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New inversion of calcite twin data for paleostress tested and calibrated on numerically-generated and natural data

Camille Parlangeau (1,2), Olivier Lacombe (1), Sylvie Schueller (2), and Jean-Marc Daniel (3)

(1) ISTeP, Université Pierre et Marie Curie, Paris, France , (2) IFPen, Rueil-Malmaison, France, (3) ifremer, Brest, France

The inversion of calcite twin data is a powerful tool to reconstruct paleostresses sustained by carbonate rocks during their geological history. Following Etchecopar's (1984) pioneering work, this study presents a new technique of inversion of calcite twin data, which allows reconstructing the 5 parameters of the deviatoric stress tensor.

In order to determine the applicability domain of the technique as well as to estimate the uncertainties on the reconstructed stress tensors, we first carried out tests on numerically generated calcite twin data and tested the separability of superimposed stress tensors with various degrees of similarity and the influence of optical bias, heterogeneities and occurrence of different grain size classes as met in natural samples.

For monophase datasets with homogeneous grain size, the errors on the different stress parameters (orientation of principal stress axes, stress ratio and differential stresses) are negligible except for the differential stress (error of 5%). In cases displaying distinct grain sizes, misfits remain negligible but may reach 20% for the differential stress if the differential stress applied is greater than 60-65 MPa. Incorporation of optical bias slightly increases uncertainties up to 25% for the differential stress, 5% for the stress ratio and 8° for the orientation of the principal stress axes.

For polyphase datasets with homogeneous grain size, the misfit on the orientation of the principal stress axes increases up to 10°, the stress ratio remains well constrained and the misfit on differential stress reaches 20% (applied differential stress > 70 MPa). Incorporation of optical bias increases the misfit of the orientation of the principal stress axes (average misfit: 6-8°; maximum: 17°), the misfit on stress ratio (average misfit: 2%; maximum: 26%) and the misfit on the differential stress (average misfit: 15%; maximum: 30%)

These tests demonstrate that it is better to analyze twin data from subsets of grains of homogeneous size in order to minimize the error on the differential stress, which is the least constrained stress parameter. This is mainly due to our poor knowledge on the critical resolved shear stress value for calcite twinning. The technique can detect and separate superimposed stress tensors with close orientations (30° of difference in orientation of principal stress axes) or tensors with stress permutations (e.g., switch of σ_2 and σ_3 axes).

The application on natural samples from veins in limestones of Tithonian-Aptian age (Monte Nero anticline, Italy) shows that even if some optical bias and natural heterogeneity exist, the inversion process finds stress regimes consistent with the opening of the successive vein sets.

In order to circumvent bias due to optical measurements, the EBSD (electron backscatter diffraction) technique has been adapted for the collection of calcite twin data. We carried out inversion of calcite twin data collected using both U-stage measurements and EBSD; the comparison of the paleostress results demonstrate the reliability of this new EBSD-based twin data collection and the potential of coupling this approach with our new inversion technique to derive the local/regional paleostresses of interest.