IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 5, Issue 6 Ver. I (Nov. – Dec. 2017), PP 10-23
www.iosrjournals.org

Reservoir quality of Upper "G" Member sandstone of Abu Roash Formation, Azhar Field, Beni Suef basin, Nile Valley, Egypt.

Mohmed.I. ELAnbaawy[1], Ahmed T. Amin[2]and Osama A. Osman[3]
[1]*(Geology Department, Faculty of science/ Cairo University, Cairo, Egypt)*
[2]*(RPS management consultant, UK)*
[3]*(Qarun petroleum company (Apache J.V), Egypt)*

Abstract: *An integrationof the resultsofwell-logging and coreanalysis, seismic interpretation, and petrographic investigation including (thin sections and XRD investigation)was used to evaluatereservoir quality of upper unit of Abu Roash"G"Member sandstone in Azhar oil field, Beni Suef basin. Seismic data including constructing depth structure contour map indicated different kinds of faults around three-way dipping anticline closure that representing the structure hydrocarbon trap.It was found that wells which are located in structural high have better reservoir quality than those located in structural low. Six sedimentary cycles have been recognized within upper unit of Abu Roash"G" Member, however, the top zone of this unit is the main cycle which consists of sandstone reservoir represented by tidal channel and tidal flat lithofacies.Depositional and digenetic mineralogy indicated that the sandstone reservoir consists of quartz, feldspar and clay matrix with different types of cementation. The XRDanalysis of clay fraction revealed the dominance of well crystalline kaolinite with mixed layer illite-smectiteand chlorite. It is evident that diagenetic processes (e.g. cementation and dissolution) associated with depositional ones are controlling reservoir quality. On the basis of the petrophysical analysis, the upper"G" sandstone is interpreted as a good quality reservoir which has been confirmed by high effective porosity ranges from 15% to 18 % and high hydrocarbon saturation reaches up to 61 % in the study wells. Based on reservoir mapping it is evident that best petrophysical properties are encountered in northeastern part of the study area.*

Keywords:*Azhar oil field, Beni Suef basin, petrography, petrophysical analysis, reservoir quality*

Date of Submission: 04-12-2017 Date of acceptance: 19-12-2017

I. Introduction

Beni Suef basin including the study areais one of the newly introduced basins in the plan of future exploration for hydrocarbon potentialities in the Eastern Desert of Egypt,it is located along both banks of the Nile Valley, at about 150 km south of Cairo, Egypt (Fig. 1). Azhar oil field(the study area) is located to the west of the Nile River bounded by latitudes 29° 06'-29° 10' N and longitudes 30° 51'-30° 58' E in the west Beni-Suef concession area.

The basin itself is bisected by the major course of the River Nile into two provinces; west of Nile Province (WON) and east of Nile Province (EON), (Fig.1). Little has been published about reservoirs in the Beni Suef basin. Zahran (2011) pointed out that main reservoirs in Beni Suef basin are Kharita, Bahariya formations, and Abu Roash (G, A) members.Production tests were performed on anupper unit of Abu Roash"G" memberalmost in all wells of Azhar oil field with good and acceptable production rates.

Reservoir quality represented by porosity and permeability are critical parameters for petroleum exploration and production. The evolution of porosity in clastic units, whether they are sandstone, siltstone or mudstone, results from the interplay of depositional and diagenetic processes. At the time of deposition, mud has up to 70% porosity while sand has up to about 45% porosity (Worden and Burley, 2003). Over time this depositionalporosity is lost due to the combined diagenetic processes of compaction and cementation. The permeability of a rock depends on its effective porosity, consequently, it is affected by the rock grain size distribution (sorting), grain packing, and the degree of consolidation and cementation. The type and texture of clay setting cementing material between sand grains also affects permeability. The success of many hydrocarbon exploration efforts depends mainly on finding reservoirs with sufficient porosity and permeability to support viable commercial development (Taylor et al., 2010). The main purpose of this study is toidentify reservoir quality of upper unit of Abu Roash "G" Member sandstonein Azhar oil field in terms of its petrographic, diagenetic and petrophysical characteristics. The petrographic characteristics is one of theimportant factors that affect reservoir quality (porosity and permeability of reservoir) because it is used for lithology determination, matrix types, grain size, sorting, identification of primary minerals, type of cementation and oil shows.

Diagenesis results in complete inversion of reservoir characteristics,lithologies that initially had excellent reservoir properties, such as high intergranular porosity and high permeability can be decreased through compaction and cementation.The main target of well logging is to evaluate the hydrocarbon potentiality of reservoir units.It has been used in exploration and development wells as a part of drilling practice, to provide more information about accuracy of reserve evaluation, well logging successfullyis used to recognize the effective productive zones, their porosity, determine depth, and thickness of these zones to discriminate between oil, gas or water reservoirs and consequently determine reservoir quality of sandstone reservoirs.

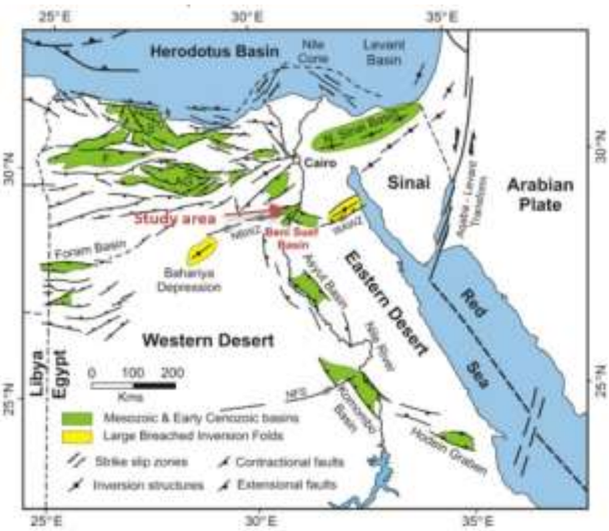
II. Geologic setting

2.1 Stratigraphic setting.

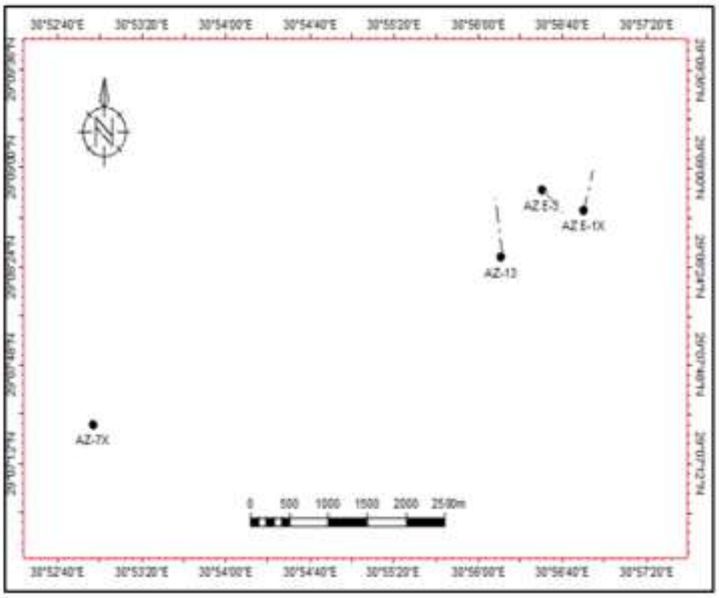
The lithostratigraphic units of Azhar oil field range in age from Cretaceous (Albian) to Cenozoic (Oligocene) (Fig.3). These units are named from base to top as; Kharita Formation (Albian), Bahariya Formation (Early Cenomanian), Abu Roash Formation (Late Cenomanian- Santonian), Khoman Formation (Campanian–Maastrichtian), Apollonia Formation (Early to Middle Eocene) and Dabaa Formation (Late Eocene to Oligocene). This stratigraphic succession rests nonconformably over the Precambrian igneous and metamorphic rocks whereas some parts of Apollonia Formation and Dabaa Formation form the exposed rolling land-surface in the study area. The Abu Roash Formation has been divided by Norton (1967) into seven informal units named from "A" to "G". Units "B", "D", "F" are clean carbonates, while units "A", "C", "E", "G" contain variable amounts of detrital materials.

Abu Roash"G" Member represents the main reservoir in Azhar oil field whereit characterizes by an apparent thickness about 900 feet. It is subdivided into three units (upper, middle and lower). Upper and lower units consist of carbonate, mudrock and sandstone lithofacies while middle unit consists of carbonate and mudrock lithofacies with no sandstone lithofacies.

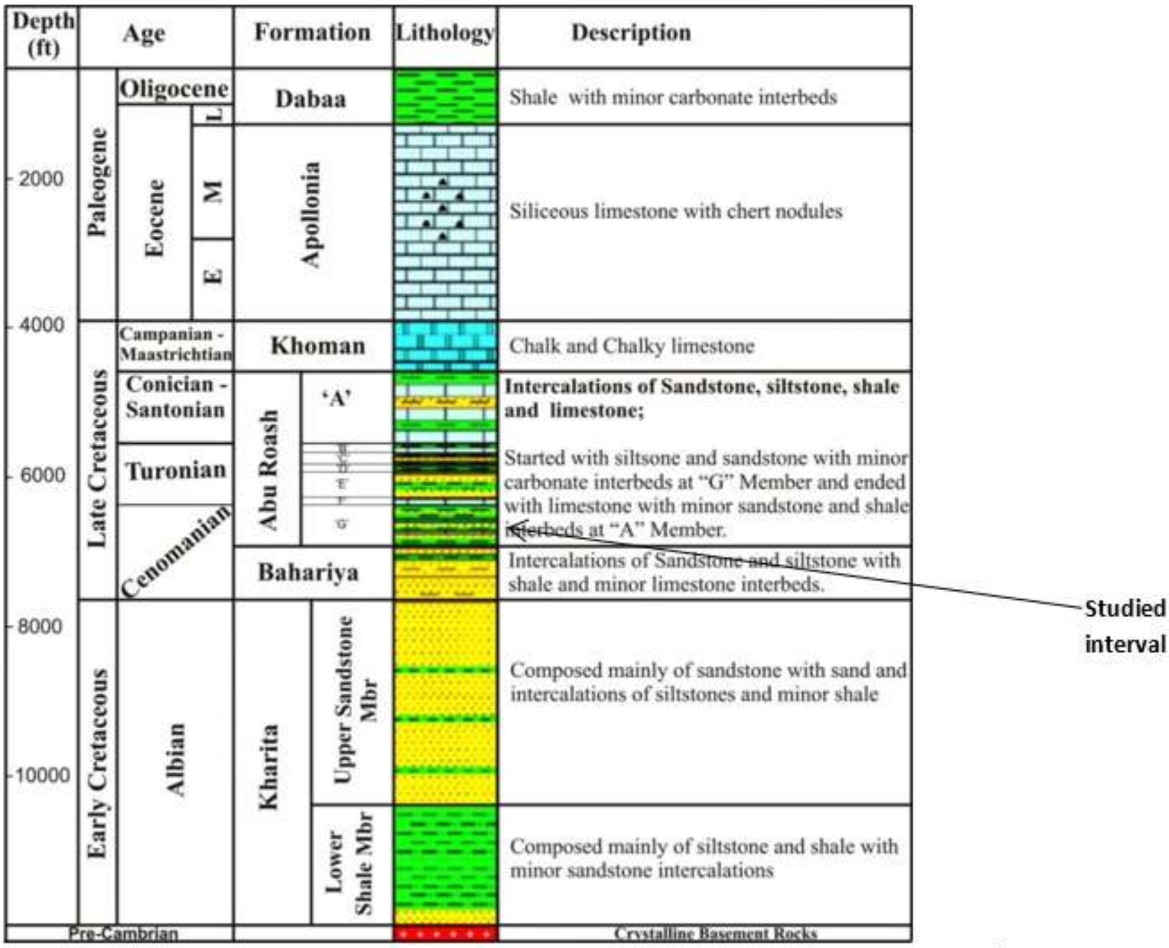
Upper unit Abu Roash "G" Member isfurther subdivided into several sedimentary cycles based on lithological interpretation of different well log response and careful correlation between the wells into (UG1, UG2, UG3, UG4, UG5, UG6,), however UG5 is the main cycle because it is the only cycle that consists of sandstone reservoir lithofacies. For comparative study between upper "G" member sandstone in the studied wells, the stratigraphic correlation chart was constructed (Fig. 4). The UG5 cycle in Azhar E-3 well characterizes by different sedimentary structures from base to top, as lenticular and wavy bedding of sandy siltstone lithofacies to flaser bedding, mud drapes, massive and inclined cross-bedding of sandstone lithofacies which reflects a high energy setting in very small thickness (about 15 feet). According to these sedimentary structures from core description, distribution, the thickness of sandstone and grain size trend from gamma-ray log, UG5 cycle can be interpreted as tidal flat sediments (sandstone lithofacies as tidalsand flat and sandy siltstone lithofacies as tidal mud flat). Based on gamma-ray response UG5 cycle is coarsening upward bell-shaped in the 3 wells (Azhar E-3, Azhar-7x, Azhar-13) which indicates that sandstone lithofacies in these wells are tidalsand flat, Azhar E-1X well characterizes by different gamma-ray response with abrupt change from shale to coarse sandstone then fining upwards to argillaceous sandstone and sandy siltstone lithofacies. Azhar E-1X UG5 cycle can be interpreted as subtidal channel lithofacies prograded by the mixed tidal(argillaceous sandstone)flat and tidal mud flat lithofacies.



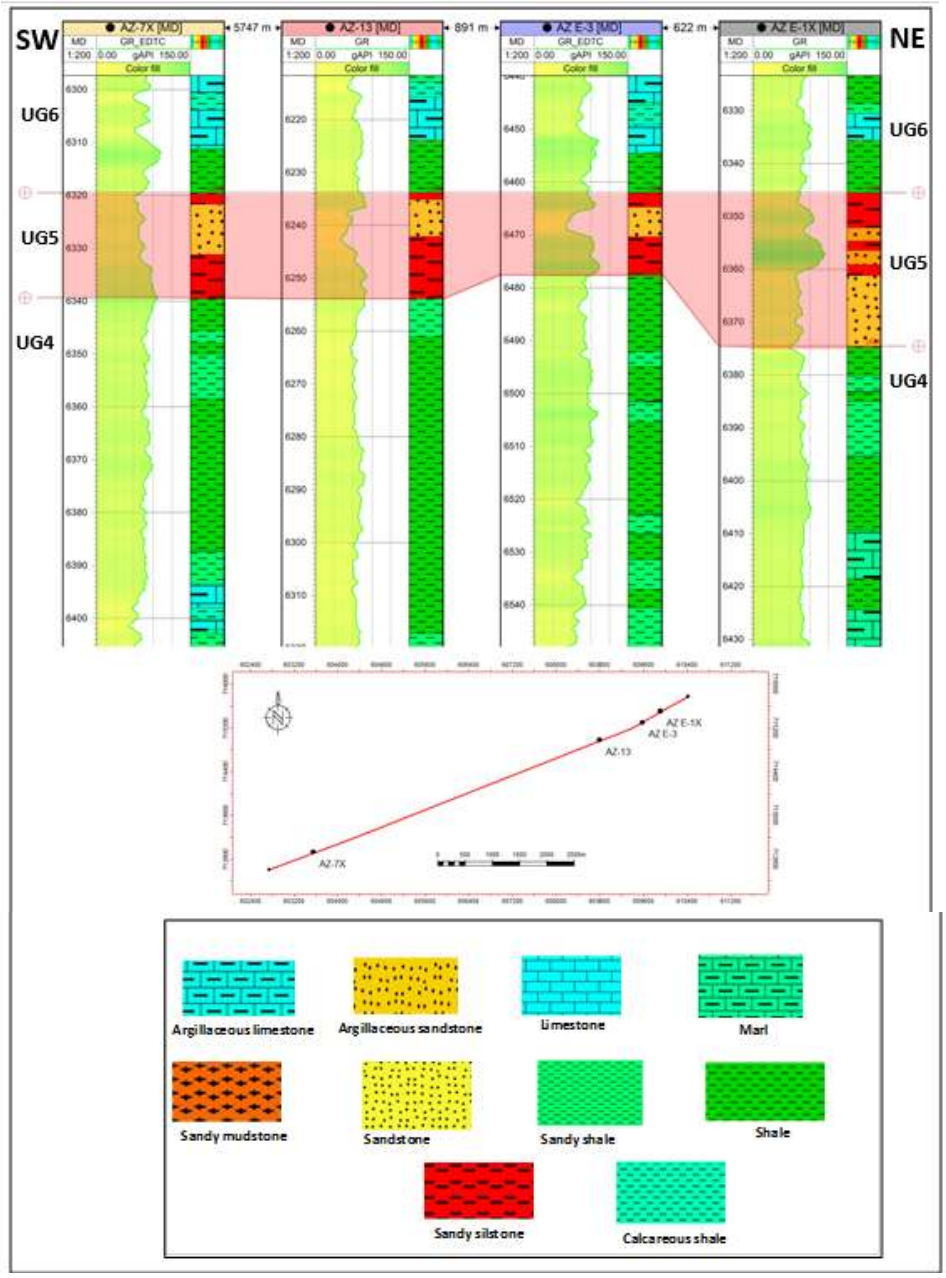
(**Fig. 1):**Location map of the Azhar oilfield in the Beni Suef Basin, Egypt.



(Fig. 2): Location map of selected wells in the study area (AZ-7X: Azhar -7x, AZ-13: Azhar-13, AZ E-3: Azhar E-3, AZ E-1X: Azhar E-1X).



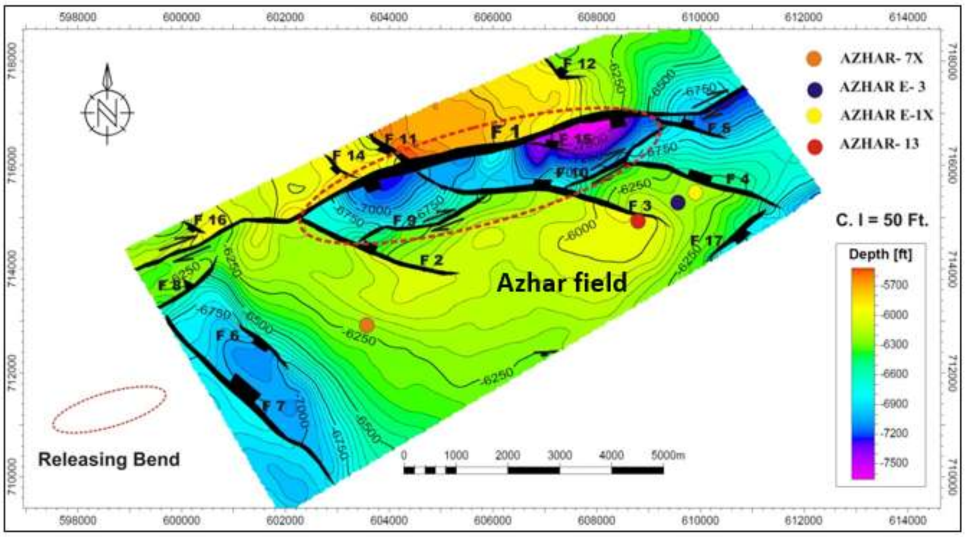
(Fig.3): The lithostratigraphic succession of the Azhar oil field (Qarun Petroleum Company, 2009).



(Fig.4):SW-NE oriented stratigraphic cross section flattened on Top UG5 cycle with scale 1-200 FT track 1 represent depth, track 2 represent gamma ray (yellow represent low gamma ray, green represent high gamma ray), track 3 represent lithology log.

2.2 Structure setting.

The structure setting of Azhar oil field (West Beni Suef Basin) is related to Early Cretaceous rifting which is followed by two phases of wrenching during the Santonian and Campanian-Maastrichtian times. The Early Cretaceous rifting resulted in the formation of half grabens bounded by NW to WNW-oriented growth normal faults. The Santonian and Campanian-Maastrichtian wrenching phases are represented by a ~E-W wrench zone associated with NE growth folds and NW growth normal faults as well as ENE, WNW and E-W strike-slip fault segments. The depth structure contour map of the upper Abu Roash"G" Member display that Azhar oil field characterizes by different structure features folding and faulting(normal faults, reverse faults and strike-slip faults). Fault F1is the main fault bounding the study area. This fault is consider asstrike-slip because it attain the criteria of Harding (1990) for recognizing of wrench faults (strike slip faults) on maps view as follows: 1- straight or nearly straight, extended through going master fault at all structure levels 2- En echelon folds or faults lie along one or both sides of master fault where folding is dipping toward NE-SW direction while faulting dipping toward NW-SE direction 3-The combination of contractional or extensional structures through master fault is most characteristic criterion for recognizing wrench fault in map view but in the study area obviously only extensional structure is clear on this map. Releasing bend in central part of the map may represents a suitable location for the maturation of the organic matter and generation of hydrocarbons. Azhar oil field is characterized by ananti-three way dip anticline closure (Fig. 5) that bounded by 3 normal faults (F2, F3, F4) with F9 and F10 segments of strike-slip faults.This structure represents the main structure hydrocarbon trap, which is related to Santonian and Campanian-Maastrichtian wrenching.



(Fig.5): The Depth structure contour map of top upper Abu Roash "G" Member in Azhar field.

III. Materials and methods.

This study used the available well logging data of 4 wells, ditch cutting samples, 3D seismic lines and core description report provided byQarun Petroleum Company, open-hole well 1ogging data recorded by service companies (Schlumberger and Halliburton) including the traditional tools such as:gamma-ray logs (GR-EDTC), density logs (RHOZ, PEF, HDRA),neutron Logs (APLC), formation resistivity logs (RLA5, RT90, RT60, RLA3, and RXOZ).

Ditch cutting samples have been used for petrographic examination. The prepared thin sections including impregnated with blue-dye in order to identify pore spaces, textural characteristics and mineralogy of the rock.X- ray diffraction analysis was carried out on somerepresentative cutting samples for bulk mineralogywhere clay minerals wereidentified in separated clay fraction(< 2µm).

Petrophysical analysis was carried out todeduce lithology andreservoir properties,usingMicrosoft Office Excel, IP interactive petrophysics 4.2.The volume of shale is calculated based on gamma-ray log,neutron-density cross plot.The minimum shale content given by these shale indicators is close to the actual value of Vsh. Reservoir porosities (total and effective) are calculated by considering the neutron-density porosity from the neutron-density logs after correcting effect of volume of shale. Formation water resistivity (Rw) determination is calculated in the studied 4 wells by calculating a bottom hole temperature with field salinity. The Water saturation wascalculated by usingArchie equation (1942). Determination of net pay was performed using effectiveporosity cut-off 12%,shale volume cut-off of 30% andwater saturation (Sw) cut-off value of 65% were used to define net pay.

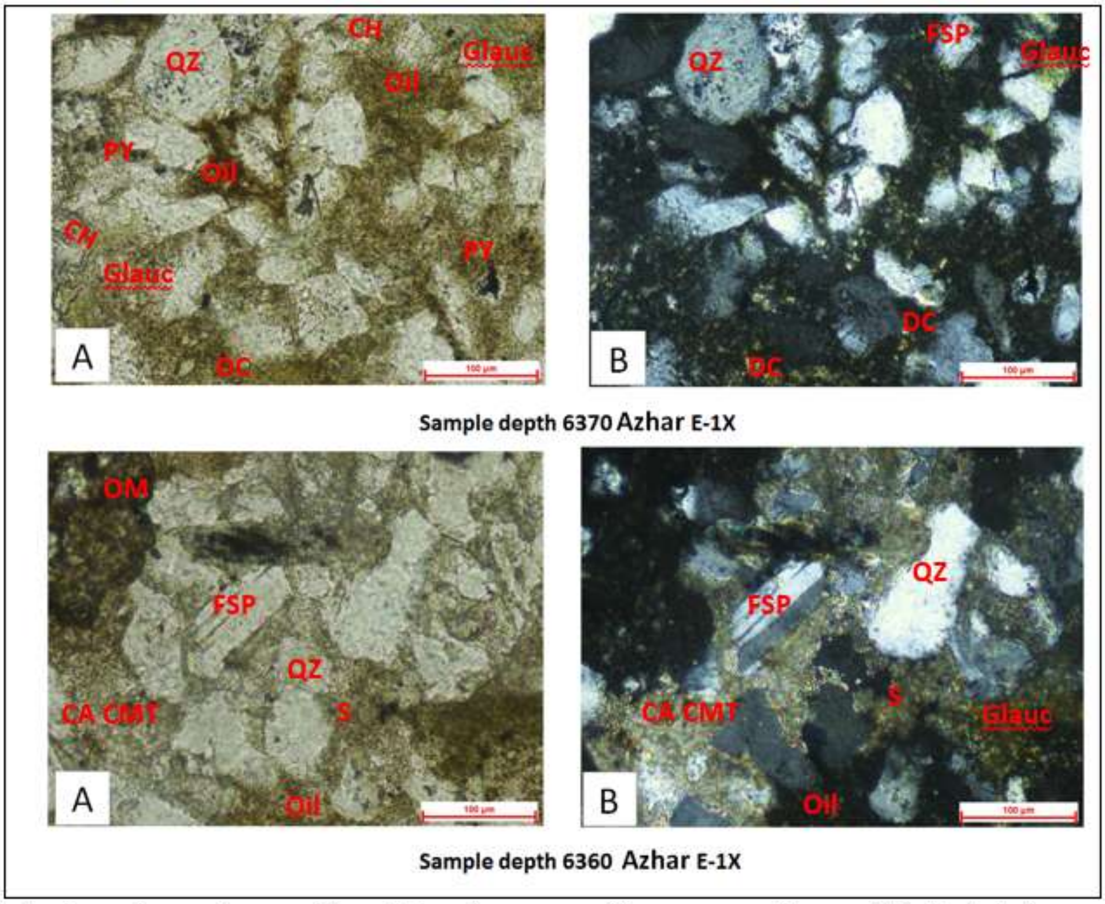
Cores description and discussion of results essentially provide sedimentological interpretation.Proper helium porosity and horizontal permeability were used for characterization of reservoir quality.

IV. Results and discussion

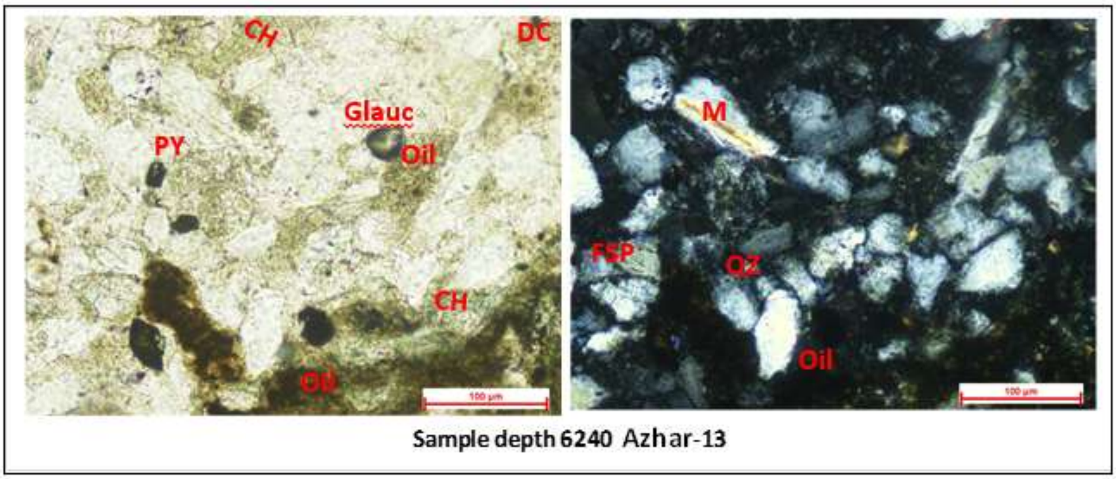
4.1Petrographic characteristics

The upper "G" Member sandstones are medium to coarse-grained. The sandstones are mainly texturally mature. Sorting ranges from moderately sorted to well sorted. The roundness of the detrital grains varies from subangularto sub-rounded. The sandstones are mostly quartz arenite to subarkose arenite with authigenic pyrite, clay andcalcareous cementation. Someorganic material and oil filling pore space are observed between grains. The sand grains are dominantlymonocrystalline quartz with abundant vacuoles are present in the samples, quartz proportions range from 78 %to88%, the quartz grains display point and traces of straight contact relationship.

Detrital clays proportions range from 8 %-12 %, feldspars proportions range from6% to 11%, the observed varieties of feldspar include K- feldspars and plagioclase,detrital glaucony are fresh green to pale green proportions range from1 % to2%,detrital pyrite grains proportions range from 1 % to2% were detected in most of the studied samples, minor organic matterranges from 1 % to 2 % is detected in some of studied samples. Clay and carbonate cementation were observed in the samples range from 5% to 30 % and traces of mica and heavy minerals were observed (Fig. 6 and 7).



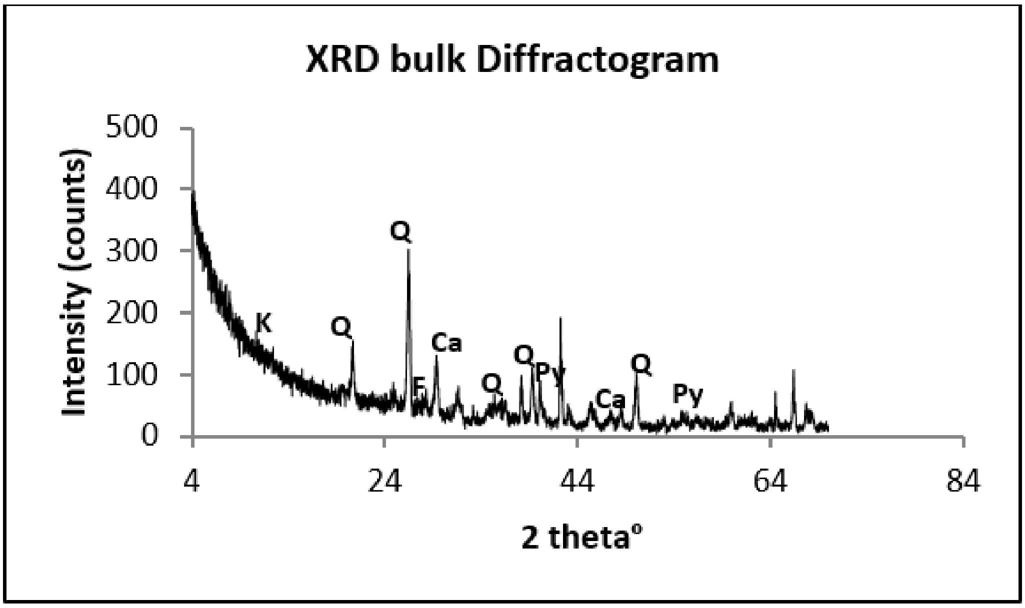
(**Fig.6):**Photomicrographic of (sandstone, argillaceous sandstone lithofacies) in two samples in Azhar E-1X well (A- under normal light, B- under plane polarized light) (QZ: quartz, oil: oil stain, OM: organic matter,CA CMT: calcareous cement, PY: pyriteFSP: feldspar and Glauc: Glaucony, CH-chlorite, DC-detrital clays).



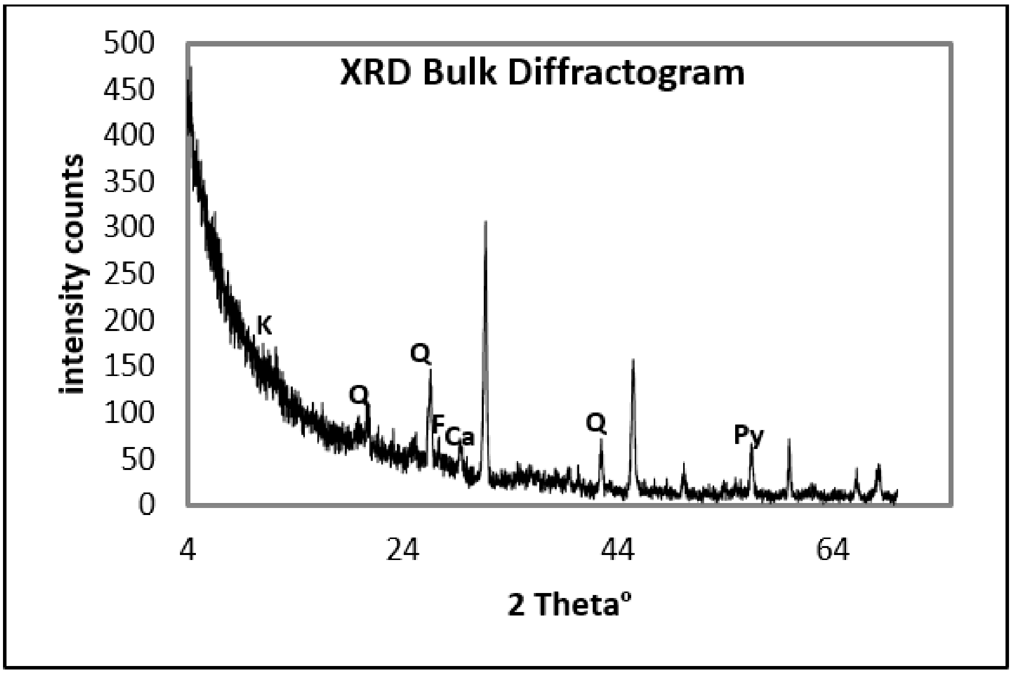
(Fig.7): Photomicrographic of (sandstone lithofacies) in one sample (6240) in Azhar-13 well (A- under normal light, B- under plane polarized light) (QZ: quartz, oil: oil stain, FSP: feldspar, Glauc: Glaucony, PY: pyrite, M-mica, CH- chlorite).

4.2 Mineralogical composition

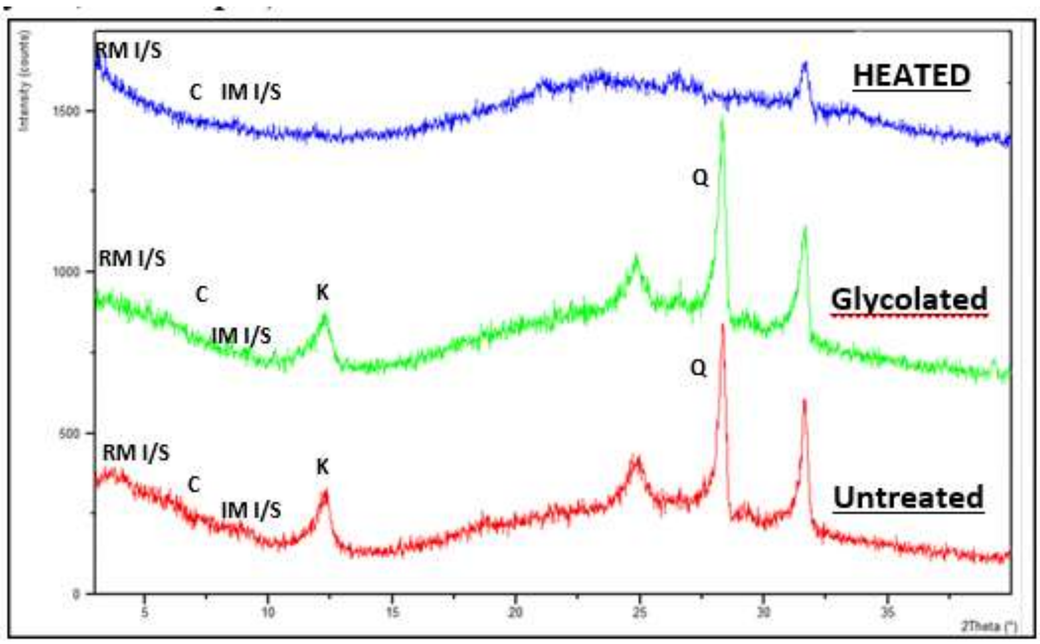
Bulk X-ray diffraction confirmed the expected dominance of quartz in most of the samples (Fig. 8 and9). Some peaks are related to drilling contamination salts which were excluded from identification and calculations of minerals from XRD results.X- ray bulk diffractionanalysis identified quartz, feldspar, calcite, pyrite and clay minerals(Fig. 8 and 9).X-ray diffraction analysis of clay fraction identifiedKaolinite, regular and irregular mixed layers illite-smectite and chlorite (Fig.10 and11), an indication of the crystallinity of the clay minerals can be given by assessment of the peak width for each component. Kaolinite can be consider as well crystalline and thereforeprobably authigenic in origin. While mixed layers illite-smectite and chlorite can be consider as poorly crystalline and therefore detrital in origin.



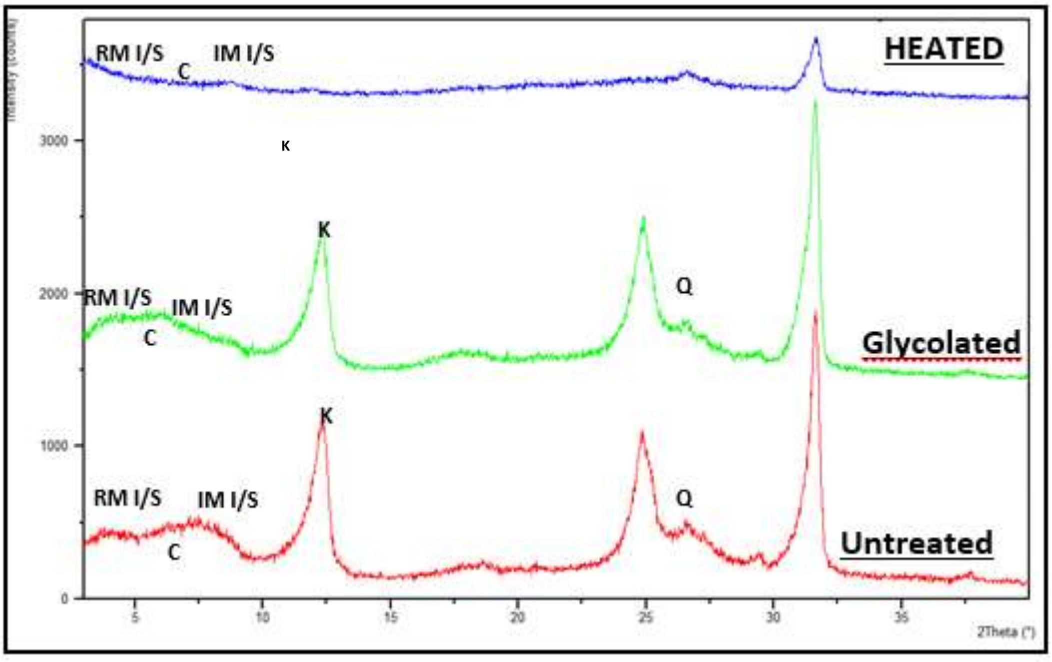
(Fig.8):X-Ray Bulk diffractogram of sample 6370 Azhar E-1X (K: kaolinite, Q: Quartz, Ca: Calcite, Py: Pyrite, F: feldspar).



(**Fig.9):**X-Ray Bulk diffractogram of sample 6240 Azhar-13(K: kaolinite, Q: Quartz, Ca: Calcite, Py: Pyrite, F: feldspar).



(Fig 10):X-Ray clay fraction diffractogram of sample 6370 Azhar E-1X (RM I/S: Regular, irregular illite/smectite, C: chlorite, IM I/S: Irregular mixed layer illite/smectite, K: Kaolinite, Q: quartz).



(Fig.11):X-Ray clay fraction diffractogram of sample 6240 Azhar-13(RM I/S: Regular, irregular illite/smectite, C: chlorite, IM I/S: Irregular mixed layer illite/smectite, K: Kaolinite, Q: quartz).

4.3 Diagenetic processes and mineralogy

Chlorite clay grain coating is observed in the studied samples (Fig.6 and7). Where it is regarded as an early stage of diagenesis which can be related to the depositional environment system. Detrital grain matrix represented by (regular, irregular mixed-layer illite/smectite) that could related to the presence of glaucony pellets and detrital clays.The alteration of Fe-Mg minerals (e.g. micas) by formational water leading to theformation of chlorite clay coating. Clay coating grains havethe following effect 1) enhancement of intergranular quartz dissolution and hence chemical compaction 2) preservation of porosity by inhibiting the precipitation of quartz overgrowths (Ehrenberg, 1993).Oil emplacement which may be formed later is observed in the studied samples partially filling pore spaces between quartz grains and partially dissolved feldspars. Well crystalline pore filling kaolinite may be formed by circulation of aluminum richformational water assisted by high porosity and permeability of these sediments. Traces of quartz overgrowth cementation in the sample gives rise to the formation of smooth rhombohedral or prismatic faces. Authigenic framboidal pyrite occurs as aggregates of several microcrystalline crystals that fill intergranular pores. Carbonate cement (calcite and minor siderite) formsignificant diagenetic product in somesamples representing alate stage of diagenesis is observed in the some samples (Fig.6).

4.4 Petrophysical Evaluation

4.4.1 Petrophysical Properties:

The petrophysics approach has been used to deduce the reservoir properties (shale volume, porosity and water saturation) to evaluate the hydrocarbon potentiality and net pay of upper "G" member UG5 cycle sandstone.

Table 1, Distribution of depositional facies, petrophysical properties and reservoir quality of upper Abu Roash"G" sandstone reservoir (zone UG5) in the studied wells of Azhar field.

Petrophysical Properties	Azhar wells			
	AZ E-1X	AZ E-3	AZ-13	AZ-7X
Depositional facies	Tidal channel & mixed tidal flat	Tidal sand flat	Tidal sand flat	Tidal sand flat
Depth interval	6352-6374	6465-6471	6234-6242	6322-6328
Reservoir thickness (FT)	14	5	5	7
Net pay thickness (FT)	14	5	5	6
Average total porosity (PHIT) %	19	17	19	18
Average effective porosity (PHIE) %	15	16	17	15.8
Average Volume of shale (V shale) %	16	12	9	11
Highest true(deep) Resistivity (ohm)	12	6	12	3
Average water saturation (SW) %	37	51	42	59
Average hydrocarbon saturation (Sh) %	63	49	58	41
Reservoir quality	Moderate to high	moderate	Moderate to high	Low to moderate

(Net pay, reservoir sand are in true vertical depth in feet).

Net pay in the studied wells ranges from 5 feet to 14 feet, highest net pay recorded in Azhar E-1x due to presence of two depositional sandstone lithofacies (tidal channel sand and mixed tidal flat sand).The total porosity of upper "G" sandstone in the studied wells ranges from 19 % to 17 % Table (1). Effective porosity of upper "G" sandstone in the studied wells ranges from 15% to 17% and is influenced by thevolume of shale which has highest value in Azhar E-1X well. The true resistivity in the studied wells ranges from 3 to 12 ohm*m recording lowest resistivity in Azhar-7x well while highest resistivity in Azhar-13 and Azhar E-1x wells indicating better reservoir quality. The estimated water saturation of these sandstones ranges from 37 % to 59 % with highestwater saturation recorded in Azhar-7x well. The hydrocarbon saturation is highest in Azhar E-1X well and lowest in Azhar-7x. From obtained results reservoir quality is the highest in Azhar E-1X and Azhar-13 while the lowest reservoir quality is recorded in Azhar-7x. it is worth to mention that Azhar E-3 core porosity range from 7.43 % to 19.87 % and core horizontal permeability ranges from 0.1 till 133 mD according to (Tiab 2004) classification of reservoir quality based on permeability data the quality of reservoir in Azhar E-3 well is considered to be a good reservoir. The results confirm hydrocarbon potentiality of the studied upper "G" sandstone as aproductive reservoir.

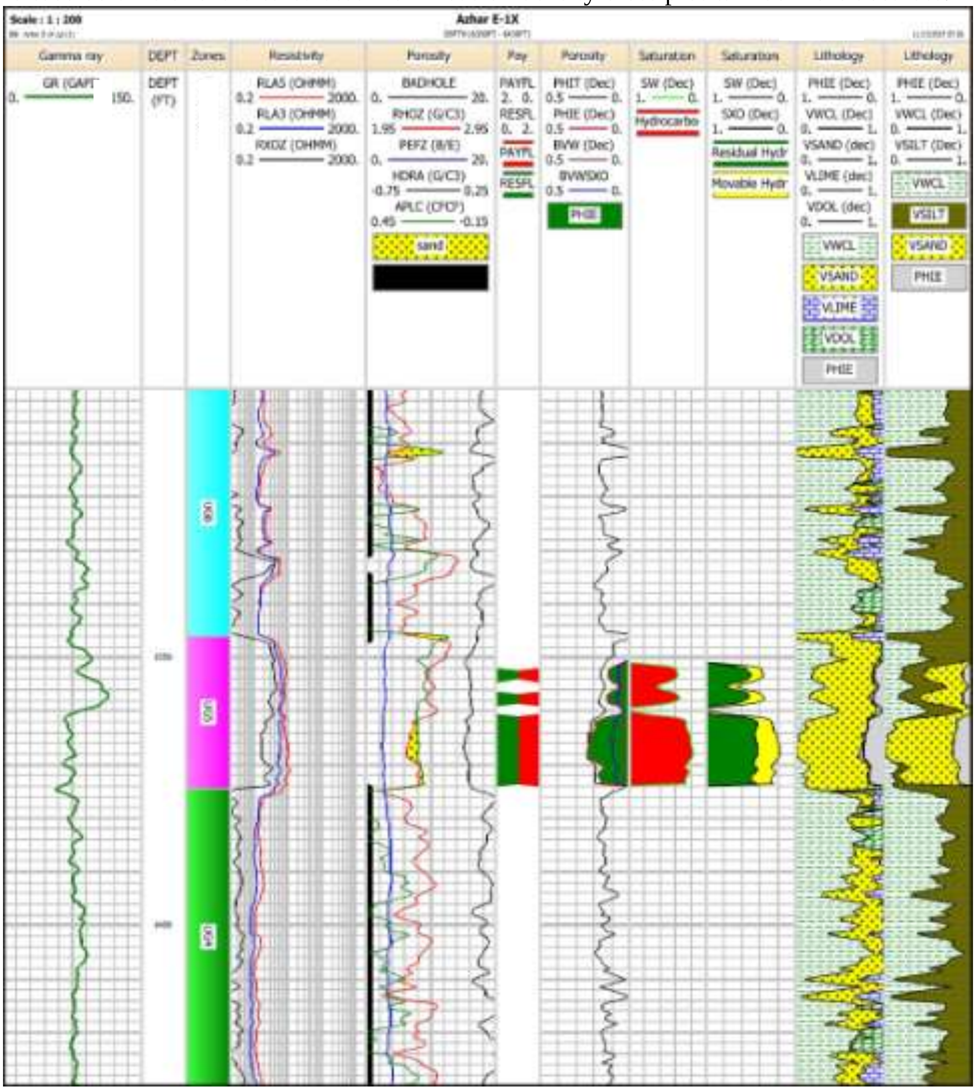
4.4.2 Litho-saturation plot:

Litho-saturation plot shows the vertical variation of lithology, porosity, density, water and hydrocarbon saturations against depth as deduced from the gamma-ray, density, neutron porosity, resistivity and photoelectric factor logging data. Analysis of obtained results using litho-saturation plot in Azhar E-1x will be discussed as this well containhighest net pay with two lithofacies (Fig.12). This well characterizes by net pay in both tidal channel and mixed tidal flat facies, tidal channel sandstone lithofacies depth interval (6374-6361 feet) characterizes by higher effective porosity and lower water saturation reaches up to 20 % than mixed tidal flat sandstone lithofacies depth interval (6352-6361)characterizes by higher water saturation reaches up to 40%. Mixed tidal flat sandstone lithofacies have highergamma-ray ranges from 80 to 100 APIwhich is the main reasonfor high volume of shale in this well while tidal channel lithofacies have lower gamma ray from 70 to 75 API. Tidal channel sandstonelithofacies revealed from this log seems to have higher reservoir quality than mixed tidal flat sandstone lithofacies due to lower gamma ray, higher resistivity and higher effective porosity. This well characterizes by good separation in resistivity curves (RLA5.RLA3 and RXOZ) which result to have good permeability. Even though this well has average high shale volume compared with other wells but also it has high reservoir quality due to high resistivity readings and presence of tidal channel sandstone lithofacies.

4.5 Reservoir quality controlling factors

4.5.1 Impact of texture and detrital component (Depositional factors):

Textural parameters such as grain size and sorting, are important primary factors which control reservoir quality. Reservoir characteristics like permeability are controlled by grain size and sorting, permeability declines with decreasing grain size because pore diameter decreases and hence capillary pressure increases (Krumbein and Monk, 1942). Porosity increases with improved sorting. As sorting decreases, the pores between the larger, framework-forming grains are infilled by the smaller particles as a matrix which decreases permeability. Upper "G" member sandstone is texturally mature which lead to good porosity and permeability. Generally the sandstone composition controls reservoir quality, However the presence of feldspars and mica in the studied samples lead to increase gamma ray result in increasing volume of shale than actual value, in this case volume of shale calculated from neutron density cross plot will be more accurate.



(Fig. 12): Computer processed interpretation (CPI) plot of upper Abu Roash "G" subdivision illustrating vertical variations in the petrophysical characteristics plot of Azhar E-1X well.

4.5.2 Impact of compaction:

Mechanical and chemical compactions play amajor role in decreasing primary porosity and permeability where it leads to decrease pore throats consequently decrease permeability and it also plays role in grain rotation and rearrangement. Evidence of minor compaction in the upper "G" member sandstones(Fig. 6 and 7) is represented by point contact grains so compaction has aminor effect on decreasing porosity.

4.5.3 Impact of Cementation:

A variety of cement materials have been identified by petrographics examination(Fig. 6 and 7) including well crystalline pore filling kaolinite, carbonate cement, authigenic pyrite and traces of quartz overgrowth. Kaolinite forms blocky crystals that fill pore spaces in sandstones, but due to its blocky nature as pore filling it does not lower permeability dramatically and it slightly decreases porosity. Presence of chlorite as clay coating have amajor role in the preservation of porosity due to inhibition of quartz of overgrowth. High percent carbonate cement is recorded in argillaceous sandstone of mixed tidal flat.Carbonate cement(calcite and minor siderite) occurs as ablocky mosaic to poikilotopic cement filling the primary pore space and as replacement of grains like partly dissolved quartz, feldspars. Quartz grains in mixed tidal flat lithofacies are floating on carbonate cement.Carbonate cement fill pore spaces between quartz grains which lead to decreasing primary, secondary porosity and permeability of the argillaceous sandstone mixed tidal flat lithofacies which lead to decrease its reservoir quality. Authigenic pyrite precipitation and replacement of organic matter have aminor effect on porosity.

4.5.4 Impact of Dissolution:

Dissolution of feldspars play a major role for increasing porosity and it is very clear on upper"G" member sandstone. Dissolution of feldspar lead to formation of clay minerals (e.g. Kaolinite) which slightly decreases porosity.Traces of partially dissolved feldspar (Fig. 6 and 7) have been observed in the studied samples which can be considered as secondary porosity for the preservation of oil.

4.6 Petrophysical properties mapping

Upper"G" member sandstone reservoir petrophysical properties were mapped to display alateral variation of thereservoir properties in the study area.

Shale volume:The shale volume distribution map of upper "G" member sandstone reservoir (Fig. 13), shows increase toward north and northeast part and decrease toward south part of thestudy area. Shale volume does not influence reservoir quality in the studied wells because it increases toward Azhar E-1X even though this well characterizes with high reservoir quality.

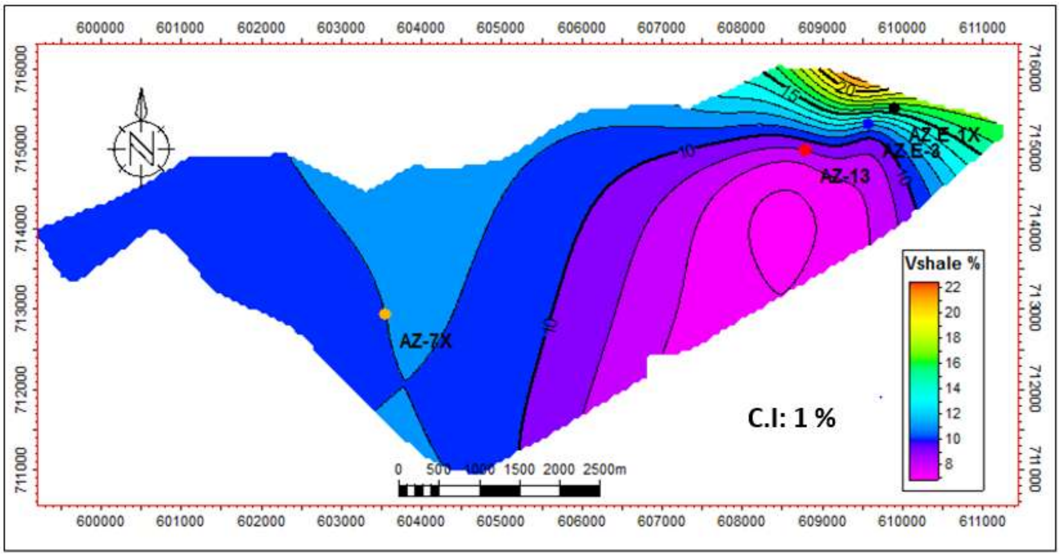
Total porosity:The total porosity distribution map of upper Abu Roash "G" membersandstone reservoir(Fig. 14), shows remarkable increase toward northeast and east direction and decrease toward north partof thestudy area.

Effective porosity:The effective porosity distribution map of upper Abu Roash "G" member sandstone reservoir (Fig. 15), shows remarkable increase toward south and southeast direction and decrease toward anorth direction.

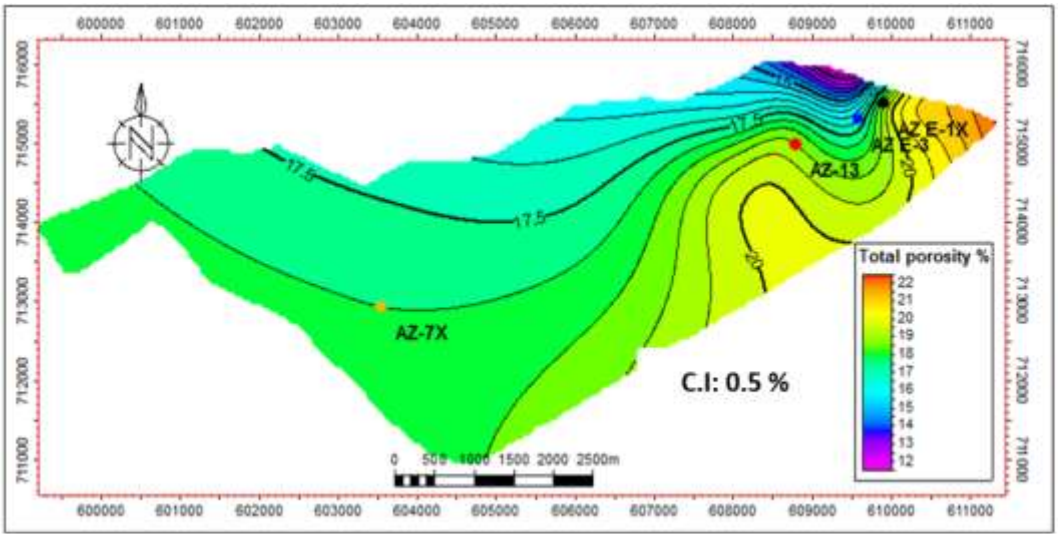
Water saturation:The water saturation distribution map of upper Abu Roash "G" membersandstonereservoir in study area (Fig. 16), shows increase toward southwest toward Azhar -7x well and toward northwest part of Azhar oil field while it decreases toward east part of study area especially Azhar E-1X well. Water saturation is increasing away from faults which indicate that is mainly related to the structural control.

Hydrocarbon saturation:The hydrocarbon saturation map of upper Abu Roash "G" member sandstone reservoir (Fig. 17), shows increase toward theeast and central part of thestudy area where it decreases toward southwest toward Azhar-7x well. Hydrocarbon saturation is related to structure control because it increases toward structural high and decreases toward thestructural low area. Consequently reservoir quality is better in theeast part of the study area than southwest part of the study area.

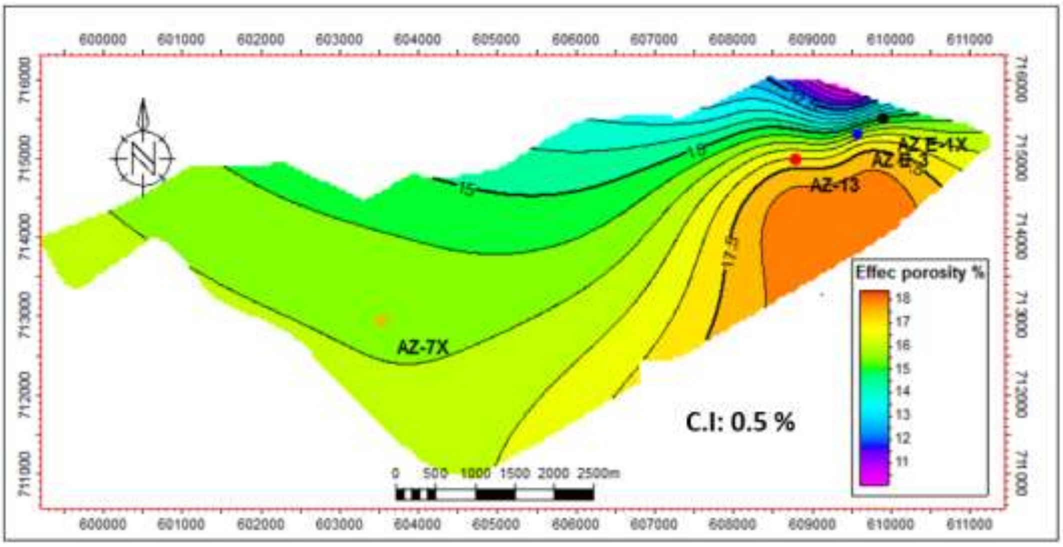
Net pay:The net pay map of upper Abu Roash "G" member sandstone reservoir (Fig. 18)shows increase toward theeast and central part of thestudy area where it decreases toward southwest toward Azhar-7x well. Net pay is related to both structural control and depositional control. Northeast part of the study area characterizes with higher net pay due to thepresence of tidal channel lithofacies which increase thethickness of deposited sandstone.



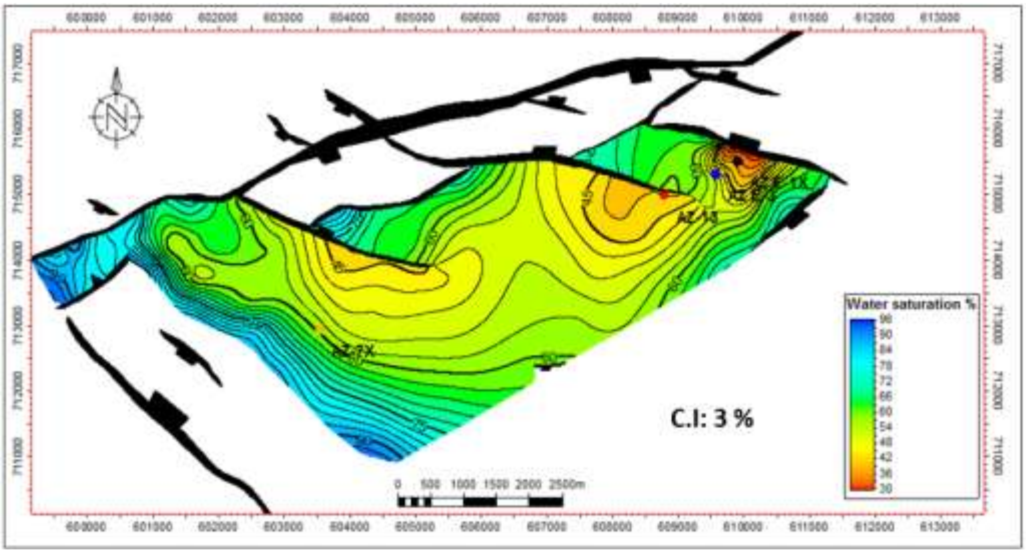
(Fig. 13): Vshale map of upper Abu Roash"G" reservoir UG5 sandstone.



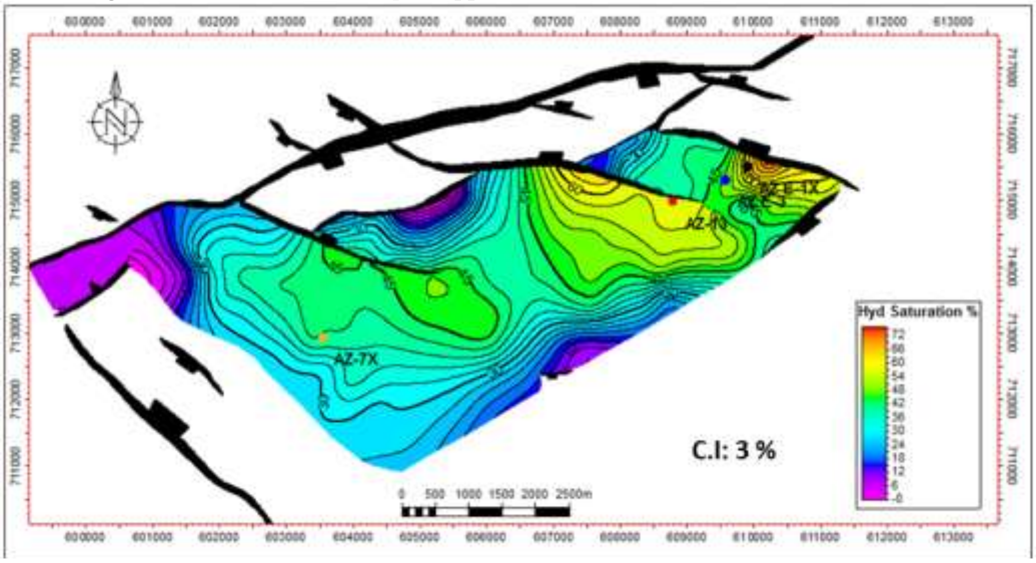
(Fig. 14): Total porosity map of upper Abu Roash"G" reservoir UG5 sandstone.



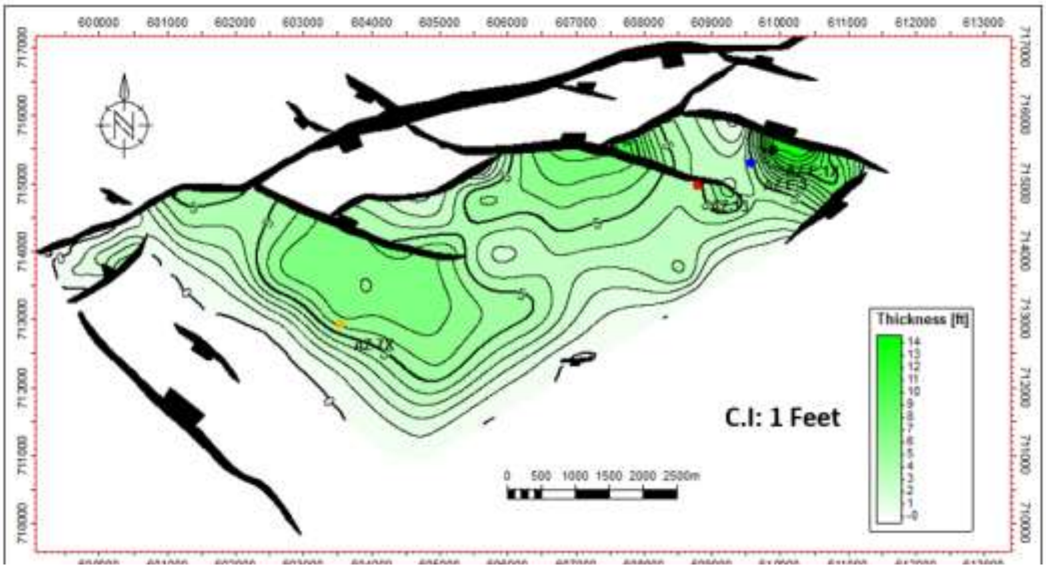
(**Fig. 15):**Effective porosity map of upper Abu Roash"G" reservoir UG5 sandstone.



(Fig. 16): Water saturation map of upper Abu Roash"G" reservoir UG5 sandstone.



(**Fig. 17):**Hydrocarbon saturation map of upper Abu Roash"G" reservoir UG5 sandstone.



(Fig. 18): Net pay map of upper Abu Roash"G" reservoir UG5 sandstone (Zero pay contour based on deepest oil down to in Azhar oil Field at depth -6400 feet).

V. Conclusion

This study revealed that reservoir quality in the study area is controlled by many variables including structural effect, depositional and diagenetic mineralogy.

Structural control on reservoir quality has been identified by depth structure contourmap of upper "G" member sandstone associated with hydrocarbon saturation map. These maps pointed out that reservoir quality represented by hydrocarbon saturation is the lowest toward south and southwest part of the study area especially toward Azhar-7x well due to it is located in thestructural low area compared with other 3 wells. Reservoir quality represented byhydrocarbon saturation is the highest toward Azhar-13 and Azhar E-1X because this wells are located in structural high.

Depositional control on reservoir quality represented by lithofacies variation (represented by different lithofacies tidal channel, tidal flat sand and mixed tidal flat) and depositional mineralogy of the studied wells. Maximum net pay have been recorded in Azhar E-1X in northeast direction of the study area due to presence of two different sandstone lithofacies (tidal channel lithofacies and mixed tidal flat lithofacies), while Azhar-13, Azhar E-3 and Azhar-7x characterizes by lower net pay than Azhar E-1X due to presence of only one sandstone lithofacies represented by tidal sand flat lithofacies. Consequently, it is recommended to drill more development wells in northeast direction of upthrown of F4 inAzhar oil field for further exploration of more tidal channel lithofacies.Depositional mineralogy from studied petrographic samples concluded that upper"G" member sandstone is texturally mature which lead to good porosity and permeability.

Diageneticprocess plays amajor role in reservoir quality of upper "G" member sandstone in the studied wells. Chlorite grain coating formed during early diagenesis seems to be preserved primary porosity by inhibiting the precipitation of quartz overgrowths, partial dissolution of feldspar lead to theformation of secondary porosity. While formation of well crystalline pore filling kaolinite booklets lead to decrease slightly porosity, oil invasion is observed in the studied samples which confirm presence of hydrocarbon. Presence of a high percentage of carbonate cementin mixedtidal flat lithofacies in Azhar E-1Xlead to decrease its porosity and permeability, and consequently will decrease its reservoir quality.

Based on reservoir mapping, it is revealed that the net pay and water saturation are affected by both structural and depositional controls while clay content hasa minor effect on reservoir quality, the best petrophysical propertieswere encountered in thenortheast part of Azhar oil field.

From previous analysis it can be concluded that thebest reservoir quality is in the structural high area associated with tidal channel sandstone lithofacies and tidal flat sand lithofacies in thethe northeast part of Azhar oil field.

Acknowledgements

The authors are grateful to the Egyptian General of Petroleum Company (EGPC) and Qarun Petroleum Company (QPC) for providing thedata and their permission to publish this paper.

References

[1]. C.E Archie,The electrical resistivity logs as an aid in determining some reservoir characteristics;*Trans; AIME*,146, 1942, 54-62.

[2]. D Tiab, C.E.Donaldson,*theory and practice of measuring reservoir rock and fluid transport propertiesPetrophysics 2nd ed,*(El SEVIER gulf professional publishing 2004). PP.120-180.

[3]. H. Zahran, K. Abu Elyazid and M. El-Aswany, Beni Suef Basin the Key for Exploration Future Success in Upper Egypt. *Adapted from oral presentation at AAPG Annual Convention and Exhibition*, *Houston, Texas, USA*, 2011.

[4]. P Norton, Rock stratigraphic nomenclature of the Western Desert. *Internal Report of GPC, Cairo, Egypt,* (1967). 557 p.

[5]. Qarun Petroleum Company, *Lithostratigraphic report of Azhar E-1X well*, 2009.

[6]. R.H Worden, S.D Burley, Sandstone diagenesis: the evolution of sand to stone. In: Sandstone Diagenesis Ancient and Recent, *Reprint Series Volume 4 of the International Association of Sedimentologists. Blackwell Publishing Ltd,* 2003, pp. 3e44.

[7]. S.N Ehrenberg, T Boassen,Factors controlling permeability variation in sandstones of the Garn Formation in Trestakk Field, Norwegian continental shelf,5, *J. Sediment. Petrol,1993, 929-944*

[8]. T.R Taylor, M.R Giles, L.A. Hathon, T.N Diggs, N.R. Braunsdorf, and G.V Birbiglia, Sandstone diagenesis and reservoir quality prediction: models, myths, and reality, *AAPG Bull. 94, 2010,* 1093e1132.

[9]. T. P Harding, Identification of wrench faults using subsurface structural data: Criteria and Pitfalls, *AAPG. V74* (10) 1990. Pp (1590-1609).

[10]. W.C Krumbein, G.D Monk, Permeability as a function of the size parameters of unconsolidated sands. *Am. Inst. Min. Metall. Eng. 1e11. Tech. Publ,* 1942, 1492.

Mohmed.I. ELAnbaawy "Reservoir quality of Upper "G" Member sandstone of Abu Roash Formation, Azhar Field, Beni Suef basin, Nile Valley, Egypt.." IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 5.6 (2017): 10-23.