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INTEGRATION OF CORE DATA AND WELL LOGS FOR RESERVOIR CHARACTERIZATION, FLOW UNITS EVALUATION AND PERMEABILITY ESTIMATION IN SHALY SAND RESERVOIRS, ONSHORE EAST NILE DELTA EGYPT

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تكامل بيانات تسجيلات الآبار والعينات اللبية لتوصيف الخواص الخزانية وتقييم وحدات التدفق وتقدير النفاذية فى الخزانات الرملية الطفلية بمنطقة شرق دلتا النيل البرية فى مصر

الخلاصة: خزان أبو ماضي فى الميسينيان العلوي يمثل التحدي الحالي في فعالية الغاز والإنتاج فى الاستكشاف البري "لدلتا النيل"، والتنمية والإنتاج، من خلال التعرف والفهم لتوزيعات الخزان وترسيم الرمال خلال مرحلة الاستكشاف والتنمية.

مفتاح البناء لنموذج الخزان وتحديد الإمكانيات الهيدروكربونية يتم من خلال دقة التنبؤ بخواص المكامن وقدرة التدفق عن طريق المسامية، وتشبع المياه والنفاذية. تقدر مواصفات الخزان باستخدام البيانات الأساسية وبيانات السجل وهي العملية الأساسية لتحديد وحدات التدفق ، وأيضا التغايرات الرأسية والأفقية. استخدام التحليل الأساسية يقلل من عدم اليقين في تقييم الخزان بتوفير بيانات تمثيلية من الخزان في الظروف الحاليه للخزان لبناء نموذج واقعي للخزان. توصيف مسامية ونفاذية الخزان هو المتحكم الرئيسى في الخواص البتروفيزيائية للخزان وإنتاجية المكمن .

في مجال الدراسة التعرف على وحدات التدفق بالخزان والتنبؤ بالنفاذية أصبحت متاحة من التكامل بين بيانات السجلات الكهربية واالعينات اللبية لآبار مختارة تغطي خزان أبو ماضي. وتم عمل نموذج متعدد التخصصات من أجل توصيف خزان أبو ماضي، يشمل تقييم العينات اللبية ووصف وتصنيف وحدات التدفق البيانات الأساسية وخواص الخزان البيتروفيزيائيه والتنبؤ بالنفاذية ، على أساس التوزيع الرأسي والترابط. السحنات المحددة يتم تجميعها في مجموعات من السحنات الرئيسية، ثم يتم وصف كل مجموعة من حيث خواصها الرئيسية، ووحدات التدفق، التي عملت كمتحكم رئيسي لتوزيع الخواص بعيداً عن الآبار وبناء نموذج جيولوجى ثلاثى الأبعاد. وأخيراً الفهم السليم وتفسير الترسيب لخزان أبو ماضي الرملى بما في ذلك البيئة الترسبيةالقديمة وتدفق وحدات التوزيع قضية أساسية في تقييم جودة خزان الميسينيان العلوى في دلتا النيل البري.

ABSTRACT: *The upper Messinian Abu Madi reservoir present a challenge in their effective gas and production in the onshore Nile Delta exploration, development and production, through recognition and understanding of the reservoir distributions and sand delineation during the exploration and development phase. The key to build reservoir model and define hydrocarbon potential through accurate prediction of reservoir properties and dynamic flow capacity by estimated porosity, water saturation and permeability. Estimation of reservoir characterization using core data and log data are primary process for identification of rock flow units, vertical and horizontal heterogeneities. Using core analysis reduces uncertainty in reservoir evaluation by providing data representative of reservoir at in-situ conditions to build a realistic reservoir model. Characterization of porosity and permeability of the reservoir is an important control on reservoir petrophysics and reservoir productivity. In the area of study the reservoir flow units identification and prediction of permeability became available from the integration between core and wireline logs data for selected wells covering Abu Madi reservoir. An inter-disciplinary workflow was followed in order to characterize the Abu Madi reservoir. The workflow combined, core data evaluation, description, and flow-units classification. Petrophysical reservoir properties and permeability prediction, based on their vertical distribution and association. The identified facies are grouped into main major facies groups, each facies group is described in terms of its main characteristics, and flow-units, which acted as a main driver for the properties distribution away from the wells and constructing a 3D Geomodel. Finally the proper understanding and interpretation of the Abu Madi sand reservoir deposition including the paleo-depositional environment and flow units distribution are a key issue in assessing upper Messinian reservoir quality of the Onshore Nile Delta.*

INTRODUCTION

The main objectives of core evaluation are to characterize the reservoir units in order to understand the geology and describe reservoir properties to build reservoir model which represent and explain the performance of different reservoir units.

The goal of any reservoir characterization is to understand the reservoir Petrophysical parameters, such as porosity (Phi), permeability (K) and water saturation (S_W) which is controlled by pore sizes and their distribution and interconnection.

This paper provides and discusses the methods of evaluation of core data and classification of different rock types which is critical for decision-making in mature fields for facies, reservoir parameter distribution and optimizing production. Various rock-typing techniques as Leverett's (1941) reservoir quality index (RQI), (Winland *R*35 (1972), flow zone indicator (FZI)

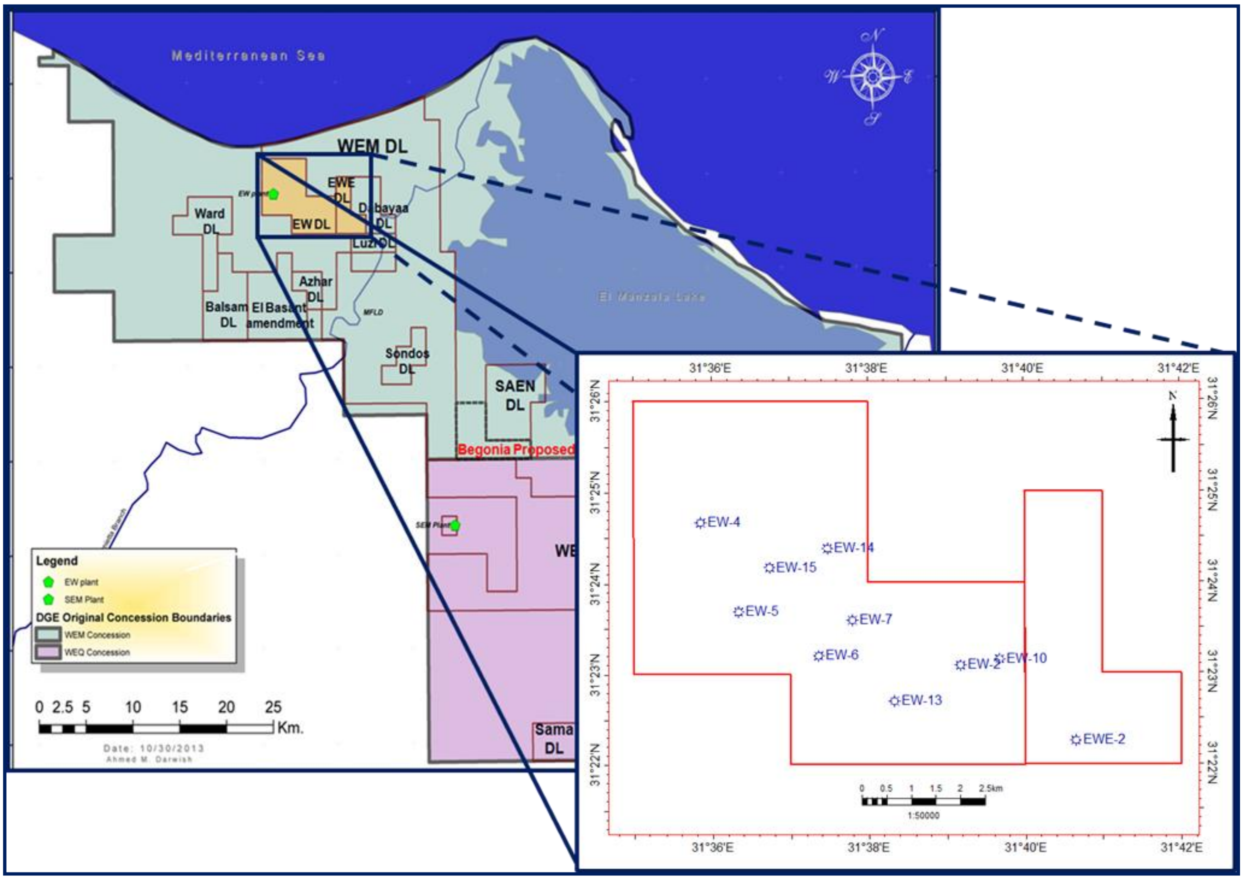


Fig. 1: Location Map North Nile Delta on Study area.

(Amaefule, 1993) are used to define the reservoir into different hydraulic flow units (HFU), and predict reservoir permeability. The study area for this reservoir characterization is located in the Nile Delta in Egypt (Fig 1).

The area of the study is covered by 11 wells with E- logs, three wells of them with cores (two for L. Abu Madi formation and one for U. Abu Madi formation).

Upper Abu Madi formation: the main reservoir composed of well-defined fluvial sandstone channels with shale and silt inter bed facies. Reservoir quality in the channels is very good. **Lower Abu Madi formation**: main reservoir composed of sandstone with shale and silt inter bed facies. Reservoir quality is variable due to the inter-fingering transgressive marine shales with more silty deltaic deposits.

Core analysis:

Conventional rock-core porosity and permeability measurements, are used to determine rock types and flow units in the cored key wells in el Wastani field, El Wastani -4, el Wastani -6 wells for Lower Abu Madi reservoir and El Wastani E-2 well for upper Abu Madi reservoir

Core Porosity:

The porosity of a rock is a measure of the storage capacity (pore volume) that is capable of holding fluids. Quantitatively It is represents the measurement of the effective porosity

The core porosity is represented by the different values which are related to different facies types and shale content

Core Permeability:

Permeability is generally defined as the ability of rock porous media to allow the passage of fluid (Friedman, 1977). Permeability is determined by the dimensions of the connected pores, and measures the flow capacity of the formation to transmit fluids. The rock permeability (k) is a very important rock property because it controls the directional movement and the flow rate of the reservoir fluids in the formation. The distribution of permeability ranges of the core samples represents a wide range between 0.1 md and 1000 md

Core depth correction:

The natural Gamma radiation of the cores was measured and the maximized smoothed Gamma emission intensity of cores and the spectral gamma are plotted against core depth to detect core depth shift.

Core data to reservoir condition correction:

In order to estimate valid reservoir parameters from the well logs they first have to be calibrated to the available core data. The most important parameter that affects the porosity and permeability of any reservoir is the net of overburden pressure (NOBP). It is the difference between overburden and internal pore pressure. The relations between the core porosity values at reservoir condition 4000 psi NOBP and ambient condition (200 psi) are given in (Fig. 2).

The relations resulted into the following equations:

$y = 0.915\ x$ (Upper Abu Madi Res.) (1)

$y = 0.919\ x$ (Lower Abu Madi Res.) (2)

Where y= core porosity at reservoir condition at 4000psi

X = core porosity at ambient condition at 200psi

The relation between the core permeability values at reservoir condition 4000 psi NOBP and ambient condition (200 psi) as shown in (Fig. 2).

The relation resulted into the following equation:

$y = 0.772\ x$ (Upper Abu Madi Res.) (3)

$y = 0.646\ x$ (Lower Abu Madi Res.) (4)

Where y = (core permeability at reservoir condition at 4000psi)

X= (core permeability at ambient condition at 200psi)

Rock Facies, Textural Characteristics and Porosities:

The first stage of the study is consists of defining rock types by relating geological framework, Lithofacies, and petrology to porosity, permeability

Upper Abu Madi formation:

The cored intervals of the Upper Abu Madi Formation in El Wastani east - 2 well comprise dominantly vertically stacked sequences of pebbly locally conglomeratic sandstones and argillaceous laminated finer grained sandstones with minor sandy siltstone facies. Detailed sedimentary facies analysis reveals a total of three facies types in the cored intervals (Fig. 3)

Lower Abu Madi formation:

The cored intervals of the Lower Abu Madi Formation in El Wastani - 6 and 4 wells comprise dominantly vertically stacked sequences of pebbly locally conglomeratic sandstones and argillaceous laminated finer grained sandstones and silty and sandy mudstones. Detailed sedimentary facies analysis reveals a total of three facies types in the cored intervals (Fig. 4)

Based on their vertical distribution and association, the identified facies are grouped into two major facies group.

Rock Types classifications:

The rock typing is a process for reservoir rock classification into units

Characterized by a unique set of petrophysical properties e.g. porosity - permeability relationship, and electric properties.

Porosity and permeability data available from the core analysis

Several semi-empirical equations have subsequently been proposed to improve the estimation of rock permeability subjected to various loading conditions (Panda and Lake, 1994; Bernabé et al., 2003; Costa, 2006; and some modified KC models are listed here.

Bayles et al. (1989) proposed a porosity-permeability relationship based on the fractal pore cross-sectional area, which can be formulated as

$$K = c\ \phi^{z+2} / (1- \phi)^2 \qquad (5)$$

Where c is a constant to determine permeability, and z is an exponent parameter for porosity. A similar permeability formulation based on fractal pore space observations developed by Costa (2006) is written as

$$K = c\ \phi^{z} / (1- \phi) \qquad (6)$$

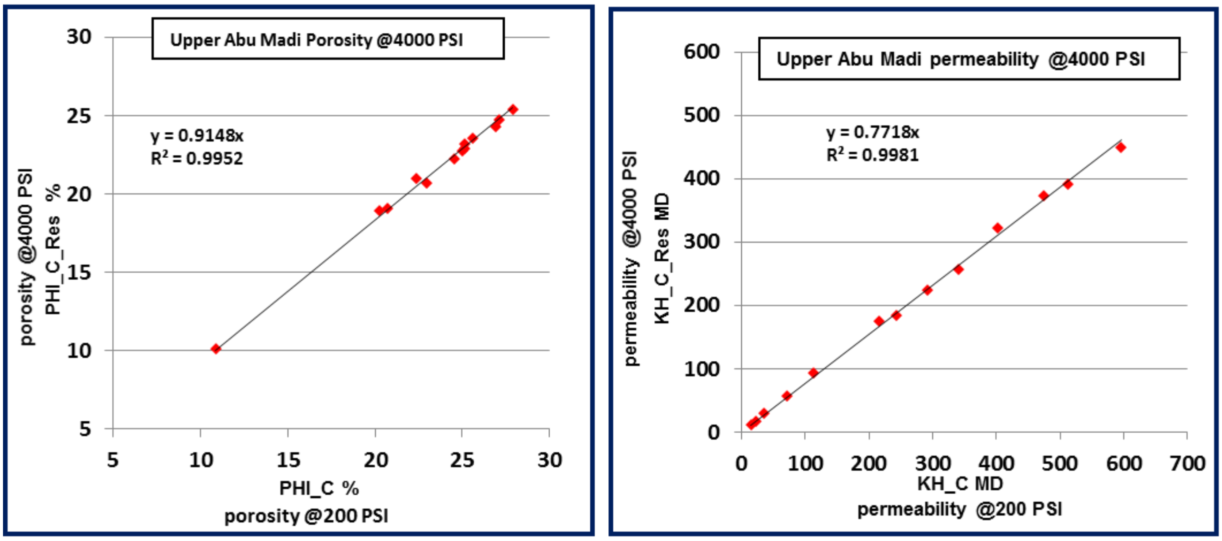
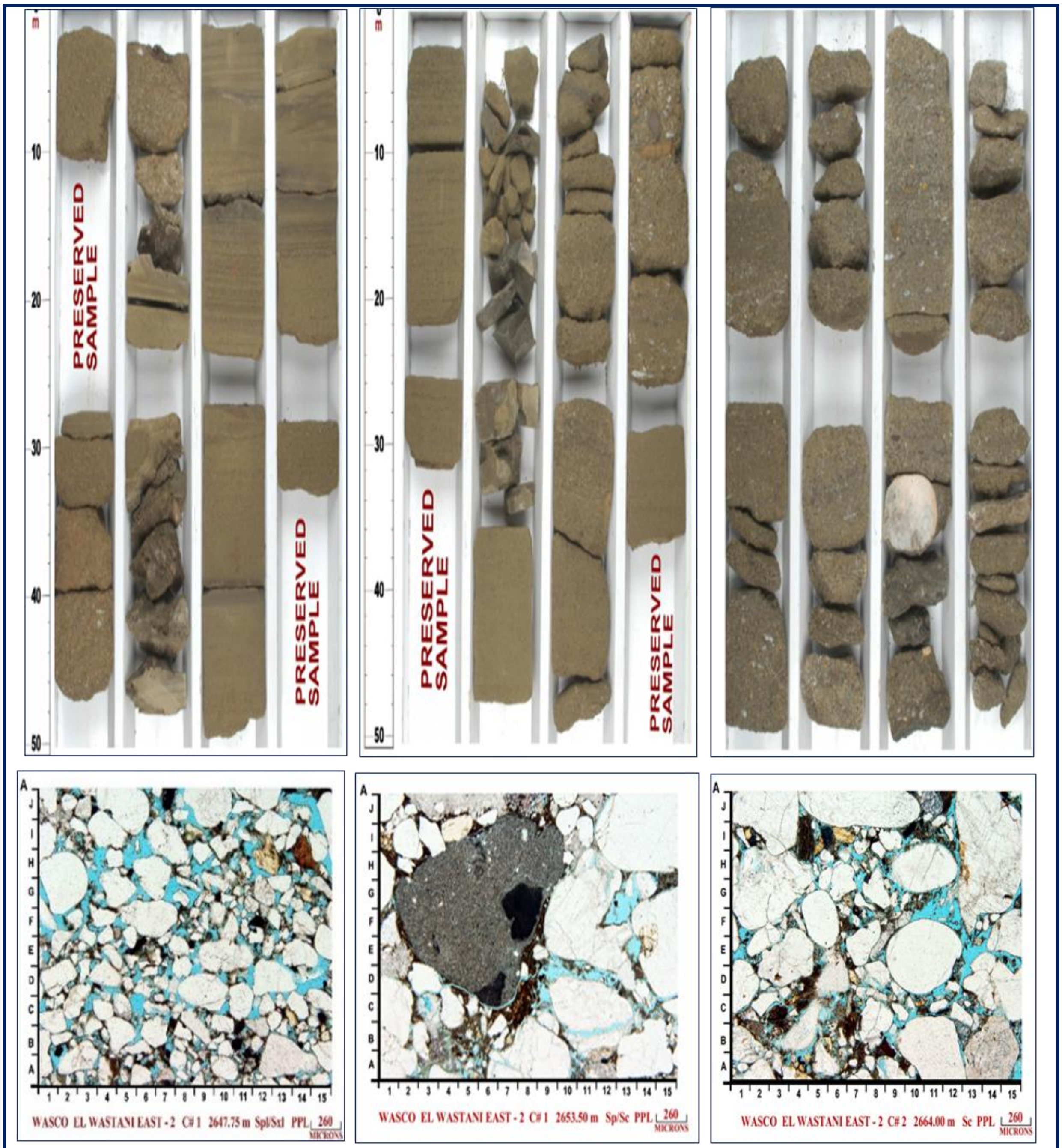


Fig. 2: correlation of core porosity and permeability at (4000psi) and ambient condition.

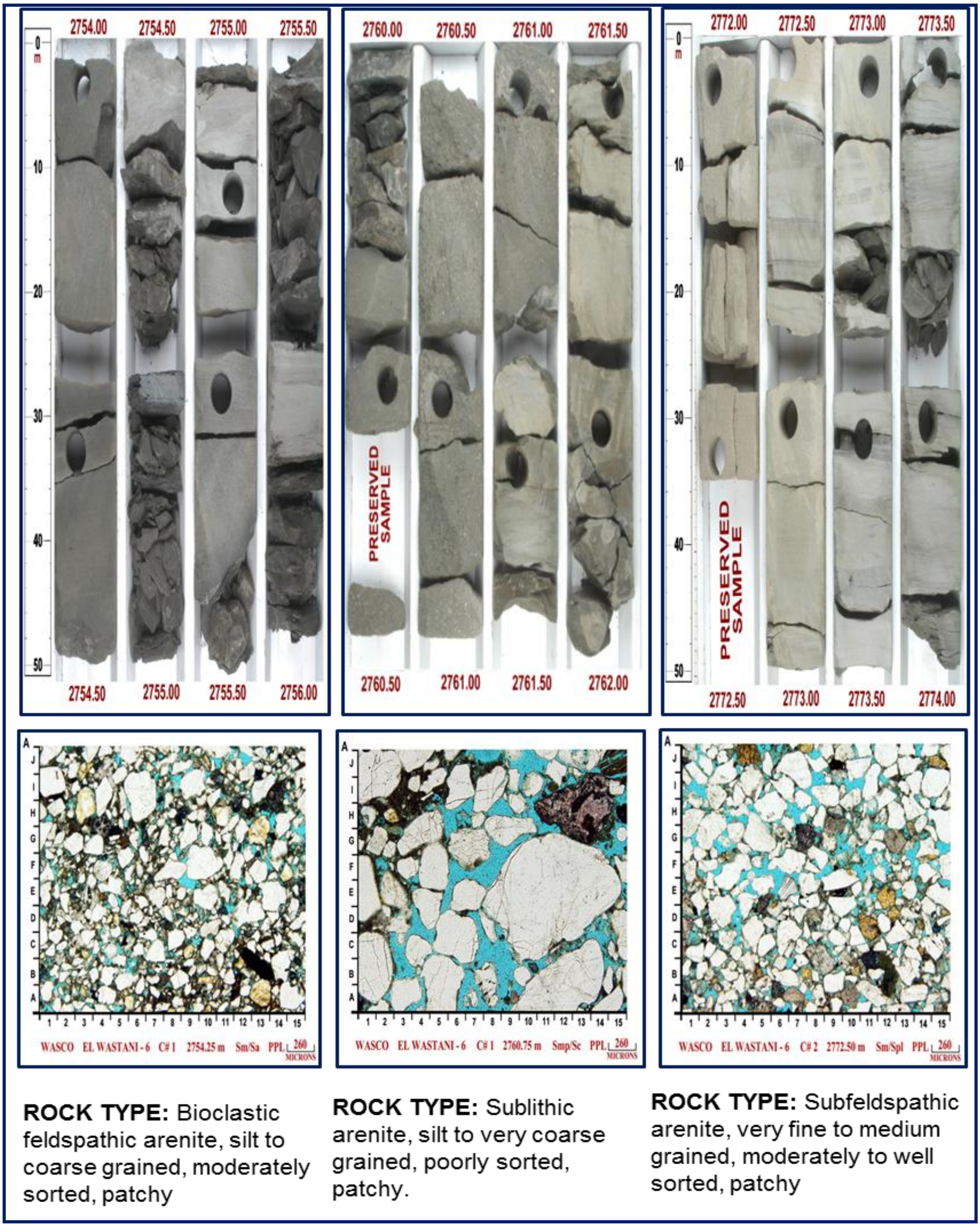


ROCK TYPE: Subfeldspathic arenite, very fine to very coarse grained, poorly to moderately sorted

ROCK TYPE: Anhydritic lithic arenite, very fine to pebble, poorly sorted, patchy cemented and poorly compacted

ROCK TYPE: Sublithic arenite, very fine to very coarse grained, moderately sorted, patchy cemented

Fig. 3: Core Interpretation and Facies Upper Abu Madi Formation.



ROCK TYPE: Bioclastic feldspathic arenite, silt to coarse grained, moderately sorted, patchy

ROCK TYPE: Sublithic arenite, silt to very coarse grained, poorly sorted, patchy.

ROCK TYPE: Subfeldspathic arenite, very fine to medium grained, moderately to well sorted, patchy

Fig. 4: Core Interpretation and Facies Lower Abu Madi Formation.

(R35) (Winland):

Winland of Amoco established an empirical relationship between porosity, permeability and pore throat radius from mercury intrusion tests, using the data to obtain net pay cut-off values in some clastic Reservoirs.

Winland define Flow unit as reservoir unit with uniform pore throat size distribution and similar flow performance, and determined by R35 (Winland 1972).

The Winland equation was used and published by Kolodzie (1980)

$$\log R35 = 0.732 + 0.588 \log Ka - 0.864 \log \phi \text{ core} \qquad (7)$$

Where R35 is the pore aperture radius corresponding to the 35th percentile of mercury saturation, Ka is air permeability (md), and ϕ is porosity (%).

In Winland's empirical relationship the highest statistical correlation (Gunter et al., 1997) was at the pore throat size corresponding to the 35th percentile of the cumulative mercury saturation curve. The concept behind the use of R35 is that, once different flow unit types have been identified and quantitatively characterized, then the wells are subdivided into smaller units having predictable flow characteristics solving for R35, we get

$$R35 = 10 \wedge (0.732 + 0.588 \log Ka - 0.864 \log \varphi) \qquad (8)$$

The ranges of R35 have distinguished five petrophysical flow units.

1. Megaport: Flow unit with R35 ranging above a threshold of 10 microns.
2. Macroport: Flow unit with R35 ranging between 2 to 10 microns.
3. Mesoport: Flow unites with R35 ranging between 0.5 and 2 microns
4. Microport: Flow units with R35 values in the range of 0.5 to 0.2 microns
5. Nanoport: Flow units with R35 values less than 0.2 microns

From Porosity-permeability plot,

We have tried to distinguish three flow units in cored interval of Upper Abu Madi Fm (Fig. 5)

With Mesoport (1-2 mic.), Macroport (2-10 mic.), and Megaport (10-20 mic.). While in Lower Abu Madi Four flow units (Fig 6), Microport (0.2-0.5 mic.), Mesoport (0.5-2 mic.), Macroport (2-10 mic.) and Megaport (10-20 mic.). Based on Winland flow unit classification four rock units can be characterize

Stratigraphic modified Lorenz Plot (SMLP):

The best way to assess the minimum number of flow units in a reservoir uses a graphical technique based on a stratigraphic modified Lorenz plot (SMLP) (Gunter et al., 1997; Tiab, D and Donaldson, 1996).

Constructing SMLP method is a plot of the percent of flow capacity (% Kh) versus percent of storage capacity (%ϕh) the partial sums are computed and totals are normalized to 100%., and arranged in stratigraphic order. The slope of the segments on these plots is indicative of the flow performance. As shown in (Fig.7&8) the shape of the SMLP curve reflects the flow performance of the reservoir units. Segments with steep slopes are associated with a high percentage of reservoir flow capacity, and therefore, a high production potential.

On the other hand, segments with flat behavior have storage capacity but little flow capacity and are typically reservoir baffles. Segments with neither flow nor storage capacity are considered seals (Salazar Luna 2004), (Gunter et al, 1997). Preliminary flow units are interpreted by selecting changes in slope or inflection

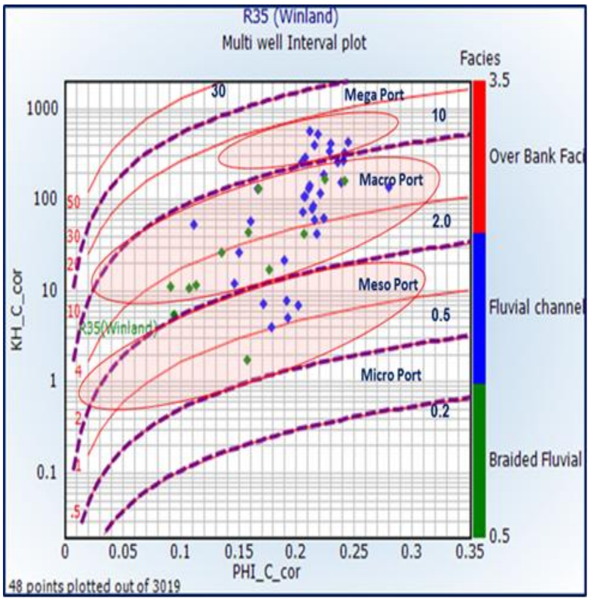


Fig. 5: U. Abu Madi core data porosity – permeability Overlaid by R35 lines.

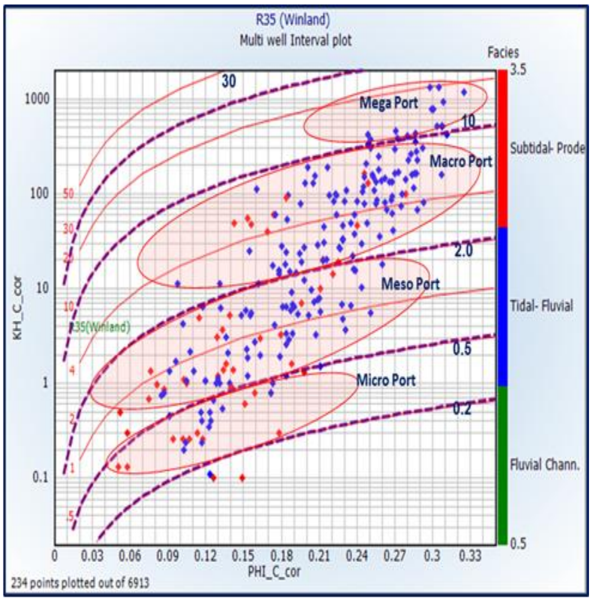


Fig. 6: L. Abu Madi core data porosity – permeability Overlaid by R35 lines.

points in the SMLP curve. Using this method, the main flow units are illustrated in their correct stratigraphic position. Segments with steep gradients have a greater percentage of flow capacity relative to storage capacity, and by definition, have a high reservoir process speed. They are referred to as “speed zones”. For example segment 3, 4, 8 and 9 in well El Wastani E-2 (Fig.7A), segments 7, 8, 9 and 10 in well El Wastani -4 (fig 8A).

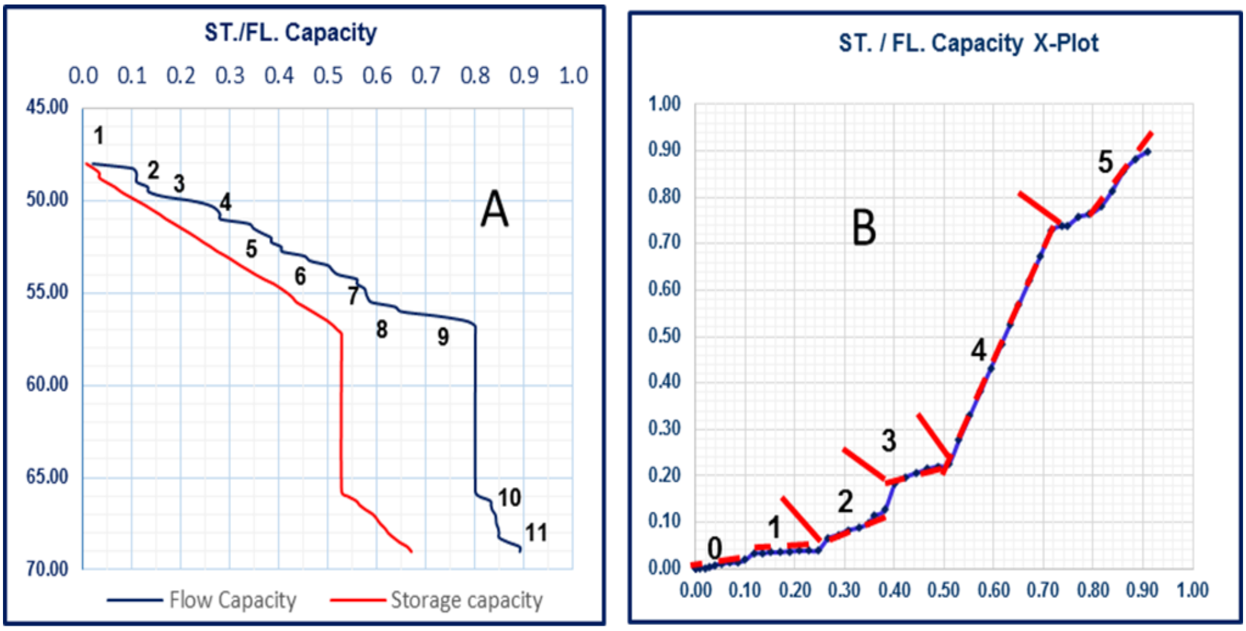


Fig. 7: EWE-2 well (A) stratigraphic modified Lorenz Plot, (B) modified Lorenz Plot sorted by porosity.

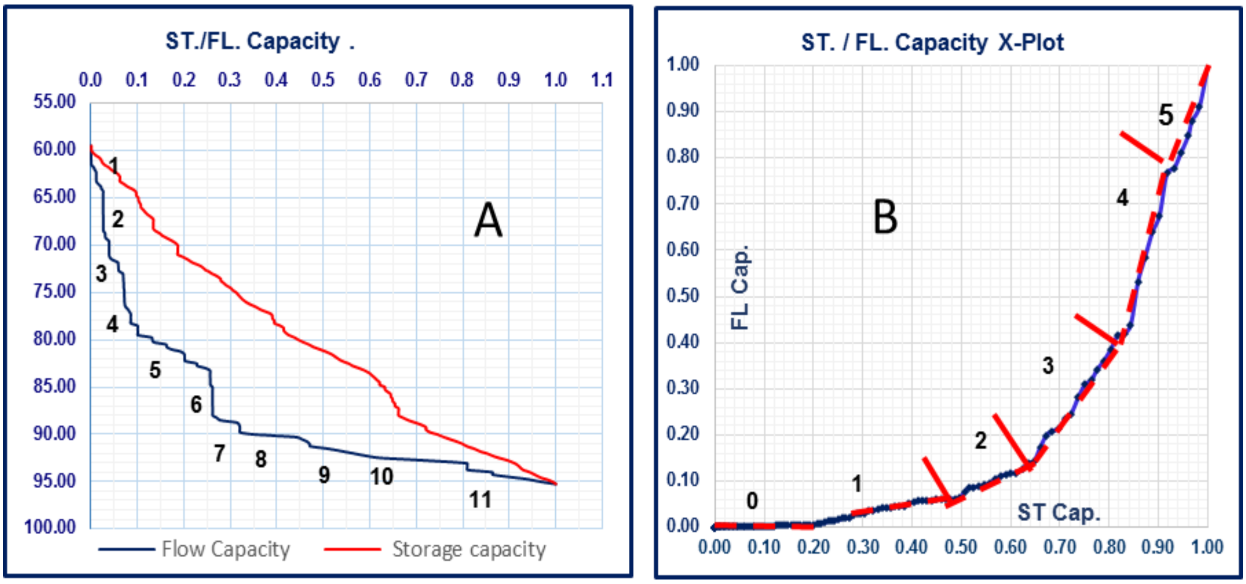


Fig. 8: E-4 well (A) Stratigraphic modified Lorenz Plot, (B) modified Lorenz Plots: sorting by porosity.

Table 1: Summary of Winland rock types.

	Upper Abu Madi			Lower Abu Madi		
	R35 (mic)	**PHI (%)**	**KH (MD)**	**R35 (mic)**	**PHI (%)**	**KH (MD)**
Megaport	10 - 20	20 -25	250 - 600	10 - 20	25 -31	300 -1500
Macroport	2 - 10	9 - 25	10 - 300	2 - 10	15 -30	10 -300
Mesoport	1 - 2	15 -21	2 - 10	0.5 -2	7 -25	0.7 -20
Microport	x	x	x	0.2 – 0.5	5 - 18	0.1 - 1

Based on these plots, the studied intervals in each well can be divided into reservoir units with different flow and storage capacity ,units can be repeated and to resume similar unite performance and define reservoir to main different flow unit MLP presented (Fig.7B & Fig 8B) In porosity order as ascending order. Reservoir can be divided into 5 main Flow units (1-5) and one baffle assigned by (0)

Reservoir Quality Index RQI:

Reservoir Quality Index (RQI) Rock typing classification and flow properties prediction method based on Kozeny-Carmen equation and the concept of mean hydraulic radius (Carmen, 1937). Derivative of RQI equation is based on assumption that porous medium can represented by a bundle of capillary tubes. Kozeny model (Kozeny, 1927) one of the earliest model proposed to estimate permeability from effective porosity and other relevant parameters by the following equation.

$$K = \text{Ø}\,r^2/8\,t \quad \text{(Kozeny, 1927)} \qquad (9)$$

Where K: permeability in md, t: tortuosity,

r= radius of capillary tubes in µm

t and r in equation (9) used by Kozeny and Carmen for realistic porous media and equation was modified in the generalized form by Carmen, 1937 as:

$$K = \left(1/\text{fs}.\,t^2.\ S^2gv\right) * \text{Ø}^3/(1-\text{Ø})^2$$

(Carmen, 1937) …. (10)

Where: K in µm^2, fs: shape factor, t: tortuosity, Ø in fraction, S^2gv specific surface area of unit grain volume in µm

RQI addresses variable Kozeny constant and S^2gv term by Flow zone indicator (FZI)

Which includes all major geological and geometrical characteristics of porous media?

$$\text{FZI} = 1/\sqrt{\text{fs}.\,t\hat{}2.\ S^2gv} \qquad (11)$$

$$K = \text{Ø}^3/(1-\text{Ø})^2 * FZI^2 \qquad (12)$$

$$\sqrt{K/\text{Ø}} = [\text{Ø}\ /\ (1-\text{Ø})\,] * \text{FZI} \qquad (13)$$

If permeability expressed in mille Darcie’s then RQI define as follows:

$$\text{RQI}\ (\mu m) = 0.0314\sqrt{K/\text{Ø}} \quad \text{(Leverett, 1941)} \qquad (14)$$

NCRQI:

Based on RQI normalized cumulative rock quality index NCRQI calculated as Eq. (13) (Siddiqui et al. 2003) for each data point and plotted against depth (Fig 9).

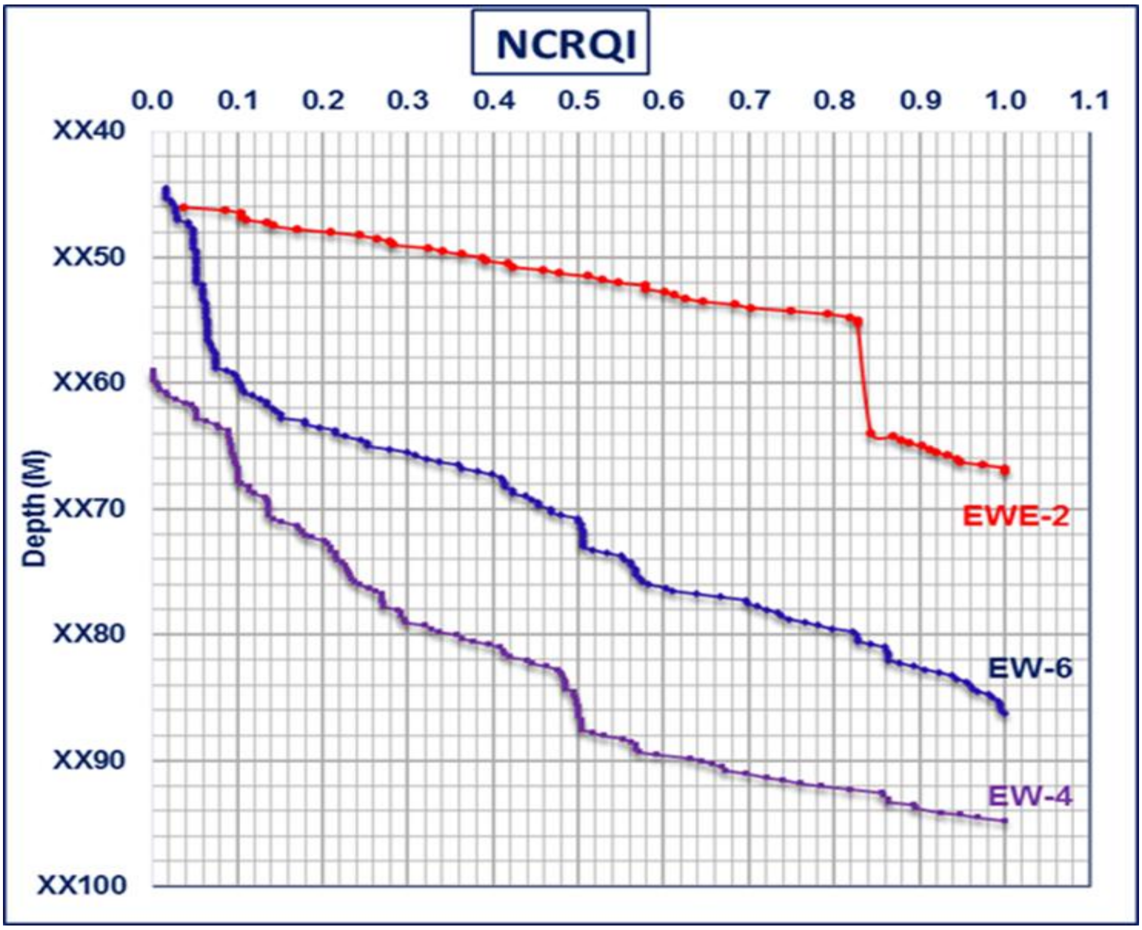


Fig. 9: NCRQI calculated for each data point and plotted against depth.

$$\text{NCRQI} = \frac{\sum_{x=1}^{i}\sqrt{\frac{Ki}{\emptyset i}}}{\sum_{x=1}^{n}\sqrt{\frac{Ki}{\emptyset i}}} \qquad (15)$$

Where, n is the total number of the data and i is the number of data points at sequential steps of calculation. Change in the slope of the NCRQI-depth curve is an indication of different flow zone. (Gomes et al., 2008). Results of applying NCRQI Show vertical change in flow units within core intervals

Hydraulic flow units:

Hydraulic flow unit (HFU) is Defined as a representative reservoir volume practically possess consistent petrophysical and fluid properties (Amaefule et al., 1993)

Hydraulic Unit concept used to divide a reservoir into distinct petrophysical types, each of which has a unique flow zone indicator (FZI) value (Al-Ajmi and Holditch, 2000). The hydraulic flow unit (HFU) concept provides a probabilistic approach for combing the geological environments units with an available petrophysical data to delineate the reservoir into “units” with similar fluid flow characteristics

Hydraulic flow units are used to rank dynamic rock-fluid properties including saturation-dependent capillary pressure and relative permeability. Hydraulic units are characterized by the following:

a) Geological attributes of texture (which includes mineralogy, sedimentary structure, bedding contacts, and permeability barriers).
b) Petrophysical properties of porosity, permeability and capillary pressure.

Amaefule et al., (1993) presented the method for the use of hydraulic flow units (HFUs) to divide rock facies as a result of the considerable variation of permeability even in well-defined rock type, and used the concept of bundle of capillary tubes and gave an equation which was re-arranged to isolate the variable that is constant within a hydraulic flow unit (HFU).

According to Amaefule et al., Guo et al. (2005) the flow units in reservoir are determined using flow zone indicators (FZI) and reservoir quality index (RQI) as follow:

$$RQI = 0.0314 * \left(\frac{K}{\emptyset}\right)^{0.5} \qquad \text{(Leverett, 1941} \quad (16)$$

$$FZI = {}^{RQI}/_{\emptyset z} \qquad \text{(Amaefule et al., 1993)} \quad (17)$$

$$\emptyset z = {}^{\emptyset}/_{(1-\emptyset)} \qquad (18)$$

Where K: Permeability md, Ø: Porosity fraction and Øz: normalized porosity.

The relationship between RQI and Øz is used to show that samples with similar FZI values lie close together on a log plot of normalized porosity versus permeability (Amaefule et al., 1993).

$$\text{Log RQI} = \text{Log } \emptyset z + \text{Log FZI} \qquad (19)$$

Fig. 10 shows a plot of RQI versus Øz for data from all cored intervals Equation (19) yields a straight line on a log-log plot of RQI versus Øz With a unit slope. The intercept of this straight line at Øz = 1 is the flow Zone indicator.

The FZI calculated using Eq. (16) and Eq. (17 after calculation of RQI, where the corrected conventional core analysis data for porosity and permeability is used in the calculation of RQI, then define FZI flow unit from the normal distribution of FZI values with the cumulative FZI values (Fig.11).

Four main hydraulic flow units (HFU’s) control reservoir performance are defined for the cored intervals in El Wastani wells (Fig. 12).

HFU-1: average FZI ranged from 0.2 to 0.55 (low quality sand stone)

HFU-2: average FZI ranged from 0.55 to 0.9 (moderate quality sand stone)

HFU-3: average FZI ranged from 0.9 to 2.95 (good quality sand stone)

HFU-4: average FZI ranged from 2.95 to 8.0 (Very good quality sand stone)

HFU’s data summary as table no 3

Permeability predication

The next step to predict the permeability for each HFU depending on FZI curve value or the average FZI values using the following equations

$$K = 1014\, FZI^2 * \emptyset^3/\,(1-\emptyset)^2 \qquad (20)$$

Using average FZI related to HFU zones as follows (Fig 13):

$K\_\text{HFU\#1} = 1014 * 0.16 * \emptyset^3/\,(1-\emptyset)^2$ For average FZI= 0.4 (21)

$K\_\text{HFU\#2} = 1014 * 0.56 * \emptyset^3/\,(1-\emptyset)^2$ For average FZI= 0.75 (22)

$K\_\text{HFU\#3} = 1014 * 4 * \emptyset^3/\,(1-\emptyset)^2$ For average FZI= 2 (23)

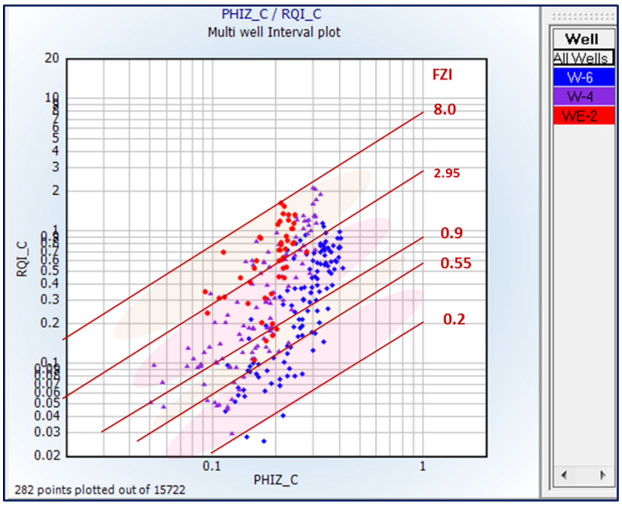
$K\_\text{HFU\#4} = 1014 * 25 * \emptyset^3/\,(1-\emptyset)^2$ For average FZI= 5 (24)

Stratigraphic distribution of the calculated HFU intervals is plot with core data (Fig.14 & 15) .

R35 VS RQI & FZI:

The three core-derived quantities have been widely used for hydraulic rock typing. Although these quantities originated from different authors using different approaches (experimental vs empirical & analytical), they bear more similarities than differences owing to the common underlying petrophysical property that they intend to quantify - pore-throat size or hydraulic radius. The three quantities are functions of porosity and permeability measured with routine core analysis.

Correlations between each pair of quantities on a logarithmic scale are consistently close to 0.9. (Fig. 16) and indicates that the key to hydraulic rock typing for reservoir characterization support the basis of reservoir distribution parameters of the three core-based quantities and use to map them accurately into the well-log domain.



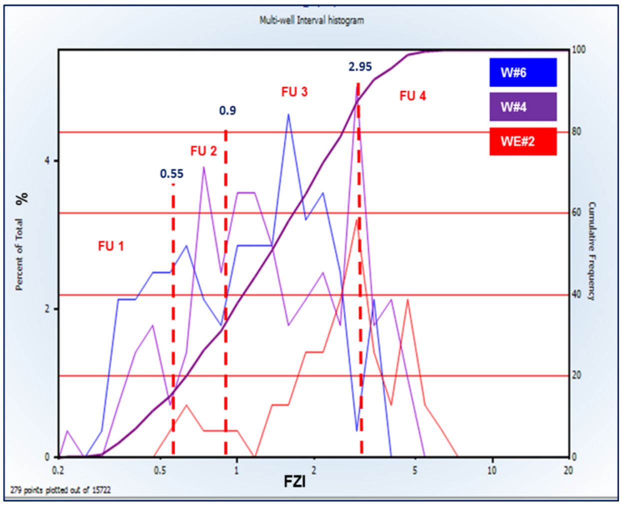
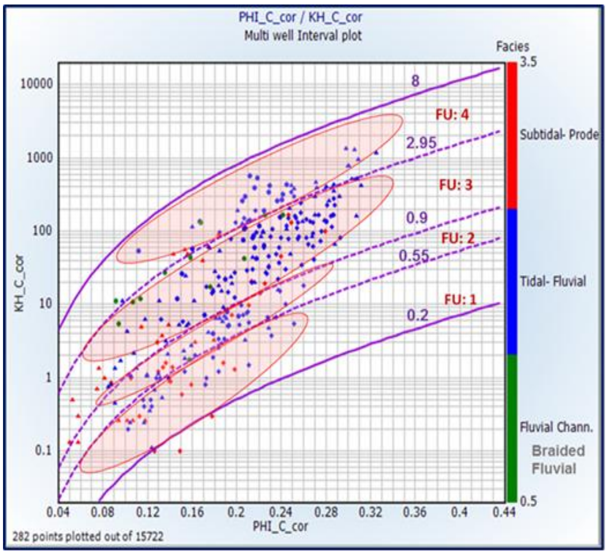


Fig. 10: Determination of FZI using PHIZ and RQI **Fig. 11: distribution of FZI curve with cumulative one**



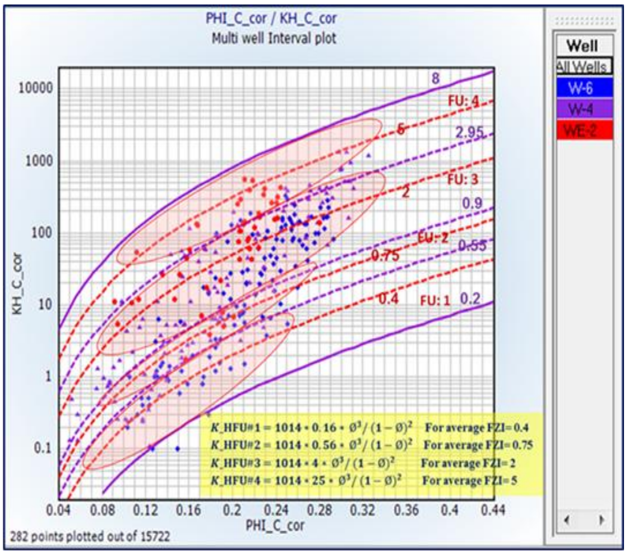


Fig. 12: PHI Vs KH X-plot super imposed on FZI lines and define HFU

Fig. 13: PHI Vs KH X-plot super imposed on average FZI lines define HFU and permeability Equation.

Table 2: Summary of Hydraulic Flow unit (HFU's).

Fm	Upper & Lower Abu Madi		
Reservoir Quality	**HFU (FZI)**	**PHI (%)**	**KH (MD)**
Very good quality sand stone	2.95 – 8.0	16 -31	40 - 1300
good quality sand stone	0.9 – 2.95	10 - 29	3 - 400
moderate quality sand stone	0.55 – 0.9	10 -24	0.8 - 20
low quality sand stone	0.2 – 0.55	9 - 22	0.1 - 6

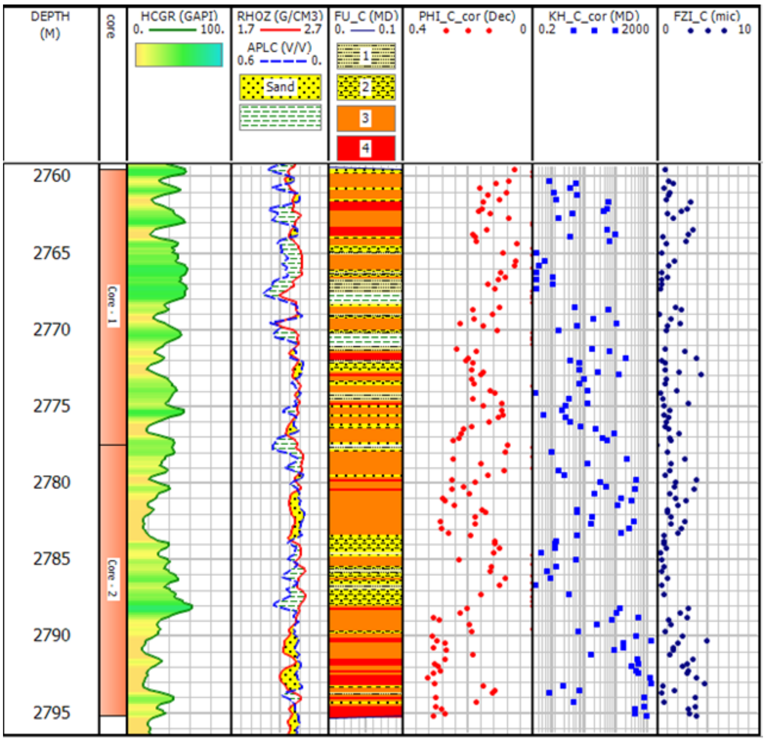


Fig. 14: Hydraulic Flow unit for cored interval in EW-4well.

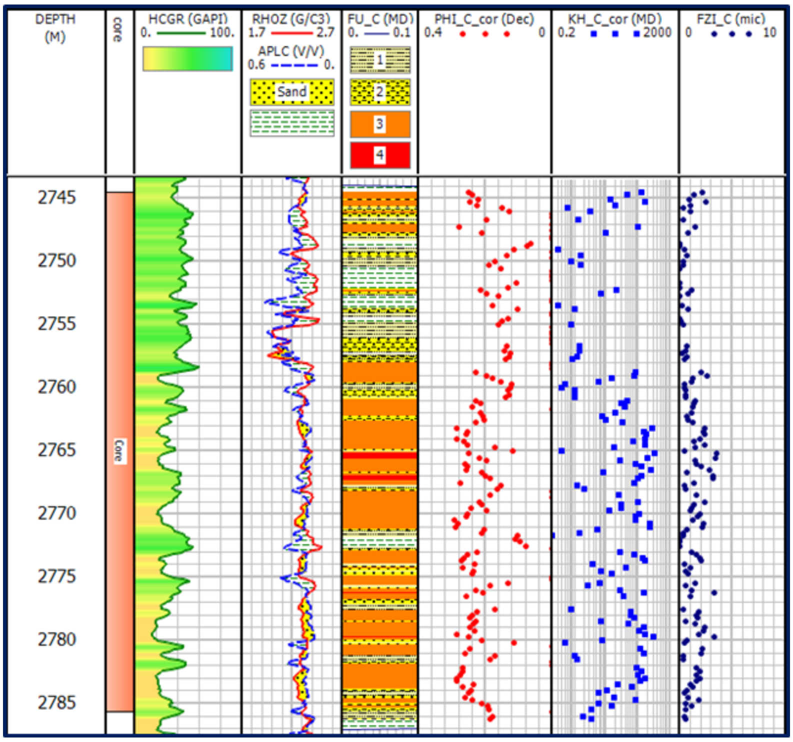


Fig. 15: Hydraulic Flow unit for cored interval in EW-6 well.

Neural network:

Neural network technique was used to reduce multidimensional data sets to lower dimensions for analysis. This technique can be useful in Petrophysics and geology as a preliminary method of combining multiple logs in to a single or two logs without losing information.

This method statistical in nature but its results are seen to be geologically consistent

Statistical modeling using Effective porosity (PHIE), Shale Volume (VWCL) and Photo electric curves (PEFZ) to predict FZI curve using FZI_C calculated within cored intervals. Correlation of predict FZI and calculated one against cored intervals till similar response and high correlation between curves then apply it in to other logged wells and predict FZI in the uncored intervals and other wells (Fig 17).

Predicted FZI curve used to calculate Permeability by using Equation (20) as shown in (Fig 18).

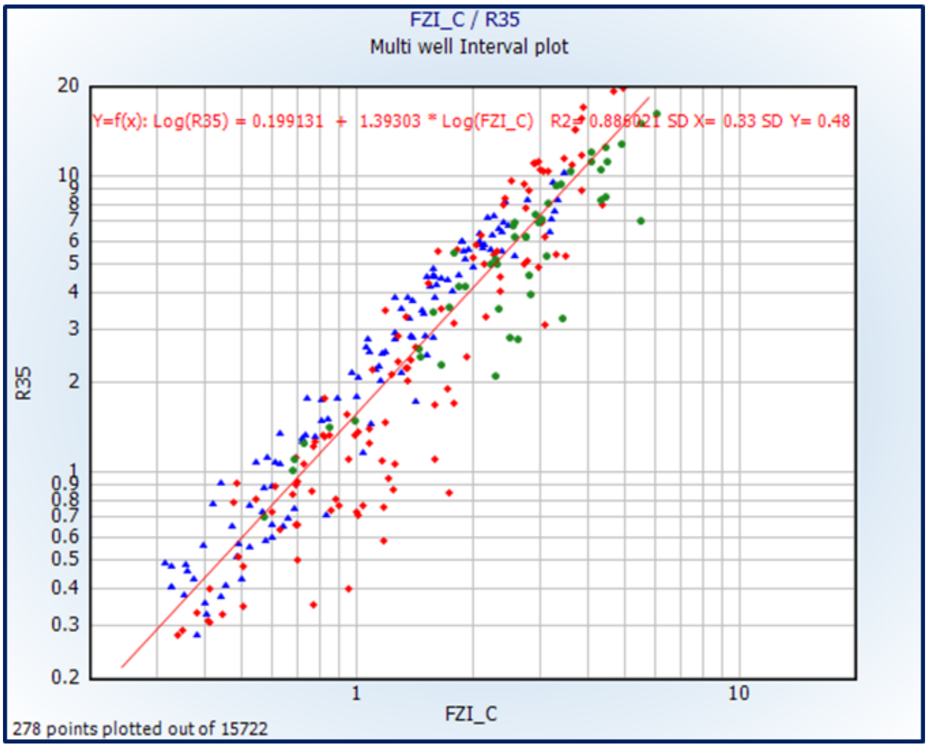


Fig. 16: Numerical testing of the correlation between Leverett's RQI, Winland *R*35 values.

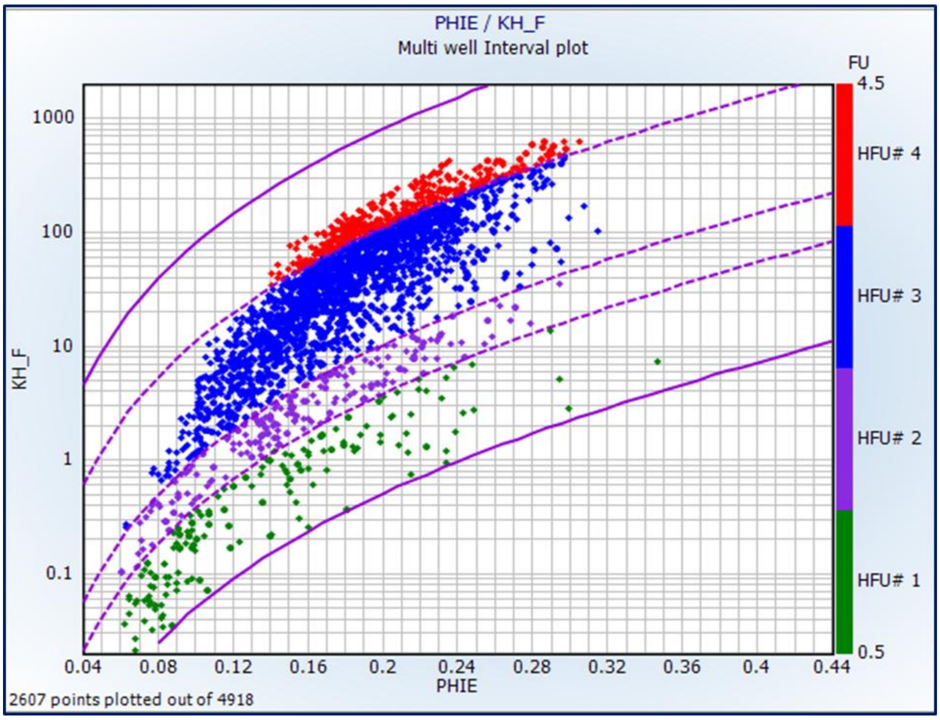


Fig. 17: Distribution of the FZI and HFU within el Wastani field using a geostatistical approach.

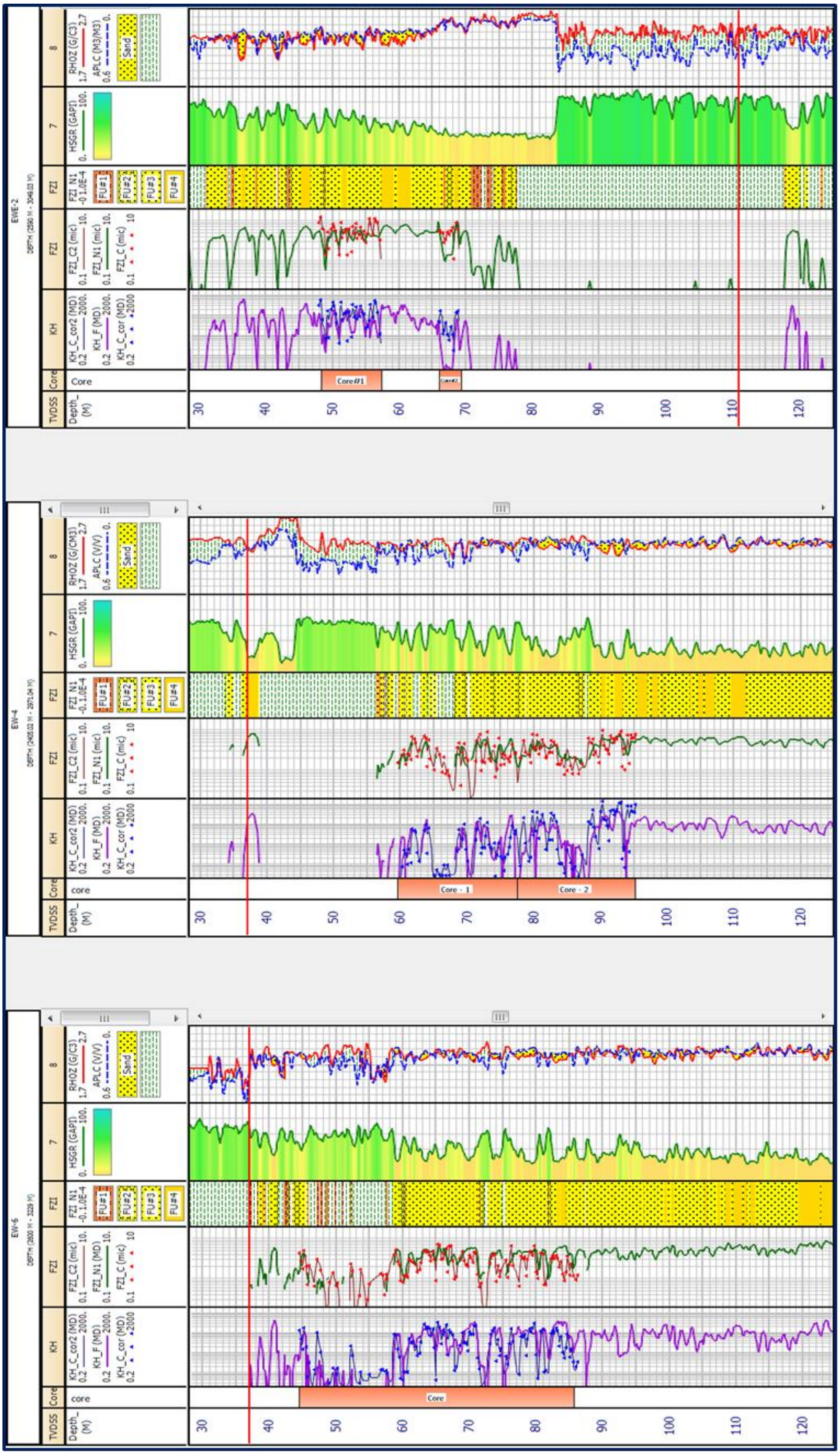


Fig 18: Hydraulic Flow unit and Permeability for all reservoir intervals in EWE-2 , EW-4 and EW-6 wells

CONCLUSION

The Detailed core description and building reliable Geological Model with Litho-facies interpretation act as the key for the Integration between the Non cored and cored wells inside reservoir

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