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Charophyte Biostratigraphy of the Late Jurassic - Early Cretaceous Sequence, Messak Formation, Murzuq Basin, Libya

Mostafa M. Hamad

Cairo University, Faculty of Science, Geology Department, Egypt.

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ABSTRACT

Analyses of the non-marine charophytes and ostrcodes are made from the Upper Jurassic – Lower Cretaceous sequence of the Messak Formation, Northwestern part of Murzuq Basin, Libya for the first time. Two stratigraphic surface sections, namely Gabal Tinfore and Gabal Yafarat are described and investigated. The Messak Formation unconformably overlies the Middle Jurassic Tilemsin Formation and unconformably underlies the Quaternary deposits. This formation is divisible into two main members, form base to top: 1- Jarmah Member and 2- Awbari Member. These two members are widely exposed and distributed in the study area and composed of different varieties of lithofacies types ranged from conglomerates, sandstones to siltstone and mudstone as well as arenaceous dolomite and subordinate black shale. These lithofacies types are assigned to different depositional environments ranged from proximal to distal braided alluvial deposits with tidal flats and to inner shelf in the Jarmah member to alluvial meandering rivers and marsh coastal swamps in the Awbari Member. Based on the stratigraphic distribution of the charophyte taxa, the Messak Formation and related beds can be divided into four local assemblage zones. Two biozones of Late Jurassic age *Echinochara peckii* Zone (Late Oxfordian) and *Porochara kimmeridgian* Assemblage Zone of Kimmeridgian age. This later zones overlain unconformably by poorly fossiliferous zone that encompasses the Late Jurassic – Early Cretaceous boundary. Overlying this zone, the *Latochara mensinkii* Zone that assigned here to Lower Cretaceous (Berriasian) age. The systematic study allowed the identification and description of twenty-one charophyte species and subspecies belonging mainly to eight genera and four families. The upper part of the Jarmah Member and also the Awbari Member have yielded a low diversity small ostracodes, represented mainly of the genera *Cetacella* sp, *Timiriassvia* sp., *Poisita* sp., *Darwinula* sp., and *Dicrorygma* sp.. This type of ostracode association strongly assigned the uppermost part of Awbari member to an Early Cretaceous age based on the correlation of this ostracodes assemblage with their counterparts in the world.

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INTRODUCTION

Non-marine sediments of the Upper Jurassic – Lower Cretaceous age have been widely distributed and well recorded in some localities in the northern parts of the Murzuq basin, Libya (Figs 1, 2). The study area is represented herein by the Awbari area that located in northern part of the Murzuq basin It represents the footscarpes of Messak escarpment that extends from Wadi Irawan and Gabal Awbari to the east to Wadi Al Hayat and Gabal Sinqo in the west and bounded by Idawan Awbari and Bir Mansour to the north and to the south by Latitude 26° 25`N (Fig. 3). Previous geologic studies dealing with that area are of limited number and concerned mainly with the stratigraphy and structural geology. The results of these studies, however, are helpful in providing a good base for further geologic investigations. The most relevant works for the present study includes Desio (1935, 1937), Burollet (1960), Allen (1964), Goudarzi (1970), Pomeyrol (1968), Klitzsch (1963 & 1972), Hamouda (1969), Kallenbach (1972), Busche (1980), Lorenz (1980), Seidl & Röhlich (1984), Pierobon (1991), Konzalova (1991), and Ali *et al.,* (1994). There have been one isolated report of charophyte in Libya, Viterbo (1968) reported for the first time in Libya the occurrence of these charophyte species, *Clavator harrisi* Peck in an assemblage of ostracodes reported from the subsurface Nubian complex of the Sirte basin, northern Libya and assigned these deposits to an Early Cretaceous age. On the other hand, little attention has been paid to charophyte biostratigraphic studies on the Late Jurassic - Early Cretaceous Messak Formation. This work provides the first detailed study on the charophyte microflora that provided an important biostratigraphic datum for this succession and also to evaluate the charophytes flora both biostratigraphically and ecologically

Corresponding Author: Mostafa M. Hamad, Cairo University, Faculty of Science, Geology Department, Egypt.
E-mail: mnhamad88@yahoo.com)

besides comparing these charophyte taxa to other ones recorded in the world. In order to achieve these objectives two stratigraphic surface sections representing the Late Jurassic - Early Cretaceous Messak sequence, have been measured, described and investigated, from east to west as follows: 1- Gabal Yafarat section and 2- Gabal Tinfore section (Fig. 3).

MATERIAL AND METHODES

Sixty-five surface samples were collected from Gabal Tinfore and Yafarat representing the Jarmah and Awbari members of Messak Formation in the Murzuq basin. These samples were examined and investigated for their charophyte content (as some of the collected samples, about 32 ones, were productive and many of these were highly fossiliferous). The samples are mainly focused on the dark gray to yellowish gray, gypsiferous, fissile, calcareous siltstone and mudstone beds and sandy dolomites with little emphasis on the well lithified, massive, fine to coarse grained, sandstone. The kerosene method was used for disintegration of samples. Dry sediment was soaked in kerosene for about 30 minutes. After decanting the kerosene, the sediments was boiled in solution of hydrogen peroxide for one hour or more depending on the degree of consolidation. Then the disintegrated samples were washed, sieved and dried for microscopic investigations. Charophytes and ostracodes were then picked from the residue and the detailed morphological description and identification were made using the SEM (Scanning Electron Microscope).

Stratigraphy:

The Upper Jurassic - Lower Cretaceous succession is best exposed in the northern part of the Messak escarpment of Awbari area. They are well developed in the thickness and distribution along the escarpment. This sequence is classified by Klitzsch (1972) as Messak Formation which in turn he subdivided it into two main units, arranged from base to top as follows: 1-Jarmah beds and 2-Awbari sandstones. Megerisi & Mangain (1980) subdivided the Messak Formation into a lower Jarmah member and an upper Awbari member (Table 1).

Messak Formation:

The Messak Formation was first described and introduced by Klitzsch (1963) who later on (1972) described its type section in the western flank of Murzuq basin, Gabal Messak in Fezzan area and suggested Messak Formation instead of Messak sandstone. In its type section, the formation overlies unconformably the Middle Jurassic Tilemsin Formation and underlies unconformably the Late Cretaceous Ben Afen beds. In the studied sections, the Messak Formation overlies unconformably Tilemsin Formation and exposed directly on the surface. Megerisi & Mangain (1980) subdivided the Messak Formation into a lower Jarmah member and an upper Awbari member (Table 1). The formation consists predominantly of fine to coarse grained, partly conglomeratic, cross - bedded sandstones with siltstone and mudstone interbeds as well as arneaceous to argillaceous dolomite and black shale thin bands. The thickness of this rock unit varies between 160 m in Gabal Tinfore to 110 m in Gabal Awbari (Fig.3). Sometimes these clastic rocks show cyclolithofacies pattern, in which each cycle begins with conglomerate bed and graded up in the sequence to pebbly sandstone then to coarse and finally fine-grained sandstone and occasionally with calcareous siltstone or mudstone lithofacies. It is noteworthy of mention that the lithostratigraphic subdivision of the Messak Formation is based mainly on the lithological characteristics where both of the Jarmah and Awbari members are composed predominantly of conglomerates, sandstone siltstone, mudstone and sandy dolomite, but the number of siltstone and mudstone beds in the Jarmah member exceed the number of same beds in the overlying Awbari member. In the following are the main lithofacies types recorded in both of the members.

Jarmah Member (Pl. 1, Fig. B):

This rock unit was originally described by Klitzsch (1963) in its type section southeast of Jarmah village and later on raised to member rank by Megerisi & Mangain (1980). In the studied sequence, it overlies unconformably The Middle Jurassic Tilemsin Formation and underlies unconformably the Awbari member. This member constitutes the footslope of the Messak escarpment (Fig. 3). Lithologically, Jarmah member is composed predominantly of alternating beds of conglomerates, pebbly sandstones, sandstones with siltstone and mudstone as well as subordinate sandy dolomites. Commonly the Jarmah sequence commences with an erosional, scoured and channeled conglomerates that cut the underlying shales and limestones of the Middle Jurassic Tilemsin Formation. The sandstone above the conglomerate is generally medium to coarse, cross – bedded grading upwards to fine sandstone and terminated with greenish gray siltstone or mudstone. The repeated upward – finning of the grain sizes in this member suggest deposition by currents with decreasing velocity upward. Fluvial origin is recognized for the Jarmah Member through the absence of the horizontal bedding, absence of the marine body fossils and presence of conglomerates as well as abundance of the plant remains and charophytes. Moreover tidal flats are recognized also through the presence of transgressive sequence of the mixed siliciclastics (siltstone and mudstone) and carbonate (arenaceous dolomite) that indicate the incursion of the Tethyan sea southwards. Jarmah member is widely distributed, attaining different thicknesses, where it reaches 50 m Gabal Tinfore, 40 m at Gabal Yafarat, and 50 m Gabal Awbari.

Awbari Member (Pl. 1, Fig. A):

This rock unit was originally described as Messak sandstone (Klitzsch & Barid, 1969), later on Klitzsch (1972) and Megerisi & Mangain (1980) adopted it as Awbari Member. It overlies unconformably the Late Jurassic Jarmah Member and unconformably overlain by the Quaternary deposits. Lithologically, it is composed essentially of polymictic conglomerates, pebbly sandstone beds with few beds of siltstone and mudstone as well as thin laminae of black shale. Subordinate kaolinitic gray, massive to fairly laminated mudstone interbeds is usually recorded at the uppermost part of the member. The Awbari member is widely distributed, attaining different thicknesses, where it reaches 50 m Gabal Tinfore, 40m at Gabal Yafarat. The careful investigations of the mudstone and sandy limestone beds showed that the occurrence of well preserved low diversified ostracodes that strongly assigned this member to Early Cretaceous age.

In the following section, the main lithofacies types recorded in every member are discussed in detail with referring to its depositional environment:

1– The conglomerates lithofacies:

This type of lithofacies commonly represents the lowermost part of each cycle, sometimes occur as massive bed and in other cases as lenticular or channel – shape bodies. They decrease upward in the thickness and sizes and graded from pebble to cobble forming the lowermost part to pebbly and coarse sandstones. The conglomerates are yellowish brown to brownish yellow, polymictic, hard consolidated clast – supported consisting essentially of cobble to pebble sizes of subangular to subrounded, poorly to moderately sorted, mostly composed of intraformational sandstone and siltstone clasts with subordinate chert and carbonate ones. These detrital clasts are embedded in fine argillaceous sand matrix. This lithofacies type is dominated by planar cross – bedding and imbrication structures especially near the lowermost parts. Small lenses of pebbly sandstone, mudstone and siltstone of very reduced thickness (some of these lenses reach 70 cm in length and 30 cm in thickness) are commonly interbedded with the conglomerates. No diagnostic charophytes have been recorded in this facies.

2- The sandstone lithofacies:

This rock type represents the dominant lithofacies in the studied Messak Formation especially in the Awbari Member (forming more than 70% of the whole Awbari Member). It extended uniformly across the entire study area without significant lateral variation in the facies. On the basis of the textural parameters, the sandstone is subdivided into two sublithofacies types. The first sulithofacies is represented by pale yellow to yellowish gray, moderate to hard consolidated, moderately sorted calcareous pebbly to coarse sandstone. This sublithofacies commonly follows the conglomerate lithofacies and normally existed at the lowermost part of each sandstone bed. The second sublithofacies type is mainly made up of stacked sheets of light yellow to brownish yellow, medium to fine grained, medium to well sorted, highly consolidated sandstone. The matrix varies from silica, ferruginous, to argillaceous materials. Tabular cross-bedded and planar cross-bedding are the most frequent primary structures (Pl. I, fig. C) and with less abundant normal to reverse graded bedding as well as lamination and bioturbation. Conglomeratic lenses that locally interbedded forming channel fill and lag deposits. The absence of the horizontal bedding, abundance of plant remains and occurrence of conglomerates with this lithofacies suggest a braided fluvial system.

3- The siltstone and mudstone lithofacies:

This lithofacies type is essentially built up of mudstone and siltstone interbeds that commonly gray to dark gray in the lower Jarmah Member becoming greenish gray to variegated (Pl. I, fig. D) in the upper Awbari Member. The beds are commonly thin laminated to massive, being bioturbated and range in thickness from 0.6 to 6 m, while in some cases they disappear due to the channeling. Sometimes kaolinitic mudstone are recorded of gray to black colour in the Jarmah Member highly fossiliferous with plant remains. Kallenbach (1972) identified the following types of these plant remains (Coniferophyta and Bryophyta) such as: *Phlebopteris* sp., *Matonidium* sp., *Dicranales* sp., *Brachyphyllum* sp., and *Pagiophyllum* sp.and assigned the Jarmah member to Late Jurassic in age. This age dating is supported also by Konzalova (1991) based on the palynological investigations. She recorded numerous pollen grains in this lithofacies type, among the different species are *Classopollenites calssoides* Pockok, *Eucommidites troedssoni* Erdtman and *Inaperturopollenites* sp. that indicate Late Jurassic age. This siltstone and mudstone lithofacies type were deposited in tidal flats, the presence of channel fills within the sediments represents subtidal upper shoreface channels indicating slight fall in the sea level. It is noteworthy to mention that in the Awbari Member of Gabal Tinfore (Fig. 4), some thin bands (ranging in thickness from 30 cm to 60 cm) are recorded interlaminated with this facies and sandstone lithofacies type and repeated for about 3 to 4 times. It is represented by dark gray to black carbonaceous shale

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Plate 1

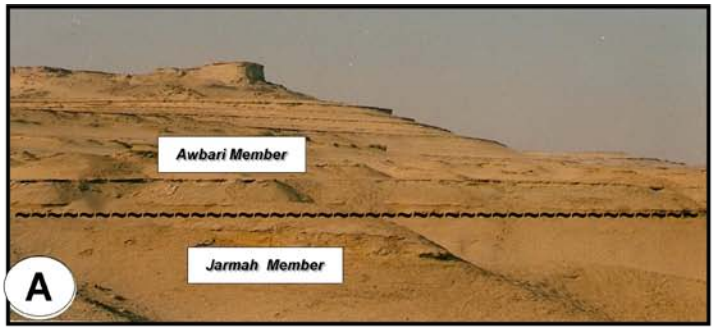

Fig. A: Field photograph showing Awbari Member unconformably overlies the Jarmah Member, Messak Formation, Gabal Tinfore .

Fig. B: Field photograph showing general view of Jarmah Member , Messak Formation, Gabal Yafarat .

Fig. C: Field photograph showing cross – bedded sandstone of Awbari Member, Messak Formation, Gabal Tinfore .

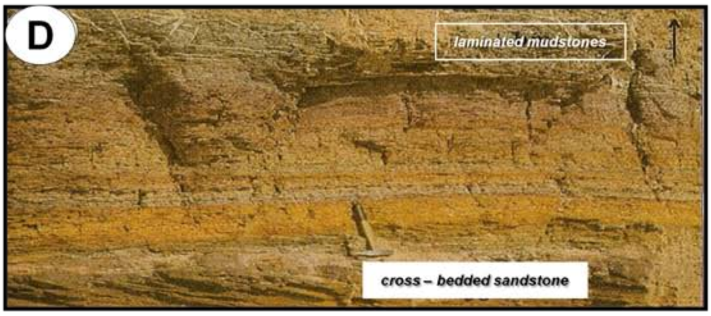

Fig. D: Field photograph showing laminated mudstones (bm) of Awbari Member, Messak Formation, Gabal Yafarat .

highly fossiliferous with organic materials (plant roots, leaves, pollen grains and spores as well as charophytes) suggesting deposition in tidal marshes to a coastal swamp (coastal lagoon) and the presence of this organic content indicate also that the climate was generally humid and temperate.

4-Sandy dolomite lithofacies:

this lithofacies type consists of yellow, grayish yellow of medium to thick bedded arenaceous dolomite with sharp, planar, basal contact with the underlying sandstone and mudstone units and sometimes the tops are gradational with the overlying sandstone and mudstone. This lithofacies type commonly recorded in the lower Jarmah Member but of rare occurrences and thin thickness in the overlying Awbari Member. This lithofacies may have been deposited deeper than the other mudstone and sandstone lithofacies types, in relatively subtidal environments or still in the lower tidal flats but accumulated during periods of low detrital influx and such periods gave the opportunity to the chemical and biochemical producing processes to take place and construct this carbonate tidal flats (Milliman, 1974, Wilson, 1975, James, 1984).

Charophyte Biostratigraphy:

Charophytes are green algae that have been found in fresh water to moderately brackish water environments. Their gyrogonites are minute oval or round calcareous bodies that represent the calcified parts of the oogonium i. e. the female reproductive organs. Most of the plant consists of organic matter that decays shortly after death. Under some circumstances the stems and branches of the plant become calcified and are also preserved in the geologic record. In the absence of the planktonic and benthonic foraminifers, ostracodes and charophytes becomes valuable biostratigraphic tool for geologic analysis and interpretation (Carbonel, 1988; Colin & Lethiers, 1988; Martin-Closas & Schudack, 1996, Schudack, 2000 & 2006). Moreover the charophytes have been the focus of intensive work since the early 1960, since it was hope to obtain valuable information on the dating, biostratigraphic and paleoecology of the strata (Schudack, 2002 & 2004). The present study attempts a comprehensive biostratigraphic evolution of the Late Jurassic – Early Cretaceous sequence at Messak escarpment based on the stratigraphic distribution of the charophytes species as this type of microfossils have not been studied before in Libya as well as the study area has never been studied for charophytes beforehand. On the basis of the stratigraphic distribution of charophytes it is possible to subdivide the Late Jurassic – Early Cretaceous sequence into four assemblage zones. These are described in ascending order below and their tentative correlation with counterparts is also discussed.

Echinochara peckii Zone:

This is the lowermost zone recognized in the studied sequence, having approximately 6 m of maximum thickness in Gabal Tinfore but it is not recorded in Gabal Yafarat (figs. 4, 6). Riveline *et al*. (1996) defined this zone as interval from the first occurrence of *Echinochara peckii* (Mädler, 1952) Grambast (1965) emend, Schudack (1993a) to the first occurrence of *Dictyoclavator fieri ramalhoi* (Grambast–Fessard, 1985) Martin – Closas, 1985. But due to the complete absence of *Dictyoclavator fieri ramalhoi,* the upper boundary of this zone is delineated herein on the basis of the first occurrence of *Porochara kimmeridgensis.* It includes five basal beds (no. 3 – 9) in Gabal Tinfore, comprising the coarse to medium pebbly sandstone and calcareous siltstone beds with thin bands of grayish yellow sandy dolomite. These successively overlain by gray gypsiferous siltstone and mudstone. Most of the calcareous siltstone and mudstone beds are productive in charophytes but very rare ostracodes were recognized and represented by *Cetacella armata* only. *Echinochara peckii* and *Aclistochara bransoni* are the most dominant species in this zone. The other predominant charophytes recorded in this zone but of long ranging are *Mesochara harrisi*, *Porochara jaccardi, Porochara westerbeckensis* and other species listed in Figure 4. It is noteworthy of mention that these species have strong affinity to the European species recorded by other authors (Riveline *et al.*, 1996, Schudack, 1998, Mischke *et al*., 2004) in the Oxfordian deposits of Saxony basin in Northwest Germany. On the basis of first appearance of *Echinochara peckii* and *Aclistochara bransoni* and correlation it with its counterpart in Europe, this zone is assigned to Late Oxfordian. This zone could be correlated to the assemblage zone no. 1 recorded by Feist & Schudack (1991) Schudack & Schudack (2012) from the nonmarine Jurassic – Cretaceous transition of Northwest Germany and Iberian Chain of Spain respectively.

Porochara kimmeridgensis Zone:

This zone is generally defined as total range *Porochara kimmeridgensis* and equated with Dictyoclavator fieri var. ramalhoi zone of Riveline *et al*. (1996) But in the studied sequence the *Dictyoclavator fieri ramalhoi* is not recorded. This zone has 30 m of maximum thickness and including ten beds (no.10 – 19) in Gabal Tinfore (Figs. 4 & 6). They are in ascending order, grayish to yellowish gray, fissile, gypsiferous siltstone and yellow, partly massive, cross – bedded of medium to coarse sized, sandstone. The topmost bed is grayish to yellowish gray, fissile, gypsiferous calcareous siltstone. However, this zone is recorded in Gabal Yafarat attaining thickness of 60 m. (Figs. 5 & 6). This zone is characterized by abundant to common occurrence of the following charophyte species: *Porochara kimmeridgensis* and *Porochara fusca* are abundant *and* make their first occurrence in this zone, *Mesochara harrisi, Porochara jaccardi, Porochara westerbeckensis*, *Porochara minima* (that restricted to the upper part of this zone), *Latochara latitrnucata, Echinochara peckii*, *Mesochara*

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voluta, Aclistochara bransonii, Aclistochara polyspirata. It is noteworthy to mention that *Porochara kimmeridgensis* is recorded in several European basins from the Kimmeridgian but not from Thitonian levels (RIVELINE *et al*., 1996). Some authors believe that this species now appeared in the Early Kimmeridgian, others suggested that it only occurs in the late Oxfordian as in northern Spain (Schudack, 1987). On the other hand, some stated that it covers the whole Kimmeridgian as in northwest Germany such as Schudack *et al*., (1996) and Schudack & Schudack (2002). From the foregoing discussion it is proved that this species is considered as diagnostic charophyte species for the Kimmeridgian age. Consequently this zone with no doubt is assigned to that age. This age assignment is also supported by the occurrences of the ostracode species *Cetacella striata* and *Cetacella inemris*.

Poorly fossiliferous Zone:

This zone is the intermediate zone, attaining maximum thickness of 20 m in Gabal Tinfore, where it reaches 15 m thickness in Gabal Yafarat. The zone is poor in charophytes and ostracodes and accordingly named as poorly fossiliferous zone. It includes 9 beds (no. 19 to 28 in Gabal Tinfore) and six beds in Gabal Yafarat (50 to 57). These beds commonly consists of reddish – brown polymictic conglomerates and cross – bedded coarse to medium, hard sandstone and pebbly sandstone with very thin laminae of gypsiferous shale that yielded a few ostracodes mainly of *Cytherella* sp. but of bad preservation. The scarcity of the charophytes and ostracodes and the predominance of siliciclastic lithofacies indicate that the beds of this zone were accumulated during the regressive phase of the sea under near shore conditions to continental environments.

Latochara mensinkii Zone:

This zone is defined by the total range of the nominated zonal taxon and represents the uppermost biozone recorded in the studied sequence having 32m of maximum thickness in Gabal Tinfore and 23 m in Gabal Yafart. It includes the top seven beds in Gabal Tinfore (from bed no. 28 to 35) and six beds in Gabal Yafarat (bed no. 57 to 65) (Fig.5). The lithofacies ranged from sandstone to calcareous siltstone and mudstone deposits with subordinate sandy limestone thin beds. *Latochara mensinkii* is the most characteristic of this zone hence the zone is named after it. Several species of Clavatoraceae appear for the first time in this zone such as *Globator maillardii* and *Atopochara trivolvis horrida.* On the basis of the the evolutionary lineage of *Globator maillardii* Schudack (1993b) subdivided the *Globator maillardii maillardii* zone into a number of subzones. It is noteworthy of mention that the different lineage forms of this taxon are not distinguished here due to the moderately to poor preservation and great similarities between these members. Of the prominent charophytes species confined to this zone are the following: *Mesochara voluta, Latochara mensinkii, Peckisphaera* sp., *Globator maillardii* and others that listed in Figures 4 & 5. The This zone is assigned here to Lower Cretaceous (Berriasian) age and could be correlated to *Globator maillardii incrassatus* zone and *Globator maillardii nurrensis* of Riveline *et al.*, 1996. It is noteworthy of mention that *Globator maillardii maillardii* zone Riveline *et al*., (1996) is not recorded in the present sequence due to the absence of its zonal taxa, that implying the unconformable nature between the Late Jurassic (Kimmeridgian) Porochara kimmeridgensis zone and the overlying Lower Cretaceous Latochara mensinkii zone. This viewpoint is confirmed also by the in-between Poorly fossiliferous Zone. Concerning the position of the Late Jurassic – Early Cretaceous boundary, due to the absence of *Globator maillardii praecursor* or *Globator maillardii* subspecies in the present material. Consequently, this boundary can yet be determined exactly by means of charophytes inasmuch as the ranges of the two taxa have not been established. Therefore this boundary is located arbitrary in the present study somewhat within the poorly fossiliferous zone, otherwise coinciding lithologically with the contact between the overlying polymictic conglomerates of the Awbari Member and the underlying coarse to medium sandstone of the Jarmah Member (denoting regressive phase). In the author opinion, the determination of exact position of the Late Jurassic – Early Cretaceous boundary within the Messak Formation awaits further studies.

Systematic Description:

The classification and the descriptive terms employed in the present work with some modifications, follows that Peck (1957) and Grambast (1974 & 1975) for Clavatoraceans as well as the more recently modified classification proposed by Martin –Closas (1989), Martin –Closas & Salas (1994), that subsequently published by Schudack (1993a, 2011, 2012). The following systematic record includes 21 charophyte species belonging to 6 genera and 4 families. Most of these species have been reported previously from other areas in the numerous studies that have been carried during the last two decades on the Mesozoic charophytes flora of Europe. In the following treatment, only the main morphological features and measurements of the examined taxa are recorded, additionally local and worldwide stratigraphic ranges are also discussed.

Division Charophyta Migula, 1890.
Class Charophyaceae G. M. Smith, 1938.
Order Charales Richard *in* Kunth, 1815.
Family Porocharaceae Grambast, 1962.
Subfamily Porocharoideae Grambast, 1961.
Genus *Porochara* Mädler, 1955 emended, Schudack, 1986
***Porochara fusca* (Mädler, 1952) Mädler, 1955**
Pl. 2, fig. 4

1955. *Porochara fusca* (Mädler). – Mädler, p.56, fig. 3.
1993a. *Porochara fusca* (Mädler) Mädler – Schudack, p.50, pl. 2, figs 1- 4.
1993b. *Porochara fusca* (Mädler) Mädler - Schudack, p. 223, figs 3 – 6, pl. 1, fig.1.
1996a. *Porochara fusca* (Mädler) Mädler - Schudack, pl. 1, fig. 1.
1998. *Porochara fusca* (Mädler) Mädler - Schudack *et al*., pl. 3, fig. 3.

Measurements:
Length averaging between 265 µm and 376 µm. Width averaging between 231µm and 265 µm. Number of convolutions 8- 9 where the width of spiral cells 36 – 48 µm.

Materials:
15 well preserved specimens and 4 broken ones are recorded.

Remarks:
This species is distinguished by its medium – sized gyrogonite and the overall shape is ellipsoidal. Rounded summit and apical opening with pentagonal shape (67- 83µm) and somewhat pointed base, the greatest diameter at midheight. Spiral cells slightly convex almost smooth. A pex closed while the basal plate of pentagonal shape (basal opening) (36- 45µm). These morphological features closely fit the original description of the holotype given by Mädler (1952) and Schudack (1996 b) from the Northwest Germany. However, the specimens under consideration showed smaller size.

Occurrences:
Porochara fusca has been recorded from various localities in the world. It is recorded from the Kimmeridgian of Northwest Germany, the Bathonian deposits of Spain and southern France. Also from the Kimmeridgian deposits of Portugal, Upper Jurassic of China, Berriasian of Sardinia and from the Tithonian – Berriasian of Spain and Switzerland. In the present material it was recorded from samples nos. 12 & 13 of Gabal Tinfore while it is occurred in samples nos. 45 & 50 of Gabal Yafart (*Porochara kimmeridgensis*) zone.

***Porochara jaccardii* (Heer, 1865) Mojon, 1989**
Pl. 2, fig. 1

1993 a. *Porochara jaccardii* (Heer) Mojon. - Schudack, p.53, pl. 3, figs 7 – 8.
1993 b. *Porochara jaccardii* (Heer) Mojon. – Schudack, p.225, fig.6, pl. 1, fig. 16.
1996a. *Porochara jaccardii* (Heer) Mojon. – Schudack, pl. 1, fig. 2.

Measurements:
Length averaging between 478 µm and 610 µm. Width averaging between 341µm and 535 µm. Number of convolutions 9 –10, where the width of spiral cells 65 - 74µm.

Materials:
18 well preserved specimens and 5 broken ones are recorded.

Remarks:
This species is distinguished by small to medium – sized gyrogonite and the ellipsoidal shape. Summit and apical opening with semi - pentagonal shape (57- 63µm) and somewhat pointed base, the greatest diameter at midheight. Spiral cells slightly convex almost smooth. Apex closed while the basal plate of pentagonal shape (basal opening) (46- 55µm). The gyrogonites show strong resemblance with *Porochara jaccardii* (Heer, 1865) Mojon (1989) in all the morphological characters that visible from the outside. However, some features in other specimens are not well observed and this is most probably due to the high degree of recrystallization of the gyrogonite.

Occurrences:

Porochara jaccardii has been recorded from different localities in the world, from the Kimmeridgian of northwest Germany, the Bathonian deposits of Spain and southern France, Kimmeridgian deposits of Portugal, Upper Jurassic of China, Berraisian of Spain and Sardinia and from the Tithonian – Berriasian of Spain and Switzerland. In the present material it was recorded from samples nos. 13 & 14 and 17 & 19 of Gabal Tinfore while it is occurred in samples nos. 45 & 48 & 50 of Gabal Yafart (Porochara kimmeridgensis zone).

Porochara kimmeridgensis (Mädler, 1952) Mädler, 1955.
Pl. 2, fig. 2.

1952. *Porochara kimmeridgensis* Mädler, p. 67, fig. 4.
1955. *Porochara kimmeridgensis* (Mädler) Mädler , p. 69, fig. 6.
1993a. *Porochara kimmeridgensis* (Mädler) Mädler - Schudack, p.52; pl. 2, fig. 8.
1996a. *Porochara kimmeridgensis* (Mädler) Mädler - Schudack, p. 31; fig. 2.
1996 b. *Porochara kimmeridgensis* (Mädler) Mädler - Schudack, pl. 1, figs 3 – 4.
1998. *Porochara kimmeridgensis* (Mädler) Mädler - Schudack *et al*., pl. 3, fig. 2.

Measurements:

Length averaging between 498 µm and 710 µm. Width averaging between 412µm and 565 µm. Number of convolutions 7- 9 where the width of spiral cells 65 – 80 µm.

Materials:

16 well preserved specimens and 5 badly preserved ones are observed.

Remarks:

The measurements, cell construction and general appearance of growth habit closely fit the holotype as illustrated and figured by Mädler (1952 & 1955). Moreover, our specimens show great similarities to the paratypes described by Feist & Schudack (1991).

Occurrences:

Porochara kimmeridgensis has a wide geographic distribution. It was originally recorded from the Oxfordian – Kimmeridgian deposits of southeast France and Switzerland; Kimmeridgian of Spain and Portugal, from Kimmeridgian – Tithonian of the USSR as well as West Germany. In the present material it was recorded in samples nos. 12 & 13 of Gabal Tinfore while it is occurred in samples nos.45 & 47 to no.50 of Gabal Yafart.

Porochara maxima (Donze, 1955) Donze, 1958
Pl. 2, fig. 3

1958. *Porochara maxima* (Donze) Donze, p. 13, fig. 4.
1993a. *Porochara maxima* (Donze) Donze. - Schudack, p.53, pl. 2, figs 11- 12.
1996a. *Porochara maxima* (Donze) Donze. - Schudack, p. 31, fig. 3.
1996b. *Porochara maxima* (Donze) Donze. – Schudack, pl. 1, figs 5 – 6.
1998. *Porochara maxima* (Donze) Donze. - Schudack *et al*., pl. 3, fig. 3.

Measurements:

Length averaging between 498 µm and 710 µm. Width averaging between 412 µm and 565 µm. Number of convolutions 7- 9 where the width of spiral cells 65 – 80 µm.

Materials:

12 well preserved specimens and 3 broken ones.

Remarks:

The gyrogonite of this species is distinguished by its typically cylindrical (ellipsoidal) with seven to eight sinisterly convex to flat spiraled cells, visible in lateral view. These cells are ascending to a truncate apical area. The cell ends are weakly calcified with flat apical area, and superficial basal opening with visible basal plate.

Occurrences:

Porochara maxima has a wide geographic distribution. It was originally recorded from the Oxfordian – Kimmeridgian deposits of southeast France and Switzerland; Kimmeridgian of Spain and Portugal, from Kimmeridgian – Tithonian of the USSR as well as West Germany. In the present material it was recorded in samples nos. 49 & 50 of Gabal Yafart and showed higher startigraphic level unlike that recorded before, but it is not recorded in Gabal Tinfore.

Porochara minima (Mädler, 1952) Shaikin, 1976

1952. *Porochara minima* (Mädler), p. 5, pl. 4, fig. 7.
1976. *Porochara minima* (Mädler) Shaikin., p. 12, fig. 4.
1993a. *Porochara minima* (Mädler) Shaikin. - Schudack, p.50 – 51, pl. 2, figs 5- 6.
1996a. *Porochara minima* (Mädler) Shaikin. - Schudack, p. 30, fig. 3.
199b. *Porochara minima* (Mädler) Shaikin. – Schudack, pl. 1, figs 5 – 7.
1998. *Porochara minima* (Mädler) Shaikin. - Schudack *et al*., pl. 3, fig. 4.

Measurements:

Length averaging between 260 µm and 3300 µm. Width averaging between 150 µm and 265 µm. Number of convolutions 8- 10, where the width of spiral cells 35 – 42 µm.

Materials:

21 well preserved specimens and 8 broken ones.

Remarks:

Gyrogonite is cylindrical to ellipsoidal shape with visible spiraled cells in lateral view. These cells are ascending to a truncate apical area. The cell ends are weakly calcified with apical area, and superficial basal opening with visible basal plate. Our specimens differ from the holotype that described by Schudack (1993a) in the number of the convolutions, however, the rest of the other morphological features are typical recorded.

Occurrences:

Porochara minima has been recorded from Late Jurassic (Kimmeridgian) deposits of NW Germany, from Oxfordian - Kimmeridgian of south central and southeastern France, Switzerland, Berriasian of Portugal, Spain, and Sardinia and Kimmeridgian – Tithonian of the USSR as well as from Kimmeridgian of northeast Germany. In the present material it was recorded in samples nos 13 & 19 of Gabal Tinfore while it is occurred in samples nos 49 & 50 of Gabal Yafart and recorded in *Porochara kimmeridgensis* zone

Porochara westerbeckensis (Mädler, 1952) Mädler, 1955.
Pl. 2, fig. 5.

1952. *Porochara westerbeckensis* Mädler, p. 9, fig. 5.
1955. *Porochara westerbeckensis* (Mädler) Mädler, p. 6, fig. 8.
1993a. *Porochara westerbeckensis* (Mädler) Mädler. - Schudack, p.53 , pl. 3, fig. 6.
1993b. *Porochara westerbeckensis* (Mädler) Mädler. - Schudack, p. 219, pl. 1, fig.12.
1996a. *Porochara westerbeckensis* (Mädler) Mädler. – Schudack, p. 31; fig. 4.
1998. *Porochara westerbeckensis* (Mädler) Mädler. - Schudack *et al*., pl. 1, fig.9.

Measurements:

Length averaging between 564 µm and 830 µm. Width averaging between 550 µm and 665 µm. Number of convolutions 8- 10, where the width of spiral cells 45 – 92 µm.

Materials:

23 well preserved specimens and 9 broken ones.

Remarks:

This taxon is characterized by its oblate gyrogonite with depressed and flat summit. Basal area is flat to rarely sunken. Four to six convex usually planar, spirals are visible in lateral view. Apical opening is with deep cog - wheel shaped furrow. Small basal pore encircled with sutures. The specimens under consideration show a great resemblance to the holotype that was figured and described by Mädler (1952) in the deep furrow surrounding the apical opening as well as the low number of spirals. However, our specimens have slightly smaller dimensions and are externally flattened.

Occurrences:

Porochara westerbeckensis has been recorded from Late Jurassic (Kimmeridgian) deposits of NW Germany, from Oxfordian - Kimmeridgian of south central and southeastern France, Switzerland, from

Kimmeridgian of Portugal and Spain. Kimmeridgian – Tithonian of the USSR as well as from Kimmeridgian of northeast Germany. In the present material it was recorded in samples nos 13, 14 & 19 of Gabal Tinfore while it is occurred in samples nos.49 & 50 of Gabal Yafart. It is recorded in both of *Echinochara peckii* and *Porochara kimmeridgensis* zones.

Subfamily Nitelloideae Ganterer, 1847 emend. Schudack, 1993
Class Stellatochareae Grambast, 1962 emend, Schudack, 1993
Genus *Latochara* Mädler, 1955, emend, Feist, 1984
***Latochara latitruncata* (Peck, 1937) Mädler, 1955**
Pl. 2, fig. 6.

1955. *Latochara latitruncata* (Peck) - Mädler, p. 43, fig. 5.
1993a. *Latochara latitruncata* (Peck) Mädler – Schudack, p.56; pl. 4, figs. 1- 4.
1993b. *Latochara latitruncata* (Peck) Mädler – Schudack, p. 219 –223; pl.1, fig. 13.
1996a. *Latochara latitruncata* (Peck) Mädler – Schudack, pl. 1, fig. 11.
1998. *Latochara latitruncata* (Peck) Mädler – Schudack *et al*., p. 31; pl. 3, fig. 7.

Measurements:
Length averaging between 390 µm and 500µm. Width averaging between 350 µm and 465 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:
15 well preserved specimens and 6 badly preserved ones are recorded.

Remarks:
Gyrogonite typically ellipsoid with tapering to flat summit. Basal area is flat to rarely sunken. Four to six concave usually planar, spirals are visible in lateral view. Apical opening is with deep cog - wheel shaped furrow. Small basal pore encircled with sutures. The specimens under consideration show a great resemblance to the holotype that was figured and described by Mädler (1955) in the deep furrow surrounding the apical opening as well as the low number of spirals. However, our specimens have slightly smaller dimensions and are externally flattened.

Occurrences:
Latochara latitruncata has been recorded from Kimmeridgian deposits of Portugal and Spain, from Late Jurassic (Kimmeridgian) deposits of NW Germany, from Oxfordian - Kimmeridgian of south central and southeastern France, Switzerland. Kimmeridgian – Tithonian of the USSR as well as from Kimmeridgian of northeast Germany. In the present material it was recorded in samples no. 13 of Gabal Tinfore while it is occurred in samples no. 45 to no.50 of Gabal Yafart

***Latochara mensinkii* Schudack, 1990**
Pl. 2, fig. 7.

1990. *Latochara mensinkii* Schudack, p. 234, fig. 4.
1993a. *Latochara mensinkii S*chudack – Schudack, p.57 – 54, pl. 4, figs. 9- 12.
1993b. *Latochara mensinkii S*chudack – Schudack, p. 219 – 223; pl.1, fig.14.
1996a. *Latochara mensinkii S*chudack – Schudack, p. 34, fig. 6.
1998. *Latochara mensinkii S*chudack – Schudack *et al*., pl. 1, figs 14 – 15.

Measurements:
Length averaging between 260 µm and 430 µm. Width averaging between 210 µm and 365 µm. Number of convolutions 8- 9, where the width of spiral cells 35 – 52 µm.

Materials:
20 well preserved specimens and 5 are slightly broken ones are observed.

Remarks:
This taxon is distinguished in the present material by its small to medium gyrogonites of ellipsoidal shape with sharp and narrow spiral ridges, spiral ends joining on the slightly protruding apex with visible basal plug at the basal part. The present specimens are quite similar in shape and size to those described from Northwest

Germany by Schudack (1996a) and Schudack (1996 b), However, the apical and basal pores in the present specimens appear to be smaller.

Occurrences:

Latochara mensinkii has been recorded from Early Cretaceous (Berriasian) deposits of NW Germany, from Berriasian of south central and southeastern France, Switzerland, and from Berriasian of Portugal and Spain. As well as from Early Cretaceous (Berriasian) of Northeast Germany. So it is diagnostic species for the Early Cretaceous (SCHUDACK, 1996 b) In the present material it was recorded in samples no. 28 & 33 of Gabal Tinfore while it is occurred in samples nos. 57 & 58 & 65 of Gabal Yafart

Family *Nitelleae* Braun & Migula, 1890 emend, Schudack, 1993
Genus *Aclistochara* Peck, 1937 emend, Schudack, 1993
***Aclistochara bransonii* Peck, 1937**
Pl. 2, fig. 8.

1993a. *Aclistochara bransonii* Peck – Schudack, p.59 – 60, pl. 5, figs 13- 18.
1996a. *Aclistochara bransonii* Peck – Schudack, pl. 1, figs 16 – 17.
1998. *Aclistochara bransonii* Peck – Schudack *et al*., p. 3, fig. 11.

Measurements:

Length averaging between 290 µm and 320 µm. Width averaging between 250 µm and 265 µm. Number of convolutions 8- 9, where the width of spiral cells 35 – 40 µm.

Materials:

15 well preserved specimens and 7 slightly crushed ones are recorded.

Remarks:

Gyrogonite of small to medium size, consists mostly of spherical to elliptical form, where the greatest diameter slightly above the midheight. Spiral cells are visible in lateral view mostly of convex shape, rounded summit to flat but the basis is slightly pointed or tapering. The present specimens are quite similar in shape and size to those described by Schudack (1993a) and Schudack (1996 b, 2012), however, the present specimens differ in the number of convolutions and the basal plate.

Occurrences:

Aclistochara bransonii has been recorded from Late Jurassic (Kimmeridgian) deposits of NW Germany and Morrison Formation of USA as well as China, from Oxfordian of south central and southeastern France, Switzerland, from Kimmeridgian of Portugal and Spain. Kimmeridgian – Tithonian of the USSR as well as northeast Germany. In the present material it was recorded in samples no. 28 of Gabal Tinfore while it is occurred in samples no. 58 and 61 of Gabal Yafart

***Aclistochara minor* Schudack, 1990**
Pl. 2, fig. 9.

1990. *Aclistochara minor* Schudack, p. 209, fig. 4.
1993a. *Aclistochara minor* Schudack – Schudack, p.60; pl. 5, figs 10 –12.
1996a. *Aclistochara minor* Schudack Schudack, p. 35, pl. 1, fig. 13.

Measurements:

Length averaging between 230 µm and 265 µm. Width averaging between 165 µm and 210 µm. Number of convolutions 7- 9, where the width of spiral cells 30 – 45 µm.

Materials:

17 well preserved specimens and 4 broken ones.

Remarks:

Gyrogonite of very small size, consists mostly of ellipsoidal form, where the greatest diameter slightly above the midheight. Spiral cells are visible in lateral view mostly of convex shape, rounded summit to flat but the basis is slightly pointed or tapering. The present specimens are quite similar in shape and size to those described by Schudack (1993a) and Schudack (1996a). Moreover, the present specimen also shows great resemblance to *Aclistochara bransonii* Peck (1937) but it differs in the number of convolutions.

Occurrences:

Aclistochara minor Schudack has been recorded from Late Jurassic (Kimmeridgian) deposits of NW Germany, from Oxfordian - Kimmeridgian of south central and southeastern France, Switzerland, Kimmeridgian of northeast Germany. In the present material it was abundantly recorded in sample no. 28 of Gabal Tinfore while it is occurred in samples no. 57 and 58 in Gabal Yafart

Aclistochara polyspirata Mädler, 1952
Pl. 2, fig. 10.

1952. *Aclistochara polyspirata* Mädler, p. 35, fig. 5.
1993a. *Aclistochara polyspirata* Mädler – Schudack, p.60 – 61, pl. 5,figs 5 – 7.
1996a. *Aclistochara polyspirata* Mädler – Schudack, p. 35, fig. 12.
1996b. *Aclistochara polyspirata* Mädler – Schudack, pl. 2, fig. 1.

Measurements:

Length averaging between 310 µm and 320 µm. Width averaging between 210 µm and 265 µm. Number of convolutions 9- 10, where the width of spiral cells 35 – 40 µm.

Materials:

19 well preserved specimens and 5 are slightly crushed ones are recorded.

Remarks:

The specimens are entirely consistent in the morphological features and dimensions with the paratypes described and figured by Mädler (1952) and Schudack (1993a) from the Late Jurassic (Kimmeridgian) deposits of NW Germany but our figured specimens show slightly smaller apical and basal pores. Its large numbers of spiral cells commonly recognizes this species.

Occurrences:

Aclistochara polyspirata Mädler has been recorded from Late Jurassic (Kimmeridgian) deposits of NW Germany, from Oxfordian - Kimmeridgian of south central and southeastern France, Switzerland, from Kimmeridgian – Berriasian of Portugal and Spain. Kimmeridgian – Tithonian of the USSR as well as from Kimmeridgian of northeast Germany. In the present material it was recorded in samples no. 28 & 29 of Gabal Tinfore while it is occurred in samples no. 58 to no. 59 of Gabal Yafart

Aclistochara sp.

Measurements:

Length averaging between 290 µm and 350 µm. Width averaging between 150 µm and 260 µm. Number of convolutions 7- 9, where the width of spiral cells 35 – 45 µm.

Materials:

18 well preserved specimens and 4 crushed ones.

Remarks:

The material under consideration is represented by small slightly crushed gyrogonites oblate with depressed and flat summit where the basal area is slightly pointed to rarely flat with seven to nine spiral cells are visible in lateral view. The relatively poor state of preservation prevents the specific attributions.

Occurrences:

In the present material it was recorded in samples no. 28 & 29 of Gabal Tinfore while it is occurred in samples no. 57 to no. 60 of Gabal Yafart

Family _Characeae_ Richard & Agardh, 1824 emended, Martin – Closas & Schudack, 1991
Genus _Mesochara_ Grambast, 1962
Mesochara canellata (Mädler, 1952) Shaikin, 1967
Pl. 2, fig. 11.

1952. *Mesochara canellata* Mädler, p.37, fig. 6.

1967. *Mesochara canellata* (Mädler)- Shaikin, p. 45, fig. 6.
1993a. *Mesochara canellata* (Mädler)- Shaikin - Schudack, p.62 –63; pl. 6, figs. 1- 3.
1996a. *Mesochara canellata* (Mädler)- Shaikin - Schudack, p. 35; fig.15.
1998. *Mesochara canellata* (Mädler)- Shaikin - Schudack *et al*., pl. 2, fig. 4.

Measurements:

Length averaging between 390 µm and 500 µm. Width averaging between 350 µm and 465 µm. Number of convolutions 8- 12, where the width of spiral cells 45 – 54 µm.

Materials:

21 well preserved specimens and 5 broken ones.

Remarks:

The specimens under consideration demonstrate a great resemblance in shape, dimensions and spiral cells to the holotype originally figured and described by Shaikin (1967) and Schudack (1993a) This species is distinguished generally by its oblate gyrogonite with depressed and flat summit while its basal area is flat to rarely sunken. Eight to twelve concave usually planar, spirals are visible in lateral view. Apical opening is with deep cog - wheel shaped furrow.

Occurrences:

Mesochara canellata has been recorded from Late Jurassic (Tithonian) deposits of NE Germany, from Kimmeridgian – Berriasian of south central and southeastern France, Switzerland, from Kimmeridgian of Portugal and Spain. Kimmeridgian – Tithonian of the USSR as well as from Kimmeridgian - Berriasian of northwest Germany. In the present material it is recorded in samples nos. 32 & 33 of Gabal Tinfore while it is occurred in samples no. 59 to no.61 of Gabal Yafart

Mesochara harrisii (Mädler, 1952) Shaikin , 1967

1967 *Mesochara harrisii* (Mädler) Shaikin, p. 43, fig. 8.
1993a. *Mesochara harrisii* (Mädler) Shaikin- Schudack, p.63 – 64, pl. 6, figs. 4- 9.
1996a. *Mesochara harrisii* (Mädler) Shaikin- Schudack, p. 31; fig. 4.
1998. *Mesochara harrisii* (Mädler) Shaikin- Schudack *et al*., pl. 2, figs. 5 – 7.

Measurements:

Length averaging between 390 µm and 500 µm. Width averaging between 350 µm and 465 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:

18 well preserved specimens and 5 broken ones are rcorded.

Remarks:

Gyrogonite oblate with depressed and flat summit. Basal area is flat to rarely sunken. Four to six concave usually planar, spirals are visible in lateral view. Apical opening has deep cog - wheel shaped furrow. Small basal pore encircled with sutures.

Occurrences:

Mesochara harrisii has been recorded from Late Jurassic (Kimmeridgian) deposits of NW Germany, from Berriasian of south central and southeastern France, Switzerland, from Lower Cretaceous (Barremian) of Portugal, Spain and China. Kimmeridgian – Tithonian of the USSR as well as from Kimmeridgian of Northeast Germany. In the present material it was recorded in samples no. 19 to 28 of Gabal Tinfore while it is occurred in samples no. 63 to no. 65 of Gabal Yafart

Mesochara voluta (Peck, 1937) Grambast, 1965
Pl. 2, fig. 12.

1965. *Mesochara voluta* (Peck) Grambast, p. 32
1993a. *Mesochara voluta* (Peck) Grambast. – Schudack, p.53 - 54, pl. 3, figs. 1- 6.
1993b. *Mesochara voluta* (Peck) Grambast. – Schudack, p. 219 –223. Pl.2, figs 1 –2.
1996a. *Mesochara voluta* (Peck) Grambast. – Schudack, p. 31, fig. 5.
1998. *Mesochara voluta* (Peck) Grambast. – Schudack *et al*., pl. 2, fig. 8.

Measurements:

Length averaging between 390 µm and 500 µm. Width averaging between 350 µm and 465 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:

25 well preserved specimens and 7 broken ones are recorded.

Remarks:

Gyrogonite medium – sized, subcylindrical, the greatest diameter slightly above the midheight (ellipsoidal), rounded base, spiral cells slightly convex at most of the gyrogonite, becoming weekly calcified and concave at the summit, basal plate unknown.

Occurrences:

Mesochara voluta (Peck) has been recorded from Kimmeridgian - Berriasian deposits of NW Germany, from Kimmeridgian of south central and southeastern France, Switzerland, Berriasian - Barremian of Portugal, Spain and China. Kimmeridgian – Tithonian of the USSR as well as from Berriasian of Northeast Germany. In the present material it was recorded in samples nos. 13 & 14 of Gabal Tinfore while it is occurred in samples no. 59 to no. 60 of Gabal Yafart

Mesochara sp.

Measurements:

Length averaging between 390 µm and 500 µm. Width averaging between 350 µm and 465 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:

10 well preserved specimens and 3 broken ones

Remarks:

The gyrogonite is very poorly preserved, thus our determination must be considered with great care. Most of the characters visible and the dimensions measured fall well within the variability of a nodular *Mesochara* species, comparable with other described by various authors from the Early Cretaceous of Germany.

Occurrences:

In the present material it was recorded in samples no. 32 of Gabal Tinfore while it occurred in samples no. 59 to no. 60 of Gabal Yafart

Genus *Peckisphaera* Grambast, 1962
***Peckisphaera verticillata* (Peck, 1937) Grambast, 1962**
Pl. 2, fig. 13.

1962. *Peckisphaera verticillata* (Peck) Grambast, p. 78.
1993a *Peckisphaera verticillata* (Peck) Grambast. – Schudack, pl. 14, figs. 14 – 33.
1996a. *Peckisphaera verticillata* (Peck) Grambast. – Schudack, pl. 2, figs 13 – 15.
2001. *Peckisphaera verticillata* (Peck) Grambast. – Luger & Schudack , figs 3-4.

Measurements:

Length averaging between 260µm and 300 µm. Width averaging between 180 µm and 215 µm. Number of convolutions 9 - 10, where the width of spiral cells 25 – 34 µm.

Materials:

17 well preserved specimens and 4 broken ones are recorded.

Remarks:

Gyrogonite of small to medium size, spherical to elliptical, with rounded bases and slightly pointed summits. Greatest diameter slightly above the midheight. Spiral cells mostly convex, in some cases flat. The specimens under consideration show a great resemblance to the holotype that was figured and described by Grambast (1962) and the paratypes figured by Luger & Schudack (2001) in the deep furrow surrounding the apical opening as well as the low number of spirals. However, our specimens have slightly smaller dimensions and are externally flattened.

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Occurrences:

Peckisphaera verticillata has been recorded from the Upper Jurassic to the Upper Cretaceous in many parts of the world It is therefore without any biostratigraphic value. In the present material it was recorded in samples nos. 28 & 29 of Gabal Tinfore while it is occurred in samples nos. 58 & 59 of Gabal Yafart

Family Clavatoraceae Pia, 1927 emend, Schudack, 1993
Subfamily Clavatorodeae Pia emend, Martin – Closas, 1989.
Genus *Clavator* Reid & Groves, 1916 emend, Schudack, 1993
***Clavator reidii* Groves, 1924 emend, Schudack, 1993**
***Clavator reidii reidii* (Groves, 1924) Martin–Closas, 1989 emend, Schudack, 1993**
Pl. 2, fig. 14.

1989. *Clavator reidii reidii* (Groves). Martin – Closas, p. 56, fig. 6.

1993a. *Clavator reidii reidii* (Groves) Schudack - Schudack, p.75; pl. 9, figs. 1- 7. 1995. *Clavator reidii reidii* (Groves) Schudack - Feist *et al*., p. 415 , pl.1, figs. 9 –13. 1996a. *Clavator reidii reidii* (Groves) Schudack - Schudack, p. 39, fig. 18.

1998. *Clavator reidii reidii* (Groves) Schudack - Schudack *et al*., pl. 2, figs 11 – 12.

Measurements:

Length averaging between 390 µm and 500 µm. Width averaging between 350 µm and 465 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:

16 well preserved specimens and 4 broken ones are recorded.

Remarks:

The measurements, cell construction and general appearance of growth habit closely fit the holotype as illustrated and figured by Groves (1924), Martin – Closas (1989), Martin – Closas & Schudack (1991, 1996) and Schudack (1996 a). Moreover, our specimens show great similarities to the paratypes described by Feist *et al*., (1995) from Lower Cretaceous (Berriasian) deposits of NW Germany and also from Berriasian of south central and southeastern France.

Occurrences:

Clavator reidii reidii has been recorded from Lower Cretaceous (Berriasian) deposits of NW Germany, from Berriasian of south central and southeastern France, Switzerland, from Berriasian of Portugal and Spain, as well as from Berriasian of Northeast Germany. In the present material it was recorded in samples nos. 28 & 29 of Gabal Tinfore while it is occurred in samples no.58 to no. 59 of Gabal Yafart

***Clavator grovesii* (Harris, 1939) emend, Schudack, 1993**
***Clavator grovesii discordis* (Shainkin, 1967), Schudack, 1993a**

1993a. *Clavator grovesii discordis* (Shainkin) Schudack- Schudack, p.77, pl. 9,fig.15.
1995. *Clavator grovesii discordis* (Shainkin) Schudack- Schudack *et al*., p.419, pl.2, fig. 5.
1996a. *Clavator grovesii discordis* (Shainkin) Schudack- Schudack, p. 39; fig. 20.
1998. *Clavator grovesii discordis* (Shainkin) Schudack- Schudack *et al*., pl. 2, fig. 14.

Measurements:

Length averaging between 530 µm and 610 µm. Width averaging between 410 µm and 565 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:

19 well preserved specimens and 3 broken ones are recorded.

Remarks:

Gyrogonite oblate with depressed and flat summit. Basal area is flat to rarely sunken. Four to six concave usually planar, spirals are visible in lateral view. Apical opening is with deep cog - wheel shaped furrow. Small basal pore encircled with sutures.

Occurrences:

Clavator grovesii discordis has been recorded from Lower Cretaceous (Berriasian) deposits of NW Germany, from Berriasian of south central and southeastern France, Switzerland, from Berriasian of Portugal

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and Spain, as well as from Berriasian of Northeast Germany. In the present material it was recorded in samples no. 28 of Gabal Tinfore while it is occurred in samples no. 57 to no. 58 of Gabal Yafart

Subfamily Atopocharoideae Peck emend, Schudack, 1993
Genus *Echinochara* Peck, 1957 emend, Schudack, 1993
***Echinochara peckii* (Mädler, 1952) Grambast, 1965 emend, Schudack, 1993**
Pl. 2, fig. 15.

1965. *Echinochara peckii* (Mädler) Grambast, p. 43, fig. 5.
1993a. *Echinochara peckii* (Mädler) Grambast- Schudack, p.93, pl. 13, fig. 19.
1996a. *Echinochara peckii* (Mädler) Grambast- Schudack, p. 39, fig. 21.
1996b. *Echinochara peckii* (Mädler) Grambast- Schudack, pl. 3, figs. 15 – 16.

Measurements:
Length averaging between 690 µm and 710 µm. Width averaging between 390 µm and 415 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:
19 well preserved specimens and 5 broken ones are recorded.

Remarks:
In characters, this species is similar to *Echinochara peckii* (Mädler, 1952) (Grambast,1965) from Late Jurassic (Kimmeridgian) deposits of NW Germany and north America, but differ in its wider upper part, nearly sharper top. This species is commonly recorded in the lower part of the two studied sections.

Occurrences:
Echinochara peckii has been recorded from Late Jurassic (Kimmeridgian) deposits of NW Germany and north America, from Oxfordian of south central and southeastern France, Switzerland, from Barremian of Portugal and Spain. Kimmeridgian – Tithonian of the USSR as well as from Kimmeridgian of Northeast Germany. In the present material it was frequently recorded in samples nos. 16 & 17 of Gabal Tinfore while it is not occurred in the studied samples of Gabal Yafart

***Genus Atopochara* Peck, 1938**
***Atopochara trivolvis* Peck, 1938 emend, Martin–Closas, 1989**
***Atopochara trivolvis horrida* (Harris, 1939) emend, Martin–Closas, 1989**

Pl. 2, fig. 16.
1989. *Atopochara trivolvis horrida* **(**Harris) - Martin–Closas, p. 65, fig. 7.
1993a. *Atopochara trivolvis horrida* **(**Harris) Martin–Closas -Schudack, p.103, pl.15, fig. 5.
1996a. *Atopochara trivolvis horrida* (Harris) Martin–Closas -Schudack, p. 40, fig. 24.
1996. *Atopochara trivolvis horrida* **(**Harris)Martin–Closas -Schudack *et al*., pl. 2, fig. 19.
1998. *Atopochara trivolvis horrida* (Harris) Martin–Closas -Schudack *et al*., pl. 3, fig. 9.
2006. *Atopochara trivolvis horrida* (Harris) Martin–Closas –Schudack, p.423, fig. 2.

Measurements:
Length averaging between 790 µm and 900 µm. Width averaging between 670 µm and 865 µm. Number of convolutions 8- 9, where the width of spiral cells 45 – 54 µm.

Materials:
17 well preserved specimens and 3 broken ones are recorded.

Remarks:
Small sized - gyrogonite possessing three rayed symmetry each consisting of short vertical units originating near the basal opening and ascending to the equatorial plane. This unit possesses as well one short right-handed cell and tow longer cell. Sinisterly spiralled cells extending which are surrounded by crests of three cells. These morphological characters closely fit the original description of the holotype given by Martin – Closas (1989) and Schudack (1999, 2002). However our specimens show smaller sizes.

Occurrences:
Atopochara trivolvis horrida has been recorded from Berriasian of NW Germany and England, from Berriasian of south central and southeastern France, Switzerland, from Berriasian of Portugal and Spain. as well

as from Berriasian of Northeast Germany. In the present material it was recorded in samples nos.34 &35 of Gabal Tinfore while it is occurred in samples nos. 64 & 65 of Gabal Yafart

Plate 2

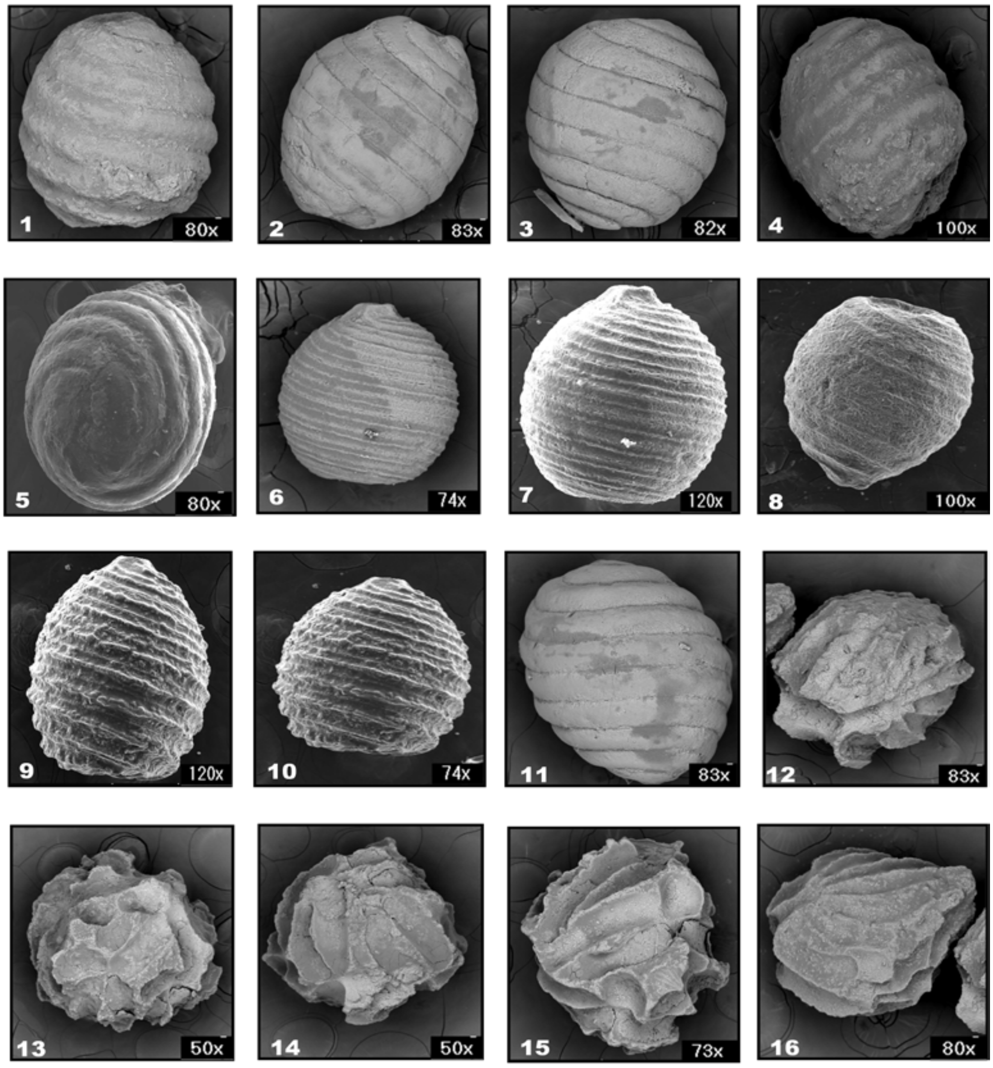

Plate 2

Fig. 1: *Porochara jaccardi* (Heer) Mojon; sample 88 Gabal Yafarat.
Fig. 2. *Porochara kimmeridgensis* (Mädler) Mädler; sample 8, Gabal Tinfore.
Fig. 3. *Porochara maxima* (Donze) Donze ; sample 69, Gabal .
Fig. 4. *Porochara fusca* (Mädler); sample 20, Gabal Tinfore.
Fig. 5. *Porochara westerbeckensis* (Mädler) Mädler; sample 88, Gabal Tinfore
Fig. 6: *Latochara latitruncata* (Peck) Mädler; sample 41, Gabal Yafarat,
Fig. 7: *Latochara mensinkii* Schudack; sample 88, Gabal Tinfore.
Fig. 8. *Aclistochara bransonii* Peck; sample 69, Gabal Tinfore.
Fig. 9: *Aclistochara minor* Schudack; sample 87, Gabal Tinfore.
Fig. 10: *Aclistochara polyspirata* Mädler; sample 69, Gabal Tinfore.
Fig. 11: *Mesochara cancellata* Schudack; sample 87, Gabal Tinfore.
Fig. 12: *Mesochara voluta* (Peck) Grambast; sample 87, Gabal Tinfore.
Fig.13: *Peckisphaera verticillata* (Peck), sample 41,Gabal Yafarat.
Fig. 14. *Clavator reidii reidii* (Groves) Martin – Closas; sample 88, Gabal Tinfore.
Fig. 15: *Echinochara peckii* (Mädler) Grambast; sample 41,Gabal Yafarat
Fig. 16: *Atopochara trivolvis horrida* (Harris); sample 41,Gabal Yafarat

Depositional Environment Of The Messak Formation:

From the foregoing lithostratigraphic description of the Messak Formation, it could be stated that this formation is characterized mostly by dominance of fluvial regime overlapped by shallow marine facies and this depicted through the vertical and lateral distribution of its lithofacies types in the studied area. In details, the depositional evolution of this rock unit could be established as follows: toward the end of the Middle Jurassic time an intense tectonic event took place resulted in the elevation of Tilsmen Formation in many parts in southern Libya (Selley, 1985) and by the advent of the Late Jurassic time, the Messak Formation started to deposited beginning with the Jarmah Member that uncoformably overlies the Middle Jurassic. This tectonic movement and the uplifting of the area resulted in the prevalence of continental regime that coupled with accumulation of fluvial sediments all over the study area and. It is also accompanied by high rate of erosion that supplied the coarse clastic (basal polymictic conglomerates). This polymictic conglomerate lithofacies type suggested regressive proximal alluvial-braided planes were developed during the early deposition of Jarmah Member. This conglomerate lithofacies graded laterally and vertically to distal plane sandstones lithofacies. The siltstone, mudstone and sandy dolomite beds were deposited by the first transgressive (marine incursion) of the Tethyan seaway. These deposits were also repeated for three times indicating the fluctuation of the sea level and this could be attributed to a tectonic pulses related to that Middle – Upper Jurassic tectonic uplift but of small magnitudes. Subsequently, towards the close of the Late Jurassic (Kimmeridgian) time, the area has been affected by another intense tectonic movement that caused the withdraw of the Tethyan seaway from the study area, giving rise to the second regression phase and this is best shown in the basal polymictic conglomerates and pebbly sandstone lithofacies that marking the Late Jurassic – Early Cretaceous unconformable contact. The Early Cretaceous Awbari Member begins to accumulate, where meandering river systems covered the entire region. This give rise to thick clastic sequence of cross – bedded sandstone. The lithofacies types in this sediments showed that the sandstone lithofacies dominated the other siltstone / mudstone one. These alluvial conditions continued and in some cases accompanied and interrupted with short transgressive periods depicted in the deposition of tidal flats siliciclastic deposits (mudstone and siltstone) that in turn intertongued with tidal marshes – coastal swamp carbonaceous shale that indicate slight fall in the sea level. At the close of the Messak deposition the Tethyan seaway retreated from the study area as well as the whole southern parts of Libya (Selley, 1985) giving rise to the deposition of the Early Cretaceous (Cenomanian) Ain Tobi Limestone (Christie, 1955; Antonovic, 1985).

Conclusion:

The exposed Late Jurassic – Early Cretaceous sequence of Messak Formation Northwestern part of Murzuq Basin, Libya has been analyzed for its non- marine charophytes and ostracodes for the first time. Two stratigraphic surface sections, namely; Gabal Tinfore and Gabal Yafarat with additional section from Gabal Awbari, are described and investigated. The Messak Formation is approximately 160m thick, unconformably overlies the Middle Jurassic Tilemsin Formation and unconformably underlies the Quaternary deposits. This formation is divisible into two main members in ascending order: 1- Jarmah Member and 2- Awbari Member. These two members are widely exposed and distributed in the study area. The lithological studies of these two members showed the presence of five main lithofacies types, they are mainly: 1 – Polymictic conglomerates 2 – Sandstone 3- siliciclastic 4- arenaceous carbonate 5- black shale. These lithofacies types commonly showed depositional environments ranged from proximal to distal alluvial braided plains, meandering rivers, tidal flats and restricted tidal marsh – coastal swamps Otherwise, these lithofacies types are mostly deposited under fluvial conditions with minor marine incursions. Based on the stratigraphic distribution of the charophyte and ostracodes taxa, the Messak Formation could be subdivided into four local charophytes assemblage zones. These biozones arranged from base to top as follows: 1- Echinochara peckii assemblage zone of Late Jurassic age (Late Oxfordian) 2- Porochara kimmeridgian zone of Late Jurassic age (Kimmeridgian) 3- Poorly fossiliferous zone and 4- Latochara mensinki zone of Lower Cretaceous (Berriasian) age. The absence of the Tithonian charophytes diagnostic microflora such as *Latochara collina* and *Perimmeste horrida* as well as the earliest Early Cretaceous *Globator* lineage in the studied sequence suggests that unconformable relationship between the Late Jurassic and the Early Cretaceous deposits. This boundary is thought to lie between the Late Jurassic Jarmah Member and the Early Cretaceous Awbari one. The systematic study these microflora, based mainly on the works of Martin–Closas (1989) and Schudack (1993, 1996), Schudack *et al*. (2013) allowed the identification and description of twenty-four charophyte species belonging to eight genera and six families. These taxa are figured for the first time using the help of Scanning Electron Microscope SEM and mounted in one plate.

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