HR: 11:20h
AN: T52A-05
TI: Folding and Fracturing at Sheep Mountain Anticline: the Role of Reactivation
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AB: Field observations of sheared fractures and bedding planes in various structural locations across Sheep Mountain Anticline, Wyoming, document the role of fracture reactivation and flexural slip in folding related deformation. Observations of shearing also constrain spatial and temporal variations of the stress state across the anticline during folding. A fracture set that pre-dates the folding has sheared in the limbs in a sense that is consistent with the kinematics of folding, but no shearing of this fracture set has been recorded in the hinge. A folding-related joint set in the hinge has a high intensity and an azimuthal dispersion toward that of the pre-existing joint set. These observations suggest that, although the stress state in the hinge supported the formation of new joints rather than shearing pre-existing joints, this pre-existing set influenced the orientation of the folding related joints. At some locations, conjugate shearing has occurred along a set of joints (striking 045°) that formed early in the folding process and a set of joints (striking 075°) that formed during the development of a secondary fold at Sheep Mountain. These observations constrain the local principal stress directions if both sets sheared at the same time. The local σ_3 direction (maximum compression) is further constrained at locations where we have recorded left-lateral and right-lateral conjugate shearing of selected members of single sets of joints. Temporally, the σ_3 direction apparently varied enough to resolve shear stress with opposite senses on these sub parallel joints. Local σ_3 directions, constrained by observations of sheared joints, vary spatially along the anticline. Using an elastic model to investigate the theoretical stress perturbations caused by slip along the faults beneath Sheep Mountain, we find that model predictions are consistent with the rotations of the σ_3 direction inferred from field observations. Splay fractures, offset joints, and slickenlines indicate top toward the hinge slip on selected bedding planes in the forelimb and backlimb. Along with polished bedding surfaces, these observations indicate that interlayer slip has occurred, and thus that the flexural slip mechanism of folding has played a role in folding-related deformation at Sheep Mountain.
DE: 8000 STRUCTURAL GEOLOGY
DE: 8005 Folds and folding
DE: 8010 Fractures and faults
DE: 8020 Mechanics, theory, and modeling
SC: Tectonophysics [T]
MN: 2006 Fall Meeting

HR: 10:50h
AN: T52A-03 INVITED
TI: On the mechanical modeling of nucleation and propagation of fractures in folding rock strata
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AB: Mechanical models that follow the evolution of stresses and deformation provide insight into the origin of folding and the sequence of fracturing in geologic strata. Modeling of fracturing and deformation banding in folding strata is not a trivial task since the intense strain along a very narrow zone in a body experiencing very large deformation is a complex kinematics that is difficult to resolve even with the most advanced numerical techniques such as the finite element and boundary element methods. In this paper we present comparative studies and critical assessments of various numerical techniques for modeling the processes of nucleation and growth of fractures and deformation bands in folding strata using the finite element method. The presentation is divided into two parts: the first part focuses on frictional sliding along a preexisting defect, while the second part focuses on nucleation and growth of a new fracture. For a preexisting discontinuity we utilize finite deformation contact mechanics to capture frictional sliding along a well-defined surface of discontinuity. Finite element sides are aligned along the prescribed surface of discontinuity, and node-to-segment contact elements impose the kinematical friction law on this surface. Contact mechanics cannot be used for capturing fracture growth, however, since neither the orientation nor extent of a future surface of discontinuity is known at the outset, which means that element sides cannot be a priori aligned with an advancing fracture. To address this difficulty we utilize two computational techniques that capture an advancing discontinuity. The first is based on an embedded strong discontinuity where a finite element is allowed to rupture completely to simulate a propagating crack that cuts through and across it. The second utilizes a so-called extended finite element method (XFEM), which allows the element to rupture partially through the introduction of additional nodes surrounding the elements intersected by the crack. By presenting the advantages and disadvantages of these numerical techniques we provide an opportunity to select the most appropriate technique for resolving the multi-scale problem of meter-scale fracturing within kilometer-scale folds.
DE: 5104 Fracture and flow
DE: 8010 Fractures and faults
DE: 8012 High strain deformation zones
DE: 8020 Mechanics, theory, and modeling
DE: 8118 Dynamics and mechanics of faulting (8004)
SC: Tectonophysics [T]
MN: 2006 Fall Meeting

HR: 1340h
AN: T43A-1626
TI: Improving geologic surface interpolations using elastic plate bending solutions with additional physical constraints
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AB: Airborne laser ranging technology (LIDAR, ALSM) provides abundant data sets containing the geographic coordinates of discrete points on the tops of folded sedimentary layers which must be interpolated to describe the three-dimensional geometry of these geologic surfaces. Owing to the potential sparsity of coverage for a particular surface due to heterogeneous erosion and lack of exposure, robust interpolation techniques must be employed to construct continuous surfaces from the discrete and sparse data. Minimum curvature splines are a common interpolation tool for geological surfaces and are the analog of fitting an elastic sheet through all the data points. This tool, however, is not well suited for studying multiple stacked layers and tends to give nonphysical predictions. Minimum curvature methods can be enhanced for the specific purpose of interpolating folded geologic strata by adding layer thickness constraints for multilayer exposures, and by including additional terms in the governing equation that specify a non-uniform bi-axial tension in the elastic sheet. Layer thickness constraints are implemented by evaluating Green's functions of sub- or suprajacent surfaces at data points on the lower or upper surface which yield additional weighting parameters in the interpolation. These weighting parameters are found such that the difference between observed and interpolated elevations at known locations are minimized. General Green's function methods have been adapted to limit erroneous interpolations where high gradients in slope exist by adding a uniform bi-axial tension term to the governing biharmonic equation. We develop the Green's functions for a non-uniform bi-axial tension in two dimensions. The interpolation method presented here is employed at Raplee monocline, Utah. Folding at Raplee is thought to be caused by thrust faulting at depth. Several resistant layers with thicknesses varying between two and 20 meter were quantified with an ALSM survey. Individual surface interpolations yield interpenetrating surfaces, or negative thicknesses, which signal an erroneous interpolation. The interpolation methods outlined here can overcome these errors. Allowing for additional terms in the governing equation provides new insight into the remote boundary conditions of the folding at Raplee monocline.
DE: 0545 Modeling (4255)
DE: 3225 Numerical approximations and analysis (4260)
DE: 8005 Folds and folding
SC: Tectonophysics [T]
MN: 2006 Fall Meeting

HR: 1340h

AN: T43A-1625

TI: Modeling folding related multi-scale deformation of sedimentary rock using ALSM and fracture characterization at Raplee Ridge, UT

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AB: Understanding and predicting the characteristics of folding induced fracturing is an important and intriguing structural problem. Folded sequences of sedimentary rock at depth are common traps for hydrocarbons and water and fractures can strongly effect (both positively and negatively) this trapping capability. For these reasons fold-fracture relationships are well studied, but due to the complex interactions between the remote tectonic stress, rheologic properties, underlying fault geometry and slip, and pre-existing fractures, fracture characteristics can vary greatly from fold to fold. Additionally, examination of the relationships between fundamental characteristics such as fold geometry and fracture density are difficult even in thoroughly studied producing fields as measurements of fold shape are hampered by the low resolution of seismic surveying and measurements of fractures are limited to sparse well-bore locations. Due to the complexity of the system, the limitations of available data and small number of detailed case studies, prediction of fracture characteristics, e.g. the distribution of fracture density, are often difficult to make for a particular fold. We suggest a combination of mechanical and numerical modeling and analysis combined with detailed field mapping can lead to important insights into fold-fracture relationships. We develop methods to quantify both fold geometry and fracture characteristics, and summarize their relationships for an exhumed analogue reservoir case study. The field area is Raplee Monocline, a Laramide aged, N-S oriented, ~14-km long fold exposed in the Monument Upwarp of south-eastern Utah and part of the larger Colorado Plateau geologic province. The investigation involves three distinct parts: 1) Field based characterization and mapping of the fractures on and near the fold; 2) Development of accurate models of the fold geometry using high resolution data including ~3.5x107 x, y, z topographic points collected using Airborne Laser Swath Mapping (ALSM); and 3) Analysis of the fold shape and fracture patterns using the concepts of differential geometry and fracture mechanics. Field documentation of fracture characteristics enables the classification of distinct pre- and syn- folding fracture sets and the development of conceptual models of multiple stages of fracture evolution. Numerical algorithms, visual methods and field mapping techniques are used to extract the geometry of specific stratigraphic bedding surfaces and interpolate fold geometry between topographic exposures, thereby creating models of the fold geometry at several stratigraphic levels. Geometric characteristics of the fold models, such as magnitudes and directions of maximum and minimum normal curvature and fold limb dip, are compared to the observed fracture characteristics to identify the following relationships: 1) Initiation of folding related fractures at ten degrees of limb dip and increasing fracture density with increasing dip and 2) No correlation between absolute maximum fold curvature and fracture density.

DE: 8005 Folds and folding

DE: 8010 Fractures and faults

DE: 8020 Mechanics, theory, and modeling

DE: 8108 Continental tectonics: compressional
SC: Tectonophysics [T]
MN: 2006 Fall Meeting