Geophysical Research Abstracts
Vol. 18, EGU2016-4136, 2016
EGU General Assembly 2016

Deformation mechanisms in experimentally deformed Boom Clay

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Bulk mechanical and transport properties of reference claystones for deep disposal of radioactive waste have been investigated since many years but little is known about microscale deformation mechanisms because accessing the relevant microstructure in these soft, very fine-grained, low permeable and low porous materials remains difficult. Recent development of ion beam polishing methods to prepare high quality damage free surfaces for scanning electron microscope (SEM) is opening new fields of microstructural investigation in claystones towards a better understanding of the deformation behavior transitional between rocks and soils.

We present results of Boom Clay deformed in a triaxial cell in a consolidated - undrained test at a confining pressure of 0.375 MPa (i.e. close to natural value), with $\sigma 1$ perpendicular to the bedding. Experiments stopped at 20 % strain. As a first approximation, the plasticity of the sample can be described by a Mohr-Coulomb type failure envelope with a coefficient of cohesion C = 0.117 MPa and an internal friction angle [U+03D5] = 18.7°. After deformation test, the bulk sample shows a shear zone at an angle of about 35° from the vertical with an offset of about 5 mm. We used the “Lamipeel” method that allows producing a permanent absolutely plane and large size etched micro relief-replica in order to localize and to document the shear zone at the scale of the deformed core. High-resolution imaging of microstructures was mostly done by using the BIB-SEM method on key-regions identified after the ”Lamipeel” method.

Detailed BIB-SEM investigations of shear zones show the following: the boundaries between the shear zone and the host rock are sharp, clay aggregates and clastic grains are strongly reoriented parallel to the shear direction, and the porosity is significantly reduced in the shear zone and the grain size is smaller in the shear zone than in the host rock but there is no evidence for broken grains. Comparison of microstructures within the host rock and the undeformed sample shows that the sample underwent compaction prior shearing that results in a change of power law exponent of the pore size distribution within the clay matrix and a slight reorientation of clastic grains’ long axis perpendicular to $\sigma 1$. Microstructures in the shear zone indicate ductile behavior before the specimen’s failure. Deformation mechanisms are bending of clay plates and sliding along clay-clay contacts. Strain is strongly localised in thin, anastomosing zones of strong preferred orientation, producing slickensided shear surfaces common in shallow clays. There is no evidence for intragranular cracking.We propose that the deformation localizes in regions without hard quartz grains.