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Growth of deformation bands in a multi-layer sequence: Orange quarry, southern France

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Deformation bands formed in high-porosity coarse-grained Cretaceous sandstones in the Orange quarry, Bassin du Sud-Est, southern France, define several sequential sets having reverse senses of shearing offset. The bands form predominantly within one layer of a multi-layer sequence, terminating against the overlying layer and propagating into the subjacent layer. We report new field observations that refine the sequence and mechanics of the bands and successfully simulate their growth within this stack by using two-dimensional finite element models.

While previous work focused on the cataclastic bands in the quarry, we identify an earlier set of reverse-sense deformation bands that lack cataclasis and imply shearing with minimal strain hardening and porosity reduction within the bands. These early bands are overprinted by cataclastic bands; both generations have similar orientations to bedding, implying that they formed during the same episode of layer-parallel contraction. Field observations indicate that the upper and lower stratigraphic contacts of the deformation banded sandstone layer did not open or slip during band formation, and that the bands formed in sequential parallel sets, rather than in mutually crosscutting conjugate sets.

We modeled deformation band growth in the multi-layer sequence by using ADELI-2D. Layer properties were idealized as Drucker-Prager materials having specified values of friction angle, cohesion, and stiffness. Application of layer-parallel shortening displacements led to deformation bands forming at low strains and at the correct angles in the sandstone layers, and not forming in the intercalated carbonate layers, consistent with the field observations. The results indicate that layer strengths, rather than stiffnesses, control the formation of deformation bands subjected to a given far-field shortening. Further, while conjugate sets are predicted under layer-parallel shortening, the field observations of sequential sets can be recreated in the numerical simulations by superposing shear onto the model boundaries and, hence, facilitating a preferential growth of particular band sets. The results from both field work and finite-element simulations are consistent with the regional fold-and thrust tectonics. Our findings provide deeper insight into the development and geometry of deformation bands in multi-layer sequences in this and other areas characterized by contractional-strain geologic settings.