

Opalinus clay (Switzerland)

Description: The Jurassic Opalinus Clay (Aalenian) consists of indurated dark grey micaceous shales that are subdivided into several litho-stratigraphic units. Some of these units contain thin sandy lenses, limestone concretions or siderite nodules. The clay mineral content ranges from 40 to 80 weight per cent (9-29% illite, 3-10% chlorite, 6-20% kaolinite and 4-22% illite/smectite mixed layers with a ratio 70/30). Other minerals are quartz (15-30%), calcite (6-40%), siderite (2-3%), ankerite (0-3%), feldspars (1-7%), pyrite (1-3%) and organic matter (<1%) (Mazurek 1999, Nagra 2001).

The investigation of the Opalinus Clay in near-surface conditions demonstrates that advective fracture flow and matrix diffusion are the dominant processes at shallow depth (Mazurek et al., 1996. Hekel, 1994 in Gautschi, 2002). The extensive data indicate that these fractures are permeable due to surface-related decompression and weathering effects. The faults (mainly represented by fault gouge and fault breccias, partly associated with minor veins of calcite) that are acting or have acted as preferential pathways for fluids may be identified by anomalies in the hydrochemical or isotopic signature of the formation.

Current geochemical investigations on the Opalinus Clay and adjacent aquifers provide large scale profiles of various porewater components across the formation. Strong evidence exists that in near-surface systems, diffusion is the major process governing solute transport in the clay (Rübel, 2000; Rübel & Sonntag, 2000; Nagra, 2001, in Gautschi, 2002). Although some of the porewater samples in the studies referred to above were derived from faulted test intervals or from cores of faults in the immediate vicinity, no hydrochemical or isotopic anomalies have been identified in the Opalinus Clay. This suggests that there is no hydrochemical evidence of a significant paleoflow along these faults.

At greater depths (>200 m) however, the faults have hydraulic properties similar to those of the undisturbed rock matrix (Bath 2000, in Gautschi, 2002). Even if there were fractures at depth (either newly induced or reactivated), they will not act as preferential pathways for significant fluid flow at anytime due to self-sealing processes (Thury, undated). This conclusion is also supported by independent evidence from clay porewater hydrochemical and isotopic data. Therefore it is concluded that reactivated existing faults or newly induced fractures will not act as pathways for significant fluid flow at anytime due to self-healing processes (Gautschi, 2002). Even if there were some leakage, the high pH conditions due to geochemical alternation are considered to provide good adsorption conditions.

Relevance: When the disposal of low level nuclear waste, or waste with a temperature beneath 100°C is considered, diffusion is the major transport mechanism through clay. As is suggested here also, the waste has to be placed at a minimum depth of 200 m in order to guarantee the self-healing of the initially fractured clay in order to avoid leakage.

Position(s) in the matrix tables: Geosphere, mudrocks, radionuclide retardation at low temperature, matrix diffusion.

Limitations: Each clay has his own characteristics with different self-healing capacities, the Opalinus Clay showing that capacity very strongly. There is an absence of high temperature nuclides or magmatic bodies so that all the estimations were undertaken in a laboratory where the conditions are far removed from the natural environment. The laboratory results therefore need to be used with some degree of caution.

Quantitative information: All hydraulic tests in deep boreholes and in the Mont Terri underground research laboratory yielded hydraulic conductivities smaller than 10^{-12} m/s, even though joints and faults were included in some of the test intervals (Gautschi, 2002).

Under laboratory conditions simulations were carried out in order to investigate the effects of basic solutions on the mineralogy, chemistry and hydraulic properties of the clay, a situation that might be expected in a low-level nuclear waste disposal (Taubald et al., 2000). The results show that the hydraulic conductivity increased from 3×10^{-10} m/s at the start to 6.2×10^{-9} m/s after 40 weeks. However, the evolution of the major and trace elements showed no such significant differences that might explain these observed differences. No change in the pH was measured during the first 6 weeks, thereafter an increase from 7.31 to 12.74 within 5 weeks was measured. These results indicate a reduction in the hydraulic barrier properties of the illite/kaolinite rich Opalinus Clay, when used as an engineered barrier system in contact with an alkaline solution (Taubald et al., 2000).

Uncertainties: The effects of the range of mineralogy of the Opalinus clay and the differences between in situ and laboratory measurements and experimentation should be borne in mind when using these data.

Time scale: geological (170 Ma)

PA/safety case applications: None known

References:

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Taubald H, Bauer A, Schäfer T, Geckeis H, Satir M and Kim JI. 2000. Experimental investigation of the effect of high-pH solutions on the Opalinus Shale and the Hammerschmiede Smectite. The Mineralogical Society, 35,p. 515-524

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Added value comments: No comments to add

Potential follow-up work: No comments to add

Keywords: clay, self-sealing, Switzerland

Reviewers and dates: Laurent Wouters & Astrid Verheyen, ONDRAF/NIRAS (March, 2004)