



## Experimental Deformation of Sandy Opalinus Clay at Elevated Temperature and Pressure Conditions

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Studying the mechanical properties of argillaceous rocks is of major interest in geoscience. For example, these rocks are important in engineering applications such as being suitable cap-rocks for the geological storage of carbon dioxide and potential host rocks for the storage of nuclear waste. Furthermore, argillaceous rocks are encountered in different natural settings such as accretionary wedges or fault zones. As a result of their sedimentary and diagenetic history clay rich rocks are often characterised by multiscale textural anisotropy and compositional heterogeneity resulting in anisotropic mechanical and hydraulic properties.

Here, we studied the anisotropic deformation behaviour of Opalinus Clay, collected from the Mont Terri underground laboratory, which is the envisaged host rock formation for nuclear waste disposal in Switzerland. We used the sandy facies of Opalinus Clay, characterized by an irregular wavy lamination of quartz-rich and carbonate-cemented lenses with clay-rich interlayers. Unconsolidated-cylindrical samples cored at 0°, 45° and 90° to the macroscopically visible bedding were deformed in undrained constant strain rate experiments using a Paterson-type deformation apparatus. For each orientation, tests were performed at dry conditions varying either confining pressure (in the range of 50 - 100 MPa), temperature (25 - 200 °C) or strain rate ( $1 \cdot 10^{-3}$  -  $5 \cdot 10^{-6}$  s<sup>-1</sup>) to study the influence of testing condition and sample orientation on the deformation behaviour. In addition, we deformed a set of back saturated samples at fixed conditions of 50 MPa, 100 °C and  $5 \cdot 10^{-4}$  s<sup>-1</sup> to investigate the effect of water content on the material strength.

The results show semi-brittle deformation with low yield strength and strain weakening behaviour, in which strain is localized in sub-millimetre to millimetre-wide shear zones at all conditions. Increasing water content reduces, whereas increasing confining pressure increases the peak strength. Samples that were deformed parallel to bedding orientation exhibit the highest strength compared to samples with an orientation of 90° and 45° to bedding. Only for the latter orientations a weak correlation was found between temperature and failure behaviour. The variation of strain rate shows no clear influence for all orientations. Within this test series, there appears to be a potentially greater influence of the porosity on the peak strength for 45° and 90° oriented samples. Clay rich layers seem to have a strong influence on localization and formation of shear zones, in particular for samples oriented at 45° and 90° to bedding. This observation was confirmed by electron microscopy performed on broad ion beam polished surfaces of deformed sample material.

Our experiments reveal that water content, sample orientation with respect to bedding and

confining pressure are the most important factors influencing the peak strength of the sandy facies of Opalinus Clay, whereas compositional heterogeneity is responsible for the localization behaviour.