Reactivation Of Natural Deformation Bands In Upper Crustal Sedimentary Rocks: Insights From Laboratory-Induced Deformation With 4D X-ray Tomography

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Reactivation of Natural Deformation Bands in Upper Crustal Sedimentary Rocks: Insights from Laboratory-Induced Deformation with 4D X-ray Tomography

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Abstract Summary :

In this study, we present experimental investigations on a low-porosity bioclastic calcarenite from the Cotiella Basin in the Spanish Pyrenees. Our objective is to elucidate the dominant failure mechanisms during the laboratory reactivation of natural deformation bands oriented at various angles to the maximum principal stress (σ1) direction. Triaxial compression experiments were conducted at the I12-JEEP beamline of the Diamond Light Source, UK, using a modified version of the Mjolnir cell employed by Cartwright-Taylor et al. (2022). Moreover, 4D (space and time-resolved) X-ray computed tomography images were acquired at 8 μm^3 voxel size resolution during the triaxial compression tests (10 MPa to 30 MPa confining pressure).

Our mechanical data show that the presence of natural deformation features within the tested samples influences the material's strength. When comparing intact samples of the host rock under the same confining pressures, we observed that these samples exhibit higher peak stresses as opposed to those containing natural deformation features. Our research reveals that new deformation bands are formed as the angle (θ) between the deformation bands and σ1 increases. In this low-porosity carbonate, the reactivation of pre-existing deformation bands only occurs when their dipping angles are close to 70°.

To investigate the spatial and temporal relationships among naturally occurring and laboratory-induced deformation bands and fractures, we employed time-resolved X-ray CT and Digital Volume Correlation (Figure 1). Utilizing the SPAM open-source software (Stamati et al., 2020), we calculated the volumetric and shear strain fields. The orientation of the laboratory-induced failure planes is influenced by the orientation, width, and presence (or absence) of porosity along the length of the pre-existing natural bands. Additionally, the pre-existing secondary deformation features may contribute to additional mechanical damage, which can either facilitate the development or divert the newly formed failure planes.

In summary, our findings emphasize that the presence of natural deformation features weakens the material. We also observe that the reactivation of pre-existing bands occurs primarily at dipping angles near 70° in this low-porosity carbonate. The use of advanced imaging techniques and the SPAM software have allowed us to explore the relationships between the naturally occurring and laboratory-induced deformation features, highlighting the influence of orientation, width, and porosity on the orientation of failure planes. Finally, the presence of pre-existing deformation features triggers additional mechanical damage, affecting the development and direction of new failure planes.

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