

## Kinneulle (Sweden)

**Description:** The Ordovician bentonite at Kinneulle consists of a sequence of limestone, shaly mudstone and bentonite strata, which is overlain by mudstones, graptolitic shales and basalt (Figure 1). Calculations of the heat-flow caused by the intrusion of basalt in post-Ordovician time suggest that the bentonite has been exposed to a temperature of 110 to 160°C for about 1000 years (Pusch et al., 1987). The maximum previous overburden due to possible Devonian sediments, and the Pleistocene ice-sheet, caused a preconsolidation pressure of at least 20 MPa. The present overburden is only about 100 kPa.

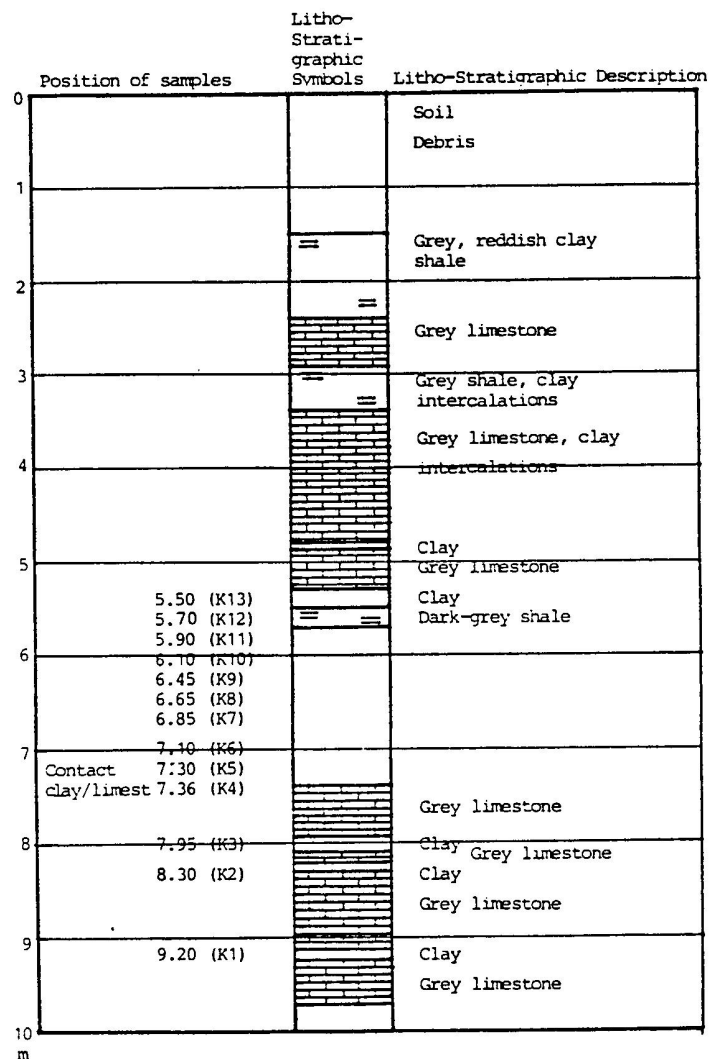


Figure 1 Stratigraphic Columnar Section (m below ground surface) (Pusch et al., 1987)

The main bentonite bed is characterized by a clay content of 35 to 40%. Analyses of the mineral composition and the element distribution have shown that montmorillonite, illite and mixed layer minerals (from 45 to 60%) are dominant. The additional minerals being mica (5-15%), quartz (10%), feldspar (10%), chlorite (10%) and kaolinite (5%). The upper part of the main bentonite has been found richer in illite than in the central part (Pusch et al., 1987) and this has been ascribed to heat-induced beidellitization of the montmorillonite and thermally aided diffusion of dissolved potassium from overlying shales (Pusch et al., 1987).

Significant resistance to dispersion of the bentonite has been reported in literature (Brusewitz, 1986; Müller-Venmoos & Kahr, 1985; Pusch, 1983; in Pusch et al., 1987). It is most certainly attributed to slight cementation, probably by precipitation of heat-released silica, as concluded from a comprehensive microstructural investigation that showed very small nodules at the edges of dense stacks of montmorillonite. Calcite precipitation, which forms macroscopic fillings of fissures and continuous pores, may also contribute to the cementation effect, which is expected to yield brittle properties in addition to the slaking resistance. Macroscopically, the bentonite has a shaly character, indicating a preferred particle orientation (Pusch et al., 1987). It is further probably that the strain at higher stresses caused mechanical breakdown of the cemented clay aggregates by which montmorillonite flakes and stacks were released and set free to expand and created new bonds in a “self-healing” process.

**Relevance:** Because of exposure to high temperatures, this natural analogue can be used for the disposal of heat emitting radioactive waste.

**Position(s) in the matrix tables:** Near-field matrix, buffer properties.

**Limitations:** The composition of a repository buffer material and the Kinnekulle bentonite may differ and so there may be some limitations in the application of the analogue to a repository system.

**Quantitative information:** Experience shows that a smectite-rich clay considered under a pressure to which the Kinnekulle series is likely to have been subjected, reaches equilibrium at a water content of 20% at the maximum. The present higher content of water demonstrates that the clay has absorbed groundwater and swelled to reach equilibrium with the overburden pressure of 100 kPa. The hydraulic conductivity of the bentonite sample is function of density (Pusch et al., 1987). Laboratory tests showed that the hydraulic conductivity of illite rich samples is 40 to 50 times greater compared to more smectite rich samples, a phenomenon that is explained by the fact that the permeability is largely controlled by the tendency of clays to disperse and form aggregates (Pusch et al., 1987).

Table 1 Main data of the clays from Mossen, Kinnekulle (Pusch et al., 1987)

Clay type	Condition	Bulk density (g cm <sup>-3</sup> )	Dry density (g cm <sup>-3</sup> )	Water content (%)
Central montmorillonite-rich part	Undisturbed	2.05	1.66	23
	Compressed by 1 mm	2.09	1.74	19
	Compressed by 2 mm	2.15	1.83	16
Upper Montmorillonitic part	Undisturbed	2.25	1.98	13
	Compressed by 1 mm	2.17	1.85	16
	Compressed by 2 mm	2.1	1.75	19

**Uncertainties:** No comments to add

**Time scale:** Geological (between 438 and 410 million years)

**PA/safety case applications:** None known

**References:**

Pusch R, Börgesson L and Erlström M. 1987. Alteration of isolating properties of dense smectite clay in repository environment as exemplified by seven pre-quatarnary clays. SKB Technical Report, 87-29, p. 110, SKB, Stockholm, Sweden.

**Added value comments:** None

**Potential follow-up work:** None suggested

**Keywords:** bentonite, illite, montmorillonite, Ordovician

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