Geological Modeling of a Gas Reservoir in the Parnaíba Basin for CO_2 Storage

Isac Brito Barreira[1], Thiago Henrique da Silva Barbosa[1], Karen M. Leopoldino Oliveira[1,2,3,4], Luis Glauber Rodrigues[1,2,3], Felipe Correa dos Santos[5], André Basso Schilling[5], Narelle Maia de Almeida[1,2,3,4]

[1] Marine and Energy-applied Geology and Geophysics Laboratory (LGMA), Federal University of Ceará (UFC);
[2] Innovation and Research Group in Energy and Mineral Resources (GIPEM), Federal University of Ceará (UFC);
[3] Integrated Multiscale Simulation Group (GSIM), Federal University of Ceará (UFC);
[4] National Institute of Science and Technology for Petroleum Geophysics (INCT-GP/CNPq);
[5] ENEVA S. A

Abstract

Carbon capture and storage require accurate three-dimensional geological models to mitigate effectively the global warming. This work aims to develop a geological model of the Gavião Real gas field in the Parnaíba Basin to understand the factors that will control the possible permanent storage of CO_2. Based on data from the National Petroleum Agency (ANP) and ENEVA S.A., it was observed that the diabase sill, responsible for the trap and seal, showed good lateral continuity. However, changes in the geometry of the intrusion resulted in the compartmentalization of the field into four accumulations. The interval of Poti Fm., the main reservoir, is composed of 79% sandstone, 13% shale, and smaller percentages of diabase, metasediment, and siltstone. The developed model allowed the recognition of important geological characteristics of the reservoir that may have impact on the CO_2 storage. These results will be useful for the development of the petrophysical model and multiscale simulations that will help in decision-making regarding the possibility of a storage project in Gavião Real.

Introduction

Global warming has a significant impact on the Earth's ecosystems and represents a serious problem. To mitigate the climate change, significant reductions in greenhouse gas (GHG) emissions are necessary, especially those of carbon dioxide (CO_2), which is primarily responsible for global warming (Wei et al, 2021).

Carbon capture, utilization and storage (CCUS) has been considered a critical technological solution to limit the global temperature increase to 2°C compared to pre-industrial levels (Mac Dowell et al., 2017). CCUS is mainly based on capturing CO_2 from anthropogenic sources (e.g. thermoelectric plants) and transporting it to a location where it can be injected into geological storage media (specific sinks, such as deep saline aquifers and depleted hydrocarbon reservoirs) (Holloway, 2007; Rackley, 2017).

One of the initial steps for this type of project is to create three-dimensional geological models of the reservoir. Geological modeling provides a critical view of uncertainties and spatial variations, offers reliable estimations of reservoir volume, and guides the allocation of wells, supporting crucial decisions for economic viability and the dimensioning of facilities (Pyrcs and Deutsch, 2014).

Therefore, this research aimed to develop a three-dimensional geological model of the Gavião Real (GVR) field (Figure 1), a gas field with a high recovery factor in the Parnaíba Basin, located 4 km from a thermoelectric plant. The focus is to understand the factors that will influence the permanent storage of CO_2 and support this operation in GVR. The results on faults and the distribution of facies, as well as the main locations for CO_2 injection wells, will help in the project's decision-making process, to reduce the environmental impact of greenhouse gas emissions and guarantee the supply of energy with a lower carbon footprint.

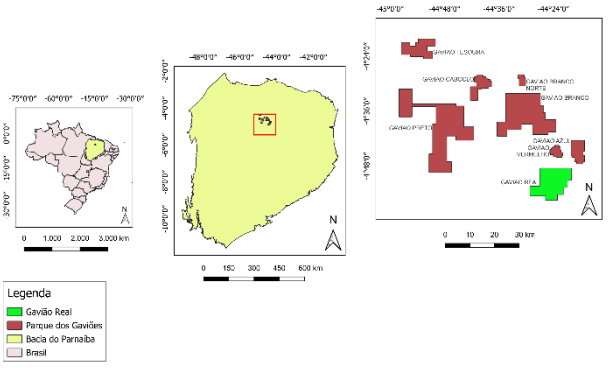

Figure 1 - Location of the study area: Gavião Real field in the Parnaíba Basin.

Methodology / Problem investigated

The Gavião Real model was developed using seismic and well data provided by ANP and ENEVA S.A. Seismic units were interpreted and correlated with well data and the regional lithostratigraphic framework from Vaz et al. (2007) (Figure 2). In addition, the top and bottom of the field's main sill were mapped, which is responsible for trapping and sealing the studied gas reservoir.

To create the structural grid, the reservoir zone was detailed for a better representation. The workflow used included the structural framework, based on the volume-based modeling methodology with the generation of corner point grids that are close to orthogonality, since this model can be used for dynamic and geomechanical simulations.

Results

The top of the main sill of the GVR field was interpreted as a high-amplitude positive reflector with positive reflectivity (Figure 2). Its base, on the other hand, is characterized by a reflector with high amplitude, negative reflectivity, and high continuity.

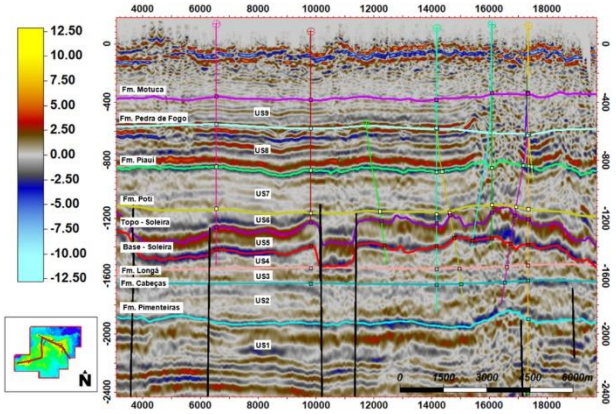

Figure 2 - Interpreted arbitrary seismic line crossing the main structures of the Gavião Real field.

As seen in Figures 2 and 3, the sill is not perfectly horizontal and planar. On the contrary, it occurs at different stratigraphic levels forming relative structural highs, which are responsible for the trapping of the studied reservoir (Miranda et al., 2018).

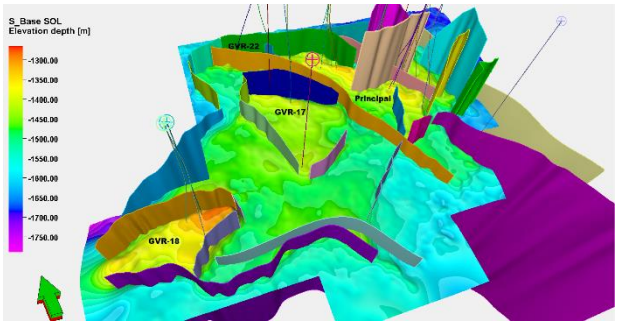

Figure 3 - Structural model showing the surface of the sill base, the main faults, and the GVR zones.

Twenty-seven faults were interpreted within the GVR ring fence (Figure 3). The deepest faults have a NE-SW orientation and the others, which are more extensive but shallower, have a NW-SE orientation. These faults act as flow barriers, separating the reservoir into four distinct producing zones.

The facies model indicated the presence of 79% sandstone, 16% shale, and smaller percentages of diabase, metasediment, and siltstone (Figure 4). The structural highs, where the gas discoveries were made, are mostly made up of sandstones from the Poti Fm. (Figure 4).

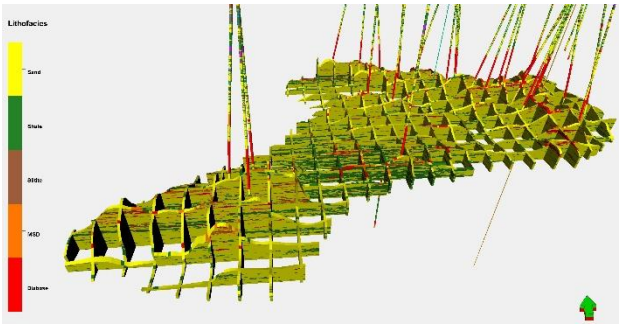

Figure 4 – Facies model showing the main lithologies of the Poti Fm., the reservoir of GVR, and their three-dimensional distributions.

Discussion and Conclusions

The geological model showed that the sill, responsible for sealing, trapping and maturation (Miranda et al., 2018), is saucer-shaped (e.g. Jerram & Bryan, 2015). It has good lateral continuity and a structural high allowed the accumulation and preservation of the natural gas. The integrity and lateral continuity of the diabase sill are extremely important for the effectiveness of the structure's seal and trap. In addition, the sealing capacity of the sill due to its very low permeability also favors the CO_2 storage project, as it increases the guarantee that there will be no gas leakage, considering the limit as the current gas/water contact of the field (Mclaughlin et al., 2014).

It is concluded that the stratigraphic level changes of the sill intruded into the Poti Fm., composed mainly of sandstones, have created an effective trap and seal structure constituted by the diabase sill. These sandstones can be considered excellent potential CO_2 injection zones. It is worth mentioning that petrophysical and geomechanical studies are being carried out to ensure the maximum safety of this activity.

These results can help guide the CO_2 storage project in the Gavião Real field, as well as in other fields with similar geological characteristics, and provide useful information for future research into combating climate change.

Acknowledgements

To the Marine and Energy-applied Geology and Geophysics Laboratory (LGMA) of the Federal University of Ceará (UFC), the ANP and ENEVA S.A. for allowing this research to be carried out.

References

Jerram, D. A.; Bryan, S. E. 2015. Plumbing systems of shallow level intrusive complexes. In: Physical Geology of Shallow Magmatic Systems. Springer, Cham, p. 39-60.

Holloway, S. (2007). Carbon dioxide capture and geological storage. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 365(1853), 1095–1107. doi:10.1098/rsta.2006.1953

Mac Dowell, N., Fennell, P. S., Shah, N. & Maitland, G. C. The role of CO2 capture and utilization in mitigating climate change. Nat. Clim. Change 7, 243–249 (2017).
Eidsvik, J. Pyrcz and Deutsch: Geostatistical Reservoir Modeling. Math Geosci 47, 497–499 (2015).

Mclaughlin, J., Ganshin, Y., Quillinan, S., Bentley, R., & Jiao, Z. (2014). Mitigating Risks Associated with Long-term CCS: Characterizing the Geologic History and Heterogeneity of Sealing Strata. *Energy Procedia*, 63, 4999-5009. https://doi.org/10.1016/J.EGYPRO.2014.11.529.

Miranda, F. S., Vettorazzi, A. L., Cunha, P. R. da C., Aragão, F. B., Michelon, D., Caldeira, J. L., … Andreola, K. (2018). Atypical igneous-sedimentary petroleum systems of the Parnaíba Basin, Brazil: seismic, well logs and cores. Geological Society, London, Special Publications, SP472.15.

Rackley, S.A., 2017. Carbon Capture and Storage. Butterworth-Heinemann. Rahman, T., Lebedev, M., Barifcani, A., Iglauer, S., 2016. Residual trapping of supercritical CO2 in oil-wet sandstone. J. Colloid Interface Sci. 469, 63–68.

Vaz, P.T., Rezende, N.G.A.M. & Wanderley Filho, J.R. 2007. A bacia do Parnaíba. boletim de geociências da Petrobras, 15, 253–263.

Wang, N., Akimoto, K., & Nemet, G. (2021). What went wrong? Learning from three decades of carbon capture, utilization and sequestration (CCUS) pilot and demonstration projects. *Energy Policy*. https://doi.org/10.1016/j.enpol.2021.112546.

Wei, Y.-M., Kang, J.-N., Liu, L.-C., Li, Q., Wang, P.-T., Hou, J.-J., … Yu, B. (2021). A proposed global layout of carbon capture and storage in line with a 2 °C climate target. Nature Climate Change, 11(2), 112–118.