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Estimation of stressing rate from seismic wave

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We have to monitor the state of stress in the crust to predict an occurrence of a large earthquake. The stress field controls the distribution of micro cracks in the crust, causing the scattering of seismic wave and the anisotropy of seismic wave velocity. Coda Q as the reference of scattering character and shear wave splitting by seismic anisotropy are considered to be a good indicator of the state of stress in the crust (Aki, 1980; Crampin et al., 1980). In fact, some researchers report that the value of coda Q or that of shear wave splitting shows a temporal change due to a stress change between before and after a large earthquake (e.g. Hiramatsu et al., 2000; Hiramatsu et al., 2005). In this paper, we estimate stressing rate in the crust from the spatial distribution of coda Q and shear wave splitting based on results of temporal changes of those due to a step-like stress change caused by a large earthquake.

We use seismic wave data in the high strain-rate zone from Kobe to Niigata. In this zone, the strain-rate is one order larger than that of the surrounding areas and also pointed that past large earthquakes occurred in this zone (Sagiya et al., 2000). Jin and Aki (2005) analyzed waveform data of Hi-net to obtain the spatial distribution of coda Q, showing the zone was characterized by low coda Q for 1-2 Hz and 2-4 Hz frequency bands. Iwatsuki et al. (2005) also reported that the delay time correlated positively with the differential strain rate in the zone from shear wave splitting analysis. We find a negative correlation between coda Q and the differential strain rate in the zone from the result of Jin and Aki (2005). These facts indicate that the crustal stress varies with the strain-rate in the zone.

We estimate the stress change in the zone from the spatial variations of coda Q and shear wave splitting. Here, we define the stress change response (SCR) as follows,

SCR_Qc = DQc/Qc/Dsigma for coda Q and SCR_S = Ddt/dt/Dsigma for shear wave splitting.

SCR_Qc is 10/MPa based on the temporal change in the coda Q in the Tamba region due to the static stress change by the Hyogo-ken Nanbu earthquake (Hiramatsu et al., 2000). SCR_S is 880/MPa based on the temporal change in the delay time due to the static stress change by the Aichi-ken Tobu earthquake (Saiga et al., 2003). DQc/Qc is about 0.25 for both 1-2 Hz and 2-4 Hz frequency bands in the zone, estimating a corresponding stress change is 25kPa. Ddt/dt is 4.4 in the zone, estimating a corresponding stress change is 5kPa.

Hiramatsu et al. (2005) reported that a time constant of the healing of cracks in the crust is about two years from the fact that the coseismically increasing time delay due to the Aichi-ken Tobu earthquake was back to the pre-event value during about tow years. The value of coda Q in the Tamba region was also back to the pre-event value during about two years (Sugaya et al., 2005). These suggest that the stress change in the zone is the change accumulated during two years. We, therefore, estimate that the stressing rate is 12.5 kPa/year for coda Q and that is 2.5 kPa/year for shear wave splitting.

The shear wave splitting reflects the state of stress in the upper crust and the coda that in the whole crust. Jin and Aki (1986) proposed the creep model in which coda Q was a parameter reflecting the degree of creep in the ductile part of the crust. We, thus, conclude that the observed difference in the stressing rate between coda Q and shear wave splitting is the difference in that of between the upper crust and the lower crust. The result of this study supports a hypothesis of Iio et al. (2002) in which a weak zone concentrates locally in the lower crust beneath the zone, causing the high strain-rate detected by GPS data.