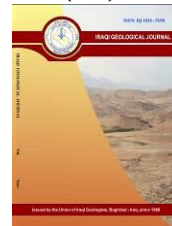




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3D Geological Model of the Zubair Reservoir: A Case Study from North and South Rumaila Oilfields, Southern Iraq

Muntadher M. Al-Nafie^{1*} , Fahad M. Al-Najm² , and Amer J. Al-Khafaji³ 

¹ Midland Refineries Company, Babil, Iraq

² Department of Geology, College of Science, University of Basra, Basra, Iraq

³ Department of Applied Geology, College of Science, University of Babylon, Babil, Iraq

* Correspondence: alnafe91@gmail.com

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Abstract

Rumaila is one of Iraq's largest and most producing oilfields. It contains Zubair reservoir, which is recognized as an important clastic reservoir in southern Iraq. The Zubair reservoir is mainly consists of layered sandstone, shale, and shaly sandstone. The Zubair Formation is around 440 m thick. This work aims to create a three-dimensional reservoir model of the Zubair Formation using digital logs and drilling information. The model assesses reservoir characteristics, including effective porosity, permeability, and water saturation, while petrophysical property models are generated using the Sequential Gaussian Simulation technique. The Zubair Formation consists of five members, and this study focuses on data from three of them: Z1, Z2, and Z4. The results show that units Z2/DJ and Z2/LN are highly economical, unit Z2/AB is moderately economical, whereas members Z1 and Z4 display variable and generally limited economic potential. The structural model of the Rumaila Oilfield is characterized by an anticline fold comprising two main domes: the North Rumaila dome and the South Rumaila dome, separated by a gradually decreasing structural saddle.

Keywords: Zubair reservoir; Effective porosity; Permeability; Water saturation; Geological model; Rumaila oilfield

1. Introduction

Constructing a 3D geological model is an essential step in understanding the subsurface properties of hydrocarbon reserves. It integrates geological, petrophysical, and geophysical data to produce a detailed model of the reservoir's structural and stratigraphic framework (Houlding, 2012). The Zubair Formation is recognized as a highly productive reservoir within the Rumaila Oilfield in southern Iraq, also considered a good source rock (Al-Khafaji et al., 2019). It is characterized by complex sedimentary facies and lateral heterogeneity, which significantly affect hydrocarbon distribution and production performance (Aqrabi et al., 2010; Al-Ameri et al., 2011). Ali and Nasser (1989) identified four lithofacies in the Zubair Formation based on sedimentary structures and textures, including the sandstone-to-shale ratio. They associated these with deposition environments that include swamp and marsh, delta front, prodelta, and shelf. According to Jassim and Goff (2006), the thickness of the net sand content in this formation usually increases towards the west, being almost non-existent near the Iraqi-Iranian border, and then gradually increases to exceed 200 m in the areas of Al-Zubair in the south and Karbala in the north. In the area between Nasiriyah and Amara, the thickness of the net sand is around 100 m, with carbonate rocks comprising about 15% of the formation near Nasiriyah, increasing

to about 35% towards Amara. Building a 3D geological model of the Zubair reservoir provides a more accurate representation of its structural geometry, lithological variations, and petrophysical properties. This model serves as a framework for reservoir simulation, well placement optimization, and field development planning.

Data are available for ten wells in the Zubair Formation: five wells located in the northern Rumaila dome (R-167, R-169, R-200, R-505, R-527) and five wells in the southern Rumaila dome (Ru-397, Ru-398, Ru-401, Ru-410, Ru-427). These data represent three members of the Zubair reservoir: the upper Shale, the upper Sandstone, and the middle Shale. This study aims to use a 3D model to identify the characteristics of the Zubair reservoir, evaluate Zubair reservoir zones with optimal production qualities, and analyze the heterogeneity of the formation. This methodology enables the creation of porosity, permeability, and fluid saturation maps, which help enhancing development and production strategies and enable more efficient, cost-effective reservoir management.

2. Study Area

The Rumaila Oil Field is a supergiant oilfield in Iraq. It covers 1,800 km² and is the 18th-largest oilfield in the world, as shown in Fig. 1 (Ghareb et al., 2025). It is situated 50 km west of Basra in southern Iraq, and 41 km northwest of the Jabal Sanam structure on the Iraq-Kuwait border. Rumaila oilfield is surrounded by Zubair oilfield, about 25 km to the east and 50 km north of Luhais oilfield. It is closely associated with the north-to-west Qurna oilfield, as they share the same geological structure (Awadh et al., 2021).

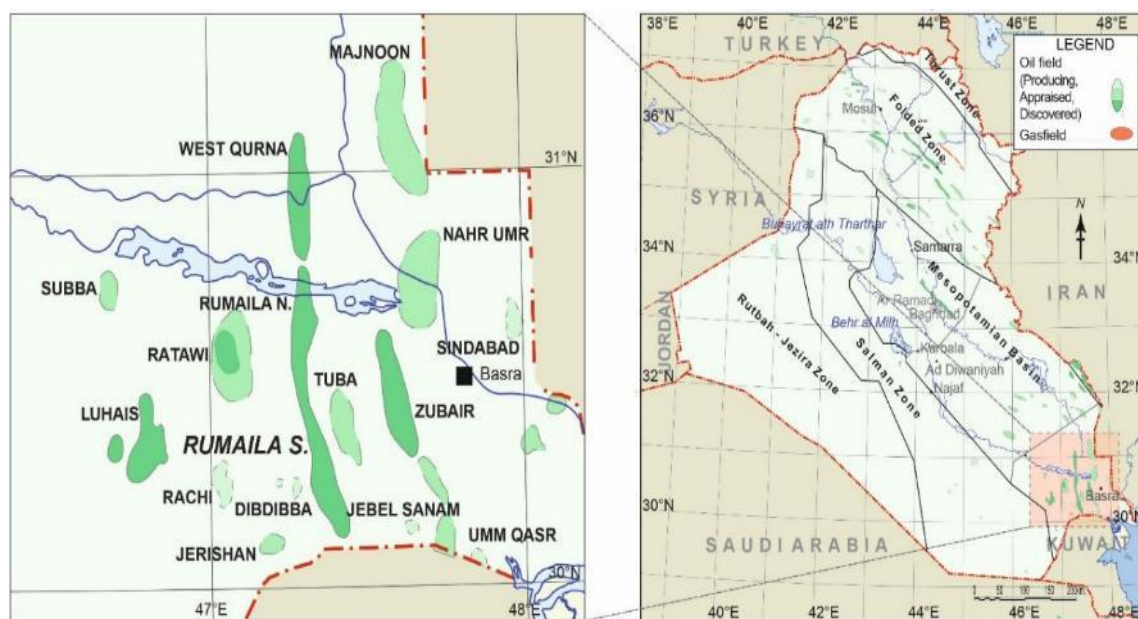


Fig. 1. Iraqi oil and gas fields that include Rumaila Oilfield, southern Iraq

3. Geologic Setting

The Rumaila Oilfield is located in the Zubair Subzone of the Mesopotamian Foredeep Basin, which is part of the stable Arabian Plate margin (Buday, 1980). Rumaila Field is a longitudinal anticline with a gentle slope, composed of two domes: North and South Rumaila (Chafeet and Handhal, 2023). These structural features are mainly associated with regional tectonic events during the Late Cretaceous and Tertiary compression phases of the Zagros orogeny (Jassim and Goff, 2006).

The geological sequence in the Rumaila area ranges from Jurassic to Quaternary deposits. The main reservoir units are the Zubair, Mishrif, and Yamama formations, with the Zubair Formation being the

dominant clastic reservoir (Marlow et al., 2014). In 1948, Glynn Jones described the Zubair Formation in the Zubair Oilfield, a definition later modified by Nasr and Hudson in 1953 (Van Bellen et al., 1959). The Zubair Formation is of Lower Cretaceous age (Aptian–Barremian) and consists primarily of sandstone interbedded with shale and siltstone, and was deposited in a deltaic to shallow-marine environment (Al-Rubaye et al., 2019). The Aptian Shuaiba Formation gradationally and conformably overlays the Zubair Formation, which conformably underlies the shales and limestones of the Valanginian-Hauterivian Ratawi Formation (Buday, 1980). Mohammed et al. (2010) divided the Zubair Formation in southern Iraq into five members, listed from lower to upper: Lower Shale Member (Z6), Lower Sand Member (Z5), Middle Shale Member (Z4), Upper Sand Member (Z2), and Upper Shale Member (Z1). Upper Sand Member, commonly known as the "main pay," consists of five important units. Three of these units are sandstone formations that serve as reservoir units (AB, DJ, LN), while the other two are shale units (C, K) that act as barriers to vertical fluid movement within the reservoir. Fig. 2 illustrates the Stratigraphic Column for the Rumaila Oilfield, and Fig. 3 shows the structure contour map and the studied wells.

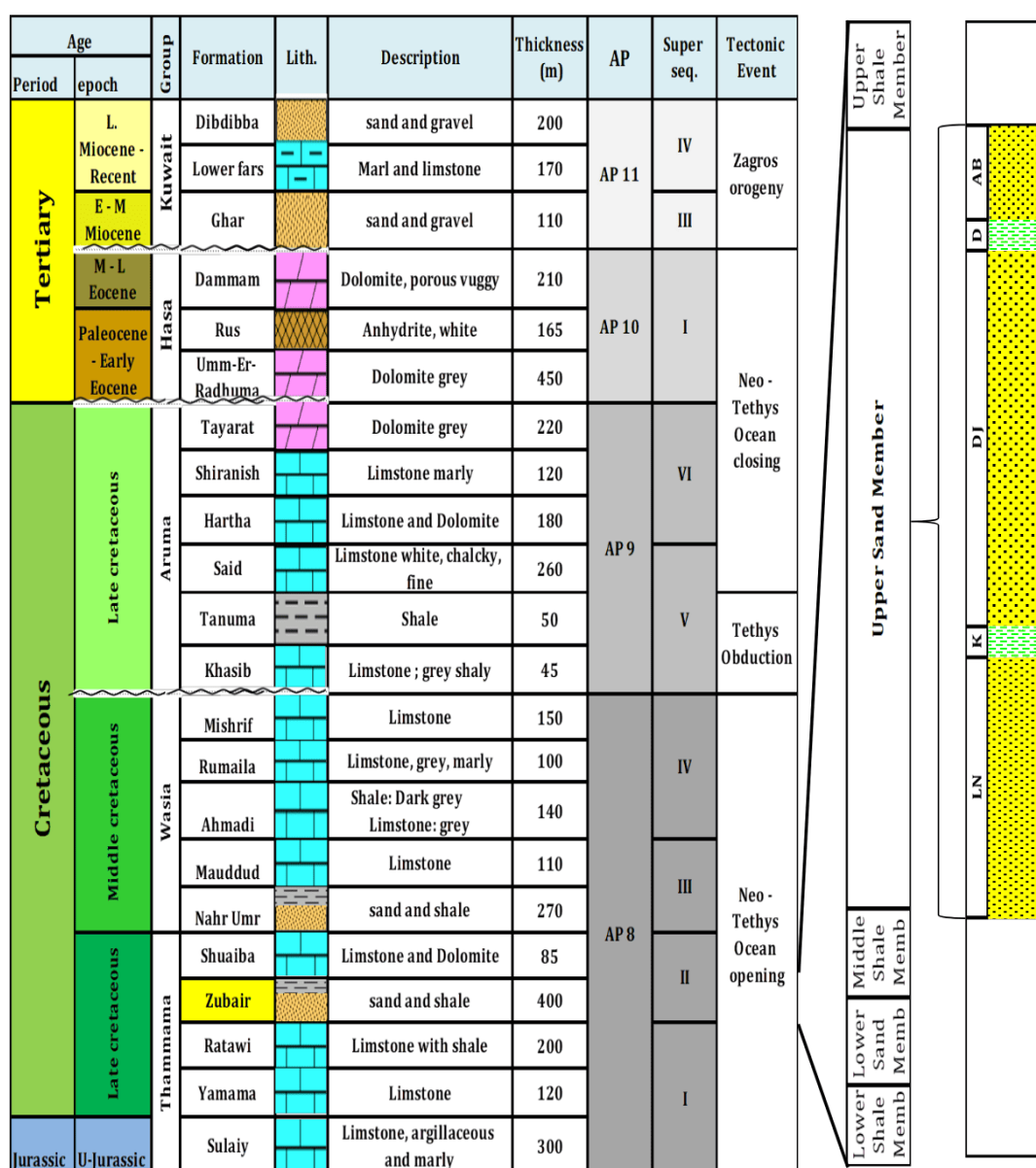


Fig. 2. The Stratigraphic Column for Rumaila Oilfield (Zubair Formation) Modified from (Aqrabi et al., 2010)

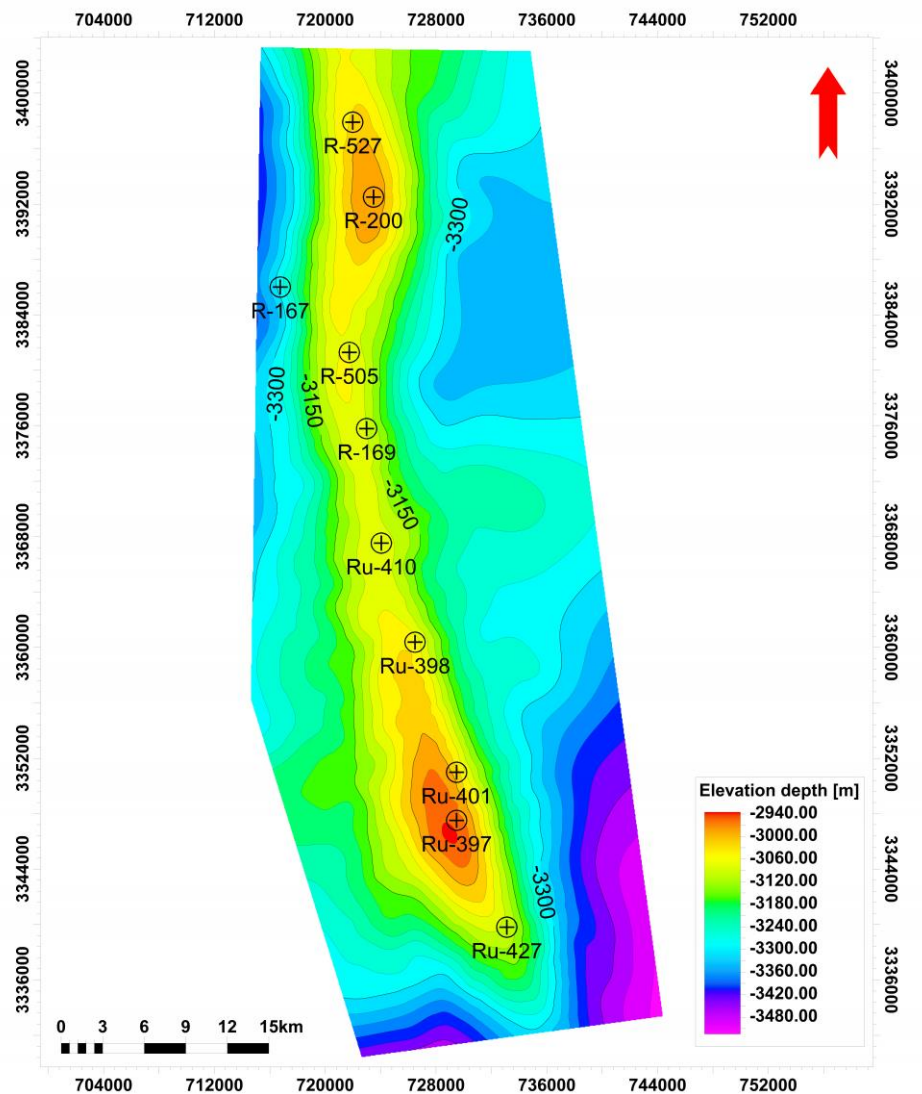


Fig. 3. The structural contour map of the Zubair formation in Rumaila Oil Field and the wells of study

4. Methodology

Field maps, reports, and well-logged data were utilized for this study. The petrophysical properties were computed using Interactive Petrophysics software (2018), and the petrophysical model was constructed in Petrel software (2019). To accomplish the purpose of this research, the investigators went through several distinct procedures, which are as follows:

4.1. Calculating Petrophysical Properties

4.1.1. Calculation of shale volume

Shale volume must be estimated to quantify hydrocarbon units in any formation, as it blocks pore space, reduces permeability, and lowers reservoir quality. The shale volume for formations of Jurassic and Cretaceous age is calculated according to Larionov (1969), using the following equation:

$$V_{\text{shale}} = 0.33 * (2^{2 \cdot \text{IGR}} - 1), \quad (1)$$

$$\text{IGR} = \frac{\text{GR}_{\text{log}} - \text{GR}_{\text{min}}}{\text{GR}_{\text{mix}} - \text{GR}_{\text{min}}}, \quad (\text{Liu, 2017}) \quad (2)$$

Where: IGR= gamma ray index; Vshale= shale volume; GRlog: Gamma-ray log reading (API); GRmax: Maximum gamma-ray log reading (shale) (API); GRmin: Minimum gamma-ray log reading (clean sand) (API).

4.1.2. The effective porosity (ϕ_e)

The effective porosity is the amount of void space that is interconnected, and thus able to transmit fluids, calculated using the equation of Schlumberger (1998):

$$\phi_e = \phi_t * (1 - V_{sh}), \quad (3)$$

$$\phi_t = \frac{\phi_{Nc} + \phi_{Dc}}{2}, \quad (4)$$

Where: ϕ_e = effective porosity; ϕ_t = total porosity; ϕ_{Nc} = corrected Neutron porosity from affected shale; ϕ_{Dc} = porosity by density log corrected from shale effect.

4.1.3. Permeability estimation

Permeability is the ability of a reservoir rock to transmit fluids through its interconnected pore space under a pressure gradient. The laminar flow of a fluid through a porous medium is described by Darcy's Law as follows (Tiab and Donaldson, 2024):

$$Q = \frac{KA\Delta P}{\mu L}, \quad (5)$$

Where: Q = Volumetric flow rate (m³/s); k = Absolute permeability of rock (Darcy); A = Cross-section area of the flow (m²); μ = Viscosity of fluid (Pa·s); ΔP = Pressure difference between two points (Pa), and L = Length of flow path (m).

In the current study, the Timur formula was calculated from wireline logs (Timur, 1968). The spatial distribution of permeability was visualized using this modeling technique, and the flow behavior within the Zubair units was better understood:

$$K = 0.136 \frac{\phi^{4.4}}{S_{wi}^2}, \quad (6)$$

Where: K = permeability in mD; S_{wi} =irreducible water saturation.

According to Asquith and Gibson (1982), irreducible water saturation can be determined using the following formula:

$$S_{wi} = \sqrt{\frac{F}{2000}}, \quad (7)$$

Archie (1942) shows that the formation factor (F) could be related to the porosity of the formation by the following formula, which was used in the current study:

$$F = \frac{a}{\phi^m}, \quad (8)$$

Where: a = tortuosity factor; m = cementation factor; ϕ = total porosity

4.1.4. Determining water saturation

Water saturation (S_w) is the volume fraction of the pore space occupied by water. S_w in the uninvaded zone is calculated according to Simandoux's equation (Simandoux, 1963). This equation was used in this study because the shale content of the Zubair Formation exceeds 15 %.

$$S_w = \left(\frac{0.4 * R_w}{\phi^2} \right) * \left[\sqrt{\left(\frac{V_{shale}}{R_{sh}} \right)^2 + \frac{5 * \phi^2}{R_t * R_w}} - \frac{V_{shale}}{R_{sh}} \right], \quad (9)$$

Where: S_w = water saturation; R_w = formation water resistivity (0.018@ 173° f); R_t = true resistivity recorded by log (Ωm); R_{sh} = true resistivity of nearby shale.

4.2. Geological Modeling

4.2.1. Stratigraphic zonation

The Zubair Formation was divided into multiple reservoir zones based on well-log correlations. This zoning plan served as the starting point for all subsequent calculations of the reservoir's rock properties and 3D models.

4.2.2. Reservoir contour maps and gridding

The structural model was used in the early stages of this research to define the subsurface properties of the Zubair Formation and to identify any potential faults or folds that may influence the reservoir geometry. Fig. 4 illustrates the structure contour map of the Zubair Formation, utilized as a fundamental input for the creation of the reservoir structural model. The reservoir contour map was digitized using Neura Map software and then loaded into Petrel software (2019) to construct a three-dimensional structural model.

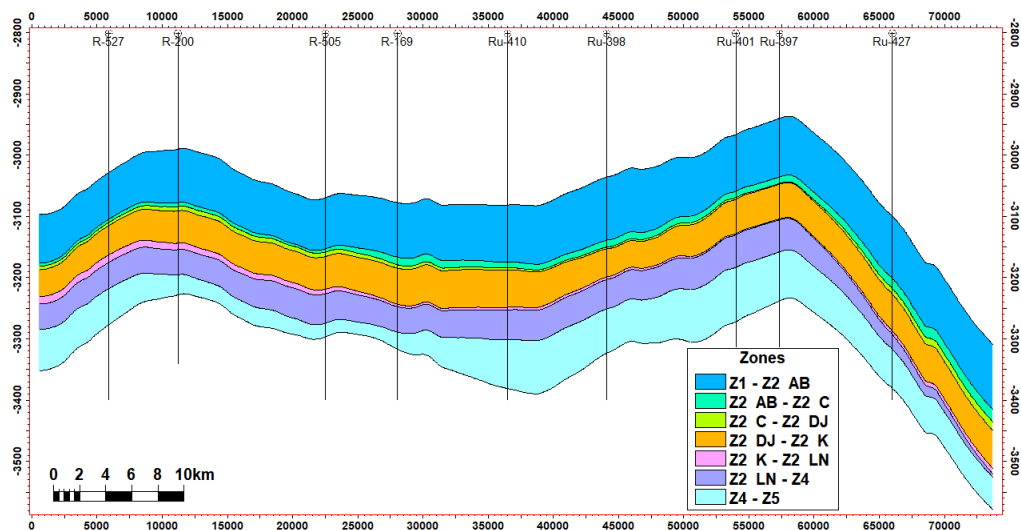


Fig. 4. Correlation of zone sections of the Zubair Formation across the northern (R) and southern (Ru) Rumaila wells, showing the stratigraphic framework and division of reservoir units based on well log correlations

Using this structural model, the reservoir grid was created, with the contour map to determine grid dimensions and cell distribution. A grid spacing of 500 m was used in both the X and Y directions to provide sufficient spatial representation of reservoir characteristics. The Zubair reservoir has been divided into three primary units: upper, middle, and lower, as seen in Fig. 5, and these stratigraphic divisions were integrated into the three-dimensional reservoir grid framework.

4.2.3. Structural model

Three-dimensional structural models were constructed using well tops from all Rumaila wells, along with an identified structural map of the top of the Zubair reservoir. Three-dimensional contour maps have been created for each zone of the Zubair reservoir. This model illustrates that the Zubair structure comprises an anticlinal fold partitioned into northern and southern parts, oriented NW-SE and delineated by depressions, as shown in Fig. 6.

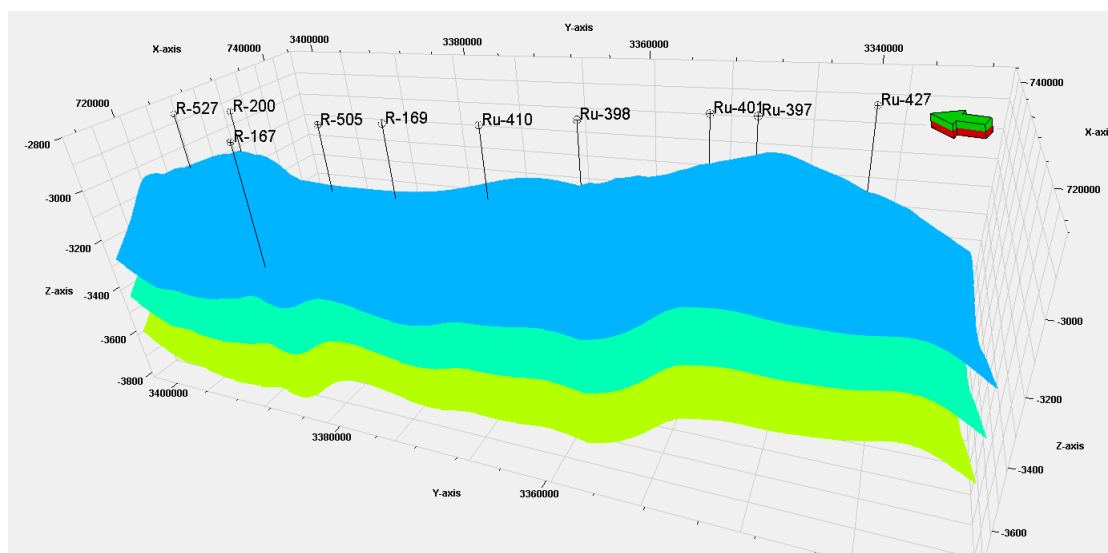


Fig. 5. Three-Dimensional Skeletons of the Zubair Formation

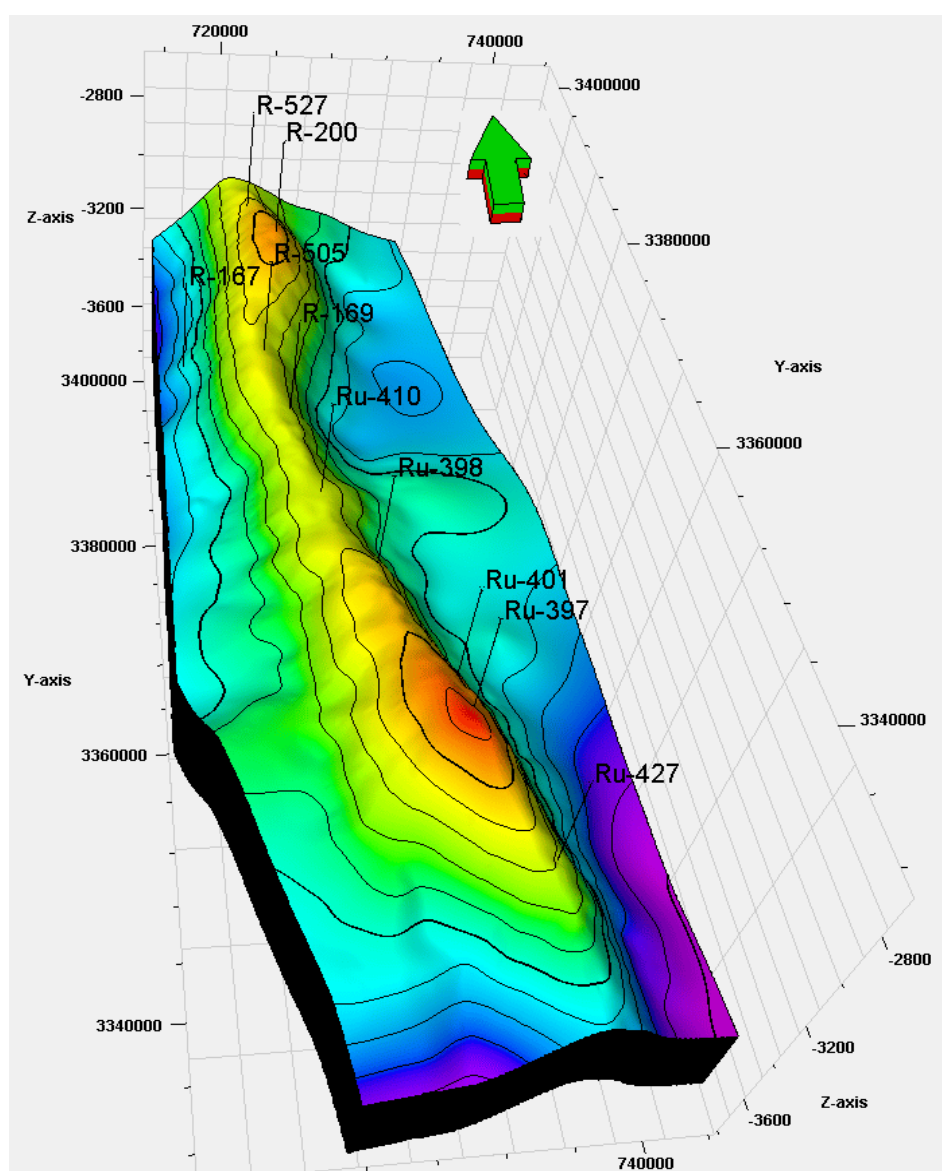


Fig. 6. 3D structural modeling of Zubair Formation in Rumaila oil field

4.2.4. Scale up for well logs

The results for the 3D grid cells penetrated by the wells are averaged using the well log scaling method. Each cell is given one value for each scaled-up log. These cells will later be utilized as a basis for property modeling (Schlumberger, 2010). The volume of the zone is represented by a 3D grid cell in petrophysical property modeling. For well logs, the cell thickness is typically greater than the sample density. Therefore, before any well-log-based modeling can be performed, it is necessary to scale the well logs to the resolution of the three-dimensional grid. Well log blocking is another name for this procedure (Denney, 2013). Several statistical techniques, including the geometric, harmonic, and arithmetic methods, are employed to scale up. In the current model, permeability, effective porosity, and water saturation parameters have been scaled up using the arithmetic average. The scale-up of PHIE, K, and Sw for wells utilized in the Zubair Formation model is shown in Figs. 7, 8, 9, 10, and 11.

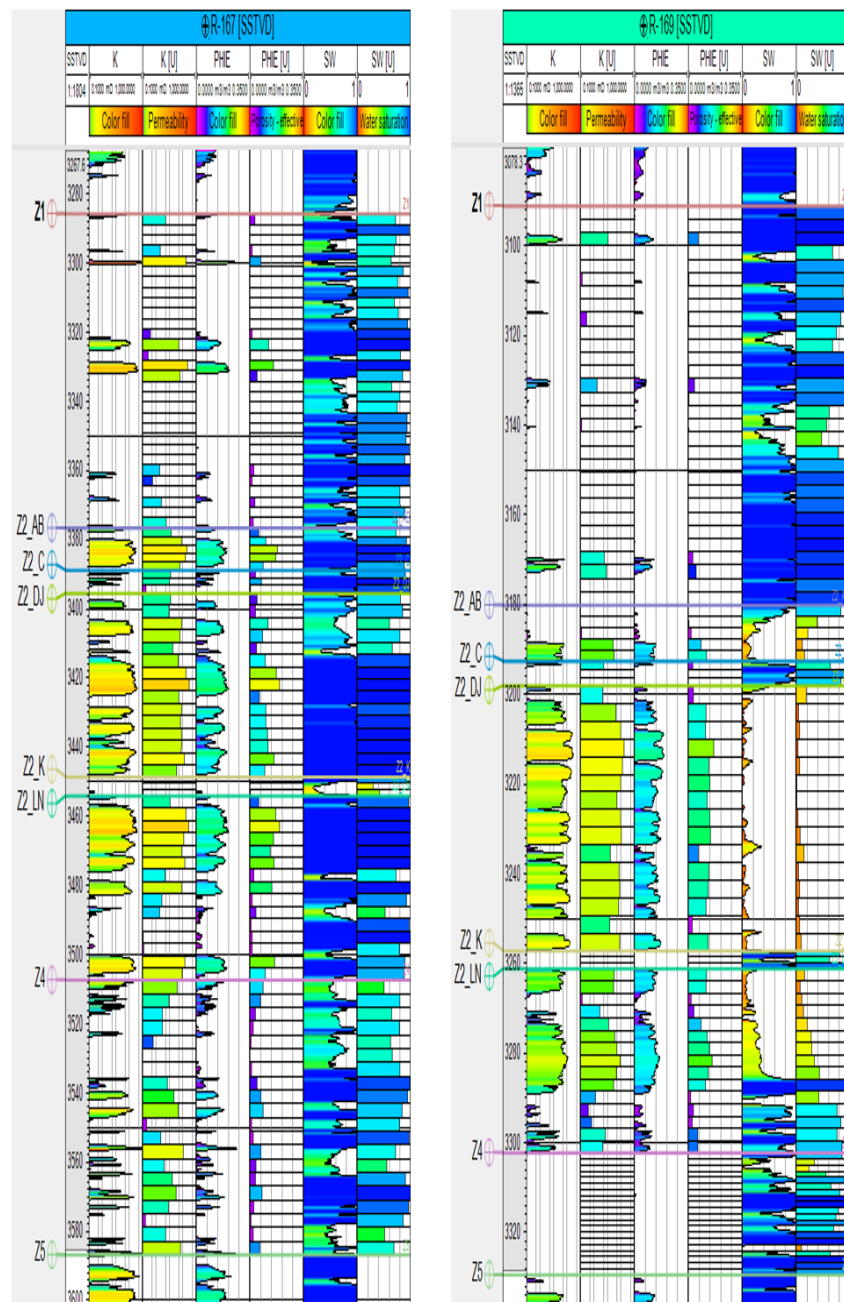


Fig. 7. Scale up of permeability, effective porosity, and water saturation for R-197 and R-169 wells

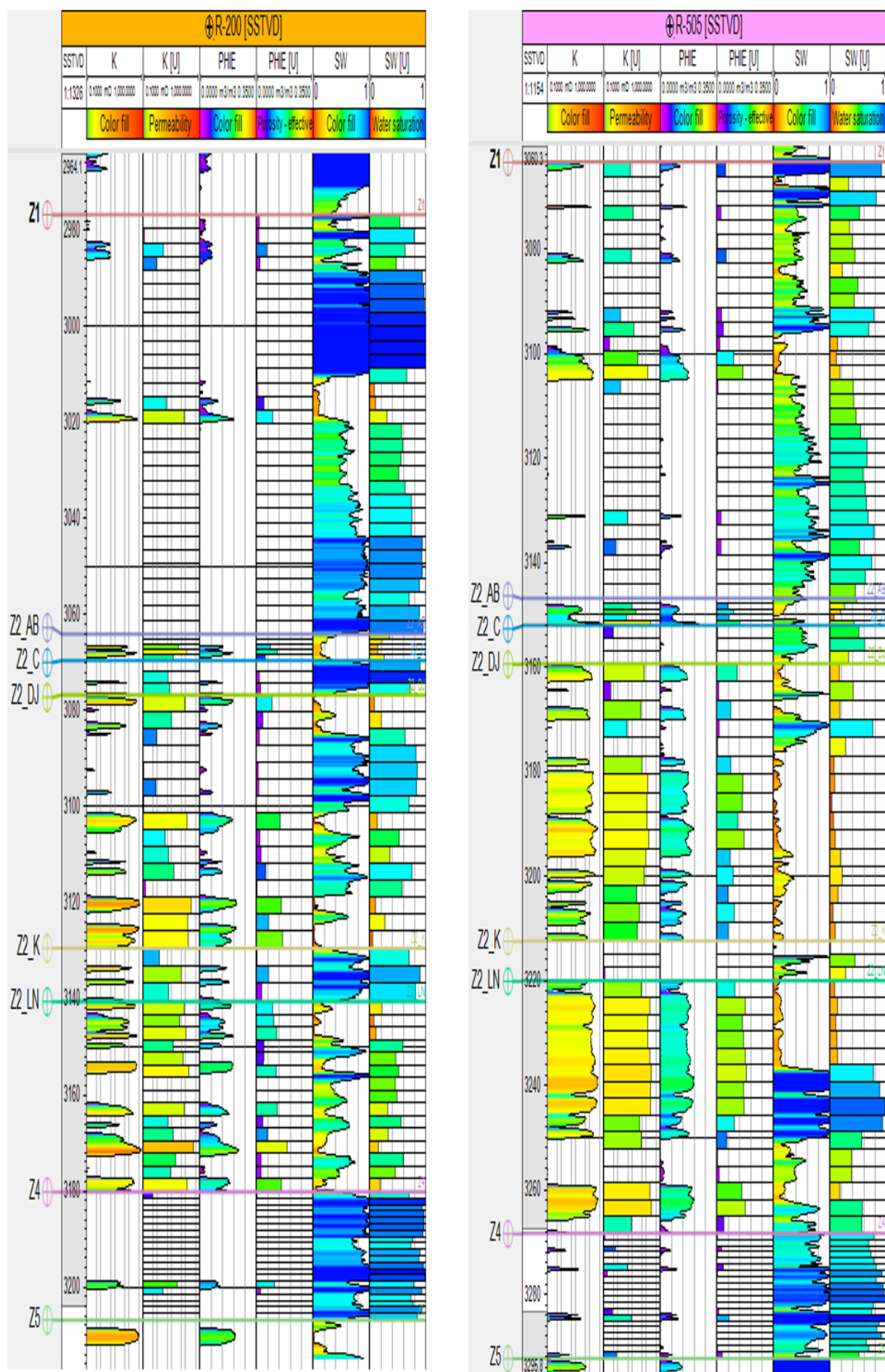


Fig. 8. Scale up of permeability, effective porosity, and water saturation for R-200 and R-505 wells

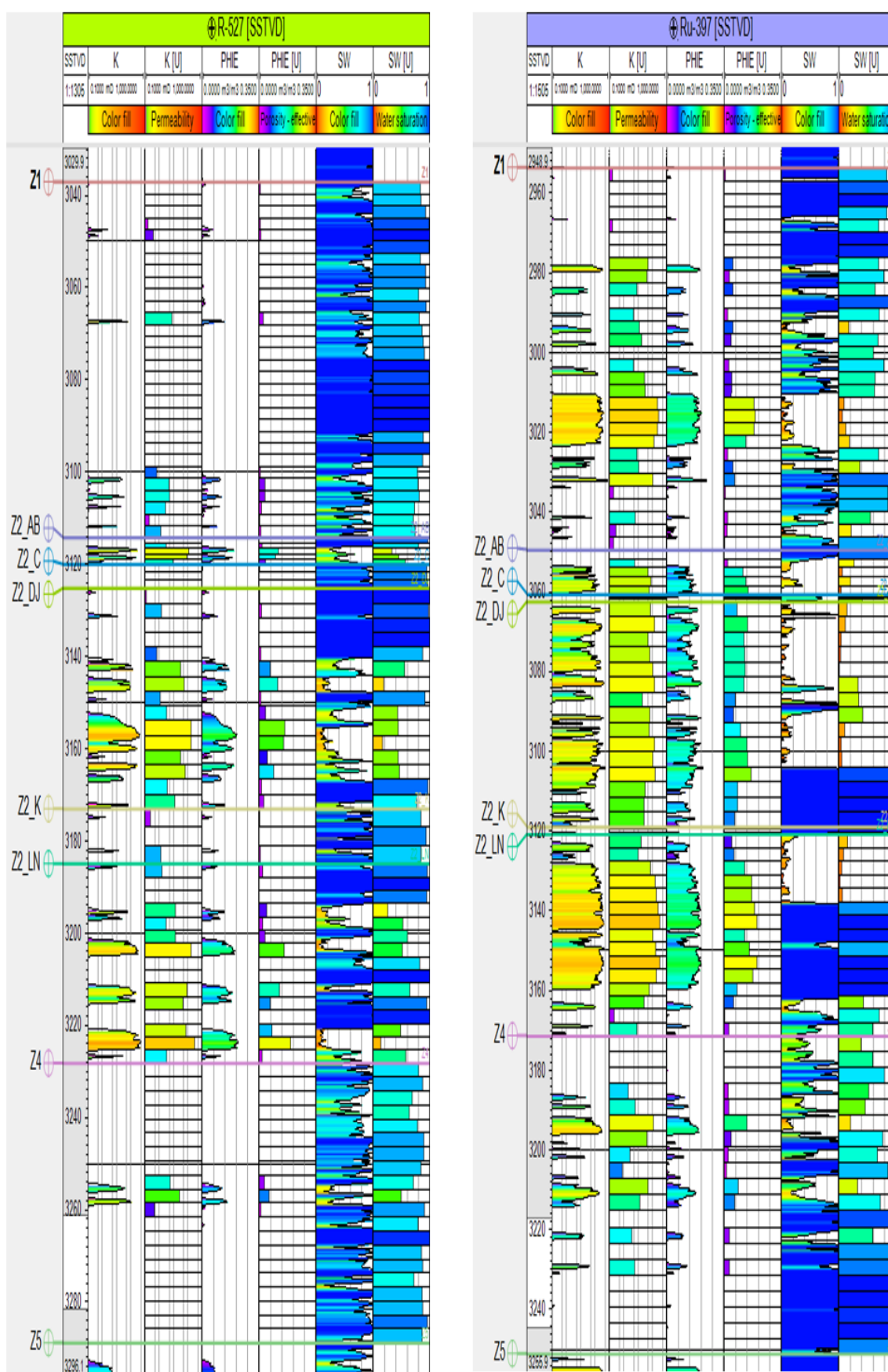


Fig. 9. Scale up of permeability, effective porosity, and water saturation for R-527 and Ru-397 wells

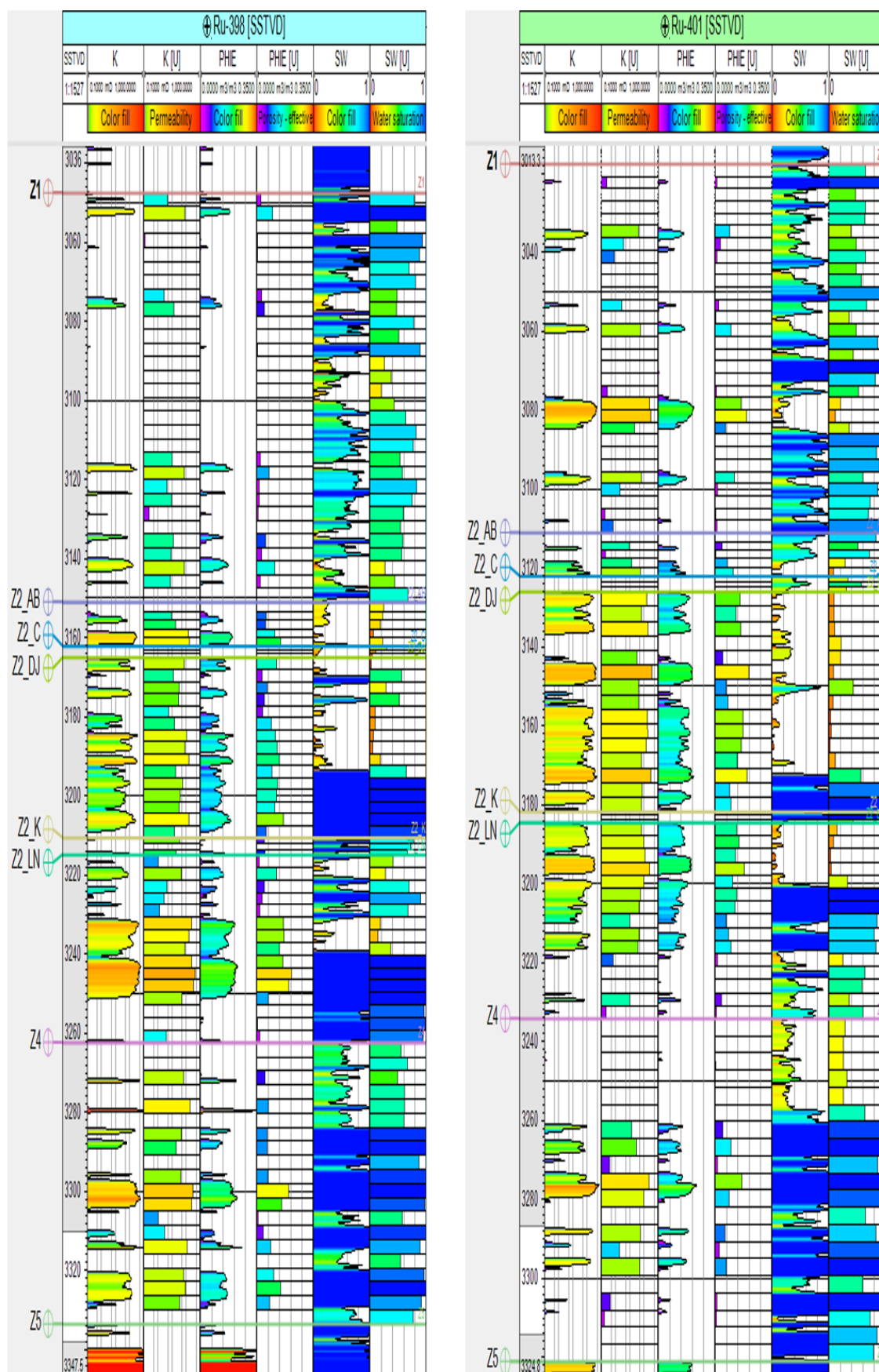


Fig. 10. Scale-up of permeability, effective porosity, and water saturation for Ru-398 and Ru-401 wells

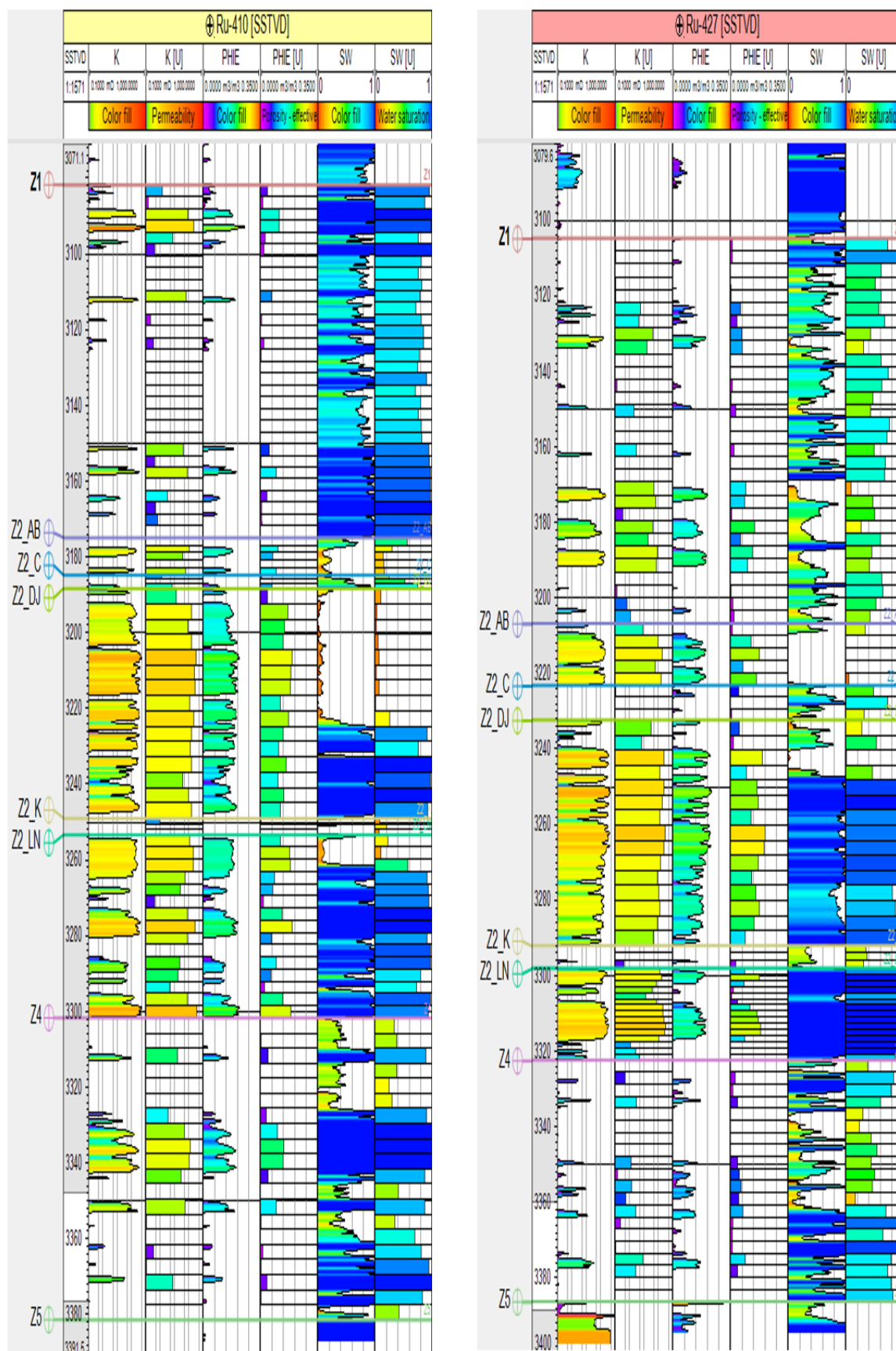


Fig. 11. Scale-up of permeability, effective porosity, and water saturation for Ru-410 and Ru-427 wells

4.2.5. Property model

The spatial distribution and variation of reservoir petrophysical properties between wells are described using property modeling (Kamali et al., 2013). The sequential simulation strategy was the traditional geostatistical method for modeling reservoir characteristics. Petrophysical properties were modeled using sequential Gaussian simulation (SGS). Each cell in the 3D grid represented a petrophysical property (Schlumberger, 2007).

5. Results and Discussions

5.1. Effective Porosity (PHIE) Models

The effective porosity (PHIE) model shows significant vertical and horizontal variations across the studied reservoir, indicating changes in the depositional facies, clay volume, and post-depositional diagenesis. Higher PHIE values are usually occur in the main sandstone reservoir units, specifically the DJ and LN units within the Z2 member, where effective porosity ranges from moderate to good. This distribution reflects a majority of clean, well-classified sandstone facies including well-preserved intergranular pores.

Vertically, Z2 members have higher porosity properties than Z1 and Z4 members (Table 1). Although Z1 has locally modest PHIE values, especially in the southern part of the field, reservoir efficiency is limited in many wells due to unfavorable fluid saturation conditions rather than low porosity. In contrast, Z4 has lower and more variable PHIE values. Wells in the southern part had higher and more laterally extended PHIE values than those in North Rumaila, as shown in Fig. 12. This pattern is likely due to changes in depositional energy and facies distribution, as well as decreased clay content, which enhances pore connectivity and reservoir quality. Fig.13 shows a 3D model of the effective porosity for the Zubair reservoir units.

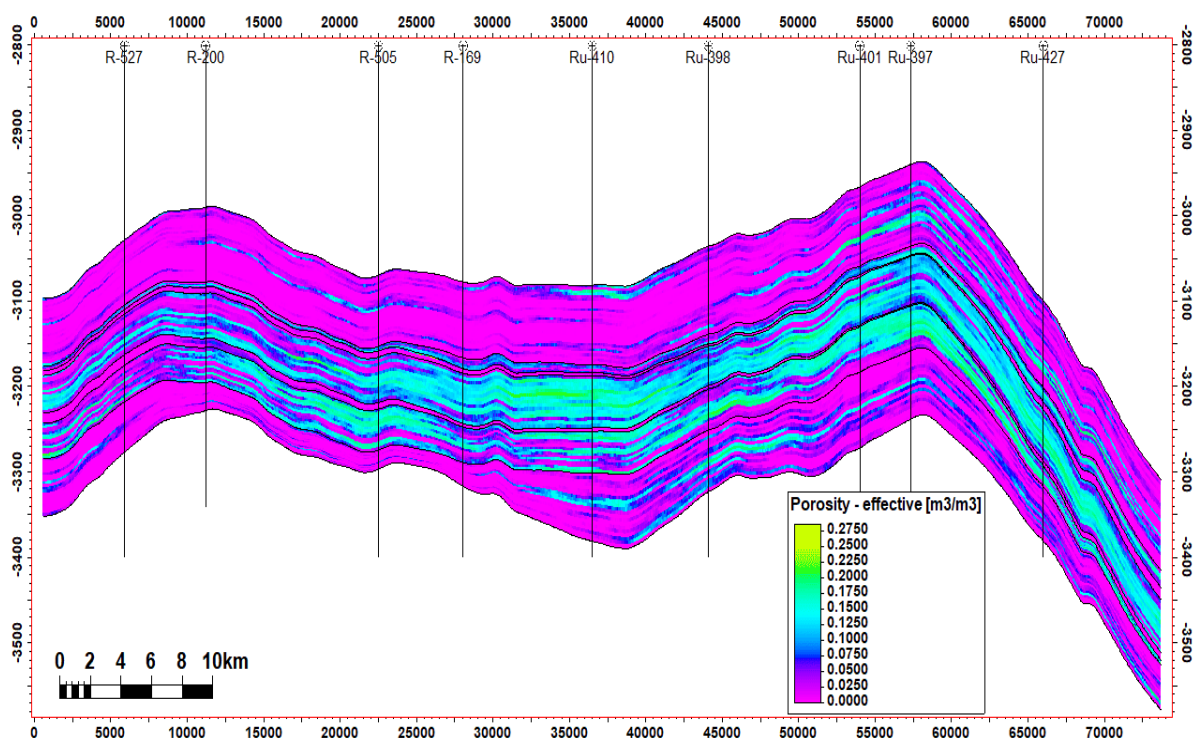


Fig. 12. PHIE model cross-section in the NW-SE direction for the Zubair reservoir in North and South Rumaila Oil Field

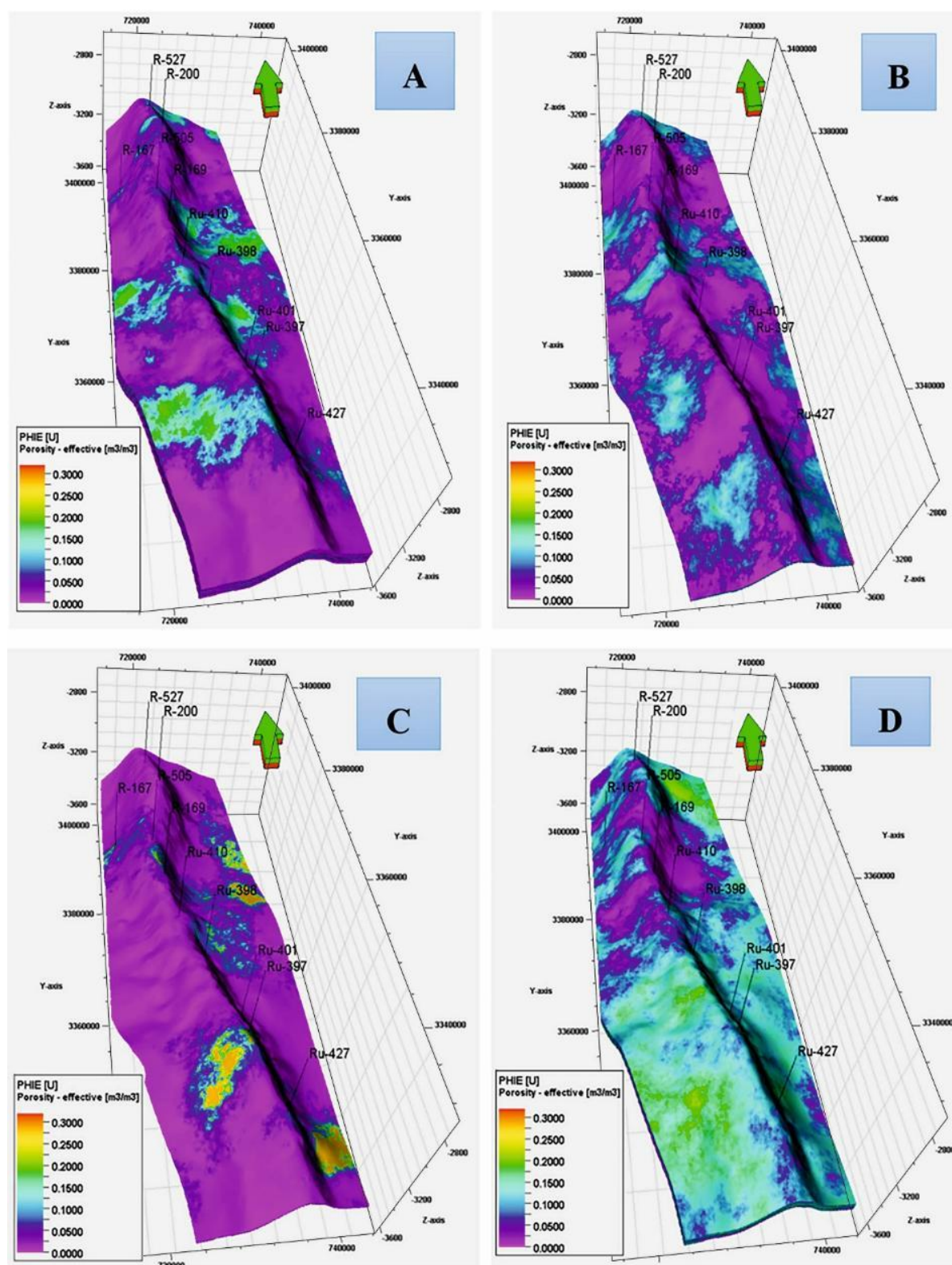


Fig. 13. I. A) An Effective porosity modeling for upper Zubair member (Z1); B) Effective porosity modeling for AB unit in upper Sandstone member (Z2); C) Effective porosity modeling for K unit; D) Effective porosity modeling for DJ unit

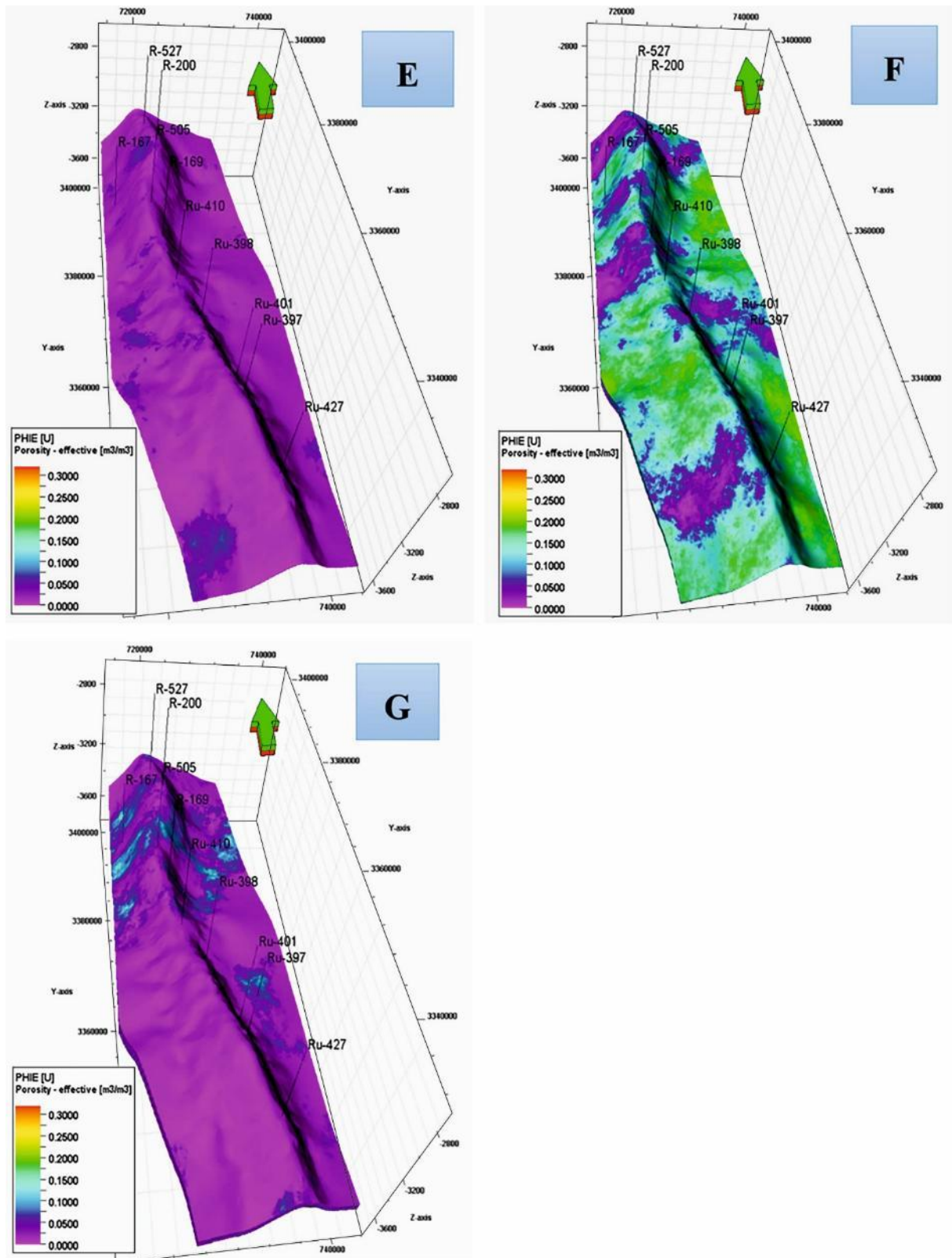


Fig. 13. II. E) Effective porosity modeling for K unit; F) Effective porosity modeling for LN unit; G) Effective porosity modeling for the middle Shale member (Z4).

5.2. Permeability (K) Model

The permeability model shows a heterogeneous distribution pattern that closely resembles effective porosity trends but shows greater spatial variation. Permeability assessments are highest in Z2,

DJ and LN units, exhibiting well-correlated pore networks with suitable aperture geometry. These correlations indicate the essential role of effective porosity and grain properties in increasing permeability.

Although the general correlation holds, specific intervals have moderate to high pore permeability index (PHIE) values but relatively low permeability. This behavior indicates a diagenetic factor, such as pore-throat reduction resulting from clay mineral infilling or cement deposition, which may seriously impede fluid flow without significantly reducing the overall pore volume. In contrast, intervals with both high PHIE and high K are the most effective reservoir facies and contribute substantially to hydrocarbon productivity.

From a side view, the wells in South Rumaila usually show higher permeability than those in the northern part of the field, which matches the observed increase in effective porosity and decrease in shale content. This trend further supports the interpretation of better reservoir permeability and depositional quality in the southern part of the field, as shown in Figs. 14 and 15.

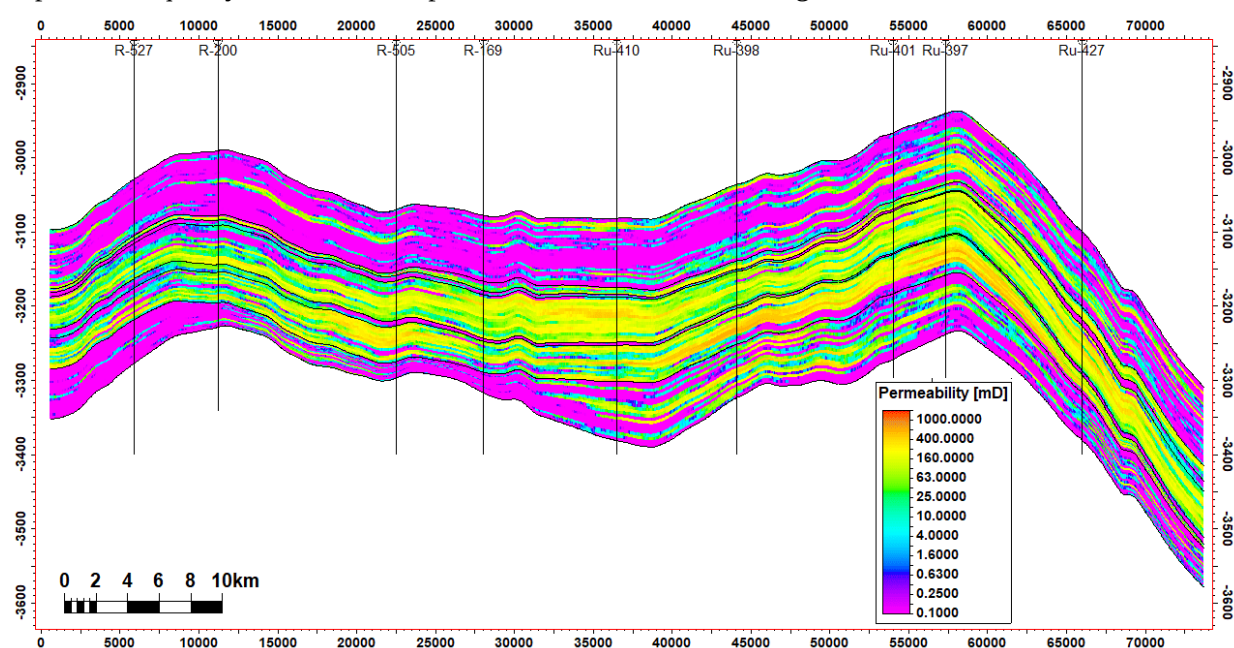


Fig. 14. K model cross-section in the NW-SE direction for the Zubair reservoir in North and South Rumaila Oil Field

5.3. Water Saturation (S_w) Models

The water saturation (S_w) model offers essential knowledge into fluid distribution and reservoir productivity. The low water saturation rate is primarily associated with the main reservoir member (Z2), practically the DJ and LN units, thereby underscoring their importance as hydrocarbon-bearing units. These units exhibit a satisfactory combination of porosity, permeability, and water saturation, leading to enhanced net pay development.

Conversely, members Z1 and Z4 in many wells display high water saturation levels, even during intervals of moderate porosity. This pattern indicates that these zones might be close to the oil-water contact, contain less hydrocarbon, or hold more water because they contain finer-grained facies or higher clay content. As a result, although they have acceptable porosity values, these zones contribute little or nothing to net pay.

The combination of the water saturation model with porosity and permeability distributions clearly shows that reservoir quality assessment cannot be based on a single petrophysical characteristic. Figs. 16 and 17 illustrate the distribution of water saturation across the field and for each reservoir unit.

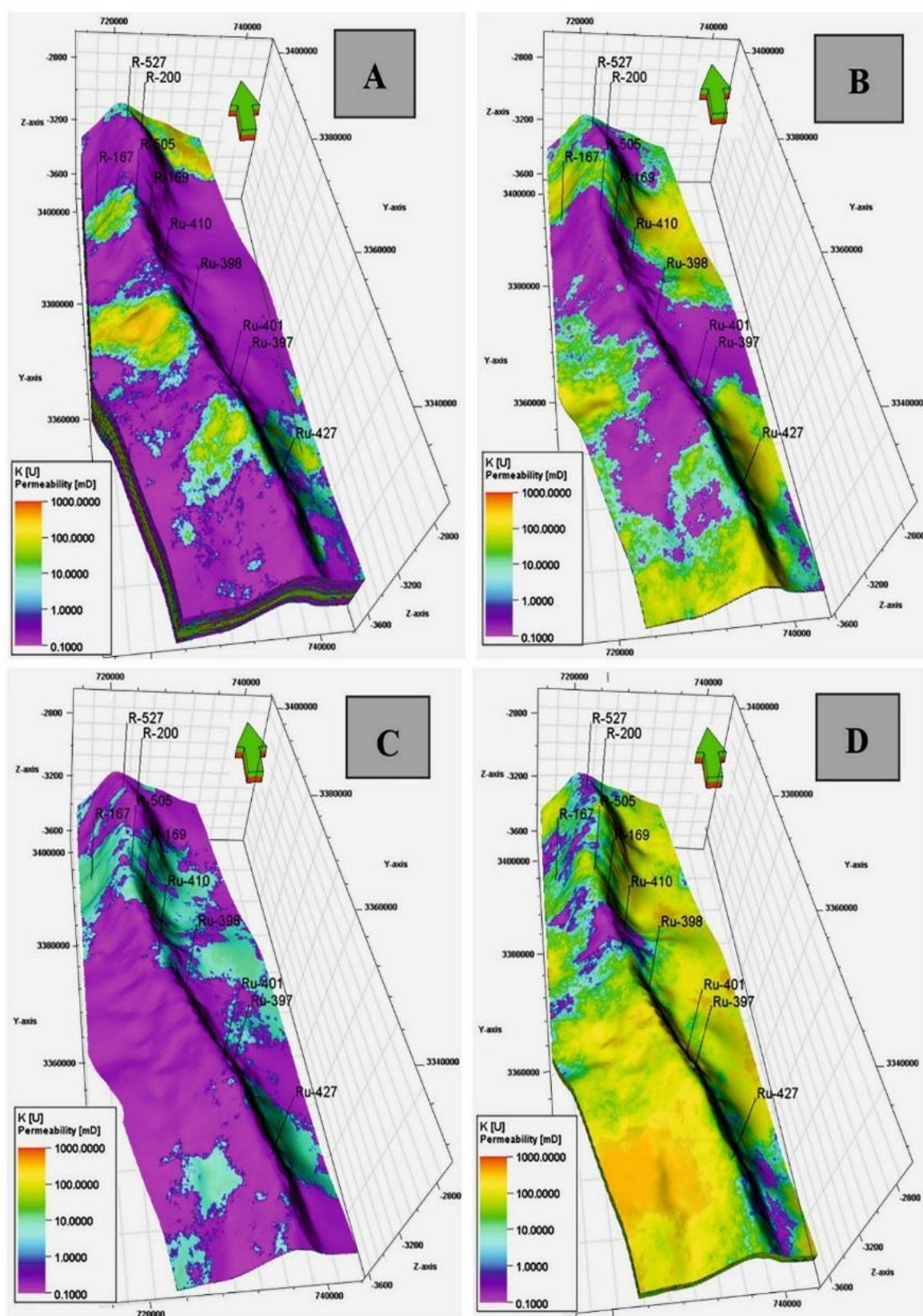


Fig. 15. I. A) Permeability modeling for upper Zubair member (Z1); B) Permeability modeling for AB unit in upper Sandstone member (Z2); C) Permeability modeling for the C unit; D) Permeability modeling for DJ

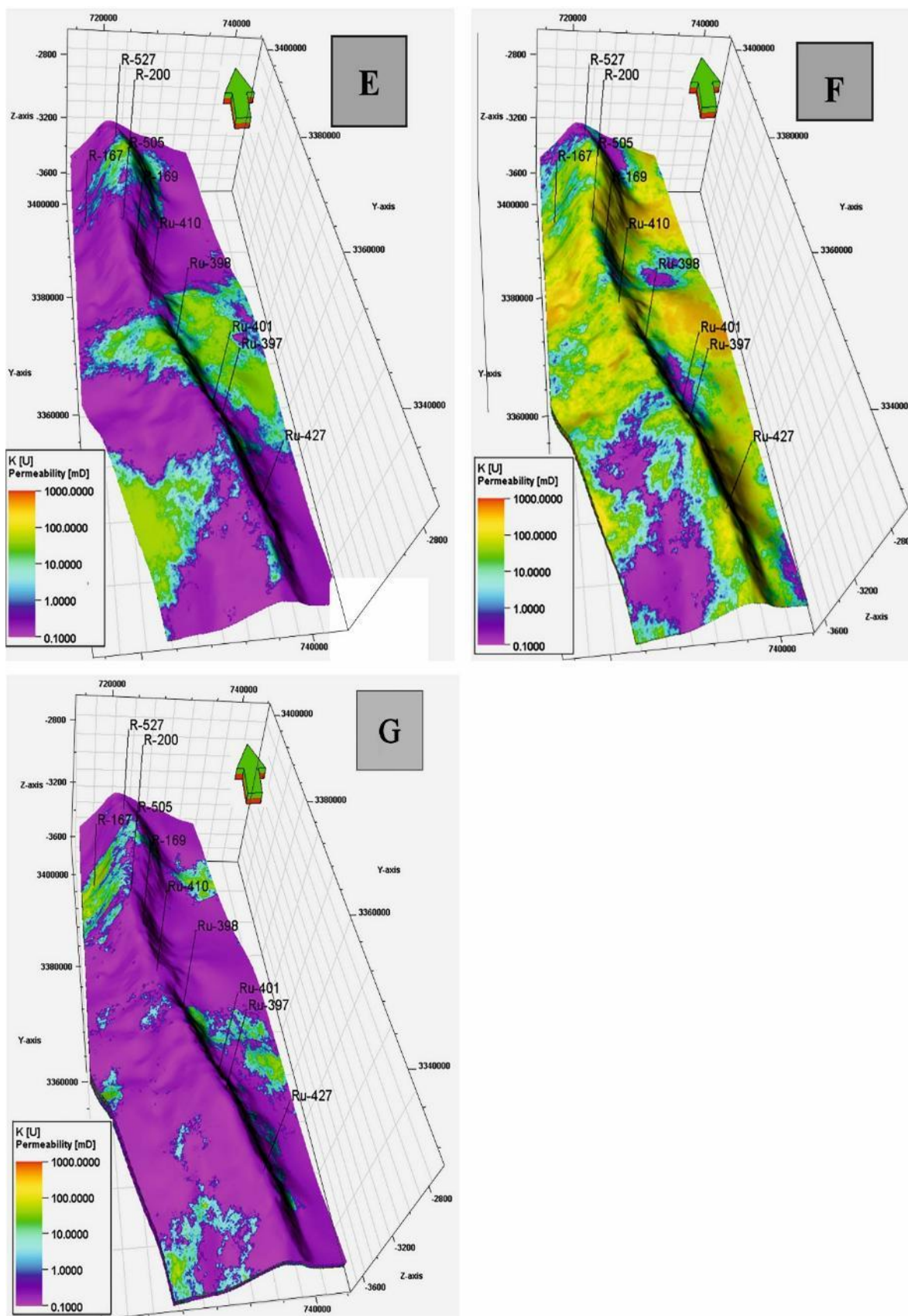


Fig.15. II. E) Permeability modeling for K unit; F) Permeability modeling for the LN unit; G) Permeability modeling for the middle Shale member (Z4)

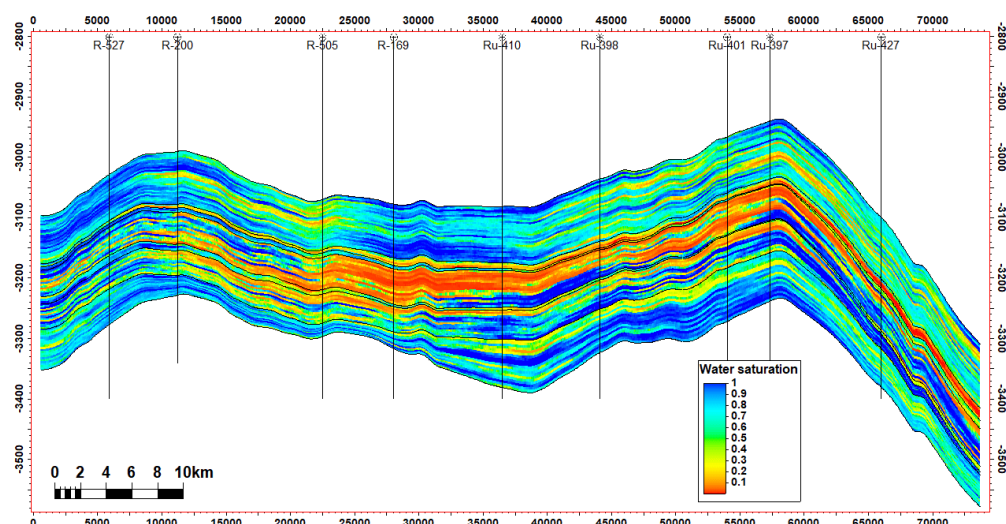


Fig. 16. Sw model cross-section in the NW-SE direction for the Zubair reservoir in North and South Rumaila Oil Field

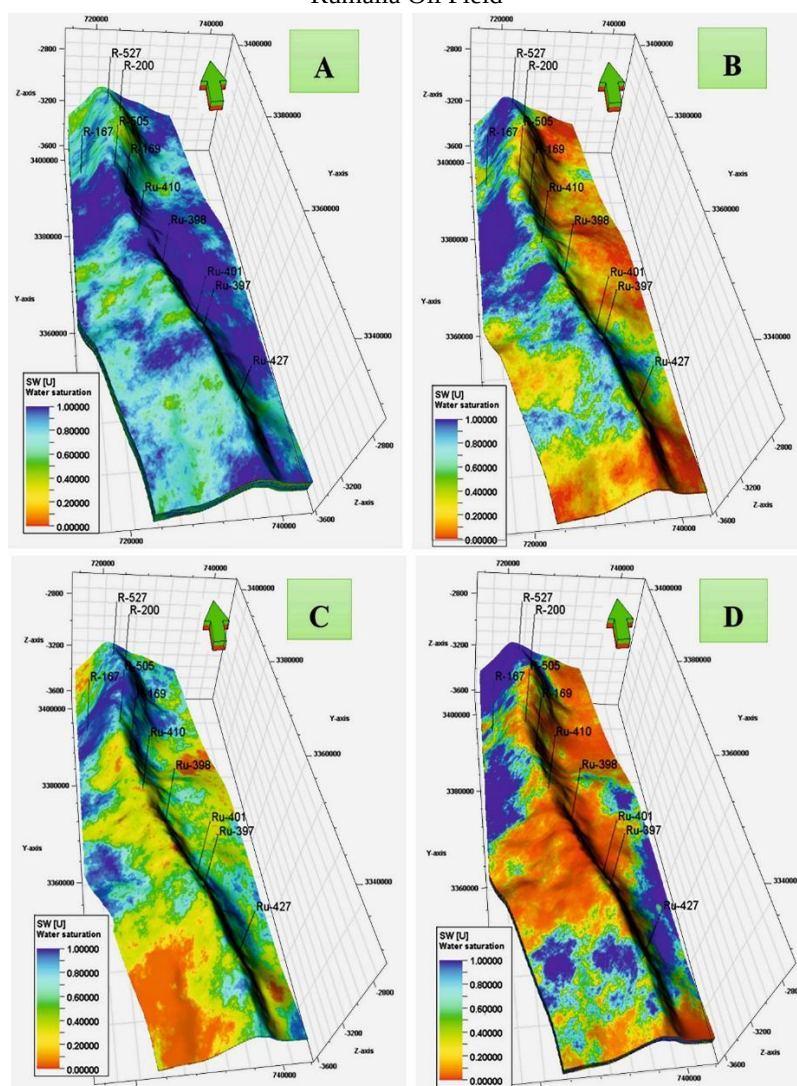


Fig. 17. I. A) Water Saturation modeling for upper Zubair (Z1) member; B) Water Saturation modeling for AB unit in upper Sandstone member (Z2); C) Water Saturation modeling for the C unit; D) Water Saturation modeling for the DJ unit

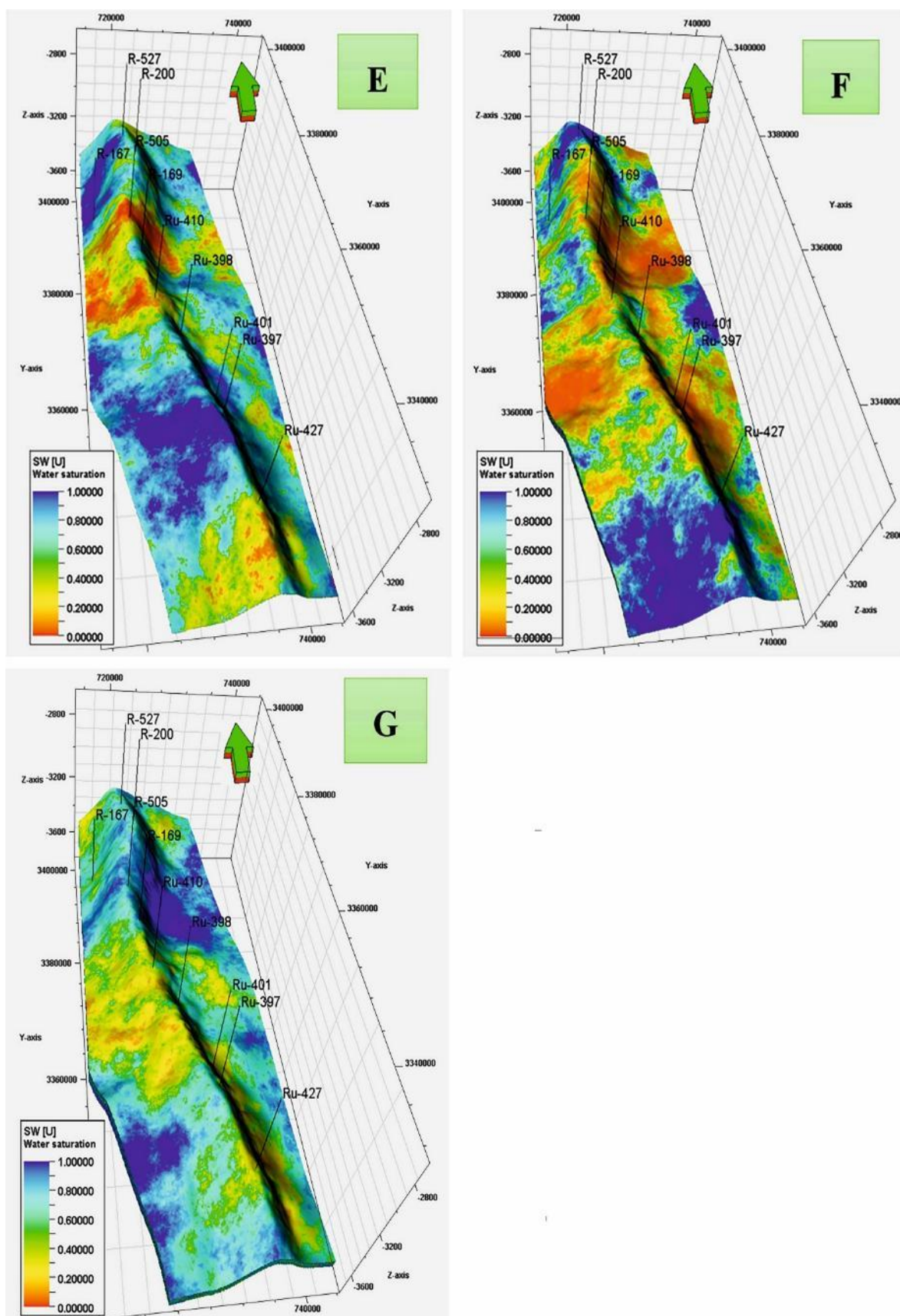


Fig.17. II. E) Water Saturation modeling for the K unit; F) Water Saturation modeling for LN unit; G) Water saturation modeling for the middle Shale member (Z4)

5.4. Geological Interpretation and Reservoir Property Variations

The reservoir units are evaluated through an integrated analysis of effective porosity, permeability, water saturation, and net pay within the field's structural framework. The average reservoir properties for studies units are summarized in Table 1. The structure of the Rumaila oilfield is defined by a NW-SE trending anticline formed of the North and South Rumaila domes, separated by a saddle. It provides primary influence on reservoir continuity and hydrocarbon distribution. According to the available data, three members of the Zubair Formation were diagnosed. The CPI interpretations are presented in Figs. 18 and 19.

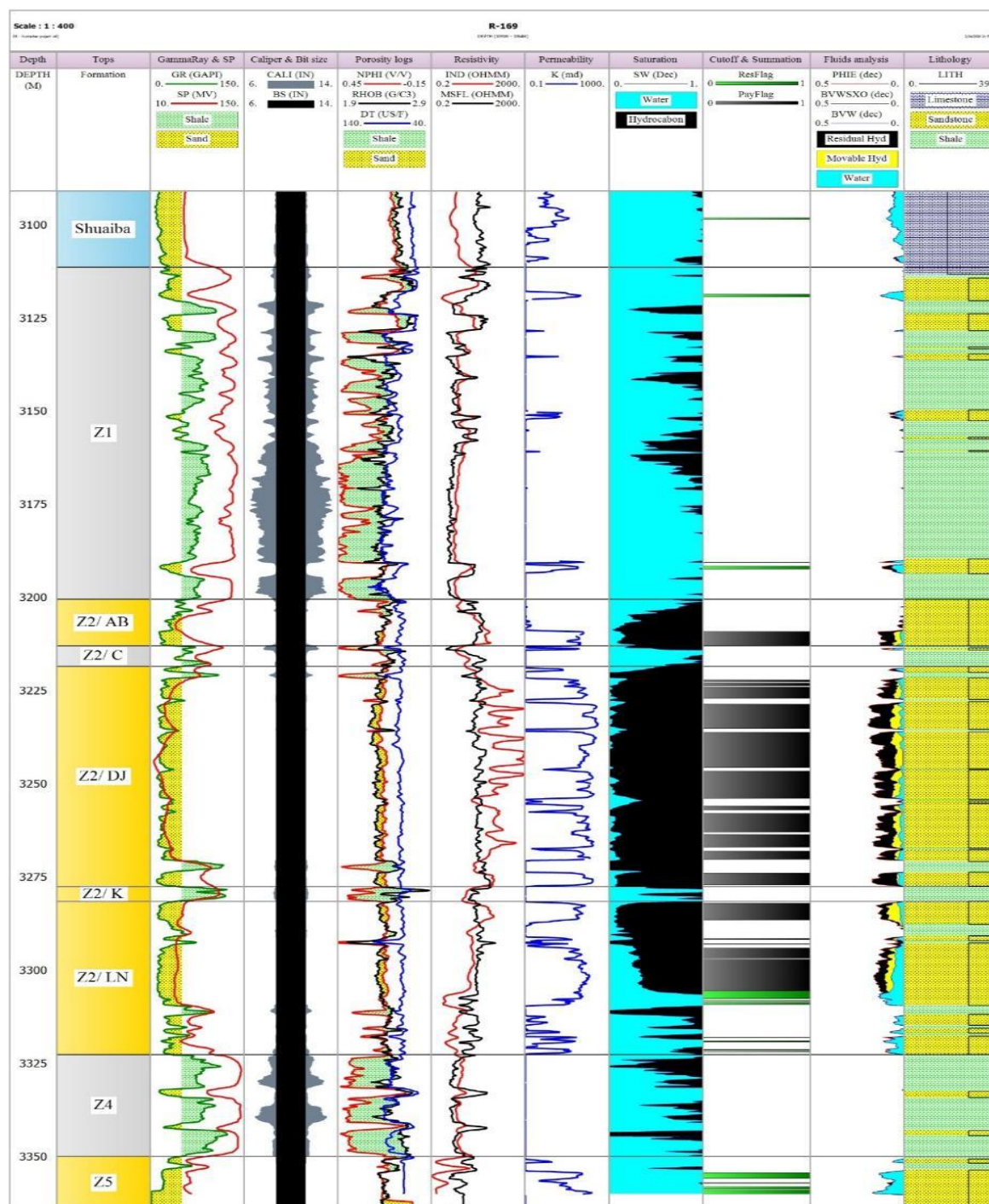


Fig. 18. CPI of the Zubair Formation in South Rumaila Oilfield, well R-169

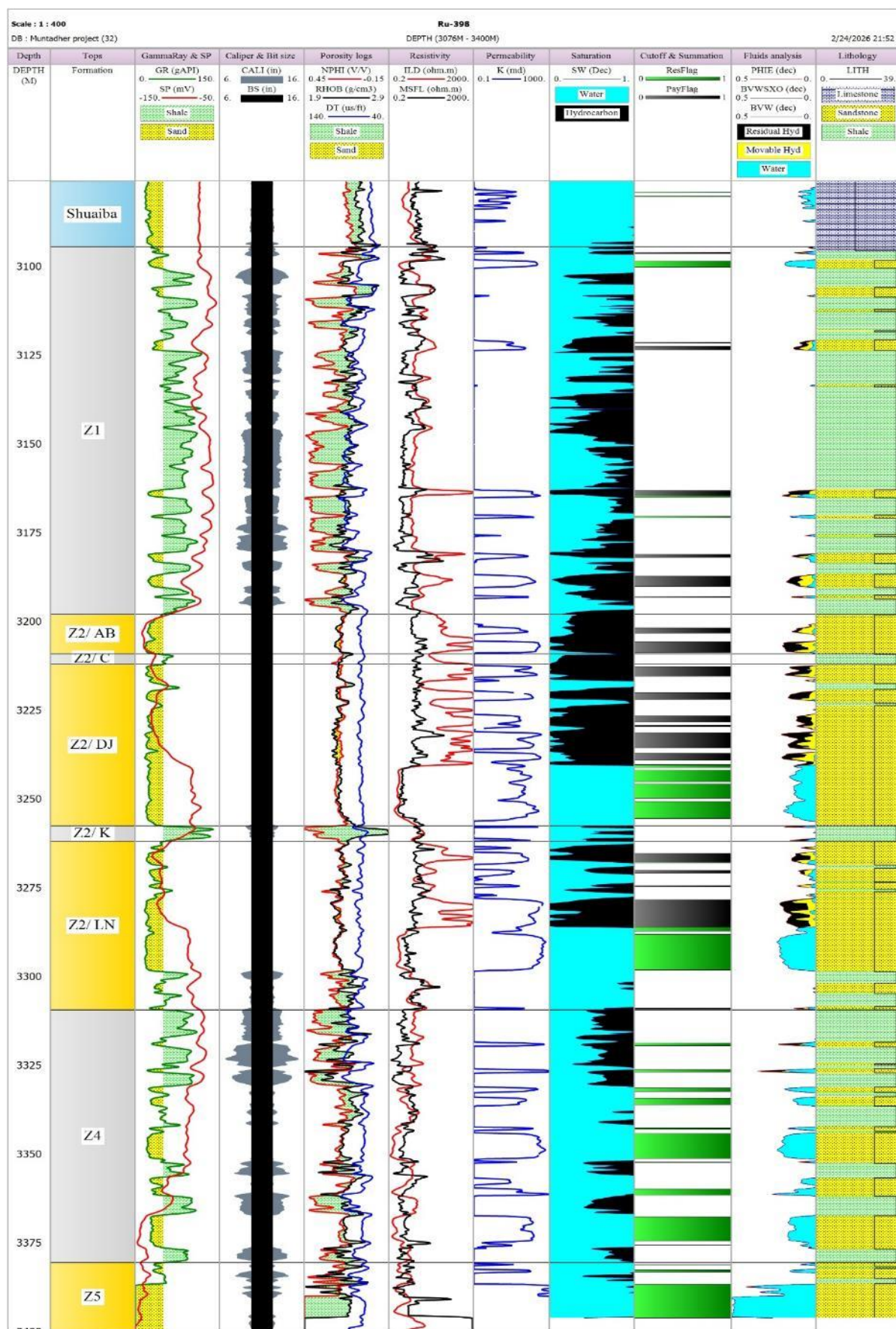


Fig. 19. CPI of the Zubair Formation in South Rumaila Oilfield, well Ru-398

Table 1. Average reservoir properties and net pay thickness for three members of the Zubair reservoir within the North and South Rumaila oil field

Well	Units	Thickness (m)	Net pay (m)	PHIE %	K (md)	Vsh %	Sw %	Sh %
R-167	Z1 (Upper shale member)	90	1.63	10	79	30	85	15
R-169		89	0	5	14	36	88	12
R-200		87	2.74	10	44	33	72	28
R-505		83.5	5.18	13	75	28	17	83
R-527		77	0	39	14	39	84	16
Ru-397		95.86	21.18	16	157	26	14	86
Ru-398		103.4	8	13.5	75	28	20	80
Ru-401		93.42	14.17	15	156	28	24	76
Ru-410		93.12	1.52	15	141	31	58	42
Ru-427		101.9	19	15	71	25	23	77
R-167	Z2 (Upper sandstone member) Unit - AB	12.25	0	14	124	5	88	12
R-169		12	3.88	12	35	17	14	86
R-200		5.5	1.22	15	132	20	21	79
R-505		5.18	1.37	10	21	25	19	81
R-527		5.8	1.83	12	129	17	14	86
Ru-397		11.13	6.25	13	66	19	13	87
Ru-398		11.13	4.7	16	156	20	13	87
Ru-401		11	3.35	12	48	25	20	80
Ru-410		9.9	3.35	15	118	21	13	87
Ru-427		16.5	11.5	15	136	20	2	98
R-167	Z2 (Upper sandstone member) Unit - DJ	53.1	0	13	102	7	90	10
R-169		59.1	43.8	14	99	17	5	95
R-200		52.7	16	15	165	12	8	92
R-505		53	29.2	15	109	22	12	88
R-527		47.8	13.7	14	118	23	24	76
Ru-397		56.54	29.57	15	120	22	7	93
Ru-398		45.57	14.7	14	104	21	8	92
Ru-401		55.8	34.1	16	170	24	6	94
Ru-410		60.6	30.6	17	206	21	6	94
Ru-427		60	7	17	190	23	6	94
R-167	Z2 (Upper sandstone member) Unit - LN	53.25	0	11	96	11	96	4
R-169		41	16.75	13	45	14	25	75
R-200		39.6	18.5	15	150	34	36	64
R-505		48.3	19.96	16	159	17	14	86
R-527		43.28	9.45	15	158	14	16	84
Ru-397		50.6	14.17	15	113	21	6	94
Ru-398		47.55	12.3	15	133	22	15	85
Ru-401		49.67	13.11	16	146	23	9	91
Ru-410		48.3	7	17	192	18	11	89
Ru-427		24.4	0	17	187	13	94	6
R-167	Z4 (Middle Shale member)	79.5	0	7	30	21	77	23
R-169		27.25	0	6	5	38	75	25
R-200		26.67	0.3	11	24	43	59	49
R-505		23.9	0	3	11	42	70	30
R-527		60.6	2.44	11	38	15	26	74
Ru-397		79.7	11	12	75	24	23	77
Ru-398		71.15	0	12	76	31	86	14
Ru-401		86.9	0	13	87	34	77	23
Ru-410		79.7	0	11	71	29	79	21
Ru-427		63.8	4.5	11	14	31	38	42

- Upper Shale Member (Z1) is dominantly shale with a thin sandy layer. In the northern three wells (R-167, R-200, and R-505), there is a small net pay (average 3.18 m), fair porosity (11), moderate permeability (66 md), and moderately water saturated (58%). This implies the occurrence of narrow, isolated sandy beds within a mostly shale sequence. In contrast, all five southern wells have net pay, characterized by an average thickness (12.77 m), good porosity (15), permeability (120) md, and low water saturation (27). The southern part has better-developed, continuous sandy lenses within Z1, which increasing its reservoir potential. Wells with zero net pay (e.g., R-169, R-527) have low gross averages (PHIE ~5, high Sw), indicating shale dominance.

- Upper Sandstone Member (Z2) is the main reservoir interval within the Zubair Formation. It is divided into three sandstone units: AB, DJ, and LN, with two primary shale barriers: the C shale separating AB from DJ and the K shale separating DJ from LN. These shales have high Vsh values (>35%) and act as effective sealants within the reservoir.

AB Unit exhibits varied development. In the North, four wells had an average net pay (2.08 m) and good pay-zone quality (PHIE= 16, K= 79.3 md, Sw=17%). The southern wells had thicker average net pay (5.83 m) and higher quality (PHIE= 15, K= 104.8 md, Sw= 12%), indicating better depositional facies in the southern part due to its proximity to the sediment supply.

- DJ Unit is the most abundant sandstone interval. In the North, four wells have a significant net pay (average 25.68 m) and good properties (PHIE = 16, K = 122.8 md, Sw = 12%). Southern wells provide uniform net pay, with an average thickness (23.19 m) and even superior pay-zone quality (PHIE = 17, K = 158 md, Sw = 6%). The exceptionally low Sw indicates an efficient hydrocarbon column and good reservoir continuity. This unit is regarded as one of the best reservoir intervals in the Zubair reservoir (Figs. 18 and 19).

- LN has good reservoir properties. In the northern region, four wells showed an average net pay 16.17 m, with PHIE = 14.8, K = 128 md, and Sw = 22%. In the South, four wells (excluding Ru-427, which displays no pay due to a water saturation of 94%, despite good porosity and permeability) display an average net pay of 11.65 m, with superior quality metrics such as PHIE = 16.8, K = 146 md, Sw =10%. It is considered the second reservoir unit.

- Middle Shale Member (Z4) is predominantly shaly but contains sporadic sandy beds. In the North, only two wells (R-200, R-527) record thin net pay (average 1.37 m) with moderate properties (PHIE= 11, K= 31 md, Sw= 42%). In the South, two wells (Ru-397, Ru-427) have thicker net pay (average 7.75 m) and somewhat better quality (PHIE 13, K= 44 md, Sw= 30%). Other wells show zero net pay, with gross averages reflecting shale (low PHIE, high Vsh).

Well R-167 has a high water saturation across all units due to its location in the western flank of the fold. The lateral change in reservoir characteristics within the southern dome, near the Arabian Shield sediment source, led to the deposition of coarser, cleaner sands in an active deltaic environment, whereas finer, more argillaceous sands accumulated in the north dome. The presence of two structural domes (northern and southern) separated by a saddle led to preferential hydrocarbon accumulation in the southern dome, hence decreasing water saturation.

6. Conclusions

The integrated petrophysical study of the Zubair Formation in the Rumaila oilfield shows vertical and lateral heterogeneity controlled by structural setting and facies distribution. Member Z2 is the main hydrocarbon-bearing interval, especially within the DJ and LN units, while the AB unit producing secondary net pay development. C and K units behave as excellent shale-dominated seals, enhancing vertical compartmentalization. Members Z1 and Z4 have variable and generally low reservoir potential. Notably, well R-167 lacks hydrocarbon-bearing intervals and is mostly water-saturated, showing local structural control over fluid distribution.

Reservoir quality improves towards South Rumaila, indicating more favorable depositional conditions and better pore preservation. These findings underscore the significance of integrated petrophysical modeling in accurate reservoir characterization and optimal field development planning.

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