Cenomanian–Turonian rudist (bivalvia) lithosomes from NW of Jordan

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A B S T R A C T

Two rudist lithosomes characterized by high abundance but low in diversity are described from five measured stratigraphic sections in the Upper Cretaceous Hummar and Wadi As Sir Limestone Formations in the Ajlun and Kitim areas, in NW Jordan. The caprinid lithosome from the Hummar Formation is characterized by abundant occurrences of canaliculate rudists such as Caprinula boissyi d’Orbigny, 1840, Neocaprina nanosi PieniC, 1961, Caprina sp. (aff. schiosensis Boehm, 1892), but rare specimens of radiolitids such as Sauvagesia sharpei (Bayle, 1857), Sauvagesia/Durania sp. and Eoradiolites sp., along with requienids (Apricardia sp.), indicating a late Cenomanian age. The hippuritid lithosome is determined from the stratigraphically higher Wadi As Sir Limestone Formation and it is represented by well-preserved specimens of Hippurites resectus Defrance, 1821 and also some specimens of Vaccinites roussei Douvillé, 1894 and Durania arnaudi (Choffat, 1891) indicating a late Turonian age.

The palaeobiogeography of determined rudists is compared with those of the carbonate platforms on northern and southern side of the Mediterranean Tethys. The presence of a depositional hiatus (or erosional unconformity) represented by the sharp boundary, karstic features, reworked carbonate lithoclasts and rudist fragments between Hummar and Wadi As Sir Limestone formations is also outlined.

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1. Introduction

Previous studies suggest that during the Late Cretaceous Jordan was a part of the Levant platform on the northern part of the Arabian Plate, where the shallow marine rudist-bearing limestones and dolomitic limestones were largely deposited on the Jordanian carbonate shelf during the Cenomanian and Turonian (Abed, 1982; Powell, 1989; Makhlof et al., 1996; Alsharhan and Nairn, 1997; Philip et al., 2000; Stampflı et al., 2001; Kuss et al., 2003; Schulze et al., 2003, 2004, 2005; Baaske, 2005; Powell and Moh’d, 2011). Despite is earlier work, except for the study based on some rudist determinations of Bandel and Mustafa (1996) from the Ishtafina area (close to Ajlun city) in the NW of Jordan, there are no detailed studies on the rudist associations in Jordan. The study of Bandel and Mustafa (1996) concerns some rudists of Cenomanian and Turonian age, and contains some stratigraphic and palaeontologic problems as discussed, below, in the rudist lithosomes section.

The aim of this study is to present the rudist lithosomes from the NW of Jordan based on the material recently collected from upper Cenomanian and upper Turonian limestones of Hummar Formation and Wadi As Sir Limestone Formation, respectively (Fig. 1). The boundary between these two formations is discussed according to new stratigraphic data. The biogeographic distribution of determined species is also emphasized.

2. Material and method

This study is based on the rudist specimens were collected from the following five measured stratigraphic sections in the area between the Ajlun city and Kitim town in the NW of Jordan (Figs. 1–6):

1-Ishafina section (Fig. 2): NW of Ajlun city, S of Ishafina town at latitude (32°21′24.699N) and longitude (35°44′16.884E).
2-An Nuaymah section (Fig. 3): 1 km SE of An Nuaymah town at latitude (32°23′20.717N) and longitude (35°51′04.663E).
3-Samta section (Fig. 4): Between Ajlun city and Kitim town, 3 km SE of Rihaba town at latitude (32°24′09.731N) and longitude (35°48′26.204E).
4-Rihaba section (Fig. 5): 1 km SW of Rihaba town at latitude (32°24′34.862N) and longitude (35°48′46.700E).
5-Kitim section (Fig. 6): 1 km S of Kitim town at latitude (32°25′56.400N) and longitude (35°51′01.127E).
3. Stratigraphy

The Jurassic succession of Jordan consists of three groups, in ascending order, Kurnub Sandstone (Berriasian to Albian), Ajlun (Cenomanian to Turonian) and Belga (Coniacian to Eocene) (Quennell, 1951; Burdon, 1959; Masri, 1963; Bender, 1974; Abed, 1982; Powell, 1989; Abdelhamid, 1995; Abu Qudaira, 2005). The Ajlun Group is composed of five formations in the north of Jordan, from bottom to top, the Naur (upper Albian-lower Cenomanian), Fuheis (Cenomanian), Hummar (upper Cenomanian), Shuayb (upper Cenomanian to lower Turonian) and Wadi As Sir Limestone formations (upper Turonian) (Wetzel and Morton, 1959; Basha, 1978; Dilley, 1985). The formations of this carbonate platform Group unconformably overlie siliciclastics of the Kurnub Sandstone Group, and is overlain unconformably by the chalk-chert-phosphorite association of the Belga Group (Quennell 1951; Powell 1989; Powell and Mobj'd, 2011). The Kurnub Sandstone Group and Naur Formation not outcropped in the study area (Fig. 1).

The rudists of present study were collected from the Hummar and Wadi As Sir Limestone formations of the Ajlun Group.

The rudist-bearing limestones and dolomitic limestones of Hummar Formation are observed in all sections, except Rihaba section (Fig. 5), but interbedded marls with ammonites are also observed at An Nuaymah section (Fig. 3). Rudist-bearing limestones of the formation are mainly characterized by monospecific clusters of canalicate rudists. However, the greater abundance of canalicate rudists are represented in the Ishtafina section than in the other sections. Gastropods are also represented in the Ishtafina section, but are characteristically present above the levels of rudist-bearing limestones. The thickness of the formation varies from 8 m to 18 m.

The lower boundary of the Hummar Formation cannot be observed in the studied sections. But, it is directly overlain with a sharp contact by the Wadi As Sir Limestone Formation as observed in the Ishtafina, Samta and Kitim sections (Fig. 7A and B). This boundary is predominantly characterized by karstic structures covering by fine grained probably beachrock carbonates, reworked carbonate lithoclasts and rudist fragments (Fig. 7C and D). Although features such as palaeosols, caliche beds and iron impregnations typically represents evidence for emergence, are not present, the features noted above and also the absence of siliciclastic-rich Shuayb Formation and any palaeontologic data showing the lower or middle Turonian indicate a hiatus (or an erosional unconformity) between these two formations. The origin of this hiatus remains unclear, and needs a detailed study outside the scope of this paper, but it just seems not to be a local phenomena to the study area. It may a result of platform drowning or Oceanic Anoxic Event (OAE) 2, which have been reported from the Cenomanian/Turonian boundary throughout Jordan (Powell, 1989; Schulze et al., 2004; Wendler et al., 2009; Powell and Mobj'd, 2011; Bandel and Salameh, 2013). A subaerial unconformity also marked by a calcrete and paleokarstic horizon separating the upper Cenomanian Hummar and Fuheis formations has been recently described from an area southeast of Amman (Abed et al., 2013), shows the presence of a crisis during this time in Jordan. The C/T crisis has been well-studied from the northern (e.g., Philip and Airaud-Crumière, 1991; Drzewiecki and Simo, 1997; Schlager, 1999; Callazep, 2008) and also southern Mediterranean Tethys such as Israel (Levy, 1989, 1990; Buchbinder et al., 2000;
Frank, 2010; Frank et al., 2010), Lebanon (Ferry et al., 2007), Sinai-Egypt (Saber et al., 2009; Bauer et al., 2001; Hannaa, 2011; El-Sabbag et al., 2011) and northern-southern Tunisia (Abdallah, 2003) indicating that it is related to a global phenomena.

Canaliculate rudists and radiolitids suggest a late Cenomanian age for the Hummar Formation (Özer and Ahmad, 2014), as explained below in the rudist associations and palaeobiogeography. Previous palaeontologic informations based on the ammonites, calcareous nannofossils and benthic and planktic foraminifers in the east–west–central–north of Jordan, support a late Cenomanian age for the Hummar Formation (Olexcon, 1967; Basha, 1978; Dilley, 1985; Abdelhamid, 1995; Schulze et al., 2003, 2004, 2005; Wiese and Schulze, 2005; Aly et al., 2008).

The Wadi As Sir Limestone Formation is widely exposed throughout most of Jordan and represent the uppermost formation of Ajlun Group (Powell, 1989). It was named A7 by MacDonald (1965) and massive limestone by Bender (1974). In the studied area, between Ajlun and Kitim towns, it consists of well-bedded massive limestones, dolomitic limestones, dolomites and limestones containing chert nodules and styloliths. The formation is observed in all of the measured–stratigraphic sections, except that of An Nuaymah (Fig. 3), and is especially characterized by the abundance of rudists in life position. Monospecific biostromes constructed mainly by Hippurites resectus Defrance, 1821 are observed in the measured–stratigraphic sections (Fig. 7F). Gastropods are also present in the above of rudist-bearing limestones. The thickness of the formation varies from 5 m to 30 m. The rudist fauna indicates a late Turonian age for the formation (Özer and Ahmad, 2014; see below rudist lithosomes and palaeobiogeography). Many studies in northern and southern Jordan region also suggest the same age for the formation (Bender, 1974; Dilley, 1985; Powell, 1989; Abdelhamid, 1995; Kuss et al., 2003; Baaske, 2005; Schulze et al., 2003).

Fig. 2. Ishtafina measured–stratigraphic section (see for location to Fig. 1) showing the distributions of the identified rudists. Legend. 1. Limestone, 2. Marl, 3. Caprinid, 4. Radiolitid, 5. Hippuritid, 6. Gastropod, 7. Chert, 8. Stylolith, 9. Subaerial unconformity/hiatus.
4. Rudist lithosomes

Two main rudist lithosomes can be distinguished in the Cenomanian-Turonian carbonate successions of the Ajlun Group in NW of Jordan as follow (Figs. 2–6):

(a) The upper Cenomanian caprinid lithosome are mainly determined in the Isthafina section, but it also observed in the Samta and An Nuaymah sections. Kitim section contain some caprinid fragments.

(b) The upper Turonian hippuritid lithosome are widely and well-represented in all the sections, except An Nuaymah section.

The lithosomes represented by high abundance/low diversity associations are probably due to the restriction of the environmental conditions. Each lithosomes consists of rudists in life position (Fig. 7E and F). Details of the two rudist lithosomes including specific characteristics of the rudists and their ages are outlined below:

4.1. Caprinid lithosome (upper Cenomanian)

The best outcrop of this lithosome is observed in the Isthafina locality, represented by abundant occurrences of caprinids, and rare specimens of radiolitids. The canaliculated rudists are observed as broken shell fragments, but many of them in growth position in the Isthafina and Samta sections that include: Caprinula boissyi d’Orbigny, 1840, Neocaprina nanosi Plenčar, 1961, Caprina sp. (aff. schiosensis Boehm, 1892), Sauvagesia sharpei (Bayle, 1857), Sauvagesia/Durania sp. and Eoradiolites sp. Apricardia sp. is also present.
The right valve transverse sections of many specimens show typical characteristics of the *C. boissyi* such as decreases in the pallial canal from the inner to the outer part in the interior shell layer, invaginated ligamental ridge, sub-equal teeth, a thin oblique plate separating the posterior cavity from body cavity connecting to the anterior tooth (Fig. 8A–C). These characteristics are well-described and recorded in the upper Cenomanian in many studies (Sharpe, 1850; Douvillé, 1888; Pejović, 1957; Pamouktchiev, 1974; Chartrousse, 1998; Sirna and Paris, 1999; Chikhi-Aouimeur, 2010). Our specimens show close similarities with those of Douvillé (1888) and Chikhi-Aouimeur (2010) determined from Portugal and Algeria, respectively.

*N. nanosi* is determined from two left valve specimens. The valves are cylindrical, 50 mm long, and one shows longitudinal radial canals in the eroded part of the postero-ventral of the valve (Fig. 8D). The transverse section of the valve is suboval, the diameter is 35 × 27 mm, the cardinal apparatus and myophores can be observed. The anterior accessory cavities/canals are rectangular and subcarre in shape and very much larger than those of posterior (Fig. 8E). These cavities are separated by thin lames. The angle of cardinal apparatus is 85°. The sample show typical characteristics of *N. nanosi* determined from the middle, upper Cenomanian by Pleničar (1961, 1963), Polšak (1967) and Sirna (1982) in the central Mediterranean Tethys. The few large and simple anterior accessory cavities of the samples may be correlated with those of *Neocaprina raghawiensis* described from the Upper Albian of northern Sinai, Egypt by Steuber and Bachmann (2002).

Two partly preserved left valves belong to caprinids present only an ovoid section and many pallial canals with a single row (Fig. 8F). These are fusiform in shape showing relatively uniform size separated by thin, simple lames. These characters reminiscent those of *Caprina schiosensis* Boehm, but due to poor preservation of the other features such as the ligamental ridge, the cardinal

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Fig. 4. Samta measured-stratigraphic section (see for location to Fig. 1 and symbols to Fig. 2) showing the distributions of the identified rudists.
apparatus and the accessory cavities, these samples are here determined as *Caprina* sp.

Many right valve transverse sections of *S. sharpei* are relatively small, the diameter varies from 20 mm to 50 mm in maximal (Fig. 9 A–D). The outer shell layer consists of cellular structure, and has large cells in some places. The ligamental ridge is small and triangular. The anterior and the posterior radial bands are flat, the first being wide than the rest. They are separated by a concave interband, narrower than the posterior one. Our sections may be correlated with this species identified from the upper Cenomanian in the northern and southern margins of the Mediterranean Tethys (see Steuber, 2002; Pons et al., 2011), but they are mainly small.

Many small right valve sections of radiolitids show cellular structure in their outer shell layer, but the ligamental ridge cannot be precisely determined (Fig. 9 E–G). The interband of some of them is narrow and concave and some of others show slowly convex posterior and anterior radial bands. They may belong to either *Sauvagesia* sp. or *Durania* sp.

We found also many conical right valves of *Eoradiolites* averaging maximal 30 mm in length and 12 mm diameter (Fig. 10A and B). Some of them show cone in cone structure. The valve is ornamented with thin, longitudinal ribs, the radial bands are flat and separated with concave interband, the anterior one is wider than other. The outer shell layer is 5 mm thick and may appear as compact structure. The ligament ridge is short and triangular. The cardinal apparatus are not preserved. These features show some resemblances with those of *Eoradiolites liratus* (Conrad, 1852) determined from Egypt, Liban, Maroc, Slovenia, Crotia and Italy (Douvillé, 1910, 1913; Parona, 1909, 1921; Caffau and Pleničar, 1991; Pleničar and Jurkovšek, 2000; Steuber and Bachmann, 2002; see for details to Pons et al., 2011). However, our specimens are small and the structure of the radial bands cannot be observed in all specimens, so we determined these samples as *Eoradiolites* sp.

Many specimens of *Apricardia* represent only right valve, that are small with strongly inclined beak (Fig. 10C). The cardinal apparatus and other internal features cannot be observed, so we

**Fig. 5.** Rihaba measured-stratigraphic section (see for location to Fig. 1 and symbols to Fig. 2) showing the distributions of the identified rudists.
determined as *Apricardia* sp. However, our specimens may be correlated because of their small size when compared to *Apricardia douvelleii* Péron (1889) determined from the upper Cenomanian of Tunisia (see Chikhi-Aouimeur, 2010).

4.2. Hippuritid lithosome (upper Turonian)

This lithosome is widely exposed in the Ajlun-Kitim area and it is mainly characterized by the *H. resectus* Defrance, 1821. Many well-preserved specimens of this species can be observed in life position. *Vaccinites rousseli* Douvillé, 1894 is also associated with this species in the Isthafina, Kitim and Samta sections and some specimens of *Durania arnaudi* (Choffat, 1891) are observed in the Isthafina, Kitim, Rihaba and Samta sections.

Many specimens of the right valve show identical externale and internale characteristics of *H. resectus* (Figs. 10D–I and 11A, B): they are cylindro-conical in shape, ornamented with finely longitudinal ribs, the ligamental ridge and pillars occur on the surface of the valve with three deeply longitudinal grooves, the valve transverse section is circular, the calcitic outer shell layer is compact and shows radial ribbings and its inner margin is straight, but sometimes slowly undulating, the ligamental ridge is open, wide, short, triangular and sharply truncated, the first pillar is open at the base, has a rounded head and shorter than other pillar; the second pillar is pinched at the base, with rounded head and inclined towards to anterior; the posterior tooth is close to the ligamental ridge; the ovaloid anterior myophore is in the gulf of the elongated ovaloid in the form of an anterior tooth and the latter is located very close to calcitic outer shell layer; the anterior tooth and posterior tooth show ovaloid sections and the first seems more developed than other; the posterior tooth is close to the ligamental ridge. The left valve is partly preserved. The surface of the valve is smooth consequently the porus system cannot be observed.

Our *H. resectus* specimens show resemblances with those of Montsech, Dordogne and Bugarach (France) determined by Douvillé (1892, pl. V, figs. 9–12; 1895, pl. XVI, figs. 1–3) and from the Constantine (Algeria) by Douvillé (1910, pl. II, fig. 6), from the Ghazir and Gheurfen (Lebanon) by Douvillé (1910, text-figs. 62–65) and from the d’Uchaux and Dordogne (France) by Simonpietri (1999, pl. 36, figs. 7–9). All of our specimens have a short ligamental ridge like the specimens of France (Douvillé, 1892, 1895; Toucas, 1903; Simonpietri, 1999), Algeria and Tunisia (Douvillé, 1910; Chikhi-Aouimeur, 2010), Lebanon (Douvillé, 1910), Greece (Stueber, 1993) and Turkey (Özer and Sari, 2008; Sari and Özer, 2009) in the old world and Mexico.
The determinations of the species from Egypt (Douvillé, 1913; Zakhera, 2011) show a longer ligamental ridge than that in our specimens. The determination of Bandel and Mustafa (1996) as *Hippurites requieni* Matheron, 1842 from the Isthafina locality, show similar features of *H. resectus*, and it seems to be synonymus with latter species as proposed by Simonpiétri (1999) and Chikhi-Aouimeur (2010).

*V. rousseli* is determined from six right valves transversal sections and a single partially preserved left valve (Fig. 11 C–E). The outer shell layer is compact, calcitic and thick showing radial ribbings and slight undulations in the inner margin. The ligamental ridge is triangle, widely open at the base and its head is truncated. The first pillar is open at the base, however it is slightly pinched in a single section; it has a rounded head and is shorter than other pillar. The second pillar is open or slightly pinched at the base having parallel bords with a rounded head that is inclined towards to anterior. The distance between ligamental ridge-first pillar and first pillar-second pillar is equal. The angle between ligamental ridge and second pillar varies between 110° and 120°. The anterior cavity is large and occupies approximately 1/5 of the body cavity. The posterior myophore is ovoid in shape. The cardinal apparatus is partially preserved. The left valve shows some radial canals and pores probably simple and rounded, but poorly preserved.

The ligamental ridge and pillars of our specimens show similar characteristics with those of the specimen of *V. rousseli* determined from col d’Argentière (Haute Savoi, France) (Douvillé, 1897, pl. 34, fig. 6), show similar characteristics with specimen of Saint-Cirq in France (Douvillé, 1894, pl. 20, fig. 3), and also specimens of Basse Province (France) determined by Simonpiétri (1999, pl. 21, figs. 1, 2, 4 and 5). Although, the pillars of our specimens show similarities with specimens of Toucas (1903, fig. 119, 120), Pejović (1957, text-fig. 45), Pamouktchiev (1969, pl. III, fig. 3) and Chikhi-Aouimeur (2010, fig. 149, 3, fig. 150, 1, 2, fig. 151, 1–3), but the ligamental ridge of these specimens no widely developed towards its head like our specimens. However, some Algerian and Tunisian specimens of *V. rousseli* determined by the latter author show clear similarity with those of Jordanian specimens. The anterior cavity of our specimens is large causing the rotation of cardinal apparatus, habitually observed in Vaccinites (Toucas, 1903; Skelton, 1978; Steuber, 1999; Simonpiétri, 1999), but it can also be determined and presented by Douvillé (1910, p. 67, pl. IV, fig. 7a, text-fig. 67) in his new species *Hippuritella libanus* from the Bmeherin (Lebanon). This character was also observed in the specimens *Hippurites libanus* from Djebel Metlili (Algeria) by Chikhi-Aouimeur (2010, fig. 150, 3, 4). Because of this characteristic and the similarities of the ligamental ridge and pillars, our specimens show resemblances with *H. libanus*. We propose that *Hippurites* (*Hippuritella*) *libanus* is synonymus with *V. rousseli* as indicated by Chikhi-Aouimeur (2010, p. 159). Some specimens were incorrectly determined as *H. requieni* Matheron by Bandel and Mustafa (1999, pl. 7,
and show similar features of the ligamental ridge and the pillars of *V. rousseli*.

One specimen with both valves, one specimen of the right valve and some right valve transverse sections show characteristic structure of the radial bands of *D. arnaudi* (Choffat) (Fig. 11F and G): the right valve is conical to cylindroconical and ornamented with thin regular ribs, it has 40 mm long and 30 mm in commissural diameter. The transverse sections of these canals can be clearly observed in the next figure. (E) The transverse section of the same specimen; note the anterior accessory cavities/canals are rectangular and subcarin in shape and very much larger than those of posterior. The arrow indicates the sections of the longitudinal radial canals of the previous figure. (F) *Caprina* sp., the natural transverse section of the left valve showing only a single row of fusiform, very little pallial canals (arrows). Ishtafina locality, sample no. I-13–31. The scale bar indicates 10 mm.

5. Palaeobiogeography and correlation

The presence of rudist-bearing formations are presented in the central and southern Jordan by many studies focused on stratigraphy, sedimentology and palaeoecology of the Upper Cretaceous sequences (Powell, 1989; Kuss et al., 2003; Schulze et al., 2003, 2004, 2005; Baaske, 2005; Powell and Moh'd, 2011). However, there has been no systematic study on rudists in the region to date, and it is impossible to discuss the biogeographic distribution of the rudists determined in this study and in other parts of the carbonate
Further palaeontologic study on rudists is required to better understand their faunal distribution and palaeoecology in the region. Despite this sparse knowledge for Jordan, the rudists of Cenomanian and Turonian are well studied or recorded from the northern and southern Mediterranean Tethys (Steuber, 2002; Bauer et al., 2002; Kuss et al., 2003; Sara and Özer, 2009; Chikhi-Aouimeur, 1995, 1998, 2002, 2004, 2010; Pons et al., 2011; Hamama, 2010; Abdel-Gawad et al., 2011). The upper Cenomanian and upper Turonian rudists species described in this study show a low diversity when compared with those of northern Mediterranean Tethys, but are more similar in diversity to its southern part.

Although C. boissyi shows a quite a large distribution in the northern side of the Mediterranean Tethys from Portugal to Greece (Sharpe, 1850; Douvillé, 1888; Pejović, 1957; Pamouktchiev, 1974; Chartrousse, 1998; Sirna and Paris, 1999), it was only determined in Algeria (Chikhi-Aouimeur, 2010) from the Arabian-African plate. There is no information about the presence of this species in Tunisia, Egypt, Lebanon and surroundings areas. Its limited occurrence (Bandel and Mustafa, 1996 and this study) indicates the distribution of this species towards to eastern part of the Arabian platform (or plate).

N. nanosi is present mainly in the central Mediterranean Tethys (see Steuber, 2002). But, Neocaprina has been determined from the Upper Cenomanian of Algeria (Chikhi-Aouimeur, 2010) and the Upper Albain of northern Sinai, Egypt (Steuber and Bachmann, 2002) in the southern side of the Mediterranean Tethys. These previous studies on Neocaprina and its occurrence in Jordan may be important for better understand of biogeographic distribution and phylogenetic evolution of this genus.

Fig. 9. Caprinid lithosome: (A)–(D) Sauvagesia sharpei (Bayle, 1857), the transverse sections of the right valves. Note relatively small valve sections showing very little, triangular ligamental ridge, the flat anterior and the posterior radial bands separating by a concave interband, (A) and (B) field photographs from Samta locality, (C) Ishtafina locality, sample no. 1-13–38, (D) An Nuaymah locality, sample no. AN-13–42. (E)–(G) Sauvagesia sp./Durania sp., the natural small transverse sections of the right valves showing generally narrow and concave interband and convex posterior and anterior radial bands, but the ligamental ridge cannot be precisely determined. (E) Kitim locality, (F) Samta locality, (G) An Nuaymah locality. The scale bar indicates 10 mm.
S. *sharpei* is common in the Upper Cenomanian beds of the northern and southern Mediterranean Tethys (see Pons et al., 2011).

*H. resectus* shows a wide distribution from France to Turkey (Steuber, 2002; Korbar and Husinec, 2003; Sari and Özer, 2009; Szente et al., 2010; Pons and Vicens, 2013) in the northern Mediterranean Tethys, but is also present on its southern side such as Algeria (Chikhi-Aouimeur, 2010), Tunisia (Pervinquière, 1912), Egypt (Douvillé, 1913; Bauer et al., 2001; Zakhera, 2011) and Lebanon (Douvillé, 1910).

*V. rousseli* was determined from Spain, France, Bosnia-Herzegovina, Bulgaria and Serbia in the northern part of the Mediterranean Tethys (Steuber, 2002). It seems to have a local distribution in the southern part of the Mediterranean Tethys; it was
D. arnaudi show a wide distribution in the northern (Portugal, France, Italy, Crotia, Bosnia-Herzegovina and Slovenia) and southern parts (Algeria, Tunisia, Libya, Oman and Egypt) of the

Fig. 11. Hippuritid lithosome: (A) and (B), Hippurites resectus Defrance, 1821, (A) many transverse sections from the biostrome of Samta locality, field photograph. (B) a bouquet from the Ishtaafina locality, sample no. I-13–49. (C) and (D), Vaccinites rousseli Douvillé, 1894, transverse sections of the right valve. Compare the size of the valve section with that of H. resectus in the previous figures. (C) Ishtaafina locality, sample no. I-13–52, (D) Samta locality, S-13–32. (E) Vaccinites rousseli Douvillé, 1894, the top view of the left valve, Samta locality, S-13–33. (F) and (G), Durania arnaudi (Choffat, 1891), (F) both valves, note the finely ribbed concave anterior and the posterior radial bands and bulge interband, Rihaba locality, R-13–12, (G) natural transverse section of the right valve showing the outer shell layer consists of polygonal cells, Kitim section, K-13–10. The scale bar indicates 10 mm.

also determined or reported from Algeria, Tunisia (Fliert, 1952; Chikh-Aouimeur, 2010) and Egypt (Youssef and Shinnawi, 1954; Bauer et al., 2004).
6. Conclusions

Two rudist associations represented by caprinid and hippocritid lithosomes are determined for the first time from five measured-stratigraphic sections (Ishitafina, Samta, Kittim, Ribaha and Ana Naufaym) of late Cenomanian and late Turonian age (Hummar and Wadi As Sir Limestone formations, respectively), in the Ajlun-Kitim areas, NW of Jordan. The sharp boundary, karstic structures, reworked carbonate lithoclasts and rudist fragments at the boundary suggest the presence of a hiatus (or eventual unconformity) between Hummar and Wadi As Sir Limestone formations in this area.

The rudist lithosomes are represented by high abundance/low diversity faunas and they are determined for the first time from a large outcrop area in the NW of Jordan. The upper Cenomanian caprinid lithosome consist mainly of canaliculate rudists such as *Caprinula aff. cedrorum* Chikhi-Aouimeur, 1995. The radiolitids (*D. arnaudi* Choffat, P., 1902; *D. schiosensis* Buchbinder, B., 1892) and the radiolitids (*D. arnaudi* Choffat, P., 1902; *D. schiosensis* Buchbinder, B., 1892) and the *Caprinula aff. cedrorum* Chikhi-Aouimeur, 1995. The radiolitids (*D. arnaudi* Choffat, P., 1902; *D. schiosensis* Buchbinder, B., 1892) and the *Caprinula aff. cedrorum* Chikhi-Aouimeur, 1995. The radiolitids (*D. arnaudi* Choffat, P., 1902; *D. schiosensis* Buchbinder, B., 1892) and the *Caprinula aff. cedrorum* Chikhi-Aouimeur, 1995. The radiolitids (*D. arnaudi* Choffat, P., 1902; *D. schiosensis* Buchbinder, B., 1892) and the *Caprinula aff. cedrorum* Chikhi-Aouimeur, 1995. The radiolitids (*D. arnaudi* Choffat, P., 1902; *D. schiosensis* Buchbinder, B., 1892) and the *Caprinula aff. cedrorum* Chikhi-Aouimeur, 1995. The radiolitids (*D. arnaudi* Choffat, P., 1902; *D. schiosensis* Buchbinder, B., 1892) and the *Caprinula aff. cedrorum* Chikhi-Aouimeur, 1995.

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References


Ferry, S., Merrat, Y., Croxhény, D., Mroueh, M., 2007. The cretaceous of Lebanon in the Middle East (Lavan) context. Carots de Géologie, Memoire 2007 (02), 38–42.


