

Estimation of stress change in ductile part of the crust inferred from seismic scattering

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In the past, stress field in the subsurface has been measured by various techniques. For example, the borehole-breakout, the stress release method, the hydraulic fracturing, the strain gauge buried in the ground are used to measure the stress field after costly drilling the subsurface. Beside the techniques requiring direct access to the subsurface, the stress field is also measured indirectly. The Electro Distance Meter, the Global Positioning System, etc. are used to measure a surface deformation in time, from which the subsurface stress change is estimated. However, the estimated stress change in the subsurface is largely affected by near-surface inhomogeneities. Thus, information on the stress field should be obtained from other indirect techniques.

Here, we focus on seismic scattering wave, particularly the coda-Q value, to measure spatial and temporal variations of subsurface stress field. The coda-Q, derived from the attenuation of coda envelope, is perceived to be an indicator of the inhomogeneity in the subsurface. Meanwhile, it has been proposed that the coda-Q has a proportional relationship with the magnitude of stress using a numerical simulation. In this study, we hypothesize that the coda-Q, obtained from seismic waves traveling over a wide range of the crust, indicates stress change in a deep subsurface. At first we numerically calculate a relationship between the coda-Q and the magnitude of stress using a homogeneous crustal model, and show that the coda-Q systematically increases against the magnitude of the stress. Then we confirm the relationship using a heterogeneous numerical model, which has a low velocity zone near the surface. It is revealed that the coda-Q indicates the magnitude of the stress change in the deep subsurface, beneath the inhomogeneity, while the surface strain distribution is largely affected by the low velocity zone near the surface. For the next step, using real seismic data acquired at the regions of the 2008 Iwate-Miyagi Nairiku earthquake and the 2004 mid-Niigata prefecture earthquake, we examine whether the coda-Q indicates stress change in the deep subsurface. The stress change estimated from the coda-Q corresponds with the theoretical one in the ductile part, calculated by a fault model acquired by a seismic wave analysis, whereas the estimated stress change does not correspond with the inferred one from GPS measurement. It means that the coda-Q can indicate stress change in the deep subsurface, which could give more accurate investigation than the GPS measurement.

Keywords: seismic scattering, stress change, ductile, heterogeneity