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Carbonate precipitates impairing drainages in an Austrian motorway tunnel – Investigation on growth dynamics and environmental dependencies

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Calcium carbonate mineral formation constitutes a serious issue if deposition and clogging (scaling) affects the water transport in tunnel drainage systems. Maintenance work including mechanical or chemical removal of the scale deposits causes major costs and traffic disturbances, arguing for a more detailed process understanding of scale formation and its ambient environmental controls.

The main hydrochemical reaction mechanisms, responsible for $CaCO_3$ precipitation in channels and pipes, comprise the dissolution of hydraulic cement phases, mixing of solutions with different compositions, degassing or absorption of CO_2 (Rinder et al., 2013). On-site sampling and observations revealed that the precipitated carbonate minerals and accessory mineral deposits are often different in their visual appearance and material consistency, even within nearby sections and over time. For instance, deposits are found to be porous and soft, while others are dense and hard. The latter are consequently more difficult to remove. In order to better understand the variable scale formation mechanisms, we collected precipitates and related drainage solutions from different sections of the drainage system in a motorway tunnel near Spital a. Semmering (Austria). Mineralogical, petrographic and chemical analyses include XRD, LA-ICP-MS, light and electron microscopy, Raman spectroscopy and stable C and O isotopes of the solids as well as the hydrochemical and isotopic compositions of the solutions.

Calcite is the main component in all of the precipitates, where only a single sample shows elevated aragonite content. Significant differences in $CaCO_3$ nucleation and growth dynamics are indicated by distinct crystal shapes, arrangements and scale textures. Elemental and stable isotopic fractionation between carbonate-precipitates and drainage solution can be used to reconstruct the distinct growth behavior. Mg, Sr and Ba concentrations in different fabrics provide information on variable precipitation rates. Equilibrium versus kinetic fractionation of stable C and O isotopes reflects the dynamic effect of (seasonal) temperature variations, CO_2 exchange and/or associated pH fluctuations, as well as evaporation and variable flow regimes. The application of this multi-proxy approach enables the evaluation of natural vs. geotechnical conditions responsible for scale formation, in order to develop drainage system maintenance strategies.

Rinder, T., Dietzel, M., & Leis, A. (2013). Calcium carbonate scaling under alkaline conditions – Case studies and hydrochemical modelling. Applied Geochemistry, 35, 132-141.