Iraqi National Journal of Earth Science
www.earth.mosuljournals.com

Identification of Reworked (Contaminated) Early Cretaceous Dinoflagellate Cysts in the Butmah Formation (Early Jurassic) in Borehole Tel-Hajar-1.

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Article information

Received: 18- Oct -2023

Revised: 12- Feb -2024

Accepted: 23- May -2024

Available online: 01- Jan – 2025

Keywords:
Early Cretaceous
Reworked Dinocysts
Butmah Formation

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ABSTRACT

During the Palynological study of well documented Lower Jurassic Butmah Formation, Lower Cretaceous reworked Dinocysts are identified (11 genera and 12) species as follows:
Spiniferites ramosus; *Endoscrinium luridum*; *Operculodinella operculata*; *Hystrichodinium pulchrum*; *Palaeo Peridinium cretaceum*; *Pareodinia ceratophora*; *Endoceratium turneri*; *Endoscrinium pharo*; *Coronifera oceanica*; *Achomosphaera neptuni*; *Glossodinium dimorphum*. The identification of these reworked Dinocysts genera and species are typical of Lower Cretaceous age. These results confirm and support that these Dinocysts were probably originated and infiltrated from the younger Garagu Formation (Lower Cretaceous) (Late Berriasian-Vallangenian) age that rests unconformably upon the Sargelu Formation of Mid Jurassic (Bajocian-Bathonian) age and supporting the presence of unconformable (a break) relationship between uppermost Jurassic (Tithonian) and lowermost Cretaceous (Early Berriasian) successions in this subsurface section, which is marked by the missing of Gotnia Formation (Late Jurassic) (early Tithonian-Callovian) age and the Lower Sarmord due to an active erosive or non-depositional processes occurred in the studied section. These associations of Lower Cretaceous Dinocysts are of great taxonomic and biostratigraphic value for further future studies on the Lower Cretaceous successions in Iraq. These species are important in palaeontology because they can be used to identify and dating the age of rock formations as well as providing information about the mode of type of life that existed during a particular time period. Dinocysts can also be used to reconstruct ancient environments and climates making them a valuable tool for understanding the history of the Earth.

DOI: 10.33899/earth.2024.143989.1161,

تسجيل أنواع من أكياس الداينوسوطيات (المنقولة) من الطباشيري المبكر في تكوين بطمة (الجوراسي المبكر) في بئر تل حجر-1

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معلومات الارشفة

تاريخ الاستلام: 18- اكتوبر -2023

تاريخ المراجعة: 12- فبراير -2024

تاريخ القبـول: 23- مايو -2024

تاريخ النشر الالكتروني: 01- يناير -2025

الكلمات المفتاحية:

الطباشيري المبكر

الداينوسوطيات الملوثة

تكوين بطمة

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الملخص

خلال الدراسة البالينولوجية الموثقة لتكوين بطمة (الجوراسي الأسفل)، تم تشخيص (11) جنسا و(12) نوعا من متحجرات أكياس الداينوسوطيات المنقولة من عمر (الكريتاسي المبكر) وهي كالاتي:

Spiniferites ramosus; Endoscrinium luridum; Operculodinella operculata; Oligosphaeridium complex; Hystrichodinium pulchrum; PalaeoPeridinium cretaceum; Pareodinia ceratophora; Endoceratium turneri; Endoscrinium pharo; Coronifera oceanica; Achomosphaera neptuni; Glossodinium dimorphum

ان تشخيص هذه الاجناس والأنواع من أكياس الداينوسوطيات المنقولة (الملوثة) كانت نموذجية لعمر(الكريتاسي المبكر). ان هذه النتائج تؤكد وتعزز ان هذه الأكياس المنقولة ربما كانت قد نشات وتسربت من تكوين كراكو الاحدث (الكريتاسي الأسفل)، عمر (البيرياسيان المتاخر-الفالانجينيان)، والذي يجلس بوضعية غير توافقية فوق تكوين سارجيلو (الجوراسي الأوسط) عمر (الباجوسيان- الباثونيان)، مما يعزز وجود علاقة عدم توافق بين تتابعات الجوراسي الأعلى (التيثونيان) والكريتاسي الأسفل (البيريسيان المبكر) في هذا المقطع تحت السطحي، والذي استدل عليه بفقدان تكوين قطنية (الجوراسي الأعلى)، عمر (الكيميريجيان-التيثونيان المبكر) وتكوين سارمورد الأسفل (الجوراسي الأعلى/الكريتاسي الأسفل)، عمر (التيثونيان- البيريسيان) والذي يعزى الى عمليات التعرية الفعالة أو عدم الترسيب الحاصلة في المقطع المدروس. ان هذه التواجدات من أكياس الداينوسوطيات المنقولة من عمر الكريتاسي المبكر ذات قيمة تصنيفية وطباقية حياتية لمزيد من الدراسات المستقبلية لتتابعات الكريتاسي الأسفل في العراق. ان هذه الأنواع ذات أهمية أيضا في علم المتحجرات كونها تستعمل في تحديد عمر التكاوين الصخرية وطبيعة الحياة التي كانت متواجدة خلال فترة زمنية معينة، كما ان متكيسات الداينوسوطيات يمكن ان تستعمل في بناءات البيئات القديمة والمناخ القديم مما جعلها أداة مهمة في فهم تاريخ الأرض.

DOI: 10.33899/earth.2024.143989.1161,

Introduction

Dinoflagellate cysts are organic-walled microfossils produced by dinoflagellates, a type of unicellular algae. They are important in biostratigraphy because they can be used to determine the age of the geological formations. Dinoflagellate cysts have a high degree of species diversity and are found in many different marine environments from coastal to continental slope making them useful indicators of past environmental conditions. The presence or absence of certain dinoflagellate cyst species can provide information about controlling factors such as water temperature, salinity, nutrient availability, and other environmental conditions during the time of sediment deposition.

The consistent and unequivocal identification of dinoflagellate cysts to species level can provide valuable information on the timing and duration of events such as sea-level changes, climate fluctuations and biotic turnovers (Fensome *et al*., 1996).

The Early Cretaceous period is significant because it marks a time of major environmental changes, including the breakup of the supercontinent Pangaea and the opening of new ocean basins. During this period, sea levels rose and fell several times leading to the deposition of marine sediments in many parts of the world. This period is also characterized by a diversification of marine life including the emergence of new groups such as Foraminifera and Dinoflagellates. The study of this type of fossils can provide important insights into the evolution of life on the Earth and the geological processes that shaped our planet.

Reworking or infiltration of fossils can happen to any fossil. It means that the fossils have been removed from the original sedimentary layer and deposited usually in a different younger layer. Another type of reworking or contamination is the cutting samples (not core), which contain younger fossils associated with older ones. In the present study, eight cutting samples are collected from Butmah Formation (Lower Jurassic age) in borehole Tel-Hajar-1 located 30 Km southwest of Sinjar City in Ninevah Governorate (Fig. 1). We recorded these reworked Dinocysts in Samples (3615; 3544; 3604; 3533 and 3627).

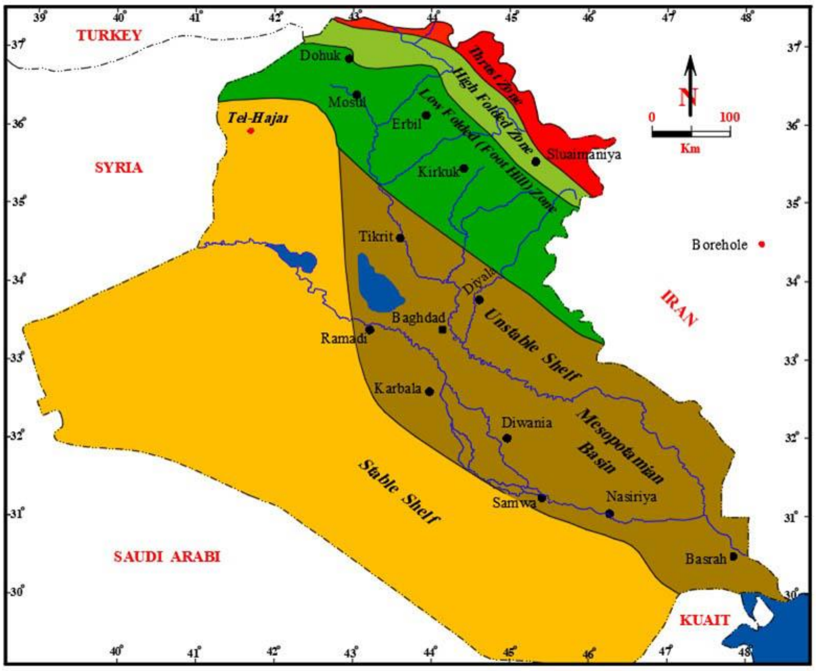

Fig.1. Location Map of Borehole Tel-Hajar-1

Butmah succession was first introduced and explained by Dunnington (1953; in Bellen *et. al.*, 1959) in Butmah-2 borehole, Northwest Mosul. The formation is not exposed at the surface, but it is penetrated by a number of wells in the Foothill zone. Dunnington had determined the formation’s thickness in the type section to be approximately 500 m. and he divided the formation in the type locality into three divisions. The lower division is 120 m thick comprising of limestone, and it consists of limestone with shale reliefs and layers of anhydrite, while the middle part is 180 m thick and consists of oolitic limestone, dolomite and sandy mixture in some parts with layers of shale. The upper part of the formation with a thickness of 200 m consists of oolitic and fake oolitic limestone and dolomitic limestone with interbedded shale and anhydrite (Fig. 2).

Butmah Formation has been investigated through many paleontological and sedimentological studies to determine its exact age. Among them is the palynological study of Kddo (2011) who established Early Jurassic (Hettangian-Sinemrian ages) for the borehole Tel-Hajar-1 succession depending on index sporomorphs species such as: *Callialasporites dampieri, C. trilobatus, Classopollis* spp. and other Lower Jurassic sporomophs assemblages. In addition, he studied the dioncyst of the same section and confirmed the Early Jurassic age depending of the index taxa as: *Suessia swabiana, Dapcodinim priscum, Liasidium variable, Luehndea spinosa*.

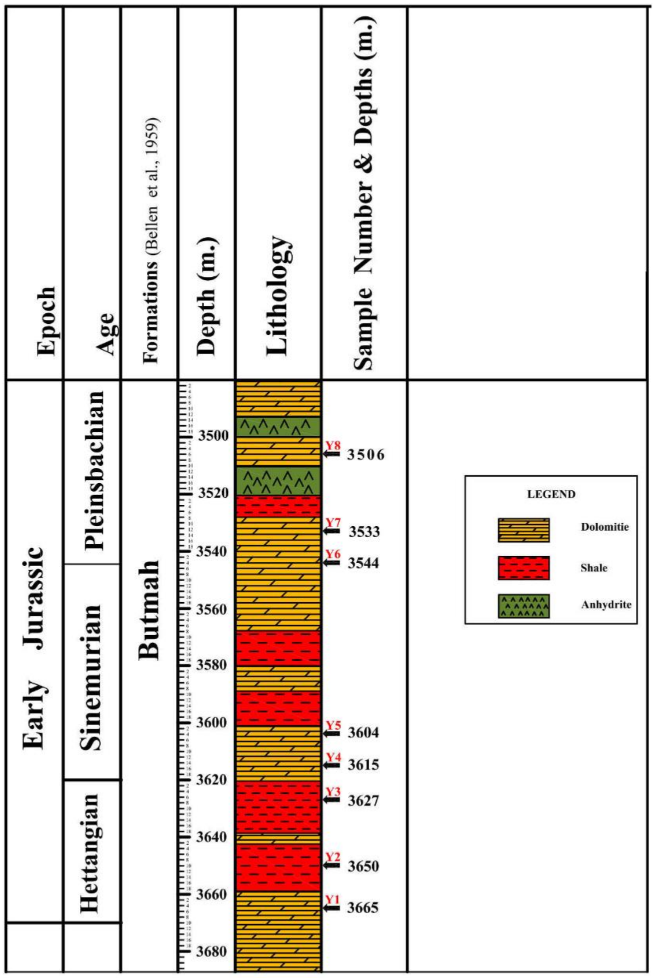

Fig. 2. Stratigraphic Section of Borehole Tel-Hajar-1.

Previous studies

All the Dinoflagellate studies of the Lower Cretaceous rocks in Iraq are few but there are many important studies on the Garagu Formation.

Among these studies (Kaddouri, 1982; Al-Abawi ,1984; Al- Khashab *et al*., 2011; Al-Ameri and Al-Nagshbandi, 2014; Ghafor and Mohialdeen, 2016; Ahmed et al., 2017; Al-Abbasi *et al*., 2023 and Fatah *et al*., 2023).

Tectonostratigraphy

Tectonically, Tel Hajar-1 well represents a part of Sinjar block covering Sinjar area in the Foothill Zone of the stable shelf of the Arabian platform (Fig. 3) (Jassim and Buday, 2006). Bellen et al. (1959) and Buday (1980) dated the Butmah Formation to be Early Liassic based on fossil evidences. The formation was included within the Liassic sequence of the Late Permian-Early Jurassic M. sequence AP6 (Jassim *et.al*., 2006a, p.104). After the Neo-Tethyan ocean opening and the rifting phase in mid -Late Jurassic time, a shallow water lagoonal carbonates deposited across the Mesopotamian basin (Jassim and Goff, 2006). The Formations included within the sequence in Tel-Hajar well (Fig. SECTION Tell Hajar) are the Butmah (Early Liassic), Adaiya, Mus and Alan, whose ages are (Late Liassic - Early Toarcian) as given by Bellen *et. al*. (1959; in Buday, 1980) and Jassim and Goff (2006).

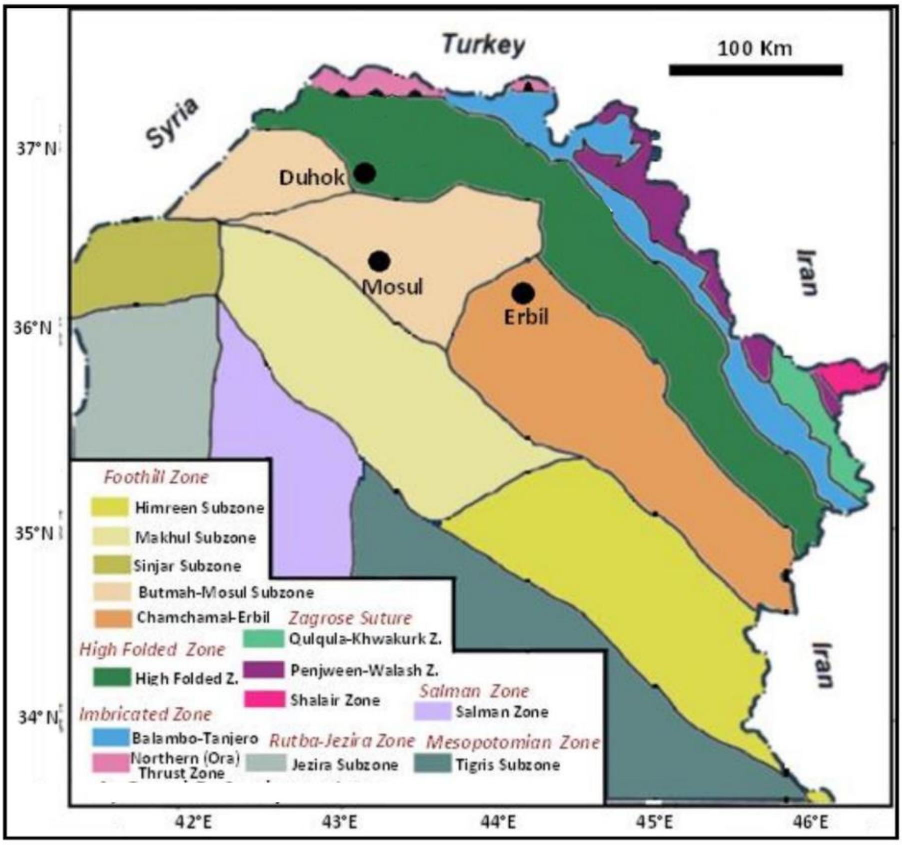

Fig. 3. Tectonic Zones and Structure elements of the Unstable Shelf Unit (modified from Budy and Jasim, 1984).

The Mid Jurassic (Late Toarcian – Callovian) sequence of the AP7 megasequence (Jassim and Buday 2006b) in Tel-Hajar well is represented by the basinal euxinic argillaceous-calcareous of transgression phase. The Sargelu Formation (Jassim and Goff 2006)is assigned to the (Bajocian-Bathonian) (mid Jurassic) age by Bellen *et. al*. (1959) and Buday 1980) based on its fossil evidences. The authors, themselves remarked that the upper Jurassic formations are the Najmah and Gotnia of (early Tithonian-Callovian) age.

The Najmah Formation of a late Jurassic age doesn't continue towards the west and north of Iraq (the studied area) (Jassim and Buday, 2006 b). Bellen et al. (1995) suggested that the Gotnia Formation is situated at Foothill Zone (studied section), but it was subsequently removed by post Jurassic erosion (Fig. 4; figure (10-1), p.117 in Jassim and Buday, 2006 b) that confirms the presence of a major unconformity detected between the Sargelu Formation (mid Jurassic) (Bajocian-Bathonian) age and the upper Jurassic (perhaps Callovian time) unrepresented by sediments making an erosional hiatus (Bellenetai., 1995; Buday, 1980; and Jassim and Buday, 2006b); so that, the Sargelu Formation in Tel-Hajar well has been truncated at the base Cretaceous unconformity by a widespread break at the upper boundary of the formation through at least, western of the studied area and southwestern Iraq because the studied area is emerged as the continuation of the Rutba uplift towards the north (Bellen *et. al*., 1959; Jassim and Buday, 2006).

During Late Tithonian-Cenomanian age, the begining of the South NeoTethys occurred, so a abig regional unconformity of middle Tithonian age (149 Ma) on the "Arabian shield" is found(Jassim and Goff, 2006), which marks the boundary between mega sequences (AP7 and AP8) (Sharland *et. al*., 2001).

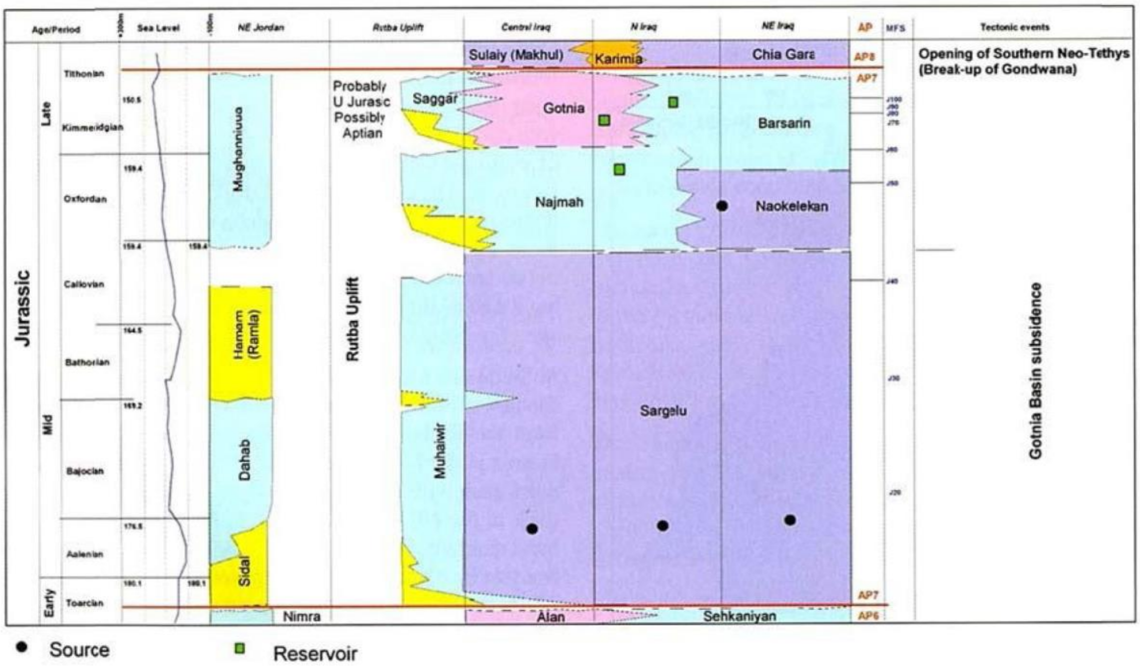

Fig. 4. Stratigraphic Correlation of Megasequence AP7.

In the studied Tel-Hajar well, the only Garaqu Formation (Valanginian- Hauterivian) age is determined by (Bellen et al., 1959 ; Buday, 1980 and Jassim and Buday, 2006 b). They also mentioned that the lower Sarmord Formation of (Tithonian-Berriasian) by Ditmar and Iraqi Russian team (1971) is absent in the west Tigris (studied area) and that the Garagu Formation rests unconformably upon the middle Jurassic Sargelu Formation due to a significance unconformity with the (Berriasian/Tithonian) or Intra-Berriasian (Late Jurassic/Early Cretaceous) (Jassim and Buday, 2006) (Fig. 5).

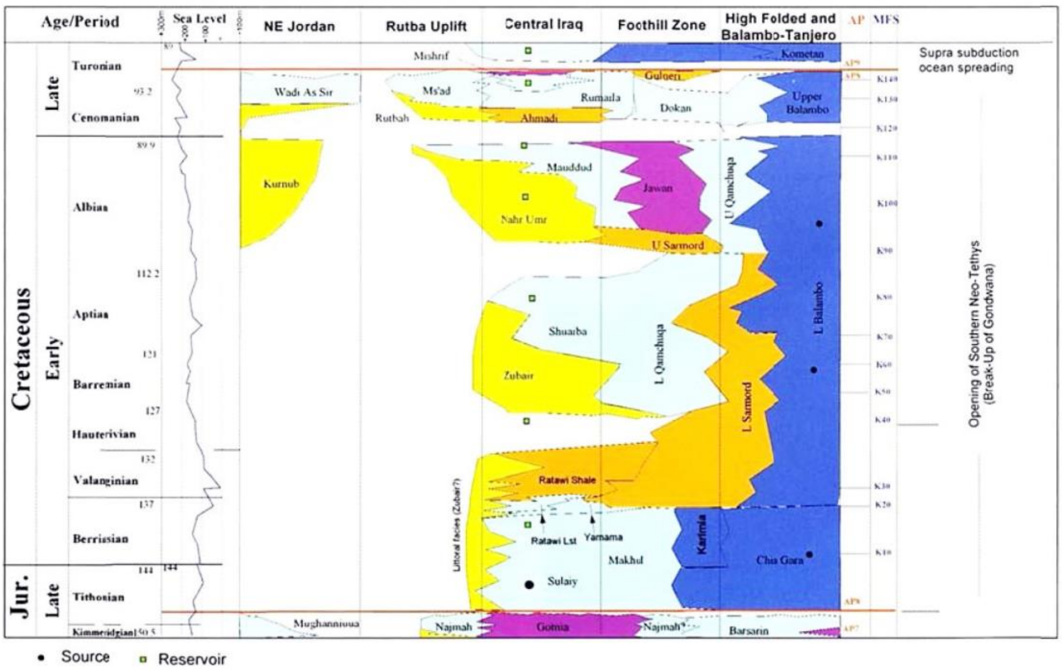

Fig. 5. Stratigrapic Correlation of Formation of Megaseqrence AP8.

Al-Abbasi et al. (2023) identified a chronostratigraphic unconformity of Berriasian and Early Valanginian in the northern Iraq sections (Fig. 6).

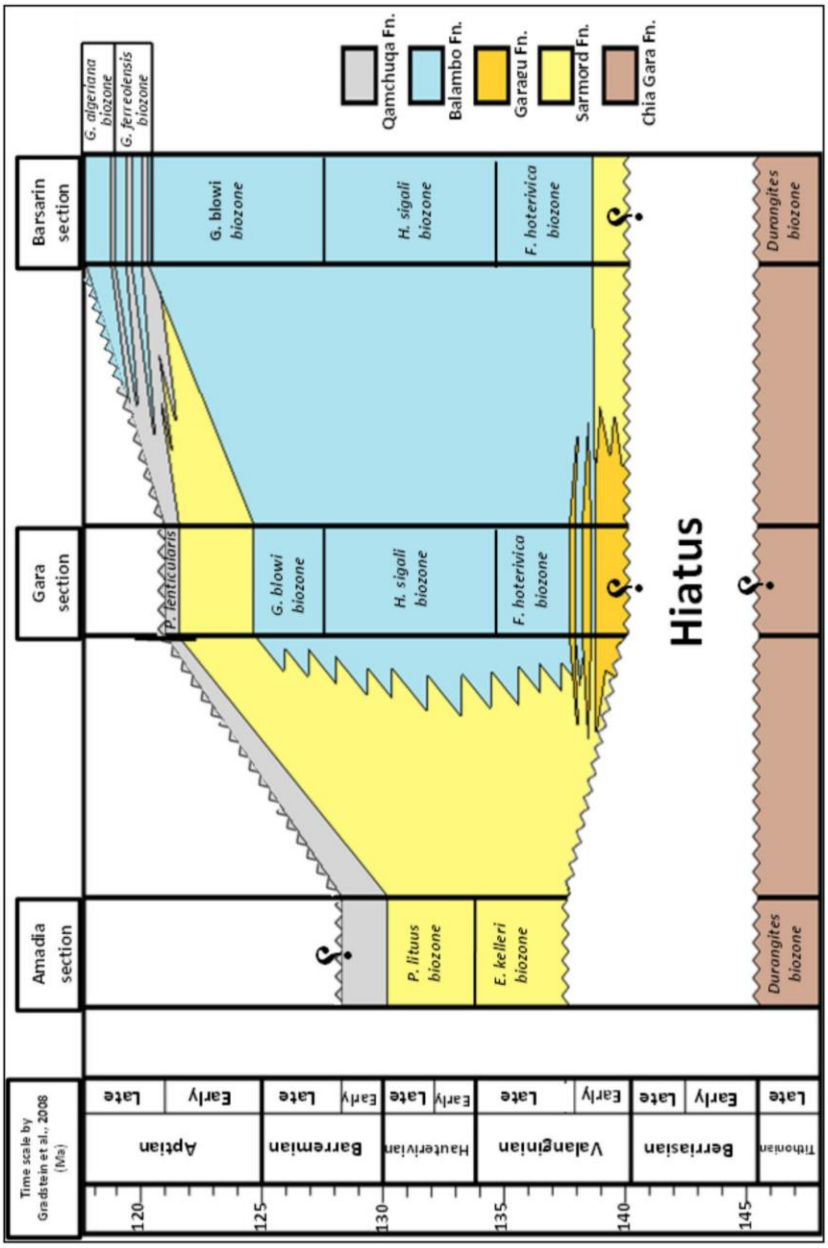

Fig. 6. Chronostratigraphic Correlation of the Garaqu Foramtion (Al-Abbasi *et. al*.,2003).

Taxonomy and Significance of the identified reworked taxa

The phytoplanktonic dinoflagellate cysts of Butmah Formation are studied by analyzing eight samples taken from borehole Tel-Hajar-1 at interval depths (3665 to 3506) m. The identification of the (12) species belonging to (11) genera of dinoflagellates is shown in Table (1).

The present study represents the first palynological record of Early Cretaceous Dinocysts derived within Butmah Formation of Early Jurassic age.

The identified reworked dinocyst of Early Cretaceous (Valanginian to Aptian) age found in the cutting samples of Butmah Formation (Plate 1) (Lower Jurassic) age are:
Spiniferites ramosus (Ehrenberg) Mantell 1854. (Sample No. 3615)
Endoscrinium luridum (Deflandre 1939) Gocht 1970. (S. No.3544)
Endoscrinium pharo Duxbury, 1977. (S.No.3615)

Operculodinella operculata, Deflandre, 1935. (S.No.3604)
Oligosphaeridium complex (White, 1842) Davey and Williams 1966**.** (S.No. 3615)
Hystrichodinium pulchrum Deflandre 1935. (S.No.3533)
PalaeoPeridinium cretaceum Pocock, ex Davey 1970. (S.No.3533)
Pareodinia ceratophora Deflandre, 1947. (S.No.3604)
Endoceratium turneri (Cookson and Eisenack,1958) StoverandEvitt1978. (S.No.3533)
Coronifera oceanica, Cookson and Eisenack 1958. (S.No.3627)
Achomosphaera neptuni (Eisenack) Davey and Williams, 1966. (S.No.3604)
Glossodinium dimorphum (Ioannides) Courtinat and Gaillard 1980. (S.No.3615).

Table 1. The Categories Classification of the Studied Species.

Kingdom	Division	Class	Order	Family	Genus	Species
Protista	Pyrrhophyta	Dinophyceae	Gonyaulacales	Gonyaulacaceae	*Spiniferites*	*Spiniferites ramous*
					Endoscrinium	*Endoscrinium luridum*
						Endoscrinium pharo
					Oligosphaeridium	*Oligosphaeridium complex*
					Hystrichodinium	*Hystrichodinium pulchrum*
					Coronifera	*Coronifera oceanica*
					Achomosphaera	*Achomosphaera neptuni*
					Glossodinium	*Glossodinium dimorphum*
				Pareodiniaceae	*Pareodinia*	*Pareodinia ceratophora*
				Ceratiaceae	*Endoceratium*	*Endoceratium turneri*
			Thoracosphaerales	Thoracosphaeraceae	*Operculodinella*	*Operculodinella operculata*
			Peridiniales	Peridiniaceae	*Palaeoperidinium*	*Palaeoperidinium cretaceum*

Spiniferites ramosus (Ehrenberg, 1838) Mantle, 1854.
Pl.1, Fig.7

Proximochorate ovoidal to spherical cysts. Very smooth outer wall. Tabulation is low structural septa. Processes are hollow and exclusively gonal, distally furcate whith bifurcate tips. Dimensions: Cyst body (15- 41) width, 30 - 46 length µm. Length processes1.2 - 12 µm. Stratigraphic range: Cretaceous to Recent. *Spiniferites* (Mantell, 1850) is one of the most stratigraphically long-ranging (Cretaceous to Recent) and geographically widespread dinoflagellate cyst genus (Hultberg and Malmgren, 1995).

(Mohammad *et al*., 2019) reccorded *S.ramosus* of Northeastern Iran on the early Cretaceous.

Endoscrinium luridum (Deflandre) Gocht, 1970.
Pl.1, Fig.9

Description: Ovate to Subspherical form, divided into approximately equal epitract and hypotract, both of them rounded broad cingulum. The periphragm forms an enclosing membrane, folded forming a funnel-like, protuberance on the antapical dorsal. Length: 88 -96 µm. Stratigraphic range: Upper Jurassic–Lower Cretaceous. Mafi *et al*. (2013) recorded the *Pareodinia ceratophora* Upper Bajocian–Lower Oxfordian of the Dalichai Formation in Binalud Mountains (NE Iran). Fatemah and Mohsen (2010) recorded this species of the Abderaz Formation in Hamam Ghaleh in Kopet Dagh sedimentary basin, Iran on the Late Turonian-Early Santonian age.

Endoscrinium pharo Duxbury, 1977.
Pl.1, Fig.11

Description: A thin-walled, fairly large, cavate cyst, derivation of Name from the Greek pharos, lighthouse, beacon in reference to the well-developed apical prominence. Periblast smooth to finely granular and apically produced into a characteristically long, distally open horn which tapers towards the apex. Endoblast smooth, ovoidal, longer than broad and with a prominent, bluntly-rounded apical prominence. A faint tabulation is outlined on the periphragm by narrow, low, smooth ridges. Nøhr-Hansen *et al*. (2020)

rocorded the Endoscrinium pharo of the NE Greenland on the Lower Cretaceous zone. Sarjeant, 1985 recorded the species from the German at Aptian.

Endoceratium turneri (CooksonandEisenack, 1958) StoverandEvitt1978.
Pl.1, Fig. 5

Endoceratium turneri is an easily identified event by its large size and distinctive ogy shape of this species (Backhouse, 2006).

(Guler *et al*., 2006) recorded this species of Austral Basins on Early Cretaceous.

(Mirzaloo and Ghasemi-Nejad, 2012) recorded the *E. turneri* of southwestern Zagros Basin, Iran on Aptian-Cenomanian.

Operculodinella operculata (Bramlette and Martini, 1964) Hildebrand-Habel *et al*., 1999.
Pl.1, Fig.1

Description: The oval and single-layered outline cysts, with flattened epicyst.

Width more than thickness. The thickness approximately equals height. Thickness and height 80% of width. Operculum simple, polyplacoid, equal diameter of archeopyle, (kidney shaped) in outline with straight ventral side. Archeopyle surrounding by a (2-to-3-μm) wide, the distinct rim of typically tangentially aligned crystallites. The wall penetrated by numerous pores. regular lines of pores parallel to equatorial plane occur directly posterior to archeopyle. Stratigraphic range: Cretaceous-Paleogene (Ahmed *et al*., 2017) were record the *Operculodinella operculata* from Cretaceous from Shiranish Formation, Northern of Iraq. (Ibrahim and Kholeif, 2000) were recorded it from the Dukhan Oil Field of Western Qatar on Albian-Cenomanian.

Oligosphaeridium complex (White, 1842) Davey and Williams 1966.
Pl.1, Fig. 4

Central body smooth or very lightly granular, ovoidal to sub-spherical shape, thin wall enophragm and periphragm, periphragm giving rise to processes. The processes simple or branched. Apical archaeopyle usually having zig-zag margin. Diameter of central body 34-55 μm. Mehrotra *et al*., 2012 recorded these species in India and Brazil on the Early Cretaceous. Al-Ameri and Al-Nagshbandi (2014) recorded the *O.complex* of Iraq on Upper Jurassic – Lower Cretaceous.

Hystrichodinium pulchrum, Deflandre, 1935.
Pl.1, Fig. 2.

Description: Subspherical to polyhedral Cyst, with thin wall, Apex occasionally surrounded by low, rounded apical horn. Surface generally ornamented, usually becoming granulate. Paracingulum well developed, para-sulcus unobserved. Parasutures vaguely defined by low ridges, with flexuous (often bladelike) processes arising, varying in length between 11-25 µm. Processes distally closed and pointed. Paratabulation indistinct. Archaeopyle unobserved, Dimensions. Cyst length 25 -35 µm; cyst width 20 -30 µm. the small form and relatively large flexuous processes. Stratigrpahic range: Lower Cretaceous. Savelieva *et al*. (2017) recorded *Hystrichodinium pulchrum* from Berriasian–Valanginian boundary in eastern Crimea (Turkey).

Palaeoperidinium cretaceum, Pocock, 1962.
Pl.1, Fig. 3.

Description: Typically, pentagonal peridinoid ambitus shape. Broad apical horn, two antapical horns of which the left one is more pronounced. Epicyst longer than hypocyst. Greatest width in cingulum. Distinct primary dorso-ventral folds. Phragma autophram thin when well-preserved showing corrugated intercalary sets delineating tabulation. Dimension: length 68 -101 μm. Stratigraphic range: Lower Cretaceous. Sharifi *et al*. (2018) recorded *Palaeoperidinium cretaceum* of the lower Cretaceous from NE Iran.

Pareodinia ceratophora Deflandre 1947 emend. Gocht 1970.

Pl.1, Fig. 6.

Description: "*Pareodinia ceratophora* was many sporadically and in weak to moderate abundances from the *W. laeviusucula* to the Z. zigzag cingulum and is variable in its morphology but is distinguished by its apical horn addition to elongate body; some specimens bear a kalyptra". Dimension**s:** mean width: 53 μm; mean length including apical horn, 78 μm. Mafi *et. al*. (2013) recorded the *Pareodinia ceratophora* Upper Bajocian–Lower Oxfordian of the Dalichai Formation in Binalud Mountains (NE Iran).

Coronifera oceanica Cookson and Eisenack, 1958.

Pl.1, Fig. 10.

Descriptions: paraplate precingular single archeopyle sometimes discerned. Could be lacked a single mid-dorsal paraplate, but the total archeopyle involved some splitting between apical and precingular paraplate series.The structure of of Coronifera, seems to be very similar to the Florentinia Davey and Verdier. 1973. The major difference between Florentinia and Coronifera appears to be the presence in the former of numerous stiff, solid spines which may furcate distally and which are proximally connected by a low-, crude surface reticulum as opposed to the sometehat flaccid processes arranged in ring complexes or tubular processes displayed by Florentinia. Lamolda and Mao (1990) recorded the Cenomanian–Turonian boundary at Ganuza (northern Spain). Stratigraphic range: Maastrichtian to Paleocene. Al-Ameri *et al*. (2000) recorded this species in middle Cretaceous from Nahr Umr and Mauddud Formations in Iraq.

Achomosphaera neptuni (Eisenack) Davey Sc Williams,1966.

Pl.1, Fig. 8.

Description: Processes gonal position, taeniate triangular and may be (bifurcate or trifurcate). The central body with slightly fibrous or reticulate surface. In the cingular zone the processes are branched. A precingrlar archaeopyle present. Diameter of central body (61-66 μm). Length of processes up to 21μm.Stratigraphic ragne: Hauterivian to Aptian. Below (2006) recorded the species of the Aptian to Cenomanian on Mazagan Plateau, Northwest Africa (Morocco). Gedl (1999) recorded *Acbomospbaera neptuni* of the Lower Cretaceous on outer Carpathians, Poland.

Glossodinium dimorphum Ioannides *et al*., 1977

Pl.1, Fig. 12

Description: In apical and antiapical view it's appearing as circular outline, in dorsaly subrhombahedral outline. The wide cingular zone divides the cyst to hypotract and epitract parts the forming broad irregularly horn shaped. The cingulum has bordered crest folds. A precingular archaeopyle is distinct, Length (98-112). Stratigraphic range: Jurassic – Cretaceous. Janquo *et al*. (2011) recorded *Glossodinium dimorphum* of the Latest Jurassic – Earliest Cretaceous on Western China (Tibet). Svobodová *et al*. (2019) recorded this species of the Jurassic / Cretaceous boundary on the northern Tethyan margin.

Previous dating of Garagu Formation is based on macrofossils (i.e., Buday 1980, p. 117) suggesting the age of Garagu Formation as (Late Berriasian- Early Valanginian). Buday stated that the bottom of Garagu Formation in the area of Foothill Zone and on the adjacent marginal parts of the Stable Shelf toward East Syria, disconformably overlies other Jurassic Formations the Najma or Chia Gara Formations (Tithonian-Berriasian) age. The studied area is located in fringing uplifted land composed of the Rutba and Khleisia Uplifts of the Stable Shelf and of the uplifted parts of the Unstable Shelf i.e., of the Mosul and Mardin-Dohuk Uplift. Al-Abbasi *et al*. (2023) proposed early Valanginian.age for the Garagu Formation in this Gara section near northern Iraq.

The identified these associations of Lower Cretaceous Dinocysts suggesting Shallow marine environments for Garagu Formation. The Ghafor and Mohialdeen (2016) study reformed the occurrence of Garaqu Formation, Dohuk area, Northeastern Iraq recognizing many types of fossils (Calcareous Algae; Coral; Pelecypoda; Echinodermata; Gastropoda; sponge spicules and Brachiopod shells). These fossil assemblages indicate the Hauterivian-Barremian age of the Garagu Formation.

Unpublished study of Kaddouri (1982) studied palynologically Tel-Hajar-1 borehole (Fig. 3) and identified the overall assemblage of Dinoflagellates associated with Miospores from the interval (3288-3240) m suggesting that they are typical of Early Cretaceous a probably (Barremian -Aptian) age which underlained by a Jurassic palynomorphs at interval (32240-3622) m supporting the presence of unconformable (a break) relationship representing uppermost Jurassic (Tithonian) and lowermost Cretaceous (Berriasian) successions (Fig. 7).

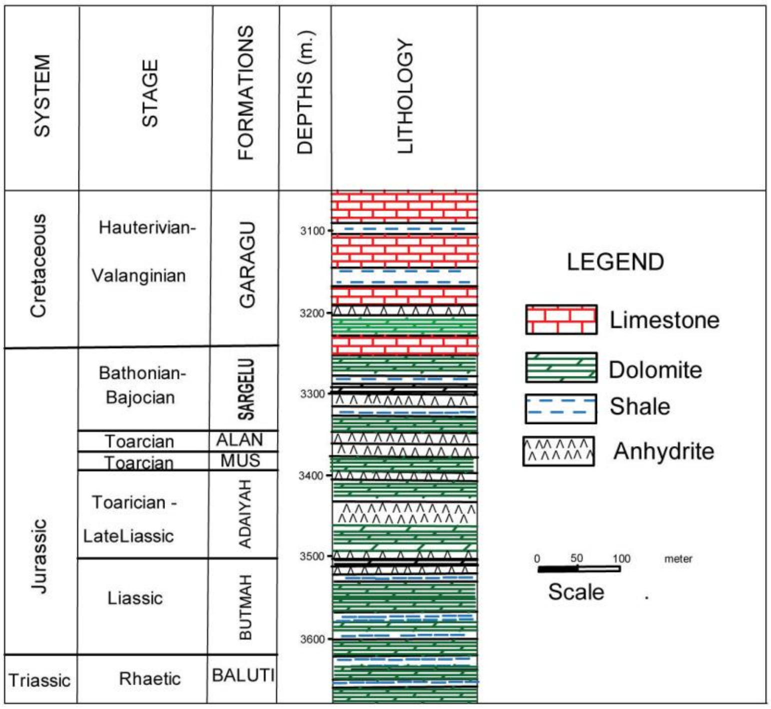

Fig.7. Stratigraphic Section of Borehole Tele-Hajar-1 (Kadouri, 1982).

The distribution of the dinoflagellate cyst fossils usually reflects their motile stages and gives a tool for palaeoenvironmental reconstruction. Therefore, the presence or absence of certain types of cysts in the sedimentary rocks can provide information about past environmental conditions such as water temperature and salinity.

The presence of these taxa reflects the wide spread of dinoflagellates in this part of the Tethyan Sea during the Cretaceous period after the limited spread at the end of the Triassic and the beginning of the Jurassic period. It is obvious that other future studies of the Cretaceous strata in this region will record many types of dinoflagellates that are globally important, knowing that these studies are very limited and the specialists in this field are also few.

Conclusion

The identification of reworked Dinocysts genera and species for the first time in this section is of great taxonomic value for future studies of Cretaceous sections. It is expected that other future studies of the Cretaceous strata in this region will record many types of globally important Dinoflagellates especially when knowing that these studies are very limited and the specialists in this field are also few.

The study discusses how reworking of palynomorphs can provide valuable data concerning the geological history of an area, and how misleading conclusions can be made if in situ taxa are wrongly considered to be reworked. By analyzing the Dinoflagellates cysts found in this region, researchers can gain insights into the environmental conditions and climate during these time periods, which can help us better understand the geological history of the northern circum-polar area.

These findings have improved our understanding of the Iraqi Cretaceous period by providing insights into the distribution and diversity of reworked dinoflagellates which were associated with sporomorphs in (Early Jurassic) documented aged Butmah Formation.

The Upper Jurassic formations are absent in Tel-Hajar well by Post Jurassic erosion, the Gotina Formation and the absence of lower Sarmord Formation (Tithonian-Berriacian) age which due to a significance of the (Berriacian / Tithonian or intra-Berriasian) Lower Cretacous unconformity, so that, the Garagu Formation (Valanginian- Hauterivian) age rests unconformably upon the Sargelu Formation of the Mid Jurassic (Bajocian-Bathonian) age; this result is detected by the presence of the contaminated index fossils of Dinofllagellates of (Late Berriasian-Vallanginian, Early Cretaceous age) within the older Butmah Formation (Early Liassic, Early Jurassic) age and the absence of the occuerence of any fossils of (Late Tithonian – Early Berriasian) age.

Our results are confirmed and complemented with unpublished study of Kaddouri (1982), who studied palynologically Tel-Hajar-1 borehole (Fig. 3) and identified the overall assemblage of Dinoflagellates associated with Miospores such as: *Oligosphaeridium complex, Muderongia tetracanth, Subtilisphaeridium sp., Kirathium sp., Densosporites sp., Cicatricosporites sp.*, from the interval (3288-3240) m suggesting that they are typical of Early Cretaceous age which underlained by a Jurassic palynomorphs at interval (32240-3622) m supporting the presence of unconformable (a break) relationship representing uppermost Jurassic (Tithonian) and lowermost Cretaceous (Berriasian) successions in this section .

Acknowledgements

We are grateful to the Petroleum and Mining Engineering College, University of Mosul for providing access to their labratories, which helped to improve the quality of this research. Thanks, and appreciation to the reviewers for their efforts in modifying and improving the research.

References

Al-Abawi, T.S, 1984. Lower Cretaceous in Iraq (Microfacies, Stratigraphical subdivision and analysisof the Middle Sarmord Formation in Kirkuk area. Erdol and Kohle-Erdgas-Petrochemi vereinigt mit Brennst off Chemie,Bd/ 37. Heft.5.

Al-Ameri, T., and Al-Nagshbandi,S., 2014. Age assessments and palynofacies of the Jurassic oil source rocks succession of North Iraq. Arabian Journal of Geosciences,pp.1-16. DOI:10.1007/s12517-013-1245-2

Al-Abbasi1, M.W., Al-Mutwali, M.M. and Al-Banna, N.Y., 2023. Biostratigraphy and Chronostratigraphy of Late Jurassic-Early Cretaceous in selected areas at Kurdistan Region, Northern Iraq, Iraqi Bulletin of Geology and Mining Vol.19, No.1, p 29 – 48. DOI: 10.59150/ibgm1901a03.

Ahmed, M.J., Tamar-Agha, M.Y. and Alwan, T.A., 2017. The Sedimentology and Facies Analysis of the Cretaceous Oceanic Red Beds (CORBs) in the Shiranish Formation, Northern of Iraq.Iraqi Journal of Science, Vol. 58, No.3A, pp. 1220-1234. DOI: 10.24996/ijs.2017.58.3A.6.

Al-Amer,T.K., Al-Najar.,T.K. and Batten, D.J., 2001. Palynostratigraphy and palynofacies indications of depositional environments and source potential for hydrocarbons: The mid Cretaceous Nahr Umr and lower Mauddud formations, Iraq. GeoArabia, Vol.5,No. 4,pp.735-742. doi.org/10.1006/cres.2001.0288.

Al- Khashab, S.S, Khalaf K. and Al-Basher J. M., 2011. Paleoecology of Garagu Formation and the Upper Part of Ratawi Formation (Lower Cretaceous) of Central Iraq. Iraqi national of Geoscience. Vol.11, No.1, pp.1-14.

Backhouse, J., 2006. Albian (Lower Cretaceous) Dinoflagellate Cyst Biostratigraphy of the Lower Gearle Siltstone, Southern Carnarvon Basin, Western Australia. Palynology.Vol. 30, pp. 43-68. DOI.10.2113/gspalynol.30.1.43.

Bellen, R.C., Dunnington, H.V., Wetzel , R. and Morton,D., 1959, Lexique Stratigraphique International Asie, Iraq. Intern. Geol. Congr. Comm. Stratigr.3, Fasc.10a,333 P.

Below,R., 2006. Aptian to Cenomanian dinoflagellate cysts from the mazagan plateau, Northwest Africa (sites 545 and 547, deep sea drilling project leg 79).Institut für. Palàontologie, Universitàt Bonn.Vol. 9,pp: 1-29. doi.org/10.1594/pangaea.809495.

Buday, T., 1980. The Regional Geology of Iraq: Stratigraphy and Paleogeography State Organization for Minerals Library, Baghdad, Iraq mv .1,445 P.

Cookson, I.C. and Eisenack, A., 1958. Microplankton from Australianand New Guinea Upper Mesozoic Sediments. Proc. R. Soc.Victoria, 70:19-79

Courtinat, B. and Gaillard, C.,1980. Les dinoflagellés des calcaires lites de Trept (Oxfordien supérieur). Inventaire et repartition comparée à celle de la microfaune benthique. Laboratoires de géologie de la Faculté des sciences de Lyon,Documents, no.78, 123 P.,10.

Davey, R.J. and Villiams, G.L.,1966. Thc genera HystrichosphaeraandAchomosphaera. In studies on Hlesozoic and Cainozoic Dinoflagellate Cysts (ed. R.J. Davey, C. Downie, W. A. S. Sarjeant and G. L.\Williams).-British hlus. (Nat. History) Bull., Geol-sediments. - Australian J. hlar. Freshw. Res. 6: 242-313.

Deflandre ,G., 1935. Considerations Biologique sur les Microorganisms D'origine Planc Tonique Conserves dans les Silex de la Craie. Bull, biol., 69: 213-244, pis. 5-9, text-figs.

Duxbury, S., 1977. A Palynostratigraphy of the Berriasian to Barremian of the Speeton Clay of Speeton, England. Palaeontographica, Abt. B, 160: 17-67.

Fatah, S.S., Sarraj, R.H., Al-Qayim, B., Mohialdeen, I.M., Al-Jubouri, Q.M., Khanaqa, P.A., and Mohammed, Z.K., 2023. Sedimentology, Palynofacies, and Hydrocarbon Potential of the Early Cretaceous Sarmord Formation from Khabbaz and Kirkuk Oil Fields, Northern Iraq. Iraqi Geological Journal, 56 (1C), pp. 110-137. doi.org/10.46717/igj.56.1C.8ms-2023-3-19.

Fatemeh, M., and Mohsen, A, 2010. Palynology of the Abderaz Formation in Hamam Ghaleh in Kopet Dagh Sedimentary Basin International Applied Geological Congress, Department of Geology, Islamic Azad University - Mashad Branch, Iran, pp. 26-28.

Fensome, R.A., Riding, J.B., Taylor, J.R., 1996. Dinoflagellates. In: Jansonius, J. and McGregor, D.C. (Eds.). Palynology: Principles and Applications; American Association of Stratigraphic Palynologists Foundation, Salt Lake City. Vol. 1, pp. 107–169.

Gedl, E., 1999. Lower Cretaceous Palynomorphs from the skole nappe (Outer Carpathians, Poland, Geologica Carpathica, Vol. 50, No. 1, pp. 90-75.

Ghafor, M., and Mohialdeen, M.J, 2016. Fossils Distribution from Garagu Formation (Early Cretaceous), Diversity and Paleoennvironmental Conditions, Kurdistan Region, North Iraq, JZS (2016) Special Issue, GeoKurdistan Vol. 2, pp. 139-150.

Gocht, H., 1970. Dinoflagellaten-Zysten aus einem Geschiebefeuerstein und ihr Erhaltungszustand. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, No.3, pp. 129-140.

Guler, M.V., Paolillo, M,A. and Martz,P.A, 2006. Early Cretaceous Dinoflagellate Cysts From The Neuquén And Austral Basins: A Review. Publicación electronica.Vol. 16(2), pp. 88–105.

Hultberg, S.U. and Malmgren, B.A., 1995. Evolutionary patterns in the dinoflagellate cyst genus Spiniferites (Cretaceous through Quaternary): relationships to sea-level changes. Hist Biol. 10:341–357.

Ibrahim, M.A., and Kholeif, E, 2000. Albian-Cenomanian Palynology, Paleoecology and Organic Thermal Maturity of Well DK-B in the Dukhan Oil Field of Western Qatar GeoArabia, Vol. 5, No. 4, pp.1-14.

Jassim, S., and Goff, J., 2006. Geology of Iraq. Dolin, Prague and Moravian Museum, Brno, Czech Republic,337.

Janguo, L.J., Riding.C., Jinhui, A.B., and Chengquan., H., 2011. Latest Jurassic – Earliest Cretaceous (Tithonian–Berriasian) Dinoflagellate Cysts from the Yanshiping Group of the Northern Qinghai-Xizang Plateau (Tibet), Western China,Review of Palaeobotany and Palynology, Vol. 166, Issues 1–2, pp. 38-45. DOI.10.1016/j.revpalbo.2011.04.007.

Kaddouri, N., 1982. Palynologıcal study of Early Cretaceous-Late Triassic sediments in Tel Hajar Well No. 1 Northwestern Iraq. (Unpublished Report) Iraqi National Oil Corporation in association with Robertson Research International Limited).

Kddo, Y.H., 2011. Palynostratigraphy of Late Triassic-Early Jurassic Strata in Boreholes TelHajar-1 and Kand-1 Northern Iraq. Unpublished Ph.D.Thesis, Mosul University, 198 P.

Lamolda, M.A., and Mao, Shaozhi, 1990. The Cenomanian–Turonian boundary event and dinocyst record at Ganuza (northern Spain). Palaeogeography, Vol. 150, Issues 1–2, pp. 65-82.

Mafi, A., Ghasemi-Nejad, E, Ashouri, A., and Vahidi-Nia, M., 2013. Dinoflagellate cysts from the Upper Bajocian–Lower Oxfordian of the Dalichai Formation in Binalud Mountains (NE Iran): their biostratigraphical and biogeographical significance, Arabian Journal of Geosciences, pp.1-13. DOI: 10.1007/s12517-013-0976-4.

Mantell, G.A., 1854. The medals of creation or first lessons in geology and the study of organic remains. Henry G. Bohn, London. Vol. 1. xxxii + 446 pp., pis. 1, 3-6, text-figs. 1-139.

Mehrotra, N,C., Tewarı, R., Arai, M, Garcia, M.J., and Oliveira, B.D., 2012. Stratigraphic ranges of dinoflagellate cysts from Cretaceous petroliferous basins of India and Brazil. The Palaeobotanist , Vol. 6, pp. 83-102. DOI: 10.54991/jop.2012.352.

Mirzaloo, M., and Ghasemi-Nejad, E., 2012. Combined use of palynology and organic geochemistry in petroleum potential evaluation and paleoenvironmental interpretation of the Kazhdumi Formation (Aptian-Cenomanian) in the southwestern Zagros Basin, Iran. JGeope 2 (1), pp. 27-40.

Mohammed, J. A., Mazin, Y. Tamar-Agha, M.Y and Alwan,T.A., 2017. The Sedimentology and Facies Analysis of the Cretaceous Oceanic RedBeds (CORBs) in the Shiranish Formation, Northern of Iraq.Iraqi Journal of Science, 2017, Vol. 58, No. 3A, pp: 1220-1234. DOI: 10.24996/ijs.2017.58.3A.6.

Mohammad, S., Fariba, F., Ebrahim, G., Ebrahim, G., Ali, S., Mohsen, Y and Mehdi, Sarfi, 2019. Integrated Biostratigraphy, Depositional Setting and Geochemical Analyses for Petroleum Potential Evaluation of the Lower Cretaceous (Barremian – Albian) Strata of the Koppeh-Dagh Basin, Northeastern Iran, Acta Geologica Sinica (English Edition), vol. 93 No.6: pp. 1885–1899. DOI.org/10.1111/1755-6724.13823

Nøhr-Hansen, H., Piasecki, S., and Alen, P., 2020. A Cretaceous Dinoflagellate Cyst Zonation for NE Greenland, A Cretaceous Dinoflagellate Cyst Zonation for NE Greenland. Geological Magazine, Vol. 157, pp. 1658–1692. DOI: https://doi.org/10.1017/S0016756819001043

Pocock, S.A., 1970. Palynology of the Jurassic Sediments of Western Canada. Part 1. Terrestrial Species. Palaeontographica, Abt. B. 130(1-2): 12-72, continued in (3-6), pp. 73-136.

Savelieva, Y.N, Shurekova, O.V., Feodorova, A.A and Manikin, A.G, 2017, Microbiostratigraphy of the Berriasian–Valanginian boundary in eastern Crimea: foraminifers, ostracods, organic-walled dinoflagellate cysts,Geologica Carpathica, December 2017, 68, 6, pp. 517–529.

Sharifi, M., Ghasemi-Nejad, E, Sarfi, M., Yasdimoghadam, M, Salehani, M.T and Akhtar, M., 2018. Marine palynology and en vi ron men tal in ter pre ta tion of the Lower Cre ta ceous (Barremian–Aptian) rock units in the Koppeh-Dagh Ba sin, NE Iran. Geo log i cal Quar terly, Vol. 62,No.1, pp. 90–99. DOI: http://dx.doi.org/10.7306/gq.1394.

Stover L.E., and Evitt,W.R., 1978. Analyses of pre-Pleistocene organic-walled dinoflagellates.Stanford University Publications, Geological Sciences 15, 300 P.

Svobodová, A., Švábenıcká, L, Reháková, D., Svobodová, M., Petr Skupıen, P., Elbra, T. and Schnabl, P., 2019. The Jurassic/Cretaceous boundary and high resolution biostratigraphy of the pelagic sequences of the Kurovice section (Outer Western Carpathians, the northern Tethyan margin), Vol. 70, No. 2, pp. 153–182. DOI: 10.2478/geoca-2019-0009.

Plate-1

Fig.1. *Operculodinella operculata,* Deflandre, 1935. Sample No.3604.
Fig.2. *Hystrichodinium pulchrum* Deflandre 1935. Sample No.3533.
Fig.3. *Palaeo Peridinium cretaceum* Pocock, ex Davey 1970. Sample No.3533.
Fig.4. *Oligosphaeridium complex* (White, 1842) Davey and Williams 1966. Sample No. 3615.
Fig.5. *Endoceratium turneri* (Cookson&Eisenack,1958) Stoverand Evitt1978. Sam. No.3533.
Fig.6. *Pareodinia ceratophora* Deflandre, 1947. Sample No.3604.
Fig.7. *Spiniferites ramosus* (Ehrenberg) Mantell 1854. Sample No. 3615.
Fig.8. *Achomosphaera neptuni* (Eisenack) Davey and Williams, 1966. Sample No.3604.
Fig.9. *Endoscrinium luridum* (Deflandre 1939) Gocht 1970. Sample No.3544.
Fig.10. *Coronifera oceanica,* Cookson and Eisenack 1958. Sample No.3627.
Fig.11. *Endoscrinium pharo* Duxbury, 1977. Sample No.3615.
Fig.12. *Glossodinium dimorphum* (Ioannides) Courtinat and Gaillard 1980.Sample No.3615.