

Probabilistic Structural Geological Modelling for Geothermal Exploration in Thurgau, Switzerland

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Introduction & Motivation

Target area



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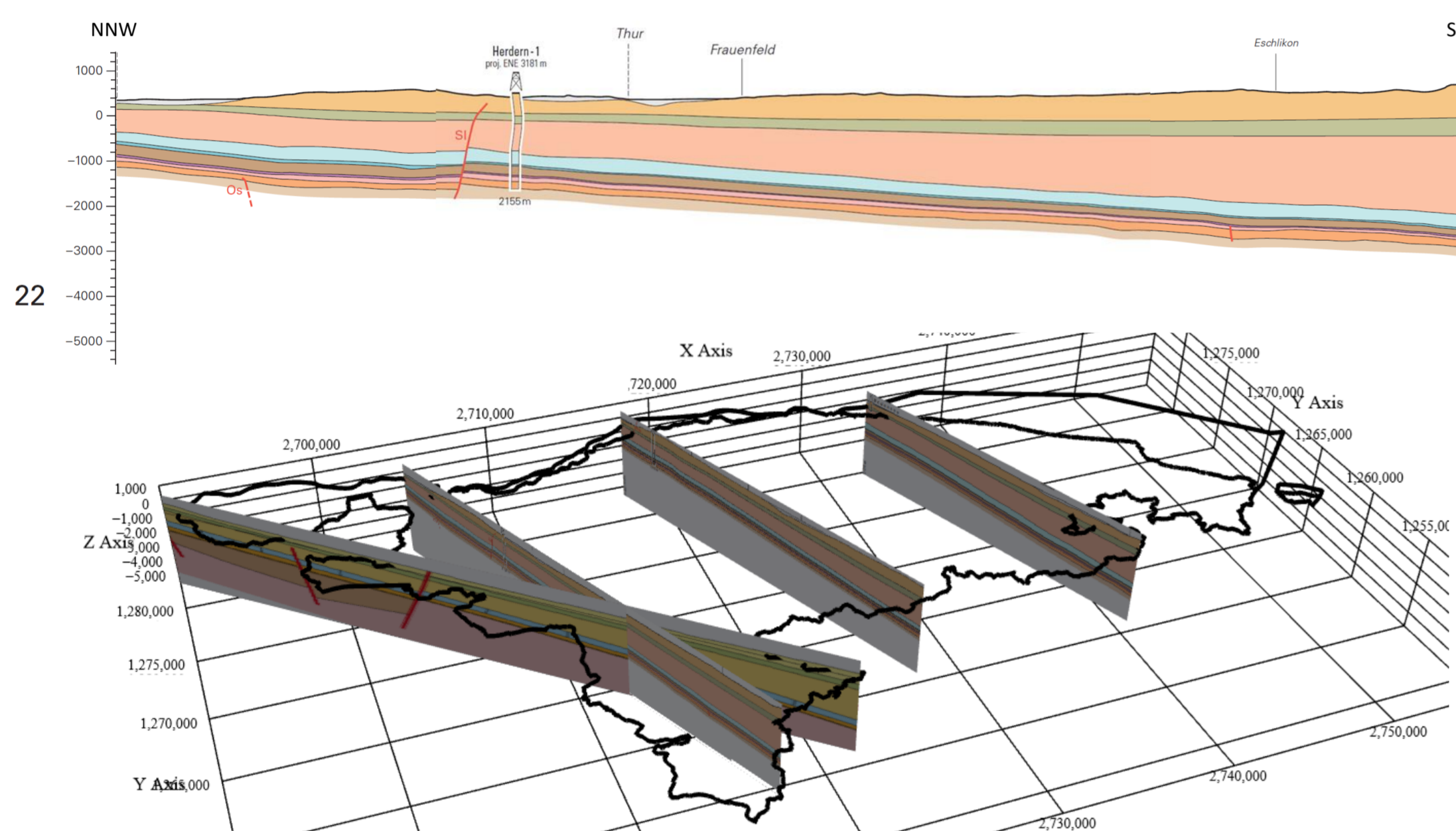
Structural Geological Modelling

- Why geothermal in the canton of Thurgau?
 - The Thurgau region has promising geothermal potential. However, the subsurface structure for deep geothermal applications remains insufficient. Further investigations are essential to reduce uncertainty and mitigate exploration risks.
- What are we doing?
 - We use GemPy (De la Varga & Wellmann, 2019), an open-source, implicit 3D structural modeling library, to efficiently construct geological models from cross-sections, surface maps, and borehole data. Implicit modeling allows for rapid model updates and, in the future, data assimilation for diverse data sources such as geophysical inversion results.
 - To address subsurface uncertainty, we (1) generate ensembles of geological models representing multiple plausible structural scenarios and (2) as a future step assimilate new type of information when available.
 - The main goal of this initial synthetic study is representing the subsurface in terms of seismic velocities allowing synthetic seismic data generation and future workflow benchmarking for combining geological modeling (Wellmann & Caumon, 2018) and geophysical inversion (Bobe et al., 2019) results.

Methodology & Results

1. Input Data

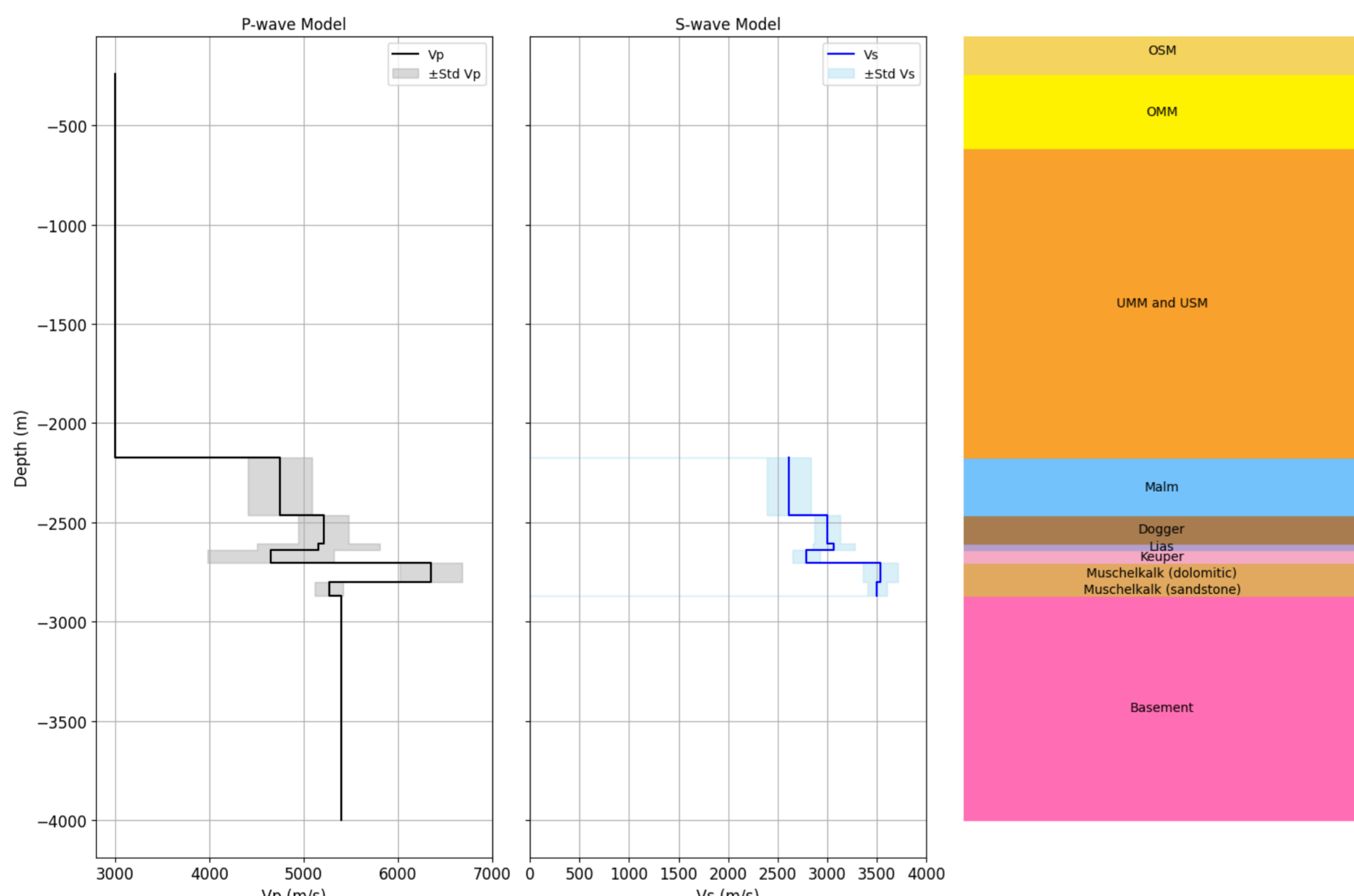
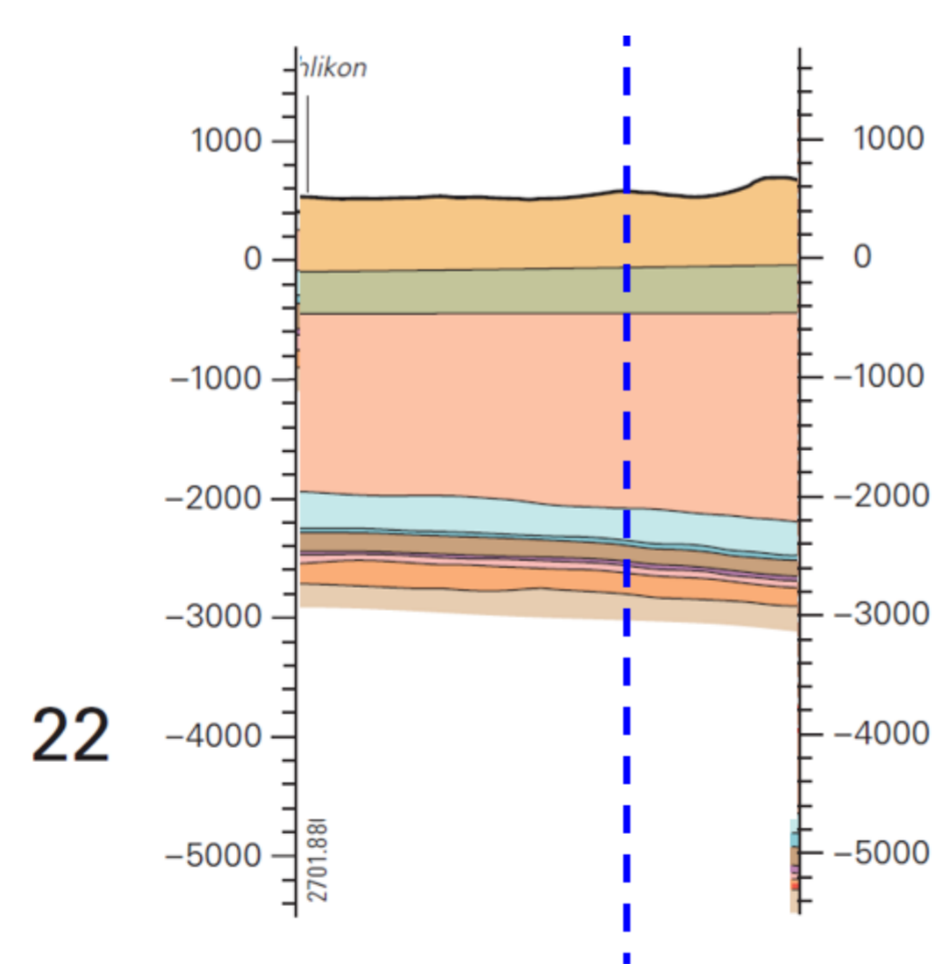
- Geological data were collected and compiled from public sources, including Swisstopo, GeoMol, and ThurGIS. The geological information is obtained from previous reports and publicly available sources



Source: GeoMol (Allenbach et al., 2017; Wyss & Link, 2015)

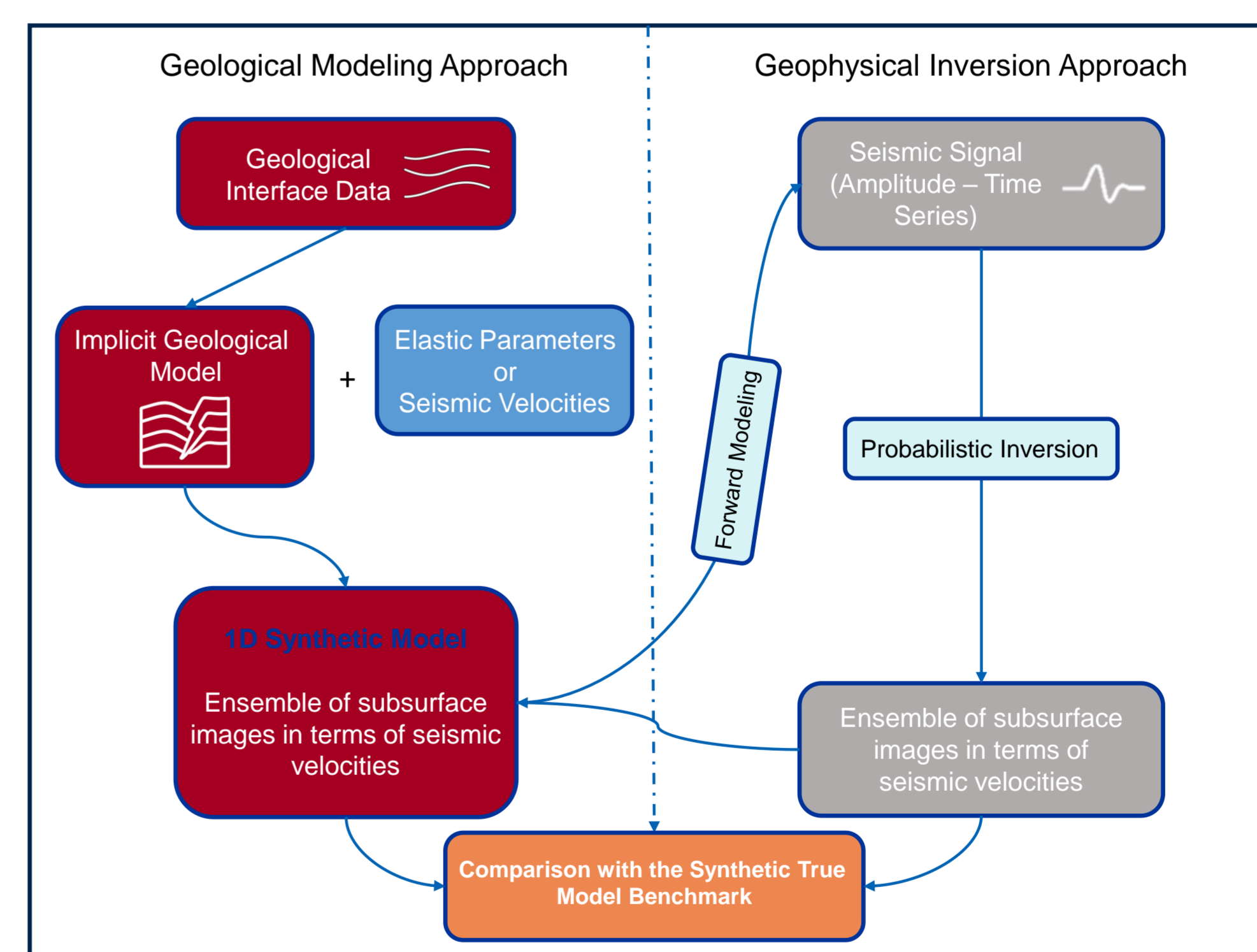
2. Synthetic Model

- The 1D synthetic geological model is constructed using structural information from the GeoMol project (Allenbach et al., 2017) and elastic property data (Vp, Vs) derived from literature on the Swiss Molasse Basin (Hefny et al., 2020). Velocity values are based on borehole conditions, with sample means representing typical seismic velocities. Standard deviations are incorporated to account for variability and maintain statistical accuracy.



Test Workflow

- **Define The Geological Model**
 - We start by defining a conceptual geological model based on geological interface information from the study area. Key stratigraphic units relevant to geothermal exploration are identified to establish the structural framework.
- **Collect Physical Properties**
 - Seismic velocities are collected from relevant literature for the Swiss Molasse Basin. These values are assigned to the defined geological units.
- **Build the 1D Synthetic Model**
 - The geological structure and elastic properties are combined to construct a 1D synthetic model representing a vertical subsurface column. This model serves as the synthetic "true" reference for testing the future workflow.
- **Forward Modeling**
 - Using the 1D model, forward simulations will be performed to generate synthetic seismic datasets. The output of times series - amplitude data will represent how seismic waves would respond to the given subsurface configuration.
- **Blind Inversion**
 - A blind inversion will be carried out using only the synthetic seismic data, without access to the input model. This simulates a realistic interpretation scenario for the geophysical data and help assess the robustness of inversion approach.
- **Model Evaluation**
 - The inversion results will be compared with the original synthetic true model to assess how well the workflow recovers the subsurface structure.



3. Future Work & Outlook

- **Extend Geological and Geophysical Modeling to Higher Dimensions:** Future work will focus on advancing the current approach by incorporating more realistic and complex 2D and 3D geological and geophysical models.
- **Develop Ensembles of Scalar Fields for Uncertainty Quantification:** To better capture the spatial and structural uncertainty in subsurface characterization. Multiple scalar fields will be used to identify and quantify regions of high model uncertainty.

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