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Influence of carbonate microfabrics on the failure strength of claystones

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ABSTRACT

Claystones are currently being investigated as a potential host rock for radioactive waste disposal. The relevant parameters are hydraulic conductivity, swelling and shrinkage, water uptake, rheological, and mechanical behavior. Much attention is paid to the Opalinus Clay (OPA) in Switzerland and the Callovo-Oxfordian Clay (COX) in France. One of the scientific challenges is to develop numerical models to predict the mechanical behavior of claystones under repository-like conditions. Recent studies have demonstrated the influence of carbonates on selected mechanical parameters (e.g. failure strength). In this study we show that OPA and COX behave differently with respect to their failure strength. The failure strength of OPA decreases with increasing carbonate content, whereas it increases with increasing carbonate content in case of the COX. The different behavior is caused by microstructural variations. Results of carbonate microfabric investigations verify that OPA mainly contains coarse-grained shell fragments, while COX shows a more homogeneous distribution of fine-grained, mainly non-biogenic carbonates. In conclusion, not only the carbonate content but in addition their grain size distribution, their shape and the spatial distribution control the mechanical behavior of both clays.

1. Introduction

Opalinus Clay (OPA) is considered a potential host rock for the storage of high level radioactive waste. The international underground rock laboratory (URL Mont Terri) was built in the Jurassic Alps in northwestern Switzerland for the investigation of this formation (Thury and Bossart, 1999; Heitzmann and Bossart, 2001). Hydrogeological, geochemical, and geotechnical characteristics are investigated within the framework of international projects such as the Heater Experiment (HE-B) (Göbel et al., 2007).

In this study the lithostratigraphic units and the definitions of rock types are abbreviated in the following way: OPA, claystones of the Opalinus Clay Formation (Freivogel and Huggenberger, 2003). COX refers to the claystones of the Callovo-Oxfordian Formation (Carpentier et al., 2007).

The mechanical characteristics of OPA (northern Switzerland) were investigated by Nüesch (1991). Deformation experiments (coaxial and simple shear configurations) were conducted on undeformed OPA samples from a borehole in the Jurassic Mountains. Nüesch investigated the influence of aggregate size, mineralogical composition, and water content on the deformation and concluded that cataclastic flow represents the main deformation mechanism (Nüesch, 1991).

The microfabric of a rock represents the spatial arrangement of minerals, their shape, size and orientation. These factors can significantly affect the physical properties. However, the measurement of all microstructural features of claystones (shape, size, orientation of the individual minerals, including all clay minerals, fissures, and cracks) is impossible due to the heterogeneity, the very fine-grained matrix and the poor crystallinity of the clay minerals. To collect all microstructural information of a claystone, an investigation on different scales would be necessary (from nm to dm-scale). Many studies exist that provide strong evidence for the effect of varying microstructure on the physical properties of rocks (e.g. Siegesmund, 1996) but especially for claystones only few studies exist, which are given in the following.

Many studies concerning the mechanical behavior and microfabric are focused on claystones of the Callovo-Oxfordian (Meuse/Haute-Marne) and Toarcian Formations (Tournemire).

Bauer-Plaindoux et al. (1998) showed that mechanical properties and swelling depend not only on the quantity and the clay mineralogy, but also on the “material structure and texture”. They observed that clays with comparable calcite contents can have a very different physical and mechanical behavior. Useful information could be provided, according to these authors, when considering the calcite and clay arrangement (granulometry and intergranular cementation). Any validation of this assumption is still lacking.

Chiarelli et al. (2000) investigated the influence of the mineralogical composition and moisture content on the mechanical behavior of COX and concluded that the rocks become more brittle

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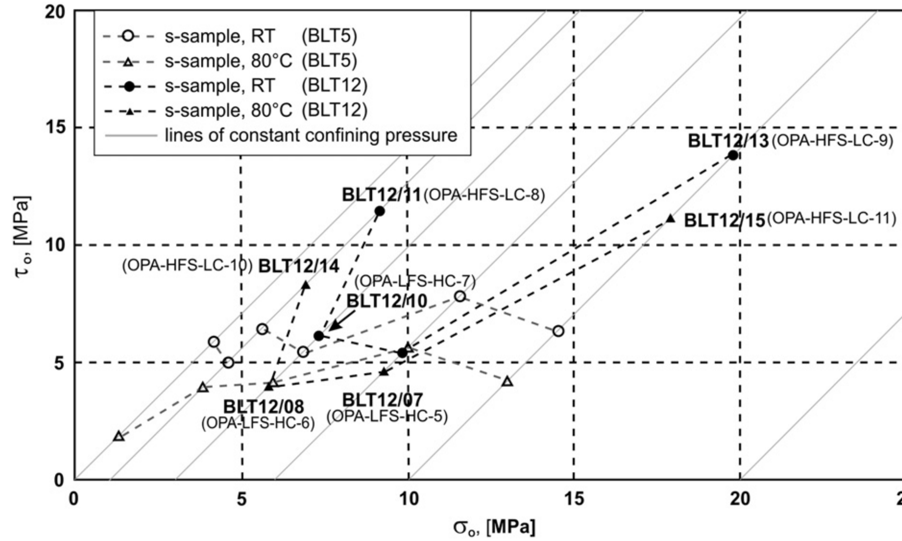

Fig. 1. Failure strength of BLT specimens (s-samples) in uniaxial and triaxial compression (figure taken from Schnier and Stührenberg, 2006, with permission).

and stiffer if the calcite content increases. Consequently, increasing clay content leads to a more ductile behavior and increased plasticity. With decreasing moisture content the material becomes more brittle. Two mechanisms were identified: plasticity induced by slip of clay sheets and induced anisotropic damage as indicated by microcracks at the interface between grains and matrix.

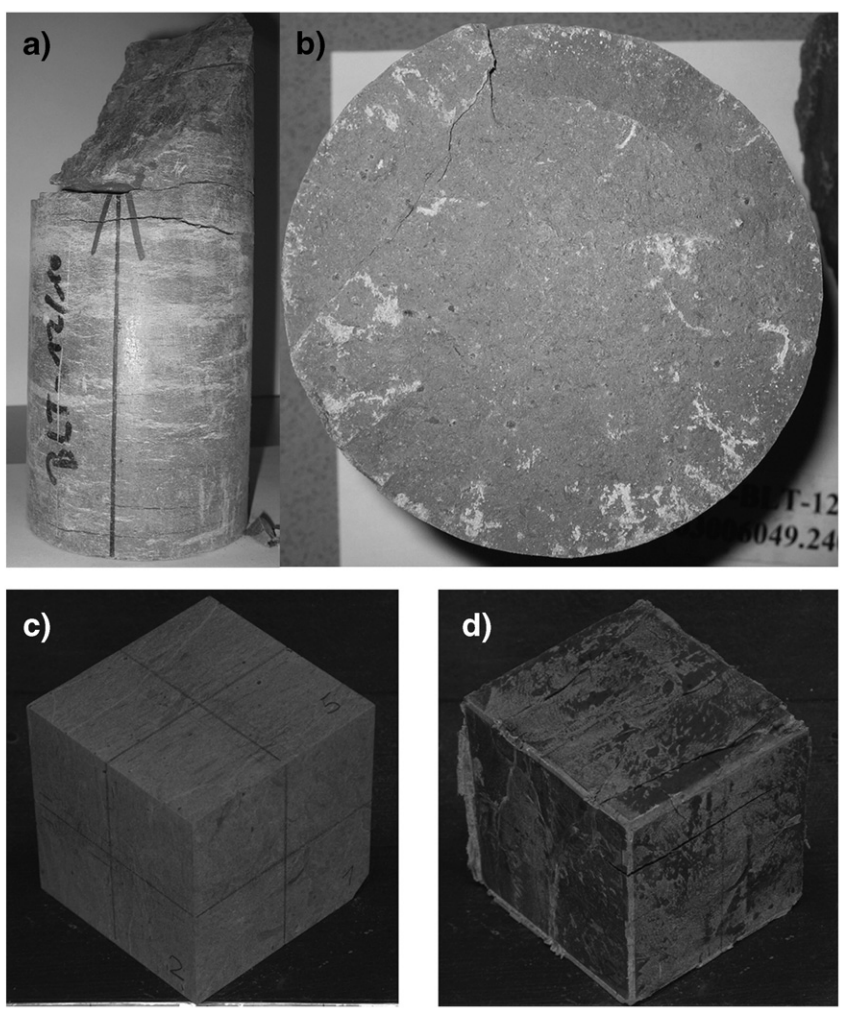

Fig. 2. Photographs of typical OPA and COX samples: a) OPA: core after mechanical testing (diameter: 10 cm) b) OPA: view on bedding plane c) COX: cubic samples (length of the edge: 53 mm) before mechanical testing d) COX: after mechanical testing.