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Could multiple ("conjugate") sets of tensile fractures develop simultaneously?

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Griffith's theory led to the convention that tensile fractures develop normal to the tensile (or least compressive) stress axis. Accordingly, it is expected that a given state of stress produces a single set of tensile fractures, and multiple sets of tensile fractures indicate multiple phases of deformation. We examine experimental and field observations which suggest that multiple sets of tensile fractures could form under a single extension phase. One case appears within sequences of brittle and ductile layers subjected to uniaxial tension (Sagy et al., 2001). Under this configuration, when the fractures in the brittle layers propagate dynamically (high propagation velocity), many of the fractures brunch to form tree-like fracture networks. The macroscopic angle between the branch and the parent fracture is 10-20 degrees, and this geometry forms "conjugate" patterns within clusters of dense fractures. A second case appears under uniaxial tension in plates of elastic-plastic solids such as metals. These solids fail in mixed mode of tensile and shear in which the fractures extend at angles ranging from about 50 to 65 degrees from the extension axis (Agnon & Eidelman, 1991; Zang et al., 2005); such diagonal fractures could lead to the development of "conjugate" sets. The hybrid fractures in rock mechanics experiments (Ramsey & Chester, 2005) belong to this group. We recently observed similar patterns of multiple sets in sandstone layers of the Jackfork Formation at quarries in Oklahoma and Arkansas. Subhorizontal, massive 5-20 m thick layers of well-cemented sandstone display multiple tree-like fractures. The fracture sets dip steeply, crosscut one another, and expose plumose and arrest-line features, and they often form 3D networks of multiple sets in rhombic geometry. The occurrence of multiple fracture sets even under uniaxial tension indicates a transitional mode from brittle to plastic failure. We propose that this mode could be active in many rock bodies in the field.