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Quantifying the effect of core plug edge effects on porosity and permeability under uniaxial and triaxial loading conditions

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Since Hawkes and Mellor (1970) it has been recognised that uneven stress distributions occur within a core during loading in the laboratory due to edge effects generated by the interface between the loading platen and the rock sample. Although these effects can be minimised by following ISRM standards of sample preparation and test conditions, the effect cannot be fully removed.

While these edge effects are recognised in stress, the impact that the varying stress distribution has on the fabric and microstructure of the sample is less well known. Critically, these effects are overlooked when taking bulk petrophysical property measurements – porosity and permeability – of cores during or after a stress test. Bulk property measurements may not be representative of the true variation in these properties that can be found along the core length. If stress is focussed in certain parts of the core leading to inelastic deformation in these areas, it could be expected that a resulting impact on porosity or permeability would be present in those areas.

Here we analyse porosity and permeability along the length of stressed cores to determine if the irregular stress distribution as modelled by Hawkes & Mellor (1970) manifests itself in variations in the permeability and porosity. We examine these effects in samples of two different lithologies (low porosity and permeability Lanhellin granite and high porosity and permeability Clashach sandstone) taken to 90% of their failure strength under both uniaxial ($\sigma_1 > \sigma_2 > \sigma_3 = 0$) and conventional triaxial ($\sigma_1 > \sigma_2 = \sigma_3$) loading conditions, to examine the impact of both loading and lithology.

Cores of each lithology were prepared according to ISRM standards. Each core was pre-characterised for bulk gas porosity (helium) and permeability (nitrogen). Six cores of each lithology were taken to failure under axial compression at three different confining pressures (0MPa, 25 MPa and 50 MPa) to determine the ultimate failure strength. Acoustic emission detection was also utilised to determine damage onset in each test.

Subsequently six cores (two at each confining pressure) were subjected to 90% of the failure strength to induce inelastic deformation (microcracking) into the core plugs. At this level of stress, inelastic deformation in the form of microcracking has been induced into the sample as evidenced by the generation of acoustic emissions.

To examine the variation in permeability and porosity along the core length, the cores were serially sectioned into eight segments with porosity and permeability data acquired for each segment. The variation in porosity and permeability along the length of the stressed cores is compared to a non-stressed sample that has undergone the same analysis.

The results of this study can be used to understand how microstructural variations along a core length that result from uneven stress distributions can affect porosity and permeability magnitudes. These results have implications for how bulk porosity and permeability data acquired for stressed samples should be contextualised with respect to the way stress is distributed within the sample.