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The Relation Between the Shale Origin (Source or non Source) and its Type forAbu Roash Formation at Wadi El- Natrun Area, South of Western Desert, Egypt

M. Ghorab, Mohmed A.M. Ramadan and A.Z. Nouh

Egyptian Petroleum Research Institute, Cairo, Egypt.

Abstract: The area of study lies in the South of Western Desert of Egypt where the six wells (Birgat-1, Natrun Gibil A-1, West Halif-1, Fayad-1, T-56-1, and Zebeida wells) selected to study Abu roash Formation at Wadi El Natrun area, south of western desert, Egypt. Clay minerals can be developed and altered during early and late diagenesis, as well as metamorphism. The main physical post-depositional process affecting the mud rocks is the compaction. Compaction in mud rocks expels water and reduces the thickness of the deposited sediment by a factor of up to 10%. When muds are deposited, they contain about 70% to 90% of water by volume. Dehydration of clays is accompanied by some changes in the clay mineralogy (Muller, 1967). Final compaction gives a mud rock with only small percent of water, which requires a much longer period of overburden pressure with elevated temperatures (Rieke and Chiligarion, 1974). There are three types of shale in the nature according to its grains shape, dispersed, structure, and laminated. In these study, what the relation between the shale organ (source and non source) and the type of shale where well logs data used and through cross plots relationship to study Abu Roash Formation which considers as a target for oil production and exploration.

Key words: Shale origin, Abu Roash formation, Western Desert, Wadi El-Natrun, Egypt

INTRODUCTION

The analysis of the stratigraphic sequence includes studying the source, reservoir and cap rocks. A petroleum source rock may be defined as a fine-grained sediment, that in its natural setting has generated and released enough hydrocarbons to form a commercial accumulation of oil or gas.

Mud rocks are the most abundant of all lithologies, constituting some 45% to 55 % of sedimentary rock sequences (Tucker, 1981). The main content of mud rocks are the clay minerals and silt-grade quartz. Since they are largely detrital, the clay mineralogy to a greater or lesser extent reflects the climate and geology of the source area (Millot, 1970).The presence of shale in any formation is considered as one of the serious problems in the determination of the formation porosities and the contained fluid saturations (Abu El-Ata and Ismail, 1984). It causes erroneous determinations for the different rock matrices. The most significant effect of shale in the formation is to reduce the resistivity contrast between oil, gas and water (Hilchie, 1978).

Abu Roash Formation is the middle part of the upper Cretaceous sequence mostly non-clastics where the Abu Roash Formation composed of calcareous rocks with argillaceous intercalation (Fig. 2). Within the study area, the Abu Roash Formation reaches (2288 ft.) as a miximum thickness in T 56-1 well and minimum thickness in Birigat-1 well (846 ft.).

The following methods were used to define the shale volumes in the current work:

Methods of Shale Determination:
Gamma-ray Method:

Gamma-ray log is one of the best tools used for identifying and determining the shale volume. The following equation is used to determine the Gamma-ray index (Dresser Atlas, 1983):

$$IGR = \frac{GR_{\log} - GR_{\min}}{GR_{\max} - GR_{\min}} \quad (1)$$

Corresponding Author: M. Ghorab, Egyptian Petroleum Research Institute, Cairo, Egypt.

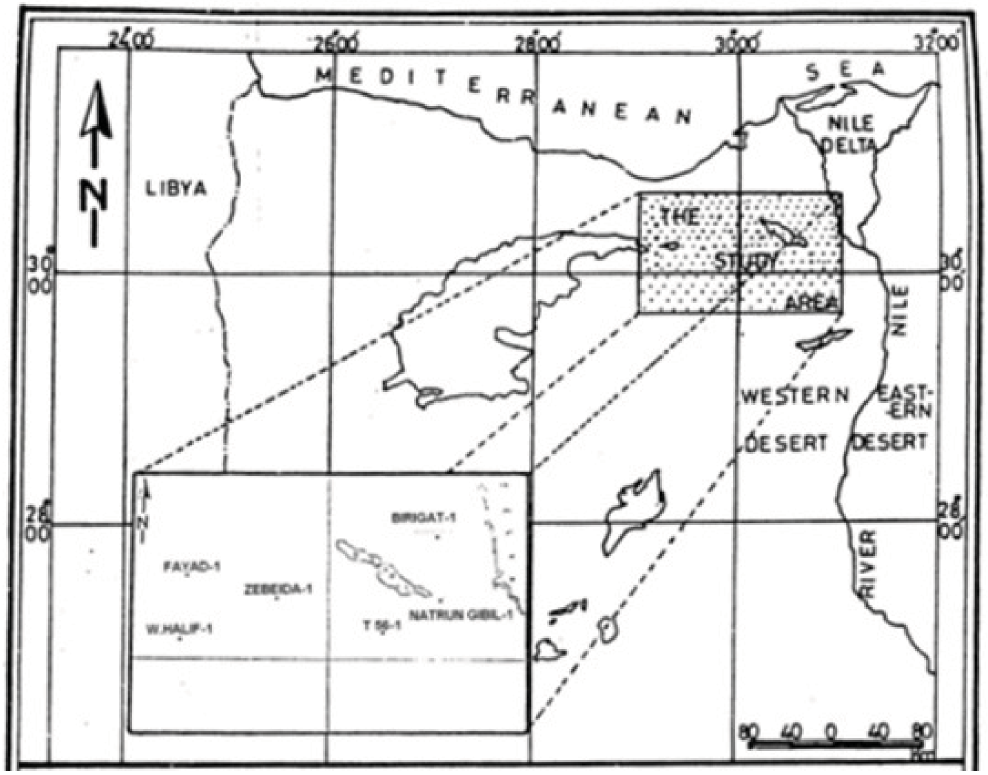

Fig. 1: LOCATION MAP OF THE STUDY.

where:

- IGR is the Gamma-ray index,
- GR_{log} is the Gamma-ray reading for each zone and
- GR_{min} and GR_{max} are the minimum Gamma-ray value (clean sand or carbonate) and the maximum Gamma-ray value (shale) respectively.

Then, the shale volume can be calculated from the Gamma-ray index, by the following formulae (Dresser Atlas, 1979):

Older Rocks (Paleozoic and Mesozoic), Consolidated:

$$V_{sh} = 0.33\ [2^{(2*IGR)} - 1.0] = \chi \qquad (2)$$

Younger Rocks (Tertiary), Unconsolidated:

$$V_{sh} = 0.083\ [2^{(3.7*IGR)} - 1.0] = \chi \qquad (3)$$

Accordingly, the first formula was applied for Abu Roash Formation in the present work.

Neutron Method:

It can be used for determining the shale volume in case of high clay content and low effective porosities, from the formula:

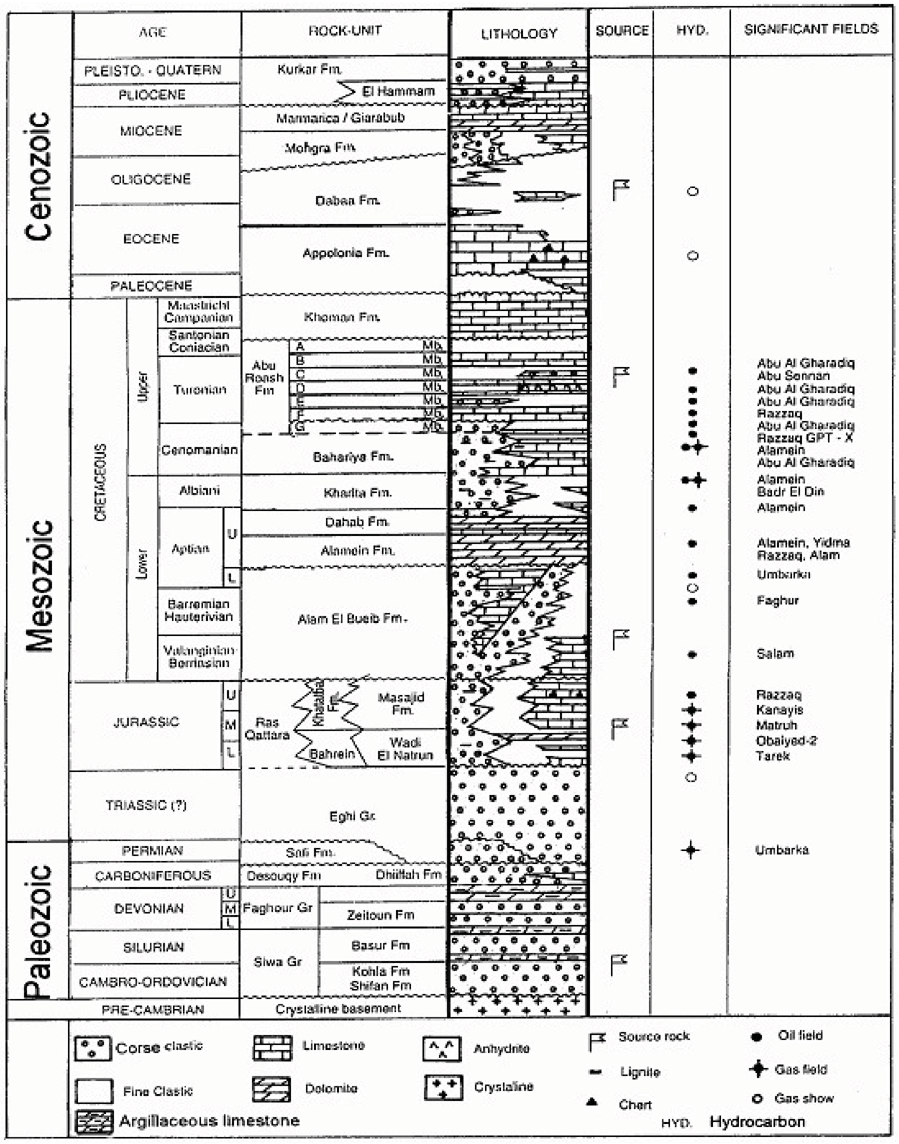

Fig. 2: Lithostratigrathic column of north western desert, comtilation of E.G.P.C. (1992) and schlumberger (1995).

$$V_{sh} \leq \frac{(\varphi_N)_{log}}{(\varphi_N)_{sh}} = \chi \qquad (4)$$

where:

- $(\varphi_N)_{log}$ is the neutron log reading for each studied zone and
- $(\varphi_N)_{sh}$ is the neutron log reading in front of a shale zone.

Resistivity Method:

It can be utilized to calculate the shale volume in case of high clay content and low (R_t) values, from the relation:

$$V_{sh} \leq \frac{R_{sh}}{R_{t\log}} \qquad (5)$$

If this ratio is more than (0.5) (i.e., 0.5 χ V_{sh} χ 1), then:

$$V_{sh} \leq (R_{sh} / R_t) = \chi \qquad (6)$$

If this ratio is less than (0.5) (i.e., V_{sh} χ 0.5), then:

$$V_{sh} \leq \left[\frac{R_{sh}}{R_{t\log}} - \frac{R_{cl} - R_{t\log}}{R_{cl} - R_{sh}} \right]^{1/B} = \chi \qquad (7)$$

where:

- R_{sh} is the resistivity log reading of a shale zone,
- R_{cl} is the resistivity log reading of a clay zone,
- $R_{t\ log}$ is the resistivity log reading for each zone and
- B is a constant, ranging in value between 1 and 2.

Correction of Shale Volume:

The values of (χ) obtained previously must be corrected by valid formulae to obtain the optimum shale values usable in the log interpretation. The first formula is:

$$V_{sh} = 1.7 - \sqrt{3.38 - (\chi + 0.7)^2} \qquad \text{(Clavier } et\ al., \text{ 1971)} \qquad (8)$$

The second formula is:

$$V_{sh} = \frac{0.5\,\chi}{1.5 - \chi} \qquad \text{(Steiber, 1973)} \qquad (9)$$

The usual approach for deciding which of the resulted shale volumes to use is to find the minimum values of the results. The minima have to be chosen, because most of the errors for any method tend to increase the apparent shale volume.

Then, the different zones were classified into clean, shaly and shale zones, depending on the following bases:

χ	If V_{sh} < 10 %	This means clean zone,
χ	If V_{sh} is from 10 to 35 %	This means shaly zone, and
χ	If V_{sh} > 35 %	This means shale zone.

Definition of Shale Types:

Since the Archie's water saturation equation, which relates the rock resistivity to water saturation, assumes that the formation water is the only electrically conductive material in the formation. Therefore, the presence of another conductive material (i.e., shale) requires either that, the Archie's equation must be modified to accommodate the existence of another conductive material or that, a new model should be developed to relate the rock resistivity to water saturation in shaly formations. The presence of clay complicates the definition or the concept of rock porosity. However, this porosity is not available as a potential reservoir for hydrocarbons. Thus, a shale or shaly formation may exhibits a high total porosity with a low effective porosity as a potential hydrocarbon reservoir.

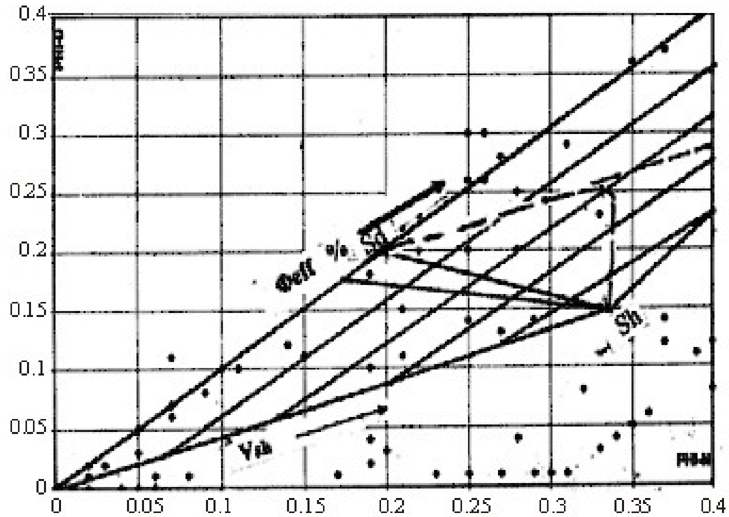

Fig. 3: THE RELATION BETWEEN PHI-N AND PHI-D FOR ABU ROASH FORMATION IN BRIGAT-1 WELL.

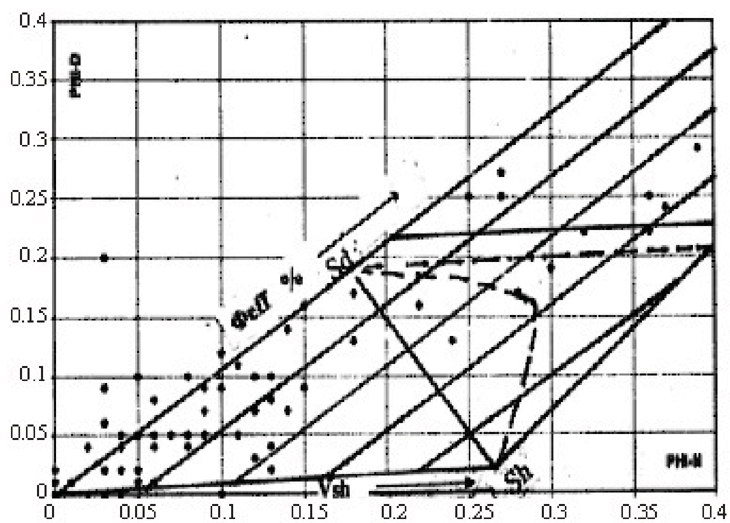

Fig. 4: THE RELATION BETWEEN PHI-N AND PHI-D FOR ABU ROASH FORMATION IN FAYAD-1 WELL.

The way of shaliness affect a log reading depends on the amount of shale and its physical properties. It also depends on the way of the shale distribution in the formation. Shaly materials can be distributed in the formation in three ways:

Laminated Shale:

Shale can exist in the form of lamina between layers of sand. The laminar shale does not affect the porosity or permeability of the sand streaks themselves. However, when the amount of laminar shale is increased and the amount of porous medium is correspondingly decreased, the overall average effective porosity is reduced in proportion.

Structural Shale:

Shale can exist as grains or nodules in the formation matrix. This matrix of shale is termed structural shale. It is usually considered to have properties similar to those of the laminar shale and near-by the massive shales.

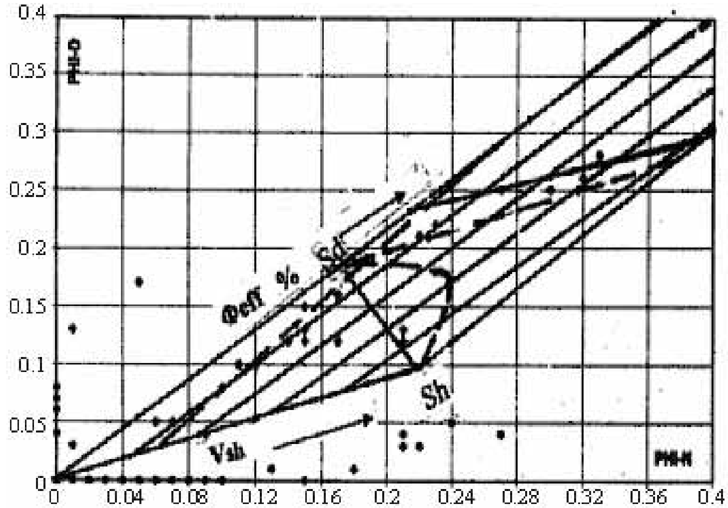

Fig. 5: THE RELATION BETWEEN PHI-N AND PHI-D FOR ABU ROASH FORMATION IN NATRTUN GABAL-1 WELL.

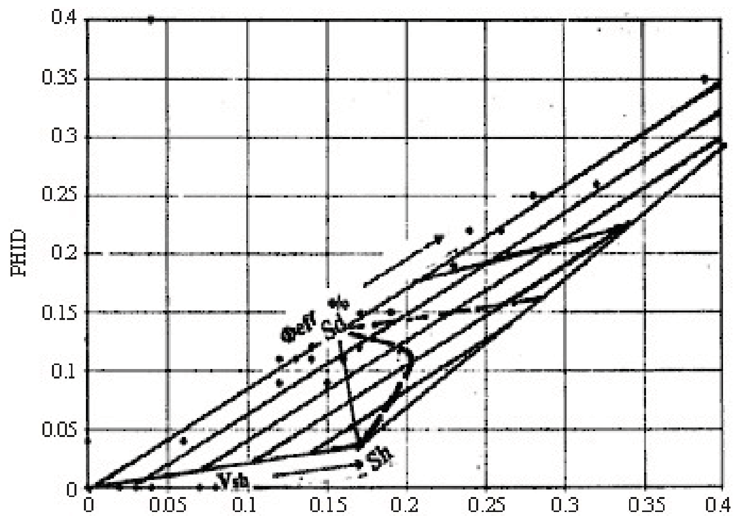

Fig. 6: THE RELATION BETWEEN PHI-N AND PHI-D FOR ABU ROASH FORMATION IN WEST HALAF N-1 WELL.

Dispersed Shale:

The shaly materials can be dispersed throughout the sand, partially if filling the inter-granular interstices. The dispersed shale may be in Laminated Shale, Structural Shale and Dispersed accumulations adhering to or coating the sand grains, or it may partially fill the smaller pore channels. Dispersed shale in the pores markedly reduces the permeability of the formation.

All these forms of shale can, of course, occur simultaneously in the same formation.

Construction of the Shale Model:

Dia-porosity crossplots is an important and specific graphical logging analysis technique for petrophysical evaluation. These plots depend on a variety of combinations between the porosity tool as (φ_N), (φ_D) and (φ_S). This is to determine the effective porosity (φ_e) as a measure for the productivity of hydrocarbons; the shale volume (V_{sh}) as a measure for the amount of matrix in the rocks; and the shale type, if it is laminar or dispersed or structural (Schlumberger Principles, 1972). The volume of dispersed shale is (V_D), while that of laminated shale is (V_L) and the structural shale is (V_S).

The laminated shale points will fall on the S_d - Sh_o line, while the dispersed shale will deviate the points to the left of the line, and the structural shale will deviate the points to the right of the line.

The volumes of the three shale types can be determined as follows:

The plotted point in the crossplot represents the point P_1, at which the values of j_1 and V_{sh1} can be determined, where:

$$V_{sh1} = V_D + V_L + V_S \quad (10)$$

The point P_1 is displaced from P_1 to P_2 parallel to the line D, until intersecting the S+L envelop. This means that, $V_D = 0$ and the remaining is structural and laminated shales. At P_2, the values of φ_2 and V_{sh2} can be determined, where:

$$V_{sh2} = V_S + V_L \quad (11)$$

The second displacement is done along a constant porosity line passing through P_2. The intersection of this line with the laminated shale line defines point P_3, through which the values of φ_3 and V_{sh3} can be determined, where:

$$V_{sh3} = V_L \quad (12)$$

From equations (11) and (12), the volume of structural shale can be defined as:

$$V_S = (V_S + V_L) - V_L = V_{sh2} - V_{sh3} \quad (13)$$

Also, from equations (12) and (13), the volume of dispersed shale can be estimated as:

$$V_D = V_{sh1} - V_{sh2} \quad (14)$$

Stratigraphic Sequence Analysis:

Sediments can be regarded as consisting of heavy and light fractions. The heavy fraction is the mineral materials and the light fraction is the formation fluids. In source rocks. which contain organic matter, there is also a part of the light fraction. During compaction, water is expelled, consequently the density increases and the sonic transit-time decreases. Because of the presence of organic material, source rocks retain a greater amount of the light fraction than the organic-lean sediments. Thus, appear on the sonic and density logs to be somewhat less compacted, giving rise to lower density and higher-transit time.

Moreover, the organic matter, like the mineral matrix. is normally electrically non-conductive. Therefore, the organic-rich sediments have a higher resistivity than the organic-lean sediments. Qualitative and quantitative conclusions for the organic content and the source rock implementations. This can be applied through the use of the density and sonic logs individually, as well as the density-resistivity and sonic transit time-resistivity combinations. The majority of petroleum accumulations are found in the clastic reservoir rocks, such as the sandstones and siltstones. The next important reservoir rocks are the carbonates, while the fractured shales, igneous and metamorphic rocks play only a minor role. The cap-rock, seal or barrier that stops the moving of hydrocarbons by virtue of its general decrease in pore diameter must exert capillary pressures greater than the driving force,

In this study, well logging analysis is utilized for determining the shale volumes and identifying the source rocks, as well as discriminating the source rocks from the non-source rocks.

Identification of Source Rocks on Wireline Logs:

The most complete and readily available well data are the wireline logs, that seem desirable to investigate the possibility of recognizing the source rocks for petroleum prospection, through the logs of gamma-ray, resistivity, density and sonic:

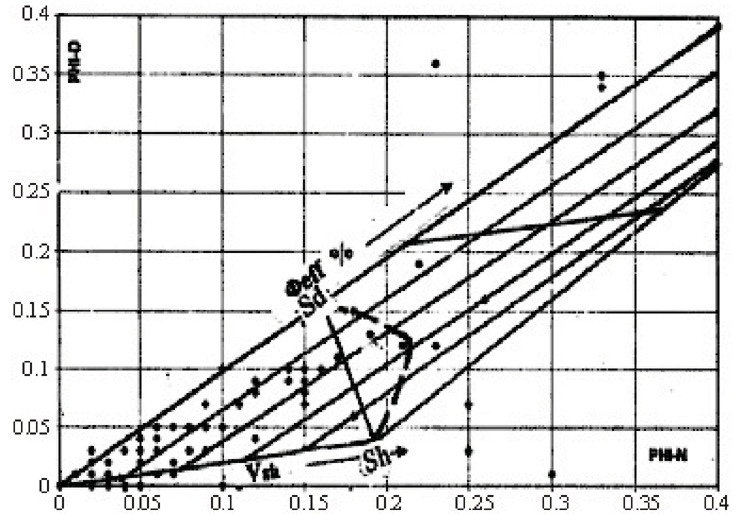

Fig. 7: THE RELATION BETWEEN PHI-N AND PHI-D FOR ABU ROASH FORMATION IN ZEBEIDA-1X WELL.

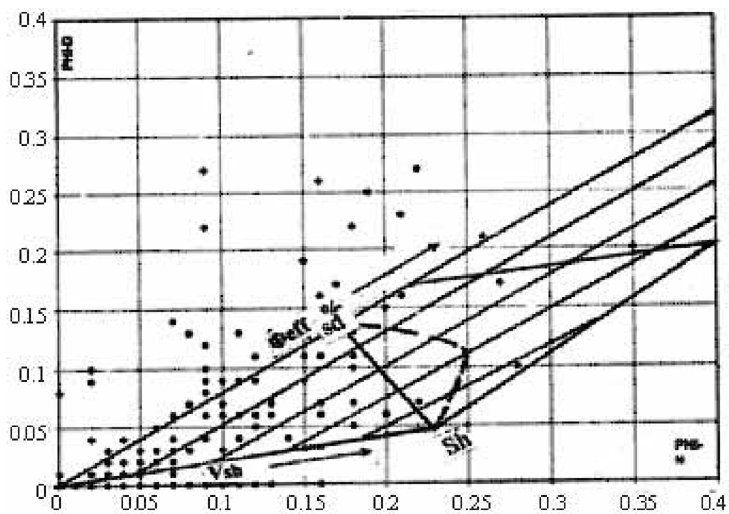

Fig. 8: THE RELATION BETWEEN PHI-N AND PHI-D FOR ABU ROASH FORMATION IN WEST T 56-1 WELL.

Gamma-ray Logs:

Organic-rich rocks can be relatively highly radioactive, that is they can have a higher gamma-ray reading than the ordinary shales and limestones (Schmoker, 1981). This result from the tendency of the planktonlcs as well as the other organic fauna to absorb the uranium ions present in the sea water and concentrate them in the source rocks.

Resistivity Logs:

The existence of organic matter in the shales often increases both the shallow and deep resistivities, because the free oil occupies the pore and fracture system. Consequently, the resistivity of the source rocks increases by a factor of 10 % or more (Du Rachet, 1981). Schmoker and Hester (1989) showed that, the resistivity increases dramatically in mature source rocks and presumably is related to the generation of non-conducting hydrocarbons.

Table 1: The shale parametrs in the different wells for Abu Roash Formation.

WELL NAME	ρ	phid	phin	TOC	Vsh	Shale Type
Birgat-1	2.27	0.39	0.11	10.80	0.5	Disperssed
	2.67	0.02	0.05	0.60	0.5	Disperssed
	2.28	0.16	0.05	10.50	0.35	Disperssed
Natrun Gibil A-1	2.62	0.03	0.05	1.71	0.45	disperssed
	2.22	0	0.03	12.33	0.49	disperssed
	2.37	0	0.03	7.93	0.41	disperssed
	2.62	0	0.01	1.71	0.55	disperssed
	2.07	0.05	0.24	17.38	1	laminated
	2.7	0.05	0.12	-0.04	0.79	disperssed
	2.23	0.03	0.01	12.02	0.49	disperssed
	2.25	0.03	0.09	11.40	0.64	disperssed
	2.8	0.05	0.09	-2.08	0.58	disperssed
West Halif-1	2.11	0.2	0.21	15.96	0.59	structure
	2.1	0.22	0.24	16.31	0.67	structure
	2.1	0	0.08	16.31	0.75	disperssed
	2.1	0	0.03	16.31	0.73	disperssed
	2.27	0.15	0.19	10.80	0.66	laminated
	2.67	0	0.02	0.60	0.43	disperssed
	2.37	0.02	0.09	7.93	0.76	disperssed
	2.22	0.03	0.08	12.33	0.44	disperssed

Density Logs:

The density logs measure normally the bulk density of the rocks, which consist of the combined effect of the shale density and the fluid density. In shales, with similar degree of compaction and analogous physical conditions, the presence of larger amounts of organic materials reduces the bulk density (Smith and Young, 1964).

Sonic Logs:

Sonic logs, also, show the difference in compaction between the organic-lean sediments and the source rocks. Therefore, they can be used to identify the sourc~ rocks for their relative decrease.

Determination of the Total Organic Carbon Content (wt. %):

The total organic carbon generated in the shale has been calculated utilizing Schmoker and Hester's equation (1989), as follows:

$$Toc = (154.497\ I\ \rho) - 57.261 \qquad (15)$$

where:

- Toc is the total organic carbon per weight (wt%.)
- ρ is the shale density within the studied unit.

Thomas (1979) classified the potential of source rock, on the basis of organic carbon content, as follows: 0.5 % is considered to be poor. 0.5 % to 1 % is fair, 1 % to 2 % is good and greater than 2% is excellent. Basu *et al.* (1980) concluded that, the source rock which is less than 0.5% organic carbon content is considered poor and that of 0.5 % to 2 % is considered to be very good source rock.

Table 2: The shale parametrs in the different wells for Abu Roash Formation.

WELL NAME	ρ	phid	phin	TOC	Vsh	Shale Type
Fayad-1	2.58	0.04	0.04	2.62	0.65	disperssed
	2.1	0.04	0.04	16.31	0.65	disperssed
	2.53	0.05	0.05	3.81	0.37	disperssed
	2.51	0.2	0.2	4.29	0.44	laminated
	2.27	0.05	0.05	10.80	0.56	disperssed
	2.54	0.2	0.2	3.56	0.49	disperssed
	2.48	0.12	0.12	5.04	0.70	disperssed
	2.68	0.25	0.25	0.39	0.38	structure
	2.45	0.03	0.05	5.80	0.57	disperssed
	2.65	0.04	0.04	1.04	0.71	disperssed
T-56-1	2.33	0.22	0.26	9.05	0.61	structure
	2.15	0.19	0.23	14.60	0.73	structure
	2.6	0.03	0.07	2.16	0.64	Disperssed
	2.51	0.19	0.2	4.29	0.75	structure
	2.45	0.03	0.16	5.80	0.56	Disperssed
	2.7	0.04	0.14	-0.04	0.54	Disperssed
	2.32	0.06	0.13	9.33	0.58	Disperssed
	2.1	0.22	0.24	16.31	0.67	structure
	2.27	0.05	0.12	10.80	0.61	Disperssed
	2.41	0	0.1	6.85	0.37	Disperssed
	2.33	0	0.02	9.05	0.5	Disperssed
	2.74	0	0.05	-0.88	0.36	Disperssed
	2.02	0.03	0.1	19.22	0.67	Disperssed
	2.27	0.25	0.19	10.80	0.6	Laminated
	2.08	0.27	0.22	17.02	0.58	Laminated
	2.2	0.02	0.05	12.96	0.76	Disperssed
Zebeida	2.62	0.02	0.07	1.71	0.51	disperssed
	2.43	0.13	0.19	6.32	0.53	laminated
	1.87	0	0.11	25.36	0.64	disperssed
	2.4	0.07	0.15	7.11	0.53	disperssed
	2.6	0.03	0.15	2.16	0.57	disperssed
	2.58	0.01	0.02	2.62	0.49	disperssed
	2.38	0.02	0.05	7.65	0.64	disperssed
	1.82	0	0.1	27.63	0.72	disperssed
	1.62	0.12	0.21	38.11	0.47	structure

Application of the Technique:

From the crossplots and by using the previous method,some of the results are tabulating in two tables and from Table (1), the shale in Birigat-1 well for Abu roash Formation is mainly dispersed, while in Natrun Gibil A-1 well is mainly dispersed with few of laminated shale, and in West Halif-1, the shale is mainly dispersed with the little of structure shale.

In Table (2), the shale type in Fayad-1 well is mostly dispersed with a few of laminated and structure shale,while in T56-1 well is dispersed with some of laminated and structure shale and in Zebeida well the shale type is like in Natrun Gibil well where the main type is disoersed with some of strucutre and laminated.

The TOC is greater than 2% in the all wells and that are excellent source rock.

Conclusion:

The area of study lies in the South of Western Desert of Egypt where the six wells(Birgat-1 ,Natrun Gibil A-1, West Halif-1, Fayad-1, T-56-1 ,and Zebeida wells)selected to study Abu roash Formation at Wadi El Natrun area, south of western desert, Egypt.

The following methods used to define the shale volumes in the current work, Gamma-Ray method, Neutron method and Resistivity method and correction of shale volume are be made by using Steiber (1973) and Claveir *et al.* (1971). Crossplot method used to determined the shale types and the results are tabulating in tables .The shale in Birigat-1 well for Abu Roash Formation is mainly dispersed, while in Natrun Gibil A-1 well is mainly dispersed with few of laminated shale ,and in West Halif-1,the shale is mainly dispersed with the little of structure shale.

The shale type in Fayad-1 well is mostly dispersed with a few of laminated and structure shale,while in T56-1 well is dispersed with some of laminated and structure shale and in Zebeida well the shale type is like in Natrun Gibil well where the main type is disoersed with some of strucutre and laminated.The dominant shale types in the study area of Abu Roash Formation are defined predominantly dispersed shale with a moderate effect of laminated and structural shales. The TOC is greater than 2% in the all wells and that are excellent source rock.

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