Busachi (Sardinia, Italy)

Description: The 10 m thick bentonite at Busachi, central Sardinia (Figure 1), covered by 2 m of rhyolite rock, was formed in marine eruptive circumstances during the Miocene. The Miocene submarine eruption of fine mesosilic pyroclastics caused, by contact of the hot glassy particles with sea water, a fast argillification process. The altered smectite-rich fraction was transported, sorted and finally deposited in calm water, where it was covered by a magma outflow (Figure 2).

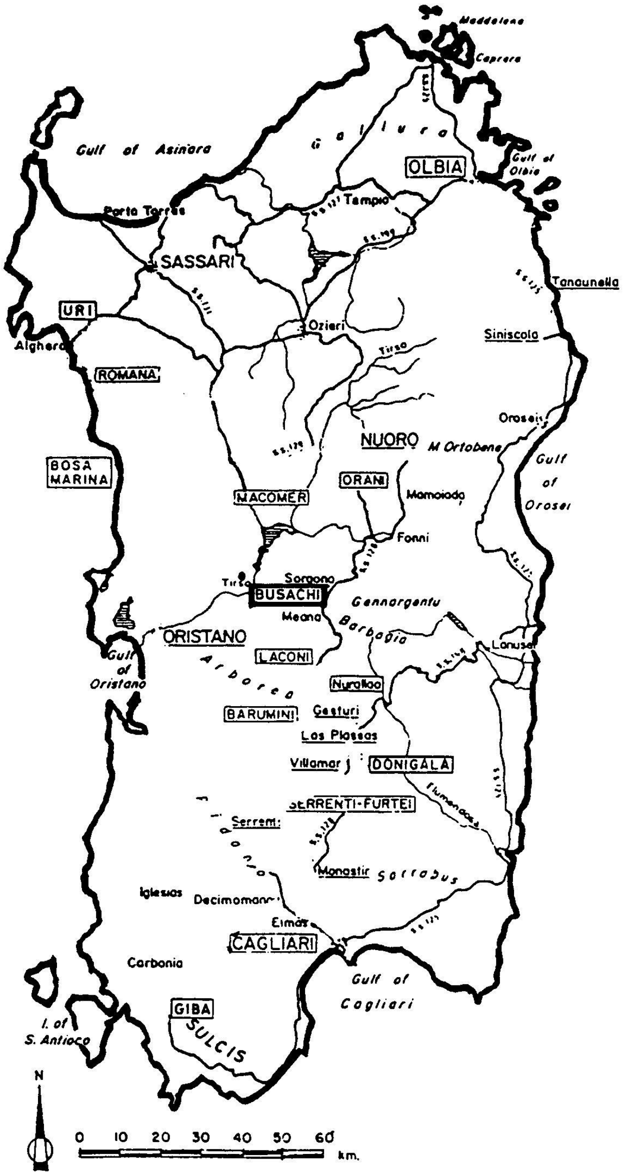

Figure 1: Location of the Busachi site (Pusch & Karnland, 1988)

The bentonite clay series has been reported to be rich in dioctahedral montmorillonite, with Ca as the major adsorbed cation. The dominant accessory minerals in the clay fraction are cristobalite, opal and zeolites. Carbonates are present to about 2% in the natural clay, mostly in the coarser fractions, which also hold quartz and feldspar minerals. Clasts of plagioclase with glass inclusions prove that the clay is of volcanic origin.

The magma covering the bentonite, caused heating to more than 200°C for several days for the upper metre, while at a depth more than 4 m, the temperature did not exceed 80°C. Due to the low temperature difference at the 4 m depth, only very small changes in composition and properties of the clay series have been reported there.

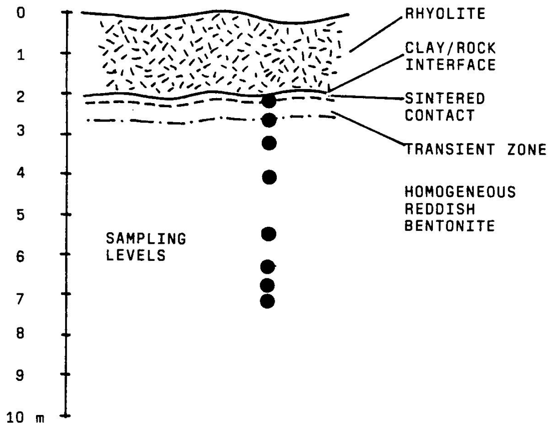

Figure 2: Stratigraphy of the sampling site at Busachi (Pusch & Karnland, 1988)

The major effect in these uppermost layers of the bentonite was precipitation of heat-released silica, which caused cementation and thereby reduction of the swelling potential and the development of brittle behaviour. The smectite content however was not reduced to less than 60% in any part of the bentonite and rhyollite.

Furthermore, the non-expanding minerals formed from the partial transformation of the montmorillonite fraction in the clay/rock contact zone, may be hydrous mica of the illite type or even a montmorillonite that collapsed after heating and then was prevented from expanding by the cementing agents. Because of the fact that so little alteration to non-expandable forms took place, it seems that the access to potassium has been the determing factor for the extent of the alteration. The subsequent continental conditions or a very low potassium availability may explain the stability of the smectite.

Cementation is relatively easily broken down to a rather homogeneous low-permeable microstructure. This means that a tectonically sheared a clay could be reactivated to a physical state that is not too different from that of a heated clay which has been subject to a hydrothermal scenario as here. Hence, it is clear that a heat pulse of the magnitude and duration that affected the Busachi clay series below about 1 m from the molten rock did not appreciably altered its isolating properties. It is generally assumed that the clay has not been exposed to a significantly higher vertical effective pressure than at present, which is in the range of 50 to 200 kPa.

For the following million years, one can foresee a pattern of transformation of smectite to illite that is similar to that proposed by Pytte (in Pusch & Karnland, 1988), i.e. a rate of alteration that is primarily dependent on temperature up to about 150°C, with the actual access to potassium as a moderating factor. At higher temperatures, and considering repository conditions, the cooling phase will yield release and precipitation of excess silica causing cementation. Here both neoformation of illite and I/S processes will take place causing the rapid conversion that is familiar to certain hydrothermal tests.

Relevance: Because of exposure to high temperatures, this case can be compared with the disposal of heat emitting radioactive waste.

Position(s) in the matrix tables: Near-field, Mechanical integrity of barriers (Mechanical failure), Buffer/Backfill (Bentonite).

Limitations: Restricted exposal time to temperature increase

Quantitative information: Chemical composition: SiO_2: 55-60 %, Al_2O_3: 16-20 %, Fe_2O_3: 3-6 %, MgO: 1-3 %, CaO: 3-5 %, Na_2O: 0.2 %.

The table bellows shows that the small difference in swelling pressure and hydraulic conductivity between the two samples supports the conclusion from the mineralogical study that the smectite contents are similar. However, the higher permeability of the shallow sample may be explained by the more porous microstructure of the heated clay.

Depth below clay/rock interface (m)	**Swelling pressure (MPa)**	**Hydraulic conductivity (m/s)**
0.7	0.48	$3*10^{-11}$
4.7	0.51	10^{-11}

Uncertainties: In this case, there has only been a very short exposal to high temperatures; the mineralogical changes that will appear after long exposal, are not known.

Time scale: somewhere between 10 to 20 million years

PA/safety case applications: None identified.

References:

Pusch R and Karnland O (1988) Geological evidence of smectite longevity: the Sardinian and Gotland cases. SKB Technical Report, 88-26, p.60, SKB, Stockholm, Sweden.

Added value comments: No comments to add

Potential follow-up work: No comments to add

Keywords: bentonite, illite, smectite, Miocene

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