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Effects of crystallographic anisotropy on fracture development and acoustic emission in quartz

Abstract

Transgranular microcracking is fundamental for the initiation and propagation of all fractures in rocks. The geometry of these microcracks is primarily controlled by the interaction of the imposed stress field with the mineral elastic properties. However, the effects of anisotropic elastic properties of minerals on brittle fracture are not well understood. This study examines the effects of elastic anisotropy of quartz on the geometry of brittle fracture and related acoustic emissions (AE) developed during indentation experiments on single crystals at ambient pressure and temperature. A Hertzian cone crack developed during blunt indentation of a single crystal of flawless Brazilian quartz parallel to the c axis shows geometric deviation away from predictions based on the isotropic case, consistent with trigonal symmetry. The visible cone crack penetration depth varies from 3 to 5 mm and apical angle from 53° to 40°. Electron backscatter diffraction (EBSD) mapping of the crack tip shows that fracturing initiates along a ~40 mm wide process zone, comprising damage along overlapping en echelon high - index crystallographic planes, shown by discrete bands of reduced electron backscatter pattern (EBSP) quality (band contrast). Coalescence of these surfaces results in a stepped fracture morphology. Monitoring of AE during indentation reveals that the elastic anisotropy of quartz has a significant effect on AE location and focal mechanisms. Ninety - four AE events were recorded during indentation and show an increasing frequency with increasing load. They correspond to the development of subsidiary concentric cracks peripheral to the main cone crack. The strong and complex anisotropy in seismic velocity (~28% Vp, ~43% Vs with trigonal symmetry) resulted in inaccurate and high uncertainty in AE locations using Geiger location routine with an isotropic velocity model. This problem was overcome by using a relative (master event) location algorithm that only requires a priori knowledge of the velocity structure within the source volume. The AE location results correlate reasonably well to the extent of the observed cone crack. Decomposition of AE source mechanisms of the Geiger relocated events shows dominantly end - member behavior between tensile and compressive vector dipole events, with some double - couple - dominated events and no purely tensile or compressive events. The same events located by the master event algorithm yield greater percentage of vector dipole components and no double - couple events, indicating that AE source mechanism solutions can depend on AE location accuracy, and therefore, relocation routine is utilized. Calculations show that the crystallographic anisotropy of quartz causes apparent deviation of the moment tensors away from double - couple and pure tensile/compressive sources consistent with the observations. Preliminary modeling of calcite anisotropy shows a response distinct from quartz, indicating that the effects of anisotropy on interpreting AE are complex and require detailed further study.

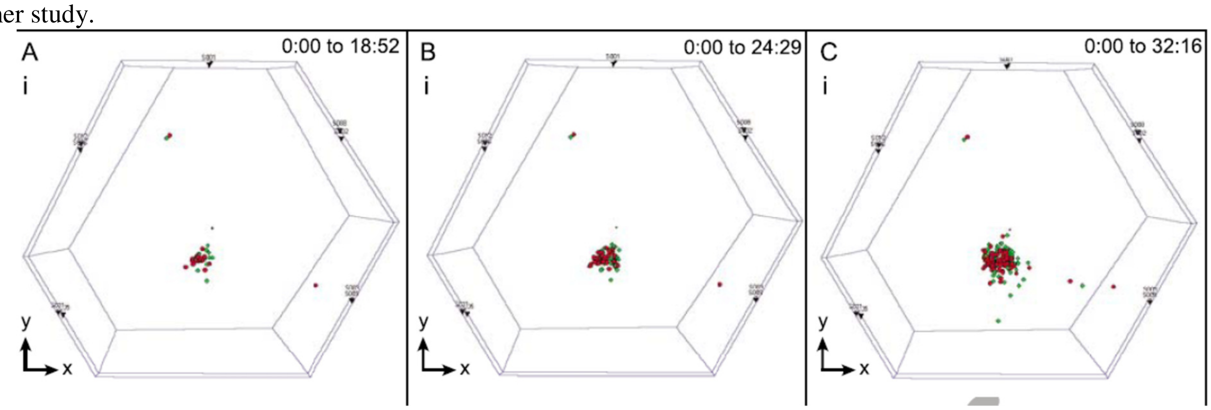

***Figure**:* Views of the cumulative AE events recorded during the blunt indentation experiment over time. A total of 94 source events were successfully located using the Geiger routine (green circles) and relatively located (red circles) using an early master event located at the upper surface of the sample.

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