A Review of Carboniferous, Permian and Middle Triassic Paleoenvironmental Linked with Thermal Maturities Interpretation of A1-9 Well, Concession 9, NW Libya

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Abstract

The present work deals with the paleoenvironmental and hydrocarbon potential of the lithostratigraphic succession in Carboniferous, Permian and Middle Triassic sediments in the north west

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Libya. Data presented in this paper are based upon a detailed subsurface lithological characteristics from ditch cutting samples and involving electric logs (gamma-ray) linked with palynofacies interpretation. The sedimentary section of this area ranges in age from Upper Paleozoic rock to Triassic. Early Paleozoic rocks have not been found in the studied well (A1-9), these rocks were eroding during the Late Carboniferous and Early Permian time. During Latest Permian and earliest Triassic time evidence for major marine transgression has occurred. From depths 5930-5940 feet, to 10800-10810 feet, the TAI of the Al Guidr, the Bir Al Jaja Al Uotia, Hebilia and the top varies between 3+ to 4- (mature-dry gas). This interval corporate the rest part of the Dembaba Formation. From depth 10800- 10810 feet, until total sediment depth (11944 feet Log) which corporate the rest of the Dembaba and underlying equivalents of the Assedjefar and M′rar Formations and the underlying indeterminate unit (Hasaouna Formation), the TAI varies between 4 and 5 (dry gas-black & deformed). The environment of deposition and the degree of thermal maturation has allowed the A1-9 well to become a key reference section in NW Libya from which correlations can be carried out.

Keywords: *Carboniferous; Permian; Middle Triassic; Depositional paleoenvironmental; maturity; north western Libya.*

1. Introduction

Our approach to interpreting the depositional paleoenvironment of the Carboniferous, Permian and Middle Triassic sediments in the A1-9 well is situated in northwest Libya in Concession 9 adjoining the Tunisian border (Fig. 1), the concession, which was acquired in 1955, covers some 2,017 km^2s, approximately 500,000 acres. This wildcat well, the first well on the concession 9 is located towards its southern margin on the Zuara (L) prospect (Fig. 1). To aid in correlation and concurrent with the drilling of the well, changes in the colouration of the palynomorphs, also has been documented as a Thermal Alteration Index (TAI), that giving some idea of changes in thermal maturities through the well section. The data obtained from the analysis of the organic matter maturity are excellent indicators of the thermal evolution of sedimentary basins (Fantoni and Scott, 2003). All the formation tops are indicated by the wireline log traces and lithology description from ditch cutting. Shale, dolomite, and dolomitic limestone's represent the M´rar, Assedjefar and Dembaba Formations, Early to Late Carboniferous, late Visean to Moscovian age (Swire and Gashgesh, 2003). They were deposited in a marginal swamp to a fully marine, inner neritic paleoenvironmental (Swire and Gashgesh, 2003). However, sediments of latest Carboniferous represent the termination of Hercynian movements in the area. Early to late Permian, (Asselian to Tatarian age). These dolomites and sandstones with minor shale, siltstones, and limestone represent the Hebilia and Al Uotia Formations (Watiah Fm). The Hebilia Formation was in an inner neritic to marginal marine Paleoenvironment. The Al Uotia Formation (Watiah Formation) was deposited in a marginal marine to terrestrial fluvial paleoenvironment. Deposition of Triassic formation alternated between a fully marine inner neritic to terrestrial, lagoon/swamp and sabkha-type paleoenvironment (Swire and Gashgesh, 2003).

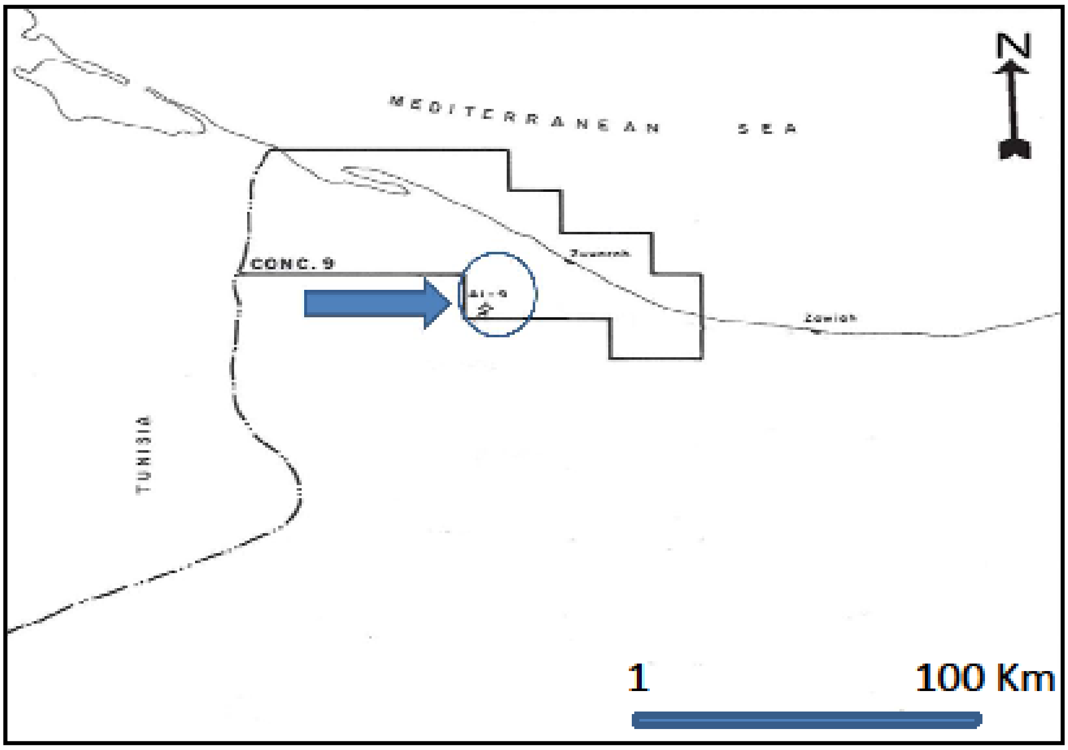

Fig. 1. Map showing the location of the A1-9 well, NW Libya (modified from Swire and Van Erve, 1993).

2. Regional geology

Carboniferous and Early Permian, the closure of several ocean resulted in the amalgamation of the western half of Pangaea, these included the Rheic Ocean between northern Europe and Gondwana and the Phoibic Ocean between Laurentia and Gondwana (McKerrow and Ziegler, 1972). Though Gondwana and northern Europe were adjacent during most of the Devonian, these appears to have been little deformation until the Late Devonian or Early Carboniferous (Holder and Leveridge, 1986). The Hercynian and Variscan Orogenies had their climax in the Serpukovian age sediments in the Western Libya were deposited in essentially a prograding deltaic environment on a slowly subsiding platform (Whitbread and Kelling, 1982). Fully marine condition as indicated by carbonate deposition were established in the Late Carboniferous (Pierobon, 1991). Palaeogeographic reconstructions for the Permo-Scythian suggest that Permian sediments were deposited in a shallow water epi-continental sea while the oceanic Paleao-Tethys was located far to the east (Argyriadis et al., 1980). The period of transition from Permian to Early Triassic shows a regressive sequence from shallow open sea deposits to barrier facies and then to restricted deposits. The filling up of the Permian sea led to lateral morphologies over very wide areas for which no contemporary analogy is known (Argyriadis et al., 1980).

In the Triassic it is noted that rifting is known to have occurred initially in the Late Anisian to Early Ladinian and is coincident with the appearance of horsts, grabens and volcanic emissions. This activity was followed by a period of relative quiescence (Argyriadis et al, 1980). During the Late Paleozoic and Mesozoic time, the African platform might have extended into the Adriatic region, forming a northward promontory (Tekbali, 2013). A regional SE-NW stress resulted in the formation of several troughs and uplifts in the middle part of North Africa during the Late Permian and Mesozoic time (Klitzsch, 1970). Schemes for stratigraphic subdivision of the Mesozoic sediments section in NW Libya are shown in (Fig. 2).

In NW Libya the main source rocks are the Silurian Tanezzuft shale's but not present in A1-9 well (Early Carboniferous sediments based on Cambrian sediments) (Fig. 3). Nearest well to penetrate Tanezzuft is J1-23, 50 kms to the south with best proven source is a lower radioactive horizon (average TOC 4.9%) (Swire, 1997), this horizon is 28 feet thick in both south and west (Swire and Van Erve, 1993). A1-9 is the only well to have penetrated basement in the area.

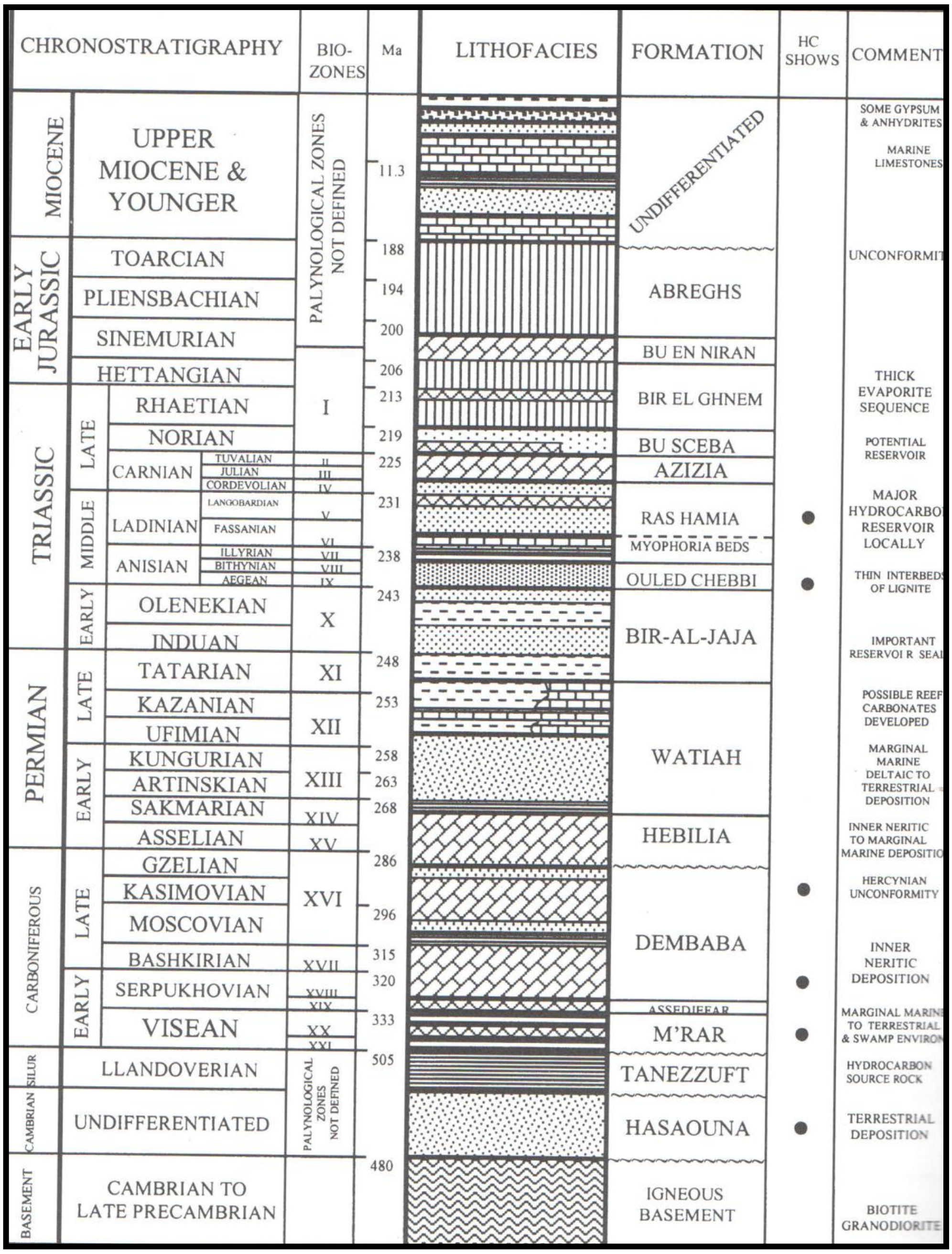

Fig. 2. Generalized stratigraphical column of the Jifarah Trough (Swire and Gashgesh, 2003).

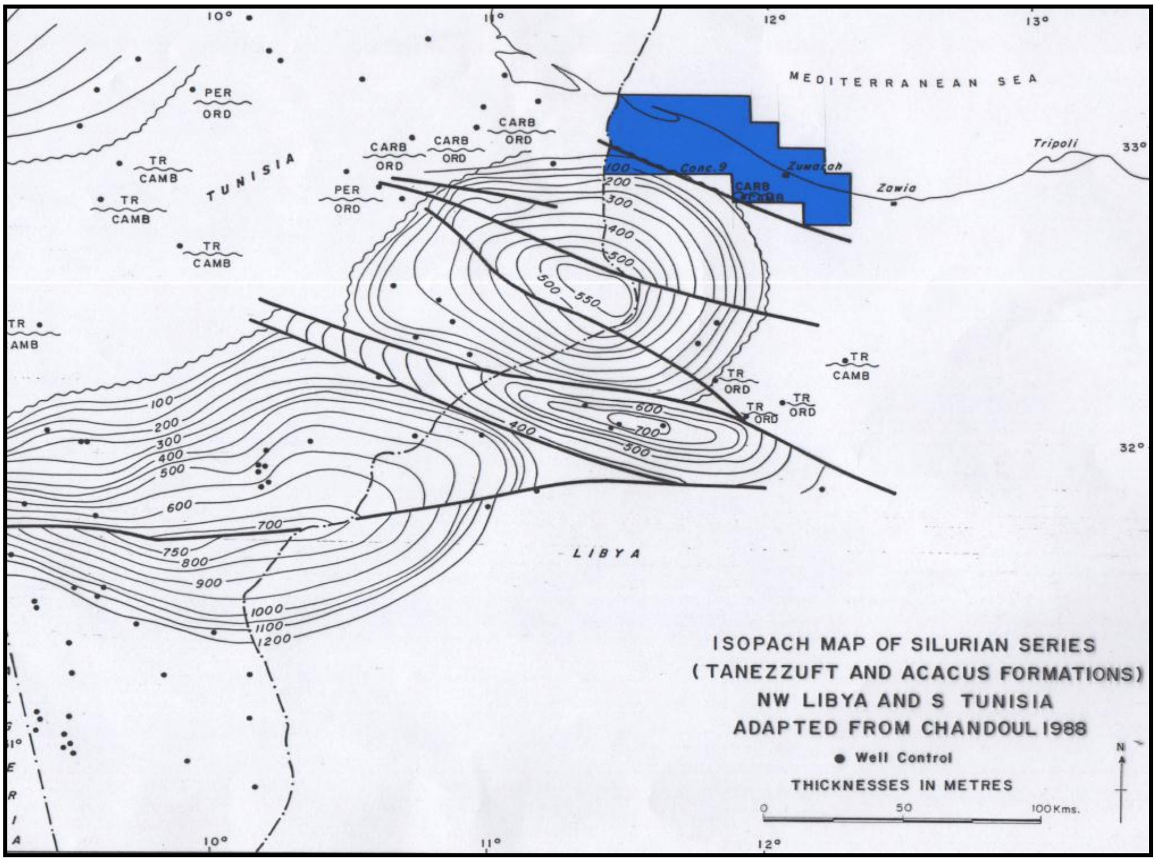

Fig. 3. Isopach map showing distribution of Silurian sediments NW Libya and South of Tunisia (Swire and Gashgesh, 2003).

3. Objectives of the study

The aim of this work is to describe the thermo-chronological evolution of the Carboniferous, Permian and Middle Triassic sediments. However, the lithological characteristics and paleoenvironmental interpretation linked with Thermal Alteration Index analysis. This well drilled as a stratigraphical test and assess the hydrocarbon potential of concession 9. The main objectives of this study are therefore to:

- To describe and interpret the sedimentary accumulations and palaeoenvironments and to note thermal maturation changes (TAI) to gain some idea of changes in thermal maturities through the well section depth.
- To giving a high resolution chronostratigraphical breakdown of the well for further correlation studies, the information provided by the palynomorphs has helped also in particular in differentiating formations (or their equivalents) within the Lower Permian and Upper/Middle Carboniferous and Middle Triassic sections.

4. Methodology

- Integration with chrono and lithostratigraphy and wireline log information to determine potential reservoir and source facies developments. Data presented here are based upon a detailed subsurface lithological characteristics and involving electric logs (gamma-ray and sonic logs).
- Seventy six samples have been analyzed to study the palynofacies from the Al-9 well.
- Results were fully integrated with the Al-9 biostratigraphy report referring palynofacies analysis to the recorded palynomorph assemblages that was done by (Swire and Van Erve, 1993). Concurrent with drilling of the well, 240 samples were studied for palynology, the sample spacing selected was every 50 feet.
- Interpretation of palynofacies data that integrated with electrofacies logs using the Schlumberger book (Serra, 1989) as a guide was undertaken. From this a detailed high-resolution paleoenvironmental breakdown of the well was achieved.

- The numerical values are referred to as the Thermal Alteration Index (TAI) that as indicated by changes in the spore colouration which increased progressively through the well section. The data obtained from the analysis of the organic matter maturity are excellent indicators of the thermal evolution of sedimentary basins. The maturity parameters used (Thermal Alteration Index) are sensitive to temperatures between 60 and 200 °C.
- Our result allow a relationship of environmental and facies development to be determined. From this an idea of hydrocarbon potential may be achieved.

5. Results and discussions:

The suggested Lithostratigraphy given below is based on lithological variations as delineated by study of the ditch cutting samples and by study of the wireline logs. Thus, the log is considered as an excellent tool for differentiating shale/mud from rocks like clean sandstone and dolostone in the subsurface. The gamma ray data was used to correlate between the wells to determine the facies changes and lithology (shaleliness) (Rider, 1986). Gamma-ray log acts as an indicator of the clay mineral content of a unit, which correlates to grain size (Miall, 1984). In contrast, texturally and mineralogically matured quartz arenite and clean carbonate give a low gamma-ray log reading.

5.1. Lithological interpretation

Interpretation of palaeofacies data (Collomb, 1962) and Lithological data for suggested Formation tops (Table 1).

Table 1: Shows Suggested Formation Tops younger to oldest in age

Formation top depth (ft)	Formation
1783	Al Aziziyah
2980	Kurrash
5747	Al Guidr
6604	Bir Al Jaja
6987	Al Uotia (Watiah Fm)
9402	Hebilia
10200	Dembiba
10950	Assedjefar(equivalent)
10990	M´rar (equivalent)
11296	Hasaouna
11944 -12439	Baisement (Logged depth T.D)
*Formation top adjusted to log pick.	

5.1.1. Hasaouna Formation

It comprises medium to coarse-grained, highly cross-bedded sandstone forming a 160-500m thick, uniform sandy complex spread over vast potions of the Saharan platform (Serra, 1989). The Hassaona Formation is unconformably overlain by fine-grained Ordovician clastics of the Achebyat Formation (Collomb, 1962) (Boote et al., 1998); in the subsurface, they are very difficult to distinguish from each other (Serra, 1989). In the A1-9 well in Jifarah Trough this unit is 650 feet thick. This formation represented by cyclic sequences of thick, regionally extensive, fluvial, and estuarine sands(Swire and Gashgesh, 2003). There is an environmental and wireline log break at the top of this formation (11296 feet). The predominantly sandstone lithology and the alternating coarsening upwards and fining upwards sequences are consistent with deposition on a delta front.

5.1.2. M´rar Formation

In the Jifarah Trough, the M´rar Formation chronostratigraphicaly equivalent of the Formation is represented by interbedded green/black shale and transparent white/grey fine-grained sandstone (Swire and Gashgesh, 2003). This grades upwards into white to pink dolomite and oolitic dolomitic limestone with thin interbreeds of black fissile shale and thin coal beds (Swire and Gashgesh, 2003). In A1-9 well, the thick section ranges between 180-240 m (600-780 feet) thick and is characterized by interbedded marine shale and sandstones of marine origin (Serra, 1989). The geological column of the M´rar Formation can be subdivided into three parts, the lower part of fine to locally coarse grained kaolinitic sandstones of cyclic appearance interbedded with dark grey to black, finely laminated, carbonaceous shale and siltstones, which become predominant in the upper and middle parts (Whitbread and Kelling, 1982). From integration of palynofacies analysis with lithological in formation and information derived from studying the wireline logs suggested the deposition was on a low energy restricted shallow water carbonate platform (Fig. 4). Abundant miospore including large pteridophytes indicate proximity to a shoreline (Swire and Gashgesh, 2003). Abundant inordinate is also consistent with strong terrestrial influences. The mixed dolomite arenaceous and argillaceous sediment is consistent with shallow water environment and suggests fluctuating margin and perhaps a restrictive barrier. Carbonate deposition indicates little clastic input. Thin coal horizons are consistent with a marginal swampy environment.

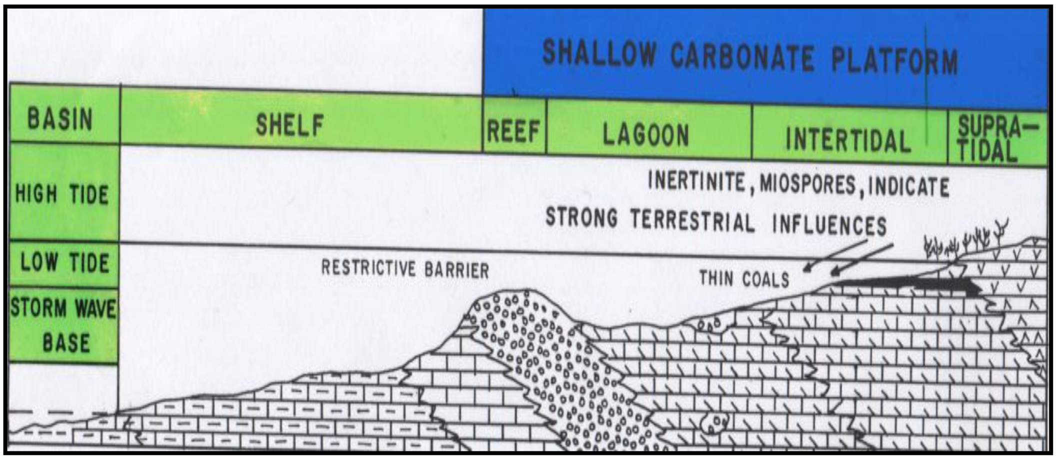

Fig. 4. Depostional paleoenvironmental for the M´rar Formation (after Swire and Gashgesh, 2003).

5.1.3 Assedjefar Formation

The Assedjefar Formation was a term introduced by (Kiltzsch, 1970), that characterized by a thick sequence of dark grey to black shale interbedded with siltstones and fine to very fine grained, argillaceous sandstones from the Murzuq Basin. The palynological assemblages of the formation were probably deposited on a shallow carbonate bank and relate more to the overlying Dembaba Formation (Alrabib, 1995).

5.1.4 Dembaba Formation

The lower boundary of this formation, towards the Assdjefar Formation, is conformable and marked by the first bed of stromatolitic limestone (Grubic,1991).

It is a marine to transitional sequence, generally white to cream-coloured, argillaceous, and dolomitic calcilutites, interbedded with varicoloured marly claystone, which grade downwards to shale's. This formation in the studied well is represented by white to light grey and pink dolomite. There is minor silty shale and dolomitic sandstone (Swire and Gashgesh, 2003). Integration of information from palynofacies study lithological information (Alrabib, 1995), and interpretation of the environment from wireline log (Fig. 5), suggests the deposition was beyond the delta front and was in a shallow water carbonate environment. The marine environment is evidenced by the recovery of microplankton (Swire and Gashgesh, 2003). Repeated swallowing sequences represented by interbedded dolomites and argillaceous sediments (Fig. 5).

5.1.5. Hebilia Formation

It is penetrated by other wells both in the Libya and Tunisian Jifarah Trough (Swire and Gashgesh, 2003). Integration of the palyno facies, wireline log, and Lithological and palynomorph assemblage information (Swire and Gashgesh, 2003), suggests that deposition was on shallow water carbonate bank beyond deltaic influences. Recoveries of microplankton indicate marine deposition (Swire and Gashgesh, 2003). Alternations of dolomites and clastic terrigenous sediments including shale and sandstone and occasional oolitic horizons are consistent with shallow water deposition. Shallowing up sequences are evidenced by the dolomite to clastic sediment repeated sections seen on the lithological log (Fig. 5), this supporting the deposition on a shallow water carbonate.

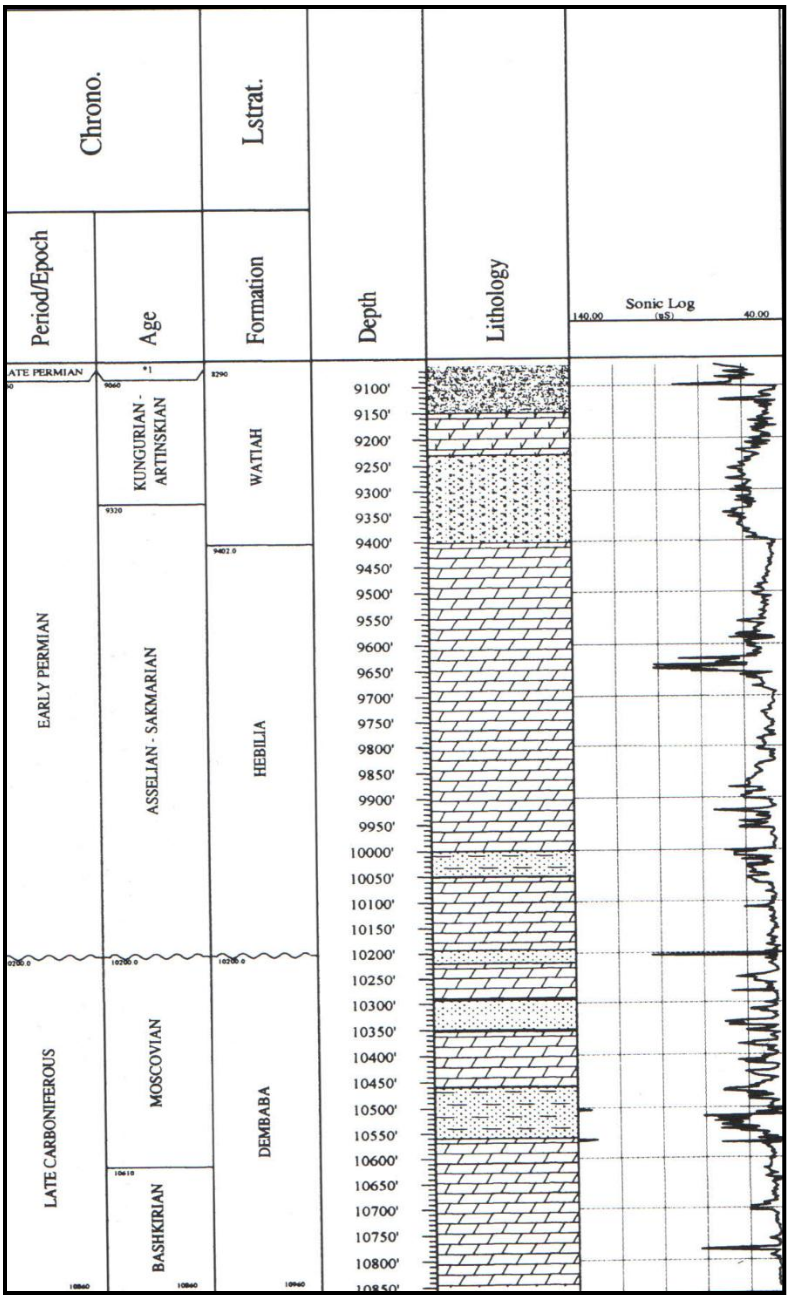

Fig. 5. A1-9 Late Carboniferous and Late Permian sonic traces (modified from Swire and Gashgesh, 2003).

5.1.6. Al Uotia Formation (Watiah Fm.)

Form the depth interval depths 9123-8482 feet the deposition was probably in a delta front environment (Fig. 7), this is evidenced by the mixed arenaceous, argillaceous, and carbonaceous sediment. The gamma ray trace shows fining and coarsening upward sequences (Fig 7). Between the depths 8482-8305 feet there is evidence for a tidal channel crossing the delta front (Fig 6), this channel has a sharp erosive base and fairly massive blocky display on the gamma ray trace. This is evidenced from the sharp contact at 8305 feet and overlying mainly argillaceous sediment from micro plankton was recovered (Swire and Gashgesh, 2003) .

5.1.7 Bir Al Jaja Formation

This formation represents deposition during a broad sea-level rise, chronostratigraphical and paleoenvironmental equivalents to the Bir-Al-Jaja Formation were also deposited in Maragh low of the eastern Sirte Basin (Kiltzsch, 1970). Where they are represented by interbedded, white to light grey kaolinitic and glaunconitic siltstones and minor sandstones). Between depths 8305-6987 feet, there is evidence for marine transgression and for deposition on a distributary mouth bar (Fig 6). Grain sediments and marine flora and lack of fining or coarsening upwards features in the section (Fig 7). Abundances of the miospore Taxa suggestive paleoenvironments in tar deltaic salt marshes (Swire and Gashgesh, 2003) .

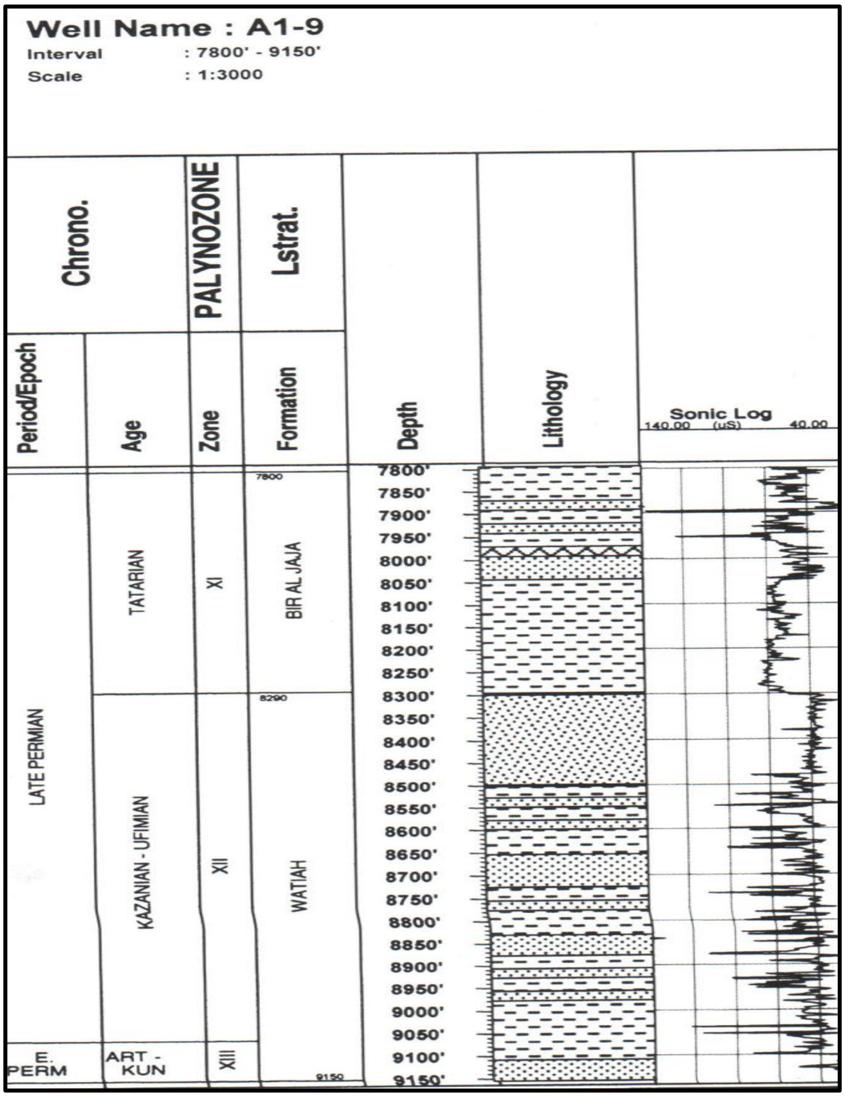

Fig. 6. A1-9. Late Permian sonic traces

(modified from Swire and Gashgesh, 2003)

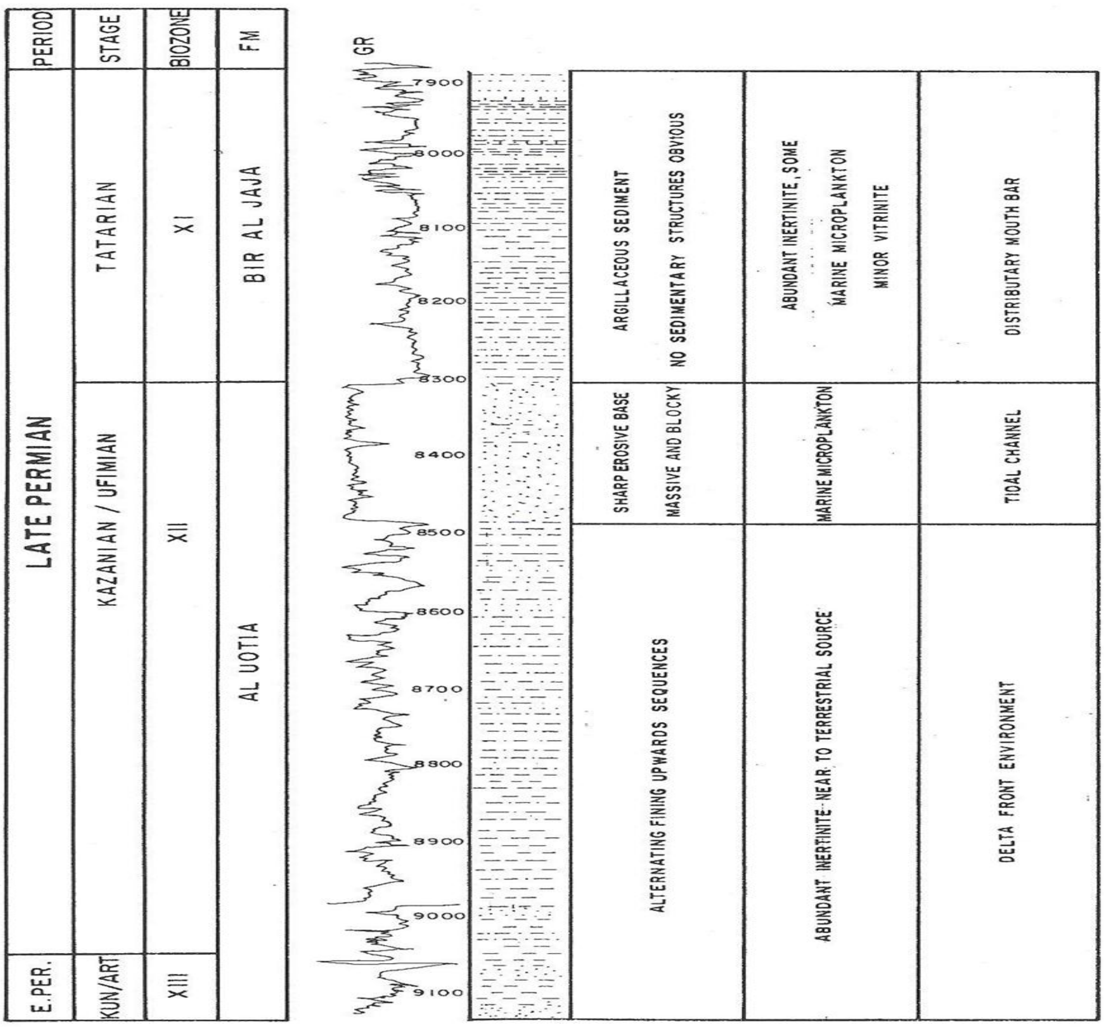

Fig. 7. A1-9 gamma ray response and lithology of the AlUotia and Bir Aljaja Formations (Alrabib, 1995).

5.1.8. Al Guidr Formation

A mouth bar environment can probably by discounted for regional reasons. During the Middle Triassic (Anisian), when the Al Guidr Formation was deposited, there was a regressive phase indicative of terrestrial rather than marine deposition (Alrabib, 1995) . In fact lignite was recorded from this formation and this supports a terrestrial environment. Fining upward sequences identified on the gamma ray trace are more suggestive of disposition in an abandoned channel on a meandering flood plain environment rather than crevasse splay deposition.

5.2. The determination of the thermal alteration index

5.2.1. Introduction

The change in colour of organic particulate debris caused by increasing thermal increments is an easily observable feature that requires only routine palynological preparations for its use (without oxidation of the organic residues, a process which lightens their colour) (Salah et al., 2015). With proper standardization techniques, arbitrary numerical values can be applied to the colour change sequence and related with other, more sophisticated means of determining the level of maturation (Rider, 1986). The numerical values are referred to as the Thermal Alteration Index (TAI).

In an attempt to standardise methodologies. Staplin, (1982) suggested that the thermal Alteration Index should be obtained by studying the bladders of bisaccate gymnosperm pollen. The colour of spore exinite depending on increases in Palaeotemperatures passes through various colours from greenish-yellow, yellow, amber, deep red brown, brown – black to black. Palaeotemperatures may be increased directly due to burial and or tectonic and igneous activity (Swire, 1997). Colour evaluation is a subjective procedure and depends in away on equipment used and operator experience.

5.2.2. Thermal alteration index for the A1-9 well

The result of geochemical analysis performed on selected rock samples from the study area is presented in (Fig 8). Thermal maturities as indicated by changes in the spore colouration increased progressively through the well section. From depths 170- 3370 feet, the TAI varies between 1+ to 2 (immature) (Fig 8). This interval incorporates the Abu Shaybah Formation, the Al Aziziyah Formation and the top part of the Kurrush Formation. From 5930 - 5940 to 10800 - 10810 feet the TAI varies between 3+ to 4- (Fig 8). This interval incorporates the rest of the Al Guidr, Bir Al Jaja, Al Uotia, Hebilia and the top part of the Dembaba Formation. From 3360 - 3370 feet to 5930 - 3940 feet the TAI varies between 2 to 3+ (Fig 8). This incorporates the rest of Kurrush Formation and the top part of the Al Guidr Formation. From depth 10800 - 10810 feet (Fig. 8), until total sediment depth (11944 feet Log) this incorporates the rest of the Dembaba and underlying equivalents of the Assed jefar and M′rar Formations and the underlying indeterminate unit (Hasaouna Formation) the TAI varies between 4 and 5 (dry gas- black& deformed) (Fig 8).

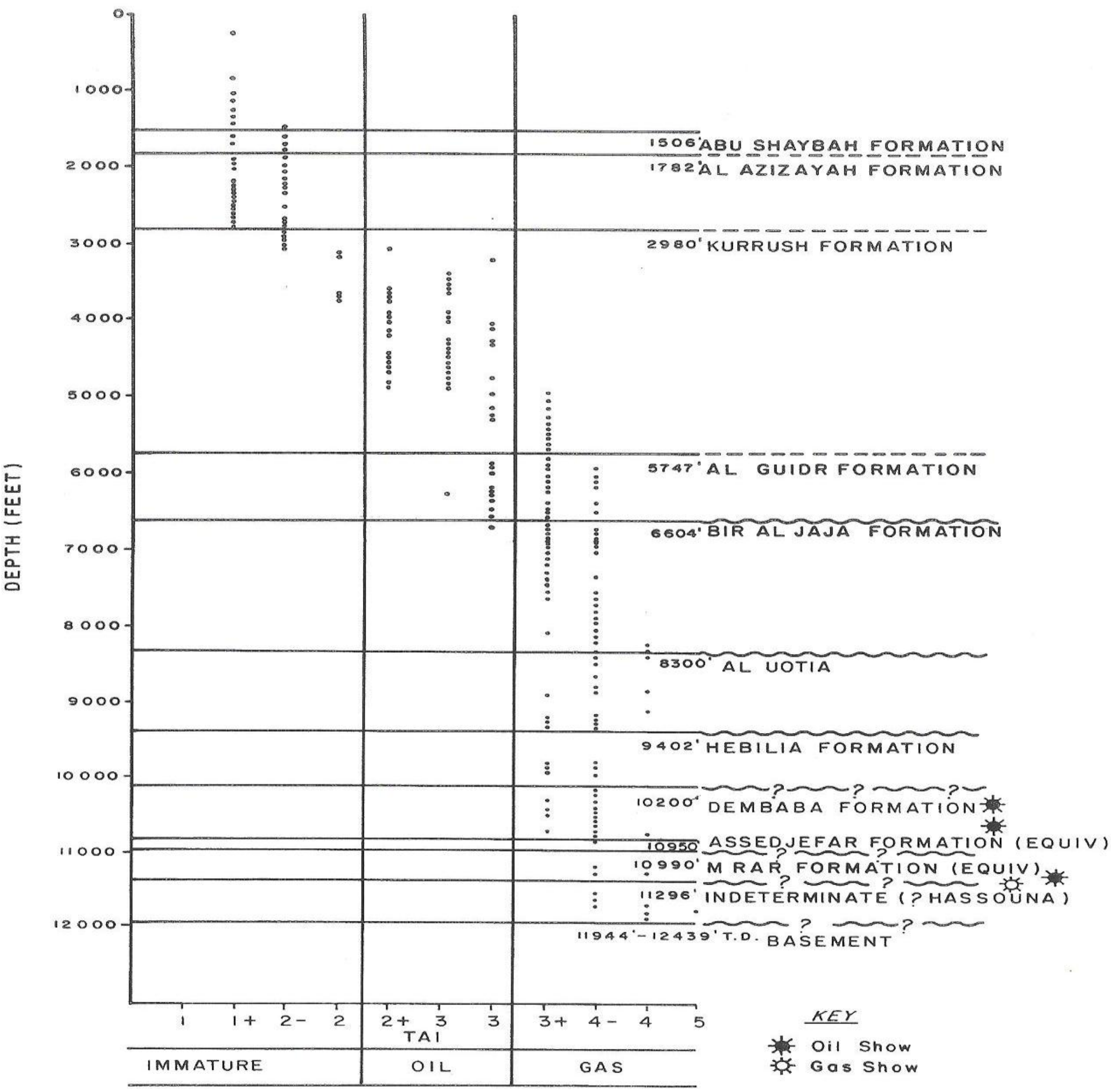

Fig. 8. The thermal alteration index (TAI) of miospores in A1-9 well (Swire and Van Erve, 1993).

6. Conclusions

- Sandstone and interbedded minor shale of indeterminate age was deposited over igneous basement in a questionable marine inner neritic and or terrestrial environment (11944 Feet (log) -11296 feet). An increase in the gamma ray trace marks the top of the basement at 11944 feet.
- Overlying is a sequence of interbedded limestone, dolomite and shale of Early Carboniferous, 11296-11100 feet, these were deposited in a marine inner neritic environment. Overlying these are dolomites with minor shale and sandstone of Late Carboniferous, 10850-10600 Feet. Siltstone, sandstones, dolomite, dolomitic limestone and dark grey to black shale conformably overlie these and were deposited in a terrestrial / marginal marine to inner neritic environment. These are succeeded by Interbedded sandstone, silty-shale and minor buff limestone of Late Permian age 9050-6780 Feet, that were deposited probable marginal marine environment. Early Triassic 6780-6630 Feet siltstone and sandstone were then deposited in a marine inner neritic environment.
- A regression to terrestrial condition and then a marine incursion to an inner neritic followed in the Middle Triassic 6630-5430 feet This is represented by the deposition of sandstones overlain by shale and dolomitic limestones. Overlying are sandstones, siltstones and dolomitic limestones of Middle Triassic 5430-3360 feet that were deposited in inner neritic to terrestrial environment. Shale, limestone, sandstone, siltstone and dolomite was then deposited of Late Triassic, these were deposited in a marginal marine to inner neritic environment.

- The overlying dolomitic limestones and siltstones with interbedded evaporitic minerals 1540-170 feet were deposited inner neritic environment.
- The environment of deposition and the degree of thermal maturation has allowed the A1-9 well to become a key reference section in NW Libya from which correlations may be carried out.
- The results of this research based on data generated from purely upon the TAI indicates that if there had been suitable organic rich facies present then oil would have been generated in the Kurrush Formation and perhaps in the Al Guidr Formation.
- Gas would have been generated below this in the Bir Al Jaja, Al Uotia, Hebilia and Dembaba Formations and in the Assedjefar and M´rar equivalents Formations. As poor oil shows were recorded from depths 10320-10370 feet, 10570-10580 feet, and 11220-11230 feet, in the gas window indication is that there must have been migration of this oil from elsewhere. A gas show was also reported from depths 11355-11361 feet. Palaeotemperatures may be increased directly due to burial and or tectonic and igneous activity.

References:

1. *Alrabib, M. A., (1995). Palynofacies of A1-9, Concession 9, NW, Libya. Unpublished internal report., 60 pp.*
2. *Argyriadis, I, de Graciansky, P. C., Marcoux, J., and Ricou, L.E. (1980). The opening of the Mesozoic Tethys between Eurasia and Arab- Africa.*
3. *Boote, D.R.D., Clark-Lowes, D.D, and Traut, M.W., (1998). Palaeozoic petroleum system of North Africa.In: Petroleum Geology of North Africa (eds.) D.S. MacGregor, R.T.J.Moody and D. D., Clark-Lowes). Geol.Soc. London. Spec. Publ.,132., P. 7-68.*

4. *Collomb, G. R., (1962). Etude geologique de jebel Fezzan et de sabordure palaeozique. Notes Mem.C.F.P., 136 pp.*
5. *Fantoni, R. m., and Scotti, P., (2003). Thermal record of the Mesozoic extensional tectonics in the southern Alps. Journal of Atti Ticinensi di Scienze della Terra, S.S. 9 (2003)., P. 96-101.*
6. *Grubic, A. M., Dimitrjjevic, M., Galecic, Z. Jakovljevic, S. Komarnicki, D. Protic, P. Radulovic,, and G. Roncevic,. Stratigraphy of western Fezzan, SW Libya. In: Salem, M. J., and Belaid, M. N. (eds.). The geology of Libya., (1991), academic press, London, New York, vol. IV, P. 1529-1565.*
7. *Holder, M.T., and Leveridge, B.E., (1986). Correlation of the Rhenohercynian Variscides. Journal of the Geological Society, London, 143., P. 141-147.*
8. *Kiltzsch, E., (1970). Die Strukturgeschichte der Zentral-Sahara:Neue Erkenntnisse zum Bau und zur Palaeogeographie eines Tafellandes. Geol.Rundsch.,59 (2)., P. 459-527.*
9. *Kiltzsch, E., (1970). Geologische Bearbeitung sudwest Egypten. Geol. Rdsch, V.67, P. 509-520.*
10. *McKerrow, W.S. and Ziegler, A.M., (1972). Paleozoic Palaeogeography. Ann. Rev. Earth. Planet. Sci., 7., P. 473-502.*
11. *Miall, A. D., (1984). Principles of Sedimentary Basin Analysis. Springer-Verlag, New York., 490 pp.*
12. *Pierobon, E. S. T., (1991). Contribution to the stratigraphy of the Murzuq Basin, SW. Libya. In: M. J. Salem, and M. N. Belaid, (eds.). The geology of Libya, Academic Press London, vol. V., P. 1767-1784.*
13. *Rider, M. H., (1986). The geology interpretation of well logs. Blackie. Glasgow and London., 171 pp.*
14. *Serra, O., (1989). Sedimentary Environments from wireline logs, sehlumberger., 229 pp.*
15. *Staplin, F. L., (1982). Determination of Thermal Alteration Index. From color of Exinite (pollen, spores). SEPM short course vol.7., P. 7-11.*

16. *Swire, P. H., and Van Erve, A. W., (1993). The Biostratigraphy Lithology and Paleoenvironments of the A1-9 well, concession 9 N, W. Libya Voo Exploration Department LIB., 278 pp.*
17. *Swire, P. H., (1997). The Biostratigraphy, Geochemistry and Structural History of the Maragh Low and Surrounding Area, Eastern Margin, Sirte Basin, Libya,Veba Oil Operations, Internal Rept.279, addendum., 120 pp.*
18. *Swire, P. H., and Gashgesh, T. M., (2003). The Bio-Chrono- and Lithostratigraphy and Hydrocarbon Prospectivity of the NW Ghadamis basin and Jifarah Trough: In: The Geology of Northwest Libya M.J, Salem, and Khalid (eds)., P. 174-215.*
19. *Salah, Y. El Beialy, Mohamed, K. Zobaa and Asmaa, A. Taha. (2015). Depositional paleoenvironment and hydrocarbon source potential of the Oligocene Dabaa Formation, north Western Desert, Egypt: A palynofacies approach, Geologic Society of America, v. 12., No. 1., P. 346-363.*
20. *Takbali, A. O., (2013). Middle Jurassic palynomorphs from the Jabal Nafusah, NW Libya, industrial research journal, year 18, no.28. P. 77-104.*
21. *Whitbread, T., and Kelling, G., (1982). M′rar Formation of western Libya; evolution of an Early Carboniferous delta system. Journal of AABG, vol. 66 (8)., P. 1091-1107.*