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Sedimentology and Petrography of the Mamuniyat Formation, Elephant Oil Field Concession NC174, NW Murzuq Basin, SW Libya

A. A. Kushlaf[1], A. Shiwa[2], Yahia A. Salem[3]

[1, 2, 3] Engineering Geology Department, Faculty of Oil and Gas, Zawia University, Zawia, Libya

E-mail: a.Kushlaf@zu.edu.ly

1. Abstract

This research aims to study the sedimentary and petrography interpretation of the Mamouniyat Formation in the El Feel oil field, concession NC174 in the Murzuq Basin through investigation and analysis of core samples, wireline log data and conventional core analysis for the key well (F2-NC174) located on the western part of E.O Field. The Mamouniyat Formation has been Lithostratigraphically divided into three members based on grain size and wireline log response. Five facies have been known in the Mamouniyat Formation, according to specific associations with rock types and their lithological and sedimentological characteristics. All these facies were collected into three different facies associations. The sandstone is internally structured by symmetrical to asymmetrical wave ripples and parallel lamination. The Petrographic study indicate that the Mamuniyat Formation consists primarily of sublitharenite rocks with the presence of some litharenites and quartiz arenites. The studies also made it clear that the average Mamuniyat porosity is approximately ranging from medium to good porosity.

Keywords: *Murzuq Basin, Mamuniyat Formation, Elephant oil field, facies patterns*

2. Introduction

The Murzuq Basin located on the SW Libya is sub-circular shape and clearly visible on satellite images [9]. Early Palaeozoic tectonism created a series of NNW trending arches and sub-basin across North Africa, filled with siliciclastic continental and shallow-marine deposits [4].This Early Palaeozoic tectonism effectively and controlled the distribution of Upper Ordovician hydrocarbon reservoir and the distribution of Silurian "Hot Shale" source and seal rocks which onlap early-formed fault blocks [8].

The Basin, approximately triangular in form, tapering toward the south from libya into Niger **(Fig.1)**. The sedimentary fill is predominately marine and continental Palaeozoic, with some Mesozoic and Cenozoic sediments overlying Precambrian crystalline basement. In the central part of the basin the total sedimentary thickness exceed 3500 m [9]. The Murzuq Basin is separated from the Illizi Basin , Algeria, to the west by the north-south ridge of the Ghat/Tikiumit Arch [3].

The reservoir study within NC174 Concession focuses on the Mamuniyat Formation, which has an Upper Ordovician (Ashgillian) age. The Cambro-Ordovician system of Libya was first defined in the Qarqaf area and is widespread over large portion of the North Africa craton [7]. Five formations, four of them formally defined by [10]Massa and Collomb (1960), represent this system in Libya.

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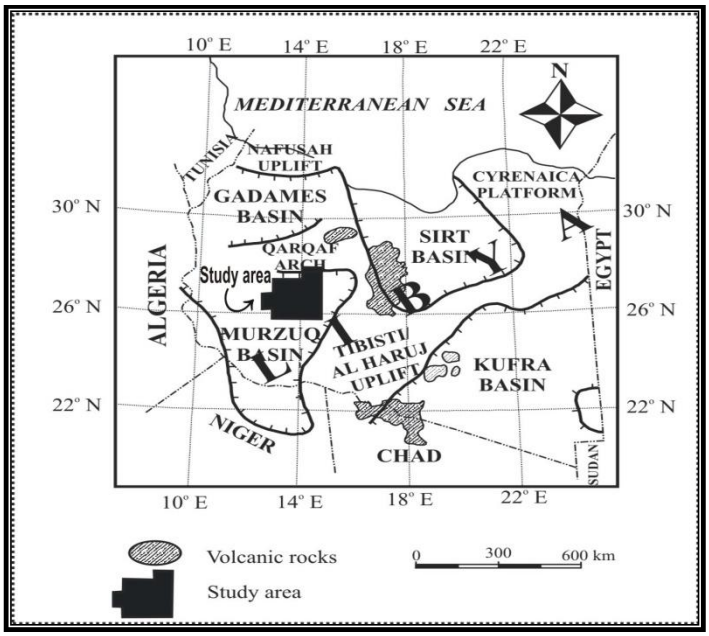

Fig.1: Location Map of the Sedimentary Basins of Libya (After Fello, 2001)

These are the Hasawnah, Ash Shabiyat, Hawaz, Melez Shuqran and Mamuniyat Formations, which have been grouped into the Qarqaf Group by [2]Burollet (1960).

Lasmo NC174 Concession lies on the north western flank of the Murzuq Basin, about (700 km) soutwest of Tripoli. It covers an area of (11,300 km²) **(Fig. 2)**.

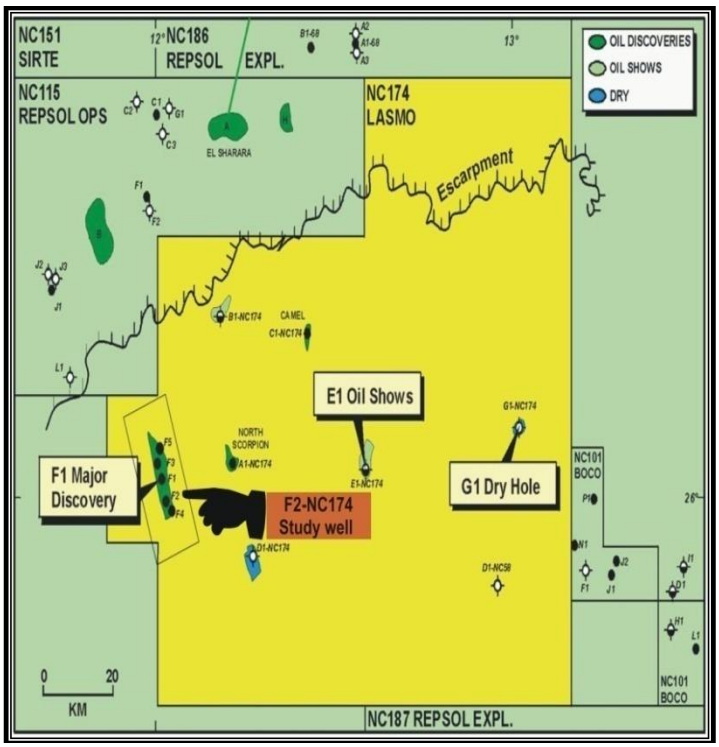

Fig. 2: General location map showing the study well F2-NC174, located on the West part of NC174.

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Facies are define from slabbed core on the basis of lithology, grain-size, sedimentary structure and wireline log response **(Fig.3)**. Sedimentological evaluation of cores from the key well F2-NC174 reveal a sequence dominated by graded-bedded, internally structureless sandstones, interbedded with local shale and/or claystone.

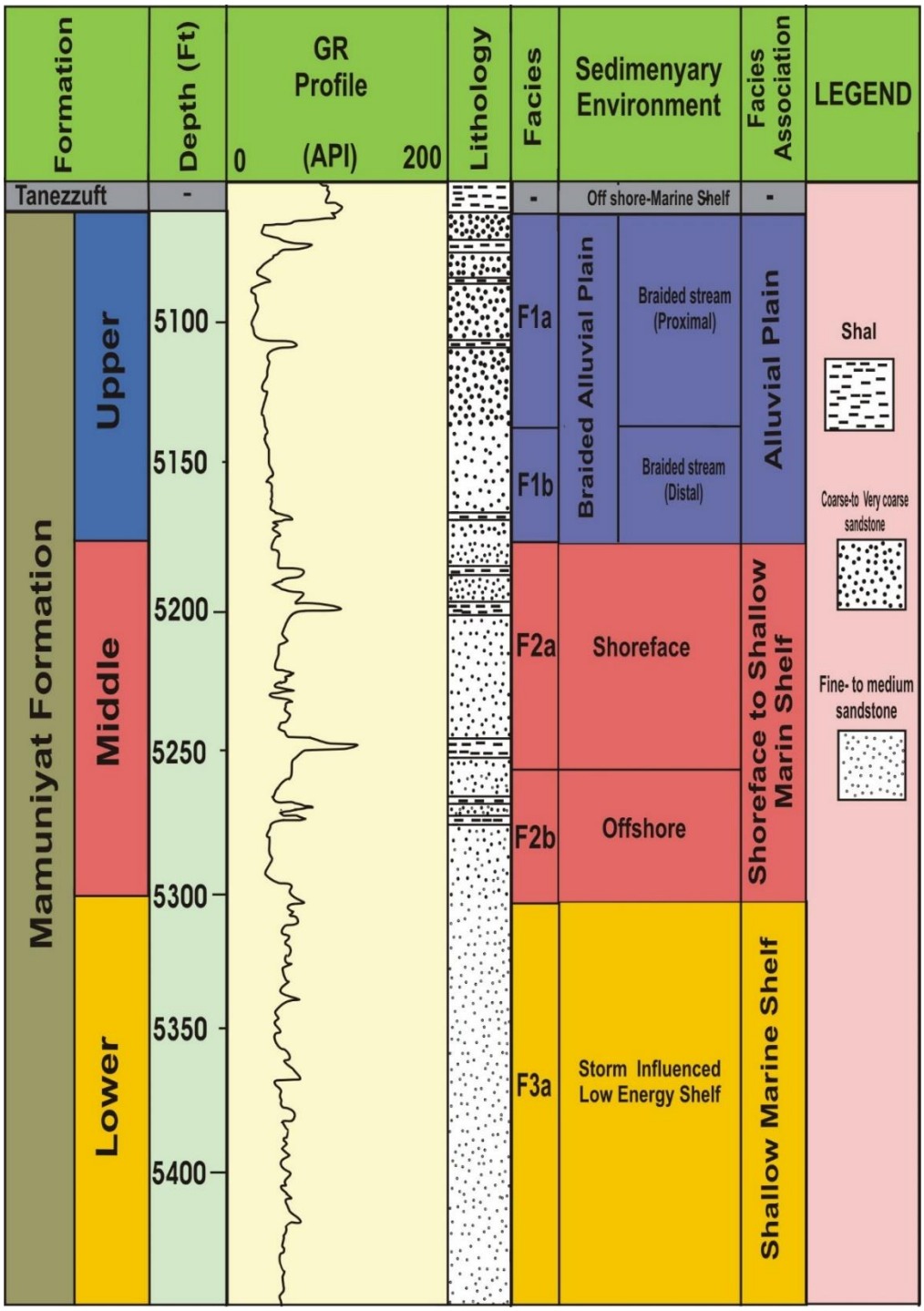

Fig. 3 Wireline logs from the key well F2-NC174, showing the GR profile integrated with lithology characteristics.

3. Methodology

A amount of material was made available as detailed below.

1) Slabbed cores were provided by (NOC), and thin sections were prepared by (LPI);
2) Wireline logs for the key well F2-NC174, have been analysed by using the compensated sonic and gamma-ray amplitudes to break down the facies;
3) A review of all relevant literature and accessible published and unpublished reports known to the author concerning the Upper Ordovician ″Ashgillian″ Mamuniyat Formation, including subsurface information.

In addition, this study is based also on a total of 8 thin sections, collected from the key well F2-NC174 of Elephant Oil Field. The thin section has been impregnated with blue resin in order to more accurately assess porosity, a technique that is partticularly useful for sediments having more than 10% porosity.

Porosity measurement was estimated by using the microscope techniques (thin section analysis). Additional information has been derived from the following wireline logs: BHC (Borehole Compensated Sonic), GR (Gamma Ray). Slabbed core has been used to assist in interpretation of the facies and depositional environments.

4. Sedimentary facies associations and facies of the Mamuniyat Formation

The maximum vertical succession thickness is approximately (281.8 ft) in the key well F2-NC174 **(Fig.4)**. Initially, the Mamuniyat Formation in the Elephant Oil Field was subdivided into three main members characterized by differing log responses.

4.1 Facies Association, Upper Mamuniyat Formation (F1): Alluvial Plain

This facies association is restricted to the uppermost part of the succession in most of the reservoir interval in the F-structure of Elephant Oil Field, particularly in type well F2-NC174 **(Fig.4).** This facies association (F1) comprises two distinctive facies; each facies type is defined on the basis of lithology, grain size, sedimentary structures and log response. These facies are described and interpreted below.

4.1.1 Facies (F1a): Coarse to very coarse grained sandstone

This facies occurs in the subsurface in the uppermost part of the Mamuniyat Formation. It has been found in the western part of the study area in the Elephant Oil Field, Block NC174. It makes up the bulk of the uppermost Mamuniyat sandstones and is represented by the cored interval from 5076 ft to 5144 ft in type well F2-NC174

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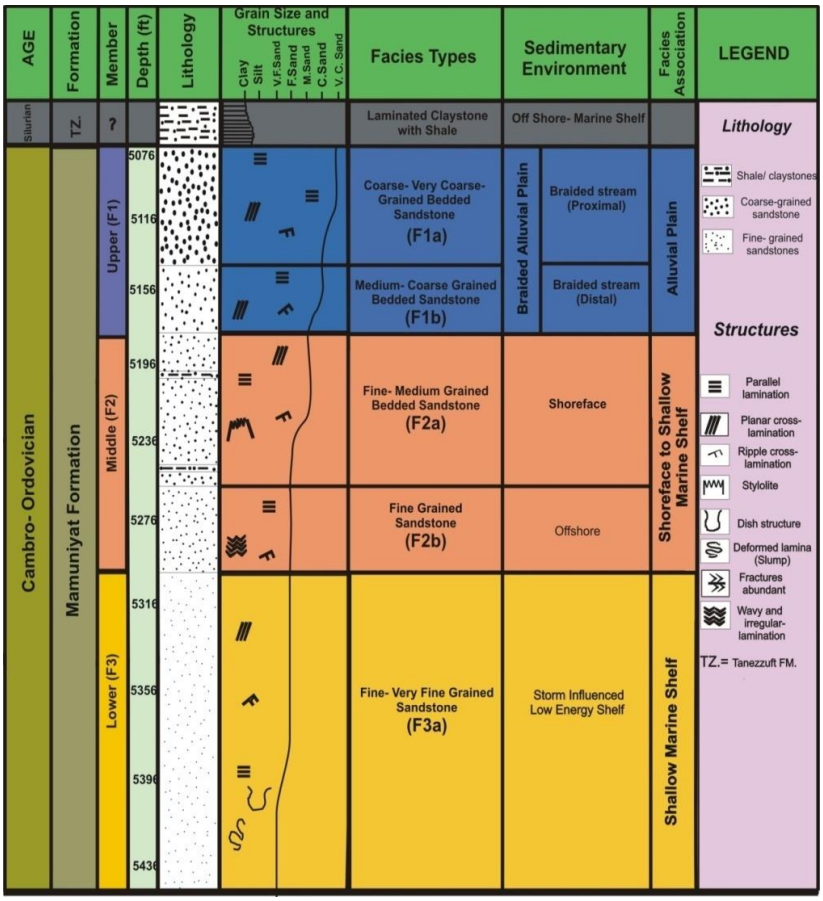

Fig.4: Lithology and sedimentary environments of the cored interval between 5440 ft and 5076 ft in type well F2-NC174 (Elephant Oil Field).

(Fig.4). It characterized by light brownish grey, brownish grey and dark brownish grey (colour reflecting degree of oil staining) sandstone with occasional pebbly sandstones. Facies (F1a) is about 68 ft thick and composed mainly of coarse- to very coarse-grained sandstones with minor pebbly sandstones (*e.g*. 5112 ft in type well F2-NC174) **(Fig.5)**. Intraformational clasts consist of sub angular to subrounded sandstone and they are poorly sorted, friable to moderately hardness, unfossiliferous, and argillaceous in character. In the uppermost part of this facies some claystone occures, which significantly lower sediment permeability. Some sandstone beds in the middle part of facies (F1a) show a fining-upward trend from very coarse to coarse-grained sandstone. A feature of this entire facies in type well F2-NC174 is the presence of alternations of thick sequences of very coarse and medium-grained sandstones. These coarsening-upward sequences occure together with locally developed fining-upward sequences giving an overall coarsening-upward trend to the entire facies (*e. g*. type well F2-NC174) **(Fig.6)**.

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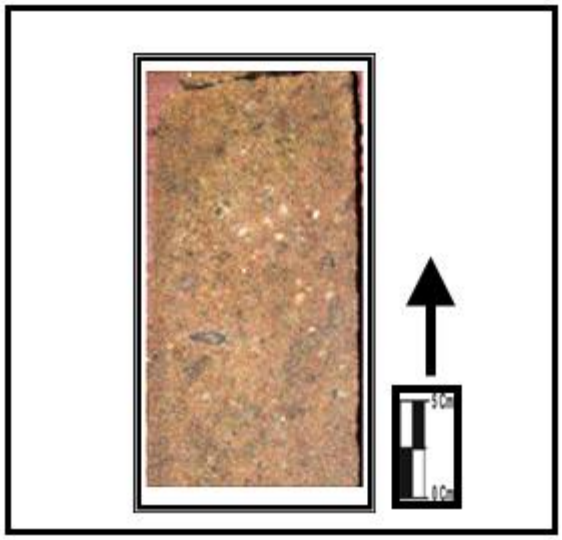

Fig.5: Slabbed core sample from well F2-NC174, at 5112 ft, showing pebbly sandstone (large arrow) coarse to very coarse sandstone (small arrow).

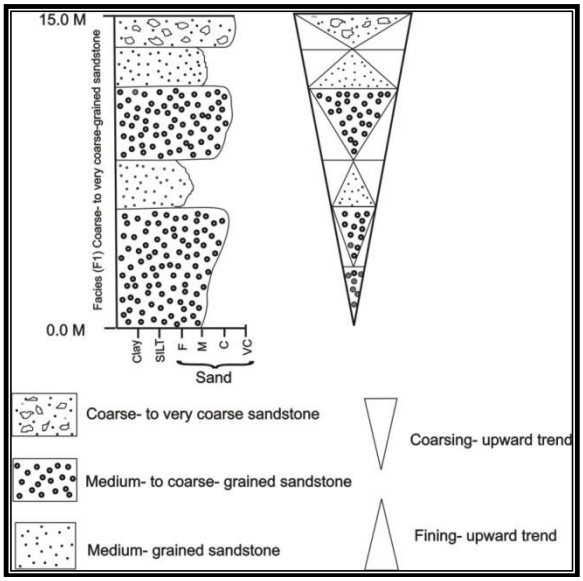

Fig.6: Generalized measured section for Facies F1a showing the coarseing-upward trend with locally developed fining-upward trend.

4.1.2 Facies (F1b): Medium to coarse grained sandstone

This facies occurs immediately beneath facies (F1a) in type well F2-NC174, between cored interval 5144 ft to 5175 ft, where it forms the lower part of the Upper Mamuniyat Formation (F1) **(Fig.4)**. It consists mainly of light brownish gray, brownish gray and dark brownish gray (colour reflecting degree of oil staining) sandstone with occasional claystone interbeds.

Facies (F1b) is about 31 ft thick and composed of medium to coarse-grained sandstones. Intraformational clasts consist of subangular to subrounded sandstone and they are poorly to

moderately sorted, moderately hardness and unfossiliferous. The sedimentary structures in these facies are characterized by horizontal laminated strata **(Fig.7)** to rippled sandstones **(Fig.8)**.

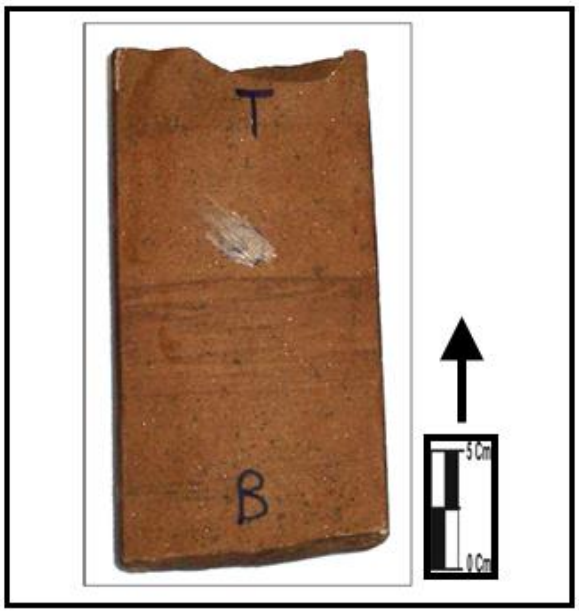

Fig.7: Slabbed core sample from well F2-NC174, at 5146 ft showing medium sandstone with horizontal lamination (arrow).

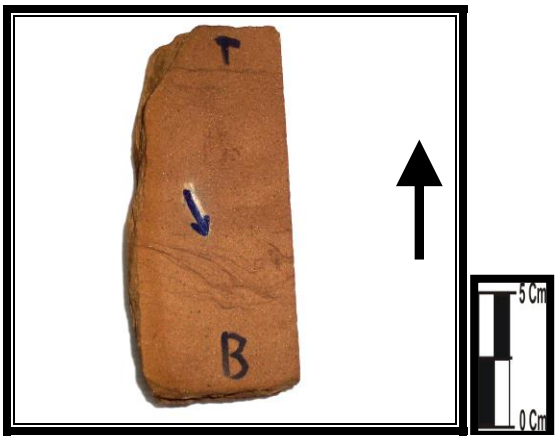

Fig.8: Slabbed core sample from well F2-NC174, at 5151 ft, showing the rippled medium sandstone (arrow).

4.2 Facies Association, Middle Mamuniyat Formation (F2):

Ths facies association recognized in the Middle part of Mamuniyat sandstone and represented by the cored interval from 5175 ft to 5300 ft, in type well F2-NC174. It comprises two distinctive facies; each facies type is defined on the basis of lithology, grain size, sedimentary structures and log response.

4.2.1 Facies (F2a): Fine- to medium grained sandstone

This facies occurs in the upper part of the Middle Mamuniyat Formation (F2). It is represented by the cored interval from 5175 ft to 5255 ft in the well F2-NC174 **(Fig.4)**. Facies (F2a) is about 80 ft thick. It characterized by light brownish, translucent, fine-to medium-grained sandstones with local coarse-grained claystones. The sandstones are well indurated, and moderately sorted, moderately hardness with indurated grains mostly sub angular to sub rounded. The sandstone beds of facies (F2a), range in thickness from 0.5 ft 6 ft, and are characterized by symmetrical to asymmetrical wave ripples and current ripples, as well as wavy ripple lamination and parallel lamination and massive bed with clay chips are common within facies (F2a).

4.2.2 Facies (F2b): Fine-grained sandstone

The facies occurs in the lower part of the Middle Mamuniyat Formation (F2). It has been found in the western part of the study area. Facies (F2b) is represented by the cored interval from 5255 ft to 5300 ft in type well F2-NC174 **(Fig.4)**. It extends over 45 ft of the cored thickness and is composed of silty shale, claystone and fine-grained sandstone. The sandstone beds of facies (F2b) are characterized by light brown, translucent, moderately- to well sorted, with grains mostly subangular to subrounded.The entire facies shows a general coarsening-upward trend and passes sharply upwards into shales, claystones and fine-grained sandstones.

The sedimentary structures in facies (F2b) are characterized by asymmetrical wave ripples (e.g. 5261 ft in type well F2-NC174), parallel laminations (e.g 5266 ft in type well F2-NC174) and massive sandstone with clay chips in some cases.The sandstones contain some deformed lamina and heterolithic-claystone. with carbonaceous fragments in the middle portion of facies (F2b). The facies formes beds ranging between 0.10 ft to 0.20 ft thick. Beds are sharp at the based, with small-scale rippled and/or parallel-lamination.

4.3 Facies Association, Lower Mamuniyat Formation (F3): Shallow Marine Shelf

This facies association is restricted to the lowermost part of the succession in most of the study formation **(Fig.4)**. This facies association (F3) comprises only one distinctive facies, and it is defined on the basis of lithology, grain size, sedimentary structures and log response.

4.3.1 Facies (F3a): Fine to very fine-grained sandstone

Facies (F3a) represented by the cored interval from 5300 ft to 5440 ft in type well F2-NC174. This facies is about 140 ft thick. It consists of fine- to very fine-grained sandstone. The sandstone is light brownish, well-sorted. These sandstones are sometimes massive but usually contain faint parallel or wavy lamination, wave-ripples and occasionally weak normal grading.

5. Compositional analysis

In this study eight thin sections were analysed according to standard modal analysis techniques in order to determine the amount of the following minerals: quartz, rock fragment, feldspar, heavy mineral, mica, chert, dolomite, kaolinite, illite, chlorite, pyrite, matrix and bitumen **(Fig.9)**. The same thin sections were used to determine grain roundness and sorting in the Mamuniyat sandstone.

Porosity measurement was estimated by using the microscope techniques (thin section analysis) and the types of porosity in the Mamuniyat Formation were classified into three types for counting purposes: primary porosity, secondary dissolution porosity and microporosity.

Detrital components for model analyses were classified into monocrystalline quartz (Q), feldspar (F) and rock fragment (RF) (including detrital polycrystalline quartz grains). The omission of cement and matrix material from this classification removes the effects of diagenesis that may mask the maturity. The mineral composition of the Mamuniyat sandstone provides evidence of the composition of the source rocks and the diagenetic events that have affected the post-depositional burial history of the sandstone.

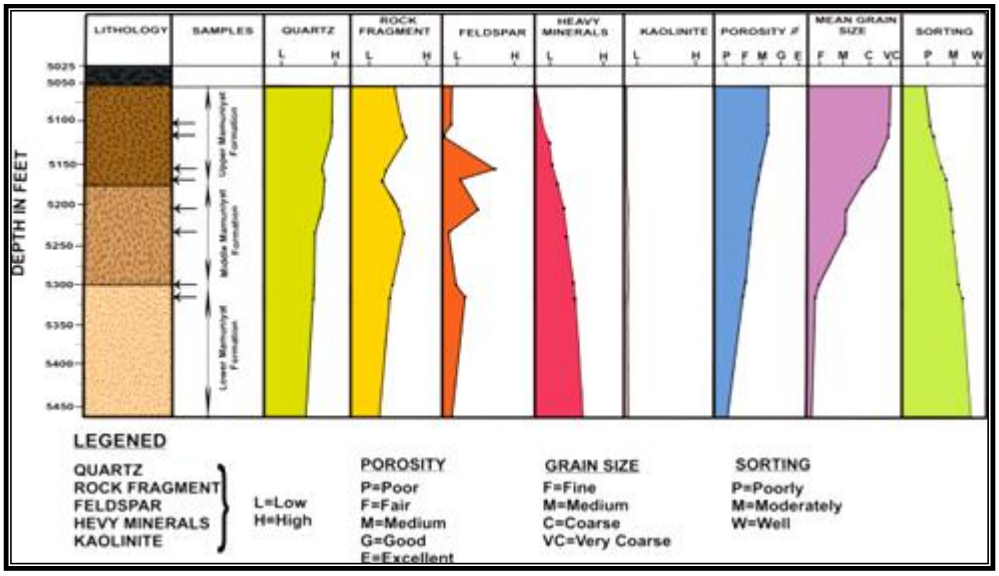

Fig.9: Petrographic characteristics of the Mamuniyat Formation throughout Elephant Oil Field, well F2-NC174, showing the sample points (arrows), quartz, rock fragment, feldspar content, heavy minerals, kaolinite clay, porosity, mean size (mm) and sorting (After Fello, 2001).

6. Classification

The Petrographic study indicate that the Mamuniyat Formation consists primarily of sublitharenite rocks with the presence of some litharenites and quartiz arenites(**Fig.10**) according to [6]. Sublitharenites are perhaps the most abundant of all sandstones. These are quartz-rich, feldspar-poor, quartz-cemented sandstones. Throughout the Mamuniyat sandstones the sublitharenites are characterised by their high quartz contents, dominated by monocrystalline quartz grains**(z) (Fig.11)** with subordinate amounts of polycrystalline quartz grains**(Fig.12)**. They are well cemented with secondary quartz overgrowths**(Fig.13)**. Although they are moderately to well sorted, the grains are subrounded to rounded with a low sphericity. However, sublitharenites have high porosity values and the best reservoir potential.

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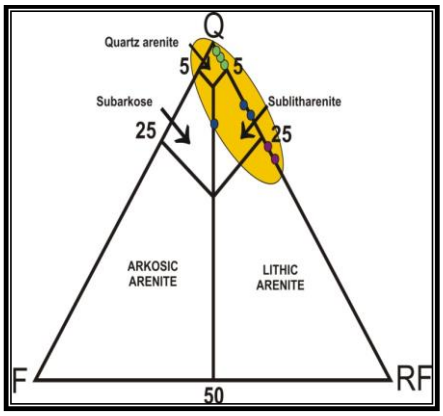

Fig. 10: Ternary QFRF plot showing the composition of thin sections from Elephant Oil Field, well F2-NC174. (Classification modified from Pettijohn *et al*., 1987). Note: Q = Quartz , RF = Rock Fragment and F = Feldspar.

The quartz arenites are common in the lower part of the Mamuniyat sandstones. These are characterised by a high quartz content, dominated by monocrystalline quartz grains with polycrystalline quartz grains locally abundant. They also contain more well-rounded and well-sorted grains, so that the textural maturity is also very high. Quartz overgrowths, chlorite **(Fig.14)** and calcite cements, are common cements.

Litharenites are characterized by a rock fragment content in excess of feldspar[5]. These are chiefly fragments of mud-rock and their low- grade metamorphic equivalents, and volcanic grains. Other components are flankes of mica, with some feldspar and abundant quartz. Litharenites account for 20% to 25% of all sandstones in the rock record.

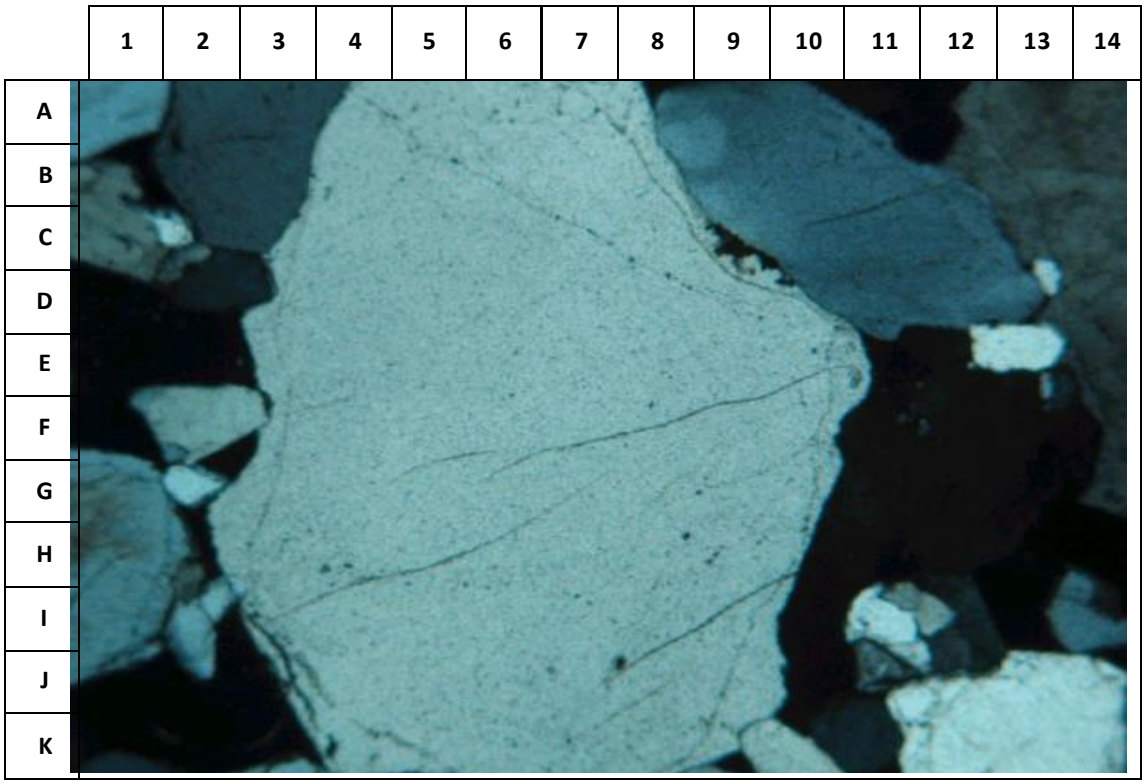

Fig. 11: Photomicrograph of Upper Mamuniyat (F1a) sandstone from F2-NC174 at depth 5118 ft showing monocrystalline quartz grain (A6-K6). XPL (X5). Sample **No. 2.2.**

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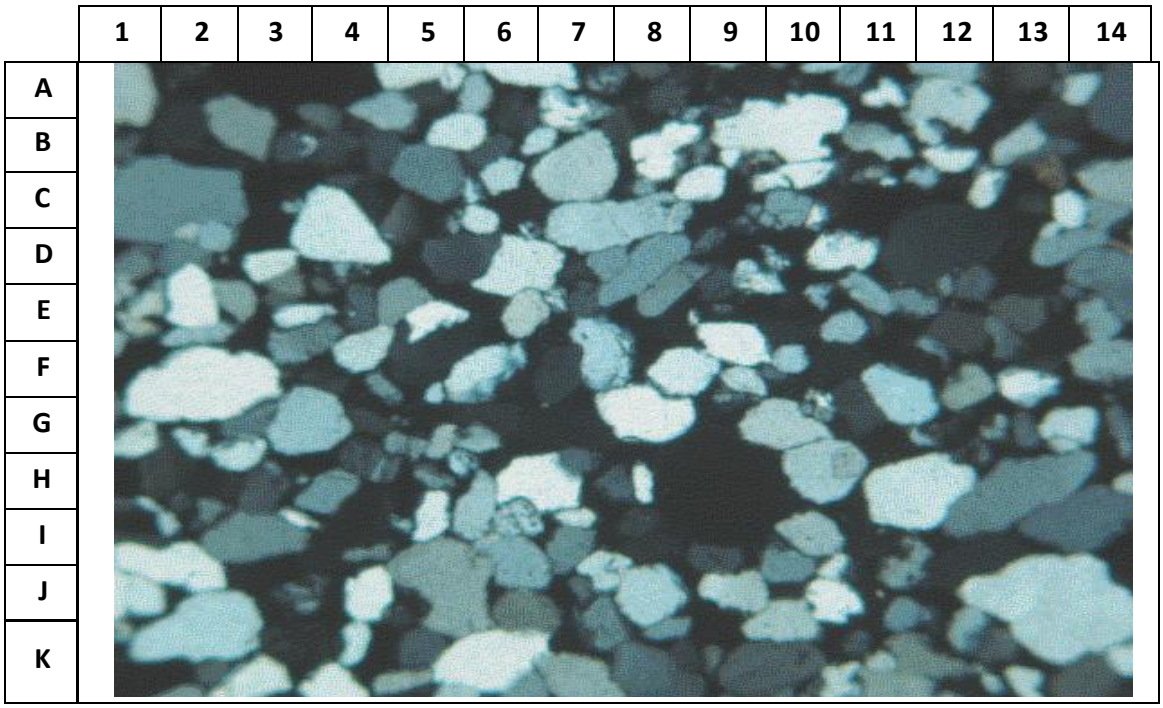

Fig. 12: Photomicrograph of medium grained, moderately sorted Upper Mamuniyat (F1b) sandstone), from F2-NC174 at depth 5151ft, showing polycrystalline, subangular to subrounded quartz grains . XPL (X200). Sample No. 3.1.

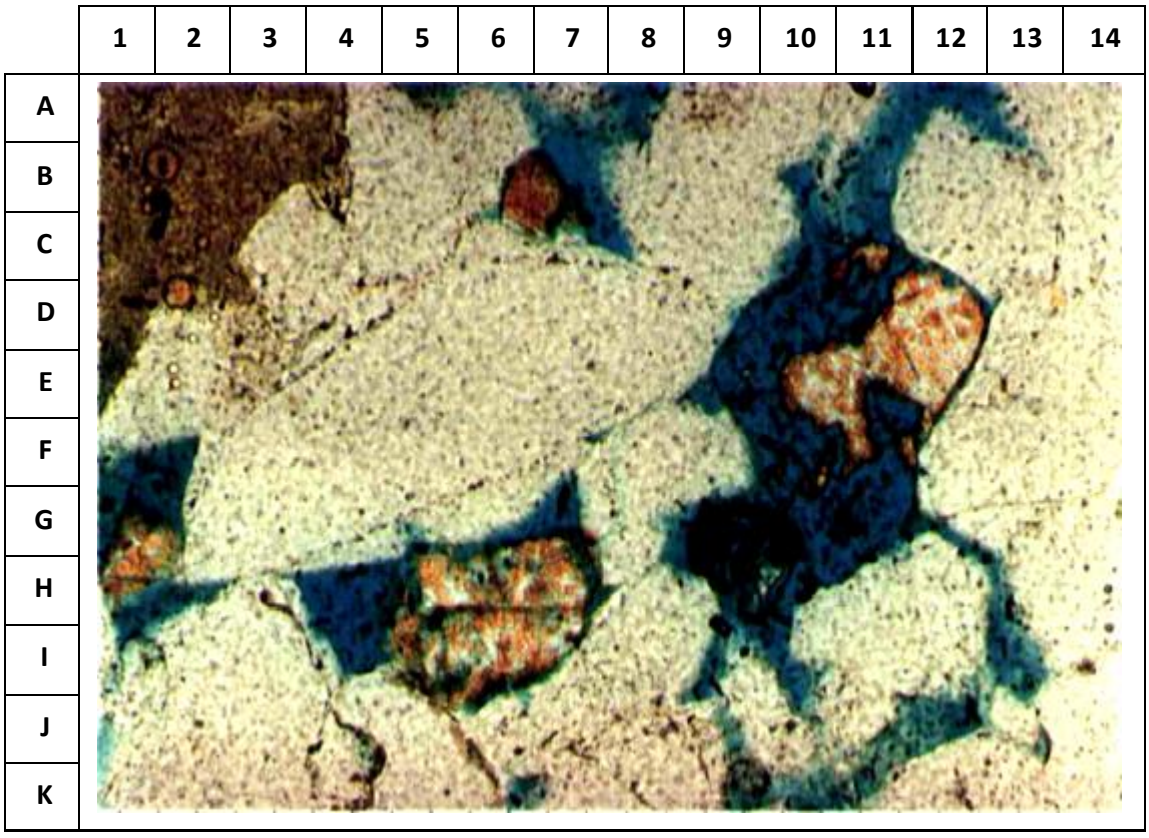

Fig. 13: Close-up view of above sample from F2-NC174 at depth 5112 ft, illustrating a partially dissolved microcline feldspar (yallow stained grain at E12). Quartz overgrowths are abundant (e.g. at G6). XPL (X100). Sample **No. 1.2**.

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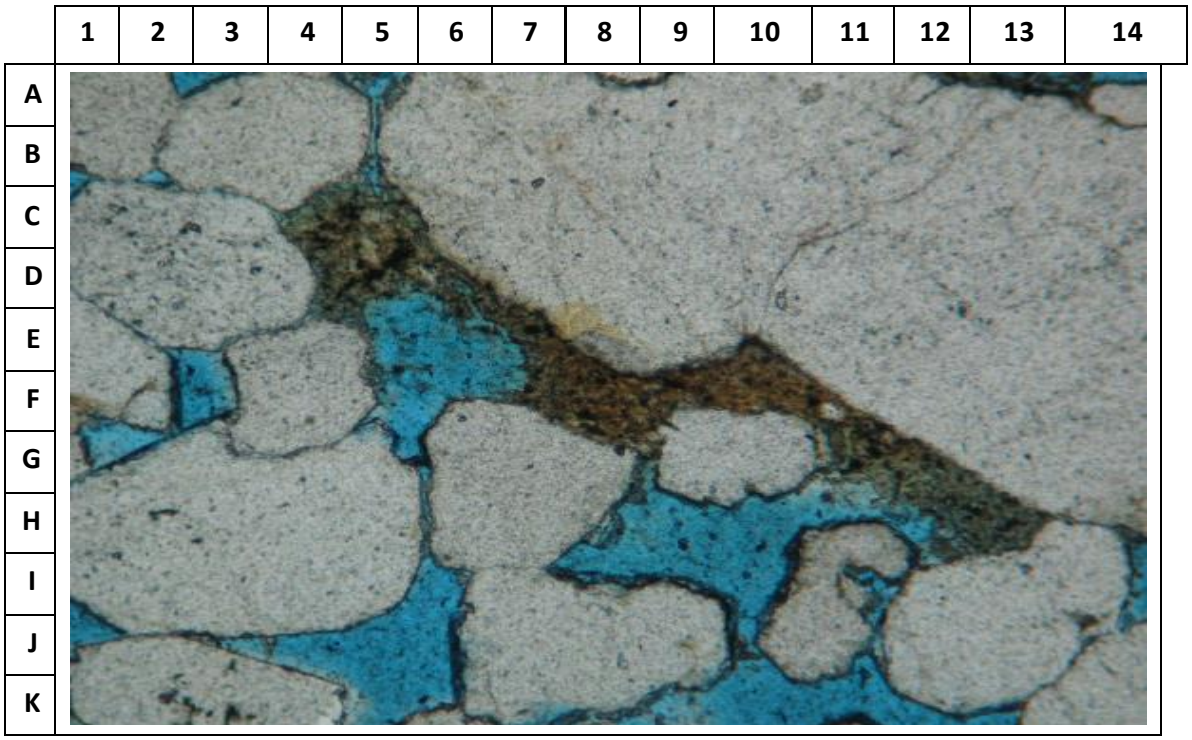

Fig. 14: Photomicrograph from F2-NC174 at depth 5228 ft, showing authigenic chlorite cement (C5-I13) and locally reduce primary porosity (blue stain). XPL (X10). Sample **No. 6.7**.

7. Porosity evolution

In the formation study Mamuniyat sandstone all three types of porosities occur. The mean *primary porosity* throughout Elephant Oil Field is medium to good porosity **(Fig.15)**.

Secondary porosity develops as a result of dissolution of unstable detrital grains and framework cement. Secondary porosity may be generated by fracture throughout the diagenetic evolution of a sandstone and there is evidence that was case within Mamuniyat Formation **(Fig.16)**.

By using the petrographic analysis and mineralogical investigation of the Mamuniyat Formation within the key well F2-NC174, the total of the entire Mamuniyat reservoir sandstone porosity was noted and expressed as average porosity is approximately ranging from medium to good porosity.

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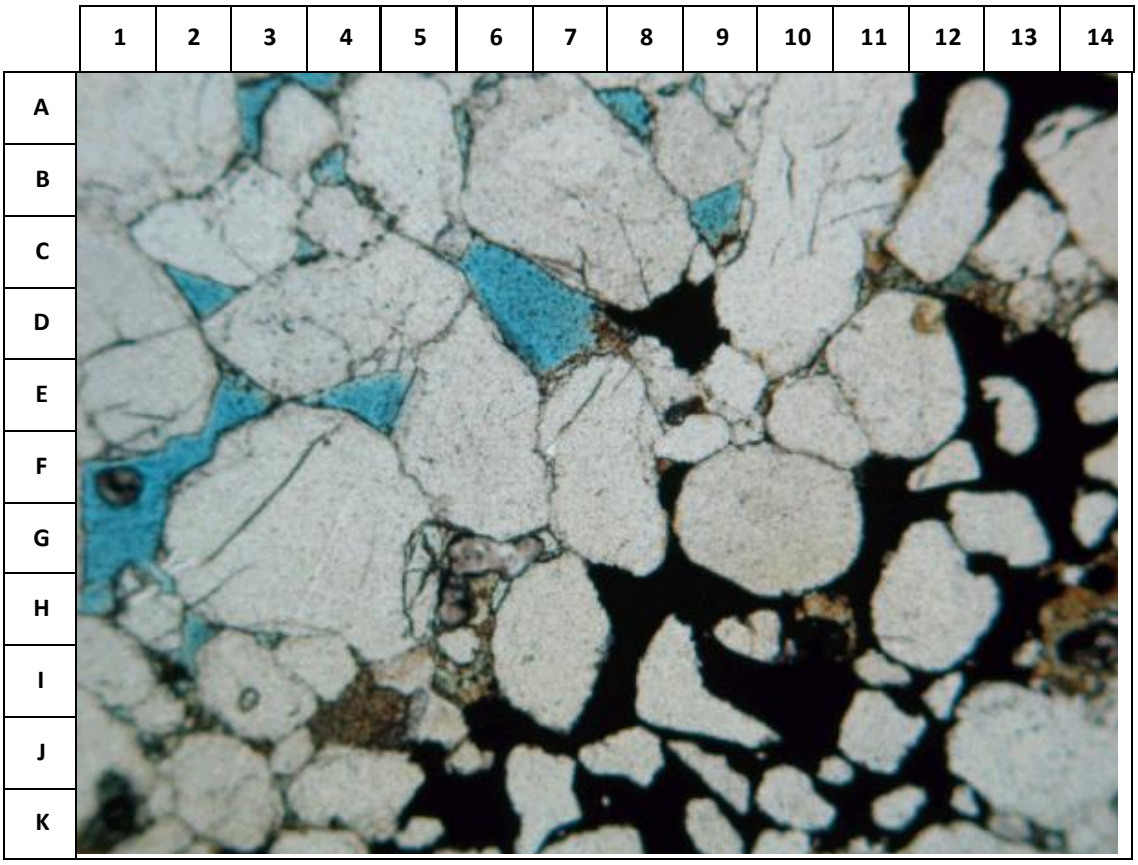

Fig. 15: Photomicrograph from F2-NC174 at depth 5118 ft of Upper Mamuniyat (F1a) sandstone showing primary porosity (blue stain) and pore-filling bitumen (black color) (A14-K7). XPL (X5).

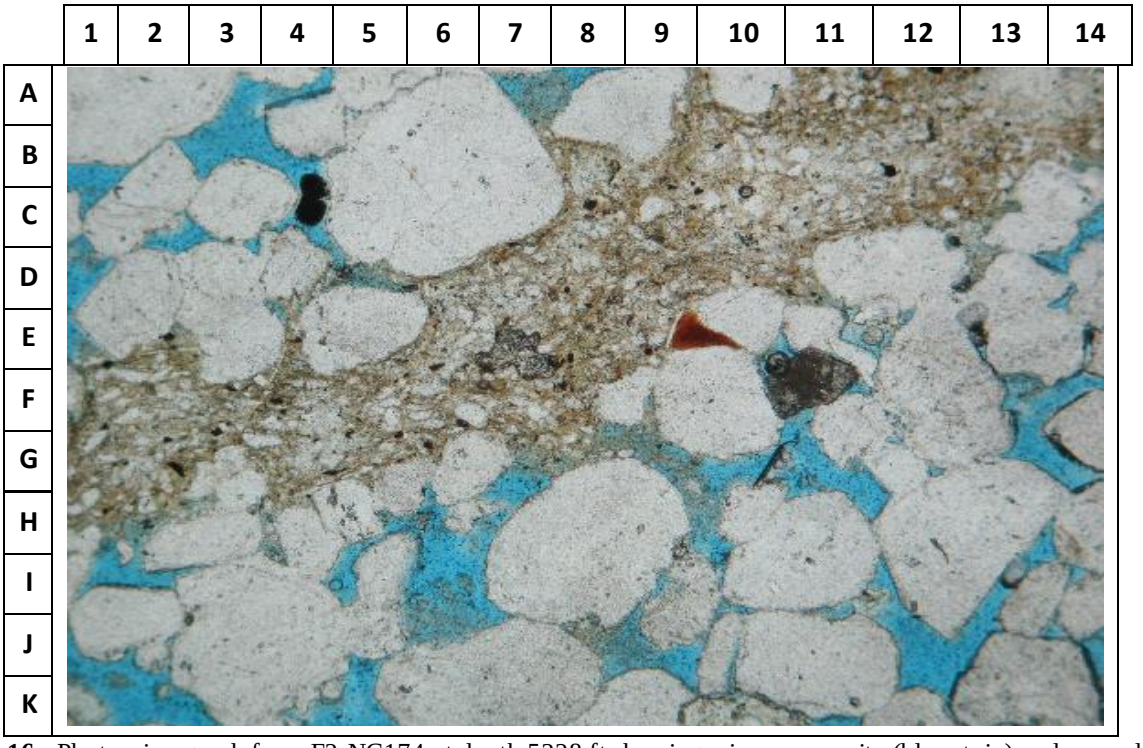

Fig. 16: Photomicrograph from F2-NC174 at depth 5228 ft showing primary porosity (blue stain) and secondary porosity (fracture filled by mud matrix) at (G1-A14). XPL (X5). Sample **No. 6.3**.

8. Summary and Conclusions

This paper has been carried out to study Sedimentology and petrography of Mamuniyat formation in Elephant Oil Field NC174Concession. The conclusions are as follows

- The study Formation divided into three Members, according to textural and sedimentological physiognomies;
- The detrital mineral components are monocrystalline quartz with subordinate polycrystalline quartz, rock fragments, heavy minerals, kaolinite and feldspar;
- The average total porosity of the Mamuniyat Formation with the key well F2-NC174 is ranging between medium to good porosity based on thin section analysis particularly in the Upper Member.
- Compositional data indicates that the sandstones in the study well were derived from a similar parent rock;
- The Petrographic study indicate that the Mamuniyat Formation consists primarily of sublitharenite rocks with the presence of some litharenites and quartiz arenites.;

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