Protection, prevention and prediction of mining induced earthquakes in South African deep gold mines

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In Japan, recurrence periods of inland large earthquakes are larger than a thousand years, those of inter-plate earthquakes being larger than a hundred years. So, inherently, earthquake prediction research can have little lesson within short period (e.g. a 5-year period or even within decades) as far as we rely on occurrences of large earthquakes in Japan. We think that seismological researchers must have as many lessons as possible by studying smaller, more frequent earthquakes at closest distance, and justify the validity of the present monitoring for prediction of large natural earthquakes.

In South African gold mines, gold reef more or less 1 m thick is mined at 2-3 km depth, inducing considerable seismicity in the proximity of mining. The mines have M2 events everyday and an M5 event sometimes. As larger events are anticipated within areas where high stress and/or low strength are estimated, we can install instruments ahead of time in seismogenic areas. So, South African deep gold mines are very important field for earthquake research.

Destructive earthquakes are not inevitable in deep mines, so safety and productivity can be maintained at reasonable levels. This situation in deep mines can be compared to the situation of a heavily populated metropolitan area undergoing a large earthquake. Therefore, deep mines are inherently interesting for the insights they can provide into seismology overall. Most mines record seismograms with wide dynamic-range and high sampling-rate data acquisition systems. Techniques to anticipate an occurrence of large events are well developed based on analysis of seismograms and seismicity. To learn their techniques is our good lesson.

In our talk, we introduce South African mining and induced earthquakes. As an example of large events, we document the underground hypocentral fault of an M4.2 event that occurs in August 2001. We also report their routine daily seismic monitoring and prediction, and review how the mines control occurrence of events and prevent disasters.

Although estimation of stress change associated with mining and prediction of seismicity and occurrence of large events are routinely carried out, they are mainly based on analyses of seismograms and seismicity. Little attempts are made to directly monitor rock-mass behavior. So, with Ishii's borehole strain meter, we have attempted to monitor dynamic response of rock-mass, compared with mine's common, seismic-data-based estimates of seismicity and occurrence of a large event. In co-operation with ISS International Ltd. (a South African seismic monitoring company), we have developed one pilot experimental field and three main experimental fields. In our talk, we report main results and new attempts. For example, in the first experimental field (2650 m deep), an M2 event and associated seismicity before and after the event took place at a remnant reef distance. They were fully recorded with 4 strain meters and 9 tri-axial strain meters at 100-200 m from the events. Then, acceleration in seismicity and change in seismic parameter were found while deformation of seismogenic zone went monotonically. In the second (2400 m deep) and third (2800 m deep) fields, we started to record full strain change in seismogenic area of M3 events with 25-Hz 24-bit continuous strain monitoring.

We also summarize the problems that we have had during our researches, and mention about future prospect, including potential collaboration with US and other countries.