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# Interaction between smectite and bacteria: Implications for bentonite as backfill material in the disposal of nuclear waste

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ABSTRACT

This study presents experimental results on the interaction between smectite clays (nontronite and MX80 bentonite) and the facultative anaerobic, heterotrophic *Shewanella putrefaciens* in two types of conditions: i) batch experiments with low solid to liquid ratios and agitated oxygenated conditions and ii) reaction-cell experiments with high solid to liquid ratios in anaerobic, confined volume conditions. The former was chosen to study the ability of *S. putrefaciens* to live on smectite as the only substrate and the latter was designed to simulate more compacted subsurface environments of underground repository waste sites. Bacterial cell counts in the batch experiments reveal the prolonged survival of *S. putrefaciens* in the smectite suspension compared to standard laboratory culture media. In the case of nontronite, variations in solution chemistry indicate bacterial consumption and/or partial binding of cations. Microscopic investigations show associated biofilm-smectite aggregates and Si-rich gels produced by the partial dissolution of clay mineral grains. In contrast, the MX80 bentonite was not seen to be chemically affected by bacterial activity in batch cultures. However, the confined volume experiments, using reaction-cell X-ray diffraction combined with peak calculations (CALCMIX), do indicate that *S. putrefaciens* has a pronounced effect on the water content of compacted MX80 bentonite. The presence of these bacteria enhances both the amount of adsorbed interlayer water and the available pore space. The anaerobic conditions were also favourable for accessory phase dissolution (notably calcite) and synchronous precipitation of lepidocrocite related to bacterially induced changes in pH and Eh. The varied response of the two studied clays to the presence of bacteria is attributed largely to the materials composition. The interlayer Ca of nontronite facilitates bacterial attachment to surfaces and Fe(III) provokes the production of chelators that enhance mineral dissolution. Although MX80 bentonite is less affected by bacterially enhanced dissolution, it is more sensitive to microstructural changes. Mechanisms involve aggregation of Na-smectite particles in voids created by cell lyses, the initial production of biofilm and the pH and Eh dependent dissolution and precipitation of accessory minerals. This investigation highlights the importance of including bacteria-mineral studies in assessing the safety issue of underground disposal of nuclear waste material.



## 1. Introduction

The complex interaction of fine-grained minerals and bacteria in soils and sediments has gained increasing attention over the last few decades. Synergistic effects are evident from the fact that bacteria can have pronounced effects on both mineral growth (Gorshkov et al., 1992; Kohler et al., 1994; Ehrlich, 1999; Kawano and Tomita, 2001) and dissolution (Bennett et al., 1996; Liermann et al., 2000; Rosenberg and Maurice, 2003; O'Reilly et al., 2006). When subjected to nutrient-poor (starvation) conditions, bacteria exhibit numerous strategies to accumulate nutrients such as the production of high affinity chelators (Hersman et al., 2000) or the systematic adhesion to surfaces (Dawson et al., 1981; Kjelleberg and Hermansson, 1984). Bacterial adherence is often facilitated by the excretion of exopolymeric substance (EPS; Van Loosdrecht et al., 1989; Omoike and Chorover, 2006): a process which is frequently associated with increasing alteration at the mineral interface (Marshall et al., 1971; Van Loosdrecht et al., 1990; Banfield and Welch, 2000; Maurice and Warren, 2006).

The effect of bacterial activity on oxyhydroxides and oxides of Mn and Fe (Myers and Nealson, 1988; Lovley et al., 1989; O'Loughlin et al., 2007), silicate weathering (Barker et al., 1997; Liermann et al., 2000; Bennett et al., 2001) and clay minerals reactions (Maurice et al., 2001; Kim et al., 2004; O'Reilly et al., 2006) has received particular attention. In a pioneering work on swelling clay minerals by Stotzky (1966a,b) and

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