Signature of the hydrothermal circulation in a deep geothermal reservoir: insights from THM modelling

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ABSTRACT

The evidences of deep hydrothermal circulation have been extensively analyzed in the Upper Rhine Graben (URG) from field observations. Recently, Bouger anomalies and ambient noise tomography have revealed variations in their signals independent of the lithology, potentially highlighting fluid pathways in the URG [Bailleux et al., 2014; Lehujeur et al., 2018]. The aim of the present study is to bring more insights about these observations by a forward simulation of the geophysical data using a thermo-hydro-mechanical (THM) model.

The two-dimensional THM model is developed for two deep geothermal reservoirs located at Rittershoffen and Soultz-sous-Forêts, France, using the finite element software *Code_Aster*. Our approach neglects the details of the fluid flow along the major faults using a representative elementary volume of 100 m. The temperature-depth profile has been already reproduced for the both reservoirs by a back-analysis of the rock properties [Vallier et al., 2018a, b]. The simulation of the gravity effect induced by the deep hydro-thermal circulation in the reservoir is computed taking into account the large-scale convection cells. The synthetic gravimetric signal is compared to the one obtained from a purely thermal diffusive case to emphasize the signature of the hydro-thermal circulation. Oscillations with amplitudes of about 10.0 µgal and 3.0 µgal have been obtained in the simulated gravity profiles for Soultz-sous-Forêts and Rittershoffen, respectively. This effect is not evidenced for the purely thermal diffusive case. Its range of magnitude also reveals that a comparison with microgravimetry surveys may support the analysis of the hydrothermal circulation.

Concerning the S-wave velocity spatial distribution, synthetic velocity models deduced from the thermo-poro-elastic effects are compared to inverted models from the EstOF experiment where ambient seismic noise tomography has been performed. The simulations highlight spatial S-wave velocity relative variations unrelated to the changes of lithology, consistently with the recent seismic interpretations [Lehujeur et al., 2018]. However, the comparison with the field measurements is not straightforward, the range of magnitude being not the same between the observed and simulated geophysical signals. The difference may be related to the temperature independencies from the elastic moduli in the THM model. The periodicity of the lateral variations for two simulated signals is also consistent with the size of the convection cells detected in both geothermal reservoirs. The signature of the hydrothermal circulation in the gravimetry and ambient seismic noise signals has been clearly highlighted in the current modeling study.

REFERENCES

Baillieux P., Schill E., Abdelfettah Y., Dezayes C., 2014. Possible natural fluid pathways from gravity pseudo-tomography in the geothermal fields of Northern Alsace (Upper Rhine Graben). Geothermal Energy. 2 (16). https://doi.org/10.118 6/s40517-014-0 16-y

Lehujeur M., Vergne J., Schmittbuhl J., Zigone D., Le Chenadec A., EstOF Team, 2018. Reservoir Imaging Using Ambient Noise Correlation From a Dense Seismic Network. Journal of Geophysical Research Solid Earth. Accepted manuscript.

https://doi.org/10.1029/2018JB015440

Vallier B., Magnenet V., Schmittbuhl J., Fond C., 2018a. Large scale hydro-thermal circulation in the deep geothermal reservoir of Soultz-sous-Forêts (France). Geothermics. Submitted manuscript.

Vallier B., Magnenet V., Schmittbuhl J., Fond C., 2018b. THM modeling of hydrothermal circulation at Rittershoffen geothermal site, France. Geothermal Energy. Revised manuscript.