Development of uniform computational mesh for stress tensor inversion

Katsushi Sato[1]; Atsushi Yamaji[2]

[1] Earth and Planetary Sci., Univ. of Tokyo; [2] Div. Earth Planet. Sci., Kyoto Univ.

Stress inversion methods are used to determine paleostress tensors optimal for observed fault-slip data. They are based on the Wallace-Bott hypothesis, according to which a fault is assumed to slip in the direction of shear stress on the fault plane. The classical inversion (Angelier, 1979) is one of the most popular methods to obtain a reduced stress tensor of four independent components by minimizing the sum of angular misfits between resolved shear stress vectors and observed slip directions. The four include orientations of three principal axes and stress ratio. We need a set of reduced tensors to test whether they fit the observed fault-slip data or not. That mesh of tensors probably affects calculation time and resultant optimal solutions. Uniformity of computational mesh is required not only for analysis of ancient geologic structures but also for stress tensor inversion using focal mechanism data of earthquakes, for example, to enhance the precision of solution and efficiency of calculation. In this study, we showed a problem in multi-inverse method (Yamaji, 2000) caused by conventional search mesh, and developed uniform one. Consequently, resolution in distinguishing plural stress tensors was remarkably improved.

Multi-inverse method (Yamaji, 2000) is one of the most powerful methods to elucidate poly-phase tectonics among various stress inversion techniques. In this method the classical inversion is repetitiously applied to numerous subsets of faults extracted from the original data set. Then paleostress fields are represented by clusters of optimal stress tensors. However, the method has relatively poor resolution in distinguishing stress tensors which differ only in stress ratios; axial and triaxial stress tensors, for example. That was shown by an analysis of artificial fault-slip data which included the same number of faults slipped in response to each stress tensors. As a result, the axial stress was clearly detected while the triaxial one subtly appeared as a weak cluster. Ununiformity of the conventional mesh is thought to cause the bias to axial stress tensors. Axial and triaxial tensors have different degrees of freedom in orientations. Namely, the former are characterized by the orientation of one principal axis while the latter need one more axis. Therefore, triaxial stress tensors have more variation in their orientation than axial ones, and they should be contained more in the mesh. In other words, the conventional mesh is fine in axial stress tensors and coarse in triaxial ones.

The uniform mesh is newly generated based on the concepts of 6-dimenstional sigma-space (Fry, 1999) and stress difference (Orife and Lisle, 2003). In the sigma-space both a stress tensor and a fault-slip datum are represented by 6-dimensional directional vectors: sigma vector and f-pole vector, respectively. Then an optimal stress tensor is determined as a sigma vector normal to f-pole vectors. Firstly, that space was improved so that a distance between two points is equivalent to the stress difference. Then, the uniform mesh was generated from uniformly distributed points on the unit hyper-sphere.

The artificial fault-slip data were again analyzed with the new mesh, and resulted in equally dense two clusters of axial and triaxial stress tensors. The uniform mesh appears to correlate the numbers of faults activated by each stress with the apparent densities of clusters obtained by the multi-inverse method. The usage of the uniform mesh is not limited to the stress inversion: inversion methods of physical quantities represented by 3-dimensional symmetric tensors with two normalizations also need the mesh.