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# PETROPHYSICAL EVALUATION OF THE UPPER QISHN CLASTIC RESERVOIR IN SHARYOOF OILFIELD, SAYUN-MASILAH BASIN, YEMEN

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## ABSTRACT

The underneath Upper Qishn clastic sediments, which they revealed in the Sharyoof oilfield have been perfectly investigated. The Upper Qishn clastic reservoir petrophysical properties such as the saturation and porosity were evaluated utilizing well logs data. The findings were used to assess the importance of the reservoir and hydrocarbon capacity. The Upper Qishn Clasty lithology has been estimated utilizing well logs, which they infer that the lithofacies of this interval consists mainly of carbonate, sandstone, and low-shale intercalation. The wireline logging data had been carefully evaluated during the processing of the data; therefore, data quality was thought to be good. The findings from the porosity reservoir tested for six wells indicate an overall average porosity of 14.62% to 24.2%, while the relative permeability is 11.98% to 18.2%. Nevertheless, the water saturation of the reservoir varies from about 50 to 84.1%. Saturation of hydrocarbons, on the other hand, is in reverse relation to saturation of water. Based on the on these investigated outcomes, this reservoir interval is interpreted as an excellent reservoir with high median of efficient porosity reach to 20% and high hydrocarbon above 50 %. The Upper Qishn clastic reservoir demonstrates excellent potential of the reservoir, particularly the topmost reservoir component to be properly considered in upcoming oilfield development. In the Upper Qishn clastic reservoir, the hydrocarbon saturation map shows an ordinary distribution pattern, with an overall rise to the north - west, and east direction, as they decrease into southwestern wards.

**Keywords:** well logs; petrophysical evaluation; reservoir characterization; sharyoof oilfield; sayun–masilah basin; Yemen

## INTRODUCTION

Drilling for hydrocarbons in Yemen began in 1961 with the first industrial discovery by Hunt Oil in 1984 in the Ma'rib Al-Jawf Basin in central Yemen. Operations extended to the East of Yemen with several explorations produced in the Say'un-Masilah basin by Nexen and Total companies. The Say'un-Masilah rift basin is a symmetrical graben made up of mid Jurassic to Paleocene sediments, which overlie Pre-Cambrian igneous and metamorphic rocks. Producible quantities of oil are found in several different reservoirs, including Pre-Cambrian/Achean granitic/metamorphic basement, Lower Cretaceous Saar Formation carbonate and dolomites and Lower Cretaceous Qishn Formation Clastics sandstone deposit. The Qishn Formation is split up into two subunits (members) from bottom to top, lower Qishn clastics and Upper Qishn Carbonates. The Qishn clastics member is largely composed of shallow marine sandstone and mudstone in east of basin and fluvio-deltaic sands, silts deposits in west of basin [1-2]. The clastic member and lower carbonate considered oldest members where they are equivalents in ages and horizontally facies. The classic member located in the west of Yemen, while the lower carbonate is better produced in the east was the best member studied well. In the Jeza-Qamar Basin, the change between the two members is seen. The middle bed is a shallow portion, regional widespread faces that are thought to contribute to a maximum flood area. The most successful regional reservoir is the upper Qishn clastics Member. Several development wells have now been drilled on the Sharyoof structure. These regionally extensive fluvial/tidal to near shore marine sand deposits generally display excellent reservoir properties, with porosities averaging 20-23% and permeability averages often exceeding 1 Darcy. The Sharyoof oilfiled is located on the northern part of Say'un Masilah Basin as in (Figure-1). The purpose of this research is to utilize petrophysical log data to qualify and calculate upper Qishn clastics reservoirs to assess Sharyoof oilfield future performance in the Say'un Masilah Basin.

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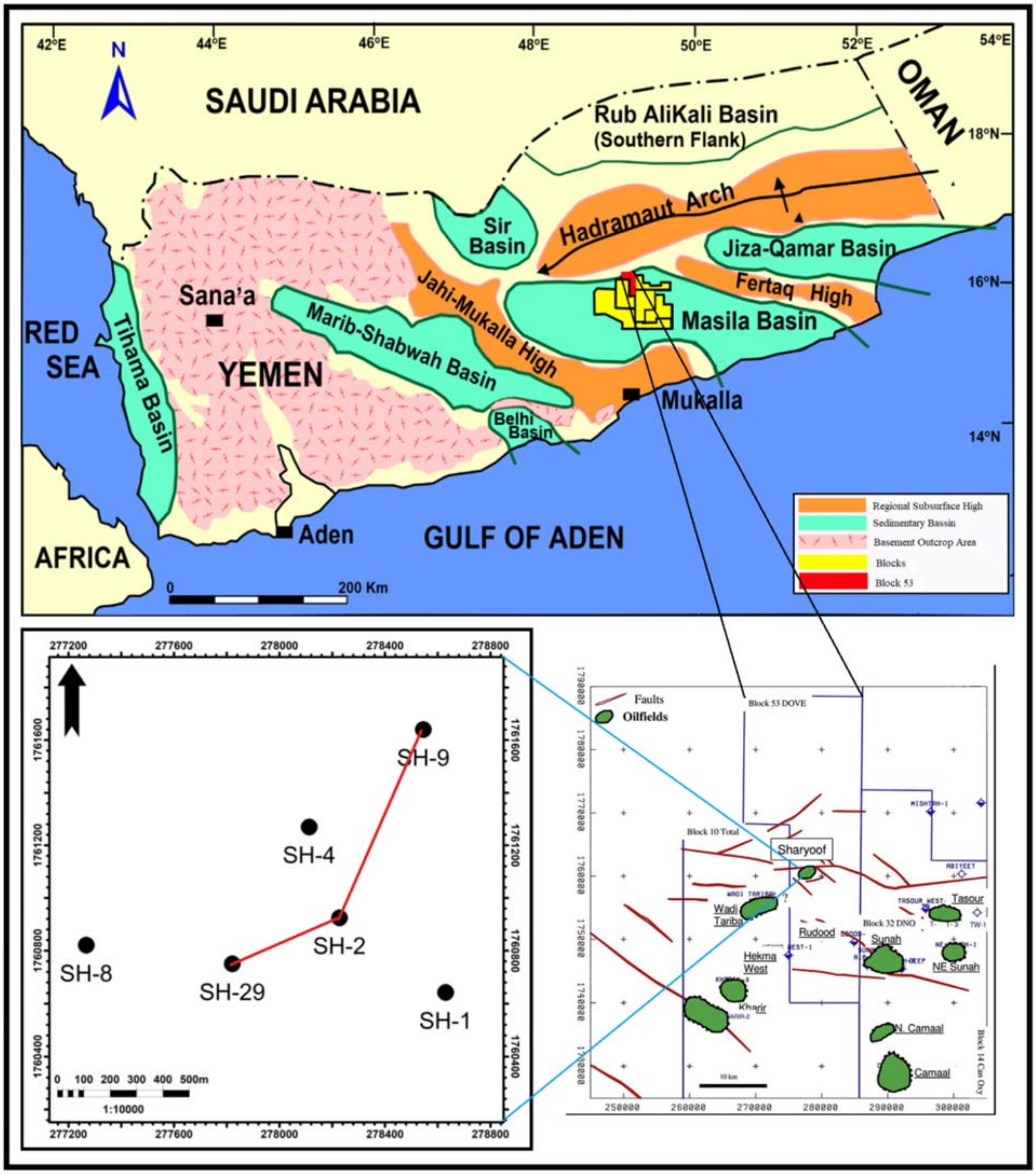


**Figure-1.** Location map of Sharyoof oilfield, showing the wells location (Block 53).

## GEOLOGICAL SETTING AND LITHOSTRATIGRAPHIC FRAMEWORKS

The structural analysis of Yemen 's petroleum basins primarily illustrates Gondwanaland's Mesozoic separation. Interior basins developed throughout most important rifting activities in the Late Jurassic and Early Cretaceous. The previous structures in the Oligocene and Miocene were overprinted and new structures were created through expansion following the opening of the Aden Gulf. [3]. Throughout two distinct rifting events, the Mesozoic basins formed in Yemen. The first activity was during the Kimmeridgian and Berriasian periods and followed the Hauterivian-Barremian warm settlement period and subsequent rifting event [4]. The basins appeared to be open from west to east, with a Ma'ribe-al-Jawf basin dominated by the early Cretan basins of late Jurassic and the Say'un-Masilah and Jiza'-Qamar basins, which were gradually filled with younger sediments. The structural trends of the Sayun-Masilah Basin are defined by NW-SE and ENE-WSW oriented faults. Both pre-and syn-ripening sediments were deposited as source and reservoir rocks, which developed traps throughout rifts in horsts and tilted faults blocks (Figure-2). In the Say'un-Masilah Basin, industrial production is primarily made from early Qishn cretaceous sands captured in suspensive rotated failure blocks with tightly screened Qishn formation clay. The accumulations are obtained from Jurassic marine shales in neighboring down-faulted lows, which permitted hydrocarbons migration into the covering and nearby reservoirs. The Qishn clastic member was deposited in a, shallow sea to innermost neritic marine phase atmosphere in the graben. Petroleum scientists have formally divided the Upper Qishn Clastics Member into three segments: top (S1), core (S2) and basal (S3). The nomenclature is used for the actual location of sandstone bearing oil, i.e. S1 , S2 and S3 responding to sandstones discovered throughout drilling, respectively, in the first, second and third reservoir. The upper Qishn clastics member in Sharyoof oilfield is divided into S1A, S1B, S1C, S2 and S3. The main reservoir across the Sharyoof oilfield is the S1A, which has delivered 90% of oilfield production to date.

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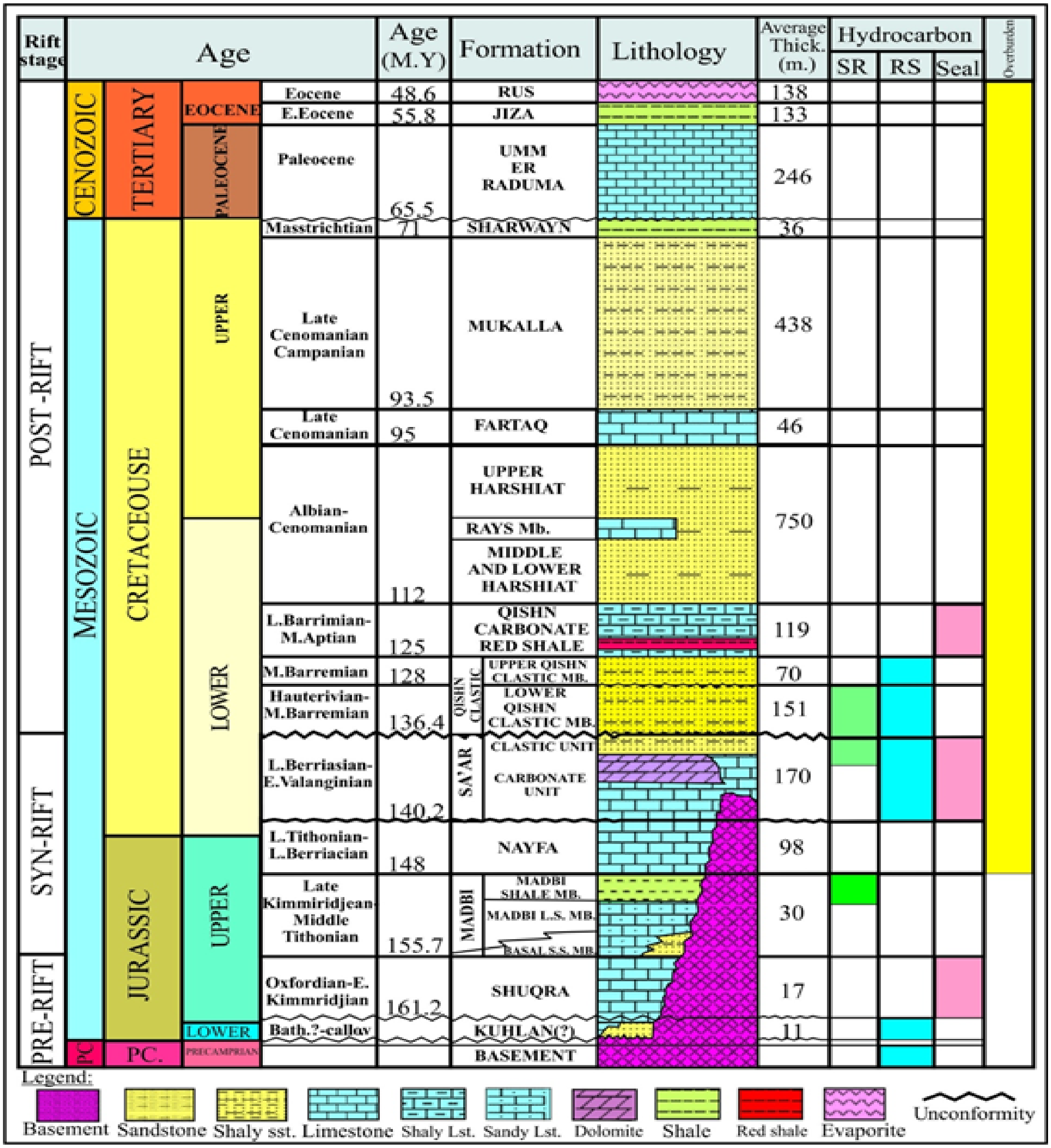


**Figure-2.** Lithostratigraphic subdivision of the Sayun-Masilah Basin, Yemen [5].

## MATERIALS AND METHODS

The available open-hole wireline log data of six wells (Sharyoof-1, Sharyoof-2, Sharyoof-4, Sharyoof-8, Sharyoof-9, and Sharyoof-29) were made accessible by Data Bank Development Project (DBDP). Based on the different log forms (Figure-1), these wells covering the study area were chosen. The existing well logs include gamma ray (GR), density compensated (RHOB), caliper (CAL), porosity (NPHI), sonic (DT), shallow and deep resistivities, spontaneous potential (SP), and compensated neutron. These logs data have been edited for quality checked and corrected the environmental setting then compared for depth relationship before processing and interpretation. In addition to the units of interest within the field, a complete petrophysical assessment was conducted using a variety of quantitative and qualitative well logging methods.

A flow chart (Figure-3) shows the implemented methods for petrophysical analysis. A Well log correlation was generated to show the general dissemination of the

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reservoir components in the Sharyoof oilfield. The logs were used to describe the composition lithology and the log correlations in the field of study. The petrophysical analysis of the well logs has been achieved using Techlog$^{TM}$ (Version 2015.3) of Schlumberger Inc. The Upper Qishn reservoir parameters obtained from the well logging data involve the total thickness, shale volume, calculate and distribution of effective porosity, water and hydrocarbon saturation.

There are a lot of ways to determine lithology from logs using some types of cross plots. These cross plots combinations were discussed in [6-7]. A range of qualitative and quantitative methods are used to measure the different lithological components of the upper classical Qishn reservoir. A good match between the outcomes of both methodologies is recognized.

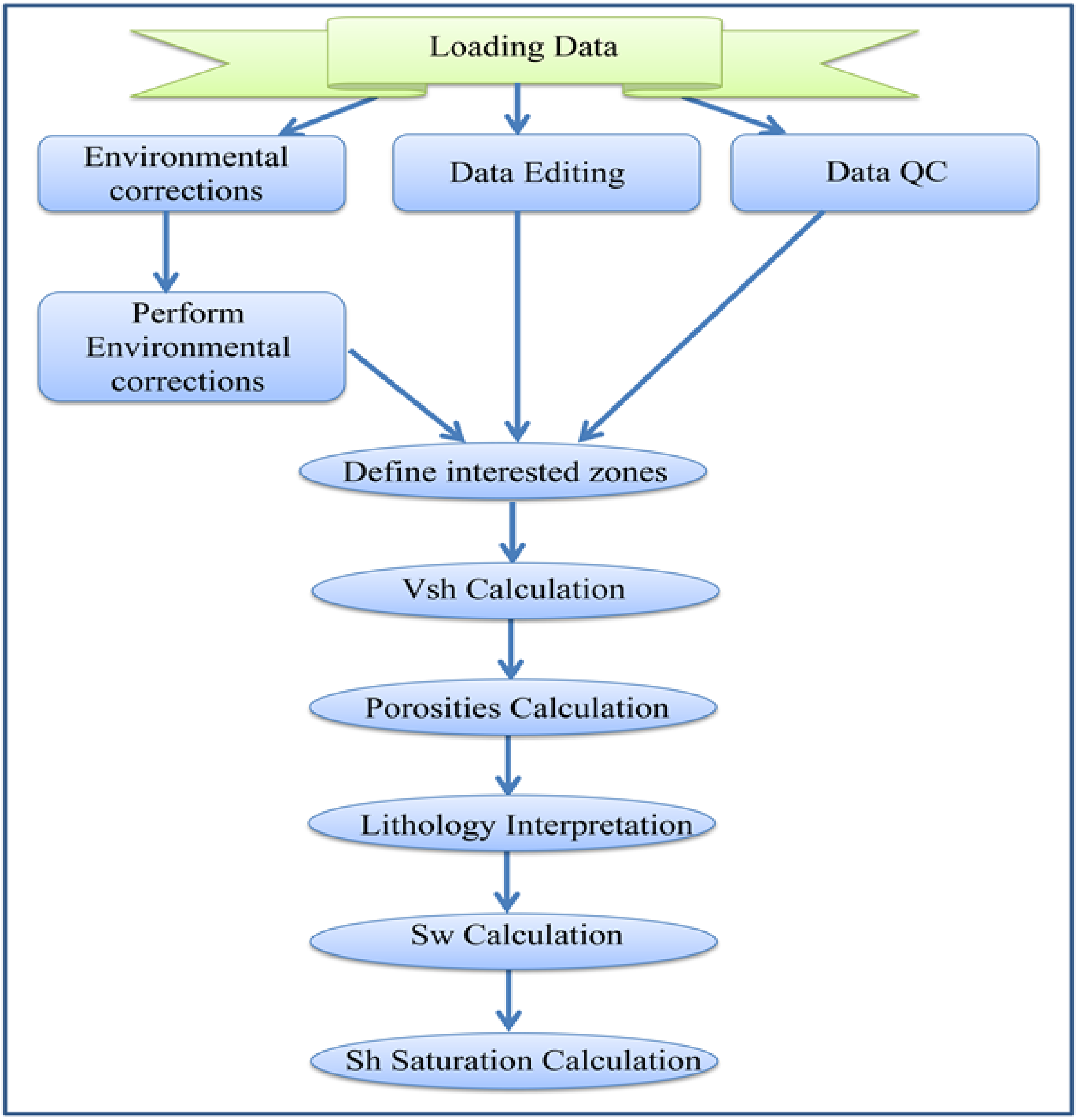


**Figure-3.** A flow chart shows the implemented methods for petrophysical analysis.

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The volume of shale (Vsh) can calculated using single clay volume indicators, e.g. gamma ray, Spontaneous Potential, Neutron or resistivity logs and double curve indictor. At each level, the lowest value was considered as the optimal shale volume value. For each zone in each well, a matchless clean zone shale value was selected for GR, SP and RLLD.

The PHIE was based on a shallowly corrected lithology model based on PEF, density, and neutron data. The neutron log assesses a liquid - filled porosity, while density logs estimate the total rock density, including its solid matrix [8-9]. The procedure is quite applicable to a broad variety of sedimentary rock types. Results were dependent on shale volume and density, and neutron shale properties were selected for calculation. The cut-off also helped in determining more suitable opportunities in the development of reservoirs [10-12].

The calculation of the hydrocarbon saturation is depending on the uninvaded zone and flushed zone. In the uninvaded zone, it is devoted as (SWE), whereas in the flushed zone it is referred to as (Sxo).

## RESULTS AND DISCUSSIONS

### Well Logs Correlation

For the stratigraphic comparison of the subunits in the study area, an NE–SW well log correlation (Lithostratigraphic cross-sectional traverse shown in Figure-4) was established (Figure-1). Such tops have been established by closely observing the log signature of various log matches. This comparison indicates the lithological character changes or any split in the continuity of deposition. This section shows the similarity of stratigraphic units and represents variation of thickness. Borehole data from five composite logs are used to create a correlation chart. The correlation chart passes through Sharyoof-29, Sharyoof-2, and Sharyoof-9 wells (Figure-4). The red shale unit used as datum plane for correlation. The chart shows two main units; they are Qishn carbonate and Qishn clastic. Qishn clastic unit is subdivided into four subunits (S1A, S1B, S1C and S2). Qishn clastic consists mainly of sandstone, siltstone, especially in subunits S1A with subordinate intercalation of shale.

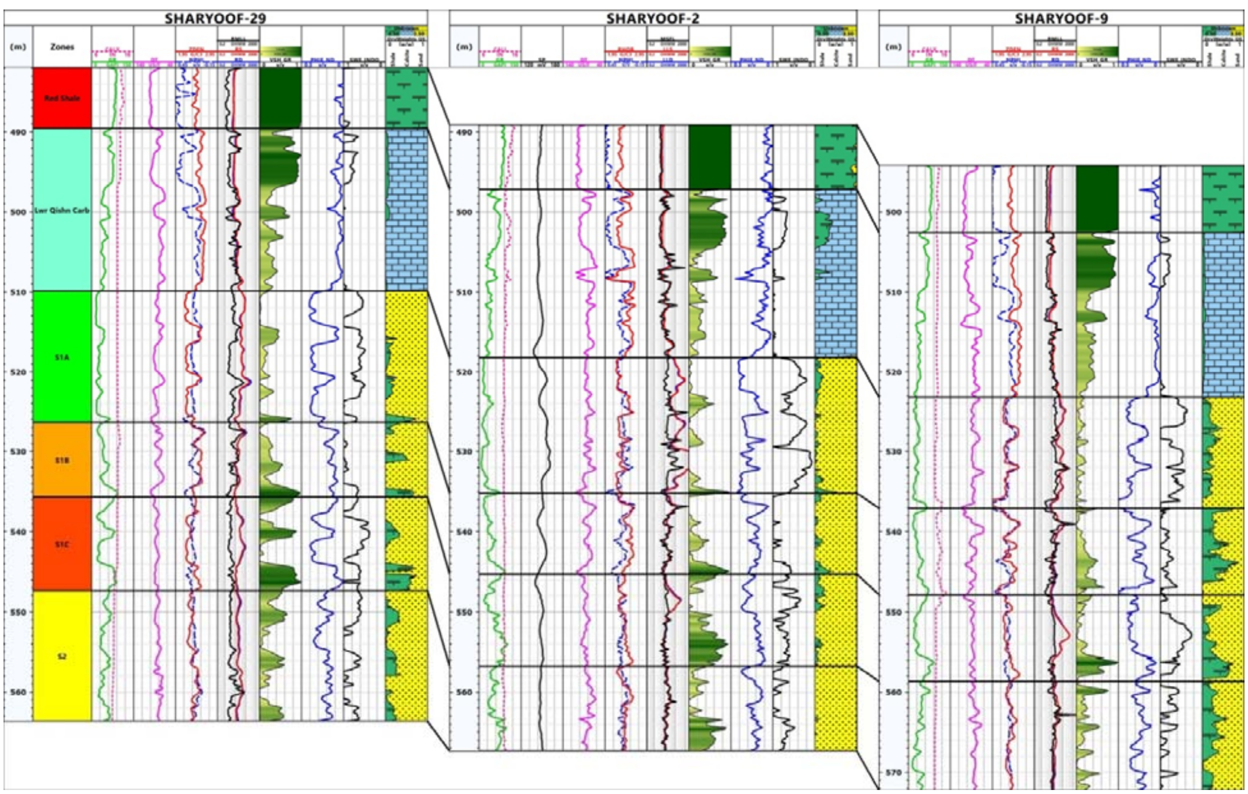


**Figure-4.** Correlation chart passes through Sharyoof-29, Sharyoof-2, and Sharyoof-9 wells in Sharyoof oilfield.

### Components of Lithology and Mineralogy

Various cross-plots clearly define the definition of the matrix components, where different matrix forms occur through the combination of different logs. The cross plots of binary and triporosity logs are convenient to display both porosity and lithology information. Different cross-plots were applied in this work to explain the Upper Qishn clastic reservoir lithological and mineralogical components.

### M–N Cross-Plots Identification

The M - N cross-plot technique is an effective lithology determination technique. It is based on the organization of three parameters of porosity. The values lie on the vertical vertices of the triangle in a ternary

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framework triangle with the three members ' mineralogies. The location of each object shows the mineral mixture of each element.

(Figure-5A) shows the mineralogical composition of the Upper Qishn clastics S1A reservoir. The predominant points are distributed between quartz and calcite areas whereas as Sharyoof-29 indicates, they tend to be near to the quartz zone. This may reveal the sandstone presence reservoir associated by calcareous cement. Some of the cross-plot points are distributed downwards due to shale. Moreover, the effect of gas appears in shifting the point of Sharyoof-29 well in the upright corner of the diagram. Also, some points (Sharyoof-1 and Sharyoof-2 wells) are distorted upwardly due to the secondary porosity. The M-N cross-plots of the S1B reservoir of Upper Qishn clastics (Figure-5B) explain that most plotted segments are distributed between dolomite and calcite due to the shale impact. The other points were distributed across sandstone and limestone lines.

This indicates the lithology of Upper Qishn clastics S1B is shale interbedded with sand channels and small streaks of limestone. Some points (Sharyoof-9 well) are distorted upwardly due to the secondary porosity, gas, or salt effect.

The most values points are distributed very near to the sandstone line as Sharyoof-29 and Sharyoof-8 wells from the M-N cross-plots of the Upper Qishn groups (Figure-5C), even though the remaining points are tracked between sand stone and limestone. This means that the sandstone reservoir with certain calcareous strips is present.

The effect of gas appears in shifting some points in the upright corner of the diagram Sharyoof-29 well. In addition to the effect of anhydrite as shifting of some point (Sharyoof-1, Sharyoof-4 and Sharyoof-8 wells) downwardly. Moreover, some points are scattered downwards due to shale Sharyoof-9 well.

(Figure-5D) shows the mineralogical composition of Upper Qishn clastics S2 reservoir. The highest plotted points are scattered to fill the quartz region and the space in between quartz and calcite regions and they tend to be close to quartz region than calcite one. The creation of a sandstone reservoir with some calcareous strips is proposed. The effect of gas is strongly observed as shifting of points upwardly. In addition to the effect of the sulfur as shifting of some point (Sharyoof-4 and Sharyoof-8 wells) downwardly. Also, some points are scattered downwards due to shale effect (Sharyoof-4 and Sharyoof-9 wells).

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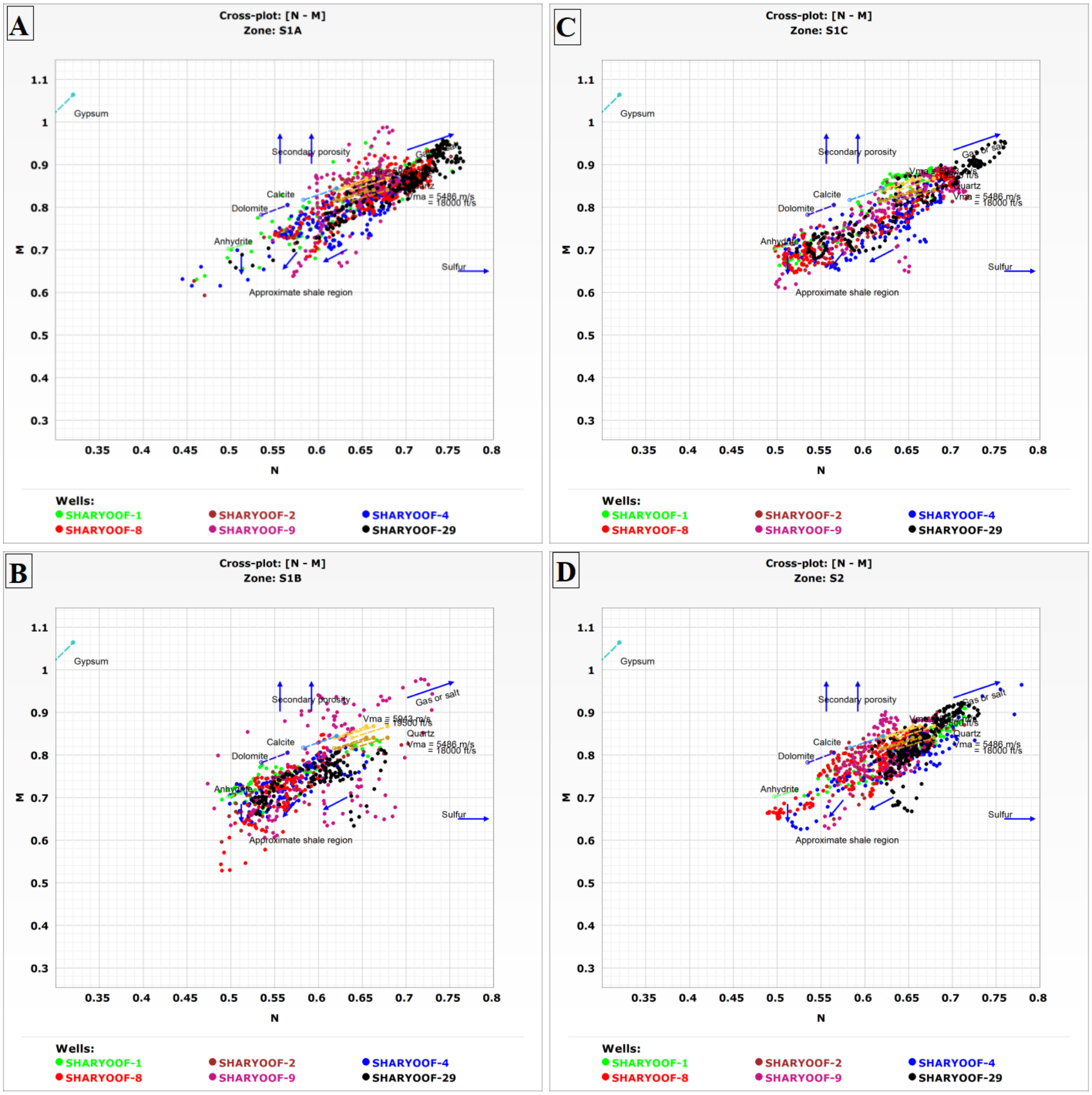


**Figure-5.** A) M-N cross plot for Upper Qishn clastics S1A reservoir, B) M-N cross plot for S1B, C) M-N cross plot for S1C and D) M-N cross plot for S2, in Sharyoof oilfield.

**Neutron-Density Cross-Plot**

The Dia-porosity cross-plots is common in well log analysis and quick look interpretation to draw cross-plots against different log driven parameters in order to identify the lithology and porosity in the formation. The Neutron-density cross-plots is considered the most widely used porosity log combination [9,13]. These cross-plots were accomplished for Upper Qishn clastics reservoir (S1A, S1B, S1C, and S2) in the wells analyzed as follow:

(Figure-6A) demonstrates the density-neutron cross-plots of Upper Qishn clastics S1A reservoir, the points between sandstone and claystone are noticed and porosity varied from 10% to 28%. This identifies the existence of lithology in the sandstone and calcareous matrix. The shift to the dolomite line may be due to the shale effect.

The Upper Qishn clastics S1B reservoir neutron-density cross plots (Figure-6B) show that the porosity is between 5% and 25%, most of the plotted points are distributed between the dolomite and the limestone line (Sharyoof-4, Sharyoof-8 and Sharyoof-29 pools) due to the shale impact. The other points spread along sandstone and limestone lines. It shows the existence of shale lithology combined with limestone and sandstone lines.

The Upper Qishn clastics S1C reservoirs density-neutron cross-plot (Figure-6C) for the shows porous area

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ranges from 10% to 25%, in which the majority of points are distributed along and closest to sandstone lines, in particular (Sharyoof-1, Sharyoof-4, Sharyoof-8 and Sharyoof-29), while the remaining points lie between sandstone and claystone. This shows the presence of a reservoir of sandstone with some limestone slices. Those points spread out along the Dolomite line are due to dolomite cement.

(Figure-6D) shows the neutron-density cross-plots of Upper Qishn clastics S2 reservoir, the preponderance of plotted points aggregates on sandstone line and in between sandstone and limestone lines, with porosity ranging from 10 to 27%. It indicates that the lithology is mainly sandstone with some calcareous cement. The shifting of some points towards the dolomite line may be due to shale effect.

We may ultimately realize from those cross-plots that the lithology of the Upper Qishn Clastics reservoir indicates that the primary lithology is carbonate cement sandstone. The four units of the Sharyoof oilfield Upper Qishn clastic formation are bearing hydrocarbons.

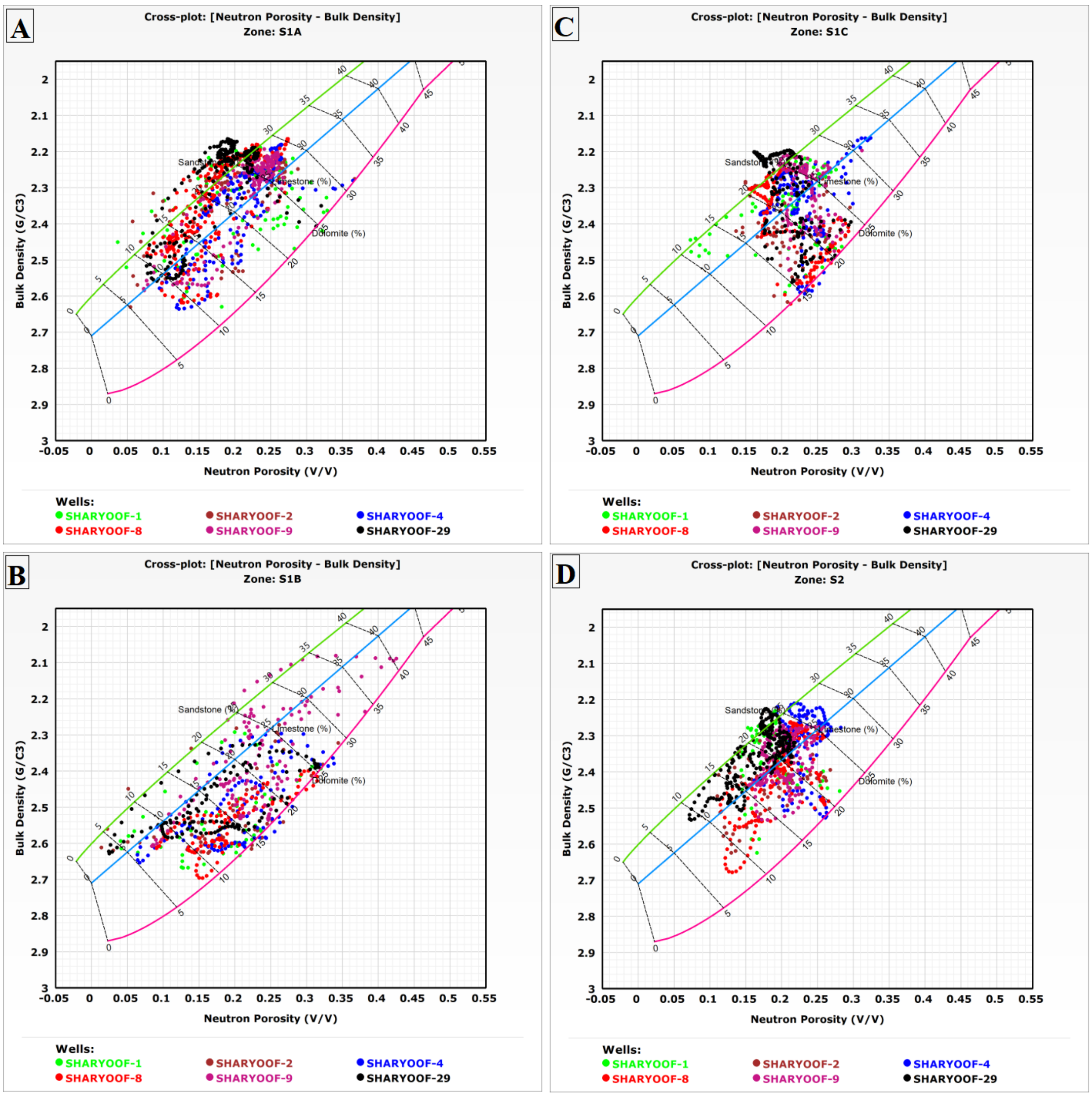


**Figure-6.** A) Neutron-density cross plot for Upper Qishn clastics S1A reservoir, B) Neutron-density cross plot for S1B, C) Neutron-density cross plot for S1C and D) Neutron-density cross plot for S2, in Sharyoof oilfield.

**Petrophysical Characteristics**

Hydrocarbon Evaluation of the reservoir rocks is depending on the results of well logging analysis carried out for the six wells in the study area. The analysis includes vertical petrophysical distribution and the horizontal iso-parametric configuration maps [14-16,11].

**Petrophysical Parameter Vertical Distribution**

The vertical distribution of the petrophysical factors achieved by the construction of the litho-saturated cross-plots in the region studied can be computed to show porosity concentrations, the shale thickness, water saturation and hence hydrocarbon saturation.

The litho-saturation cross-plots reflect the rock portion and its fluid content with the depth of the wells in an area that is prudent. The rock elements are clay, quartz, dolomite, and calcite while water and hydrocarbon saturation are part of the fluid content. These reservoirs characterization cross plots of S1A, S1B, S1C, and S2 reservoirs in the Upper Qishn clastics sequence of the three well in the study area are shown and interpreted in the following:

**Reservoir Characterization Of Sharyoof-2 Well**

The lithosaturation cross plot for the studied interval in the Sharyoof-2 well (Figure-7) displays that this interval extends from 1455.36 m. to 1472.36 m., the thickness of the Upper Qishn clastics S1A reservoir is 17 m. and the thickness of the net pay in Upper Qishn clastics S1A reservoir is 17 m. The net pay distributed in all zone. It shows that, the reservoir consists of mainly sandstone with minor streaks of Shale.

The gamma ray log shows in the S1A reservoir as low reading. The low gamma ray against the sand reflects the low amount of shale in Upper Qishn clastics at the pay zone. The neutron-density shows the mixed lithology from sandstone, siltstone, and shale. Sandstone increase in upper part of Upper Qishn clastics S1A reservoir and decreased at middle and increase in bottom of the reservoir. The resistivity log is generally characterized by relatively high resistivities reading that coincides with the major hydrocarbon interval. Reservoir quality was found excellent where multi hydrocarbon bearing intervals have been encountered.

The volume of shale varies from 0 % - 35 %, but the mean value is 6%. The effective porosity of the net pay S1A zone varies from 19% to 24%, but the mean value is 19.4%. The water saturation for Upper Qishn clastics S1A reservoir ranges from 8 % to 100 %, but the mean value is 34 %. The average hydrocarbon saturation for Upper Qishn clastics S1A reservoir is 65.7%. The average petrophysical parameters are presented as histograms in (Figure-8A).

The litho-saturation cross plot for S1B reservoir in the Sharyoof-2 well (Figure-7) shows that this interval extends from 1472.357 m. to 1482.455 m., the gross thickness of the Upper Qishn clastics S1B reservoir is 10.098 m. The net pay distributed in all zone. It shows that, the reservoir consists of sandstone with streaks of Shale. The volume of shale varies from 10 % – 96 %, but the mean value is 31.5 %. The effective porosity of net pay zones varies from 3 % to 23 %, but the mean value is 14.5 %. (Figure-8B) The water saturation for Upper Qishn clastics S1B reservoir ranges from 56 % to 100 %, but the mean value is 83.6 %. The average hydrocarbon saturation for Upper Qishn clastics S1B reservoir is 16.4%.

The litho-saturation cross plot for the S1C reservoir in the Sharyoof-2 well (Figure-7) display that this interval extends from 1482.455 m. to 1493.953 m., The gross thickness of the Upper Qishn clastics S1C reservoir is 11.498 m. It shows that, the reservoir consists of mainly sandstone with minor streaks of Shale.

The average petrophysical parameters are presented as histograms in (Figure-9A). The volume of shale varies from 5 % - 95 %, but the mean value is 8.2 %. The effective porosity of net pay zones varies from 5% to 22%, but the mean value is 19.6 %. The water saturation for Upper Qishn clastics S1C reservoir ranges from 32 % to 90 %, but the mean value is 44.9 %. The average hydrocarbon saturation for Upper Qishn clastics S1C reservoir is 55.1%.

The lithosaturation cross plot for the S2 reservoir in the Sharyoof-2 well demonstrate that the interval extends from 1493.953 m. to 1504.551 m., The gross thickness of the Upper Qishn clastics S2 reservoir is 10.598 m. The reservoir consists of mainly sandstone with minor streaks of Shale.

The volume of shale varies from 5 % – 88 %, but the mean value is 30.9 % (Figure-9B). The effective porosity of net pay zones varies from 7% to 22%, but the mean value is 13.6 %. The water saturation for Upper Qishn clastics S2 reservoir ranges from 48 % to 100 %, but the mean value is 79.5 %. The average hydrocarbon saturation for Upper Qishn clastics S2 reservoir is 20.5 % (Figure-9B).

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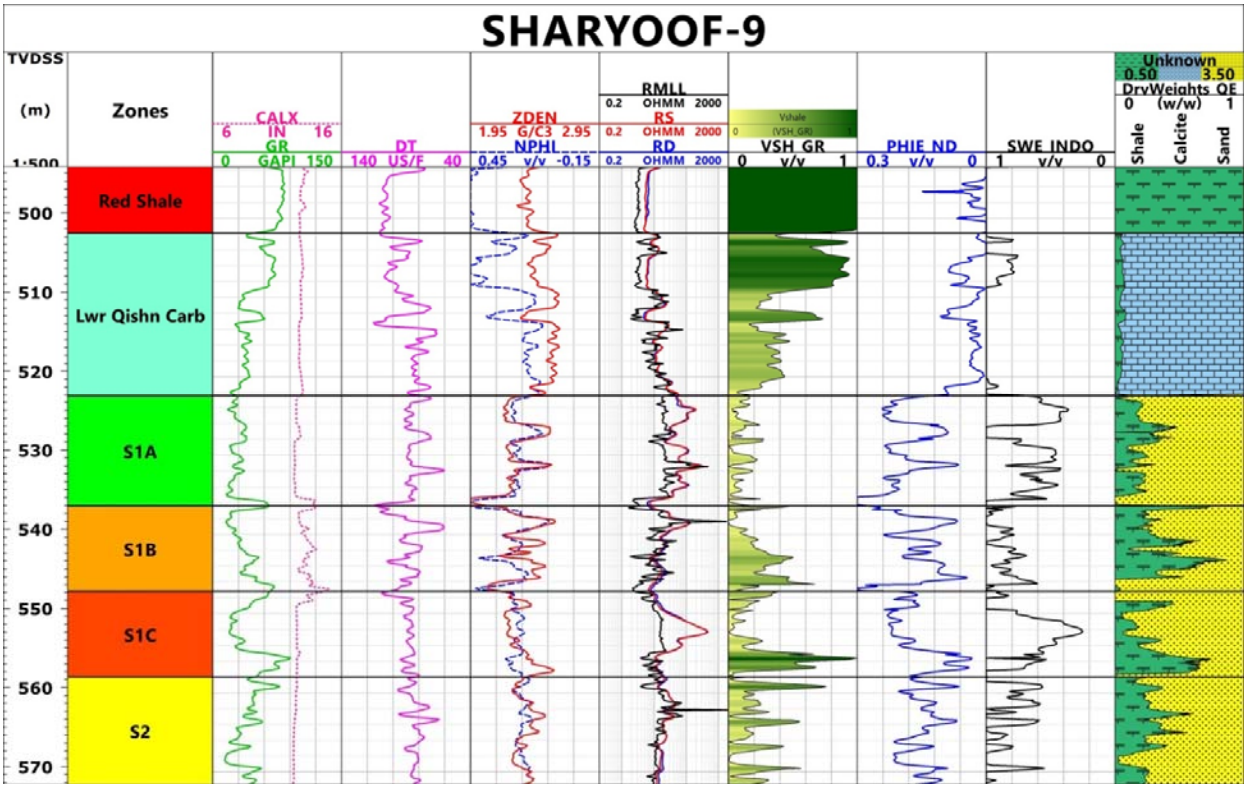


**Figure-7.** Lithosaturation cross-plot of the Upper Qishn clastics reservoirs in Sharyoof-2 well.

**Reservoir Characterization of Sharyoof-9 Well**

The lithosaturation cross plot for the S1A reservoir in the Sharyoof-9 well extends from 1452.5 m. to 1466.4 m. (Figure-10). The gross thickness of the Upper Qishn clastics S1A reservoir is 13.9 m. It shows that, the reservoir consists of mainly sandstone with minor streaks of Shale.

The volume of shale shows serrated signature typically of shaly sand along interval from 0 % - 25 %, but the mean value is 10.3 %. The effective porosity of the S1A reservoir varies from 13% to 24%, but the mean value is 20.3 %. The water saturation for the S1A reservoir ranges from 36 % to 100 %, but the mean value is 55.5 %. The average hydrocarbon saturation for the S1A reservoir is 44.5% (Figure-8A).

The lithosaturation cross plot for the S1B reservoir in the Sharyoof-9 well (Figure-10) illustrate that this interval extends from 1466.4 m. to 1477.2 m., The gross thickness of the Upper Qishn clastics S1B reservoir is 10.8 m. It shows that, the reservoir consists of sandstone with streaks of Shale.

The volume of shale varies from 10 % - 66 %, but the mean value is 31.3 %. The effective porosity of net pay zones varies from 4 % to 24 %, but the mean value is 14.2 %. The water saturation for Upper Qishn clastics S1B reservoir ranges from 55 % to 100 %, but the mean value is 78.2 %. The average hydrocarbon saturation for Upper Qishn clastics S1B reservoir is 21.8% (Figure-8B).

The lithosaturation cross plot for the S1C reservoir in the Sharyoof-9 well (Figure-10), shows that this interval extends from 1477.2 m to 1488 m. The gross thickness of the Upper Qishn clastics S1C reservoir is 10.8 m. It shows that, the reservoir consists of mainly sandstone with minor streaks of Shale.

The volume of shale varies from 3 % - 98 %, but the mean value is 12.9 %. The effective porosity of net pay zones varies from 5% to 23%, but the mean value is 19.8 %. The water saturation for Upper Qishn clastics S1C reservoir ranges from 25 % to 100 %, but the mean value is 49.2 %. The average hydrocarbon saturation for Upper Qishn clastics S1C reservoir is 50.8 % (Figure-9A).

The litho saturation cross plot for the S2 reservoir in the Sharyoof-9 well (Figure-10) show that this interval extends from 1488 m to 1501.6 m. The gross thickness of the Upper Qishn clastics S2 reservoir is 13.6 m. It shows that, the reservoir consists of mainly sandstone with minor streaks of Shale.

The volume of shale varies from 0.7 % - 75 %, but the mean value is 27 %. The effective porosity of net pay zones varies from 6% to 21%, but the mean value is 14.2 %. The water saturation for Upper Qishn clastics S2 reservoir ranges from 55 % to 100 %, but the mean value is 74.3 %. The average hydrocarbon saturation for Upper Qishn clastics S2 reservoir is 25.7 % (Figure-9B).

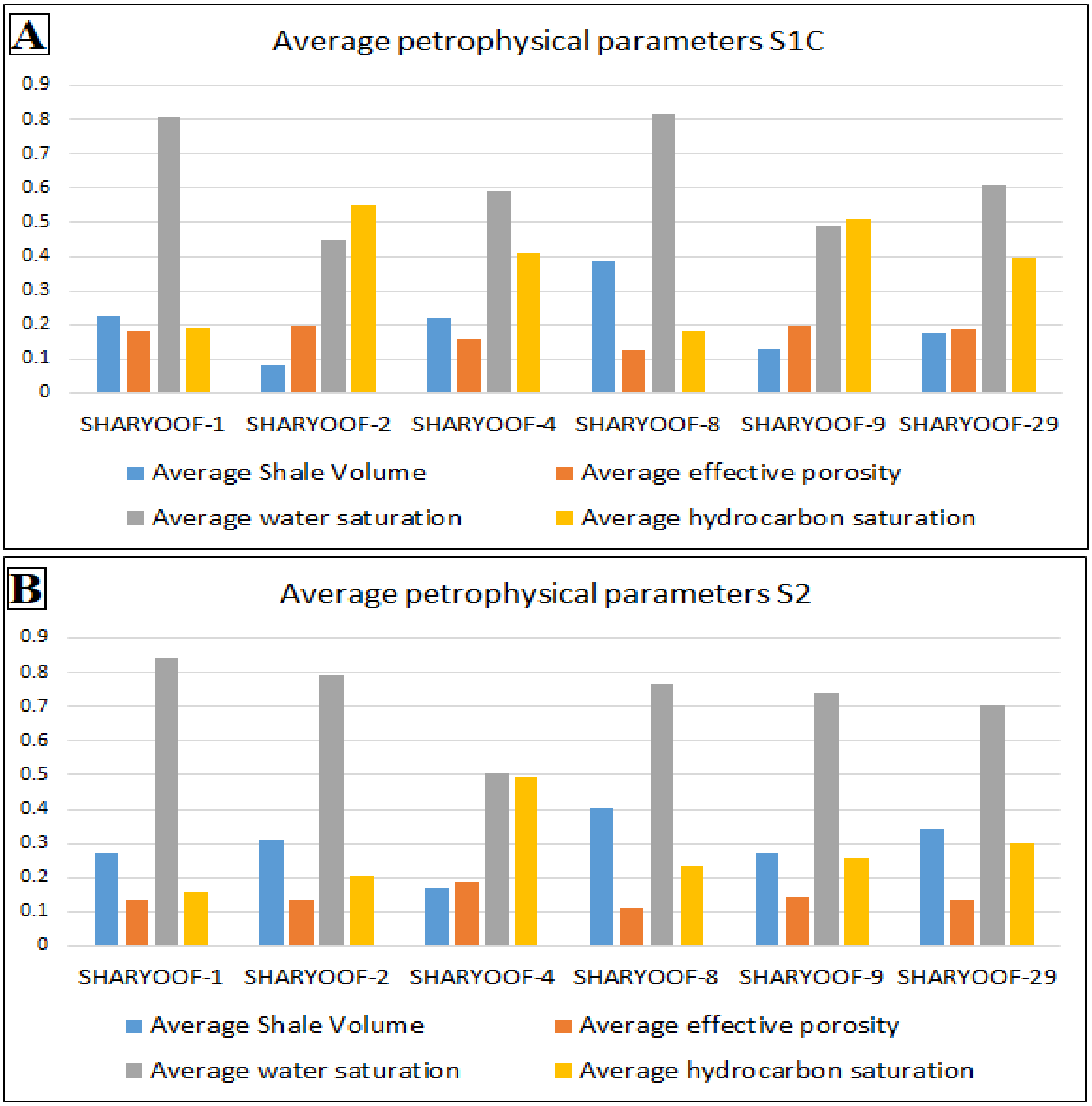


**Figure-8.** The average petrophysical parameters of the A) Upper Qishn clastics S1A reservoir and B) Upper Qishn clastics S1B reservoir, in Sharyoof oilfield.

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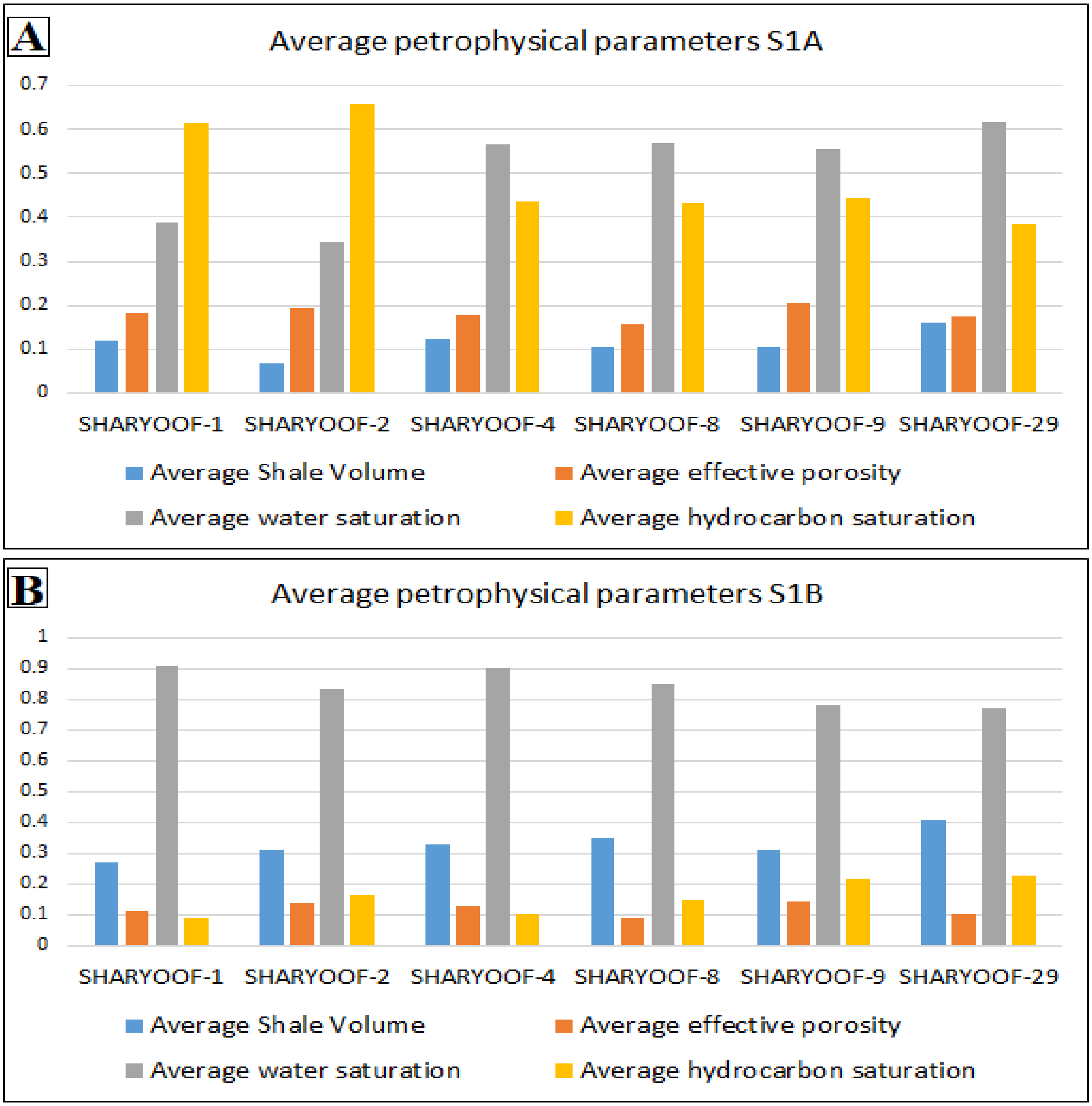


**Figure-9.** The average petrophysical parameters of the A) Upper Qishn clastics S1C reservoir and B) Upper Qishn clastics S2 reservoir, in Sharyoof oilfield.

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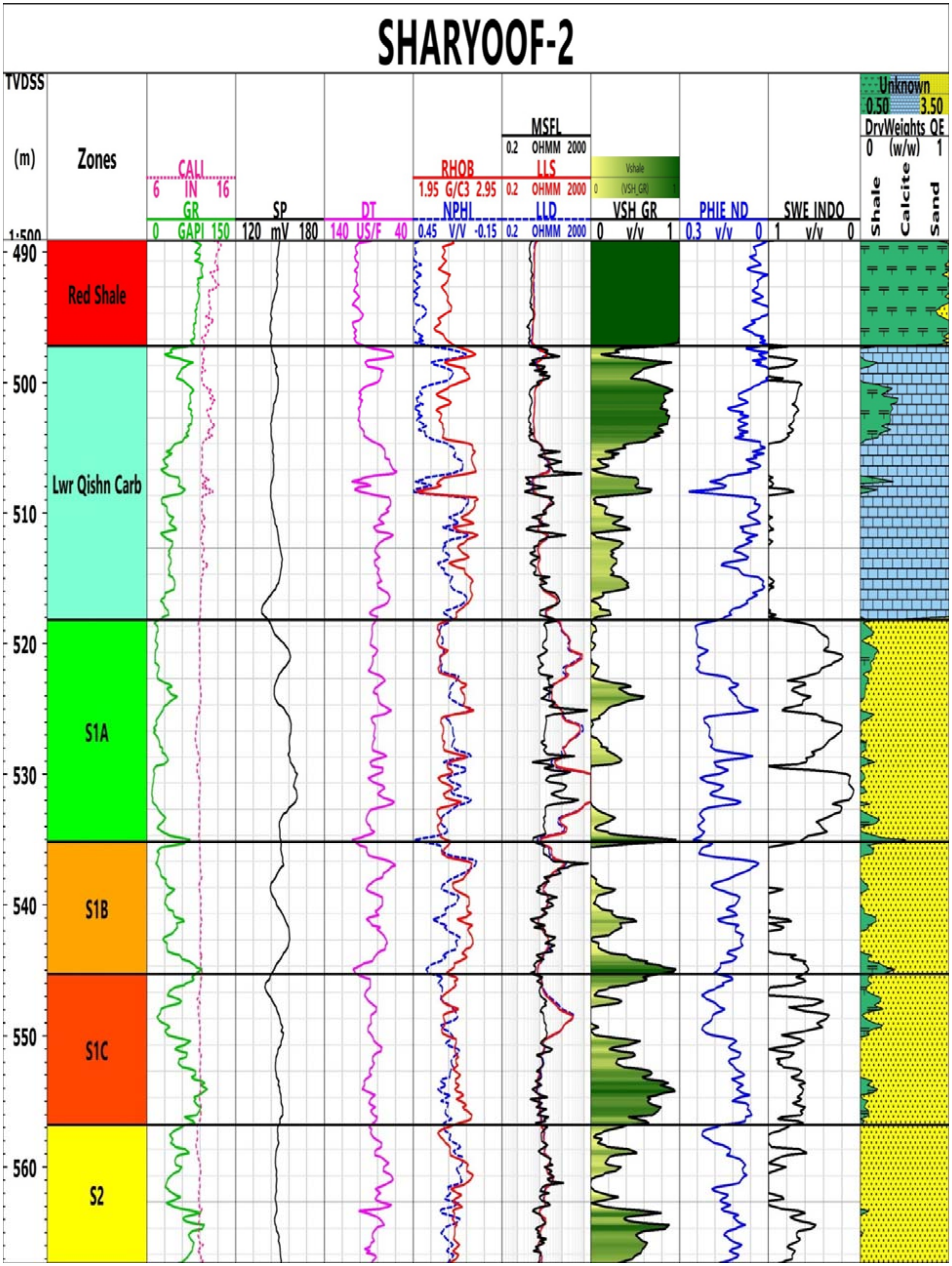


**Figure-10.** Lithosaturation cross-plot of the Upper Qishn clastics reservoirs in Sharyoof-9 well.

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**Petrophysical Parameter Horizontal Distribution**

The horizontal distribution of petrophysical parameters achieved by construct the isoparametic maps of the study area [17-18]. The mapping includes four reservoirs (Upper Qishn clastics S1A, S1B, S1C and S2) of different six wells in Sharyoof oilfield (Sharyoof-1, Sharyoof-2, Sharyoof-4, Sharyoof-8, Sharyoof-9 and Sharyoof-29).

**Reservoir Characterization of Upper Qishin Clastics S1A Reservoir**

The volume of shale values increases in the southern and northern directions while it decreases at east direction (Figure-11A). The effective porosity varies from 15 % at Sharyoof-8 well to 20.3 % at Sharyoof-9 well. It is increasing at northeast part and is decreasing toward western part, as displayed in (Figure-11B). Hydrocarbon saturation of Upper Qishin Clastics S1A Reservoir varies from 38 % around Sharyoof-29 well at the southwest to 60 % at Sharyoof-2 well, it shows increasing directions northeast and east wards and decreases in the northern and southern directions (Figure-11C). The net pay Sand of Upper Qishin Clastics S1A reservoir increasing in western direction and it is increase toward the middle part of the study area as shown in (Figure-11D). These maps show that the middle part of the study area is the best location to drill new wells.

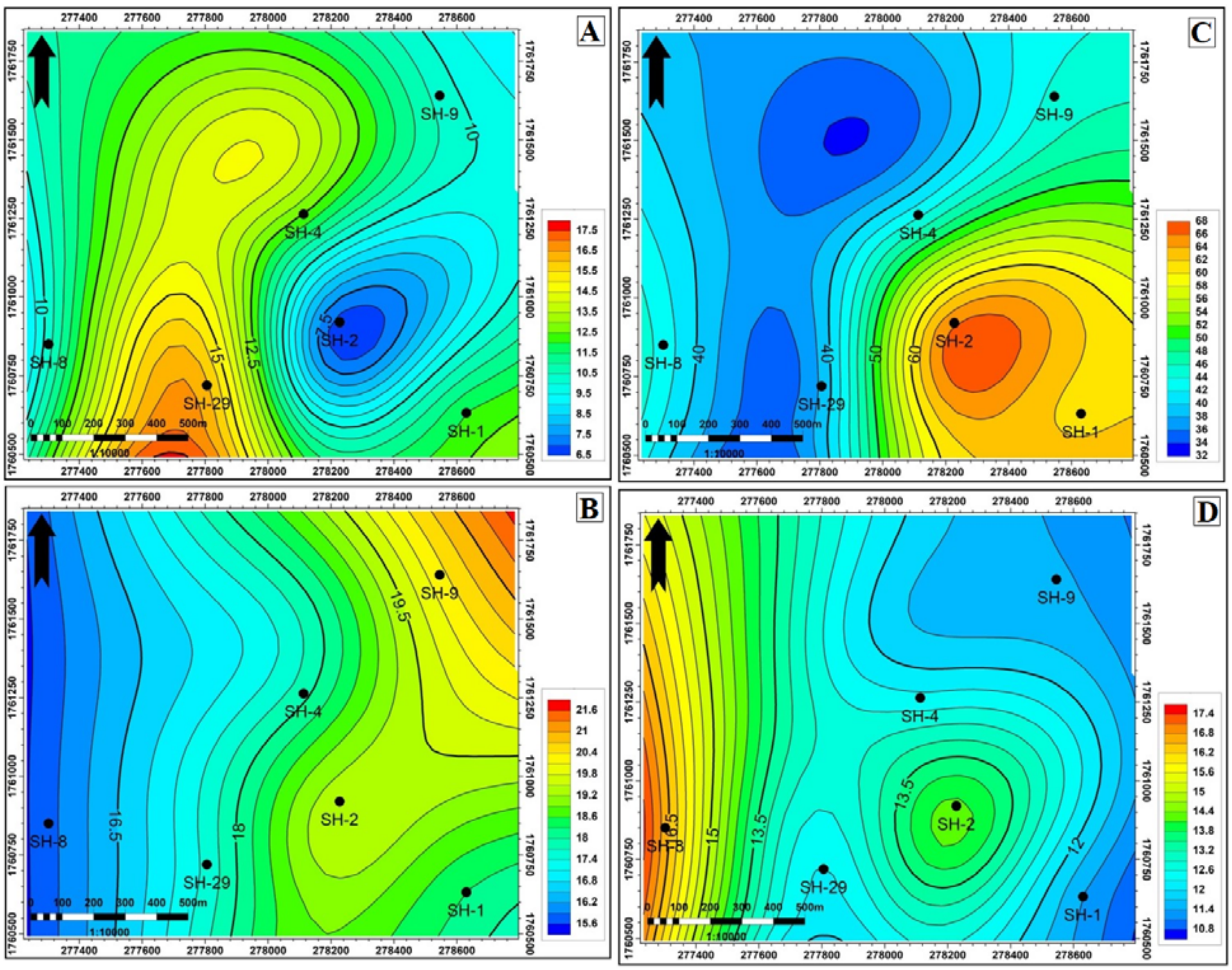


**Figure-11.** (A) Volume of shale, (B) Effective Porosity, (C) Hydrocarbon Saturation and (D) Net pay Sand in Upper Qishn clastics S1A reservoir in Sharyoof oilfield.

**Reservoir Characterization of Upper Qishin Clastics S1B Reservoir**

The reservoir characteristics is relatively looking like the same characteristics of S1A reservoir maps. The volume of shale increases in the southwest direction and a decreases in the east and north directions (Figure-12A). The effective porosity value increases in the central and north parts of the study area. Meanwhile it decreases at south west part (Figure-12B), and it varies from 9 % at Sharyoof-8 well to 14.2 % at Sharyoof-9 well. Hydrocarbon saturation distribution map (Figure-12C) shows that it increases in the northeast and south directions of the study area. The net pay Sand map (Figure-12D) shows that the distribution increases to the

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northeast and southeast directions in the study area. The Upper Qishin Clastics S1B Reservoir has minimum distribution, 0 m in west direction.

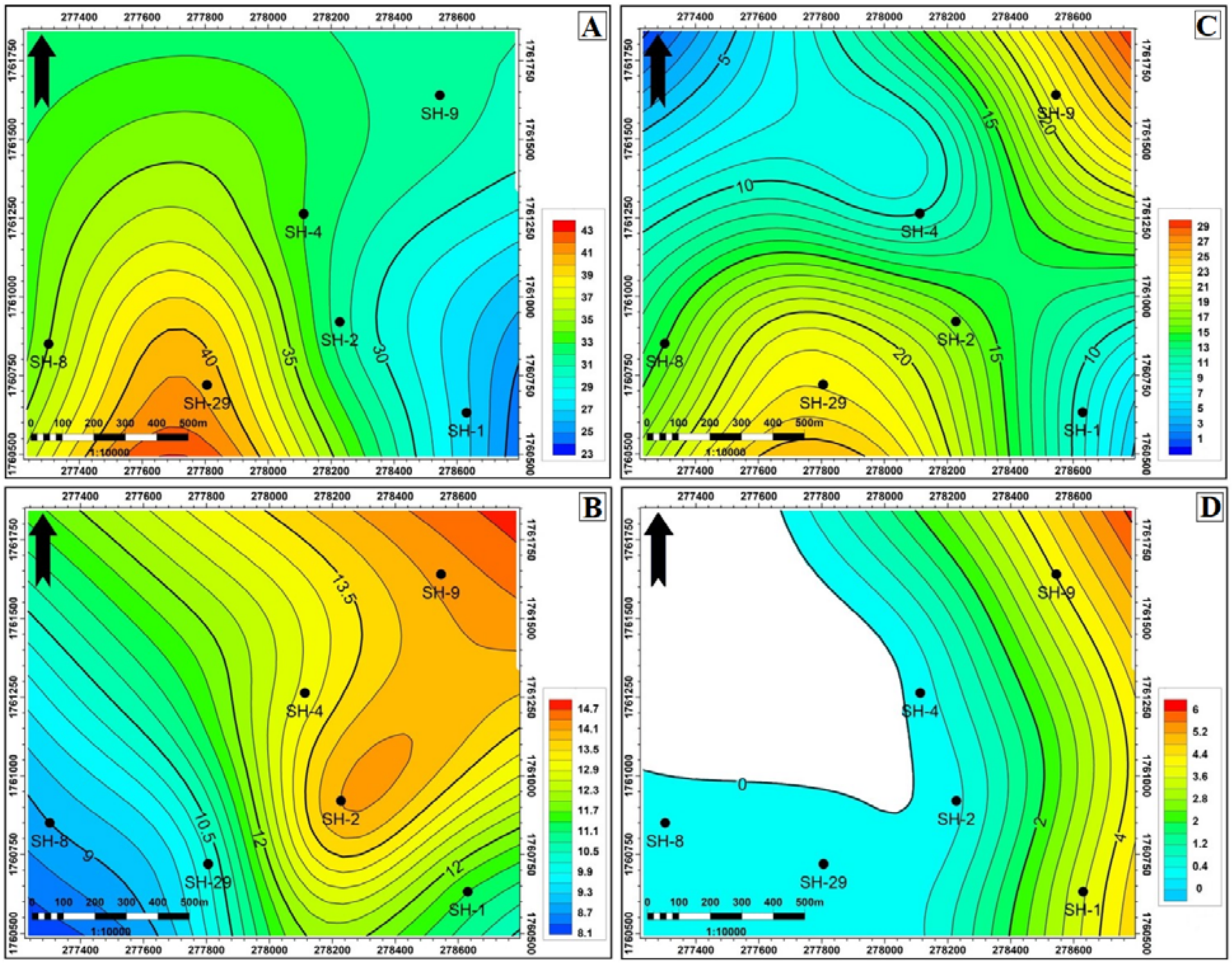


**Figure-12.** (A) Volume of shale, (B) Effective Porosity, (C) Hydrocarbon Saturation and (D) Net pay Sand in Upper Qishn clastics S1B reservoir in Sharyoof 0ilfield.

**Reservoir Characterization of Upper Qishin Clastics S1C Reservoir**

The volume of shale distribution map shows that Upper Qishin Clastics S1C of studied wells varies from 8.2 % at Sharyoof-2 well to 38.4 % in Sharyoof-8 well (Figure-13A). Shale volume is increasing gradually in the west direction. The effective porosity (Øeff) of Upper Qishin Clastics S1C reservoir changes from 12.3 % at Sharyoof-8 well to 19.8 % It increases toward northeast and south directions and is decreasing toward the northeast part (Figure-13B).

Hydrocarbon saturation of the Upper Qishin Clastics S1C reservoir fluctuates between 19 % around Sharyoof-1 well and 55 % at Sharyoof-2 well. It increases at the middle, northeastern and south parts and decreasing toward the west direction, as shown on (Figure-13C).

The net pay sand of the Upper Qishn Clastics S1C reservoir varies from 2.28 m at Sharyoof-2 well to 6.89 m at Sharyoof-1 well. It increases toward the southeastern and northwest directions then it is decreasing toward the middle. The net wage map of S1C shows that the net wage is very low around Sharyoof-2 well, with a slight rise in the northern, eastern, and western directions (Figure-13D).

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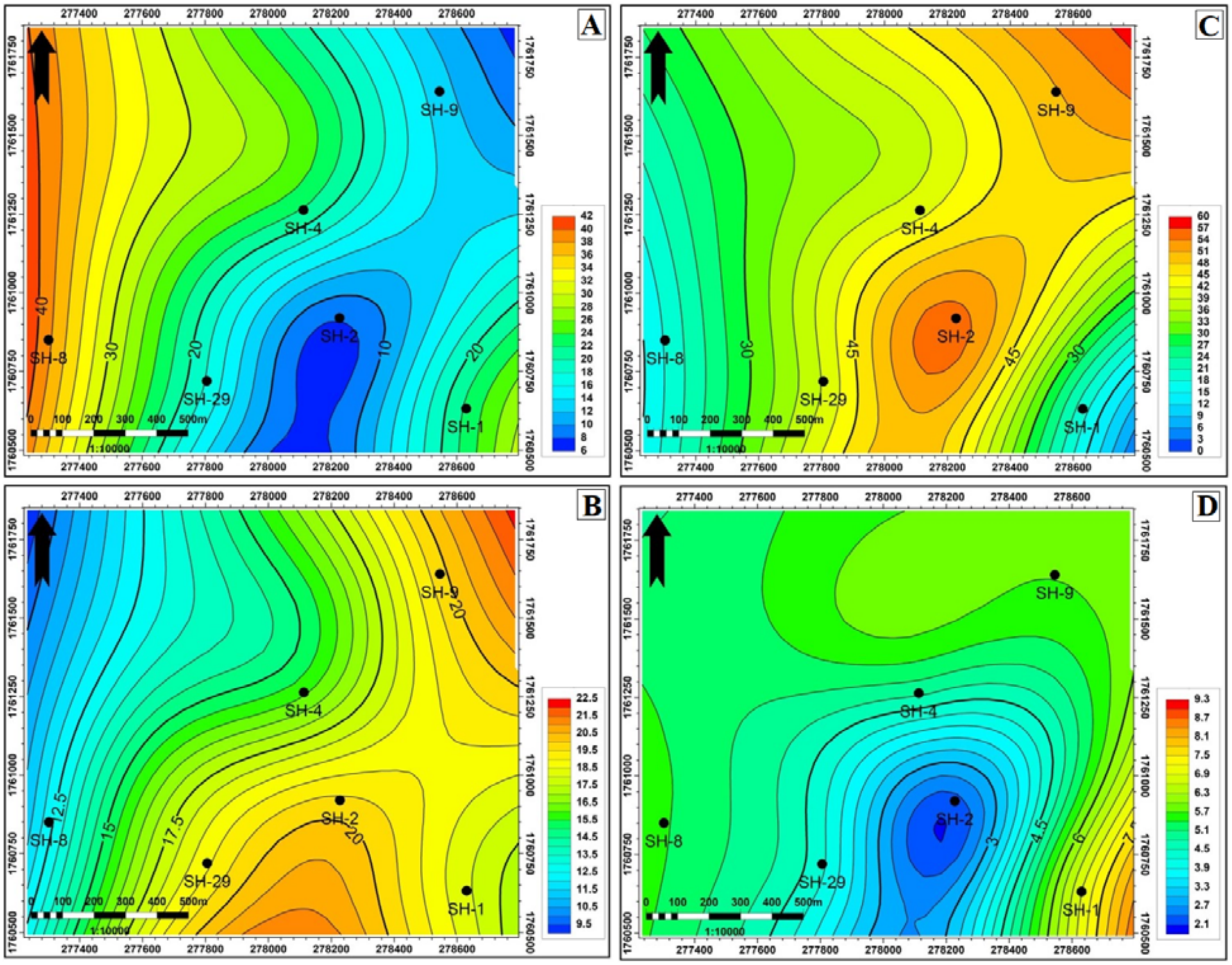


**Figure-13.** (A) Volume of shale, (B) Effective Porosity, (C) Hydrocarbon Saturation and (D) Net pay Sand in Upper Qishn clastics S1C reservoir in Sharyoof oilfield.

**Reservoir Characterization of Upper Qishn Clastics S2 Reservoir**

The volume of shale distribution map shows that Upper Qishin Clastics S2 of studied wells varies from 16.9 % at Sharyoof-4 well to 40.6 % in Sharyoof-8 well (Fig. 14A). It shows the volume of shale increases towards southwest and gradually decreases to the north direction. The effective porosity distribution map in the north-northwest direction shows high values and gradually decreases to the south-southwest direction (Figure-14B). The average effective porosity of the Upper Qishin Clastics S2 reservoir ranges from 11.2 % at Sharyoof-8 well to 18.8 % at Sharyoof-4 well.

The hydrocarbon saturation distribution map of the Upper Qishin Clastics S2 reservoir varies from 15.8 % around Sharyoof-1 well at the southwest to 49.6 % at Sharyoof-4 well (Figure-14C). The hydrocarbon saturation increases in the middle and northwest parts and gradually decreases in the south and southeast directions. (Figure-14D) show the net pay sand in Upper Qishn Clastics S2 reservoir varies from 2.7 % at Sharyoof-2 well to 8.2 % at Sharyoof-4 well. The net pay sand value increases in the central and northwest parts and decreases in the south and southeast part of the study area. The most important location for accumulation and production are north and northwest directions.

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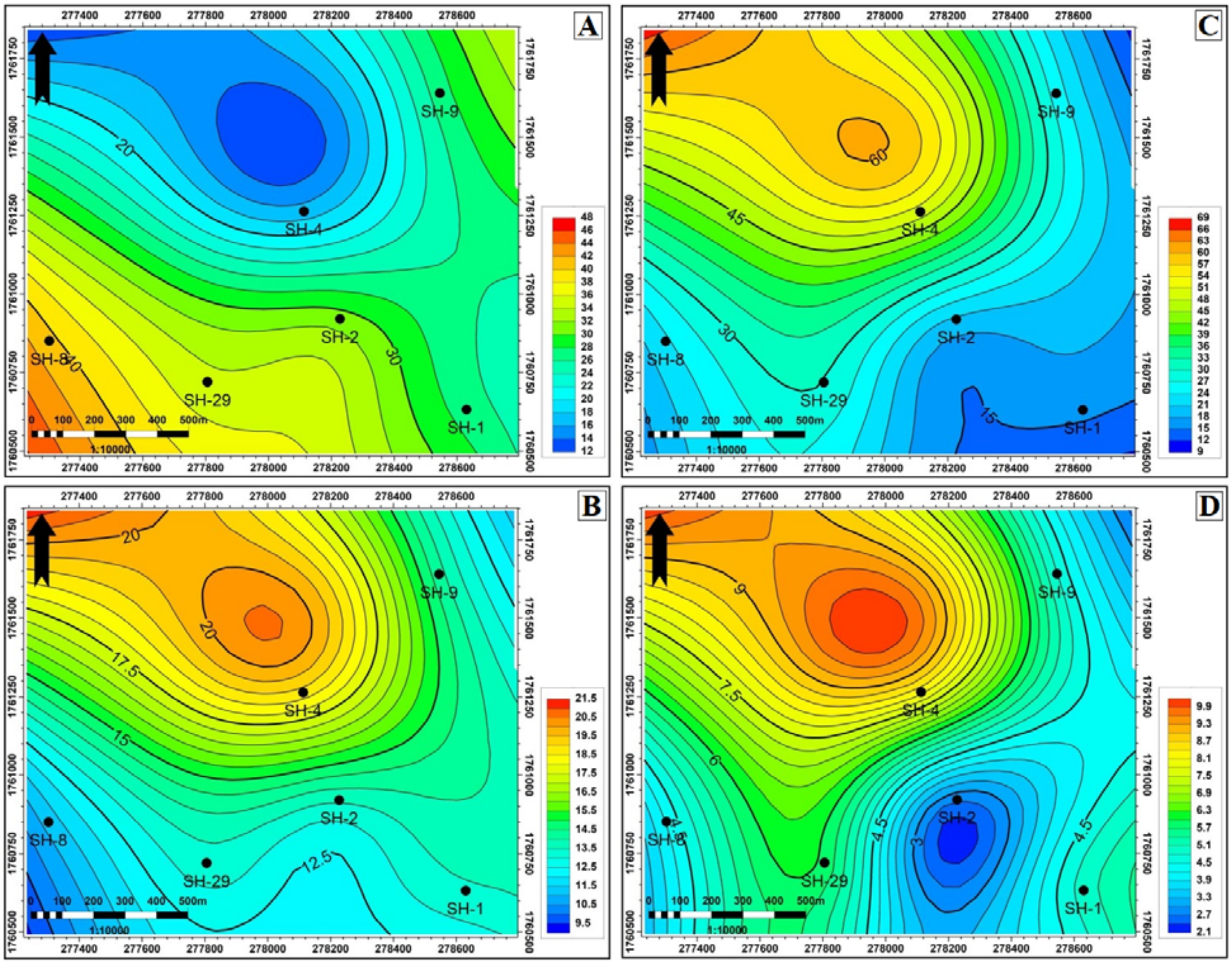


**Figure-14.** (A) Volume of shale, (B) Effective Porosity, (C) Hydrocarbon Saturation and (D) Net pay Sand in Upper Qishn clastics S2 reservoir in Sharyoof oilfield.

## CONCLUSIONS

Comprehensive petrophysical evaluation for Upper Qishn Clastic reservoirs in Sharyoof oilfield were attempted and assessed. The results obtained using the well log analysis techniques, discussed in this paper. The results of this study were used to evaluate the petrophysical characteristics and hydrocarbon prospect of the Qishn Clastic reservoir rocks, and have consequently revealed the following:

- The petrophysical research conducted in this study is carried out on the most beneficial Qishn Clastics reservoir S1A, S1B, S1C and S2.
- The shale content of Upper Qishn clastics S1A reservoir varies between 11 % and 28 %, the volume of shale values increases in the southern and northern directions while it decreases at east direction, while in S1B reservoir, the volume of shale increases in the southwest direction to 45 % and a decrease in the east and north directions. And shale volume of S1C reservoir is increasing gradually in the west direction to 40 %. Instead, the volume of shale in S2 increases towards southwest and gradually decreases to the north direction (Southwestern direction usually has a high content of shale).
- The effective porosity in all units is high in the northeast, up to 20-22%, while it decreases in the south and southwest directions to 10 %, except Upper Qishn clastics S1B reservoir, the effective porosity is low in the northeast to14.5 % and in the southwest to 9 %.
- The results of the study show that hydrocarbon saturation is high in S1A reservoir it increasing directions northeast and east wards and decreases in the northern and southern directions, while in S1B reservoir, hydrocarbon saturation is almost non-existent due to the increase in shale content and water saturation that reaches 90% and the decrease in effective porosity. Also, hydrocarbon saturation in S1C reservoir increases at the middle, northeastern and south parts and decreasing towards the west direction. The hydrocarbon saturation in the Upper Qishn clastics S2 increases in the middle and northwest parts and gradually decreases in the south and southeast directions.

- The Net Sand for the Upper Qishin Clastics S1A ranges from 11.4 m to 16.6 m, this reservoir is growing in the west and to the center of the study area. The net pay sand of the Upper Qishin Clastics S1B varies between 0.15 m and 4 m, It distribution increases to the northeast and southeast directions in the study area. Net pay sand of the Upper Qishin Clastics S1C varies between 2.2 m and 6.9 m. It increases toward the southeastern and northwest directions then it is decreasing toward the middle. The net pay sand of the Upper Qishin Clastics S2 varies between 2.7 m and 8.2 m. the thickness value increases in the central and northwest parts and decrease in the south and southeast part of the study area.
- The results of Upper Qishn clastic S1B properties shows the volume of shale is high, the effective porosity is low, the water saturation is very high, this is what causes the upper Qishn clastics S1B reservoir not to be carried with hydrocarbon.
- The porosity analysis of the Upper Qishn Clastics reservoir assessment for the six wells studied showed that the Upper Qishn Clastics S1A and Upper Qishn Clastics S1C subunits are the best performing of the four units listed.

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