3-D Characterization and Analysis of Fold-Fracture Relationships Using Airborne Laser Swath Mapping (ALSM) and Differential Geometry with Application to Raplee Monocline, Utah

Ian Mynatt, George Hilley and David Pollard
Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115, imynatt@pangea.stanford.edu.

Folding and fracturing can be intimately related processes in which the overburden stress, the remote tectonic stress, local folding related stresses and stress perturbations due to pre-existing fractures all influence new fracture formation. The development of tools for the prediction of fracture orientations would have important consequences for reservoir and aquifer assessment as fractures can act as conduits channeling fluids into reservoirs or break sealing capacity and disperse accumulated fluids. As a case study, we examine the relationship between the current fold geometry and fractures of Raplee Monocline. Raplee is a Laramide aged, N-S oriented, ~14-km long fold exposed in the Monument Upwarp of south-eastern Utah. The study involves three distinct parts: 1) Field based characterization of the fractures on and around the fold, 2) development of accurate models of the fold's geometry using high resolution data collected by ALSM, and 3) analysis of the fold's shape using the concepts of differential geometry.

Field observations of fracture characteristics in multiple stratigraphic units exposed at the anticline are summarized in conceptual models of fracture evolution based on these data. We describe five stages of fracturing: 1) the formation of pre-folding E-W Set I fractures by regional stress, 2) the formation of pre-folding N-S Set II fractures probably by regional stress, 3) the formation of tail-cracks off Set II and the flow of fluids through these and the main Set II fractures, 4) right lateral shear induced by folding creating NW-SE Set III fractures as tail-cracks of Set I fractures and as independent fractures and 5) the formation of Set II fractures as tail-cracks from slip along bedding planes. We also develop an algorithm to extract the geometry of exhumed folds using ALSM high-resolution topographic data. Our fold geometry extraction and interpolation algorithm identifies areas of the landscape that are likely to be bedding surfaces, extracts

elevation points from these bedding surfaces, and interpolates fold geometry between topographic exposures of bedding planes in the landscape. Finally, using algorithms based on differential geometry, the shape characteristics of fold models of Raplee Monocline can be precisely quantified. Specific geometric characteristics of the fold model, such as magnitude and direction of maximum curvature, can then be compared to the observed fracture characteristics. By combining the fracture data, fold shape models and geometric analysis, correlations between fold geometry and fracture characteristics can be examined and eventually predicted.