Fault Failure Modes, Deformation Mechanisms, Dilation Tendency, Slip Tendency, and Conduits Versus Seals

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Abstract

Faults have complicated shapes caused by variations in failure modes dictated by mechanical stratigraphy interacting with the ambient stress field, as well as by linkage of fault segments. Different portions of a fault or fault zone may experience volume gain, volume conservation, and volume loss simultaneously depending on the position along a fault's surface, the stresses resolved on the fault, and the associated deformation mechanisms. This variation in deformation style and associated volume change has a profound effect on the ability of a fault to transmit (or impede) fluid both along and across the fault. Here we explore interrelated concepts of failure mode and resolved stress analysis, provide examples of fault geometry in normal faulting and reverse faulting stress regimes that illustrate effects of fault geometry on failure behavior, and consider the importance to fluid transmission. Examples from Central and West Texas include refracted normal faults from the Cretaceous Glen Rose Formation and Austin Chalk, and thrust faults in the Boquillas Formation (Eagle Ford equivalent). These examples exhibit various failure or reactivation modes - including tensile, hybrid, shear, compactive shear, and compactive failure - that occurred simultaneously during fault slip. The examples illustrate that fault segments with high dilation tendency and associated low to high slip tendency are likely to experience tensile (opening mode) to hybrid failure or reactivation, resulting in positive dilation or volume gain. Segments with low dilation tendency and associated low to moderate slip tendency experience compactive to compactive shear failure or reactivation, resulting in negative dilation or volume loss. Segments with moderate to

high dilation tendencies and high slip tendencies experience shear failure, that may be non-dilational or volume neutral. Analyzing dilation tendency versus slip tendency on fault patches can be used as a predictor of deformation behavior. Furthermore, this parameter space provides a new tool for evaluating conduit versus seal behavior of faults, applicable to faults at any scale and for any stress regime to predict failure or reactivation behavior, and the related potential for sealing versus conduit behavior. A key ingredient to such an analysis is detailed fault interpretation, as stress analysis of a simplified or smoothed fault interpretation will not correctly represent the detailed fault zone behavior.