

CHARACTERIZATION OF THE THM PARAMETERS OF CALLOVO-OXFORDIAN MUDSTONE BY INTERPRETATION OF AN *IN SITU* HEATING TEST

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INTRODUCTION

To advance in the precise knowledge of the thermo-hydro-mechanical response of Callovo-Oxfordian mudstone, a heating experiment (TER) is being performed by ANDRA at the main level of Bure underground laboratory. The test consists in placing a heater in a horizontal borehole drilled from one of the drift excavated at this level. Temperature sensors, pore pressure sensors and extensometers installed in the rock around the borehole (Fig. 1.a) allow for the observation of the evolution of the variables concerned by the heating of the rock mass (Wileveau & Su, 2007). To help to the interpretation of measurements, a Finite Element model has been defined in parallel to the experiment and several simulations run with the objective to propose values for the THM parameters of the rock. Theoretical formulation allows for solving simultaneously equations of stress equilibrium, water mass balance, solid mass balance and energy balance. When completed with the corresponding restrictions and adequate constitutive equations (in particular the state equations for solid and water density and an elastic mechanical law), the system of partial differential equations can be shown to be equivalent to Biot formulation. Because of the large number of simulations required at this stage of analysis, a 2D axisymmetric geometry has been considered (Fig. 1.b) to limit the computational effort.

BACK-ANALYSIS OF THE FIRST HEATING PHASE

TER experiment is composed up to date by two main phases of heating. During Phase I, a power input of 238W was applied during 20 days and then increased to 975W for the next 20 days. After that, power was cut up to 200 days. Data obtained during the first 40 days have been used to calibrate the model. Three distances has been defined between, respectively, the temperature, pore pressure and displacement fields measured *in situ* and computed by the model. Then, maps of iso-distances have been built from a large

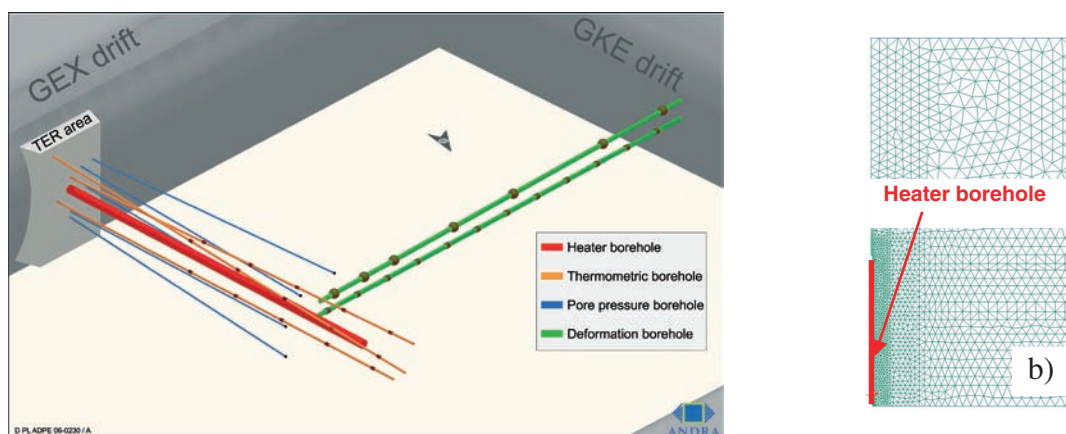


Figure 1: a) Setup of the field experiment; b) mesh used for the analysis.

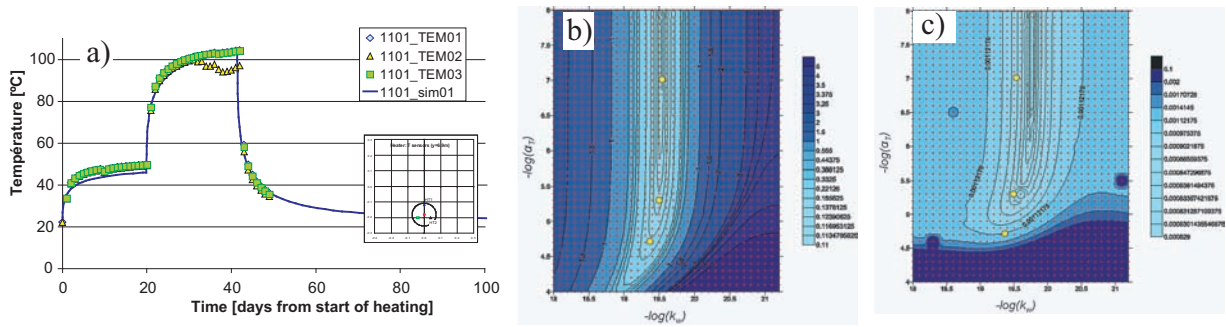


Figure 2: Back-analysis of the first heating phase.

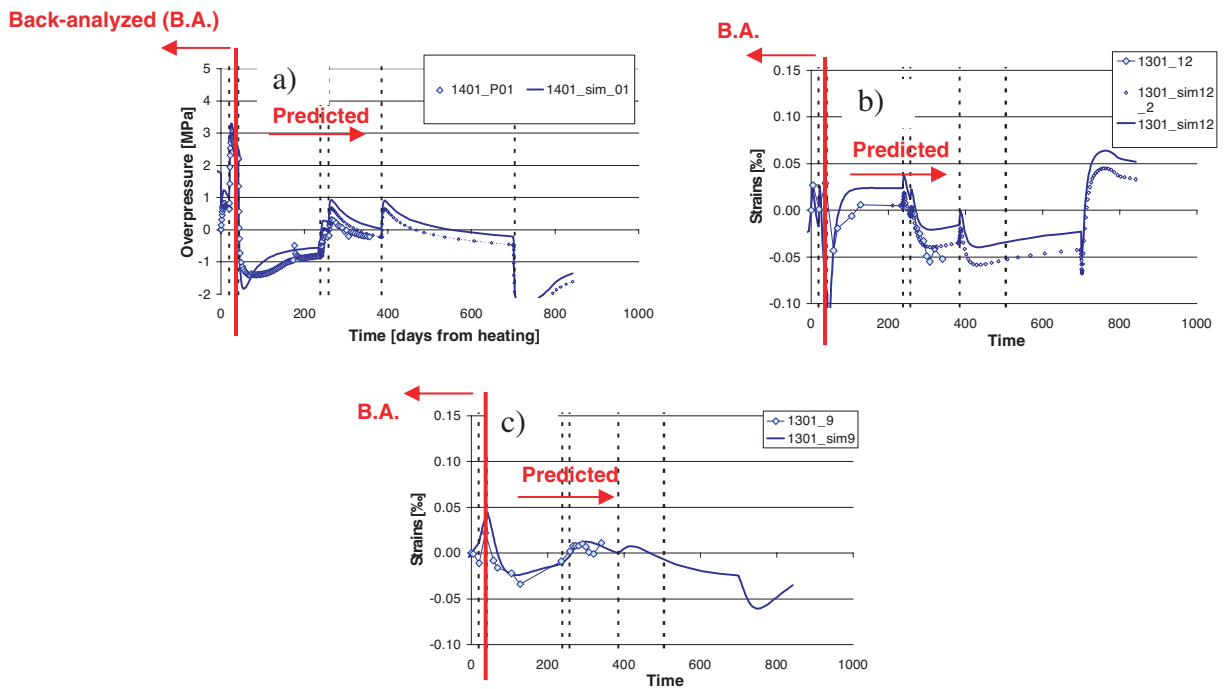


Figure 3: Comparison between model prediction and measurements for the second heating phase: a) pore pressure at sensor 1401; b) strain close to the heater; c) strain far for the heater.

number of simulations that covered systematically a wide range of THM parameters. Fig. 1.b and 1.c show for example maps of iso-distances in pore pressure and displacement fields obtained for different values of intrinsic permeability k_w and thermal expansion α_T . Best values are found at the minimum distance *i.e.* $k_w = 3.6 \cdot 10^{-20} \text{ m}^2$ and $\alpha_T = 5 \cdot 10^{-6} \text{ K}^{-1}$. Fig. 1.a shows the evolution of temperature at the contact heater-rock for the back-analyzed thermal conductivity.

PREDICTION OF THE SECOND HEATING PHASE AND COMPARISON WITH RECENT DATA

Phase II is composed by a first heating at 150W during 20 days, followed by a second heating at 300W that is still running. A prediction of this phase has been performed with the parameters back-analyzed during the first heating. This prediction is compared in Fig. 3 with recent data of pore pressure and strain. A very good agreement can be observed between computed values and field measurements.

References:

Wileveau, Y. & Su, K. (2007): “In situ thermal experiments carried out in Opalinus clay and Callovio-oxfordian claystones by ANDRA – experimental design and measurement results”, this conference.