Diffusion-reaction modelling of the degradation of oil-well cement exposed to carbonated brine

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ABSTRACT

Carbon dioxide (CO_2) storage in abandoned oil/gas reservoirs is considered a viable alternative to reduce greenhouse gas emissions to the atmosphere. An important element of the risk associated with long-term CO_2 storage effectiveness is the integrity of the cement seals of the abandoned wells in the reservoir. Any loss of seal integrity may become a potential leakage pathway, which can generate environmental impacts, cause economic losses, and reduction of CO_2 storage efficiency [1]. In particular, the degradation processes associated with the chemical reactions between the cement paste of the well seal and the acidic carbonated brine in the reservoir has deserved special attention in recent years (e.g. [2-4]).

In this paper, general aspects of a diffusion-reaction model in development for the degradation process of oil-well cement exposed to carbonated brine are presented. The formulation consists of two main diffusion/reaction field equations for the concentrations of aqueous calcium and carbon species in the hardened cement paste pore solution, complemented by a number of chemical kinetics and chemical equilibrium equations. The volume fraction distribution of the solid constituents of the hardened cement paste and the reaction products evolve with the progress of the reaction, determining the diffusivity properties of the material. A sensitivity analysis of some parameters of the model is presented to illustrate the capabilities to reproduce realistically some aspects of the degradation process.

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