Experimental $CaCO_3$ scaling of different substrate materials: Unravelling the effects of temperature, corrosion, crystal nucleation and growth

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Thermal water is increasingly used for heat and electric power production and provides base-load capable renewable and virtually unlimited geothermal energy. The generally highly mineralized deep thermal water can, however, induce the formation of mineral precipitates along the water circuit of geothermal power plants, which can considerably impact on the plant's efficiency. In order to explore the processes and effects of temperature, corrosion, crystal nucleation and growth on carbonate ($CaCO_3$) scaling, we performed basic laboratory experiments, in which we exposed different substrate materials (e.g. corroded and uncorroded carbon steel coupons) to synthetic geothermal solutions at temperatures ranging from 30 to 90°C. The incorporation of divalent Mg and Sr cations into the precipitated carbonate scales are thereby investigated as environmental proxies. Fluid chemistry and solid phase analysis (e.g. XRD, FT-IR, SEM) complement our approach.

The experiments, based on solid and liquid phase analysis, as well as variable Mg/Ca and Sr/Ca ratios, revealed a strongly temperature-dependent precipitation behaviour of different $CaCO_3$ polymorphs (calcite, aragonite, vaterite) also depending on the particular substrate being present. At lower and intermediate temperatures, stainless steel and polyamide substrates seem to favour calcite formation, whereas the carbon steel substrate supports aragonite formation. Vaterite formation is clearly promoted by polyamide substrates. Contrary to observed wall crystallization on substrates, homogenous (particulate) nucleation of aragonite further occurs from aqueous solution. Importantly, the different polymorphs and crystallization modes result in a strong effect on the actual scale material characteristics, e.g. density, mechanical and chemical resistance. Our experimental results clearly indicate that $CaCO_3$ crystal nucleation and growth, as well as element fractionation strongly depend on the materials used in geothermal applications.