GRAND JUNCTION GEOLOGICAL SOCIETY

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TWO APRIL MEETINGS

Joint meetings with the CMU geology students

SACCOMANNO LECTURE HALL

(In the Wubben Science Building)

THURSDAY APRIL 7, 2016 7:30 pm

AAPG DISTINGUISHED LECTURER

David A. Ferrill

Director, Dept. of Earth Material and Planetary Sciences, Southwest Research Institute

San Antonio, Texas

Will Speak On

"Mechanical Stratigraphy and Normal Faulting"

Abstract On Reverse

WEDNESDAY APRIL 27, 2016 7:30 pm

Colorado Mesa Students Will Present Posters On Their Current Research

Guests Are Always Welcome At Both Meetings

ABSTRACT

Analyses of normal faults at displacements spanning 7 orders of magnitude (mm to km) in mechanically layered strata reveal that mechanical properties of rock layers strongly influence nucleation points, failure mode (shear versus hybrid), geometry (e.g., refraction through mechanical layers), rate of propagation with respect to displacement (and potential for fault tip folding), displacement partitioning (e.g., synthetic dip, synthetic faulting, fault core displacement), fault core and damage zone width, and fault zone deformation processes.

In layered carbonate and shale strata, faults nucleate first in more competent limestone or dolostone beds and with steeper dips than fault segments in more argillaceous carbonate or shale layers. Consequently, faults commonly refract through mechanically layered strata, defined by steep hybrid or shear failure segments in competent layers, and more gently dipping shear failure segments in less competent strata. Slip along more gently dipping segments results in dilation of steep fault segments, even at depths of several kilometers. Systems of steeply dipping normal faults in brittle competent units may drive displacement into less competent strata where displacement is accommodated by distributed shear or slip on a system of low angle faults. With increasing extension and displacement, this may develop into an imbricate normal fault system, and a series of low angle faults may link to form a through-going detachment. Whereas slip initiation on a low angle normal fault is mechanically unlikely, driving of slip from high-angle faults in competent mechanical layers into an incompetent layer is mechanically viable, and can explain geometries of small scale systems observed in the field and seismic reflection data, as well as enigmatic earthquake patterns.

Fault propagation may slow or cease in incompetent units such as clay or evaporite-rich layers. Continued displacement on a fault with an arrested tip leads to folding beyond the fault tip, producing a fault tip monocline or fault propagation fold. Such folds are therefore the result of arrested or delayed fault propagation. With continued displacement, the fault may break through the monocline and leave tilted layers with dip in the same direction as the fault (i.e., synthetic dip) in the hanging wall, footwall, or both fault blocks. While this synthetic dip is often described as fault drag, we conclude that it is the product of folding prior to fault break-through and not the result of frictional drag on the fault.

The width of the faulted monocline is a primary control on fault zone (or damage zone) width, and is determined at the onset of folding related to the mechanical stratigraphy rather than a simple function of fault displacement. The other primary determinant of fault zone width is the spacing between overlapping fault segments (or width of relay ramps) that cooperate to define a fault zone. This spacing develops early and the displacement tends to localize into a narrower zone with increasing displacement, straightening and smoothing the fault surface by severing asperities that are poorly oriented for slip in the ambient stress field. The width of the segmented fault array is established early, and therefore this control on damage zone width is also not directly related to fault displacement. Analog modeling shows that fault systems develop in displacement versus length space along a stair-step path rather than a linear self-similar path, due to periodic jumps in fault length when fault segments link. With increasing displacement, fault zones with increasingly wide separation begin to cooperate and link. Thus fault zone width also grows along a stair-step trajectory with respect to displacement, the widening steps again associated with cooperation and linkage.

Similar to fault refraction described in carbonate rich strata, fault refraction is also seen in faulted volcanic strata of different competence. Where unconsolidated or poorly consolidated material overlies dilational fault segments in competent layers near the ground surface, drainage of material downward into the resulting voids along dilational fault segments leads to formation of pit craters and troughs, and incorporates externally sourced material into the fault zone. Faulting in volcanic rocks at the ground surface in some cases also shows evidence of fault tip folding, fissuring due to outer-arc extension (bending strain), and reactivation of cooling joints to define irregular largely dilational fault zones that experience toppling failure at the ground surface. Young and active fault zones developing at the surface in jointed volcanic rocks may appear to be degraded fault scarps, when in fact this is the character of the faulting process associated with upward fault propagation, fault tip folding, dilation of cooling joints to accommodate bending strain in the outer arc(s) of the monoclinal fold, and block toppling and sliding.

These detailed investigations are progressively dispelling some common myths about normal faulting, for example: (i) planar fault shape in dip profile, (ii) imbricate normal fault initiation due to sliding on low angle detachments, (iii) mechanism of frictional fault drag, (iv) self-similar fault zone widening as a direct function of fault displacement, and (v) that faults are not dilational features and/or important sources of permeability.