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EVALUATING RESERVOIR HYDRAULIC PROPERTIES USING GEOPHYSICAL WELL LOGGING IN (O) OIL FIELD, NC – 115, MURZUQ BASIN, LIBYA

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ABSTRACT

Production of oil and gas is usually accompanied by the production of water. This produced water consists of formation water, or flood water previously injected into the formation. As exploited reservoirs mature, the quantity of water produced increases. Consequently, the management of produced water requires a structured and integral approach of technologies and strategies.

To assist building strategies for enhancing oil production, two successful supplementary methods are in use at this time: water injection and steam injection. So, the need for hydraulic properties as well as petrophysical characteristics of the oil reservoir is a must for evaluating the locations of the injection system.

An attempt in this work is made to study hydraulic and petrophysical properties of Hawaz reservoir of the O-Oil Field located in south eastern part of the concession NC-115 of Murzuq Basin in Sharara Oil Field in south western of Libya. The approach uses geophysical well logs of five selected oil wells in the study area. These logs include, resistivity, gamma ray, sonic, neutron and density. With the aids of simple spreadsheets, reservoir properties such as porosity, hydraulic conductivity, transmissivity and storage coefficient were calculated.

KEYWORDS: Hydraulic Properties, Geophysical Well Logging, Murzuq Basin, Libya

INTRODUCTION

The oil industry has developed methods for supplementing the production of crude oil that can be obtained mostly by taking advantage of the natural reservoir energy. These supplementary methods, collectively known as enhanced oil recovery technology, can increase the recovery of crude oil, the recovery of crude oil has been increased to an overall average of 33 percent of the original oil. Two successful supplementary methods are in use at this time: water injection and steam injection.

In a completely developed oil field, the wells may be drilled anywhere from 60 to 600 m (200 to 2,000 ft) from one another, depending on the nature of the reservoir. If water is pumped into alternate wells in such a field, the pressure in the reservoir as a whole can be maintained or even increased. In this way the rate of production of the crude oil also can be increased; in addition, the water physically displaces the oil, thus increasing the recovery efficiency. In some reservoirs with a high degree of uniformity and little clay content, water flooding may increase the recovery efficiency to as much as 60 percent or more of the original oil in place.

Keys (1989) postulated that although geophysical logs have been used in the water well industry for years, the level of sophistication is usually not as high as that associated with petroleum industry. Accordingly, a decision was made to use geophysical well logs associated with the petroleum industry to provide information necessary to evaluate the potential of the drilled oil well to change to injection well of water for enhancing oil production.

PREVIOUS WORK

Geophysical well logging was first developed for the petroleum industry by Marcel and Conrad Schlumberger in 1927. In groundwater exploration and assessment, it is also central to the delineation of aquifers and producing zones. Tome and Mike (1996) stated that geophysical well logging in the groundwater industry was first described by Jones and Skibitzke (1956). While Keys and MacCary described the dominant logs in use in 1970s.

To the present time, very few work have been published on using geophysical well logging in groundwater exploration. Most of work carried out in this field dealt with evaluating porosity and permeability and quantifying quality, salinity of the aquifers. The recent work deals with Oil Wells showing intervals of water saturation.

MURZUQ BASIN STRATIGRAPHY

O oil Field is located in the south eastern part of the NC-115 of Murzuq Basin in Sharara oil field in south western of Libya (Figure 1), approximately 30 km west of Awbari Town. The stratigraphic column of Murzuq Basin comprises deposits that range from Cambrian to Quaternary; the maximum sedimentary thickness probably never exceeds 5000 m (16,400 ft.). The age, lithostratigraphic subdivision, bounding unconformities, and major tectonic events are controlling the Paleozoic sedimentary infill of the Murzuq Basin as shown in (Figure 2).

The Cambro-Ordovician section is laterally very extensive in North Africa. It extends into Algeria in the west and the Sirte basin to the east, and in both cases it is an important petroleum reservoir. The Early to Middle Cambrian Hasawnah formation underline Hawaz Formation has a continental origin, with the remaining Paleozoic section being predominantly marine with pri-glacial cycles in the Ordovician to Early Silurian (David Thomas, 2010).

Hawaz Formation of Ordovician age mainly consist of deltaic and shallow marine sequences. Again, sandstones dominate the sequence, although siltstone and mudstone also occur, and bioturbation is common.

The Hawaz Formation represents the onset of the first major Paleozoic Marine transgression in the area (Echikh and Sola, 2000). It consists of fine to medium grained, coarsening upward, well cemented, hard sandstone, with siltstone, mudstone and fine sandy interbeds (Aziz, 2000).

The Melaz Shuqran Formation immediately overlies the Hawaz Formation, consisting of varicolored, chloritic, thinly bedded shale and siltstones intercalated with fine – grained sandstone.

Hawaz reservoir was delineated in the five selected wells for study depending on gamma ray logs. This delineation indicates top and bottom of the formation at 5000 and 5900 ft.

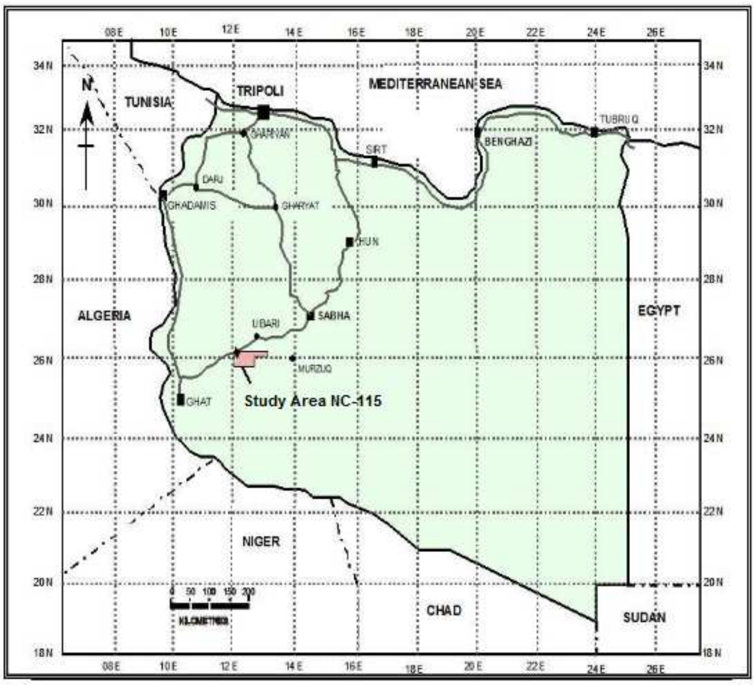

Figure 1: Location Map of the NC-115 Concession

METHODOLOGY

Drilling Information (Logs and Core data) of five wells selected (O1, O5, O8, O6i and O11) from all 13 wells drilled in Hawaz reservoir of the (O) oil field were gathered. Logs such as (resistivity, gamma ray, sonic, neutron and density) and core data (porosity and permeability) were used in this study. Core data used to assist evaluation of porosity and permeability since these two properties represent the more effective parameters on which a decision of water injection can be made. Microsoft Excell was used for tabulating logs reading and calculating reservoir properties, such as petrophysical and hydraulic characteristics.

CALCULATION BACKGROUND

Porosity

Due to the importance of porosity and permeability among petrophysical and hydrological subjects, these two parameters calculated first as they assist evaluating other reservoir characteristics. To determine these two parameters from geophysical well logs, numerous methods constructed utilizing sonic log, density log, and neutron log.

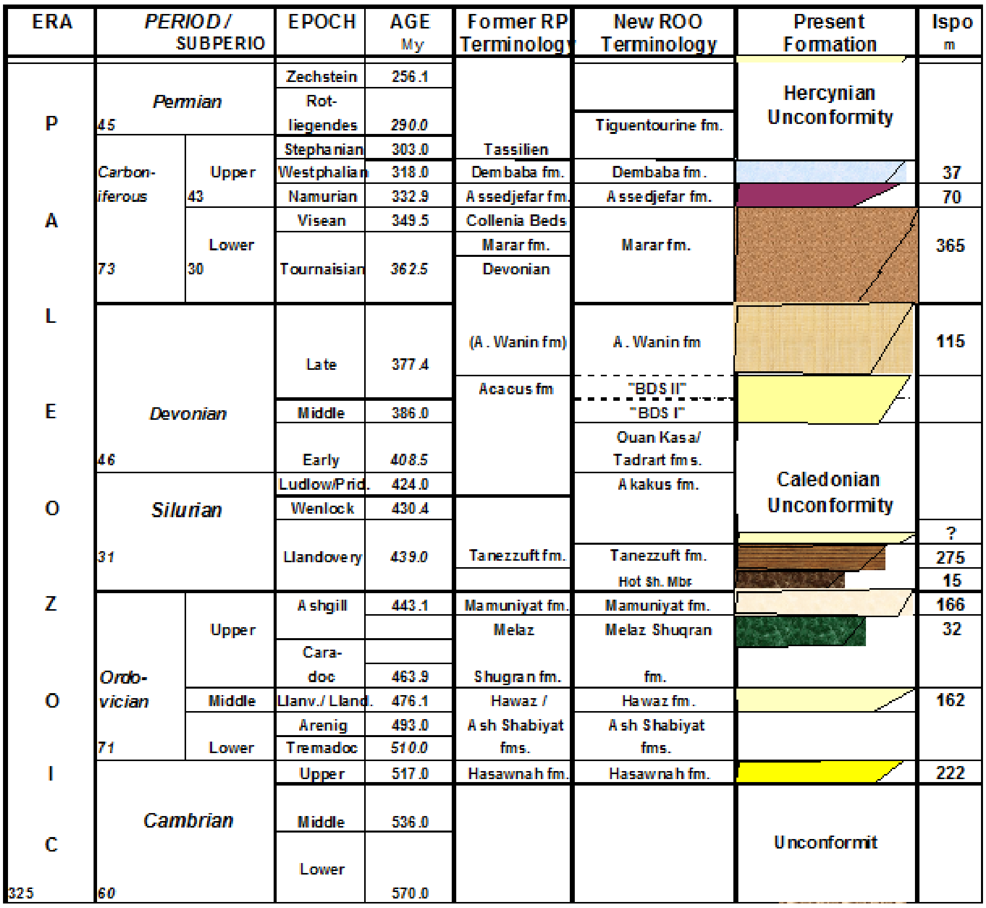

Figure 2: Stratigraphic Columnar Section of Murzuq Basin (Remsa Oil Company, 1985)

It is known that velocity of sound travels through sedimentary rocks is a function of the matrix material and porosity. So, as porosity increase, the travel time of the sound wave through the rock increases. Considering this phenomena, measuring sonic velocity of a formation is used to calculate porosity using Wyllie-Average Equation (Wyllie et al., 1958).

$$\text{Ø} = \frac{(tlog - tma)}{(tf - tma)} \tag{1}$$

Where:

t_{log} = the value from the sonic log (µs/ft), t_{ma} = the transit time of the matrix material(µs/ft).

t_f = the transit time of the fluid in the pores (185 µs/ft for fresh water).

The values yield from equation (1) do not need correction because the sandstones of study formation are compacted (Schlumberger, 1989), the only evaluation done is that calculated porosity for the five wells were compared with that measured from another source such as a core (Table, 1).

By taking the density of a rock with zero percent porosity and comparing it to the values from the density log. The porosity can be determined with the following equation:

$$\text{Ø}= \frac{(\rho ma - \rho b)}{(\rho ma - \rho f)} \quad (2)$$

Where:

ρ_{ma}= density of the matrix (g/cc), ρ_b= bulk density from the log (g/cc).

ρ_f = density of the fluid in the formation (g/cc).

Density values are affected by the presence of clays in the formation. They become either higher or lower depending on the mineralogy of clays and the degree of their compaction. To solve equation (2) to determine porosity values, sandstone matrix set to 2.65 g/cc and fluid density to 1.1 g/cc. An evaluation of different methods to derive porosity values was done by Schlumberger (1989), result that cross plotting density log versus neutron log is the accepted method. Since porosity value determined by equation (2) is close to effective porosity value derived from core analysis, the approach given by Tom and Mike (1996) to calculate effective porosity using spreadsheet is followed through equation (3)

$$\text{Ø}_{eff} = \frac{D_{\text{Ø}} + N_{\text{Ø}}}{2} + \left(\frac{(D_{\text{Ø}})^2 + (N_{\text{Ø}})^2}{2}\right)^{0.5} \quad (3)$$

Where:

DØ= the density porosity derived from the log (fr), NØ= the neutron porosity derived from the log (fr.).

All values of porosity calculated from logs are compared with those measured from cores (Table, 1) showed an agreement over the interested zone of Hawaz reservoir in the five selected wells.

Permeability

Many equations exist to calculate permeability values from geophysical well logging (Tixier, 1949; Timur, 1968 and Coats and Dumanoir, 1973), all of these methods require the knowledge of irreducible water saturation and assume that moveable oil is flushed out and that there are some residual hydrocarbons present (Tome and Mike, 1996). Although, there are many attempts and trials to determine permeability values from logs, it is still difficult to justice the values obtained from geophysical logs.

According to Archie (1950) and Bredehoeft (1964), constructing a relation between porosity and permeability might give better way to evaluate permeability. So, using the cores data given in table (1), an equation was generated that allowed permeability to be estimated from porosity. The cross plot of porosity and permeability (Figure 3) generate the equation that had a correlation coefficient equal to 0.63. The equation obtained from this relation is:

$$\mathbf{K = 0.0002 \exp (67.112 \times \text{Ø})} \quad \mathbf{(4)}$$

Where is:

K: Permeability (md), Ø: Porosity (fracture).

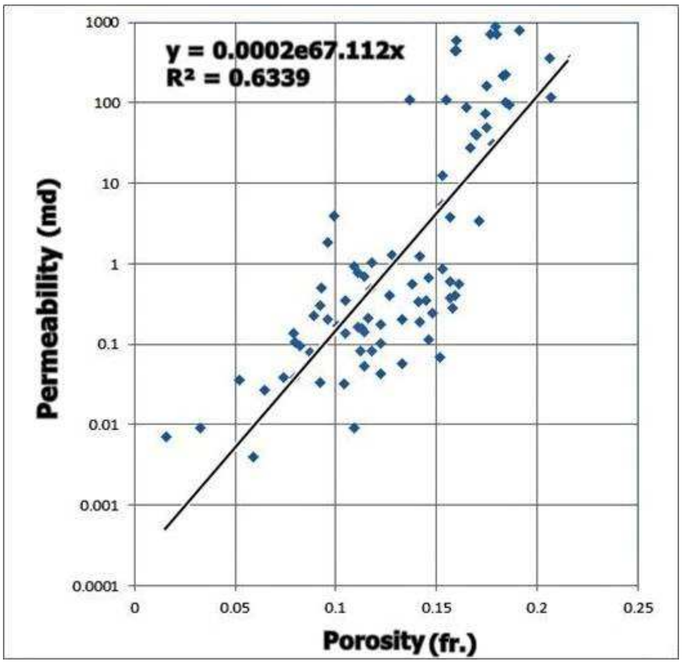

Figure 3: Relationship of Core Porosity versus Core Permeability

After knowing the permeability of the formation (intrinsic permeability) hydraulic conductivity can be determined using Bear (1979) equation. All values obtained for the five selected wells are shown in table (2).

$$\mathbf{K} = \boldsymbol{k}\left(\frac{\rho\, g}{\mu}\right) \quad \mathbf{(5)}$$

Where:

μ = the dynamic viscosity of the fluid (g/s.cm), ρ = the density of the fluid (gm/cc).

k = the permeability derived from the logs or core data (mD).

Transmissivity (T)

Transmissivity is the product of the average hydraulic conductivity K and the saturated thickness of the formation (D). Consequently, transmissivity is the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the whole saturated thickness of the formation. This parameter was calculated for all the intervals of interest of Hawaz Formation (Table 2).

$$\mathbf{T = K \times D} \quad \mathbf{(6)}$$

Where:

K = Hydraulic conductivity (ft/d), D = Thickness of the aquifer (ft).

Table 1: Measured Cored Porosity and Permeability, and Calculated Porosity from Logs of the Interval of Interest in the Five Wells

Well 01

Depth	Kcore(md)	Øcore(fr.)	Log Ø(fr.)
5265.0	0.069	0.103	0.105
5267.0	0.018	0.056	0.092
5268.1	0.008	0.033	0.102
5269.0	0.011	0.114	0.121
5269.5	0.347	0.111	0.139

Well 05

Depth	Kcore(md)	Øcore(fr.)	LogØ(fr.)
5224.0	10.374	0.17	0.131
5225.0	1.272	0.12	0.085
5226.0	11.657	0.146	0.087
5227.0	1.047	0.13	0.129
5228.0	0.103	0.079	0.227

Well 06i

Depth	Kcore(md)	Øcore(fr.)	LogØ(fr.)
5529.0	370.013	0.20	0.152
5530.0	504.321	0.198	0.149
5533.0	43.693	0.155	0.125
5534.0	71.649	0.14	0.145
5535.0	7.003	0.99	0.152

Well 08

Depth	Kcore(md)	Øcore(fr.)	LogØ(fr.)
5395	439.358	0.139	0.193
5395.5	794.278	o.165	0.217
5396.5	554.411	0.133	0.259
5398	561.596	0.159	0.201
5399	394.872	0.148	0.180

Well 011

Depth	Kcore(md)	Øcore	Log Ø(fr.)
5464.0	0.047	0.081	0.169
5465.0	0.039	0.08	0.171
5466.0	206.404	0.148	0.136
5468.0	0.064	0.97	0.188

Storage Coefficient (S)

The storage coefficient of a saturated confined formation of thickness (D) is the volume of water released from storage per unit surface area of the aquifer per unit decline in the component of hydraulic head normal to that surface. In a vertical column of unit area extending through the confined formation, the storage coefficient equals the volume of water released from the aquifer when the piezometric surface drops over a unit distance.

Storage coefficient (S) is one of the important parameters used to describe hydraulic properties of the water saturated formation. Lohman (1972) equation is used in this work to calculate storage coefficient as:

$$S = Ø \times \gamma \times b \left(\frac{1}{E_w} + \frac{C}{Ø \times E_s}\right) \tag{7}$$

Where:

Ø = Porosity as a decimal fraction, γ = Specific weight per unit area(ft^{-1}).

E_w = Bulk modulus of elasticity of water ($3*10^5$ lb/in^2).

C = Dimensionless ratio. Equal to one in un-cemented formation matrix, and in cemented formations such as limestone, is equal to the porosity.

E_s = Bulk modulus of the rock forming the formation of interest in (lb/in^2).

Bulk Modulus (E_s)

A combination of density log, shear velocity and compressional velocity, were used to calculate Bulk modulus according to the equation given by Atlas Wireline (1985). These elastic modulus parameters were evaluated with aid of sonic log.

$$E_s = \rho \times \left(\frac{(3 \times \Delta t_s^2) - (4 \times \Delta t_c^2)}{(\Delta t_s^2 * \Delta t_c^2)}\right) \times (1.34 \times 10^{10}) \tag{8}$$

Where:

Δts = shear velocity of the formation(s/ft), Δtc = compressional velocity of the formation(s/ft)

Compressional Velocity (Vp)

The Compressional velocity is known as the primary waves and move in the direction of wave propagation. It is calculated by taking the inversion of the Compressional travel time wave.

$$\mathbf{Vp} = \frac{1}{\Delta tc} \tag{9}$$

Where:

Vp = Compressional velocity (km/s), Δts = sonic log (s/km)

Shear Velocity (Vs)

Shear velocity is known as the short wave or secondary wave. Its movement is perpendicular to the direction of spread and more slower than compressional wave. Shear wave velocity can be calculated using equation (10).

$$\mathbf{Vs} = \frac{(Vp - 1.36)}{\Delta t1.16} \tag{10}$$

Where:

Vs = Shear velocity (km/s), Vp = Compressional velocity (km/s)

RESULTS AND DISCUSSIONS

Basic knowledge of the rocks under examination is needed to interpret geophysical logs. Basic lithology is determined from gamma ray or from SP log or from combination with sample description. Since permeability is a function of porosity, these two parameters are evaluated over the interest zone of Hawaz formation leading to construct the relation from which an intrinsic permeability can be read and use.

After calculating permeability the zones of interest (saturated with water) were classified accordingly into six zones in well no. 01 and 06i, five zones in well no. 05, four zones in well no. 011 and three zones in well no. 08 (Table, 2). The classification depends on the variation of permeability values along the depth in each well. Other parameters mentioned previously were followed in reading, the classification set and read into a spreadsheet including the previously mentioned equations. Then calculation were executed by the spreadsheet for effective porosity, permeability, hydraulic conductivity, transmissivity, bulk modulus, and storage coefficient (Table, 2).

Results obtained for the five examined wells indicate that in each well there is permeable zone good enough to select for potential screen zone and/or for water injection processes.

Through evaluation, the calculated hydraulic parameters of the best area or well can be suggested for executing water flood or injection. In addition, these characteristics can be used in designing mathematical model to assist making decision for the best place aids enhancing oil production.

CONCLUSIONS

Geophysical well techniques usually used to evaluate aquifer potential. By transferring the attempt to evaluate hydraulic properties of oil reservoir rocks, managing enhancing oil production can be done with ease and with less cost.

Collecting all data in excel spreadsheet to determine values of porosity, permeability, hydraulic conductivity, transmissivity, and storage coefficient, is to faster decision making process. It is worth to mention that using the relation between porosity and permeability from core data is particular to Hawaz formation of the O oil field.

The evaluated parameters can be used to select screen zone in case of drilling a new water well and in case of selecting an old oil producing well for water injection. So, the integration of the evaluated hydraulic parameters, provides geologist and engineers with necessary information to make proper decisions about enhancing oil production in an oil field and /or developing aquifers for the same reasons.

Table 2: Calculated Hydraulic Parameters of the Interest Interval Depths of Hawaz Formation in the Five Wells Selected for the Study

Well 01

Units	Depth	K (ft/d)	T (ft^2/d)	S	Ø (fr.)
1	5151 -5156.5	0.062	0.064	$1.27*10^{-7}$	0.172
2	5265- 5267.5	0.007	0.019	$1.69*10^{-7}$	0.120
3	5611.5-5613	0.048	0.098	$1.22*10^{-7}$	0.168
4	5615.5-5618.5	0.015	0.052	$1.13*10^{-7}$	0.143
5	5623.5-5625.5	0.062	0.156	$1.25*10^{-7}$	0.172
6	5650.5-5656	0.318	1.908	$1.34*10^{-7}$	0.185

Table 2

Well 05

Units	Depth	K (ft/d)	T (ft^2/d)	S	Ø (fr.)
1	5224-5228	0.279	1.258	$1.12*10^{-7}$	0.126
2	5502.5-5504.5	0.025	0.063	$1.14*10^{-7}$	0.158
3	5559.5- 5561.5	0.010	0.022	$1.51*10^{-7}$	0.131
4	5562.5-5587.5	0.011	0.286	$1.01*10^{-7}$	0.139
5	5589- 5609	0.029	0.583	$1.01*10^{-7}$	0.140

Well 06i

Units	Depth	K (ft/d)	T (ft^2/d)	S	Ø (fr.)
1	5529- 5530.5	0.012	0.023	$1.07*10^{-7}$	0.148
2	5532.5-5534	0.004	0.008	$1.55*10^{-7}$	0.131
3	5535-5537	0.044	0.112	$1.19*10^{-7}$	0.164
4	5542-5547.5	0.011	0.057	$1.04*10^{-7}$	0.143
5	5549-5561.5	0.010	0.129	$1.03*10^{-7}$	0.141
6	5565.5-5574.5	0.016	0.153	$1.07*10^{-7}$	0.147

Well 08

Units	Depth	K (ft/d)	T (ft^2/d)	S	Ø (fr.)
1	5395-5396.5	7.99	15.98	$1.66*10^{-7}$	0.229
2	5579.5-5586.5	0.19	0.29	$1.36*10^{-7}$	0.187
3	5606.5- 5608.5	0.83	2.09	$1.53*10^{-7}$	0.212

Well 011

Units	Depth	K (ft/d)	T (ft^2/d)	S	Ø (fr.)
1	5140.5- 5149	0.082	0.122	$1.01*10^{-7}$	0.13
2	5163- 5171.5	0.016	0.153	$1.05*10^{-7}$	0.14
3	5253- 5262	0.004	0.006	$1.47*10^{-7}$	0.13
4	5532.5- 5541.5	0.036	0.323	$1.14*10^{-7}$	0.15

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REFERENCES

1. Archie, G. E. (1950). Introduction to petrophysical of reservoir rocks. AAPG Bulletin v. 34, pp. 943-961.
2. Atlas Wireline Services, (1985). Log Interpretation Chart, Western Atlas International, Houston, 203 pp.
3. Aziz, A. (2000). Stratigraphy and hydrocarbon potential of the Lower Palaeozoic succession of License NC-115, Murzuq Basin, SW Libya. In: M. A. Sola and D. Worsley (Eds), Geological Exploration in Murzuq Basin, Elsevier Science, Amsterdam, pp. 349-368.
4. Bear, J. (1979). Hydraulic of Ground Water, McGraw-hill, New York. 569pp.

5. Bredehoeft, J. D. (1964). Variation of permeability in the Tensleep Sandstone in the Bighorn Basin, Wyoming, as interpreted from core analyses and geophysical logs. U. S. Geological Survey Professional Paper 501-D, pp. D166-D170

6. Coats, G. R. and J. L. Dumanoir, (1973). A new approach to improve log derived permeability. SPWLA. Transactions 14th Annual Logging Symposium. P. 77

7. David Thomas, (2010). Libya Basins-1 geology, Murzuq oil development could boost S. W. Libya prospects, Penn Well Corporation, 1455 West Loop South Houston, Texas 77027 (713) 621-9720.

8. Echikh and Sola, (2004). Geology and Hydrocarbon Occurrences in Murzuq Basin : In Geological Exploration of Murzuq Basin (Ed By M. A. Sola and D. Worsely) Elsevier. Amsterdam pp 175_221Exploration in Murzuq Basin. Elsevier, Amsterdam, pp. 95–320.

9. Jones, P. H. and Skibitszke H. E. (1956). Subsurface geophysical methods in ground water hydrology, in: Landsburg, H, E, ed.

10. Keys, W. S. and Maccary L. M., (1971). Application of borehole geophysical to water resources investigation. bk, 2, 126 pp.

11. Keys, W. S. (1989). Borehole Geophysics Applied to Ground-Water Investigation. National Water Well Association., Dublin, OH. 313pp.

12. Lohman, S. W. (1972). Ground- water hydraulics, U, S, Geologic survey Professional Paper 708, 70p.

13. Remsa Oil Company, (1985). Comparison of Stratigraphic Schemes - Murzuq Basin, Exploration Department. Acacus oil Company.

14. Schlumberger (1989). Log interpretations Principles/Applications. Schlumberger Educational Services Inc., Houston.

15. Timur, A. (1968). An Investigation of permeability, porosity and residual water saturation relationships. Transactions SPWLA 9th Logging Symposium, and The Log Analyst. 1968, V. 9, no. 4, p.8

16. Tixier, M. A. (1949). Evaluation of permeability from electric logs resistivity gradient. Oil and Gas Journal. June 16, pp. 113-122.

17. Tom J. Temples and Mike, G. Waddell, (1966). Application of petroleum geophysical well logging and sampling techniques for evaluation aquifer characteristics. Groundwater, vol. 34, No. 3

18. Wyllie, M. R. J., Gregory, A. R. and Gardner, L. W., (1985). An experimental investigation of factor affecting elastic wave velocities in porous media. Geophysics, 23, 459-493.