



## Numerical modelling of well-bore cement degradation during CO<sub>2</sub> sequestration

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The sealing efficiency of a geological structure intended for CO<sub>2</sub> disposal has been numerically evaluated. Calculations were performed to predict the physico-chemical transformations that could occur in proximity to an abandoned gas production well under high-P<sub>CO2</sub>, low-pH conditions.

Simulations were performed using the multicomponent reactive fluid flow and geochemical transport simulator TOUGHREACT (Xu, T., E.L. Sonnenthal, N. Spycher, and K. Pruess. Lawrence Berkeley National Laboratory Report LBNL-55460, Berkeley, California, 2004). Based on field data, calculations were carried out under isothermal (T=45°C) and isobaric conditions (P=140 bar). Simulation time was 100 years. Simplified 1D and 2D geometries were adopted to investigate reservoir-wellbore cement, and reservoir-wellbore cement-caprock interactions, respectively.

In our calculations fully water-saturated conditions (liquid saturation,  $S_L = 1.0$ ) were assumed in order to realistically reproduce the behavior expected in the marginal sector of a gas-depleted reservoir, where groundwater inflow has already occurred since the end of industrial exploitation. Due to the lower elevation and the relatively great distance of this portion of the field from the area where CO<sub>2</sub> injection is planned, liquid conditions are expected to predominate in the study area also during CO<sub>2</sub> disposal. Accordingly, we assume that the CO<sub>2</sub>-dominated gas phase buffering the pH of pore waters will act as a passive by-stander and will not advect and/or diffuse from the reservoir into the overlying media (caprock and wellbore cement). Molecular diffusion in the aqueous phase is the dominant process controlling the geochemical evolution of the system under study.

The main results of our calculations are:

1) after 100 years simulation time, most of the mineralogical transformations predicted by the code had occurred in the wellbore cement domain. The mineralogical assemblage of the caprock is relatively unaffected by diffusive migration of chemicals from the underlying acidified reservoir;

2) two distinct chemical perturbations were observed in the wellbore cement domain. The first, is characterized by the occurrence of portlandite dissolution and the precipitation of secondary calcite. A slight reduction in porosity is associated with this process. The onset of the second major mineralogical transformation is related to the total removal of primary portlandite, and is characterized by a drastic decrease in pH and a progressive dissolution of the secondary neo-formed calcite. An appreciable increase in porosity is associated with this process;

3) under the control of molecular diffusion, propagation of the reactive front is slow, and the mineralogical transformations described so far can be observed in the first few centimetres only (up to 20 cm after 100 years) of the wellbore cement domain.

The main conclusion is that the persistence over time of high- $P_{CO_2}$  values, i.e. the existence of a stoichiometric excess of  $CO_2$  with respect to the initial abundance of portlandite, may be a critical factor with regard to sealing efficiency of conventional wellbore cements. Cement degradation may be significant in the medium term, i.e. for simulation times greater than 100 years.