Rupture initiation process of small earthquakes found from seismograms at three boreholes

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We studied the complexity of the rupture initiation process of small earthquakes by using waveform data recorded at three borehole stations at Ohtaki, the western part of Nagano Prefecture, where 48 seismic stations are operated by NIED with sampling frequency of 10 kHz. The region is one of the most active seismic areas in Japan. Most earthquakes occur at depths from near surface to 10 km. Station OT0a has borehole seismometer at 800 m depth, which is set up by GSJ. Stations OT01 and OT02 have 145 m and 100 m depths, respectively. Distances among three boreholes are smaller than 2.7 km. We analyzed waveforms of M -1.1 to 1.2 earthquakes of which focal distances are 0.8 to 3.4 km, and M 3.8 earthquake of which focal distance from OT0a and OT01 are 4.4 km and from OT02 is 6.6 km. Since observed seismograms are deformed by path effect, we estimate [delta t*] by comparing spectral ratio of seismograms for an earthquake recorded at all pairs of three boreholes. By choosing the seismogram for one station, which is most attenuated by path, we corrected seismograms for the other two borehole stations so that they become seismograms deformed similar amount compared with the most attenuated one.

We calculated pulse durations for the initial part of seismograms for the three borehole stations and found that most of them becomes nearly same. This shows that the attenuation correction by the above method works well. However, small phases, which cannot be explained by the self-similar crack model, can be seen before or after the large pulse. For large events (M3.8, M1.2), these phases can be seen in three borehole seismograms, but they can be seen only one or two borehole seismograms for small events. These phases can be originated from a reflector near source, or by complexity of source process. These phases can be seen at around 0.01 s before or after the main pulse. If they are the reflected waves, the reflector have to be located at about 50 m away from the source. Or they can be explained with a sub crack with the size of 20 m radius preceding to the main rupture, but they cannot for small earthquakes.