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Importance of stress distance in stress inversion analysis and its physical meaning

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Stress inversion methods are widely used to infer crustal stress states from fault-silp data. For the purpose of detecting different stresses separately from a heterogeneous fault-slip data set, we need to measure the difference between stress tensors. A statistical assessment of optimal stress solution or a comparison of solutions obtained through several methods also requires a measure of difference. However, it is not easy to define the difference of tensors. The unknown of stress inversion analysis is called reduced stress tensor, which carries the orientations of three pricipal stress axes and a stress ratio, the shape factor of stress ellipsoid. The problem is how to synthesize the differences in orientations and stress ratios.

Orife and Lisle (2003) proposed a solution to this problem. They calculated so-called "stress difference" between various stress tensors, which is defined as square root of second basic invariant of the difference tensor of two tensors, and showed its convenience. For example, given a nearly axial compressional stress with magnitude of sigma3 comparable to sigma2, a rotation around sigma1-axis yields small value of stress difference, while a rotation of sigma1-axis is evaluated as large difference. Although the stress difference was useful, its characteristics were clarified only empirically and its physical meaning remained unclear.

The physical meaning was given by Yamaji and Sato (2006). The stress difference approximately has one-to-one correspondence to the expected angular difference in shear stress directions on a randomly-oriented fault surface exerted by two stresses in comparison. In other words, the difference in stress tensor can be measured by that in fault-slip direction according to the Wallace-Bott hypothesis, which states a fault slips in the direction of shear stress. This fact means that the stress difference is suitable for solutions of stress inversion analyses based on the hypothesis.

The author recently found that the above-mentioned physical meaning was not exact. The stress difference turned out to be analytically equivalent to the expected difference in shear stress vectors on a randomly-oriented fault surface. The differences not only in directions, but also in magnitudes of shear stresses are involved in a value of stress difference. This discovery is inconvenient for the usage of stress difference in inversion analyses in which the magnitudes of stress are normalized. We need to pay attention to the fact that the way of normalization inevitably affects the values of stress differences.

References

Orife, T. and Lisle, R.J., 2003. Jour. Struct. Geol. 25, 949-957.
Yamaji, A. and Sato, K., 2006. Geophys. Jour. Int. 167, 933-942.

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