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Numerical Modeling of Fracturing in Non-Cylindrical Folds: Case Studies in Fracture Prediction Using Structural Restoration

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Abstract
This thesis contains several distinct studies aimed at better understanding fracturing in compressional fault-cored folds. At outcrops of growth strata in the Oliana anticline in the Spanish Pyrenees, the relationship of two joint sets may reflect changing mechanical properties (i.e. via diagenesis) during the folding process. Using a Schmidt hammer, I assess the rigidity contrast between the individual units and suggest that late-stage, throughgoing joints formed in strata with conditions similar to those of the present day and that early, bed-contained joints formed when the rigidity contrast between beds was significantly greater than the present day contrast. Modeling algorithms that are used for fracture prediction assume plane strain to construct, model and restore fault-cored folds. Using mechanical models that allow heterogeneous transport in three dimensions, I explore the distribution and magnitude of out-of-plane transport in plunging fault-cored anticlines and provide guidelines of

where plane strain should and should not be applied. I show that out-of-plane transport is significant in the simplest non-cylindrical folds, and suggest that complex non-cylindrical structures should not be modeled using plane strain. I mapped five bed-orthogonal fracture sets associated with folding and faulting events at Sant Corneli anticline, a non-cylindrical, fault related anticline in the Spanish Pyrenees. Fold axis perpendicular, calcite healed joint sets associated with similarly oriented normal faulting both pre-date, and are cross cut by calcite healed, N-NW striking joints. Later bed strike oblique joint sets are distinguished by the presence of iron oxide mineralization that probably occurred during Paleocene-Oligocene time. This study directly links fold-related fracturing to fold evolution because fracture sets can be dated relative to the structural evolution of the anticline. I use three-dimensional restorations of Sant Corneli anticline in the Spanish Pyrenees to test the fracture prediction capability of a fully three-dimensional finite element geomechanical restoration algorithm. Reconstruction of the three-dimensional architecture of the syn-tectonic strata provides a template for incrementally unfolding the anticline. Strains predicted by the restorations are compared to the fracture sets that formed over the corresponding time intervals, which are consistent with the observed fracture patterns at