بسم الله الرحمن الرحيم

FORMATION EVALUATION AND CORRELATION WITH CORE DATA WITH AREIDEBA AND BANTUE FORMATION IN HAMRA EAST-8

تقييم التكوين و المضاهاة مع بيانات اللباب لتكوين عرديبة و بانتيو في بئر حمره شرق-8

A Research

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By

Assad Faisal Nimer

Asaad Elhadi Elhelo

Rayan Sir Alkhatim Ahmed

Supervisor:

Eltayeb Adam Mohammed, Petrodar

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Abstract

Formation evaluation is a phrase used to describe the process that determines the viability of a formation to produce oil and other petroleum products. The petroleum exploration process of formation evaluation actually includes several component procedures. Using geological assessments, exploratory drilling, coring, and other procedures, petroleum drilling companies are able to assess the value of a bore hole for production. Special core analysis (SCAL) is one of the main sources of data available to guide the reservoir engineer in assessing the economic potential of a hydrocarbon accumulations . The laboratory measurements subjected to water saturation and permeability limitation. In this paper gamma-ray, Neutron-density and Archie equation were used in a well called Hamara E-8 to determine shale volume, porosity and water saturation. Zones were picked and the properties used to determine the types of reservoir and then pay zones . Porosity and water saturation results were correlated with the special core data and we obtained a match in Zone-AD.

تقييم التكوين هي عبارة تستخدم لوصف العملية التي تحدد قابلية التكوين لإنتاج النفط والمشتقات البترولية الأخرى. عملية التنقيب عن النفط لتقييم التكوين تتكون في الواقع من عدة إجراءات و/ أو عمليات . باستخدام التقييم الجيولوجي ، والحفر الاستكشافي ، تحليل أو تقييم اللباب ، والإجراءات الأخرى . شركات الحفريات قادرة على تحديد حجم فتحة البئر لبداية الانتاج . التحليل المتخصص للباب هو واحد من المصادر الرئيسية للبيانات التي تساعد مهندس المكامن في تقييم تراكمات الهيدروكربونات ذات الجدوى الاقتصادية . تتأثر القياسات المعملية بدرجة التشبع بالمياه و درجة القصور في النفاذية. في هذا الصدد ، تم استخدام كل من تسجيل أشعة غاما ،و تسجيل الكثافة للنيوترون ، و معادلة آرشي في بئر حمرة شرق-8 لتحديد كلٍّ من حجم الطفل والمسامية و درجة التشبع بالمياه . تم انتقاء المناطق واستخدام الخصائص الجيولوجية لتحديد نوع المكامن و ثم تحديد المناطق ذات الإنتاجية، ثمّ قورنت النتائج المتحصل عليها بالتحليل المتخصص للباب (للحصول على مطابقة تأكيداً لدقة و صحة التقييم في "طبقة / منطقة" عرديبة). حددنا أوجه القصور ، و حددنا ما قمنا به للتغلب عليها.

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We would like to thank our families for providing the means to live to this day, and the collage of petroleum and minerals for supporting us throughout the years with little help they receive and their hard work to make this the collage running.

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أهداء

فلقد كان له الفضل الأوَّل في بلوغي التعليم العال

(والدي الحبيب)، أطال الله في عُمره.

(أمي الغالية)، إلى من وضعتني على طريق الحياة، وجعلتني رابط الجأش، وراعتني حتى صرت كبيرًا. طيَّب الله ثراها.

إلى إخوتي؛ من كان لهم بالغ الأثر في كثير من العقبات والصعاب.

إلى جميع أساتذتي الكرام؛ ممن لم يتوانوا في مد يد العون لي.

أُهدي إليكم بحثي بلا كبر و لا خيلاء.

عن عبد الله بن مسعود ـ رضي الله عنه ـ عَنْ النَّبِيِّ ـ صَلَّى اللَّهُ عليهِ وَسَلَّمَ ـ قَالَ :(لا يَدْخُلُ الْجَنَّةَ مَنْ كَانَ فِي قَلْبِهِ مِثْقَالُ ذَرَّةٍ مِنْ كِبْرٍ، قَالَ رَجُلٌ: إِنَّ الرَّجُلَ يُحِبُّ أَنْ يَكُونَ ثَوْبُهُ حَسَنًا، وَنَعْلُهُ حَسَنَةً، قَالَ: إِنَّ اللَّهَ جَمِيلٌ يُحِبُّ الْجَمَالَ، الْكِبْرُ بَطَرُ الْحَقِّ، وَغَمْطُ النَّاسِ). صدق رسول الله صلى الله عليه وسلم.

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Nomenclature

a = tortuosity of the rock, unit less

CEC = Cation exchange capacity (meq/mg)

C_{sh} = shale conductivity (mho/m)

C_t = total formation conductivity (mho/m)

C_w = conductivity of formation water (mho/m)

DPHI = Density porosity (v/v)

GR = Gamma ray, API.

I_{GR} = Gamma ray index.

OWC = Oil water contact

m = Cementation exponent, dimensionless

n= Saturation exponent, dimensionless

N-D = Neutron-Density porosity logs.

PHE = Effective porosity from neutron-density logs (v/v).

ø= Formation porosity, (v/v).

R_{sh} = Shale formation resistivity, Ohoms-meter.

R_t = Formation resistivity, ohms-meter

R_w = Formation water resistivity, ohms-meter.

S_w_AR = Archie water saturation, (v/v).

S_{wavg}= Average water saturation

S_w = Water saturation

V_{sh}_GR = Volume of shale calculated from gamma ray log, (v/v).

V_{sh}_ND = Volume of shale from neutron-density porosity logs, (v/v)

AD= Aradiba

CHAPTER ONE

INTRODUTION

The measurement and analysis of formation and fluid properties through an examination of formation cuttings or through the use of tools integrated into the bottom hole assembly while drilling, or conveyed on wireline or drill pipe after a borehole has been drilled is called formation evaluation. Formation evaluation is a key analytical process contributing to the identification of economically productive reservoirs. The tools of formation evaluation for conventional reservoirs are applicable for unconventional reservoirs but must be adapted to the necessity of hydraulic fracturing of shale to induce permeability in an otherwise substantially impermeable rock.

Formation evaluation gives answers to the following questions:

- Is there any oil or gas there?
- Where are they located?
- How much of it?
- How much can we produce, which answers the question, "How much money can we make?

The types of information we can be acquired using Formation evaluation can be summarized into:

- Estimation of formation of physical properties.
- Lithology identification and rock typing.
- Identification of geological environment.
- Evaluating rock stresses.
- Locating reservoir fluid contact.

Formation evaluation methodology can be also summarized into:

- Drilling operation logs (cutting analysis; mud analysis; and drilling data).
- Core analysis (qualitative; quantitative).
- Wireline logs (Electrical; acoustic; radioactive).
- Production logs and testing (formation testing; drill stem testing; production testing)

Formation evaluation methodology was applied on Hamrah East.8 well with the focus on these aspects:

- Shale volume: using (gamma-ray; density).
- Porosity: using (Neutron-Density)
- Water saturation (SW): using (Archie equation).

1.1. PROBLEM STATEMENT:

Because of the high cost of the evaluation process on the lap inaccuracy of sample properties between the reservoir and the surface, we intend to use formation evaluation techniques with the help of Schlumberger`s Software (Techlog) to prove that the technique is indeed economic and accurate by comparing the results with expensive core samples.

1.2. Project Outline

To accomplish the objectives, the project will be carried out using Schlumberger`s Software (Techlog). Data sorting or data quality control is

performed at the early stage before qualitative and quantitative interpretation is

performed.

The study is organized in the following ways: Introduction part- description of the study area, Literature review- describes the theory of the presented topic, Methodology-describes in details the evaluation steps as performed in Techlog, Qualitative interpretation-provides detailed information of the lithology and possible contained fluids from well logs, Results and discussion-presentation of figures, tables, and arguments of the findings, and lastly is the Conclusion and recommendations which gives specific judgments of the arguments and possible suggestions of the lack or gap that have to be improve.

1.3. Objectives.

1.3.1. Main Objective

1. Assessment of the Hamra's layers in terms of existence (oil, gas, water).
2. Study classes properties in terms of (shale volume, porosity, water saturation)

3. Identify zones of interest and correlate it with Special core data

1.3.2 Specific Objectives.

- Lithology and fluid interpretation from well log characteristics
- Porosity and water saturation determination

1.4. Study Area

The GNPOC well Hamra East-8 was spudded in at 16:30 on February 16, 2013 as a development well drilled by Rig PPS #103 in block 2A and CNLC SLC-915 performed the mud logging services including geology, mud, engineering monitoring, gas analyzing and recording.

Hamra East-8 is a development well designed as producer well located in Block 2A area as shown in Figure-1. The well is located in the south of main Heglig field. The geology is similar with Hamra-1 structure, located in the down thrown of the fault, and found oil in Aradeiba and Bentiu formation by the wildcat well Hamra E-01. Hamra East-1 structure is a faulted nose, located.

The 24" conductor hole was drilled to 30m. After setting the 20" conductor at 30m, the 17 ½" surface hole was drilled to 915m, the target depth of surface hole on February 21, 2013. This surface hole phase includes Pre-Nayil, Nayil shale and part of Amal Massive Sand formations. The 13 ⅜" surface casing shoe was set at 914m on February 22, 2013.

No shows were encountered in this 17 ½" surface hole formations.

No CO_2 and H_2S were encountered in this 17 ½" surface hole formations.

No wire line logging was carried out in this 17 ½" surface hole.

After cementing and nipped up blow out preventer stack and function test blow out preventer to 500psi low and 2500psi high, OK.

The drilling of the 12 ¼" main hole was commenced from 915m at 11:15 on February 25, 2013. Reached the target depth of main hole to 1900m at 20:00 on March 14, 2013. This 12 ¼" main hole phase includes: Part of Baraka shale, Ghazal Shale, Zarqa Shale, Aradeiba upper shale, Aradeiba Main Sand, Aradeiba lower shale, Aradeiba D Sand, Aradeiba F Sand and Bentiu Sandstone formations.

Weak to good oil shows were encountered in this 12 ¼" main hole formations.

No CO_2 and H_2S were encountered in this 12 ¼" main hole formations.

12 ½" main hole was logged by CNLC wire line at 15:00 on March 15, 2013. Two types of logs were: Run #1 SLAM log and run #2 Caliper-GR. The logging programs were finally completed at 01:30 on March 16, 2013.

On completion of drilling and conditioning 12 ½" main hole, run 167 joints of 9 ⅝" production casing plus one pup joint to 1900m on March 17, 2013. Casing shoe set at 1899.63m, float collar at 1887.67m and marker joint set at 9 ⅝" Marker joint at 1516. 58m.Then Dynamic cementing company performed cementing job and PPS #103 crew nipple down blow out preventer, choke line and kill line, lay down all drill pipes and bottom hole assembly. Rig was released at 24:00 on March 18, 2013

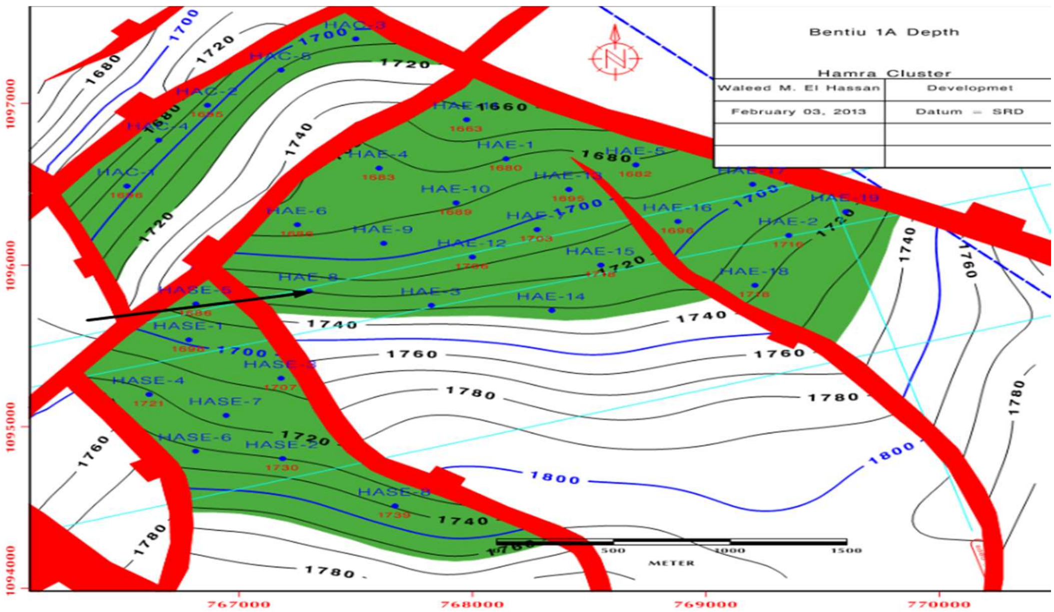

Figure 1: Hamra east-8 location

1.5. Clays and Shale

The accurate estimation of hydrocarbon resources in shaly clastic reservoirs requires knowledge of clay minerals and shale. Clays are described in terms of rock and particles, as a rock, they earthy, fine-grained materials that undergo plasticity when mixed with small amount of water; as particles, they are less than 4µm in size (Ruhovets and Fertl 1982). Clay minerals are defined as hydrated silicates with a layer of chain lattices consisting of sheets of silica and tetrahedral arranged in hexagonal form alternating with octahedral layers and are usually of small size (Mackenzie 1959). Most of the clay minerals have some substitution of aluminum by other cations, such as magnesium, iron, etc. The substitution process creates charge deficiency on the surface of clay minerals, making a room for cations from brine solution to be absorbed onto clay`s surface. CEC values of clay relate directly to their capacity to absorb and hold water. The montmorillonite (smectite) has the highest CEC and therefore have the highest capacity to absorb water. Kaolinite and chlorite on the other hand, have the lowest Cation Exchange Capacity (CEC) and low capacity to hold water on their surface. The portion of the water contained in the pores of shaly formations is closely associated with the clay mineral as hydration or bound water (Hill, Klein et al. 1979). Shale can be defined as an earthy, fine-grained sedimentary rock with specific laminated character deposited in low energy environment. Shaly sand and shales have similar mineralogy because they are derived from the same source, transported and emptied into the basin by the same agent (river). Sand and shales are differentiated as the particles begin to settle at differing rates due to their particle size and transporting energy and not mineral type (Thomas and Stieber 1975). Shaly sands behave as perm-selective cation-exchange membranes with their electrochemical efficiencies increases with increasing clay contents (Waxman and Smits 1968). The electrochemical behavior is related to the cation exchange capacity per unit pore volume of the rock (Hill, Klein et al. 1979). Montmorillonite has the highest cation exchange capacity due to its large 7 interlayer surfaces between sheet structures. Also, there is a close linear relationship between cation exchange capacity and specific surface area of the clay minerals (Ellis and Singer 2007).

1.6. Effects of Shaliness on Log response

Shaly-sand reservoirs often contain clay minerals, which introduces another conductive path for cations in the brine (De Waal 1989). Clay minerals have electrical charge deficiency that can be compensated (by positive or counter ions) to maintain electrical charge neutrality of the clay structure. The amount of these compensating ions constitutes to the so-called Cation Exchange Capacity (CEC) which is related to the surface area of the clay minerals. The positive ions provide an additional conductivity of the rock as they leave the surface of the clay.

There are two components associated with shaly formations; conductivity associated with free fluids filling porosity and that associated with Cation Exchange Capacity (CEC). The low resistivity anomaly caused by clay compensating ion can be regarded as a surface effect associated with clay grain and bound water associated with clay minerals (Hamada and Al-Awad 2000). It is therefore that, the low formation resistivity can also be associated with the matrix instead of the clay bound water (Berg 1996). The conductivity of shaly sand depends on the shale type, the amount of shale and the way it distributed in the reservoir.

Clays in formation often affects porosity logs (density, neutron, sonic, etc) and hence complicates the determination of resistivity, porosity and saturation due to their associated properties, nature, and their distribution**.**

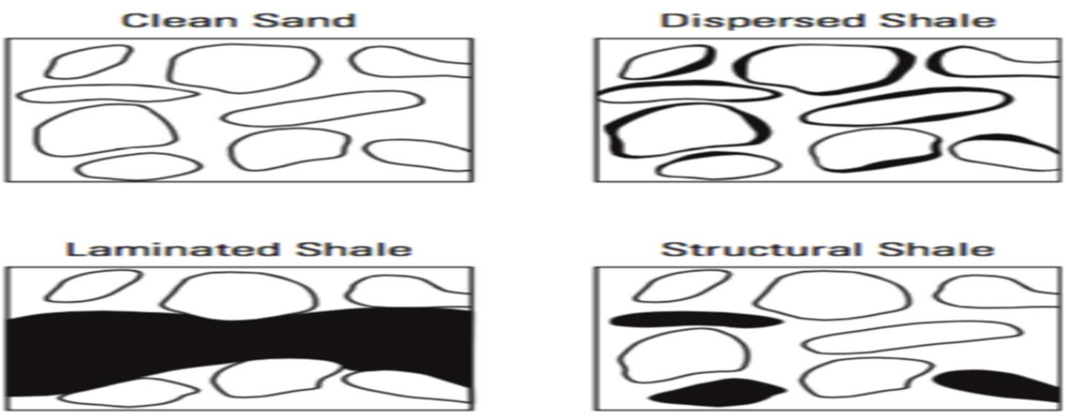

Figure 2: Distribution of shale in sand.

CHAPTER TWO

LITERATURE REVIEW

Shaly sand formation evaluation involves a number of steps; these include lithology and fluid identification, shale volume estimate, porosity estimates, water saturation estimates, and permeability estimates. This chapter outlines the concepts related to these parameters as used in the study.

2.1. Petrophysical Properties:

Determination of petrophysical parameters is a paramount step in formation evaluation to determine the economic viability of hydrocarbon-bearing reservoirs (Fens, 2000).

2.1.1. Shale Volume (V_{sh}):

The determination of reservoir quality in terms of porosity, types and distribution of reservoir fluids is based mainly on the evaluation of the shale volume. Therefore, qualitatively evaluating shaly sand requires an accurate estimate of the amount of shale (Soto Becerra, Arteaga et al. 2010).

The following are some of the clay indicators used to estimate shale volume from well logs.

2.1.1.1. Vsh From GR log:

Gamma ray tool uses naturally emitted gamma ray radioactivity from the formation. The emitted gamma rays from the formation are counted at the gamma ray detectors. If no non-clay radioactive minerals are present and the level of radioactive clay is constant, the gamma ray reading can be expressed as a linear function of clay content as follows in **equation 1**

$$I_{GR} = GR_{log} - GR_{sand} / GR_{Shale} - GR_{sand}$$

Equation 1

where,

GR_{log} = Gamma ray reading tool in the zone of interest

GR_{sand} = Gamma ray reading in clean zone or interval

GR_{shale} = Gamma ray reading in shale interval.

The equation overestimates the clay volume in a clean interval (sands) rich in radioactive minerals other than shale (Poupon, Clavier et al. 1970), particularly

true for radioactive sands and dolomite (Kamel and Mabrouk 2003). The gamma ray parameter is correlated as a linear relationship to shale volume. However, shale in a reservoir can be distributed in different ways such as laminated, dispersed and structural. Because of this distribution gamma ray responses will vary depending on the geometry of shale in the sand (Thomas and Stieber 1975). Because of overestimating of shale volume by this technique for the presence of non-clay radioactive minerals, some early workers developed non-linear models such as Larionov, Clavier, and Stieber as illustrated in **Figure 3**. These methods are based on specific geographic areas or formation age to correct the shale volume estimated from linear relationship gamma (Kukal and Hill 1986). All these models are optimistic the fact that they yield shale volume that is lower than that given from linear gamma ray. Radioactive black organic materials in carbonate reservoirs cause an overestimation of
methods (David, Rodolfo et al. 2015).

The use of linear and non-linear to estimate the shale volume of the reservoir depends on the way the minimum and maximum values are defined in the sand line and shale line respectively. The sand line and shale line may have one GR value in some parts but differs in some deeper level of the well. In all situations, water saturation and consequently affect the original of oil in place or reserves. Example of shale volume corrections as a function of Gamma Ray Index (I_{GR}) shale volume from these developed

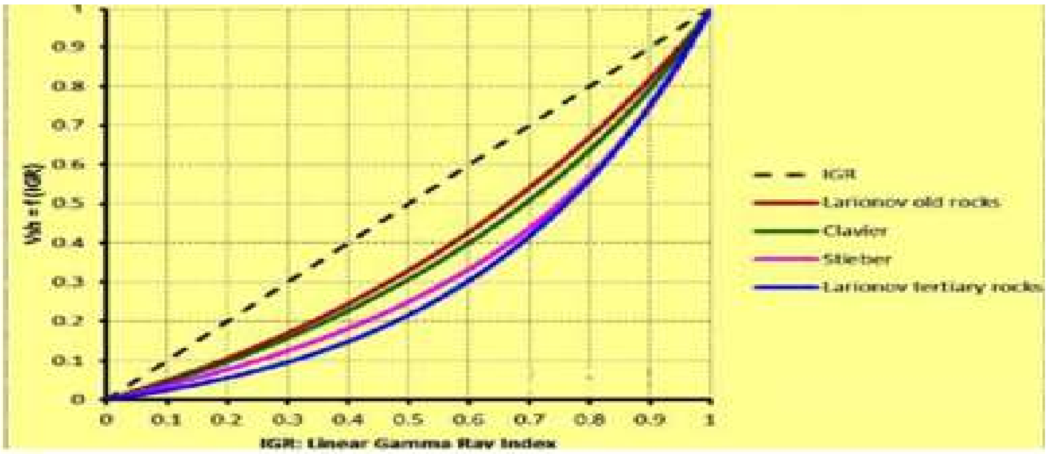

Figure 3: Vsh as a function of IGR (David, Rodolfo et al. 2015)

2.1.1.2. **Vsh From Neutron and Density logs:**

The neutron and density porosity logs are common techniques and straightforward method for estimating the shale volume of the reservoir (Bhuyan and Passey 1994). The estimation of the volume of shale basing of naturally occurring gamma ray frequently overestimates the shale volume when encounters radioactive sands as sands will appear as shaly. From this consequence, the volume of shale estimated from neutron-density curves yields more accurate shale volume. However, the presence of gas or light hydrocarbon in the reservoir makes this method is pessimistic (Adeoti, Ayolabi et al. 2009). Gas in the formation affects neutron reading considerably by reducing the neutron porosity values due to low hydrogen index of the gas. On the other hand, clay or shale cause neutron reading increases dramatically making neutron apparent porosity too high. The effect of shale on density log depends on the density of shale present in the formation.

The neutron-density Equation can be written as follows

$$\mathbf{V_{sh\ neutron-density} = \emptyset_N - \emptyset_D / \emptyset N_{SH} - \emptyset D_{SH}}$$

Equation 2

where,

$\emptyset_N$= Neutron porosity in sand

$\emptyset_D$= Density porosity in sand

$\emptyset N_{SH}$= Neutron porosity in adjacent shale

$\emptyset D_{SH}$= Density porosity in adjacent shale

2.1.2. Porosity Estimation (ø)

Porosity is the fraction of the pore space that is not occupied by the rock matrix. Porosity is one of the key parameters used to estimate the initial hydrocarbon in place. Any wrong calculation in porosity can translate directly to an error in volume estimation (Anyaehie and Olanrewaju 2010). There are various types of porosity being recognized within the petroleum industry. Only two types are mainly considered in use, which are effective porosity and total porosity.

Total porosity is defined as the fraction of the bulk volume of reservoir rock that is not occupied by fluid and Effective porosity is defined as the total porosity subtracting clay bound water (Gimbe, 2015).

2.1.3. Porosity Types and Determination

Porosity can be determined from direct measurements (neutron) or can be calculated from various logs e.g. neutron and density, sonic, density, and NMR logs (standalone). Or can be obtained from the combination of logs e.g. neutron and density logs. On the other hand, porosity can be obtained from laboratory measurements on cores samples.

2.1.4. Effective porosity (PHIE) from neutron and density logs

Density and neutron logs are two common physical measurements used in the formation evaluation. Because of their combined applications such neutron-density overlay, neutron-density crossplot they are widely used in determining lithology, estimating porosity and detecting gas zones from their crossover (Mao

2001). The neutron-density combination is still often the most reliable technique to estimate formation porosity from well logs. However, inaccurate characterization of matrix yields less accurate porosity and saturation estimates especially in complex lithology (Ijasan, Torres-Verdín et al. 2013).

In gas-bearing formation neutron porosity and density porosity are not equal caused by opposite effect the gas has on both tool's responses (Quintero and Bassiouni 1998). Like water, hydrocarbons contain hydrogen but at variable concentration which basically depend on the density of hydrocarbon in the reservoir. Practically, some oil has the same hydrogen as in water; gas on the other hand gas or light hydrocarbon has considerably lower hydrogen concentration and density as the result gas or light hydrocarbon have mucheffect on both density and neutron logging tool's responses (Gaymard andPoupon 1968). The presence of gas or light oil in the reservoir, a density-neutron technique underestimates the formation porosity and therefore effects on saturation and initial hydrocarbon in place volume.

The properties of shaly sand will have an influence on the behavior of the neutron reading. Shale is the rock that includes clay minerals containing bound hydrogen in the form of hydroxyl (OH-) as part of their structures. The bound hydrogen in the hydroxyl will affect the same way as hydrogen in water and hydrocarbon in pores. The neutron apparent porosity in shaly formation will increase slightly from expected trend due to extra hydrogen in the hydroxyl group associated with clay minerals in shale (Ellis, Case et al. 2004). The effects of shale on density tool greatly depend on the density and type of clay minerals.

2.1.5. Water Saturation (Sw)

Water saturation is the fraction of the pore volume occupied by a certain fluid. Determination of water saturation is one of the important parameters in formation evaluation from which initial oil in place can be calculated, which depend on the volume of the reservoir, porosity, and water saturation (Fleury, Efnik et al. 2004). In petrophysical formation evaluation, water saturation can be calculated from different saturation models depending on whether the reservoir is clean or shaly. Water saturation models in shaly sand hydrocarbon reservoirs are the expansion of the Archie equation with the extra term to accommodate the volume of shale and their associated electrical properties. There are many shaly sand interpretation models that are often used today because no uniquely satisfactory results have been reached (Doveton 2001). The following Equations or Models are mostly used today to evaluate the hydrocarbon reservoirs depending on shale contents and characteristics of the reservoir. The Archie Equation/Model The electrical log interpretation for evaluation of hydrocarbon saturated permeable formation is based on Archie's equation, which relates the water saturation to formation water resistivity, porosity and resistivity of saturated formation (Alfosail and Alkaabi 1997). However, the use in a quantitative evaluation has limitation due to various factors that tend to obscure its reading obtained obtained (Archie 1942).

This relationship is given by the following Archie's Equation.

$S_w{}^\wedge n = a * R_w / \emptyset{}^\wedge m * R_t$

Or

$S_w = \sqrt{} a * R_w / \emptyset{}^\wedge m * R_t$

Equation 3

where,

a= tortuosity of the rock

m= Cementation exponent

n= saturation exponent

$\emptyset$= Porosity

S_w= Formation water saturation

R_w= Resistivity of formation water

R_t= Formation resistivity

Archie's equation was specifically established for clean sands and does not take into account the clayey materials (Worthington 1985). In a clean formation, the matrix is an electrical insulator such that only fluids in the pores of the formation have the ability to conduct electrical current. In shaly sand formations the determination of water saturation is the more complicated task; shale constitutes a part of the rock matrix and is able to conduct electrical current and consequently, influence on rock resistivity, and complicate log interpretation (Bhatt, Helle et al. 2001); (Poupon, Loy et al. 1954).

Archie assumed that the rock matrix is nonconductive. However, clay materials in sandstone add conductivity enough to influence the Archie derived water saturation values from being high and therefore pessimistic for potential hydrocarbon reservoir (Doveton 2001).

In shaly sand formation, Archie equation are less applicable and therefore other modified models (shaly sand saturation models) have to be applied to estimate hydrocarbon saturation of the reservoir.

These models consider shale's conductivity as an additional term to the origin Archie's equation. The conductivity of shaly saturation models is given by the following general equation:

$C_t = C_w/F + C_{sh}$

Equation 4

where,

C_t = total formation conductivity

C_w = conductivity of formation water

F = formation factor

C_{sh}= conductivity of shale

CHAPTER THREE

METHODOLOGY

Formation evaluation was performed using a composite of well logs (Gamma ray, Neutron, Density logs, Resistivity. The well logs used in the study were supplied by the Sudan University of Science and Technology (**SUSTECH**) and was acquired by **Hamra East-8** in the south of main Heglig field **Figure 4** and shows the well logs used for the evaluation.

The task involves lithology and fluid interpretation and quantification evaluation (shale volume, formation porosity, saturation, and permeability computation) from logs.

3.1. Lithology Identification

The Gamma-ray, and neutron-density cross plot were examined for lithologic discrimination. The GR which measures the natural radioactivity reflects clay contents in the formation. The separation between neutron porosity and bulk density logs was then used to characterize the particular lithology type. The neutron-density cross plot was then used to discriminate the type of lithology and the information for complete lithologic characterization.

3.2. Fluid Identification and possible fluids contact estimation

Resistivity logs, combined neutron and density logs were used to characterize and identify fluid types in the reservoir (hydrocarbon and non-hydrocarbon bearing zones). The presence of gas in the reservoir results in large crossover between neutron density logs as shown that there is no gas-bearing interval zone when plotted in the same log scale. However, the presence of oils in the reservoir results in decreased separation between neutron porosity-bulk density log and an increase in resistivity readings. Differences in fluid densities, neutron-density separation varies and being large in gas and decreases through oil to water zones. Resistivity logs were then used to identify the formation fluids (gas/oil/water) and possible fluids contact. Hydrocarbon bearing zones were indicated in **Figure 4**.

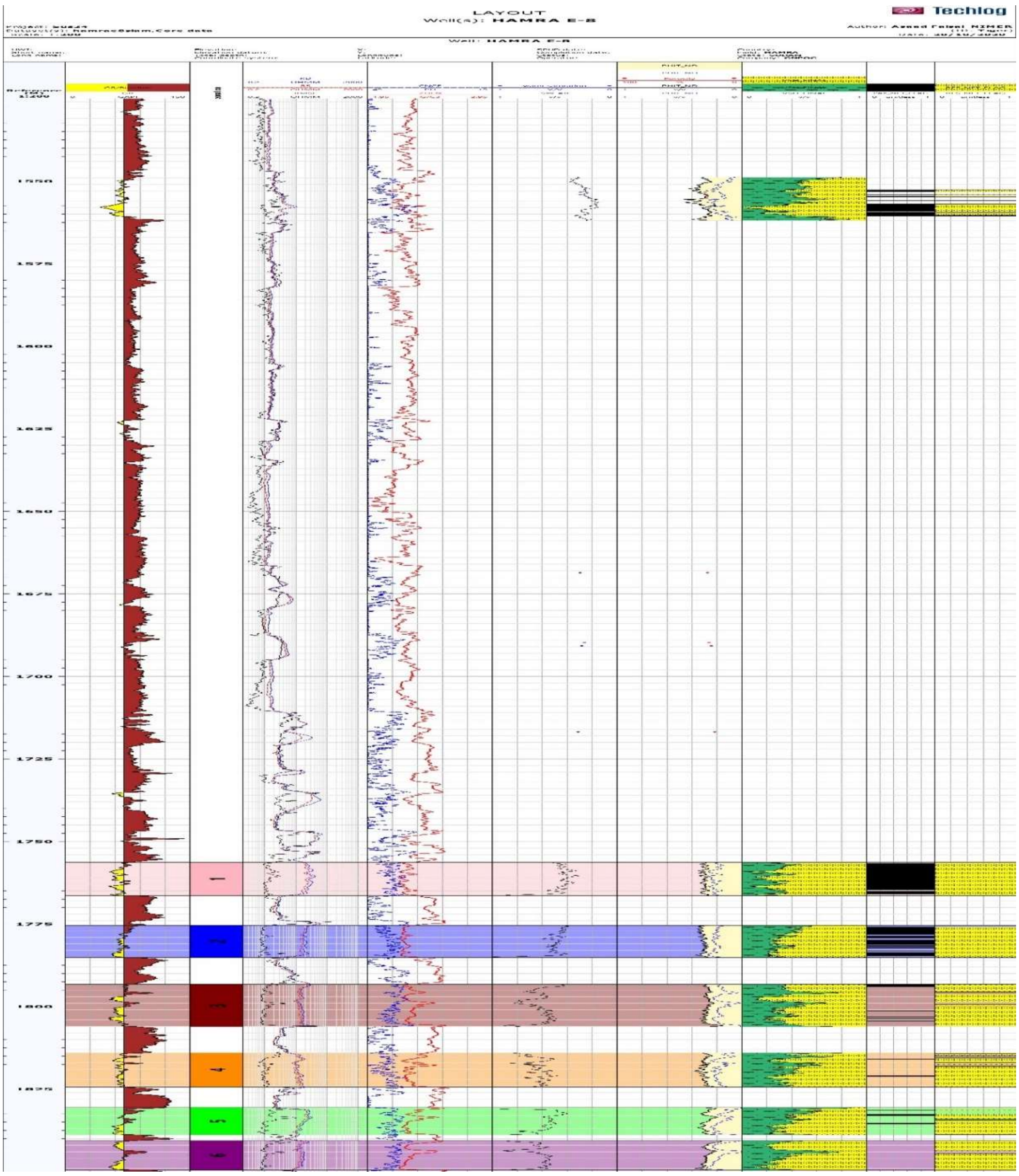

Figure 4: Hamra E-8 result log.

3.2.1. Shale Volume Estimation:

The shale volume (**Vsh**) was calculated from equation 1 which utilizes the differences in fluid densities, neutron-density separation varies and being large in gas and decreases through values of Gamma Ray (GR) are found in Schlumberger Techlog software.

The gamma ray index (IGR) is estimated from the following relationship:

$$\mathbf{IGR = GR_{log} - GR_{min} / GR_{min} - GR_{max}}$$

Equation 5

where,

GR_{log}= measured GR from log

GR_{min}= GR reading in the zone of interest

GR_{max}= maximum GR reading in the zone of interest

The corresponding values of GRmax and GRmin is 102API and 80API which were read in the sand and shaly sand.

GR_{log} is directly supplied from the GR log.

3.2.2. Porosity Determination (∅)

Porosity for potential hydrocarbon-bearing zones was calculated from DPHI

The density–neutron log is a combination log that simultaneously records neutron and density porosity. In some zones, porosities recorded on the logs differ for three reasons:

- The matrix density used by the logging program to calculate porosity is different from the actual formation matrix density.
- Shale/clay is present in the formation.
- Type of fluid in the formation

And DPHI is estimated density porosity formula

$$DPHI = \rho_{matrix} - \rho_{log} / \rho_{matrix} - \rho_{fluid}$$

Equations 6

where,

DPHI = density-derived log porosity

ρmatrix= matrix density and was assumed to be 2.65 $g/cm3$ (sandstone matrix)

ρlog= formation bulk density $g/cm3$, supplied from density log.

ρfluid= fluid bulk density and was assumed to be 1 $g/cm3$.

The effective porosity was estimated from a combined neutron and density logs available in Schlumberger Techlog 2015.3.

3.2.3. Water Saturation Calculation (Sw)

Water saturations of shaly-sand saturation Equation.

Archie Equation

S_w^ n = a ∗ R_w/Ø^m ∗ R_t

Or

S_w = √ a ∗ R_w /Ø^m ∗ R_t

Equation 4

3.3. Data Determination

Formation resistivity values (R_t) was directly supplied from deep Laterolog (RT_HRLT) of uninvaded zone. Similarly, the resistivity of shale (R_{sh}) was obtained from the same resistivity (deep resistivity) log in the shale zone. Formation water resistivity (R_w) at formation temperature was determined from two methods; from Archie Equation in the water zone and from precomputation available in Schlumberger Techlog software at formation temperature. From the Archie equation in the water zone the values was obtained and was applied to all zones in saturation calculations (shaly sand models).

3.4. Net Pay

The net pay is the thickness that contains economically productive interval. It was determined by applying cut-offs to rock properties. The reservoir interval was defined by applying the porosity of greater than 12% and shale volume of less than 50%. Water saturation cut-offs value of 50% was used. The net pay was considered to contain hydrocarbon if the S_w<=50% within the reservoir.

3.5. QUALITATIVE INTERPRETATION

Well logs have many applications in formation evaluation including lithology and fluid identification and many other applications can be obtained them. These logs can be used as the single log (eg. GR log) or combined logs (eg. neutron and density logs) to give information about lithology and fluid types contained in the reservoir. **Figure 4** and shows the composite logs used in the lithology and fluid identification.

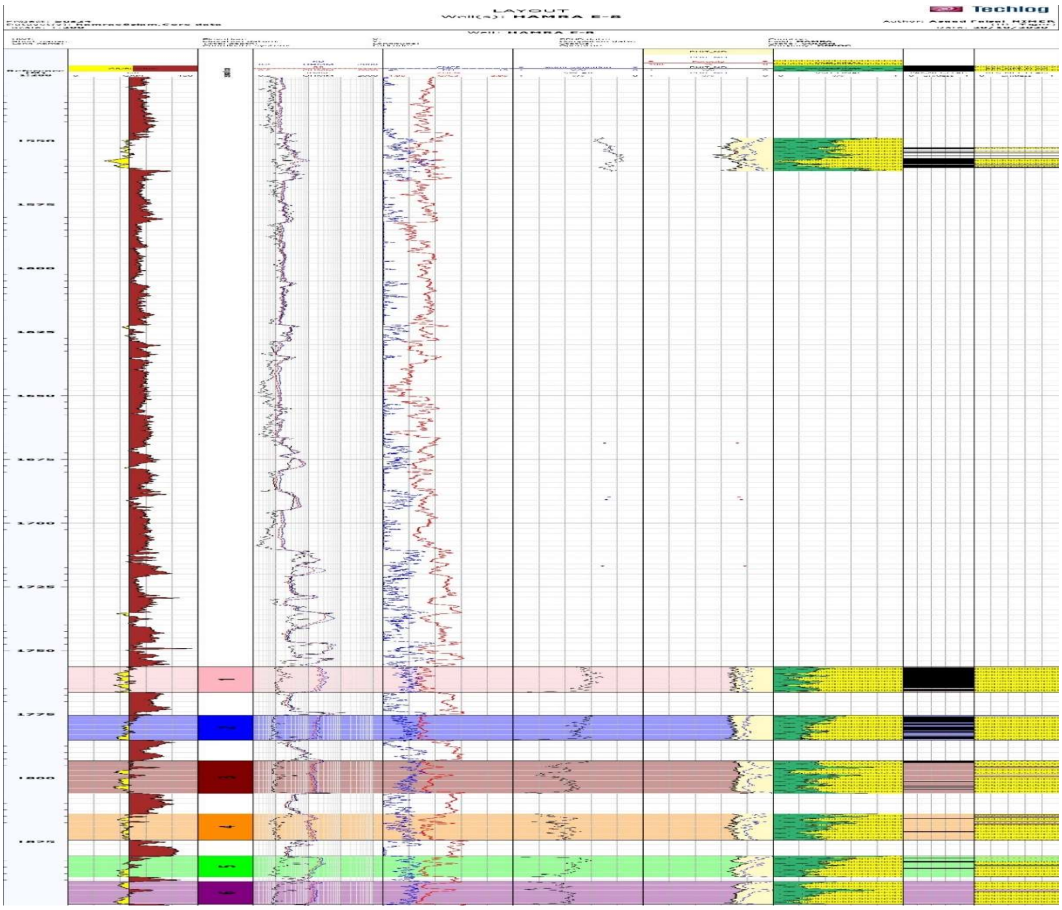

Figure 4: Hamra E-8 result log.

3.5.1 Lithology Identification

The lithology identification penetrated by any well involves a combination of different logging curves. The following logs are used to identify the lithology; the Gamma ray and Neutron and density logs.

Based on log response the whole interval is divided into seven zones.

All seven zones are shaly sand with different shale percentage as shown in **Figure 4.**

3.5.2. Fluid Identification

Availability of gamma ray, resistivity, neutron, and density logs in the study area enabled the reservoir and its contained fluid to be easily identified on logs.

Resistivity and neutron-density logs have different response characteristics on different fluid types.

The resistivity logs are characterized by higher resistivity readings than the adjacent shale. The large crossover between neutron-density curves in **Zone-AD** is the reflection of the hydrocarbon-bearing oil interval (1548.814-11561.992 m).

The presence of shale in the interval may cause a slight reduction in formation resistivity values.

The even higher resistivity readings accompanied by the minor crossover separation between neutron and density suggesting oil-bearing **Zone-1** (1756.359 1766.378 m).

The same reason explained above for higher abnormally resistivity values in some secrete interval

The transition **Zone-3** interval (1793.287 -1806.111) we find that the water content is 65.2% which indicate the start of the water zones below.

The water zone (**Zone 4-5-6**) is marked by decreased resistivity readings and neutron and density separation. The small separation between all resistivity curves may be due to small contrast between formation water resistivity and mud filtrate used.

Resistivity logs were then used to identify the formation fluids (gas/oil/water) and possible fluids contact. Hydrocarbon bearing zone is indicated by high resistivity readings and decreases in water zone. This information is combined with neutron-density curves to predict the possible fluid contacts as indicated in **Figure 4.**

CHAPTER FOUR

RESULTS AND DISCUSSION

From the result tables below, we evaluated the Hamara E-8 well and achieved results in seven zones.

We determined zones from (**Ad,1,2**) are Oil zones (Pay zones) because the cutoff water saturation is less than 50%, as show in (**Table 4)**

4.1. Zone-AD:

the water saturation value 23.1% is the least value for all the zones, even thou it doesn't have the most oil duo to the fact that it has relatively significant amount of shale which decrease the sand amount that contain oil.

There is a distribution of oil and water where the water content is higher than the oil,

It was determined by the relatively low value of resistivity.

The effective porosity distribution in the zone calculated with histogram in **(Figure 7**), which shows low porosity distribution overall.

The Lithology of the zone is sand and shalysand, where the shaly sand is content is a lot more, hence there is a little bit of oil due the lack of sand as the **(Figure 5)** indicates:

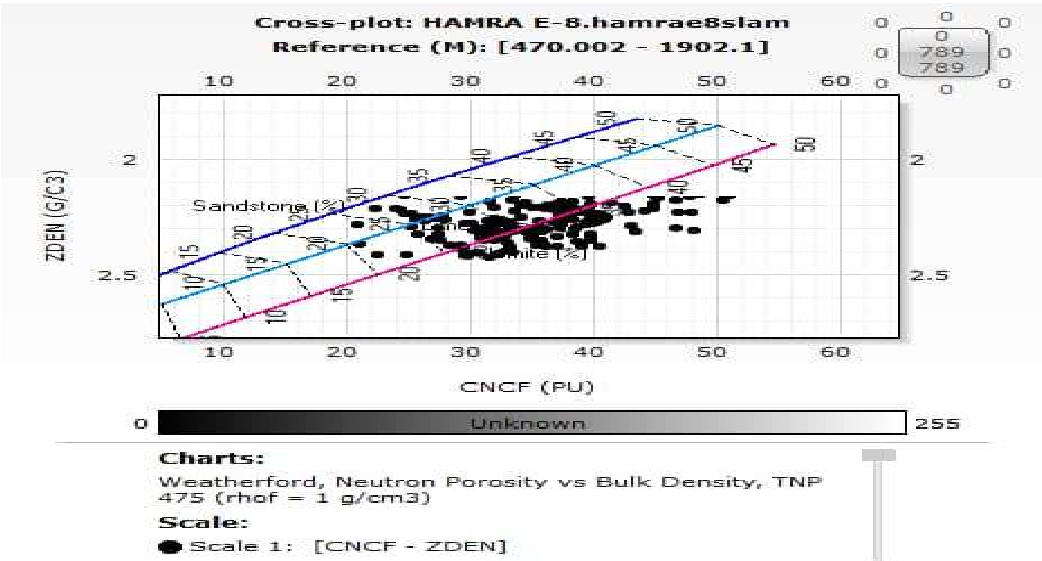

Figure 5: N-D Cross-plot Hamra East-8

Gamma-ray histogram shows the distribution of shaly sand and sand in the zone with value range of (60-85) at the frequency range of (0-0.1), as it shows in **(Figure 6).**

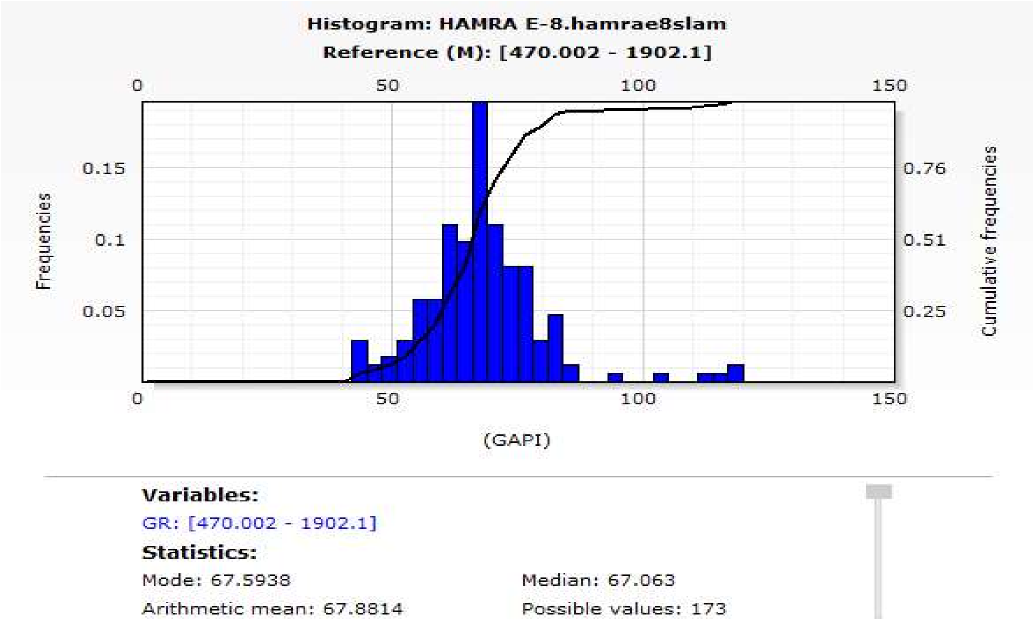

Figure 6: Gamma-ray histogram for AD zone.

Porosity histogram the zone shows the porosity distribution at value range of (0.225-0.125) at frequency range of (0.3-0.05).

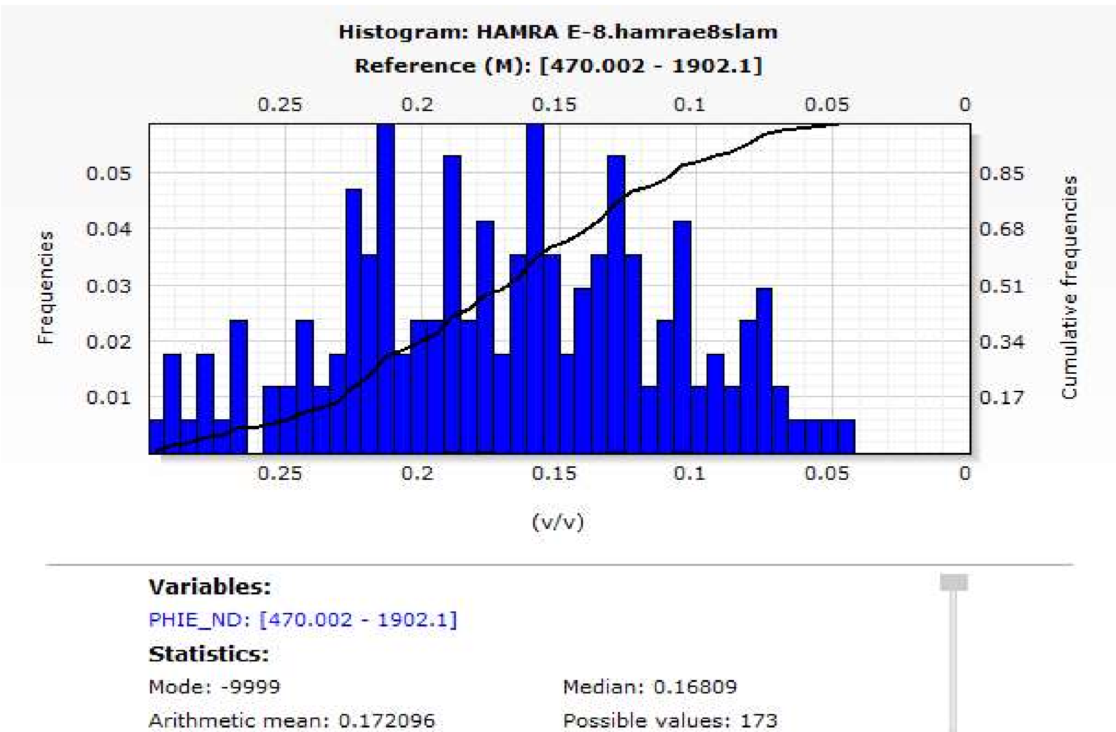

Figure 7: Effective Porosity histogram for zone AD.

4.2. Zone-1:

Water saturation value is 41.9% but it has a more oil (almost the whole zone) due to the fact it has more amount of sand than shaly sand, even though the fact of the value water saturation is that low compared to **zone-AD** we determined that this amount of water located in the shaly sand area.

4.3. Zone-2:

Water saturation value is 45% with convergent distribution of oil and water, with moderately resistivity values. And sand amount is around 65% compared to shaly sand volume.

4.4. Pay Zones:

Gama ray histogram shows the distribution of shaly sand and sand in the zones with value range of (55-110) at the frequency range of (0.01-0.12), as it shows in **(Figure 8)**.

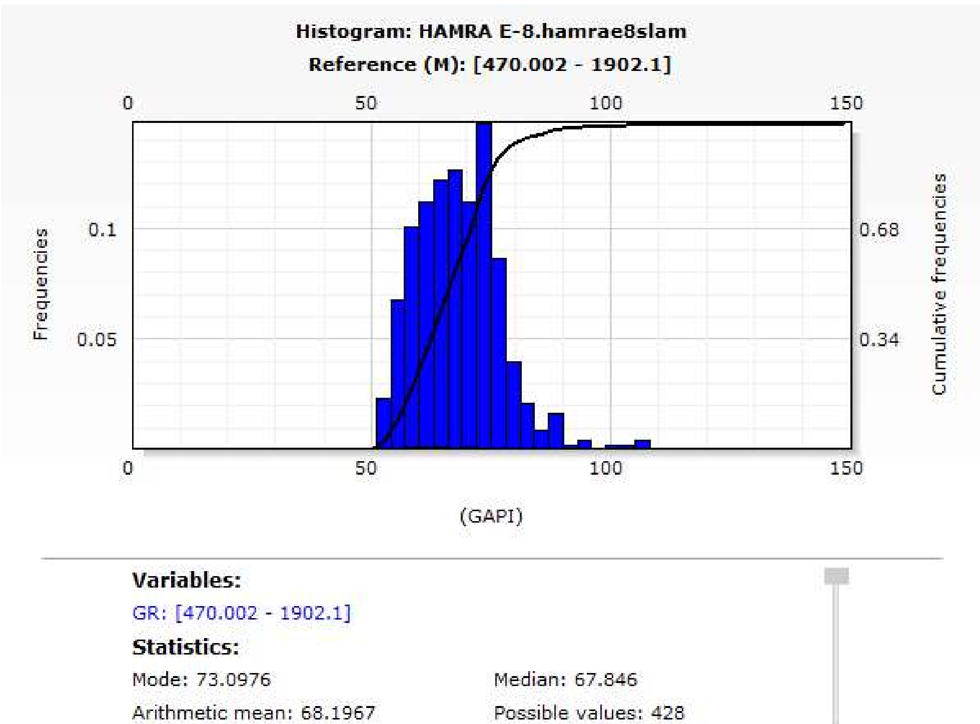

Figure 8: Gamma-day histogram for pay zones.

Porosity histogram shows the distribution of porosity throughout the zones with value range of (0.01-0.28) at frequency range of (0.01-0.07), as it shows in **(Figure 9)**

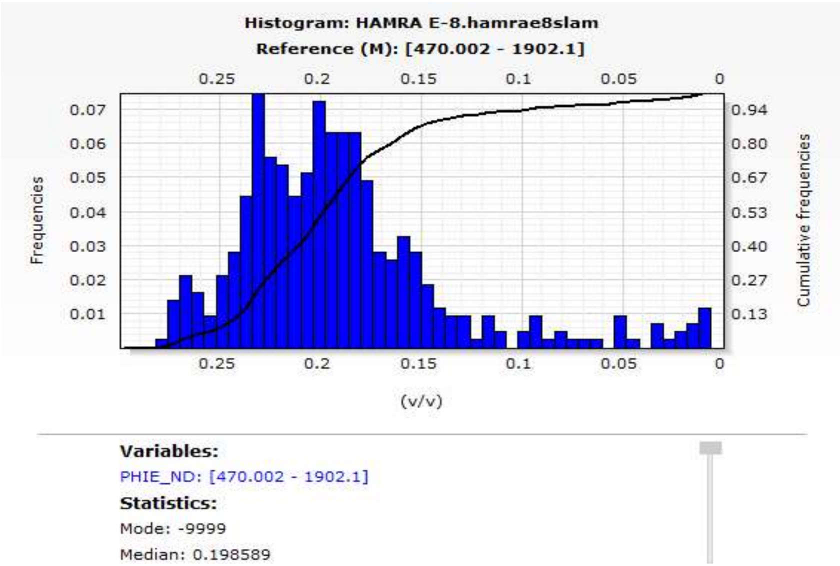

Figure 9: Porosity histogram of pay zone

All in all, we come up with:

- Table of reservoir properties showing

Reservoir Table Result MD											
	Well	Zones	Flag Name	Top	Bottom	Gross	Net	Av_Shale Volume	Av_Porosity	Av_Water Saturation	Result
				m	m	m	m	v/v	v/v	v/v	
1	HAMRA E-8	AD	RES	1548.8	1562	13.18	4.419	0.251	0.292	0.231	oil
2	HAMRA E-8	1	RES	1756.4	1766.4	10.02	9.968	0.27	0.3	0.441	oil
3	HAMRA E-8	2	RES	1775.4	1785.1	9.733	9.183	0.324	0.31	0.495	oil
4	HAMRA E-8	3	RES	1793.3	1806.1	12.82	11.13	0.321	0.277	0.592	transation
5	HAMRA E-8	4	RES	1814	1824.3	10.31	8.624	0.348	0.299	0.609	water
6	HAMRA E-8	5	RES	1830.6	1838.9	8.301	6.172	0.342	0.288	0.566	water
7	HAMRA E-8	6	RES	1840.6	1849.5	8.874	7.983	0.28	0.282	0.609	water

Table 1: Net reservoir properties result table

- Table of Net pay properties showing

Net pay table Result MD											
	Well	Zones	Flag Name	Top	Bottom	Gross	Net	Av_Shale Volume	Av_Porosity	Av_Water Saturatio	Result
				m	m	m	m	v/v	v/v	v/v	
1	HAMRA E-8	AD	PAY	1548.8	1562	13.179	4.419	0.251	0.292	0.231	oil
2	HAMRA E-8	1	PAY	1756.4	1766.4	10.019	8.763	0.269	0.303	0.419	oil
3	HAMRA E-8	2	PAY	1775.4	1785.1	9.733	5.487	0.351	0.323	0.45	oil

Table 2: Net pay properties result table.

- Comparison table of pay zones

We compared the obtained results from the pay zones with core data from the field, the results were match with each other with average values of porosity and water saturation, as indicated in **Zone-AD** in **Figure 10** where is the blue dots are the matching values of water saturation and the red dots are the matching value of porosity.

Depth (m)	Porosity /OV (%)	S_{wi} (% PV)
1553.4	29.3	29
1554.1	29.4	29.5
1555.1	28.3	22.3
1668.6	27.3	29.5
1689.7	26	26.2
1690.8	24.4	28.1
1716.8	21.7	31.2

Table 3: Matched points values between Core data and well

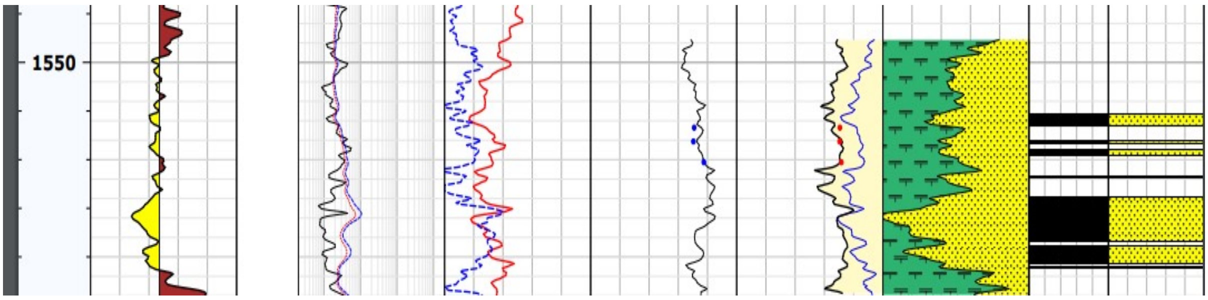

Figure 10 : Zone-AD

CHAPTER FIVE

CONCLUTION AND RECOMMEDATION:

Formation evaluation is a key analytical process contributing to the identification of economically productive reservoirs. That's true when you have access to enough accurate data.

We used special core data which limited our information to use more methods.

Gamma-ray, Neutron-Density and Archie Equation are used to determine the average property values of:

1. Shale Volume = 27.9%
2. Porosity =26.5%
3. Water saturation = 17.89%

The cutoff of these properties are as followed:

1. Shale Volume = 50%
2. Porosity = 12%
3. Water saturation = 50%

The obtained pay zones are as followed:

1. Zone-AD with Sw = 23.1%
2. Zone-1 with Sw = 41.9%
3. Zone-2 with Sw = 45%

Their formation is a mix of sand and shaly-sand, even thou the water saturation values are good but the oil content is low because the shaly-sand content was superior, it is also notice the existence of water mixed with shaly-sand, hence the relatively low resistivity values in them.

The effective porosity and shale volume distribution indicated the range falls in the shaly-sand side where the most frequent values of porosity were low.

We correlated the values of porosity and water saturation with the special core data, they were matched with **Zone-AD,** thus the values achieved are correct, although it was three points each, and hence the data worked on is limited.

Recommendation to improve this paper:

1. To have an access to RCAL data.

- To obtain accurate basic data to be used as foundation.

2. The use of ECS.

- To measure elemental concentrations in rocks and estimate the major matrix properties from them, hence more data to work with and obtain satisfying correlation.

3. The use of NMR.

- To have more accurate porosity results and help with permeability determination.

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