A fundamentals mineralogical investigation of downhole cements within the context of underground hydrogen storage

Sammer, Thomas[1]; Ravi, Krishna[2]; Raith, Johann G.[1]

1 Chair of Resource Mineralogy, Montanuniversität Leoben, Peter-Tunner-Straße 5, A-8700 Leoben, Austria; 2 Chair of Drilling and Completion Engineering, Montanuniversität Leoben, A-8700 Leoben, Austria.

Hydrogen is nowadays considered a promising way of storing energy from renewable energy sources, helping to overcome capricious weather as well as seasonal variations, hence increasing the efficiency of renewable energy sources. When it comes to storing energy, the calorific value per volume of the energy-storing medium is one of the most important key figures. Due to the low density of hydrogen, the calorific value per volume is significantly lower compared to other common energy fuels (e.g., natural gas). Therefore, vast storage volumes are needed. Underground Hydrogen Storage (UGHS, e.g., the idea of using natural geological reservoirs like depleted gas fields) promises great potential due to vast storage capacities. However, to make UGHS a feasible process, fundamentals research investigating not just the integrity of reservoir and cap rocks but also downhole materials used in boreholes against hydrogen is essential. Boreholes provide access to geological reservoirs but are also the bottleneck of any production or storage operation. In general, boreholes are lined with downhole materials, consisting of a steel casing surrounded by cement. The cement acts as a bonding between the steel casing and the wallrock, providing mechanical stability and tightness for the hole. However, the effect that hydrogen might have on the mineralogical phase composition and subsequently on physical and mechanical parameters of downhole cement is still very scarcely known. This project, which is part of a PhD programme of Montanuniversität Leoben on H_2 production and storage, aims to contribute to a better fundamental understanding of this issue. Basic mineralogical methods (XRD, FE-SEM, EPMA) were applied to determine the mineralogical phase composition of a downhole cement class G (according to American Petroleum Institute classification). Additionally, the influence of additives (silica fume and carbon black) on the phase composition and subsequently physical and mechanical parameters was investigated. Physical parameters such as porosity, pore size distribution and permeability were measured using Hg porosimetry, N_2 sorption and nitrogen permeation. The mechanical properties were characterized by determining compressive and tensile strength as well as applying hardness measurements of the individual phases using nanoindentation. Thermodynamic modelling using the software GEMS (Gibbs Energy Minimization Selector) indicates that certain phases within hardened cement pastes are susceptible to hydrogen alteration caused by the strong reducing character of hydrogen. Especially ferric iron and sulphate bearing phases like brownmillerite, AFm (Al, Fe monosulphate) and ettringite are altered, resulting in the formation of magnetite and iron sulphides. In a next step, autoclave experiments are planned to try validating hydrogen induced mineralogical reactions as indicated by thermodynamic modelling.