Sedimentological control on permeability heterogeneity: case study of the Middle Buntsandstein sandstones, East France

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Résumé

1 Introduction

Sedimentological studies of sandstones provide information about permeability and porosity distribution, as well as variations in geobodies' geometries, which can have a significant impact on predictions of flow models. Sandstone heterogeneities are characterized by the physical processes acting to transport, deposit and bury sediments and are present in all scales (4), from the control of grain size and sorting, sedimentary facies distribution and bedding patterns, up to stratigraphic cycles that affect the reservoir in a regional scale.

The present study focusses on the Middle Buntsandstein sandstones, more specifically on the Lower Grès Vosgien Formation (LGV), which is widely used for geothermal water exploration, groundwater public supply, and more recently recognized as hosting the most promising lithium deposits in Europe (3). The LGV is dominated by sandstones interpreted as been deposited by fluvial processes, intercalated with aeolian deposits. The scientific objective is to understand to which extent sedimentological and stratigraphic processes generate significant heterogeneities to heat transfer and mass transport models, using outcrops of the Buntsandstein Group at the Vosges mountains as analogues to the Middle Buntsandstein aquifer.

2 Methodology

The study applies a high-resolution sedimentological characterisation coupled with handheld air permeameter data to identify correlations between sedimentary characteristics and permeability response. The sedimentological dataset consists of 260 meters of rock descriptions from twelve different outcrops, along with eleven thin sections for petrographic analysis. The petrographic analysis aims to understand the controlling factors of permeability at a porous scale. Outliers in the permeability data were identified using the IQR method and removed, which resulted in a dataset composed of 1045 measurements linked to sedimentological characteristics. To quantify the correlation between permeability and sedimentology,

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the rank correlation coefficient Kendall's Tau (
tau) is applied (1)(2). Additionally, a digital outcrop model (DOM) generated using an unmanned aerial vehicle (UAV) drone is used to measure the lateral extent of sedimentary facies and bounding surfaces. The DOM serves as a reference to create realistic geocellular models, with the resolution of cell size determined by permeability variograms range.

3 Results

Three facies associations have been recognized: fluvial channel fill, wet aeolian sand sheet and aeolian dune. The results reveal the necessity to differentiate sandstones deposited at the different facies associations, as well as the predominant sedimentary facies within them, in order to generate realistic hydrogeological conceptual models. Permeability contrasts of more than one order of magnitude are present at different scales, including within a single sedimentary facies, between facies and among facies associations (Figure 1). The distribution of these heterogeneities is controlled by the dynamics of the fluvial system, associated with sediments compaction that affected differently the fluvial and the aeolian facies. The rank correlation coefficient (
tau) demonstrates a strong correlation between permeability and sedimentary facies. In terms of diagenetic processes, the amount of early eodiagenetic quartz overgrowth controls the degree of grains compaction, which is the primary factor responsible for macroporosity preservation (Figure 2).

4 Outlook

Further work is underway and is focused on (1) creating 3-D geologic models to represent the distribution of the Buntsandstein permeability heterogeneities and (2) defining the best approaches for using geologic models in flow and transport models. Based on this, targeted simulations using the flow and transport models are planned.

References

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