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Late Cretaceous Muwaqqar Formation Ammonites in Southeastern Jordan

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Abstract

Three Maastrichtian ammonite species belonging to two families, were recorded in the upper part of Muwaqqar Formation (MCM). Two planispiral species belong to the family, namely, Sphenodiscidae, Sphenodiscus lobatus and Libycoceras ismaeli while the third, straight species, belongs to Baculitidae family; Baculites sp. The Paleocene strata are represented by 6 m in the measured section below the Rijam Formation. This might indicate a long erosional unconformity at the end of the MCM which was documented by other workers several tens of kilometers west of the study area. The erosional unconformity is also supported by the presence of tree trunks at the Muwaqqar-Rijam formations contact. Microfacies analysis indicates that the upper Muwaqqar Formation in the Jebal Khuzayma area was deposited in an offshore, open marine conditions affected by upwelling currents. This is evidenced by the abundant planktonic fauna exceeding benthic fauna, the abundant matrix represented by lime mudstone, and the relatively high phosphate particles and organic matter.

Keywords: Ammonites, microfacies, Muwaqqar Formation, Jebal Khuzayma, southeastern Jordan.

1. Introduction

The Muwaqqar Formation (MCM) crops out extensively towards the eastern parts of the Jordanian plateau and covers wide areas east of the Desert Highway, the Risha area and the extreme northern Jordan (Bender, 1974; Powell, 1989; Abed, 2000). It consists of a uniform soft chalk - marl material throughout its thickness all over the country where the famous oil shale deposits of Jordan occupy its lower part. The age of the MCM is Maastrichtian – Paleocene (Yassini, 1979; Powell, 1988).

During the deposition of the MCM, the Jordan and the adjacent areas witnessed a major marine transgression transforming the area into the outer continental shelf (Powell and Moh'd, 2011). Thus, the MCM was deposited in a pelagic environment evidenced by the abundant planktonic foraminifera especially in northern Jordan (e.g. Yassini, 1979). The formation of the oil shale seems to have been associated with cold, deep upwelling currents from the Neo-Tethys onto the area which fertilized the photic zone water with nutrients and enhanced bioproductivity and thus organic matter deposition (Abed and Amireh, 1983; Almogi-Labin et al, 1993; Abed, 2013).

Ammonite studies in Jordan are rather limited. Al-Harithi and Ibrahim (1992) had studied four cephalopod species from the Maastrichtian of Wadi Usaykhim outcrop section, Al Azraq area in east Jordan. One species is new: *Eutrephoceras azraqensis*. The other three taxa are *Sphenodiscuss* cf. *lobatus*, *Libycoceras ismaeli* and *Baculites ovatus*. Nazzal and Mustafa (1993) had studied the Upper Cretaceous ammonites from north Jordan. They described the genera *Acanthoceras*, *Neolobites*, *Baculites*, *Pseudoshloenbachia*, *Pachydiscus* and *Libycoceras* from the Wadi Shueib, Wadi As Sir Limestone, Wadi Umm Ghudran, Amman Silicified Limestone and Muwaqqar formations. Makhlouf et al. (1996) had studied the Ajlun group in three sites in Jordan; they found some ammonites species in two sites, Ras en Naqab section: aff *Metoiceras* sp., and Wadi ben Hammad section: *Vascoceras* aff. Cf. *cauvini,* aff *Schloenbachia* spp., aff *Tropitiodes* sp., *Neolobites* sp., aff *vascoceras* spp. These ammonites are older than those of the study area because they all belong to the Ajlun Group.

The study area is located at Jebal Khuzayma, (30 º 33` N, 36 º 20` E) in south eastern Jordan (Fig. 1). The study area is situated 160 km (aerial) south east of Amman and some 40 km SW of Bayer. Jebal Khuzayma can be reached from Amman via the Desert Highway, Suwaqa-Tuba road then Azraq –Jafr Highway.

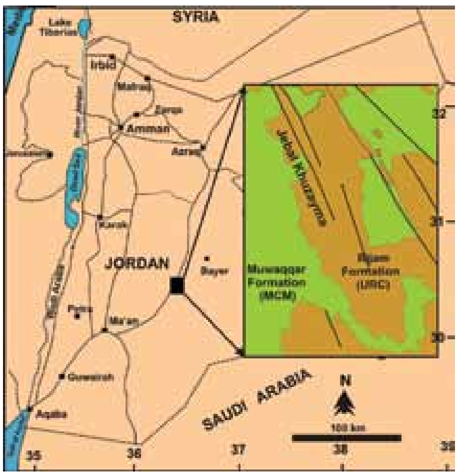

Figure 1: Location map of the study area in southeastern Jordan. The inset map is a geological map of the study area. (Modified from Kherfan, 1987).

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The aim of this work is a) try to identifying and classifying the ammonites in the Muwaqqar Chalk Marl Formation (MCM), b) determine the age of MCM in SE Jordan, and c) to deduce the depositional environment of the MCM through its microfacies.

2. Geological setting

By the onset of the Cenomanian, early Late Cretaceous, a global marine transgression took place, and almost all the Eastern Mediterranean, including Jordan, was flooded (Sharland et al. 2001; Haq and Qahtani, 2005; Powell and Moh'd, 2011). Jordan became part of the shallow, epeiric, tropical Neo-Tethys continental shelf and consequently, the scene for carbonate production and deposition. This essentially carbonate regime continued from the Cenomanian throughout the Eocene, a duration of around 65 million years with the deposition of more than 1000 m of carbonates and associated sediments in north Jordan decreasing to the south and southeast (Powell, 1989; Abed 2000; Powell and Moh'd, 2011).

This regime has been subdivided into two groups: lower or Ajlun Group and upper or Belqa Group (Burden, 1959). Both groups were further subdivided into formations especially by Masri (1963) as shown in Table (1). The Ajlun Group is of Cenomanian - Turonian age. It consists of alternating limestone/dolomite and marl horizons of varying thicknesses. Some of these horizons are highly fossiliferous with ammonites especially in the Hummar through Wadi As Sir Limestone Formations (Bender, 1974).

Table 1: Nomenclature of the Upper Cretaceous rock units in Jordan using the geographic names of the formation without the lithology (Masri, 1963; El-Hiyari, 1985; Powell, 1989).

Age		Group	Formation Member	
Tertiary	Eocene	Belqa	Shallala (WSC)	
			Rijam (URC)	
	Paleocene		Muwaqqar (MCM)	
Late Cretaceous	Paleocene - Maastrichtian		Al-Hisa (AHP)	Qatrana Phosphorite
				Bahiyya Coquina
				Sultani Phosphorite
	Campanian – Santonian		Amman (ASL)	
	Coniacian		Ghudran	Dhiban Chalk
				Tafila
				Mujib chalk
	Turonian	Ajlun	Wadi As Sir	
			Shueib	
	Cenomanian		Hummar	
			Fuheis	
			Na'ur	
Early Cretaceous	Aptian - Albian	Kurnub (Hathira) Sandstone Group		

The Belqa Group overlies the Ajlun Group and extends from the Coniacian through the Eocene. It consists of chert, phosphorite, and oil shale with limestone, marl, and chalk. The deposition of chert, phosphorite, and oil shale was taken to indicate prevailing of cold upwelling currents from the Neo-Tethys proper in the north onto its southern continental shelf, which led to the deposition of these rocks (Abed et al., 2005; Abed, 2013). These conditions remained the same until about the upper Eocene when the Neo-Tethys Ocean regressed due to the start of continent-continent collision between the Afro-Arabian Plate in the south and the Eurasian Plate in the north. (Powell, 1989; Abed and Sadaqah, 1998; Sharland et al.,, 2001; Haq and Qahtani, 2005; Abed, 2013).

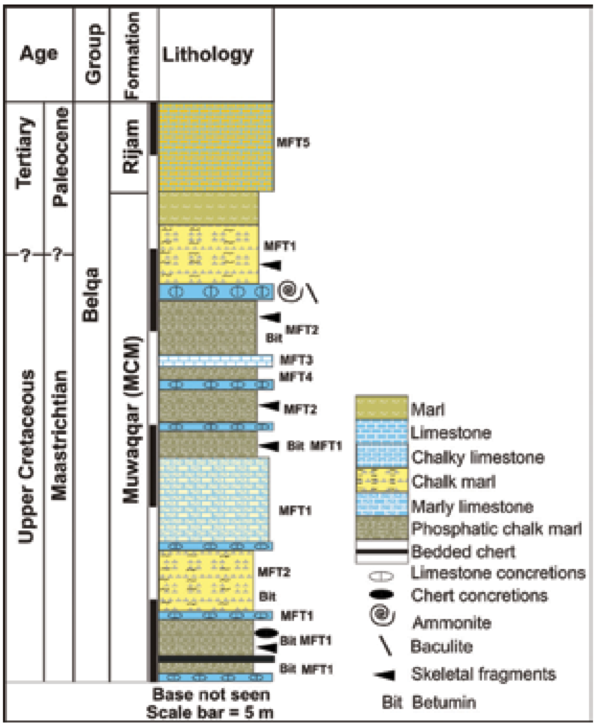

Figure 2: Columnar section measured in the study area showing the upper Muwaqqar Formation with overly base of the Rijam Formation.

The Belqa Group consists of the following formations from older to younger (Table 1): Ghudran, Amman, Al-Hisa, Muwaqqar, Umm Rijam and Shallala Formations. The Muwaqqar Formation (MCM) is made essentially of chalk - marl with varying thicknesses decreasing form the northern parts of Jordan to its south. It is characterized by the abundant organic matter at its lower part known locally as the "oil shale horizon" giving it a black to dark colors.

Jebal Khuzayma are the product of uplift along the Karak-Faiha Fault zone running from just east of the Dead Sea into a southeastern direction into Saudi Arabia (Fig. 1). Jebal Khuzayma consists of the Muwaqqar Formation at their base and ending up with the Rijam Formation. However, the base of the Muwaqqar Formation is not exposed in the study area and only the upper part is cropping out overlain by Rijam Formation. Fig. 2 shows the columnar section measured in the study area. Its lithology consists of phosphatic bituminous chalk marl, bituminous chalk marl, marly limestone, limestone, chalk marl and marl with abundant concretions.

3. Material and methods

Forty nine (49) ammonite samples were collected from the study area during the field work during the year 2010. The collected samples include well preserved, complete shells as well as fragments of shells. All the ammonite samples were found within the uppermost part of the MCM as shown in Fig. 2. Fig. 3 Is a field photo showing the position of the ammonite locality within the columnar section. The samples were treated with a soft brush and water to remove any material adhering to it. They were then stored at the Department of Geology, the University of Jordan.

Twelve samples were collected from the cropping part of the MCM for microfacies analysis. The samples were chosen to represent the variations in the lithology along the measured section (Fig. 2).

Figure 3: Field photo showing the position of the ammonite samples within concretion level sex towards the top of the Muwaqqar Formation. Amani for scale = around 1.65 m

Ammonite systematic paleontology:

The ammonite specimens were assessed on the base of preserved morphological characters which include the most frequently used features: the suture line, shell coiling, whorl cross section and shell ornamentation (Arkell, 1990; Miller et al. 1990). The paleontological study of the ammonite fauna led to identify three species belonging to two families. The taxonomic list, including a description of the taxa, is as follows;

Order Ammonoidea Zittel, 1884
Suborder Ammonitina Hyatt, 1889
Superfamily Acanthocerataceae Hyatt, 1900
Family Sphenodiscidae Hyatt, 1900
Genus *Sphenodiscus* Meek, 1871
Sphenodiscus lobatus (Tuomy, 1856).
Fig. 4a and b, Fig. 5a

Table 2: Dimensions of three samples representing Sphenodiscus lobatus

Sample no.	Diameter (mm)	Whorle Height (mm)	Whorle Width (mm)
1	105	55	?
2	150	45	40
3	195	80	50

Occurrence: Masstrichitian of Africa, Europe, both Americas and Jordan (Al-Harithi and Ibrahim, 1992; Ifrim et al. 2010).

Synonyms:

1852*Ammonites lenticularis* OWEN. - OWEN : p.579 pl. 8, fig. 5

1854 *Ammonites lobata* TUOMEY. - TUOMEY : p.168

1995 *Sphenodiscus lobatus* TUOMEY. - COBBAN & KENNEDY : p.12 figs. 6.2-6.3, 8.4, 8.6-8.11, 12.18-12.19, 16.16-16.17

1996 *Sphenodiscus lobatus* TUOMEY. - KENNEDY & COBBAN : p.802 figs. 2.4-2.6, 2.13-2.14, 2.19-2.21

1997 *Sphenodiscus lobatus* TUOMEY. - KENNEDY ET AL. : p.4 figs. 3-8,9a-i,10

2005 *Sphenodiscus lobatus* TUOMEY. - IFRIM ET AL. : 54, 55, 57, 59 figs. 4d-g; 5a-d, 6a-e, 7d-f

Material: One well preserved external shell and four well preserved internal moulds (three entire samples and two fragmented) found in the final concretion level of Jebal Khuzayma section.

Description: The specimens are involute. The whorl section is triangular; the ventral side is thinner than the umbilicus. The whorl height is greater than the whorl width. The shell is smooth (there is no ornamentation). The suture line is well preserved (belongs to pseudoceratites suture), the saddles are entire and elongated and the lobes are highly teethed. The saddles and lobes tend to become smaller from the venter toward the umbilicus.

Dimensions: specimens differing in size, but height of the whorl generally exceed 4.5cm; width 4-5cm, diameter 10-20cm (Table 2).

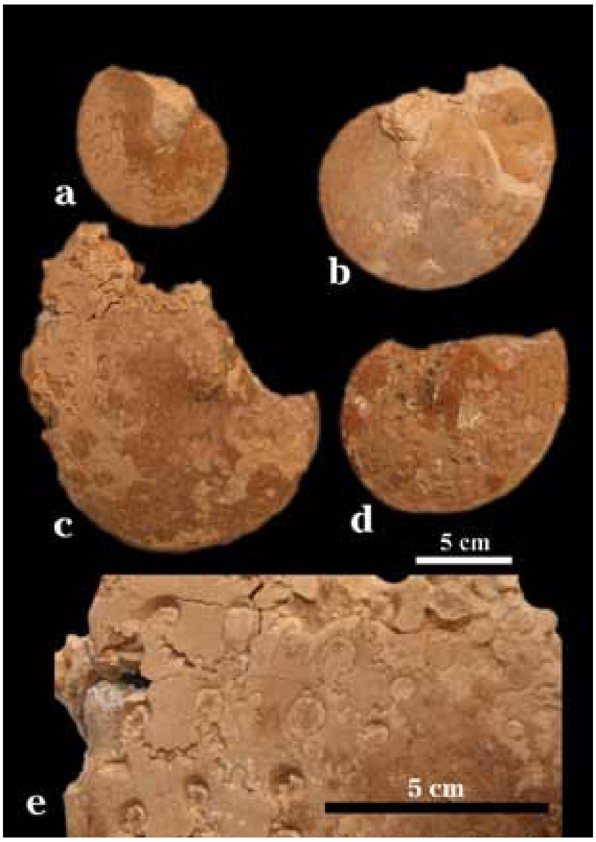

Figure 4: a and b Sphenodiscus lobatus (Tuomy, 1856) lateral view; c and d

Libycoceras ismaeli (Zittel, 1895) lateral view; e) *Sphenodiscus lobatus* (Tuomy, 1856) close view to show the suture line. The photos are smaller than the natural size which is shown in Table 2.

Genus Libycoceras Hyatt, 1900
Libycoceras cf. ismaelis (ZITTEL 1884)
Fig.4c and d, Fig.5b and c.

Synonyms:

cf. 1884 Sphenodiscus ismaelis - ZITTEL, p. 451; fig. 63 1.
cf. 1902 Libycoceras ismaeli ZITTEL - QuAs, p. 302; Plate 29, figs. 3-7; Plate 30, figs. la-b.
cf. 1996 Libycoceras ismaelis (ZITTEL) - WIESE et al., p. 109; Plate 2, fig. 1 (and synonymy).
cf. 1999 Libycoceras ismaelis (ZITTEL) var. soudanense PEREBASKINE, ZABORSKI & MORRIS, text-figs. 4/9-10.

Material: two samples with external shell and 6 well preserved internal moulds (three entire samples and five fragmented)

Description: the specimens are involute. The whorl section is triangular, the ventral side is thinner than the umbilicus. The whorl height is greater than the whorl width. The shell is smooth (there is no ornamentation) the suture line is well preserved (belongs to pseudoceratites suture), the saddles are entire and rounded and lobes are highly teethed. The saddles and lobes tend to become smaller from the venter toward the umbilicus.

Dimensions: specimens differing in size, height of the whorl range from 5-6cm; width 3-4cm, diameter 14-15.5cm (Table 3).

Table 3: Dimensions of three samples representing *Libycoceras ismaeli*

Sample no.	Diameter (mm)	Whorle Height (mm)	Whorle Width (mm)
1	105	55	?
2	150	45	40
3	195	80	50

Occurrence: Masstrichtian of Africa, Europe, Americas, Nigeria, Libya and Jordan (Zaborski, 1982; Al-Harithi and Ibrahim, 1992; Amard, 1996; Ifrim and Stinnesbeck, 2010).

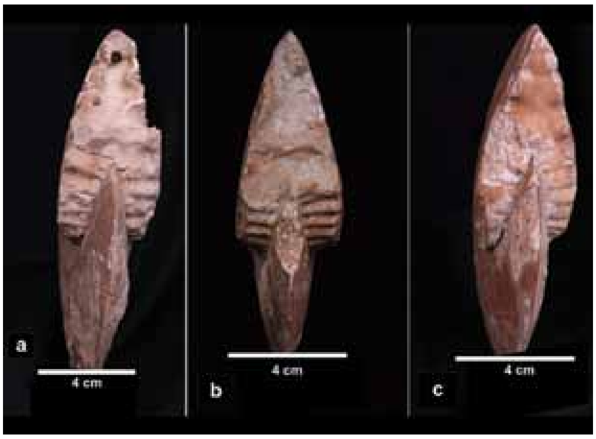

Figure 5: a Sphenodiscus lobatus (Tuomy, 1856) ventral view; b and c) Libycoceras ismaeli (Zittel, 1895) ventral view. The natural size of the specimens can be seen in Table 3.

Suborder Lytoceratina Hyatt, 1889
Superfamily Turrilitaceae Meek, 1876
Family Baculitidae Meek, 1876
Genus Baculites (Lamark, 1799)
Baculites sp. Lamark, 1799.
Fig. 6 a and b

Synonyms:

1786 Homaloceras Hubsch, 1786 (non. binom.), p. 110.
1861 Baculites faujasi Lamarck. – Binkhors, 1861, p. 33
1925 Baculites vertebralis Lamarck. – Diener, 1925, p. 40
1993 Baculites cf. vertebralis Lamarck. - Ward & Kennedy, 1993, p. 114, pl. 7
1995 Baculites sp. C . - Cobban & Kennedy : p. 22, 24 fig. 15.1, 15.5, 16.1-16.6, 16.10-16.12, 16.25-16.27, 16.31-16.38

Material: two large and thirteen small, incomplete samples.

Description: the specimen is a part of a fragmented phragmocone. The cross section is ovate, smooth surface, some samples have arcuate ribs. The ammonitic suture line is moderately complex, the saddles and lobes are teethed.

Occurrence: Masstrichtian of Jordan. Baculites were recorded from Egypt, Mexico, Palestine and North America; it indicates Campanian-Maastrichtian age (Ifrim et. al., 2010). They were recorded in Jordan in Wadi Usaykhim, Al Azraq area as of Maastrichtian age (Al-Harithi and Ibrahim, 1992).

Age of the section studied

Sphenodiscidae ammonites were widespread during the Maastrichtian, with records from localities in Africa, Europe and both Americas (Turekian and Armstrong, 1961; Kennedy and Cobban, 1996; Landman et al., 2004).. Outside North America, however, their record is rather scattered. The genus is known from Maastrichtian sediments in Western Europe (Hancock, 1967; Bandel, Landman and Waage, 1982; Kennedy, 1986), in the lower Maastrichtian of India and in the upper Maastrichtian of Poland and Bulgaria, Madagascar and West Africa. The most widespread species of Sphenodiscus is, however *Sphenodiscus lobatus*. Zaborski (1982) suggested that the Sphenodiscidae originated in the African epicontinental seas from unknown ancestor of Campanian age. Sphenodiscids dispersed and radiated during the latest Campanian and Maastrichtian, until they went extinct at or near the Cretaceous-Paleogene boundary (Ifrim and Stinnesbeck, 2010). *Libycoceras ismaeli* (Zittel) has been reported from the upper Maastrichtian of the Algerian Sahara, North Africa and Niger, and it has been reported from the upper Campanian in the Middle East and the Eastern desert, Egypt (Amard, 1996). The two species were recorded in Jordan in Wadi Usaykhim, Al Azraq area as Maastrichtian age (Al-Harithi and Ibrahim, 1992).

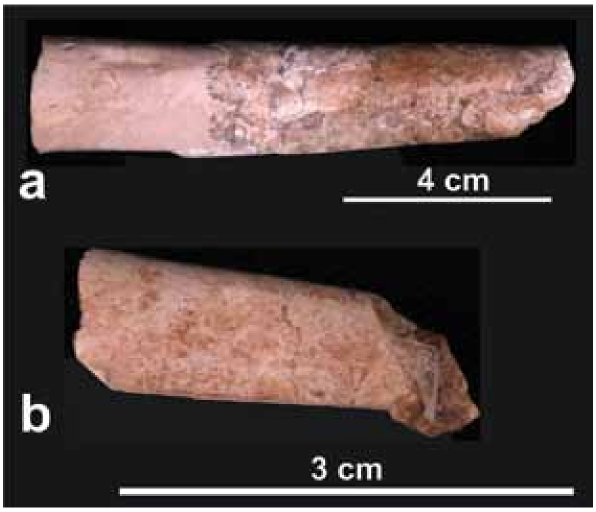

Figure 6: a, b: Baculites sp. (Lamark, 1799). Lateral view.

Baculites were recorded from Egypt, Mexico, Palestine and North America indicating Campanian-Maastrichtian age (Ifrim et. al., 2010). They were recorded in Jordan in Wadi Usaykhim, Al Azraq area as of Maastrichtian age (Al-Harithi and Ibrahim, 1992).

Microfacies analysis

Twelve samples representing the nearly 30 m measured section in Jebal Khuzayma in southeastern Jordan. It should be mentioned that almost all these facies, in varying proportions, are matrix (micrite) supported.

MFT1: Phosphatic foraminiferal wackestone

This microfacies represents several horizons (Fig. 2) with different thickness. It consists of phosphate particles (peloids, intraclasts and skeletal fragments) and foraminiferal tests and fragments supported by lime mudstone (matrix) stained dark because of the presence of organic matter (Fig. 7a, b and c). Depending on the horizon, the phosphate particles range is 4 – 13%, foraminiferal tests and fragments 22 – 39%, and the matrix 49 – 72%. The identified foraminifera belongs to the following families Bulminidae, Heterohelicidae, Rotaliporidae, and others such as Trochospiral foraminifera. Champers are filled with micrite or sparite cement. Some benthic foraminifera tests are also found in at least one horizon at mid section within this microfacies. The abundant matrix as well as planktonic foraminifera would indicate the deposition of this microfacies in a calm, offshore, open marine conditions (Flugel, 2004). The presence of appreciable amounts of phosphatic material and organic matter might indicate that upwelling currents were still reaching the study area (Almogi-Labin et al, 1993; Abed 2013). However, the non transformation of these deposits into true phosphorites is possibly due to depth of water column which caused no reworking and winnowing of deposited sediments (Glenn et al., 1994; Abed and Sadaqah, 1998).

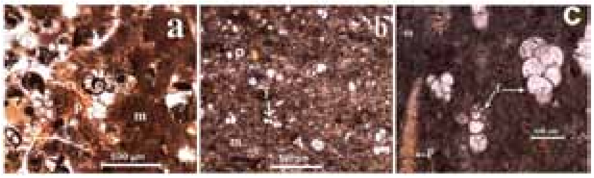

Figure 7: MFT1 Phosphatic foraminiferal wackestone. a) represents the lowest 4 m of the section Fig. 2, b) from the 4.5 m marly limestone, 10 m from the base, c) From the 60 cm limestone horizon mid section. p, phosphate particles; f. foraminiferal test; m, matrix. Plane polarized light (PPL).

MFT2: Laminated phosphatic foraminiferal packstone

MFT2 is essentially similar to MFT1 except that the constituent particles and the matrix are laminated (Fig. 8 a, b and c). Small fossils and phosphate particles have their longer axes nearly parallel to bedding. The foraminiferal tests can be up to 48% by volume of the thin section while the phosphate particles are up to 12%. Lamination most probably is due to compaction in a calm offshore environment without reworking.

MFT3: Lime mudstone

This microfacies consists of lime mudstone with less than 10% highly fragmented fossils and phosphate particles (Fig. 9a). This microfacies is restricted to one horizon only.

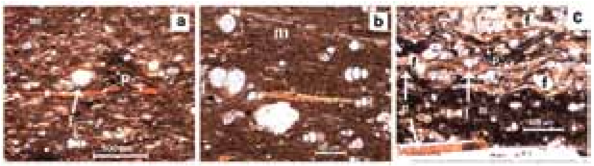

Figure 8: Laminated phosphatic foraminiferal packstone MFT2. Note long axis of the phosphate particles and some fossil tests are parallel to bedding. a) from the 4.5 m chalk marl, 6 m above the base, b) represents 3.5 m phosphatic marl horizon mid section, c) from a 4 m greyish, laminated phosphatic-rich, underlying the upper concretion horizon.
p, phosphate particles; f, foraminiferal tests; m, matrix. Plane polarized light (PPL).

MFT4: Phosphorite grainstone

This microfacies is also restricted to one horizon and is almost completely made of phosphate intraclasts with seldom fossils (Fig. 9b). The phosphate particles are of various sizes and shapes bounded by sparry calcite. Fossils and fossil fragments are rather rare. for these characteristics, this microfacies looks similar to the phosphorite grainstone of the Al-Hisa Phosphorite Formation (e.g. Abed and Sadaqah, 1998). The abundant phosphate intraclasts and the lack of matrix indicate a higher energy regime compared with the environments of previous microfacies. A higher energy regime is possibly needed to produce such concentrates of phosphorite through reworking and winnowing (Abed, 2013).

MFT5: Foraminiferal packstone

This microfacies represents the lowest five metres of the Rijam Formation overlying the MCM (Fig. 9c). It is composed of 26% micrite and 74% highly fragmented foraminifera belong to the following families: Heterohelicidae (pl.4f), Rotaliporidae? (pl.5f) and fragmented foraminifera belong to the Globigerinacea superfamily, with calcite cement filling the chambers. Other undefined foraminifera is also present. Please note the non presence of phosphate particles as compared with the microfacies of the MCM Formation. This microfacies is interpreted to have been deposited in a calm, offshore, open marine environment. The lack of phosphatic material might be explained by the waning upwelling current in this part of the eastern Mediterranean. The Rijam Formation, throughout Jordan, is known to contain very minor phosphorite especially in the eastern most parts of the country. For more details, see Abed (2013).

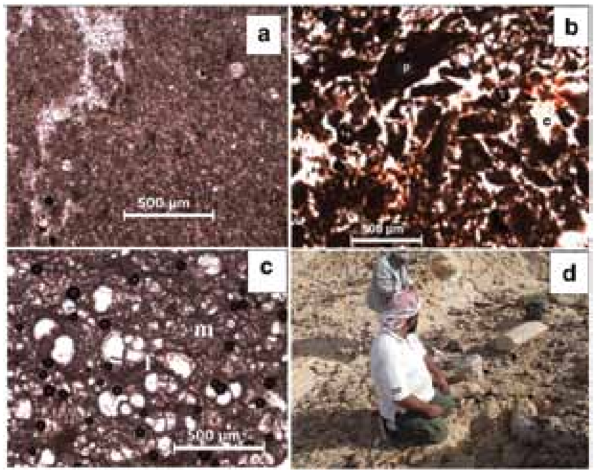

Figure 9: a) Lime mudstone MFT3, from the 4 m chalk marl towards the top of the section, b) Phosphorite grainstone MFT4, dominated by phosphate intraclast cemented by calcite at mid section. C) Foraminiferal packstone, with phosphate particles making the base of the Rijam Formation, black circles are air pubbles. f, foraminiferal tests; m, matrix. Plane polarized light (PPL). D) Field photo of the tree trunks (not in situ) in Jebal Khuzayma several metres below the MCM-URC formations contact, N. Hmaidan for a scale.

4. Discussion

The studied section represents the upper part of the MCM Formation because its base is not cropping out. However, the section is the best at Jebal Khuzayma in SE Jordan. The microfacies analysis shows a rise in sea level compared with the underlying Al-Hisa Phosphorite Formation (AHP). The AHP, in central and south central Jordan, is characterized by small basins in an essentially onshore environments indicated by the conspicuous oyster buildups and the rarity of planktonic fauna (e.g. Abed and Sadaqah, 1998). The AHP was then followed by a regional sea level rise documented throughout the eastern Mediterranean (e.g. Almogi-Labin et al. 1993; Powell and Moh'd, 2011, 2012). In the study area, this is indicated by the abundant planktonic foraminifera and the high percentage of lime mudstone in the rocks investigated (Wilson, 1975; Flugel, 2004). Consequently, the study area seemed to have formed part of the open shelf environment with relatively deeper water, thus differentiated it from the small basins in central Jordan such as El-Lajjun.

The presence of relatively higher content of organic matter and phosphatic material, in the investigated section compared with upper MCM in central Jordan, might be taken to indicate the ongoing activity of upwelling currents onto the area. Upwelling currents spread deep, cold marine water on the sea surface of the continental shelf usually rich in nutrients bioproductivity in the photic zone, the upper 100-200 m of the sea water column. Under such upwelling conditions, higher than normal organic matter is deposited which consequently leads to the diagenetic formation of phosphatic material (Burnett, 1990; Almogi-Labin et al., 1993; Glenn et al, 1994). The non transformation of the phosphate material into high grade phosphorites can be explained by the absence of reworking and winnowing, very much like the recent phosphate deposits of the Peru-Chili shelf documented by Burnett (1990). The phosphate deposits in the Peru-Chili shelf consist of small and large phosphate nodules embedded in an organic rich lime mud.

Based on ammonites, a Maastrichtian, Late Cretaceous age is given to the studied section of the MCM in Jebal Khuzayma in southeastern Jordan. Other authors arrived to the same conclusion much earlier (e.g. Al-Harithi and Ibrahim 1992; Nazzal and Mustafa (1993). It is not possible, in this work, to assign a shorter age duration for the investigated section; e.g. Lower or Upper Maastrichtian. Fig. 2 clearly shows that studied section belongs to the upper part of the MCM immediately underlying the Rijam Formation of the Eocene. Moreover, the Maastrichtian ammonites are only 6 m below the contact with the Rijam Formation (Fig. 2), leaving, at best, 6 m of strata to represent the Paleocene. The MCM is well known, for a long time to be of Maastrichtian – Paleocene age (e.g. Bender, 1974; Yassini, 1980; Powell, 1989). So, how to solve this problem with Paleocene strata and the underlying upper Maastrichtian and the overlying Rijam Formation in this part of the country? Al-Mashagbah (2012), amongst others, documented the presence of at least two unconformities (gaps) in the MCM in southern Jordan (around 50 kilometers east of Jurf Ed Darawish), one at the base of the Paleocene and another at its top. Furthermore, abundant tree trunks are wide spread at the contact between the MCM and the Rijam Formation in Jebal Khuzayma area and further southeast (Fig. 9d and Ammar Khammash pers. Comm. 2012). The presence of the trees below the Rijam Formation indicates a long subaerial exposure towards the top of the MCM in southeast Jordan, thus supporting the findings of Al-Mashagbah (2012) and indicating that a considerable part of the Paleocene might have been eroded through this subaerial event. In the authors opinion, the Jebal Khuzayma and the area southeast of it needs a detailed micropaleontological investigation to solve the above discussed stratigraphic problems during the Maasrichtian-Eocene.

5. Conclusions

1. The paleontological study led to identify three ammonite species belonging to two families, recorded in the upper part of Muwaqqar Formation. Two planispiral species belong to the family Sphenodiscidae (Hyatt, 1900); Sphenodiscus lobatus (Tuomy, 1856) and Libycoceras ismaeli (Zittle, 1895).The third one (straight species) belongs to Baculitidae family (Meek, 1876); Baculites sp. (Lamark, 1799).
2. The age of the measured section is Maastrichtian and it was not possible to obtain a shorter duration age; i.e. lower or upper Maastrichtian.
3. The Paleocene strata are, at best, represented by 6 m in the measured section below the Rijam Formation. This might indicate a long erosional unconformity at the end of the MCM which was documented by other workers (e.g. Al-Mashagbah, 2012) several tens of kilometers west of the study area. The erosional unconformity is also supported by the presence of tree trunks at the Muwaqqar-Rijam formations contact.
4. Microfacies analysis indicates that the upper Muwaqqar Formation in the Jebal Khuzayma area was deposited in a calm, offshore, open marine conditions affected by upwelling currents. This is evidenced by the abundant planktonic fauna exceeding benthic fauna, the abundant matrix represented by lime mudstone, and the relatively higher than normal phosphate particles and organic matter.

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