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Shear fracture strength of faults (V): The orientation of in-situ stress and the direction of GPS velocity

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1. Introduction: The in-situ stress measurements by DRA have revealed as follows; 1) The smallest horizontal stress in the Kitakami Mountains lies almost parallel to the GPS velocity. 2) The direction of the smallest horizontal stress in ODP Hole 794C is close to that of the largest P-wave velocity of the upper mantle beneath the Sea of Japan. 3) The largest horizontal stress is almost perpendicular to the fault strike in the vicinity of the Nojima fault. The results (1) and (2) suggest that the crust is driven by the motion of the upper mantle and the result (3) suggests that the strength of the fault is small or the fault is weak.

A fault zone model has been proposed to explain the weak faults by Yamamoto (in preparation). The result (1) suggests that the direction of GPS velocity can be employed in place of the principal direction of in-situ stress. In order to show that the model is universal for every fault, Yamamoto and Yabe (2007) have investigated the relationship of the direction of a fault strike to that of GPS velocity for the recent large earthquakes. They have found that the directions are parallel or perpendicular to each other within an error less than about 15 degree. In-situ stress data by DRA are newly obtained for 6 sites in the Tohoku district (Yabe, 2005). The relationship between the in-situ stress and the GPS velocity will be reexamined in this study.

2. Results: The in-situ stress measured by DRA is thought to be the average in-situ stress, to which a rock has been subjected at a depth for a time longer than a few years at least (Yamamoto, 2009). Therefore, the GPS velocities to be used for the comparison should be their averages over a time longer than a few years. In this study, the GPS velocity means the shift rate of the coordinate of a GPS station from 1997/4 to 2007/5. The direction of the largest or the smallest horizontal stress is compared with the directions of GPS velocity at the stations located at a distance within 20 km from the site of stress measurement. When a site (GNB) in the back born mountain range is neglected, the average difference in the direction between the largest or the smallest stress and the GPS velocity is about 10 degree. The largest is about 23 degree at a site FDI on the northern coast of the Pacific Ocean. It has been already shown that the largest horizontal stresses in the vicinity of the Nojima Fault lie nearly parallel to the GPS velocity.

The precision of the direction determined by DRA is about 5 degree. Referring to the data at the sites near the Nojima Fault by Sato et al. (2003), the direction of the largest horizontal stress varies by 25 degree at largest with depth in a hole. This suggests that the direction of the principal direction of stress has an ambiguity of about +/-13 degree at largest. The direction of GPS velocity shows the changes due to an earthquake occurrence. We divide the period from ’97 to ’07 into two periods, ’97 to ’02 and ’02 to ’07, to know the fluctuation of the direction with the period. The large difference between the two periods is seen for the stations around ENS and SND in the southeastern part of the Tohoku district. The difference amounts to +/- 25 degree. This may be caused mainly by the earthquakes that have occurred in and around the district during the period after 2003.

3. Conclusion: Although the direction of GPS velocity changes with an earthquake near a region, it is confirmed that the direction of GPS velocity in a long term approximates the principal direction of stress with an error smaller than about 10 degree. Yamamoto and Yabe (2007) have shown that the fault strikes are perpendicular or parallel to the GPS velocity with an error smaller than about 15 degree for the relatively large earthquakes that have recently occurred. The present results support thus that the fault surface is nearly equal to one of the principal plane of stress, or, the faults are weak.

Keywords: weak faults, GPS velocity, in-situ stress, deformation rate analysis (DRA), strike of a fault, ODP Hole 794C