

Reservoir Quality Assessment of Subsurface Sections Across Jurassic Period (Mus and Sargelu) Formations in Duhok Governorate, Kurdistan Region, Iraq

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Abstract

This study investigates the reservoir characteristics of Jurassic subsurface formations, specifically the Mus and Sargelu formations in Duhok Governorate within the Kurdistan Region of Iraq. Through the interpretation of detailed well log data from the X Well, essential petrophysical properties such as porosity, permeability, water saturation, and lithology are assessed to pinpoint potential hydrocarbon-bearing zones. The Sargelu Formation, encountered between depths of 1345 and 1420 meters, is characterized by heterogeneous lithologies dominated by fractured limestones interbedded with shale layers. Notably, this interval reveals effective porosity values reaching up to 18%, enhanced permeability due to fracturing, and favorable water saturation, especially between 1385 and 1400 meters. In contrast, the Mus Formation, situated between 1875 and 1925 meters, comprises primarily limestone and dolomite, displaying variable porosity and resistivity patterns. Crossplot interpretations and Pickett plots indicate potential hydrocarbon presence despite limited direct evidence from gas indicators. Overall, both formations exhibit considerable but variable reservoir quality controlled by lithologic heterogeneity, degree of fracturing, porosity distribution, and shale content. The integrated petrophysical analysis provides a deeper understanding of Jurassic reservoir behavior in this relatively underexplored region of northern Iraq.

Keywords:

Petrophysical properties, Reservoir quality, Jurassic, Well log analysis, Porosity, Permeability.

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1. Introduction

The Jurassic succession in northern Iraq plays a critical role in the region's petroleum systems, particularly due to the presence of rich source rocks such as the Sargelu and Naokelekan formations (Abdula, 2015; Abdula, 2017a). These formations play a pivotal role in hydrocarbon generation, migration, and entrapment, and are therefore of strategic importance for petroleum exploration and development activities. The Mus Formation represents the only Lower Jurassic unit in Iraq deposited under normal marine conditions, contrasting with the sabkha and evaporitic environments of other Lower Jurassic formations (Bellen et al., 1959). The Mus Formation in Jabal

Kand-1 Well is thermally mature, but has a low potential for generating hydrocarbons (Al-Habba, 1988; Abdula, 2017b). In contrast, the Mus Formations are the source of the condensate that is produced from the Samawa-1 Well in southern Iraq (Samarrai, 1988, in Sadooni, 1997). These Jurassic formations, containing Type IIS kerogen, are the main contributors to oil generation and expulsion from the Late Cretaceous to the Pliocene (Pitman et al., 2004). Supporting units such as the Gotnia Formation act as regional seals, while others like the Butmah Formation offer potential reservoir facies. Depositional environments shaped by transgressive-regressive cycles favored both organic-rich sedimentation and reservoir development (Pitman et al., 2004).

Petrophysical log analysis is a valuable and essential tool to describe reservoir properties (Asquith et al., 2004). The importance of petrophysical understanding of well logs is to distinguish the volumetric portions of the geologic unit constituents (solid, liquid, and gas states) by merging the data offered by different types of well logs (Ellis and Singer, 2007).

Agada et al. (2013) examined fractured systems in the Sargelu and Naokelekan formations, illustrating how fracture networks enhance reservoir permeability and fluid migration. Tectonostratigraphic contrasts were addressed by Al-Naqib and Al-Juboury (2014), who delineated petroleum and non-petroleum zones based on regional geological variation. The Lower and Middle Jurassic formations in Zab-1 Well have kerogen types II and II-S in the immature to early mature stage of thermal maturity of oil (Abdula, 2016).

Petrophysical characterization using well log data was applied by Zangana et al. (2020) to assess Early Jurassic reservoirs such as Butmah Formation, while Ali et al. (2022) further classified porosity types across multiple wells. Dohan et al. (2022) provided detailed petrographic insight into the Sargelu Formation, identifying its depositional environments and diagenetic features. Recent advancements include integrated petrophysical and geochemical approaches by Alrekabi and Al-Fatlawi (2024), Khudhair and Idan (2024), and Al-Dabagh and Asaad (2025), highlighting the growing emphasis on reservoir heterogeneity and rock-type distinction in oil fields such as Garraf and Shaikan. Despite these efforts, many Jurassic successions in northern Iraq remain underexplored or inconsistently evaluated, underlining the importance of this study in contributing a more detailed and localized understanding of reservoir quality and hydrocarbon distribution. Well consideration of reservoir depiction signifies the main key element for successful field development planning, and precise reservoir description is essential for effective and improved control of heterogeneity (Shedid, 2018). Recognition of reservoir quality is an important objective in the reservoir characterization process. The quality of a reservoir is defined by its hydrocarbon storage capacity, and storage capacity is a function of porosity, whereas deliverability is a function of permeability. Thus, both porosity and permeability

are the main reservoir quality controlling factors (El Sharawy and Nabawy, 2019).

The aim of this study is to assess the reservoir quality of Mus and Sargelu Jurassic formations in the Duhok area, northern Iraq. This evaluation is achieved by analyzing well log data to determine key petrophysical parameters, identify productive reservoir intervals, understand the distribution of hydrocarbons, and evaluate the factors influencing reservoir heterogeneity and effectiveness. This study may be of strategic importance in regional hydrocarbon exploration and development.

2. Study Location

The present study focuses on the Jurassic stratigraphic succession within the Kurdistan Region of northern Iraq, specifically in the Duhok area. The investigation is based on subsurface data obtained from the X Well, which penetrates several Jurassic formations that are critical to the regional petroleum system. The selection of this area is justified by its geological complexity and its potential for hosting both source and reservoir rocks within a relatively well-preserved stratigraphic framework. The well location is illustrated on the location map (Figure 1), which incorporates elements adapted from Sissakian and Al-Khalidi (2012) and supplemented with satellite imagery obtained from Google Earth.

This well intersects key Jurassic stratigraphic units. The studied formations (Mus and Sargelu), as part of the Jurassic succession of Iraq are exhibit varied lithologies, predominantly comprising limestones, dolomites, and shales. Both formations hold significant reservoir potential, primarily influenced by factors such as natural fracturing and dolomitization, which enhance porosity and permeability characteristics within these carbonate units. A stratigraphic column illustrating the vertical distribution, lithological composition, and relative thicknesses of the Mus and Sargelu formations in the X Well is provided to support the subsurface interpretation (Fig. 2). Mackertich and Samarrai (2013) present a detailed well-specific stratigraphic column for the Kurdistan region, showcasing the Jurassic succession in the area, including the Sargelu and Mus formations along with their thickness variations.

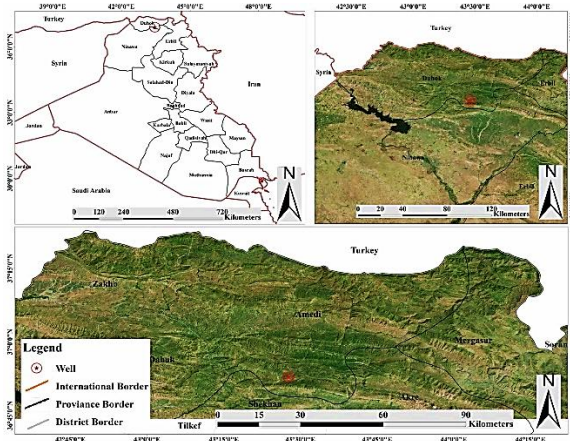


Fig. 1: Location map showing the studied area with locations of oil exploration wells. The upper part of the map is adapted from Sissakian and Al-Khalidi (2012), while the lower part is based on imagery from Google Earth.

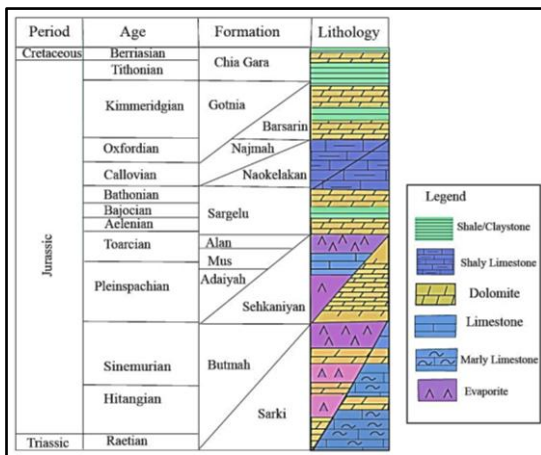


Fig. 2: Schematic stratigraphic column showing Jurassic succession in the Kurdistan Region of northern Iraq (Mackertich and Samarra, 2013) based on data from X Well, and highlighting key formations, particularly Mus and Sargelu formations, along with associated lithologies such as limestone, dolomite, marl, shale, and evaporites. The column is not to scale and is intended only as a conceptual illustration of the stratigraphic relationships.

3. Geological Setting

Iraq lies in the transition between the Arabian Shield in the Southwest and the extremely distorted Taurus and Zagros Suture Zone in the North and Northeast. It is strongly affected by eustatic sea-level fluctuations. The development of the region has been influenced by the mobility of the Precambrian basement and by tectonism along the Neo-Tethyan margin (Jassim and Buday, 2006). Depending on the tectonic subdivision of

Iraq, the study area is located in the Foothill Zone in northern Iraq.

The major tectonic event was begun after Triassic when the Gondwana splits, Indian Plate started to separate and, in the Late Jurassic isolated from Arabia (Grabowski Jr. and Norton, 1995). A new passive margin and new accommodation space were developed along the subsiding shelf at the plate's northeast edge as a consequence of rifting that occurred in the late Early Jurassic (Sharland et al., 2004). The Triassic was a time of general steadiness as represented by the deposition of evaporite and carbonate units, e.g., Butmah, Alan, Mus, and Adaiyah, or their equivalents, Sarki and Sehkaniyan formations. Due to Toarcian rifting, a new basin formed in the Middle Jurassic. It was characterized by the deposition of the Sargelu and its equivalents throughout the region (Sadooni, 1997). The variety in Najmah Formation thickness as described by Dunnington (1958) reflects the basin geometry from the Bathonian onwards. The Najmah oolites are developed along the western margin of a basin, which is represented to the east-northeast by the Naokelakan Formation in the Mountainous Zone (Sadooni, 1997).

4. Methodology

This study utilizes well log data to characterize reservoir properties, focusing on porosity, permeability, lithology, and hydrocarbon saturation. Data from the X well log were analyzed to interpret Jurassic formations, including the Mus and Sargelu formations. The methodology involves petrophysical interpretation utilizing gamma-ray (GR), neutron porosity (NPHI), bulk density (RHOB), resistivity (LLD & MSFL), and other log-derived parameters to evaluate reservoir quality. Cross plots and well log correlation techniques were employed to distinguish lithological variations, shale content, and hydrocarbon-bearing zones. The porosity-permeability relationships were assessed to determine reservoir effectiveness, while water saturation calculations aided in identifying hydrocarbon saturation potential. Additionally, stratigraphic correlations and formation thickness variations were analyzed to understand reservoir distribution and heterogeneity. The integration of petrophysical data with geological information provides a comprehensive interpretation of

reservoir characteristics, aiding in the identification of productive hydrocarbon zones.

5. Result

The X well log provides an in-depth profile of lithology, rock types, fossil content, and mineral content. The differentiation of the Mus and Sargelu formations in the studied well (X Well, Duhok area) is based on a combination of wireline log signatures, lithological characteristics, and regional stratigraphic context. Although petrographic thin sections were not initially included, future versions of this study will incorporate petrographic imagery from representative samples, highlighting features such as micritic vs. sparry textures, fossil fragments, dolomitization, shale content, and porosity types (e.g., vuggy, intercrystalline, moldic). These features are essential for confirming facies assignments and lithological boundaries, especially when differentiating closely spaced carbonate units with similar log signatures.

The Sargelu Formation, in turn, exhibits a distinct gamma-ray log character due to its high organic content and interbedded shale and limestone units. Sargelu Formation covers the depth interval between 1345 and 1420 meters (Figs. 3 and 4), and directly beneath it, the Alan Formation extends from 1420 m to 1875 m, primarily characterized by evaporites and anhydrites, acting as an effective seal between the Sargelu and Mus formations. The lower boundary of the Sargelu Formation is characterized by a shift from organic-rich, dark argillaceous, pyritic shales or micritic limestones with elevated gamma ray in the Sargelu Formation, with increased gamma ray, bitumen staining, and vuggy porosity into cleaner, more anhydritic dolomites (Alan Formation). The upper contact with the Naokelekan Formation is recognized by the appearance of argillaceous, pyritic shales and finely crystalline micritic limestones with elevated gamma-ray values—belonging to the Naokelekan Formation. These boundary interpretations are consistent with regional stratigraphy and supported by petrophysical parameters such as bulk density, neutron porosity, and resistivity trends.

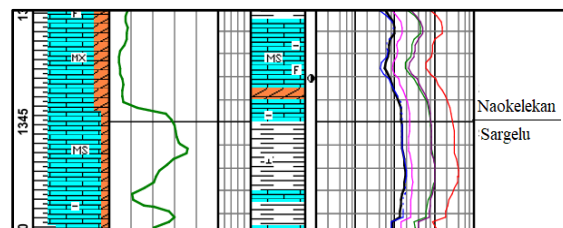


Fig. 3:Upper boundary of Sargelu with Naokelekan formations is situated at 1345 meters.



Fig. 4: Lower boundary of Sargelu with Alan formations is situated at 1420 meters.

The Mus Formation is covering the depth between 1875 and 1925 meters (Figs. 5 and 6), all of which critically influence reservoir characterization. The upper boundary of the Mus Formation is marked by a sharp increase in gamma-ray response and a distinct change from the overlying clean, evaporitic dolomite or anhydrite facies (interpreted as part of the Alan Formation) to downward tight, crystalline dolomite and anhydrite with very low porosity and high resistivity (Mus Formation), consistent with descriptions by Jassim et al. (2006), then the transition into dark-colored, organic-rich laminated limestones with bitumen staining, increased gamma-ray values, and signs of vuggy porosity—typical markers for the lower contact of Mus Formation with Adiyah Formation.

The thickness of the formations in this study also shows slight variation compared to their respective type sections. The Sargelu Formation in the studied well is approximately 75 meters thick, while the Mus Formation measures around 50 meters. These thicknesses differ slightly from standard regional averages due to structural setting, local depositional dynamics, and possibly erosional truncation or facies change. Such thickness variations are not uncommon in subsurface sections, particularly in tectonically active areas like the High Folded Zone of northern Iraq. The dominant lithology includes dolomitic limestones (DOLICLS), marlstones (MARLST), and shales (SH). For a detailed interpretation of the Jurassic formations in the X well log, let's break down each formation's key properties and

potential for hydrocarbons, focusing on their depth, lithology, reservoir properties, and overall hydrocarbon potential.

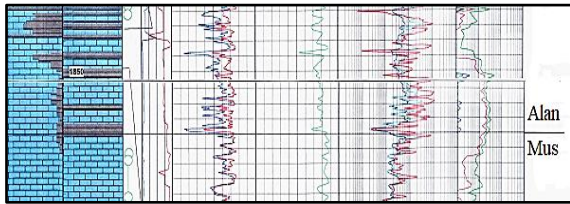


Fig. 5: Upper boundary of Mus with Alan formations is situated at 1875 meters.

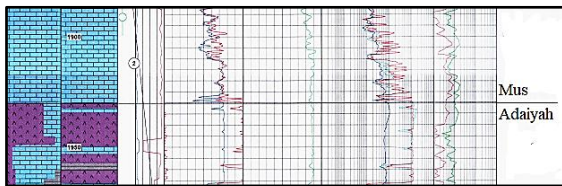


Fig. 6: Lower boundary of Mus with Adaiyah formations is situated at 1925 meters.

Mus Formation

Mus Formation is found at depths of approximately 1875-1925 meters. It is composed of limestone, dolomite, and some marl (Jassim et al., 2006) (Fig. 7). The crossplot in Fig. 8 of RHOMAA (bulk density) vs. DTMAA (acoustic transit time) for the Mus Formation reveals that the data points primarily cluster around a density of approximately 2.7 g/cm³ and a transit time of about 50 μ s/ft, indicating that the formation is predominantly composed of limestone (calcite).

There is also a minor trend in the crossplot data toward dolomite, suggesting localized dolomitization within the Mus Formation. Additionally, scattered points trending toward quartz and anhydrite indicate the possible presence of these minerals in smaller quantities. The figure includes arrows marked as "gas direction" to denote data points with decreased bulk density and increased transit time, features typically associated with gas-filled porosity.

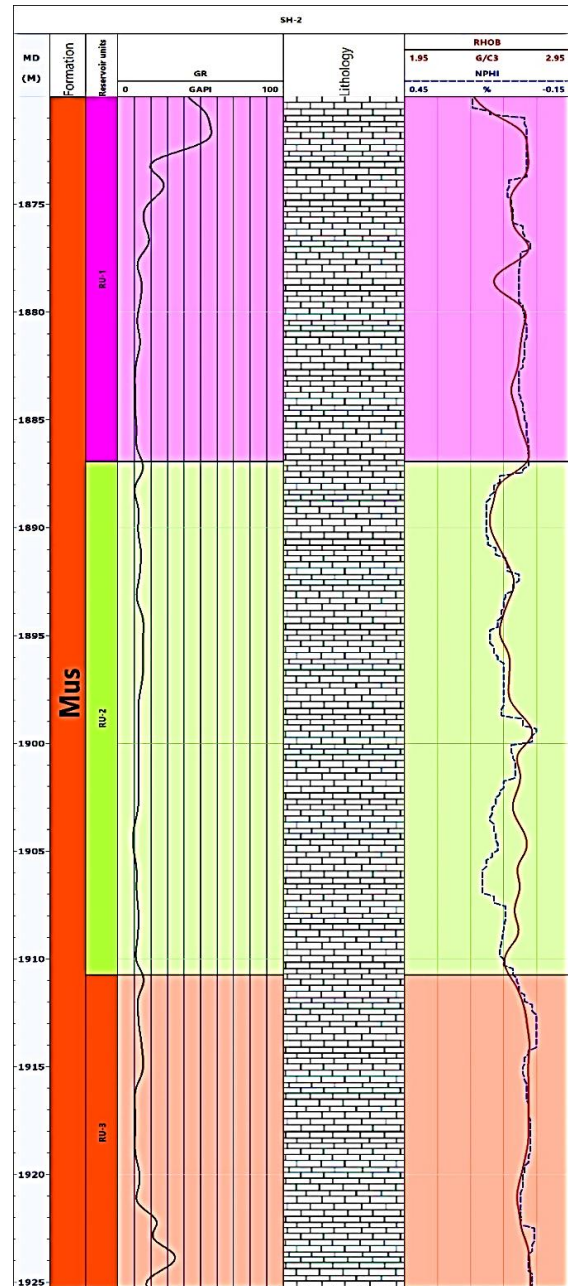


Fig. 7: Well log data of the Mus Formation showing gamma-ray (GR), neutron porosity (NPHI), bulk density (RHOB), lithology, and reservoir units RU-1, RU-2, and RU-3. The well log data used in this study were obtained from the Ministry of Natural Resources (MNR) of the Kurdistan Regional Government (KRG).

It is important to clarify that no direct evidence of gas (such as mud gas shows, formation testing, or pressure measurements) is available in this study; therefore, these indications should be considered as log-based anomalies rather than conclusive proof of gas accumulation. Furthermore, salt-related responses inferred from SNP (Sigma Neutron Porosity) and CNL (Compensated Neutron Log) signatures are visible

in the plot but do not correlate with the main data cluster of the Mus Formation. These signals are likely attributable to nearby salt-bearing units or lithological inclusions from adjacent formations. The Mus Formation demonstrates characteristics of a carbonate reservoir, with localized dolomitization and potential, though unconfirmed, indicators of gas presence.

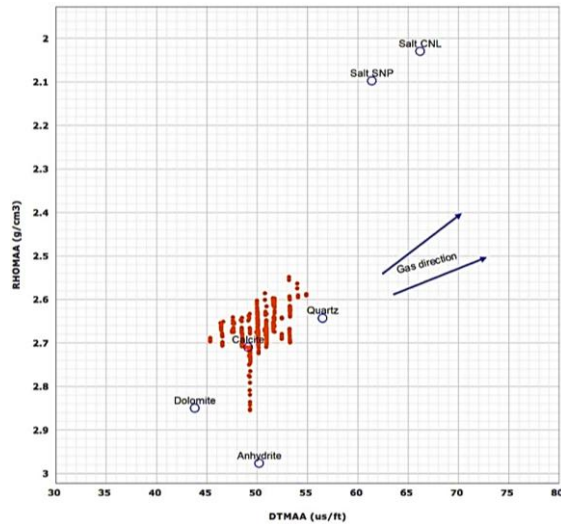


Fig. 8: Crossplot of RHOMAA (bulk density) versus DTMAA (acoustic transit time) for the Mus Formation, illustrating a predominantly limestone composition. Minor trends toward dolomite suggest localized dolomitization, while log-based anomalies may indicate potential zones of gas presence.

The V_{sh} curve shows a high volume of shale, which diminishes the RU-2 interval of the Mus Formation is the cleanest zone with the lowest V_{sh} values, indicating its potential as the primary reservoir target. In contrast, RU-1 and RU-3 have higher shale content, which could impact porosity and permeability negatively. Further analysis, such as porosity and saturation logs, would be necessary to confirm the reservoir quality of RU-2 (Fig. 9).

The Mus Formation has variable porosity and permeability, often ranging from 5-12% in the limestone layers. Dolomite intervals can have better porosity (10-15%) and permeability. The crossplot of effective porosity versus deep resistivity for the Mus Formation indicates a variation in fluid saturation and rock properties across the formation.

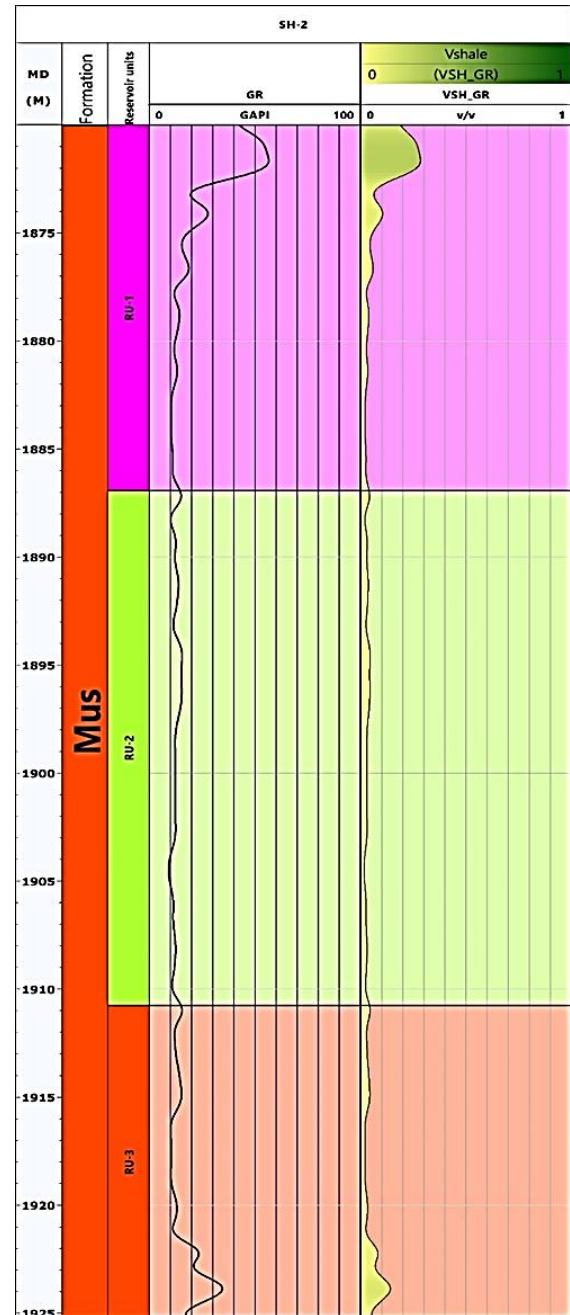


Fig. 9: Well log of the Mus Formation showing gamma-ray (GR) and shale volume (V_{sh}) distribution across reservoir units RU-1, RU-2, and RU-3.

Data points with high resistivity (>100 Ohm-m) and moderate to low porosity suggest potential hydrocarbon-bearing zones, as hydrocarbons impede electrical conductivity compared to water. Points with moderate resistivity (10–100 Ohm-m) and moderate porosity may indicate mixed fluid zones, with both hydrocarbons and water present in the pore spaces. In contrast, low resistivity values (<10 Ohm-m) correspond to water-saturated zones, where the higher electrical

conductivity is due to the presence of formation water. The porosity values range between 10% and 25%, consistent with carbonate reservoirs, and higher porosity zones indicate better reservoir quality with greater potential for fluid storage (Fig. 10). The clustering of data points at moderate to high resistivity with significant porosity highlights intervals of interest that may serve as hydrocarbon reservoirs. Further analysis, such as fluid saturation modeling and integration with other well logs, is required to validate these observations. This approach aids in the evaluation of water saturation and hydrocarbon potential of the reservoir.

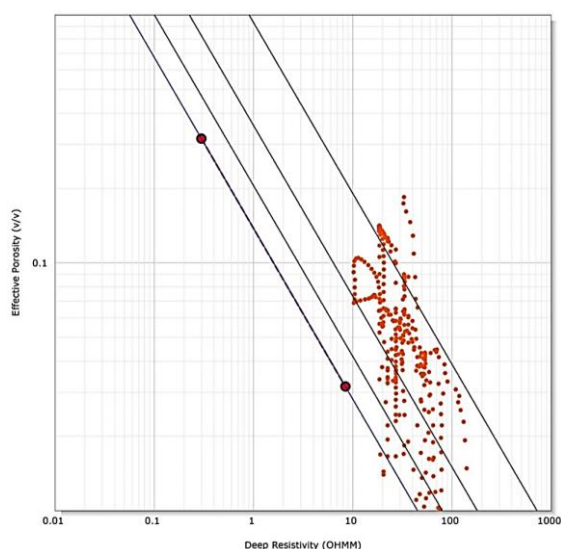


Fig. 10: Pickett plot displaying the relationship between deep resistivity and effective porosity.

Sargelu Formation

The petrophysical analysis of the Sargelu Formation, covering the depth interval between 1345 and 1420 meters (Fig. 11), reveals a complex and heterogeneous subsurface sequence that is predominantly composed of limestone interbedded with minor shale layers and dolomite (Abdula et al., 2015). Figure 11, which was generated using Techlog 2018 software, represents a well log section of the Sargelu Formation between the depths of 1345 and 1420 meters. It displays gamma-ray (GR) readings and the derived shale volume (V_{sh_GR}).

The GR curve, measured in GAPI units, indicates the natural radioactivity of the formation. Higher GR values (closer to 150 GAPI) correspond to shale-rich intervals, while lower GR values

(closer to 0 GAPI) suggest cleaner lithologies, such as limestone or dolomite.

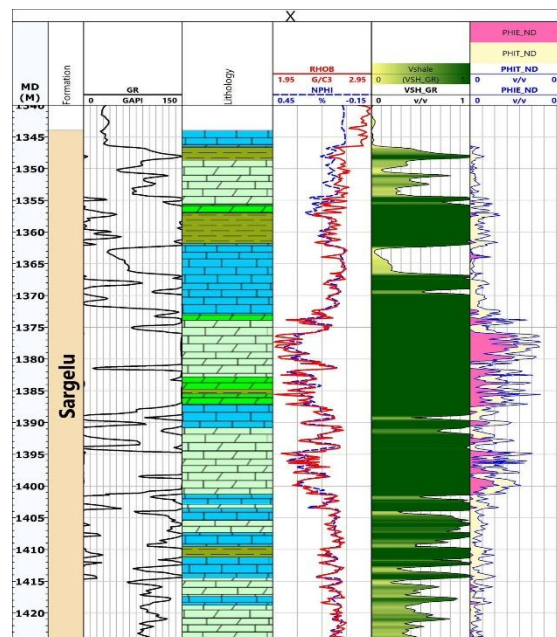


Fig. 11: Well log interpretation of the Sargelu Formation (1345–1420 m). Clean carbonate zones with low shale content and high porosity indicate good reservoir quality.

The V_{sh_GR} track, derived from the GR curve, quantifies the shale content, with a scale ranging from 0 (clean rock) to 1 (100% shale). Dark green areas in the V_{sh_GR} track indicate high shale content, while light green or white areas represent lower shale content. The alternating high and low GR values reflect lithological variability within the Sargelu Formation, which is characterized by interbedded shale and carbonates. Shale-rich intervals may act as barriers or seals for hydrocarbons, whereas the cleaner carbonate layers likely represent potential reservoirs, especially if enhanced by natural fractures. This interpretation aligns with the Sargelu Formation's role as both a source and reservoir rock in the Jurassic petroleum system. Figure 11 provides a detailed well log interpretation for the Sargelu Formation, focusing on effective porosity (PHIE) and other reservoir properties. The left track shows neutron (NPHI_D, in blue) and bulk density (RHOB, in red) curves, which are essential for lithological identification and porosity estimation. Deviations between these curves often indicate gas presence or changes in lithology. The middle track includes the gamma-ray (GR) curve and the derived shale volume (V_{sh_GR}), where green shading highlights shale content, and lighter areas

represent cleaner lithologies, such as carbonates. The right track displays total porosity (PHIT_ND, in blue) and effective porosity (PHIE_ND, in pink). Effective porosity (PHIE) represents the interconnected pore spaces available for fluid flow, excluding isolated pores or clay-bound water. In contrast, total porosity (PHIT) includes both interconnected and isolated pores (Fig. 11). The Sargelu Formation shows variable effective porosity, with higher values corresponding to cleaner carbonate intervals and lower values in shale-rich zones with higher GR and V_{sh_GR} readings. This variability emphasizes the potential of the Sargelu Formation as a hydrocarbon reservoir, where intervals with higher PHIE are more favorable for hydrocarbon storage and flow, particularly in fractured or carbonate-rich zones.

The analysis of well log data in this study reveals that the Sargelu Formation exhibits notable variability in porosity and fluid saturation in Fig. 12. Specifically, the SW_AR (water saturation in the uninvaded zone) and SXO_AR (water saturation in the flushed zone) curves indicate significant hydrocarbon presence within the depth interval of 1385 to 1400 meters. In this zone, low SW_AR values suggest that the pores are predominantly occupied by hydrocarbons, while higher SXO_AR values reflect partial displacement of hydrocarbons by drilling mud filtrate in the flushed zone. These interpretations are based directly on the petrophysical analysis conducted. On the other hand, the resistivity logs (LLD and MSFL) confirm the presence of hydrocarbons in these zones, with high deep resistivity values correlating with lower water saturation. The distribution of moved hydrocarbons (green) and residual oil (brown) further supports the interpretation that the Sargelu Formation has experienced hydrocarbon migration and entrapment. Figure 12 displays that the Sargelu Formation exhibits good reservoir potential, with intervals of effective porosity and hydrocarbon saturation. Limestone intervals exhibit porosities ranging from 8% to 12% and permeability between 5 and 30 millidarcies, providing excellent reservoir characteristics. Porosity greater than 5% is significant, while more than 25% is exceptional porosity (Selley, 1998).

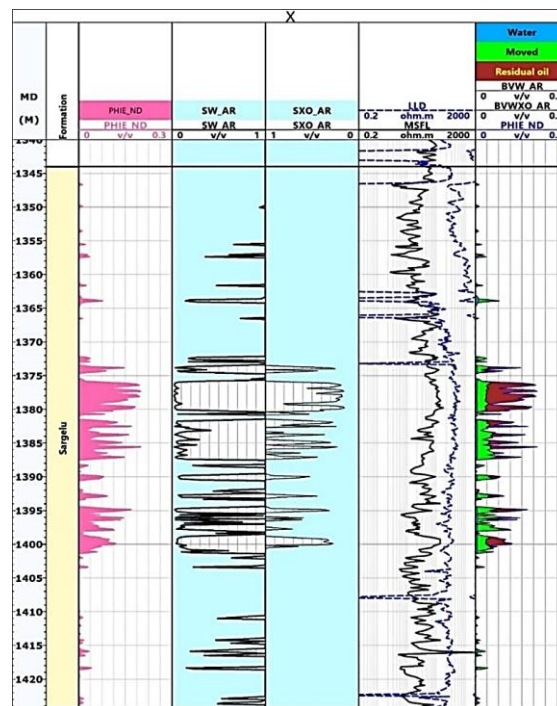


Fig. 12: Revised well log interpretation of the Sargelu Formation. The highlighted zone shows hydrocarbon presence characterized by low water saturation (SW_AR), higher flushed zone saturation (SXO_AR) indicating mud filtrate displacement, and high resistivity confirming hydrocarbon saturation.

The permeability-porosity crossplot indicates a logarithmic relationship between effective porosity (PHIE_ND) and permeability (K), where higher porosity generally results in increased permeability. The provided cutoff values—PHIE_ND = 0.03 v/v and SW = 0.24—help define productive reservoir intervals (Figures 13 and 14).

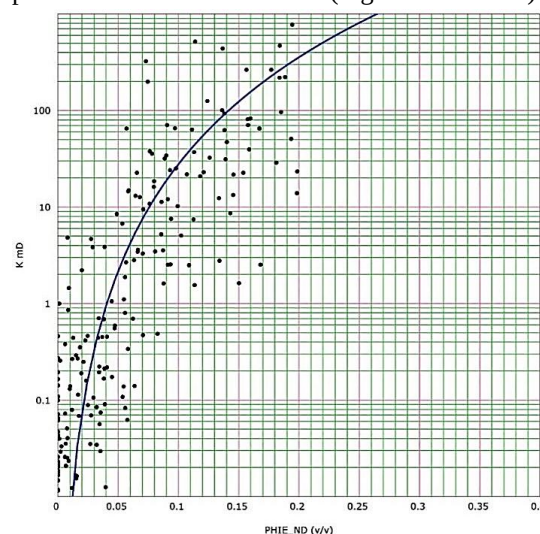


Fig. 13: Permeability vs. effective porosity (PHIE_ND) crossplot.

The cutoff values of $PHIE_ND = 0.03$ v/v and $Sw = 0.24$ were derived based on the data distribution and fitted trendlines observed in Figures 13 and 10, which represent crossplots of permeability vs. porosity and water saturation vs. porosity, respectively.

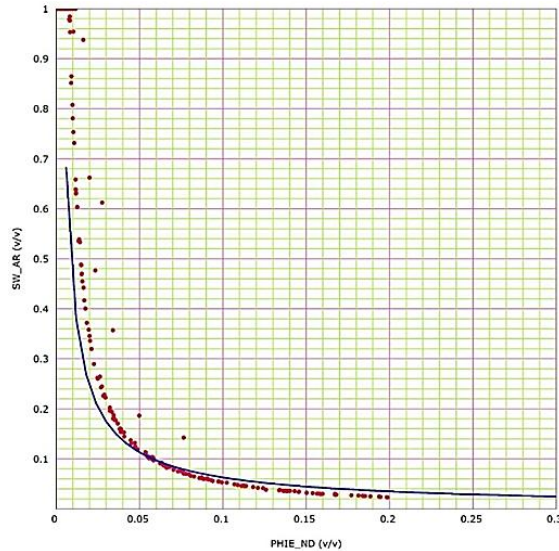


Fig. 14: Crossplot of effective porosity (PHIE_ND) versus water saturation (Sw) for the Sargelu Formation.

In Figure 13, the permeability (K) versus effective porosity (PHIE_ND) crossplot displays a strong positive correlation as porosity increases, permeability also increases, particularly beyond the 0.03 v/v threshold. Below this porosity value, permeability remains consistently low, often below 1 mD, indicating poor fluid flow capacity. However, once porosity exceeds 0.03 v/v, there is a marked increase in permeability, often surpassing 10 mD, which is indicative of effective reservoir intervals. This inflection point justifies using 0.03 v/v as the lower porosity cutoff for identifying productive zones.

Similarly, in Figure 14, which shows the relationship between water saturation (Sw_AR) and porosity, a clear inverse trend is observed: water saturation decreases as porosity increases. The majority of the data points fall below the Sw value of 0.24, particularly in the porosity range above 0.03 v/v. These low Sw values indicate reduced water content and higher hydrocarbon saturation, which are favorable for hydrocarbon production. The fitted curve reinforces this trend, further validating the $Sw = 0.24$ cutoff as an effective threshold for distinguishing between hydrocarbon-bearing and water-bearing zones.

Both cutoff values are not arbitrarily chosen but are empirically supported by the clustering and trends seen in the data. The intersection of porosity above 0.03 v/v and Sw below 0.24 marks the transition into zones with both sufficient pore volume and favorable fluid saturation, which are key indicators of reservoir productivity.

In Figure 15, the provided well log from the Sargelu Formation covers a depth interval from approximately 1345 m to 1415 m, and includes gamma-ray (GR), density (RHOB), neutron porosity (NPHI), and permeability (K) measurements. The gamma-ray log indicates moderate to high natural radioactivity, reflecting a sequence dominated by alternating shale and carbonate lithologies.

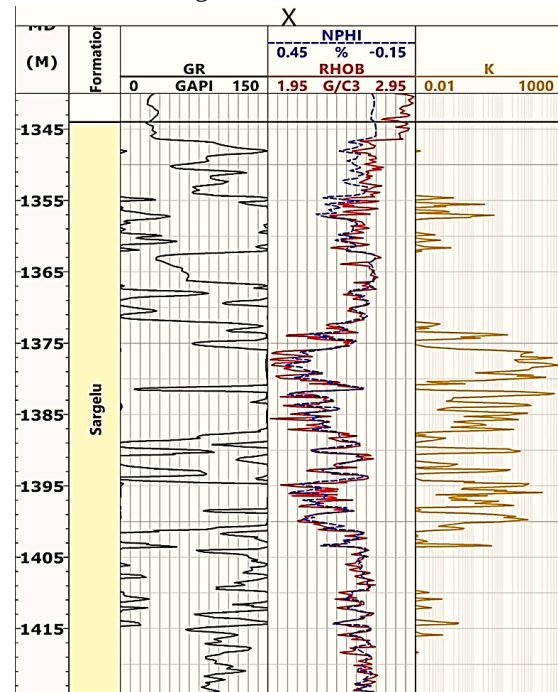


Fig. 15: Well log analysis of the Sargelu Formation showing gamma ray (GR), neutron porosity (NPHI), bulk density (RHOB), and permeability (K) curves.

The neutron and density porosity logs display variable separation, suggesting heterogeneous porosity typical of mixed carbonate-shale successions. Permeability is relatively low in the upper part of the interval, from 1345 m to about 1365 m, corresponding to tighter lithologies. Between 1365 m and 1385 m, permeability improves moderately, while the most significant and continuous permeability enhancement occurs between 1385 m and 1400 m. This zone likely represents cleaner carbonate beds or intervals affected by secondary porosity development such

as fracturing. Below 1400 m, permeability decreases markedly, indicating a transition to tighter, more shale-rich rocks. The Sargelu Formation in this section shows its best reservoir potential between 1385 m and 1400 m, while both the upper and lower sections are characterized by poorer reservoir quality.

Three RU zones refer to distinct reservoir units within the Sargelu Formation identified based on well log data. These zones are classified based on key reservoir characteristics, such as gamma ray values, porosity, bulk density (RHOB), and permeability.

RU-1: This is the first reservoir unit, characterized by moderate porosity and lower permeability compared to RU-2. While it may still contain hydrocarbons, its lower permeability suggests limited fluid flow capacity and potentially lower reservoir quality.

RU-2: This is considered the best reservoir unit, showing favorable characteristics such as lower gamma ray values, a strong RHOB-NPHI crossover (indicating good porosity), and higher permeability. These attributes suggest that RU-2 has significant hydrocarbon potential with good fluid flow capacity.

RU-3: This reservoir unit is similar to RU-1, with moderate to low porosity and permeability, but it may also exhibit some heterogeneity, which could affect its overall reservoir potential. Though it could contain hydrocarbons, the lower permeability and potential for variability make it less favorable than RU-2.

RU-2 appears to be the best reservoir zone due to lower gamma ray values, strong RHOB-NPHI crossover, and higher permeability (Fig. 16). RU-1 and RU-3 may contain hydrocarbons, but exhibit lower permeability and potential heterogeneity (Fig. 16).

Natural fracturing within the formation further enhances its capacity for hydrocarbon storage and flow. Renowned as one of the most significant Jurassic reservoirs in the region. The Sargelu Formation holds substantial hydrocarbon potential, particularly within its fractured limestone zones. Log-based indicators, including density-neutron crossovers, gamma ray lows, and sonic-density separation, further support the presence of fracture-enhanced porosity in the carbonate sections (Aqrawi et al., 2010). Structurally, the Sargelu Formation is situated within the High Folded Zone of the Zagros Fold-

Thrust Belt, where compressional tectonics have created extensive fracture systems in Jurassic carbonates (Garfunkel, 2004; Al-Ameri and Zumberge, 2012). Numerous regional studies have also recognized the Sargelu Formation as a key petroleum system element, acting both as a source and a fractured reservoir unit in northern Iraq (Jassim and Al-Gailani, 2006; Aqrawi et al., 2010; Abdula, 2020).

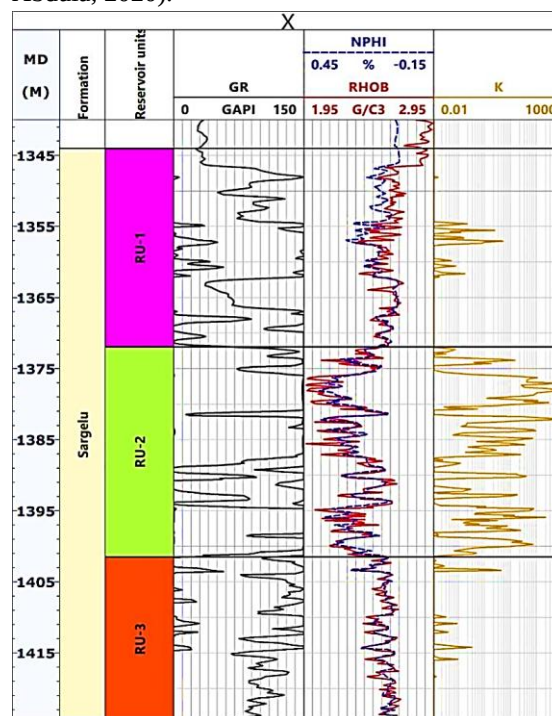


Fig. 16: Well log data of the Sargelu Formation with reservoir units RU-1, RU-2, and RU-3.

6. Conclusion

This study highlights the differing reservoir potentials of the Jurassic Sargelu and Mus formations in the Duhok region, as revealed through comprehensive petrophysical analysis. The Sargelu Formation stands out for its superior reservoir quality, particularly between 1385 and 1400 meters, where fractured limestones and interbedded shales exhibit high porosity, favorable water saturation, and enhanced permeability due to natural fracturing. Well log interpretations identify clean carbonate intervals within this depth range, which are likely to serve as productive hydrocarbon reservoirs. In contrast, the Mus Formation displays more lithological diversity, consisting mainly of limestone and dolomite, along with subordinate marl and shale. While some sections of the Mus Formation show moderate

porosity and resistivity values suggesting hydrocarbon potential, the increased shale content in other zones may hinder reservoir performance. Overall, the Sargelu Formation demonstrates more favorable reservoir characteristics than the Mus Formation, largely due to its cleaner lithology and greater fracture development. The integration of petrophysical data including porosity, resistivity, and lithological profiles offers valuable insights into reservoir heterogeneity and highlights promising zones for hydrocarbon exploration within the Jurassic stratigraphy of northern Iraq.

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8. Conflict of Interest

The authors declare that they have no conflict of interest.

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10. Author Contributions

Parween Ramadhan Abid performed analysis and conducted result interpretation and wrote the whole manuscript. Rzger Abdulkarim Abdula contributed to critically reviewing the manuscript and contributing ideas to improve the paper.

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تقييم جودة الخزن في تكوينات العصر الجوراسي (موس و سرگلو) في محافظة دهوك،

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الملخص

تبحث هذه الدراسة في خصائص أماكن التكوينات تحت السطحية الجوراسية، وتحديدًا تكويني موس وسارگلو في محافظة دهوك، ضمن إقليم كردستان العراق. ومن خلال تحليل بيانات مجسات الآبار التفصيلية من بئر X، تم تقييم الخصائص البتروفيزيائية الأساسية، مثل المسامية والنفاذية وتشبع الماء والخصائص الصخرية لتحديد المناطق المحتملة الحاملة للهيدروكربونات. يتميز تكوين سارگلو، الواقع بين أعماق 1345 و 1420 مترًا، بخصائص صخرية غير متجانسة تهيم عليها أحجار جيرية متشققة متداخلة مع طبقات الصخر الطفل الصفحي. ويكشف هذا الفاصل عن قيم مسامية فعالة تصل إلى 18%، ونفاذية متزايدة نتيجة التشقق، وتشبع مائي مناسب، خاصةً بين 1385 و 1400 مترًا. في المقابل، يتكون تكوين موس، الواقع بين 1875 و 1925 مترًا، بشكل أساسي من الحجر الجيري والدولوميت مع أنماط متفاوتة من المسامية والمقاومة. تشير تفسيرات المخططات المتقاطعة ومخططات بيكيت إلى احتمال وجود هيدروكربونات على الرغم من محدودية الأدلة المباشرة من مؤشرات الغاز. بشكل عام، يتميز كلا التكوينين بجودة خزن كبيرة، وإن كانت متفاوتة، تتحكم فيها التباينات الصخرية، ودرجة التشقق، وتوزيع المسامية، ومحتوى الصخر الطفل الصفحي. يوفر التحليل البتروفيزيائي المتكامل فهماً أعمق لسلوك الخزانات الجوراسية في هذه المنطقة غير المستكشفة نسبيًا في شمالي العراق.

الكلمات المفتاحية:

خصائص البتروفيزيائية، جودة الخزانات، الجوراسي، تفسير مجسات الآبار، المسامية، النفاذية.

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