Applied Geophysics Research Project

Proof of Concept: Value of Information as measure in model-based exploration

In advance of the Master Thesis in 2024, AGP Students carry out a related research project. In this document, the proposed topic of the research project is outlined, and its envisioned results.

Project Outline

As preparation for the Master Thesis *Value of Information as a measure for exploration and economical evaluation of geothermal resources,* this research project covers a methodological proof of concept.

At the core is generating a Monte Carlo ensemble of a simplified ("2.5D") geothermal reservoir model using the geological modeling software GemPy. The model comprises a sedimentary graben system eroded by a younger sequence of sediments, similar to the model presented in Figure 1.

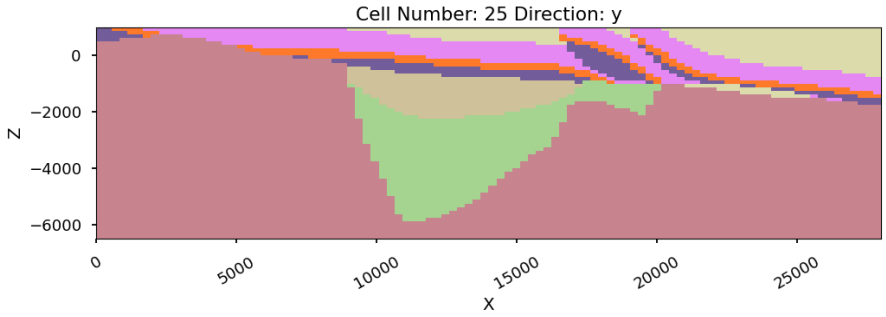

Figure 1: Cross section through an example model of the to-be-explored reservoir system.

Imagine that this system is based only on conceptual knowledge, and thus its structure (not speaking yet of the hydrothermal properties) is uncertain. We developed a method to visualize the uncertainty of a model using a measure called information entropy. In Figure 2 you see the entropy (brighter, non-black regions) when we assume some interfaces between model units to have depth uncertainty.

One major task of this research project is to create an ensemble of multiple hundred realizations of a geological model similar to the one described. One reservoir target within the model will be defined.

Drilling an exploration borehole is a planned activity to reduce uncertainty in this model. Following a workflow described in Hall et al. (2022), the added "Value of Information" of drilling an exploration borehole will be estimated. Not only the quantity of the VoI, but also its dependency on the drilling location.

For this, the main equations from Hall et al. (2022) have to be programmed into a python workflow to analyze the generated GemPy ensemble.

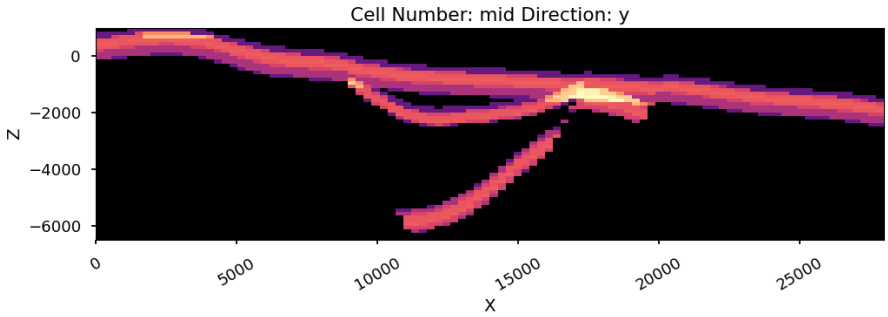

Figure 2 Information Entropy visualization of the uncertain reservoir model. Variations are visualized in: Depth of the units in the Graben system, as well as the base of the unconformity.

Tasks:

1. Familiarization with GemPy
    a. Installation and follow the tutorials on www.gempy.org and https://geg-ethz.github.io/PSGeothermieAargau/Tutorials/
    b. Create a Monte Carlo model ensemble comprising 200 to 300 model realizations
2. Literature survey and review of:
    a. Methods behind GemPy (implicit co-kriging, see de la Varga et al. (2019)
    b. Decision Trees and Value of Information in Exploration
    c. (optional) LCOH of operating geothermal systems worldwide
3. Optional (if time):
    a. Implementation of a sequential VoI assessment workflow as described in Hall et al. (2022) in python.
    b. VoI analysis of different exploration borehole locations on the MC ensemble created in 1.
4. Familiarization with Geophires (if time)
    a. Installation and understanding of the software https://github.com/NREL/python-geophires-x, potentially first via the Web-GUI https://jonathanpezzino.com/geothermal/geophires

Results / Deliverables

The results of the described research project should be submitted as a final report, no longer than 10 pages (excluding references, data management description and appendix), consisting roughly of:

- Abstract (300 words max)
- Introduction / Motivation
- Methodology
- Results
- Discussion and Outlook for the Master thesis project
- Data management description

The final structure will be decided together.

References

de la Varga, M., Schaaf, A., & Wellmann, F. (2019). GemPy 1.0: open-source stochastic geological modeling and inversion. Geoscientific Model Development, 12(1), 1-32.

Hall, T., Scheidt, C., Wang, L., Yin, Z., Mukerji, T., & Caers, J. (2022). Sequential value of information for subsurface exploration drilling. Natural Resources Research, 31(5), 2413-2434.