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The relationship between deformation band properties, tectonic regime and burial in porous sandstone

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Based on field data and inferred stress states, we examine the dependence of deformation band geometrical and kinematic attributes on the far-field tectonic regime.
We have studied three different sets of deformation bands in the Upper Cretaceous sandstone in the South of France (Uchaux and Orange quarries, Provence). These band sets were formed during the N-S Paleocene-Eocene Pyrenean compression and potentially also during the NW-SE Oligocene extension related to the Gulf of Lion opening. The first set is composed of conjugate shear-enhanced compaction bands, closely spaced and showing wide variations in band thickness distribution. Microstructural observations in damaged areas adjacent to the compaction bands suggest that the force distribution at granular scale is bimodal, as predicted by theoretical and numerical studies of frictional granular materials. In thin section, we observe (1) chains of fragmented particles that are parallel to the compressive direction, which we interpret as force chains in the strong force network; and (2) intact or poorly deformed particles, which we interpret as making part of the weak force network. The force chains are recognized oblique to the bands, and bisecting their conjugate geometry at $\sim$45°. The second set is composed of conjugate E-W trending cataclastic shear bands of reverse sense. They show a regular spacing and a positive correlation between shear displacement and band thicknesses. The third set consists of conjugate $\sim$ N-S oriented cataclastic shear bands of normal sense, interacting with strike-slip fault zones by increasing their dip and their density. They show no clear regular spacing (clustered around the strike-slip faults) and a positive correlation between shear displacement and band thickness. Using thicknesses of sediments still present and potentially eroded above, we estimate that all the band sets have been buried between 300 and 800 m. Both the orientation and kinematic analysis of the first (compaction) and the second (reverse movement) band sets relate them to the Pyrenean compression. The tectonic origin of the third band set is less obvious. Both their orientation and their kinematic relation to the strike-slip fault zones make their link to the Oligocene extension debatable.
To understand the kinematics and spatial distribution of these deformation band sets, we analyze conceptual scenarios of tectonic stress evolution in q – p diagrams. These diagrams represent Drucker-Prager Cap yield envelopes consistent with the studied sandstones. We investigate several candidate stress paths during sediment burial based on theory and experiments. From the analysis of these diagrams and the integration of field data (from this study and the literature), we suggest that cataclastic deformation banding can occur during the burial history of a basin with (or without) tectonic compressive stresses, rather than under extensional stresses. We also show that frictional shear (evolution to faulting) and strain localization are likely in extensional tectonic stress conditions, and that compaction and strain distribution is favored for compressive tectonic conditions.