3-D Attenuation structure, source parameters and site amplification by simultaneous inversion and predicting strong ground motion

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Short period seismic ground motion is affected by 3-D attenuation structure and decrease isotropically with focal distance with frequency dependence.

Firstly, the 3-D attenuation Qs structure beneath the Japanese islands, source spectra and site amplification factors were obtained in spectrum domain (1-10 Hz) through simultaneous inversion by using a large number of short period strong motion records of K-NET (1,035 stations) and KiK-net (675 stations) of the National Research Institute for Earth Science and Disaster Prevention (NIED). We used 121,367 seismograms of 1,804 earthquakes recorded during 1997-2007. Secondary, seismic ground motion was be predicted by using the 3-D attenuation Qs structure obtained by the inversion.

The formulation of the inversion is fundamentally similar to that of Hashida and Shimazaki [1984], but we added an unknown site amplification factor for the six groups [Nakamura and Uetake, 2002]:

We classified all stations into six groups by ground conditions mainly based on S-wave logging data. To avoid the tradeoff between the source spectrum and the site amplification, we fixed the site amplification to 2.0 (free field) for the hard rock site group in inversion.

The result of the 3-D attenuation structure Qs shows that the Pacific plate and the Philippine sea plate have High Qs; active volcanoes or volcanic front in shallow areas tend to have Low Qs. In spite of non-volcanoes, large Low Qs zones estimated along the Hokkaido central axis with North-South trend in the depth of 0-30 km and Kanto at the depth of 30-60 km. The Low Qs zone along the Hokkaido central axis well correspond to the Low Vs obtained by Nishida et al.(2008) and concordant with metamorphic belt of ophiolites as a accretionary complex had been created since the Cretaceous era at ancient plate boundary. The Low Qs zone beneath Kanto corresponds to serpentine, as inferred from the material having a high Poisson ratio (Kamiya and Kobayashi, 2000). The Qs frequency dependence was weak at the Low Qs zones of volcanoes and the Hokkaido central axis.

Stress drop was calculated from the source spectrum obtained by the inversion and seismic moment. The stress drop increases with increased earthquake depth. Crustal earthquakes and interplate thrust earthquakes of the Pacific plate show significantly different tendencies in this respect. The interplate earthquakes are about 40 km deeper than the crustal earthquakes at the same stress drop level. The stress drop of the crustal earthquake also depends on the fault type. We find that reverse faulting events have the highest stress drop values. Normal faulting events have the lowest, and strike-slip faulting events have intermediate values.

The result of the site amplification in each groups shows that the frequency band at which large amplification factors are obtained by inversion well agrees with the predominant frequency. This result means that the site amplification could be isolated by the inversion.

We predicted peak ground acceleration (PGA) for some significant earthquakes using the estimated Qs structure and the stress drop of each earthquake. The PGA distributions were quantitatively well reproduced the observations for intermediate earthquakes by assuming point source. It is important to consider the 3-D attenuation structure for seismic ground motion prediction. However, the observation for large earthquake, the 2003 Tokachi-Oki earthquqake, was could not explained. For overcoming this problem, we introduced the stochastic green function method considering fault plane source model, and the PGA distribution could be reproduced the observation well.

As mentioned above, we could obtain a lot of new knowledge concerning about 3-D Qs structure and source parameter by using short period strong motion records and present the method of predicting seismic ground motion using these parameters.