Well integrity assessment under temperature and pressure stresses by a 1:1 scale wellbore experiment

Jean-Charles Manceau, Joachim Tremosa, Catherine Lerouge, Pascal Audigane, Francis Claret, C. Nussbaum, Y. Lettry, T. Fierz, L.J. Wasch, F. Gherardi, et al.

Well integrity assessment by a 1:1 scale wellbore experiment in the Mont Terri Underground Rock Laboratory: temperature and pressure stresses, exposition to dissolved CO2 and overcoring

J. C. Manceau[1], J. Tremosa[1], C. Lerouge[1], P. Audigane[1], F. Claret[1], C. Nussbaum[2], Y. Lettry[3], T. Fierz[3], L.J. Wasch[4], F. Gherardi[5], P. Alberic[6]

[1] BRGM, Orléans, France / [2] SWISSTOPO, Wabern, Switzerland / [3] SOLEXPERTS AG, Monchaltorf, Switzerland / [4] TNO, Utrecht, The Netherlands / [5] IGG-CNR, Pisa, Italy / [6] ISTO-OSUC-Université d'Orléans, Orléans, France

An innovative *in situ* experiment has been proposed for observing and understanding well integrity evolution, in the context of CO_2 storage operations. This experiment took place between 2012 and 2015 and is documented in Manceau et al. (2015) and in Manceau et al. (2016).

A small section of a well is reproduced at scale 1:1 in the Opalinus Clay formation, representative of a low permeable caprock formation (in Mont Terri Underground Rock Laboratory, Switzerland). The well-system behavior is characterized over time both by performing hydro-tests to quantify the hydraulic properties of the well and their evolution, and sampling the fluids to monitor the chemical composition and its changes. A first stage (stage A) has been focused on the well integrity assessment under different imposed temperature (17–52°C) and pressure (10–28 bar) conditions. A second stage (stage B) has been dedicated to the exposure of the system to CO_2-rich pore water. A final overcoring stage has allowed retrieving the well system and the surrounding clay.

Multidisciplinary methods (hydraulic tests and modelling, fluid sampling and modelling, analysis of cement and clay samples on the overcore) are used together to get better insight, in a realistic wellbore context, on the interplay between the geochemical questions, and the operational and construction issues.

The following key messages have been identified regarding the understanding of processes affecting the integrity of a well

- The relatively high initial effective well permeability (observed at the beginning of stage A) has been explained by a migration along the cement/clayinterface, possibly due to cement shrinkage, while the cement matrix and the clay-rich caprock close to the well appeared to be a very good barrier to unwanted fluid migration : this showed that the potential weakest points are interfaces between well elements rather than the well elements themselves, if appropriate materials are used.
- The significant variations of the effective well permeability observed after setting pressure and temperature stresses indicate that operations could influence well integrity in similar proportions than the cementing process.
- The cement has correctly protected the steel casing from corrosion, except in one small area, where the cement sheath was absent and where the corrosion was important. This showed that an appropriate cementing is compulsory to avoid issues regarding well integrity but also the importance of corrosion prevention measures implementation.
- The hydraulic conductivity of the well-system was significantly lowered during exposure to CO_2-rich pore water. In that context, the well integrity did not appear to have been compromised, but rather improved by the geochemical reactions. This showed that,when good integrity pre-exists before a well is in contact with car-bonated water, the exposure to dissolved CO_2 does not seem to lead to a degradation of the well hydraulic properties but rather to their improvement.

Finally, this study confirms the ability of this type of experiment (1:1 scale in a controlled environment) to improve our knowledge on complex phenomena (thermal, mechanical, hydraulic and geochemical) occurring at a realistic scale, which is especially important for well integrity. Such experimental works may indeed allow an integration of a maximum of realistic processes, the monitoring of parameters usually only measurable in the field (e.g. effective well permeability) and the validation of the upscaling of laboratory results.

References:

Manceau, J. C., J. Tremosa, P. Audigane, C. Lerouge, F. Claret, Y. Lettry, T. Fierz, and C. Nussbaum (2015), Well integrity assessment under temperature and pressure stresses by a 1:1 scale wellbore experiment, Water Resour.Res.,51, 6093–6109, doi:10.1002/2014WR016786.

Manceau J.C., J. Tremosa, C. Lerouge, F. Gherardi, C. Nussbaum, L.J. Wasch, P. Alberic, P. Audigane and F. Claret (2016), Well integrity assessment by a 1:1 scale wellbore experiment: exposition to dissolved CO2 and overcoring, Int. J. Greenh. Gas Control, 54, pp. 258-271