A depth-dependent deformation structure to explain geodetic and geologic observations in the Niigata–Kobe Tectonic Zone

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Crustal deformation around plate boundary zones has been observed by geodetic and geologic methods. Geodetic observations by GNSS can measure ongoing deformation with high accuracy, but the observation period is limited to the last few decades. On the other hand, geologic records such as active faults have information on past deformations over tens of thousands of years, but the temporal and spatial resolution is limited. To understand deformation processes leading to the generation of tectonic landforms and earthquakes, it is necessary to unify geodetic and geologic observations.
It has been reported that geodetically observed plate motion velocities and geologically observed fault slip velocities are consistent for major plate boundary faults (e.g., Ward 1998; Bourne et al. 1998). In some regions with complex fault systems, however, the relationship between geodetic and geologic observations is not clear. We focus on the Niigata-Kobe Tectonic Zone (NKTZ) as a typical region of the latter. From GNSS observations, the NKTZ shows a high horizontal strain rate ($>10^{-7}$ strain/year), where the crust appears to be divided to two blocks. On the other hand, the distribution of active faults does not show major structural discontinuities corresponding to the boundary of the crustal blocks. The process by which crustal deformation observed by GNSS is converted into fault slips on active faults remains unexplained.
To solve this problem, we used the method of Noda & Matsu'ura (2010) to objectively estimate the distribution of inelastic deformation, such as brittle fracture and plastic deformation, in the crust which causes crustal deformation during the interseismic period. In this method, inelastic deformation is represented as a moment density tensor, and the 3-D spatial distribution of the moment density tensor is estimated by inversion of geodetic data. To reduce high number of degrees of freedom in the model, the ratio of six components of the moment tensor is assumed to be the same as that of the background stress. We applied this method to the GNSS velocity data in the target area (35.8–37.2°N, 136–139°E) from March 2005 to February 2011. The result shows different spatial distributions of inelastic deformation in the upper and lower crusts: inelastic deformation in the upper crust is distributed along a complex distribution of active faults, whereas inelastic deformation in the lower crust is distributed along a single basement fault. The reconstruction test using synthetic data supports this depth-dependent characteristics. This depth-dependent deformation structure can explain both geodetic and geologic observations in the NKTZ.
A crustal block modeling approach is conventionally used to understand crustal deformation in the NKTZ. The crustal block models and the new depth-dependent model in this study reproduce similar surface deformation, but the stress loading occurring in the subsurface is quite different from each other. To understand the mechanisms of landscape-forming and earthquake generation in the NKTZ, it is necessary to develop a mechanical model based on the depth-dependent deformation structure estimated in this study.

Keywords: Niigata-Kobe Tectonic Zone, Strain rate paradox, Elastic/inelastic strain, GNSS data , Active faults

