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The route to shear failure in a non-porous rock revealed by X-ray microtomography

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The rocks in the crust of the Earth are heterogeneous at the microscale, which has implications on the mode of failure and the existence of precursors to rupture. Using high-resolution X-ray microtomography technique and a triaxial deformation rig called Hades installed at the European Synchrotron Radiation Facility, it is now possible to simulate in-situ rock deformation under crustal conditions at the laboratory scale. We report experiments on deformation of centimetre-scale cylindrical marble samples under compressive loading and confining pressure in the range 20 to 30 MPa. The rock is non-porous and the heterogeneities correspond to the grains and grain boundaries. High-resolution X-ray microtomography acquisitions at a voxel size of 6.5 micrometers are performed while the axial load is increased in steps until reaching the shear failure of the sample. Failure is preceded by numerous micro-fracturing events, which we call damage, that ultimately accumulate into a shear fault. Damage volume and sample density show significant accelerations with applied differential stress before rupture, indicating that precursory signals are present before rupture. This acceleration of damage towards the peak stress as well as the associated micro-fracture size distributions show power-law scaling that argues for an interpretation of rock failure as a critical phenomenon. The present study, therefore, sheds new light on precursory phenomena preceding failure in low-porosity carbonate rocks, which can be of help in unraveling the physics of precursors to earthquakes.