Proposition d'un sujet de thèse (2021-2024)

Title: To which extent 3D anisotropy of clastic geobodies is significant for detailed fluid-flow modelling?

Institution / Research unit: University of Strasbourg / Institut Terre et Environnement de Strasbourg – ITES (UMR 7063)

Director: Renaud Toussaint

Doctoral School: Institut Terre et Environnement de Strasbourg (ED n° 413)

Supervision:

Supervision integrating an innovative joint research group involving researchers from both teams "Transfert dans les Hydrosystèmes Continentaux" and "Géologie Océans Lithosphère Sédiments" is proposed for this PhD project:

- Frederick Delay (fdelay@unistra.fr) – Supervisor (HDR, 1 supervision in 2021)
- Guilherme Bozetti (bozetti@unistra.fr) – Co-supervisor

Support team:

- Mathieu Schuster (mschuster@unistra.fr)
- Philippe Ackerer (ackerer@unistra.fr)
- Jean-François Ghienne (ghienne@unistra.fr)

Scope of the project and scientific questions:

Understanding processes responsible for the transport of natural resources through the rocks depend not just on the role played by local and regional fractures; but also specific characteristics of the porous rocks they migrate through; especially their architectural elements, which control facies distribution and therefore permeability, porosity, as well as baffles and barriers of these geobodies. For example, negative water-mass balance in the Rhine Graben suggests that large volumes of meteoric water is transported and potentially stored in sedimentary/fractured deposits, and the corresponding fluxes remain unknown.

In order to explain these critical issues encountered in hydrogeological models, the aim of this research project is to understand to which extent 3D anisotropy of clastic (sandstone, conglomerates, ...) geobodies is significant for detailed flow and associated transport of solutes or heat. Additionally, how do facies associated with large-scale palaeosurfaces (i.e. sequence boundaries) are related to these fluxes? The remaining question is how do depositional environments and their particular characteristics affect small- to large-scale fluid migration: fractures versus 'matrix' transfer properties?

Answering these questions is pivotal to bridge the gap between environmental engineers and geologists, and lead to better response to issues encountered in fluid-flow models, generating not just an analogue for similar systems worldwide, but also a great local case study with strong practical applications.

Research topics and specific questions:

The project consists of two main research pillars which will complement each other:

1) Sedimentological and architectural analysis of the fluvio-aeolian deposits along the western margin of the Rhine-graben (Vosges mountain), aiming the detailed three-dimensional palaeoenvironmental and geological reconstruction of their depositional elements, measuring sections, producing photomosaics and generating three-dimensional drone models of the most relevant outcrops.
2) The elaboration of detailed flow and transport models that take into consideration sedimentary facies properties. In order to precisely generate these hydrodynamic models, it is important to understand whether structured sandstones, which are rather anisotropic, can be easily simplified? Under what conditions? And to understand whether inherited sedimentary structures actually facilitate (or difficult) optimal flow trends? Is it valid only locally or also regionally?

This project is a bold attempt to pursue a bilaterally beneficial multidisciplinary collaboration between two research teams of ITES, benefiting from a vast database about the regional water regime, and from the quality and proximity of the superb Lower Triassic outcrops of the Buntsandstein, which will be used as a case study.

Hydrological issues

The hydrological issues are focused on (i) the modelling of flow and transport processes in the Buntsandstein Formation at outcrop scale (1-100 m), and (ii) upscaling the model to large-scale architectural elements and formation scale (100 m to few km). The first topic is aimed at the building of a physically based model that takes into account the detailed local heterogeneities of a Buntsandstein outcrop. The upscaling will be based on sensitivity analysis of local heterogeneities on global fluxes of water (solute, heat) at the scale of architectural elements and/or formation. The sensitivity analyses should lead to a ranking of the most relevant local heterogeneities inherited from the past sedimentary evolution that have to be taking into account at the formation scale.

Geological context

The Buntsandstein Formation was deposited in the Germanic Basin during the Lower Triassic, in a setting interpreted to be dominated by braided fluvial systems discharging into playa-lakes, and arid alluvial plain. The basin margins were fringed by massive alluvial fans merging to braid plains of ephemeral streams, which are interpreted to have lasted for a long time given the thickness of rather homogeneous braided river sedimentary facies. In some central and northern regions of the basin, the system was much more diverse, with development of aeolian dunes and seasonal lakes in the more distal parts of the sand plain. In the western part of the basin more precisely, braided fluvial deposits interdigitate with both *in situ* and reworked aeolian deposits, with palaeocurrents oriented towards the NNE, suggesting river source areas located in the present-day Armorican Massif. The resulting sandstones, exhumed, partly eroded and largely exposed over the Vosges Mountains were subsequently deeply buried in the Rhine Graben or are present at shallower depths along the Tertiary basin margins.

PhD Candidate:

He/she must hold a MSc in Geosciences, with experience in sedimentary geology and hydrology, skills in mathematics, computer programming will be considered.