HYDROGEOCHEMICAL INVESTIGATIONS AT THE ANDRA MEUSE/HAUTE-MARNE UNDERGROUND RESEARCH LABORATORY

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Context and objectives

The Callovo-Oxfordian formation of the eastern Paris Basin is a 130 m thick clay rich sedimentary sequence. Its water content is around 8 %wt and its hydraulic permeability is below 10^{-11} m.s^{-1} (10-18 m^2).

The geochemical composition of pore water is one of the elements required to assess the confining properties of this argillaceous rock.

From the outset, the Callovo-Oxfordian pore water composition has been studied through measurements performed on core samples from deep boreholes [1].

In 2004, in situ direct sampling of the water was carried out for the first time in this type of formation. For that purpose, two short (15 m long) boreholes were drilled in two drifts at 445 m and 490 m depth (Fig 1).

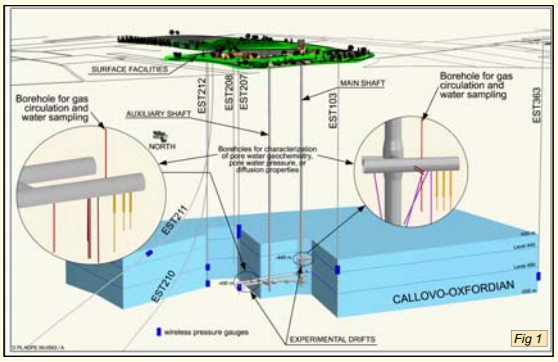


Fig 1

Design of the experiment dedicated to gas circulation and water sampling

Drilling phase

Taking into account the feedback from the Mont Terri project [2, 3], these boreholes were drilled with nitrogen to avoid rock oxidation. Great care was taken to restrict the development of bacterial activity in the boreholes by cleaning the drilling tools and implementing a specific protocol for their handling.

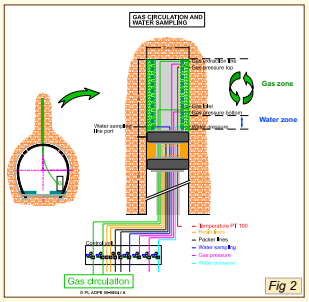


Fig 2

Equipment

The borehole equipment comprises packers isolating the test interval and 6 gas, water and pressure control lines that link the test interval to the controls in the drift (Fig 2). Once the installation completed, the open section and control lines were filled with argon.

The control lines are linked to the so-called “surface” equipment (controls) located in the drift. This equipment consists of pressure gauges connected to a data acquisition system and two modules: a water sampling module and a gas circulation module.

Monitoring and control of the experiment

During the experiment, the water pumping flow rate is adjusted to maintain the water level between 10 and 40 cm at the bottom of the test interval. Above this section, the gas is circulated in contact with the rock. Gas pressure has been maintained between 1.1 and 1.2 bars.

Main results

Hydraulic properties

The water production in the two boreholes is about 0.5 L per month at -430 m and 1.3 L per month at -475 m, respectively. The natural hydraulic head around the boreholes is close to 40 bars. Results of calculations obtained through this data show hydraulic permeabilities of about 10^{-13} m/s.

Gas composition

The composition of the circulating gas evolves from pure argon. The main gases are carbon dioxide and methane.

Water composition

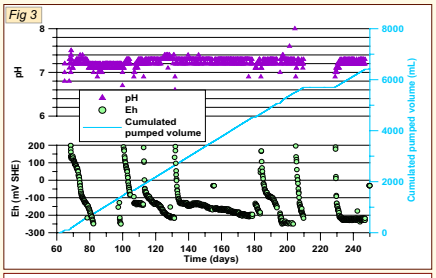
Fig 3 presents online measurements of pH and Eh carried out on the water pumped in the borehole located in the drift at -490 m. The pH is very stable at 7.3 ± 0.1. The Eh maximum positive values correspond to calibration phases. Minimum values below -200 mV SHE are considered to be the most representative of the pore water.

Fig 4 shows the results of chemical analyses performed on the sampled water.The observed compositions at these three depths are very similar; the main difference concerns chloride concentration. The study of this concentration on cores revealed that it varies slightly with depth [4, 5].

The fourth curve of Fig 4 corresponds to the composition worked out through thermodynamic equilibrium modelling before the first in situ collection of water samples. This computation relies on the hypothesis of an equilibrium with the minerals identified in the rock in neoformed states, of reactions of cation exchanges at the surface of the argillaceous minerals and on the average chloride concentration deduced from the core measurements [1].

Comparison between the observed compositions and the calculated composition shows a discrepancy bellow a factor of two for all the species except potassium. For this species an acceptable modification in the model of the potassium and sodium exchange constant leads to the observed concentration.

Fig 3



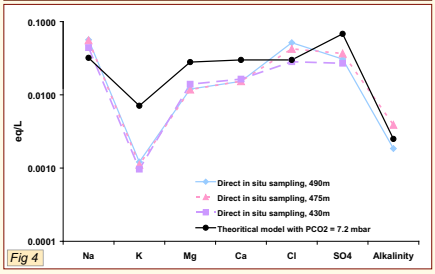


Fig 4

Conclusions

The gas circulation and water sampling experiments implemented in the Andra laboratory made it possible and analyse for the first time Callovo-Oxfordian pore water. pH stability over several months demonstrate that the water samples collected through dedicated experiments remain unaltered. The model provided satisfactory prediction for the pore water below a factor 2 for most of the major species. The compositions observed on the water samples should help improve the conceptual model. They confirm the vertical variations of the chloride concentrations and should help refine the results obtained on cores for this species over the entire profile.

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