## Unwanted mineral deposits in geotechnical settings – Scaling forensic investigation of formation conditions and related material characteristics

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Unwanted mineral deposits (scaling) including various carbonates, sulfates, sulfides and (hydro)oxides constitute a common obstacle impairing water and energy transfers in diverse geotechnical settings, such as geothermal power plants, motor- and railway tunnels, potable water infrastructure or artificial channels. The clogging of wells, pipelines, drainages, filters, valves or heat exchangers mostly depends on natural and man-made (operational) environmental conditions (e.g. physicochemical gradients, flow rate, materials used, geometries, mixing). Based on their installation-specific spatiotemporal evolution, the mineral deposits represent a chemical-sedimentary archive which can be “read” in a scaling forensic approach, i.e. a reconstruction and process understanding of variable environmental conditions determining the scaling progress and scale material characteristics is targeted. We therefore apply high-resolution geochemical and imaging techniques, such as stable isotope and minor/trace element profiles, distribution mapping and fractionation relationships (EPMA, LA-ICP-MS), (electron)microscopic and fluorescence staining techniques in combination with on-site and on-line environmental monitoring of the aqueous solutions, solid phases and the surrounding atmosphere using established and newly developed (e.g. “sinter guard”) data loggers. Hydrochemical modeling and laboratory experiments on fluid-solid interaction complete our approach.

Focusing on the carbonate system, the variable scaling progress and scale material consistency exert a major influence on the frequency of maintenance intervals and cleaning procedures (mechanical, chemical) becoming necessary. Our investigations reveal different depositional mechanisms resulting in hard/soft, compact/porous and rhythmic growth successions (layering) in scales. More specifically, inorganic crystallization mechanisms, such as heterogeneous wall crystallization, homogeneous suspended particulate nucleation or carbonate precipitation from either $CO_2$ degassing or absorption from the atmosphere are important. Microbially mediated deposition comprises of active (changing chemical gradients, catalytic promotion) and passive (substrate for nucleation and particle entrapment) mechanisms. Further, distinct interfaces exert major effects on crystal nucleation and the overall scaling progress, e.g. carbonate scale vs. substrate (steel, plastics) interface, intercalated mineral layers and the scale growth surface vs. streaming fluid.