Verification of the reserve of Al-Hamada oil field V-NC6 area by application of well logs.

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A B S T R A C T

The motivation behind this paper is to enrich and deepen our knowledge in the field of logging and log interpretation. The ultimate target is to have in situ assaying of a particular zone. In petroleum application this means determining the amount of oil and/ or gas that is contained in the formation. The Geological structure of V- NC6 area in AL-HAMADA oil field has been studied and volumetrically estimated in seeks of the amount of hydrocarbons in the structure. To achieve this, a bunch of well logging data from different wells in V-NC6 area have been reviewed, analyzed and interpreted. Physical properties of the reservoir have been measured which include porosity and water saturation by interpretation of SP log and Induction – Electrical logs. In situ porosity has been determined by applying the Archie's equation on a real data from different resistivity tools. The average porosity of the multi pay zones structure was 14.23 % of the total volume of the reservoir 83336.3 acre ft. The second basic parameter which has been determined for in situ assaying is the saturation of the V- NC6 structure with water and hydrocarbons and they were 30% and 70% respectively. The V- NC6 area in AL-HAMADA oil field volumetrically occupied around 5.44 Million Stock tank barrels of oil.
Keywords: well logging; log interpretation; resistivity log, SP log, porosity; Water saturation.

1 Introduction

The volume of hydrocarbon reserves is a primary component of an energy company's value. Estimating that volume is a complicated, but essential and regulated, part of the resource industry's business. Geophysical methods continue to advance and are playing a more fundamental role in reservoir assessment (Hardage, 2009; PRMS-AD, 2011). To achieve this, physical properties of the reservoir have to be measured which include porosity and water saturation. Unfortunately, no one tool can give these results. Therefore, tool combinations that will measure porosity and hydrocarbons in place in the reservoir have been developed for various targets. Determining in situ properties (porosity and fluid saturation) can be done by the use of three porosity tool and resistivity tool as well. Those porosity tool that are used normally are the sonic, density and the Neutron porosity tools. A second basic parameters to be determined for in situ assaying is the saturation of the formation with hydrocarbons and water. The V- NC6 area has been owned and running by the Arabian Gulf Oil Company, on November 1976 the reservoir engineers have been estimated the original hydrocarbons in place to be around 5 MM STB, and this value was economically stratified for the operator to start production from this area. In this paper we tried to redo the same job and estimate the volume of hydrocarbons occupied originally in place.

2 Materials and Methods

Al Hamadah al hamra area is located on the southern flank of the Ghadamis basin between lat 29' 00' to 29' 40' N and long 12' 35' to 13' 10' E occupying a strategic position midway between Al Qarqaf arch to the south and centre of the basin to the north.

Over 1200 ft of sediments are accumulated in the basin and range in age from Precambrian to Paleocene. While most of the lower two-thirds are clastics, the upper third is mostly marine carbonates and evaporates. Most of the lower Paleozoic units pinch out rapidly against AL Qaraqaf arch to the south in addition to their being cut off by several unconformities. These unconformities represent different erosodes during early and late Paleozoic and Mesozoic times.

Large ENE-WSW tending compressional faults and folds were associated with the early Alpine progeny which were later modified with smaller N-S and NW-SE normal faults.
Where; ENE – East North East and WSW – West South West

2.1 Well Location and Prospective Horizons

Based on correlation with the nearby wells, the following are the expected stratigraphic, table (1) shows tops of the interested zones in V8 –NC8 well.

Table 1 shows tops of the interested zones in V8 –NC8 well.

Lower Devonian	**-2950 Ft**
Do-Sandstone	- 2950 Ft.
Do-Shale	- 2969 Ft.
D1-Sandstone	- 2917 Ft.
D1 –Shale	- 3000 Ft
D2 –Sandstone	- 3019 Ft.
D2 –Shale	- 3065 Ft.
D3-Sandstone	- 3083 Ft.
Total Depth	**- 3250 Ft.**

3 Theory and Calculation

In this section we will show the calculation of each parameter we did use in our research and we have used real logs to interpret the data to come out with these results.

3.1 Volumetric Method:

The volumetric method requires the exactest possible data on :

a) The thickness of the reservoir rock. b) Its extension.

c) Its porosity and d) its saturation.

By a multiplication of these 4 factors we then get the original reserves in the field under reservoir conditions as in equation (1). The thickness of the pay horizon is usually obtained from downhole measurements (SP, resistance). As only the net thickness is measured

$$N = \frac{7758 * A * h * \emptyset * (1 - S_{wi})}{B_{oi}}$$

Where; N= Oil in place STB, A= Productive area Ft^2 , h= net thickness Ft, Ø= porosity %

Swi= connate water saturation %, Boi = Formation Volume Factor Rb/STB.

3.2 Volumetric Reserve Calculation:

3.2.1 Thickness (h):

The gross net pay thickness has been estimated from logs.

3.2.2 Calculation of the bulk volume of the reservoir by using ISOPACH MAP:

A net Isopach map is a map showing lines connecting points of equal net formation thickness. The bulk volume of the reservoir has been determined by using these maps. The Trapezoidal equation has been used to determine the volume of the production zones from planimeter reading.

A) Trapezoidal Equation:

$$\Delta VB_n = h/2(A_{n-1} - A_n) \quad \text{.............(1)}$$

$$BV = \{\Delta VB = h/2(A_0 + 2A_1 + 2A_2)\}$$

This equation used when

$$\frac{A_n}{A_{n-1}} \geq 0.5$$

3.2.3 Porosity (Ø):

It is generally measured directly in the laboratory from cores or cutting and then plotted in a porosity profile these measurements are usually verified by various downhole measurements. In this paper we did use an Arche's equation to calculate the average porosity of multi strata reservoir.

$$\emptyset_{avg} = \frac{\sum h * \emptyset}{\sum h} \quad \text{.........................(2)}$$

3.2.4 Water saturation (SW):

It is major factor the irreducible water saturation Swi is best established by capillary pressure measurements carried out on cores or cutting in addition to this the (archie) formula is also useful in this respect an exact determination of the oil/water contact is usually difficult and requires experience.

a. Calculation of water saturation (SW) from SP log

The fluid saturation of a rock is the ratio of the volume of the fluid within the pores of the rock to the total pore volume. In this paper the water saturation has been calculated within two different methods; chart method and ARP'S equation method.

To estimate the water saturation of the formation must determine the Ro , Rt and Rw

Where

Ro: oil resistivity , Rt: true resistivity, Rw: water resistivity & F: formation resistivity factor

ARP'S equation method:

Compute the constant K

K=(60+.133Tf) ……(3)

Where K : a termal convention constant.

Solve for Rweq

Rweq=Rmfeq/10^(-sp/k) ………..(4)

Convert Rweq to Rw

If Rweq<0.12 then use

Rw=(77Rweq)+5/146-(377Rweq)…………(5)

If Rweq>0.12 then use

Where; Rw_{eq} : Equivalent resistivity of the formation water , R_{mf} : Resistivity of the mud filtrate and SSP : static SP the maximum deflection possible for a given Rmf/Rw.

Rw=-0.58+10^(0.69Rweq-0.24)……………(6)

SW=√(Ro/RT)

F=Ro/Rw

Ro=FRw

Sw=√(FRw/Rt))……………(7)

b. Formation factor (F):

Archer experimentally determined that the formation factor could be determined from the porosity cementation (m) and rock texture (a)

Thus F=a/ϕ^m)……………(8)

Though extensive use of the relationship the following values have been used with great success

$$F=\frac{Ro}{Rw}=\frac{resistivity\ of\ rock\ saturated\ with\ fluid}{resistivity\ of\ the\ saturating\ fluid}$$

Where ; R_m: Resistivity of the mud , R_{mf} : Resistivity of the mud filtrate, Rmc - Resistivity of the mud cake, and F: Formation resistivity factor

4 Results and Discussion

4.1 Estimate the total volume of the reservoir from the Isopach map:

The figure (1) is an isopach map of V-NC6 area that we used to calculate the volume of the reservoir. Table 2 shows the results of reservoir volume calculations.

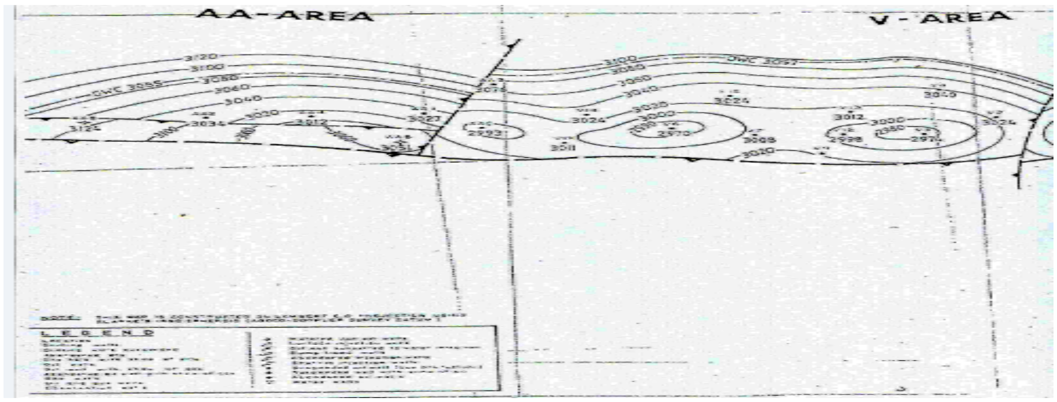


Figure (1) an isopach map of V-NC6 area of Alhamada Alhamra oil field.

Table 2 shows the results of reservoir volume calculations

Area	A (Cm^2)	A (Acre)	A_n/A_{n-1}	Method Used	ΔVP(acre.ft)
A_0	13.77	851.123	-	-	-
A_1	9.31	575.137	0.6757	Trapezoidal	3565.65
A_2	5.76	355.831	0.6186	Trapezoidal	2327.42
A_3	3.11	192.124	0.5399	Trapezoidal	1369.88
A_4	1.7	105.019	0.5466	Trapezoidal	742.85
A_5	0.975	60.232	0.5735	Trapezoidal	330.502

Total net pore volume (ΔVP) = 8336.302 acre.ft

4.2 Estimate the porosity of the reservoir from the well logging:

As example to calculate the porosity from well logging we estimated it from well V8. The figures 2 & 3 show the well head logs and the SP & Electrical logs of the well V8- NC6, respectively. Table 3 shows the results of the net pay thickness and porosity for each horizon of well V8.

Table 3 show the results of the net pay thickness and porosity for each horizon of well V8.

Formation	Depth (ft)	Thickness (ft)	Porosity (%)
D_0	2950	19	0.253
D_1	2977	23	0.141
D_2	3019	46	0.144
D_3	3083	67	0.153

And by Arche's method Equation (2), we can estimate the average porosity of the well (V8) as following:

$$\emptyset_{avg} = \frac{\sum h * \emptyset}{\sum h} \qquad \emptyset_{v8} = \frac{(4.807 + 3.243 + 6.624 + 10.251)}{(19 + 23 + 46 + 67)} = 16.08\ \%$$

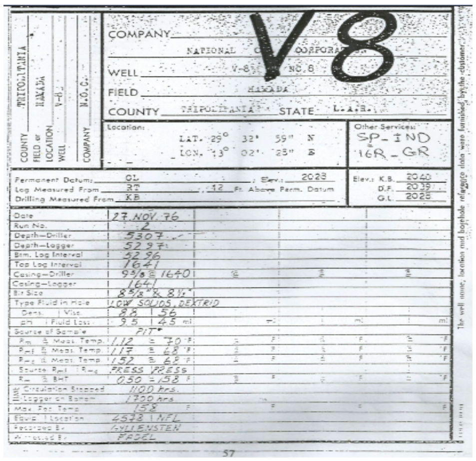
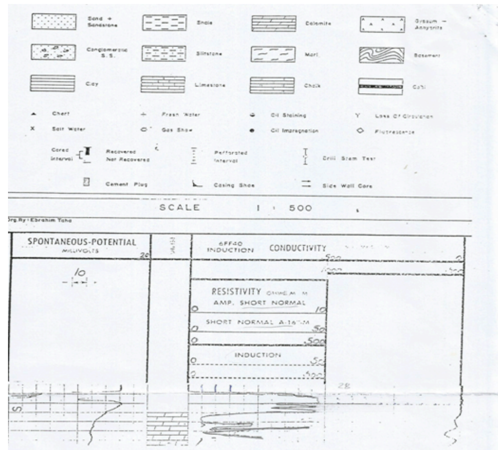
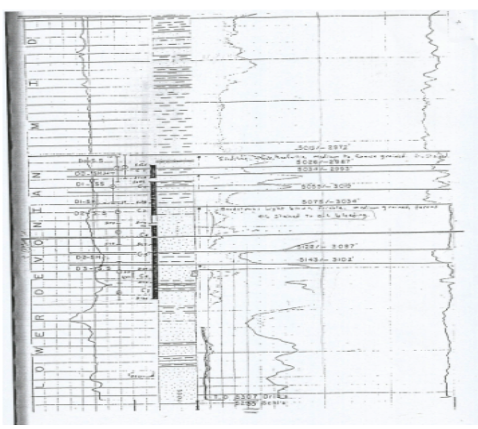
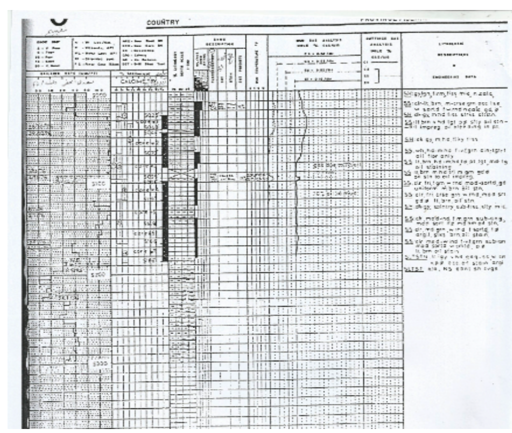



Figure 2 shows the well head logs of well V8

Figures 3 shows the SP & Electrical logs of well V8

In addition, when we applied this equation for all the wells in the reservoir, we will estimate the average porosity of the reservoir. Table 4 shows the calculation and results of the average reservoir porosity of V-NC6 area.

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Well	Layer	H net (Ft.)	Ø %	H* Ø
V2	D_0	11	0.132	1.452
	D_1	10	0.125	1.25
	D_2	16	0.147	2.352
	D_3	26	0.131	3.406

V4	D_0	14	0.15	2.1
	D_1	18	0.139	2.5
	D_2	32	0.15	4.8
	D_3	20	0.146	2.92
V6	D_0	0	0	0
	D_1	29	0.13	3.8
	D_2	16	0.123	1.9
	D_3	32	0.14	4.55
V7	D_0	0	0	0
	D_1	17	0.13	2.21
	D_2	29	0.154	4.54
	D_3	15	0.164	2.46
V9	D_0	10	0.253	2.53
	D_1	9	0.141	1.26
	D_2	51	0.144	7.344
	D_3	13	0.153	1.989
V13	D_0	0	0	0
	D_1	16	0.088	1.45
	D_2	18	0.142	2.55
	D_3	0	0	0
V14	D_0	3	0.144	0.432
	D_1	9	0.135	1.215
	D_2	29	0.133	3.79
	D_3	22	0.137	3.014
V15	D_0	0	0	0
	D_1	30	0.148	4.514
	D_2	0	0	0
	D_3	0	0	0
V18	D_0	12	0.152	1.748
	D_1	21	0.095	1.995
	D_2	0	0	0
	D_3	0	0	0
$\sum$		630		89.729

$\sum$ H * Ǿ = 89.729
$\sum$ H = 630.5

$$\emptyset_{avg} = \frac{89.729}{630.5} = 0.1423 \approx 14.23\,\%$$

The average reservoir porosity is 0.1423

4.3 Estimate the water saturation (Sw) from the well logging:

As example to estimate (Sw) from well logging we will estimate it from well V8:

Firstly we must find the value of (Rt) and (Rw)

-Rt from reading of the log =17.5 ohms mm

- Estimate of Rt

i- Rw with chart method at:

TD = 3250 ft , BHT =158 F, Tavg = 68 F & Rmf = 1.17 Ohm mm @ 68. The geothermal gradient = 2.769 F degree/ 100 feet.

The chart (4) has been used to estimate the formation temperature, Tf. From chart (4)

Tf=130 F

The chart (5) has been used to estimate the mud and mud filtrate resistivities.

From chart (5) Rmf@130 F = 0.6 Ohm mm

The chart (6) has been used to estimate the equivalent mud filtrate resistivity

From chart (6) Rmfeq= 0.375 Ohm mm

The chart (7) has been used to estimate the equivalent water resistivity.

From chart (7) and at SP = -70 milvolts (from log)

Rweq = 0.046 Ohm mm

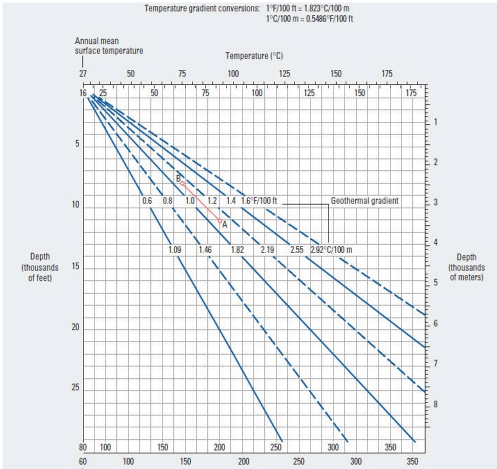
From chart (6) Rw =0.062 Ohm mm

ii- Rw with ARP'S equation at :

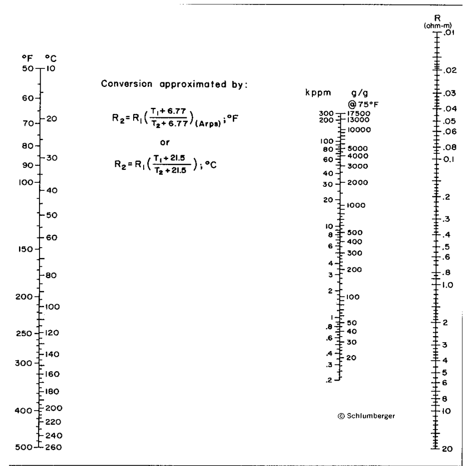
Tavg =68 F, BHT =158 F, Df = 2950 ft & Dt = 3250 ft

R1 – 1.17 @68 F and SP= -70 milvolts (from log) and T2=149.7°F

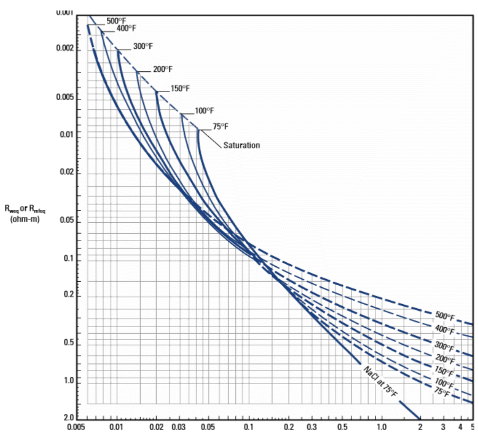
R2 (New Rmf); R2=0.5591 Ohm mm, thus (New Rmf) R2>0.1



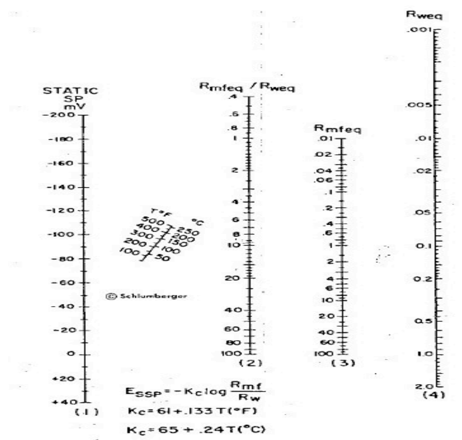
The chart (4) estimation of formation temperature, Tf.



The chart (5) to estimate the Rmf & Rweq.



The chart (6) to estimate the Rm & Rw.



The chart (7) to estimate the Rmfeq.

iii- Rmfeq= 0.4752 Ohm mm

iv- Constant (K) = 79.91

Rw =-0.58+0.7158=0.131 Ohm mm

Convert the Rw to Rw @Tf ; Rw= 0.0626 Ohm mm

vii- To find Ro =F * Rw

For sand stone formation and Ø is average porosity of well V8

F = 31.54, thus Ro = 1.97447 Ohm mm

Sw v8 = 0.33532 = 33.5%

And by applied the Arch,s equation for all the wells in the reservoir, we will estimate the average water saturation of it. Table 5 shows the application of Arch's equation for all wells on V-NC6 area.

Table 5 shows the application of Arch's equation for all wells on V-NC6 area.

Well	Layer	H net (Ft.)	Ǿ %	Sw %	H* Ǿ*Sw
V2	D_0	11	0.132	0.201	0.2918
	D_1	10	0.125	0.208	0.26
	D_2	16	0.147	0.279	0.656
	D_3	26	0.131	0.303	1.032
V4	D_0	14	0.15	0.19	0.399
	D_1	18	0.139	0.228	0.57
	D_2	32	0.15	0.193	0.94
	D_3	20	0.146	0.36	1.051
V6	D_0	0	0	0	0
	D_1	29	0.13	0.494	1.894
	D_2	16	0.123	0.596	1.172
	D_3	32	0.14	0.429	1.951
V7	D_0	0	0	0	0
	D_1	17	0.13	0.251	0.544
	D_2	29	0.154	0.372	0.168
	D_3	15	0.164	0.377	0.927
V9	D_0	10	0.253	0.399	1.009
	D_1	9	0.141	0.474	0.601
	D_2	51	0.144	0.303	2.225
	D_3	13	0.153	0.299	0.594
V13	D_0	0	0	0	0
	D_1	16	0.088	0.371	0.538
	D_2	18	0.142	0.278	0.710
	D_3	0	0	0	0
V14	D_0	3	0.144	0.614	0.2652
	D_1	9	0.135	0.188	0.22842
	D_2	29	0.133	0.274	1.038
	D_3	22	0.137	0.381	1.1483
V15	D_0	0	0	0	0
	D_1	30	0.148	0.238	1.0743
	D_2	0	0	0	0
	D_3	0	0	0	0
V18	D_0	12	0.152	0.409	0.7149

	D_1	21	0.095	1.097	1.09725
	D_2	0	0	0	0
	D_3	0	0	0	0
∑		630			26.93079

$\sum$ H * Ǿ = 89.729 & $\sum$ H * Ǿ * Sw = 26.93079

$$SW_{avg} = \frac{26.93097}{89.729} = 0.30013 \approx 30\ \%$$

4.4 Estimate the Original Oil in Place (OOIP) with Volumetric Equation:

ΔBV = 8336.3 acre ft., porosity of the reservoir = 0.142314 , average water saturation of the reservoir = 0.300137 and the oil formation volume factor (Boi) = 1.165

OOIP = 5.43924 * 10^6 STB

5 Conclusions and Recommendations

From drilling, testing and logging results, it is concluded that V8-NC6 well proved to be one of the best oil wells in Elhamada Alhamra oil field in the "V" structure. The gross thickness of the pay zone attains 154` while the net oil sands attains about 105`. On top of the pay zone "Lower Devonian Sandstone". The D_0 Sandstone was net at 2971` leveled with V6-NC6 well. The $D_2$ Sandstone was proved the thickness in the area since it attains 53` in the well V8 while its thickness is 40` in V6. It was decided to start production from $D_3$ sandstone at first through the perforated interval 5151`-5159` and left the other zones for future planning. It was recommended to drill a development well between the eastern and western culmination of the "V" structure I.e. between V7 and V8-NC6 wells to check the oil water contact in the D_2 sandstone unit.

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