Egyptian Geophysical Society
EGS Journal, Vol. 9, No. 1, 75-85 (2011)

MINERAL CONSTITUENTS AND COMPOSITION OF ABU MADI FORMATION IN EL QARA FIELD, NILE DELTA AREA, EGYPT

A.Z. Nouh and M.F. Abu-Hashish
The British University in Egypt, El Sherouk City, Cairo, Egypt
Geology Department, Faculty of Science, Menoufiya University, Egypt

التركيب المعدنى لمتكون أبو ماضى فى حقل القرعة، دلتا النيل، مصر

الخلاصة: تتناول هذه الدراسة تحديد المعادن الداخلة فى تركيب متكون أبو ماضى فى حقل القرعة وذلك عن طريق استخدام التسجيلات الكهربائية والإشعاعية للآبار، ومن ثم تفسيرها وتمثيل نتائج هذه البيانات، وكذلك عن طريق استخدام المعادلات و النماذج الرياضية لتمثيل هذه البيانات وعرضها. وقد اتضح من خلال ذلك وجود معادن مثل الكوارتز والإليت. و تبين من النتائج أيضا أن صخور الميوسين المتأخر فى حقل القرعة تتراوح فيها المسامية بين ٠,٧% الى ٢٩,١ % بمتوسط ١٧,٨% فى حين تبين من قياسات النفاذية أنها تتراوح ما بين ٠,٠٢ ملى دارسى الى ١٣٦٩ ملى دارسى.

وقد تبين أيضاً بالفحص البتروجرافى لمتكون أبو ماضى أنه يتكون اساساً من الحجر الرملى الذى يتكون من الكوارتز الدقيق الحبيبات الى المتوسط الحجم. وتم تقسيم تكوين أبو ماضى إلى ثلاث وحدات صخرية هي١ و٢ و٣ حيث تعتبر الوحدة رقم ٣ هى أهم الوحدات الصخرية حيث أن معظم تجمعات الغاز موجودة فى تلك الوحدة الصخرية.

ABSTRACT: *The available open-hole well log data of the studied Nile Delta area are subjected to computer processed analysis to determine the mineralogic composition of the Abu Madi Formation. This analysis started by the correction of the density and neutron readings for the environmental errors, then presenting the available log data in the form of crossplots to facilitate the qualitative interpretation needed for defining the mineralogic composition for the studied rock unit; Abu Madi Formation. The mathematical equations, describing the mineral constituents suggested in each model, are established to compute the mineralogic composition and the total porosity for the studied unit. The resulted mineralogic constituents and porosity were represented in the form of histograms to show the different mineralogic constituents of this formation. Moreover, the lithologic-geologic model of Abu Madi Formation, shows that, the presence of illite and montmorillonite is revealed to a near-by source from the site of deposition of intertidal environment. The existence of quartz in considerable proportion with high radioactivity reflects the detrital nature and the high chemical maturity. The occurrence of kaolinite reflects the high uranium content, which is produced from the concentration of the uranium rich fluids that migrated through fault planes. Kaolinite favors continental to near-shore (fluvio-lacustrine) environments through the deposition. The occurrence of potash feldspars is attributed to the denudation of the underlying acidic basement complex.*

It was found that the porosity data of the selected samples of the Abu Madi Formations at El Qara Field indicated that the porosity varies from 0.7 % to 29.10 % with a mean value of 17.8 %, while the analyses of the permeability of these samples varies from 0.02 mD and 1369 mD, with a mean value of 123.8 mD. In addition, the water saturation values of the Late Miocene rocks, at El Qara Field, varies from 16.1 % and 96.4 %, with a mean value of 63.1 %.

To investigate the mineralogical composition of the studied lithofacies XRD analysis was conducted to the whole samples side by side with the microscopic investigations. It was found that the major constituent of the studied sandstones is the quartz with different forms (monocrystalline and polycrystalline), with little amount of feldspar minerals and rock fragments. The studied lithofacies of the Abu Madi Formation in the study area is mostly quartz arenite, with about 95 % quartz.The Abu Madi Formation (lithologically) can be divided into three sand levels or units separated by thick silty mud bed. These are designated as sand level I, II and III. The present study concentrates on Level III since it comprises most of the gas accumulation in the study area.

INTRODUCTION

The Abu Madi Formation (Late Messinian) is the sedimentary infilling of fluvial paleovalley developing in the subsurface from south (East Delta concession) to north (Baltim lease) for about 140 km from East to West for about 2 km (Fig.1). It has an average thickness of 300 m and is characterized by stacked fluviodeltaic sandstone and shales onlapping landword (southward) and to the valley flanks against the basal erosional surface (unconformity) cutting the Qawasim and Sidi Salim formations.

The crossplot techniques (from well logs) show very useful roles for matrix identification and mineralogical composition. In the study area, the log data in four wells were considered. This analysis was applied for four wells distributed in the north-eastern part of the Nile Delta area, in the Qara field, namely Qara-2, Qara-3, Qara-6 and Qara-7 wells. It has an average thickness of 300 m. and is characterised by stacked fluvio-deltaic sandstones and shales onlapping landward (southward) and to the valley flanks against the basal erosional surface (unconformity) cutting the Qawasim and Sidi Salim formations (Fig. 2).

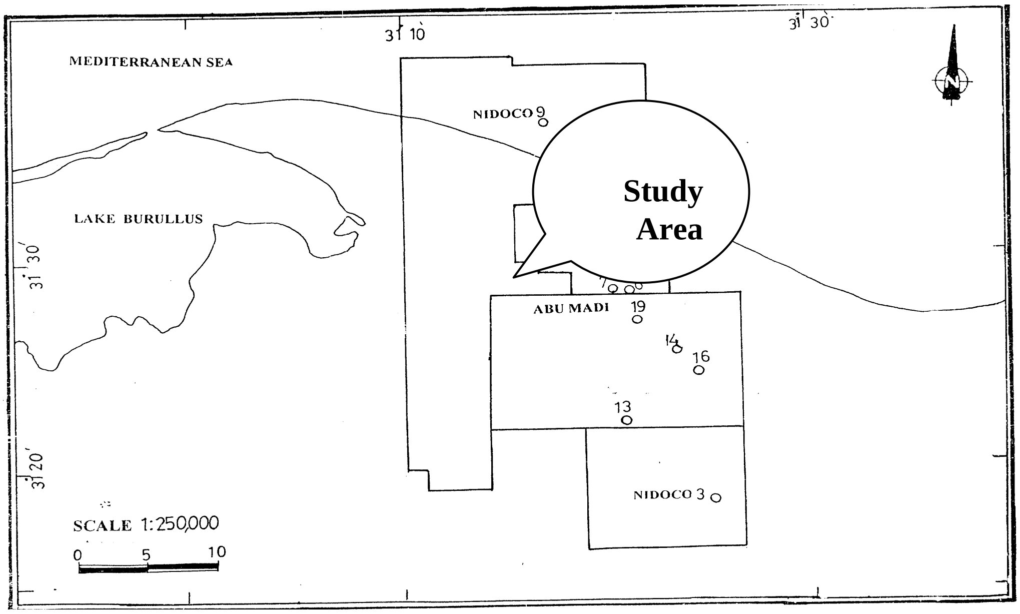


Fig. (1): Location map of the study area.

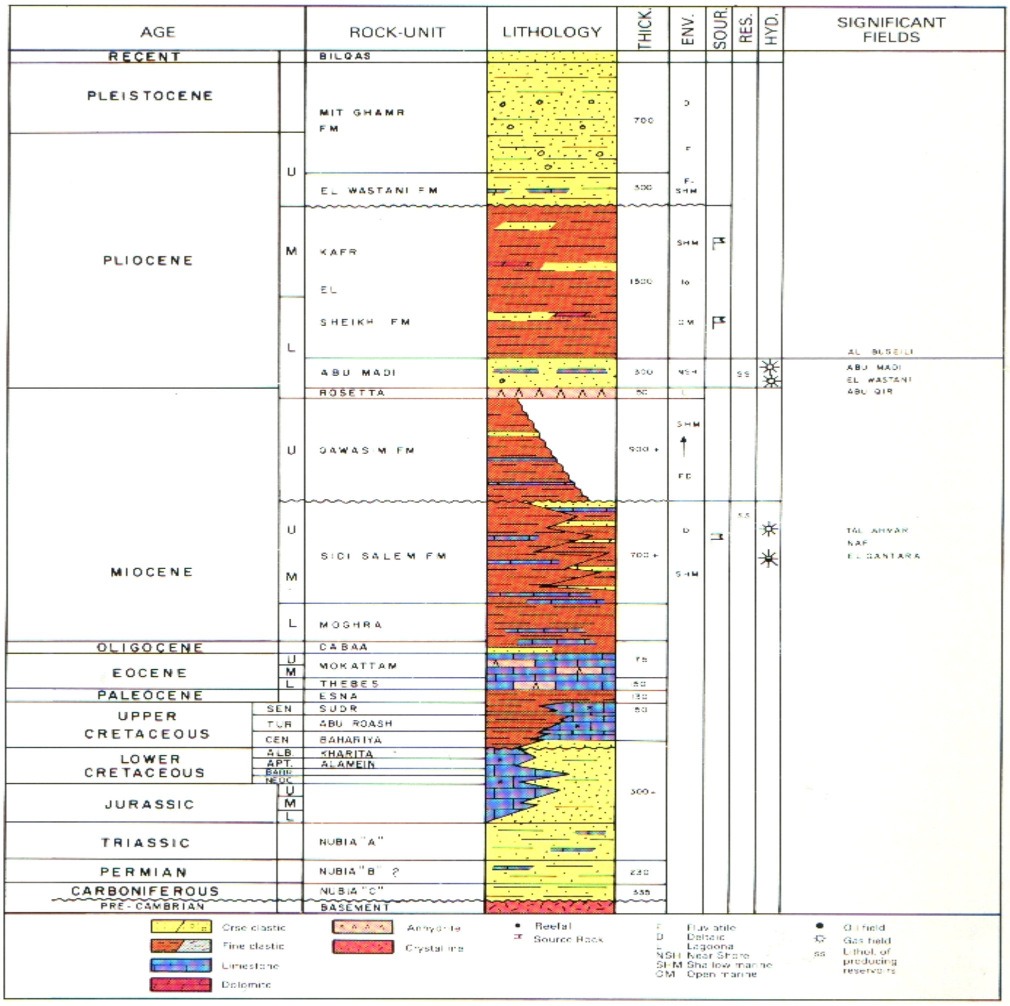


Fig. (2): Generalized litho-stratigraphic column of the Nile Delta Area. (after gexco and jepco, 1975).

In addition, the mineralogic modeling is a very important tool for studying both the reservoir and source rocks. Rocks are normally made-up of mixtures of minerals. Consequently their physical manifestations and atomic properties influence the measured log responses (Poupon et al., 1971). These responses are not only functions of the characteristics of the mineral associations present in the rocks and their relative percentage in the zones of investigation, but also on the natures and percentages of the fluids occupying the inter-granular pore spaces. Therefore, if rocks contain more than four different major minerals (Cram, 1986 and Serra, 1986), it is necessary to have a preliminary knowledge about their types and log parameters (ρb, Δt,ΦN GR...etc).

CROSSPLOTS APPLICATION

The core analysis results, ditch cutting description and well log data, supported the lithology subdivision of level III into three units; which designated as lower, middle and upper subunits. The lower level III unit consists of sandstone with sandy siltstone, and shale interbeds, while the middle level consists mainly of medium to coarse grained sandstone. The sequence contains some amount of mud interclastics. But considering the upper level, lithologically it is composed of fine to very fine grained sandstone interbedded with siltstone and dark grey shale. Therefore, these three units of level III are becoming finer upward (Fig. 3).

The well-log data extracted for the studied rock unit are presented in the form of crossplots. These crossplots are, sometimes. two-dimensional (of two log parameters), or combination all three porosity logs to provide the lithology characteristics (M-N).

By this way, any mineral with M coefficient can be plotted on any of these crossplots to aid the qualitative mineralogical interpretation, (Sanyal et al., 1980). On all types of crossplots, it is of prime importance to locate the position of the most probable presented minerals. The following is a detailed presentation for the various crossplots constructed for the evaluated rock unit (Abu Madi Formation (Level III)) in the studied wells.

1. Bulk Density (ρb) versus Neutron Porosity(ΦN) :

This plot (Fig. 4) is an example of several plots drawn for all wells. The first glance reveals the chemical nature of this rock unit. The majority of the presented points in this plot lies around the sand line. This reflects the presence of shaly sandstone rather than the dolomitic one. Some points are located around the illite and kaolinite, added to the quartz.

2. MID plot:

Such a plot is considered a complementary way for identifying the lithology, gas, and secondary porosity. It depends principally on the determination of the apparent matrix parameters (ρma)a and (Δtma)a, which are given through computation (Wyllie, 1963), as exhibited:

a) Clean zones: $\rho b\ log = \rho Pf + (1- \Phi)\ \rho ma$ or

$\rho ma = (\rho b\ \ log\ \ \rho b_f)\ /\ (1- \Phi)$ (1)

$\Delta TIog\ = \Phi\ \Delta Tf\ (1- \Phi)\ \Delta Tma$ or

$\Delta Tma = (\Delta TIog - \Phi\Delta Tf\ )\ I\ (1- \Phi)$ (2)

b) Shaly zones:

$\rho b\ log = \rho bf + Vsh\ \rho sh + (l\text{—}\Phi\text{-}Vsh)\ \rho ma$ or

$\rho ma = (\rho b\ log\text{-}\ \Phi\rho f\text{-}Vsh\ \rho sh)/\ (l\text{-}\Phi\text{-}Vsh)$ (3)

$\Delta TIog = \Phi\Delta Tf + VshTsh + (l\text{-}\Phi\text{-}Vsh)$

$\Delta Tma = (\Delta TIog + \Phi\Delta Tf\text{-}\ Vsh\Delta Tsh)/(l\text{-}\Phi\text{-}Vsh))$ (4)

The crossplot between (ρma)*a* and *(*ΔTma*)a*, that proposed by Clavier and Rust (1976), separates the different matrix contents, as shown in Fig.(5), which is an example of different plots drawn for Abu Madi Formation in the studied wells. This plot shows a group of points around the clay minerals (illite and montmorillonite), with other points lying between the quartz, k-feldspars, and carbonates in the form of calcite and dolomite. Also it shows that the main hydrocarbon was gas, since most of the points are lying around the gas line.

3. M-N plot:

This plot depends essentially on the fluid and log parameters, which are incorporated together in three porosity logs (ρb, ΔT, ΦN). From these values, two functions (M and N) are calculated, which are independent of the primary porosity (Burke et al., 1969). The M and N functions are computed by the following formulae:

$M\ lith = (\Delta Tf - \Delta TIog)\ /\ (\rho b\ log\ - \rho f) * 0.01$ (5)

$N\ lith = (\Phi Nf - \Phi N\ log)\ /\ (\rho b\ log\ - \rho f)$ (6)

M lith is the sonic-density lithology factor (fractional).
N lith is the neutron-density lithology factor (fractional).

By using the M-N plot for matrix identification, the lithology contents for each zone can be defined with respect to the standard M and N values of the common minerals and rocks, as shown by Shlumberger Principles (1972).

The mineral composition, detected in this plot (Fig. 6), reflects that, montmorillonite, kaolinite, quartz and k-feldspars are presented in this crossplot (this plot is one of several plots which are represented for all investigated wells).

PETROGRAPHIC ANALYSIS

Petrographic analysis of Abu-Madi Formation in Qara Oil Field were studied into two parallel ways; X-ray diffraction analysis and thin section analysis.

X – ray analysis (XRD):

A small portion from the available core samples representing Abu Madi Formation (10 samples) at the different depths in most of the studied wells in El-Qara filed , were powdered to provide a fine grained material for the whole rock mineralogy using X-ray diffraction techniques.

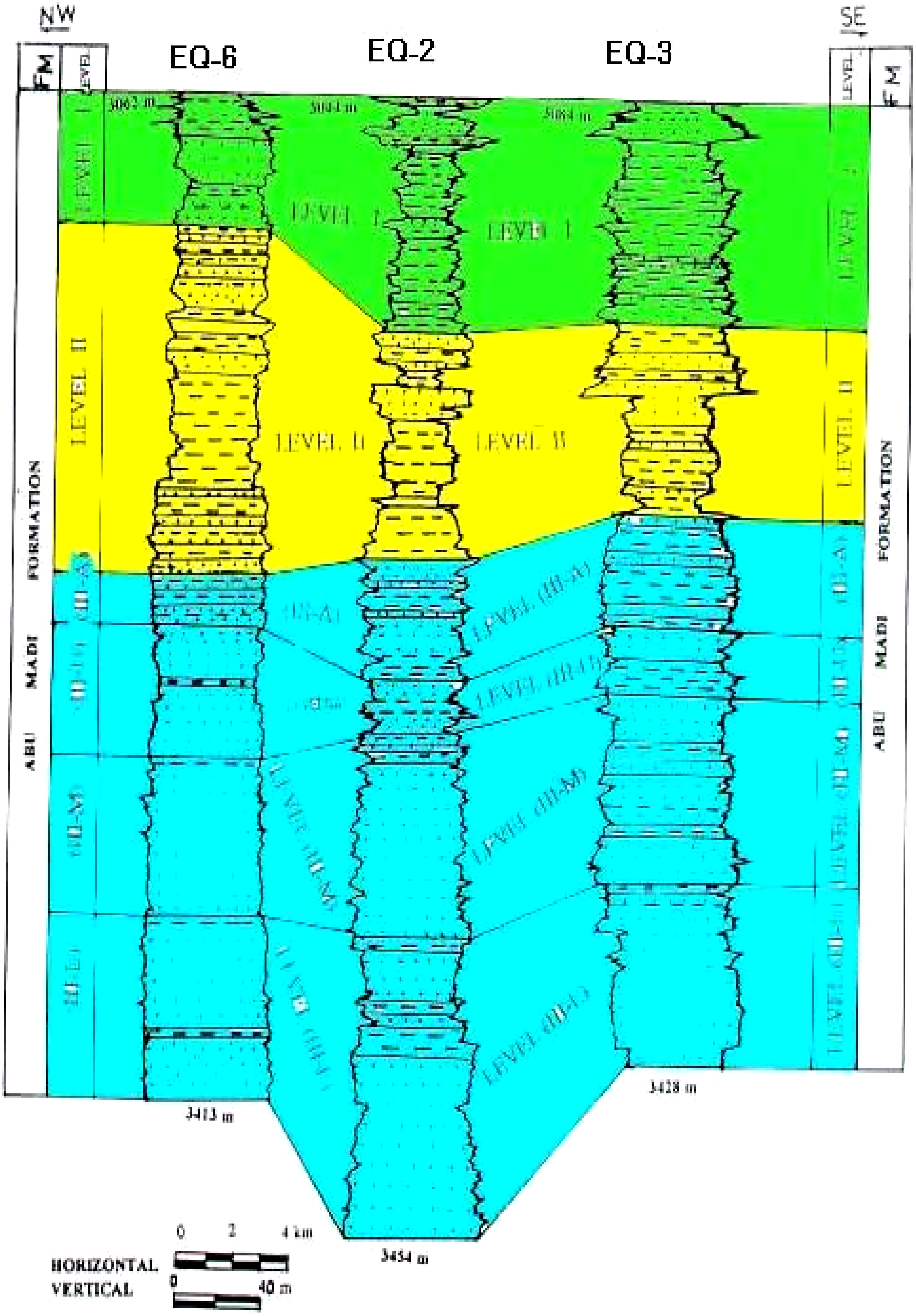


Fig. (3): Straigraphic pannel of Abu Madi Formation through qara-6, qara-2 and qara-3 wells.

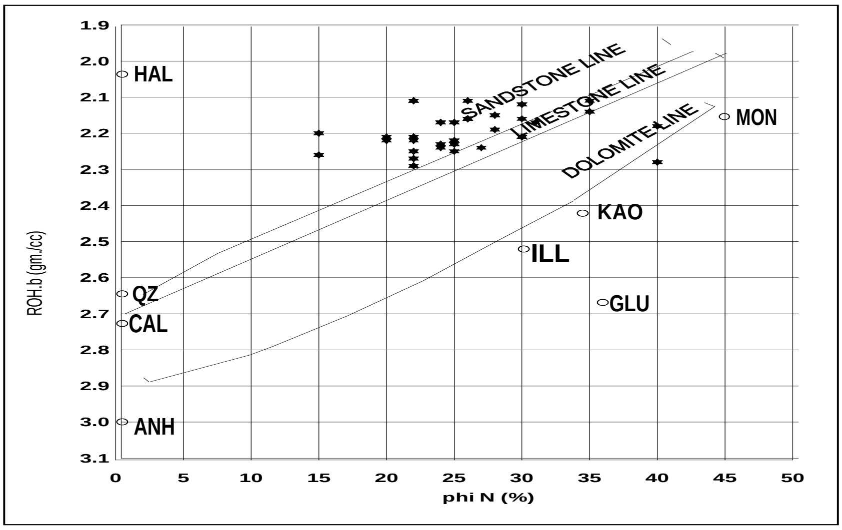


FIG.(4) DENSITY VERSUS PHI NEUTRON WITH FOR ABU MADI FORMATION (LEVEL III) IN QARA-6 WELL.

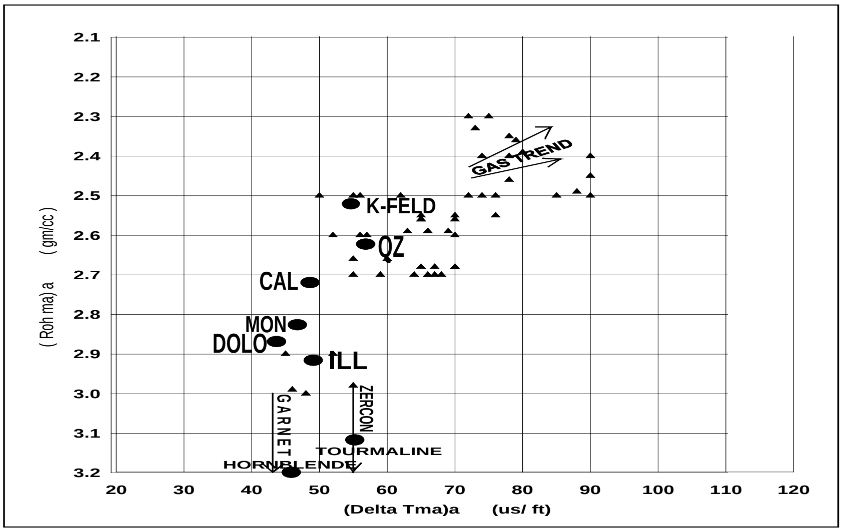


FIG.(5) MID PLOT FOR ABU MADI FORMATION (LEVEL III) IN QARA-2 WELL

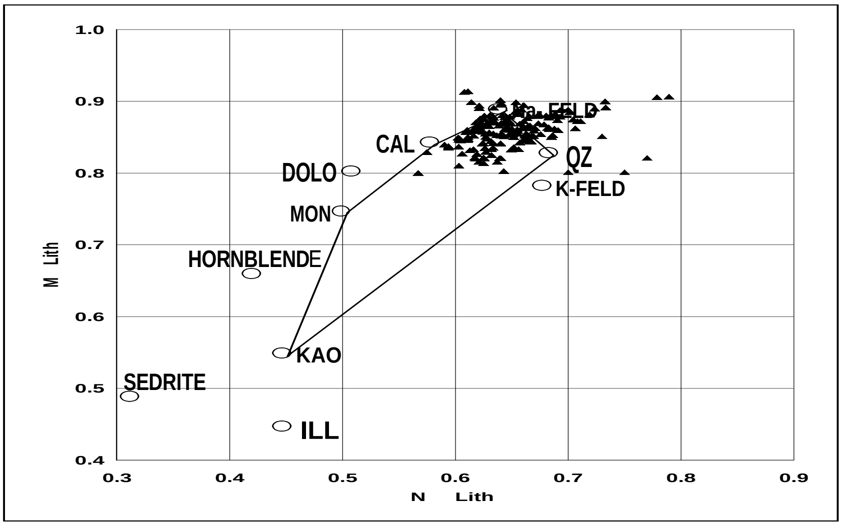


FIG.(6) M Lith-N Lith CROSSPLOT FOR ABU MADI FORMATION (LEVEL III) IN QARA-2 WELL

All samples were scanned from 2 to 70 using CoK □□ radiation, The identified minerals by XRD analysis include quartz as it represents the most frequent mineral in the studied rocks. The detected clay minerals in the most studied rocks are kaolinite and illite. As indicated from the XRD analysis data, kaolinite has a well developed crystallinity in most cases. This may be indicated from the sharp and narrow reflections. Kaolinite is recorded at other reflections, but the above mentioned reflections are the most clear and frequent. Millot (1970) noted that kaolinite is a detrital mineral and is not marine.

Illite is a general term for the clay constituents of argillaceous sediments belonging to the mica group. It may be deposited in a marine environment as a detrital and/or authigenic mineral. Detrital illite in marine sediments may result from the erosion of rocky substrates in tectonic unstable areas (Robert and Chamley, 1968). Illite is well crystalline yielding sharp reflections. The X-ray diffraction analysis for the whole mineral constituents indicate that Abu Madi Sandstone has the following mineral phases :

- Quartz which is found in various percentage in the formation at different depths .It varies from 2 % to 29 % in the wells under study which were conducted to the analysis.
- Clays and micas are most frequent minerals phase that can be detected from XRD analysis. They constitute from 47 % to 88 % from the whole mineral constituents. Fig.9 shows an example for the mineral phases that detected from XRD and their reflections.

To know the type of clay minerals that found in the sandstone core samples of the Abu Madi Formation, a fraction of clays from these samples are concentrated on a slide and have been conducted to the XRD technique to know the type of clays. The analysis revealed that ,the clays are mainly smectite, mixed layers, illite, kaolinite and chlorite (Fig.10).

THIN SECTION INVESTIGATION

To perform this study eight thin sections were prepared for the available core samples in the drilled wells. The constituents of the selected core samples were examined using the petrographic micrscope. The nomenclature and terminology that used to describe the sandstone lithofacies in this work is based on Pettijohn et al., 1973 (Fig. 1).

The petrographic features of the detected three levels of sands in theAbu Madi Formation (I, II and III) are summarized in the following lithofacies : Quartz arenite, kaolinitic quartz arenite, and sublithic arenites.

(i) The Quartzarenite lithofacies :

It is the most frequent lithofacies, especially in both II and III levels. Lithologically this interval of the Abu Madi Formation consists of sandstone with sandy siltstone and shale interbeds.From petrography point of view the essential component of the quartzarenite lithofacies is the quartz that constitutes more than 95 % of the whole rock framework.

(ii) Kaolinitic quartzarenite lithofacies :

This lithofacies has a limited occurrence in the Abu Madi Formation. It is discontinuously recorded at the Lower and Middle levels III.

(iii) Sublithic quartzarenite lithofacies :

This lithofacies is found less frequently than the quartzarenite, it is composed mainly from quartz grains, clay minerals (about 30 %) of the whole rock constituent. The clay is mainly montmorlonite and kaolinite.

PETROGRAPHIC ANALYSIS

Ten thin sections were prepared from Abu Madi Formation in Qara oil field and were examined using the polarizing microscope to detect the mineral constituent and textural relations of the Abu Madi Formation (Plate 1).

SUMMARY AND CONCLUSIONS

This study was performed to determine the mineral constituents and composition of the Abu Madi Formation through mathematical modeling, crossplots application and the petrographic analysis. To achieve this aim, five wells were selected to determine the mineral constituents and composition of the Abu Madi Formation.

1- Mathematical Modeling:

Based on the mineralogical modeling obtained from the previous technique, a mathematical modeling was established. Through this modeling process, one has to select the equations, which enable to relate the log data to the desired computed parameters, like mineral constituents and porosity. The response equations of the minerals, present in each model, are performed and a statistical analysis is carried out on each mineral, in a probabilistic test, for establishing the mineralogical composition that frequently occurred in each studied zone (Delfiner et al., 1984). Based on the mineralogic model of the Abu Madi Formation for example in El Qara-2 well, which is composed of quartz, k-feldspars, calcite, dolomite, illite and kaolinite.

2- Crossplot applications:

The well - log data extracted for the studied rock unit are presented in the form of crossplots. Crossplots assist in the selection of interpretation parameters and the identification of trends and problems of the mineralogical models. These crossplots are, sometimes two-dimensional (of two-log parameters), or combination all three porosity logs to provide the lithology characteristics (M-N).

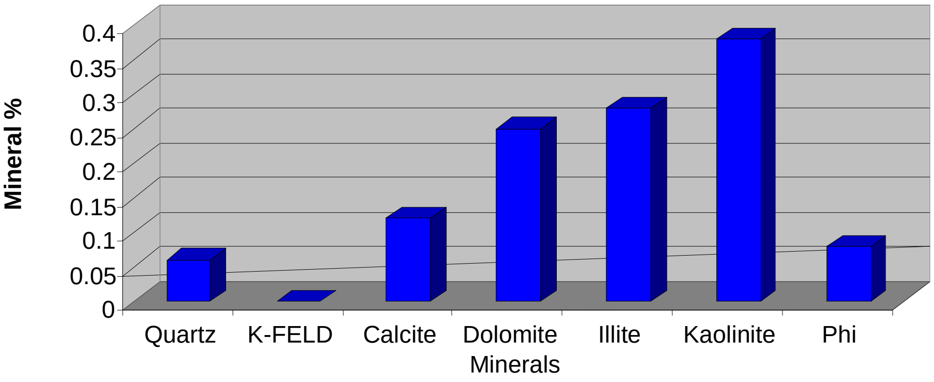


Fig. (7): Mineral identification for qara-3 well.

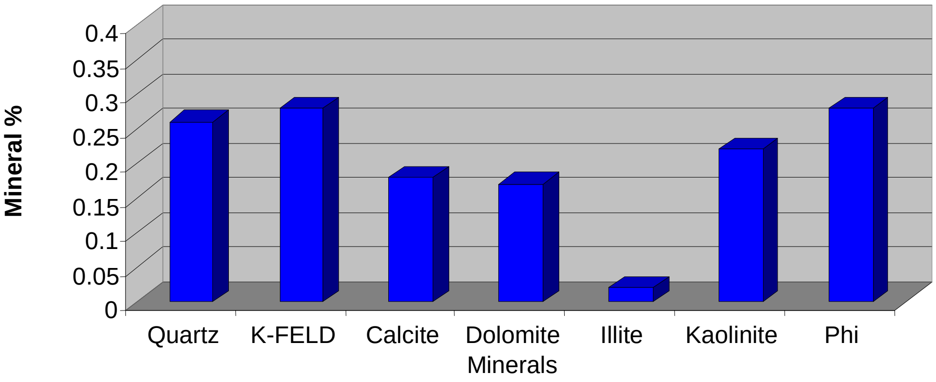


Fig. (8): Mineral identification for qara-7 well.

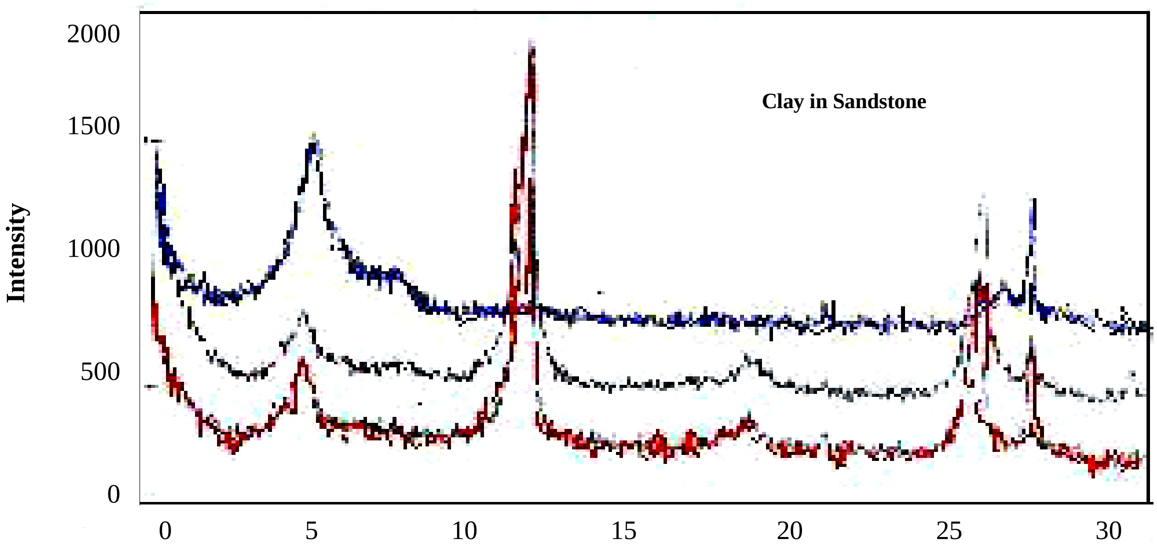


Fig. (9): X-ray chart showing clay mineral in qara-3 well.

ABU MADI WELL NO.9, AIR- DRIED SAMPLE.
ABU MADI WELL NO.9, GLYCOL SAMPLE.
ABU MADI WELL NO.9, HEAT TREAT SAMPLE.

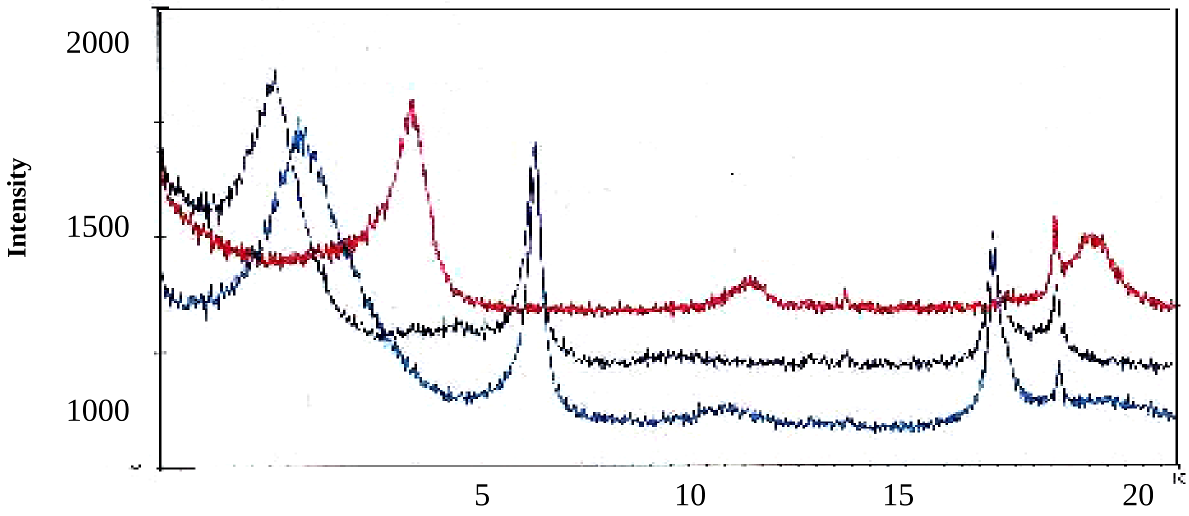


Fig. (10): X-ray diffraction chart showing the resulted clay Minerals : Smectite, Illite, Mixed layers in qara-7 well.

ABU MADI WELL NO.9, AIR- DRIED SAMPLE.
ABU MADI WELL NO.9, GLYCOL SAMPLE.
ABU MADI WELL NO.9, HEAT TREAT SAMPLE.

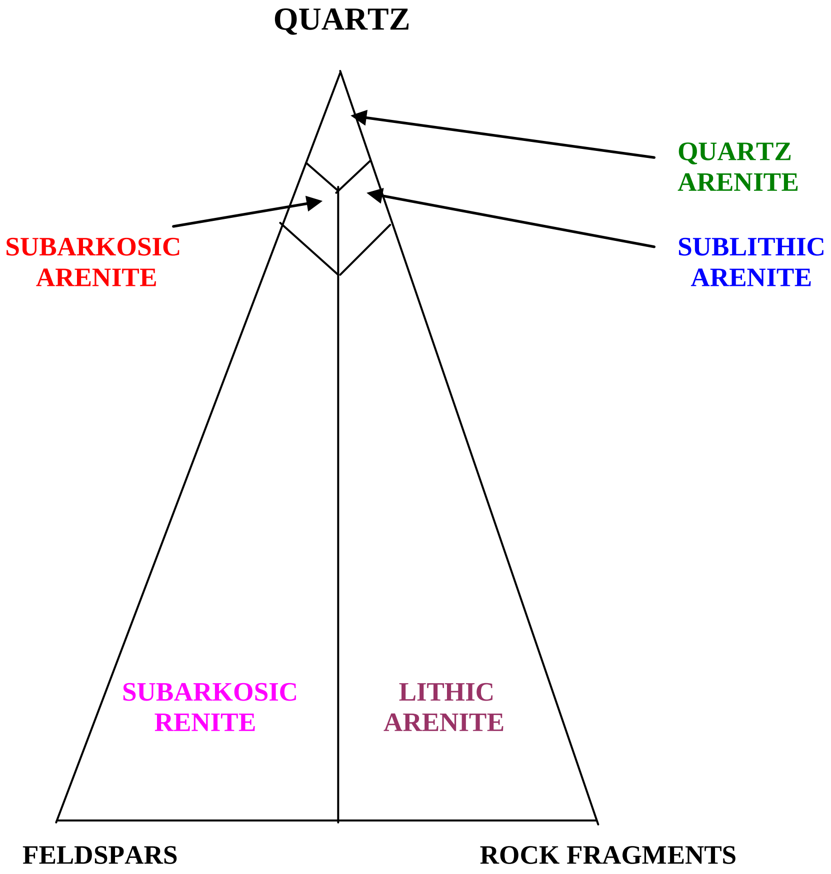
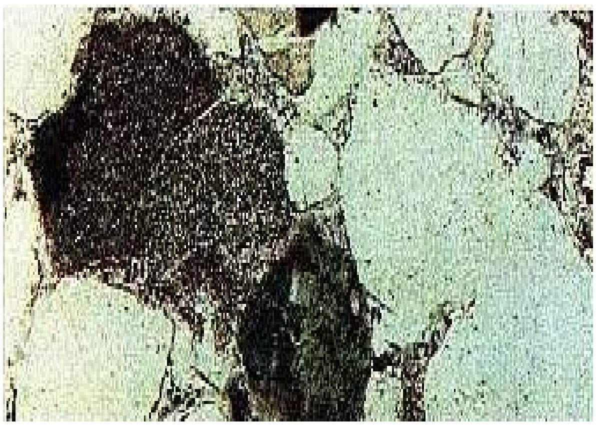
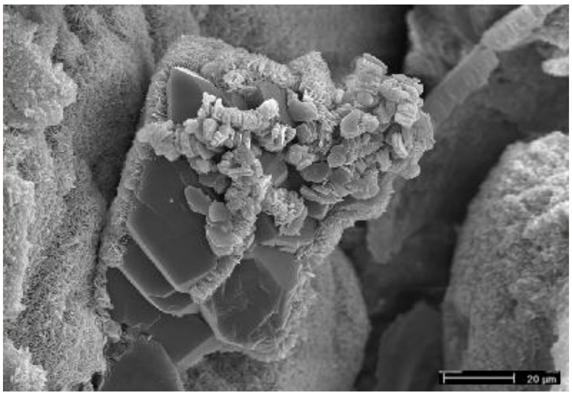


Fig. (11): Classification of Sandstone, (after pettijohn et al., 1973).

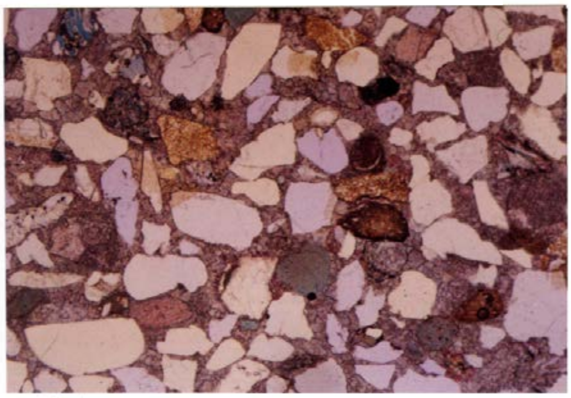
A



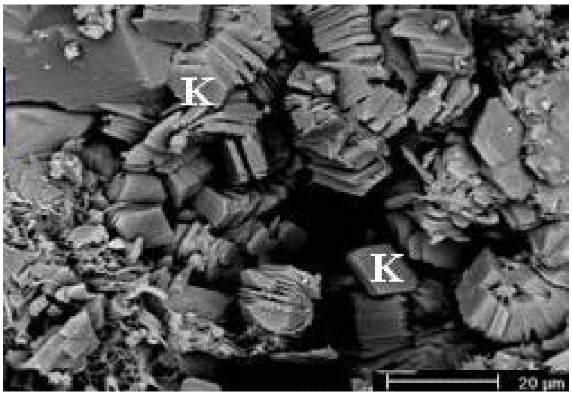
B



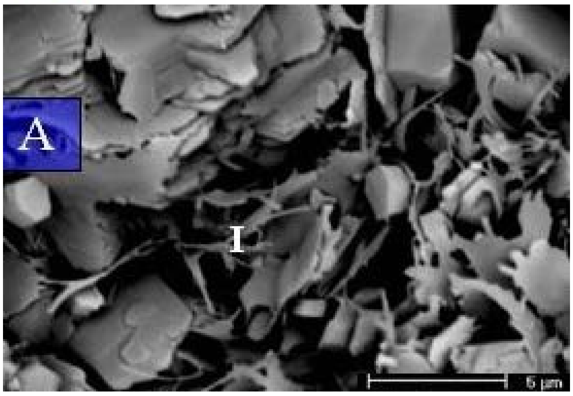
C



D



E



F

1- **Fig. (A): Photomicrograph showing the sublithic quartzarenite lithofacies note the partial dissolution of feldspar mineral in some parts**

2- **Fig. (B): Photomicrograph showing the sublithic quartzarenite lithofacies with altered feldspar fragments.**

3- **Fig. (C): Photomicrograph showing the quartzarenite lithoacies with carbonate cement**

4- **Fig. (D): SEM photo showing the chlorite between the quartz grains Well Qara-2 (Magnification x 40).**

5- **Fig. (E): SEM photo showing the kaolinite filling the pores between the quartz grains**

6- **Fig. (F): SEM photo showing the Illite filling the pores.**

By this way, any mineral with M coefficient can be plotted on any of these crossplots to aid the qualitative mineralogical interpretation, (Sanyal et al. 1980). On all types of crossplots, it is of prime importance to locate the position of the most probable presented minerals. The following is a detailed presentation for the various crossplots constructed for the evaluated rock unit (Abu Madi Formation, Level III) in the studied wells. For example, The mineral composition, detected in these plots reflects that, montmorillonite, kaolinite, quartz and k-feldspars are presented in this crossplot The majority of the presented points in this plot lie around the sand line. This reflects the presence of shaly sandstone rather than the dolomitic one.

3-Petrographic Analysis

Petrographic analysis of the Abu-Madi Formation in Qara oil field were studied in to two parallel ways; X-ray diffraction analysis and thin section analysis.

3-1- X – ray analysis (XRD):

A small portion from the available core samples representing the Abu Madi Formation (10 samples) at the different depths in most of the studied wells in El-Qara filed, were powdered to provide a fine grained material for the whole rock mineralogy using X-ray diffraction techniques. All samples are scanned from 2 to 70 using CoK □□ radiation; The identified minerals by XRD analysis include quartz as it represents the most frequent mineral in the studied rocks. The detected clay minerals in the most rocks samples are kaolinite and illite. As indicated from the XRD analysis data, kaolinite has a well developed crystallinity in most cases, this may be indicated from the sharp and narrow reflections. Illite is a general term for the clay constituents of argillaceous sediments belonging to the mica group. Illite is well crystalline yielding sharp reflections. The X-ray diffraction analysis for the whole mineral constituents indicate that the Abu Madi sandstone has the following mineral phases :

1) Quartz which is found in various percentages in the Formation at different depths .It varies from 2 % to 29 % in the wells under study which were conducted to the analysis.
2) Clays and micas are most frequent minerals phase that can be detected from XRD analysis. They constitute from 47 % to 88 % from the whole mineral constituents.
3) To know the type of clay minerals that found in the sandstone core samples of the Abu Madi Formation, fraction of clays from these samples are concentrated on a slide and have been conducted to the XRD technique to know the type of clays. The analysis revealed that, the clays are mainly smectite, mixed layers, illite, kaolinite and chlorite.

3-2- Thin section investigation:

To perform this study 8 thin sections were prepared for the available core samples in the drilled wells. The constituents of the selected core samples were examined using the petrographic micrscope. The nomenclature and terminology that used to describe the sandstone lithofacies in this work are based on Pettijohn et al. (1973) (Fig. 10). The petrographic features of the detected three levels of sands in the Abu Madi Formation (I, II and III) are summarized in the following lithofacies: quartz arenite, kaolinitic quartz arenite and sublithic arenites.

(i) The Quartzarenite lithofacies :

It is the most frequent lithofacies. Lithologically, this interval of the Abu Madi Formation consists of sandstone with sandy siltstone and shale interbeds.From petrography point of view the essential component of the quartzarenite lithofacies is:

(ii) Kaolinitic quartzarenite lithofacies

This lithofacies has a limited occurrence in the Abu Madi Formation. It is discontinuously recorded at the Lower and Middle levels III.

(iii) Sublithic quartzarenite lithofacies

This lithofacies is found less frequently than the quartzarenite, and composed mainly from quartz grains, clay minerals (about 30 %) of the whole rock constituent. The clay is mainly montmorlonite and kaolinite.

In the light of the above mentioned results, the Abu Madi Formation (lithologically) can divided into three sand levels or units separated by thick silty mud bed. These are designated as sand level I, II and III. The lower level III unit consists of sandstone with sandy siltstone which can considered as the most important unit comparing with the two other units hence it contains the most accumulation of gas within its sand. The quartz that constitute more than 95 % of the whole rock framework.

REFERENCES

Abu El-Ata, A.S.A. and Ismail, A.A., 1985: A computerized solution for the simultaneous equations to identify the rock matrices of the Abu Madi and Sidi Salem Formations in the central part of the Nile Delta, Egypt, E.G.S. Proc. of 4th Ann. Meet., PP. 376-397.

Burke, J.A.; Compbell, Jr.R.L. and Schmidt, A.W., 1969: The litho-porosity crossplot; SPWLA, 10th Ann. Log. Sump. Trans, 220P.

Clavier, C. and Rust, D.H., 1976: Mid-plot, a new lithology technique, The Log Analyst, V. 17, No. 6, PP. 16-3 1.

Cram, E.R., 1986: The log analysis handbook, Penn-Well PubI. Co., Tusla, Oklahoma, U.S.A, 450 P.

Degens, E.T.; Dodd, J.R. and Reider, A.S., 1957: Environmental studies of carboniferous sediments, part; AAPG. Pubi., V. 41, PP. 24-37.

Delfiner, P.; Peyret, O. and Serra, O., 1984: Automatic determination of lithology from well logs, 59th Ann. Tech. Conf. Of SPE of Aime, Houston, USA, PP. 35-38.

Doveton, H.J., 1986: Log analysis of subsurface geology, concepts and computer methods, John Wiley, New York, 220.

Millot, G., 1970: "Geology of Clays ". New York, Springer-Verlag, 429 P.

Pettijohn, F.J., Pottter, P.E. and Siever, R., 1973: "Sand and Sandstone ". 1 st Edition Springer - Vorlage Neo - Heidelberg. Berlin, 618 P.

Poupon, A.; Hoyle, W.R. and Schmidt, A.W., 1971: Log analysis in formations with complex lithologies, Jour. Pet. Tech., V. 23, PP. 103-127.

Reda, M.A., 1997: The role of well logging analysis in delineating the mixed lithology models of the Miocene rock units in the area west of Feiran field, Gulf of Suez province, Egypt. Ph.D. Thesis, Am Shams University, Cairo, Egypt. 293.P.

Robert, C. and Schmley, C. 1968: "Cenozoic Evaluation of Continental Humidity and Paleoenvironment, Deduced from the Kaolinite Content of Oceanic Sediments ". Pal Geog., Pal Climat., Pal Ecol., V. 60, PP. 171 - 187.

Sanyal, S.K.; Jupraserts, S. and Jusbasche, E.M., 1980 :“An Evaluation of a Rhyolite-Basalt-Volcanic Ash Sequence from Well Logs”; the Log Analyst., V. 21, No. 1, PP.3-19 .

Schlumberger, 1972: “The Essentials of Log Interpretation Practice”, Schlumberger Publication, 225 P.

Serra, O., 1986: Fundamentals of well log interpretation, Volume II: Developments in Petroleum Science; Elsevier Pubi. Co., Amsterdam, V. 20, No. 1, PP.5-29

Szendro, D., 1983: A statistical method for lithologic interpretation from well logs, The Log Analysts, V. 34, PP. 16-23.

Wyllie, M.R.J., 1963: The fundamentals of well log interpretation, New York, Academic Press, V. 25, PP. 18-23.