Hydrogen induced changes in the mineralogical phase composition of downhole cements: fundamentals research within the context of Underground Hydrogen Storage

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Hydrogen is nowadays commonly considered a promising way of storing energy from renewable energy sources, hence increasing the efficiency of renewable energy sources. However, to store large volumes of hydrogen on a seasonal (e.g., winter – summer) time scale fast storage volumes are needed (Reitenbach et. al. 2015). Underground hydrogen storage (UHS, e.g., the idea of using natural geological reservoirs like depleted gas fields) promises exactly that. To make UHS a feasible process, fundamentals research investigating not just the integrity of reservoir and cap rocks, but also the interaction of hydrogen with downhole materials (e.g., cement) used in boreholes 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 (Reitenbach et. al. 2015). This project, which is part of a PhD programme on H_2 production and storage at Montanuniversität Leoben, Austria aims to contribute to a better understanding of this issue.

The mineralogical phase composition of a cement class G, a standard type portland cement used in the petroleum industry, before and after hydrogen treatment was investigated and the influence was evaluated that potential reactions might have on the physical and mechanical properties.

The mineralogical methods applied were: XRD, FE-SEM, EPMA. Physical parameters such as porosity, pore size distribution and permeability were measured using Hg-porosimetry, N_2 sorption and nitrogen permeation, respectively. The mechanical properties were characterized by determining compressive and tensile strength. Additionally Young´s modulus was determined from the stress-strain curves obtained during compressive strength testing.

Additionally, thermodynamic modelling using Gibbs Energy Minimization Software (GEMS) was carried out. The modelling indicates that certain redox-sensitive 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, monosulfoaluminate (AFm) and ettringite (AFt) are altered, resulting in the formation of native iron, magnetite, and iron sulphides.

Reitenbach V, Ganzer L, Albrecht D, Hagemann B (2015): Influence of added hydrogen on underground gas storage: a review of key issues. – Environ Earth Sci 73, 6927