Exploring CO_2 storage potential in Lithuanian deep saline aquifers using digital rock volumes: a machine learning guided approach

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Abstract. The increasing significance of carbon capture, utilization and storage (CCUS) as a climate mitigation strategy has underscored the importance of accurately evaluating subsurface reservoirs for CO_2 sequestration. In this context, digital rock volumes, obtained through advanced imaging techniques such as micro-Xray computed tomography (MXCT), offer intricate insights into the porous and permeable structures of geological formations. This study presents a comprehensive methodology for assessing CO_2 storage viability within Lithuanian deep saline aquifers, namely Syderiai and Vaskai, by utilizing petrophysical properties estimated from digital rock volumes of samples from analogous formations. It also demonstrates the potential of integrating advanced imaging techniques, machine learning, and numerical modeling for accurate assessment and effective management of subsurface CO_2 storage.

Keywords: carbon capture, utilization and storage (CCUS), saline aquifers, storage potential, digital rock volumes, machine learning, lattice Boltzmann method, numerical modeling.

1. Introduction

In recent years, anthropogenic activities have led to a global increase in greenhouse gas emissions. To mitigate this, Carbon Capture, Utilization, and Storage (CCUS) has emerged as a potential solution [1]. In Lithuania's Baltic Basin, research is still in its early stages regarding the long-term fate of geological CO2 storage [2, 3]. This study focuses on the deep saline aquifers, Syderiai and Vaskai of the Baltic Basin (shown in Fig. 1) and aims to demonstrate the effective application of machine learning in extracting optimized estimates of storage and flow potential using non-destructive digital rock volumes (DRV).

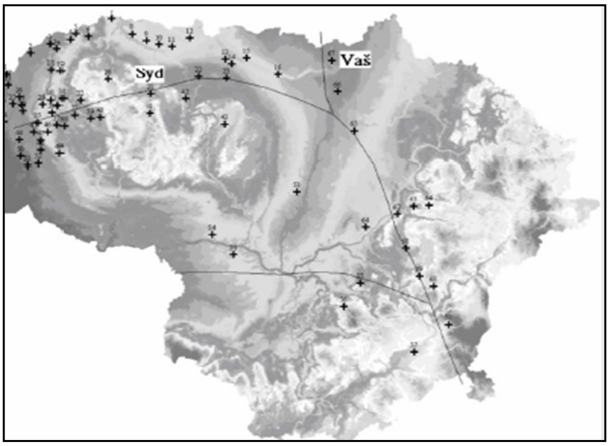

Fig. 1. Location of Syderiai and Vaskai regions

Machine learning algorithms offer an accurate and fast alternative to time-consuming conventional Digital rock physics method for determining optimized estimates of petrophysical properties [4-6]. The storage of captured CO_2 can be done in underground geological formations such as depleted oil and gas reservoirs, deep saline aquifers, or coal seams. Amongst these, deep saline aquifers are considered as the most prospective site due to their large storage capacity and widespread geographic distribution, making it easier to find storage locations closer to the sources of CO_2 emissions [3].

2. Methodology

In this study, digital volumes of rocks were obtained from formations analogous to Lithuanian reservoirs using Micro Xray Computed Tomography (MXCT) scanning technique. The Machine learning (ML) algorithm was then employed to estimate the porosity, and Lattice Boltzmann Method (LBM) simulations were conducted to estimate permeability values of 3D DRVs [7]. Sub-volumes were extracted from segmented volumes to investigate fluid flow behavior and determine the representative element volumes (REVs) (as shown in Fig. 2). These sub-volumes can also be used to analyze the geo-chemical aspect which includes the impact of fluids on porosity and its distribution.

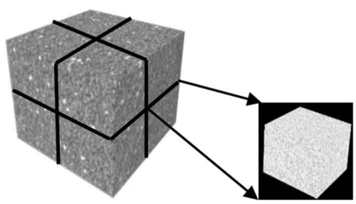

Fig. 2. Illustration of the sub-volume extraction for REV estimation

3. Results

The estimated petrophysical properties were compared with those measured in laboratory. It was observed that the estimated values closely matched the laboratory measurements. The error percentages for porosity were in the range of '1 %-8 %', while for permeability (Table 1) they ranged from '20 %-55 %', as shown in Table 1.

Table 1. Permeability estimation on sub-volumes of samples from analogous formation using LBM

Sample	Average permeability of sub-volumes (mD)	Laboratory (mD)	Error (%)
S1	330	275	20
S2	96	62	55
S3	396	327	21

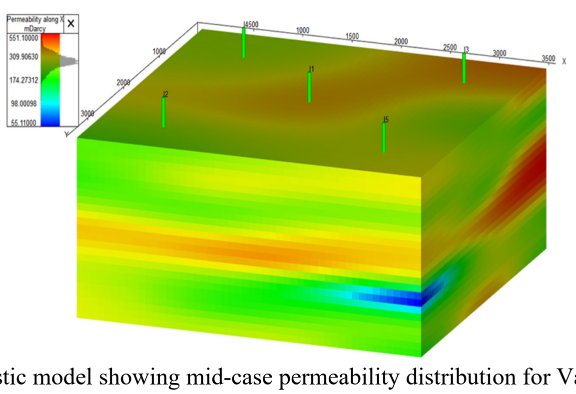

Fig. 3. Mechanistic model showing mid-case permeability distribution for Vaskai aquifer [8]

Further, the numerical modeling of CO_2 injection into saline aquifers was performed, to estimate the storage capacity using tNavigator software [8, 9]. Three test cases were defined, wherein the reservoir properties extracted from published literature served as the mid-case values. A low case was defined, in which parameters were decreased by 10 % from the mid-case values, and a high case where the parameters were increased by 30 % from the mid-case values [8]. The mechanistic model showing the mid-case permeability distribution for Vaskai aquifer is shown in Fig. 3.

4. Conclusions

The current study aims to explore the CO_2 storage potential of deep saline aquifers in Lithuania, specifically the Syderiai and Vaskai formations, using numerical modeling of CO_2 injection into these formations. Measurements on samples from formations analogous to those in Lithuania were used to establish a baseline understanding, which will aid in the analysis of Lithuanian reservoir samples.

Further, this work will be extended to include samples from actual Lithuanian reservoirs and to study the geochemical reactions and geo-mechanical behaviour of the rocks. Such studies shall further facilitate identification of reservoir(s) wherein sequestration potential can be reliably explored.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

Shruti Malik: investigation, methodology, software, writing – original draft preparation. Pijus Makauskas: methodology, software, writing – review and editing. Ravi Sharma: methodology, supervision, writing – review and editing. Mayur Pal: conceptualization, investigation, methodology, supervision, writing – review and editing.

Conflict of interest

The authors declare that they have no conflict of interest.

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