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GEOLOGICAL AND PETROPHYSICAL STUDIES OF ABU ROASH "D" RESERVOIR IN G.P.T. FIELD, ABU SENNAN AREA, WESTERN DESERT, EGYPT

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دراسات جيولوجية وبتروفيزيائية لخزان أبورواش "D" فى حقل G.P.T. ،
منطقة أبو سنان– الصحراء الغربية – مصر.

الخلاصة: يتناول هذا البحث تحديد خواص الخزان لصخور عضو أبو رواش "D" التابع للعصر التورونى لحقل G.P.T. بمنطقة أبوسنان – بالصحراء الغربية بهدف تقييم هذا المتكون كصخر خازن للهيدروكربون فى منطقة الدراسة باستخدام التسجيلات الكهربية و الأشعاعية للآبار. و قد تضمن البحث دراسة ليثوستراتيجرافية لمنطقة الحقل وكذلك تحديد التراكيب الجيولوجية والعوامل التكتونية السائدة فى هذه المنطقة بالإضافة إلى تحديد الخواص البتروجرافية .

وقد تم تمثيل البيانات التى تناولتها الدراسة فى صورة تسجيلات بيانية للتشبع الليثولوجى وكذلك خرائط التوزيع و التركيز الجانبى للطفل، المسامية المؤثرة و نسبة التشبع و أيضاً الخريطة التركيبية للمنطقة. حيث أمكن إستنتاج بعض النتائج التى يمكن تلخيصها فيما يلى :

تعتبر منطقة الدراسة طية محدبة غير متماثلة ذات صدوع تتجه شمال شرق – جنوب غرب ويحيط بها من ناحية الجنوب صدع يمتد شرق – غرب ومن الشرق صدع يمتد شمال شمال غرب – جنوب جنوب شرق ومن ناحية الشمال الغربى صدع رئيسى يمتد شمال شرق – جنوب غرب. وينقسم التركيب إلى كتل صدعية منفصلة بواسطة سلسلة من الصدوع الأعتراضية. والجزء الشمالى الشرقى للمنطقة متأثر بصدع معكوس (محلى) يقطع البئر (GPT-15) داخل طبقات أبورواش "B" ونتيجة لذلك حدث تكرار فى طبقات عضوى أبو رواش "A&B" .

أظهرت الدراسة البتروجرافية إن التركيب الليثولوجى لعضو أبو رواش "D" يتضمن سحنات صخرية دقيقة ممثلة بالباكستون الجيرى المحتوى على الانتراكلاستك والتى تكون متناوبة مع الطين الغنى بأصداف الحفريات ذات المصراعين، المضستون، الواكستون والباكستون ذات الحب المتغالظ والمتغاير والفتات العضوى والجرينستون.

كما تبين أن المحتوى الطفلى لعضو أبو رواش "D" يزداد فى إتجاه الأجزاء الخارجية للمنطقة ويقل فى إتجاه الأجزاء الوسطى، و أن المسامية الفعالة تزداد بشكل عام نحو الجزء الأوسط لمنطقة الدراسة، كما أن الجزء الأكبر من المسامية يتمثل فى المسامية الثانوية نتيجة لعوامل الترسيب، وأن درجة التشبع بالماء تتزايد فى إتجاه الأجزاء الخارجية من منطقة الدراسة. وعليه فإن الفرص الأفضل للإستكشاف والتنمية بالمنطقة قيد الدراسة تتركز فى الجزء الأوسط حيث تتزايد نسبة كل من المسامية الفعالة بالإضافة لقلة المحتوى الطفلى ونسبة التشبع بالماء.

ABSTRACT: *This paper is concerned with geological and petrophysical characteristics of the Abu Roash "D" resesvoir in the G.P.T. Field, Abu Sennan area, using primarily the well log data. The subsurface geological studies were accomplished through the study of the lithostratigraphy, the regional structural deformations and the tectonic implications in the field area in addition to petrographic analysis. Computer-assisted log analyses were used to evaluate petrophysical parameters such as the shale content, effective porosity, water saturation, hydrocarbon saturation, flushed zone saturation and true resistivity. Litho-saturation crossplots of the studied wells, and isoparametric maps of the weighted petrophysical parameters of the investigated rock unit (shale content, effective porosity, water saturation and net pay thickness of hydrocarbon saturation) have been constructed to illustrate the spatial variation of petrophysical parameters and to show their relationships with the geologic setting of the study area. Based on the obtained results, the oil potential and the development of the Abu Roash "D" Member in the G.P.T. Field should be taken into consideration. The reservoir rock analysis revealed that Abu Roash "D" Member may be considered as a good reservoir and the better chances for more hydrocarbon reserves in the field area may exist in the central parts that have high effective porosity, low shale content and low water saturation.*

INTRODUCTION

The well log analysis is the most important to any well after drilling to detect the reservoir rocks among all the drilled formations. It can be used for identifying the reservoir productive zones, determining the depths and thicknesses of these zones, distinguishing between fluid components (oil, gas and water) and estimating the hydrocarbon reserves, as well as defining their different petrophysical characteristics, such as lithology, porosity, water saturation and permeability. The Turonian Abu Roash "D" Member was subjected to a comprehensive integrated study (geological, petrographic and petrophysical properties) as it represents one of the most important horizons of high hydrocarbon potential. The study area is located in Abu Sennan concession within Abu El-Gharadig basin in the northern part of the Western Desert. It is approximately bounded by longitudes 28° 00 and 29° 00 E and by latitudes 29° 00 and 30° 00 N (Fig. 1). In the present work 20 wells were studied through the different subsurface geological methods and 16 wells of them were chosen for providing information on the hydrocarbon content of the stratigraphic units having any oil accumulations, in order to add some other producing zones.

GENERAL GEOLOGY

The northern part of the Western Desert of Egypt has been studied by many geologists of which one may mention Abdine (1974), Deibis (1976), Barakat et al. (1980), Robertson (1982), Demerdash et al. (1984), Moussa (1986), Puglies and Kamel (1992), Said (1990), Darwish et al. (1994), El Shaarawy and Montasser (1996), Abd El-Rahman (1998), Shalaby et al. (2000), Abd El-Gawad et al. (2002), Khalifa et al. (2005), Shalaby et al. (2006), Ali et al. (2008), Yousef, et al.(2010) and others. The oldest sediments peneterated in the area under study belong to the Kharita Formation where the GPT - 1, 3, 7, 9, 13, 17 & 20 wells are bottomed. The stratigraphic sequence penetrated by these different wells (20 wells) is interrupted at many levels by several unconformities of different magnitudes. The stratigraphic column penetrated in the area by wells is illustrated in Fig. (2) . It shows that the Abu Roash “D” Member was unconformably deposited on the Abu Roash “E” Member; it is composed mainly of limestone with thin beds of silty shale and shaly limestone interbedded shales. The environment of depostion is a restricted shallow marine shelf in low energy conditions.

The isochore map of Abu Roash “D” unit (Fig. 3) shows an elongated body extending NNE – SSW with asymmetric dips on both sides as a result of a change in the climatic conditions and /or structural setting of the study area . It also indicates that the basinal areas (thickening areas) exist at the flanks of the study area, while the ridge like areas (thinning areas) occupy the central part of the study area. The maximum thickness penetrated of the Abu Roash “D” Member is 120 m in both GPT-3, 6 and 15 wells. The minimum thickness cannot precisely be determined since the wells with minimum thickness are faulted out.

The structure on top of the Abu Roash “D” Member (Fig. 4) indicates that the Abu Roash “D” Member top is an asymmetric faulted anticline tilted towards the northeast and dissected by two sets of faults. The first set is trending NW-SE (clysmic) led to faulting of the area into several step blocks. The second is composed of two main shear faults assuming the Aqaba trend. The two sets confine a horst block in the central part of the study area. Locally, there is a reversed fault (F8) in the northeastern part of the study area which is evidenced by the repetition of the top part of Abu Roash “A and B” Members (El Kawa and Taha, 1986). The dip in the southern part is steeper than that in the other parts of the map area. The fault throws vary from 5 m to 245 m. The constructed cross sections confirmed the previously deduced structural configuration of the field area (see Fig. 5). Fault criteria are incorporated from two-way time structure map and cross sections.

PETROGRAPHY

To determine the petrologic components and diagenetic features which may affect the porosity and permeability of studied reservoir rocks, a petrographic examination of a number of samples from the Abu Roash “D” Member (only one 17 m core was cut from from this unit in GPT-3 well, plate 1) was achieved. The sediments of this member are divided into three groups:

l) Intraclastic lime packstones:

This lithotype is dominated by intraclasts (50-55%) of partially lithified bivalve lime packstone/wackestone with some bioclast debris (<3%) and a matrix of lime mud (9-22%) and detrital clay (2-8%). Cements include blocky ferroan calcite and ferroan saddle dolomite. Some mouldic macropores are present, with minor microporosity in the clay matrix.

2) Peloidal and bioclastic lime mudstones, wackestones and wackestone/ packstones:

Variations within this lithotype are caused by variations in the ratio of grains to matrix. Grains are commonly dominated by peloids (5-16%) and skeletal grains (8 - 14%) with subordinate pellets (<4%) and rare intraclasts (<3%). The sediments are poorly sorted (fine to 4mm) and the matrix is all lime mud. Cement is of minor importance (<4%), dominated by ferroan blocky calcite with traces of dolomite and pyrite. Porosity is dominated by matrix microporosity but some intragranular and mouldic porosity also occurs.

3) Peloidal and bioclastic lime packstones and grainstones:

These sediments are commonly dominated by peloidal grains (<68%) with subordinate bioclasts (<17%) and pellets (<7%) and variable volumes of lime mud matrix (<35%). Grain sorting is generally good. Cements include blocky ferroan and non - ferroan calcite and ferroan saddle dolomite which partially fill a variety of pores. However, open macropores are still present as intergranular (<22%), intragranular (<7%) and mouldic (<6%) pores and vugs (<10%), with microporosity within the matrix (Robertson, 1982).

LOG ANALYSIS

Computer assisted interpretation was introduced for the quantitative determination of rock constituents and evaluation of the petrophysical characteristics of the Abu Roash "D" Member. The different types of data (resistivity, neutron, density, gamma ray, caliper logs) corrected prior of being used for determination of the average petrophysical parameters of the Abu Roash "D" Member. The value of water resistivity (R_w) was determined through the mathematical formula given by Pickett (Fig. 6).

The determination of shale content was achieved through three indicators, namely, gamma ray log, resistivity log, neutron-density logs. The lowest value of these indicators is likely to be very close to the actual value. The determination of the corrected effective porosity ($Ø_e$) is mainly based on the combination of density and neutron logs after applying various corrections by using the equation of Schlumberger (1975):

$$Ø_{N-D} = \sqrt{(Ø_{Ncor}^2 + Ø_{Dcor}^2) / 2}$$

and

$$Ø_e = Ø_t \times (1 - V_{sh})$$

where: $Ø_{Ncor}$ is the corrected neutron porosity, $Ø_{Dcor}$ is the corrected density - derived porosity and V_{sh} is the shale volume.

The determination and discrimination of the fluid contents as water and hydrocarbon saturations are also carried out through poupon (Indonesia) equation:

$$\frac{1}{\sqrt{R_t}} = [\frac{V_{Sh}(1-V_{Sh}/2)}{\sqrt{R_{Sh}}} + \frac{\phi^{m/2}}{\sqrt{aR_w}}] Sw^{n/2}$$

Where: V_{Sh} is the shale content, R_t is the true resistivity, R_{Sh} is the resistivity of shale, R_w is the formation water resistivity, a coefficient in Archie formula and m is the cementation factor.

The hydrocarbon saturation (S_h) and its subdivision, the residual hydrocarbon saturation (S_{hr}) and the movable hydrocarbon saturation (S_{hm}), were determined by the normal analytical equations of Schlumberger Applications (1974):

$$S_h = 1- S_w , S_{hr} = 1- S_{xo} , S_{hm} = S_h - S_{hr} ,$$

$$\text{or } S_{hm} = S_{xo} - S_w$$

RESULTS

The study of reservoir potentials of the Abu Roash "D" Member encountered in the studied wells is achieved through the evaluation of its petrophysical parameters. This is illustrated through the litho-saturation crossplots and the distribution maps of petrophysical parameters (shale content, effective porosity, water saturation and hydrocarbon saturation).

A- Iitho-saturation crossplots of Abu Roash "D" Member:

For example, Fig.(6 & 7) represent the of litho-saturation crossplots for GPT- 4 & 11 wells. The shale content in the limestone of Abu Roash "D" Member ranges from 8% to 42%. The effective porosity of this litho- stratigraphic unit is generally high for most of the section and ranges from 4% in GPT- 4 well to 16% in GPT-11 well. The movable and residual hydrocarbons are shown by considerable amounts along most of the section, except in the lower part of GPT-11 well, where they completely disappeared. The prevalence of water is cearly implied.

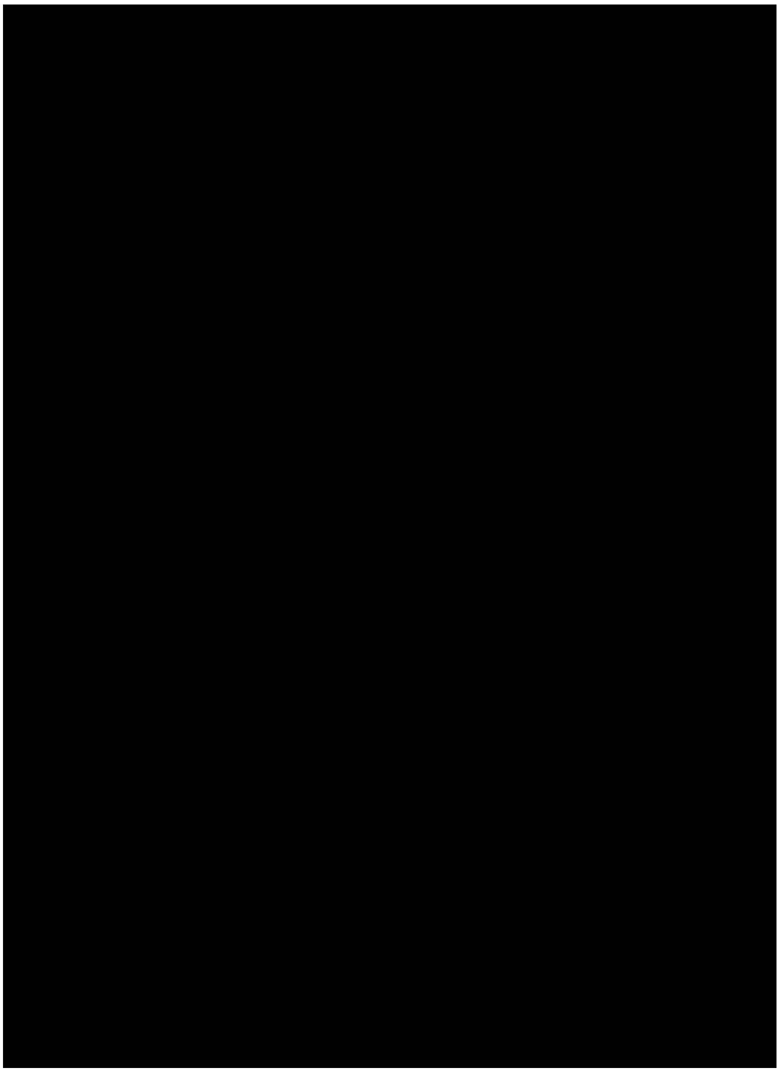
B- Isoparametric Maps of Abu Roash "D" Member:

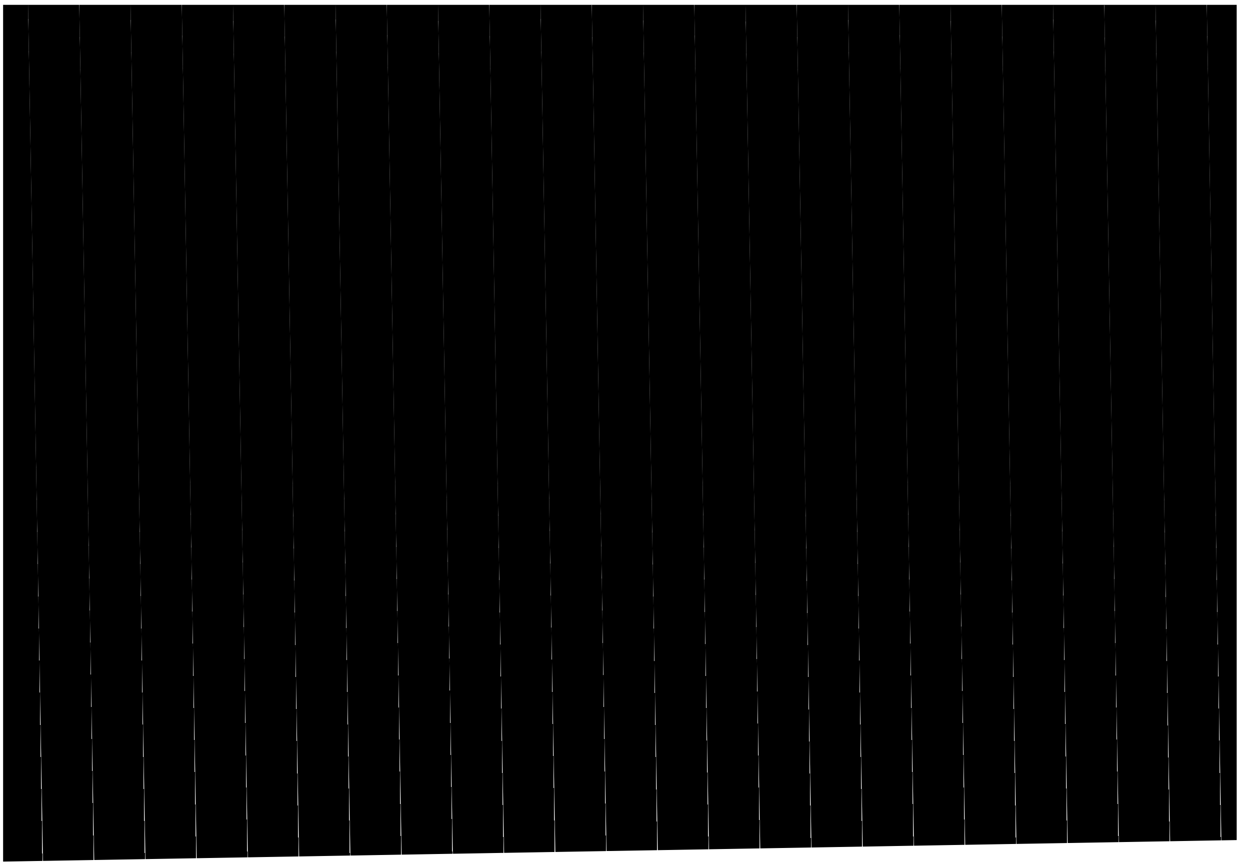
1) The iso-shaliness map (Fig. 8) reveals that the shale content varies from 16 % in GPT-1 & 17 wells to 36 % in GPT-18 well. It can be noticed that the shale content decreases towards the central area of the studied field. This is the same increasing trend of porosity, which confirms the reversible relationship between the porosity and shaliness.

2) The iso-effective porosity map (Fig. 9) shows a general increase of the porosity towards the central part of the map area. The porosity values range from 6 % in the GPT- 6 , 9 & 16 wells to 12 % in GPT-15 well . The structural elements may affect the porosity development, but not as much as the facies of deposition which has a great influence on the porosity. This deduction is manifested by the absence of any porosity anomalies in the porosity contour lines at or near the fault sites on the map, which implies that the effect of these faults on the porosity is minor, and that the porosity differences are fabric dependant rather than structural dependant.

3) The water saturation distribution within the studied member (Fig. 10) is affected by the structural position of the unit; the deeper unit, the higher is water saturation. The highest water saturation value 84% is recorded in GPT - 8 well (depth of Abu Roash "D" Member = -1780 m.), whereas the lowest value 21% is recorded in GPT-1 well (depth of Abu Roash "D" Member = -1347 m.). The general trend of water saturation increase is outwards from the center of the study area.

4) Fig. 11 shows that the net pay thickness of hydrocarbon within Abu Roash "D" Member varies from 1 m in GPT-2, 3, 6, 8, 9 & 13 wells to 8 m in GPT-4 &17 wells. The net hydrocarbon is concentrated in the central part of the field area.





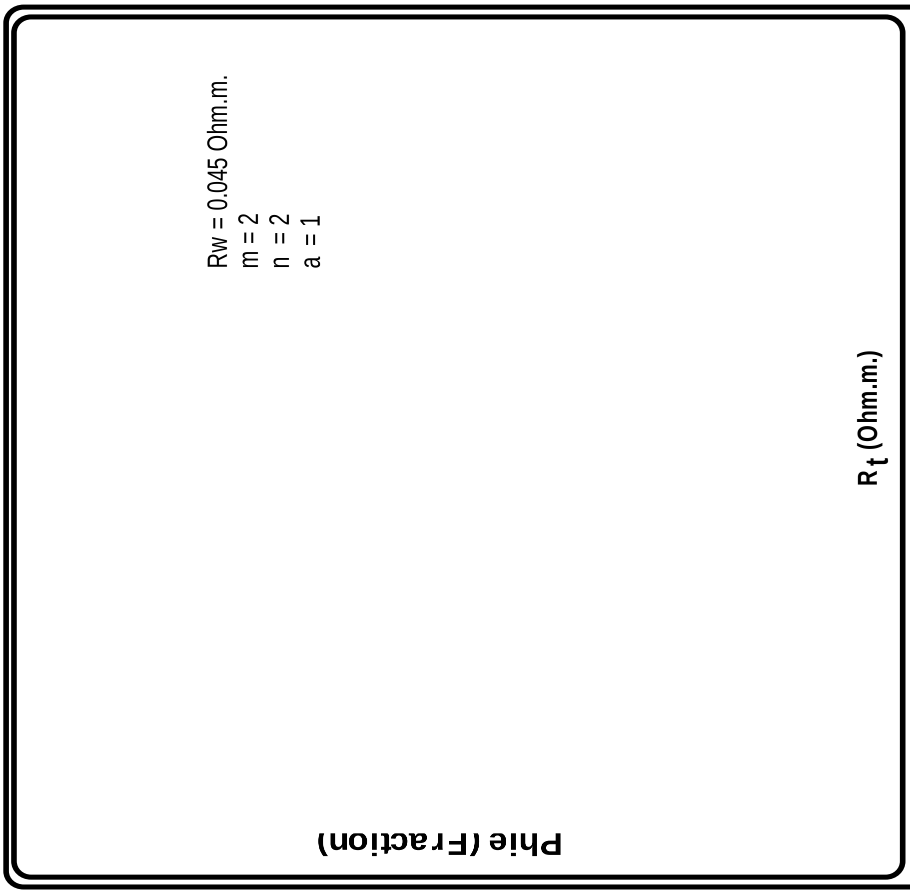


Fig (6) A Pickett Plot for (Rw) Determination of Abu Roash "D" Mbr., GPT-15 Well.

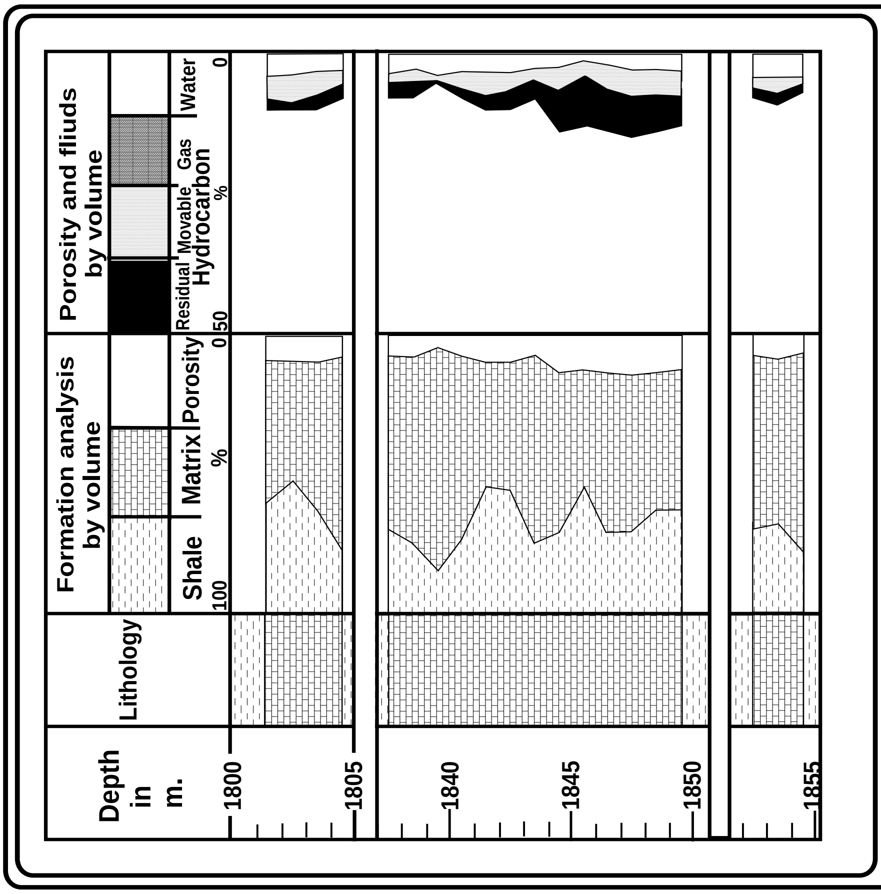


Fig.(7) Litho-saturation crossplot of Abu Roash " D" Member, GPT- 4 Well.

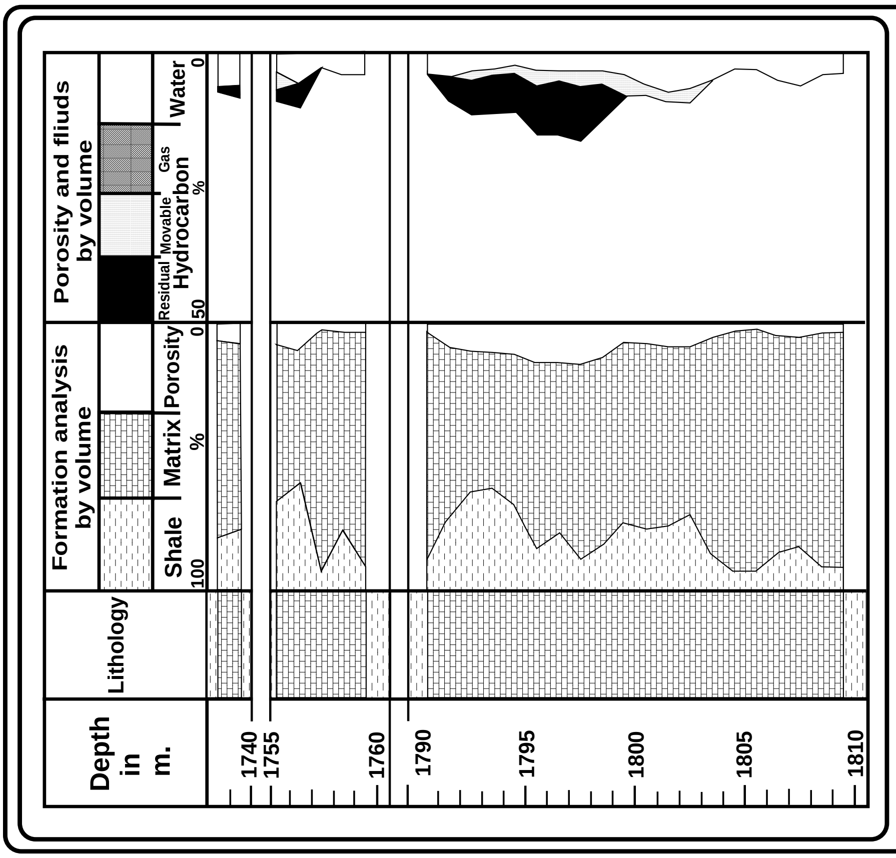


Fig.(8) Litho-saturation crossplot of Abu Roash " D" Member, GPT-11 Well.

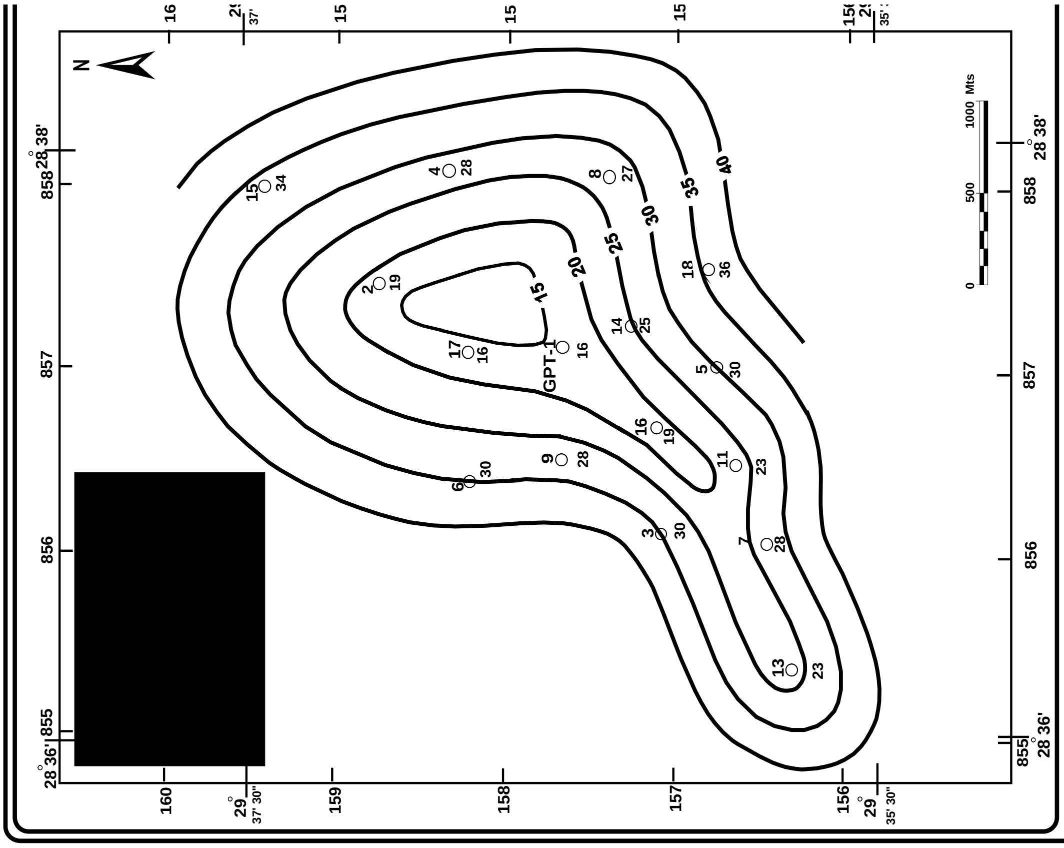


Fig. (9) Iso-shaliness map of Abu Roash "D" Mbr.(Turonian), GPT Field, Abu Sennan area, Western Desert-Egypt. (C. I. = 5%)

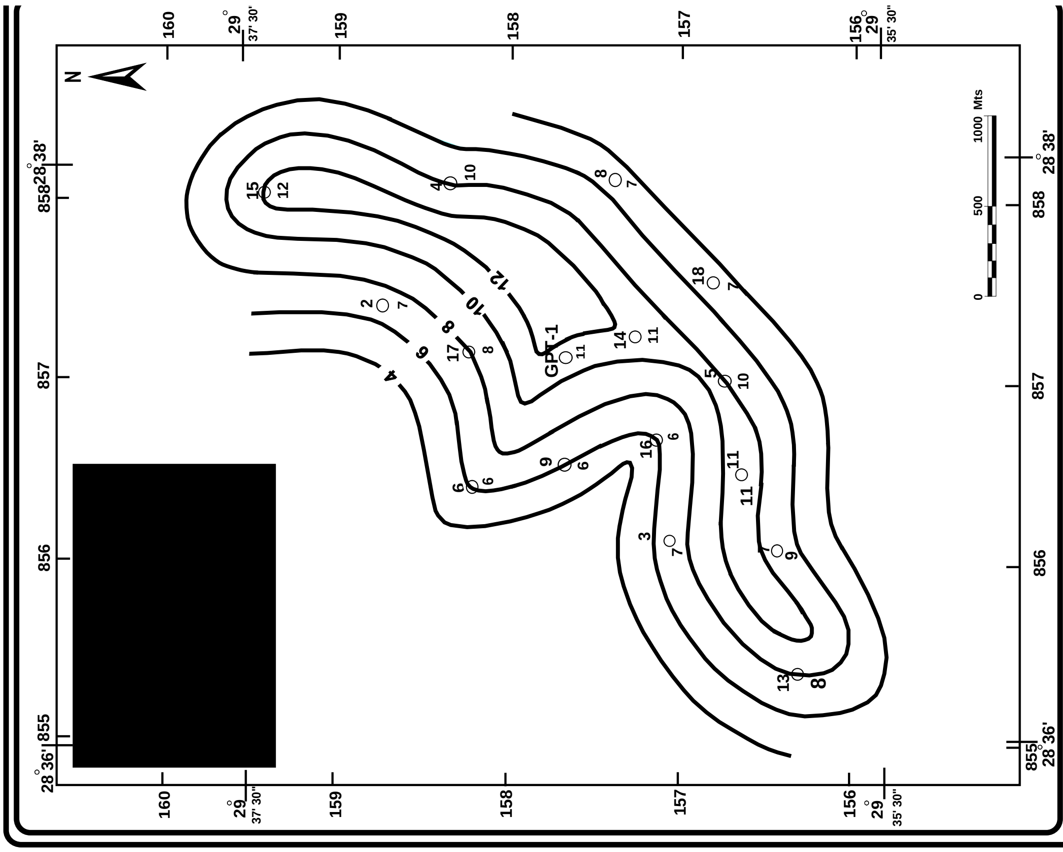


Fig. (10) Iso-effective porosity map of Abu Roash "D" Mbr.(Turonian), GPT Field, Abu Sennan area, Western Desert-Egypt. (C. I. = 2%)

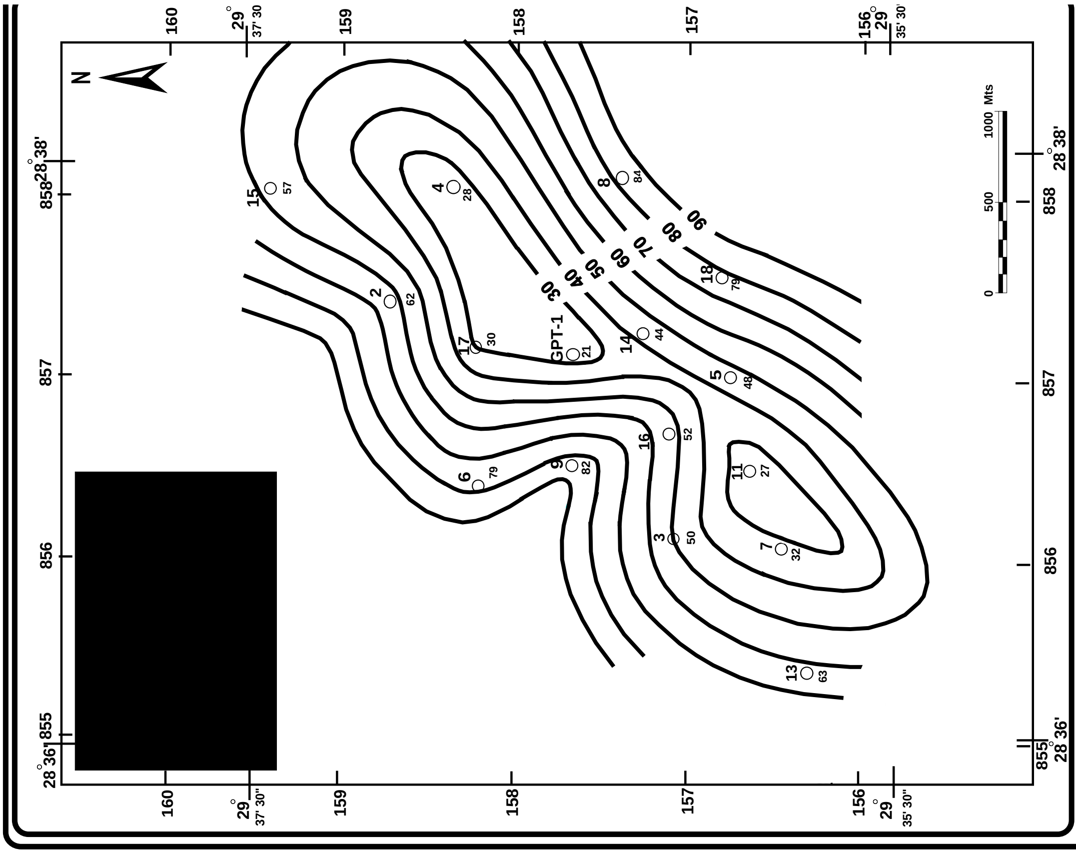


Fig. (11) Distribution of water saturation in Abu Roash "D" Mbr.(Turonian), GPT Field, Abu Sennan area, Western Desert-Egypt. (C. I. = 10%)

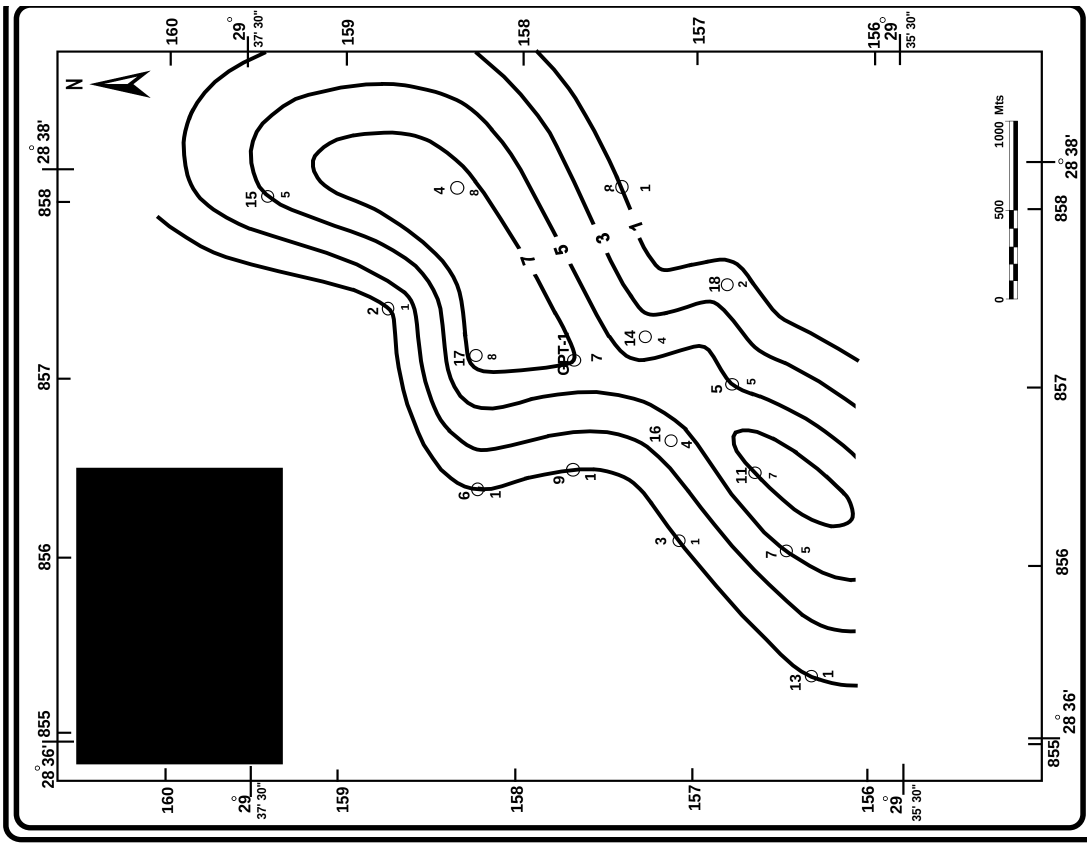


Fig. (12) Net pay hydrocarbon map of Abu Roash "D" Mbr.(Turonian), GPT Field, Abu Sennan area, Western Desert-Egypt. (C. I. = 50 m.)

Plate 1

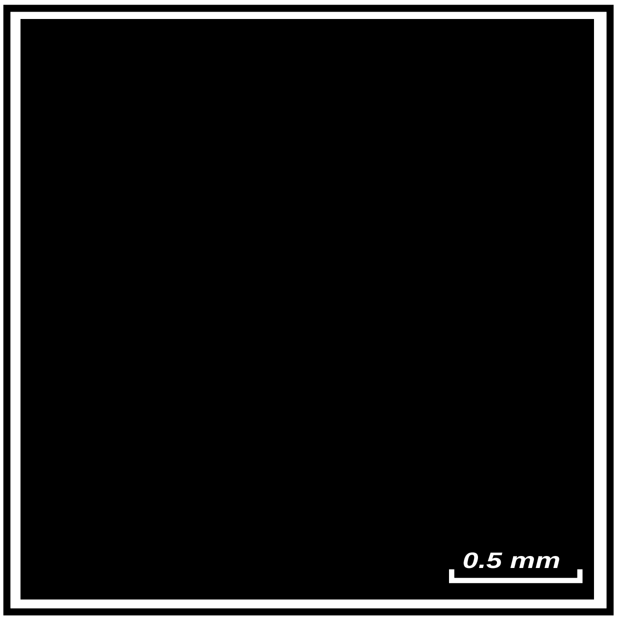


Fig. (A): Photomicograph; Illustrates one of the interclasts which form the dominant grain type in a slightly argillaceous, intraclastic lime packstone.The intrclast illustrated contains well preserved skeletal grains, ferroan calcite cemented mouldic pores and open mouldic pores. The matrix is porous.

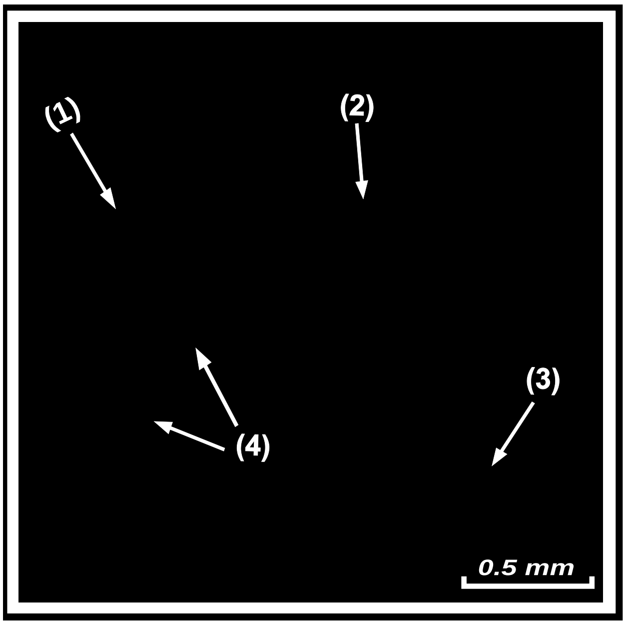


Fig. (B): Photomicograph; The very high intergranular porosity contained within this poorly consolidated peloidal and bioclastic lime grainstone/pacstone. It is the dominance of fabrics like this which make Member "D" carbonates good reservoir quality (high porosity and permeability) lithologies, (1); micritised bioclast, (2); peloids, (3); foram, (4); intergranular pores.

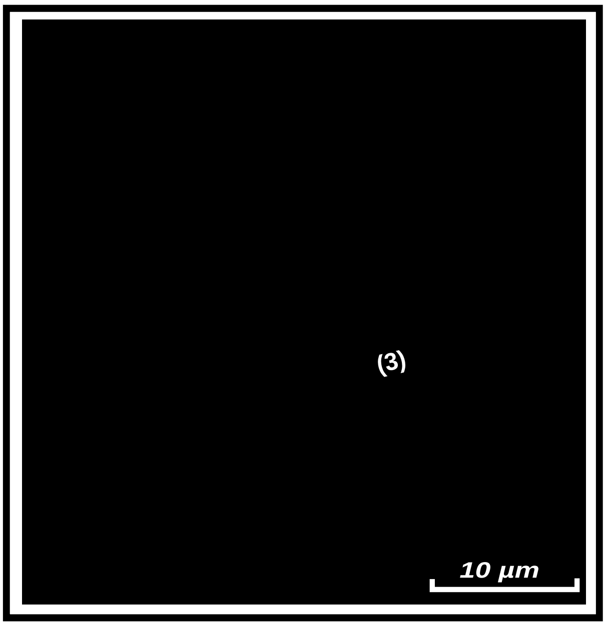


Fig. (C): Scanning electron micrograph; This micrograph illustrates a partially cemented mouldic/solution channel pore within low porosity lime mud matrix, (1); mouldic/solution channel pores, (2); dense matrix, (3); blocky calcite cement.

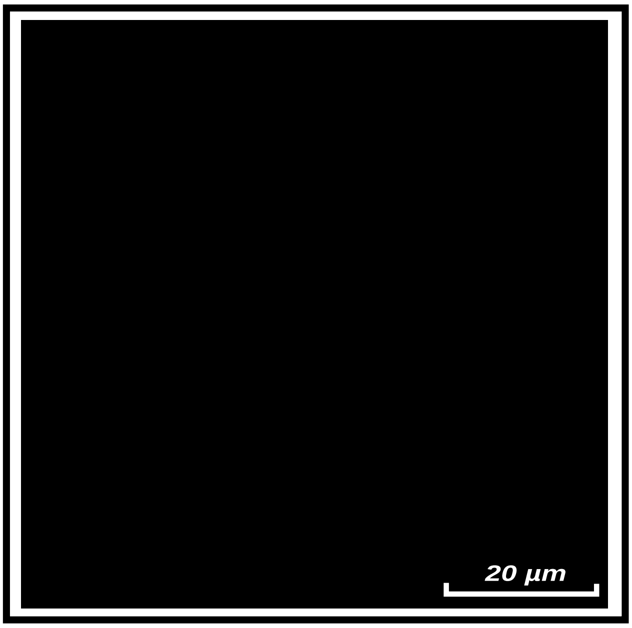


Fig. (D): Scanning electron micrograph; Illustrated is a micropelletal matrix fabric, which contains appreciable micro-intergranular microporosity (matrix pores). Note the planar crystal faces on the micrite grains which are due to overgrowth cementation, (1); micropellet, (2); blocky calcite cement, (3); overgrowth cemented micrite, (4); micro-intergranular pores (After Robertson, 1982).

CONCLUSIONS

The formation evaluation of the Abu Roash "D" Member in Abu Sennan area, Western Desert revealed the following:

1. The study area is an asymmetric faulted anticline trending northeast-southwest bounded on the south by an east-west fault, to the east by a NNW-SSE fault and to the northwest by a major fault trending northeast-southwest and divided into separate fault blocks by a series of cross cutting faults.

2. The Abu Roash "D" limestones show a facies including intraclastic lime packstones, which are often interbedded with bivalve-rich shales, peloidal and bioclastic lime mudstone, wackestone and wackestone/packstone and peloidal and bioclastic lime packstone and grainstone.

3. Most of the effective porosity of studied rock unit may be of secondary origin due to diagenetic effects that reflected from petrographic study.

4. The shale content and the water saturation of the Abu Roash "D" Member increases towards the marginal parts of the study area.

5. The effective porosity distribution indicates that porosity of limestones of the Abu Roash "D" Member generally increases towards the central part of the study area.

6. The better chances for more hydrocarbon accumulation in the field area may exist in the central (crestal) parts that have a high effective porosity, low shale content, low water saturation of Abu Roash "D" Member.

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