Log Permeability And Injection Log Tool Comparison, Upper Shale Member Of Zubair Formation In X-Field As Case Study

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Abstract
This study compares permeability enhancement and water injection, two crucial techniques in optimizing hydrocarbon recovery. Both methods aim to maximize production rates and ultimate recovery from oil and gas reservoirs. The essay analyzes the principles, applications, advantages, and limitations of each technique. Water injection, a common secondary recovery method, involves injecting water into the reservoir to mobilize hydrocarbons towards production wells. A comparative analysis will be presented to evaluate the effectiveness and suitability of each approach in different reservoir conditions. This study assesses the effectiveness of reservoir stimulation treatments, such as hydraulic fracturing and acidizing, by analyzing changes in injection performance. An increase in injection rates post-treatment indicates improved permeability and reservoir connectivity, facilitating fluid flow. Additionally, a decline in wellhead and borehole pressures further confirms successful stimulation. Comparative analysis of injection volumes before (2016) and after (2017) treatment reveals a substantial rise from limited volumes (~200 barrels) to over 2000 barrels in targeted reservoir zones, demonstrating the positive impact of stimulation methods on reservoir injectivity and flow characteristics.

1. INTRODUCTION

The fundamental components of a reservoir model include porosity, permeability, and fluid saturation. While porosity and fluid saturation are typically estimated with high confidence from wireline logs, permeability is often more challenging to determine accurately. Direct measurement of permeability requires core analysis, pressure transient testing, or formation pressure data obtained from wireline logs. Since not all wells are cored, permeability is frequently inferred from wireline log responses. The science of predicting permeability has advanced significantly, with each additional level of analysis gradually improving the accuracy of predictions (Skalinski and Sullivan, 2001). Permeability is one of the most responsive parameters in reservoir modeling using numerical flow simulators. Consequently, creating reliable methods to measure this parameter is a primary focus within the oil industry. Today, various techniques exist for estimating rock permeability: some are derived directly from flow experiments in porous media, while others are inferred indirectly from the reservoir's physical properties, as previously mentioned. These include magnetic resonance

[1] **.Study area**

The Mesopotamian Basin, a geologically important area, features a vast and intricate hydrocarbon system that dates back to the Early Cretaceous-Miocene period. This ancient petroleum system, shaped by millions of years of geological development, includes a complex interaction of source rocks, cap rocks, and reservoir rocks that have played a crucial role in establishing the region's abundant oil resources (Mahdi et al., 2022; Lazim et al., 2024). The sediments of the Tigris and Euphrates rivers extensively blanket the Mesopotamian region, contributing to its recent landscape. Additionally, the Dibdibba Formation enriches this geological tapestry with a diverse array of clastic materials, ranging from fine clay to coarse gravel (Mahdi and Soltan, 2021). The X- oilfield is the biggest oil field in Iraq situated in southern Iraq which is borders Kuwait from the south and approximately 50 kilometers west of Basrah city, (Al-Ali, et al., 2019). (fig. 1).

tool measurements, correlations based on porosity and irreducible water saturation, and multivariate statistical methods applied to wireline logs. The techniques previously discussed rarely account for all the heterogeneities that significantly influence the reservoir's future performance, as the volume of reservoir rock contributing to each measurement is typically small. This study introduces a methodology to estimate the permeability distribution using production logging data collected during well testing in a vertical well. This in-situ estimation is conducted under reservoir conditions that closely resemble those expected during the production phase (Del Rey et al., 2007).

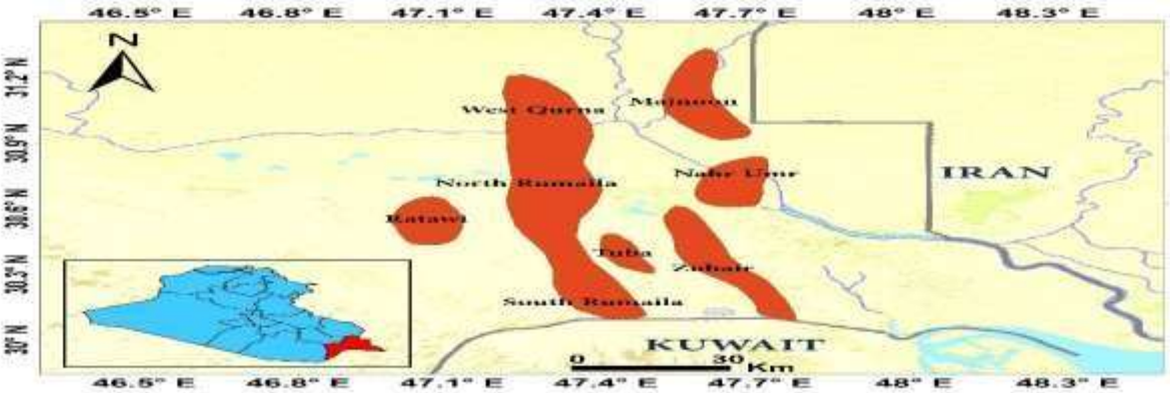

Figure 1: Location map showing the important oilfields southern Iraq

This study focuses specifically on the Upper Shale Member of the Zubair Formation located in X -oilfield southern Iraq. Zubair Formation consist of alternating sandstone, siltstone, and mudstone/shale layers. Fossil evidence (foraminifera and molluscs) suggests a Hauterivian to Aptian or Barremian to early Aptian age, as proposed by Bellen et al. (1959). Ali & Nasser (1989) further categorized the rock types into four lithofacies based on sedimentary features, notably the sandstone-to-shale ratio, which they linked to depositional environments like swamps, marshes, delta fronts, prodeltas, and shelves (Al-Ameri and Batten, 1997). The Shuaiba Formation lies conformably above the underlying layers, although its basal contact with the Ratawi Formation is unconformable. It gradually transitions into the Zubair Formation (Aqrawi et al., 2010). The top of the Shuaiba Formation is characterized by the presence of *Hedbergella tunisiensis* (Al-Shawi et al., 2019; Mahdi et al., 2020). Meanwhile, the Ratawi Formation gradually thins and transitions both upward and westward into the Zubair Formation (Jassim and Goff, 2006). Tectonically, Fouad (2015) put the Mesopotamian zone with the outer platform within the Mesopotamian foredeep. Greater knowledge of the nature of sedimentation, structural development, and petroleum accumulations in the Mesopotamian zone can be gained, however, through historical research on the passive margin of the Arabian plate (Al-Kaabi, et al, 2023). In the Eocene epoch, the initial stage of collision began, marked by the edge of the Arabian continental plate beginning to rise and stretch as it curves around the outer swell. This movement occurred just prior to its incorporation into the subduction system by the descending slab, signaling the impending collision (Maziqa, et al., 2023).

2. METHODOLOGY

The methodology to achieve the goal of the study (compare the log derived inflow vs. injection log tool (ILT) inflow) involved the following:

1. The log permeability is calculated from the model and the total rate is calibrated from the spinner data.
2. Any intervals with unperforated permeability are set null in the script
3. This revised permeability is then integrated to produce a cumulative, perforated permeability

4. The cumulative permeability is then normalised, so the cumulative flow rate is comparable
5. Again, the cumulative total flow rate is normalised so that both can be compared (Fig.2)

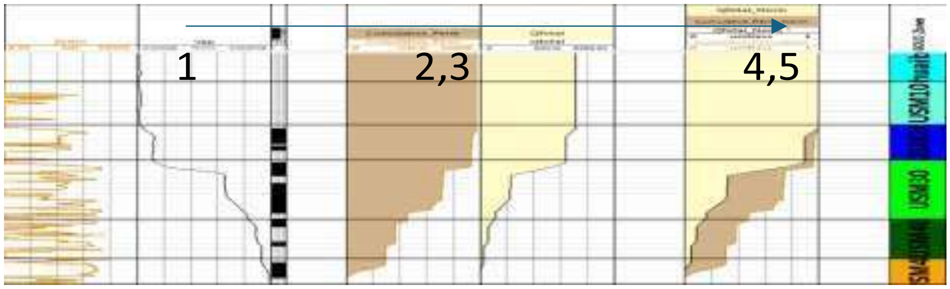

Figure 2. Process the log permeability and ILT inflow in the units of Zubair Formation

3. RESULTS

In the field of reservoir engineering, accurately calculating permeability is crucial for evaluating and optimizing hydrocarbon production.

The static modeling method incorporates data derived from open-hole logs and core samples. It depends on direct measurements of rock properties from core analyses, along with indirect data from logs, to estimate permeability. Although this approach can yield useful information, it typically reflects an average condition that may not accurately account for the impacts of reservoir stimulation or other dynamic processes that occur over time (Ismagilov et al., 2018).

Conversely, dynamic calculations utilize real-time data to deliver a more responsive and detailed evaluation of permeability. An effective dynamic technique involves analyzing data from Production Logging Tools (PLT) and Injection Logging Tools (ILT) by applying Darcy's Law to assess fluid flow within the reservoir. Darcy's Law connects the flow rate of a fluid through a porous medium to the medium's permeability, the fluid's viscosity, and the pressure gradient. This method can account for the effects of reservoir stimulation methods, such as hydraulic fracturing or acidizing, thereby providing a more precise measurement of how permeability evolves over time (Teng and Zhao, 2000).

For this project, the dynamic calculation approach has been used to evaluate permeability prior to and following stimulation treatments. By examining data from Production Logging Tools (PLT) and Injection Logging Tools (ILT), we can detect variations in fluid flow and pressure, enabling a more accurate determination of the increased permeability around the wellbore (Kortukov et al., 2020). This technique provides a more immediate and detailed assessment of the stimulation's effects, as it captures the current conditions and fluid dynamics within the reservoir in real time.

Analyzing the permeability changes before and after stimulation with this dynamic method demonstrates how effectively the stimulation has enhanced reservoir performance. An increase in permeability around the wellbore typically signifies a successful stimulation, resulting in improved fluid flow and potentially higher hydrocarbon production. This comprehensive comparison is crucial for refining reservoir management strategies and maximizing recovery efficiency.

4. Injection Log Tool Data from Two Periods in 2016 and 2017

In reservoir engineering, evaluating the success of stimulation treatments is essential for maximizing hydrocarbon extraction. The Injection Log Tool (ILT) serves as a useful instrument for this purpose, enabling surveys to be conducted both prior to and following stimulation events (Guo et al., 2020). This discussion examines how ILT data can verify notable improvements in permeability caused by stimulation and considers the wider impact of these enhancements on overall reservoir performance (Yuan et al., 2023). The Injection Log Tool (ILT) is employed to assess a well's injection properties, offering valuable information about the reservoir's response. Performing ILT surveys both prior to and following stimulation allows engineers to precisely determine alterations in permeability. The outcomes from the ILT highlight two main signs of effective stimulation: a rise in injection rate and reductions in wellhead and borehole pressures (Salem et al., 2024) (Fig. 3).

Firstly, a rise in the injection rate indicates an improvement in the reservoir's permeability. Stimulation methods like hydraulic fracturing or acidizing aim to create or enlarge flow pathways within the reservoir rock. When permeability increases, fluids can be injected more readily, resulting in higher injection rates. This improved injectivity demonstrates that the stimulation has successfully enhanced the reservoir's connectivity and fluid flow properties (Guo et al., 2020). Secondly, a reduction in wellhead and borehole pressures further supports the effectiveness of the stimulation treatment. An examination of injection activities in 2016, before stimulation, showed that the injection volumes were quite limited

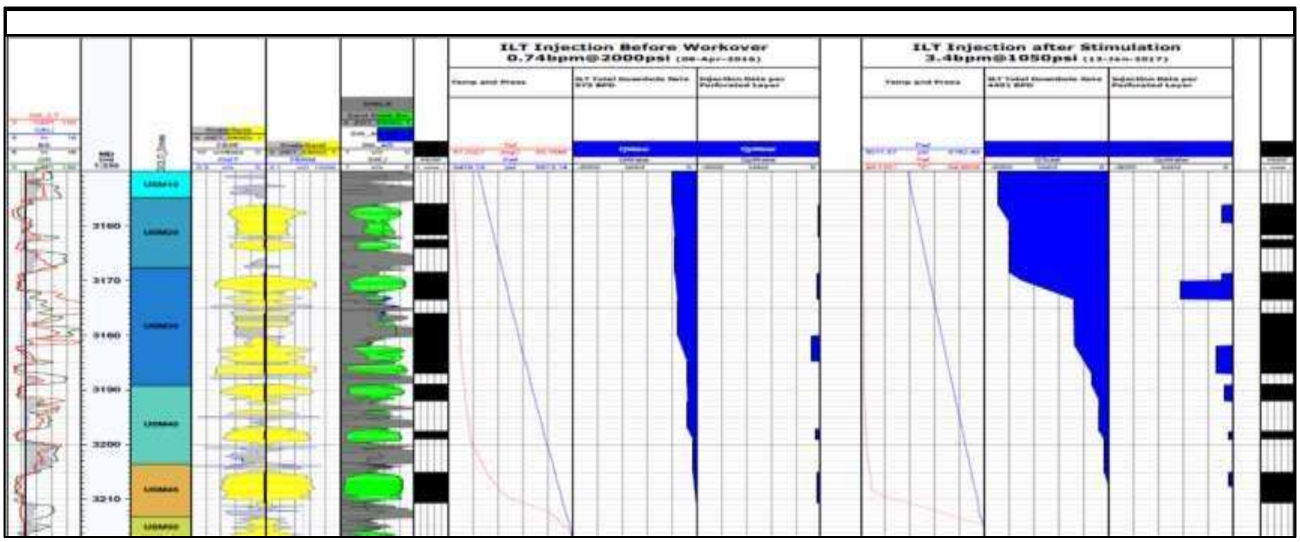

Figure 3. ILT injection from April 2016 to Jan 2017 in the units of Zubair Formation

The highest recorded volume was 200 barrels, mainly concentrated in the central section of the shale unit (USM30), while other areas such as USM45 and the middle part of USM40 typically received less than 100 barrels. In 2017, a sharp rise in injection volume was recorded, with amounts reaching 2000 barrels in the upper section of the USM30 unit. Notable increases in injection volumes were also observed in the upper regions of USM45 and USM40. These considerable changes in injection volume are mainly attributed to the execution of hydraulic fracturing and acidizing treatments (Fig. 3).

Damage zones or low-permeability regions surrounding the wellbore can hinder fluid flow, leading to elevated pressure measurements. Following stimulation, these damage zones are typically reduced or eliminated, resulting in decreased injection pressures (Shalev and Lyakhovsky, 2013). This decline in pressure suggests improved connectivity between the wellbore and the deeper reservoir, enabling more efficient fluid transfer. The main advantage of increasing permeability around the wellbore is better connectivity with the reservoir. Stimulation techniques focus on disrupting or dissolving damage zones that restrict fluid movement, thereby expanding the wellbore's access to productive reservoir sections. This improved connection promotes greater fluid flow and enhances the reservoir's sweep efficiency. Higher sweep efficiency allows injected fluids to contact a larger portion of the reservoir, resulting in more effective hydrocarbon displacement and potentially increased recovery rates. Additionally, enhancing permeability and eliminating damage zones through stimulation help sustain the overall reservoir pressure in the treated region. Maintaining higher pressure is essential for achieving consistent production rates and ensuring the long-term stability of the reservoir. Better pressure support enables the reservoir to produce hydrocarbons more efficiently over time, supporting a more successful and economically sustainable operation (Bennion et al., 2000; Adeoti et al., 2014; Salem et al., 2024). In summary, ILT surveys offer critical evidence of the success of stimulation treatments by revealing notable improvements in permeability. Increased injection rates coupled with reductions in wellhead and borehole pressures serve as clear signs that damage zones have been healed and communication between the wellbore and reservoir has been enhanced. These improvements not only increase the efficiency of fluid injection and hydrocarbon extraction but also help maintain reservoir pressure, supporting overall reservoir management goals. Utilizing ILT data enables engineers to assess and refine stimulation strategies more effectively, resulting in more efficient and economically beneficial hydrocarbon production (Muggeridge et al., 2014; Muggeridge et al., 2019; Akbarabadi et al., 2023).

5. DISCUSSION

The research region is located in Basrah, within the Zubair Subzone, and is completely covered by Quaternary sediments and recent soils. This geological period is particularly important in Iraq's history, as most of the country's oil deposits were formed during this time (Al-Shawi et al., 2019). The Zubair Formation is considered the main hydrocarbon reservoir in the central and southern parts of Iraq's oil fields. It is composed of five members: the Upper Shale, Upper Sand, Middle Shale, Lower Sand, and Lower Shale members.

In the evolving field of hydrocarbon extraction, optimizing recovery methods is essential. Among these, permeability enhancement and water injection are two prominent techniques in petroleum engineering, both designed to increase production rates and maximize overall recovery from oil and gas reservoirs. This essay provides a comparative analysis of these methods, examining their underlying principles, applications, benefits, and drawbacks. Water injection, commonly referred to as water flooding, is a secondary recovery technique that involves injecting water into the reservoir to push hydrocarbons toward the production wells. This process helps sustain reservoir pressure, increases sweep efficiency, and boosts oil recovery by directing trapped oil toward the wellbores. Estimating permeability involves various techniques and data sources for calculation and prediction. One widely used method is to determine permeability from core samples and then extrapolate these measurements using different geological modeling approaches. However, despite its widespread use, this method carries significant uncertainties due to the limited availability of core data and the difficulties in accounting for formation coverage differences when comparing core plug measurements with the reservoir's overall properties.

The primary objective of this study is to obtain more dynamic data to validate the concepts and methods used in permeability calculations. Injection logging serves as a reflection of formation permeability, incorporating various parameters that either enhance or diminish reservoir quality. The proposed approach involves comparing calculated permeability values with injection data, specifically Injection Logging Tool (ILT) measurements, which entail cumulative total injection rates correlated with cumulative permeability. This initial stage of the study focuses on validation. Subsequent steps will involve refining the model using both injection and production data to enhance permeability calculations, aiming for an improved representation of formation quality. The study dealt with one of the most important geological formations containing hydrocarbons, which is the Upper shale member in the X oilfield, and the results showed great importance in this field.

6. CONCLUSION

The Zubair Formation, and specifically its members, serve as a major hydrocarbon reservoir in central and southern Iraqi oilfields, making the study of its components highly relevant. The study provides a detailed understanding of the characteristics of the Upper Shale Member of the Zubair Formation within the X-oilfield. The data from this study may have practical applications for optimizing extraction techniques, estimating reserves, or identifying areas for potential future exploration within the X- oilfield. The primary aim of the study is to gather dynamic data that will validate existing methods and concepts used for calculating permeability in reservoirs. Injection logging is a critical tool used to assess formation permeability and reflects the overall quality of the reservoir, considering various factors that impact permeability. The approach proposed in the study involves a comparative analysis between calculated permeability values and measurements obtained from the Injection Logging Tool (ILT), particularly focusing on the correlation between cumulative total injection rates and cumulative permeability. Future Refinement: The study is set to progress beyond validation, with plans to refine the permeability model by incorporating both injection and production data in subsequent steps, enhancing the overall understanding of reservoir behavior.

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