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# How Stress Biaxiality Controls Crack Morphology and Apparent Fracture Energy of Rocks

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## Abstract

The emplacement of dikes and sills plays a crucial role in crustal mechanics. Notably, the parameter used to describe their resistance to propagation, fracture energy, is subject to controversial variations. Here, we show how different stress biaxiality levels experienced by dikes can directly affect the micromechanisms of crack propagation in rocks, consequently impacting fracture energy.

We performed tensile crack propagation experiments on Carrara marble under opposite stress biaxialities, measured by the T-stress. We chose the modified ring tests (MRT) and wedge splitting tests (WST) for their average T-stress values of -8.7 and 3.5 MPa, respectively. Their steady propagation allows for continuous monitoring of fracture energy using a compliance-based method. On post-mortem specimens, we extracted thin sections at the crack tip to acquire backscatter electron (BSE) and electron backscatter diffraction (EBSD) images using a scanning electron microscope.

These experiments reveal test-dependent fracture energy ranging from 20 to 35 J/m<sup>2</sup> on MRT and 20 to 65 J/m<sup>2</sup> on WST, depending on crack tip position. BSE and EBSD scans display straighter cracks traversing grains under negative T-stress (MRT). While under positive T-stress (WST), cracks stray and fork along grain boundaries to circumnavigate tougher heterogeneities, further devolving into fragmentation of the crack front. This yields a higher fracture energy that we attribute to front roughening and bridging mechanisms. The bridging toughening is gradual and increases with crack size, aligning with the growth of out-of-plane excursions adding tearing stresses (mode I + III) that promote these topological instabilities. This suggests a scale dependency of fracture energy in dikes and sills that also experience positive T-stress.

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