Radiation Efficiencies and Apparent Stresses of Small Earthquakes in a South African Gold Mine

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Analyses of source processes of small earthquakes are important for investigating whether or not there are dynamic differences between small and large earthquakes. However, it is difficult to resolve details of the source of small earthquakes because close station spacing near the hypocenter and data with high sampling rates are necessary. Such observations of mining induced earthquakes are being carried out in a South African gold mine. Nine tri-axial borehole accelerometers were installed within 200 m along a 2,650-m-deep haulage tunnel in the Mponeng gold mine (Figure 1). Many seismic events (M-2.7 to M3.3) were recorded with a sampling frequency of 15 kHz from February to October, 1996. In this study we focused on the rupture velocity, which is important for investigating characteristics of initiations, arresting mechanisms, and radiation efficiency of earthquakes. We carried out kinematic wave-form inversions for 6 larger events (M0.7 to M1.4) that occurred within 200 m of the stations.

First, we determined the velocity structure using arrival time data. Velocities of P and S waves were estimated to be 6.00 km/s and 3.83 km/s, respectively. Next, we determined focal mechanisms from amplitudes of P, SH, and SV waves. Finally we carried out kinematic wave-form inversions for both nodal planes of the focal mechanisms, assuming various rupture velocities, in order to distinguish the fault plane and the best-fitting rupture velocity.

We could determine the fault plane for five of the six events because the model fit to the data for the fault plane was significantly better than for the auxiliary plane (Figure 2). On the other hand, we could not determine the rupture velocities with complete confidence. One problem is that in general, residuals are likely to be smaller by assuming higher rupture velocities. However, we can conclude that rupture velocities were not less than 50 % of the S-wave velocity, on the basis that the slower rupture velocities could not explain wave-forms very well. Therefore, we conclude that rupture velocities of small earthquakes in the South African gold mine are not extremely low and almost the same as those of larger natural earthquakes.

The radiation efficiency can be written as a function of the rupture velocity and becomes greater with increase of the rupture velocity. This study indicates that radiation efficiencies of small earthquakes in the South African gold mine are almost equal to those of larger natural earthquakes.

We also calculated radiated energies of the six events. They show that apparent stresses, or the ratios of radiated energies to seismic moments, are constant compared with those of larger natural earthquakes. Our result shows that radiation efficiencies and apparent stresses of small earthquakes in the mine are equal to those of larger natural earthquakes.

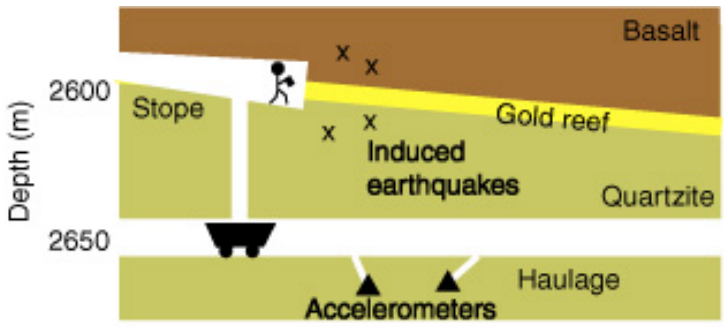

Fig. 1. Schematic view of observation system of induced earhquakes in the Mponeng mine

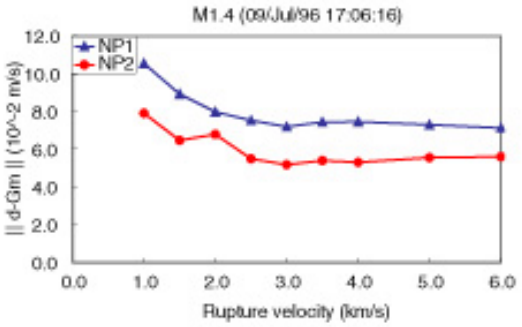

Fig. 2. Residuals of fits to the two nodal planes for various rupture velocities