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CALCAREOUS NANNOFOSSILS BIOSTRATIGRAPHY OF JADDALA FORMATION IN WELL (AJEEL-10), CENTRAL IRAQ

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ABSTRACT

A detailed systematic study of calcareous nannofossils was carried out for the Jaddala Formation in (Aj-10) well, Central Iraq. Seventy one species belong to twenty four genera of calcareous nannofossils were identified including sixty two of them were previously named and nine species were identified for the first time and they would not be given names until more information is obtained in the future to support this identification.

It is a recorded of five biostratigraphic zone, which suggested the age of the Jaddala Formation to be of early to late Eocene. The recorded biozone includes the following: *Reticulofenestra dictyoda* (Deflandre in Deflandre & Fert, 1954) Stradner & Edwards, 1968 Partial Range Biozone (CNE 5); *Discoaster sublodoensis* Bramlette and Sullivan, 1961 Interval biozone (CNE 6-7); *Nannotetrina cristata* (Martini, 1958) Perch-Nielsen, 1971 Interval biozone (CNE 8); *Nannotetrina alata* (Martini in Martini & Stradner, 1960) Haq and Lohmann, 1976 Interval biozone (CNE 9); *Chiasmolithus gigas* Bramlette & Sullivan, 1961Range Biozone (CNE 10-11).

Keywords: Biostratigraphy, Calcareous, Eocene, Iraq, Jaddala, Nannofossils.

INTRODUCTION

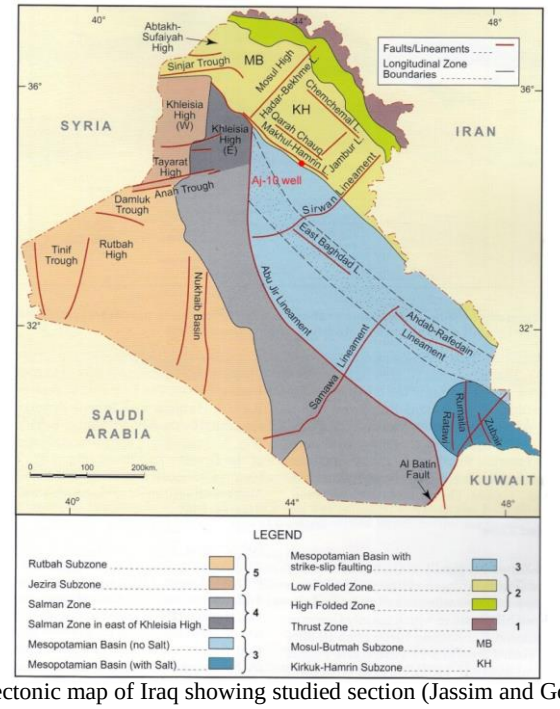
The Jaddala Formation was first described by Henson in 1940 near Jaddala village in north Iraq (Bellen *et al.*, 1959). The Jaddala Formation outcrops showed up on narrow area of the Foothill Zone of Sinijar Mountain in the Northwestern of Iraq. It was occupied most of sediments in north areas during Eocene period and observed in most of subsurface sections with different thicknesses. The studied section from Ajeel well No. (10) is located 34º 50′ 14.8″ N. and 43º 53′ 59.0″ E, North East of Tikrit City, Central Iraq (Map.1), within the Low Folded Zone belonging to Unstable Shelf of the Nubio-Arabian platform (Buday and Jassim, 1987). The sampled stratigraphic succession of the Jaddala Formation in this well (15 samples) consists of marly limestone.

The stratigraphic succession of the Eocene in Iraq was studied based on the calcareous nannofossils by many authors such as Al-Badrani (2007); Al-Badrani (2011); Al-Badrani and Al-Nima (2010); Al-Badrani and Al-Ubaidi (2012) and Al-Badrani and Al-Zubaidi (2015, 2017, 2019 a and b). The aim of the present work is to determine the age of the Jaddala Formation by using calcareous nannofossils.

MATERIALS AND METHODS

A detailed study of calcareous nannofossils was carried out for stratigraphic successions of Jaddala Formation which is about 68m and consists of marly limestone, overlies Aaliji Formation and underlies Oligocene Group. Fifteen cutting samples were used and examined under the light microscope. The extracted calcareous nannofossils were identified by using the Armstrong and Brasier (2005) methods for paleontological studies.

It is an extraction method for microfossils that can be properly examined when it is extracted from the rocks. The sample preparation included smear slides preparation which provides method for producing slides of calcareous nannofossils by placing a small amount of the disaggregated sample in distilled water and a drop of a dispersant. Then, the cover slip was left to dry on a warm hot plate. And to make permanent mounts, the slide and residue were allowed to dry at a low temperature away from possible sources of contamination. Finally, a drop of mounting medium (e.g. Canada balsam) was placed on a clean cover slip which in turn placed over the residue. Then, it was allowed to dry before examining under the transmitted light.



Map (1): Tectonic map of Iraq showing studied section (Jassim and Goff, 2006).

RESULTS AND DISCUSSION

The aim of the systematic classification is to provide images of the notable calcareous nannofossils from the Tanjero Formation in Azmeranticline, Northern Iraq and to describe the seventy one species. All the observed taxa are listed below (Diag. 1). The higher taxonomy essentially follows the scheme of Young and Bown (1997) in addition to Perch-Nielsen's (1985). The material and images are stored at the Department of Geology, Science College, University of Mosul.

(A) Systematic and Classification

I-Heterococcoliths

Family: Helicosphaeraceae Black, 1971

Genus: *Helicosphaera* Kamptner, 1954

Helicosphaera ampliaperta Bramlette & Wilcoxon, 1967(Pl.1a)
Helicosphaera compacta Bramlette & Wilcoxon, 1967(Pl.1b)
Helicosphaera lophota Bramlette & Sullivan, 1961 (Pl.1c)
Helicosphaera papillata Bukry & Bramlette, 1969 (Pl.1d)
Helicosphaera reticulata Bramlette & Wilcoxon, 1967(Pl.1e)
Helicosphaera salebrosa Perch-Nielsen, 1971 (Pl.1f)
Helicosphaera seminulum Bramlette & Sullivan, 1961(Pl.1g)
Helicosphaera wilcoxonii (Gartner, 1971) Jafar & Martini, 1975 (Pl.1h)
Helicosphaera sp. (Pl.1i)

Family: Pontosphaeraceae Lemmermann, 1908

Genus: *Pontosphaera* Lohmann, 1902

Pontosphaera distincta (Bramlette & Sullivan, 1961) Roth &Thierstein, 1972(Pl.1j)
Pontosphaera fimbriata (Bramlette & Sullivan, 1961) Romein, 1979(Pl.1k)
Pontosphaera multipora (Kamptner, 1948) Roth, 1970(Pl.1 l)
Pontosphaera ocellata (Bramlette & Sullivan, 1961) Perch - Nielsen, 1984(Pl.2a)
Pontosphaera plana (Bramlette & Sullivan, 1961) Haq, 1971(Pl.2b)
Pontosphaera scissura (Perch - Nielsen, 1971) Romein, 1979(Pl.2c)

Genus: *Transversopontis* Hay, Mohler & Wade, 1966

Transversopontis prava Locker, 1967(Pl.2d)
Transversopontis sp. (Pl.2e)

Family: Zygodiscaceae Hay & Mohler, 1967

Genus: *Lophodolithus* Deflandre in Defalndre & Fert, 1954

Lophodolithus nascens Bramlette & Sullivan, 1961(Pl.2f)

Genus: *Nannotetrina* Achuthan & Stradner, 1969

Nannotetrina alata (Martini in Martini & Stradner, 1960) Haq & Lohmann, 1976(Pl.2g)
Nannotetrina cristata (Martini, 1958) Perch - Nielsen, 1971(Pl.2h)
Nannotetrina quadrata (Bramlette & Sullivan, 1961) Bukry, 1973(Pl.2i)

Family: Rhabdosphaeraceae Lemmermann, 1908
Genus *Blackites* Hay & Towe, 1962
Blackites inflatus (Bramlette & Sullivan, 1961) Kapellos & Schaub, 1973 (Pl.2 j)
Blackites piriformis (Pavsic in Khan *et al*., 1975) Aubry, 1999 (Pl.2 k)
Blackites singulus Bown and Jones, 2006 (Pl.2 l)
Blackites sp. (Pl.3a)

Family: Coccolithaceae Poche, 1913
Genus: *Chiasmolithus* Hay, Mohler & Wade, 1966
Chiasmolithus gigas Bramlette & Sullivan, 1961(Pl.3b)
Chiasmolithus grandis (Bramlette & Riedel, 1954) Radomski, 1968(Pl.3c)

Genus: *Coccolithus* Schwarz, 1894
Coccolithus crassus Bramlette & Sullivan, 1961(Pl.3d)
Coccolithus pelagicus (Wallich, 1877) Schiller, 1930(Pl.3e)
Coccolithus sp. (Pl.3 f)

Genus: *Cruciplacolithus* Hay & Mohler in Hay *et al*., 1967
Cruciplacolithus frequens (Perch - Nielsen, 1977) Romein, 1979(Pl.3 g)

Genus: *Erocsonia* Black, 1964
Erocsonia formosa (Kamptner, 1963) Haq, 1971(Pl.3 h)

Family: Noelaerhabdaceae Jerkovic, 1970
Genus: *Cyclicargolithus* Bukry, 1971
Cyclicargolithus floridanus (Roth & Hay in Hay *et al*., 1967) Bukry, 1971c (Pl.3 i)
Cyclicargolithus abisectus (Muller, 1970) Wise, 1973 (Pl.3 j)

Genus: *Dictyococcites* Black, 1967
Dictyococcites bisectus (Hay, Mohler & Wade, 1966) Roth, 1970(Pl.3 k)
Dictyococcites scrippsae Bukry and Percival, 1971(Pl.3 l)

Genus: *Reticulofenestra* Hay, Mohler & Wade, 1966
Reticulofenestra dictyoda (Deflandre in Deflandre & Fert, 1954) Stradner in Stradner & Edwards, 1968 (Pl.4 a)

Family: Prinsiaceae Hay & Mohler, 1967
Genus: *Prinsius* Hay & Mohler, 1967
Prinsius bisulcus (Stradner, 1963) Hay & Mohler, 1967(Pl.4 b)

Genus: *Toweius* Hay & Mohler, 1967
Toweius occultatus (Locker, 1967) Perch - Nielsen, 1971(Pl.4 c)
Toweius pertusus (Sullivan, 1965) Romein, 1979(Pl.4 d)

Family: Papposphaeraceae Jordan & Young, 1990
Genus: *Thoracosphaera* Kamptner, 1927
Thoracosphaera saxae Stradner, 1961(Pl.4 e)

II– Holococcoliths
Family: Calyptrosphaeraceae Boudreaux & Hay, 1969
Genus: *Zygrhablithus* Deflandre, 1959
Zygrhablithus bijugatus (Deflandre in Deflandre & Fert, 1954) Deflandre, 1959(Pl. 4 f)
Zygrhablithus sp. (Pl.4 g)

III– Nannoliths
Family: Braarudosphaeraceae Deflandre, 1947
Genus: *Br*
Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947(Pl.4 h)
Braarudosphaera discula Bramlette & Riedel, 1954 (Pl.4 i)
Braarudosphaera stylifera Troelsen & Quadros, 1971(Pl.4 j)
Braarudosphaera sp. (Pl.4 k)

Genus: *Micrantholithus* Deflandre, 1950
Micrantholithus pinguis Bramlette & Sullivan, 1961(Pl.4 l)
Micrantholithus sp. (Pl.5a)

Family: Discoasteraceae Tan, 1927
Genus: *Discoaster* Tan, 1927
Discoaster adamanteus Bramlette & Wilcoxon, 1967(Pl.5 b)
Discoaster deflandrei Bramlette & Riedel, 1954 (Pl.5 c)
Discoaster floreus Bystricka, 1964 (Pl.5 d)
Discoaster germanicus Martini, 1958 (Pl.5 e)
Discoaster kuepperi Stradner, 1959 (Pl.5 f)
Discoaster martinii Stradner, 1959 (Pl.5 g)
Discoaster nodifer (Bramlette & Riedel, 1954) Bukry, 1973(Pl.5 h)
Discoaster saipanensis Bramlette & Riedel, 1954(Pl.5 i)
Discoaster sublodoensis Bramlette & Sullivan, 1961 (Pl.5 j)
Discoaster triangularis Bystricka, 1966(Pl.5 k)
Discoaster trinus Stradner, 1961(Pl.5 l)
Discoaster sp. (Pl.6 a)

Family: Heliolithaceae Hay & Mohler, 1967
Genus: *Heliolithus* Bramlette & Sullivan, 1961
Heliolithus cantabriae Perch-Nielsen, 1971(Pl.6 b)

Family: Lithostromationaceae Deflandre, 1959
Genus: *Rhomboaster* Bramlette & Sullivan, 1961
Rhomboaster cuspis Bramlette & Sullivan, 1961(Pl.6 c)

Genus: *Tribrachiatus* Shamrai, 1963
Tribrachiatus contortus (Stradner, 1958) Bukry, 1972(Pl.6 d)

Family: Sphenolithaceae Deflandre, 1952
Genus: *Sphenolithus* Deflandre, 1952
Sphenolithus arthurii Bown, 2005 (Pl.6 e)
Sphenolithus editus Perch - Nielsen in Perch - Nielsen *et al*., 1978 (Pl.6 f)
Sphenolithus obtusus Bukry, 1971a (Pl.6 g)
Sphenolithus primus Perch-Nielsen, 1971(Pl.6 h)
Sphenolithus pseudoradians Bramlette & Wilcoxon, 1967(Pl.6 i)
Sphenolithus radians Deflandre in Grasse, 1952(Pl.6 j)
Sphenolithus sp. (Pl.6 k)

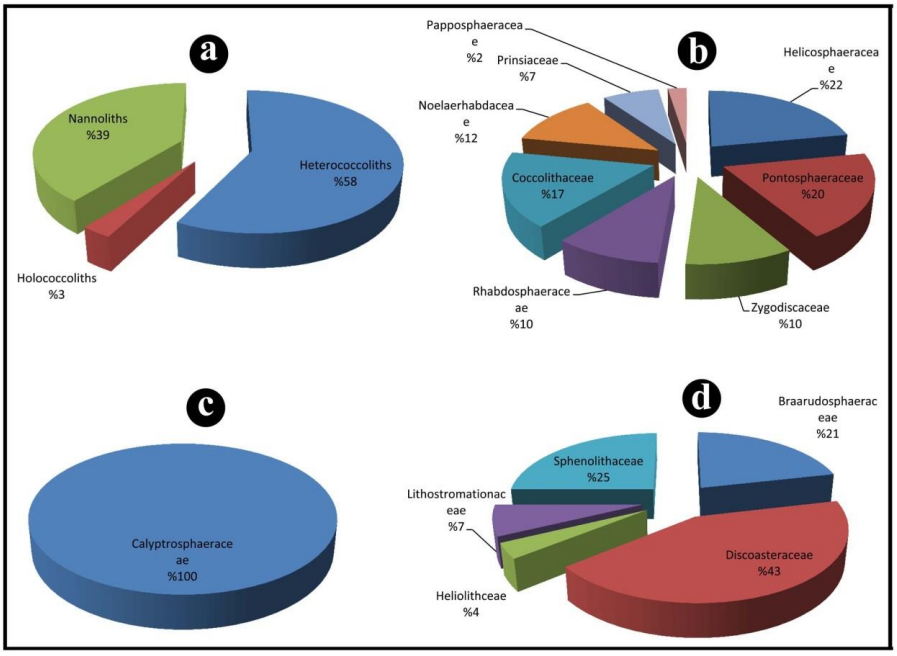


Diagram (1): Percentage of studied calcareous nannofossils taxa; (a) calcareous nannofossils groups, (b) Heterococcolithus families, (c) Holococcoliths families, (d) Nannoliths families.

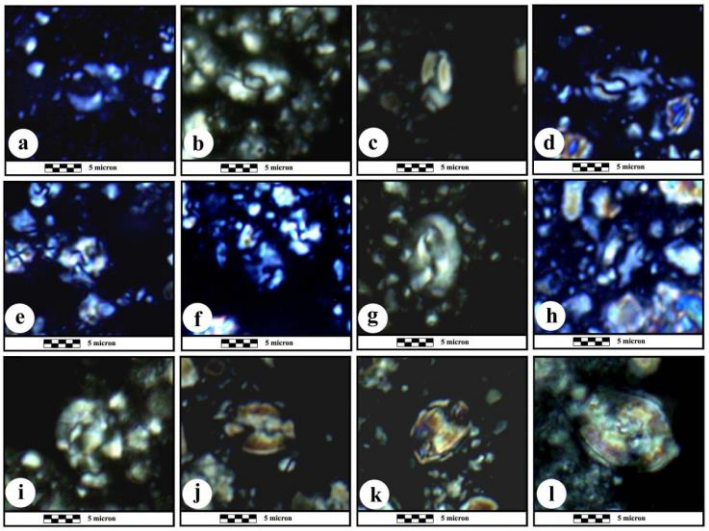


Plate (1): Cross-polarized photos of significant calcareous nannofossil taxa from Jaddala Formation; (a) *Helicosphaera ampliaperta*, (b) *H. compacta*, (c) *H. lophota*, (d) *H. papallata*, (e) *H. reticulate*, (f) *H. salebrosa*, (g) *H. seminulum*, (h) *H. wilcoxonii*, (i) *Helicosphaera* sp., (j) *Pontosphaera distincta*, (k) *P. fimbriata*,(l) *P. multipora*. (Scale bar: 5 micron).

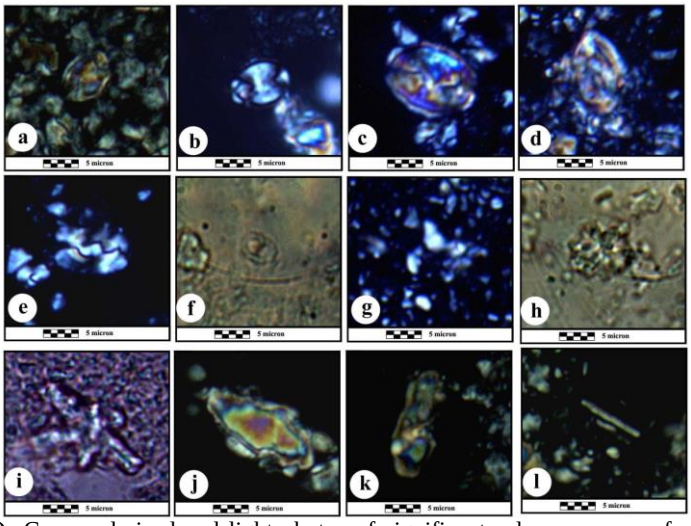


Plate (2): Cross-polarized and light photos of significant calcareous nannofossil taxa from Jaddala Formation. (a) *Pontosphaera ocellata*, (b) *P. plana*, (c) *P. scissura*, (d) *Transversopontis prava*, (e) *Transversopontis* sp.,(f) *Lophodolithus nascens*, (g) *Nannotetrina alata*,(h) *N. cristata*, (i) *N. quadrata*, (j) *Blackites inflatus*, (k) *B. piriformis*, (l) *B. singulus*. (Scale bar: 5 micron).

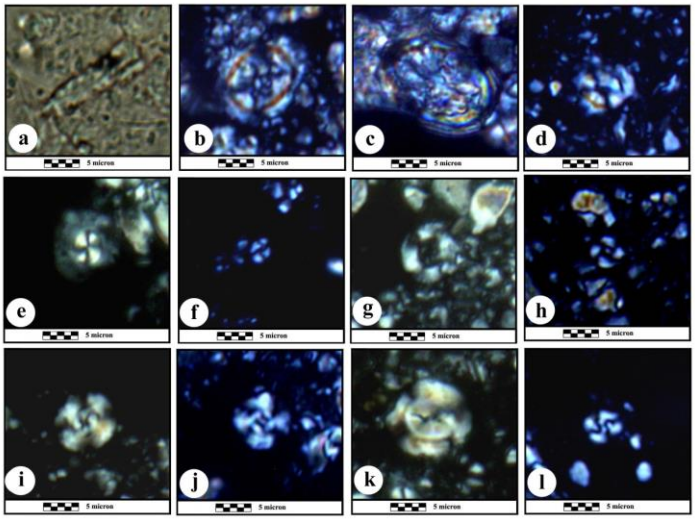


Plate (3): Cross-polarized and light photos of significant calcareous nannofossil taxa from Jaddala Formation; (a) *Blackites* sp., (b) *Chiasmolithus gigas*, (c) *C. grandis*, (d) *Coccolithus crassus*,(e) *C. pelagicus*, (f) *Coccolithus* sp.,(g) *Cruciplacolithus frequens*, (h) *Erocsonia formosa*, (i) *Cyclicargolithus floridanus*, (j) *C. abisectus*, (k) *Dictyococcites bisectus*, (l) *D.scrippsae*. (Scale bar: 5 micron)

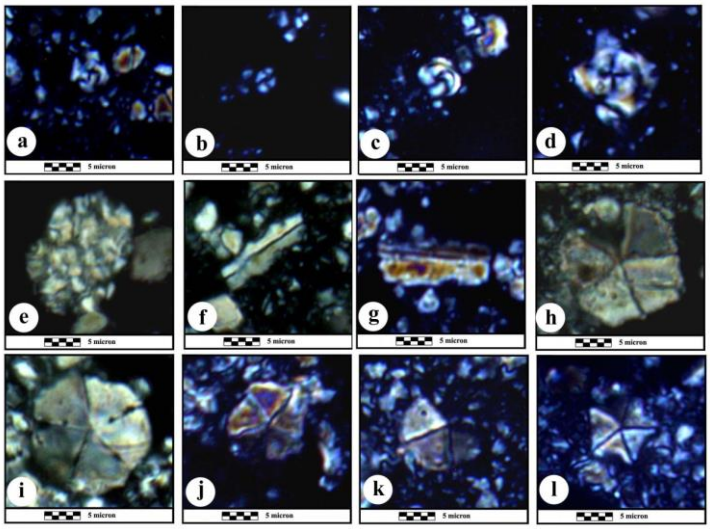


Plate (4): Cross-polarized photos of significant calcareous nannofossil taxa from Jaddala Formation; (a) *Reticulofenestra dictyoda*,(b) *Prinsius bisulcus*, (c) *Toweius occultatus*, (d) *T. pertusus*, (e) *Thoracosphaera saxae*, (f) *Zygrhablithus bijugatus*, (g) *Zygrhablithus* sp., (h) *Braarudosphaera bigelowii*, (i) *B. discula*, (j) *B. stylifera*, (k) *Braarudosphaera* sp.,(l) *Micrantholithus pinguis*. (Scale bar: 5 micron).

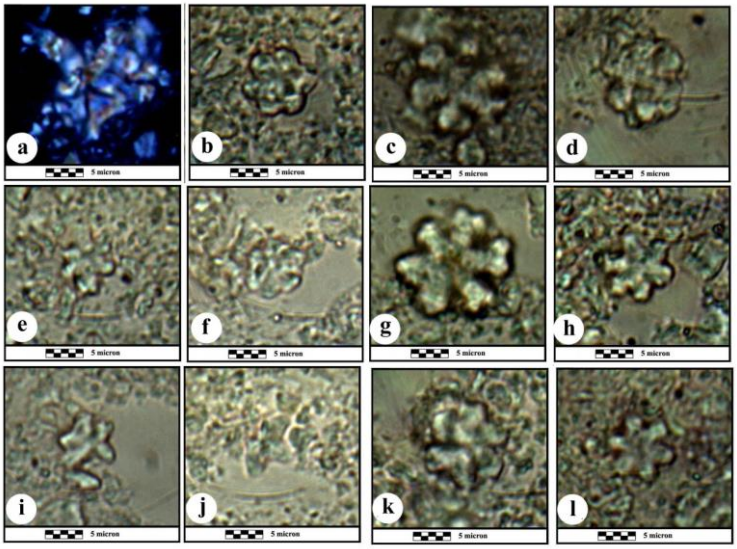


Plate (5): Cross-polarized and light photos of significant calcareous nannofossil taxa from Jaddala Formation; (a) *Micrantholithus* sp., (b) *Discoaster adamanteus*, (c) *D. deflandrei*, (d) *D. floreus*, (e) *D. germanicus*, (f) *D. kuepperi*, (g) *D. martini*, (h) *D. nodifer*, (i) *D. saipanensis*, (j) *D. sublodoensis*, (k) *D. triangularis*, (l) *D. trinus.* (Scale bar: 5 micron).

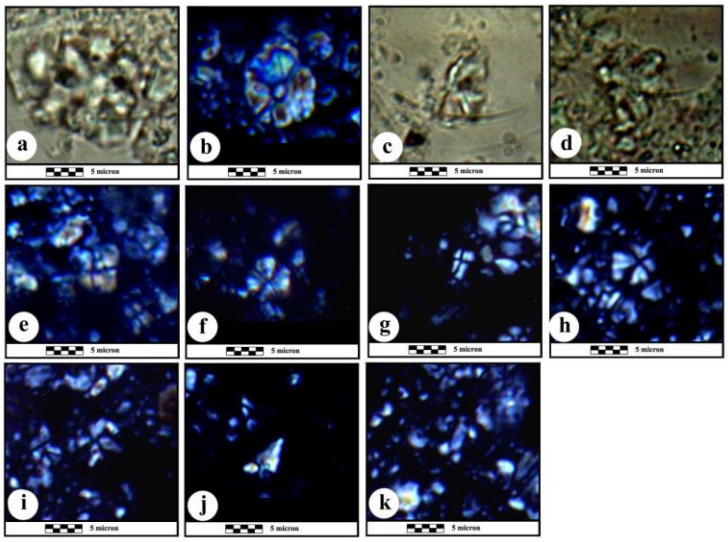


Plate (6): Cross-polarized and light photos of significant calcareous nannofossil taxa from Jaddala Formation; (a) *Discoaster* sp., (b) *Heliolithus cantabriae*, (c) *Rhomboaster cuspis*, (d) *Tribrachiatus contortus*, (e) *Sphenolithus arthurii*, (f) *S. editus*, (g) *S. obtusus*, (h) *S. primus*, (i) *S. pseudoradians*, (j) *S. radians*, (k) *Sphenolithus* sp.. (Scale bar: 5 micron).

B-Nannobiostratigraphy

1- *Reticulofenestra dictyoda* Partial Range Biozone (CNE 5)
Definition: Partial range biozone of *Reticulofenestra dictyoda.*
Boundaries: The biozone is determined by the last occurrence of *Tribrachiatus orthostylus*, to the first occurrence of *Discoaster sublodoensis.*
Thickness: Between (1265-1250) m. depths.

Correlation and Discussion: This biozone is correlated to the biozone NP13 which was studied by Martini (1971) aged of the Early Eocene (Ypresian) and to biozone CP11which was studied by Okada and Bukry (1981) aged of the Early Eocene (Y prsian). This biozone corresponds to biozne CNE 5 which was studied by Agnini *et al*. (2014) aged of the Early Eocene (Y prsian); therefore; Early Eocene was suggested in this study. (Gradstein *et al*., 2012) (Diags.1-3).

2 – *Discoaster sublodoensis* Interval biozone (CNE 6-7)
Definition: Interval biozone of *Discoaster sublodoensis.*
Boundaries: The biozone is determined by the first occurrence of *Discoaster sublodoensis* to the first occurrence of *Nannoterina cristata*.
Thickness: Between (1250-1240) m. depths.

Correlation and Discussion: This biozone is correlated to the lower biozone of NP14 which was studied by Martini (1971) aged of the Early Eocene(Y presian) and to Subbiozone CP12a which studied by Okada and Bukry (1981) aged of the Early Eocene (Yprsian). This biozone corresponds to bioznes CNE 6 and 7 which was studied by Agnini *et al*. (2014) aged of the Early Eocene (Y prsian), therefore, Early Eocene was suggested in this study as well (Gradstein *et al*., 2012) (Diags.1-3).

3 – *Nannotetrina cristata* Interval biozone (CNE 8)
Definition: Interval biozone of *Nannotetrina cristata*.
Boundaries: The biozone is determined by the first occurrence of *Nannotetrina cristata* to the first occurrence of *Nannotetrina alata*.
Thickness: Between (1240-1225) m. depths.
Correlation and Discussion: This biozone is correlated to the upper biozone of NP14 which was studied by Martini (1971) aged of the Middle Eocene (Lutetian) and to Subzone CP12b which was studied by Okada and Bukry (1981) aged of the Middle Eocene (Lutetian) this biozone corresponds to biozne CNE 8 which was studied by Agnini *et al*. (2014) aged of the Middle Eocene (Lutetian) therefore, the middle Eocene was suggested in this study. (Gradstein *et al*., 2012) (Diags. 1-3).

4 – *Nannotetrina alata* Interval biozone (CNE 9)
Definition: Interval biozone of *Nannotetrina alata*.
Boundaries: The biozone is determined by the first occurrence of *Nannotetrina alata* to the first occurrence of *Chiasmolithus gigas*.
Thickness: Between (1225-1220) m. depths.

Correlation and Discussion: This biozone is correlated to the lower biozone of NP15which was studied by Martini (1971) aged of the Middle Eocene (Lutetian) and to Subzone CP5 which was studied by Okada and Bukry (1981) aged of the Middle Eocene (Lutetian). This biozone corresponds to biozne CNE 9 which was studied by Agnini *et al*. (2014) aged of the Middle Eocene (Lutetian) therefore, the middle Eocene was suggested in this study (Gradstein *et al*., 2012) (Diags.1-3).

5 – *Chiasmolithus gigas* Range Biozone (CNE 10-11)
Definition: Range biozone of *Chiasmolithus gigas*.
Boundaries: The biozone determinate by the first occurrence of *Chiasmolithus gigas* to the last occurrence of *Chiasmolithus gigas*.
Thickness: Between (1220-1195) m. depths.

Correlation and Discussion: This biozone is correlated to the middle biozoneof NP15 which was studied by Martini (1971) aged of the Middle Eocene (Lutetian) and Subzone CP13b, which was studied by Okada and Bukry (1981) aged of the Middle Eocene (Lutetian). This biozone corresponds to biozones CNE 9 and 10 which was studied by Agnini *et al*. (2014) aged of the Middle Eocene (Lutetian) therefore, the middle Eocene was suggested in this study as well. (Gradstein *et al*., 2012) (Diags. 1-3).

CONCLUSIONS

The Jaddala Formation in (Aj-10) well has five biostratigraphic zones, which include the following: *Reticulofenestra dictyoda* Partial Range Biozone (CNE 5); *Discoaster sublodoensis* Interval biozone (CNE 6-7); *Nannotetrina cristata* Interval biozone (CNE 8); *Nannotetrina alata* Interval biozone (CNE 9) and *Chiasmolithus gigas* Range Biozone (CNE 10-11). These Biozones are correlated with other calcareous nannofossils biozones from both local and regional sections leading to conclude that the age of the studied section is Early to Middle Eocene (Yprsian toLutetian).

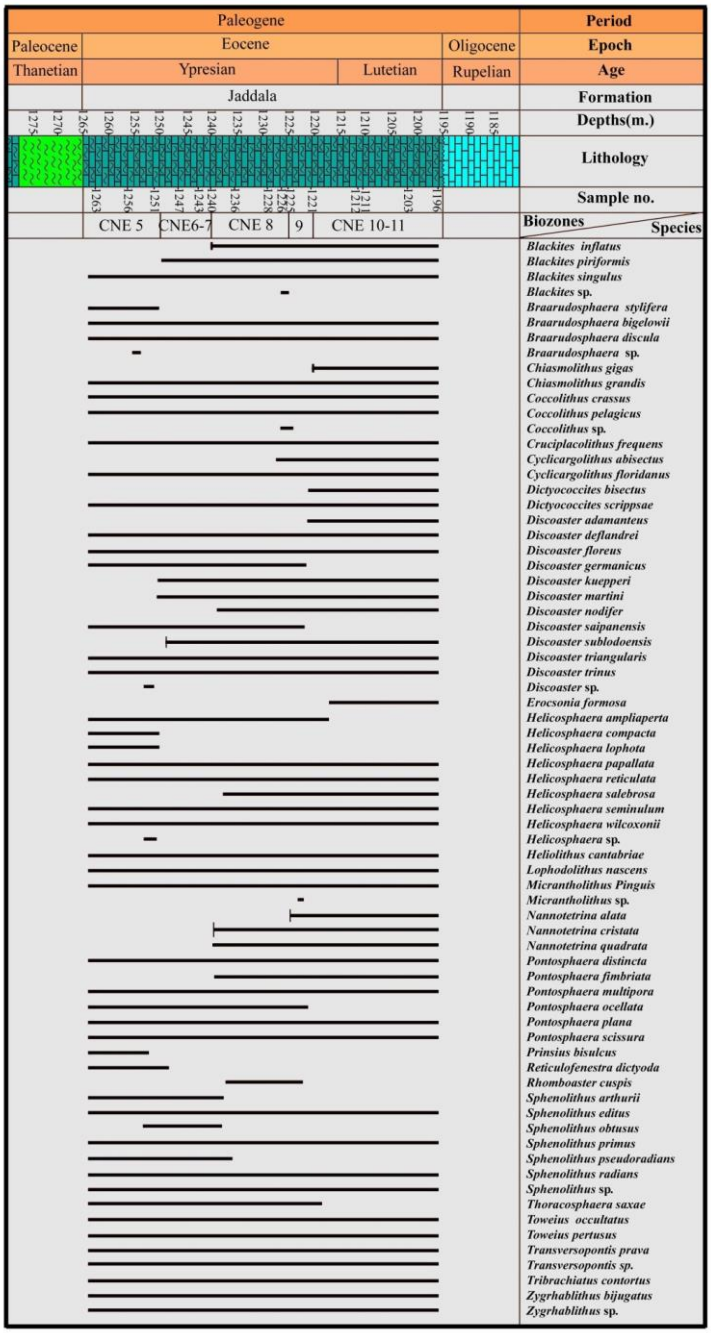


Diagram (2): Range chart of calcareous nannofossils throughout studied section.

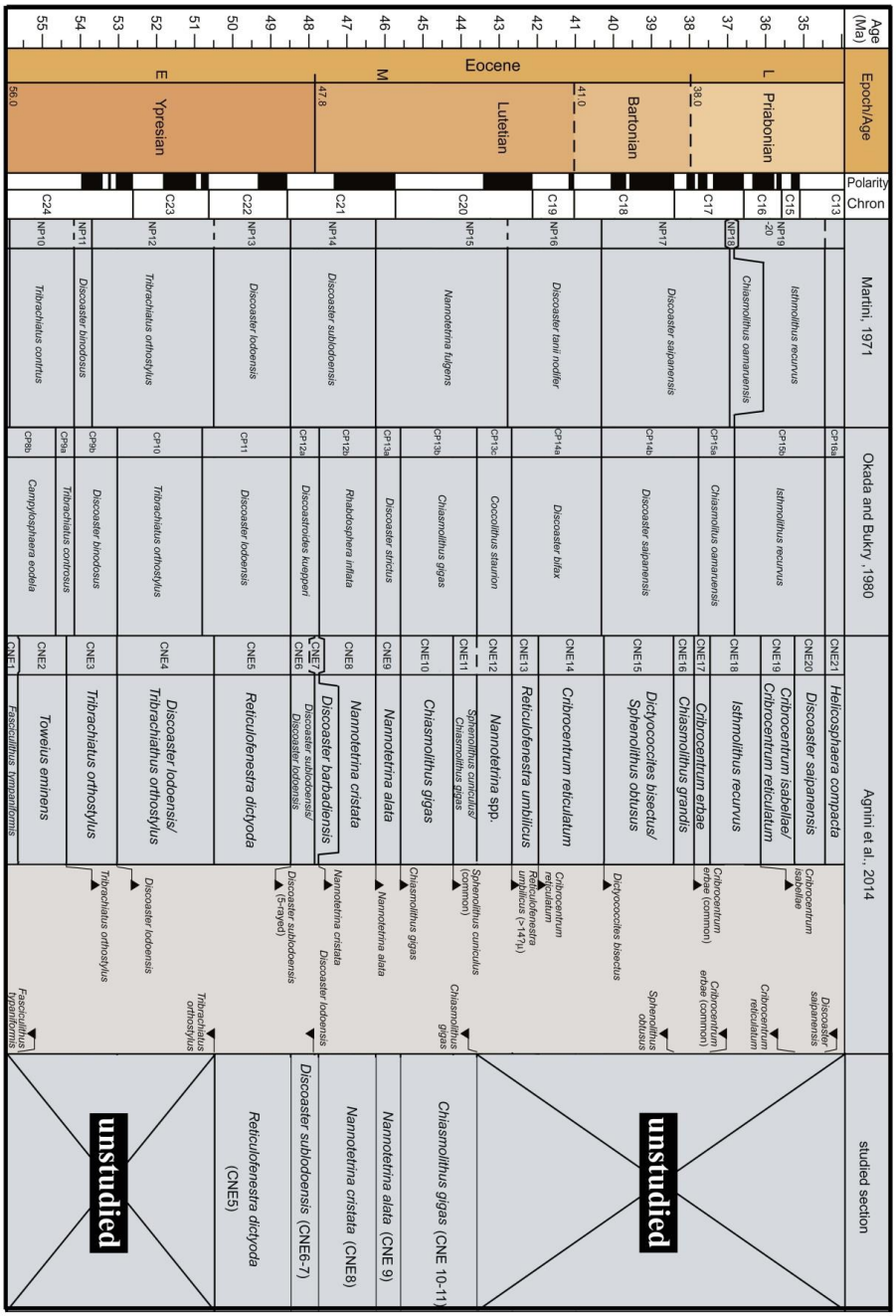


Diagram (3): correlated chart of calcareous nannofossils biozones for studied section

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الطباقية الحياتية لمتحجرات النانو الكلسية لتكوين جدالة في بئر(Aj-10) وسط العراق

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الخلاصة

اجريت دراسة تفصيلية لمتحجرات النانو الكلسية لتكوين جدالة في بئر (Aj-10) وسط العراق. شخص واحد وسبعون نوع من اجناس متحجرات، البعض منها ترك مفتوح التسمية، وبالاعتماد على الامتدادات الطباقية لها تم تحديد خمسة انطقة حياتية لتكوين جدالة هي:

(1)*Reticulofenestra dictyoda* Partial Range Biozone (CNE 5), (2)*Discoaster sublodoensis* Interval biozone (CNE 6-7), (3)*Nannotetrina cristata* Interval biozone (CNE 8), (4)*Nannotetrina alata* Interval biozone (CNE 9), (5)*Chiasmolithus gigas* Range Biozone (CNE 10-11).

قورنت هذه الانطقة الحياتية بمثيلاتها قادت الى تحيد عمر التكوين في هذا المقطع بالايوسين الاوسط (البيرسيان الى اللوتيشيان).