where only Type-B or Type-C groups existed, which likely corresponds to a newly emerged or terminated macroscopic slow slip respectively. Meanwhile, there were areas where Type A-C existed within a tiny area of a-few-meter scale. Only in such area, we found some Type C groups whose events size decreased with time. We consider the emergence and disappearance of the repeaters in such areas represent formation and dissipation of unstable patches of the fault, resulting from newly encountered protruding portions or frictional wear of the contacts by the progress of fault creeping.

Keywords: Acoustic Emission, Induced Earthquake, Repeating Earthquake

