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Estimation of crustal stress orientations from long-term trends of borehole strainmeters around Kii and Shikoku regions

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Long-term trends measured by borehole strainmeters can be interpreted as the relaxation process of stress disturbance caused by a borehole drilled in stressed rock mass. On the base of this model, the differences of long-term deformations in different orientations are due to an anisotropic stress field so that a borehole is compressed in the direction of maximum horizontal stress. Geological Survey of Japan, AIST has been constructing 14 integrated borehole observation stations in and around the Kii Peninsula and the Shikoku Island since 2006. Crustal strains are being observed with 4-component borehole strainmeters deployed at each station. In this study, we examine the long-term strain measured at each station from a view point of the model of the relaxation process due to stress disturbance by boreholes, and try to estimate the orientation of the maximum horizontal compressive stress by applying this model to strain data.

Firstly we use the strain data of about 700 - 1600 days up to September 2011 since instrument installations at 13 stations, where the strainmeter data were calibrated by comparing actual and theoretical tidal strains with a method of Matsumoto et al. (2011). Secondly, an average strain of 4-component data is extracted from original data to analyze only the anisotropic stress field. Thirdly we calculate the azimuthal distribution of relative change in radial 4 components during 90 days. As radial strain varies with cos2x as shown by this model, we fit a curve of cos2x to the relative change of strain and determine the orientation of maximum compression from the direction of minor axis of a fitted curve, where x is the angle between maximum horizontal stress and strain gauge. Finally time-varying stress orientations are obtained throughout the entire observed period by moving a time window of 90 days by each one day. The obtained stress orientations are nearly constant in time within a standard deviation of 2 degrees for 9 stations, while the orientations obtained at the other stations show large fluctuations. The stress orientations estimated at the 9 stations are not definite but rather dispersed, being distributed from northeast to southeast. We will compare the stress orientations estimated from this method with other results by hydraulic fracturing, stress-induced wellbore failure and anelastic strain recovery at each station to examine a validity of the proposed method in the next step. Further we will test a viscoelastic model or a poroelastic one to understand a mechanism of the long-term trend of the borehole strain data.

Keywords: crustal stress orientation, borehole strainmeter, long-term trend, Kii Peninsula, Shikoku Island