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Development Challenges in a Heavy Oil Field, Subject to Water Production: A Case Study of Diamond Field in Central Africa

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Abstract: ***The Diamond field from onshore in Gabon was brought into production by Perenco in 2000, but its development has mainly focused on deep light oil reservoirs. This study reassesses the potential of the shallow Senonian and Turonian reservoirs, which have remained underexploited due to technical challenges, including the presence of heavy oil (18-22 API) and significant water production. The results of structural modelling and petrophysical analysis (CMR) estimate a total oil in place (STOIIP) volume of 48 Mmstbo for the base case, rising to 718 Mmstbo in the high scenario. The analysis identifies 12 potential productive intervals, including six (6) in the light oil zone and six (6) in the heavy oil zone. Although the current recovery factor for the EM1 & LC2 zone is only 5.5%, as illustrated by the RK-3 well's historical production of 500,000 barrels in July 2010, the study shows that recovery rates of up to 40% are possible. Confirmation of these volumes, representing possible contingent resources of 287 Mmstb, now requires a dedicated appraisal phase to reduce structural uncertainties.***

Keywords: ***Diamond Field (Gabon), Heavy oil, Water production, STOIIP (Oil in place), Senonian & Turonian, Petrophysical analysis (CMR)***

Nomenclature:
SP: Spontaneous Potential
GRV: Gross Rock Volume

I. INTRODUCTION

Understanding the reservoir/cap rock system in the Rembo Kotto area is highly complex. This difficulty stems from the mixture of systems at the formation, member, and parasequence (une unité de base constituée d'une succession de couches sédimentaires, une strate) scales. Ahmed T. (2018) pointed out in their fundamental work on reservoir engineering that accurate characterization of these interactions is crucial for resource evaluation [1].

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At Liu, H., Jiang, Y. (2025) [2], the exceptional nature of the deposits has favoured the local development of reservoir/cap rock pairs at the parasequence scale, creating multiple thin stacked reservoirs with oil columns ranging from 3 to 20 meters. The deposition process of these prograding parasequences places the best-quality sands at the top of each cycle, just below the sealing event. This configuration, confirmed by CMR tool data at the RK-38 well, ensures that oil is concentrated in the best sections despite the thinness of the columns. The interpretation of these logs is based on the principles described by Liu, H. H. (2016) [3] and Kamayou, V.M et al. (2021) concerning the geological analysis of well logs [3].

The trapping of hydrocarbons in these reservoirs meets several key criteria:

A four-way anticlinal closure is essential, as the absence of clayey materials limits the chances of closure by faulting.

The best sands are located immediately below the waterproofing levels.

There is an alternation of oil and water reservoirs, making flow analysis complex, a challenge often addressed in the literature by Bordbar, A et al. (2018) and da Cunha Teixeira, J. et al. (2021) [4] [5].

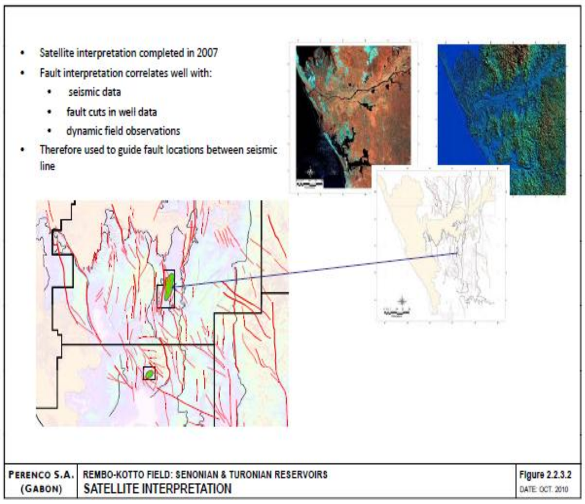
Although combined stratigraphic and structural traps may exist, the “layer cake” stratigraphy suggests that purely stratigraphic trapping is not predominant.

Water production management, as noted by Bhattacharyya, K., & Singh, V. P. (2019), is a significant technical challenge for the future profitability of these shallow reservoirs [6].

II. PRESENTATION OF THE STUDY AREA

In the framework of the system put in place by Bhattacharyya, K., & Singh, V. P. (2019) [7], Perenco has been exploiting the Champ Diamond, a terrestrial petroleum site in Gabon, since the beginning of its production in 2000 while taking into account the increasing vulnerability of the resources and incorporating the principles of evaluation related to sedimentation in the reservoirs. Although initial exploitation focused on the deep light oil reservoirs of the Cap Lopez formation, the specific study area here concerns the shallower Senonian and Turonian reservoirs, including the Azile (Sibang and Lowe members) and Milango (Early, Main, and Late Milango members) formations, following the same principles of work carried out by Madumere, N. (2021) [8]. This area is characterised by complex technical challenges, including heavy oil (18-22 API), high H_2S content, and thin, stacked oil columns that produce significant amounts of water. This research contributes to the overall objective of sustainable development in the oil and gas sectors by providing insights into the understanding, monitoring, and mitigation of H_2S corrosion Vakili, M. et al., 2024) [9].

The analysis of this zone is based primarily on petrophysical and structural data from the RK-38 well, supplemented by observations from neighbouring fields such as Oba and Assewe, to better assess the still untapped potential of these shallow levels, as mentioned in the research works of Lawson, I. D., & Balogun, A. O. (2023) [10] and Harry et al. (2022) [11].



[Fig.1: Seismic Data Correlation with Well Information]

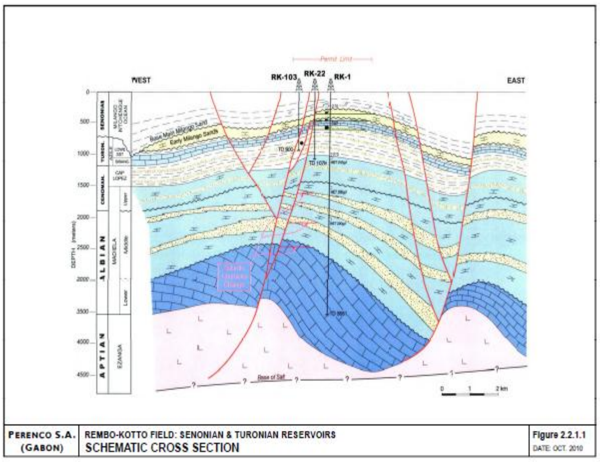
III. MATERIALS AND METHODS

The study uses a deterministic approach for volumetric assessment, with a 3D structural model built in Petrel software to calculate gross rock volume (GRV). Due to the lithological complexity of the Azile and Milango formations (a mixture of sand, limestone, and dolomite) and the absence of clay materials, total porosity derived from the magnetic resonance tool (TCMR) was preferred over effective porosity. Conventional logging data, such as Gamma Ray, were ineffective due to the radioactivity of the sands, so the CMR tool from the RK-38 well was the primary source for resolving interpretation issues and identifying productive zones (>2m).

Table 1: Results of Petrophysical Properties (net-to-Gross, Porosity, Water Saturation, Bo and STOIIP)

	GRV MMm3			N/G %			Porosity %			Sw %			Bo vol/vol			STOIIP MMstb		
-	LOW	BASE	HIGH	LOW	BASE	HIGH	LOW	BASE	HIGH	LOW	BASE	HIGH	LOW	BASE	HIGH	LOW	BASE	HIGH
LM1	2.0	25.6	448.0	40.0	50.0	60.0	25.0	30.0	35.0	65.0	50.0	35.0	1.02	1.02	1.02	0.4	**11.8**	377.0
MM3	2.7	9.7	57.6	40.0	50.0	60.0	20.0	24.0	28.0	65.0	50.0	35.0	1.02	1.02	1.02	0.5	**3.6**	38.8
MM2	3.4	10.2	56.5	70.0	80.0	90.0	28.0	30.0	32.0	65.0	50.0	35.0	1.02	1.02	1.02	1.4	**7.5**	65.2
MM1	2.1	10.1	59.8	90.0	95.0	100.0	26.0	29.0	32.0	65.0	50.0	35.0	1.02	1.02	1.02	1.1	**8.6**	76.7
EM1/LC2	12.0	25.0	116.0	50.0	60.0	80.0	15.4	19.3	23.2	55.0	47.7	33.1	1.05	1.05	1.05	2.5	**9.1**	86.3
L10	2.0	5.5	56.0	15.0	32.0	49.0	20.0	22.0	24.0	79.8	65.0	50.2	1.05	1.05	1.05	0.1	**0.8**	19.6
L9	2.8	12.0	50.5	15.0	32.0	49.0	30.0	32.0	34.0	70.0	55.0	40.0	1.05	1.05	1.05	0.2	**3.3**	30.2
L6	2.8	6.2	22.4	21.0	45.0	69.0	27.0	30.0	33.0	79.9	65.0	50.1	1.05	1.05	1.05	0.2	**1.8**	15.2
S2	1.1	1.6	7.8	75.0	85.0	95.0	21.0	25.0	29.0	65.0	50.0	35.0	1.05	1.05	1.05	0.4	**1.0**	8.4
																6.7	**47.5**	717.5

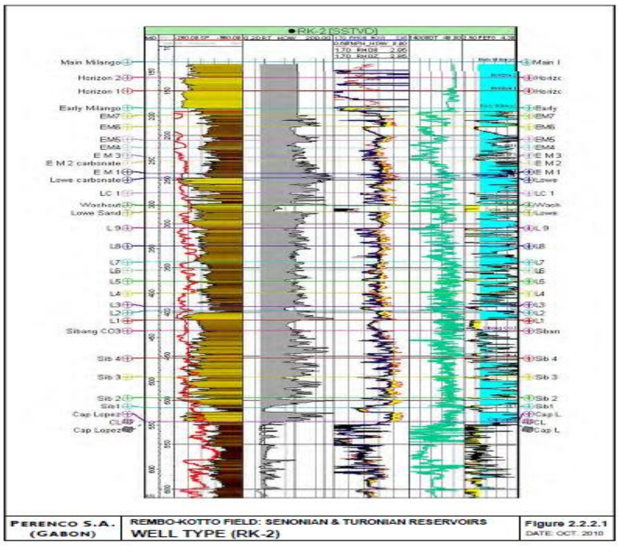
To complete the analysis, petrophysical properties (net-to-gross, porosity, water saturation) were derived from interpretations of the RK-38 well for most reservoirs. At the same time, data from the RK-4 well were used for the Main and Late Milango formations. In the absence of sufficient core samples from the Diamond field, a comparative database from the neighbouring Assewe field was integrated to establish porosity-permeability relationships. Finally, spontaneous potential (SP) measurements were used, where available, to confirm the identification of permeable reservoirs and track variations in formation water salinity.



[Fig.2: Reservoir in Water Salinity Formation]

IV. RESULTS

The methodology is primarily based on advanced petrophysical analysis using the CMR (Combined Magnetic Resonance) tool on the RK-38 well to overcome the lack of core data and the complex lithology (a mixture of sand, limestone, and dolomite). This method permitted the definition of total porosity (TCMR) rather than effective porosity, given the low clay content. The results of this analysis identified 12 potentially hydrocarbon-bearing intervals, evenly distributed between 6 light oil zones (approximately 42 API) and 6 heavy oil zones (18-22 API).



[Fig.3: Well log Data in the Senonian Formation]

Next, a deterministic approach to volumetric calculation was implemented, using a 3D structural model built in

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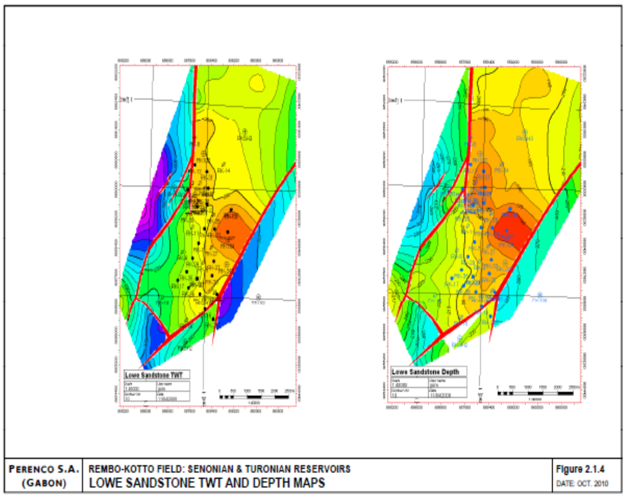
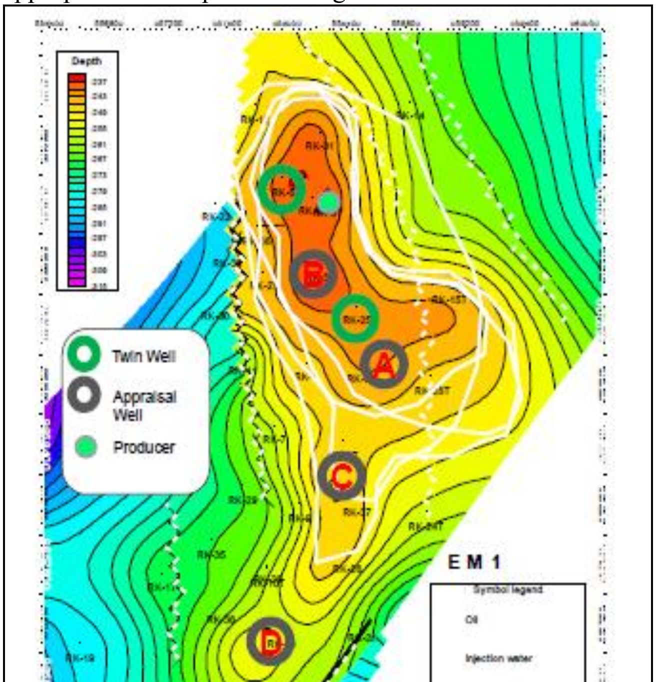
Petrel. This methodology incorporates anticlinal closures in four directions and oil-water contacts defined by well data. The results of this modelling estimate a total oil in place (STOIIP) for the base case of 48 Mmstbo, with an uncertainty range from 6.8 Mmstbo (low case) to 718 Mmstbo (high case).



[Fig.4: STOIIP Medeling Estimated Using Petrel]

Finally, a comparative and historical analysis of production performance was conducted, focusing on the RK-3 well and neighbouring fields, including Oba and Assewe. This method enabled validation of the commercial potential of the shallow reservoirs and the definition of recovery factors. The results indicate that for the EM1 & LC2 zone, the current recovery factor is 5.5% (based on a STOIIP of 9.1 Mmstbo), but that recovery rates of up to 40% are technically feasible with appropriate development strategies.



[Fig.5: Well Reservoir Appraisal]

V. DISCUSSION

The validity of this study's results is based on comparing the methods used with established theories in scientific literature. The following discussion analyses our methodological approaches: The first method, magnetic resonance (CMR) petrophysical analysis, was crucial in overcoming the limitations of conventional logging in the Azile and Milango formations, as pointed out by Soro, D. D. (2017) in his doctoral thesis entitled Characterization and hydrogeological modelling of an aquifer in a fractured basement environment [12],

Adagunodo, T. A et al. (2017) [13] and Adagunodo, T. An et al. (2022) [14] note that interpreting logs in complex lithologies requires advanced tools to distinguish total porosity from effective porosity.

The use of TCMR porosity enabled overcoming the lack of data on clays, thereby validating the presence of hydrocarbons in thin columns. However, uncertainty in formation water salinity (Rw), a critical error factor, remains a concern for the accuracy of calculated saturations. The second method, the deterministic approach for calculating STOIIP, is based on a 3D structural model developed in Petrel [15] [16]. This methodology follows volumetric calculation standards, in which the accuracy of the gross rock volume (GRV) is the most sensitive parameter. Discussion of our results shows that the significant difference between the “Low Case” and the “High Case” (from 6.8 to 718 Mmstbo) is a direct consequence of the lack of well data to calibrate oil-water contacts, a classic reservoir engineering challenge identified [17] [18]. The deviation error detected in the RK-38 well underscores the importance of precise structural geometry to avoid substantial estimation errors.

Finally, analysis of the analogy with neighbouring fields (Oba, Assewe) enabled compensation for the almost total absence of core sampling on the Diamond field. This method of comparison, recommended for contingent resource assessments, allows optimistic recovery factors to be projected up to 40%. However, these analogies must be applied with caution due to the problems of water coning specific to thin columns, phenomena widely documented by Varges, P. R. et al. (2022) [19] and Belkhir, S. A. (2025) [20]. These authors agree that the production dynamics in such heterogeneous reservoirs require a rigorous completion strategy to maintain the project's economic viability.

VI. CONCLUSION

The study contributed to the construction of a detailed 3D structural model to assess the potential of the Diamond field reservoirs, identifying 12 intervals potentially containing hydrocarbons: 6 in the light-oil zone and 6 in the heavy-oil zone. Estimates of total oil in place (STOIIP) vary significantly across scenarios, ranging from a base case of 48 Mmstbo to a high case of 718 Mmstbo, underscoring the significance of the untapped resources. Despite the current recovery factor of 5.5% for the EM1 & LC2 zone, analyses indicate that rates of up to 40% are technically feasible, bringing contingent resources to 287 Mmstbo. Ultimately, although uncertainties remain regarding the gross rock

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volume due to limited data, the historical success of the RK-3 well and the identified potential fully justify the implementation of a dedicated appraisal program, including the drilling of two additional wells and extensive petrophysical data acquisition to optimise future development.

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DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted with objectivity and without any external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

REFERENCES

1. Ahmed, T. (2018) "Reservoir Engineering Handbook". 5th Edition - December 19, 2018. Latest edition. Imprint: Gulf Professional Publishing. Hardback ISBN: 9780128136492. eBook ISBN: 9780128136508 https://shop.elsevier.com/books/reservoir-engineering-handbook/ahmed/978-0-12-813649-2
2. Liu, H., Jiang, Y. (2025). Reservoirs and Cap Rocks. In: Petroleum Geology. Springer, Singapore. DOI: https://doi.org/10.1007/978-981-96-7086-4_3
3. Liu, H. H. (2016). Generalisation of Darcy's Law: Non-Darcian Liquid Flow in Low-Permeability Media. In *Fluid Flow in the Subsurface: History, Generalisation and Applications of Physical Laws* (pp. 1-43). Cham: Springer International Publishing. https://link.springer.com/chapter/10.1007/978-3-319-43449-0_1
4. Kamayou, V.M., Ehirim, C.N. and Ikiensikimama, S.S. (2021). Estimating Volume of Shale in a Clastic Niger Delta Reservoir from Well Logs: A Comparative Study. International Journal of Geosciences, 12, 949-959. DOI: https://doi.org/10.4236/ijg.2021.1210049
5. Bordbar, A., Faroughi, S., & Faroughi, S. A. (2018). A pseudo-TOF-based streamline tracing for the streamline simulation method in heterogeneous hydrocarbon reservoirs. *American Journal of Engineering Research*, *7*(4), 23-31. file:///C:/Users/ASUS/Downloads/D07042331.pdf
6. da Cunha Teixeira, J., do Nascimento Guimarães, L. J., & de Carvalho, D. K. E. (2021). Streamline-based simulation in highly heterogeneous and anisotropic petroleum reservoirs using a non-orthodox MPFA method and an adaptive timestep strategy with unstructured meshes. *Journal of Petroleum Science and Engineering*, *201*, 108369. DOI: https://doi.org/10.1016/j.petrol.2021.108369
7. Bhattacharyya, K., & Singh, V. P. (2019). *Reservoir sedimentation: assessment and environmental controls*. CRC Press 1st Edition. eBook ISBN9781351027502. Pages342 DOI: https://doi.org/10.1201/9781351027502
8. Madumere, N. (2021). The impact of stakeholder management on the oil and gas industry in Africa: A case study of oil companies and African host communities. *African Journal on Conflict Resolution*, *21*(2), 8-32. Published Online:12 Apr2022 https://hdl.handle.net/10520/ejc-accordr_v21_n2_a2
9. Vakili, M., Koutník, P., & Kohout, J. (2024). Addressing hydrogen sulfide corrosion in oil and gas industries: a sustainable perspective. *Sustainability*, *16*(4), 1661. DOI: https://doi.org/10.3390/su16041661
10. Lawson, I. D., & Balogun, A. O. (2023). Reservoir characterisation using petrophysical evaluation of the W-field, onshore Niger delta. *Asian Journal of Physical and Chemical Sciences*, *11*(2), 9-23. DOI: https://doi.org/10.9734/ajopacs/2023/v11i2197
11. Harry, T. A., Etim, C. E., & Agbasi, O. E. (2022). Petrophysical Evaluation of H-field, Niger Delta Basin for Petroleum Plays and Prospects. *Materials and Geoenvironment*, *69*(2), 119-129. https://reference-global.com/article/10.2478/rmzmag-2021-0020?tab=download
12. Soro, D. D. (2017). Hydrogeological characterization and modeling of an aquifer in a fractured basement environment: the case of the Sanon experimental site (Central Plateau region of Burkina Faso) (Doctoral thesis, Pierre and Marie Curie University-Paris VI; International Institute for Water and Environmental Engineering). Page 304 HAL Id: tel-01653089 https://theses.hal.science/tel-01653089v1
13. Adagunodo, T. A., Sunmonu, L. A., & Adabanija, M. A. (2017). Reservoir characterization and seal integrity of Jemir field in Niger Delta, Nigeria. *Journal of African Earth Sciences*, *129*, 779-791. DOI: https://doi.org/10.1016/j.jafrearsci.2017.02.015
14. Adagunodo, T. A., Bayowa, O. G., Alatise, O. E., Oshonaiye, A. O., Adewoyin, O. O., & Opadele, V. O. (2022). Characterization of reservoirs and depositional study of JP Field, shallow offshore of Niger Delta Basin, Nigeria. *Scientific African*, *15*, e01064. DOI: https://doi.org/10.1016/j.sciaf.2021.e01064
15. Sahu, A. K., & Talukdar, P. (2025). Optimizing Field Development with Petrel-14: A Case Study of the Penobscot Field in Nova Scotia, Canada. This work is licensed under a CC BY 4.0 License DOI: https://doi.org/10.21203/rs.3.rs-7288712/v1
16. Justine, B. G., Leroy, M. N. L., Theodore, T., & Jordan, E. E. (2024). Combining Deterministic and Probabilistic Approaches in an Improved Volumetric Model to Reduce Geological Uncertainties for Accurate Hydrocarbon Reserve Estimation: Case Study in the Rio Del Rey Basin, Cameroon. *Geofluids*, *2024*(1), 3020626. Volume 2024, Article ID 3020626, 24 pages DOI: https://doi.org/10.1155/2024/3020626
17. Dedy Kristanto et al (2023) Dedy Kristanto, Hariyadi, Emanuel Jiwandono Saputro. Uncertainty Analysis of Reservoir Static Modelling: A Case Study of KMJ Oil Field. International Journal of Oil, Gas and Coal Engineering. Vol. 11, No. 1, 2023, pp. 9-16. DOI: https://doi.org/10.11648/j.ogce.20231101.12 https://www.sciencepublishinggroup.com/article/10.11648/j.ogce.20231101.12
18. Rashid, M., & Hamd-Allah, S. M. (2023). Uncertainty assessment of reservoir modelling for an oilfield in the south of Iraq. *Journal of Petroleum Research and Studies*, *13*(4), 50-65.

DOI : http://doi.org/10.52716/jprs.v13i4.739
19. Varges, P. R., Rodrigues, E. C., Moraes, L. C., de Souza Mendes, P. R., & Naccache, M. F. (2022). Flow instabilities in fluid displacement through enlarged regions in annular ducts. *Journal Of Non-Newtonian Fluid Mechanics*, *305*, 104834. DOI: https://doi.org/10.1016/j.jnnfm.2022.104834Get rights and content
20. Belkhir, S. A. (2025). Investigation and prediction of excessive water production in bottom water-drive naturally fractured reservoirs using machine learning and deep learning. Dissertations from 2025 https://scholarworks.uaeu.ac.ae/cgi/viewcontent.cgi?article=2328&context=all_theses

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