G122-P001 Room: Poster Session Hall Time: May 25

Fast Rf/phi strain analysis and a suitable parameter space for the analysis

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Strain analysis is an essential technique for complete understanding of the finite deformations of the lithosphere. Various methods have been developed to evaluate strain or deformation of rocks. Among the two-dimensional strain analysis using elliptical strain markers is a popular one. This paper is aimed at presenting a fast computer method of determining the optimal strain and its error for this two-dimensional strain analysis by means of a simple non-Euclidean geometry. The present method is applicable to non-elliptical strain markers.

A curved surface in the three-dimensional Minkovskii space, called the unit hyperboloid, is used as the parameter space for elliptical strain markers and the strain ellipse to be determined from the markers. A point on this surface has one-to-one correspondence with the combination of the orientation and aspect ratio of ellipses normalized by their areas in the physical space.

Given strain markers observed on a plane such as a planar outcrop or a section of a deformed rock, the same number of points on the unit hyperboloid are defined corresponding to the orientations and aspect ratios of the markers. Then, the optimal strain for the markers is simply determined as the center of mass of the points. No iterative calculations are needed for determining the strain at all.

The hyperboloid allows us not only to calculate strain but also to evaluate the dissimilarity between ellipses. That is, distance between two points on the hyperboloid always equals the doubled logarithmic strain needed to transform one ellipse to another represented by the two points. In this respect, the curved surface is suitable as the parameter space for two-dimensional strain analysis.

Thanks to the fast computation of the optimal strain and to this distance, we are able to draw, for example, the 95% confidence region of the optimal strain on the curved surface. Bootstrap resampling from strain markers yields a great number of strain ellipses optimal for the bootstrap samples. Then, those ellipses are transformed onto points on the surface. The spread of those points indicates the uncertainty of the optimal strain for the given strain markers. The 95% confidence region of this optimal solution is defined by the closed region encompasses the 95% of points around: the remaining points have greater distance from the optimal strain upon the surface.

The hyperboloid and points on it are mathematical entities in a non-Euclidean space, but they can be illustrated on a Euclidean plane by a simple transformation like the map projection from the globe to a paper. Strain markers and strain ellipses are represented by points, and confidence regions are also depicted by closed regions on this map.