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Numerical modeling of conjugate 'Riedel' deformation bands in sandstone

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Deformation bands in porous rocks are low-displacement deformed zones that increase cohesion and reduce porosity and permeability, and are commonly formed in a Riedel pattern (e.g. Antonellini et al., 1994; Davis et al., 1999). The term 'Riedel' refers to a specific fault pattern first created in clay cake models (Riedel, 1929). The pattern exhibits relatively short, en echelon fault segments of synthetic R and antithetic R' shears oriented at low- and high- angles to the main fault zone, respectively (Fig. 1).

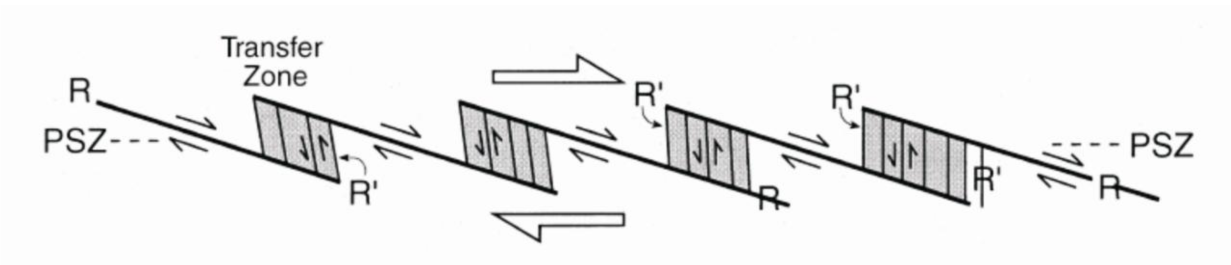

Fig. 1. Schematic sketch showing a Riedel shear zone composed of R and R' shears linked by transfer zone (after Davis et al., 1999).

Conjugate 'Riedel' pattern in sandstone has been documented in many studies (Davis et al., 1999; Fossen et al., 2007), and considerable amount of theoretical work on the development of deformation bands has been carried out (e.g. see review in Fossen et al., 2007). In this study, we have adopted numerical approach to simulate nucleation and growth of conjugate 'Riedel' deformation bands in sandstone. The advantage of numerical over other modeling techniques is that it allows user to model any particular physical/geological phenomenon and associated problem in various steps that follow sets of executable commands based on mathematical equations. The executable commands are written in a meaningful semantics that lead to answerable simulation. The results can be directly comparable to given physical process/problem at any stage with an advantage of quantitative outputs. We used Finite Difference Code (FDC) to simulate the structural evolution of deformation bands in sandstone. To generate model steps, FDC requires mechanical properties of sandstone that is an essential ingredient of the data file for execution. In this regard, the mechanical properties of sandstone are very carefully taken from the literature and used for modeling purposes (e.g. Okubo and Schultz, 2005).

We adopted Mohr-Coulomb material model with variable boundary conditions. In order to generate deformation bands, we first applied lateral shear to the mesh (strike-slip) as assumed in the theoretical models. However, surprisingly, no ‘Riedel’ geometries were formed at any stage during the given number of steps. We applied force ($\sigma 1$) on top of the mesh and observed the nucleation of conjugate pattern. The pattern consists of two cross-cutting sets oriented at an acute angle to $\sigma 1$. Each set consists of a zone with deformed antithetic pattern. We propose that this pattern may be the manifestation of R' shear. Our work is in progress and aimed to produce ‘Riedel’ pattern in sandstone. Based on the existing results, we can conclude that the formation of ‘Riedel’ geometry is not solely dependent on lateral shear, rather their growth is controlled by conjugate sets that are lying at an acute angle to $\sigma 1$.

References

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