Rupture Velocities of Small Earthquakes in a South African Gold Mine: Constraints on Fracture Energy

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Analyses of rupture velocities of earthquakes are important to investigate characteristics of fracture energies, initiations, and arresting mechanisms. But it is especially difficult to resolve rupture velocities of small earthquakes because close station spacing near the hypocenter and high sampling rates are necessary. Such observations are being carried out in a South African gold mine for mining induced earthquakes. Nine tri-axial borehole accelerometers were installed within 200 m along a 2,650-m-deep haulage tunnel in the Mponeng gold mine. More than 25,000 seismic events with magnitudes between -2.7 and 3.3 were recorded with a sampling frequency of 15 kHz from February to October, 1996. We carefully picked 3 events with magnitudes 1.4, 1.1, and 0.8 having good azimuthal coverage and analyzed the waveforms to try to determine rupture velocities.

The studied events have rather complicated waveforms and individual subevents could be identified. Arrival times of the subevents were picked relative to the initial arrival. These differential arrival times were used to locate the subevents relative to the initial hypocenter. Approximate rupture velocities could be obtained by dividing the distance to the subevent by the delay time.

We obtained results that showed rupture velocities ranging from 2.10 to 3.01 km/s. These values are from 55 to 78 % of the shear-wave velocity and consistent with those of larger natural earthquakes. This result suggests that the ratios of fracture energies to radiated energies of small earthquakes in a South African gold mine are not particularly large and almost the same as those of larger natural earthquakes.