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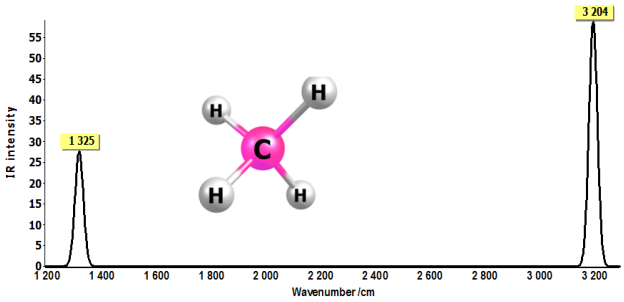

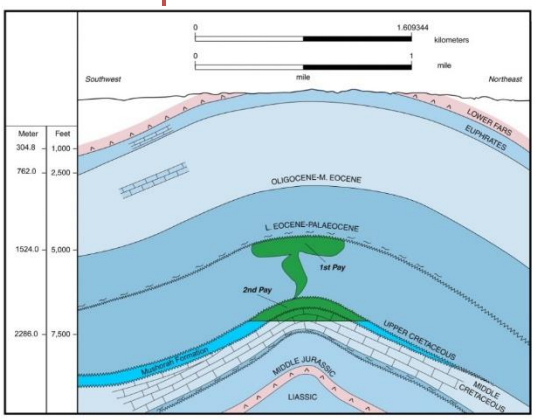

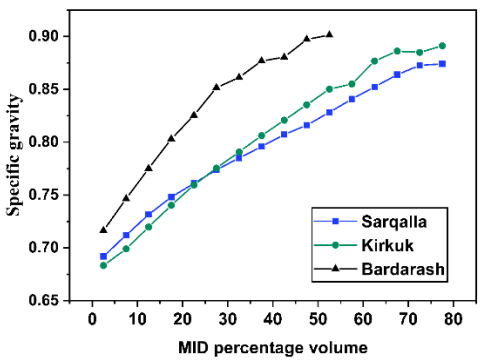

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Nannobiostratigraphy of The Mushorah Formation in (AZ.29) well, Ain Zalah oil field, Northwestern Iraq

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Abstract

A Detailed calcareous nannofossils study for the Mushorah Formation from subsurface section at Az. (29) well, Ain Zalah oil field, Northwestern Iraq. This is the first documentation of calcareous nannofossils in the Mushorah Formation, the Paleontological classification of this flora led to determine forty species. The nannobiostratigraphic analysis suggested three calcareous nannofossils biozones these are: (1) *Calculites obscurus* Interval Biozone; (2) *Broinsonia parca* Interval Biozone; (3) *Misceomarginatus pleniporus* Interval Biozone. These biozones concluded that the age of studied section of the Mushorah Formation is Early to Middle Campanian.

Introduction

The studied section from Ain Zalah oil field well no. (29), about 64 km North West of Mosul city, northern Iraq (Figure 1 and 2), Located at lat. 36°57'03"N., long. 42°25'41"E., the anticline of Ain Zalah oil field is extending east-west. Its length is about 19.3 km., this study site is within belonging to the Foothill Zone of the Unstable Shelf of the Arabian plate [1].

The Mushorah Formation in its type section of the Mushorah oil well (1), consists of limestone and recrystallized alligostiganal limestone (Dunnington, 1953 in [2]. However, [3] determine the boundaries of the Mushorah Formation and confirmed the Wajna Formation underlies it in many wells in the northwestern Iraq regions [4].

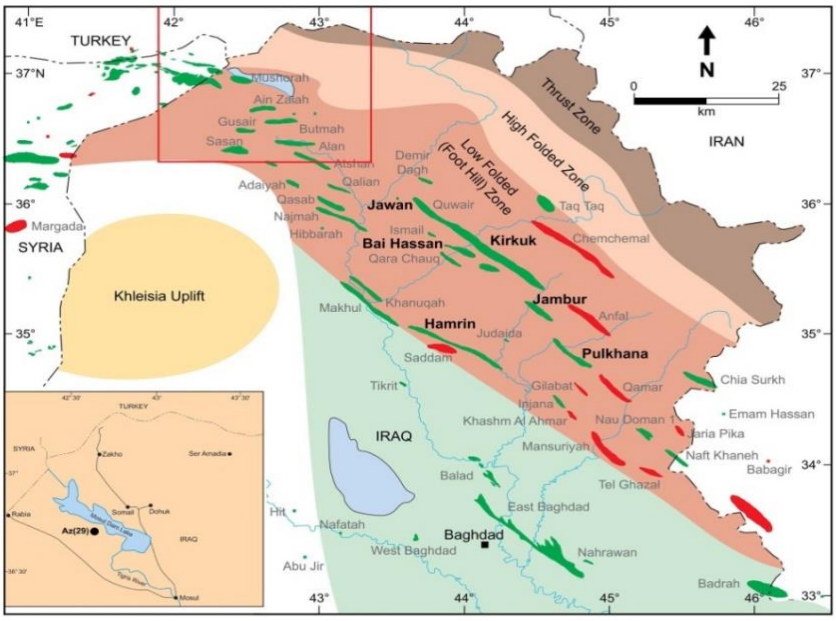

Figure (1) Tectonic map showing the studied section (After [5,6]

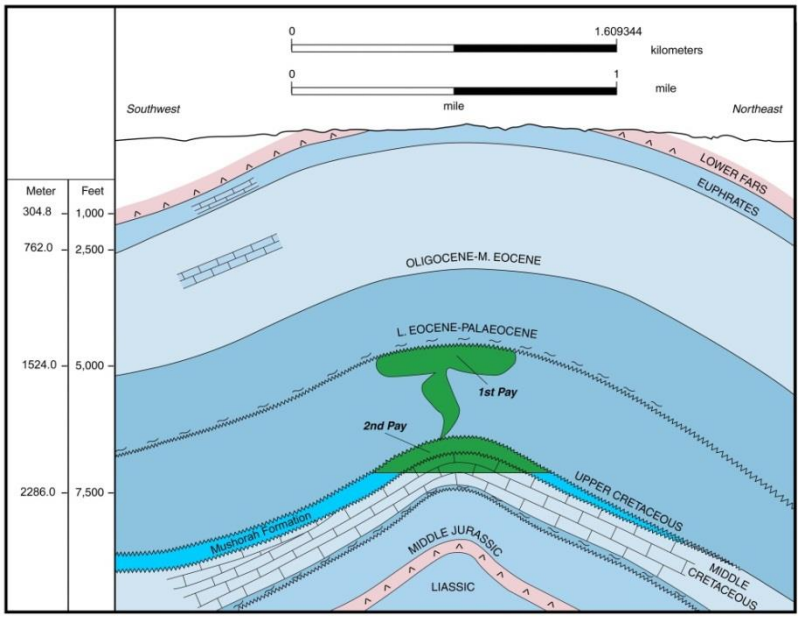

Figure (2) Ain Zalah oil field showing the studied formation [7]

The Mushorah Formation belongings to the Upper Turonian to Lower Campanian sedimentary cycle which was studied by [8] in northern Iraq (Figure 3), The biostratigraphy of the Mushorah Formation was studied by [9] and the lithostratigraphy by [10]. The goal of this study is to determine the calcareous nannofossils biozones of The Mushorah Formation and to conclude the stratigraphic age for the formation.

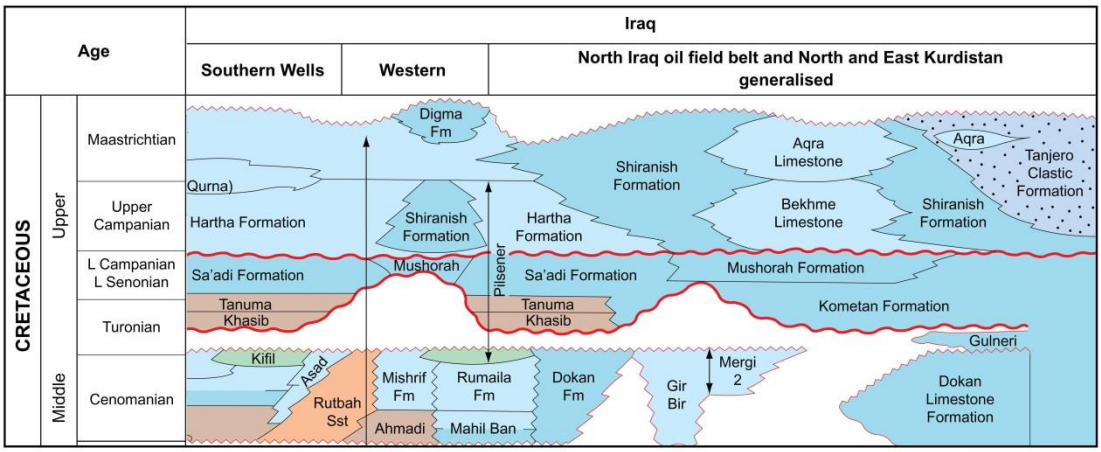

Figure (3) Schematic regional rock unit correlation [8]

The Upper Turonian-Lower Campanian cycle was deposited in a comparatively located seaway resides in the region of the High Folded and Foothill zones. The area of Rutba-Jezira zone of the Stable Shelf was emergent, while another area of the submerged Mosul High was dominated by deep water carbonates, bordered on the West and East by deep water basins in which basinal limestones were occurred (the Mushorah facies) after the Lower Turonian activities. The lower part of the sedimentary cycle called AP9 is epitomized by the Khasib, Tanuma, Sa'di, the Mushorah and Kometan formations. The upper part of the megasequence is distinguished by the Hartha, Tayarat, Digma, Aqra, Bekhme, Shiranish, Tanjero and Hadiena formations [4].

The thickness of the Mushorah Formation in wells is as follows: Anah-2 (88 m), Butmah-2 (58 m), Qara Chauq- 1 (282 m), Sasan-2A (160 m) and Sufaya-A-2 (33 m). The Mushorah deposited was dated as Upper Turonian to Lower Campanian age [11].

Methodology

Materials

Data for this study was generated from Seventeen samples of cutting samples from the Mushorah Formation. Samples were collected at different intervals which was obtained from one well namely Az. (29), with depth range of 2250 m.-2400 m. Lithologic mainly from Limestone.

Laboratory Analysis

(1) Nannofossil Slides preparation making by using the method (H) [12], the procedure is as follows:

- About 5 grams of each rock sample is crushed to pass through a sieve of 45 μm and then soaked in filtered water. A small size drop is added to implement as a dispersant.
- A direct low heat source (hotplate) is used to lasting dry the slide and residue, taking into account during all stages of work, be careful and avoid contamination.
- Amorphous oleoresin called (Canada balsam) has been placed over an uncontaminated thin cover slip. Then it is flipped over the previously placed dry drop of crushed sample solution and left to dry and stick well, so the sample is then ready for examination under the transmitted microscope.

(2) Observation Techniques

The slides were examined for calcareous nannofossil content under a light microscope in transmitted lights with cross-polarized and gypsum plate. Detailed investigation for the assemblages were made by using x1000 magnification. Identification of species was made by catalogue published from library and on the internet by various authors.

Results and discussions

The systematic classification of the calcareous nannofossils depending on many paleontological references [13] and [14] to identify forty species of calcareous nannofossils. The material and images are stored in the Dept. of Geology, Science College, University of Mosul, Mosul, Iraq (Figs. 4,5,6).

Nannopaleontology

A-Heterococcolith

Family Chistozygaceae

Genus *Chiastozygus*

Recorded species: *Chiastozygus litterarius.*

Genus *Reinhardtites*

Recorded species: *Reinhardtites elkefensis*; *Reinhardtites levis*.

Genus *Tranolithus*

Recorded species: *Tranolithus orionatus*.

Family Eiffellithaceae

Genus *Eiffellithus*

Recorded species: *Eiffellithus collis; Eiffellithus eximius*; *Eiffellithus gorkae*; *Eiffellithus primus*; *Eiffellithus turriseiffeli*.

Family Rhagodiscaeae

Genus *Rhagodiscus*

Recorded species: *Rhagodiscus robustus*

Family Prediscosphaeraceae

Genus *Prediscosphaera*

Recorded species: *Prediscosphaera cretacea*; *Prediscosphaera grandis*.

Family Cretarhabdaceae

Genus *Retecapsa*

Recorded species: *Retecapsa crenulata*.

Family Watznaueriaceae

Genus *Watznauria*

Recorded species: *Watznaueria barnesiae*; *Watznaueria biporta*; *Watznaueria fossacincta*.

Family Arkhangelskiellaceae

Genus *Arkhangelskiella*

Recorded species: *Arkhangelskiella cymbiformis*; *Arkhangelskiella paucipunctata*; *Arkhangelskiella specillata*.

Genus *Broinsonia*

Recorded species: *Broinsonia enormis*; *Broinsonia parca*.

Genus *Misceomarginatus*

Recorded species: *Misceomarginatus pleniporus*.

B- Holococcoliths

Family Calyptrosphaeraceae

Genus *Calculites*

Recorded species: *Calculites additus*; *Calculites anfractus*; *Calculites obscurus*.

C - Nannoliths

Family Microrhabdulaceae

Genus *Lithraphidites*

Recorded species: *Lithraphidites alatus*; *Lithraphidites carniolensis*; *Lithraphidites* cf.*quadratus*; *Lithraphidites grossopectinatus*.

Genus *Microrhabdulus*

Recorded species: *Microrhabdulus belgicus*; *Microrhabdulus decorates*.

Family Polycyclolithaceae

Genus *Lithastrinus*
Recorded species: *Lithastrinus* cf. *grillii*; *Lithastrinus quadricuspis*.
Genus *Micula*
Recorded species: *Micula concave*; *Micula staurophora*.
Genus *Uniplanarius*
Recorded species: *Uniplanarius bengalensis*; *Uniplanarius gartneri*.
Genus *Ceratolithoides*
Recorded species: *Ceratolithoides kamptneri*; *Ceratolithoides prominens*; *Ceratolithoides sagittatus*.

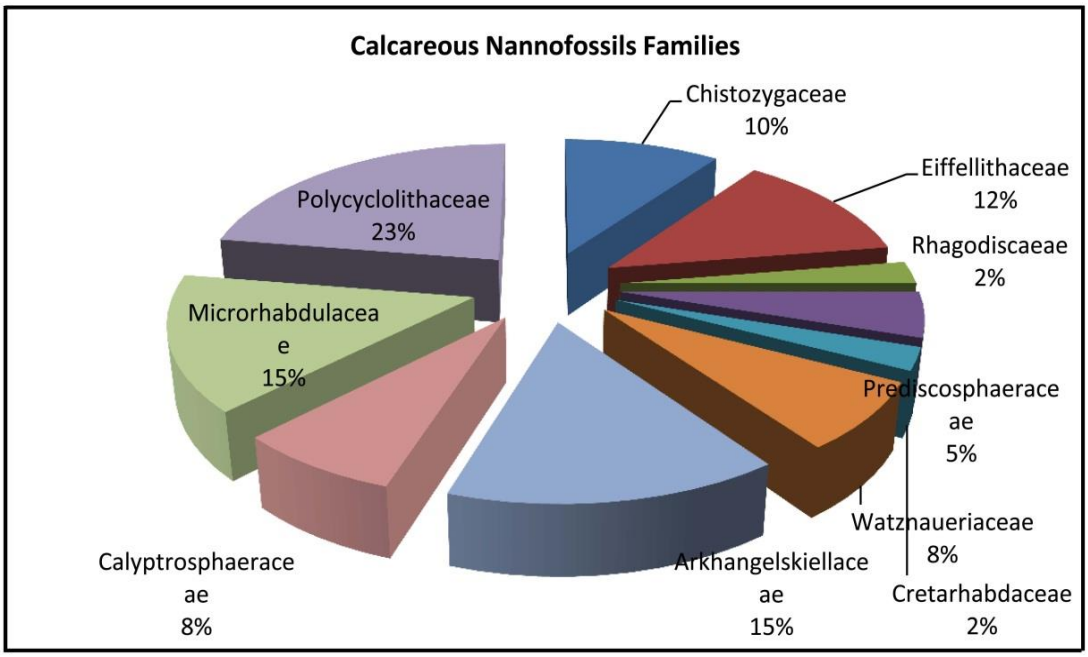

Figure (4) Percentage of calcareous nannofossil from the Mushorah Formation.

Nannobiostratigraphy

- *Calculites obscurus* Interval Biozone

This biozone is an Interval biozone for the species *Calculites obscurus*. The lower boundary is determined by the first occurrence for the species *Calculites obscurus* and the upper boundary is determined by the first occurrence the species *Broinsonia parca*. The thickness of this biozone is between (2395-2372 meter) in depths. This biozone is compared with the biozone called CC17 (*Calculites obscurus* biozone) by [15] that aged early Campanian and [16]. After update the age of zone by GTS2016 by [17], we suggest the age of this stratigraphic successions is early Campanian (Figs.7,8).

- *Broinsonia parca* Interval Biozone

This biozone is an Interval biozone of the species *Broinsonia parca*. The lower boundary is determine by first occurrence the sepcies *Broinsonia parca*, and the upper boundary is determine by the first occurrence for the species *Misceomarginatus pleniporus*.The thickness of this biozone is between (2364-2322m.) in depths. This biozone is compared with the biozone called CC18 (*Broinsonia parca* biozone) by the [15] that aged of the early Campanian, also compared with [18] and [16]. After update the age of zone by GTS2016 by [17], we suggest the age of this stratigraphic successions is early Campanian (Figs.7,8).

- *Misceomarginatus pleniporus* Interval Biozone

This biozone is an Interval biozone for the species *Misceomarginatus pleniporus*. The lower boundary of this biozone determine by first occurrence of the species *Misceomarginatus pleniporus*, and the upper boundary is determined by first occurrence of the species *Ceratolithoides aculeus*. The thickness of this

biozone is between (2322-2255m.) in depths. This biozone is compared with the biozone called CC19 (*Calculites ovalis* biozone) by the [15] that aged of the early Campanian, also compared with [18] and [19] and [20]. After update the age of zone by GTS2016 by [17], we suggest the age of this stratigraphic successions is early to middle Campanian (Figure 7 and 8).

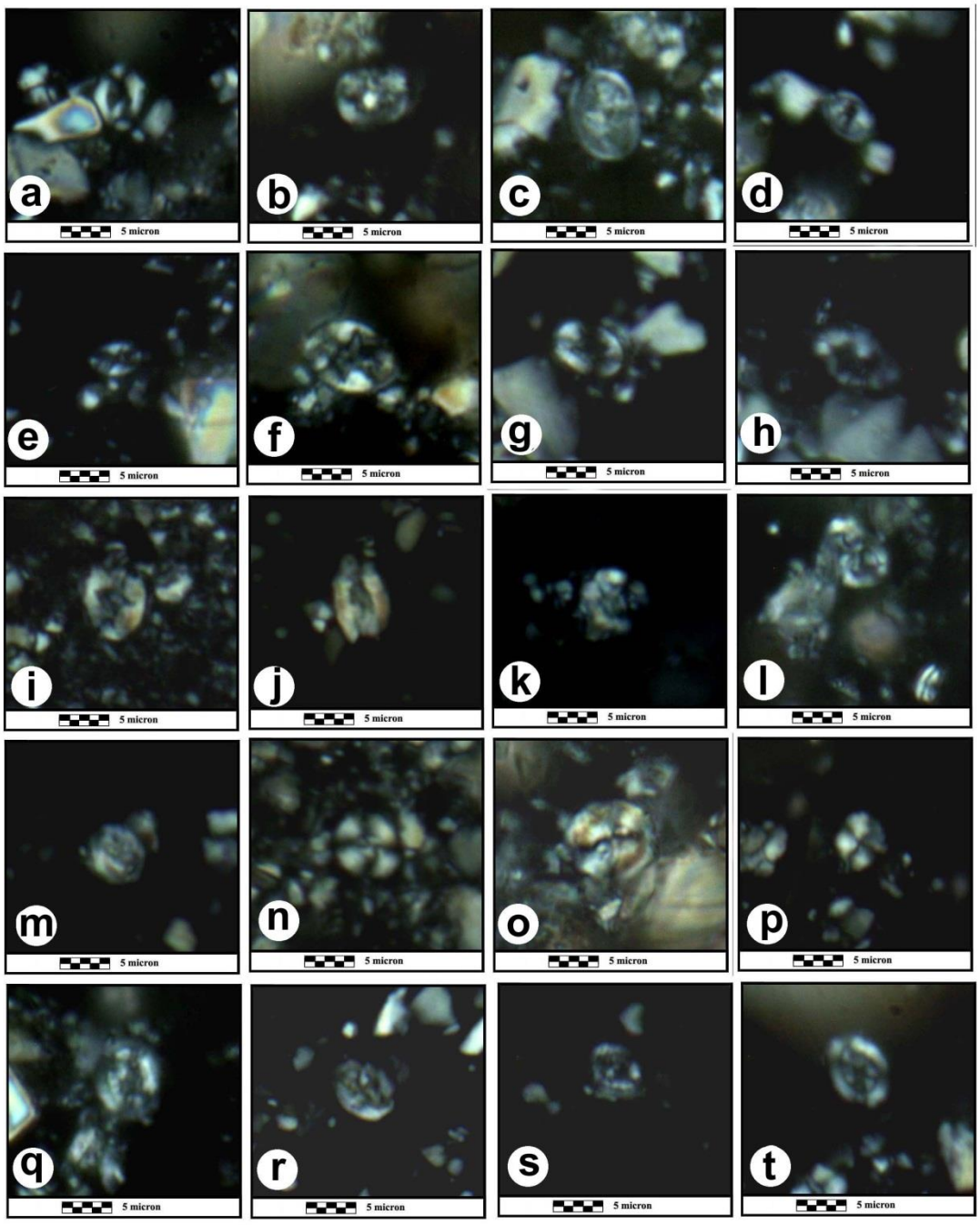

Figure (5) Photos of calcareous nannofossil taxa in cross-polarized from The Mushorah Formation.
(a) *Chiastozygus litterarius*; (b) *Reinhardtites elkefensis*; (c) *Reinhardtites levis*; (d) *Tranolithus orionatus*; (e) *Eiffellithus collis*; (f) *Eiffellithus eximius*; (g) *Eiffellithus gorkae*; (h) *Eiffellithus primus*; (i) *Eiffellithus turriseiffeli*; (j) *Rhagodiscus robustus*; (k) *Prediscosphaera cretacea*; (l) *Prediscosphaera grandis*; (m) *Retecapsa crenulata*; (n) *Watznaueria barnesiae*; (o) *Watznaueria biporta*; (p) *Watznaueria fossacincta*; (q) *Arkhangelskiella cymbiformis*; (r) *Arkhangelskiella paucipunctata*; (s) *Arkhangelskiella specillata*; (t) *Broinsonia enormis*.

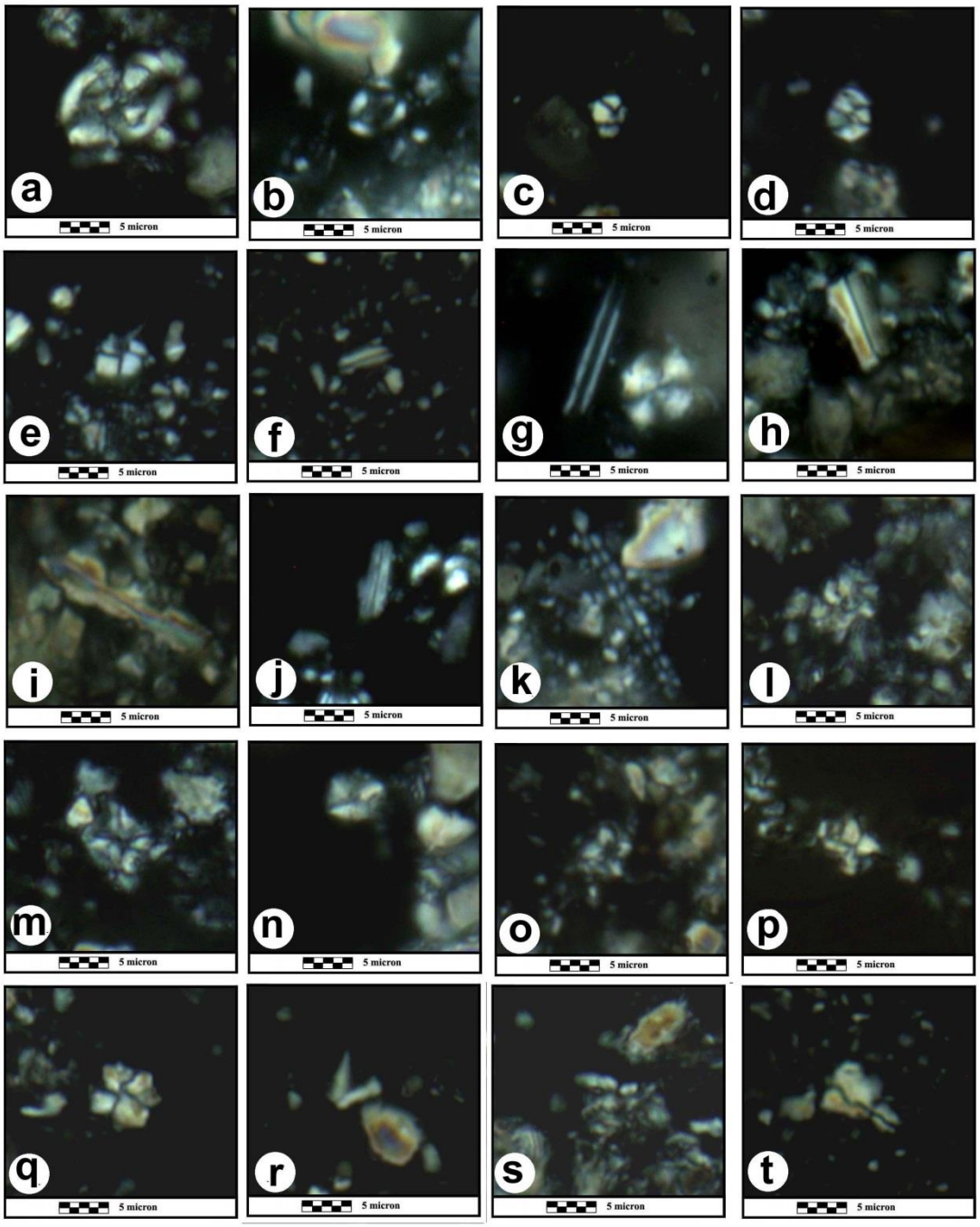

Figure (6) Photos of calcareous nannofossil taxa in cross-polarized from The Mushorah Formation.

(a) *Broinsonia parca*; (b) *Misceomarginatus pleniporus*; (c) *Calculites additus*; (d) *Calculites anfractus*; (e) *Calculites obscurus*; (f) *Lithraphidites alatus*; (g) *Lithraphidites carniolensis*; (h) *Lithraphidites* cf.*quadratus*; (i) *Lithraphidites grossopectinatus*; (j) *Microrhabdulus belgicus*; (k) *Microrhabdulus decoratus*; (l) *Lithastrinus* cf. *grillii*; (m) *Lithastrinus quadricuspis*; (n) *Micula concava*; (o) *Micula staurophora*; (p) *Uniplanarius bengalensis*; (q) *Uniplanarius gartneri*; (r) *Ceratolithoides kamptneri*; (s) *Ceratolithoides prominens*; (t) *Ceratolithoides sagittatus*.

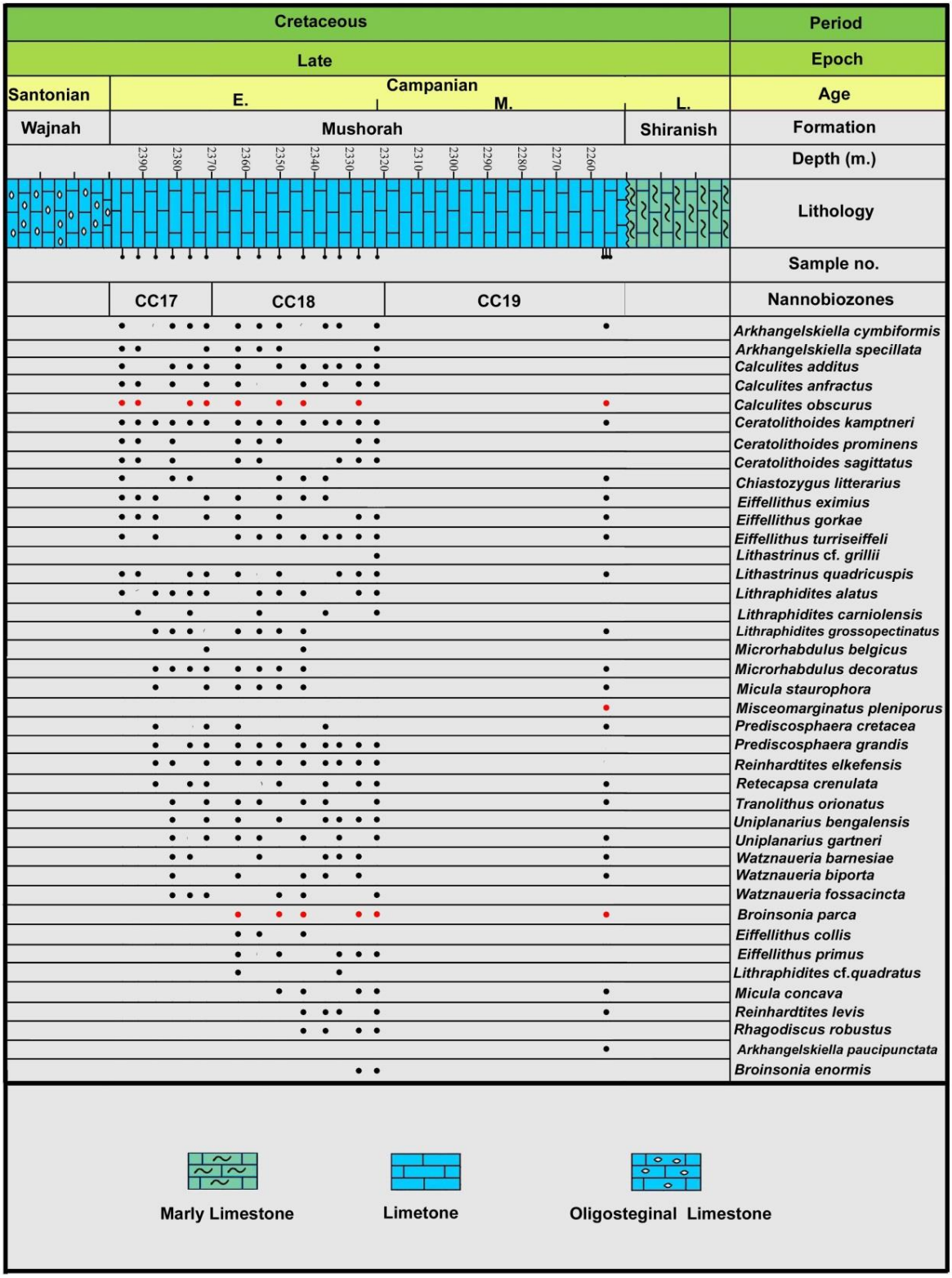

Figure (7) Range chart of calcareous nannofossils for the Mushorah Formation, Northern Iraq

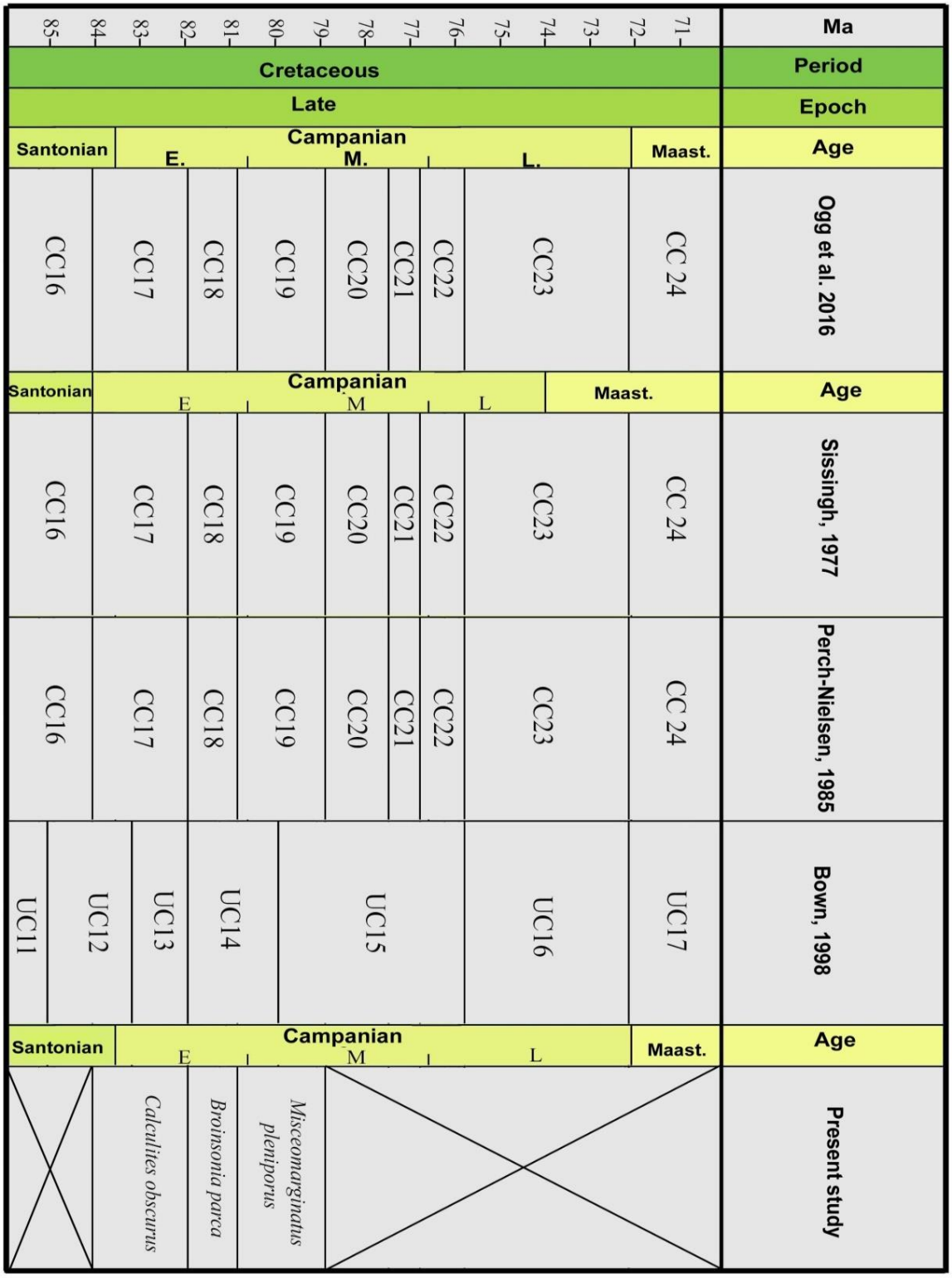

Figure (8) Age correlation chart of calcareous nannofossils for the Mushorah Formation, Northern Iraq

Conclusions

This study concluded that the formation have about (40) species belonging to calcareous nannofossils, and three biozones were determinates for the Mushorah Formation, these are:

- *Calculites obscurus* Interval Biozone
- *Broinsonia parca* Interval Biozone
- *Misceomarginatus pleniporus* Interval Biozone

The calcareous nannofossils biozones suggest the Early to Middle Campanian age for the studied section.

Conflict of interest

The authors declare no conflict of interest.

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