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# CALCAREOUS NANNOFOSSILS OF THE RATGA FORMATION, SWAB MEMBER (EARLY EOCENE) IN KEYHOLE (KH7/7), IRAQI WESTERN DESERT

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## ABSTRACT

This study focuses on identifying the relative age in rock sequence of the Ratga Formation (Swab Member), Iraqi Western Desert. To achieve this goal, five samples are collected (mainly limestone) from the Keyhole KH7/7, at a depth between (119 – 130). Nineteen species belonging to eleven genera of calcareous nannofossils are described. The recorded assemblages identified from the stratigraphic succession of this formation confirm Early Eocene (Early Ypresian) age by the biozone *Tribrachiatus contortus* Interval Biozone CP9a.

## متحجرات النانو الكلسية لتكوين رطكة، عضو صواب (الايوسين المبكر) في بئر (KH7/7)، الصحراء الغربية العراقية

**عمر احمد البدراني و ابراهيم يونس الشريفي و علاء صباح الزبيدي**

**المستخلص**

تهدف هذه الدراسة الى تحديد العمر النسبي للتتابع الصخري لتكوين رطكه (عضو صواب) في الصحراء الغربية. لتحقيق هذا الهدف تم التقاط خمسة نماذج (معظمها حجر جيري) من التتابع الصخري لبئر (KH7/7) على عمق بين (119 – 130) متر. تم تشخيص تسعة عشر نوعا يعود الى احد عشر جنسا من متحجرات النانو الكلسية. قادت هذه المتحجرات المسجلة في التكوين الى تحديد عمره بالايوسين المبكر(اليبريسيان المبكر) بحسب النطاق الحياتي المسجل فيه (*Tribrachiatus contortus* Interval Biozone CP9a).

## INTRODUCTION

The Ratga Formation is one of the important rock units in the Iraqi Western Desert. It was previously included within the Dammam Formation, Hagopian (1979) agreed with Al-Hashimi (1972) and divided the Lower – Upper Eocene series in the Western Desert to five units. It is exposed in the Western Desert of Iraq extending from Wadi Halgum (east of the Gaàara Depression) to Wadi Swab, and to the Iraqi – Saudi Arabian borders southwards. The name Ratga Formation was introduced by Jassim *et al*. (1984) to the Eocene sequence of the western part of the Western Desert and assigned the Lower – Upper Eocene age for the formation. Later, it got its official name by Karim and Al-Bassam (1997) who divided the formation into three main members:

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- Swab Member (LowerYpresian)
- Damluk Member (Upper Ypresian – Upper Lutetian)
- Mugur Member (Priabonian – Bartonian)

The type locality of the formation is documented in four localities; these are defined as follows (Karim and Al-Bassam, 1997):

1. Swab Member (Wadi Swab), Longitude 38° 45' 00" E and Latitude 33° 45' 00" N, of Lower Ypresian age, the thickness of this Member is 32 m.
2. Damluk Member:
   - Damluk A (Wadi Akash), Longitude 40° 07' 30" E and Latitude 33 ° 52' 00" N, of Upper Ypresian to Lower Lutetian age, the thickness of this Member is 28 m.
   - Damluk B (Wadi Halgum), Longitude 40° 30' 00" E and Latitude 33° 52' 00" N, of Upper Lutetian age, the thickness of this Member is 52 m.
3. Mugur Member (Wadi Ratga), Longitude 40° 10' 00" E and Latitude 34° 00' 00" exposed in Wadi Ratga near Mugur Al-Deeb. The age is Priabonian to Bartonian and the thickness is 119 m.

The lower contact of the Ratga Formation is with the Akashat Formation (Paleocene) and the contact is conformable. The upper contact is with the Sheikh Alas/Shurau Formation (Oligocene) and it is also conformable (Karim and Al-Bassam, 1997).

The stratigraphic succession of the Eocene in Iraq have been studied by many authors such as: Al-Hashimi (1973); Jassim *et al*. (1984); Al-Badrani (2007); Al-Badrani (2011); Al-Badrani and Al-Nima (2010); Al-Badrani and Al-Ubaidi (2012); Al-Badrani and Al-Zubaidi (2015); Al-Badrani and Al-Zubaidi (2017); Al-Badrani and Al-Zubaidi (2019a); Al-Badrani and Al-Zubaidi (2019b); Al-Qayim *et al*. (2019).

Many geological studies focused on the Ratga Formation in different specialties such as stratigraphy, paleontology, ores and minerals and sedimentology. Among these are:

- Al-Hashimi (1980) studied the Lower Eocene (Upper Ypresian) rocks underlying the phosphorite unit and recognized the larger species of *Nummulites planulatus* (Lamark), *Nummulites globules* Leymerie, *Nummulites atacicu*s Leymerie, *Nummulites lucasanus* (De Archiac), and *Nummulites murchisoni* (Rutimeyer).
- Jassim *et al.,* (1984) introduced this formation for the phosphatic facies representing the whole of the Eocene age in the West of Iraq.
- Buday and Jassim (1987) studied this formation through an extended study of the geological survey of the Iraqi Western Desert.
- Al-Bassam and Hagopian (1983) studied the Lower Eocene phosphorites in the Iraqi Western Desert.
- Karim and Al-Bassam (1997) officially introduced the Ratga Formation as a new Eocene lithostratigraphic unit in the Western Desert of Iraq.
- Al-Mutwali and Abawi (2001) studied the biostratigraphy of the Ratga Formation in different Wells, Western Iraq.
- Jassim and Goff (2006) referred to this formation in terms of its composition, divisions, stratigraphy, fossils, and economic importance, and placed it within the Middle Paleocene – Eocene Megasequence (AP10), phosphatic inner shelf deposits.

- Al-Hashimi and Al-Bassam (2006) mentioned that the Eocene phosphorites are part of the Ratga Formation (Damluk Member) which is one of the widely exposed rock units in the Western Desert of Iraq. Their paleontological investigation of the Ratga Formation also revealed the presence of planktonic foraminiferal assemblages such as *Globorotalia bolivariana* Petters, *Globorotalia aspensis* (Colom), *Globorotalia bullbrooki* Bolli, *Globorotalia centralis* Cushman and Bermudez and small benthonic species such as *Lenticulina* spp., *Bulimina* spp., *Dentalina* spp. and *Nodasaria* spp..
- Sissakian and Mohammed (2007) reviewed the stratigraphy of the Iraqi Western Desert and explained that the fauna of Swab Member, determined by many authors such as Al-Hashimi (1974); Shakir (1979); Karim and Ctyroky (1980) and Buday (1980), are *Nummulites frass*i De Laharpe, *N.deserti* De Laharpe, *Assilina* sp., *Rotalia trochidiformis* Deshays, *Opericulina libyca* Schwager and *N. akashensi* Al-Hashimi.
- Sissakian *et al*., (2018) studied the Ratga Formation within an extended study of the geology of the Euphrates River with emphasis on the Iraqi part.
- Al-Qayim *et al*. (2019) presented a study on facies modeling and sequence stratigraphy of the Damluk Member of the Ratga Formation in the Iraqi Western Desert.

This study deals with the Lower Eocene stratigraphic succession in well KH7/7 located in the Iraqi Western Desert, at depths between (119 – 130 m) which belong to the Swab Member and consist mainly of limestone. The study is based on five core samples (Fig.1) where many calcareous nannofossils are extracted.

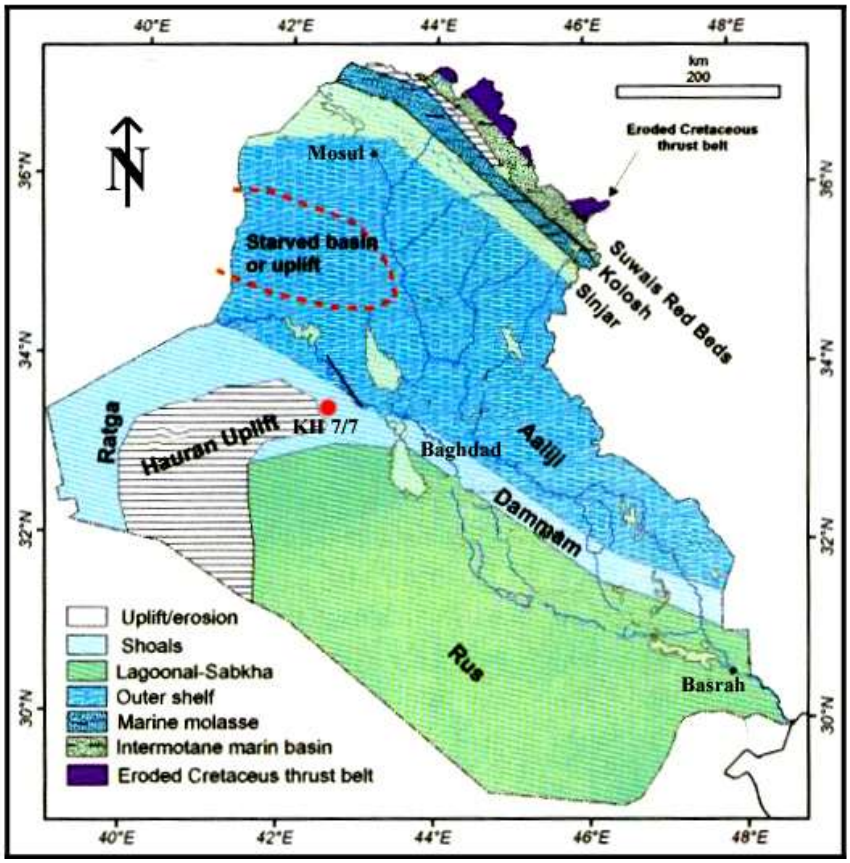


Fig.1: Geologic and paleoegeographic map of Iraq during the Eocene age shows the location of the studied well (Jassim and Goff, 2006)

## METHODOLOGY

Five limestone samples are selected from the studied succession to study the calcareous nannofossils using thin sections (under transmitted-light microscope). The calcareous nannofossils are extracted using the method (H) (Armstrong and Brasier, 2005). The sample preparation included decantation and preparation of smear slides that provide method for producing slides of calcareous nannofossils. A small amount of the disaggregated sample is placed in distilled water and a drop of cellulose is added to act as a dispersant. The cover slip is left to dry on a warm hotplate. To make permanent mounts, the slide and residue were left to dry at a low temperature away from possible sources of contamination. A drop of mounting medium (e.g. Canada Balsam) was dropped on a clean cover slip, in addition to another drop on the residue, and left them to dry before the microscopic examination.

## RESULTS AND DISCUSSION

- **Systematic paleontology**

The taxonomic study of calcareous nannofossils in this study is based on the classification proposed by Perch-Nielsen (1985). The following species are identified in the samples:

- Kingdom Protista
- Division Chrysophyta
- Class Coccolithophyceae

- **Family Braarudosphaeraceae** Deflandre, 1947

Genus *Braarudosphaera* Deflandre, 1947

– **Type species:** *Braarudosphaera bigelowiii* (Bran and Braarud) Deflandre, 1947.
*Braarudosphaera bigelowii* (Gran and Braarud, 1935) Deflandre, 1947.

– **Distinguishing features:** Pentaliths pentagonal with straight edges and flat top surface (Fig.2a).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007) and Al-Zubaidi (2017).

*Braarudosphaera discula* (Bramlette and Riedel, 1954).

– **Distinguishing features:** Pentaliths pentagonal with curved edges and flat top surface (Fig.2b).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007) and Al-Zubaidi (2017).

Genus *Micrantholithus* (Deflandre, 1950).

– **Type species:** *Micrantholithus flos* (Deflandre and Fert, 1954).
*Micrantholithus flos* (Deflandre and Fert, 1954).

- **Distinguishing features:** Pentaliths with sutures emerging through corners; edge often indented giving stellate outline with relatively straight edges, sutures often raised (Fig.2c).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007).

- **Family Coccolithaceae** (Poche, 1913)
  Genus *Coccolithus* (Schwarz, 1894).

– **Type species:** *Coccolithus oceanicus* (Schwarz, 1894).
*Coccolithus eopelagicus* (Bramlette and Riedel, 1954; Hay *et al*., 1966).

– **Distinguishing features:** Elliptical placolith coccolith with central area, open or spanned by a disjunct bar on the proximal surface but very large (Fig.2d).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007), Al-Zubaidi (2017), Al-Hayaly (2019), Al-Hayaly and Al-Badrani (2019).

*Coccolithus pelagicus* (Wallich, 1877; Schiller, 1930).

– **Distinguishing features:** Elliptical placolith coccolith with central area open or spanned by a disjunct bar on the proximal surface (Fig.2e).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007), Al-Zubaidi (2017), Al-Hayaly (2019) and Al-Hayaly and Al-Badrani (2019).

- **Family Prinsiaceae** (Hay and Mohler, 1967)
  Genus *Cyclicargolithus* (Bukry, 1971)

– **Type species:** *Cyclicargolithus floridanus* Hay *et al*., 1967.
*Cyclicargolithus floridanus* (Hay *et al*., 1967; Bukry, 1971)

– **Distinguishing features:** Coccoliths circular to sub-circular with small central-area (Fig.2f).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Zubaidi (2017), Al-Hayaly (2019), and Al-Hayaly and Al-Badrani (2019).

Genus *Reticulofenestra* (Hay *et al*., 1966)
*Reticulofenestra reticulata* (Gartner and Smith, 1967; Roth and Thierstein, 1972)

– **Distinguishing features:** Coccoliths circular medium to large with narrow central area crossed by a distinctive, robust and visible net (Fig.2g).

- **Occurrences:** It is recorded from the Ratga Formation of Iraq (this study).

*Reticulofenestra bisecta* (Hay *et al*., 1966) Roth, 1970

– **Distinguishing features:** Coccoliths circular medium to large with a solid central plug (Fig.2h).

- **Occurrences:** This study recorded it from the Ratga Formation of Iraq.

Genus *Toweius* (Hay and Mohler, 1967)
*Toweius occultatus* (Locker, 1967; Perch-Nielsen, 1971)

– **Distinguishing features:** Coccoliths circular, medium to large with two large openings in the central area (Fig.2i).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Hayaly (2019), and Al-Hayaly and Al-Badrani (2019).

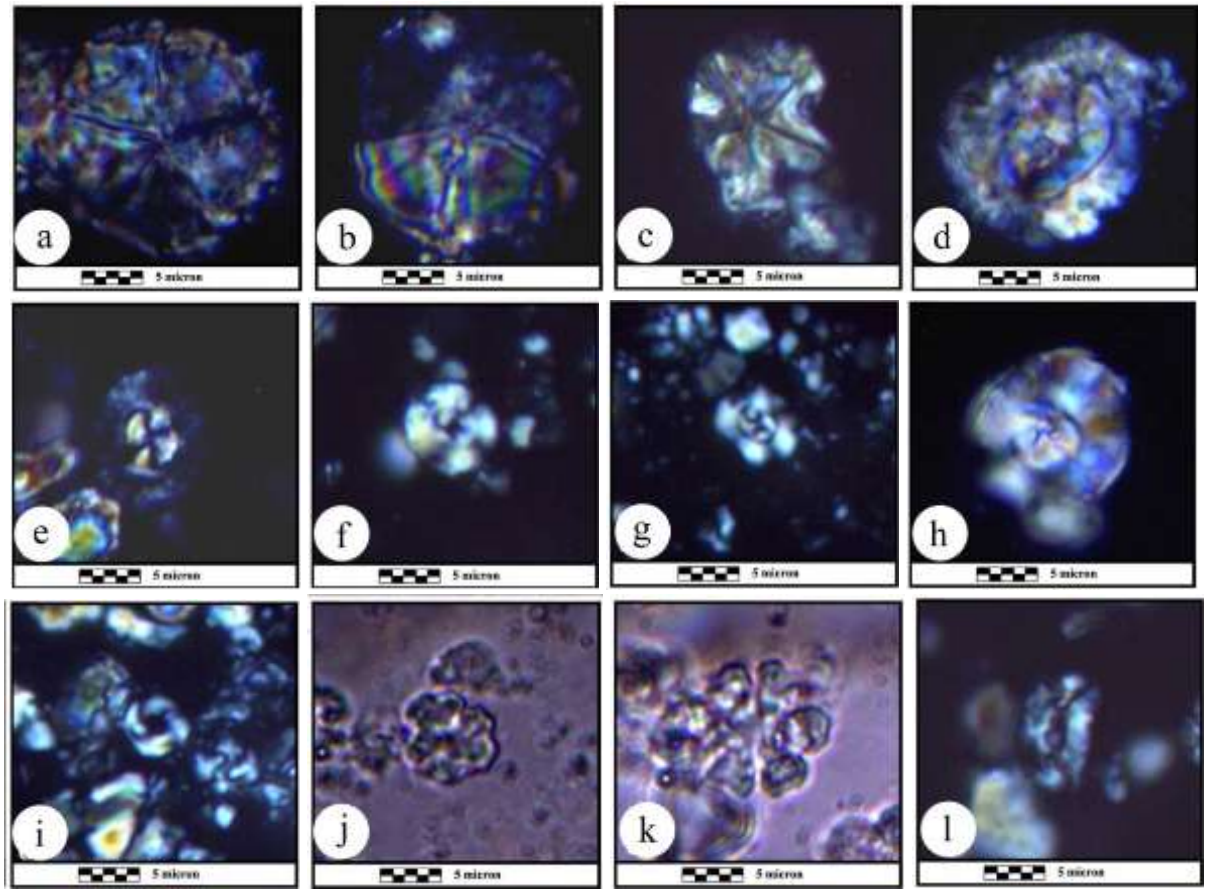


Fig.2: Cross-polarized light photos of receded calcareous nannofossils from the Ratga Formation:

**a)** *Braarudosphaera bigelowii* (Gran and Braarud, 1935; Deflandre, 1947)
**b)** *Braarudosphaera discula* (Bramlette and Riedel, 1954)
**c)** *Micrantholithus flos* (Deflandre and Fert, 1954)
**d)** *Coccolithus eopelagicus* (Bramlette and Riedel, 1954; Hay *et al*., 1966)
**e)** *Coccolithus pelagicus* (Wallich, 1877; Schiller, 1930)
**f)** *Cyclicargolithus floridanus* (Hay *et al*., 1967; Bukry, 1971)
**g)** *Reticulofenestra reticulata* (Gartner and Smith, 1967; Roth and Thierstein, 1972)
**h)** *Reticulofenestra bisecta* (Hay *et al*., 1966; Roth, 1970)
**i)** *Toweius occultatus* (Locker, 1967; Perch-Nielsen, 1971)
**j)** *Discoaster cubensis* (Furrazola and Iturralde, 1967)
**k)** *Discoaster deflandrei* (Bramlette and Riedel, 1954)
**l)** *Helicosphaera lophota* (Bramlette and Sullivan, 1961; Locker, 1973)

▪ **Family Discoasteraceae** (Tan, 1927)
Genus *Discoaster* (Tan, 1927)

– **Type species:** *Discoaster pentaradiatus* (Tan Sin Hok, 1927).
*Discoaster cubensis* (Furrazola and Iturralde, 1967)

– **Distinguishing features:** Radiate nannoliths with each ray formed of a discrete crystal-unit, with the c-axes perpendicular to the nannolith surface (Fig.2j).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007), Al-Badrani (2011) , and Al-Zubaidi (2017).

*Discoaster deflandrei* (Bramlette and Riedel, 1954)

– **Distinguishing features:** Radiate nannoliths with 6-rayed with a well-developed central area; rays ending in strong short wide bifurcations (Fig.2k).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007), Al-Badrani (2011), and Al-Zubaidi (2017).

▪ **Family Helicosphaeraceae** (Black, 1971)
Genus *Helicosphaera* (Kamptner, 1954)

– **Type species:** *Coccosphaera carteri* (Wallich, 1877).
*Helicosphaera lophota* (Bramlette and Sullivan, 1961; Locker, 1973)

– **Distinguishing features:** Elliptical, oblong with wide flange and central area spanned by a broad, near-longitudinal disjunct bar usually with distinct median suture (Fig.2l).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Zubaidi (2017).

▪ **Family Heliolithaceae** (Hay and Mhler, 1967)
Genus *Heliolithus* (Bramlette and Sullivan, 1961)
*Heliolithus kleinpellii* (Sullivan, 1964)

– **Distinguishing features:** Large coccoith, heliolith with two thin birefringent cycles. The narrow cycle is around 3/4 of the width of the wider cycle (Fig.3a).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Hayaly (2019), and Al-Hayaly and Al-Badrani (2019).

▪ **Family Pontosphaeraceae** (Lemmermann, 1908)
Genus *Pontosphaera* (Lohmann, 1902)

– **Type species:** *Pontosphaera syracusana* (Lohmann, 1902).
*Pontosphaera plana* (Bramlette and Sullivan, 1961; Haq, 1971)

– **Distinguishing features:** Elliptical coccolith with Simple unadorned plate, typically with two narrow longitudinal slits; margin narrow or inconspicuous (Fig.3b).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007) and Al-Zubaidi (2017).

*Pontosphaera pectinata* (Bramlette and Sullivan, 1961; Sherwood, 1974)

– **Distinguishing features:** Elliptical coccolith with plate scalloped towards its outer edge and pierced by two longitudinal slits or small holes (Fig.3c).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Zibaidi (2017).

*Pontosphaera punctosa* (Bramlette and Sullivan, 1961; Perch-Nielsen, 1984)

– **Distinguishing features:** Elliptical coccolith with plate that has marginal furrows and small pores, and larger pores towards the center (Fig.3d).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Zubaidi (2017).

▪ **Family Sphenolithaceae** (Deflandre, 1952)

Genus *Sphenolithus* (Deflandre in Grasse, 1952

– **Type species:** *Sphenolithus radians* (Deflandre, 1954).

*Sphenolithus anarrhopus* (Bukry and Bramlette, 1969)

– **Distinguishing features:** Nannolith with medium sized, short to relatively long spine that is slightly asymmetrical and dark at 0° (Fig.3e).

- **Occurrences:** It is recorded in the current study from the Ratga Formation of Iraq.

*Sphenolithus editus* (Perch-Nielsen *et al.*, 1978)

– **Distinguishing features:** Nannolith with medium sized, short spine, broad triangular shape (dart shaped) and wide base in which the lower quadrants dominate (Fig.3f).

- **Occurrences:** It was recorded by Al-Zubaidi (2017).

▪ **Incertae sedis**

Genus *Tribrachiatus* (Shamrai, 1963)

– **Type species:** *Tribrachiatus* (Shamrai, 1963).

*Tribrachiatus contortus* (Stradner, 1958; Bukry, 1972)

– **Distinguishing features:** Nannolith, Tri-radiate forms with long ray tip bifurcations that deviate strongly from the plane of the nannolith, giving the appearance of two asymmetrically offset and superimposed tri-radiate cycles (Fig.3g).

- **Occurrences:** It was recorded from the Ratga Formation of Iraq by Al-Badrani (2007) and Al-Zubaidi (2017).

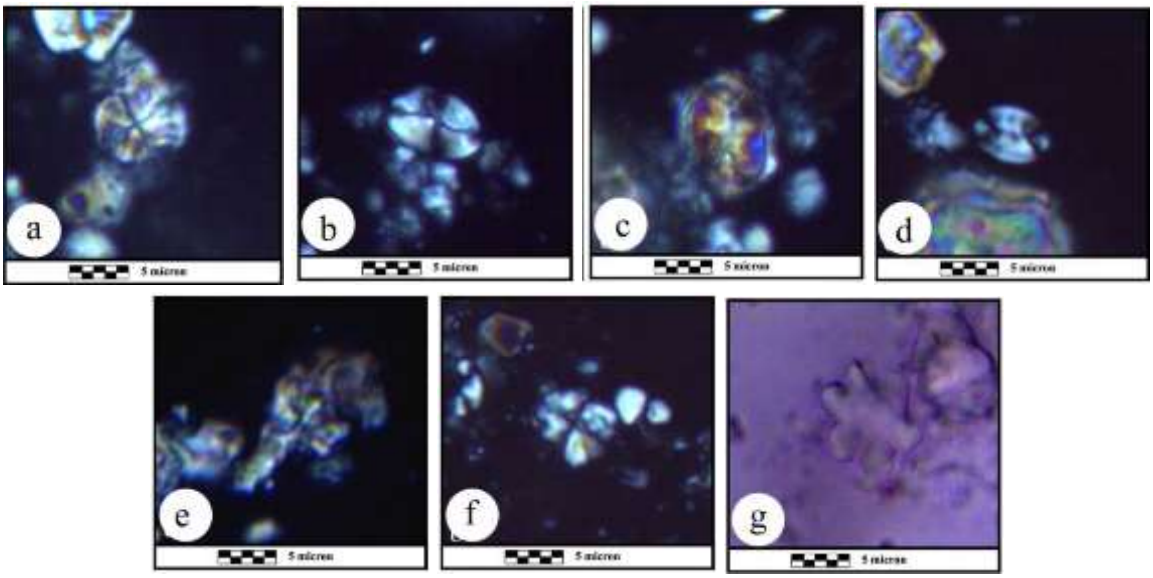


Fig.3: Cross-polarized light photos of receded calcareous nannofossils from the Ratga Formation:

**a)** *Heliolithus kleinpellii* Sullivan, 1964;
**b)** *Pontosphaera plana* (Bramlette and Sullivan, 1961) Haq, 1971;
**c)** *Pontosphaera pectinata* (Bramlette and Sullivan, 1961; Sherwood, 1974)
**d)** *Pontosphaera punctosa* (Bramlette and Sullivan, 1961; Perch-Nielsen, 1984)
**e)** *Sphenolithus anarrhopus* (Bukry and Bramlette, 1969)
**f)** *Sphenolithus editus* (Perch-Nielsen *et al.*, 1978)
**g)** *Tribrachiatus contortus* (Stradner, 1958; Bukry, 1972)

## BIOSTRATIGRAPHY

Depending on the stratigraphic position of the recorded species of the studied succession, the following biozones (Figs.4 and 5) are recognized:

*Tribrachiatus contortus* {Interval Biozone CP9a (part)}

– **Definition:** Interval biozone from first occurrence of *Discoaster diastypus* (Bramlette and Sullivan, 1961) to last occurrence *Tribrachiatus contortus* (Stradner, 1958; Bukry, 1972).

– **Thickness:** 11 meter of limestone

– **Boundries and Discussion:** The lower boundary of this biozone is not exposed in the studied section which is marked by first occurrence of *Discoaster diastypus* (Bramlette and Sullivan, 1961), and the upper boundary of this biozone is not exposed in the studied section too, which is marked by the last occurrence of *Tribrachiatus contortus* biozone (Martini, 1965).

This biozone is correlated with *Tribrachiatus contortus* Biozone CP9a by Okada and Bukry (1980), and agree to *Tribrachiatus contortus* Biozone NP10 by Martini (1971) based on Hay (1964) and Bukry (1973). All the authors above assigned the Early Ypresian age to this biozone, therefore the section age is Early Eocene (Early Ypresian) (Gradestein *et al*., 2012).

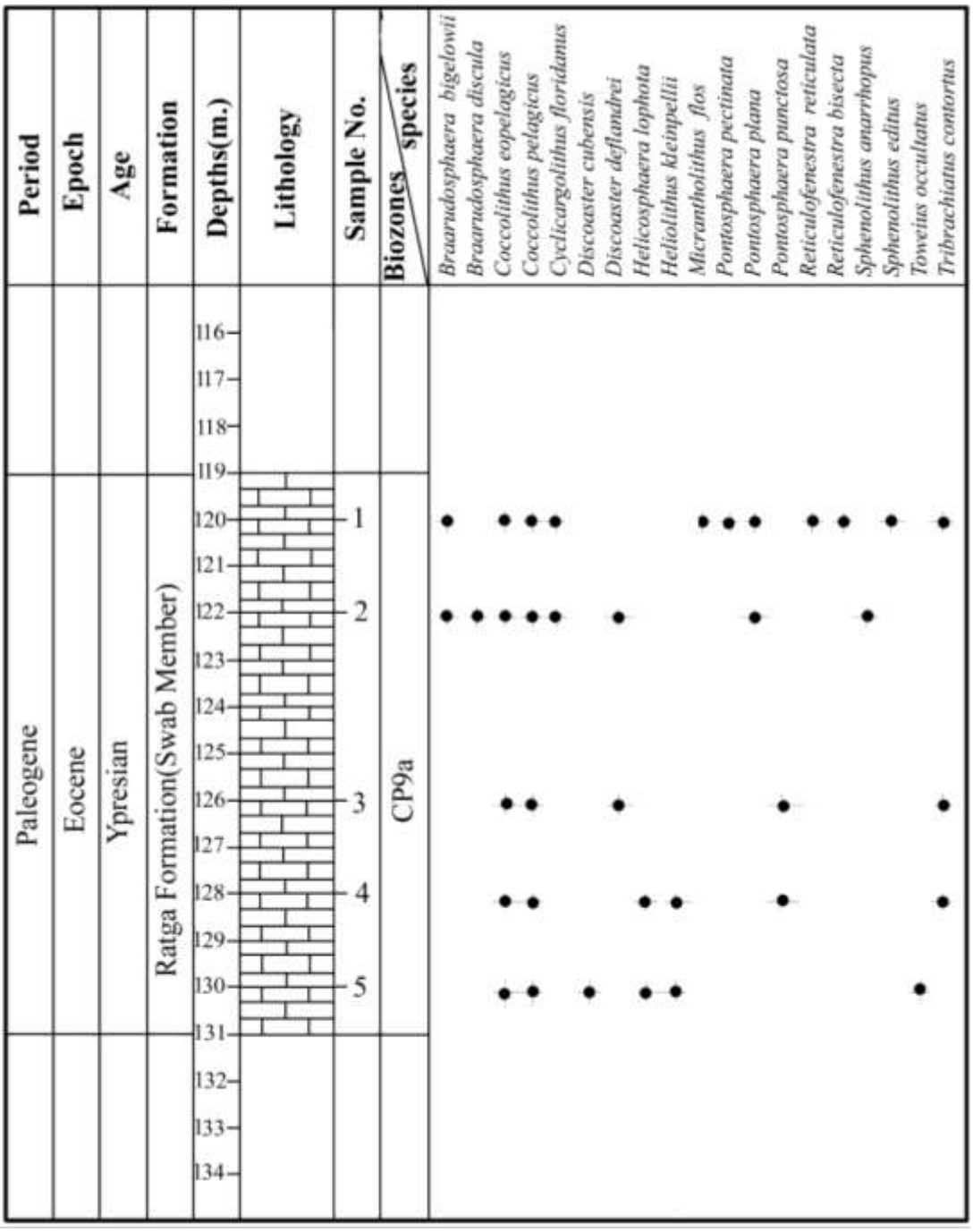


Fig.4: Calcareous nannofossils biostratigraphy of the Ratga Formation (Swab Member) for the studied section

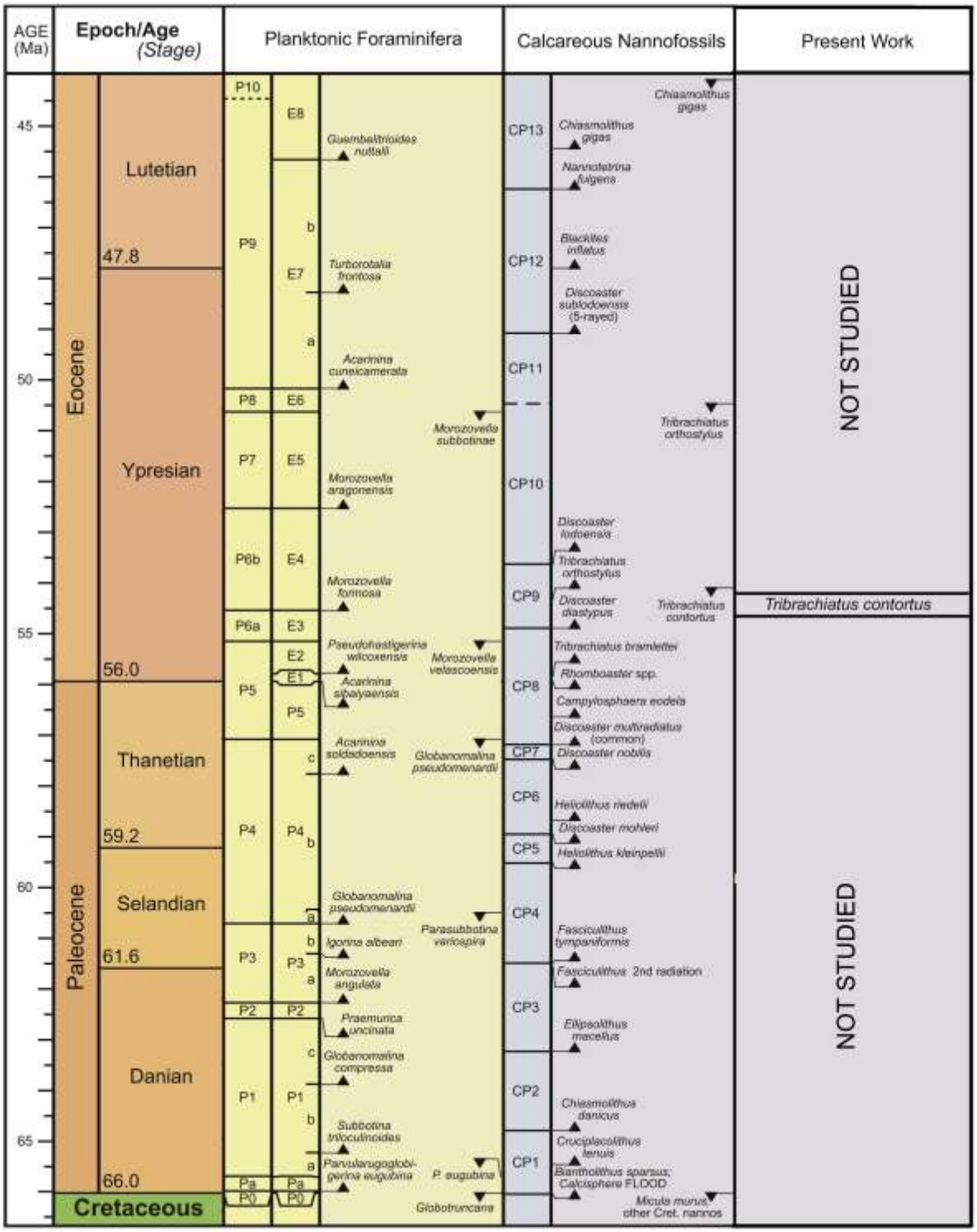


Fig.5: Calcareous nannofossils biozones correlated with Foraminiferal biozones, E: Eocene, P: Paleocene, CP: Coccolith Paleogene (Gradestien *et al*., 2012)

## CONCLUSIONS

The existence of *Tribrachiatus contortus* (Stradner, 1958; Bukry, 1972), which defines the upper boundary of this biozone, and the disappearance of the other species represent the upper biozones in the Eocene epoch. Moreover, the existence of *Tribrachiatus bramlettei* (Bronniman and Stradner, 1960; Proto Decima *et al*., 1975) indicates the Ypresian age for studied section.

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## REFERENCES

Al-Badrani, O.A., 2007. The study of Calcareous Nannofossils of Middle Eocene – Lower Miocene successions in Sinjar Anticline section, Northwest Iraq. Unpublished Ph.D. Thesis, College of Science, University of Mosul, 119pp (in Arabic).

Al-Badrani, O.A., 2011. Nannobiostratigraphy of Jaddala Formation in well (Kh 12/7) West Iraq. Iraqi Journal of Earth Sciences, Vol.11, No.1, p. 71 – 84.

Al-Badrani, O.A. and Al-Nima, R.R., 2010. Recognition between Eudiscoaster and Heliodiscoaster using Competitive Neural Network. Iraqi Journal of Earth Sciences, Vol.10, No.2, p. 97 – 110.

Al-Badrani, O.A. and Al-Ubaidi, M.H., 2012. *Transversopontis omarians* sp.nov. calcareous nannofossils from Jaddala Formation (Eocene) in Dh.1 well, Central Iraq. Iraqi Journal of Earth Sciences, Vol.12, No.3, p. 73 – 78.

Al-Badrani, O.A. and Al-Zubaidi, A.S., 2015. Nannobiostratigraphy of Jaddala Formation (type section), Sinjar anticline, NW Iraq. Journal of Nannoplankton Researches, Vol.35, special Issue (Abstracts), 15pp.

Al-Badrani, O.A. and Al-Zubaidi, A.S., 2017. Two new species of calcareous nannofossils from Jaddala Formation, type section, Northwestern Iraq. Kirkuk University Journal/ Scientific Studies, Vol.12, No.4, p. 1 – 12.

Al-Badrani, O.A. and Al-Zubaidi, A.S., 2019a. Paleoclimatology Evidence of Eocene from Jaddala Formation in Northwestern Iraq. In: Zhang, Z., Khelifi, N., Mezghani, A. and Heggy, E..Patterns and Mechanisms of Climate, Paleoclimate and Paleoenvironmental Changes from Low-Latitude Region. Springer Nature, 188pp.

Al-Badrani, O.A. and Al-Zubaidi, A.S., 2019b. Paleogene Calcareous Nannofossils. Lambert Academic Publishing, 104pp.

Al-Bassam, K.S. and Hagopian, D., 1983. Lower Eocene phosphorites in the Western Desert, Iraq. Sedimentary Geology, Vol.33, p. 295 – 316. doi.org/10.1016/0037-0738(83)90077-5.

Al-Hashimi, H., 1972. Foraminiferidea of the Dammam Formation (Eocene) in Iraq. Unpublished Ph.D. Thesis University of London, 350pp.

Al-Hashimi, H. A., 1973. The sedimentary facies and depositional environments of the Eocene Dammam and Rus Formations. J. Geol. Soc. Iraq,Vol.6, p.7 – 18.

Al-Hashimi, H.A.J., 1974. The Sedimentary facies and depositional environment of the Eocene Dammam and Rus Formations. J. Geol. Soc. Iraq. Vol.VI, p. 7 – 18.

Al-Hashimi, H.A., 1980. Biostratigraphy of Eocene – Lower Oligocene of Western Desert, Iraq. Actes du VIe. Colloqu. Africain de Micropaleontologie-Tunis, 1974. Annales des Mines et de la Geologie, Tunis, No.28, Tome III, p. 209 – 229.

Al-Hashimi, H.A. and Al-Bassam K.S., 2006. Early Lutetian phoshorites in Wadi Akash, Western Desert, Iraq. Iraqi Bull. .Geol. Mining, Vol.2, No.2, p. 23 – 38.

Al-Hyaly, R.S. 2019. Calcareous Nannofossils Biostratigraphy of Aaliji Formation in (K-116) Northern Iraq. Unpublished MSc. Thesis, College of Science,University of Mosul, 154pp.

Al-Hyaly, R.S. and Al-Badrani, O.A. 2019. Calcareous Nannofossils Biostratigraphy of Aaliji Formation in (K-116) Northern Iraq. Iraqi National Journal of Earth Sciences, Vol.19, No.1, p. 35 – 45.

Al-Mutwali, M.M. and Abawi, T.S., 2001. Biostratigraphy of the Ratga Formation (Early Eocene) in Selected Wells, Western Iraq. Rafidain Journal of Science, Vol.12, No.3, p. 56 – 63.

Al-Qayim, B.A., Al-Rawi, A.M. and Al-Bassam, K.S., 2019. Facies modeling and sequence stratigraphy of an Eocene carbonate – phosphorite ramp: Damlouk Member, Ratga Formation, Western Desert, Iraq. Iraqi Bull. Geol. Mining Vol.15, No.1, p. 15 – 30.

Al-Zubaidi, A.S., 2017. Calcareous Nannofossils Biostratigraphy of Jaddala Formation, type section, Northwestern Iraq. Unpublished MSc. Thesis, College of Science, University of Mosul, 241pp.

Armstrong, H. and Brasier, M., 2005. Microfossils. Black well publishing, 296pp. On line ISBN:9781118685440.

Black, M., 1971. The systematics of coccoliths in relation to the palaeontological record. In: B.M. Funnell and W.R. Riedel (eds.) The Micropaleontology of Oceans, p. 611 – 24. Cambridge University Press.

Bramlette, M.N. and Riedel, W.R., 1954. Stratigraphic value of Discoasters and some other microfossils related to recent coccolithophores. J. Paleontology, Vol.28, No.4, p. 385 – 403. https://www.jstor.org/stable/1300155.

Bramlette, M.N. and Sullivan, F.R., 1961. Coccolithophorids and related nannoplankton of the early Tertiary in California. Micropaleontology, Vol.7, No.2, p. 129 – 188, pls. 1 – 14. doi.org/10.2307/1484276.

Bronniman, P. and Stradner, H., 1960. Die Foraminiferen – und Discoasteridenzonen von Kuba und ihre interkontinentale Korrelation. Erdoel Zeitscher., Vol.76, No.10, p. 364 – 369, Pl.1, Figs. 1 – 44. (in German).

Buday, T., 1980. The regional geology of Iraq. Vol.1, Stratigraphy and paleogerography., Iraq Geological Survey, Baghdad, Iraq, Dar Al Kutub Publishing House, Mosul, Iraq, 445pp.

Buday, T. and Jassim, S.Z., 1987. The Regional Geology of Iraq. Vol.2: Tectonism, Magmatism and Metamorphism. Iraq Geological Survey,, Baghdad, Iraq, 352pp.

Bukry, D., 1971. Coccolith stratigraphy Leg. 6, Intial Report of the Deep Sea Drilling Project. VI, p. 965 – 1004, Pl.8.

Bukry, D., 1972. Further comments on coccolith stratigraphy, Leg 12, Deep Sea Drilling Project. Initial Rep. Deep Sea drill. Pro., Vol.12, p. 1071 – 83.

Bukry, D.,1973. Coccolith stratigraphy, eastern equatorial Pacific, Leg 16 Deep Sea Drilling Project. In: van Andel, T.H., 1-Health, G.R., et al., Initial report of the Deep Sea Drilling Project. Volume XVI. Washington, D.C. US. Gov. printing office, p. 653 – 711.

Bukry, D. and Bramlette, M.N., 1969. Coccolith age determinations, Leg 1, Deep Sea Drilling Project. Initial Rep. Deep Sea drill. Proj., Vol.1, p. 287 – 369.

Deflandre, G., 1947. Braarudosphaera nov. gen., type d'une famille Nouvelle de coccolithophorides actuels a elements composites. C.R. Acad. Sc., Vol. 225, p. 439 – 441, Figs. 1 – 5. (in French).

Deflandre, G., 1950. Observations sur les coccolithophorides, a propos d'un nouveau type de Braarudosphoridé, Micrantholithus, á éléments calastiques. C.R. Seances Acad. Sci, Paris, 231, Vol.40, p. 1156 – 1164.

Deflandre, G., 1952. Classe des coa:olitbophorides. In: P.P. Grasse (ed.), Traite de loologie, Vol.I, p. 439 – 70.

Deflander, G. and Fert, C., 1954. Observation sur les coccolithophoridés actuels et fissiles en microscope ordinaire et electronique. Annales de Paléontologie, Vol.40, p. 115 – 176.

Furrazola-Bermudez, G. and Iturralde, V.M., 1967. Esudio Micropaleontol-ogica del Oligoceno supeior de Cuba,en el pozo Pijuan no, 47.Tecnologica , Vol.5, No.1, p. 3 – 11, pls. 1 and 2, text-Figs. 1 – 4.

Gartner, S. Jr and. Smith, L.A., 1967. Coccoliths and related calcareous nannofossils from the Yazoo Formation (Jackson, Late Eocene) of Louisiana. Univ. Kansas Paleontol. Contrib., Vol.20, p. 1 – 7.

Gradstein, F.M., Ogg, J.G., Schmitz, M.D. and Ogg, G.M., 2012. The geological time scale 2012, Elsevier, 1176pp. EBook ISBN: 9780444594488.

Gran, H.H. and Braarud, T., 1935. A quantitative study of the phytoplankton in the Bay Fundy and the Gulf of Marine ( including obersevations on hydrography, chemistry and turbidity). J. Biol. Board Canada, Vol.1, No.5, p. 279 – 467. doi.org/10.1139/f35-012.

Grasse, P.P. 1952. Traite de Zoologie. Masson, Paris. Vol.1, No.1, p. 439 – 470. (in French).

Hagopian, D., 1979. Regional Geological Mapping of the Nhadain – Altinif area. GEOSURV, Int. rep. no. 1983.

Haq, B.U., 1971. Paleogene calcareous nannoflora Parts I-IV. Stockholm Contrib. Geol., Vol.25, p. 1 – 158.

Hay, W.W., 1964. The use of the electron microscope in the study of fossils. Annu. Rep. Smithsonimt lnst., 1963, 409-I 5.

Hay, W.W. and Mohler, H.P., 1967. Calcareous, nannoplankton from Early Tertiary Rocks at Pont Labau, France, and Paleocene – Early Eocene Correlations. J. Paleontology, Vol.41, No.6, p. 1505 – 1541, pls.: 196 – 206, text-Figs. 1 – 5.

Hay, W.W., Mohler, H.P., Roth, P.H., Schmidt, R. R. and Boudreaux, J.E., 1967. Calcareous nannoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean-Antillean area, and transoceanic correlation. Trans. Gulf Coast Assoc. geol. Soc., Vol.17. p. 428 – 466. doi.org/10.1306/5D25C21F-16C1-11D7-8645000102C1865D.

Hay, W.W., Mohler, H.P. and Wade, M.E., 1966. Calcareous nannofossils Nal'chik (northwest Caucasus). Ecolg. Geol. Helv., Vol.59, p. 379 – 399.

Jassim, S.Z. and Goff, J., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, 341pp.

Jassim, S.Z., Karim, S.A., Basi, M.A., Al-Mubarak, M. and Munir, J., 1984. Final report on the regional geological survey of Iraq, Vol. 3, Stratigraphy. GEOSURV, int. rep. no. 1447.

Kamptner, E., 1954. Untersuchungen uber den Feinbau der Coccolthen. Arch. Protistenk., Vol.100, p. 1 – 90.

Karim, S.A., and Al-Bassam, K.S., 1997. The Ratga Formation: a new name for the Eocene Lithostratigraphic Unit in the Western Desert of Iraq. Iraqi Geol. Jour., Vol.30, No.1, p. 46 – 60.

Lemmermann, E., 1908. Flagellatae, Chlorophyceae, Coccospaerales und Silicoflagellatae. In : K. Brandt and C.Apstein (eds.), Nordisches Plankton, p. 1 – 40. Lipsius and Tischer, Kiel and Leipzig.

Locker, S., 1973. Cocc olithineen aus dem Paliiogen Mitteleuropas. Pafiiobotanik, Vol.3, p. 735 – 836.

Locker, S.,1967. Neue, Stratigraphisch wichtige Coccolithophoriden (Flagellata) aus dem norddeutschen Alttertiär, Monatsber. Deutsch. Akad. Wiss. Berlin, Vol.9, No.9, 10, p. 758 – 768.

Lohmann, H., 1902. Die Coccolithophoridae, eine Monographie der Coccolithen bildenden Flagellaten, zugleich ein Beitrag zur Kenntnis des Mittelmeerauftriebs. Arch. Protistenk., Vol.1, p. 89 – 165.

Martini. E., 1965. Mid-Tertiary calcareous nannoplankton from Pacific deep-sea cores. In: W.F. Whittard and R.B. Bradshaw (eds.). Submarine Geology and Geophysics. Proc. I 7th Symp. Colston Res. Soc. London, p. 393 – 411. Butterworths.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. In Farinacci, A., (Ed.), Proceedings II Planktonic Conference, Roma, 1970, Vol.2, p. 739 – 785, Pl.4, Fig.6.

Okada, H. and Bukry, D., 1980. Supplementary modification and introduction of code numbers to low-latitude coccolith biostratigraphy zonation (Bukry, 1973, 1975). Marine Micro-Paleontology., Vol.5, No.3, p .321 – 326.

Perch-Nielsen, K., 1971 Neue Coccolithen aus dem Palaozan von Danemark, der Bucht von Biskaya und dem Eozan der Labrador See. Bull.geol.Soc. Denmark, Vol.21, p. 51 – 66.

Perch-Nielsen, K., 1984. Validation of New combinations. INA Newsletter, Vol.6, No.1, p. 42 – 46.

Perch-Nielsen, K., 1985. Cenozoic calcareous nannofossils. In: H.M. Bolli., J.B. and K. Perch-Nielsen (eds.), Plankton Stratigraphy. Cambridge University Press, Cambridge, p. 427 – 554.

Perch-Nielsen, K., Sadek, A., Barakat, M.G. and Teleb, F., 1978. Late Cretaceous and Early Tertiary calcareous nannofossils and planktonic foraminifera zones from Egypt. Ann. Min. Geol., Tunis, no. 28, Actes du vle colloque African de Micropaleotologie, Tunis 1974, Tome II, p. 337 – 403.

Poche, F., 1913. Das System der Protozoa. Arch. Protistenk., Vol.30, p. 125 – 321.

Proto Decima, F., Roth, P.H. and Todesco, L., 1975. Nannoplancton calcareo del Paleocene é dell' Eocene della Sezione di possagno. Schweiz, Paleontology, Abh., Vol.97, p. 35 – 55.

Roth, P.H., 1970. Oligocene calcareous nannoplankton biostratigraphy. Eclog. geol. Helv., Vol.63, p. 799 – 881 .

Roth, P.H. and Thierstein, H.R., 1972. Calcareous nannoplankton, Leg 14, Deep sea drilling project. In Hayes D.E., Pimm, A.C. et al., Initial reports of the deep sea drilling project. Washington, (U.S. Government Printing Office), Vol.14, p. 421 – 485.

Schiller, J., 1930. Coccolithineae. In: Dr. L. Rabenhorst's Kryptogamen-Fiora von Deutschland, Osterreieh und der Schweiz, Vol.10, No.2, p. 89 – 267. Leipzig, Akad. Verlagsgesellscbaft.

Schwarz, E.H.L., 1894. Coccoliths. Ann. Mag. Nat. Hist., ser., Vol.6, No.14, p. 341 – 346.

Shakir, Sh., 1979. Lower – Middle Eocene larger foraminefera of the Dammam Formation, Western Desert, Iraqi – Jordanian – Saudi Arabian Borders – Traibeel area. Part II. GEOSURV, int. rep. no. 983.

Shamrai, I.A., 1963. Certain forms of Upper Cretaceous and Paleogene coccolithus and discoasters from the southern Russian platform. Izv. Vyssh. Ucheb. Zavtd. Geol. i Razv., Vol.6, No.4, p. 27 – 40.

Sherwood, R.W., 1974. Calcareous nannofossil systematics,paleoecology, and biostratigraphy of the Middle Eocene Weches Fonnat:ion of Texas. Tulane Stud. Geol., Vol.II, p. 1 – 79.

Sissakian, V.K. and Mohammed, B.S., 2007. Stratigraphy. Iraqi Bull. Geol. Min. Special Issue, 2007: Geology of Iraqi Western Desert, p. 51 – 124.

Sissakian, V.K., Al-Ansari, N., Adamo, N., Knutsson, S. and Laue, J., 2018. Geology of the Euphrates River with Emphasize on the Iraqi Part. Journal of Earth Sciences and Geotechnical Engineering, Vol.8, No.3, p. 167 – 185.

Stradner, H., 1958. Die fossi1en Discoasteriden Osterreichs. I. Erdoi-Z., Vol.74, No.1, p. 78 – 88.

Sullivan, F.R., 1964. Lower Tertiary nannoplankton from the California Coast Ranges, I. Paleocene. Univ. Calif. Publ. Geol. Sci., Vol.44, No.3, p.163 – 227.

Tan, S.H., 1927. Discoasteridae incertae sedis. Proc. Sect. Sc. K. Akad. Wet. Amesterdczm, Vol.30, p. 411 – 419.

Wallich, G.C., 1877. Observations on the coccosphere. Ann. Mag. nat. Hist., ser. 4, Vol.16, p. 322 – 339.

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