ADJUSTED MODELS FOR AQUIFER THERMAL ENERGY STORAGE (ATES) SYSTEMS SIMULATIONS

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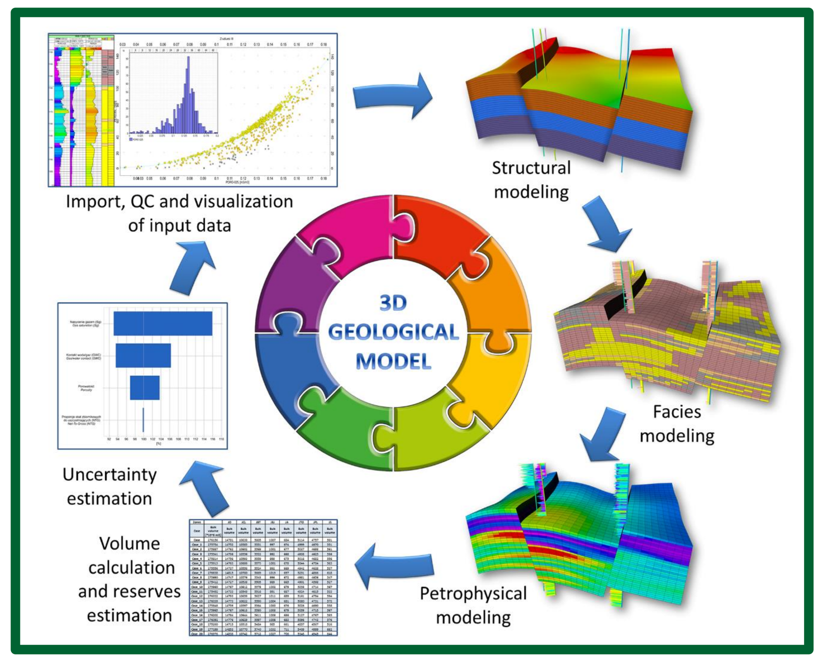

Recent 3D static geomodels from petroleum exploration built for R&D purposes of Department of Energy Resources AGH University of Krakow were adjusted for further geothermic and energy storage fields (ATES, CO_2 sequestration) purposes.

These parametric geomodels are very complex, handling large quantities of input data. A typical static modelling workflow comprises 6 main phases of modeling (Fig. 1).

Fig. 1 A workflow for static models (Halaj et al., 2022).

One of the examples of use of adjusted model is a performance simulation of ATES in the Lower Cretaceous reservoir in Tuszyn Anticline (Central Poland), where a regional Petrel© static parametric model prepared prior to dynamic simulations in Feflow© software.

The static geological model of the Tuszyn Anticline was prepared with the use of Petrel©. The basic workflows and input data used by authors to create geothermal 3D models of the Mogilno-Łódź Trough included models calculated with the use of the Corner Point Griding [CPG] method (Kepińska et al. 2017). To utilize CPG based geomodelling results for Feflow© simulations, the regional CPG structural model (Fig. 2A) has to be transformed into the local Structural Framework model (Fig. 2B).

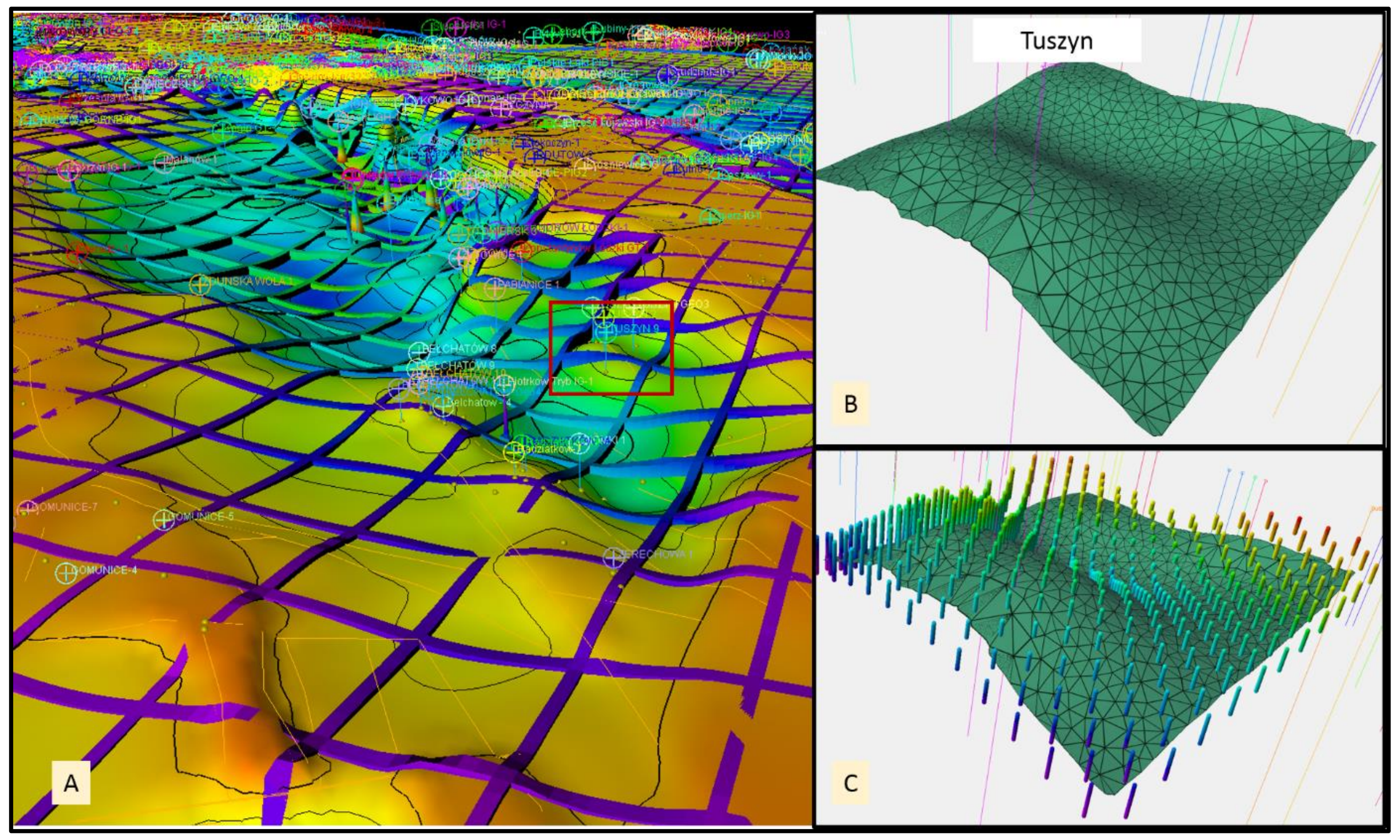

Fig. 2 The adaptation of Petrel© static model to the FEFLOW modelling requirements. (**A**) Regional structural and parametric Corner Point Grid of the Lower Cretaceous in the Mogilno - Łódz Trough (the Tuszyn area is marked with a red box); (**B**) Local (Tuszyn Anticline) tetrahedral mesh of the Lower Cretaceous Top surface (based on (A)); (**C**) Cells of a parametric temperature model (fences on panel (A)) converted into XYZG points used in FEFLOW modeling (Halaj et al., 2022).

The dynamic ATES model uses the local structural and parametric framework, being the part of the basin scale parametric model of the temperature and effective porosity of the Lower Cretaceous reservoir. They were constructed as CPG grids, using the multiscale structural and parametric modelling workflows. This allows for high quality local geomodels to be obtained, even in regions poorly controlled with data (like in this case).

The basic surfaces constraining the geometrical framework of the dynamic model — in particular top and base on the Lower Cretaceous — were extracted from the regional model. The square part of this model was extracted and subsequently converted into formats applicable in Feflow©.

Horizons from the CPG 3D grid were adopted as an input for the large scale, local structural model, created with the use of the Structural Framework procedure in Petrel©. It allowed to estimate the surfaces of the Lower Cretaceous top and base in the form of the Triangular Irregular Network (TIN, Fig. 2a, b). These TIN surfaces were next applied as an input for the geometrical Framework of the Feflow© dynamic model.

The lack of high quality petrophysical data in the Tuszyn Anticline, enforced the application of regional to local modelling workflows used in the petroleum exploration practice (Demmisse et al 2019, Papiernik and Michna 2019). Such a downscaled regional model of the temperature was based on stabilized temperature logs from 222 wells and the porosity (PHI) logs from 257 wells, including the Tuszyn-2 well in the research area. The thermal model of the area was then validated and compared with the geological static model.

The thermal model of the area was validated by comparing it with the geological static model (Fig. 3). The assessed temperature difference in selected points is mostly less than 2.5 K, which was assumed as satisfactory. Using validated parameters and boundary conditions, the performance of ATES systems was then examined.

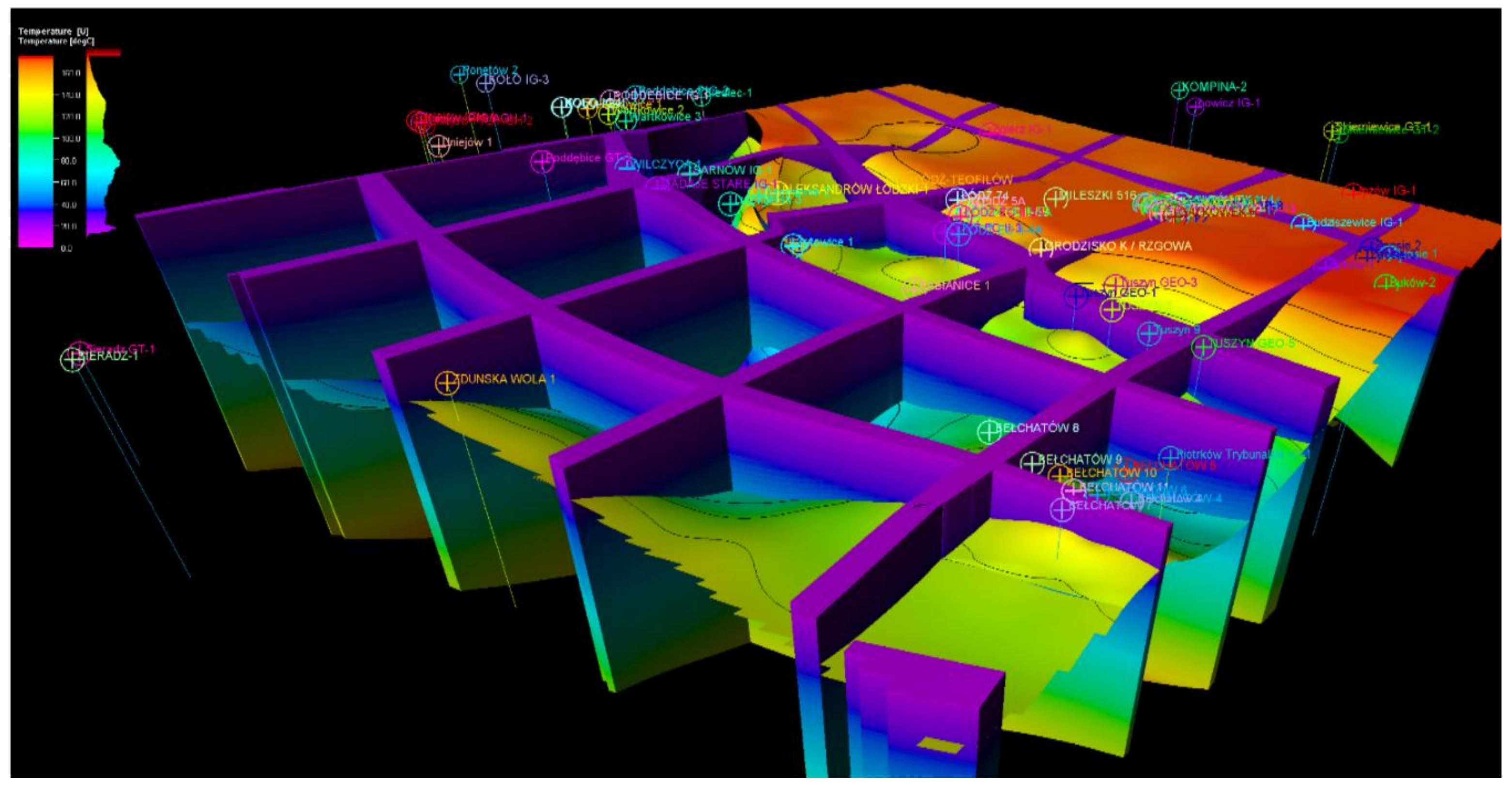

Fig. 3 Temperature model in the Łódź Trough presented against the background of a map of the Lower Cretaceous top (Papiernik B. unpublished).

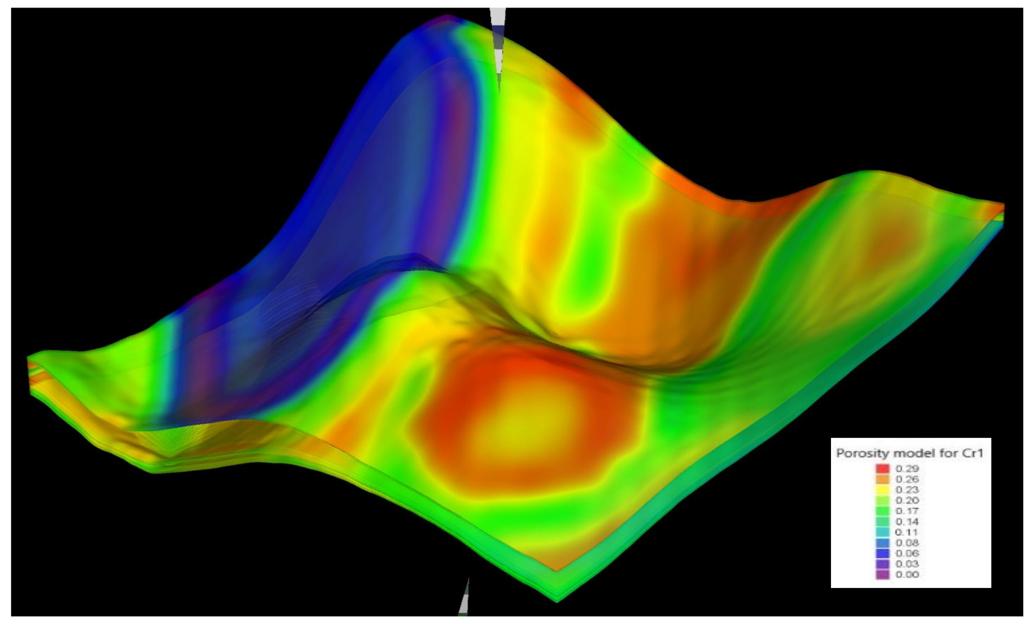

Fig. 4 The porosity model for Lower Cretaceous formation in Tuszyn Anticline (Halaj et al., 2022).

The petrophysical parameters for the dynamic model were approximated using the results of the regional static model (example: Fig. 4). The model was generated with the use of the CPG method. In result, the ATES systems can be simulated as a doublet of multilayer wells, which applies a pre-defined extraction or injection nodes along a well screen. The dynamic model was divided in sub-layers of variable thickness.

The dynamic simulations of ATES system were conducted according to its specific demand profiles for 30 years (Fig. 5). A static model, which can correctly represent the geological nature of the reservoir, is necessary in order to achieve a reliable evaluation and assessment through numerical simulations for the thermal regime of the system.

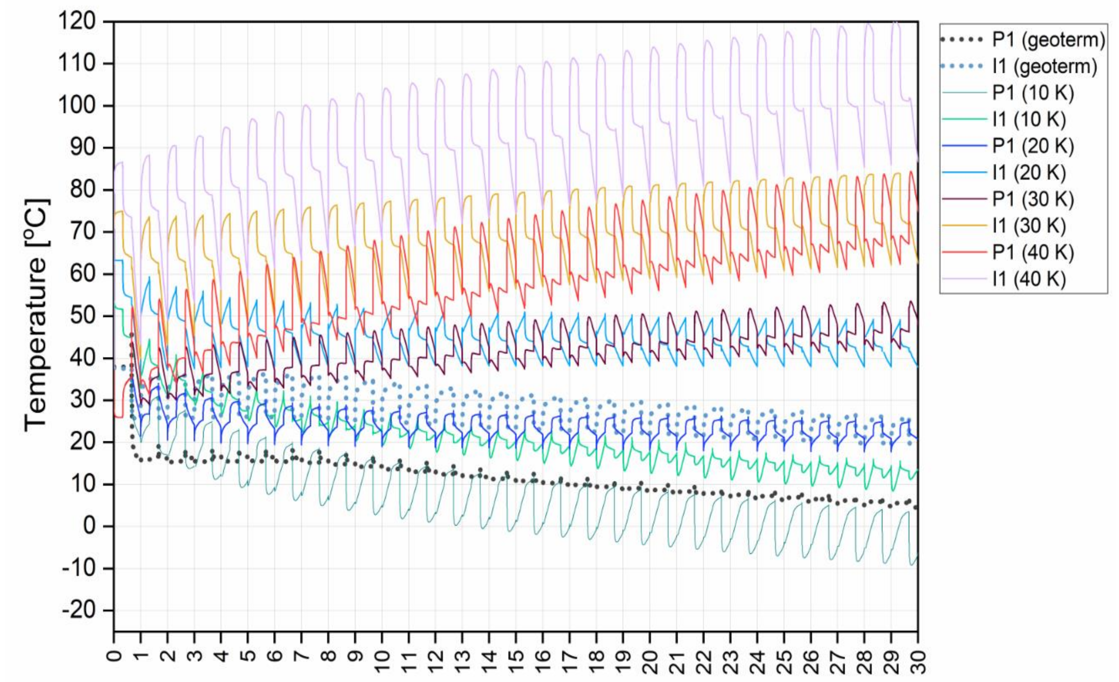

Fig. 5 Simulated temperature changes around P-I 1 doublet during 30 years of operation for 10 K, 20 K, 30 K, 40 K temperature differential of ATES operation (solid lines) and geothermal application (dotted lines) (Halaj et al., 2022).

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References:

Dommisse, R., Janson, X., Male, F., Price, B., Payne, S., Lewis, A. (2019). An Integrated, Multiscale Geomodel of the Northern Delaware Basin. Unconventional Resources Technology Conference.

Halaj E., Pajak L., Papiernik B. (2022) Simulation study of the Lower Cretaceous geothermal reservoir for aquifer thermal energy storage. Environmental Geochemistry and Health. 44, 7:2253 – 2279

Kępińska B., Pająk L., Bujakowski W., Kasztelewicz A., Hajto M., Sowiżdżał A., Papiernik B., Petursson B., Tulinius H., Thorgilsson G., Einarsson O. P., Karska A., Peraj A., (2017). Geothermal utilization potential in Poland – the town of Poddębice. Part 1: selected reservoir and exploitation aspects of current and further geothermal district heating and other uses' development in Poddębice Instytut Gospodarki Surowcami Mineralnymi i Energią PAN, Technika Poszukiwań Geologicznych. 56, 1: 3—21

Papiernik, B., Michna, M. (2019). Methodology and results of digital mapping and 3D modelling of the Lower Palaeozoic strata on the East European Craton, Poland. Annales Societatis Geologorum Poloniae. 89: 405—427.