

# MINERALOGICAL IDENTIFICATION & DEPOSITIONAL ENVIRONMENT ESTIMATION OF NUBIAN SANDSTONE FORMATION USING WIRE-LINE LOGS ANALYSIS

By

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## ABSTRACT

The Nubian Sandstone Group is one of the most important oil bearing formation in Sirt Basin **Abadi** [1]. The group is comprised of non-marine sediments of Lower Cretaceous age and is subdivided into three formations; Lower Nubian Sandstone, Upper Nubian Sandstone and Varicoloured Shale separating two sandstones. Locally the Lower Nubian Sandstone is subdivided into upper pool, separated by the middle shale. Identifying the rock lithology has important meaning for estimating the reserve of petroleum as reservoir capacity and storage ability. The lithology identification from well log based on not conventional cross plot proposed and studied, which is easier instead of rock core data observation results. However, this work carried out comparison between chart and analytical solution of matrix parameter ( $\rho_{ma}$  and  $\Delta T_{ma}$ ) estimation values of producer shaly sand reservoir, and present the main depositional environment affects. In addition to influences of pyrite, ferruginous encrustations, organic material throughout this studied reservoir Ben Ghawar BM [2]. Consequently, variety of matrix parameters values is contributed by clay minerals present in this reservoir type. This study based on wire line data measured over than 872AT Q2 with an 646 feet produced Upper Nubian Sandstone belong to three oil fields, E Sirt Basin. This shaly reservoir divided into three main units (V59, 97II and OO82), from bottom to top according to depositional and petrophysical properties. The available cores (cut in the lower Nubian sandstone formation) of some wells drilled in 3v59 structure are analysed according to their sedimentology, petrology and diagenetic products. Analysis are correlated with the results obtained from wire-line log interpretation. Analysis of these logs based on different cross plots results, with the support of petrographic and diagenetic investigation, allows analysis of the mineralogical composition, particular clay minerals, and estimation of the depositional environment. Petrography examination shows that the sands are mineralogically and texturally mature. Diagenetic processes resulted in different cements of illite and chlorite. Confirmation of mineralogical identification and estimation of depositional environments using different cross-plots of data derived from wire-line log analysis are fair to medium coarse sands. These values reflect quartz/kaolinite composition the latter and presence of iron carbonates (e.g. siderite and/or ankerite) and pyrite in the former. These characteristics are confirmed by cross plots of ROME (MATRIX DENSITY) versus UMA (absorption cross section of matrix). Plotting of PEF (photoelectrical absorption index) against log TK/K and confirm kaolinite as the most common clay mineral. Various cross plots obtained from analysis of spectral gamma-ray logs show that the sandstone is characterized by abundant thorium, minor amounts of potassium and locally uranium, interpreted as

indicating fluvial continental environment. Higher amounts of potassium and the middle shale define a lacustrine environment

## الملخص

مجموعة صخور النوبية الرملية هي واحدة من أهم التكوينات الحاملة النفط والغاز في حوض سرت العبادي [1]. وتتكون المجموعة من الرواسب غير البحرية من العصر الطباشيري السفلى وتنقسم إلى ثلاثة تشكيلات. الحجر الرملي النوبي السفلي ، والحجر الرملي العلوي النوبي والطبقة الصخرية الطينية تفصلهما اثنتين من الأحجار الرملية، محليا تقسم الحجر الرملي النوبي السفلى و النوبي العلوي، مفصولة بالصخر الزيتي الأوسط. تحديد الصخور الحجرية له معنى مهم لتقدير احتياطي النفط من حيث كفاءة الخزان والقدرة على التخزين. إن تحديد هوية المعدنية للصخور من سرود الابار مهم جدا ،حيث عملت مقارنة بالرسم البياني  $\Delta Tma$  و  $\rho_{ma}$  والعلاقة التحليلية لمعرفة بنية التركيب المعدني للخزان الرمل الصخري، وعرض البيئة الترسيبية الرئيسية المؤثرة. بالإضافة إلى تأثيرات معدن البيراييت، في المواد العضوية في جميع هذه الخزانات المدروسة بن غوار بم [2]. وبالتالي، فإن مجموعة متنوعة من قيم العلاقات البيانية ساهمت في ذلك خصوصا في المعادن الطينية الموجودة في هذا النوع من الخزانات. هذه الدراسة استندت إلى بيانات سرود الابار لاكثر من Q2 872 قدم 3V3 646 قدم ، من أسفل إلى أعلى وفقا للخصائص الترسيبية والبيتروفيزيائية. وتمت عمل التحليل المتاحة (بالإضافة لقطع العينات في تكوين الحجر الرملي النوبي السفلي) من بعض الابار التي تم حفرها في تراكيب 3، 59 V وفقا لعلم الرسوبيات والبتروولوجيا والعمليات الدياجينيتيك التي ارتبطة بالتحليل مع النتائج التي تم الحصول عليها من تفسير سرود الابار . تحليل هذه السجلات استنادا إلى نتائج العلاقات البيانية المختلفة، بدعم من التحقيق البيتروغرافيك و الديجينيتيك، سمح بتحديد نوعية المعادن، وتحديد معادن الطينية في التكوين، وتقدير البيئة الترسيب. هذا التكوين تشمل الابار 3V3، 3V4، Q1، Q2 . تحليل سرود الابار تم من خلالها الحصول علي معلومات هامة ،حيث الكوارتز نجده في كل النطاقات والطين الناتج من العمليات التحويرية نتج عنه الكاولينات في الجزء العلوي من منطقة الدراسة . أما معدن الاليت والسمكيات الناتج من تحلل الطين والملتحم بالكلسيات والكاولينات في الجزء الأوسط من النطاق والمونتمورليت و الاليت - الكاولينات في الجزء السفلي . المادة اللاحمة لتكوين النوبه تكونت أساسا من إعادة التبلور للكوارتز و معها الانهيدرايت والكلوريت وبعض معادن الطين ( الكاولينات والكلوريت مع الاليت - سمكيات ). الفحص البيتروغرافي يظهر أن الرمال هي مكونات معدنية وتم نضوجها. وأسفرت العمليات الدجينية عن أنواع مختلفة من الإسمنت والكلوريت. إن التأكد من تحديد المعادن وتقدير التغيرات الترسيبية باستخدام مختلف العلاقات البيانية المتاحة والبيانات المستمدة من تحليل الكور اللبوبي السفلي هي رمال عادت متوسطة الحجم. وتعكس هذه القيم تكوين الكوارتز / الكاولينيت الأخير ووجود كربونات الحديد (على سبيل المثال سيديريت و / أو أنكيريت) والبيريت في السابق. تم تأكيد هذه الخصائص من قبل العلاقات البيانية (ماتريكس الكثافة) بالمقابل و (مقطع امتصاص عرضي من السرد). و (مؤشر امتصاص الكهروضوئية) ضد سجل TH / K وتأكيد الكاولينيت كاحد

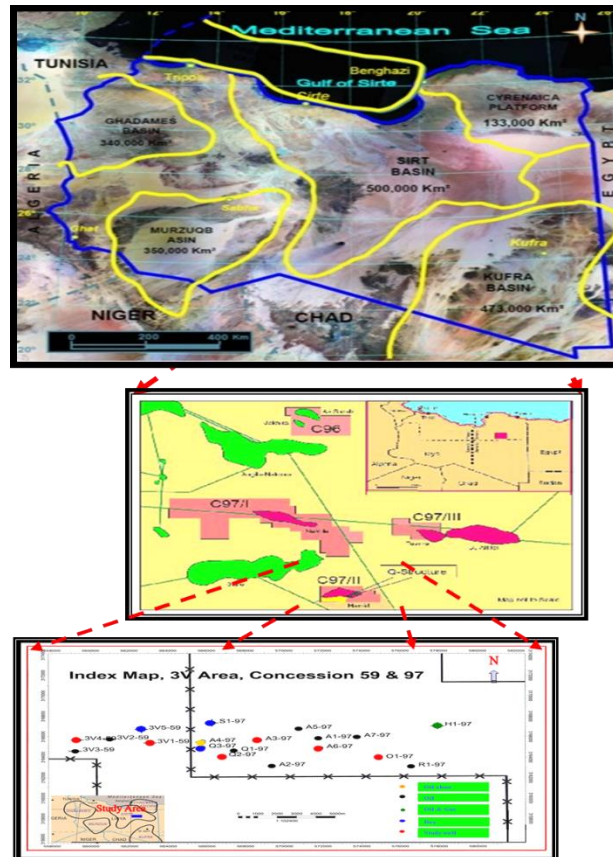
معادن الطينية الأكثر شيوعا. وتظهر مختلف القطع المتقاطعة التي تم الحصول عليها من تحليل سجلات أشعة جاما الطيفية. أن الحجر الرملي يتميز وبوفرة الثوريوم ، وكميات ضئيلة من البوتاسيوم واليورانيوم المحلي، وتفسر على أنها تشير إلى البيئة القارية النهرية. كميات أعلى من البوتاسيوم والصخر الزيتي الوسطى تحدد بيئة ترسيبية البحرية.

## 1.1 Introduction

Formation Evaluation is the process of using borehole measurements to evaluate the characteristics of subsurface formations. It applies to many purposes of engineering where various rock properties are needed. However, our efforts will be directed toward the identification and evaluation of commercial hydrocarbon –bearing formations. Well Logging is one of the most important technique in the oil field, done to define the reservoir characteristics; identification of lithology, formation evaluation and petrophysical analysis in the determination of the reserve of the hydrocarbon **Asquith, G.B** .[3] This study will show reservoir properties of Nubian Formation which selected from some wells within from different fields in eastern Sirt Basin.

## 1.2 Location of the Study Area:

The study area is located in the eastern part of the Sirt Basin, (Fig 1.1).



## 2.1 Routen Core analysis:

The samples analyzed are as follows: Clays with well-developed crystalline structures do not display collapse or damage. for example, where high crenulated illite/smectite and well crystallized kaolinited minerals are present, no determination is noted. Moderately crystallized kaolinite exhibiting vermicular form shows small amount of deterioration throughout and rare collapse of minerals. Figure (2.1). Showing Digenetic events observation by thin section for Nubian reservoir of the Well 3V4-59E(after LPI) Scanning electrical microscope Data : SEM investigation of selected core samples cut across the reservoir has led to that Nubian Formation in Q1 contains Quartz overgrowth as cement in all zones and authogenic Clays are kaolinite in Upper Nubian, illite/ smectite cement in the middle Nubian, while the Montmorillonite and kaolinite in the lower Nubian as show in plates of Figures,(2.2,2.1) Wnithershall Oil Company [4] .

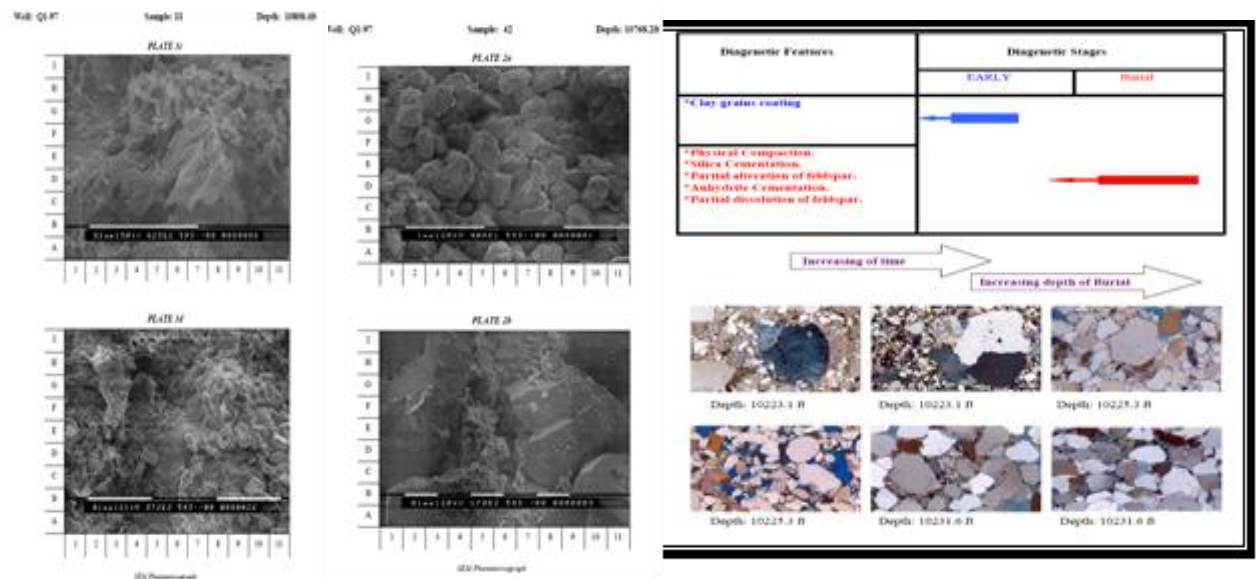


Figure (2.2)(2.1). Show the (SEM photomicrographs) analysis(Q1-97) 10808.4 Wnithershall OIL. BASF Group, Libya, Tripoli

## 3.1 MID Cross plot:

The MID\* matrix identification cross plot, like the M-N\* is a cross plot technique which helps identify lithology and secondary porosity. Also, like the M-N\* plot, the MID\* plot requires data from neutron, density and sonic logs, **Bassoon** [6]. An apparent matrix transit time,  $\Delta t_{maa}$  and an apparent grain density,  $\rho_{maa}$  can be determined

from the chart, Figure (3,1) show, the relationship between  $\Delta t_{maa}$  and  $\rho_{maa}$  of data from Nubian formation, cluster together in the end – members: Kaolinite, illite/Smectite and Calcite cement, and Montmorelite and kaolinite.

$$\rho_{maa} = \frac{\rho_b \log - \phi t * \rho_f}{1 - \phi t} \text{ Schlumberger 1994[7].}$$

$$\Delta t_{maa} = \frac{\Delta t \log - \phi t * t_f}{1 - \phi t} \text{ Schlumberger, 1994[7].}$$

Where:

$\rho_{maa}$  = an apparent grain density

$\Delta t_{maa}$  = an apparent matrix transit time.

$\Delta t_{log}$  = sonic log reading from log

$\Delta t_{fl}$  = travel time in fluid= 189μsec/ft (salt mud)

$\rho_{blog}$  = Bulk density log reading from log

$\rho_{bfl}$  = density value of fluid (1.1g /cc)

$\Phi_t$  = apparent total porosity

$U_{maa}$  can be determined from the chart (CP-14). As Figure 3.1 show, the relationship between (  $U_{maa}$  &  $\rho_{maa}$  ) of data from Nubian formation, cluster together in the end – members: Clays are Kaolinite, illite/Smectite and Calcite cement, Montmorelite and kaolinite.

$$U_{maa} = \frac{Pe \rho_e - \phi t U_f}{1 - \phi t} \text{ Schlumberger, 1972[7].}$$

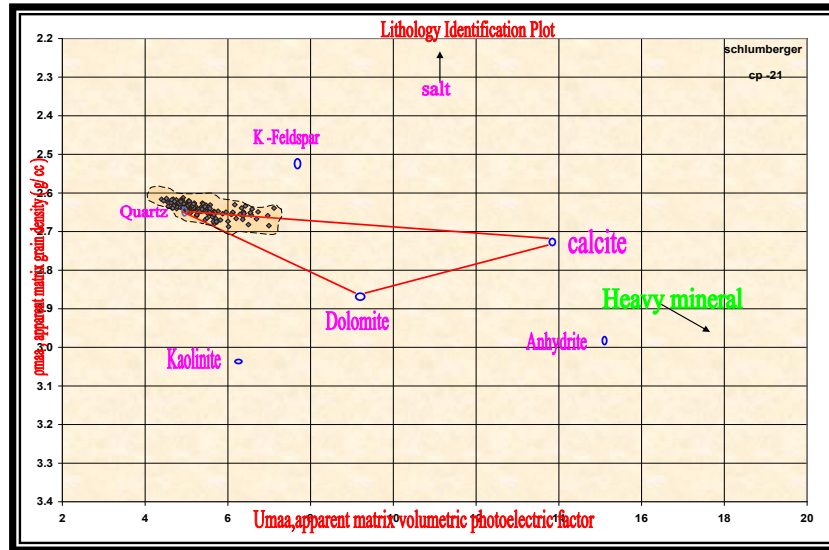
Where:

Pe is photoelectric absorption cross section Index

$\Phi_t$  is apparent total porosity

$U_f$  constant is 0.389

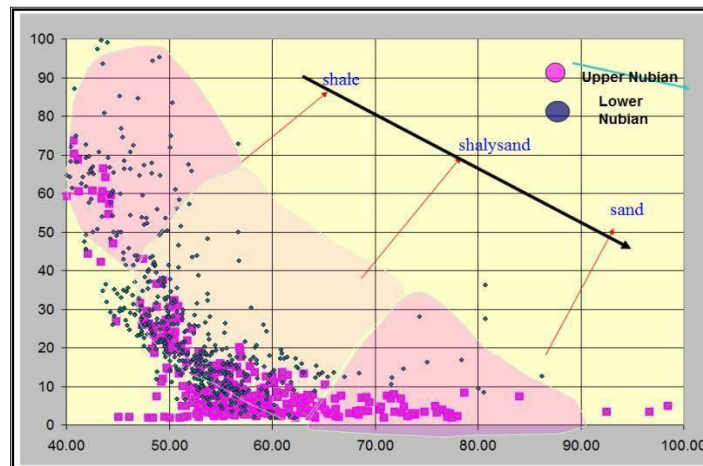
$\rho_e$  is electron density where  $\rho_e = \frac{\rho_b + 0.1883}{1.0704}$  Donald [8].



**Figure (3.1):** The MID plot  $\rho_{maa}$  &  $U_{maa}$  of data from Nubian Formation of the well Q2 - 97/11

### 3.2 Vsh vs. MN Cross plot

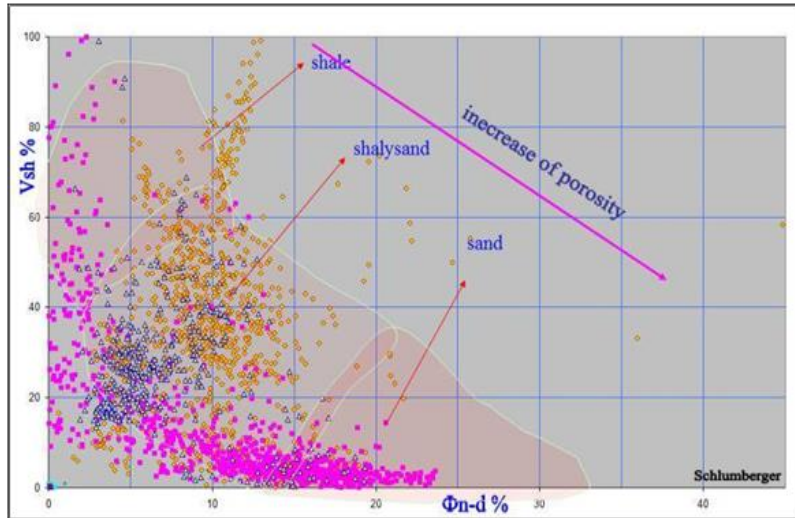
In addition to the previous relationships which are used in determining of lithology identification, there are other relationships to identify the types of rocks and depositional environment **Baghut [9]**. The petrophysical properties are ones in Geology, especially in sedimentology, and this gives a good indication on what lays underneath the surface, as can be noticed in the relationship between (**Vsh**) and (**MN**) as shown in Figure (3.2).



**Figure (3.2):** Illustrates the relationship between (Vsh) and (MN) of data from Nubian Formation of the well 3V3-59E

### 3.3 Volume of Shale Vs $\Phi_t$ porosity Cross plot

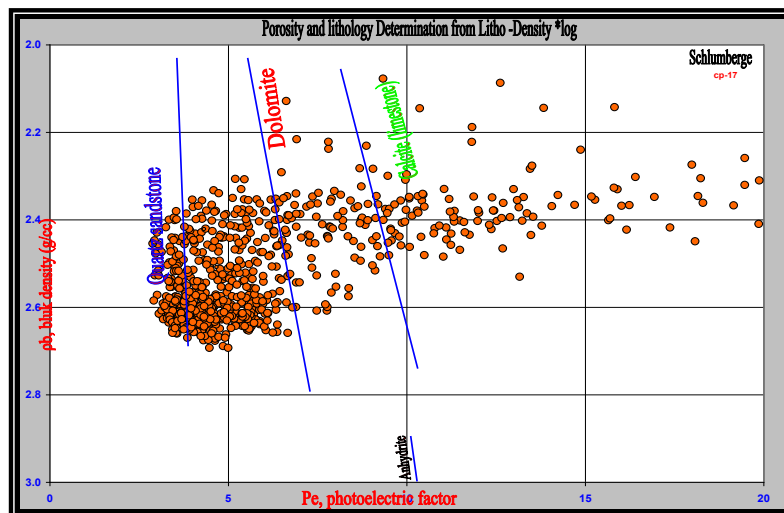
The relationship between total porosity and Vsh% data from Nubian Formation of the well Q1 - 97/11, the well Q2 - 97/11 and the well 3V3-59E in the Study Area is shown in Figure (3.3):



**Figure (3.3):** Illustrates the relationship between total porosity vs Vsh% of data from Nubian Formation of the well Q1 - 97/11, the and the 3V3-59E in the Study Area

### 3.4 Density - Photoelectric Cross Section Cross plot: -

This type of cross plot an excellent lithological detector when the borehole shape is good and the mud loaded with Barite, for. (3V3 -59E). The Barite has a very large photoelectric cross-section (2.67) as compared with 1.8 for sandstone), in figure (3.5). Thus, the Lithology should exhibit a very sharp peak in front of a fracture filled with Barite loaded mud cake. But in well (Q1-97/11) result of this cross plot is not effective in determination of type of rock figure (3.5). While in others wells this log is not run. PEF data versus density log cross plots are on the other hand, used to identify clay minerals types. The result obtained abundance of pyrite, and authigenic kaolinite.



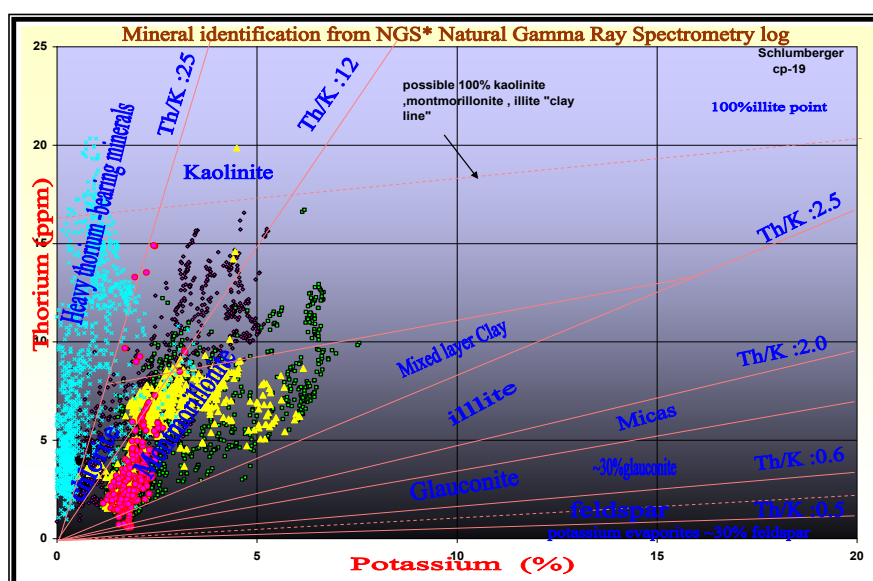
**Figure (3.4):** Illustrates the relationship between Formation Density Log Photoelectric Cross Section Cross Plot Log of data from Nubian Formation of the well 3V3

#### 4. Minerals Identifications from NGT cross plots

Various cross plots obtained from analysis of Spectral Gamma ray logs show that the Sandstones are characterized by abundant thorium, minor amounts of potassium and locally uranium, interested as indicting Fluvial continental environment. High amounts of potassium and uranium in the middle shale define a lacustrine environment. Figure (4.1). Clay minerals identification according to the photoelectrical index is a function of their content of iron, in characterized by free iron (e, g, Kaolinite) often have values similar to Quartz. They propose that cross plots of these parameters can help in identification of mineral composition. By identification of data from different logs analysis (NGS, LDT logs), cross plot methods are made for minerals descriptions which are represented by known selected point and / or clusters on the cross plots. Cross plot of (pbma) versus (Uma) is used to separate lighter minerals such as pure Quartz and kaolinite from heavier ones, which often contain iron concentration for abundances iron carbonates and / or pyrite **Baghut [9]**.

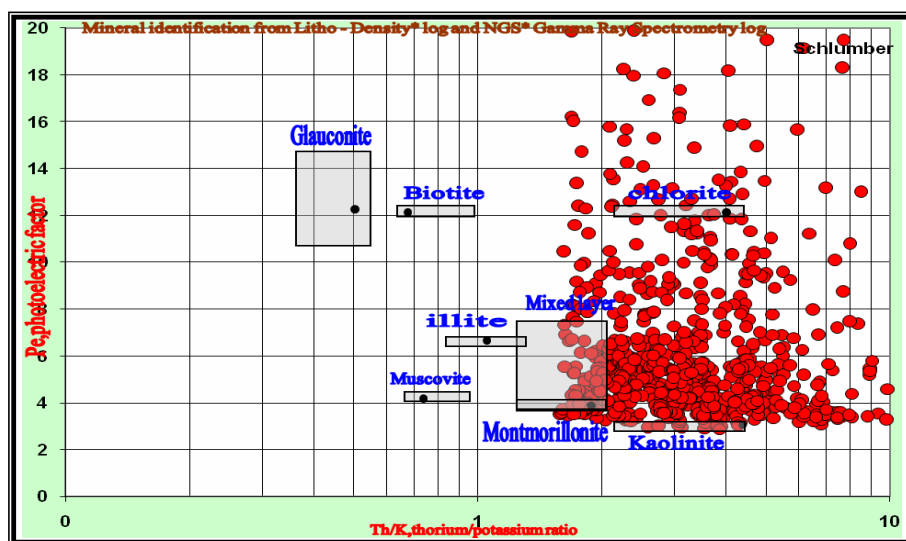
Data of thorium, potassium, and uranium were identified from analysis of spectral gamma ray in the Q1-3v3-OO5-Q2 wells, and plotted on the same cross plots of the study area to identify if there are any data variations related to the mineralogical compositions (Figure 4.2).

Accurate interpretation of the mineralogy is obtained from application of cross plot of different data derived from log curves analysis. The dominant clay minerals characterized the upper Nubian and lower Nubian sandstone Formation is kaolinite with minor amounts of illite and chlorite in contrast, illite and mixed lays characterized the middle shale, as result, the gamma –ray values indicate quite low to fair API units within the whole sandstone section, except those intervals characterized by abundance of detrital clays and which accommodate amounts of iron carbonates and pyrite.



**Figure (4.1):** Illustrates the relationship between Potassium Log and Thorium Log of data from Nubian Formation of the well (3V3,3v4,Q1,Q2,OO5).

The different cross plots of thorium versus potassium and (log Th/K) against (PEF) are shown to be reliable means of estimation minerals types in the Nubian sandstone of the study area. This was achieved by recognition of abundance of kaolinite clay minerals, which is considered as a signature for the non –marine environment. In general clay mineralogy is relatively significant in the lower Nubian sandstone as compared to the upper Nubian sandstone. Clay types in the lower Nubian sandstone are mainly illite and mixed illite /smectite, chlorite although minor, locally common in the upper most part of the lower Nubian sandstone. On the other hand clay type in the upper Nubian sandstone are mainly illite, illite/ smectite and chlorite



**Figure (4.2):** Cross plot between Photoelectric Factor (Pe) & Th/K

The relationships between these properties give clear indication of rock types, but we note shale intrusion, and calculation the volume of shale to this formation, permeability in this shale was high some kind of, comparing with porosity which is might be underprivileged, and this quality might be in Quarts overgrowth as cement in all zones and autogenetic clays are kaolinite in upper zones, illite /smectite and calcite cement in the middle zone and montmorillonite and kaolinite in lower zone. Fig (4.2)

## Conclusion

- The deposition of the Nubian has been subdividing facies. Their depositional environment is fluvial and lacustrine environment. This phase had led to the Formation of braided river sequence.
- In general Clay mineralogy is relatively significant in the Lower Nubian sandstone as compared to the Upper Nubian sandstone which it mainly illite and mixed illite /smectite, chlorite, although minor, locally common in the Upper most part of the lower Nubian sandstone, On the other hand clay types in the upper Nubian sandstone are mainly illite, illite /smectite and chlorite.
- in averages about 28%. Nubian formation contains Quartz overgrowth as cement

in all zones and autogenic clays are kaolinite in upper zone. illite /smectite and calcite cement in the middle zone and montmorolote and kaolinite in lower zone. Nubian formation the cement is Quartz overgrowth and pore filling cements including anhydrite, chlorite and autogenic clays (kaolinite, chlorite and illite/smectite).

- Various cross plots obtained from analysis of Spectral Gamma ray logs show that the Sandstone are characterized by abundant thorium, minor amounts of potassium and locally uranium interested as indicting Fluvial continental environment. High amounts of potassium and uranium in the middle shale define a lacustrine environment.
- It is highly recommended to use up date set of well logs such as spectral gamma ray, SGR, resistivity logs, (MSFL, SFLU, and ILD), etc.) Sonic logs, neutron, density, photoelectric log PEF, SP log, Caliper log and the quick look method is the first milestone of quantitative interpretation method.

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