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Analysis of Transmission Mud Losses and Coherence in North Rumaila Oilfield, Southern Iraq, Mishrif Formation as a Case Study

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Abstract

One of the biggest oilfields in the world is the Rumaila field in southern Iraq. Drilling through the Mishrif Formation puts wells drilled in this field at risk of lost circulation issues. Lost circulation occurrences are a major problem in field development and can range from seepage losses to the total loss of the borehole. Drilling mud losses have been reported in seven wells; however, this issue affects numerous wells. In order to ascertain the most effective cures for each sort of loss, the lost circulation method to the Mishrif Formation has been presented based on 3D geological models (3D seismic section) and frithogram analysis. The results of the coherency data showed that the coherent zones are located in the western and southwestern regions of the Rumaila oilfield, while these zones diminish as one moves towards the east and southeast. Oil wells that were coded as A to G are situated within the incohesive zones, whereas the other wells are located at cohesive zones. Firhograms can be plotted alongside other real-time drilling data to analyze how conditions evolved over time. These graphs illustrate the events leading up to mud losses, providing valuable insights into the underlying causes. After a careful study of seven wells that had a mud loss and comparing them with one of the wells that had no loss, the results showed that the mud losses were primarily due to the nature of the lithology; microfacies study of the affected depths revealed that the losses were also associated with extensive dissolution processes. Large channels and significant porosity were observed at these depths, further contributing to the losses.

Keywords: Coherency; Mud loss; Firhogram; Mishrif Formation; Rumaila oilfield

1. Introduction

Loss of circulation can occur in any formation, as this issue has been observed in various rock types at different depths (Howard and Scott, 1951). Certain formations are more likely to be affected by drilling fluids, such as naturally or artificially fractured zones, high-permeability formations, and unconsolidated materials, commonly found in limestone and dolomite (Shehab et al., 2023). Inadequate hole cleaning conditions often lead to wellbore instability, which is a significant contributor to increased nonproductive time (NPT) during drilling operations. This instability can result in challenges such as blocked pipes. Unproductive time can occur at various stages, including well completion, cementing, casing or liner installation, and drilling itself. While the costs associated with lost drilling fluid can be substantial, the repercussions of loss of circulation can be even more severe, potentially leading to far greater expenses and even jeopardizing the entire drilling operation (Al-Hameedi et al., 2018). Every year, $2 billion USD is spent to prevent and reduce lost circulation (Arshad et al., 2015). It is a common problem in the formations of the Hartha and Dammam, but recording it in the Mishrif Formation is considered a rare case, such as in previous studies (Al-Hameedi et al., 2017, 2018; Alkinani et al., 2018; Shehab et al., 2023).

The degree of similarity or consistency between seismic signals or data points in a well log is known as coherency. It is a crucial metric for interpreting well logs and seismic data. High coherency suggests continuous and homogenous geological formations since it shows that the data points or seismic signals are similar or consistent with one another (White, 1984). Coherency attributes can be represented through seismic attribute maps or volumes, which allow interpreters to swiftly spot significant areas. Both horizontal and vertical slices of coherence emphasize geological features like faults, channels, and stratigraphic boundaries. Furthermore, integrating coherence data into 3D geological models provides a detailed view of the subsurface, improving interpretation and decision-making (Chopra and Marfurt, 2018). Coherency analysis aids geologists and engineers by identifying faults and fractures through low coherency zones, delineating stratigraphic boundaries with high coherency, and characterizing reservoirs to pinpoint hydrocarbon zones and inform drilling plans (Chopra and Marfurt, 2005, 2007). The study aims to mitigate potential hazards; a comprehensive risk assessment is being conducted by matching the spatial distribution of losses in the Mishrif Formation with the spatial distribution of seismic features. This detailed analysis aims to identify areas that are most susceptible to damage or loss, thereby enabling the implementation of targeted preventative measures to minimize future losses. By integrating these two datasets, a precise risk area can be delineated, allowing for the allocation of resources and efforts to where they are most needed, thereby reducing the likelihood and impact of future losses. Similar studies follow the same approach in the analysis of transmission mud losses and coherence in different oilfields (e.g., Alkinani, 2017; Al-Mansory and Alrazzaq, 2021; Al-Asadi, 2021).

2. Geological Setting

The Mishrif Formation represents the most important carbonate reservoir unit in southern Iraq, containing as much as 30% of the country's total oil reserves (Al-Mimar et al., 2018). This formation consists of thick carbonates from the middle Cenomanian to Early Turonian period, which were formed on a shallow-water platform across the basin (Mahdi and Aqrawi, 2014). The accommodation space necessary for sediment deposition was created by a significant eustatic rise in sea level during the middle Cenomanian (Razoian, 2002). The lower boundary with the Rumaila Formation is conformable, whereas in contrast to the top, it is disconformable with the Khasib Formation in southern Iraq (Sherwani and Aqrawi, 1987; Al-Ali et al., 2020) (Fig.1). The carbonate facies of the Mishrif Formation are deposited in shallow marine environments, encompassing shoal, lagoon, and shallow marine shelf (Razoian, 2002). The Mishrif Formation in the current study was studied in the Rumaila oil field as a case study for monitoring the lost circulation of drill mud.

The Rumaila oilfield represents an enormous anticline structure situated in southern Iraq, discovered in 1953. It is the most important oilfield in the region and is recognized as the largest subsurface structure in the southern Mesopotamia Plain of Iraq, featuring north-south and northwest-southeast trends.

The Rumaila oilfield is located approximately 45 km west of Basra city and 32 km from the Kuwait border, containing two major reservoirs: the Mishrif Formation and the main bay of Zubair Formations. Structural mapping of the field indicates that it extends 117 km in length and around 20 km in width. The field's structure comprises two domes, known as North and South Rumaila, separated by a distinct depression (saddle) (Aqrawi et al., 2010; Al-Kaabi et al., 2023; Lazim et al., 2024).

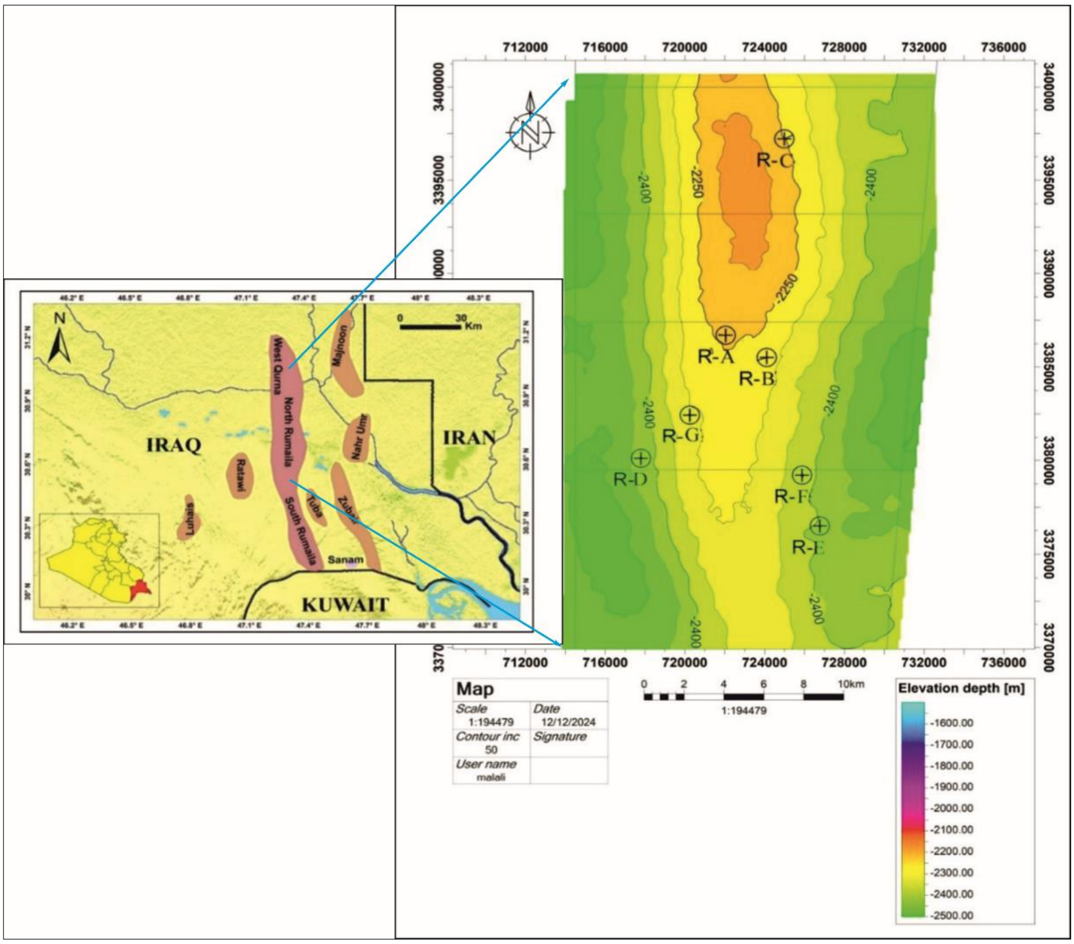

Fig. 1. Structural map of Rumaila oilfield, the studied wells are coded (A-G)

3. Methodology

Seven wells were selected for this study, as shown in Fig. 1. These wells were specifically chosen due to their documented instances of fluid losses. However, to comply with confidentiality agreements established with the Basrah Oil Company, the wells have been assigned coded identifiers.

To meet the objectives of the study, the following steps have been implemented. First, field data relevant to the study area is gathered from various sources, including final geological well reports, traditional well logs, technical and final reports, as well as previous studies, theses, and published articles. Second, the process involves importing 3D seismic sections of the Rumaila oilfield in SEGY format into Petrel software to generate detailed subsurface images of the field. This advanced analysis allows for the plotting of time horizon structural maps, facilitating a comprehensive interpretation of the factors contributing to non-productive time (NPT).

By examining the in-line, cross-line, and time slice sections, valuable insights into the geological features and anomalies within the reservoir are gathered, ultimately aiding in the enhancement of resource management and operational efficiency. Most of the other information about the seismic section is not allowed by Basrah Oil Company for publication. An Excel sheet for treating the Firthgram data, A comprehensive analysis was conducted on over fifty-five thin sections extracted from the wells under investigation, specifically targeting the depths identified through seismic surveying.

Core samples were also collected from depths experiencing a cavity or loss of integrity. Following that, ten thin sections were taken from the areas exhibiting clay loss for a detailed examination of the most significant lithology and the prevailing diagenetic processes.

4. Losses Types

The drilling mud loss is one of the most uncontrollable and expensive acts in the drilling process. It has been evaluated to cost the drilling industry more than one billion dollars a year in rig time, materials, and other economic resources (Phillips and Economics, 2015).

There are two significant types of losses, static and dynamic. The definition of static loss is the amount of mud lost during the drilling process while the pump was turned off, while the dynamic loss is defined as the mud filtrate to the weak zones through the drilling process. Generally, there are seepage loss, partial loss, and complete or severe mud loss (Al-Hameedi et al., 2018). The Seepage loss is defined as a total mud rate of between 0 and 2 m^3/h. This loss can be caused by a variety of drilling operations, including high drilling rates, displacement of drilled solids with fluids, equivalent circulation density, and/or the characteristics of the formation lithology being drilled. The partial loss involves drilling with partial loss, ranging between 2 and 15 m^3/hr, which might be risky if the fluid is reasonably inexpensive and the pressures are within operational limitations.

Depending on the amount of mud leakage and the physical properties of the thieving zone, a more containment-treatment approach may be attempted. To maximize the efficiency of this cure, the drilling mud in use must meet acceptable parameters, such as using LCM that does not adversely affect the physical qualities of the drilling fluid or equipment in the hole. The complete loss, up to 15 m^3/hr, occurs in gravels, natural horizontal cracks, partially opened produced vertical fractures, and vuggy development (Messenger, 1981; Nayberg and Petty, 1986) (Table 1).

Table 1. Losses classification with definitions (Shehab et al., 2023)

No.	Losses classification	Definition
1	Complete losses	Losses rate over 45 m^3 /h
2	Sever losses	Losses rate 15- 45 m^3 /h
3	Partial losses	Losses rate 2-15 m^3 /h
4	Seepage losses	Losses rate 0-2 m^3 /h

5. Results

The results were collected by coherency data and Frithogram.

5.1. Coherency

Coherency is a seismic attribute that measures the similarity of waveforms from trace to trace within a seismic volume. It's a quantitative measure that helps identify geological features that might not be easily seen in conventional seismic amplitude data (Chopra and Marfurt, 2007). Coherency data can be integrated into 3D geological models, providing a comprehensive view of the subsurface and aiding in more accurate interpretation and decision-making (Santos et al., 2017).

Three-dimensional (3D) seismic data from the Rumaila oilfield were imported into the Petrel software platform, in SEGY format, to create subsurface images of the field. Using this dataset, structural maps were generated and visualized, enabling the analysis of non-productive time (NPT) causes through examination of in-line, cross-line, and time-slice sections.

Fig. 2, which presents the result of the seismic section, displays a map with dark and light green areas representing cohesive and incohesive zones. The dark green colour presents a coherent zone across the map. It is observed that the coherent zones are located in the western and southwestern regions, while these zones diminish as one moves towards the east and southeast. The light green wells are situated within the incohesive zones, whereas the other wells are located in the cohesive zones (white wells).

5.2. Drilling Mud Losses

Drilling data from the Rumaila oil field were primarily evaluated using daily drilling reports from the wells. These reports contained information on the progress of drilling operations, the drilling parameters used, and the associated time data. Daily mud reports were analyzed to determine mud properties, including, mud weight (MW), rate of penetration (ROP), weight on bit (WOB), standard pipe pressure (SPP), flow rate (FR), and equivalent circulation density (ECD). These reports also documented any daily losses. The results consistently pointed to specific depth intervals, ranging from 2176 to 2230 m, where loss events were most likely to occur (Fig. 3).

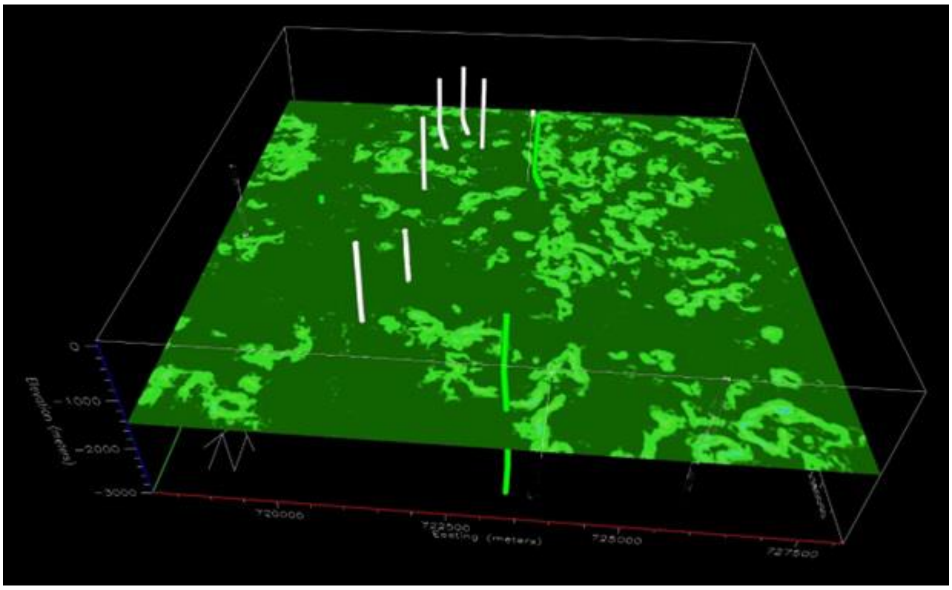

Fig. 2. Three-dimensional (3D) seismic section from the Rumaila oilfield, with places of coherency (light green color)

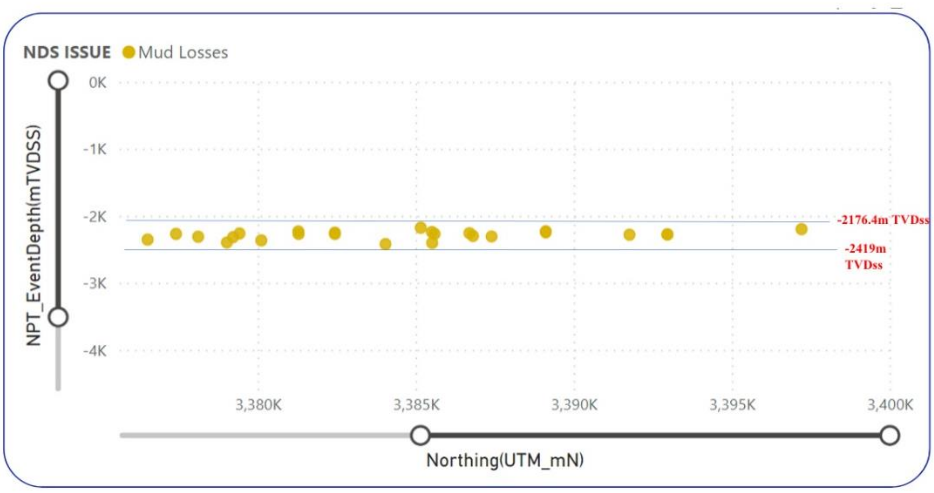

Fig. 3. The depths of mud losses in the Mishrif Formation, North Rumaila oilfield

5.3. Frithogram

It is a graphical representation of bit depth vs. real time/date used to confirm the loss depths. It may be plotted alongside other real-time drilling data to understand how they changed. These graphs depict events leading up to losses (Shehab et al., 2023). The following Figures from 1 to 6, show the locations of losses with drilling, which are different from the normal shape in areas where there is no loss at Fig. 7. The details of the Frithogram are as follows:

Fig. 4 shows the fractogram of well R-A, illustrating the relationship between bit depth and drilling time. The Mishrif Formation exhibits various types of fluid losses at different depths. Specifically, between depths of 2351 and 2363 m, there is clear evidence of partial losses. These losses are characterized by dynamic loss rates of 3 to 11 m³/h during drilling. To address this, 9 m³ of LCM (Lost Circulation Materials), including one cement plug, was used as a treatment (Table 2).

The Frithogram of well R-B between bit depth and drilling time is shown in Fig .5. The Mishrif Formation is influenced by partial types of losses in the depth of 2303 m, which have 25 m^3/h while drilling, are treated by spotting 8 m^3 of 80 ppb LCM pill and 1 cement plug (Table 2). In well R-C, the Mishrif Formation is influenced by p dynamic hole losses at depths 2363-2519 m (Fig. 6), which have 25 m^3/h while drilling treated by spotting LCM material and 1 cement plug (Table 2).

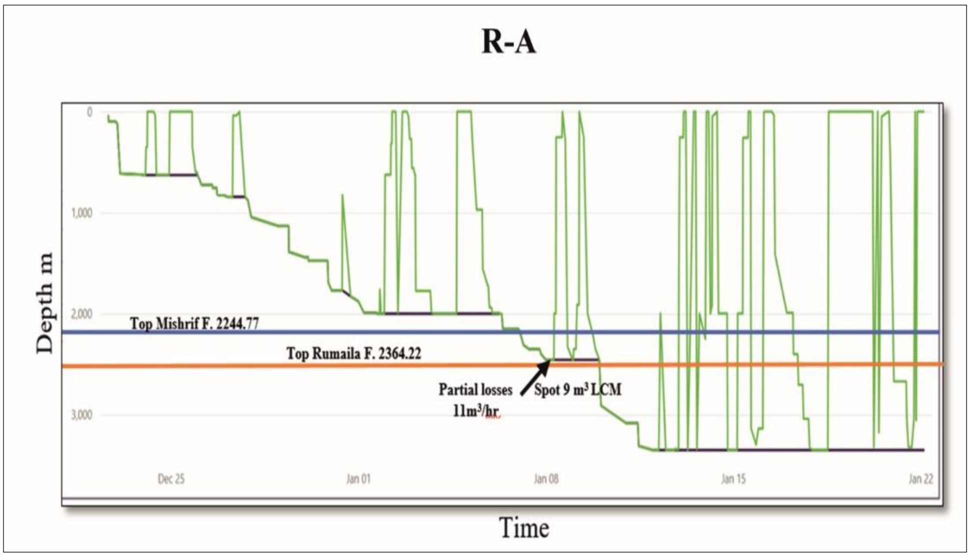

Fig. 4. The Frithogram of well R-A, North Rumaila oilfield

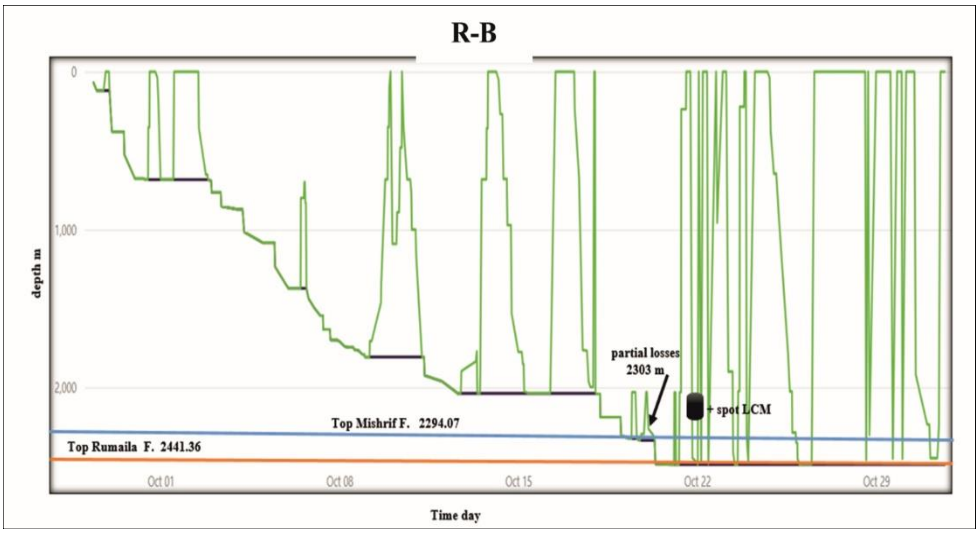

Fig. 5. The Frithogram of well R-B, North Rumaila oilfield

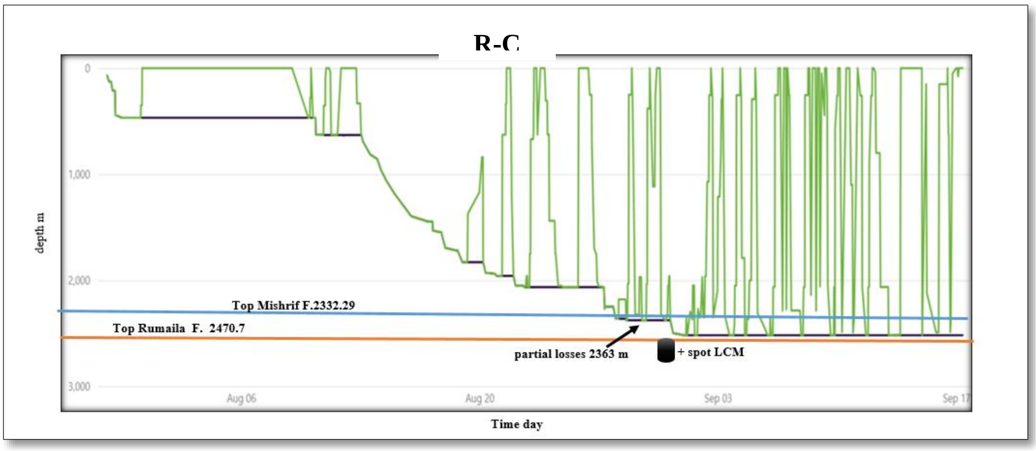

Fig. 6. The Frithogram of well R-C, North Rumaila oilfield

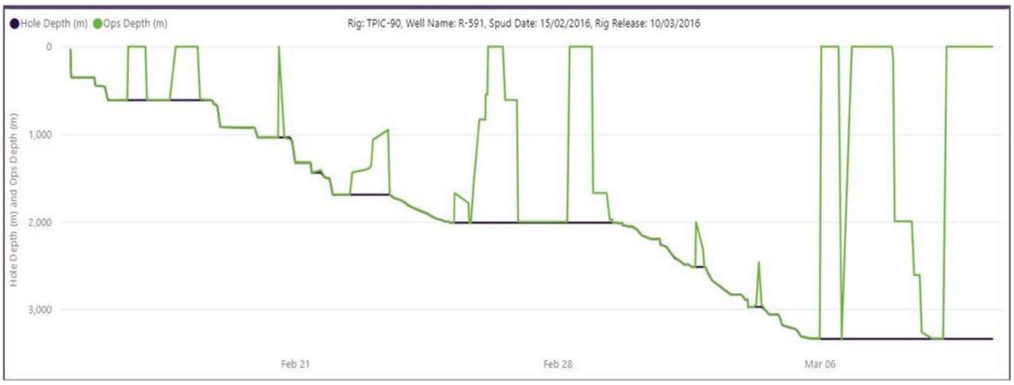

Fig. 7. The Frithogram for the other wells, illustrated the regular drilling without losses of Mishrif Formation, Rumaila oilfield

Table 2. Detail study wells information, showing treatment of the loss depths

Well	Top	Bottom	Event depth m	Event detail	Response
R-A	2244.77	2364.22	2351-2363	dynamic losses 3-11 m3/hr while drilling	1 cement plug
R-B	2332.29	2470.7	2363-2519	Dynamic hole losses	Spot LCM and 1 cement plugs
R- C	2294.07	2441.36	2303	25 m3/hr partial loss	Spot 8 m3 of 80 ppb LCM pill and 1 cement plug
R-D	2376.69	2524.9	2406	DH losses while drilling	Mix 30m3 LCM mud and 1 cement plug
R-E	2368.4	2525.8	2383	Down hole losses while drilling	Spot LCM pills on bottom and displaced same with string volume by 1.22 sg mud
R-F	2324.8	2473.5	2350	Partial losses while drilling	Pumped 10m3 of 40 ppb of CaCO3 M pill.
R-G	2257.77	2396.97	2266-2285	While Drilling 8.5 hole from 2285- 2486m observed partial losses	Continue drilling

6. Discussion

The seismic and drilling data highlight the role of coherency analysis in subsurface characterization and its integration with drilling data to address fluid loss challenges in the Rumaila oilfield.

Drilling fluid losses, a common challenge in drilling operations, can stem from a combination of geological and operational factors. The formations with high permeability, such as sandy or fractured rocks, readily absorb the drilling mud. Similarly, naturally occurring fractures in the rock provide pathways for the fluid to escape. Drilling through poorly consolidated or loosely packed materials can also lead to mud flowing into the surrounding formation rather than returning to the surface (Zhao et al., 2019). The map in Fig. 2 illustrates the coherent zones that predominantly occupy the western and southwestern parts of the field, while incoherent zones are more prevalent toward the east and southeast. This spatial variation in coherency suggests differences in subsurface properties, which can influence drilling and production strategies. Based on this data, the study strongly recommends avoiding drilling in the areas highlighted by the seismic section on the eastern and southeastern flanks, which are characterized by significant mud loss issues.

Operational issues also contribute significantly. If the drilling mud's properties, such as viscosity or density, are not adequately maintained, it may fail to seal permeable zones, resulting in fluid loss. Insufficient mud weight can also be a culprit, as it may not exert enough pressure to counteract formation pressures (Cunningham and Eenink, 1959). Unexpectedly high formation pressures can force drilling mud into the formation if they exceed the pressure exerted by the mud column. Furthermore, encountering unforeseen changes in the geological environment, including variations in rock types or structural features, can trigger lost circulation as the mud interacts with different materials (Mouchet and Mitchell 1989; Fattah and Lashin, 2016; Orun et al., 2023). Specifically, Figs. 4 to 6 depict the relationship between bit depth and drilling time across different well sections (R-A, R-B, and R-C), emphasizing the occurrence of fluid losses at various depths within the Mishrif Formation.

For example, the partial losses at approximately 2351–2363 m (Fig. 4) and 2303 m (Fig. 5), as well as dynamic losses from 2363 to 2519 m (Fig. 6), correspond to zones where seismic incoherency may be observed. These zones necessitated targeted interventions, including the placement of Lost Circulation Materials (LCM) and cement plugs, as documented in Table 2. The combination of coherency seismic attribute analysis with detailed drilling event data provides a robust framework for understanding subsurface heterogeneity and managing fluid loss issues. Such integrated approaches enhance the accuracy of geological models and support more informed decision-making in complex formations like the Mishrif, ultimately leading to more efficient and safer drilling operations in the Rumaila oilfield.

7. Conclusions

Based on the analysis of lost circulation issues in the Rumaila oilfield, particularly within the Mishrif Formation, it is evident that preventing or combating this problem is challenging. Lost circulation in this field is a significant impediment to development, ranging from minor seepage to complete loss of the borehole. While seven wells have reported mud losses, the issue affects numerous others. A detailed examination utilizing 3D geological models and frithogram analysis has been employed to identify effective treatments based on the type of loss.

The coherence data suggest that cohesive zones are primarily located in the western and southwestern parts of the field, diminishing towards the east and southeast, which correlates with the location of wells experiencing losses. Frithograms prove to be a valuable tool for analyzing the evolution of conditions leading to mud losses by integrating them with real-time drilling data. A comparison between wells experiencing losses and one without revealed that the primary cause of mud loss is the nature of the lithology. Further microfacies studies are required to confirm the effect of extensive dissolution processes, creating large channels and significant porosity at affected depths, which are strongly associated with these losses.

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