Journal of African Earth Sciences 107 (2015) 119–133

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

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

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ARTICLE INFO

*Article history:*
Received 29 December 2014
Received in revised form 17 March 2015
Accepted 19 March 2015
Available online 24 March 2015

*Keywords:*
Rudists
Lithosomes
Upper Cenomanian
Upper Turonian
Palaeobiogeography
Jordan

ABSTRACT

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* Pleničar, 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 rousseli* 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.



## 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; Makhlouf et al., 1996; Alsharhan and Nairn, 1997; Philip et al., 2000; Stampfli 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-Ishtafina section (Fig. 2): NW of Ajlun city, S of Ishtafina 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).

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http://dx.doi.org/10.1016/j.jafrearsci.2015.03.013
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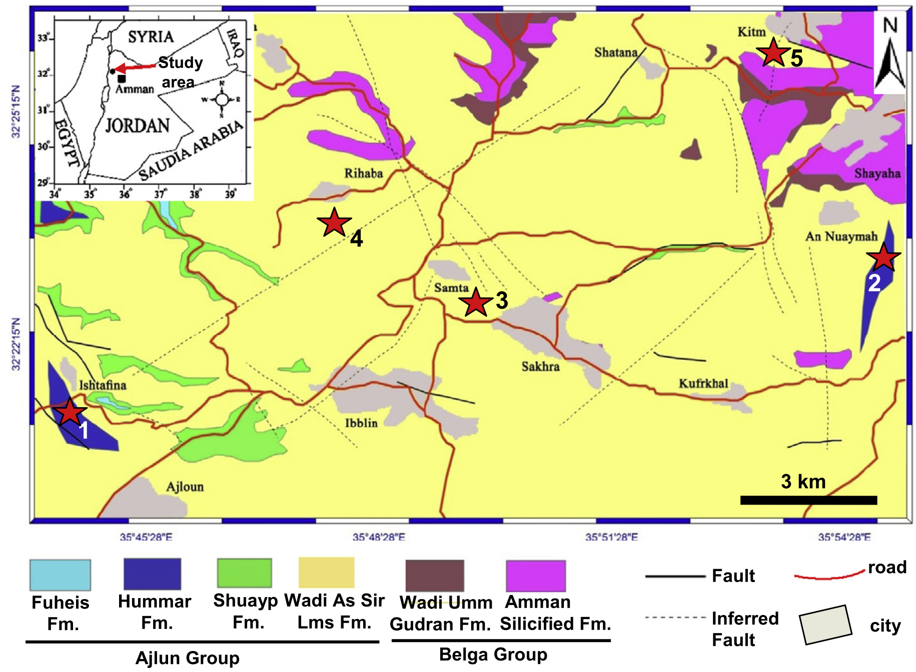


**Fig. 1.** Location map of the studied area (inset top left) and geological map (modified from Abu Qudaira, 2005) showing the measured-stratigraphic sections (red asterisks: 1.Ishtafina, 2. An Nuaymah, 3. Samta, 4. Rihaba, 5. Kitim). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The radiolitids are mostly embedded within the limestones, but the many free specimens of the canaliculate rudists and hippuritids allowed us to prepare the transverse sections of the valves.

The rudist specimens are deposited in the first author's collection in Dokuz Eylul University, İzmir, Turkey, and also in the Hashemite University, Faculty of Natural Resources and Environment, Department of Earth and Environmental Sciences, Jordan.

## 3. Stratigraphy

The Cretaceous succession of Jordan consists of three Groups, in ascending order, Kurnub sandstone (Berriaisan 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 Moh'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 canaliculate rudists. However, the greater abundance of canaliculate 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 Moh'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; Callapez, 2008) and also southern Mediteranean Tethys such as Israel (Lewy, 1989, 1990; Buchbinder et al., 2000;

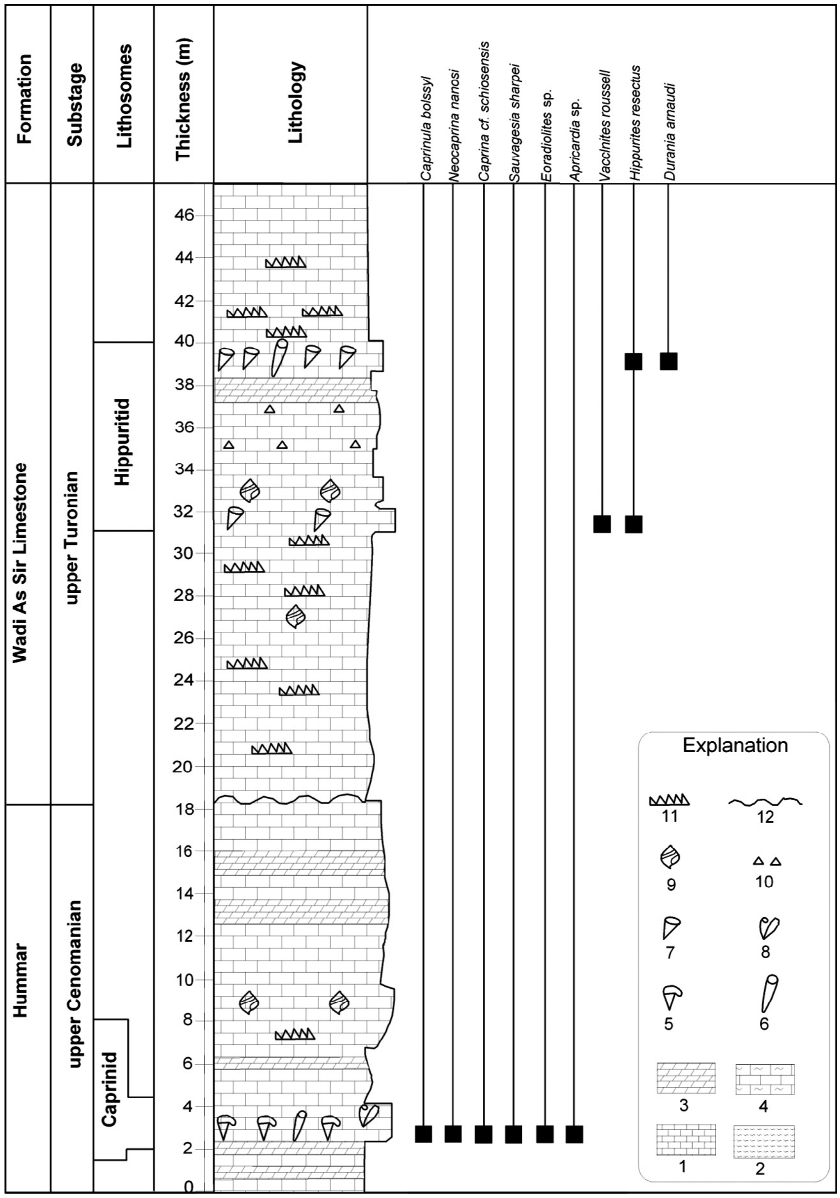


**Fig. 2.** Ishtafina measured-stratigraphic section (see for location to Fig. 1) showing the distributions of the identified rudists. Legend. 1. Limestone, 2. Marl, 3. Caprinid, 4. Radiolitid, 5. Hippuritid, 6. Gastropod, 7. Chert, 8. Stylolith, 9. Subaerial unconformity/hiatus.

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).

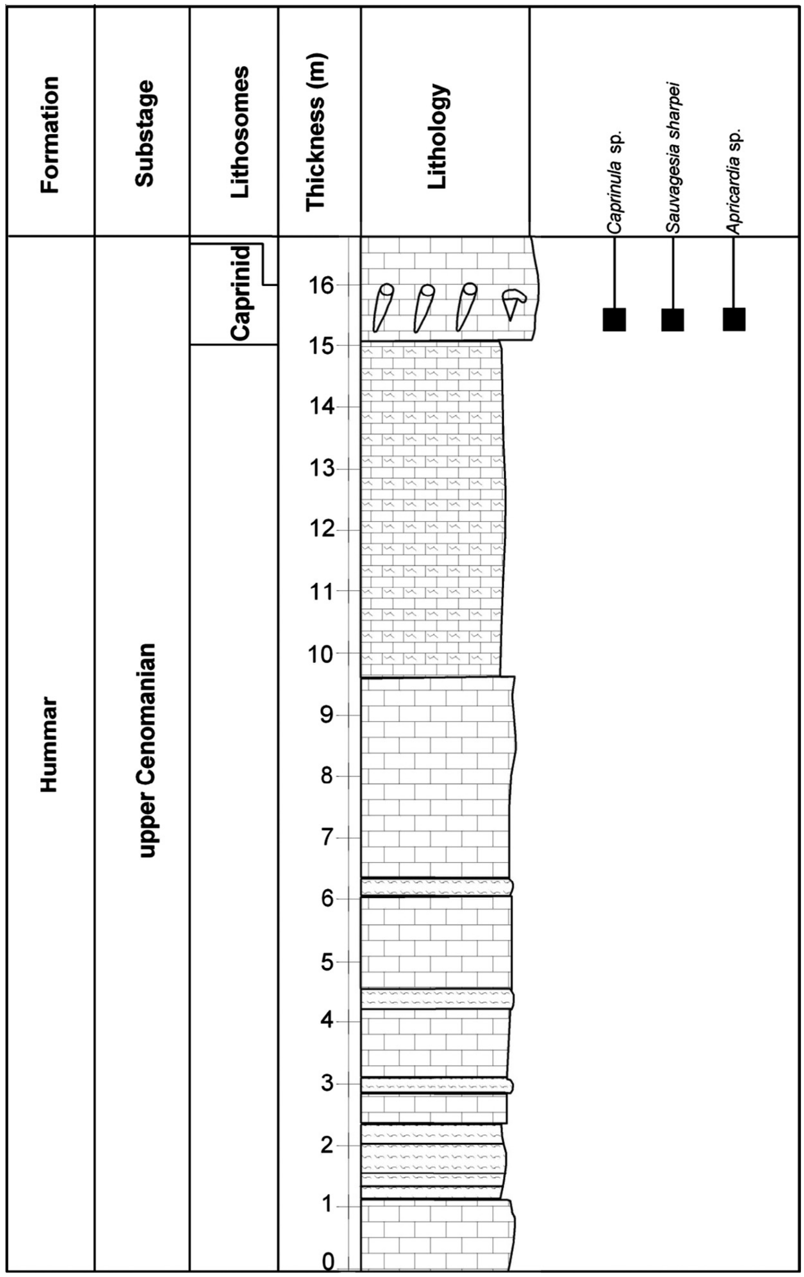


**Fig. 3.** An Nuaymah measured-stratigraphic section (see for location to Fig. 1 and symbols to Fig. 2) showing the distributions of the identified rudists.

## 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* Pleničar, 1961, *Caprina* sp. (aff. *schiosensis* Boehm, 1892), *Sauvagesia sharpei* (Bayle, 1857), *Sauvagesia*/*Durania* sp. and *Eoradiolites* sp. *Apricardia* sp. is also present.

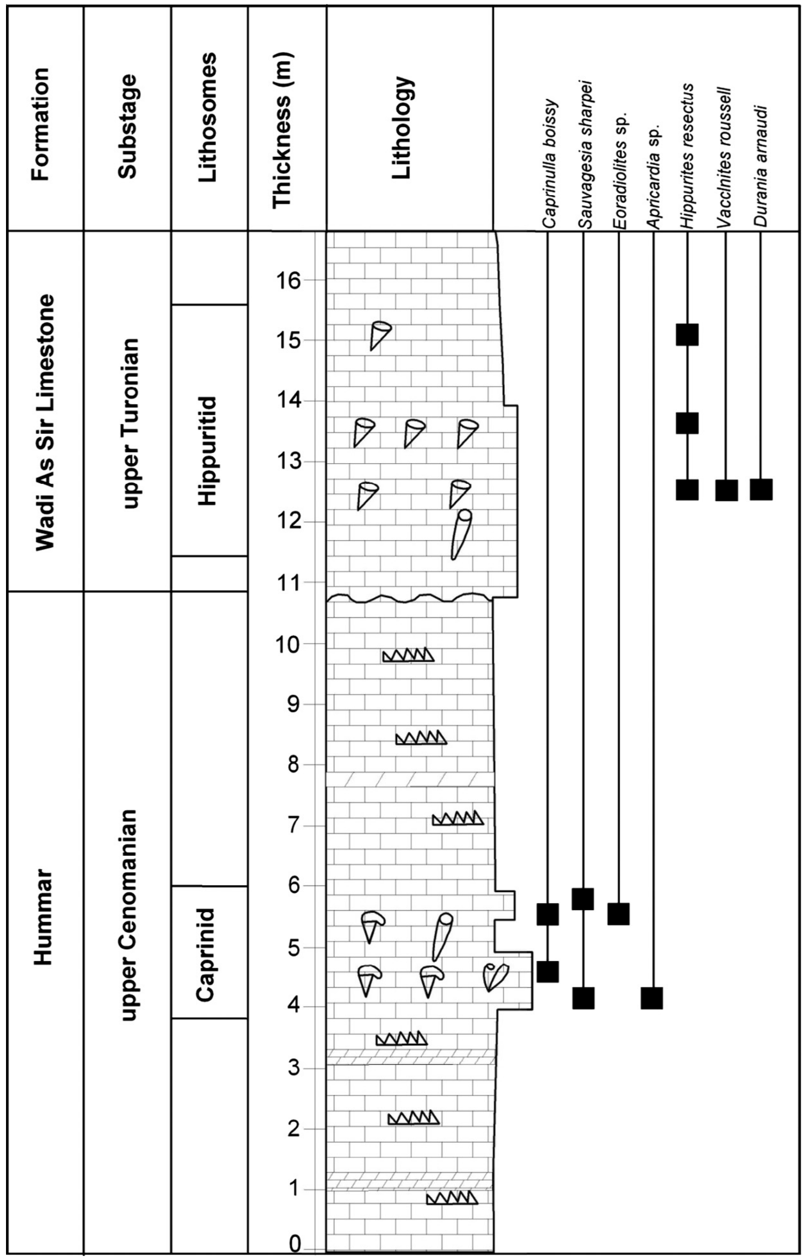


**Fig. 4.** Samta measured-stratigraphic section (see for location to Fig. 1 and symbols to Fig. 2) showing the distributions of the identified rudists.

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 large 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

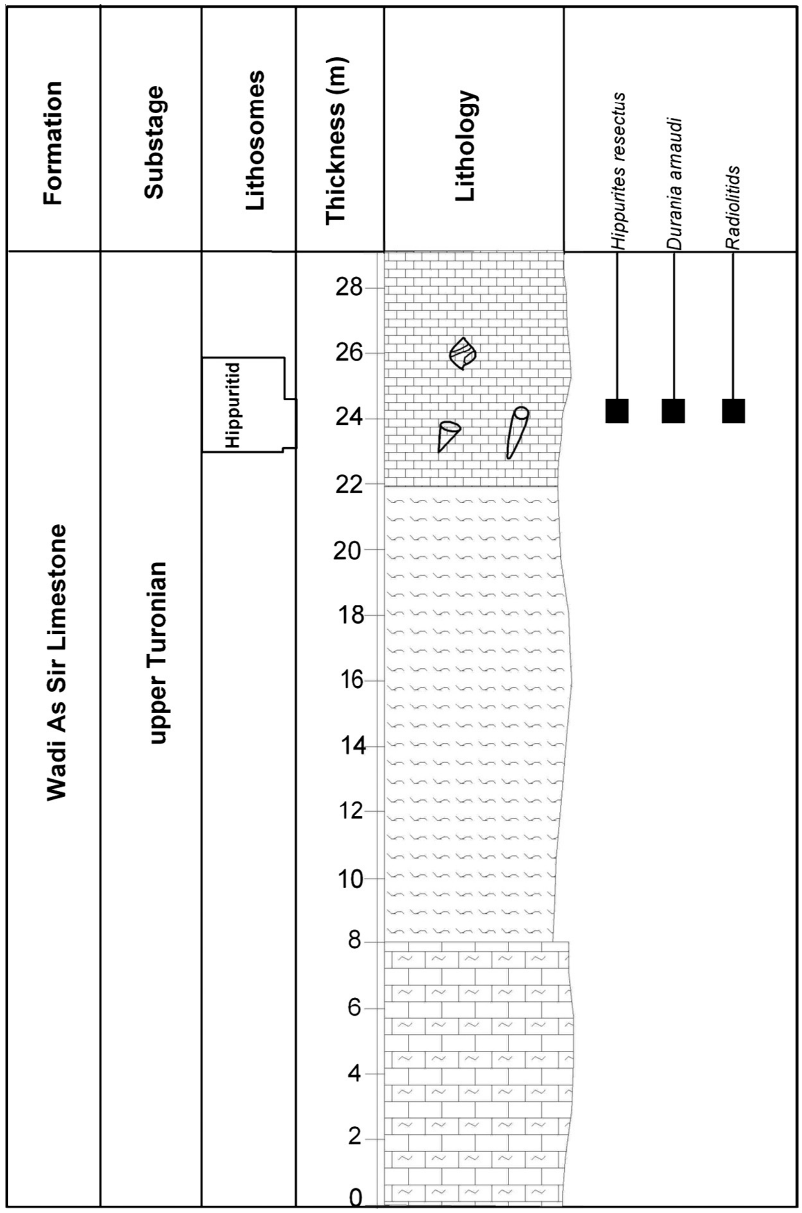


**Fig. 5.** Rihaba measured-stratigraphic section (see for location to Fig. 1 and symbols to Fig. 2) showing the distributions of the identified rudists.

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. 9A–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, narrow 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. 9E–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

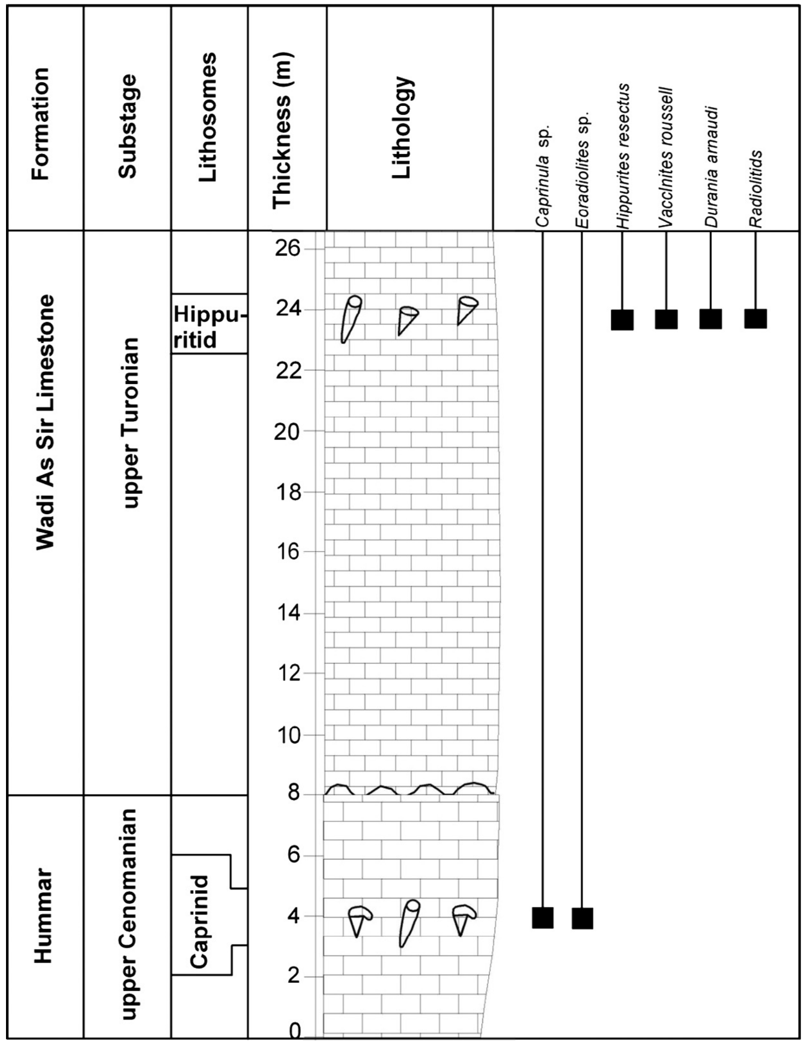


**Fig. 6.** Kitim measured-stratigraphic section (see for location to Fig. 1 and symbols to Fig. 2) showing the distributions of the identified rudists.

determined as *Apricardia* sp. However, our specimens may be correlated because of their small size when compared to *Apricardia douvellei* Péron (1889) determined from the upper Cenomanian of Tunisia (see Chikhi-Aouimeur, 2010).

### *4.2. Hippuritid lithosome (upper Turonian)*

This lithesome 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 Simonpiétri (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; Simonpiétri, 1999), Algeria and Tunisia (Douvillé, 1910; Chikhi-Aouimeur, 2010), Lebanon (Douvillé, 1910), Greece (Steuber, 1993) and Turkey (Özer and Sarı, 2008; Sarı and Özer, 2009) in the old world and Mexico

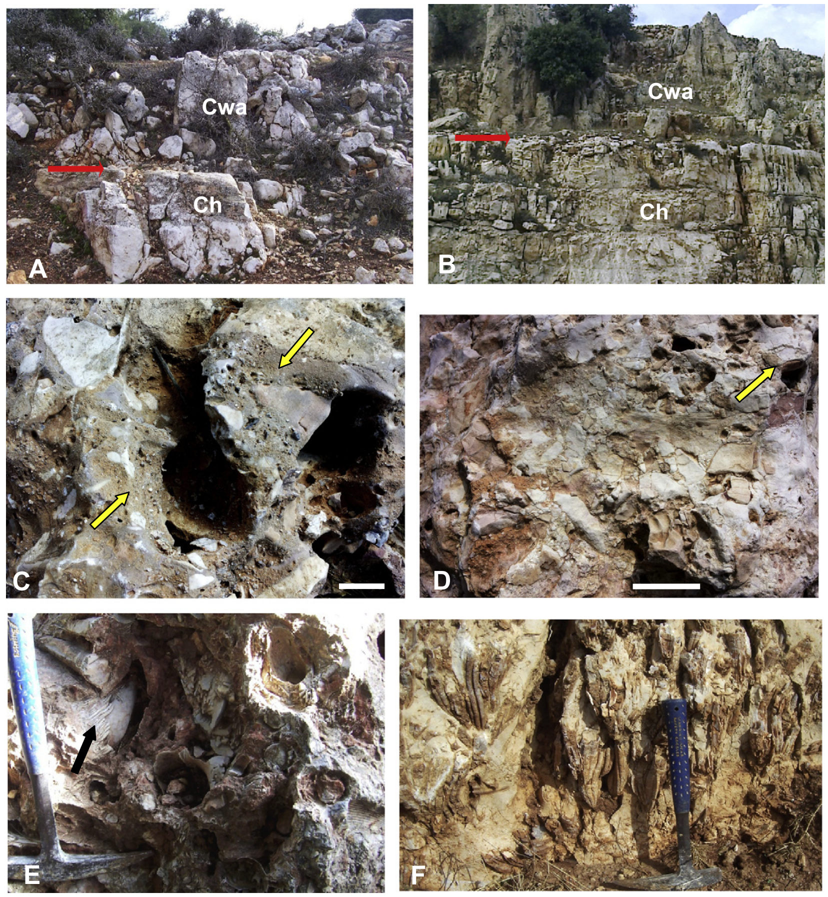


**Fig. 7.** (A) and (B). The field photos showing the sharp boundary (red arrow) between the Hummar (Ch) and Wadi As Sir Limestone (Cwa) formations, (A) Ishtafina and (B) Samta localities. (C) The karstic structures covered by fine grained limestones (yellow arrows) containing reworked carbonate lithoclasts, the boundary of Ch and Cwa, Samta locality. (D) The reworked carbonate lithoclasts and rudist fragments (yellow arrow), the boundary of Ch and Cwa, Ishtafina locality. (E) The field photo showing the general view of the caprinid lithosomes, Ishtafina locality. Note the pallial canals (black arrow). (F) The biostrome constructed by *Hippurites resectus*, note in life positions and three deeply longitudinal grooves of the ligamental ridge and pillars on the surface of the cylindro-conical right valves, Ishtafina locality. The scale bar indicates 10 mm for (C and D). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Oviedo, 2005) in the new world. 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. 11C–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), Pejovič (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 of *H. 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,

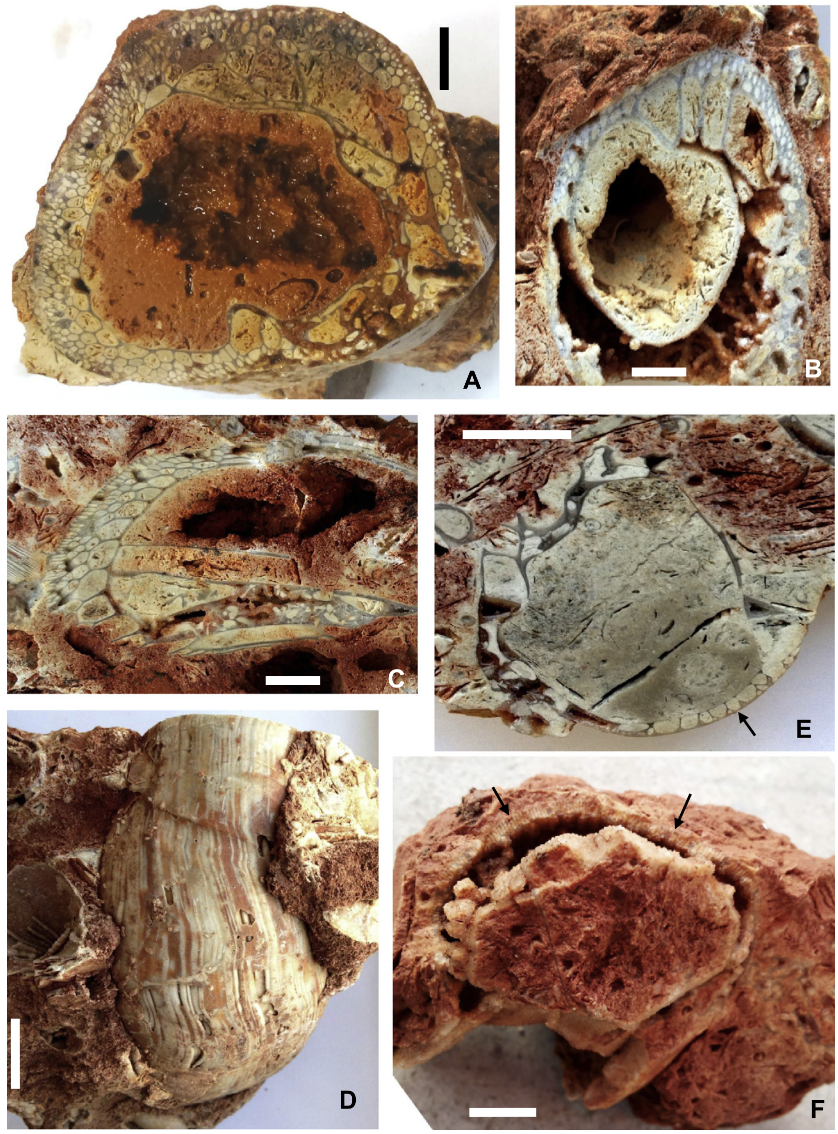


**Fig. 8.** Caprinid lithosome: (A)–(C). *Caprinula boissyi* d'Orbigny,1840, the transverse sections of the right valve, note the decreases the pallial canals from the inner to the outer part in the aragonitic inner shell layer, (A) and (B) Ishtafina locality, sample nos I-13–22, I-13–26 and (C) Samta locality, sample no S-13–13. (D) and (E) *Neocaprina nanosi* Pleničar, 1961, sample no. I-13–29, (D) the postero-ventral view of the left valve showing the longitudinal radial canals in the eroded parts of the thin calcitic outer layer. 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 subcarre in shape and very much large 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.

figs. 1–6) and show similar fetaures 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 section is ovaloid without the ligamental ridge and the outer shell layer consists of polygonal cells. The radial bands are finely ribbed, the anterior and the posterior radial bands are concave, but, the interband is bulging. The left valve is smooth or slowly convex with thin calcitic outer shell layer. Our specimens show clear similarities with those of determined from the upper Cenomanian in northern and southern Mediterranean Tethys (Choffat, 1902; Toucas, 1909; Pervinquière, 1912; Polšak, 1967; Douvillé, 1910, 1913; De Castro and Sirna, 1996; El-Sabbag and El Hedeny, 2003; Abdel-Gawad et al., 2004, 2011) and also from Mexico (Oviedo, 2005). However, they are small in size, so they may be correlated with specimens of northern Sinai, Egypt (Aly et al., 2005; Saber et al., 2009; Hamama, 2010).

## 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

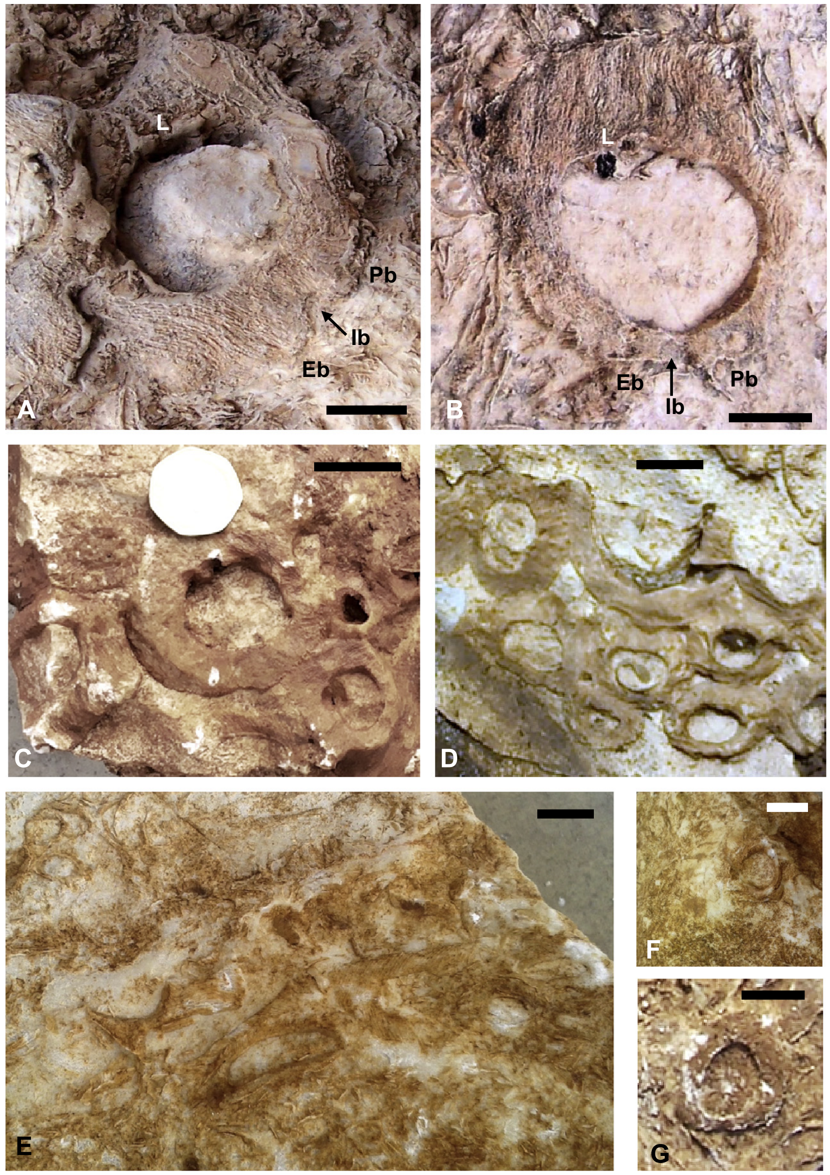


**Fig. 9.** Caprinid lithosome: (A)–(D) *Sauvagesia sharpei* (Bayle, 1857), the transverse sections of the right valves. Note relatively small valve sections showing very little, triangular ligamental ridge, the flat anterior and the posterior radial bands separating by a concave interband, (A) and (B) field photographs from Samta locality, (C) Ishtafina locality, sample no. I-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.

platform exposed in Jordan. 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; Sarı 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 Albian 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.

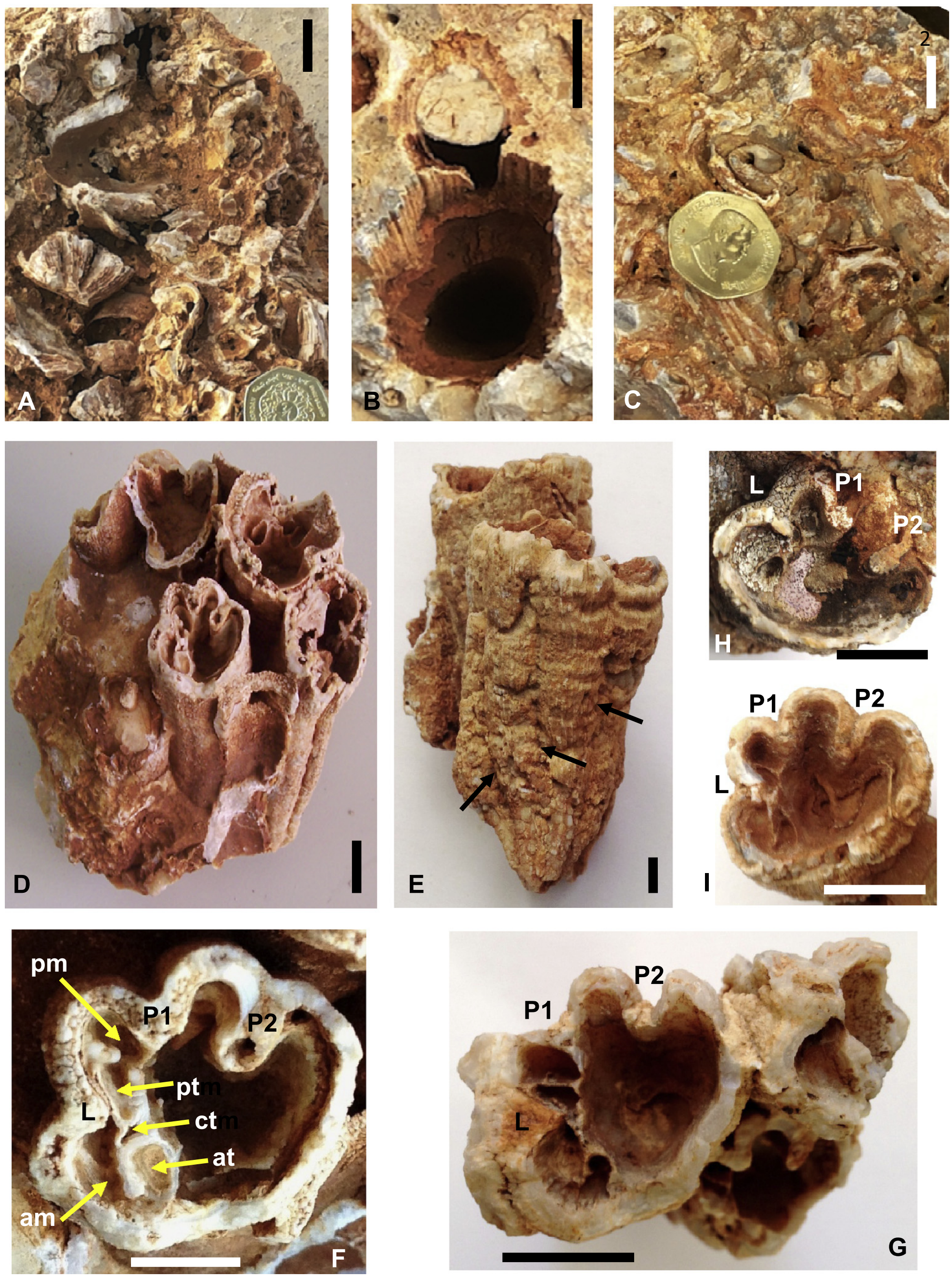


**Fig. 10.** (A)–(C) Caprinid lithosome: (A) and (B). *Eoradiolites* sp., (A) the conical, small in size right valves and their transverse sections from Samta locality, sample no. S-13–42. (B) Two transverse sections from Kitim locality, sample no. K-13–48. (C) *Apricardia* sp., many small right valves showing fortly inclined beak, field photograph from Ishtafina locality. (D)–(I) Hippuritid lithosome: *Hippurites resectus* Defrance, 1821, (D) a bouqet from Ishtafina locality, sample no. I-13–42. (E) Two conjoined right valves, the L and pillars are represented on the surface of the valve with three deeply longitudinal grooves (arrows). The surface of the valve is ornamented with finely longitudinal ribs, Ishtafina locality, sample No. I-13–44. (F)–(I) Transverse sections of the right valves showing the well-preserved of ligamental ridge (L), pillars (P1, P2) and myocardinal apparatus (at, anterior tooth, ct, central tooth, pt, posterior tooth, pm, posterior myophore, am, anterior myophore). Compare the myocardinal apparatus with that of figures G to I. (F)–(G), Ishtafina locality, sample nos. I-13–46 and I-13–47, (H) Samta locality, S-13–28, (I) Rihaba locality, R-13–12. 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; Sarı 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

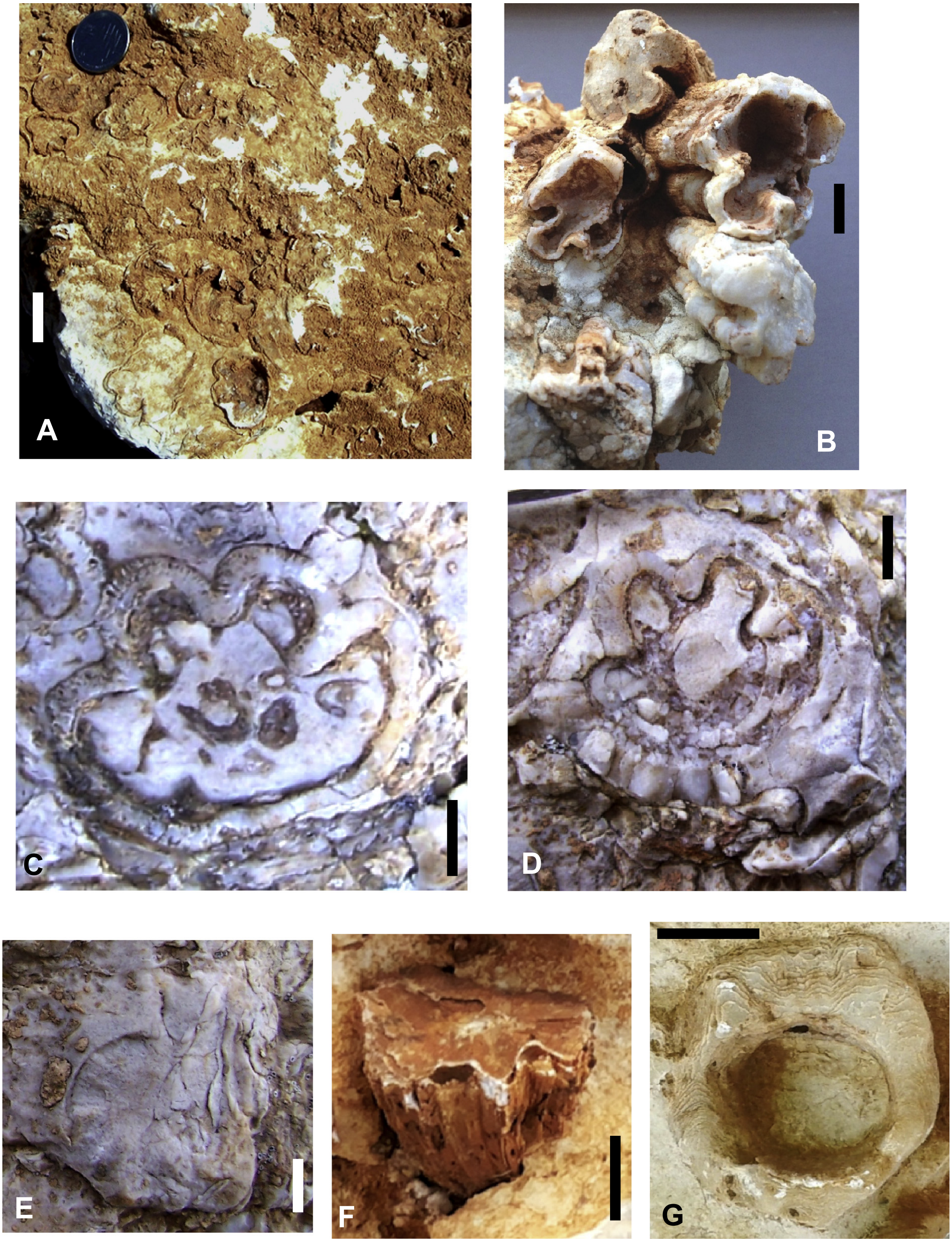

**Fig. 11.** Hippuritid lithosome: (A) and (B), *Hippurites resectus* Defrance, 1821, (A) many transverse sections from the biostrome of Samta locality, field photograph, (B) a bouqet from the Ishtafina locality, sample no. I-13–49, (C) and (D), *Vaccinites rousseli* Douvillé, 1894, transverse sections of the right valve. Compare the size of the valve section with that of *H. resectus* in the previous figures. (C) Ishtafina 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; Chikhi-Aouimeur, 2010) and Egypt (Youssef and Shinnawi, 1954; Bauer et al., 2004).

*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

Mediterranean Tethys (Steuber, 2002; Abdel-Gawad et al., 2004, 2011; Aly et al., 2005).

## 6. Conclusions

Two rudist associations represented by caprinid and hippuritid lithosomes are determined for the first time from five measured-stratigraphic sections (Ishtafina, Samta, Kitim, Rihaba and An Nuaymah) 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 erosional 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 *C. boissyi* d'Orbigny, 1840, *N. nanosi* Pleničar, 1961, *Caprina* sp. (aff. *schiosensis* Boehm, 1892). The radiolitids (*S. sharpei* (Bayle, 1857), *Sauvagesia*/*Durania* sp. and *Eoradiolites* sp.) and requienids (*Apricardia* sp.) are rare. Incontrast, the upper Turonian hippuritid lithosome is characterized by numerous, well-preserved specimens of *H. resectus* Defrance, 1821 in life position. It also contains some specimens of *V. rousseli* Douvillé, 1894 and *D. arnaudi* (Choffat, 1891). The determinations and comparisons of these rudists are outlined.

It is not possible to compare the biogeographic distribution of the rudists of the Ajlun-Kitim area with other parts of the carbonate platform areas in of Jordan, because of the absence the systematic study on rudists in the country. However, the biogeography and correlation of the rudists determined in this study show a low diversity compared to those of northern Mediterranean Tethys, but are similar to reported occurrences on its southern margin and to the distribution and diversity of these species towards to eastern part of the Arabian platform.

## Acknowledgements

We are grateful to Dr. John H. Powell (British Geological Survey) for his English corrections and some comments on the manuscript. We thanks two anonymous reviewers for corrections and comments and the editor for final corrections.

## References

Abed, A.M., Hamad, A.A., Khair, H.A., Kraishan, G., 2013. Development of calcrete and clinoforms during emergence and flooding of the Late Cenomanian carbonate platform, Jordan. Facies 59 (4), 829–842.
Abdallah, H., 2003. Genesis and diagenesis of the gattar carbonate platform, lower turonian, northern southern Tunisia. In: Gili, E., Negra, H., Skelton, P.W. (Eds.). North African Cretaceous Carbonate Platform Systems. Nato Sci. Ser. vol. 28, pp. 31–51.
Abdelhamid, G., 1995. The geology of jarash area, map sheet (3154-1). NRA, Geol. Directorate, Bull. 30, 1–51.
Abdel-Gawad, G.I., Orabi, O.H., Ayoub, W.S., 2004. Macrofauna and biostratigraphy of the Cretaceous section of Gebel El-Fallig area, northwest Sinai, Egypt. Egypt. J. Paleontol. 4, 305–333.
Abdel-Gawad, G.I., Saber, S.G., El Shazly, S.H., Salama, Y.F., 2011. Turonian rudist facies from Abu Roash area, North Western Desert, Egypt. J. Afr. Earth Sci. 59, 359–372.
Abed, A.M., 1982. Microfacies and paleoenvironment of the wadi sir formation (Upper Cretaceous), North Jordan. Facies 7, 229–236.
Abu Qudaira, M., 2005. Geological Map of Dayr Abu Sàid. Map sheet No. 3154 IV. Natural Resources Authority, Amman, Jordan.
Alsharhan, A.S., Nairn, A.E.M., 1997. Sedimentary Basins and Petroleum Geology of the Middle East. Elsevier, Amsterdam, 843+99p.
Aly, M.F., Saber, S.G., Abdel-Gawad, G.I., Ferieg, Y.F., 2005. Cenomanian–Turonian rudist buildups of northern Sinai, Egypt. Egypt. J. Paleontol. 5, 253–286.
Aly, M.F., Smadi, A., Abu Azzam, H., 2008. Late Cenomanian-Early Turonian ammonites of Jordan. Revue de Paléobiologie Genève 27 (1), 43–71.
Baaske, U.P., 2005. Sequence stratigraphy, sedimentology and provenance of the Upper Cretaceous siliciclastic sediments of South Jordan. Phd thesis, Institut für Geologie und Paläontologie der Universität Stuttgart, pp. 1–135.
Bandel, K., Mustafa, H., 1996. Constructional morphology of some Upper Cretaceous rudists of the Ajlun (Jordan). In: Spaeth, C. (Ed.), Proceedings of the 4th International Cretaceous Symposium, Hamburg 1992. Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg, vol. 77, pp. 603–635.
Bandel, K., Salameh, E., 2013. Geologic Development of Jordan. Evolution of Its Rocks and Life. The University of Jordan Press, pp. 1–278.
Basha, W., 1978. Foraminifera from the Ajlun Group of east Jordan. J. Geol. Soc. Iraq 11, 67–91.
Bauer, J., Marzouk, A.M., Steuber, T., Kuss, J., 2001. Lithostratigraphy and biostratigraphy of the Cenomanian–Santonian strata of Sinai, Egypt. Cretaceous Res. 22, 497–526.
Bauer, J., Kuss, J., Steuber, T., 2002. Platform environments, microfacies and systems tracts of the upper Cenomanian-lower Santonian of Sinai, Egypt. Facies 47, 1–26.
Bauer, J., Steuber, T., Kuss, J., Heimhofer, U., 2004. Distribution of shallow-water benthics (rudists, calcareous algae, benthic foraminifers) in the Cenomaman - Turoman carbonate platform sequences of Sinai, Egypt. In: Höfling, R. (Ed.), Contributions to the 5th International Congress on Rudists, Erlangen, Germany 1999, Courier Forschungsinstitut Senckenberg, vol. 247, pp. 207–232.
Bayle, E., 1857. Nouvelles observations sur quelques espèces de rudistes. Bulletin de la Société géologique de France 2 (14), 647–719.
Bender, F., 1974. Geology of Jordan. Borntraeger, Berlin, pp. 1–196.
Boehm, G., 1892. Ein Beitrag zur Kenntnis der Kreide in den Venetianer Alpen. Berichte der naturforschenden Gesellschaft zu Freiburg i. Br. 6, 134–149.
Buchbinder, B., Benjamini, C., Lipson-Benitah, S., 2000. Sequence development of Late Cenomanian–Turonian carbonate ramps, platforms and basins in Israel. Cretaceous Res. 21, 813–843.
Burdon, D.J., 1959. Handbook pf the geology of Jordan; to accompany and explain the three sheets of 1:250,000 Geological Map, Kingdom of Jordan, Benham, Golchester, 82p.
Callapez, P.M., 2008. Palaeogeographıc evolutıon and marıne faunas of the mıd-cretaceous western portuguese carbonate platform. Thalassas 24 (1), 29–52.
Caffau, M., Pleničar, M., 1991. Rudistid fauna from Turonian deposits of the locality "Archi"/Mo_s_cenice in the surroundings of Duino (Karst of Triest). Razprave IV. Razreda SAZU 32 (8), 259–315.
Chartrousse, A., 1998. The myocardinal organisation of coalcomaninid rudists revisited. In: Masse, J.-P., Skelton, P.W. (Eds.), Quatrième Congrès international sur les Rudistes. Geobios, Mémoire spécial, vol. 22, pp. 75–85.
Chikhi-Aouimeur, F., 1995. *Caprinula aff. cedrorum* (Blanckenhorn, 1890) from the Upper Cenomanian of western Algeria. In: Alencáster, G., Buitrón-Sánchez, B.E. (Eds.), Number Devoted to the Third international Conference on Rudists. Revista mexicana de Ciencias geológicas, vol. 12, pp. 179–184.
Chikhi-Aouimeur, F., 1998. Sauvagesiinae du Cénomanien supérieur de la région de Berrouaguia (Sud d'Alger, Algérie). In: Masse, J.-P., Skelton, P.W. (Eds.), Quatrième Congrès international sur les Rudistes. Geobios, Mémoire spécial, vol. 22, pp. 101–109.
Chikhi-Aouimeur, F., 2002. Etude quelques radiolitides du crétacé superieur de l'Algerie Orientale. In: Proceedings 1st International Conference on Rudists (Beograd, 1988), "Rudists", UGYS, Mem. Publ., pp. 61–79.
Chikhi-Aouimeur, F., 2004. Description of some rudists collected by J. Savornin in the Cenomanian–Turonian of northeastern Algeria (Sétif and Hodna region). In: Höfling, R. (Ed.), Contribution to the 5th International Congress on Rudists, Erlangen, Germany 1999. Courier Forschungsinstitut Senckenberg, vol. 247, pp. 49–61.
Chikhi-Aouimeur, F., 2010. L'Algérie à travers son Patrimoine paléontologique, Les Rudistes. Sarl Baosem, 269p.
Choffat, P., 1891. Crétacique de Torres-Vedras, 211p.
Choffat, P., 1902. Recueil d'études paléontologiques sur la faune crétacique du Portugal. 4eme série, Espèces diverses. Comunicaçoes dos Serviços geologicos de Portugal, 171p.
Conrad, T. A., 1852. Description of the fossils of Syria, collected in the Palestine expedition. Official report of the United States expedition to explore the Dead Sea and the River Jordan 235 p.
De Castro, P., Sirna, G., 1996. *Durania arnaudi* biostrome of El-Hassana, Abu Roash area, Egypt. Geol. Rom. 32, 69–91.
Defrance, J.L.M., 1821. Hippurites. In: Defrance, J.L.M., (Ed.), Dictionnaire des sciences naturelles, vol. 21, pp. 195-197.
Dilley, F.C., 1985. Cretaceous correlations in the Hamza Wells 1–5. NRA Palaeontological Report, 6.
Douvillé, H., 1888. Etudes sur les caprines. Bulletin de la Société Géologique de France 3 (16), 699–730.
Douvillé, H., 1892. Etudes sur les rudistes. Révision des principales espèces d'Hippurites (deuxième partie). Mémoires de la Société géologique de France, Paléontologie 6 (2), 33–56.
Douvillé, H., 1894. Etudes sur les rudistes. Révision des principales espèces d'Hippurites (quatrième partie). Mémoires de la Société géologique de France, Paléontologie 6 (4), 95–138.
Douvillé, H., 1895. Etudes sur les rudistes. Distribution régionale des Hippurites. Mémoires de la Société géologique de France, Paléontologie 6 (5), 139–186.

Douvillé, H., 1897. Etudes sur les rudistes. Distribution régionale des Hippurites. Mémoires de la Société géologique de France, Paléontologie 6 (6), 187–230.
Douvillé, H., 1910. Etudes sur les rudistes. Rudistes de Sicile, d'Algérie, d'Egypte, du Liban et de la Perse. Mémoires de la Société géologique de France, Paléontologie 41, 83p.
Douvillé, H., 1913. Description des Rudistes de l'Égypte. Mémoires de l' Institut d'Égypte 6, 237–256.
Drzewiecki, P.A., Simo, T., 1997. Carbonate platform drowning and oceanic anoxic events on a mid-Cretaceous carbonate platform, south-central Pyrenees, Spain. J. Sedimentary Res. 67, 698–714.
El-Sabbag, A.M., El Hedeny, M.M., 2003. Upper turonian radiolitidae (Rudist Bivalves) from the actaeonella series, El-Hassana Dome, Abu Roash, Egypt. Egypt. J. Paleontol. 3, 243–269.
El-Sabbag, A.M., Tantawy, A.A., Keller, G., Khozyemd, H., Spangenberg, J., Adatte, T., Gertsch, B., 2011. Stratigraphy of the CenomanianeTuronian oceanic anoxic event OAE2 in shallow shelf sequences of NE Egypt. Cretaceous Res., 1–18
Ferry, S., Merran, Y., Grosheny, D., Mroueh, M., 2007. The cretaceous of Lebanon in the Middle East (Levant) context. Carnets de Géologie, Memoir 2007 (02), 38–42.
Fliert, J.van de, 1952. Liste de rudistes du Crétacé du Constantinois. XIXème Congrès géologique international, Monographies régionales. Deleau, P.: Le pays constantinois 1 (13), 47–52.
Frank, R., 2010. Facies, genetic evolution and paleoecological control of mid-Cretaceous carbonate system in the northern Levant Margins: northern Israel. Report of Geological Survey of Israel, 185p.
Frank, R., Buchbinder, B., Benjamini, C., 2010. The mid-Cretaceous carbonate system of northern Israel: facies evolution, tectono-stratigraphy configuration and global control on the central Levant margin of the Arabian plate. In: Homberg, C., Bachmann, M. (Eds.), Evolution of the Levant Margin and Western Arabia Platform Since the Mesozoic, Geological Society, Special Publication, vol. 341, pp. 133–170.
Hamama, H., 2010. Morphology and wall structure of some turonian rudists (Bivalvia, Hippuritoida) of gabal yelleg, Northern Sinai, Egypt. J. Am. Sci. 6 (12), 1682–1701.
Hannaa, W.S.A., 2011. Taxonomy and palaeoecology of the Cenomanian–Turonian macro-invertebrates from eastern Sinai, Egypt. Doctorat Thesis, Bayerischen Julius-Maximilians-Universität Würzburg, 411p.
Korbar, T., Husinec, A., 2003. Biostratigraphy of turonian to (?) coniacian platform carbonates: a case study from the Island of Cres (Northern Adriatic, Croatia). Geol. Croat. 56 (2), 173–185.
Kuss, J., Bassiouni, A., Bauer, J., Bachmann, M., Marzouk, A., Scheibner, C., Schulze, F., 2003. Cretaceous-Paleogene sequence stratigraphy of the Levant Platform (Egypt, Sinai, Jordan). In: Gili, E., Negra, H., Skelton, P.W. (Eds), North African Cretaceous carbonate platform systems. Nato Sci. Ser. vol. 28, pp. 171–187.
Lewy, Z., 1989. Correlation of lithostratigraphic units in the upper Judea group (late Cenomanian–late Coniacian) in Israel. Israel J. Earth Sci. 38, 37–43.
Lewy, Z., 1990. Transgressions, regressions and relative sea level changes on the cretaceous shelf of Israel and adjacent countries. A critical evaluation of cretaceous global sea-level correlations. Paleoceanography 5, 619–637.
Macdonald, M., 1965. East Bank water resources Hydrogeological Survey of the Irbid and Amman Areas, Geol. Maps 1:25,000, vol. 6, Central Water Authority, Amman (unpublished).
Makhlouf, I., Abu-Azzam, H., Al-Hiyari, A., 1996. Surface and subsurface lithostratigraphic relationships of the Cretaceous Ajlun Group in Jordan. Subsurface Geology Bulletin, No. 8. The Hashemite Kingdom of Jordan, Ministry of Energy and Mineral Resources, Natural Resources Authority, Amman, pp. 1–95.
Masri, M., 1963. Report on the geology of the Amman-Zegra area. Centarl Water Authority, Amman, Jordan, 70p (unpublished).
Matheron, P., 1842. Catalogue méthodique et descriptif des corps organisés fossiles du Département des Bouches-du-Rhône et lieux circonvoisins. 266p.
Olexcon Int., 1967. Micropalaeontology, palynology, stratigraphy and oil source rock identification, various wells and sections. NRA, Amman (unpublished report).
Oviedo, A., 2005. Rudistas del Cretácico superior del centro al sureste de México (Recuento sistemático de rudistas americanos). Ph.D. Thesis. Universitat Autònoma de Barcelona. 123p. <http://www.tdx.cat/TDX-0620106-232433>.
Özer, S., Sarı, B., 2008. Rudist-bearing marbles of the metamorphic Menderes Massif and the Upper Cretaceous rudistid limestones of the Bey Dağları (western Taurides) carbonate platform: Eighth International Congress on Rudists. Cretaceous Rudists and Carbonate Platforms, İzmir-Turkey, Post-meeting Field Trip (2) Excursion Guide, June 26–28, 2008, 35p.
Özer, S., Ahmad, F., 2014. Cenomanian-Turonian rudists from NW Jordan. Tenth International Congress on Rudists Bivalve, Rudists 2014, Bellaterra June 22–27, Scientific Program and Abstracts, pp. 20, 21.
Parona, C.F., 1909. *Radiolites liratus* (Conr.) e *Apricardia nötlingi* (Blanck.) nel Cretaceo superiore della Siria. Reale Accademia delle Scienze di Torino 44, 183–187.
Parona, C.F., 1921. Fauna del Neocretacico della Tripolitania. Molluschi. Parte I.-Lamellibranchi (Rudiste). Memorie per servire alla descrizione della Carta Geologica d'Italia 8, 3, 21pp.
Pamouktchiev, A., 1969. La faune des rudistes du village Lyalintzi, Bulgarie de l'Ouest. Annuaire de l'Université de Sofia, Faculté de Géologie et Géographie, Livre 1, Géologie 61, 1-14.
Pamouktchiev, A., 1974. Sur quelques espèces de la famille Caprinidae du Balkan central et du Srednogorié occidental. Annuaire de l'Université de Sofia, Faculté de Géologie et Géographie, Livre 1. Géologie, vol. 66, pp. 15–23.
Pejović, D., 1957. Geologie und Tektonik der weiteren Umgebung von Pocuta (Westserbien) mit besonderer Berücksichtung der Biostratigraphie der oberkretazischen Bildungen. Geoloski Institut ''Jovan Zujovic'', vol. 8, pp. 1–147.
Péron, A., 1889. Description des invertébrés fossiles des terrains crétacés de la région sud des hauts-plateaux de la Tunisie recueillis en 1885 et 1886 par M. Philippe Thomas. 405pp.
Pervinquière, L., 1912. Etudes de Paléontologie Tunisienne. II Gastropodes et lamellibranches de terrains crétacés. Carte géologique de la Tunisie, pp. 1–352.
Philip, J., Airaud-Crumière, C., 1991. The demise of the rudist-bearing carbonate platforms at the Cenomanian/Turonian boundary: a global control. Coral Reefs 10, 115–125.
Philip, J., Babinot, J.-F., Tronchetti, G., Fourcade, E., Ricou, L.-E., Guiraud, R., Bellion, Y., Herbin, J.-P., Combes, P.-J., Cornee, J.-J., Dercourt, J., 2000. Late Ceonamanian. In: Dercourt, J., Gaetani, M., Vrielynck, B., Barrier, E., Biju-Duval, B., Brunet, M.F., Cadet, J.P., Crasquin, S., Sandulescu, M. (Eds.), Atlas Peri-Tethys Palaeogeographical Maps, Map 14. CCGM/CGMW, Paris.
Polšak, A., 1967. Macrofaune crétacée de l'Istrie méridionale (Yougoslavie). Palaeontol. Jugoslavica 8, 1–219.
Pleničar, M., 1961. The stratigraphic development of cretaceous beds in southern primorska (Slovene littoral) and notranjska (inner Carniola). Geologija 6, 22–145.
Pleničar, M., 1963. Caprinidae and the genus *Radiolitella* from the upper cretaceous strata of southwestern Slovenia. Slovenska Akademija Znanosti in Umetnosti, Razred za Prirodoslovne in Medicinske Vede, Razprave 7, 559–587.
Pleničar, M., Jurkovšek, B., 2000. Rudists from the Cenomanian bioherms of hrusice and nanos, Slovenia. Geologija 42, 69–116.
Pons, J.M., Vicens, E., 2013. Evolution and extinction patters amongst Pyrenean rudist bivalves. In: 9th International Symposium on the Cretaceous System, pp. 1–5, September 2013, Ankara, Abstract Book, p24.
Pons, J.M., Vicens, E., Tarlao, A., 2011. Cenomanian radiolitid bivalves from Malchina, Karst of Trieste, Italy. Cretaceous Res. 32, 647–658.
Powell, J.H., 1989. Stratigraphy and sedimentation of the phanerozoic rocks in central and South Jordan – Part B: Kurnub, Ajlun and Belqa Groups. Geological Bulletin No. 11. The Hashemite Kingdom of Jordan, Ministry of Energy and Mineral Resources, Natural Resources Authority Amman, pp. 1–130.
Powell, J.H., Moh'd, B.K., 2011. Evolution of cretaceous to Eocene alluvial and carbonate platform sequences in central and south Jordan. GeoArabia 16 (4), 29–82.
Quennell, A.M., 1951. The geology and mineral resources of (former) transjordan. Colon geol Mia Resource, vol. 2, pp. 85–115, London.
Saber, G.S., Salama, Y.F., Scott, R.W., Abdel-Gawad, G.I., Aly, M.F., 2009. Cenomanian -turonian rudist assemblages and sequence stratigraphy on the North Sinai carbonate shelf, Egypt. GeoArabia 14 (4), 113–134.
Sarı, B., Özer, S., 2009. Upper Cretaceous rudist biostratigraphy of the Bey Dağları Carbonate Platform, Western Taurides; SW Turkey. Geobios 42, 359–380.
Schlager, W., 1999. Type 3 sequence boundaries. In: Harris, P.M., Saller, A.H., Simo, J.A. (Eds.), Advances in Carbonate Sequence Stratigraphy: Application to Reservoirs, Outcrops and Models, SEPM (Society for Sedimentary Geology) Special Publication, vol. 63, pp. 35–45.
Schulze, F., Lewy, Z., Kuss, J., Gharaibeh, A., 2003. Cenomanian-Turonian carbonate platform deposits in west central Jordan. Int. J. Earth Sci. (Geol Rundsch) 92, 641–660.
Schulze, F., Marzouk, A., Bassiouni, M.A.A., Kuss, J., 2004. The upper Albian to turonian carbonate platform succession of west central Jordan-stratigraphy and crisis. Cretaceous Res. 25 (5), 709–737.
Schulze, F., Kuss, J., Marzouk, A., 2005. Platform configuration, microfacies and cyclicities of the upper Albian to Turonian of west-central Jordan. Facies 50, 505–527.
Sharpe, D., 1850. On the Secondary district of Portugal which lies on the north of the Tagus. Q.J. Geol. Soc. London 6, 135–201.
Simonpiétri, G., 1999. Systématique phylogenèse ontogenèse chez les hippuritidae (rudistes du Crétacé Supérieur). Doctorate thesis, Université d'Aix-Marseille 1, Marseille, 317p.
Sirna, G., 1982. Quelques rudistes cénomaniens du Monte Pellegrino (Palermo, Sicile). Geol. Rom. 21, 79–87.
Sirna, G., Paris, A., 1999. Le rudiste del Museo di paleontologia del dipertimento di Scienze della terra dell'Università ''La Spienza'' di Roma. Geol. Rom. 35, 45–87.
Skelton, P.W., 1978. The evolution of functional design in rudists (Hippuritacea) and its taxonomic implications. Philos. Trans. R. Soc. London B 284, 305–318.
Stampfli, G.M., Borel, G., Cavazza, W., Mosar, J., Ziegler, P. A., 2001. The paleotectonic Atlas of the Peritethyan domain. European Geophysical Society, CD-ROM., Electronic Publishing and Consulting Berlin.
Steuber, T., 1993. Hippuritiden aus dem turon des ptoon-gebirges, mittelgriechenland. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 190, 37–55.
Steuber, T., 1999. Cretaceous rudists of Boeotia, central Greece. Spec. Pap. Palaeontol. 61, 1–229.
Steuber, T., 2002. A palaeontological database of Rudist Bivalves (Mollusca: Hippuritoidea, Gray1848). <http://www.ruhr-uni-bochum.de/sediment/rudinet /intro.htm>.

Steuber, T., Bachmann, M., 2002. Upper Aptian-Albian rudist bivalves from northern Sinai, Egypt. Palaeontology 45 (4), 725–749.

Szente, I., Baron-Szabo, R.C., Hradecká, L., Kvaček, J., Svobodová, M., Schlagintweit, L., Lobitzer, F., 2010. The Lower Gosau subgroup of the kohlbachgraben and "station billroth" north of St. Gilgen (Turonian–?Coniacian, Salzburg, Austria). Geol. Bundesanstalt, Wien, Abh. Geol. B.-A 65, 135–154.

Toucas, A., 1903. Etudes sur la classification et l'évolution des Hippurites, première partie. Mémoires de la Société géologique de France, Paléontologie 30 (11), 1–64.

Toucas, A., 1909. Etudes sur la classification et l'évolution des Radiolitidés: *Sauvagesia* & *Biradiolites*. Mémoires de la Société géologique de France, Paléontologie 36 (17), 79–132.

Wendler, J., Wendler, I., Kuss, J., 2009. Early Turonian shallow marine red beds on the Levant carbonate platform (Jordan), Southern Tethys. In: Hu, X. (Ed.). Cretaceous Oceanic Red Beds: Stratigraphy, Composition, Origins, and Paleoceanographic and Paleoclimatic Significance SEPM Special Publication No, vol. 91, pp. 171–179.

Wetzel, R., Morton, D.M., 1959. Contribution à la géologie de la transjordanie. In: Dubertret, L. (Ed.), Notes et Memoires sur le Moyen Orient, vol. VII, pp. 95–191.

Wiese, F., Schulze, F., 2005. The upper Cenomanian (cretaceous) ammonite *Neolobites vibrayeanus* (d'Orbigny, 1841) in the Middle East: taxonomic and palaeoecologic remarks. Cretaceous Res. 26, 930–946.

Youssef, M.İ., Shinnawi, M.A., 1954. Upper Cretaceous rocks of Wadi Sudr, western Sinai. Bull. de l'Institut du Desert d'Egypte 4, 94–111.

Zakhera, M.S., 2011. Cenomanian-Turonian rudists from Western Sinai, Egypt: Systematic paleontology and paleoecology. Geobios 44, 409–433.