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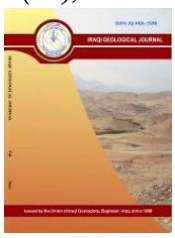

Investigating the Bubble Point Pressure Discrepancy by History Matching for Mishrif Reservoir, Southern Iraqi Oil Field

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Abstract

Carbonate reservoirs have been a primary focus for academics and oil and gas companies for many years. However, the complex nature of these rocks has always posed challenges. This is particularly true in the study area, which is located in the unstable Mesopotamian Basin, where multiple oil fields produce hydrocarbons from NW-SE-trending anticlines along the Zagros Fold-Thrust Belt. The primary goal of reservoir simulation is to forecast reservoir performance and apply different techniques to improve hydrocarbon recovery under different conditions. The study area faces a problem of discrepancy in the bubble pressure at the same reservoir unit, which is attributed to the faults in the Mishrif reservoir. A study was conducted to investigate the causes of this phenomenon. The proposed method for verification involves simulating history matching using the Petrel platform after building two geological models on the probability of the fault and the reef; as a result of seismic survey interpretation. Field data for gas production of the reservoir and Pressure-Volume-Temperature analyses, especially the wells (well pad F), were used to determine the causes of the discrepancy. The current study found that the calculated and observed data match more consistently in the case of the fault rather than in the case of the reef, indicating the presence of fault in the area near the well pad F. This caused compartmentalization, leading to the discrepancy in the bubble pressure. This study could significantly improve regional exploration, especially in Iraq.

Keywords: Mishrif reservoir; Bubble point; History matching; Reef; Fault

1. Introduction

In the southern part of Iraq's Jurassic-Cretaceous petroleum system, hydrocarbons are primarily found in sandstone and carbonate reservoirs from the Lower Cretaceous rocks. The crude oil is produced from the organic-rich Upper Jurassic Sargelu and Sulaiy formations, transforming the Lower Cretaceous carbonates of the Yamama and Zubair formations into a clastic reservoir (Boschetti et al., 2020). Seismic surveys provide crucial geophysical data from the rocks beneath the earth's surface. The general principle involves sending artificially generated acoustic waves down the column into subsurface of the earth, where the different structures and objects within the Earth's crust reflect this energy according to their acoustic impedance. When combined with other analytical methods, such as well-log and core analyses, tracer, and well-test analyses, this data enables the creation of highly accurate geologic maps and models. The 3D seismic data is particularly useful in characterizing reservoir heterogeneity, vertical zonation, lateral compartmentalization, and anisotropy or directional fluid flow in the reservoir (Mondol, 2010; Baker and Al-Rikaby, 2017; Al-Rubaye and Hamd-Allah, 2019; Alameedy et al., 2023). Seismic

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reflections offer an excellent graphical presentation of the subsurface and geologic features, providing seismic data, velocity, and time contour maps to identify various traps (Trezzi et al., 2022; Alher et al., 2018; Al-Jawad and Kareem, 2016). Additionally, the reflections help interpret sedimentary architecture and environmental paleogeographic depositions (Ali et al., 2018; Khawaja and Thabit, 2021). The study area is remarkable for interpreting 3D seismic reflections, post-stack times migrated data, and well data. In the petroleum industry, the static (geological) model is essential as the initial stage in reservoir modelling for estimating reservoir performance under various hydrocarbon production scenarios (Baker and Al-Rikaby, 2017; Alher et al., 2018; Baker et al., 2019). This model represents real-world events or things and incorporates all geological features of the number of hydrocarbons trapped in subsurface rocks (Abbas and Mahdi, 2020; Alhusseini and Hamd-Allah, 2022). The findings of these several phases are incorporated into a 3D framework to create a full static model (Al-Fatlawi et al., 2017; Abd Talib and Al-Jawad, 2022). This model identifies the reference setting for determining the quantity of hydrocarbon in the reservoirs and serves as the foundation for the dynamic model's initialization (Witter et al., 2016; Al-Rikaby and Baker, 2017). Using static and reservoir models enables engineers to determine which development options will result in the most secure and cost-effective development plan (Abdulredah and Al-Jawad, 2022; Aziz and Hussein, 2021). This static model can be utilized to construct a dynamic model to identify reservoir behaviors, detect and resolve reservoir problems, and simulate multiple scenarios, considering various exploitation schemes and working environments to enhance its depletion strategy most accurately (Alher et al., 2018; Al-Jawad and Kareem, 2016; Abdulredah and Al-Jawad, 2022; Al-Joumaa and Al-Jawad, 2019; Abdulameer and Hamd-Allah, 2020). There was an issue with the bubble point discrepancy in the study area, which required a comprehensive reassessment of the Mishrif Formation.

The study aimed to investigate the problem and identify its causes, including faults and reefs, by re-evaluating the seismic survey with a subscription of log data such as density, acoustic, and vertical seismic profile (VSP) obtained from the Iraqi Ministry of Oil. These logs were a crucial component of the comprehensive re-evaluation of the formation or reservoir. To determine whether faults or reefs were accountable for the issue, the current study compared the reservoirs and matched their historical models following the construction of a static model based on two probabilities: fault and reef. This novel approach confirmed this uncommon geoscience and reservoir engineering problem. The hydrocarbon samples from the reservoir under consideration had various measured bubble point pressures between wells, indicating that the reservoir compartment might be responsible for this discrepancy. Therefore, the seismic survey, along with the density, acoustic, and VSP records, were re-evaluated in this study, revealing anomalies that may be attributed to faults or reefs. This study's strategy was to compare each probability to the measured reservoir production data, and the one that matched the measurements was selected. The new methodology introduced in this work is useful for resolving some reservoirs' abnormal behaviors, which may result from unpredictability in reservoir compartments.

2. Geological Settings

The study area is situated in the southern part of Iraq, specifically in Thi-Qar Governorate, approximately 5 km northwest of Rifai towny and 85 km north of Nasiriya city (Petronas, 2017). The oil reserves in the field were first discovered by the seismic survey crew of the National Oil Company in 1984. As a result, three exploratory wells were drilled to confirm the oil reserves of the four reservoirs, namely Mishrif, Zubair, Ratawi, and Yamama as seen in Fig. 1. The Mishrif Formation, a heterogeneous carbonates reservoir, is the most significant reservoir in Garraf field and other oilfields in the southern part of Iraq which is a shallow water limestone succession with a Cenomanian-Early Turonian age that prograde from basinal deposits (Al-Mimar et al., 2018; Alameedy et al., 2023). The Khasib Formation overlies the Mishrif, while the Rumila Formation underlies it. Currently, 117 wells are drilled in the

Mishrif reservoir, with a production capacity of 120,000 barrels per day based on variations in the bubble point pressure. Additionally, water injection of 100,000 barrels per day is done from the Third River, officially named the main outfall drain (MOD).

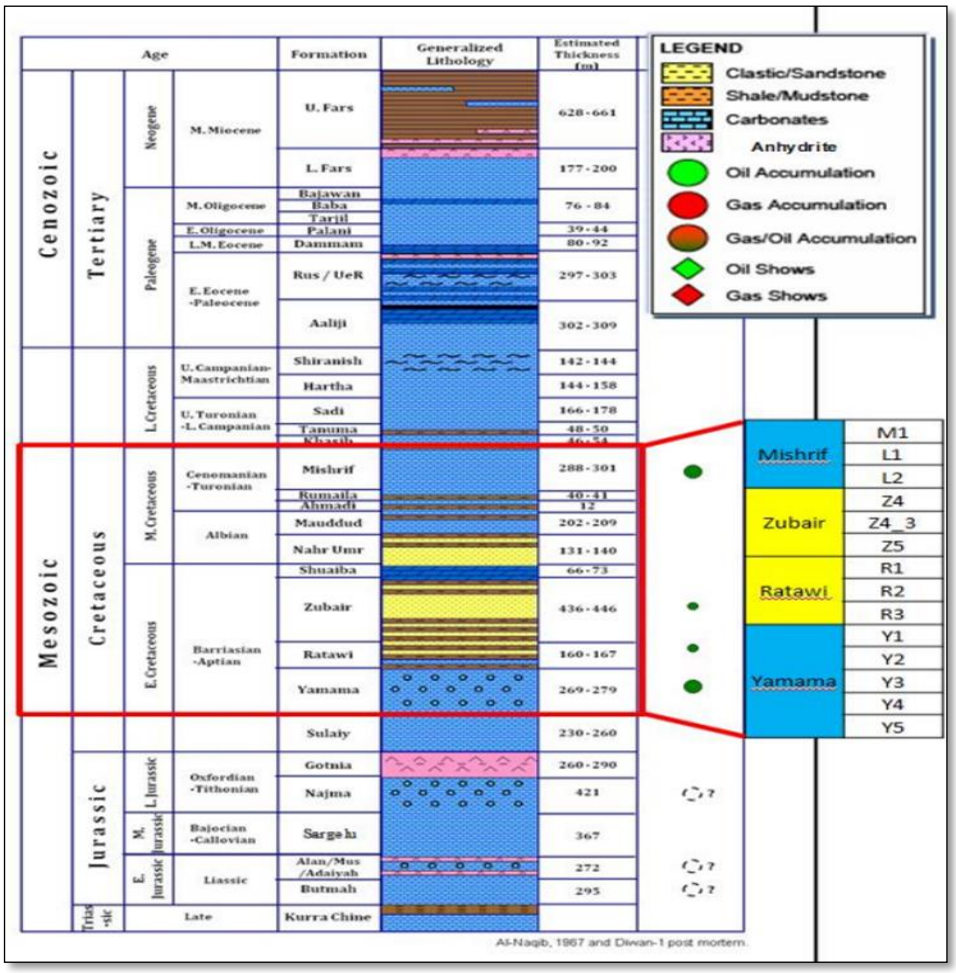

Fig. 1. Lithostratigraphic column of the study area (Petronas, 2017)

The research region is located in an unstable region within the Mesopotamian basin of the Arabian Plate (Al-Ameri et al., 2009), as shown in Fig. 2. It is surrounded by several oil fields that produce hydrocarbons from NW-SE-trending anticlines, which are compatible with the direction of the Zagros folded axis (Jassim and Goff, 2006).

3. Materials and Methods

To reach the current study's goals and uncover the ambiguities of the Mishrif reservoir, it is necessary to review again the seismic data and perform a structural analysis to detect any faults or reefs based on a 3D seismic survey. With the assistance of well-logging (VSP, density log, and sonic) and well tops, seismic data has been gathered, and a synthetic seismogram has been created. This seismogram results from 1D forward modelling of earth layers as a seismic response or the actual well seismic trace. Converting well tops from depth to time domain would enable us to follow the behavior of each one in the oil field and better understand seismic interpretation. Additionally, a synthetic

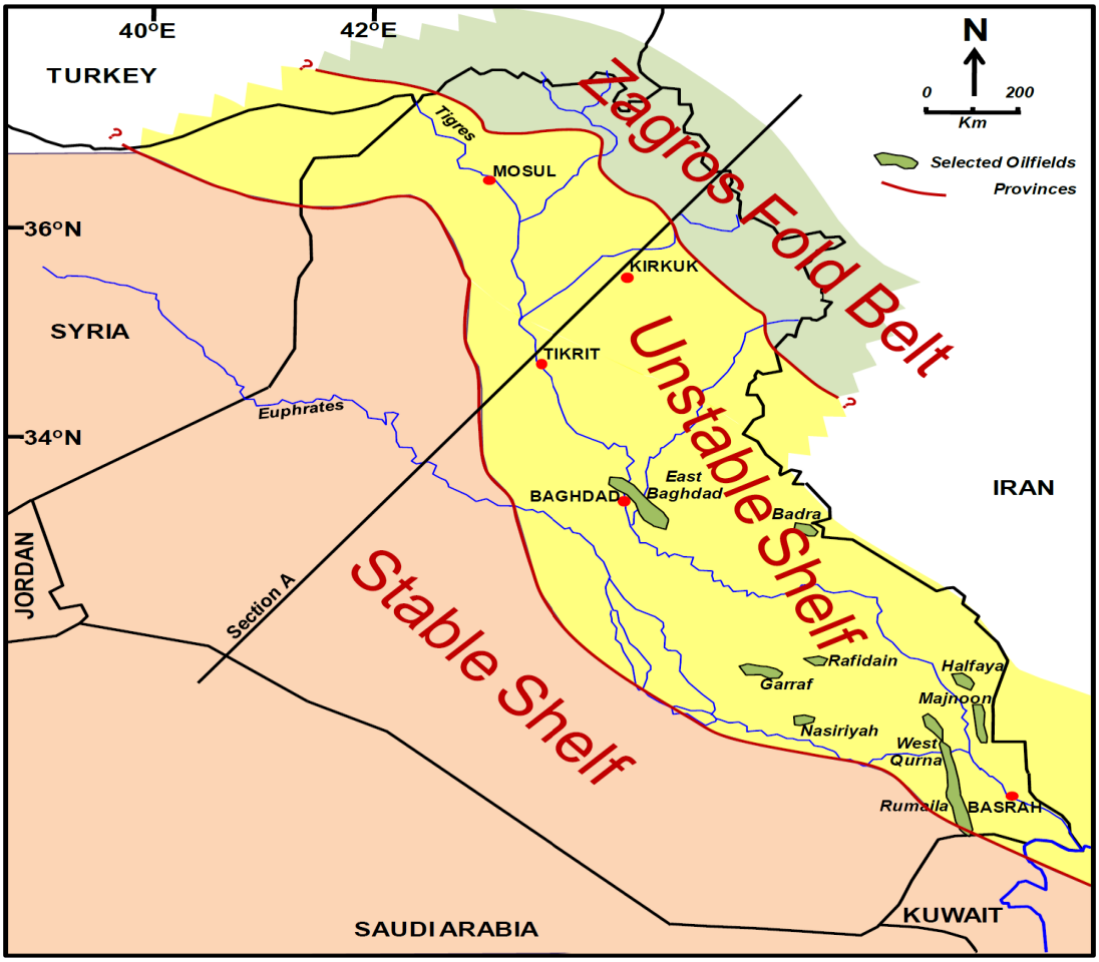

Fig. 2. Tectonic provinces of Iraq (Jassim and Goff, 2006)

seismogram distinguishes the true primary reflector of the formation's tops from the multiple reflectors, helping the interpreter track false structures. The seismic interpretation has revealed several abrupt discontinuities in the seismic reflectors of the reservoir's units of the Mishrif Formation. Seismic analysis indicates the possible existence of either a reef or a fault, as shown in Fig. 3A geological model has been generated based on two probabilities; fault and reef. Subsequently, using the Petrel 2021 software, a dynamic model has been created based on the geological model, and successful history matching has been achieved to determine the correct probability. The wells (well pad-F) between potential faults have different oil specifications, particularly regarding Pressure-Volume-Temperature (PVT) analysis, as they have a bubble point of 2135 psi, which is different from other wells with a bubble point of 2646 psi. In the case of faults, the reservoir is divided into two regions based on the mentioned bubble point and the location of potential faults; as shown in Fig. 4. History matching was carried out for each region separately. Subsequently, the reef case was history-matched based on the bubble point pressure of 2646 psi for the entire reservoir, treating it as one region. Table 1 represents the two regions of two cases and their bubble points.

4. Results and Discussion

The concerned oilfield has produced oil for about ten years. However, matching the observed production data with the simulated model requires multiple iterations. To optimize gas production in the Mishrif reservoir, specific actions are taken to alter its sensitive qualities. The horizontal permeability in the X and Y directions, Kx and Ky, respectively, is multiplied by 2.3. The skin factors

Table 1. The two regions of the two cases with bubble point values

Region	Bubble point pressure
Region 1 for reef case	2646 psi (for the whole reservoir)
Region 1 for fault case	2135 psi (between two potential faults)
Region 2 for fault case	2646 psi (for remainder of reservoir)

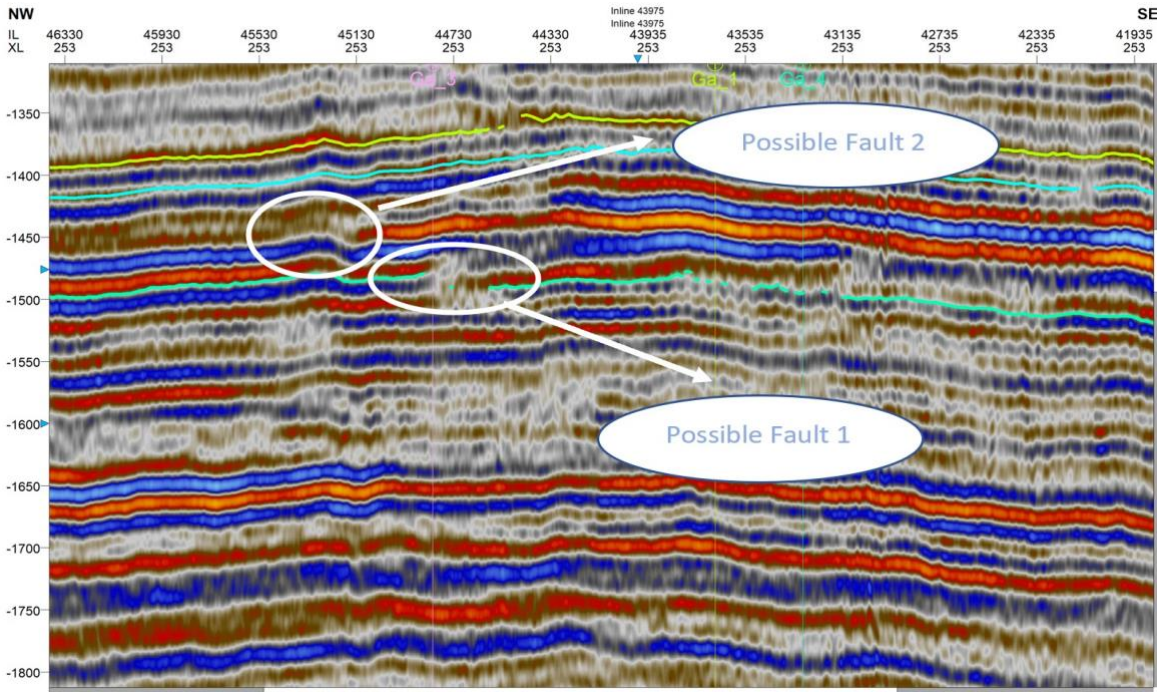

Fig. 3. Locations of possible faults on seismic inline section

of multiple wells are calibrated to match the oil production rate generated by the simulation model with the observed data. The compressibility factor can be reduced to modify it; since it has an inverse relationship with the reservoir pressure. To make a history matching of a fault case with a different bubble pressure (2135 psi), the fault zone needs to be isolated as region 1. The well pad (F) PVT data is used for this purpose. The remainder of the reservoir is set to the original PVT data with a bubble pressure of 2646 psi, referred to as region 2.

Similarly, for the reef case, the Mishrif reservoir is treated as a single region, and history is matched according to the bubble point pressure of 2646 psi for the whole reservoir. Fig. 5 illustrates how the fault case (blue line) has become more consistent and identical with observed data (green ball) from the reef case (red line) for the entire field. The field gas data provides an initial indication of the Mishrif reservoir's fault validity.

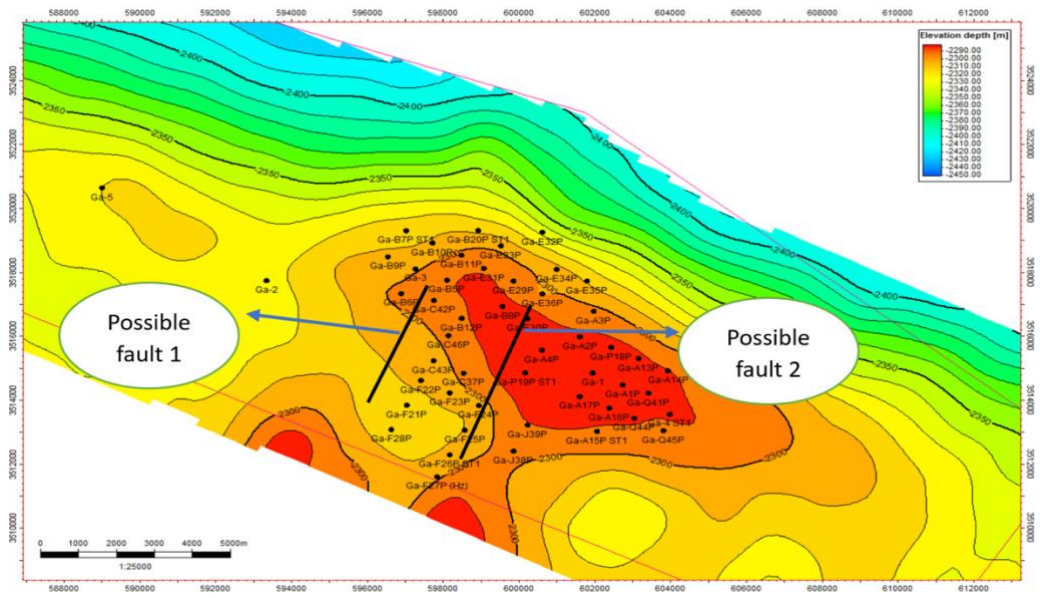

Fig. 4. Potential faults' locations on the contour map for the top of the Mishrif reservoir

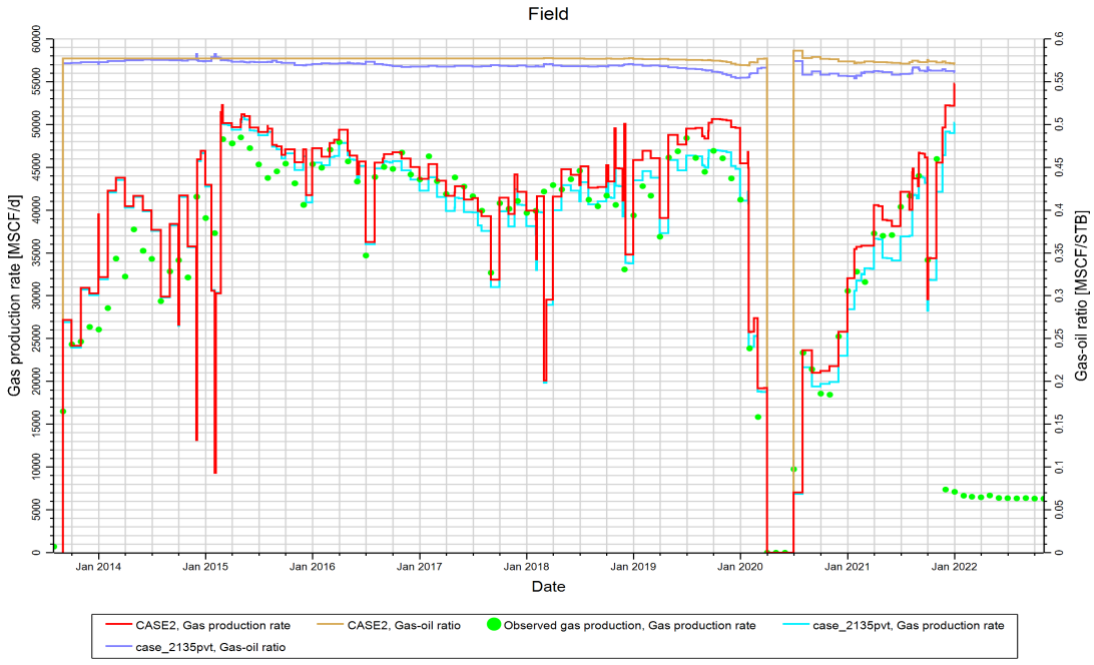

Fig. 5. History matching for fault and reef cases in the Mishrif reservoir

Figs. 6 and 7 compare the history matching as well behaviour for both cases of fault and reef scenarios. The results indicate that the well behaviour gave a second indication of a fault case, which did not match the reef case's scenario.

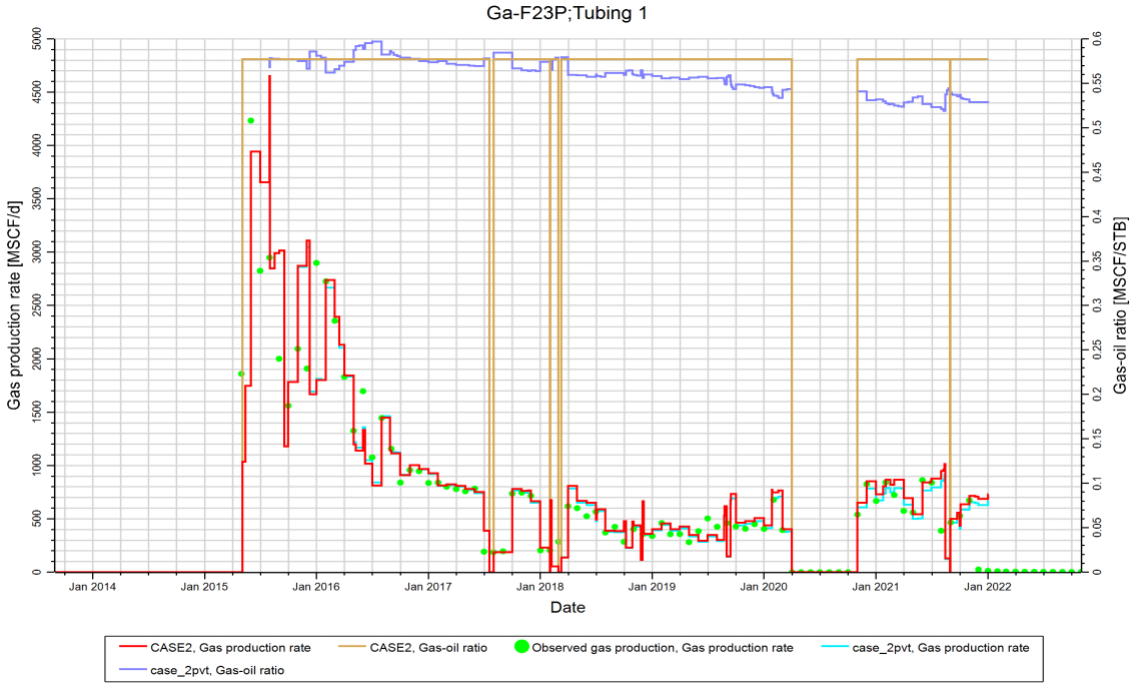

Fig. 6. History matching for fault and reef cases in well Ga-F23P

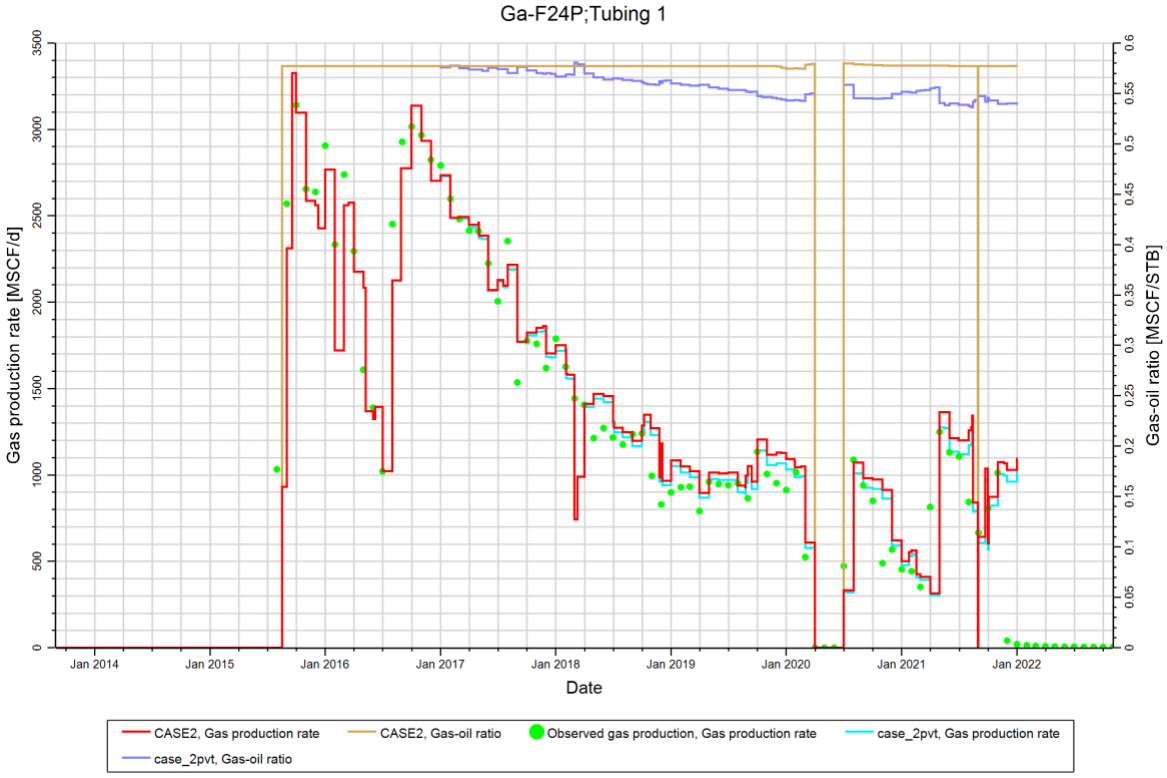

Fig. 7. History matching for fault and reef cases in well Ga-F24P

5. Conclusions

The study area, which consists of carbonate rocks, is located in the unstable Mesopotamian basin within the Arabian Plate, which makes it a field with high heterogeneity. Re-interpreting the data of the seismic survey with a subscription of log data, including density, sonic, and vertical seismic profile (VSP), gave an excellent graphical representation of the subsurface and geologic features, especially when it was combined with the geological model and was used together in reservoir simulation. It is crucial to emphasize the significance of seismic interpretation in effectively identifying and detecting faults, reefs, and other geological structures. History matching simulation is an innovative method for investigating geological faults and structures using the necessary data. The history matching simulation indicated the presence of two faults that created a compartment within the Mishrif reservoir, resulting in the bubble point discrepancy.

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References

Abbas, L. K., Mahdi, T. A., 2020. Reservoir modeling of Mishrif Formation in Majnoon Oil Field, Southern Iraq. Iraqi Geological Journal, 53 (1B), 89- 101.

Abd Talib, M. Q., Al-Jawad, M. S., 2022. Assessment of the Common PVT Correlations in Iraqi Oil Fields. Journal of Petroleum Research and Studies, 34, 68-87.

Abdulameer, H. A., Hamd-Allah, S. M., 2020. Reservoir model and production strategy of Mishrif Reservoir-Nasiriya Oil Field Southern Iraq. Journal of Petroleum Research and Studies, 10(3), 54-85.

Abdulredah, S. K., Al-Jawad, M. S., 2022. Building 3D geological model using non-uniform gridding for Mishrif reservoir in Garraf oilfield. Petroleum Science and Technology.

Al-Ameri, Th. K., Al-Khafaji, A. J., John, Z., 2009. Petroleum system analysis of the Mishrif reservoir in the Ratawi, Zubair, North and South Rumaila oil fields, Southern Iraq. GeoArabia, 14(4): 91–108. Gulf Petro Link, Bahrain.

Alameedy, U. S., Almomen, A. T., Abd, N., 2023. Evaluating machine learning techniques for carbonate formation permeability prediction using well log data. Iraqi Geological Journal, 56(1D), 4-23.

Alameedy, U. S., Farman, G. M., Al-Tamemi, H., 2023. Mineral inversion approach to improve Ahdeb Oil Field's mineral classification. Iraqi Geological Journal, 56(2B), 8-17.

Al-Fatlawi, O., Vimalroy, A. R., Hossain, M. M., Kabir, A. H., 2017. Optimization of infill drilling in which range field in Australia. Society of Petroleum Engineers (SPE) Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition.

Al-Mimar, H.S., Awadh, S.M., Al-Yaseri, A.A., Yaseen, Z.M., 2018. Sedimentary units-layering system and depositional model of the carbonate Mishrif reservoir in Rumaila oilfield, Southern Iraq. Modeling Earth Systems and Environment, 4, 1449-1465.

Alher, A. A., Aljawad, M. S., Ali, A. A., 2018. Static model of Zubair reservoir in Luhais oil field. Iraqi Journal of Chemical and Petroleum Engineering, 19(1), 57-60.

Alhusseini, A. K., Hamd-Allah, S. M., 2022. Estimation of initial oil in place for Buzurgan oil field by using volumetric method and reservoir simulation method. Iraqi Geological Journal, 55 (2C), 106-120.

Ali, k. k., Al-Sharaa, H. G., Rasheed, H. A., 2018. 3D Seismic structural and stratigraphy study of Shuaiba Formation in Kumait Oil Field-Southern Iraq. Iraqi Journal of Science, 59(3C), 1665–1672.

Al-Jawad, M. S., Kareem, K. A., 2016. Geological Model of Khasib Reservoir-Central Area/East Baghdad Field. Iraqi Journal of Chemical and Petroleum Engineering, 17(3), 1-10.

Al-Joumaa, J. H., Al-Jawad, M. S., 2019. Calculating heterogeneity of Majnoon Field/Hartha reservoir using Dykstra Parsons method. Journal of Petroleum Research and Studies, 9(2), 54-63.

Al-Rikaby, A. S., Baker, H. A., 2017. Mathematical modeling of Mishrif reservoir for Amara oil field. Master thesis in petroleum engineering department, University of Baghdad, unpublished study.

Al-Rubaye, W. I. T., Hamd-Allah, S. M., 2019. A High-resolution 3d geomodel for giant carbonate reservoir- a field case study from an Iraqi oil field. Journal of Engineering, Baghdad University, 26(1), 160–173.

Aziz, Q. A. A., Hussein, H. A., 2021. Mechanical rock properties estimation for carbonate reservoir using laboratory measurement: A case study from Jerib, Khasib and Mishrif Formations in Fauqi Oil Field. Iraqi Geological Journal, 54(1E), 88-102.

Baker, H. A., Al-Rikaby, A. S. 2017. Reservoir characterizations and reservoir performance of Mishrif Formation in Amara Oil Field. Journal of Engineering, Baghdad university, 23(12).

Baker, H. A., Al-Rikaby, A., Salih, I. S. 2019. Evaluation of formation capacity and skin phenomena of Mishrif Reservoir-Garraf Oil Field. IOP Conference Series: Materials Science and Engineering, 579 (2019) 012039.

Boschetti, T., Awadh, S.M., Al-Mimar, H.S., Iacumin, P., Toscani, L., Selmo, E., Yaseen, Z.M., 2020. Chemical and isotope composition of the oilfield brines from Mishrif Formation (southern Iraq): Diagenesis and geothermometry. Marine and Petroleum Geology, 122, 104637.

Jassim, S.Z., Goff, J.C., 2006. Geology of Iraq, Czech Republic, Brno, 341.

Khawaja, A. M., Thabit, J. M. 2021. Interpretation of 3D seismic reflection data to reveal the stratigraphic setting of the reservoir of Mishrif formation in Dujaila Oil Field, Southeast of Iraq. Iraqi Journal of Science, 62(7), 2250–2261.

Mondol, N. H., 2010. Seismic exploration. In Petroleum Geoscience: From Sedimentary Environments to Rock Physics, 375–402, Springer Berlin Heidelberg.

Petronas, c. I. H., 2017. Garraf Final Development Plan (FDP), unpublished study.

Trezzi, S., Seliem, A., Mahgoub, M., Cambois, G., Glushchenko, A., Vasilyev, P., al Kobaisi, A. S., 2022. Unlocking UAE's Largest 3D onshore seismic survey- processing challenges in Eastern Abu Dhabi. Society of Petroleum Engineers - ADIPEC 2022.

Witter, J. B., Siler, D. L., Faulds, J. E., Hinz, N. H., 2016. 3D Geophysical inversion modeling of gravity data to test the 3D geologic model of the Bradys geothermal area, Nevada, USA. Geothermal Energy, 4, 14 (2016).