Failure mechanisms in low-porosity carbonate rocks during the reactivation of deformation bands with various orientations

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Deformation bands, or tabular zones of localised strain, are a common manifestation of deformation in upper crustal sedimentary rocks. Any mining or energy-related engineering applications must consider the possibility of reactivating these pre-existing failure planes because doing so can cause seismicity and compartmentalise the reservoir. However, there has only been a small amount of research done on laboratory-induced deformation in rocks with natural deformation features.

On a low porosity bioclastic calcarenite from the Cotiella Basin, Spanish Pyrenees, our current experimental work aims to capture, for the first time to our knowledge, the dominant failure mechanisms during the reactivation of natural deformation bands oriented at different angles to the principal stress direction. At the I12-JEEP beamline at the synchrotron facility of Diamond Light Source, UK, we carried out triaxial compression experiments using a modified version of the Mjolnir cell used by Cartwright-Taylor et al., (2022) to examine how these highly heterogeneous rocks respond to additional mechanical deformation. During the deformation experiments, 4D (time and space) x-ray tomography images (8 m voxel size resolution) were acquired. We tested confining pressures between 10 MPa and 30 MPa.

The mechanical data demonstrate that the existence of natural deformation features within the tested samples weakens the material. For instance, solid samples of the host rock subjected to the same confining pressures had higher peak differential stresses. Additionally, our findings demonstrate that new deformation bands form as their angle, θ, to σ1 increases, while the reactivation of pre-exiting deformation bands in this low porosity carbonate only occurs for dipping angles close to 70^{o}. The spatio-temporal relationships between the naturally occurring and laboratory-induced deformation bands and fractures were investigated using time-resolved x-ray

tomography and Digital Volume Correlation (DVC). Volumetric and shear strain fields were calculated using the SPAM software (Stamati et al., 2020). The orientation of the recently formed failure planes is influenced by the orientation of the pre-existing bands, as well as their width and the presence (or absence) of porosity along their length. Additionally, pre-existing secondary deformation features found in the tested material trigger additional mechanical damage that either promotes the development or deflects the new failure planes.

References

Cartwright-Taylor et al. 2022, Nature Communications 13, 6169, https://doi.org/10.1038/s41467-022-33855-z

Stamati et al. 2020, Journal of Open Source Software, 5(51), 2286, https://doi.org/10.21105/joss.02286