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Catching failure in the act: mapping fracture initiation and spreading using X-ray tomography

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We are using high-resolution X-ray computed tomography to understand the circumstances behind sudden rock failure, caused by the onset of a brittle cascade. Using a uniaxial press, we have deformed a series of 5 cm diameter cores of magnesite and gabbro just up to, and beyond, the point of failure, and imaged them using high-resolution X-ray computed tomography (CT). Fractures occur across a range of scales, and thus some will be above and some below the resolution of a CT system. To maximize the range we observe, we use subvolume scanning to image the centers of the cores at higher resolution, along with whole-sample scans when 3D context is useful. We measure fracture apertures at sub-voxel resolution using partial-volume calculations, which we recently added to the Blob3D software created at the University of Texas. The algorithm uses a grid of parallel traverses near-normal to the fracture to reduce uncertainty in the calculation and determine 3D orientation, allowing us to both map orientation distribution and correct for apparent-thickness effects. Using these capabilities, we find evidence for the onset of brittle behavior in the pre-failure sample as a series of sparse micro-cracks, on the order of 2 mm long and 5-20 μm wide at their centers, without an obvious preferred orientation in the uniform magnesite sample. The failed sample with the same lithology contains larger master fractures spanning the core that reflect the final failure, but also a web of fractures encompassing the range of initial orientations. The mode of occurrence of these secondary fractures thus both predates and postdates catastrophic failure, and its topological configuration is influenced by the rock fabric, or lack thereof.