First Libyan International Conference on Engineering Sciences & Applications (FLICESA_LA)
13 – 15 March 2023, Tripoli – Libya

Investigate the Petrophysical Characteristics of Lower Akakus Reservoir in (A) Structure -NC118 Oil Field by Using Well Logging Data, Ghadames Basin, West Libya

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Abstract: evaluation of low resistivity reservoir pay in lower Akakus Formation is very challenging and important to the development of an oil field.

The main purpose of this study is evaluate and investigate the Petrophysical characteristics of lower Akakus reservoir in A Structure oil Field by using available logging data for two wells (A1 and A2 NC118) which located in Ghadames Basin ,West Libya.

According to final well report the lower Akakus Formation can be divide into five sand units from top to bottom of the lower Silurian the reservoir sand 1, sand 3, sand 3, sand 4 and sand 5 (SS1, SS2, SS3, SS4 and SS5).

Petrophysical analysis for studied wells by using Techlog software is indicated type of lithology by using cross plot between Neutron porosity and Bulk density for each unit in lower Akakus is mainly sandstone interbedded with shale with average volume of shale range from 0.2 % to 15%, porosity range from in sand 1 about 2% ,sand 2 about 22%, sand 3 about 22 %, sand 4 about 17% and sand 5 about 15 % and the average water saturation range from in sand 1 about 60% ,sand 2 about 72%, sand 3 about 62 %, sand 4 about 17% and sand 5 about 56 %.

The petrophysics result show of oil and gas zones that sand 1 to sand 5 were low resistivity. However the well production test data of these interval confirm hydrocarbon present instead, the petrophysics and well test result indicate that the main reason for of the above sandstone units was related due to high water saturation salinity and highly water salinity more than 250,000 ppm.

Keywords— Techlog, Lower Akakus Formation, Petrophysical Analysis, Well Production Test

I. Introduction

The “A Structure” Field is situate in Block NC-118 which located about 250 km Southwest of Tripoli and about 300 km Northeast of Wafa Field. The NC-118 block is located on the northern flank of the Ghadames Basin of North-western Libya, which develops along a NE-SW direction across Algeria and Libya. Such basin is bounded by the following highs: Dahar and Garian to the South, Amguid el Biod to the West, and Tripoli-Asswada to the East.

A Structure” Field was discovered In 1985,by drilled well A-1 crossed the so-called “A Structure”, discovering five hydrocarbon layers in Lower Akakus Formation of Silurian age, different type of hydrocarbon were identified : gas condensate ,saturation (or close to) oil ,under saturation oil, In 1995, appraisal well A-2 was drilled at about 1.5 km south of well A-1 and confirmed the shape of the “A” structure the oil bearing formation and defining the areal extent of the hydrocarbon ,the oil gravity range from 34 (layer5) to 40 API(layer3) and solution gas range 540 to 3200 Scf/bbl.

The main objective is to better describe the vertical distribution of the Lower Akakus reservoir facies’ variations in study area. The Petrophysical characterization of the Lower Akakus reservoir through well log, Identified stratigraphic layering in the Lower Akakus reservoir.,

The main method used in this study were applied Petrophysical analysis for two selected wells (A1 , and A2-NC118) based on electrical logs, include Gamma-ray (GR) , Neutron (N) , Resistivity log , density log and Sonic log by using Techlog 2015 software, in order to determine the quantity of Petrophysical properties for the lower Akakus Formation such as Porosity, water saturation and net pay, and integrate them with the well test results to enable precise understanding and define the present of hydrocarbon in such low resistivity intervals within the study

II.Regional Tectonic Setting

The Ghadames Basin is a large intracratonic basin on the North African platform. Formed during the early Palaeozoic era, it covers an area of 350,000 km2 and straddles the borders of Libya, Tunisia, and Algeria. The Libyan portion represents the eastern flank of the basin and covers an area of about 183,000 km2. It is an important hydrocarbon province since the 1950s (Echikh, 1998). The main tectonic elements bounding the Ghadames Basin are the Dahar–Nefusa uplift to the north, the Gargaf arch to the south, partially bounded by the extension of Tihemboka uplift to the west, and the western flank of the younger Sirt Basin to the east Many of these structural features were initiated in the late Precambrian Pan-African orogeny, with repeated reactivation of older structures occurring throughout the Phanerozoic. The basin contains up to 5,200 m [~17,000 ft] of Palaeozoic and Mesozoic sediments, the Palaeozoic section being separated from the Mesozoic de-posits by a major regional unconformity of the Hercynian(Devonian-Carboniferous) age. This Hercynian unconformity is represented as the most conspicuous feature of the basin as Palaeozoic sequence is overlain by Mesozoic succession with a markedly different basin configuration. Erosion patterns and the topography that developed on the surface of this regional unconformity have had a direct influence on the petroleum systems within the basin. (Hallett, 2002). The Ghadames Basin comprises four major tectonic cycles. The oldest one, that represents the Cambro-Ordovician cycle, ended by the Early Caledonian tectonism; the second one of Silurian age ended by the Late Caledonian epeirogeny and the third one of Devonian–Carboniferous age terminated by the Hercynian epeirogeny. The Alpine Orogeny, represented by Mesozoic sedimentary cycle, has increased the northern extension of the basin and changed it into a marginal sag basin (Hallett, 2002). Palaeozoic deposits are dominated by non-marine and marine clastics: conglomerates, sands, silts and shales that comprise more than 95% of the total section. There are much more carbonates and evaporates in Mesozoic deposits, while the Cenozoic deposits consist of limestone and shale. The depositional setting in Palaeozoic is an interior, cratonic regime of subsidence characterized by shallow marine and non-marine environments. The depositional setting of marginal plat-form regime dominates during Mesozoic time.

III. Structure of Study Area

The structure contour map of Top lower Akakus formation shown on Figure (2.2) ,the high structure in the central part of study area then trend to low structure in to the west part also in the eastern part north part in general the area anticline structure

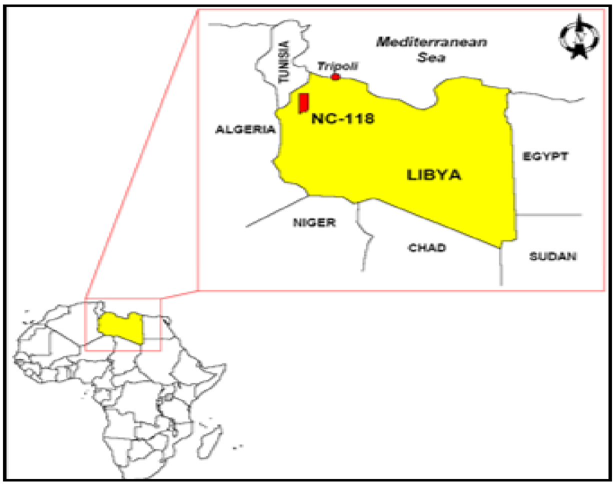


FIG (1) LOCATION MAP OF NC118

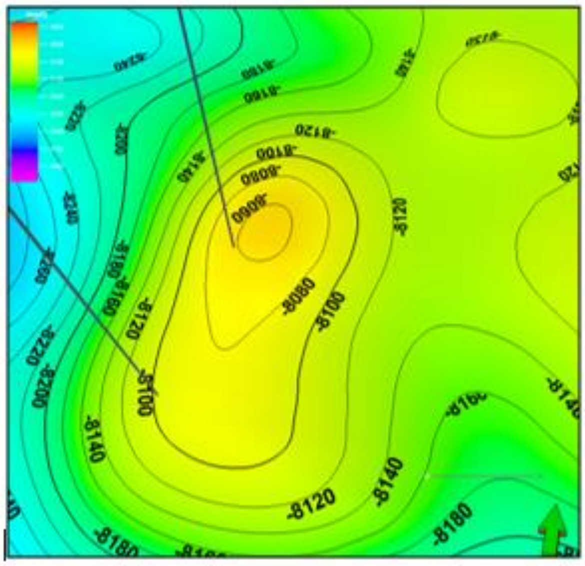


Fig (2) structure contour map of Top lower Akakus

B-Stratigraphic)

The stratigraphic Scheme used in this study following final well reports.

The Silurian sediments are consists of three formations termed the Bir Tlakshin (also known as the Iyadhar Formation over the Atshan Saddle), the Tanzzuft Formation and the Akakus Formation The upper portion of the Bir Tlakshin Formation is marked by a fine to medium grained quartzose sandstone similar in lithology to the

underlying Mamuniyat Formation. The sandstone is frequently underlain by a dark grey to greyish brown hard *fissile shale. The Bir Tlakshin is frequently absent over the older structural high areas due to the unconformity at the top of the Cambro- Ordovician. It can reach thickness of well over 100m (328ft) but generally has an average thickness of about35m (115ft). The overlying Tanezzuft Formation consists of a thick succession of grey to dark grey shales varying in thickness from 300-600m (984-1,969ft), Some siltstone and sandstone interbeds occur in the upper part where it grades into sands of the overlying Akakus Formation. In the north-eastern part of the basin the shales are highly micaceous and almost metamorphosed in appearance whilst in the south-east they become more sandy. The upper contact with the overlying Akakus Formation is rather diffuse and involves facies changes from sandstones to shale units.*

Akakus Formation

The Akakus Formation can be subdivide into three members , lower sand, middle shaly and upper sandy members The lower member consists of a thick sandstone/siltstone complex interbedded with shales. The sandstone is light colored and interbedded with light grey siltstones and dark grey shales.The Middle Akakus shaly unit represents of shales intercalated with thin beds of siltstones and hard sandstone layers.a regionally extensive, but relatively short-lived flooding event, with the top of the Lower Akakus being defined. The upper is composed of an irregular alternation of sandstones siltstones, and shales. The total Akakus thickness varies up to a maximum of about The Middle Akakus is also an effective regional top seal for

the Lower Akakus reservoirs. However, measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

Reservoir rock Lower Akakus formation is main reservoir rock in study area and consists sandstone interbedded with shale. the lithofacies of the lower Akakus formation according to geologist of company), the lower Akakus sandstones are divided into about five sandstone units from bottom to top (ss1 ,sst2 ,sst3,sst4 and sst5) , where regional integration of wireline-logs and sample cutting description permits evaluation analysis of the units as they appear the most thicker, of great extension, and most prolific units throughout the area study . The description of these units and their representative lithofacies is as following.

IV. Sedimentology and facies analysis

Sedimentology and facies in two wells A1 and A2-NC118 based on cores study report result , the result was define and recognized four main facies associations through the analysis of the cores of Lower Akakus sandstone

1 Massive medium-fine grained sandstones with some trough cross bedding (the deposited processes : unidirectional currents into a high energy context);shaly streaks and intraclasts may occur along with some rare bioclasts .

2Fine-very fine grained sandstones with hummocky cross stratification ,wave ripples and big occurrence of shaly streaks with some intense burrowing hiding the primary sedimentary structures (depositional processes :storm and wave action under low energy conditions)

3Very fine grained silty-shaly sandstones with starved ripples, wave ripples and abundant burrowing (depositional processes interaction between high energy due to the wave action and relatively calm phases when burrowing can develop.)

4Black shales with rare starved ripples and intense bioturbation (depositional processes rare storms and/or wave activity occurring into a low-energy context).

According to the sedimentological facies described and to their vertical stacking pattern induced both unidirectional currents (tidal) and waves action, the depositional setting where high energy condition alternate with lower ones may be inferred , this occurs mainly for relative sea level oscillations even of small entity ,the flat and wide ramp physiographic setting may be assumed of low gradients where small relative oscillations of the sea level allow both deposition pf high energy sandstone bodies (sea level falls with downward shifting) and quick deactivations' of the sandy system (sea level rise with rapid transgression) . the low gradient ramp platform with occurrence of a large number of coalescing bars forming sandstone sedimentary bodies which could be arranged in tabular sheets for tens of kilometers , these sedimentary bodies maybe separated laterally by finer grained facies better developed in the offshore domain

V. Petrophysical study

The identification and evaluation of low resistivity in lower Akakus reservoir bypassed pay is very challenging and important to the development of an oil and gas field. The problem of ‘low resistivity pay’ is not new. There are many reasons for low resistivity pay zones. It is crucial to identify the origin of this phenomenon. the identification and petrophysical evaluation of low resistivity hydrocarbon-bearing in lower Akakus sand reservoirs to understand why low resistivity occurs in the lower Akakus sandstone reservoirs, and how to conduct a petrophysical analysis to obtain accurate petrophysical properties, particularly water saturation. An integrated workflow to understand the low resistivity phenomenon and how to identify it was presented and performed to evaluate low resistivity pay in sandstone reservoirs.

identification, characterization and evaluation of low resistivity hydrocarbon-bearing in Akakus sand reservoirs in order to understand the low resistivity phenomenon in sandstone reservoirs, the characterization of the rock types and how to conduct petrophysical analysis. An integrated study based on petrographical, rock typing and petrophysical methods is conducted and applied

Determination of rock type

The rock type was determined based on the relationship of the density and neutron log cross plot . It is important to classify the characteristic for each rock type in low resistivity reservoirs in order to identify and understand the typical response of logs and petrophysical properties of low resistivity pay-bearing sand reservoirs.

The Neutron-Density Crossplot

The neutron-density crossplot is widely used in the petroleum industry investigations for lithologic identification and estimates of porosity, and matrix density. Apparent neutron porosity measurements were plotted against measurements of bulk density for each zone. Matrix-density values used for pure lithologies are: silica, 2.65 g/cm3; limestone 2.71 g/cm3; and dolomite, 2.87 g/cm3. The lithology and porosity can be calculated by this cross plots. This cross plot, has the maximum resolution and is the best detector of porosity among the different lithologies The cross plot well distinguishes lithology lime, dolomite and sandstone. it should be noted that, before drawing given data should be corrected for the presence of shale and hydrocarbon. In wells with uneven walls or heavy drilling mud, information density may not show correlation, so there are limitations to the use of cross-platform

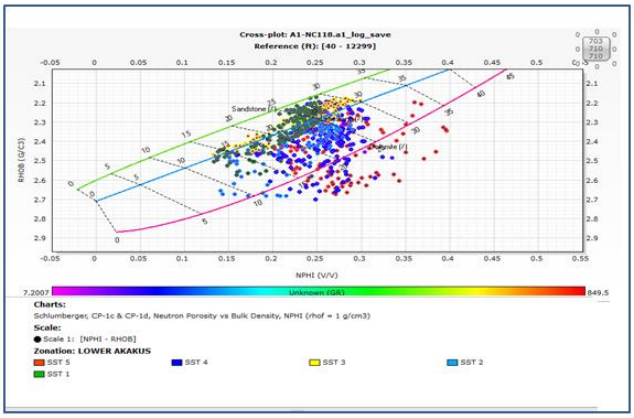


Fig (3) Neutron - density cross plot in well A1-NC118

The result of cross plots in studies wells indicates the lithology of the lower Akakus Formation is sandstone interbedded with shale in all wells , figures 3 shown applied the cross plot for all sandstone units in wells A1-NC118 **Petrophysical analysis**

Petrophysical analysis was performed in order to identify the factors that cause low resistivity in sandstone reservoirs. Petrophysical analysis was employed to explicitly determine reservoir quality, petrophysical analysis, the three basic parameters that are determined are shale volume (Vsh), effective porosity, and water saturation (Sw). These parameters were calculated using the standard procedures available in the well logging data .

Volumetric shale

Volumetric shale fraction was calculated using a GR lo

Where the volume of shale into calculated from gamma ray log shown in equation

$$VSH=(GRlog-GRmin) / (GRmax-GRmin)$$

Where: GR log: is the Gamma ray.-reading (log). GRclean: is the minimum reading a log. GRsh: is the maximum reading a log. Vsh is the Volume of shale (%).

Porosity calculation

For the porosity calculation, neutron–density logs were used to calculate non-shale porosity whenever they were available

Porosity Determination: ¬

The total porosity values were determined by using steps below:

Porosity from density log (ØD)

The density porosity (ØD) is determined from equation based the rock type of the reservoir.

$$\textbf{ØD} = (\rho bma - \rho blog) / (\rho bma - \rho f)$$

Where: ØD =.Density porosity. ρb = Bulk Density, gm/cc (log). ρf = Fluid Density, equal 1gm/cc. ρbma = Matrix Density, equal 2.65gm/cc for sandstone

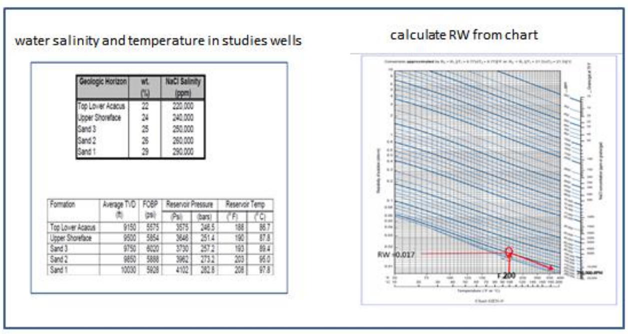
The neutron porosity has been directly read from the neutron logs. The total porosity represents the mean of the combined neutron and density porosities readings for water and hydrocarbon zones.

$$\textbf{ØN-D} = [(ØN^2 + ØD^2) / 2]^{½}$$

Where: ØN = Neutron porosity % (log). ØN-D =Total porosity

Formation Water Resistivity:-

In this study the formation water resistivity was obtain from the company ,value of salinity average 250,000 ppm and temperature average 200 F° from figures bellow shown how calculate the RW from chart and the RW is 0.017 Ω.m.



Geologic Horizon	wt. (%)	NaCl Salinity (ppm)
Top Lower Acacus	22	220,000
Upper Shoreface	24	240,000
Sand 3	25	250,000
Sand 2	26	260,000
Sand 1	29	290,000

Formation	Average TVD (ft)	FOBP (psi)	Reservoir Pressure (Psi)	Reservoir Pressure (bars)	Reservoir Temp (°F)	Reservoir Temp (°C)
Top Lower Acacus	9150	5575	3575	246.5	188	86.7
Upper Shoreface	9500	5854	3646	251.4	190	87.8
Sand 3	9750	6020	3730	257.2	193	89.4
Sand 2	9850	5888	3962	273.2	203	95.0
Sand 1	10030	5928	4102	282.8	208	97.8

Fig (4) water salinity and temperature results

Determining accurate water saturation values was challenging but important in order to identify hydrocarbon distribution in low resistivity sand reservoir. Thus, water saturation calculation method was applied in low resistivity sandstone reservoirs. Qualitative log interpretation was performed in all of the four well log data. The water saturation is calculated using the archaic

$$Sw= [(a \times Rw)/ (Ø^{m} \times Rt)]^{1/n} ..$$

Where: Ø= Total Porosity (%).m = Cementation factor, equal 2. Rt = Formation resistivity, Ω.m. n = Saturation exponent, equal 2. a = is the Archi factor and equals to 1. Rw=is the formation water resistivity 0.017 Ω.m.

VI. Results and discussions

The result of well logging interpretation of wells A1 and A2-NC 118, the lower Akakus Formation; from well log show the GR log response is small enough less than 75 API, and the resistivity value is big enough at about less than 12 ohm-meter in clean sandstone in units SS1, SS2, SS3.and SS5, Neutron–density log curves show that there is not separation between the neutron–density log curves as caused by high density log reading. The cross plot between neutron–density log for define type of lithology in the lower Akakus formation for all units which indicate the sandstone is main rock with shale.

Low resistivity Pay

The reasons for the low resistivity phenomenon are mainly classified into two groups. The first consists of reservoirs where the actual water saturation can be high but water free hydrocarbons are produced. The mechanism responsible for the high water saturation is usually described as being caused by micro porosity (Edo Pratama), The second group consists of reservoirs where the calculated water saturation is higher than the true water saturation. The mechanism responsible for the high water saturation is described as being caused by the presence of conductive minerals such as clay minerals and pyrite in clean reservoir rock. Clay minerals are conductive minerals due to their high cation exchange capacity (CEC) value, where illite has the highest CEC value of about 26.6–69.0 meq 100 g−L There is a decreasing resistivity value in sandstone containing clay minerals. The ability of clay minerals to combine with or bind to water is one factor associated with the decreasing low resistivity value (Edo Pratama, 2017) . Another factor causing a decreasing resistivity is the presence of iron minerals, particularly pyrite. The presence of pyrite will cause the density log reading to be higher than the matrix density (sand). This is due to the high density value of pyrite mineral of about 5.0 g cc−1 (Rider 2002). In addition, the measured resistivity on dry pyrite ranges between 0.03 and 0.8 Ω m which affects the low resistivity reading. In this study area the lower resistivity log in sandstone units due to water saturation is higher than the true water saturation based on water samples analysis. From a petro physical point of result of lower Akakus Formation is characterized by a peculiar interpretation problem: the presence of sodium chlorite. Its occurrence affects in different way the petrophysical parameters), but it makes difficult the computation of SW because have a strong impact in electrical measurements (Resistivity Logs) Studies on lower Akakus Formation indicate that the 'n' value (saturation) exponent in the formula for water saturation evaluation measured presence of Chlorite was 1.4-1.8) instead of 2 used in the formula for water saturation. The main results of Water saturation, computed in petrophysical, was higher than SWI from well test results have confirmed:

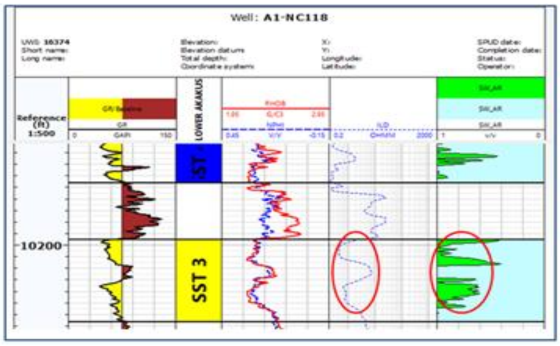
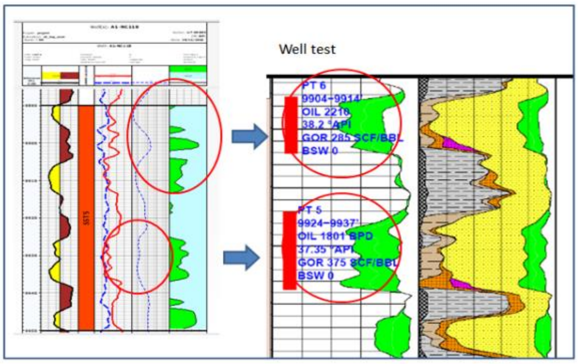


Fig (5) low resistivity log in well A1-NC118

Well test result with petrophysics result

The compared the well test result with petrophysics result on the Lower Akakus Formation in well A1-NC118 for all units In all unit SS from the bottom to top of formation the well production test was run in two zone in unit SS5 first from (9904-9914 ft) and other from 9924-9937ft) the rsult in zone one is oil about 2216 bbpd with GOR 285 SCF/BB with no water cut and the result in zone two about 1891 BOPD With 375 scf/bb , all two zones with low resistivity.



VII. Conclusion

Integration of well logs analysis and well test result were applied in the lower Akakus formation, the A Structure oil field which located in concession NC-118, western part of the Ghadames Basin by using available logging data for four wells (A1, A2,) The lower Akakus can be divide into five sand units from top to bottom of the reservoir (SS1, SS2, SS3, SS4 and SS5). Petrophysics result indicated lithology by using cross plot between Neutron porosity and bulk density With Average volume of shale range from 3.2 % to 32.68%, porosity range from 9.1% to 20.6 %, average water saturation range from8.7 % to 99 % . Formation water analysis of Lower Akakus zone revealed high water salinity with high sodium chloride confirmed salinity range from 220,000 -290,000 ppm . Although well test logs analysis indicated the low resistivity for this interval (L.A) the well test result confirm present oil in the Lower Akakus zone.

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Fig (6) compared between well test and Petrophysics result in zone SS5 of Lower Akakus Formation well A1-NC118

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