3D geological and petrophysical numerical models of E6 structure for CO₂ storage in the Baltic Sea

Kazbulat Shogenov¹ Edy Forlin² Alla Shogenova¹

¹ Institute of Geology, Tallinn University of Technology, Ehitajate tee 5, Tallinn 19086, Estonia
² Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Borgo Grotta Gigante, 42/c, 34010 Sgonico, Trieste, Italy

Abstract
Effective application of CO₂ Capture and Storage (CCS) technology to ensure efficient climate change abatement needs estimation of reservoir properties of storage site and possible risks due to injection of CO₂ in supercritical state into the deep saline aquifer. To monitor behaviour of CO₂ plume in the deep geological trap a number of modelling routines could be applied. Previous studies show that the most prospective structures for CO₂ geological storage (CGS) in the Baltic region (Estonia, Latvia and Lithuania) are available in Latvia represented by number of onshore and offshore anticline structures [1, 2, 3, 4]. The offshore E6 structure, was assessed as the largest among all the studied in the Baltic Region structures [4, 5]. Prospective for CGS reservoir is represented by the Cambrian Series 3 Deimena Formation (848–901 m depth at the well E6-1/84) composed by quartz oil-impregnated sandstones. The structure is an anticline fold bounded on three sides by faults. The E6 structure consists of two different compartments divided by inner fault.

The total area of the structure is 600 km² considering the closing contour of the reservoir top located at a depth of 1350 m below sea level (BSL). An approximate area of the larger part (E6-A) of the structure is 553 km², while the smaller part (E6-B) is 47 km². The average thickness of the reservoir unit is 53 m. The E6-A was considered for the modelling. The Deimena Formation unconformably covered by 146 m thick impermeable Ordovician rocks, consisting mainly of shales, marlstones and limestones. Upper part of the Ordovician is formed by Saldus Formation carbonate rocks (10.5 m of thickness) of Porkuni Stage and represents oil deposit [4, 5].

Two models (Model-1 and Model-2, Figures 2 a, b, c) with different area and 3D volumetric grid size dimension of the E6 oil-bearing structure were composed. The bigger one (Model-1, Figure 2 a, b) should allow visualization of complete migration of CO₂ plume within the developed 3D grid model using fluid-flow simulation (cell size 500 m). The smaller one (Model-2, Figure 2 a, c) is focusing on the uppermost part of the Cambrian Series 3 Deimena Formation reservoir close to the drilled well, assuming that CO₂ injection will take place in this area. The Model-2 with a finer gridding (cell size 30 m) was adopted for seismic numerical modelling purpose. We reduced grid size in the Model-2 as much as possible, to satisfy seismic modelling requirements.

We considered three main surfaces in the model, corresponding to stratigraphic boundaries interpreted using well logs and seismic data: (1) top of the Ordovician Formation (part of the secondary cap rock), (2) top of the reservoir–the Deimena Formation and (3) bottom of the reservoir. Points` sets representing geological horizons were then converted into gridded surfaces. All the obtained surfaces (faults and horizons) were edited in order to obtain a watertight configuration. After editing of the surfaces, the volumetric grid has been created. Two main zones have been defined in the model representing respectively reservoir and cap rock units. The layering was set up to take into account the lithological and petrophysical partitioning of the reservoir.
Thus, we could accurately populate our geological models with both lithological and petrophysical parameters (porosity and permeability). We defined five layers within the cap rock (10, 56, 44, 26 and 10 m of thickness) and also in the reservoir formation (10, 3, 15, 6 and 19 m of thickness). Proportional layering method in the stratigraphic modelling was applied, resulting in the grid proportional to the corresponding top and base surfaces.

According to the geological setting of the region [6] the faults were considered to be propagating through the cap rock. No transmissivity values are available for the faults in the area. The seismic reflection data of 1970’s was insufficient for the detailed characterization of the faults and did not allow confident prediction of CO$_2$ flow in the fault zone. Nevertheless, looking at experience of the largest Latvian onshore Inēkals underground natural gas storage, showing comparable structural setting, we suggested that faults in the E6 structure could act as sealing surfaces [4, 6].

Generally, petrophysical properties are highly correlated to facies type and, for this reason the facies are modelled first in order to populate the geological model with porosity and permeability. Stochastic modelling was applied to populate the volumetric grid with data obtained from composite log analysis, core measurements and bibliography into the 3D grid [4, 5, 7, 8, 9]. Eight facies were identified within the model by analysing core data and assigned to the model.

Proposed 3D models have significant importance and play linking role for coupling fluid-flow simulation and seismic numerical modelling. Therefore, present study has crucial role in developing an optimal offshore storage seismic monitoring plan in the studied area. Results of this work could be applied in fluid-flow simulations to predict CO$_2$ plume evolution and migration within the studied area. This will permit to predict seismic response to the CO$_2$ plume migration at different time scales within the studied reservoir structure, and, will support basis for the further monitoring plan design in the region. This study offers new possibilities for economic, petrophysical and geochemical modelling of regional transboundary CCS scenarios in the Baltic Sea Region. However, lack of faults transmissivity data together with the uncertainties in facies distribution call for further investigations in order to increase the accuracy of
the geological static model for the E6 offshore structure.

References


