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Time-development of sulphate hydration in anhydritic swelling rocks

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Anhydritic claystones are among the most problematic rocks in tunnelling due to their distinctive swelling properties. They consist of a clay matrix with distributed anhydrite particles, veins and layers and have caused severe damage to numerous tunnels excavated in the Gypsum Keuper formation in North-Western Switzerland and South-Western Germany. The swelling of anhydritic claystones which is mainly attributed to the transformation of anhydrite into gypsum (a chemical process which leads to an increase in the solids of 61 percent), is a markedly time-dependent process. It may take several decades to complete in nature and is therefore important for the design particularly of the final tunnel lining.
Anhydrite occurs either in the form of particles or of layers and veins of different thicknesses and spacings. The particles may have an approximately spherical or rather prismatic form, while their size lies within a wide range (from few micrometer to few centimeter). The shape and size of the anhydrite particles and layers are important for the specific surface of anhydrite and thus for the evolution of its hydration over time.
In the present contribution we focus on the kinetics of the chemical reactions in sulphatic rocks, limiting ourselves to closed systems, i.e. without investigating the effects of seepage flow and diffusive transport, which may also be important. In order to achieve this, a consistent and comprehensive dissolution and precipitation model has been developed that accounts for arbitrary geometrical forms of anhydrite as well as for the sealing of anhydrite by a layer of gypsum.
The investigations have shown that anhydrite dissolution represents the limiting mechanism if anhydrite occurs in the form of larger particles or thicker veins (> 1 millimeter) and there are sufficient nuclei for gypsum growth (e.g. precipitation takes place on of the surfaces of inert minerals). It has also been indicated that the time required for the whole amount of anhydrite to hydrate may vary by orders of magnitude. Moreover, for systems where dissolution is the governing mechanism, the initial volume fraction of anhydrite does not play any role in terms of the hydration time.
The effect of sealing has been shown to be decisive for the time evolution of the hydration process where gypsum with low porosity precipitates on thick layers of anhydrite. Depending on the gypsum porosity and the thickness of the anhydrite layers, the hydration time of anhydrite may increase by many orders of magnitude and far exceed the usual service life of tunnels (100 years). The quantitative results provide a theoretical explanation for the well-known observation that anhydrite layers of at least a few centimeter thick hardly swell at all.