SESSION 2:
SUSTAINABILITY – GREEN TRANSITION

In order to accelerate the deployment of green energy solutions like geothermal energy, hydrogen storage, and carbon capture storage, geological models covering the mid-deep subsurface are required at different scales for different purposes. These models can provide input to territory-wide models that for example evaluate total storage capacities or available geothermal heat, regional models that evaluate dissipation of pressure due to CO_2 injection, or local models that simulate extraction of heat or the migration of a CO_2 plume at a specific location. In this session we invite presentations concerning geological models of the mid-deep subsurface targeting acceleration of the green energy transition.

MID-DEPTH BASIN MODEL FOR SUSTAINABLE SUBSURFACE USE: 500+ M THICK SALT, LEGACY OIL AND GAS, HOT-DRY ROCK AND GEOTHERMAL RESOURCES IN POROUS MEDIA ALL IN ONE PLACE – A CASE STUDY FROM NW POLAND

Zbigniew Małolepszy, Ewa Szynkaruk

Mid-depth regional model built for the central-northwest part of Poland (Gorzów block) [1] is an example of stacked resources comprising, from bottom to top:

- Rotliegend (Lower Permian) volcanics presumably considered as hot-dry rock geothermal resources,
- Upper Permian hydrocarbon traps – legacy and under exploitation, offering possible CO2 storage space or other unconventional use,
- Thick Upper Permian (Zechstein) salt in domed but otherwise relatively undisturbed salt pillows for potential storage of heat or energy carriers.
- Mid-temperature Mesozoic geothermal reservoirs down to ca. 2000 m bsl.

Tapping into the high number of legacy oil-and-gas seismic and borehole data offered an opportunity to construct a well-constrained 3D regional model, with added advantage of linking it – within the GeoERA framework – to the Brandenburg state model across the border. The resulting parametric grid allows informed screening for unconventional resources and provides a rigorous starting point for managing use conflicts and synergies.

Planned analytical extensions to web model viewer (https://geo3d.pgi.gov.pl/en/project/3d-geological-model-gorzow-block) will provide tools for more thorough exploration of modelling results, and disseminating raw model files through National Geological Archives ensures efficient re-use of data compliant with FAIR principles.

[1] Szynkaruk E. (red.), 2020. Trójwymiarowy, cyfrowy model pokrywy osadowej bloku Gorzowa – opracowanie końcowe [3D digital model of the Gorzów block – final report]. National Geological Archives, PGI-NRI, Warszawa, Poland.

SEEMS DEEP – GEOPHYSICS BASED 3D GEOMODELING FOR MINERAL EXPLORATION

Suvi Heinonen, Jochen Kamm, Tuomo Karinen, Tuomas Leskelä & the SEEMS DEEP working group

In the project SEEMS DEEP, we are developing geophysical methodologies for deep imaging of the bedrock for mineral exploration. The test area of the project is the Koillismaa area, Finland, that provides a full-scale natural laboratory with geophysical anomaly that has been of interest for geoscientist several decades. This anomaly is a 50 km long zone connecting the distant parts of the same mafic intrusion, and it is observed with gravity, seismic reflection and AMT surveys. The recent drilling of 1700 m long diamond drill core has confirmed that the anomaly reflects the presence of 2.45 Ga mafic-ultramafic intrusions. The deep borehole has detailed geological and geophysical logs suitable as prior constraints to inversion and interpretation that lead to 3D geomodel. The rocks of the age group of the intrusion are very potential for several commodities included in the EU critical material listing. We aim to improve the deep exploration success date in order to supply the raw materials needed for the energy transition and especially for the battery industry, and 3D geomodels provide a means to visualize results of various surveys also in a form understandable for wider audience.

Petrophysical data analysis provides links between different physical rock properties and lithologies which need to be understood in order to conduct successful geophysical imaging or geomodeling.

The background petrophysical data from Koillismaa region include density, magnetic susceptibility and remanence, seismic P-wave velocity and galvanic specific electrical resistance measurements from drill core samples. Low-fold seismic and sparsely sampled AMT measurements indicate high acoustic impedances and elevated electrical conductivity values, respectively, of the ultramafic rocks at depth. We have created a 3D geomodel based on the petrophysical data analysis and available data set. This model will consist of surfaces representing the lithological contacts, fracture zones, dikes and faults and ultimately it will be converted into a volumetric model populated with interpreted rock-physical properties. The geomodel is currently used for geophysical modelling and inversion of synthetic seismic and EM/ERT/IP data. These simulations will facilitate optimized survey design for the large field data acquisition campaign planned for autumn 2023. Later the results of new geophysical measurements are used to improve the current geomodel.

Koillismaa geomodel aim to facilitate strategic drilling, which means that roughly 20-50% less exploration drill holes will be needed to achieve sufficiently detailed characterization of the deep geological environment or 3D delineation of the ore hosting rock units. To reduce the number of exploration drilling during the exploration phase, geoscientists need to limit the geological uncertainties with more reliable geophysical data, which leads to more reliable 3D geomodels.

MAKING THE DUTCH 3D GEOMODELS SUITABLE FOR THE ENERGY TRANSITION – CHALLENGES AND SUCCESSES FOR GEOTHERMAL ENERGY

Johan ten Veen, Denise Maljers, Hans Veldkamp, Andreas Kruisselbrink, Anuska Kaliar (TNO – Geological Survey of the Netherlands)

ThermoGIS is a public, web-based geographical information system that contains depth, thickness, porosity and permeability and temperature maps of many potential aquifers in the Netherlands. These property maps are used to calculate the most important outputs of ThermoGIS which are geothermal potential maps of the Netherlands that can be consulted in a map viewer. The ThermoGIS workflow consists of several steps of which the three most important ones are: (1) modelling aquifer geometry; (2) estimating aquifer properties and temperature; and (3) incorporating technical and economical parameters. This presentation focuses on the aquifer modelling.
ThermoGIS builds upon the nationwide 3D DGM-deep model that includes 13 stratigraphic levels that represent the (near) bases of the Palaeozoic, Mesozoic, and Cenozoic lithostratigraphic units. This model is based on seismic interpretation and well data and supported by biostratigraphy. It does not contain information on individual saline aquifers. To incorporate these aquifers a workflow is developed to model the depth and thickness of all aquifers that reside within the DGM-deep units by using information of nearly 4000 wells. All aquifers within a DGM-deep unit are modelled with respect to the base of that unit, making ThermoGIS and DGM-deep fully consistent. This consistency is not obvious as the number of wells used for ThermoGIS is considerably higher than that used for the calibration (well-tying) of DGM-deep.
Therefore, a reiterating process is employed in which the bases of the aquifers are derived by interpolating the difference between base of the aquifer from well data and base of the group-level grid and adding it to the latter. Subsequently, the interpolated thickness is added to obtain the top of the aquifer. Multiple aquifers are stacked between groups' base and top and intersections are corrected for. The interpolation process is assisted by polygons demarcating the aquifers' spatial extent. These polygons have thickness values assigned that can be used to steer the thickness at pinch-outs and faults. The aquifer thicknesses are stochastically modelled using kriging and the resulting kriging variance which represents the thickness uncertainty is used to calculate P10 and P90 thickness maps.
Each modelled aquifer is populated with vertically averaged well porosities and -permeabilities. Subsequently, the heat in place (HIP) is calculated by using these flow properties, net thickness of the aquifer and its temperature. In a next step, technical (doublet) and economical parameters are incorporated to derive the technical and economic potential and the potentially recoverable heat.
In the future, ThermoGIS will also focus on shallow geothermal energy and heat storage for which the shallow aquifers of the hydrogeological model REGIS II need to be incorporated. This model includes Neogene aquifers and uses the geological DGM-model for the shallow subsurface as a basis.

CONSTRUCTION OF A PROVINCIAL SCALE 3D GEOLOGICAL MODEL OF THE WESTERN CANADIAN SEDIMENTARY BASIN IN SASKATCHEWAN, CANADA

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3D geological models are becoming an important asset for geological surveys for addressing societal challenges of sustainability and climate change. Solutions to these challenges, including initiatives such as searching for critical minerals, subsurface storage, and geothermal potential all benefit from the characterizations of subsurface geometry that 3D geological models provide. In collaboration with the Saskatchewan Geological Survey, the Geological Survey of Canada engaged in the construction of a provincial scale 3D geological model of the Western Canadian Sedimentary Basin (WCSB) in Saskatchewan with the intent to model the entire basin in the future. The basin hosts many resources such as critical minerals (e.g. lithium, helium, potash) and is targeted for deep CO2 storage, groundwater, and geothermal applications. The model can serve as a knowledge layer for these applications as well as for 3D mineral prospectivity mapping. The dataset for the 3D WCSB geological model in Saskatchewan consists of approximately 142, 900 formation top and unconformities markers interpreted from about 11, 900 oil and gas wells. The dataset sampled 49 units from the Phanerozoic sedimentary basin, 7 major regional unconformities and the undivided Precambrian basement.

The 3D geological model was constructed in Gocad/SKUA geomodelling platform using a hybrid implicit-explicit approach. The model was constrained using the stratigraphic markers along with available geological knowledge including the bedrock geology map and previously interpreted subsurface areal extents of the units. Challenges related to modelling using vast amounts of data and strategies for tackling provincial scale modelling efforts are presented. The constructed model can provide valuable information for applications previously mentioned including formation thickness and depth, relations with adjacent formations or unconformities. In addition, the model can be used for model validation for ongoing development of other geological modelling methods. Finally, collaboration with the provincial survey was critical in constructing stratigraphically coherent and geologically validated model and important for future work in modelling the entire basin across four other provinces and territories.