Significance of Very Small Repeating Earthquakes Observed in a Deep Gold Mine in South Africa

Naoi, M.[1], Yamaguchi, J.[1], Nakatani, M.[2], Moriya, H.[3], Igarashi, T[2]., Kgarume, T.[4], Murakami, O.[5], Masakale, T.,[6] Yabe, Y.[7], Otsuki, K.[7], Kawakata, H.[8], Ribeiro, L.[9], Ward, A.[9], Durrheim, R.[10], Ogasawara, H.[8]

1. *Graduate School of Engineering, Kyoto University, Japan*
2. *Earthquake Research Institute, University of Tokyo, Japan*
3. *Graduate School of Engineering, Tohoku University, Japan*
4. *Council for Scientific and Industrial Research, South Africa*
5. *Tono Research Institute of Earthquake Science, Japan*
6. *Open House Management Solutions, South Africa*
7. *Graduate School of Science, Tohoku University, Japan*
8. *College of Science and Engineering, Ritsumeikan University, Japan*
9. *SeismoGen Cc, South Africa*
10. *School of Geosciences, University of the Witwatersrand, South Africa*

We deployed an Acoustic Emission (AE) monitoring network consisting of 30 very sensitive AE sensors and 7 accelerometers at a 1-km depth in the Cooke 4 gold mine in South Africa, where many earthquakes up to M ~3 were induced by stress increase due to mining. This network could detect AEs down to $M_W \sim -5$ and has revealed on-fault AE activities, dominated by very small AEs (99.7% of them were smaller than M_W -2) [Naoi et al. 2015b]. In this presentation, we discuss the occurrence and significance of repeating earthquakes in the on-fault AE activities.

In the data obtained by the network during a 14 months period, we found very small repeating earthquakes of $-5.10 \leq M_W \leq -2.35$ that occurred in a region of ~100-m extent on a geological fault [Yamaguchi et al. in revision]. Out of the 4214 events along the fault, 1785 events (42%) were identified as repeating earthquakes on the basis of the waveform similarity and the proximity of hypocenters. The estimated rupture area of the repeaters significantly overlapped each other, indicating that those were repeat ruptures of a locked patch loaded by surrounding macroscopic aseismic creep, as known for repeaters at plate boundaries [Naoi et al. 2015c]. For the repeating earthquakes, we applied the Nadeau and Johnson [1998] empirical formula (NJ formula), a well-established empirical relation between the amount of background creep and the plate-boundary repeater activity, and obtained an impossibly large estimate of the background creep. This implies that the presently studied repeaters were produced more efficiently, for a given amount of background creep, than predicted by the NJ formula.

Although the repeater activity basically continues steadily during the 14 months, some groups newly emerged or disappeared during the period. Both types often coexisted within a distance as small as ~0.5 m, within which background fault creep should be coherent. Such variations in short distance are unlikely explained by spatial heterogeneity of aseismic creep and may imply the formation and dissipation of topographical asperity contacts on the fault. In addition, some disappearing groups showed a decrease in the event magnitude with time. The abrasion of the asperity may cause the decrease in M_W.