Estimation of geological strain rates in the Japanese Islands

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For the deep geological disposal of high-level radioactive waste, it is important to assess the long-term stability of the geological environment around a repository for time frames greater than 100,000 years. Under the current framework, empirical laws, which indicate uniform modes and rates of crustal movements of the Japanese Islands, have been determined from previous research on the crustal deformation in the latter half of the Quaternary period (Kasahara and Sugimura, 1978; Matsuda, 1988). Applying the empirical laws to estimate the condition of future geological environments, extrapolation of well known crustal velocities has been done as one approach for making long-term predictions. However, strain rates estimated from geodetic data are about one order of magnitude larger than those estimated from geological data (Ikeda, 1996; Sagiya, 2004; Shen-Tu et al, 1995). Accordingly, it is necessary to consider spatiotemporal variation of crustal deformation in order to estimate future geological environments with higher reliability. Therefore, we have endeavored to establish a method to estimate long-term crustal movements by considering deformation patterns from past to present based on geological data and by conducting numerical simulations introducing the heterogeneous viscoelastic structure of the crust and mantle derived from geophysical observations.
To this end, we estimated the geological strain rate of the Japanese Islands using inland active fault data. Applying the dislocation theory of Okada (1985), we calculated crustal velocities accompanied with fault slips on 443 active inland faults in an elastic half space, based on the fault parameters such as average slip rate for 1,000 years, fault strike, dip, rake, length, and fault location. This calculation illustrates the geological velocities of crustal deformation when earthquakes occur on active inland faults. Next, we calculated geological strain rates from the crustal velocities. In this study, the average strain rate at any specific grid point is determined by assuming that the crustal deformation progresses with a uniform strain rate within a certain radius around the grid point (Shen et al., 1996).
From the calculations, horizontal crustal velocities of less than 4 mm/yr and vertical velocities varying between -1 mm/yr to 3 mm/yr were determined. For the vertical deformation, we determined uplift of ~0.3 mm/yr across the entire Japanese Islands, and subsidence of ~1 mm/yr along the Niigata Kobe Tectonic Zone and on the Pacific side of the Tokai district. Subsidence of up to 5 mm/yr on the Pacific side of Northeast Japan has been shown from the results of GPS observations and leveling (Murakami and Ozawa, 2004). The deformation pattern indicated from geodetic data seems to be the reverse of the pattern determined from geological data. A feature of the estimated strain rate field is that the Japanese islands are characterized by crustal shortening in the direction of oceanic plate subduction. We found that crustal shortening of the Ou Backbone Range is in the E-W direction, in the Niigata Kobe Tectonic Zone it is in the NW-SW direction. Crustal shortening and extension which reflects the right-lateral strike slip of the faults along the Median Tectonic Line and extension of the Kyushu district in the N-S direction were found. These results are generally consistent with those in geodetic observations (e.g., Sagiya et al., 2000). In future, we plan to compare the strain rate derived from GNSS data and to develop a method to estimate long-term crustal movement.

This study was carried out under contract with the Agency of Natural Resources and Energy (ANRE), part of the Ministry of Economy, Trade and Industry (METI) of Japan as part of its R&D program supporting development of technology for geological disposal of high-level radioactive waste. We used the active fault database of the National Institute of Advanced Industrial Science and Technology for the analysis.

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