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Shear fracture strength of faults: Relation between fault-strikes and displacement vector fields (III)

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INTRODUCTION: Yamamoto and Yabe (2009) proposed a damage zone/asperity model of faults on the basis of the results of stress measurements. According to the model, faults are weak and their shear strengths are less than 5 MPa at depths smaller than 10 km. When the displacement vectors are parallel to each other in a region, the direction is parallel to one of the principal stress axes. If we assume that there is no shear stress on a fault plane, the plane should be parallel or perpendicular to one of the principal planes of stress, that is, displacement vectors lie in parallel or perpendicularly to the fault plane.

The directions of fault strikes have been compared with the horizontal directions of the coordinate shift of GPS stations in the GRS80 system, where the strike directions are from the source mechanisms of recent large intra-earthquakes and geological faults in catalogs (Yamamoto and Yabe, 2007, 2008). These comparisons have been performed on the following assumptions: 1) The stress field is uniform in region by region. 2) The displacement field does not vary with depth. 3) The field does not vary with time. 4) The coordinate shift of a GPS station in GRS80 system represents the displacement of the station in the absolute coordinate system. 5) The strength of faults is negligibly small. 6) The displacement vector lies in the horizontal.

The strike directions have been found to be equal to the shift directions of GPS stations with the differences or the errors smaller than about 15 degree for the earthquakes and about 20 degree for the geological faults. These differences may be caused by the incomplete assumptions in addition to the nonuniform distributions of geological structures and temporal changes in the displacement field. In the present study, I will discuss the errors caused by the assumptions (5) and (6).

RESULTS: On the assumption (5), the displacement vector lies on or perpendicular to a fault plane. For discussing the errors caused by the assumption (6), we will consider a dipping plane of a fault such as a reverse fault, we write the strike direction and the displacement direction by x and X, respectively. The vertical is expressed by z, where the depth direction is negative. The fault normal is taken as Z. The angle between z and Z is written by (De) and that between x and X is by (Th). (De) corresponds to the dip angle. In this case, the angle between the displacement direction and the vertical is written by [sin(De)sin(Th)]. When (De) = 30 Deg. and (Th) = -15 Deg., the displacement vector directs downward by about 7 Deg. from the horizontal. When the displacement vector is perpendicular to the strike, the errors are independent of the dip angle of the fault.

The assumption (5) can causes the errors, too. At the depth of about 10 km, the shear strength tc of a fault is estimated at about 5 MPa. The shear stress t on a fault plane inclined by (Ph) from a principal direction is written by t = tm (sin 2(Ph)), where tm is the maximum shear stress around the fault. If a fault is stable at an angle of 20 Deg. from the principal stress axis, the shear stress tm is estimated to be smaller than about 8 MPa from the condition of t < tc.

DISCUSSIONS: The result of the discussions on (6) implies that the principal direction of stress is not in the vertical direction near a reverse fault. This can be confirmed by 3D stress measurements near the fault.

According to the damage zone/asperity model of faults, the maximum shear stress around a fault is less than 5 % of lithostatic stress at 10 km in depth. The relatively large errors can be produced in the region where the maximum shear stress is small. This may be another cause of errors.

Keywords: in-situ stress, principal axis of stress, displacement, strike, shear strength of faults,
weak faults