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Implications from the 2004 Mid-Niigata Earthquake Sequence Based on the Spectral Ratio Analysis

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The 23 October 2004 Mid-Niigata prefecture earthquake (MW6.6) sequence consists of a number of aftershocks including six large events with Mw5.5 or greater. Preliminary studies of the hypocenter distribution and the source mechanisms suggest that these earthquakes involve in the ruptures of at least four different faults. The earthquake occurrence in such a complex manner is typical for hidden thrust faults reflecting stress redistribution during the sequence. We investigate the spectral characteristics and radiated energy using broadband waveform data of a pair of 57 events (i.e., the main event and a small event in the sequence) with similar focal mechanisms. Using such a pair of events, one can assume that the propagation path and receiver site effects can be minimized (or reduced) in the spectral ratios for data recorded at common stations. We determine corner frequencies (fc) of the aftershocks assuming an omega-square model and evaluate the relationship between seismic moments (Mo) and fc, and other spectral characteristics.

The Mo-fcs (the fc of smaller earthquakes) relation shows substantial scatter relative to a straight line of Mo proportional to fcˆ-3 in the narrow range of Mw. The spectral ratios become more complex in the vicinity of fcs than those expected from a typical omega-square model. The scatter indicates variation of radiated energy among the events and corresponds to complicated hidden thrust faults reflecting stress redistribution. Based on the spectral characteristics, events in the aftershock area are distinguished in five groups. These groups appear to be related to the distribution of several faults identified in the earthquake source area. The slopes of the spectral ratios vary among the groups (in the frequency band of 1Hz or higher). This means that the steeper the slope is, the more the seismic energy release by the smaller event was. The seismic energy releases by events in groups 3 and 4 are larger than events in groups 1, 2, and 5. Groups 3 and 4 are associated with the faults that involved in the main event and the largest aftershock (Mw6.3 on 10/23). Moreover, the two foreshocks took place in the vicinity of group 1 several weeks prior to the main event. Their spectral ratios (the main event spectra divided by the spectra of each of the foreshocks using data at the four F-net stations) suggest relatively small radiated energy. It is also noted that the spectra of the largest aftershock show more high frequency energy than the other large aftershocks (with Mw5.5 or greater). Results suggest that the seismic energy release took place in a complex manner during the aftershock sequence.