Available online at www.elixirpublishers.com (Elixir International Journal)

Bio Diversity

Elixir Bio Diver. 46 (2012) 8152-8156

ISSN: 2229-712X

Integrated data approach to the determination of hydrocarbon saturation

Molua O.Collins
Physics Department, college of Education, Agbor Delta state Nigeria.

ARTICLE INFO

Article history:
Received: 23 February 2012;
Received in revised form:
15 April 2012;
Accepted: 30 April 2012;

Keywords
Molco model,
Hydrocarbon, Saturation,
porosity,
Permeability

ABSTRACT

The first stage of the study consists of defining rock types by relating Geological framework, lithofacies, petrology to porosity, permeability, and Water saturation. Rock types represent reservoir units with a distinct porosity -permeability relationship and a unique water saturation range for a given height above the free water level. We also describe the conventional methodology used to evaluate water saturation from sections of the electric log of a well. The second stage of the work involved the analysis of the cored samples of the well (SANDS D 2, E1-8).Which will lead to the determination of the water saturation of the well. The third stage of the work dealt with the integration of the core analysis result with formation evaluation data to define reservoir water saturation. By using a proposed water saturation model, known as the molco water saturation model. It was observed that the conventional Archie water saturation gave the water saturation for the well section as 74.26% while the model gave it as 41.6%, giving a consolidated difference of 33.20%. This result will contribute to the understanding of tight reservoirs and making an impact on reservoir development.

Introduction

In an integrated reservoir study, a multidisciplinary team of geophysicists, geologists, petrophysicists, and engineers works closely towards a common goal i.e. Better understanding of the reservoir and formation of an optimal reservoir development plan. In spite of modem technology advancements and the multidisciplinary team's efforts to integrate people, data, technology, and tools, many uncertainties still exist for various reasons. The objectives of this work are to quantify water saturation using the integrated reservoir studies, which will enable sound reservoir management decisions at different stages of reservoir development.(Molua and Ujuanbi,2005) Traditionally, reservoir studies were not integrated. Each discipline worked on its own specialty separately; projects often followed a linear approach: geophysics, geology, and then reservoir engineering. People did not realize the interdependency of other groups' results, even though they were working for a mutual objective. Sometimes geoscientists and engineers got different conclusions because they did not communicate effectively. Within the last two decades, the value of integrated reservoir studies has been recognized gradually. Different disciplines have realized that they depend on each other, and their goals can be accomplished with mutual support. Working as a team, they feel a sense of ownership for their jobs because they are committed to the goals they helped to establish. They work more effectively and efficiently as teams than as individuals, and thus their synergy realizes a whole greater than the sum of its parts.

With the recognition of the importance and advantages of integrated reservoir studies, people are employing them more and more. The members of a multidisciplinary team formed for integrated reservoir study meet periodically to discuss the problem and the progress, fix possible disagreements as early as possible, and solve the problem in a timely, efficient manner, avoiding the inconsistent results reached by different disciplines. In the process of integrated reservoir study, the team members usually learn as they become familiar with each other's expertise, which is definitely beneficial to the whole team and the project, and which is one purpose of integrated reservoir study. Usually, trust is established among the team members, and they can do a better job on the next project. Integrated reservoir study has been conducted for various purposes.(Juan Diego et al) conducted an integrated reservoir study of a carbonate reservoir developed with waterflooding. They developed a geological/petrophysical model, evaluated the past reservoir performance, predicted future performance for various operating plans, and made appropriate recommendations based upon technical and economic considerations. A large-scale integrated study was performed in the Bachaquero Intercampos field, Lake Maracaibo, Venezuela, with the aim of identifying new reserves and defining a new development plan. In early 2000, LUKOil and PetroAlliance completed one of the largest integrated reservoir studies in the western Siberian basin, which contains some of the largest oil fields in Russia and the former Soviet Union. They used state-of-the-art technology to create a new 3D geological model of Vatyogan's six major producing zones, which range in age from Upper Jurassic to Upper Cretaceous and cover a wide range of depositional environments. With the new model, they estimated reserves and prepared a drilling program in the undeveloped areas, identified areas of by-passed oil, and developed an optimal infill drilling and enhanced recovery program to improve production in the developed areas. Bouman et al, 2001. conducted an integrated reservoir study to solve the puzzle of the rapidly declining reservoir pressure in the Obaiyed Field. Cosentino et al, 2001. simulated the irregular water advance observed in part of the field as a consequence of peripheral water injection.

Theory

This method usually provides a more reliable value of Sw than the previous one (as the assumptions are less constricting).

Tele:
E-mail addresses: moluaogom@hotmail.com

However it is slightly more time consuming. The equation used is:

$S^2w = F \times \frac{Rw}{Rt}$

Where

F is formation of resistivity factor.

To use this in practice, we assume:

(1) R_{deep} $=R_L$ (negligible correction)

(2) Clean formation (shaliness < about 5%

(3) R_w constant

(4) Porosity = quick – look porosity

Knowing R_w, or estimated, we can solve the above equation by:

(1) Deriving Φ from quick – look

(2) Deriving F from chart

(3) $R_t = R_{deep}$

(4) Calculating S_w.

Once S_w is known, then hydrocarbon saturation (S_n) can be calculated using

$S_n = 1 – S_w$

But a new integrated data model is being introduced which is a combination data from logs and core analysis results " the MOLCO MODEL" (which is a combination of log parameters and core analysis data's). The main assumptions of this model are

1. = 90 (from log)
2. Ro m = 2 (cementation factor)
3. Ø = the median from core graphs (for regions where core boxes where not recovered)
4. c = Molco constant= 2 = minimum grain density from core analysis.

The Molco model is written as

$$S_w = C\left[\frac{\Phi^m R_0}{DXR_t} XK^{-z}\right]^{\frac{1}{2}} X\Delta L$$

Methodology

Archie water saturation equation (Archie, 1942) is used to compute an initial value of of water saturation. This initial water saturation is progressively adjusted using the modified Archie water saturation equation (The MOLCO MODEL) until an acceptable match is obtained which provided a reduction in water saturation this technique embodies a novel procedure to estimate in-situ water saturation that is consistent with the length of investigation and vertical resolution of electric logs.

Stratigraphy And Geology Of Studied Area

The Niger Delta occur at the southern end of Nigeria bordering the Atlantic ocean and extends from about longitude 3o.9 E and latitude 4o.30' – 5o.20'N. The proto delta developed in the northern part of the basin during the capanian transgression and ended with the poleocene transgression.

It has been suggested that the formation of the modern delta basin which enhanced and controlled the development of the present day Niger delta, developed by rift faulting during the Precambrian . Sedimentological and funal data suggest that the modern Niger delta has a configuration similar to that of the past.(Kogbe et al, 1975)

Short lengths were taken of $R_{(deep)}$ in the hydrocarbon bearing interval in order that R_t could be read off the logarithmic scale e.g. in sand G_1 interval 8728-8732 Ft of length 4 was read off as 400 approximately. Same was done for all the lengths of sand intervals of, From which the ratio I was calculated and obtained for all the interval lengths. From table $I^{1/2} = S_w$. Consequently, S_w was calculated for all the chosen lengths of the sand intervals.

For sand G_1, $\Sigma\Delta L. S_w = 16.1566$

For sand G_2 $\Sigma\Delta L. S_w = 1.8932$

The average water saturation S_w (ave) for each sand is

Sand G_1, $S_w(ave) = \Sigma\Delta L . S_w / \Sigma\Delta L = 16.1566/30 = 0.5386$

Sand G_2 , $S_w (ave) = \Sigma\Delta L. S_w / \Sigma\Delta L = 1.8932/02 = 0.9466$

Consequently, the hydrocarbon saturation can be estimated from the above values using $S_{h =}$ (1- S_w) where S_h is the hydrocarbon saturation.

The total average water saturation ($S_{w[t]}$) for the two sand zones of well section G is $S_{w[t]}$ = 0.5386 + 0.9466/2 =1.4852/2 =0.7426

Therefore $Sh_{=}$ (1- S_w) = 1-0.7426 = 0.25

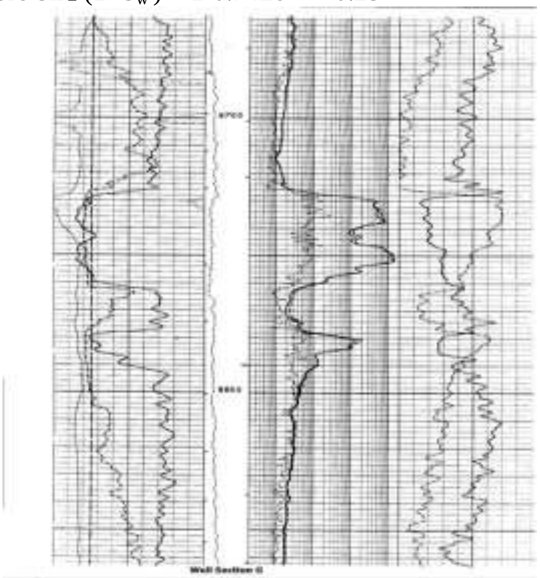

Fig 1: Data Analysis Of Well Section G Using Molco Model

By inspection the well section G has two sand intervals and has been interpreted below using the MOLCO MODEL (which is a combination of log parameters and core analysis data's). The main assumptions of this model are

5. Ro = 90 (from log)
6. m = 2 (cementation factor)
7. Ø = the median from core graphs (for regions where core boxes where not recovered)
8. c = Molco constant= 2 = minimum grain density from core analysis.

The Molco model is written as

$$S_w = C\left[\frac{\Phi^m R_0}{DXR_t} XK^{-z}\right]^{\frac{1}{2}} X\Delta L$$

1. Where R_o = 90 (from log)
2. m = 2 (cementation factor)
3. Ø = Porosity (Horizontal)
4. c = Molco constant= 2 = minimum grain density from core analysis
5. R_t = true resistivity from log
6. K = Permeability from core
7. Z = Lorenze coefficient
8. D = Dykstra-parsons variations

Data Analysis For Well Section G

Well G is of sand interval 8728-8782 ft of well. The values of Ø, Z, K and D where obtained from core analysis and using the model ie

$$S_w = C\left[\frac{\Phi^m R_0}{DXR_t} XK^{-z}\right]^{\frac{1}{2}} X\Delta L$$

E.g. for sand interval 8728-8732 ft of well section G, the model interpretation is as follows:

$$S_w = 2\left[\frac{0.322^2 x90}{0.387X400} X3280^{-0.383}\right]^{\frac{1}{2}} X2$$

$$S_w = 4\left[\frac{9.33156}{154.8} X \frac{1}{22.212}\right]^{\frac{1}{2}}$$

$$S_w = 4\left[\frac{9.33156}{3438.3544}\right]^{\frac{1}{2}} \otimes$$

$$S_w = 4[0.002713961]^{\frac{1}{2}}$$

$$S_w = 0.416$$

Same was done for all the sand intervals lengths of G_1 and G_2 to obtain S_w and the results are shown in Core/log petrophysical evaluation worksheet (Table 5)

Therefore the average water saturation for well section G is 0.408+0.437+0.446+0.247+0.6504+0.1533+0.1302+0.1354+0.2832+0.2006 Divide by 10

$S_{w(ave)} = 0.27911$

$S_h = 1 - S_{w(ave)} = 1 - 0.27911 = 0.7236$

Discussion of Results

It will be observed that the conventional Archie water saturation gave the water saturation for the well section of well as 74.26% while the model gave it as 41.6%, giving a consolidated difference of 33.20%.

With some well-documented exceptions sandstone reservoirs are water-wet; the water being held as a thin film around grains, and in greater volumes in collars at grain contacts and in pores bounded by smaller than usual throats. Minimum water saturations of producing sands are seldom less than 10%, and commonly fall in the range 15-40%. Small amounts of clay can greatly increase the amount of water held in the pores, and shaly sands can produce water-free oil when their water saturation is as high as 65%. Small-scale packing heterogeneities are probably the chief factor responsible for the levels of irreducible water saturation in clean sands.

The estimation procedure described above requires that relative permeability, Horizontal porosity, and Archie's parameters be known a priori. It is also required that mud properties, Lorenze coefficient and Dykstra-parsons variations, be known from core analysis.

Further, the estimation procedure assumes that relative permeability, Horizontal porosity data, along with fluid properties, are available from laboratory measurements of rock-core samples retrieved from a key cored well.

These parameters can be specific to a given flow unit but are assumed spatially constant within the hydrocarbon field under consideration. The availability of petrophysical and rock fluid properties in the key well, including permeability, provides a way to "calibrate" the invasion model and hence to refine the estimates of water saturation which will lead to the accurate determination of the hydrocarbon saturation of the well section.

Despite some technical difficulties, the attractive components of the estimation of water saturation based on the physics of core and log data: (a) the petrophysical model itself is consistent with the physics of multi-phase fluid flow displacement in the borehole region, (b) the estimated permeability honors all of the available measurements, and (c) the estimated water saturation is consistent with the length of investigation and vertical resolution of well logs and, therefore, provides an "up scaled" version of water saturation compared to that of the conventional method logging-while-drilling and openhole logs, to improve the accuracy and reliability of the calculated values of permeability. An automatic inversion procedure is also in order to perform the adjustments of water saturation with an efficient minimization method such as those used in the field of geophysical inverse theory. Further

Conceptual and algorithmic developments are needed to apply the estimation technique in wells drilled with an oil-based mud.

Conclusion

We have developed and successfully tested a new technique for the accurate, reliable and cost effective estimation of water saturation from well logs and Core data. The technique which involves the use of a new model, the MOLCO model, was tested on a well Log with the combination of its core analysis results. The well was cored along the sand deposits of interest and the corresponding rock-core data were used to calibrate the petrophysical invasion of the model. The model is therefore recommended for the petrophysical evaluation of tight reservoirs.

References

Archie G.E.1942. The electrical resistivity log as an aid in determining, some reservoir characteristics: petrol technical. vol. 5 no. 1

Diego, J., Lopez, Y., Ferreira, H. and Carnes, AC. 1998. "An Integrated Reservoir
Study to Improve Field Performance," paper SPE 39843 presented at the
SPE International Petroleum Conference and Exhibition, Villahermosa, Mexico 3 -5 March.

Bouman, L., Koopman, A and Ibrahim, N.S. 2001 "The Obaiyed Gas Recovery Project - A Fully Integrated Study," paper SPE 68182 presented at the 2001 SPE Middle East Oil Show, Bahrain, 17 - 20 March

Cosentino, L., Coury, Y., Daniel, J.M., Manceau, E., Ravenne, C. 2001. "Integrated Study of a Fractured Middle East Reservoir With Stratiform Super-K Intervals - Part 2: Upscaling and Dual Media Simulation," paper SPE 68184 presented at the SPE Middle East Oil Show, Bahrain, 17 - 20 March.

Kogbe C A, *Geology of Nigeria*. 1989. Rock view (Nig) Ltd, pp311-313

Molua, O.C, & Ujuanbi, O.2005. Log derived values of water saturation as it affects the producibility of a well, *Journ. Maths & Comp. Sci*. Vol 16 No 2, pp 185.

Results of field study

Data analysis for well section g

Table 1 : log petrophysical evaluation worksheet

Sand Name	Interval Length L	Δ L	LLD Rt	$R_w/\varphi^m R_t$	$I^{-1/2}$ (S_w)	Δ L. S_w
G_1	8728-8732	4	400	0.2240	0.4733	1.8932
	8732-8736	4	400	0.2240	0.4733	1.8932
	8736-8738	2	800	0.112	0.3347	0.6694
	8738-8740	2	300	0.2987	0.5465	1.093
	8740-8746	6	100	0.896	0.9466	5.6796
	8746-8748	2	800	0.112	0.3347	0.6694
	8748-8750	2	1050	0.0853	0.2921	0.5842
	8750-8752	2	1050	0.0853	0.2921	0.5842
	8752-8754	4	1000	0.0896	0.2993	1.1972
	8754-8756	2	100	0.896	0.9466	1.8932
G_2		εΔL=30				εΔL.Sw=16.1566
	8780-8782	2	100	0.896	0.9466	1.8932
		εΔL=02				εΔL.Sw=1.8932

Table 2: Core Analysis Results

SAMPLE NUMBER	DEPTH ft	PERMEABILITY		POROSITY (HELIUM) %	GRAIN DENSITY gm/cc	DESCRIPTION	GAMMA
		(HORIZONTAL) Kair md	(VERTICAL) Kair md				
365	8738.0 8738.5	2330.00		32.0	2.66	Sst,brn,f-m gr.lam.mica,mod cmt.	20.00 27.00
366	8739.0 8739.5	1080.00		31.2	2.65	Sst,brn,f-m gr.lam.mica,mod cmt.	21.00 27.00
367	8740.0 8740.5	2400.00	1500	33.1	2.64	Sst,brn,f-m gr.lam.mica,mod cmt,Frac-No ka.	20.00 16.00
368	8741.0 8741.5			28.9	2.64	Sst,brn,f gr.lam.mica,mod cmt.	15.00 19.00
369	8742.0 8742.5	4130.00		28.6	2.65	Sst,brn/gry,f gr.lam.carb,mica,mod cmt.	22.00 23.00
370	8743.0 8743.5	2940.00		28.2	2.65	Sst,brn,m gr.lam.mica,p cmt.	14.00 20.00
371	8744.0 8744.5	8030.00		31.6	2.65	Sst,brn,f-m gr,p cmt.	08.00 12.00
372	8745.0 8745.5	10270.00	5810.0	32.7	2.65	Sst,brn,f-m gr,p cmt.	24.00 28.00
373	8746.0 8746.5	5570.00		33.5	2.65	Sst,brn,f-m gr,mod cmt.	18.00 14.00
374	8747.0 8747.5	5730.00		30.7	2.65	Sst,brn,f-m gr,lam,mod cmt.	22.00 13.00
375	8748.0 8748.5	5030.00		33.5	2.63	Sst,brn,f-m gr.lam.mod cmt.	18.00 12.00
376	8749.0 8749.5	2750.00		30.7	2.67	Sst,brn,f-m gr.lam.mica,p cmt.	24.00 15.00
377	8750.0 8750.5	2150.00	490.0	32.6	2.64	Sst,brn,f gr.lam.mod cmt.	21.00 16.00
378	8751.0 8751.5	2610.00		31.7	2.65	Sst,brn/gry,f gr.lam.mica,mod cmt.	22.00 14.00

Table 3: Core Analysis Results

SAMPLE NUMBER	DEPTH ft	PERMEABILITY (HORIZONTAL) Kair md	PERMEABILITY (VERTICAL) Kair md	POROSITY (HELIUM) %	GRAIN DENSITY gm/cc	DESCRIPTION	GAMMA
379	8752.0 8752.5	3680.00		33.9	2.64	Sst,brn,f gr.lam.mica mod cmt.	22.00 30.00
380	8753.0 8753.5	3770.00		34.9	2.65	Sst,brn,f gr.lam.mica mod cmt.	16.00 20.00
381	8754.0 8754.5	21270.00		34.6	2.63	Sst,brn,f gr.lam.mica mod cmt.	10.00 16.00
382	8755.0 8755.5	4070.00	3020.0	34.4	2.65	Sst,brn,f gr.lam.mod cmt.	23.00 30.00
383	8756.0 8756.5	6.00		15.5	2.65	Sst,brn/gry,f gr.lam.carb w cmt.	35.00 37.00
384	8757.0 8757.5	3280.00		31.8	2.62	Sst,brn,f-m gr.lam.carb mod cmt.	47.00 52.00
385	8758.0 8758.5					SHALE-NO ANALYSIS	56.00 45.00
386	8759.0 8759.5					SHALE-NO ANALYSIS	32.00 28.00
CORE 2 E6.0/E7 SAND DEPTHS: 8760.00—8763.00 FEET							
387	8760.0 8760.5					SHALE-NO ANALYSIS	20.00 25.00
388	8761.0 8761.5					SHALE-NO ANALYSIS	37.00 46.00
389	8762.0 8762.5					SHALE-NO ANALYSIS	27.00 34.00

Two sand intervals exist, these are:
Sand G_1 (Intervals 08728-08756 Ft of well)
Sand G_2 (Intervals 8780-8782 Ft of well)

Sand Name	Interval Length L	Δ L	LLD Rt	ø	(S_w)	
G_1	8728-8732	4	400	0.322	0.408	K=3280md Z=0.383 D=0.387
	8732-8736	4	400	0.338	0.437	
	8736-8738	2	800	0.320	0.146	
	8738-8740	2	300	0.331	0.247	
	8740-8746	6	100	0.335	0.6504	
	8746-8748	2	800	0.335	0.1533	
	8748-8750	2	1050	0.326	0.1302	
	8750-8752	2	1050	0.339	0.1354	
	8752-8754	4	1000	0.346	0.2832	
	8754-8756	2	100	0.155	0.2006	
G_2						
	8780-8782	2	100	0.195	0.2488	K=260md Z=0.392 D=0.559