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Mechanical behavior and localized failure modes in a porous basalt from the Azores

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Basaltic rocks are the main component of the oceanic upper crust. This is of potential interest for water and geothermal resources, or for storage of CO_2. The aim of our work is to investigate experimentally the mechanical behavior and the failure modes of porous basalt as well as the permeability evolution during deformation.

Cylindrical basalt samples, from the Azores, of 30 mm in diameter and 60 mm in length were deformed the triaxial cell of the Laboratoire de Geologie at the Ecole Normale Supérieure (Paris) at room temperature and at a constant axial strain rate of 10-5 s-1. The initial porosity of the sample was 18%.

The Geodesign triaxial cell can reach 300MPa confining pressure; axial load is performed through a piston and can reach 900 MPa (for a 30mm diameter sample); maximum pore pressure is 100MPa (applied using two precision volumetric pumps). In our study, a set of experiments were performed at confining pressure in the range of 25-290 MPa.

The samples were deformed under saturated conditions at a constant pore pressure of 5MPa. Two volumetric pumps kept the pore pressure constant, and the pore volume variations were recorded. The evolution of the porosity was calculated from the total volume variation inside the volumetric pumps. Permeability measurements were performed using the steady-state technique.

Our result shows that two modes of deformation can be highlighted in this basalt. At low confining pressure ($Pc < 50$ MPa), the differential stress attains a peak before the sample undergoes strain softening; the failure of sample occurs by shear localization. Yet, the brittle regime is commonly observed in this low Pc range, the experiments performed at confining pressure higher than 50 MPa, show a totally different mode of deformation.

In this second mode of deformation, an appreciable inelastic porosity reduction is observed. Comparing to the hydrostatic loading, the rock sample started to compact beyond a critical stress state; and from then, strain hardening, with stress drops are observed. Such a behavior is characteristic of the formation of compaction localization, due to grain crushing and pore collapse. In addition, this inelastic compaction is accompanied by a decrease of permeability, indicating that these compaction bands or zones act as barrier for fluid flow, in agreement with observations done in sandstone (Fortin et al., 2005).

Further studies, including microstructural observations carried out by mapping the compaction bands or zones throughout a mosaic of SEM images at high resolution and acoustic emission recording will be carried in order to confirm the formation of compaction localization, and the micromechanisms (pore collapse and grain crushing) taking place in this second mode of deformation.

REFERENCES

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