

Geophysical signature of the transition zone between the sedimentary cover and the basement: an analogue approach to help de-risking geothermal prospects

Names of Authors (please underline corresponding author) M. DARNET¹, C. DEZAYES¹, J. F. GIRARD², J.M. BALTASSAT¹, C. LEROUGE¹, T. REUSCHLE², P. BAUD², M. HEAP², A. KUSHNIR², N. COPPO¹, F. BRETAUDEAU¹, J. PORTE¹, Y. LUCAS⁴, A. GENTER³

Institution/Company ¹BRGM, ²EOST, ³ES-G, ⁴LHyGeS

Address of corresponding author 3 av. Claude-Guillemin - BP 36009
45060 Orléans
Cedex 2 – France

Telephone number of corresponding author Tel.: +33 (0)2 38 64 30 18
m.darnet@brgm.fr

Within the frame of the ANR-funded CANTARE-Alsace project, we have undertaken a multi-scale and multi-disciplinary approach to increase our knowledge of the transition zone between the sedimentary cover and the basement and provide fundamental knowledge for the assessment of its geothermal potential. In this paper, we report out the results of a study performed on an exhumed transition zone in the Ringelbach area in the Vosges Mountain, on the flank of the Rhine graben. In this analogue of a deeply buried transition zone of the Rhine Graben, a thin layer of Permian sandstones is still present on the top of the fractured and altered granitic basement providing the unique opportunity to study in-situ the physical properties of this transition zone. In this paper, we focused on electrical and acoustic properties of the transition zone as they are the main physical parameters usually assessed with the help of geophysical methods during the exploration phase of a geothermal project.

To characterize the electrical resistivity distribution of the transition zone, we acquired both shallow electrical resistivity tomography (ERT) profiles and deep 3D controlled-source electromagnetic (CSEM) soundings. To interpret such data, we looked into the resistivity logs acquired in two 150m-long exploratory boreholes drilled in this area cutting through the transition zone as well as resistivity measurements performed on representative core-plugs from the two boreholes. This study shows that the fractured and altered basement exhibits a low resistivity signature (several hundreds of Ohm.m) over several hundreds of meters, mainly caused by the presence of alteration clay minerals and fluid filling the fractures. On the contrary, unaltered and unfractured basement exhibits high resistivity signatures (several thousands of Ohm.m), mainly caused by the absence of alteration and fluid. This strong contrast of resistivity makes it possible to image deeply fractured and altered (and hence porous and permeable) transition zones with electromagnetic methods (e.g. Magneto-Tellurics, CSEM).

To characterize the acoustic properties of the transition zone, we acquired both shallow refraction and reflection seismic profiles. Similarly to the resistivity case, we interpreted such data with the help of sonic logs and laboratory measurements. Here also, the fractured and altered basement exhibits a low P-wave velocity signature (<4500 m/s) over several hundred of meters, mainly due to the presence of large fractured and altered zones. On the contrary, the unaltered and unfractured basement exhibits high velocities (>5000 m/s). This strong contrast of velocity makes it also possible to image deeply fractured and altered transition zones with seismic methods (e.g. reflection seismics, passive seismics).

This work provides fundamental knowledge on the physical properties (electrical and acoustic) of the transition zone between the sedimentary cover and the basement. It is not only useful for the interpretation of prospective electromagnetic and seismic surveys over geothermal prospects targeting the transition zone but also for the proper design of future exploration surveys (e.g. to ensure sufficient resolution is achieved at target level).