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CALCAREOUS NANNOFOSSILS AND CHEMOSTRATIGRAPHY OF THE EARLY APTIAN OCEANIC ANOXIC EVENT 1A FROM NORTHERN IRAQ

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ABSTRACT

Calcareous nannofossils were documented from the upper part of the Cretaceous Balambo Formation in northern Iraq with the aim of determining an evidence for the Oceanic Anoxic Event. A detailed investigation of the calcareous nannofossils led to the identification of twenty-four species. Regarding these data, *Discolithus litterarius* (Górka, 1957) was identified at the studied interval with the age of Early Aptian.

Early Aptian assemblages are dominated by nannoconids that drop sharply within the *D. litterarius* nannofossil zone, which may be related to the nannoconid crisis recorded in the Early Aptian in the other parts of the world. This event is coincided by a decrease in $CaCO_3$ content and higher content of the Total Organic Carbon (TOC).

Key words: Aptian, Balambo Formation, Iraq, Nannoconid, OAE1a.

INTRODUCTION

Oceanic Anoxic Events (OAEs) are intervals in the earth history where depletion in oxygen occurred at depths over a large geographic area. Climatic changes and paleoceanographic conditions during these intervals show major disturbances in the global carbon cycle (Jenkyns, 2010). OAEs are commonly characterized by marine organic matter accumulation (Erbacher *et al.*, 1996). Several OAEs in the Mesozoic Ocean that manifestly caused major chemical change were recorded and included; Early Toarcian (Posidonienschiefer event, T-OAE, ~183 Ma), Early Aptian (Selli event, OAE 1a, ~120 Ma), Early Albian (Paquier event, OAE 1b, ~111 Ma) and Cenomanian-Turonian OAEs (Bonarelli event, C/T OAE, OAE 2, ~93 Ma) (Jenkyns, 2010). Furthermore, Early Aptian OAE1a black shale followed by 'nannoconid crisis' and a 'schizosphaerellid crisis' prior to the Toarcian OAE were also recorded. In both OAEs, rapid nannofloral speciation generally exists at 1.5 Ma before the OAE, but without extinctions (Erba, 2004).

In northeastern Iraq, Al-Khafaf (2018) mentioned that the lower part of the Balambo Formation at Azmer area was Early Aptian in age, with an overall decrease in type and abundance of nannofossils that may relate to an Oceanic Anoxic Event OAE1. The studied area lies at the imbricated zone of Iraq which is part of the Zagros belt and characterized by thrust folded structures and over-thrust blocks. Zagros belt is formed as a result of the closure of the Neo-Tethys oceanic basin and late Cretaceous and Cenozoic convergence of the Arabian plate with continental Eurasia (Stöcklin, 1968; Snyder and Barazangi, 1986; Talbot and Alavi, 1996; Stampfli and Borel, 2002).

The Balambo sediments belong to the Arabian Plate Megasequence (AP8) of Late Jurassic 149Ma - Late Cretaceous 92Ma (Sharland *et al.*, 2001), that were deposited in intrashelf basin on a passive continental margin. The Balambo Formation is one of the common marine Cretaceous successions in northern and northeastern Iraq and is divided in its type section in the Sirwan valley near Halabja in northeastern Iraq into two portions; the lower comprises 259 m thickness of uniform thin-bedded blue ammonite bearing limestone, greenish marl and black shale. Moreover, the upper part with 503 m thickness consists of thin-bedded globigerinal limestone, passing downwards to grey radiolarian limestone. The age of the Balambo Formation is regarded as Valanginian-Turonian based on biostratigraphicdata (van Bellen *et al.*, 1959; Buday, 1980).

The age of the formation is variable in other sections in Iraq, the lower part of the formation in Azmer anticline east of Sulaimaniya city is ranging from the late Early Hauterivian to Late Aptian based on calcareous nannofossils assemblages (Al-Mutwali and Al-Khafaf, 2019), while the age of the formation extends from Late Valanginian to Late Aptian in Barsarin village (Rawanduz area) at northeastern Iraq (the studied section) based on planktonic foraminiferal data (Al-Mutwali *et al.*, 2018). Therefore, the lower part of the Balambo Formation in Azmer section correlates with the Balambo Formation at the studied section in Barsarin village. The studied section is composed of dark colored limestone and marly limestone in addition to shale intercalations.

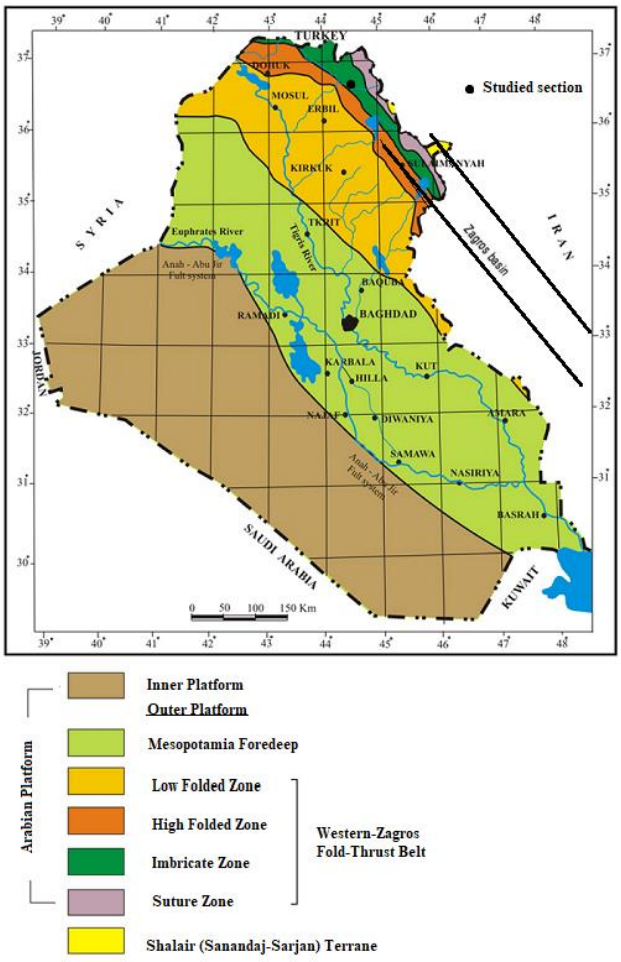
In the present work, an attempt is made to follow the nannofossils distribution in the Cretaceous Balambo Formation from Barsarin section (northern Iraq) with the focus on the Early Aptian nannoconid drop which may relate to 'nannoconid crisis along with Total Organic Carbon (TOC) and carbonate $CaCO_3$ content.

MATERIALS AND METHODS

Fifteen samples within 400 cm thick of marly limestones, shales and limestones from Barsarin section, northern Iraq (Map 1, Diag. 1), were selected and prepared using the simple smear slide technique for the study of calcareous nannofossils which are studied with a transmitted-light microscope (Optika B-353POL, Italy). The calcareous nannofossils are extracted at the Department of Geology, University of Mosul, Iraq using the method (H), (Armstrong and Brasier, 2005). For the nannofossil slide preparation, small amount of the disaggregated sample is placed in distilled water and a drop of cellosize is added to act as a dispersant. The cover slip is left to dry on a warm hotplate; then the slide and residues are

allowed to dry at a low temperature away from possible sources of contamination. A cover slip mounted by Canada balsam is put over the residue and left to dry before examining with transmitted light microscope.

Geochemical analysis is focused on seven samples covering the studied part of the OAE1a at Barsarin section. The organic carbon (OC) is analyzed using the compensation method in an elemental analyzer mass spectrometer (EA-IRMS, Thermo Finnigan Flash HT and Thermo Finnigan Delta V Advantage), whereas, $CaCO_3$ content is carried out by Varian 720-ES ICP-OES. Both analyses were done at laboratories of Katholieke University of Leuven (KULeuven, Belgium). Species identification with their occurrence in Iraq is done at Department of Geology, University of Mosul.



Map (1): Tectonic divisions of Iraq and the location of the studied Barsarin section which is marked with a black circle (after Fouad, 2015).

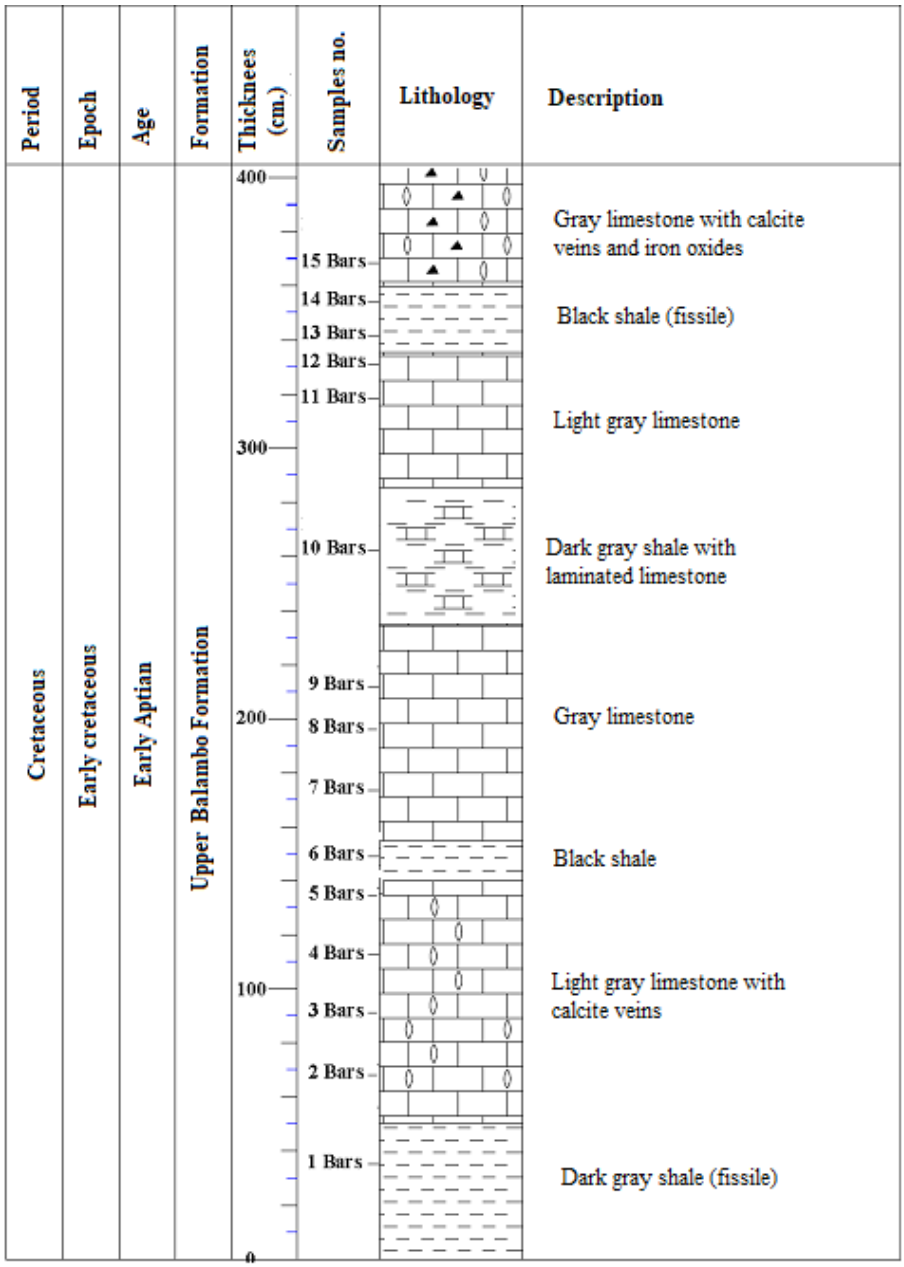


Diagram (1): Lithologic section of the upper Balambo Formation at Barsarin area showing the samples location.

RESULTS

Systematic paleontology

Species identification with their occurrence in Iraq as follows:

Kingdom Protista

Division Chrysophyta

Class Coccolithophyceae

Family Braarudosphaeraceae Deflandre, 1947

Genus *Braarudosphaera* Deflandre, 1947

Braarudosphaera bigelowii (Gran and Braarud, 1935) Deflandre, 1947 (Pl. 1a)

Description: It is a nannolith with pentagonal outline.

Occurrences: It is recorded from Iraq at Balambo Formation (this study) and from Iraq by Al-Badrani (2007) and Al-Badrani and Al-Khashab (2013).

Genus *Micrantholithus* Deflandre and Fert, 1954

Micrantholithus hoschulzii (Reinhardit, 1966) Thierstein, 1971 (Pl.1b)

Description: It is a nannolithwith of deeply indented sides and gracile, long rays. The height of the pentalith results in a ragged LM appearance.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Micrantholithus obtusus Stradner, 1963 (Pl.1c)

Description: It is a nannolith with stellate outline due to shallow indentations in each segment.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Micrantholithus speetonensis Perch-Nielsen, 1979 (Pl.1d)

Description: It is a nannolith with crenulated outline due to two indentations in each segment.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Micrantholithus sp. (Pl.1e)

Description: It is a nannolith with crenulated outline.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Family Chiastozygaceae Rood, Hay and Barnard, 1973

Genus *Chiastozygus* Gartner, 1968

Discolithus litterarius (Górka, 1957) Manivit, 1971 (Pl.1f)

Synonym: *Chiastozygus litterarius* (Górka, 1957) (GBIF Secretariat, 2019)

Description: It is a Loxoliths with a relatively broad rim and thick, weakly birefringent cross-bars. Unicyclic or diffusely bicyclic rim image in XPL.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Genus *Zeugrhabdotus* Reinhardt, 1965

Zeugrhabdotus embergeri (Nöel, 1959) Perch-Nielsen, 1984 (Pl.1g)

Description: It is a Coccolith with heavily calcified species has a rhomb-shaped, composite bar and very small to no perforations in the central area.

Occurrences: It is recorded from Iraq at Balambo Formation (this study) and by Al-Mamari (2019).

Family Nannoconaceae Deflandre, 1959

Genus *Nannoconus* Kamptner, 1931

Nannoconus cf. *colomii* (de Lapparent, 1931) Kamptner, 1938 (Pl.1h)

Description: It is a nannolith with Bulbous basal cavity.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Nannoconus kamptneri Brönnimann, 1955 (Pl.1i)

Description: It is a nannolith with Pear-shaped to tapering.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Nannoconus cf. *Multicadus* Deflandre and Deflandre, 1959 (Pl.1j)

Description: It is a nannolith with Tall elongate and cylindrical with one or two constrictions.

Occurrences: It is recorded from Iraq at Balambo Formation in this study; and previously was registered by Al-Badrani (2012).

Nannoconus quadriangulus Deflandre and Deflandre, 1967 (Pl.1k)

Description: It is a nannolith with Short-cylindrical (quadriangular) nannoconids with central cavity that is similar in width to the wall.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Nannoconus steinmannii Kamptner, 1931 (Pl.1l)

Description: It is a nannolithwith Tapering, pear-shaped nannoconids with narrow central openings (canals) and walls formed from low-angled, narrow cycles.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Nannoconus truitti Brönnimann, 1955 (Pl.1m)

Description: It is a nannolith with Barrel-shaped or slightly tapering nannoconids with canal width similar to, or slightly narrower than, the wall.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Nannoconus wassallii Brönnimann, 1955 (Pl.1n)

Description: It is a nannolith with Pear-shaped nannoconids with wide central cavities and thick walls; the cavity is two to four times the width of the wall.

Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Nannoconus sp. (Pl.1o)
Description: It is a nannolith with Pear-shaped nannoconids with wide central cavities.
Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Family Podorhabdaceae Noël, 1965
Genus *Retecapsa* Black, 1971
Retecapsa angustiforata Black, 1971(Pl.1p)
Description: It is a coccolith with a relatively wide central area spanned by an axial cross with one centrally-placed broad lateral bar in each quadrant.
Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Family Polycyclolithaceae Forchheimer, 1972
Genus *Assipetra* Roth, 1973
Assipetra terebrodentarius Roth, 1973 (Pl.1q)
Description: It is a coccolith with Blocky, globular nannoliths formed from six or more complexly intergrown calcite blocks that are joined along broadly radial sutures.
Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Assipetra sp. (Pl.1r)
Description: It is a coccolith with Blocky to globular nannoliths typically formed from intergrown elements that may show radial symmetry.
Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Family Watznaueriaceae Rood, Hay and Barnard, 1971
Genus *Watznauria* Reinhardt, 1964
Watznaueria barnesae (Black and Barnes, 1959) Perch-Nielsen, 1969 (Pl.1s)
Description: It is a coccolith with Central-area closed or very narrow, with no central area structures.
Occurrences: It is recorded from Iraq at Balambo Formation (this study); previously this species reported from Iraq by Al-Badrani *et al*. (2012) and Karim *et al*. (2013).

Watznaueria sp. (Pl.1t)
Description: It is a coccolithwith central-areas that are typically closed or narrow but may be spanned by transverse bar.
Occurrences: It is recorded from Iraq at Balambo Formation in this study.

Biostratigraphy
Depending on the stratigraphic distribution of the recorded species, only one calcareous nannofossils biozone is recorded in this study, which is *Discolithus litterarius* Biozone, Early Aptian. This biozone is determined by the first occurrence of *D. Litterarius* to the first occurrence of *Prediscosphaera columnata* (Stover, 1966; Perch-Nielsen, 1984) that is not

recorded in this study, this biozone is recorded at the upper part of the Balambo Formation within the studied 4 m out of the total 100 m thick of the formation in Barsarin area (see Diag. 1). Where correlated with CC7 biozone of Sissingh (1977) it correlates exactly to CC7a aged by Early Aptian (Gradstein *et al*., 2004), (Diag. 2). The most important and common nannofossil taxa are shown in Diagram (1) and Plate (1).

By the correlation of recorded calcareous nannofossils biozones with regional schemes, it is concluded that the age of studied section is Early Aptian (Diag. 3).

Geochemistry

Bulk-rock data are presented in Diagram (2). The $CaCO_3$ content decreases from 86.15 to 28.7 that is accompanied by a decline of nannoconid near the Early Aptian nannoconid crisis. The average Total Organic Carbon (TOC) of the analyzed samples content is 0.34%, with the highest values (0.51%) recorded at the nannoconids decline interval (Diag. 2).

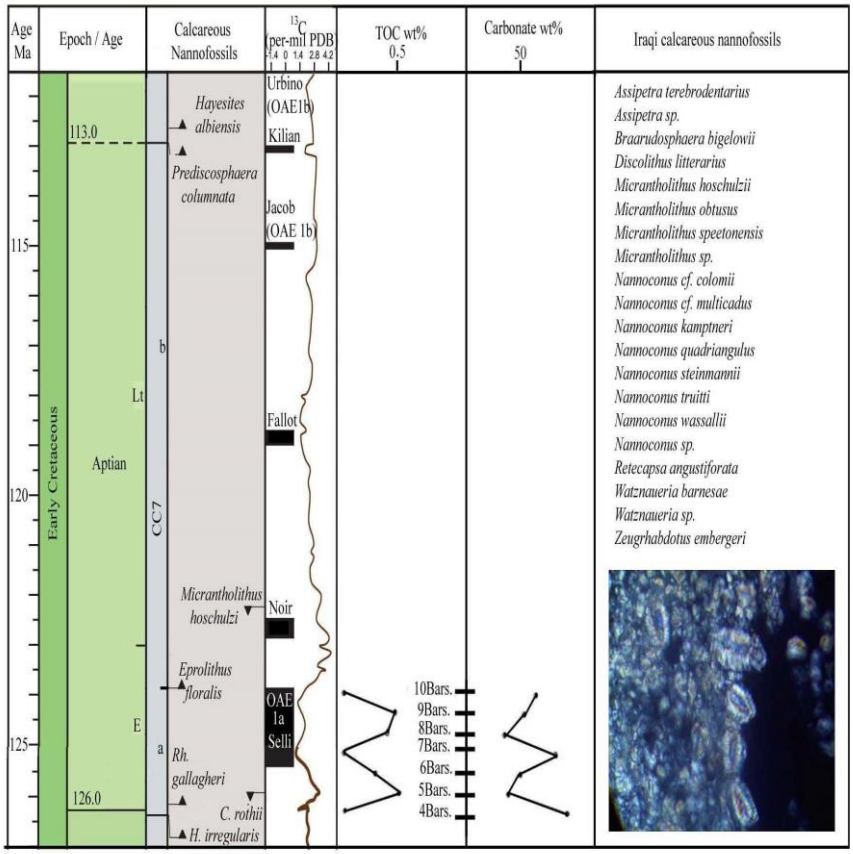


Diagram (2): Calcareous nannofossils and geochemistry data of the investigated Barsarin section (after Gradstein *et al*., 2012).

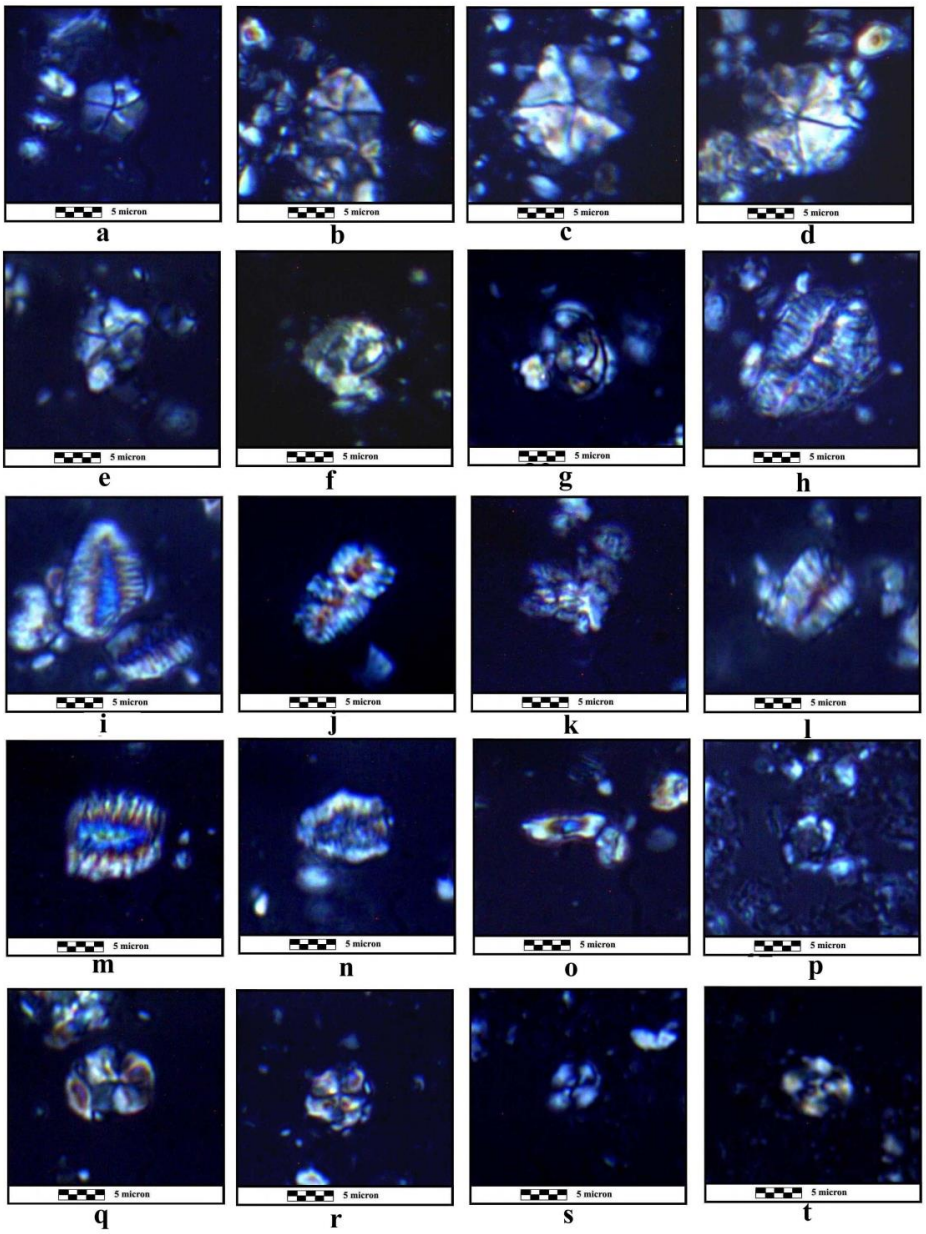


Plate (1): Cross-polarized light photos of significant calcareous nannofossil taxa from Balambo section. (a) *Braarudosphaera bigelowii* (Gran and Braarud, 1935) Deflandre, 1947; (b) *Micrantholithus hoschulzii* (Reinhardit, 1966) Thierstein, 1971; (c) *Micrantholithus obtusus* Stradner, 1963; (d) , *Micrantholithus speetonensis* Perch-Nielsen, 1979, (e) *Micrantholithus* sp., (f) *Discolithus*

litterarius (Górka, 1957) Manivit, 1971, (g) *Zeugrhabdotus embergeri* (Nöel, 1959) Perch-Nielsen, 1984, (h) *Nannoconus* cf. *colomii* (Delapparent, 1931) Kamptner, 1938, (i) *Nannoconus kamptneri* Brönnimann, 1955, (j) *Nannoconus* cf. *Multicadus* Deflandre and Deflandre, 1959, (k) *Nannoconus quadriangulus* Deflandre and Deflandre, 1967, (l) *Nannoconus steinmannii* Kamptner, 1931, (m) *Nannoconus truitti* Brönnimann, 1955, (n) *Nannoconus wassallii* Brönnimann, 1955, (o) *Nannoconus* sp., (p) *Retecapsa angustiforata* Black, 1971, (q) *Assipetra terebrodentarius* Roth, 1973, (r) *Assipetra* sp., (s) *Watznaueria barnesae* (Blackand Barnes, 1959) Perch-Nielsen, 1969, (t) *Watznaueria* sp.

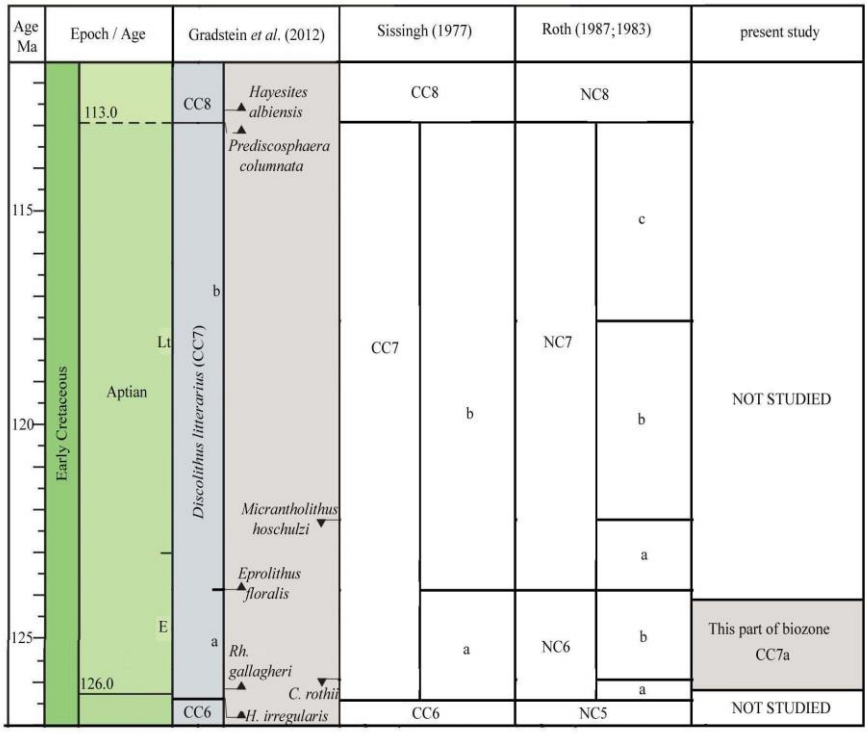


Diagram (3): Correlation of the recorded calcareous nannofossils biozones with regional schemes**.**

DISCUSSION

Nannoconid crisis existed during the Late Barremian and Early Aptian (126 to 122 Ma) on the carbonate rock-forming organisms (nannoconids) and culminated during the OAE1a (Mutterlose and Bottini, 2013). A virtual absence of this calcareous nannoplankton in the Early Aptian may experience a crises called "nannoconid crisis" (Erba, 1994). This absence was recovered later in Late Aptian (Diag. 2) without extinctions but the widespread nature of

this event suggested a global factor. This crisis is recorded within the *Discolithus litterarius* nannofossil zone (Diag. 2).

A synchronous acme event of the genera *Braarudosphaera* Deflandre, 1947 and *Nannoconus* Kamptner, 1931in this section was close to the top of Early Aptian boundary as a result of shallowing of the studied interval. Morphometric data revealed dwarfing trends in the species *Watznaueria barnesiae*, (see Plates 1-r, s) which may suggest a possible productivity control due to increasing in the nutrient input (Mahanipour *et al.*, 2019). The above mentioned species is also considered as an opportunistic species that are related to more stressful conditions (Aguado *et al.*, 2016; Mahanipour *et al.*, 2019).

Early Aptian assemblages are dominated by nannoconids with minor contributions from other nannofossil taxa. Nannoconids are robust taxa so their presence without the presence of other taxa might be the result of diagenesis (Mahanipour *et al.*, 2019). The abundance of nannoconids drops sharply within the *Discolithus litterarius* nannofossil zone.

The Early Aptian "nannoconid crisis" was followed by a short interval virtually barren of nannoconids and dominated by other nannofossils, only later did a return of nannoconids mark the Late Aptian N. truittii (Erba, 1994, see Diagram (2), present study).The studied Early Aptian assemblages are dominated by nannoconids that drop sharply within the *Discolithus litterarius* nannofossil zone, which may be related to nannoconid crisis recorded in Early Aptian. This work is supported by geochemical data illustrating that this event is accompanied with decrease in $CaCO_3$ content and higher content of Total Organic Carbon (TOC) similar to those recorded in many regions in the world and specially at Zagros Basin in Iran (Mahanipour *et al.*, 2018, 2019) giving an evidence of global change during this time, like those of Early Cretaceous chalk of the North Sea (Mutterlose and Bottini, 2013). Change in lithology to marls is followed by a decline in nannoconid accompanied by an increase in TOC (Diag. 2).

The abundance trends, palaeoenvironmental and morphological changes among Mesozoic calcareous nannofossil have been widely studied worldwide (Williams and Bralower, 1995; Erba, 1994, 2004; Mutterlose and Ruffell, 1999; Lees, 2002; Bornemann *et al.*, 2003; Mattioli *et al.*, 2004).

Braarudosphaera and Nannoconus are generally common in Early Cretaceous sediments opposite to the Late Cretaceous which is not common (Lees, 2002); the Braarudosphaera is an extant taxon in recent seas, but Nannoconus became extinct in the Late Campanian, making palaeoecological inferences more difficult for this latter genus. Recent and fossil Braarudosphaera are typically restricted to shelf, and their distributions must be influenced by some aspect of the neritic environment because the planktonic life in seas. However, Nannoconus have been studied in details in the Lower Cretaceous (Roth and Krumbach, 1986; Mutterlose, 1989, Busson and Noël, 1991; Erba, 1994). Nannoconus was recorded and widely distributed in the marginal basins of the past oceanic ecosystem (Mutterlose, 1989, 1992; Street and Bown, 2000). This distribution pattern has led to a range of explanations

concerning their biology and paleobiology, but most have noted the link with tropical paleoenvironments (Roth and Krumbach, 1986; Mutterlose, 1989; Bown, 2005).

The paleoecology of nannoconoids suggested that they were adapted to oligotrophic environments; the decline of nannoconid abundances in the Oceanic Anoxic Event successions commonly is accompanied with an inverse relationship between nannoconid and coccolith abundances (Busson and Noël, 1991; Coccioni *et al.*, 1992; Erba, 1994; Watkins *et al*., 2005). However, Cunha and Shimabukuru (1997) reported alternating Nannoconus and Braarudosphaera-rich horizons and attributed these to eutrophic conditions, a feature also recorded in the black shales of the Albian OAE1b in France (Kennedy *et al.*, 2000; Herrle, 2003).

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دليل ظاهرة نقص الاوكسجين البحري في شمالي العراق من متحجرات النانو الكلسية

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الخلاصة

سجلت متحجرات النانو الكلسية في الجزء العلوي من تكوين بالمبو (عمر الطباشيري) في شمالي العراق بهدف تشخيص ظاهرة نقص الاوكسجين البحرية. الوصف التفصيلي للنانو الكلسية ادى الى تشخيص ووصف اربع وعشرون نوعا منها. وفقا لذلك، فان فترة المتحجر *Discolithus litterarius* (Górka, 1957) قد تم تشخيصها في الدراسة الحالية بانها تعود الى عمر الابتيان المبكر.

مجاميع الابتيان المبكر تتميز بشيوع متحجر النانوكونيد، حيث يقل بشكل كبير في النطاق nannofossil zone *D. litterarius*، و الذي قد يعود الى فترة كارثيه مسجلة في السجل الجيولوجي في عمر الابتيان المبكر في اماكن عديدة في العالم والمسماة"nannoconid crisis"هذه الظاهرة تنطبق في الدراسة الحالية مع نقصان في كمية كاربونات الكالسيوم مع زيادة في كمية الكاربون العضوي الكلي في الصخور قيد الدراسة.