

## **NMR contribution in sub-horizontal well for porosity-permeability heterogeneity characterization in limestones: implications for 3D reservoir prediction and flow simulation in a world class geothermal aquifer**

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With around 50 heating networks today operating, the area around Paris is the European region which concentrates the most heating network production units in terms of deep geothermal energy. In France, the energy-climate strategy plans to produce 6.4TWh in 2023, compared to 1.5TWh produced in 2016 [1]. Despite an exceptional geothermal potential, the current average development rate of 70MWh/year will not allow this objective to be achieved, it would be necessary to reach a rate of 6 to 10 times higher. The optimization of the use of deep geothermal energy is a major challenge for France, and in Ile-de-France, which has a population of nearly 12 million inhabitants. This project aims to reconstruct and simulate heat flows in the Paris Basin using an innovative methodology (1) to characterize, predict and model the properties of reservoirs (facies, porosity, permeability) and (2) simulate future circulations and predict the performance at a given location (sedimentary basin) on its geothermal potential. This study focuses on a high density area of well infrastructures around Cachan, (8 doublets, 1 triplet in 56 km<sup>2</sup>). A new sub-horizontal doublet concept has been recently (2017) drilled at Cachan to enhance heat exchange in medium to low permeability formations [2]. Nuclear Magnetic Resonance (NMR T<sub>2</sub>) logs have been recorded in the sub-horizontal well (GCAH2) providing information on pore size distribution or permeability. We integrated all logging data (gamma ray, density, resistivity, sonic, NMR T<sub>2</sub>) of the 19 wells in the area and 120 thin section observations from cuttings to derive a combined electrofacies-sedimentary facies description. A total of 10 facies is grouped into 5 facies associations coded in all the 19 wells according to depths and 10 3rd order stratigraphic sequences are recognized. The cell size of the 3D grid was set to 50 m x 50 m for the XY dimensions. The Z-size depends on the thickness of the sub-zones, averaging 5 m. The resulting 3D grid is composed of a total of nearly 800 000 cells. After upscaled, facies and stratigraphic surfaces are used to create a reliable model using the "Truncated Gaussian With Trends" algorithm. The petrophysical distribution "Gaussian Random Function Simulation" is used to populate the entire grid with properties, included 2000 NMR data, considering each facies independently. The best reservoir is mainly located in the shoal deposits oolitic grainstones with average porosity of 12.5% and permeability of 100 mD. Finally, hydrodynamic and thermal simulations have been performed using Pumaflow to give information on the potential risk of interference between the doublets in the area and advices are given in the well trajectory to optimize the connectivity and the lifetime of the system. NMR data, especially permeability, allow to greater improve the simulations, defining time probabilities of thermal breakthrough in an area of high density wells.

### **Référence**

[1] Ministère de la Transition écologique et solidaire, Stratégie Française pour l'énergie et le climat, Programmation pluriannuelle de l'énergie. 2019.

[2] Wielemaker, E. Cavalleri, C., Dahlhaus, L., Reynaldos A., Sosio, G., Ungemach, P., Antics, M., Davaux, M., 2020. Delineating the geothermal structure and flow properties in a sub-horizontal well with the use of wireline and LWD data in a multiphysics approach. SPWLA 61st Annual Logging Symposium