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A Novel Method to Recognise Faults and Reefs from History Matching of Gas Production- Case Study: Mishrif Reservoir, Southern Iraq.

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Abstract

The study area is located within the Mesopotamian Basin, the habitat of several oil fields that extract hydrocarbons from NW-SE-trending anticline formations parallel to the Zagros folding belt. The study aimed to determine if discrepancies in bubble pressure values were caused by faults or reefs using historical matching of gas production. The study revealed a distinct Mishrif reservoir seismic graph and seismic reflectors exhibiting many severe discontinuities, indicating the presence of a reef or fault. Field production data matched the fault case more consistently than the reef case during reservoir simulation, as per the well results (C37P, C43P, C46P). The history-matching simulation confirmed the two faults and rejected the reef. After seismic interpretation and historical matching, the Mishrif reservoir has two faults that were the cause of the bubble point pressure discrepancy during production operations. This method is suitable for discovering geological structures and deformations that cause bubble pressure differences for use by other researchers.

Keywords: Mishrif reservoir, Seismic interpretation, fault, reef, History matching.

طريقة جديدة للتعرف على الفوالق والحيد المرجاني من خلال المطابقة التاريخية لإنتاج الغاز – دراسة حالة: مكمن المشرف، جنوب العراق

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الخلاصة

تعد منطقة الدراسة الواقعة في حوض بلاد ما بين النهرين في الصفيحة العربية غير المستقرة موطنًا للعديد من حقول النفط التي تستخرج الهيدروكربونات من تكوينات الخطوط المحدبة التي تتجه شمال غرب وجنوب شرق البلاد على طول حزام طية زاغروس. تهدف الدراسة إلى تحديد ما إذا كانت التناقضات في قيم ضغط الفقاعة ناجمة عن أخطاء أو شعاب باستخدام المطابقة التاريخية لإنتاج الغاز. كشفت الدراسة عن رسم بياني زلزالي مميز لخزان المشرف، وتظهر العاكسات الزلزالية العديد من الانقطاعات الشديدة، مما يشير إلى وجود شعاب مرجانية أو فالق. تطابقت بيانات الإنتاج الميداني مع حالة الفالق بشكل أكثر اتساقًا من حالة

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الشعاب المرجانية أثناء محاكاة المكمن، وفقًا لنتائج البئر (C37P، C43P، C46P). أكدت محاكاة مطابقة التاريخ الفالقين ورفضت الشعاب المرجانية. وبعد التفسير الزلزالي والمطابقة التاريخية، تبين أن خزان المشرف به فالقين كانا السبب في اختلاف ضغط نقطة الفقاعة أثناء عمليات الإنتاج. هذه الطريقة مناسبة لاكتشاف التراكيب الجيولوجية والتشوهات التي تسبب اختلافات في ضغط الفقاعات ليستخدمها باحثون آخرون.

1. Introduction

Seismic surveys are an informative approach that acquires adequate geophysical data on subsurface rock structures, such as faults that act as a compartment to isolate a region of an oil reservoir and discrepancy its reservoir properties. By joining this dataset with other analytical techniques, such as well-log, core, tracer, and well-test analyses, geologic maps and models can be developed with high accuracy. The use of three-dimensional seismic data proves to be particularly advantageous in characterising aspects such as reservoir heterogeneity, vertical zonation's, lateral compartmentalisation, and anisotropy or directional fluid movement within the reservoirs [1], [2], [3]. Seismic reflections provide an effective visual depiction of subsurface and geologic characteristics, making it easier to analyse seismic data, velocity, and temporal contour maps to identify different traps [4], [5], [6]. Moreover, using seismic reflections is beneficial in interpreting sedimentary architecture and the deposition of environmental palaeogeography [7], [8]. The research conducted in the study area is noteworthy for its use of several data sources, including 3D seismic reflections, post-stack times migrated data, and well data, to provide valuable interpretations. A 2D seismic survey verified the oil reserves in the four reservoirs in 1984. Three exploratory wells were subsequently drilled in the field. A 3D seismic survey was carried out in 2009, and the results were used to create a final development plan [9] and drilled two appraisal wells that penetrated the Yamama and Mishrif Formations. Since then, the Mishrif Formation has been penetrated by several productive wells, and more are scheduled for the future.

The study discovered a discrepancy in bubble point pressure, which led to a thorough re-evaluation of the Mishrif reservoir. To investigate the issue (reefs and faults) and identify its reasons, the re-evaluation of the 3D seismic survey with log data subscription, including density, sonic, and vertical seismic profile (VSP), is recommended. This proved to be an essential aspect of the overall re-evaluation of the reservoir. The first step was to identify whether the fault or reef was the source of the issue, and the second was to match the reservoir model's historical data to ascertain the correct probability. After a static model building based on reef and fault, this approach helped verify this rare problem in geosciences and reservoir engineering. The findings are immensely significant, providing valuable insights for future studies. An extensive analysis was conducted on the core sample, including routine geological, routine core, special core, and digital rock analyses. The formation was deposited on a broad carbonate shelf extending from a low-energy deep open-marine outer shelf to moderate to high-energy shallow-marine middle and inner shelf settings [9], as seen in Figure 1. There are doubts about a fault within the Mishrif Formation due to the discrepancy in the bubble point values in more than one area. This prompted us to reinterpret and evaluate the seismic survey, build two static models based on reef and fault, and later build the reservoir model and historical matching to prove the possibility. We will discuss this further later.

2. Geological settings

The Garraf oilfield is located in the south of Iraq, approximately 5 km northwest of Rifai city and 85 km north of Nasiriya city [9], as depicted in Figure 2. The field is located in an unstable region within the Mesopotamian Basin of the Arabian Plate [10], as shown in Figure 3. It is surrounded by numerous fields that extract hydrocarbon from NW-SE-trending anticlines formations, in line with the direction of the Zagros folded axis [11]. Tectonic and isostatic processes govern the deposition of the Mishrif reservoir in Iraq.

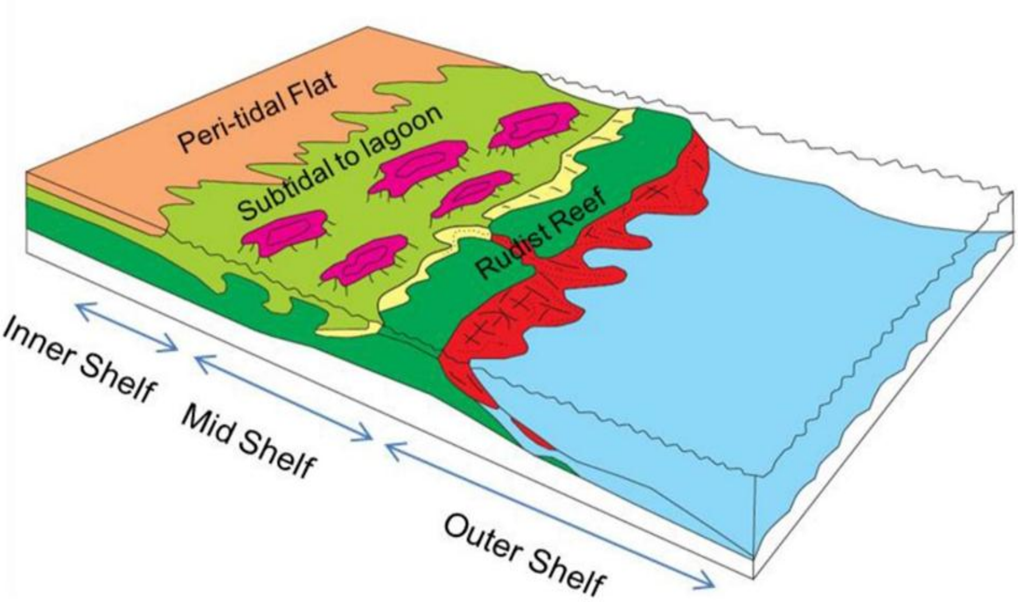

Figure 1: Depositional environment of Mishrif formation [9]

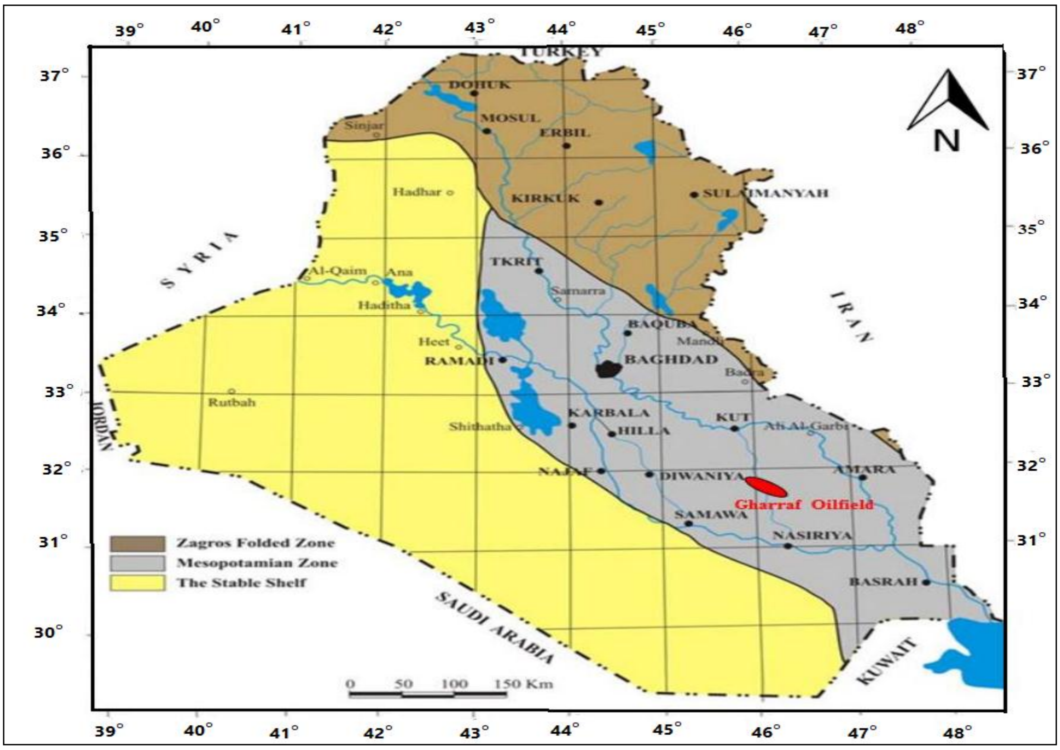

Figure 2: Garraf oil field location [12]

It belongs to the Cenomanian-Turonian Supersequence of the uppermost component of the tectonic, stratigraphic Megasequence deposited along a passive border [13]. The area is split into Tigris, Euphrates, and Zubair tectonic subzones within the Mesopotamian structural zones [11], [14]. The Tigris subzone's stratigraphic profile reveals significant subsidence rates, as evidenced by a prominent thickness of the Mishrif Formations. During the Cenomanian and Early Turonian epochs, the deformation of the northeastern Tethyan border of the Arabian Plate resulted in the construction of distinctive high and low structures in each subzone [15]. Salt diapirism caused negative residual gravity beneath some supergiant field structures, such as Rumaila and Zubair, in southern Iraq [8], [16], [17]—several structures developed during the Early Jurassic period [18]. Hydrocarbon accumulations in the Mesopotamian basin form reservoirs that accumulate oils from Jurassic source rock, Cretaceous and Tertiary reservoir, and Paleozoic and Tertiary structural trap [19]. Figure 4 overviews the total petroleum system dynamics specific to the basin (generation, migration, and accumulation).

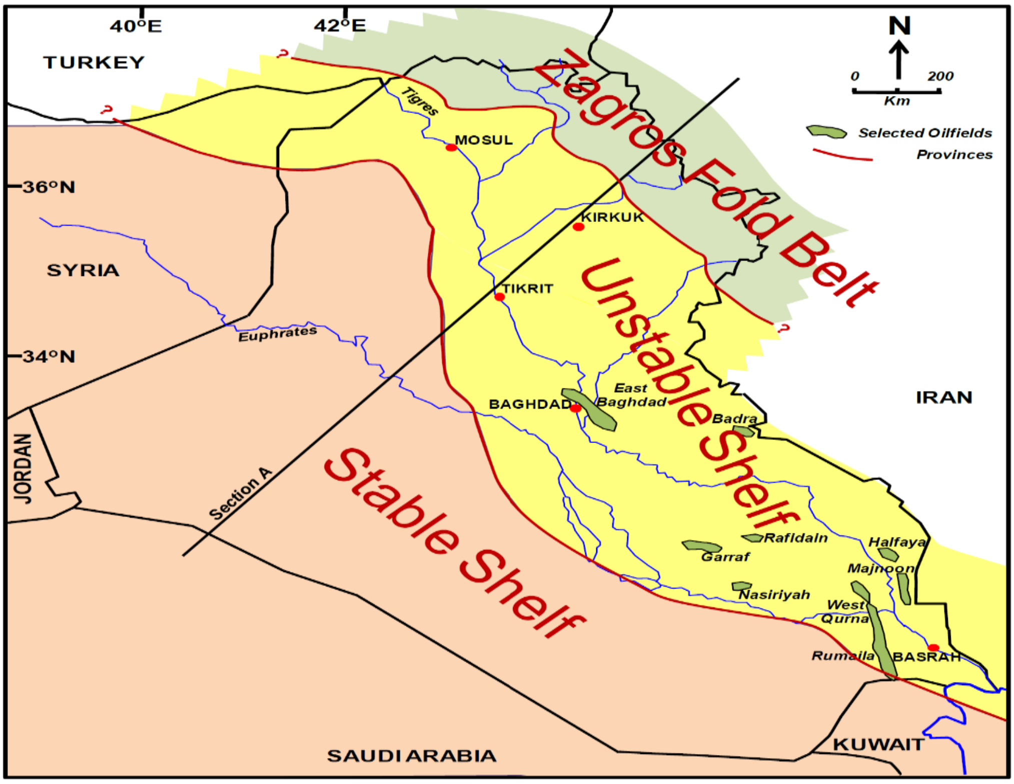

Figure 3: Tectonic provinces of Iraq [11].

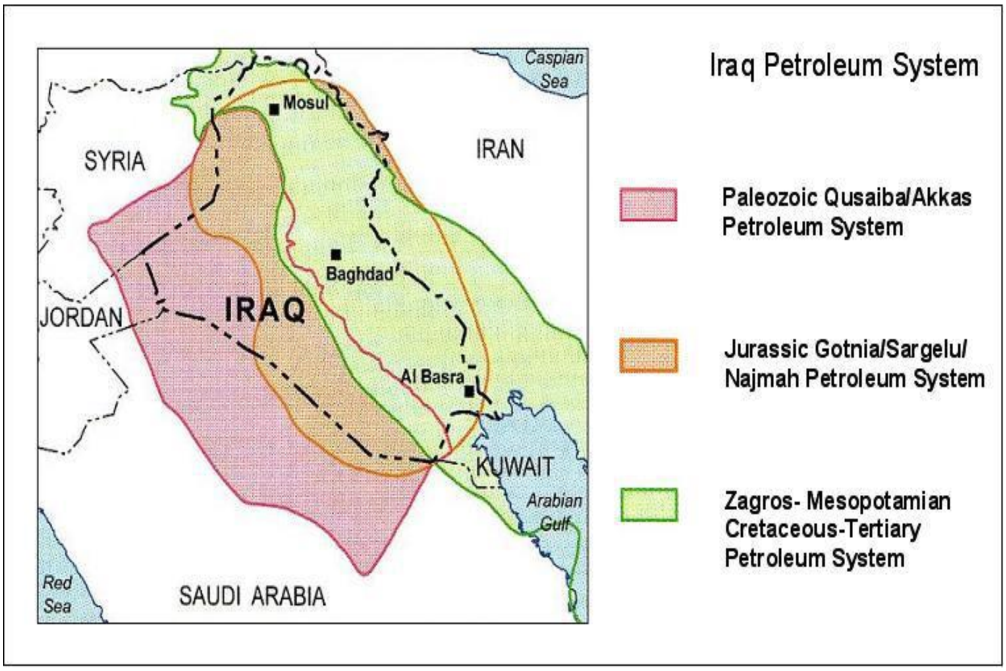

Figure 4: Petroleum System in Iraq and surrounding area [20].

3. Methodology

In order to achieve the study targets and open the mysteries of Mishrif Formation, the study involves three steps to achieve its goal:

- It is important to re-examine the seismic survey data and perform a structural analysis to identify any fault or reef based on this process, with the help of well top and well-log (VSP, density, and sonic logs). The seismic reflectors within the reservoir units of the Mishrif Formation exhibit distinct and abrupt changes, as revealed by the seismic data analysis, indicating a possible presence of either a reef or a fault, as shown in Figure 5.
- The static model construction is based on two possibilities, reef and fault, with no differences in the distribution of petrophysical properties and the calculation of oil in place in both cases, as depicted in Figures 6 and 7.
- The dynamic model is used to verify the correct possibility. History matching is conducted according to gas production (observed and simulated) to determine the presence of faults and reefs.

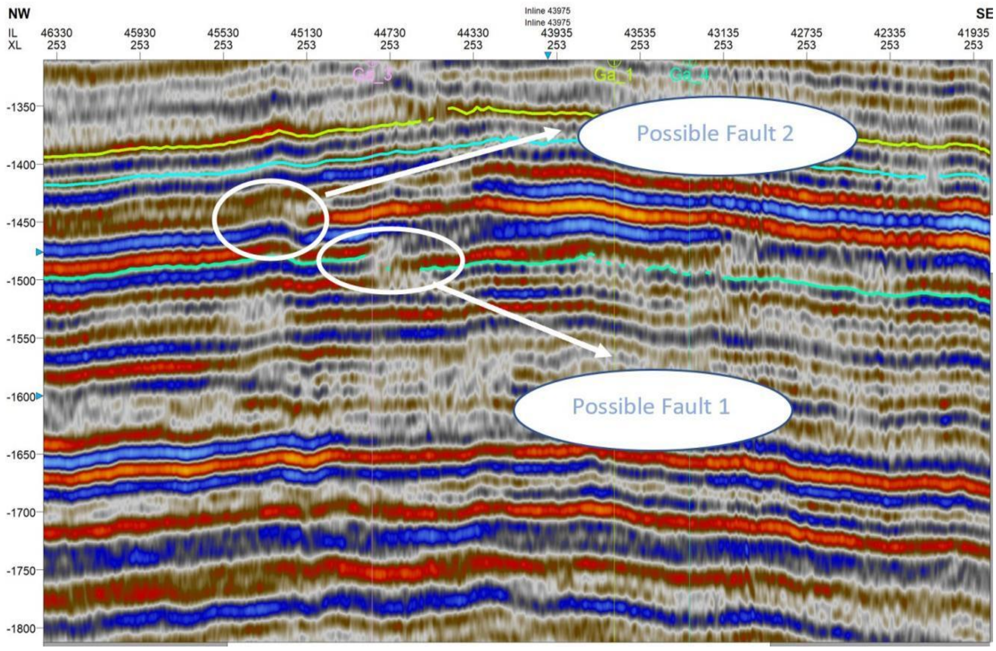

Figure 5: Possible fault location on seismic inline sections.

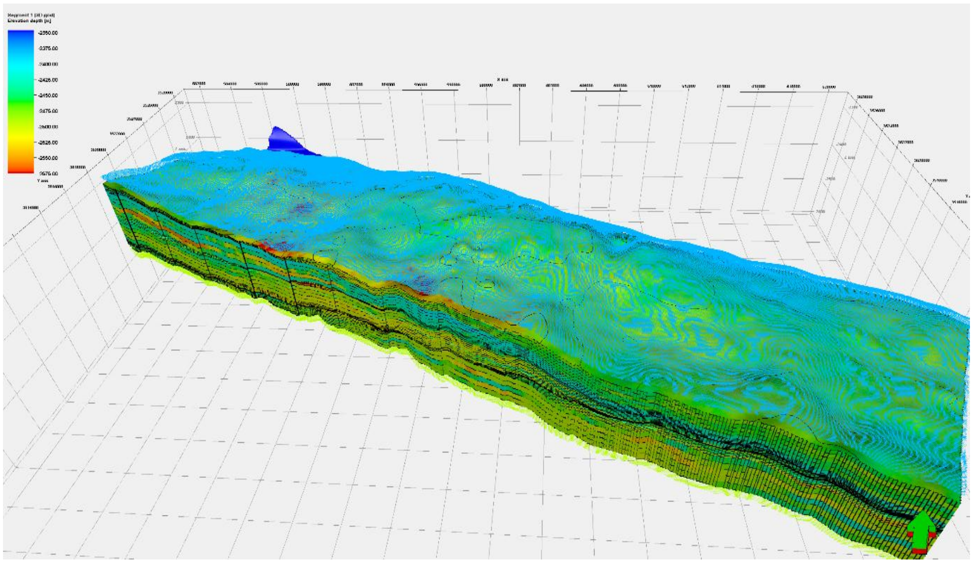

Figure 6: Structural framework for the Mishrif reservoir

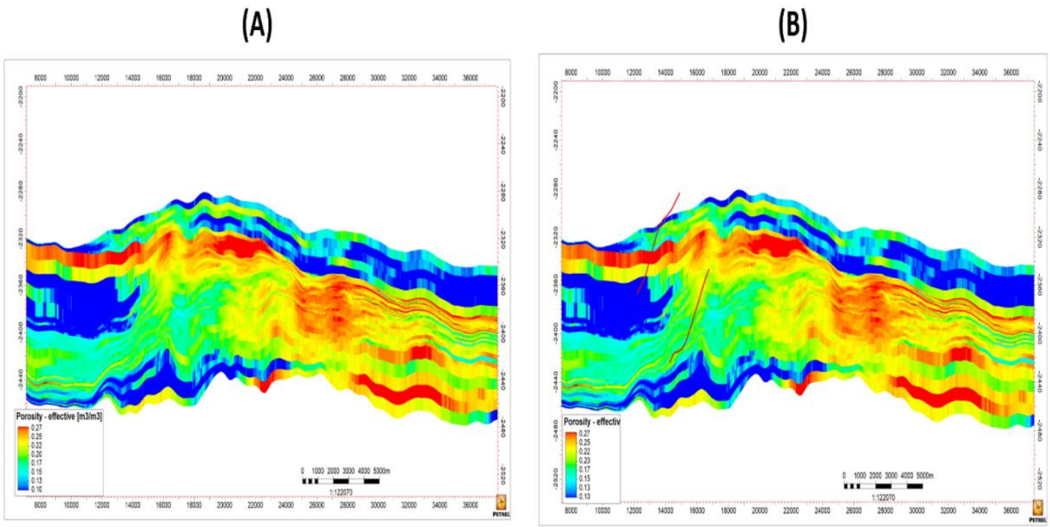

Figure 7: NW- SE geological cross sections of porosity distribution (A) with reef & (B) with fault.

4. Results and Discussion

The Garraf oilfield has a production period of around ten years. The history-matching process requires several runs to match the observed production data with the simulated model. To adjust the sensitive properties of the Mishrif reservoir for gas production matching, the following steps are considered:

A- The permeability in all directions (Kx, Ky, and Kz) is modified by multiplying them by 2.3.

B- The skin factor for many wells of the Garraf oilfield is adjusted to match the gas production rate created by the model with the gas observed data.

C- The compressibility (Cr) factor is adjusted by reducing it, as it is inversely proportional to the reservoir pressure.

According to the location of a potential fault in the Mishrif reservoir, as seen in Figure 8, the production gas of wells (C42P, C46P, & C37P) located between two faults will be tested in the history matching simulation due to cases of fault and reef. These wells have bubble point pressure, which differs from other wells outside the fault zone.

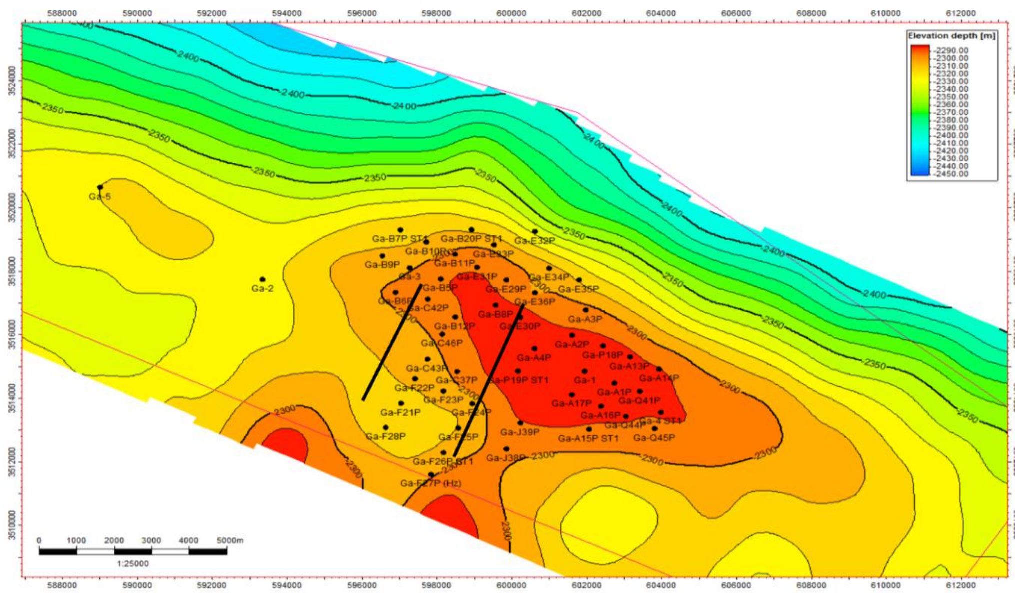

Figure 8: Contour map with possible fault location on top of the Mishrif reservoir.

The fault region must be isolated as region 1 for making a history matching of fault case with a bubble point pressure (2335 psi) according to PVT of well pad (C). The remaining reservoir is setting to bubble point pressure (2646 psi) according to the original PVT data obtained from the well (Ga-4) as region 2.

For the exact adjustment of the sensitive properties of the Mishrif reservoir, the reef case was history matched according to bubble point pressure (2646 psi) for the whole of the Mishrif reservoir (as one region). Figures 9, 10, and 11 show the variation in history matching between the wells located in the fault region (C37P, C42P, C46P) and the degree of difference in their matching accuracy for both reef (red line) and fault (brown line) cases.
Upon validating the seismic interpretation outputs with history-matching results, the study revealed two faults in the Mishrif reservoir, per the well's outputs (C37P, C43P, and C46P). The study found that the field production data matched the fault case (brown line) more consistently than the reef case (red line).

The study has determined that the faults significantly impact the reservoir properties, particularly the bubble pressure. They create a compartment in a specific region of the oil reservoir, leading to bubble pressure discrepancy. This will ultimately affect the future development strategy, including the production profile and reservoir pressure behavior.

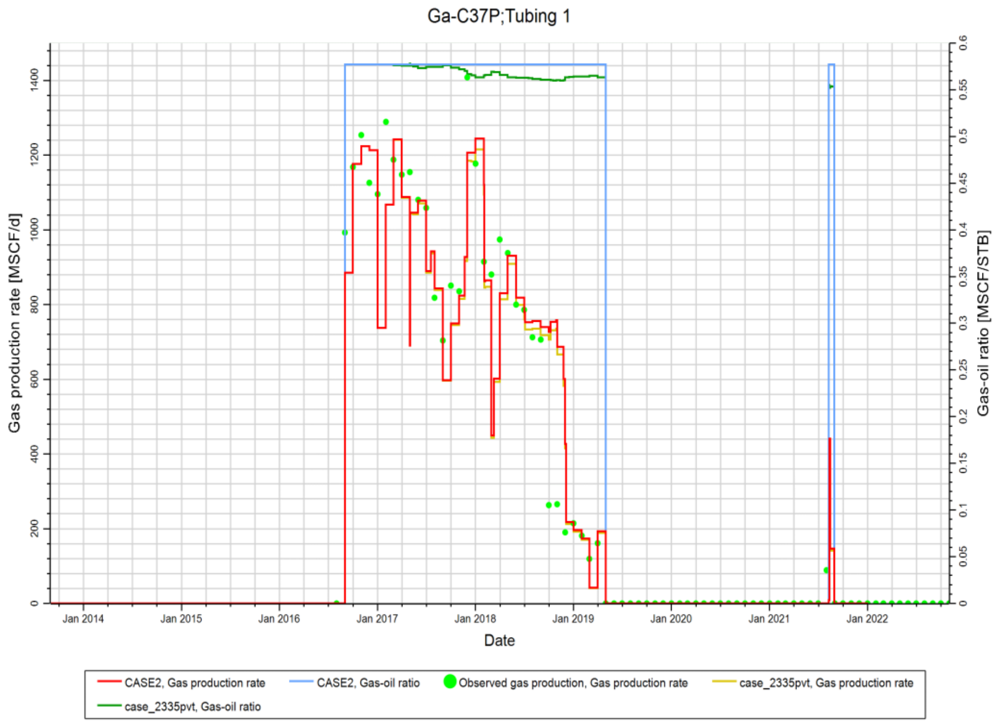

Figure 9: History matchings of gas productions for both fault and reef cases in well (C37P).

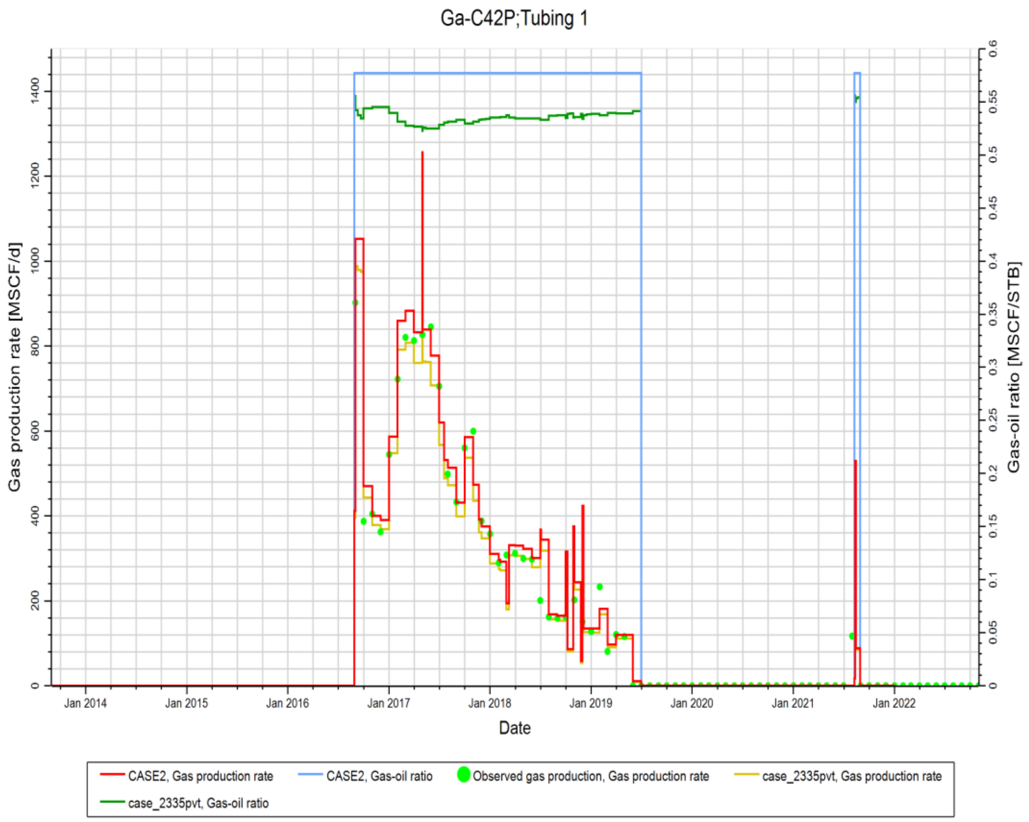

Figure 10: History matchings of gas productions for both fault and reef cases in well (C42P).

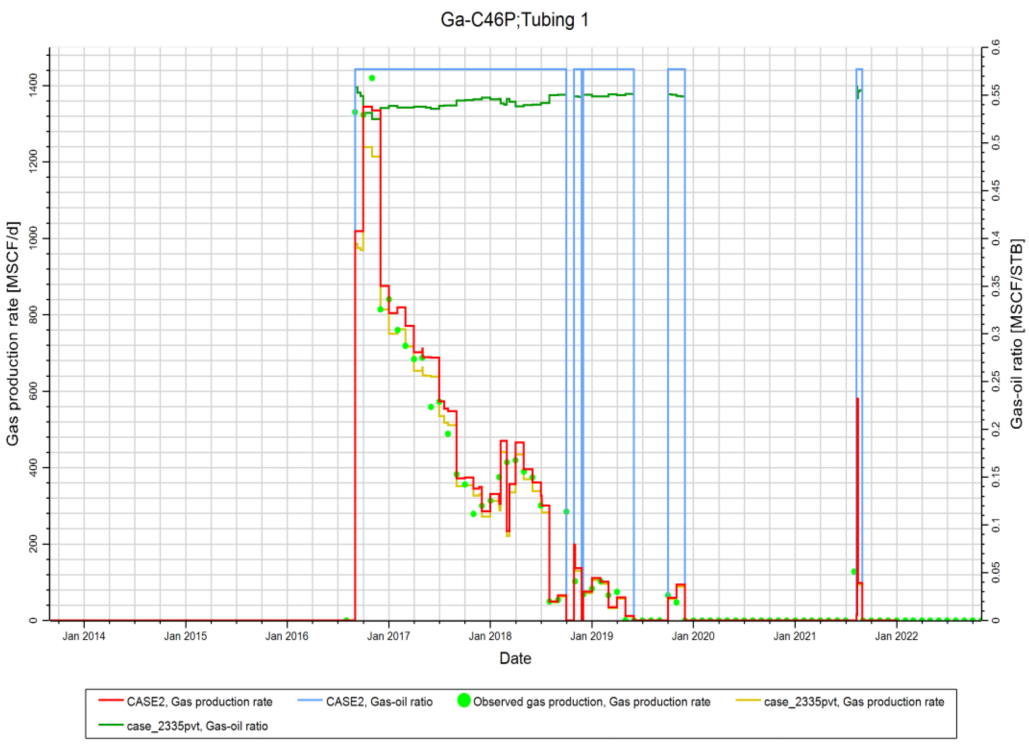

Figure 11: History matchings of gas productions for both fault and reef cases in well (C46P).

5. Conclusions

1- Advanced techniques such as 3D seismic, VSP, density, and sonic logging were used during the survey to accurately depict the subsurface and geological characteristics.

2- The survey revealed a distinct graphical representation of the Mishrif reservoir, including sharp discontinuities later identified as minor faults. The seismic reflectors within the reservoir units of the Mishrif Formation exhibit distinct and abrupt discontinuities, as revealed by the seismic data analysis, indicating a possible presence of either a reef or a fault.
3- After verifying the seismic interpretation results through historical matching, it was discovered that the Mishrif reservoir has two faults, according to the well results (C37P, C43P, C46P). Upon analysing the well data, it was found that the field production data matched the fault case (brown line) more consistently than the reef case (red line).
4- The results of the history-matching simulation confirm the existence of the two faults and rule out the possibility of the reef's existence.
5- The faults significantly impact reservoir properties, including bubble pressure, and potentially affect future development strategy, including production profile and reservoir pressure behavior.

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