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RESERVOIR CHARACTERIZATION OF ALAM EL BUEIB Dl SAND RESERVOIR IN UMBARAKA AND SOUTH UMBARKA OIL FIELDS,WESTERN DESERT, EGYPT.

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ABSTRACT

Alam El-Bueib Formation (AEB) is a productive rock unit in the Egyptian Western Desert .It ranges in age from Middle Jurassic (Callovian) to Early Cretacecus (Barremian). It is mainly composed of sandstone with siltstone, shale and carbonate streaks. Lignite and carbonaceous shales are occasionally common, particularly near the base. It covers most of the areas of the northern Western Desert. It uncomfortably overlies the Masajid Formation.

Objectives of this study are to describe the reservoir petrophysical characteristics of the sand seen in Umbarka and South Umbarka fields, to study the petrography, to study the effect of lithology on the distribution of petrophysical parameters, and to evaluate the hydrocarbon potentialities of the AEB-D1 Sand reservoir.

Well log data belonging to seven drilled wells were interpreted and integrated with the other subsurface information to evaluate the petrophysical characteristics of the AEB Sand Reservoir. The log data were corrected prior being used for determination of the average petrophysical parameters of the AEB-D_1 Formation. These parameters were plotted in the form of maps representing the areal distribution of three petrophysical parameters (shale volume, total and effective porosities, and water and hydrocarbon saturations.

In this study, the potential un-tested bypassed zones were identified and mapped. According to the petrophysical distribution of the maps of AEB-D1, the Original Oil Inplace (OOIP) is estimated to be about 19.5 Million Stock Tank Barrels (MMSTB). The maps also highlight a prospective area in the South Umbarka area (Khepri-Sethos).

Keywords: Reservoir Characterization, Petrophysics, Weastern Deseret, Umbaraka Field, Alam El Bueib

INTRODUCTION:

The study area is located in the central eastern part of Faghur area and the northwestern part of the Qattara Depression, some 100 Kilometers southwest of Marsa Matruh coastal town and slightly over 200 kilometers west of the Alamein field. The area of study, including Khepri-Sethos oilfields, lies between latitude 30° 27' and 31° 00' N and longitudes 26° 08' and 26° 36' E (Fig. 1).

The main hydrocarbon reservoir rock units, in the Western Desert, are mainly Cretaceous in age, with some limited production from the Jurassic rocks, Bahariya, Kharita, Alamein and Alam El Bueib (unit D) Formations represent a great part of the Cretaceous section. Several intervals within these formations produce most of the hydrocarbons, and they are considered the main targets for drilling (Regan, et al., 1986). Tertiary rocks and several sedimentary basins of varying ages; namely Abu Gharadig, Gindi, the northern basins and their extension in the Mediterranean water, Matruh basin and its extension to Shushan, Siwa and its link westwards in the Libyan side and others are characterized by having not only the oil/gas generating source rocks, but also the presence of the reservoir rocks with appreciable porosities and permeabilities (Deibis, 1994).

METHODOLOGY:

1- The main objectives of the present study are to delineate the subsurface geology (lithostratigraphy and structures), to study the petrography, to determine the petrophysical parameters, to study the effect of lithology on the distribution of petrophysical parameters and to evaluate the hydrocarbon potentialities. These objectives have been achieved by the application of integrated approaches, which are well logging evaluation and petrographic analysis.
2- Tracing the stratigraphic rock units through the studied wells by correlation of composite well logs.
3- Petrographic analysis using polarizing microscope and Scanning Electron Microscope (SEM) to study the main diagentic features, which

affected the porosity and permeability through the available studied wells.

4- Determination of the petrophysical parameters of the Lower Cretaceous rock units that could be a potential hydrocarbon reservoir, which include Alam El-Bueib (unit D1). The main petrophysical parameters include shale content, porosity, matrix components and fluid saturations.

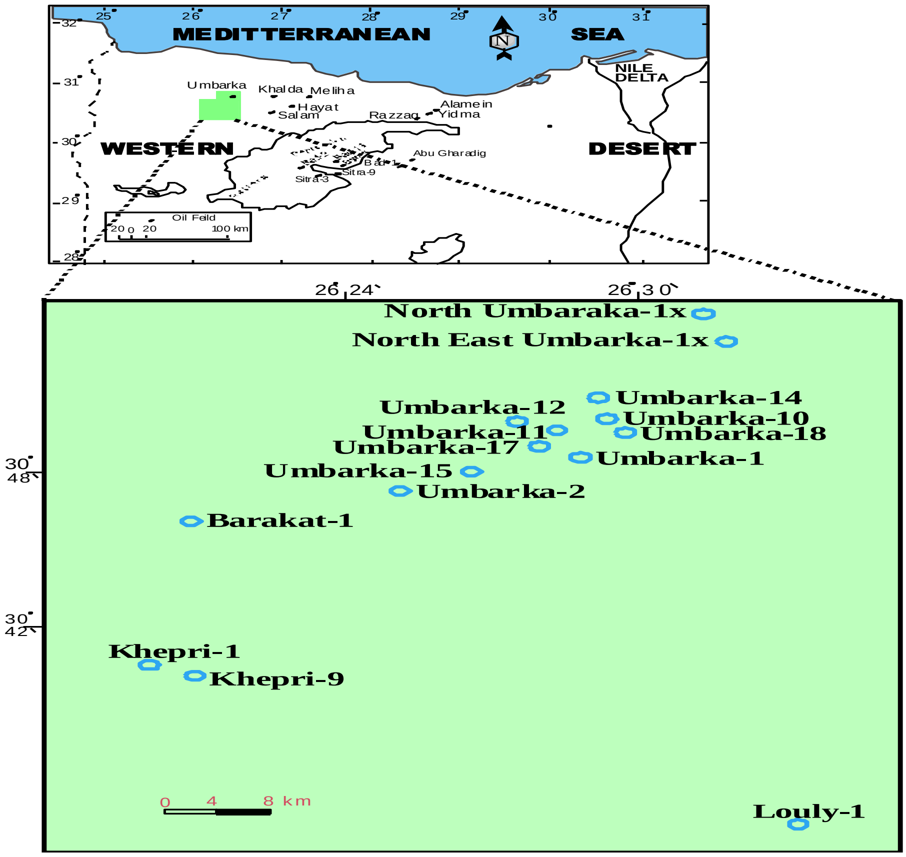

Fig.1: Location map of the study area.

AVALABLE DATA

Seven core samples were available for Alam El Bueib (unit D1) in two wells, beside five samples in Umbarka-11 well and two samples in North East-Umbaraka-1x well. The logs of seven wells were used; namely Umbarka-10, Umbarka-11, Umbarka-12, Umbarka-14, Umbarka-17, Umbarka-18 and North East Umbarka-1x wells. The input data include: Gamma Ray logs, Spontaneous Potential logs, which include Compensated neutron Logs (CNL) or Sidewall Neutron Logs (SNP), and Resistivity logs, which include Deep Induction, Laterolog, Short Normal and Spherically Focused logs.

GEOLOGIC SETTING

LITHOSTRATIGRAPHY:

Two major provinces were separated by the Ras Qattara uplift that occupies the northern Western Desert. The northern Province includes: Shushan, Matruh and Alamein Basins. The southern province includes mainly the Abu El Gharadig Basin (Meshref, 1996) (Fig. 2). The geological history of the concerned area is a part of the whole picture of the northern Western Desert, which belongs to the unstable shelf. The evolution of the area is related to the tectonic regimes, that affected the north Western Desert of Egypt.

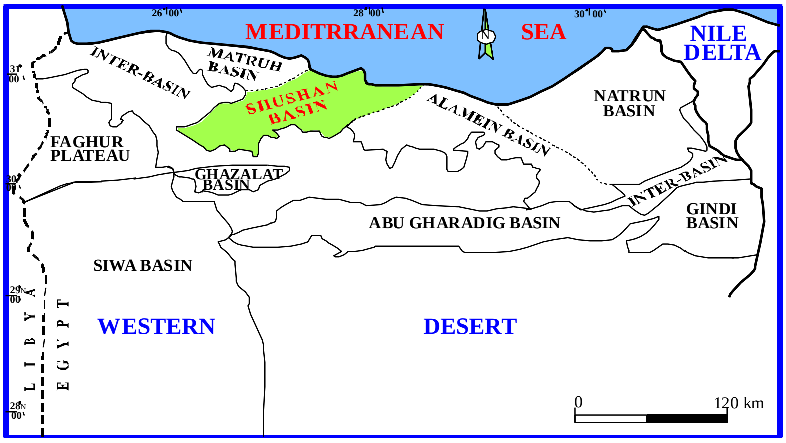

Fig. (2) North Western Desert Basins, Egypt. (EGPC, 1992).

The stratigraphic column of the study area is thick and includes most of the sedimentary succession from Recent to Pre-Cambrian basement complex (Fig.2). The stratigraphic sequence, as revealed by drilling in Umbarka, is illustrated by the attached table and is quite similar to that normally penetrated in Matruh area wells down to the Alamein Dolomite. However, the uppermost Cretaceous section down to and including Turonian in Umbarka shows considerable thickening, if compared with its equivalent in Meleiha, Yidma and Alamein. Thickening is in the order of about 700, 1200 and 1400 feet, respectively. The underlying Cenomanian to Aptian section is rather uniform in all of these areas. The Alamein Formation in the Faghur area, as well as in "Burg El Arab area", comprises two wells defined dolomite bodies (Fig.3).

In Umbarka-South Umbarka, the sequence underlying the Alamein Formation is entirely composed of clastic units. Most of the interval is assigned to Aptian age, but the lowermost coarse clastics in the said wells are questionably referred to as Paleozoic, in age.

The Alam El-Bueib Formation has been subdivided into five main lithologic units. These are from E (bottom) to A (top) with units D&C further subdivided into seven subunits from D1 (top) to D7 (base), D1, D3, D5 and D7 are mainly sandstone, while D2 D4 and D6 are mainly shale. Unit C is subdivided into C1 (top), C2 and C3 with C1 and C2 are mainly composed of interbedded sandstone and consists of shale, siltstone and sandstone. It is observed, that some units or subunits are absent through the studied wells. The thickness of the Alam El-Bueib Formation is recorded in Khepri-1x, Khepri-9, Umbarka-1x, Umbarka-2x and North East and Umbarka-1x wells, while it is not recorded in Umbarka-15 and Umbarka-11 wells because the drilling was stopped within it. The thickness increases from the center (Umbarka-1x) well towards the northeast and southwest. The maximum thickness (3713 feet) is recorded in Khepri-9 well and the minimum thickness (2465 feet) is recorded in Umbarka-1x well (Metwalli and Elmaadaway).

FORMATION EVALUATION AND RESERVOIR PARAMETERS

AEB-D1 reservoir was subjected to a comprehensive formation evaluation process using two computer programs; namely Logpack (Metwally, 1999) and Landmark Geographix (2003). These systems were developed to perform a quantitative estimation for reservoirs in subsurface sequences using well log techniques. The formation was also evaluated with respect to oil potentialities through a number of litho-saturation crossplots, distribution and saturation maps including the iso-shaliness and iso-porosity maps, beside the water saturation and hydrocarbon saturation.

RESERVOIR ROCK EVALUATION

A number of Density-Neutron crossplots were made using a computer program for lithology identification of AEB-D1 reservoir (Fig.4-8). These crossplots reflect two types of sandstones; nearly clean sandstone as in Umbarka-10, Umbarka-12 and Umbarka-18 wells. The other wells have sandstones that can be considered as mixtures of the fore-mentioned types of sandstones.

A. VERTICAL DISTRIBUTION OF HYDROCARBON OCCURRENCES

Litho-Saturation Crossplots:

In order to illustrate the vertical distribution of rock constituents and hydrocarbon saturations, a number of litho-saturation crossplots were constructed (Fig. 9-12). These plots exhibit a number of continuous logs showing the variations inherited in rock materials and fluid contents against depth. Such variations include shale and sand percentages, as well as fluid contents effective porosity, and fluids saturations such as hydrocarbon and water saturations.

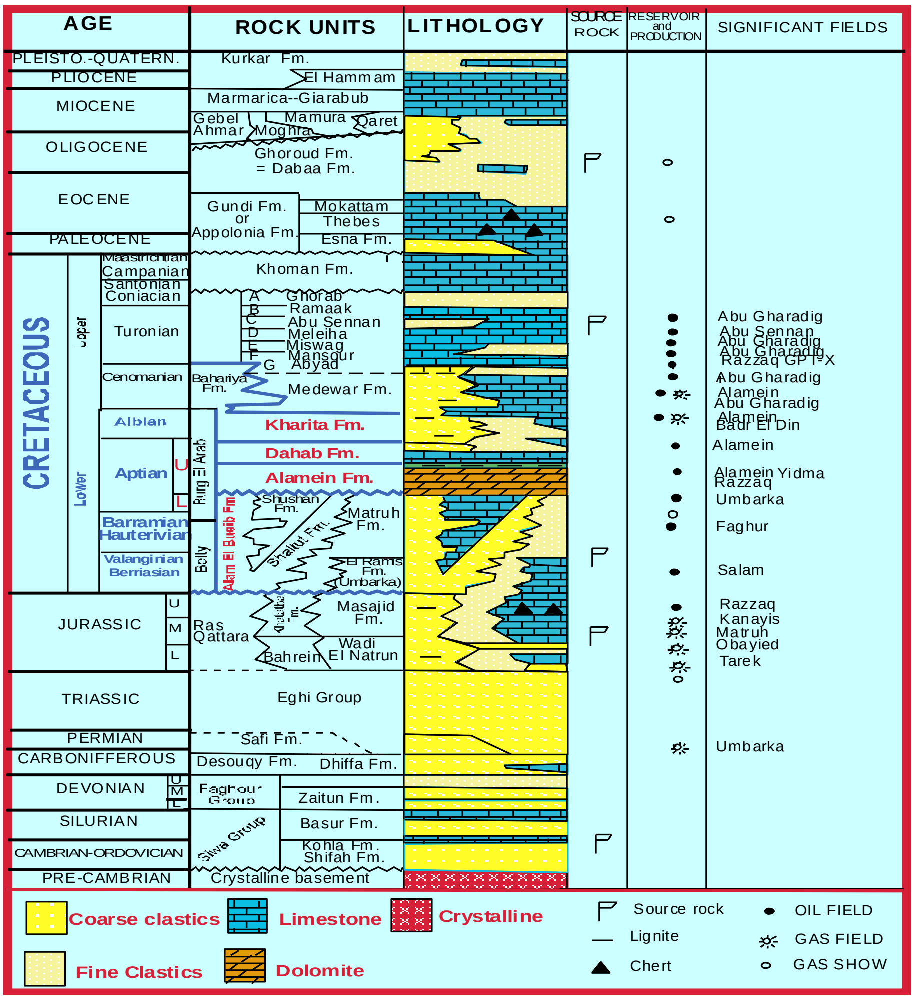

Fig. (3) Generlized lithostratigraphic column of the Northern Western Desert, (after Schlumberger 1995).

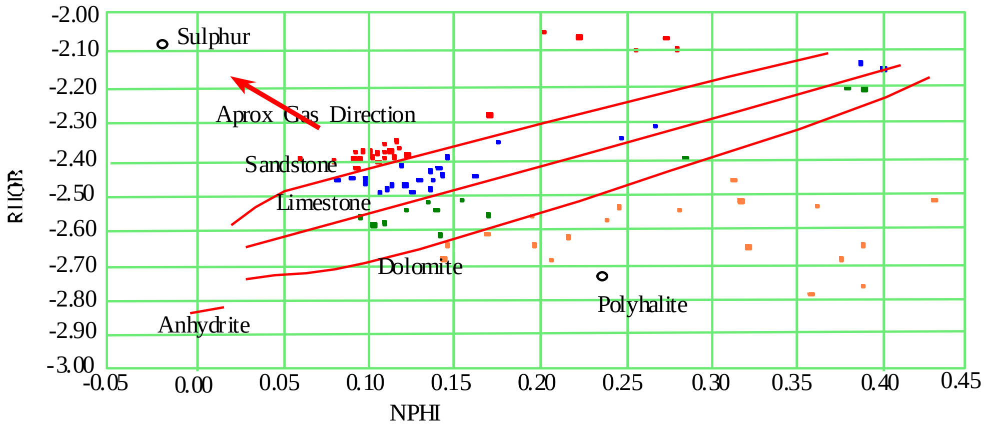

Fig. (4) Neutron (NPHI) -desity (RHOB) crossplot of Umbarka-11 well.

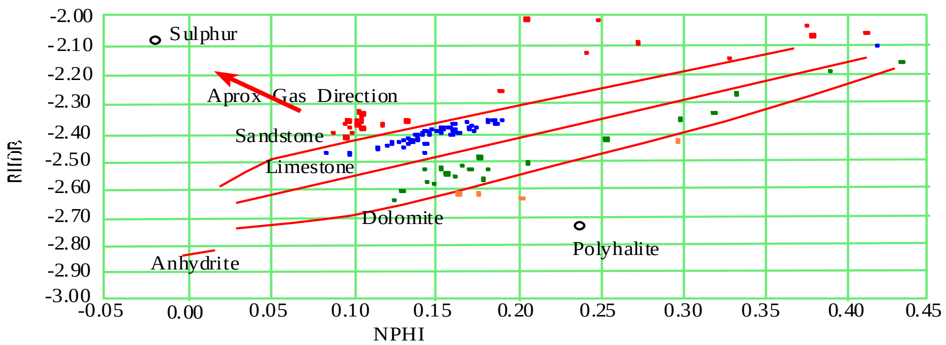

Fig. (5) Neutron (NPHI) - density (RHOB) crossplot of Umbarka-12 well.

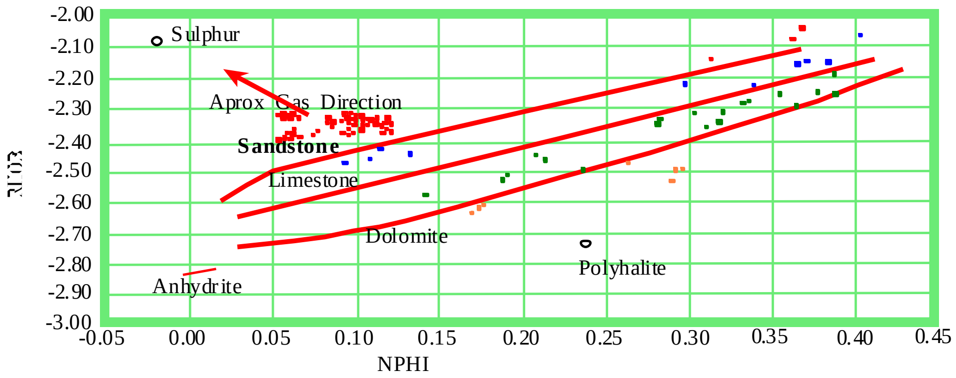

Fig. (6) Neutron (NPHI) - density (RHOB) crossplot of Umbarka-14 well.

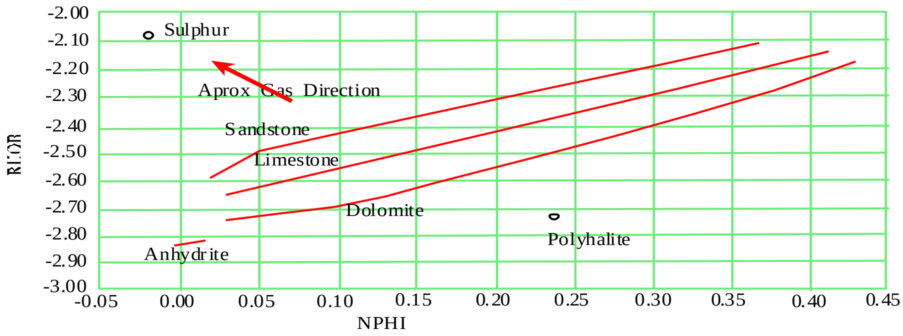

Fig. (7) Neutron (NPHI) - density (RHOB) crossplot of Umbarka-17 well.

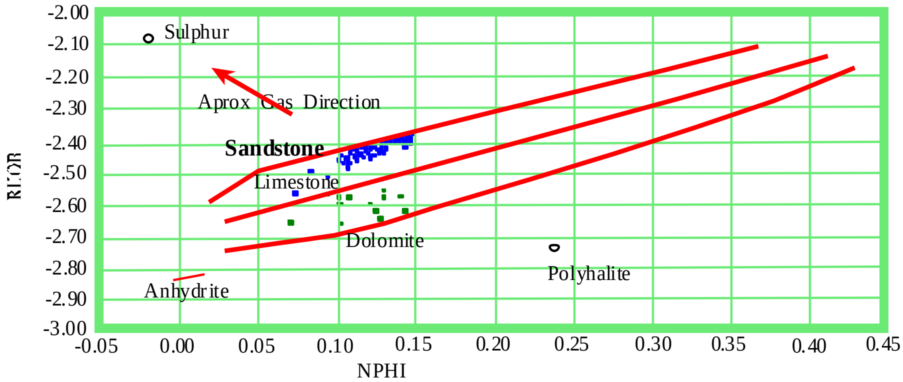

Fig. (8) Neutron (NPHI) - density (RHOB) crossplot of Umbarka-18 well

1- LITHO-SATURATION CROSSPLOT OF UMBARKA-10 WELL

This well is located in the eastern part of the area. A litho-saturation crossplot and log data display for the interval from 10623 to 10720 ft. are exhibited in Figure (9). The sandstone in this interval is intercalated with shale ranging from zero to 57%. The lithologic components can be considered of shallow marine depositional conditions, allowing a good source of reservoir affinity for AEB-D1 in the study area.

The calculated effective porosity of such litho-saturation crossplot is considered for the overall section. It ranges from 1% to 25% with a weighted value of 23%. Such porosity level may store economic quantities of hydrocarbons. In the middle and the lower parts of the intervals, remaining amounts of movable and residual hydrocarbons are detected, while they decrease in the upper part of the interval, in which water is predominant.

2- LITHO-SATURATION CROSSPLOT OF UMBARKA-11 WELL

This well is located in the southern part of the area (Fig. 10). It represents the litho-saturation crossplot for the interval from 10640 to 10740 ft. The sandstones of this interval are intercalated with shale, that range from zero to 63%. Shale occupies the upper and lower parts of this interval. Such variations in lithology give us a good chance for a good reservoir affinity to form in this interval of this well. The overall effective porosity of the rock section is good and ranges from 1% to 21%, with a weighted porosity of about 18%.

Movable and residual hydrocarbons are concentrated in the middle and lower parts, while they are decreased in the upper parts to become minor values, where water is predominant. This can be explained by the presence of the Oil Water Contact (OWC) in the upper part at 10660 ft.

3- LITHO-SATURATION CROSSPLOT OF UMBARKA-12 WELL

This well is located in the southwestern part of the area (Fig.11). It represents the litho-saturation crossplot and log data display for the interval from 10653 to 10749 ft. The sandstones of this interval are intercalacted with shale content ranging from zero to 63%. The shale content encountered in the middle and lower parts of this interval show high percentages. The effective porosity of such section ranges from 4% to 24%, with a weighted value of 22%.

Movable and residual hydrocarbons are mostly concentrated in the upper and lower parts of this interval, while they decrease in the middle part to become minor values. OWC is located in this interval at a depth of 10692 ft.

4- LITHO-SATURATION CROSSPLOT OF UMBARKA-14 WELL

The litho-saturation crossplot of Umbarka-14 well for the interval from 10523 ft to 10710 ft. is shown in Figure (12). Sandstones of this interval are nearly clean in most parts, especially in the middle part, while the shale content increases in the uppermost and lowermost parts.

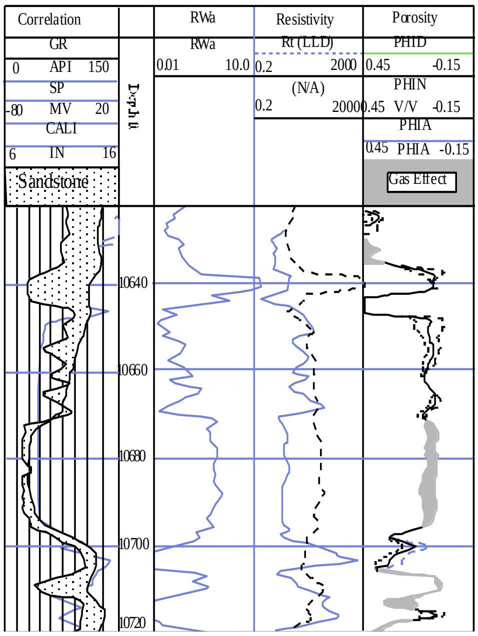

Fig. (9) Litho-saturation crossplot of Umbarka-10 well.

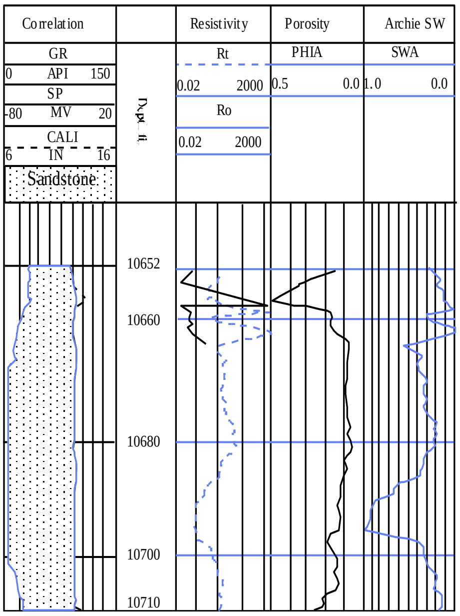

Fig.(10) litho-saturation crossplot of Umbarka-12 well.

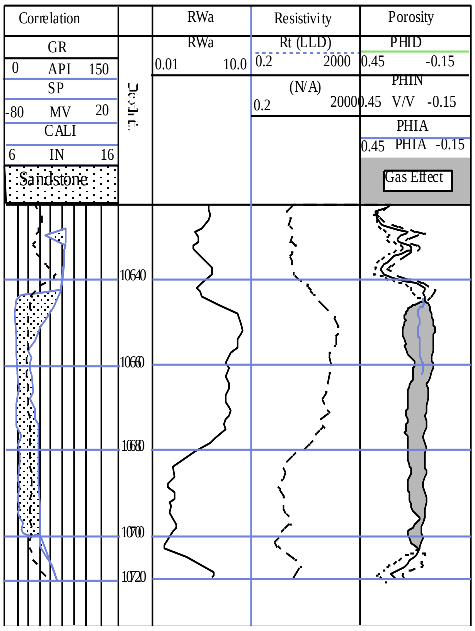

Fig. (11) Litho-saturation crossplot of Umbarka-14 well.

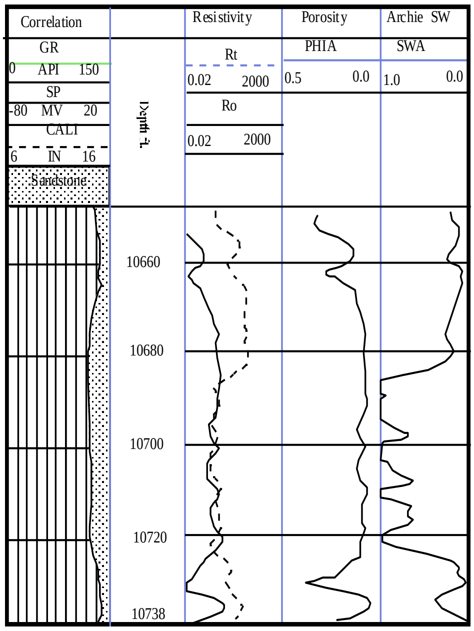

Fig. (12) Litho-saturation crossplot of Umbarka-17 well.

The effective porosity of this interval ranges from 8% to 40%. It increases in the upper part and decreases in the lower part, through most of the interval, except for the uppermost and lowermost parts, where the effective porosity is about 22%. Opposite the same interval, the resistivity is high and the water saturation is low. From all the above, the Alam El Bueib-D1 is a good reservoir, that contains hydrocarbons and could be oil producer in this well.

From the above, it can be concluded that, the vertical distribution in the litho-saturation crossplots (volumetric analysis) indicates the change of lithological composition, water saturation and residual and movable hydrocarbons with the effective porosity in conjunction.

B. LATERAL VARIATIONS OF HYDROCARBON PLAYS

The lateral variations of hydrocarbons can be studied through a number of shaliness, effective porosity and saturation maps. These maps utilize the important effect of some petrophysical parameters such as shale content, effective porosity, water saturation and hydrocarbon saturation. The study of these parameters in the available maps is very essential for judging their lateral variations and the factors controlling their changes.

ISO-PARAMETRIC MAPS OF ALAM EL BUEIB-10 RESERVOIR

Mapping of the reservoir thickness and its petrophysical parameters was carried out, using the well data (Table 1).

1- ISO-SHALINESS MAP

The iso-shaliness map (Fig. 13) shows a general increase in shale content toward the middle part. It reaches zero at Umbarka-18 and Ubarka-19 wells to the northeast and Khepri-9 well to the southwest. It increases toward the middle part, where it reaches 68% at Umbarka-15 well.

2- ISO-EFFECTIVE POROSITY MAP

The iso-effective porosity map (Fig. 14) exhibits an increase of porosity toward the southwestern parts of the area, with the exception of Umbarka-17 well, which has the lowest value of effective porosity (13%). Porosity increases toward the northeastern part of the area, where NE Umbarka-1x well is located with a maximum value of 24%. Porosity decreases toward the central part of the area.

3- WATER SATURATION MAP

The water saturation map of Alam El Bueib-D1 reservoir (Fig.15) reveals a pattern of values largely affected by the porosity distribution, but is not affected by the shale content distribution. The water saturation increases toward the central and northeastern parts of the field. The water saturation values range from 14% in Umbarka-14 well to 39% in Umbarka-18 well.

4- HYDROCARBON COLUMN MAP

The hydrocarbon column map (Fig. 16) shows an increase of hydrocarbon column from 11% to 22% towards the central and southwestern parts of Umbark oilfield. It shows a maximum value at Umbarka-10 well.

5- NET PAY MAP

The net pay map (Fig. 17) illustrates the net pay thicknesses with Alam El Bueib-D1 reservoir. The thickness varies from 11 ft in Umbarka-18 well to 56 ft in Umbarka-12 well, with an increase toward the southeastern part of the study area.

The above comprehensive study on Alam El Bueib D1 sand in six wells of Umbarka oil field, using well log analysis techniques has revealed that, the Alam El Bueib-D1 remains as the main reservoir in the area of study and it has a promising oil potentiality. Further activity in the study area is recommended for AEB sand to the west, in the up-dip direction. The studied wells show good petrophysical parameters across the field.

Table (1) Weighted reservoir parameters of AEB-D1 Member through Umbarka oil field.

Well name	**Interval ft (KB)**	**Net Pay (ft.)**	**Ave. Porosity**	**Ave. S_W**	**H.C. Column**	**Ave. Vsh**
Umbarka-10	10632-10720	38	23%	19%	22%	8%
Umbarka-11	10640-10740	46	18%	20%	11.70%	4%
Umbarka-12	10653-10720	56	22%	17%	11.80%	7%
Umbarka-14	10622-10710	47	18%	14%	11.95%	5%
Umbarka-17	10649-10737	37	13%	21%	6.67%	6%
Umbarka-18	10700-10771	11	14%	39%	10.04%	10%
NE Umbarka-1x	10580-10991	55	24%	39%	7%	7%

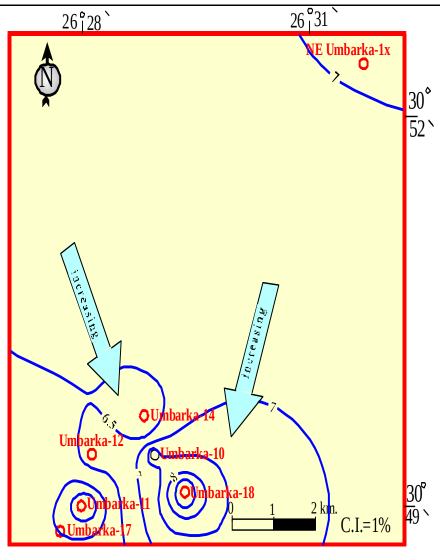

Fig. (13) Iso-shaliness map of AEB-D1 Member

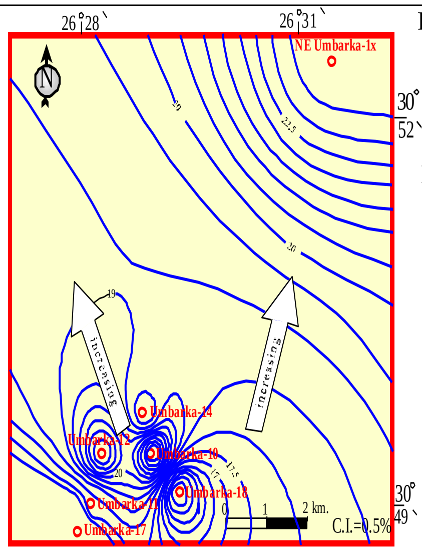

Fig. (14) Iso-porosity map of AEB-D1 Member.

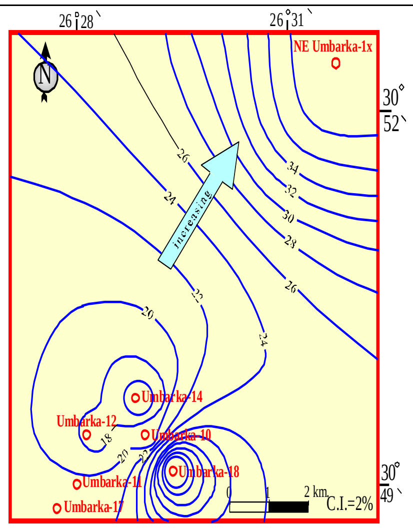

Fig.(15) Water saturation map of AEB-D1 Member.

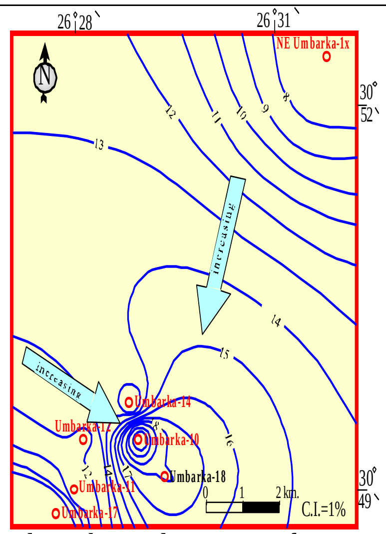

Fig. (16) Hydrocarbon column map of AEB-D1Member.

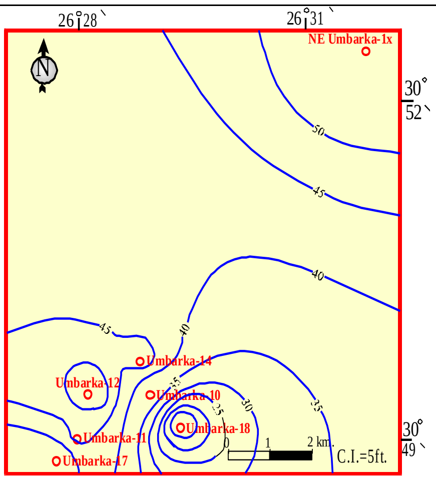

Fig. (17) Net pay map of Alam El Bueib D1 Member.

PETROGRAPHIC ANALYSIS

Core samples are available for the Alam El Bueib (D1) rock unit in NE Umbarka-1x and Umbarka-11 wells. Seven core samples are available, five samples in Umbarka-11 well and two samples occur in North East Umbarka-1x well. Alam El Bueib (D1) is considered a reservoir rock in Umbarka, which is composed mainly of sandstones. Core samples were analyzed by polarizing microscope and Scanning Electron Microscope (SEM). The thin sections were prepared from conventional cores and cut normal to bedding, and stained with blue dye for porosity illustration, causing the pores to have blue colour.

The main framework of sandstones grains are entirely made up of quartz (quartz-arennite), in which quartz grains make more than 95% of the grains. Quartz grains are mainly monocrystalline with few polycrystalline as shown in Plate 1-A of Umbarka-11 well at depth of 10686 ft. Roundness, generally ranges from subrounded to rounded in all samples. The extinction of quartz grains is mainly uniform with few undulose or wavy. The boundaries between quartz grains are mainly straight, concave-convex and sutured contacts presented by both (Plate 1-B) in North East Umbarka-1x at depth of 10592 ft. sorted. The feldspar framework grains are not recorded in the investigated thin section. Friis (1987) mentioned that, the most important changes in feldspar framework grains are dissolution, replacement by kaolinite or carbonates, and diagenetic growth. He also mentioned that, it is not possible to estimate how many feldspar grains have been totally dissolved. Oversize pores occur, either open or filled with authogenic kaolinite. They probably originate from the dissolution of feldspar. Rock fragments in the investigated thin sections constitute only few grains of the framework detritals. Several types of cement are present in pores between the grains in quartz-arenite facies.

DIAGENESIS

In general, the principal processes are compaction and pressure solution, silica and calcite cementation, clay mineral and feldspar authogenesis and the formation of hematite coatings (Larsen & Chilingar, 1979). Cementation is the occlusion of the intergranular volume by the precipitation of authogenic minerals, with no directly related reduction of bulk volume. Cementation always results in the reduction of the intergranular porosity (Housekencht 1987). Generally, cement is a crystalline substance, which is precipitated within the pores of sediment after their deposition (Selley, 1982). The net effect of these cements is to decrease or completely destroy porosity and permeability.

1- QUARTZ OVERGROWTH

Authogenic quartz occurs as optically uncontinuous overgrowths on detrital grains. Those quartz grains and their overgrowths are corroded, shown in North Esat Umbarka-1x well at depth of 10592 ft. (Plate 1-D). The quartz overgrowth not only appears with a dust rim, but also appears as well developed edges (euhedral faces) of quartz grains in Umbarka-11 well at a depth ranged from 10686 to 10688 ft. (Plate 1-E). The sources of the silica for cementation have been frequently attributed to pressure solution, that the pore solution becomes enriched in silica, which is then reprecipitated as overgrowth.

2- CLAY MINERALS AUTHIGENESIS

Authogenic clay minerals occur as pore-filling cements and clay rims around grains. The precipitation of clay rims is usually early or on the first diagenetic event, often predating quartz overgrowth or calcite cementation. Kaolinite identification is based on thin sections and SEM data. It occurs within pores between grains either as pore filling in Umbarka-11 well at depth from 10667.5 to 10668.5 ft. that shown in plate (1F) or arranged in booklets at the same well and same depth (Plate 2A & B).

The precipitation of even small amount of clay in sandstone can have a great effect on permeability and other properties of the rock and may reduce its reservoir potential (Wilson and Pitman, 1977). Montimorillonite, for example has the worst effect because its lattice structure can absorb water, expand and destroy permeability. Illte is the next most destructive clay, which tends to form fibrous crystals, that grow radially from the sand grain. Kaolin by contrast grows as discrete crystals, which, though they may diminish porosity by the same amount as illite, it is far less destructive of permeability. Thus it is important to predict the distribution of authogenetic kaolin and illite.

Kaolinite is irregularly distributed with variable amounts. It may occur densely in the pores as replacive kaolinite. This case is recorded in one sample of Umbarka-11 well in the thin sandy intercalations within siltstone. In this part of the rock unit, the replacement of framework grains are common and in general, the nature of original framework grain is not known in all samples as no relics occur to indicate the original grains, Chlorite and illite cements are defined only by SEM data, uncommon and irregularly distributed, that occur as pore filling in Umbarka-11 well, at depth of 10688 ft. (Plate 2C) and in North East Umbarka-1x well, at depth of 10592 ft. (Plate 2D).

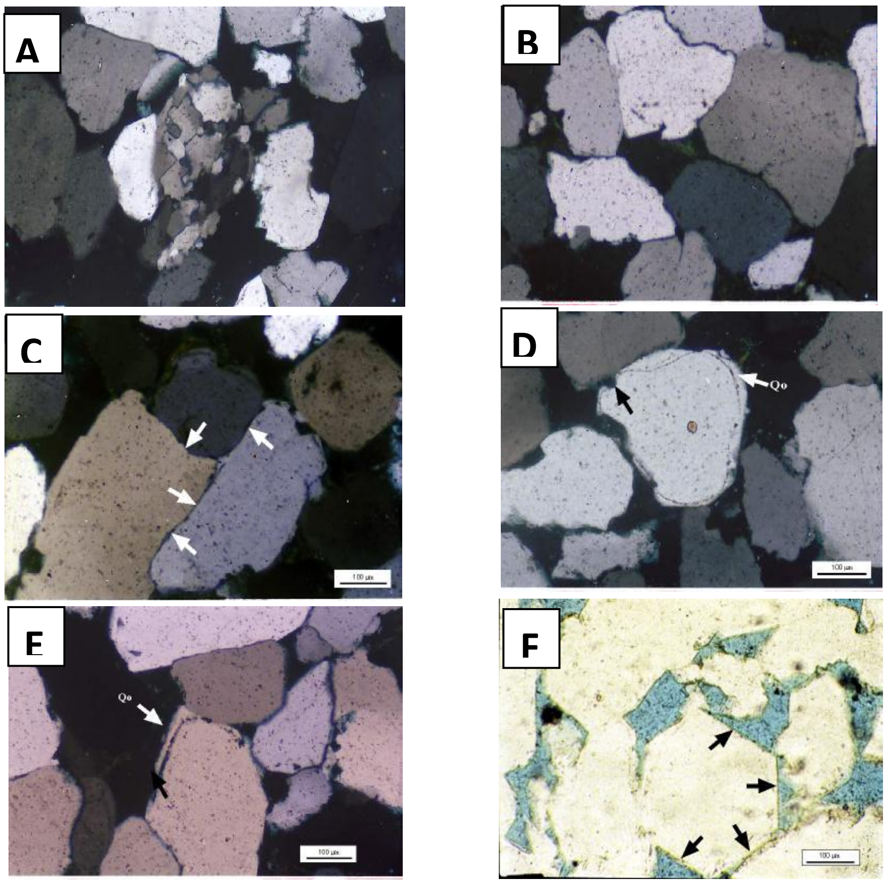

Plate 1: A Photomicrograph (C.N.) showing polycrystalline quartz grain in Umbarka-11 well (depth 10686-10688 ft.). **B** Photomicrograph (C.N.) showing sutured (black arrow), straight and concave-convex contacts (white arrows) between quartz grains. North East-Umbarka-1x well (depth 10592 ft.). **C** Photomicrograph (C.N.) showing straight and concave-convex contacts, Umbarka-11 well (depth 10686-10688 ft.). **D** Photomicrograph (C. N.) showing quartz overgrowth (Qo) with dust rim around the detrital grain. North East-Umbarka-1x well (depth 10592 ft.). **E** Photomicrograph (C. N.) showing corrosion of quartz overgrowth (Qo) and edges of the quartz grain (black arrow). North East-Umbarka-1x well (depth 10592 ft.). **F** Photomicrograph (C. N.) showing euhedral syntaxial quartz overgrowth (arrowed) and oversized pores (blue color). Umbarka-11 well (depth 10686-10688 ft.).

3- CARBONATE CEMENT

Calcite is one of the most common cements in sandstone. Other carbonate cements of more local importance are dolomite and siderite. The two main types of calcite cement are poikilotopic crystals and drusy calcite spars. Poikilotopic crystals are large single crystals, which envelop many sand grains. Drusy calcite is mosaics of quaint crystals, which fill the pores between grains. Quartz grains cemented by calcite are commonly corroded. Calcite cements are common in grain-supported sandstones, such as quartz arenites, arkoses and litharenites. The early precipitation of calcite inhibits later quartz overgrowth formation and feldspar alteration to clays, but it can result in total loss of porosity and permeability (Tucker, 1985). Carbonate cement is found as relics recorded in one sample as pore filling in Umbarka-11 well, at depth ranged from 10667.5 to 10668.5 ft. and it is defined only by SEM, as calcite in the same well at the same depth (Plate 2-E).

4- ANHYDRITE CEMENT

Anhydrite cement is recorded only in the samples of North East Umbarka-1x well. It forms poikilotopic patches with replacement features affecting the margins of the enclosed quartz grains. This is indicated by the common occurrence of corroded edges of quartz grains. Quartz grains embedded in the anhydrite cement don't show overgrowth, as recorded in Umbarka-11 well at a depth of 10592 ft. (Plate 2F).

5- IRON OXIDE CEMENT

Iron oxide cement is recorded as brownish red patches as pore filling that is not common in all samples, as shown in Umbarka-11 well at a depth ranged from 10676 to 10677 ft (Plate 3A).

6- COMPACTION

Mechanical compaction is the bulk volume reduction resulting from processes other than framework grain dissolution, as produced by lithostatic stress. It is characterized by the reorientation and repacking of grains. Chemical compaction is the bulk volume reduction caused by the dissolution of framework grains at the points of contacts, that leads to intergranular pressure solution, as indicated by straight, concave-convex and suture contacts, which is recorded in NE Umbarka-1x well at a depth of 10592 ft (Plate 3B) and in Umbarka-11 well at a depth interval ranged from 10686 ft.

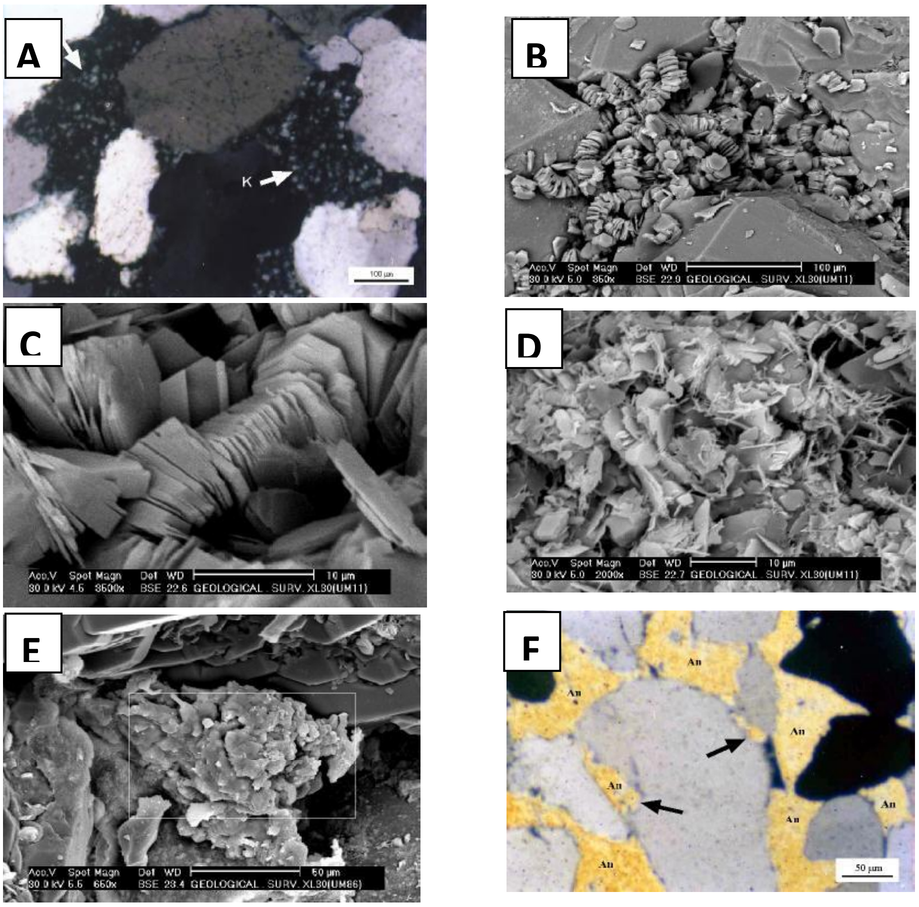

Plate 2: **A** Photomicrograph (C. N.) showing kaolinite cement aggregate (K) filling the pores between grains. Umbarka-11 well (depth 10667.5-10668.5 ft.). **B** SEM photomicrograph showing kaolinite cement as pore filling between quartz grains. Umbarka-11 well (depth 10667.5-10668.5 ft.). **C** SEM photomicrograph showing booklets habit of kaolinite. Umbarka-11 well (depth 10667.5-10668.5 ft.). **D** SEM photomicrograph showing chlorite cement. Umbarka-11 well (depth 10686-10688 ft.) **E** SEM photomicrograph showing calcite cement (light gray in rectangular). Umbarka-11 well (depth 10667.5-10668.5 ft.). **F** Photomicrograph (C. N.) showing poikilotopic anhydrite cement (An) replaces the margins of the enclosed quartz grains (arrowed). North East-Umbarka-1x well (depth 10592 ft.).

7- POROSITY

Through the investigated thin sections, the porosity is appearing as a blue color between grains and pores. It may be connected through narrow constrictions, as shown in Plate (3-C) in Umbarka-11 well at a depth interval ranged from 10686 ft., where the thin section porosity varies from 7% to 13%. SEM data also show porosity as dark caves between quartz grains in NE Umbarka-1x well at a depth of 10592 ft (Plate 3-D).

As demonstrated by Priisholm (1983), there is a steady decline in the average porosity with depth. According to Priisholm and Christensen (1985), the expected porosity decreases from about 40% at the surface conditions to about 8% at a depth of 3500m. decreasing 9% per 1000m. At a depth of less than 1500 ms., the cementation is generally insignificant, and the average porosity decreases with depth, partly explained by simple mechanical compaction in the immature stage of the mesodiagenesis as defined by Schmidt and McDonald (1979). There may be an important formation of secondary porosity also in these shallow parts, due to the dissolution of detrital feldspar.

Three important diagenetic processes modify the intergranular porosity to mechanical compaction, chemical compaction and cementation. The generation of hydrocarbons takes place during deeper burial (1.5-3 km) depth, that leads to the formation of acidic pore waters, which are able to leach grains and carbonate cements, producing secondary porosity (Surdam and Crossey 1985) The secondary porosity produced by dissolution of feldspars is still open and may represent a major part of the total porosity, but it may also be partly filled by later cement. This cement may invade the intergranular porosity marginally, as seen with quartz cement.

DIAGENETIC SEQUENCES

The relative timing of diagenetic events in sandstones is important in terms of the introduction of hydrocarbon. If sandstones porosity is occluded by early cementation, then it cannot act as an oil reservoir. Diagenetic processes take place in an aqueous medium so that the influx of oil terminates diagenesis and prevents further reactions (Hancok and Taylor, 1987).

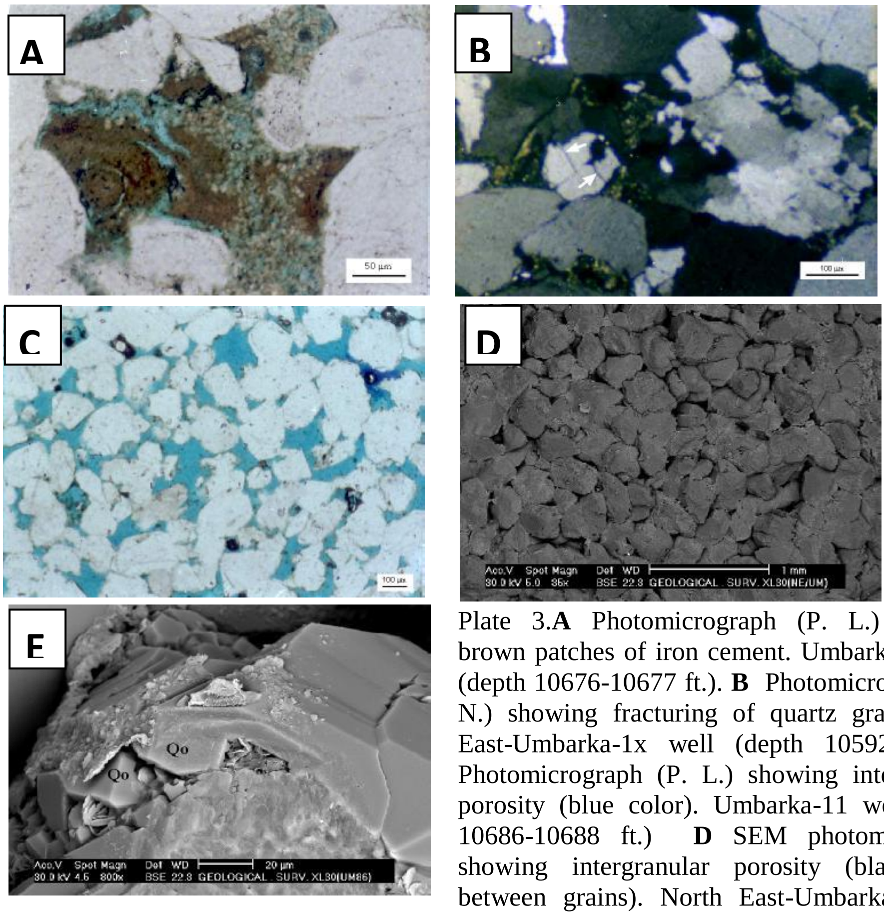

Plate 3.**A** Photomicrograph (P. L.) showing brown patches of iron cement. Umbarka-11 well (depth 10676-10677 ft.). **B** Photomicrograph (C. N.) showing fracturing of quartz grain. North East-Umbarka-1x well (depth 10592 ft.). **C** Photomicrograph (P. L.) showing intergranular porosity (blue color). Umbarka-11 well (depth 10686-10688 ft.) **D** SEM photomicrograph showing intergranular porosity (black color between grains). North East-Umbarka-1x well (depth 10592 ft.). **E** SEM photomicrograph showing quartz overgrowth (Qo) around the quartz grain separating from it by clay minerals. Umbarka-11 well (depth 10686-10688 ft.)

Based on textural relationships, the relative timing of the main diagenetic features has been reconstructed. The reservoir properties are controlled by several key diagenetic modifications, that have occurred at or near the surface conditions (eodiagenesis) and during burial (mesodiagenesis). These diagenetic regimes are those adopted by Schmidt and McDonald, 1979. They mentioned also that, there are indications of dissolution of carbonate cement and grains, as well as of feldspar grains during late diagenesis as indicated by irregularly distributed relics of cement, large pores caused by selective dissolution of particles, dissolution of feldspar grains, and fracturing of sand grains caused by punctual transfer of pressure after decementation. All these fabrics are observed only in sequences rich in hydrocarbons, that occur at depths of more than 2500-3000m.

In general, the studied rock unit belongs to the mesodiagenesis phase (late burial) of mature stage, according to the description by Schmidt and McDonald (1979). This is indicated by large pores caused by selective dissolution of particles, dissolution of feldspar grains, fracturing of sand grains, as shown in NE Umbarka-1x well at a depth of 10592 ft (Plate 3-E) and irregularly distributed relics of cement, such as carbonate and iron. The relative timing of the most diagenetic features has not been well reconstructed because of the lack of samples of different lithofacies from the upper intervals, which may represent immature or semimature stages. According to the available samples, some diagenetic events can be reconstructed. Thin sections and SEM data show that, quartz is commonly seen growing over the authogenic clays, that are represented by dust line (Plate 1-C & D) and it may be illite and kaolinite, as shown by SEM in Umbarka-11 well at the depth interval ranged from 10686 to 10688 ft. This relation demonstrates that the quartz growth phase occurred after the formation of clay authogenesis. Quartz overgrowth may have also occurred prior to kaolinite formation, as indicated by quartz overgrowth and represented by euhedral faces without dust line (Plate 1F).

The main compaction of the sediment occurred prior to the dissolution of the framework grain. Oversize pores occur, either open or filled with authogenic kaolinite. It probably originates from the dissolution of feldspar, which took place after the main compaction. Also, the formation of authogenic kaolinite occurred after the main compactional event, so that the relation between kaolinite and feldspar dissolution is not known, as no relics of feldspar grain or its fragile skeletons occurred.

Pressure solution is an important mechanism for porosity reduction at depths of the semimature and mature stages of mesodiagenesis (Schmidt and McDonald, 1979). Fuchtbaur (1974) suggested that, because of the very low solubility of silica, repreicipitatation of silica would occur simultaneously with pressure solution of quartz, but Nielson and Friis (1987) mentioned that, this is not always the case. Fuchtbaur (1974) suggested that, the effect of pressure solution has been the way to further compaction for the sandstone. During this compaction, the protective clays were partly removed, exposing the detrital quartz grains to the pore fluid, forming overgrowths.

Anhydrite cement recorded in the samples of NE Umbarka-1x well, occurs as patches. It is distributed irregularly filling entirely some pores. Textural relations show that, anhydrite has replaced quartz marginally, as well as between detrital grains and overgrowth (Plate 2F), as defined by Fuchtbaur (1982). This implies that, anhydrite cement took place after grain dissolution or the main compactional event.

CONCLUSIONS

The analysis of well logging data belonging to AEB-D1 sand reservoir from seven wells scattered in the concerned area has been achieved and accordingly an important conclusion has been arrived. This can be summarized, as that the best reservoir characteristics are detected in the southern western part of the concerned area where it has high porosity, low water saturation, low shale volume content and highest hydrocarbon saturation.

The petrographic analysis indicates that, the main framework grains of the AEB-D1 sandstone are entirely made up of quartz (quartz arenite). Quartz grains are mainly monocrystalline with few polycrystalline. Roundness generally ranges from subrounded to rounded in all samples. The extinction of the quartz grains in mainly uniform with few undulose.

Authogenic minerals of the AEB-D1 sandstone are the quartz overgrowth, which appears with a dust rim. Also, it appears as well developed edges (euhedral faces) of quartz grains. Kaolinite identification is based on thin sections and SEM data. It occurs within pores between grains, as pore filling arranged in booklets. Kaolinite is irregularly distributed with variable amounts. It may occur densely in the pores as replacive Kaolinite. The nature of original framework grain is not known in all samples, as no relics occur to indicate the original grains. Chlorite and illite cements are defined only by SEM data, which are uncommon and irregularly distributed to occur as pore filling. Carbonate cement occurs as relics, which was recorded in one sample of Umbarka-11 well as pore filling. Carbonate cement was defined only by SEM. It is calcite anhydrite cement that forms poikilotopic patches with replacement features affecting the margins of the enclosed quartz grains. This is indicated by common occurrence of corroded edges of quartz grains. Iron oxide cement is recorded as brownish red patches.

Mechanical compaction resulted in the reduction of intergranular volume and therefore, porosity. Chemical compaction is the bulk volume reduction caused by dissolution of framework grains at the points of contracts that lead to intergranular pressure solution, as indicated by straight, concave-convex and suture contacts.

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توصيف الخزان الرملى بمتكون علم البويب فى حقلى ام بركة وجنوب ام بركة للزيت، الصحراء الغربية ، مصر

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تهدف هذه الدراسة الى توصيف و تقييم **الخزان الرملى بمتكون علم البويب** (AEB-D1) **فى حقلى ام بركة و جنوب ام بركة للزيت** فى حوض شوشان شمال الصحراء الغربية بمصر للمنطقه الواقعه بين خطى عرض `٨ ٢٦˙ ، `٣٦ ٢٦˙ شرقا وخطى طول `٢٧ ٣٠˙ ، `٠٠ ٣٠˙ شمالا. بالاضافة الى تحديد الوضع التركيبى و دراسة السحنة الصخرية لعلم البويب (AEB-D1) والتى من المتوقع أن تمثل صخور مستودع تحتوى على الهيدروكربونات وحساب متوسط العناصر الكمية لتلك الوحدة وكذلك دراسة تأثير الخواص البتروفيزيائية على التنمية المستقبلية لمنطقة الدراسة.

وتم عمل دراسة بتروجرافية للعينات الأسطوانية لمتكون علم البويب(AEB-D1). المتاحة لبئرين لدراسة المسامية الأولية والثانوية والماده اللاحمة و تأثيراتها على الهيدروكربونات عن طريق عمل قطاعات رقيقة لدراستها تحت الميكروسكوب المستقطب وكذلك تصوير بعض العينات بالميكروسكوب الإليكترونى (SEM). واتضح من تلك الدراسة أن علم البويب(AEB-D1) عباره عن حجر رملى يتكون من كوارتز فقط فى كل القطاعات المدروسة وعلى ذلك فالوحدة الصخرية هى كوارتز أرينيت، والمواد الاحمة هى السيليكا التى توجد حول حبيبات الكوارتز، والكاولينيت الذى يوجد فى المسام بين حبيبات الكوارتز والأنهيدرايت وأكاسيد الحديد والمعادن الكربوناتية. توجد مسامية ثانوية جيده عن طريق ذوبان الفلسبار.

يشمل التقييم الكيفى و الكمى لتسجيلات الأبار لتحديد الخواص البتروفيزيائية لوحده صخرية لعلم البويب والتى تمثل صخور مستودع للهيدروكربونات فى منطقة الدراسة ويشمل التقييم تعيين المعاملات البتروفيزيائية المختلفة مثل محتوى الطفلة، المسامية، والتشبع بالماء والهيدروكربونات. وعن طريق رسم مجموعة من الخرائط لتلك المعاملات وجد أن الخزان جيد وتزداد كفاءتة ناحية الغرب والشمال الغربى.