RELATIONSHIPS BETWEEN VEINING AND FAULTING AT TOADSTOOL GEOLOGIC PARK, NW NEBRASKA

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Abstract: A suite of veins and normal faults are well exposed in the badlands of Toadstool Geologic Park, and are being mapped into a GIS database as an undergraduate research exercise. Many gradations between smaller tensile veins and larger faults occur. At horizontal lengths > ca. 10 m slip is often evident along vein walls or along calcite median zones. Fault surfaces commonly change laterally into vein tips, steepening as they do so. Other fault tips transition into en echelon vein arrays. Fault zones are segmented into individual fault surfaces that link via tip curls. The same geometry is observed with the veined. Most faults have a zoned vein in their core. Both faults and veins are associated with wall rock alteration. These relationships, plus common orientations, indicate the faulting and veining are part of one deformation event. Similar veins and faults occur 30 miles to the W and are known from the Big Badlands (S.D.), indicating a more regional extent. Assuming these geometries represent brittle structures arrested at different stages of development, the following model for vein-to-fault evolution is proposed. Failure starts as a vertical tensile feature with local fluid migration depositing silica gels. Once the tensile fracture achieves a critical length, normal slip nucleates on the vein surface or along a calcite interior, producing striae or slickensides, respectively. Despite a sub-vertical orientation the vein surface may be weak enough to resolve sufficient shear stress to slip in the extensional regime. Continued vertical shear propagation at the fracture margin is in a mixed mode along a dipping surface, while horizontally is along a sub-vertical tensile surface. Brecciation, veining, and wall rock alteration with continued slip causes fault zone widening. What determines the threshold for shear to initiate on the veins is presently uncertain. The vein-to-fault transition eventually causes local strain hardening (by dilation and fluid pressure decrease, and/or mineralization), eventual strain migration, and a more distributed strain pattern.

Background information: Stratigraphic units involved in ascending order are: Cretaceous Pierre Shale, and the Chadron and Brule Formations of the White River Group. The stratigraphy has been recently redescribed by Terry & LaGarry (1998). Several lines of evidence indicate that the deformation is Anikareen in age. This implies that deformation was shallow, perhaps < 1 km.

Quick summary on vein-fault propagation literature: The literature on models for fault growth and propagation has burgeoned. Early models stressed linkage of pre-existing or precursory structures, with tensile fractures such as veins providing an example of the later (review by Crider & Peacock, 2004). They also recognized that propagation mechanisms vary along the fault margin dependent on the orientation of the slip vector relative to the margin (similar to screw and edge dislocations). In one common model, tensile fractures and/or other features that form due to stress concentrations at the fault tip represent a ‘process’ zone. Linkage of tip structures with continued strain occurs and the fault tip migrates through its precursory process zone (e.g. Marchal et al., 2003). In addition, faults can join to form a longer, segmented fault system when 2 separate fault tips enter each other’s area of stress influence and link through a relay zone. D’Alessio & Martel (2004) consider how barriers to fault growth influence fault terminations and tip structures. In this case tip structures may reflect fault growth arrest. Walsh et al. (2003), stressing the importance of a 3-D perspective, contrast isolated (similar to the model described above) vs. coherent fault models (where fault segments “are kinematically interrelated from their initiation”). Toadstool provides an opportunity to explore the utility of some of these models.

Description of the Toadstool GIS mapping project: We are building a GIS data base of features related to deformation in the Toadstool, Nebraska area. Layers include fault attributes, vein attributes, fracture density, sandstone channel positions, paleocurrent directions, USGS air photos, 10m USGS DEMs, and north central U.S. deformation localities (e.g. above map). Fault and vein attributes include orientations, thicknesses, fault throws, types of mineralization, and types of structures and/or textures. More than 1200 GPS localities with attribute information have been entered for the Toadstool area so far, and there is potential for several times this amount of data (i.e. mapping is far from complete). Objectives of the project are to: a) investigate fault-vein propagation mechanics, b) explore fault and vein scaling relationships, c) possibly constrain fluid flow patterns, d) constrain the regional strain pattern and place in a context of intraplate strain history and deformation mechanisms, e) to explore the utility of GIS in investigating the above, and to give undergraduates research experiences (all but the first author are undergraduate students). We intend to study other localities (e.g. S. D. Big Badlands) in a similar way. This poster is a progress report focusing on fault-vein relationships seen at Toadstool.

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Conclusions:
- A complex, distributed, strain pattern characterizes the area.
- Fault and vein formation was coeval.
- Veins occur in the middle portion of the map, here, but have not been mapped yet.

References: