Stress evolution and fracturing during folding: 2D and 3D numerical simulations and application to chocolate-table structures in folded turbidites, SW Portugal

Jacqueline E. Reber*, Stefan M. Schmalholz[+], Jean-Pierre Burg

Department of Earth Sciences, ETH Zurich, Switzerland

* Now at PGP, Physics of Geological Processes, University of Oslo, Norway

[+] Now at University of Lausanne, Switzerland

j.e.reber@fys.uio.no

We present field data and numerical modeling of the evolution of stress and strain patterns during folding. We test the hypothesis that observed orthogonal fracture systems formed during folding. The case study is located near Almograve, SW Portugal, and the folded rocks are turbidites of Carboniferous age with low sandstone to shale ratio. Syn-folding metamorphic conditions are very low grade. Three outcrops display chocolate tablet structures in folded sandstone layers. Detailed observation of cross-cutting relationships reveals that the two, sub-orthogonal fracture sets occurred at different times. Fractures parallel to fold axes are younger than fractures orthogonal to the fold axis and both sets are orthogonal to the bedding.

Our working hypothesis was that the older fractures were mode 1 fractures generated during early compression (shortening), while layers were still approximately horizontal. The younger fractures were generated in response to local extension in the fold limbs, while the regional shortening direction remained constant.

We tested this hypothesis with 2D and 3D numerical simulations of viscous folding of single- and multilayers. Models show that the local σ_1 direction remains parallel to the far field σ_1 direction (i.e. shortening direction) but rotates by almost 90° with respect to bedding during folding. At the same time, the local σ_3 direction rotates with and within bedding, in the fold limb, from a fold-axis-parallel to a fold-axis-orthogonal direction. Therefore, mode 1 fractures can only open perpendicular to bedding during folding. Rotation of the local σ_3 controls the successive opening of suborthogonal fractures and veins.
We conclude that chocolate tablet structures in folded regions document a flattening strain regime as far as the total strain is considered, but this total strain is the addition of two orthogonal and successive events of similar shortening and stretching strains, which track and depend on the limb rotation.