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Polymodal faulting by crack or anticrack interaction

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Faults in the upper crust are composite brittle shear fractures formed through the interaction and coalescence of tensile microcracks. One mechanism for subduction seismicity below 300 km is phase transformation faulting through the interaction and coalescence of compressive anticracks. The geometry of these flaws and their surrounding elastic stress fields exert a fundamental control on the orientation of the final shear planes. The Coulomb-Mohr failure criterion predicts the development of conjugate bimodal shear planes inclined at an acute angle to the maximum compressive principal stress and parallel to the intermediate principal stress. However, Coulomb-Mohr theory is incapable of explaining more complex three-dimensional fracture populations that are widely observed in rocks and recorded in subduction zone seismicity in which multiple sets of shear fractures are oriented oblique to the intermediate principal stress direction.

We show that the elastic stress fields around tensile microcracks and compressive anticracks in three-dimensions promotes interaction and coalescence to form shear planes oriented oblique to the remote principal stresses, and can therefore account for polymodal fault patterns. Previous models of crack interaction have employed some form of simplifying two-dimensional approximation. Our fully three-dimensional model is based on the solution of Eshelby. The commonly observed spread in orientations of apparently conjugate bimodal faults in published datahas previously been ascribed to noise caused by some combination of measurement error, material anisotropy (e.g. due to layering), or heterogeneous remote stress fields. However, these variations in the orientation of shear fractures may be of primary significance, and at least partially reflect the oblique nucleation of many shear fractures under triaxial stress conditions in the lithosphere.

An improved understanding of the controls on the orientations of brittle shear planes in three-dimensions has important implications for earthquake seismology, rock-mass stability and hazard assessment, as well as fluid migration and the efficient recovery of mineral resources from fractured host rocks.