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Cenomanian canaliculate rudists (Bivalvia) from the Geyik Dağı-Hadim area (Central Taurides, S Turkey): systematic paleontology, stratigraphic importance and depositional environment

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A B S T R A C T

A rudist fauna consisting of Cenomanian canaliculate rudists is described from the Geyik Dağı-Hadim area, Central Taurides-south of Turkey. The stratigraphic section was measured on the eastern slope of Geyik Dağı, at an altitude of about 2700 m. The rudists are observed in the uppermost part of the Bajocian-Cenomanian Polat Limestone of the Anamas-Akseki autochthon (=Geyik Dağı unit). In the study area, only the Cenomanian part of the Polat Limestone crops out. The rudist-bearing limestones are overlain with sharp contact by the Maastrichtian-Lutetian pelagic Kuşça Limestone. The rudist fauna consists mainly of canaliculate rudists such as ichthyosarcolitids (*I. triangularis*, *I. monocarinatus*, *I. bicarinatus*, *I. rotundus*), caprinids (*Caprina baylei*, *Caprina* cf. *schiosensis*, *Sphaerucaprina woodwardi*) and caprinulids (*Caprinula sharpei*, *Neocaprina gigantea*). Rudists are dominant and are accompanied by nerineid gastropods, corals and *Conicorobitolina conica*. The fossil content indicates an early-middle Cenomanian age for the rudist-bearing limestones, contrary to the Campanian-Maastrichtian age previously suggested. Four main lithofacies have been recognized: (1) scarce ichthyosarcolitid-gastropod packstone, (2) canaliculate rudist packstone-floatstone-rudstone, (3) packstone-grainstone-rudstone with canaliculate rudist-gastropod-coral fragments and whole shells and (4) mixed canaliculate rudist-gastropod-coral fragments rudstone-grainstone and rudstone. The facies characteristics indicate a middle carbonate ramp depositional environment with slightly to moderately and strongly agitated-water conditions for the rudist-bearing limestones. Their faunal and facies characteristics shows similarities with those from central region of the Mediterranean Tethys.

1. Introduction

The Taurus Mountains consist mainly of platform carbonate successions, and they extend from the Bey Dağları in the west to the Munzur Dağları in the east along approximately 1600 km within the “Tauride-Anatolide Carbonate Platform” (Fig. 1A) (Blumenthal, 1951; Brunn et al., 1971; Özgül, 1976, 1984, 1997; Şengör and Yılmaz, 1981; Dercourt et al., 2000). Although many studies reported on the occurrence of rudists and rudist fragments in the Upper Cretaceous limestones of the Taurus Mountains, systematic paleontological studies of rudists have been mainly focused on their occurrences in the Western Taurides, the Bey Dağları Carbonate Platform (Özer, 1988; Sarı et al., 2004; Özer and Sarı, 2008; Sarı and Özer, 2009). Recently, upper Campanian-Maastrichtian and upper Maastrichtian rudists were reported from the Central Taurides around the Seydişehir area by Solak et al. (2017, 2019).

Geyik Dağları is located in the SW of Hadim-Konya and it is one of the highest mountains (altitude 2887 m.) of the Central Taurides (Fig. 1B, C). The Cenomanian rudists are discovered on the eastern slopes of the mountain around 2700 m altitude (Fig. 1D).

This study is mainly focused on the rudist-bearing limestones of the Geyik Dağı area. It aims to (1) describe rudist species, (2) compare the stratigraphy with previous studies, (3) determine the facies characteristics and depositional environment, and (4) correlate with rudist-bearing deposits of the Anatolide-Tauride platform and Mediterranean Province.

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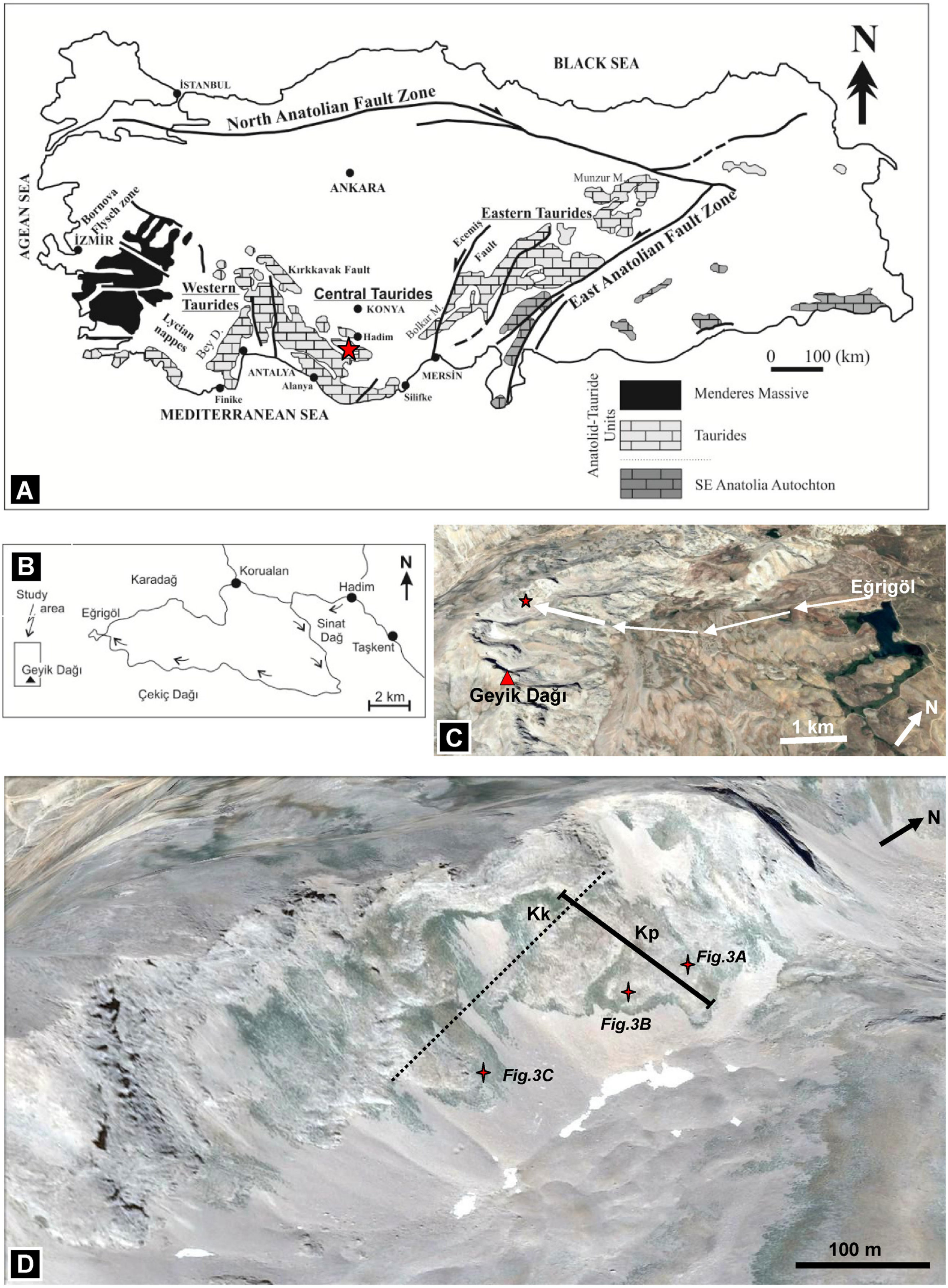

A
N
BLACK SEA
İSTANBUL
North Anatolian Fault Zone
ANKARA
AGEAN SEA
Bornova Flysch zone
İZMİR
Munzur M.
Eastern Taurides
Ecemiş Fault
East Anatolian Fault Zone
Kırkkavak Fault
Western Taurides
Central Taurides
KONYA
Hadim
Lycian nappes
Bey D.
Bolkar M.
ANTALYA
Alanya
MERSİN
Silifke
Finike
MEDITERRANEAN SEA
0 100 (km)
Anatolid-Tauride Units
Menderes Massive
Taurides
SE Anatolia Autochton
B
Karadağ
Korualan
Hadim
Study area
Eğrigöl
Sinat Dağ
Taşkent
Geyik Dağı
Çekiç Dağı
2 km
C
Eğrigöl
Geyik Dağı
1 km
D
Kk
Kp
Fig.3A
Fig.3B
Fig.3C
100 m

2. Material and method

The state of the outcrop of the rudist-bearing limestones allowed us to measure only a single stratigraphic section (36^0 53´ 57´´N/36^{0}53´ 54´´N), which is located in the eastern slope of the Geyik Dağı (Fig. 1B-D, 2, 3A-C). The section is measured at the point where the complete thickness of the formation is best observed.

All rudists are embedded in tightly packed and indurated limestones. However very distinct rudist sections and valves showing the characteristics of canaliculate rudist species were observed. So, we have benefited from the field appearances for the descriptions of rudist species as applied in many studies on the Cenomanian canaliculate rudist-bearing limestones. However, we also tried to collect limestone samples including rudist sections. We have also collected limestone samples and prepared thin sections for microfossil determinations and microfacies analysis in the laboratory of the Geological Department, Dokuz Eylul University, İzmir, where they are stored. Lithofacies determinations are based on both of thin section studies and field observations.

This study is mainly focused on the rudists; the gastropods and orbitolinids will be presented in a separate paper.

3. Geological setting and stratigraphy

The Taurus Mountains form an eastern segment of the Alpine Orogenic Belt in the south of Turkey and are subdivided into western, central and eastern Taurides consisting of Paleozoic, Mesozoic and Cenozoic autochthonous and allochthonous rock assemblages (Fig. 1A) (Şengör and Yılmaz, 1981; Özgül, 1976, 1984, 1997). The Geyik Dağları-Hadim area is located in the western part of the Central Taurides which is bounded by the Ecemiş and Kırkkavak strike-slip faults. In this area, the autochthonous rocks were named as the Geyik Dağı unit by Özgül (1997). These rocks were subsequently referred to as the autochthonous rocks or the Anamas-Akseki autochthon by Turan (2000) and Şenel et al. (2016) for the Geyik Dağları-Hadim area, respectively. The allochthonous rocks consist of many tectonic slices (Özgül, 1997; Turan, 2000; Şenel et al., 2016).

The Polat Limestone name proposed by Özgül (1997) was accepted in this study. The rudists are found in the limestones belonging to the uppermost part of the Bajocian-Cenomanian Polat Limestone overlain by the pelagic micritic limestone and mudstones of the Maastrichtian-Lutetian Kuşça Limestone (Fig. 2, 3A-C). According to Özgül (1997), the Kuşça Limestone contains planktonic foraminifers suggesting a Maastrichtian-Lutetian age around the Geyik Dağı area. There are normal faults between these units. The olistostromal Lutetian Sübüçimen Formation unconformably overlies these units (Özgül, 1997; Şenel et al., 2016) which belong to the Anamas-Akseki autochthon (=Geyik Dağı unit).

3.1. Geyik Dağı stratigraphic section

The uppermost part of the Polat Limestone consist of 82-m-thick rudist-bearing platform-type carbonates (Fig. 2), in ascending order:

(I) a 4-m-thick, beige, thick bedded limestone with scarce ichthyosarcolitids such as *Ichthyosarcolites triangularis* Desmarest (1817), and a caprinid, *Caprina baylei* (Gemmellaro, 1865), gastropods, corals, *Conicorbitolina conica* (d'Archiac, 1837), and bioclasts;
(II) a 10-m-thick, dark grey, thick bedded limestone with abundant ichthyosarcolitids (*I. triangularis* Desmarest, 1817, *I. monocarinatus* Slišković, 1966, *I. bicarinatus* Gemmellaro, 1865), some caprinid fragments (*Caprina baylei* (Gemmellaro, 1865), *Caprina* cf. *schiosensis* Boehm, 1892) and caprinulids like *Caprinula sharpei* (Choffat, 1885), nerineid gastropods, solitary corals and *C. conica*, passing up to bioclastic limestone with mainly canaliculate rudists;
(III) an 8-m-thick, grey, thick bedded bioclastic limestone consisting of canaliculate rudist and gastropod fragments;
(IV) a 20-m-thick, grey, thick bedded limestone in the lower part with canaliculate rudist fragments, but in the other parts with well-preserved canaliculate rudist sections, *C. conica*, nerineid gastropods and some solitary corals, other bioclasts are very rare;
(V) a 1-m-thick beige limestone level consisting mainly of nerineid gastropods visible in sections;
(VI) a 12-m-thick, grey, thick bedded limestone, in the lower and middle parts with canaliculate rudists (abundant *I. rotundus* Polšak), nerineid gastropods and *C. conica.* Bioclastic limestone towards the upper part of this unit contains abundant fragments of *Neocaprina gigantea* Pleničar (1961) and *Caprina* cf. *schiosensis* Boehm (1892);
(VII) a 15-m- thick, grey, thick-bedded limestone including canaliculate rudist and gastropod fragments and sections in the lower part, but in the middle and upper parts consisting mainly of canaliculate rudists, gastropods and *C. conica*;
(VIII) a 12-m-thick, grey, mainly bioclastic limestone containing canaliculate rudists and *C. conica.*

The Polat Limestone shows continuation towards the south of the area (Fig. 1D, 3A, C), but only the middle and upper parts of the formation can be observed due to cover by moraines and slope deposits.

The rudist fauna and the presence of *Conicorbitolina conica* suggest an early-middle Cenomanian age for the Geyik Dağı section, as explained in another section of this paper.

The Kuşça Limestone rests unconformably on the rudist-bearing Polat Limestone and consists of pelagic white-gray, micritic limestones and marls (Fig. 3A-C). Some samples yield badly preserved microfossils (?globuntruncanid), but according to Özgül (1997), the Kuşça Limestone contains planktonic foraminifers suggesting a Maastrichtian-Lutetian age in the Geyik Dağı area (Özgül, 1997), which is accepted here for the age of the this unit.

3.2. Stratigraphic remarks

The geology of the tectonostratigraphic units of the Hadim area has been firstly studied in detail by Özgül (1997). Later, the same area has also been examined by Turan (2000). However, the area in which rudist-bearing limestones were exposed, was not included in previous studies. It has been stated by Özgül (1997, p. 121) that “the carbonates of the Geyik Dağı area, which have not been adequately investigated, could be included in the Polat Limestone due to similar characteristics”. Although the same author also

Fig. 1. A) Sketch map showing the distribution of the Taurides in the south of Turkey (after Göncüoğlu et al., 1997) and the location of the study area (red asterisk) in the Central Taurides. B) Location map showing the studied area and the most convenient route to go up to Eğrigöl from Hadim (arrows). C) Google-Earth map showing the location of the Geyik Dağı (red triangle: the highest peak of the mountain) and the measured-stratigraphic section (red asterisk). The white arrows show the possible climbing path leading to the Geyik Dağı from Eğrigöl. D) Google-Earth map showing the boundary (black dotted line) between the Polat Limestone (Kp) and the Kuşça Limestone (Kk) and the location of the measured section (black line). Note abundant moraines and slope deposits. The locations of figure 3A-C are indicated by red crosses. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

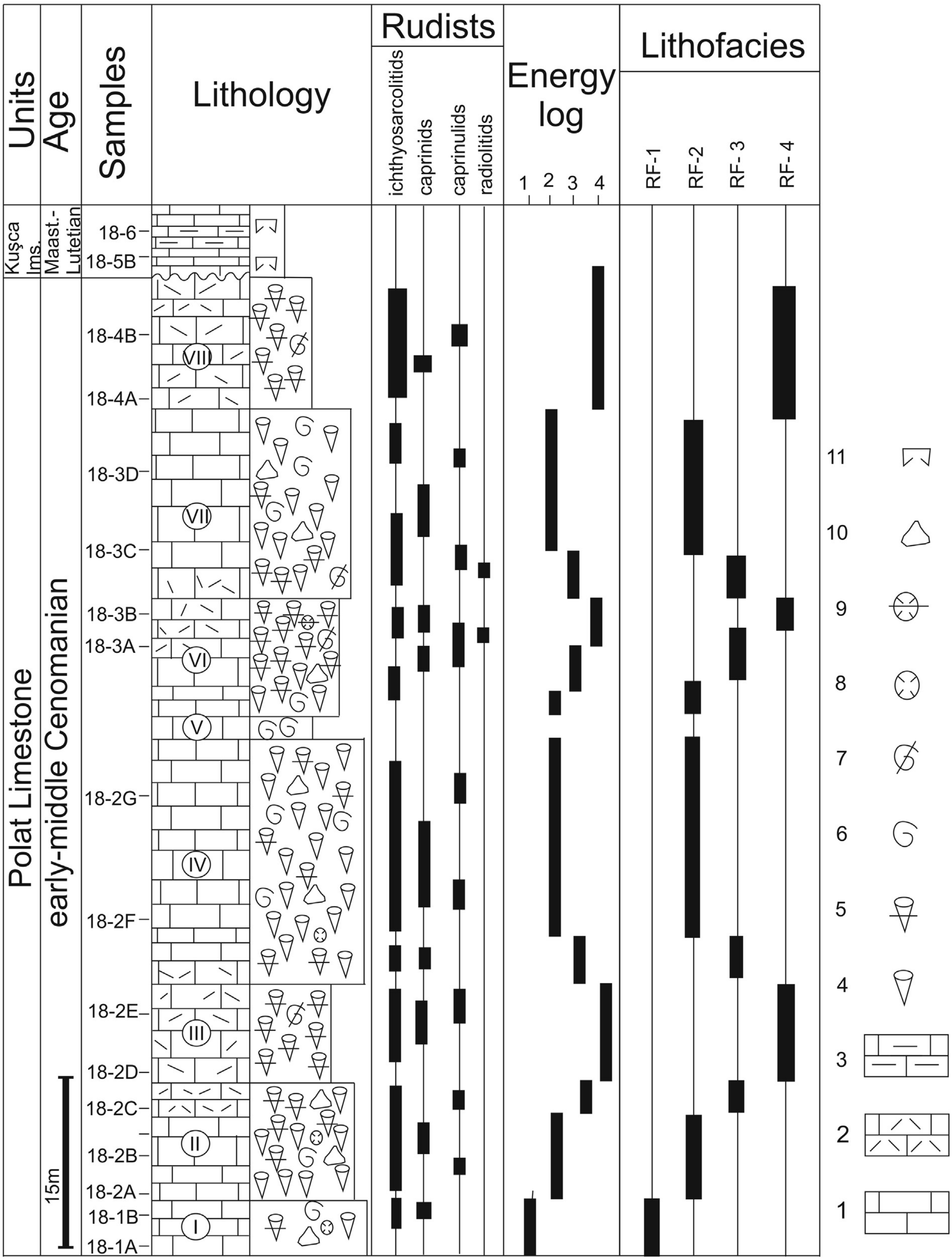


Fig. 2. The Geyik Dağı measured section with marked distribution of the canaliculate rudists, the change of the energy gradient and the lithofacies. Levels of the water-energy: 1. quiet-water, 2. quiet- and slightly agitated, 3. moderately agitated, 4. strongly agitated. Lithofacies: RF-1. scarce ichthyosarcolitid-gastropod packstone, RF-2. canaliculate rudist packstone-floatstone-rudstone, RF-3. packstone-grainstone-rudstone with canaliculate rudist-gastropod-coral fragments and whole shells, RF-4. mixed canaliculate rudist, gastropod, and coral fragments rudstone-grainstone and rudstone. Legend: 1. limestone, 2. bioclastic limestone, 3 marl, 4. rudist, 5. rudist fragment, 6. gastropod, 7. gastropod fragment, 8. coral, 9. coral fragment, 10. orbitolinid, 11. planktonic foraminifera. See text for more details.

Fig. 3. Field photographs of the Geyik Dağı area. View of S in A, NW in B and C. See Fig. 1D for the locations of photographs. Note substantial moraines and slope deposits. A) Panoramic view of the Geyik Dağı area showing the boundary (black dotted line) between the Polat Limestone (Kp) and the Kuşça Limestone (Kk) and the location of the measured-stratigraphic section (white line). Black arrow indicates the highest peak of the mountain (2887 m). B) Outcrop of the Polat Limestone where the stratigraphic section is measured. C) The field view showing the sharp boundary (black arrow) between the Polat (Kp) and Kuşça (Kk) limestones.

indicated that “the carbonate sequence of the Geyik Dağı area shows some differences from the dolomitic Polat Limestone and consists of completely wackestone-grainstone facies with benthic foraminifers and algae”, no information has been provided on the existence of rudists. The Hadim area and its surroundings have been recently studied by Şenel et al. (2016), who presented a geological map of the Geyik Dağı area. According to these authors, the limestones of the studied Geyik Dağı area belong only to the Campanian-Maastrichtian Seyrandağı Limestone.

The present study results in new paleontological data for the platform-type carbonate succession of the Geyik Dağı area, which belongs to the uppermost part of the Polat Limestone, and in new stratigraphic data about the boundary between the Polat Limestone and pelagic Kuşça Limestone as explained below.

The Upper Cretaceous formations of the studied area belong to the Anamas-Akseki autochthon (=Geyik Dağı unit), which is a single tectonostratigraphic autochthonous unit in the Hadim area. According to Özgül (1997) and Şenel et al. (2016), the Polat Limestone is composed of a Bajocian-Cenomanian neritic carbonate sequence and its uppermost Aptian-Cenomanian part consists of dark grey, massive limestones with algae and benthic foraminifers in the Hadim area. A rich fauna of canaliculate rudists, gastropods (mainly nerineids), corals and orbitolinids is here first presented for the Cenomanian part of the formation. The absence of rudist fauna in other Cenomanian outcrops of the formation in the Hadim area, may be explained by different environmental conditions on the carbonate platform. The agitated-water conditions of the rudist-bearing limestones around the Geyik Dağı area were not developed outside of the studied area around Hadim. Instead of this, shallow-marine low-energy conditions with periodical subaerial exposures persisted on the carbonate platform (Özgül, 1997).

A disconformable contact between the Polat Limestone and Maastrichtian neritic limestones of the Çataloluk Limestone is well-known in the Hadim area (Özgül, 1997). The Çataloluk Limestone is not present in the study area, where the rudist-bearing limestones of the Polat Limestone are overlain by Maastrictian-Lutetian pelagic Kuşça Limestone.

The studied area does not include only the Campanian-Maastrichtian Seyrantepe Limestone as presented by Şenel et al. (2016), but two units (the Polat and Kuşca limestones) are distinguished showing different age and facies characteristics.

According to this new information, the stratigraphy in the study area is in need of revision. Also, the rudist-bearing limestones should be added to the stratigraphy of the uppermost part of the Polat Limestone.

A disconformity between the Cenomanian and uppermost part of the Senonian (Campanian-Maastrichtian) units is known from some localities through the Taurides. The stratigraphic relation between the neritic Polat Limestone and pelagic Kuşça Limestone of the studied area may be compared with those of the Bey Dağları Carbonate Platform from the Western Taurides. The upper Campanian-Maastrichtian pelagic limestones rest unconformably on the rudist-bearing middle-late Cenomanian and late Turonian-Coniacian platform-type carbonates around Korkuteli in the Bey Dağları Carbonate Platform (Sarı, 2006a, b; Sarı and Özer, 2009; Sarı et al., 2009). The upper Campanian shallow-marine limestones overlying disconformably the Cenomanian neritic limestones, without rudists, were recently described from the Anamas-Akseki autochthon in the Akseki-Seydişehir region in the Central Taurides by Solak et al. (2017, 2019).

3.3. Facies and depositional environment

The canaliculate rudists are main components of the limestones, accompanied by gastropods and corals. Microfossils are represented only by orbitolinids. On the basis of the preservation of the rudists and fossil assemblages, and also of thin sections studies, four main lithofacies associations have been recognized as follows (Fig. 4-6):

3.3.1. Scarce ichthyosarcolitid-gastropod packstone (RFI)

This lithofacies consists of very scarce canaliculate rudists, gastropods, inconsiderable rudist fragments and is found at the base of the stratigraphic section (Fig. 4. A, B). The depositional texture is packstone with rare rudist and indeterminate shell fragments, some solitary corals and orbitolinids (*Conicorbitolina conica*) (Fig. 5 A-C). Blocky sparry equant calcite cement and rare thin isopachous dog-tooth calcite spar fringes are present. Coarse to medium equigranular megaquartz totally or partially replaces calcitic parts of the shell structures (Fig. 5C).

3.3.2. Canaliculate rudist packstone-floatstone-rudstone (RF2)

It is mainly characterized by sections of the well preserved canaliculate rudists, however rudist fragments are also present (Fig. 4C, D). Ichthyosarcolitids are more abundantly represented than caprinulids and caprinids. Ichthyosarcolitids are of recumbent morphotype (Skelton and Gili, 2002; Gili and Götz, 2018). Some caprinids and caprinulids are observed in growth position. Despite the abundance of ichthyosarcolitids, none were observed in life position. Some nerineid gastropods and solitary corals are also present. The bioclastic parts of the limestones show packstone depositional texture that includes the orbitolinids (*Conicorbitolina conica*), rudist and indeterminable fragments (Fig. 5D, E). Silicification resulted in development of coarse to medium equigranular megaquartz in the rudist and other shell fragments. The equigranular megaquartz totally or partially replaces calcitic parts of the shell structures.

3.3.3. Packstone-grainstone-rudstone with canaliculate rudist-gastropod-coral fragments and whole shells (RF3)

This lithofacies is characterized by abundant canaliculate rudist fragments as well as scarce, whole identifiable canaliculate rudists, gastropods and corals (Fig. 4E, F; 6A-E). The rudist fragments are poorly sorted, and abraded angular and coarse shell fragments are present. Small-sized monospecific ichthyosarcolitids and caprinulids are represented by their transverse, oblique and radial sections, which can be locally observed within the bioclastic limestones. A single well-preserved radiolitid radial section showing the tabulae (Fig. 6D) and a radiolitid transverse section (probably *Radiolites* sp.) presenting the ligamental ridge and cardinal apparatus are found in this lithofacies (Fig. 6E). The occasionally abundant whole nerineid gastropod shells and their fragments are locally present. The bioclastic limestones are mainly represented by rudist and indeterminable fragments-bearing packstone-grainstone depositional texture (Fig. 5F, G). Orbitolinids (*Conicorbitolina conica*) are also observed. Blocky sparry equant calcite cement is present. The shell fragments are rarely rounded. The orientation of shell fragments with micritic envelopes is commonly observed. Borings, produced probably by algae and fungi can be observed in some fragments.

3.3.4. Mixed canaliculate rudist, gastropod, and coral fragments rudstone-grainstone and rudstone (RF4)

This facies is characterized by the presence of the mixed fragments which are composed mainly of the different canaliculate rudists. However, fragments of the gastropods and the corals are also present, but less commonly (Fig. 6F, G). Intact canaliculate rudists are not observed, but the characteristic features of the caprinids and the caprinulids species can be observed in their fragments. Bioerosional features and strong shell dissolution are commonly observed. Despite the presence of minor preferred shell orientation in some levels, pronounced shell orientation is not present. The rudstone-grainstone and rudstone textures consist of rudist fragments showing intense fragmentation, compaction, micritic envelopes, bioerosional features. Scarce preservation of fragmented orbitolinids (*Conicorbitolina conica*) is also noted (Fig. 5H, I).

These lithofacies, except RF1, are alternating in the sequence (Fig. 2).

3.3.5. Interpretation

The facies characteristics indicate that the rudist-bearing limestones were deposited in a carbonate ramp environment. An energy log is suggested here with four levels (EL1 to EL4) marking changes of the water-energy conditions in the depositional environment according to the field observations and microscopic studies of the distinguished four lithofacies (Fig. 2). Lithofacies RF-1 is observed only at the bottom of the sequence and reflects no suitable conditions for the development of a rich fauna. It contains very limited rudists, gastropods and shell fragments pointing out to a quiet-water of deposition environment (EL1). Lithofacies RF-2 shows well-preserved determinable rudist, gastropod and coral sections, and minor shell fragments, but also limited silicification in its bottom levels suggesting the influence quiet- and slightly agitated-water environments (EL2). Lithofacies RF-3 is represented by shell fragments, together with determinable rudists and nerineid gastropods, rarely rounded and oriented shell fragments indicating moderately agitated-water environment (EL3). Lithofacies RF-4 is characterized mainly by the abundant shell fragments suggesting the development of strongly agitated-water conditions in the depositional environment (EL4). Presence of *Conicorbitolina conica* in every lithofacies indicates that it could have been adapted to wide spectrum of energy changes in the environment.

The facies features and richness of the rudists and other faunal components show that the rudist-bearing limestones were deposited at various hydrodynamic levels. Alternation of limestones with determinable rudists, gastropods and corals and bioclastic limestones with intensely mixed fragments reflects changes in energy conditions in the carbonate ramp (Fig. 2).

Cenomanian low-energy inner shelf deposits with canaliculate rudists have been reported from the western region of the northern side in Mediterranean Province (Philip and Auiraud-Crumiere, 1991; Philip et al., 1989; Martin-Chivelet et al., 1990), its central (Cestari and Laviano, 2012), and eastern regions (Özer et al., 2017) and its southern side (Philip et al., 1995; Bachmann et al., 2003; Bauer et al., 2002, 2003; Schulze et al., 2003; Saber et al., 2009; Özer and Ahmad, 2015). Cenomanian higher energy environments with abundant canaliculate rudists developed in the platform edges have been more widely observed in the central and eastern regions of the northern side of the Mediterranean Province (Carbone et al., 1971; Philip, 1980; Özer, 1988; Philip and Mermigis, 1989; Mermigis et al., 1991; Carbone, 1993; Sartorio et al., 1992; Cestari and Sartorio, 1995; Laviano et al., 1998a, b; Steuber, 1999; Di Stefano and Ruberti, 2000; Husinec et al., 2000; Stössel and Bernoulli, 2000; Korbar et al., 2001; Sarı, 2006a, b; Parente et al., 2007; Sarı and Özer, 2009; Sarı et al., 2009; Cestari and Laviano, 2012; Troya et al., 2011; Frija et al., 2015), but rarely found in the western region (Caus et al., 1993; Troya et al., 2011). Similar energy environments have been also reported in its southern side (Ferrandini et al., 1985; Philip et al., 1989; Razgallah et al., 1994; Schulze et al., 2003, 2004; Chikhi-Aouimeur et al., 2006). The facies features of the Geyik Dağı lower-middle Cenomanian platform carbonates may be compared with those of the Periadriatic domain, the southern Apennines, Sicily in Italy (Cestari and Sartorio, 1995; Di Stefano and Ruberti, 2000; Cestari and Laviano, 2012), Cres island in Croatia (Husinec et al., 2000) and the Boeotia in central Greece (Steuber, 1999) due to the clear similarities of the faunal components (canaliculate rudists, nerineid gastropods, corals, *Conicorbitolina conica*), its age, the alternation of the lithofacies and the change of the energy in the environment. The Geyik Dağı limestones present also close similarities in term of the development and the energy index of the lithofacies with those known of the upper Cenomanian of the Central Apennines (Carbone et al., 1971).

4. Systematic paleontology

The classification scheme and terminology for higher taxa of rudists used here follows Skelton (2013a, b).

Abbreviations: LV, left valve; RV, right valve; L, ligamental ridge; am, anterior myophore; pm, posterior myophore; at, ats, anterior tooth and socket; pt, pts, posterior tooth and socket; ct, cts, central tooth and socket; bc, body cavity; pc, posterior cavity; ol, calcitic outer shell layer; il, inner (originally aragonitic) shell layer; cp, celluloprismatic outer (calcitic) shell layer; Vc, ventral carina; ec, ectomyophoral cavity/canals.

Class BIVALVIA Linnaeus, 1758
Order Hippuritida Newell, 1965
Suborder Hippuritidina Newell, 1965 (Skelton, 2013b)
Superfamily: Radiolitoidea d'Orbigny, 1847
Family Ichthyosarcolitidae Douvillé, 1887

Genus *Ichthyosarcolites* Desmarest, 1812
Type species Ichthyosarcolites triangularis Desmarest, 1812

Ichthyosarcolites triangularis Desmarest, 1812
Fig. 7A-I.

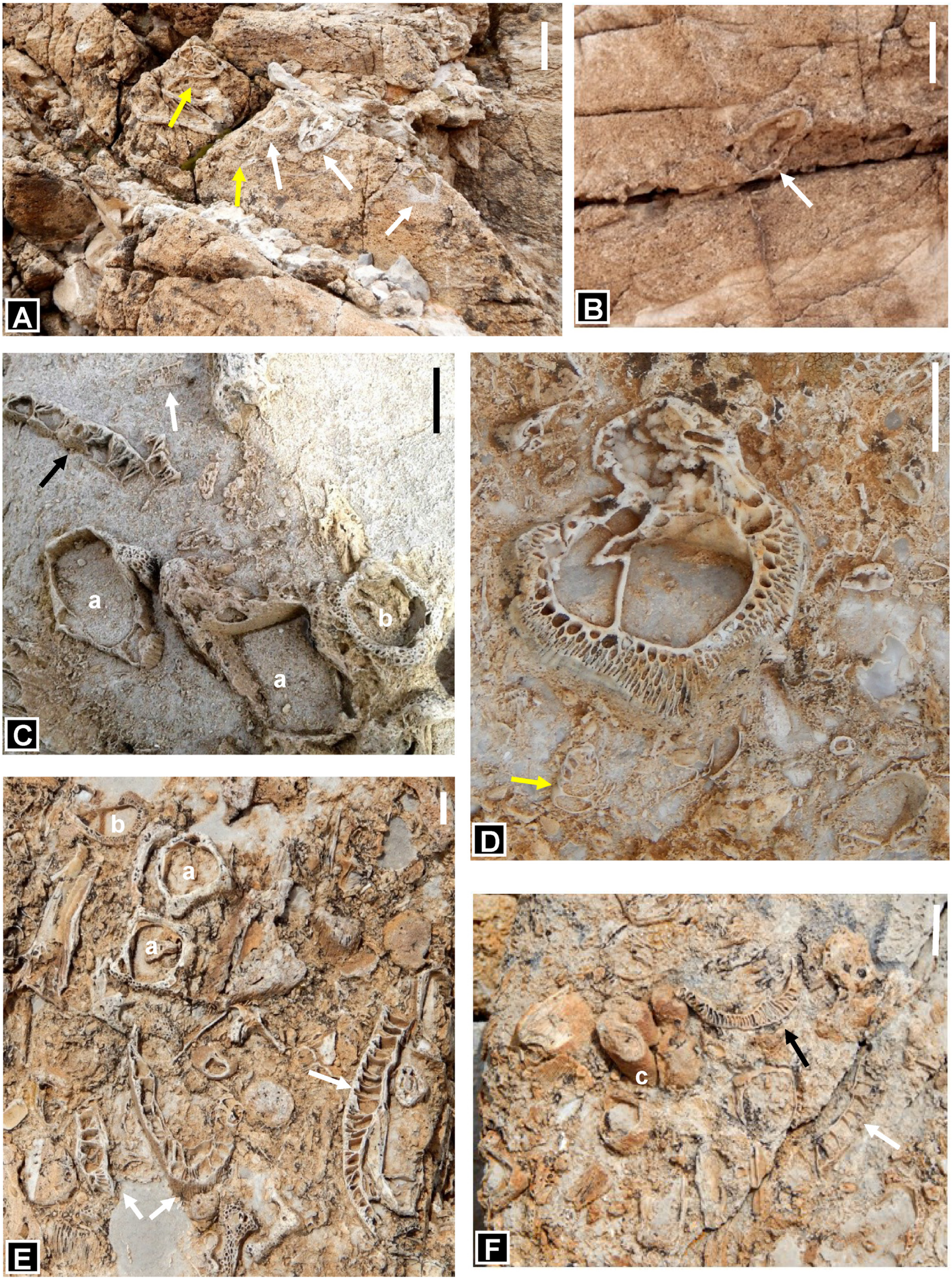
1812 *Ichthyosarcolites triangularis,* Desmarest, p. 324.
1817 *Ichthyosarcolites triangularis*, Desmarest, p. 50, pl. 2, figs 9-10.
1887 *Ichthyosarcolites triangularis*, Douvillé, p. 792, text-figs 15–17.
1921 *Ichthyosarcolites triangularis*, Parona, p. 10, pl.1, fig.1, text-fig.9.
2000 *Ichthyosarcolites triangularis*, Skelton and Smith, p. 111, 123, fig. 4c-d.
2010 *Ichthyosarcolites triangularis*, Chikhi-Aouimeur, p. 96, fig. 87.1.
2015 *Ichthyosarcolites triangularis*, Troya Garcia, p. 248–254, 267, 271, figs 139–141.
2018 *Ichthyosarcolites triangularis,* Rineau and Villier, figs 1B (copy of Desmarest, 1817), C (copy of d'Orbigny, 1847), 5 (see for complete synonym list).

Material. Many RV transverse and radial sections, RV and fragments.
Description. The RV is cylindrical, straight or slightly curved towards the dorsal part of the valve and the preserved length varies from 50 mm to 85 mm (Fig. 7A-B). The surface of the valve is smooth. The RV has a single flange on the dorsal side of the valve, it is longitudinal and triangular in transverse section. The calcitic ol is very thin, its eroded parts reveal the longitudinal thin pallial canals of the il (Fig. 7B-D). Concave tabulae are present in the internal moulds of the bc (Fig 7A, B, D, E). They can be observed in both transverse and radial sections of the valves. The transverse section of the RV is suboval or subround, but for the projecting flange (Fig. 7C-H). Its diameter varies from 15 × 10 mm to 30 × 20 mm. The formerly aragonitic il consists of dense, small canals of round to slightly ovoid cross section, 2–5 mm wide, but wider in the dorsal part. The bc is very large. The pts, the ats and the ct can be observed in some sections, however they can be partially preserved due to filling with pallial canals. The at can be observed in a single specimen showing an oblique radial section of LV (Fig. 7I). The myophores are very thin, but partially preserved.
Discussion and remarks. The triangular shell shape, the presence of tabulae in the internal moulds of the bc and sockets were proposed as the main characteristcs of the species by Desmarest (1817). The thick il is also another feature of the species as represented by d'Orbigny (1847). Recently, Rineau and Villier (2018) proposed that *Ichthyosarcolites triangularis* has only a single, dorsal flange. Our sections show these features of the species: the flange (Fig. 7G and H) shows clear similarity in shape with that figured by d'Orbigny (1850, pl. 542.3), the mould of the bc of Fig. 7A and B presents similar tabulae like those figured by Desmarest (1817, pl. 2, figs 9, 10) and Rineau and Villier (2018, fig. 5, A-D) and the transverse section and tabulae of Fig. 7C-F are similar to those figured by Troya Garcia (2015, fig. 140 A and C, E). The myocardinal apparatus of our sample (Fig. 7I) may be compared with that figured by Skelton and Smith (2000, fig. 4c).

Ichthyosarcolites monocarinatus Slišković (1966)
Fig. 8A-F.

1966 *Ichthyosarcolites monocarinatus*, Slišković, p. 177, text-fig. 1.
1967 *Ichthyosarcolites monocarinatus*, Polšak, p. 80, 186, pl. 6, fig. 1, pl. 8, figs 1-5, pl. 9, fig. 1.
2015 *Ichthyosarcolites monocarinatus*, Troya Garcia, p. 260–264, 269, figs 145–147.
2018 *Ichthyosarcolites monocarinatus*, Rineau and Villier, fig. 3B (holotype, copy of Slišković, 1966) (see for complete synonym list).

Material. Many RV transverse and oblique sections, RV and fragments.
Description. The cylindrical RV is slightly curved towards the antero-ventral part of the valve and the unique flange is represented by a longitudinal bulge on the valve (Fig. 8A-D). The ol is partially preserved and the thin, longitudinal pallial canals of the il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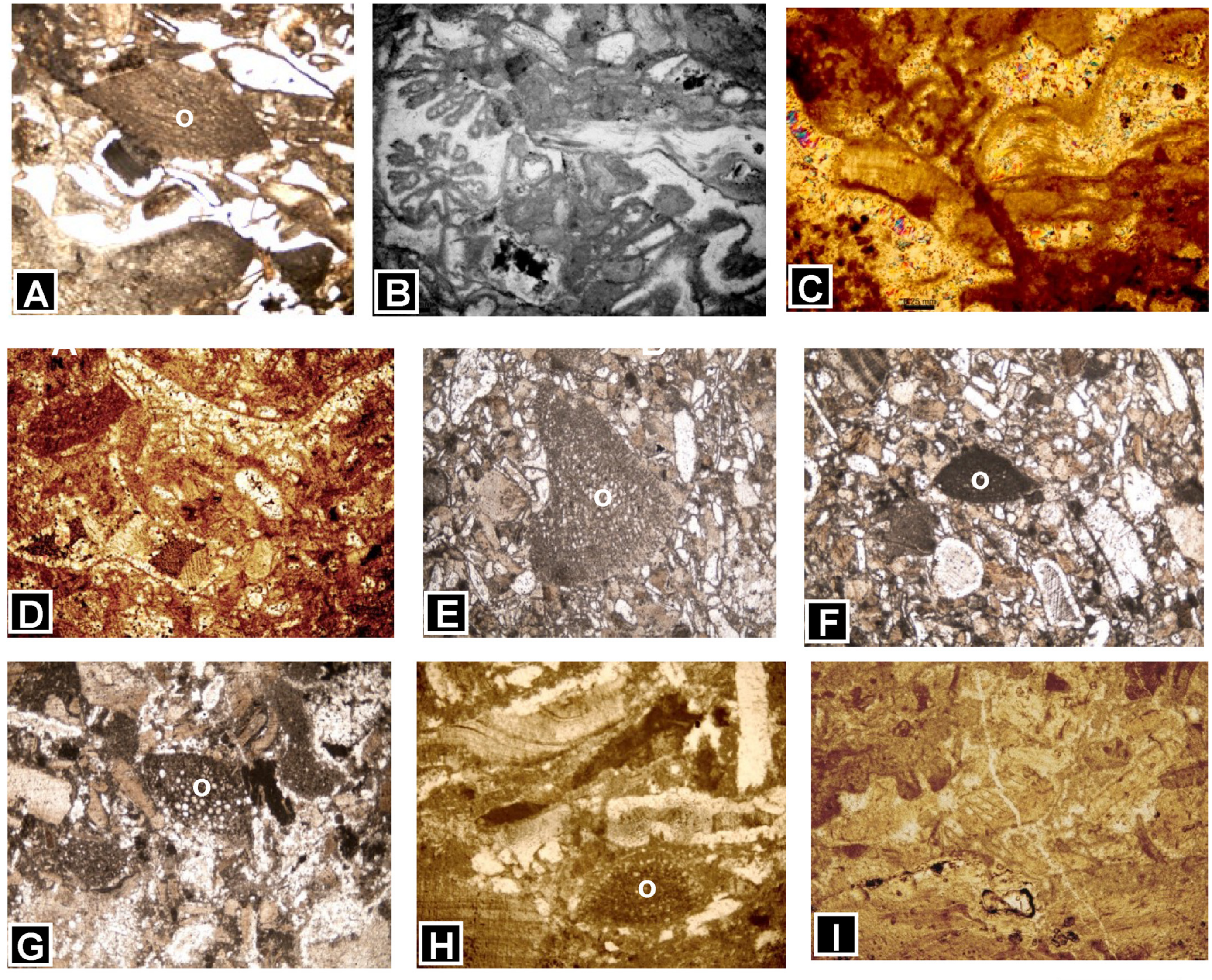
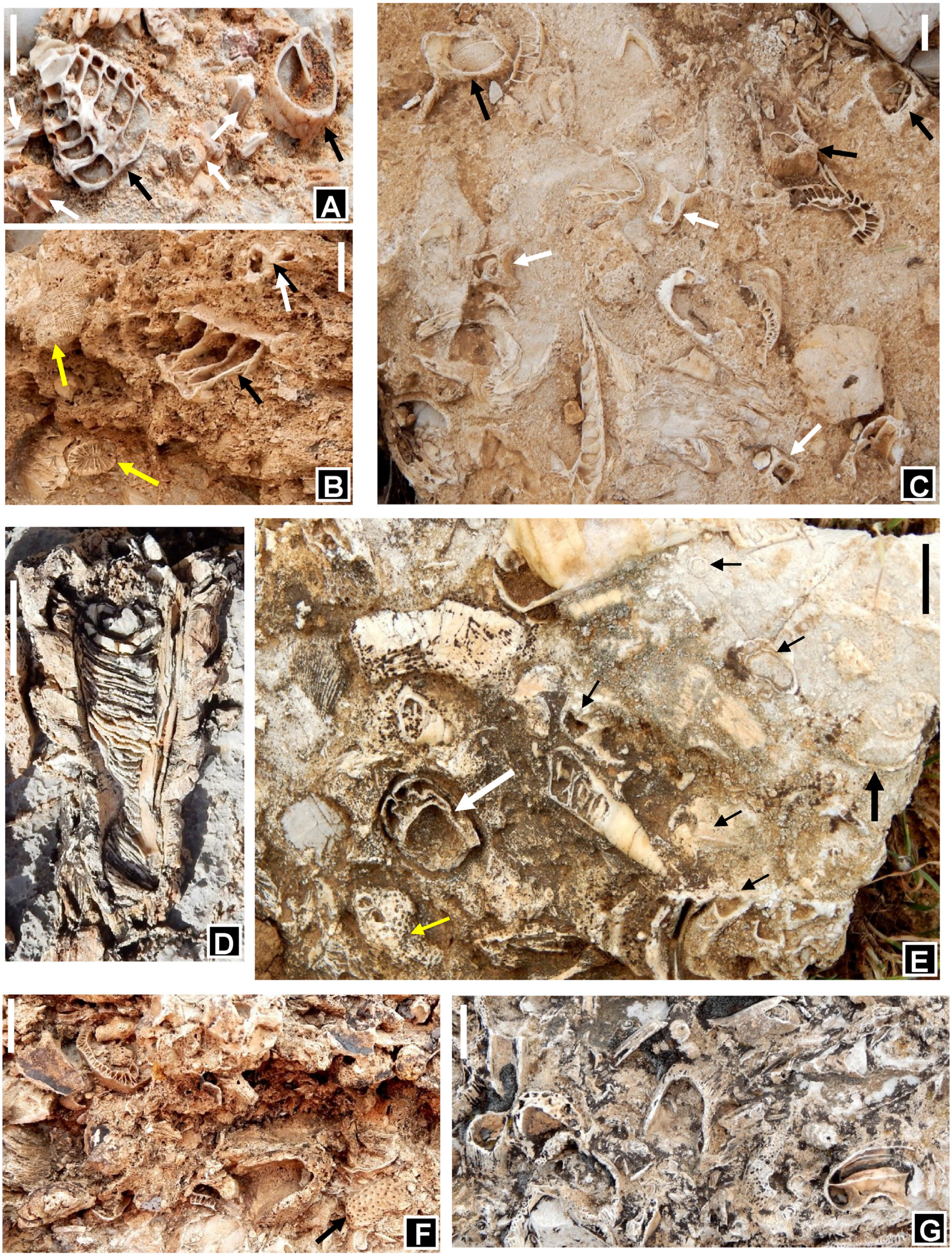


Fig. 5. Microfacies photographs of the lithofacies. C and D cross-polarized light, others parallel-polarized light. Scale bar is 0.25 mm for all photos. A-C) Packstone, RF-1 lithofacies. The shell fragments are rare, some solitary corals, *Conicorbitolina conica* (O), the blocky sparry equant calcite cement and rare thin isopachous dog-tooth calcite spar fringes are present, Fig. A, B, sample no DEU.18-1A. Shell fragments show silicification in C, the quartz growth destroying the calcitic parts of shells can be observed, sample no DEU.18-1B. D, E) Packstone, RF-2 lithofacies. D) The silicification can be observed in the shell fragments. The calcitic parts of shells are totally or partially replaced by equigranular megaquartz, sample no DEU.18-2A. E) *Conicorbitolina conica* (O) and some shell fragments are present, sample no DEU.18-2B. F, G) Packstone-grainstone, RF-3 lithofacies. The micritic envelopes and the bioerosional features are commonly observed. *Conicorbitolina conica* (O) is present. Sample nos DEU.18-2C and DEU.18-3A respectively. H, I) Rudstone-grainstone and rudstone, RF-4 lithofacies. Shell fragments show intense fragmentation, compaction, micritic envelopes and bioerosional features. *Conicorbitolina conica* (O) is present. Sample nos DEU.18-2E and DEU.18-4A respectively.

are observed in its eroded parts. The transverse section of the valve is circular and slightly elliptical with a single flange in the antero-ventral part (Fig. 8B-F). It is characterized by a bulge with a rounded end. The dorso-ventral diameter is variable from 10 mm to 35 mm. The il has 2 mm–5 mm thickness, more thick in the dorsal side and consists of dense, round and ovaloid pallial canals. These are larger (1–1.5 mm) in the dorsal part than other parts of the valve. A row of radially elongated subrectangular pallial canals in the external part of the il is observed in only a single section (Fig. 8E). Tabulae are present in the bc, but very thin and rare. Some valves have no tabulae due to sediment fillings and also dissolution. But some of the others show only a single tabula in cross-sections of the bc probably due to wide spacing of the tabulae in the bc (Fig. 8A, E). The LV teeth sockets are small and elongated, the pallial canals are not present between the inner margin and sockets. The ct is partially or totally covered by the pallial canals in some sections,

Fig. 4. Field photographs of the lithofacies. A, B) RF-1 lithofacies. Note the presence of the scarce ichthyosarcolitid (white arrows) and gastropod (yellow arrows) sections. C, D) Floatstone-rudstone, RF-2 lithofacies. It is mainly characterized by well preserved ichthyosarcolitid sections in C (a: *Ichthyosarcolites triangularis*, b: *Ichthyosarcolites monocarinatus*) and caprinid section in D (*Sphaerucaprina woodwardi*). Scarce canaliculate rudist fragments (*Neocaprina*: black arrow, *S. woodwardi*: white arrow) and nerineid gastropod section (yellow arrow) can be observed in C and D respectively. E, F) Rudstone, RF-3 lithofacies. Note abundant canaliculate rudist fragments (*Neocaprina gigantea*: white arrows, *Caprina* cf. *schiosensis*: black arrow), and the presence of canaliculate rudist sections (a: *Ichthyosarcolites bicarinatus*, b: *Caprinula sharpei*, c: *Ichthyosarcolites monocarinatus*). Scale bar is 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)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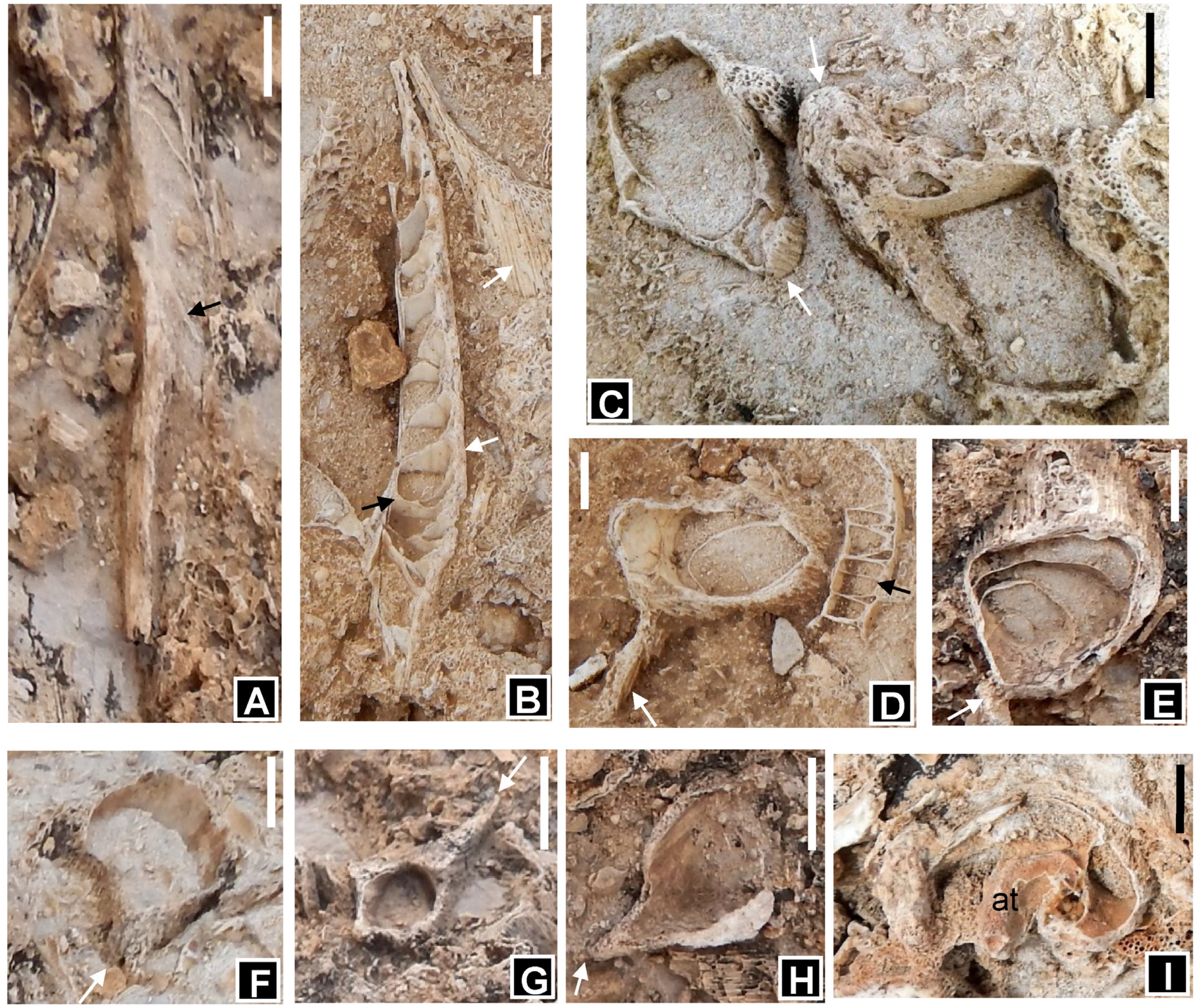


Fig. 7. A-I. *Ichthyosarcolites triangularis* Desmarest (1817). Outcrop photographs. A-H. The sections of the RV. A-B. Concave tabulae in the internal moulds of the bc (black arrows) and the longitudinal pallial canals of the il (white arrows) observed in the radial sections. C-H. The transverse sections showing a flange with rounded end in dorsal side (white arrows), adumbonal view. Some sections (D and E) have tabulae in the bc. The RV fragment of *Neocaprina* is present in D (black arrow). I. An oblique radial section of a curved LV (umbo to right) showing the at. Scale bar indicates 10 mm.

but it can be preserved (Fig. 8C, F). The myophores seem to be very thin, but are very diffucult to recognize.

Discussion and remarks. Our sections show typical characteristics of the species such as circular and slightly elliptical transverse section of the RV and a single flange in the antero-ventral side of the RV. They present close similarities with holotype of Slišković (1966, text-fig. 1). The longitudinal bulge a flange on the surface of the RV of our specimens shows clear resemblance with that figured by Polšak (1967, pl. VIII, fig. 1a). Our slightly elliptical transverse sections may be compared with fig. 1 of Cestari et al. (1998). A row of radially elongated subrectangular pallial canals in the external part of the il, which was determined by Cestari et al. (1998, figs. 2.1 and 2.2), Pleničar and Jurkovšek (2000, pl. 11, fig. 3a) and Troya Garcia (2015, fig. 146 D, E, fig. 147 A–F), has been observed only in a single section (Fig. 8E).

Ichthyosarcolites rotundus Polšak (1967)
Fig. 8G-J

Fig. 6. The field photographs of the lithofacies. A-E) Rudstone, RF-3 lithofacies. A) Transversal and radial sections of nerineid gastropods (black arrows) and some small canaliculate rudist fragments (white arrows). B) Gastropods (black arrow), canaliculate rudist fragments (white arrow) and solitary and colonial corals (yellow arrows). C) Preserved canaliculate rudist sections (*Ichthyosarcolites bicarinatus*: white arrows, *Ichthyosarcolites triangularis*: black arrows). D) A radial section of radiolitid showing the tabulae and ol. E) Gastropod, coral (yellow arrow) and canaliculate rudist fragments and in determinable ichthyosarcolitids (thin black arrow). A transverse section may be belong to caprinids (thick black arrow). Note the transversal section of a radiolitid showing the well-preserved L and myocardinal apparatus (thick white arrow). F, G) Rudstone, RF-4 lithofacies. Note the intense fragmentation of the canaliculate rudists, bioerosional features and strong shell dissolution. Gastropod and coral fragments (black arrow) are also present, but less common. Scale bar is 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

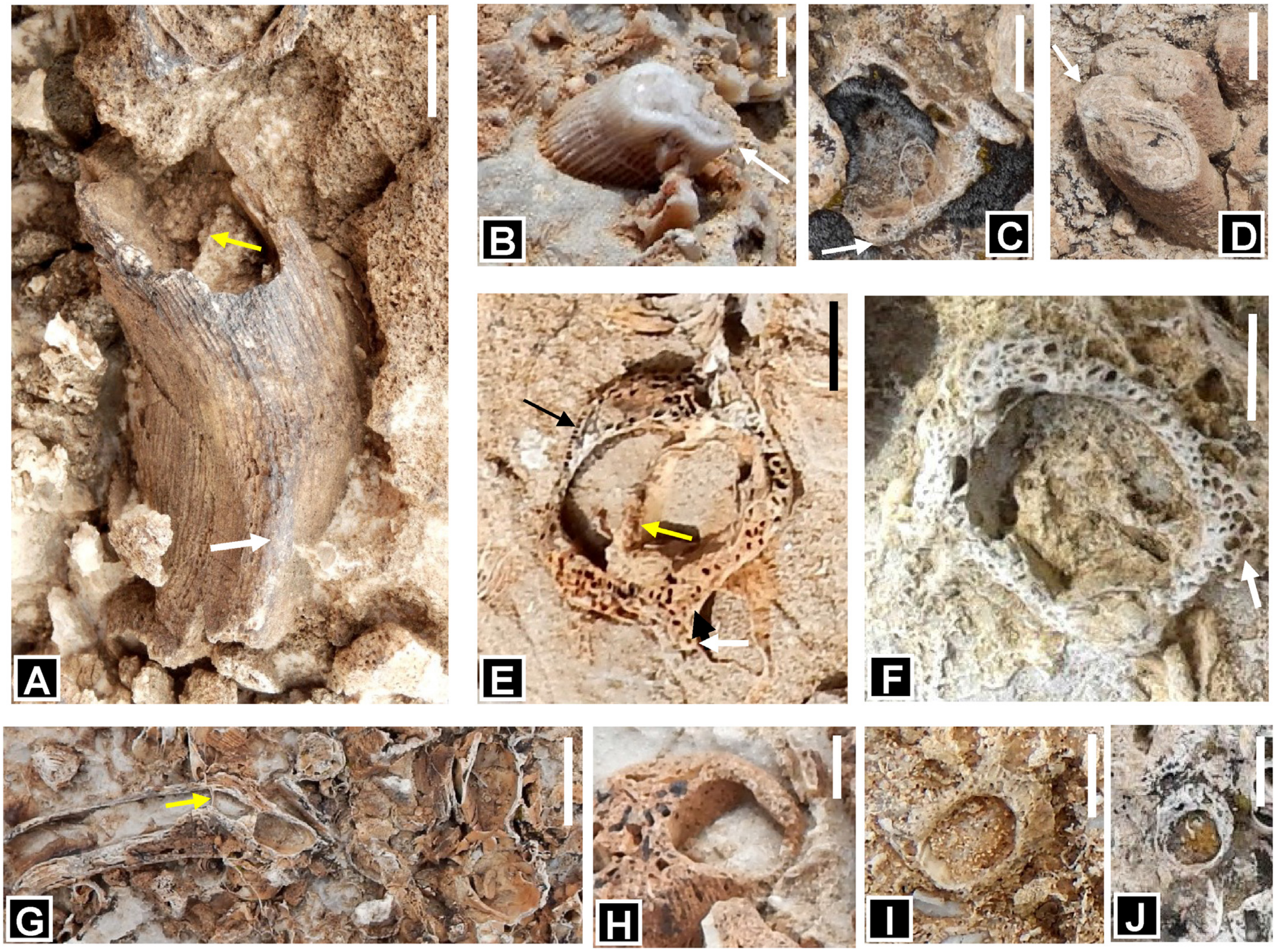


Fig. 8. A-F. *Ichthyosarcolites monocarinatus* Slišković (1966). All photographs are taken from the field. White arrows indicate the flange of the RV. A-B. The unique flange is represented by a longitudinal bulge and the longitudinal pallial canals of the il are observed in the eroded parts of the ol. C–F. The adumbonal view of the transverse sections. Note the presence of a row of radially elongated subrectangular pallial canals in the external part of the il (black arrow) in E. A single tabula (yellow arrow) is present in the bc in A and E. The LV teeth sockets and the ct are seen in C, E and F. Note that pallial canals are not present between the inner margin and teeth sockets. G-J. *Ichthyosarcolites rotundus* Polšak (1967). The sections of the RV. G. The transverse and radial sections showing tabula (yellow arrow). H-J. ransverse sections, adumbonal view. Scale bar is 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

1967 *Ichthyosarcolites rotundus*, Polšak, p. 80, 187, pl. 6, fig. 2, pl. 9, figs 2, 3.
1971 *Ichthyosarcolites rotundus*, Carbone et al., p. 147, fig. 16.
2018 *Ichthyosarcolites rotundus*, Rineau and Villier, fig. 3A (holotype, copy of Polšak, 1967), 4A (see for complete synonym list).

Material. Many RV and their transversal and radial sections.
Description. The RV is straight, cylindrical, narrow with smooth surface and present length is 50 mm (Fig. 8G). The transverse section is generally circular 10 mm–30 mm in diameter or slightly elliptical along the dorso-ventral in axis and 30 mm in diameter (Fig. 8H-J). The ol is thin (1–2 mm) and the il is 3–10 mm thick, but thicker in the dorsal side. The il consists of dense, very small and round pallial canals. Tabulae are present, but very rare. The LV teeth sockets are small, elongated and very close to each other. The myophores are not preserved.
Discussion and remarks. The circular transverse section of the RV and the absence of the flange are the main characteristics of this species. A short and triangular L is reported in the description of this species by Polšak (1967, p. 187), however it can not be observed in Polšak's figures and in all described species until today. If L is really present, as *Ichthyosarcolites rotundus* should be transferred to the new genus *Oryxia* which was recently described by Rineau and Villier (2018). Although the presence of the continuous row of pallisading canals alongside the shell outline is indicated by Rineau and Villier (2018, fig. 4A), it is not observed in our specimens and in the orginal description of the species (Polšak, 1967), and others descriptions. Therefore, it may not be one of the main features of the species.

Ichthyosarcolites bicarinatus (Gemmellaro, 1865)
Fig. 9A-H

1865 *Caprinella bicarinata*, Gemmellaro, p. 26, 27, pl. 4, figs 5, 6.
1898 *Caprinella bicarinata*, Douvillé, p. 150.
1914 *Ichthyosarcolites bicarinatus*, Parona, p. 21.
1921 *Ichthyosarcolites bicarinatus*, Parona, p. 12, 13, pl. 2, fig. 1, text-figs 7, 10.
2017 *Ichthyosarcolites poljaki*, Özer et al., p. 127, fig. 5C (copy of Özer, 1998, p 861, fig. 11, 4).
2018 *Ichthyosarcolites bicarinatus*, Rineau and Villier, fig. 3C-E, 4B–F (see for complete synonym list)

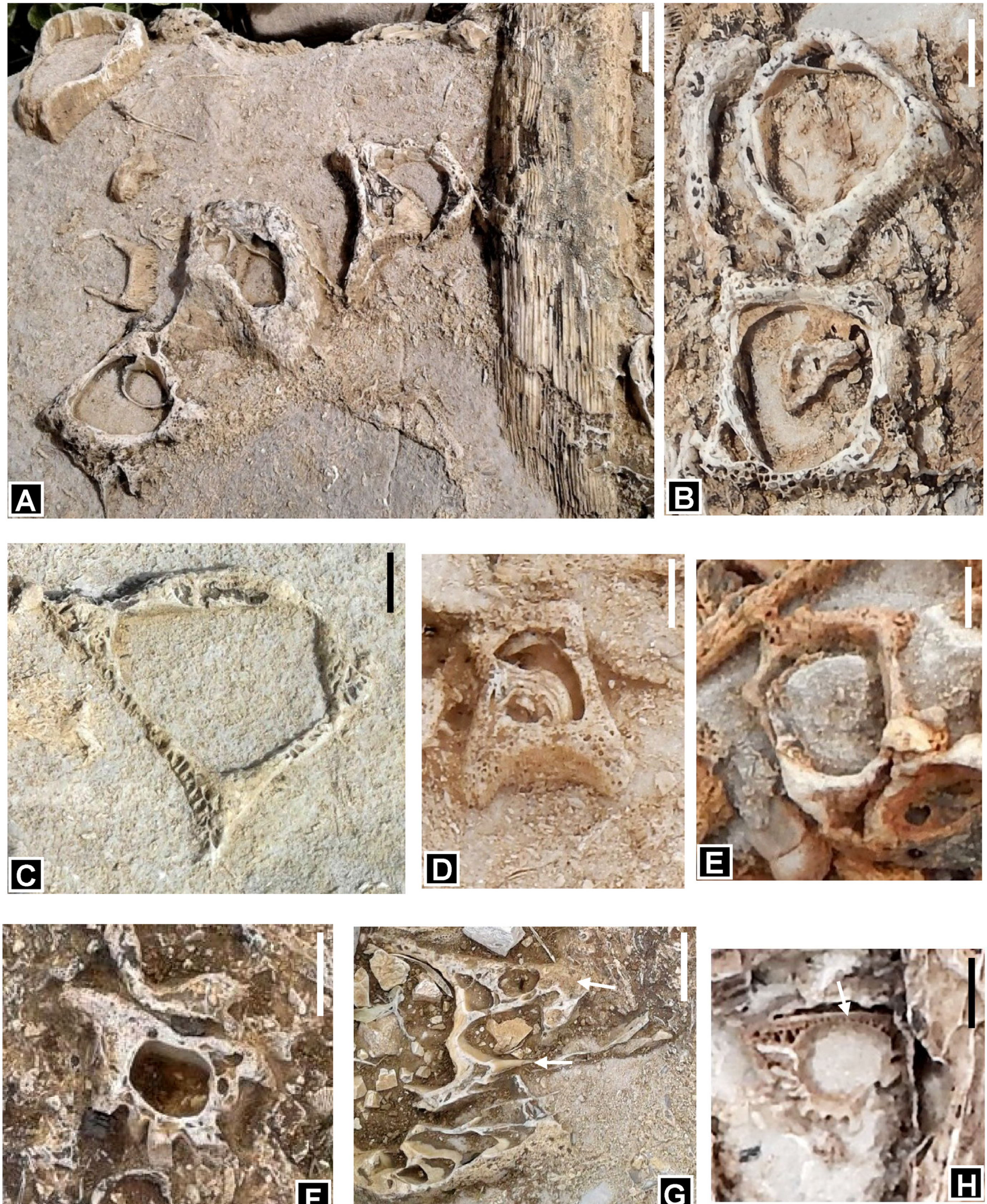


Fig. 9. A-H. *Ichthyosarcolites bicarinatus* Gemmellaro (1865). All photographs are taken from the field. The transverse sections of the RV with three to seven flanges. The straight and cylindrical RV shows the longitudinal pallial canals of the il in the right of the transversal sections in A. B, D-F. The adumbonal view of the transverse sections. Tabulae are seen in A and D. A fragment of the posterior side of the valve shows two flanges (white arrows) in G, compare with the previous figure. Single row of subrectangular pallial canals can be seen in H (white arrow). Scale bar is 10 mm.

Material. 14 RV transversal and radial sections and many RV fragments.
Description. The RV is straight and cylindrical showing longitudinal pallial canals of the il due to complete erosion of the ol (Fig. 9A). Its present length is 90 mm. The RV has three to seven of flanges, which determine the cross-section of the valve as follows: the triangle section has three flanges, the quadrate with four and the pentagon with five flanges with rounded end (Fig. 9A-E). The shape of the transverse section with seven flanges is completely different from others; its dorsal side is flat with more pronounced two flanges in large triangle shape and the others have large size, parallel sided with truncated or rounded end and they are mainly localised in the postero-ventral side (Fig. 9F-H). The thin ol can be only seen in some sections. The il consists of dense, round to polygonal pallial canals. The il of the triangle shell section has large rectangular and oval canals (Fig. 9C). A single row of subrectangular pallial canals in the external side of the il is only preserved in a section with more flanges (Fig. 9H). The bc is quadrangular in shape. The myocardinal apparatus is badly preserved in some sections. The ct is not observed. The tabulae are preserved in the bc of some sections (Fig. 9A, D).
Remarks. Several species of *Ichthyosarcolites* with two and multiple flanges are recently attributed to a single species *Ichthyosarcolites bicarinatus* according to the morphometric analysis by Rineau and Villier (2018).

Family: Caprinulidae Yanin, 1990

Genus *Caprinula* d'Orbigny (1847)
Type species. *Caprina boissyi* d'Orbigny, 1840

Caprinula sharpei (Choffat, 1885)
Fig. 10A-H

1885 *Ichthyosarcolites Sharpei*, Choffat, p. 63.
1888 *Caprinula Sharpei*, Douvillé, p. 712, pl. 12, fig. 4, pl. 23, fig. 5-6.
1961 Caprinula sharpei, Pleničar, p. 48, pl. 6, fig. b, pl. 9, fig. a, text-fig. 7.
1981 Caprinula sharpei, Pamouktchiev, p. 154, pl. 75, fig. 4.
2002 Caprinula sharpei, Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).
2016 *Caprinula sharpei*, Özer and Ahmad, p. 145–147, fig. 5A-E.

Material. Ten LV transverse and some slightly oblique sections, two LV, several LV fragments and a single RV.
Description. The LV is conical with the beak loosely coiled or curved towards the antero-dorsal side, its present length is about 60 mm (Fig. 10A, B). Thin radial pallial canals of the il are seen through eroded parts of the partially preserved ol. The transverse section of the LV is suboval, its diameter varies from 45 × 30 mm to 30 × 25 mm (Fig. 10C-G). The ol is generally badly preserved, but the very thin ol (0.5 mm) can be observed in some sections. The il is thin (4–5 mm) and contains one or occasionally two marginal rows of polygonal or suboval pallial canals in the inner part and a single row of very small, fine pyriform pallial canals in the outer part (Fig. 10C-G). The pallial canals are separated by thin lamellae. Pyriform canals are occasionally bifurcated in the exterior row. The anterior side of the valve is usually crushed, however one row of big accessory cavities/canals can be seen in a few sections (Fig10C). Large ectomyophoral canals are also seen on the posterior side in some sections (Fig. 10C, E, F). The pc is smaller than the bc. It is separated by a pronounced oblique lamina from the bc connecting the ats. The myophores are represented by thin plates. The at is larger than the pt. The ct is suboval and situated between the at and pt. L is invaginated.
The RV is conical, its present length is 50 mm. The very thin ol is partially preserved and the longitudinal thin pallial canals of the il can be clearly observed in its eroded parts. The myocardinal apparatus is partially dissolved (Fig. 10H). L is invaginated. A large ectomyophoral cavity is present between the pt and the bc.
Discussion and remarks. Our sections are characterized by relatively few rows of pallial canals which is the main differences between *C. sharpei* and other species of the genus. The LV canals show clear similarities with those illustrated by Douvillé (1888, pl. XXII, fig. 4a, XXIII, fig. 5a). A large cavity between the pt and bc of the RV may be compared with that of Douvillé (1888, pl. XXII, 4b, pl. XXIII, 5b: 'Of') and Özer and Ahmad (2016, fig. 5, D). The il of the LV described by Pleničar (1961, pl. 6, fig. b, text-fig. 7) is thicker than in our sections. The thin il of the LV of our sections shows similarities with *Caprinula boissyi* of Sharpe (1850, pl. 16, fig. 3).

Genus *Neocaprina* Pleničar, 1961
Type species. Neocaprina gigantea Pleničar (1961)

Neocaprina gigantea Pleničar (1961)
Fig. 11 A-G

1865 *Caprinella gigantea*, Gemmellaro, p. 24, pl. 3, figs 5-8.
1961 *Neocaprina gigantea*, Pleničar, p. 44, text-fig.4.
1963 *Neocaprina gigantea*, Pleničar, p. 564, 583, pl. 3, fig. 5, pl. 4, fig. 6.
1967 *Neocaprina gigantea*, Polšak, p. 46, 167, pl. 14, figs 1, 2, pl. 15, figs 1, 2, pl. 16, fig.1, text-figs 9, 12, 13.
2002 *Neocaprina gigantea*, Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).
2009 *Neocaprina gigantea*, Sarı and Özer, p. 365–367, fig. 5, 1-3.
2010 *Neocaprina gigantea*, Chikhi-Aouimeur, p. 91, fig. 80, 1, 2.
2017 *Neocaprina gigantea*, Özer et al., p. 127, fig. 5A (copy of Özer, 1998, p. 861, fig. 11, 1), B.

Material. Seven RV fragments.
Description. The RV fragments show the characteristic features and allow the reconstruction of the valve (Fig. 11A-D). The transverse section of the LV is suboval with externe somewhat obtuse external carina (Fig. 11C-F), its diameter seems to be about 80 × 45mm. The surface of the valve is partially observed in the ventral and posterior side of the valve and it is possible to detect the radial lamellae due to erosion of the ol (Fig. 11C). The latter is very thin (1 mm). The il consists of large, rectangular and suboval pallial canals separated by thin lamellae. They are bifurcated in the posterior side (Fig. 11B, D, E, G). The pallial canals are absent in the ventral margin. The sockets of teeth are fairly pronounced, the pts is subrectangular in section and the ats is elongated, subrectangular and larger than pts. The cts is approximately located between the LVs sockets. An ectomyophoral cavity is present between the pts and the bc. The myophores are represented by thin plates. The angle between the line ats and pts and the axis of symmetry is about 45–50°.
Discussion and remarks. Neocaprina gigantea show some resemblance due to the shape of the pallial canals with *Neocaprina nanosi* Pleničar. *N. gigantea* is clearly different by the large pallial canals, by their more complex organisation in the dorsal side and especially by the smaller inclination between the line ats and pts and the axis of symmetry.

Family Caprinidae d'Orbigny, 1847

Genus *Sphaerucaprina* Gemmellaro, 1865
Type species. *Sphaerucaprina Woodwardi* Gemmellaro, 1865

Sphaerucaprina woodwardi Gemmellaro, 1865
Fig. 12A-D

1865 *Sphaerucaprina Woodwardi*, Gemmellaro, p. 222, pl. 1, figs 1-5.
1892 *Sphaerucaprina forojuliensis,* Boehm, p. 142, pl. 6, fig. 1, text-fig. 2.

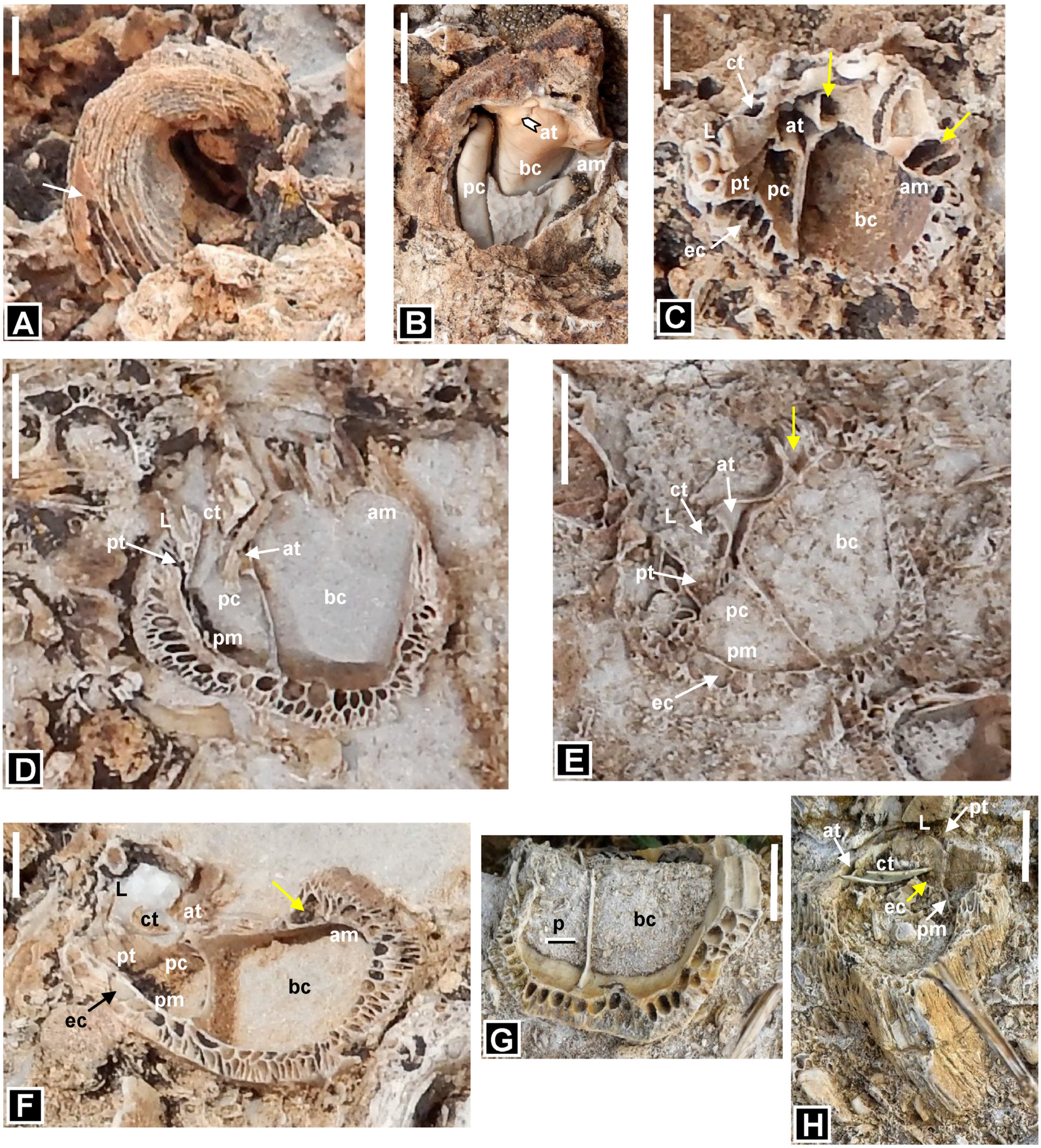


Fig. 10. A-H. *Caprinula sharpei* (Choffat, 1885). A-F and H are outcrop photographs; G is sample no DEU 18-3D. A, B. The LV showing the thin radial pallial canals of the il in the eroded part of the ol (white arrow) in A and the internal features in B. C-G. The adumbonal view of the transverse sections of the LV. The ectomyophoral cavity/canals (ec) are present in C, E and F. The anterior side of the valve is usually crushed, however one row of big accessory cavities/canals can be seen in C, E and F (yellow arrows). H. RV, adumbonal view, showing the dissolved cardinal apparatus and a large ectomyophoral cavity (yellow arrow) between the pt and bc. Scale bar is 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

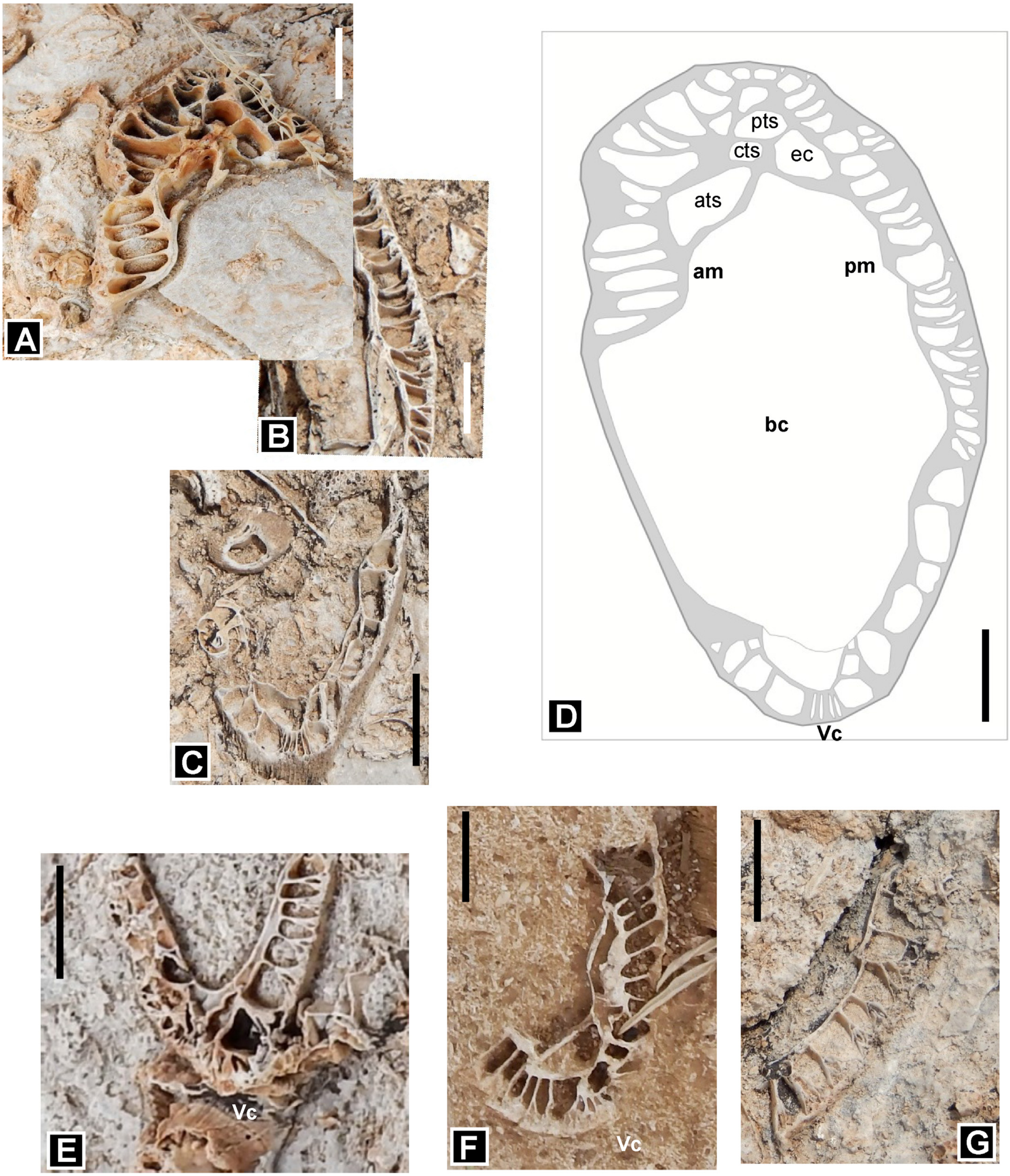


Fig. 11. A-G. *Neocaprina gigantea* Pleničar (1961). Outcrop photographs. The fragments of the RV. A-C. The fragments from different side of the valve. D. Reconstruction of the previous fragments, the adumbonal view. E-F. The fragments from the ventral side, the adumbonal views. G. A fragment from the postero-ventral side. Scale bar is 10 mm.

1908 *Sphaerucaprina forojuliensis,* Parona, p. 28, text-fig. 30.
1910 *Sphaerucaprina Woodwardi*, Douvillé, p. 30, text-figs 31–35.
1999 *Sphaerucaprina woodwardi*, Steuber, p. 44–45, text-fig. 23.
2002 *Sphaerucaprina woodwardi*, Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).
2010 *Sphaerucaprina forojuliensis,* Chikhi-Aouimeur, p. 90, fig. 79, 2.

Material. A single LV and two LV sections, three LVs fragments.
De*scription*. The conical LV with beak is curved strongly towards the posterior side, it looks orthogyral and is composed of a very thin (1 mm) ol and the moderately thick (4–5 mm) il showing the elongate sections of the pallial canals (Fig. 12A, B). The LV has an suboval transverse section showing the internal characters (Fig. 12B,C). The il is much thicker (10–12 mm) in the ventral part than other parts. Two or three rows of pyriform pallial canals are present in its outer part. Two or three rows of large, suboval and/or polygonal pallial canals can be observed in its inner part (Fig. 12B-D). The large canals are smaller in the ventral side than those of the anterior and the posterior sides. The size of the pallial canals decreases from the inner to outer part of the il and they reach to L. LV widens in the anterior side and has three large ectomyophoral accessory cavities/canals. The first large canal is located close to the pallial canals and is sub-square in shape, whereas the following canal is strongly elongated and third one is also elongated, but shorter than second. These canals are separated by thin lamellae. There are some oval shaped canals in front of the ectomyophoral accessory cavities/canals. One of them is strongly elongated and located close the second ectomyophoral canal (Fig. 12B). Some sub-cylindrical canal-like sections are present between the am and the large ectomyophoral accessory cavities/canals. The bc is bigger than the pc and a thick (2 mm), lamina separates it from the pc and connects the ats. The L is invaginated, the pt is smaller than the at and the ct is large. Thin lamina between the ct and the pc seems to be present. The myophores are represented by thin plates.
Discussion and remarks. The LV section may be compared with *Caprinula boissyi* as discussed by Douvillé (1910), however it clearly differs by the presence of the big ectomyophoral accessory cavities/canals in the outside of the am and also the regularity of the pallial canals around the valve. Our sections present all the characteristic features of the species. It has three large ectomyophoral canals and close similarity with the descriptions of shells from Sicily (Douvillé, 1910), northern Italy (Parona, 1908) and Boeotia-Greece (Steuber, 1999). Canals located in front of the ectomyophoral canals and

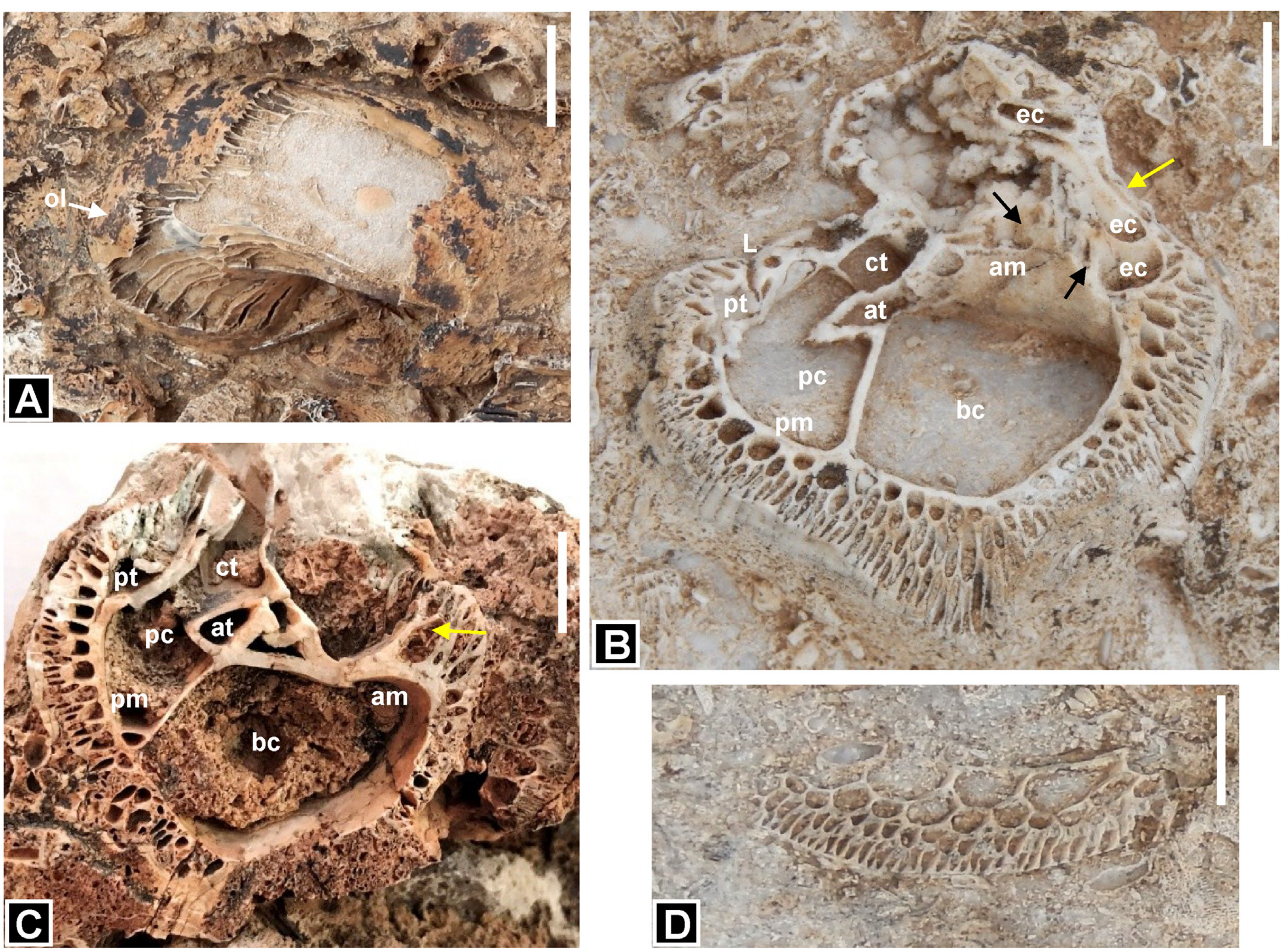
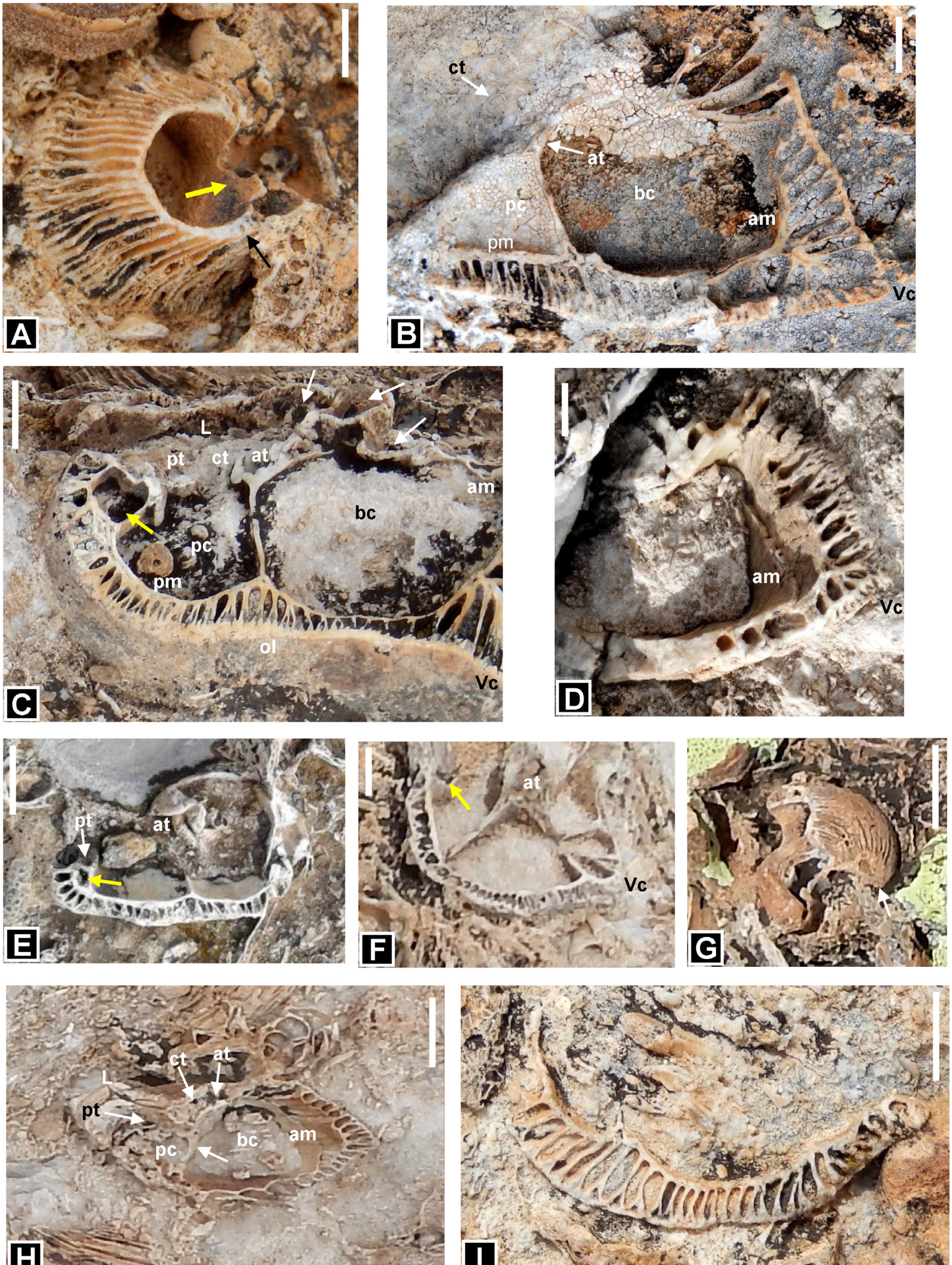


Fig. 12. A-C. *Sphaerucaprina woodwardi* Gemmellaro (1865). A, B and D from the outcrop, C sample no DEU.18-2F of the LV. A. Curved beak with a very thin (1 mm) ol (white arrow) and the il showing the elongate sections of the pallial canals. B, C. The adumbonal view of the transverse sections showing all internal features. Note the LV widens in the anterior side and has three large ec. The canals can be seen in front of the ec and one of them is strongly elongated (yellow arrow). Some sub-cylindrical canal-like sections are present between the am and large ec (black arrows). D. Fragment of the il showing that the size of the pallial canals decreases from the inner to outer part. Scale bar is 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)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G
L
ct
at
pt
am
bc
pc
H
I

the canal-like shapes between the am and the ectomyophoral canals may be compared with the Abruzzi Mountains-Italy specimen described by Praturlon and Sirna (1976, fig. 17) and northern Italy specimen by Parona (1908, fig. 30) respectively.

Genus *Caprina* d'Orbigny, 1822
Type species Caprina adversa d'Orbigny, 1822

Caprina baylei (Gemmellaro, 1865)
Fig. 13A-F

1865 Caprinella Baylei, Gemmellaro, p. 232, pl. III, figs 1-4.
1865 Caprinella caput. equi, Gemmellaro, p. 230, pl. II, figs 5-9, pl. IV, fig. 1.
1908 Caprina carinata, Parona, p. 16, text-figs 13–19.
1995 Caprina baylei, Bonanno and Sirna, p. 135–144, pl. 1, figs 1, 3-6, fig. 1A, C.
2002 *Caprina baylei*, Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).

Material. A single LV and six LV sections.
Description. The LV is conical and slightly curved, showing the radial pallial canals of the il due to the erosion of the ol. Pallial canals are bifurcated towards the external part of the il. Some small fusiform pallial canals can be observed in the transverse section of the uppermost part of the valve. A thick lamina separates the bc from the pc and connects the ats (Fig. 13A).
The transverse section of the LV is trapezoidal or suboval in shape with a pronounced ventral carina (Fig. 13B-F). The ol is very distinct, 1–1.5 mm thick and the il is 10–15 mm thick. The il consists of the elongated oval pallial canals bifurcated regularly in the external part and separated by thin lamellae. These canals are big and radially arranged in the ventral carina side and also the antero-dorsal side. The L is invaginated, the teeth of the LV seem to be in the same size, the ct is sub-rounded and the myophores are represented by thick laminae. The antero-dorsal side of the valve is generally crushed, however some big ectomyophoral accessory cavities/canals are observed in this part of the valve. A large, subsquare cavity is present between the pt and the il (Fig. 13C, E, F). Bc is wider than the pc. The latter is triangular or sub-oval in shape and separated by a thick lamina (1.5–2 mm) from the bc. This lamina is connected with the ats.
Discussion and remarks. The trapezoidal LV section with ventral carina shows characteristic features of the species. The specimens with ventral carina have been described as *Caprina carinata* by many authors, but the synonymy of this species with *Caprina baylei* was clearly demonstrated by Bonanno and Sirna (1995). One of our sections (Fig. 13C) with its sub-oval transverse section and also having a subsquare cavity located between the pts and the il, may compare with that of Parona (1908, p. 17, fig. 13).

Caprina cf. ***schiosensis*** Boehm, 1892
Fig. 13 G-I

1892 *Caprina schiosensis*, Boehm, p. 7, pl. 6, fig. 2, text-fig. 1.
1895 *Caprina schiosensis*, Boehm, p. 101–124, text-figs 4a, 8a-d, 10a-c, 11, 12a, b, 15a, b, 18, 19, pl. 9, figs 2-4, pl. 10, fig. 1a, b.
1908 *Caprina schiosensis*, Parona, p. 9, text-fig. 1-8 u. 1–2.
1967 *Caprina schiosensis*, Polšak, p. 39, 162, pl. 12, fig.4, pl.13, fig.1, text-figs. 6,7.
2002 *Caprina schiosensis,* Steuber (see Web Catalogue of the Hippuritoidea (rudist bivalves) for complete synonym list).
2009 *Caprina schiosensis,* Sarı and Özer, p. 365–367, fig. 5. 4, 7.
2010 *Caprina schiosensis,* Chikhi-Aouimeur, p. 88, figs. 74.1–3, 75.1, 2.
2015 *Caprina* sp. (aff. *schiosensis*), Özer and Ahmad, p. 123, 124, fig. 8 F.

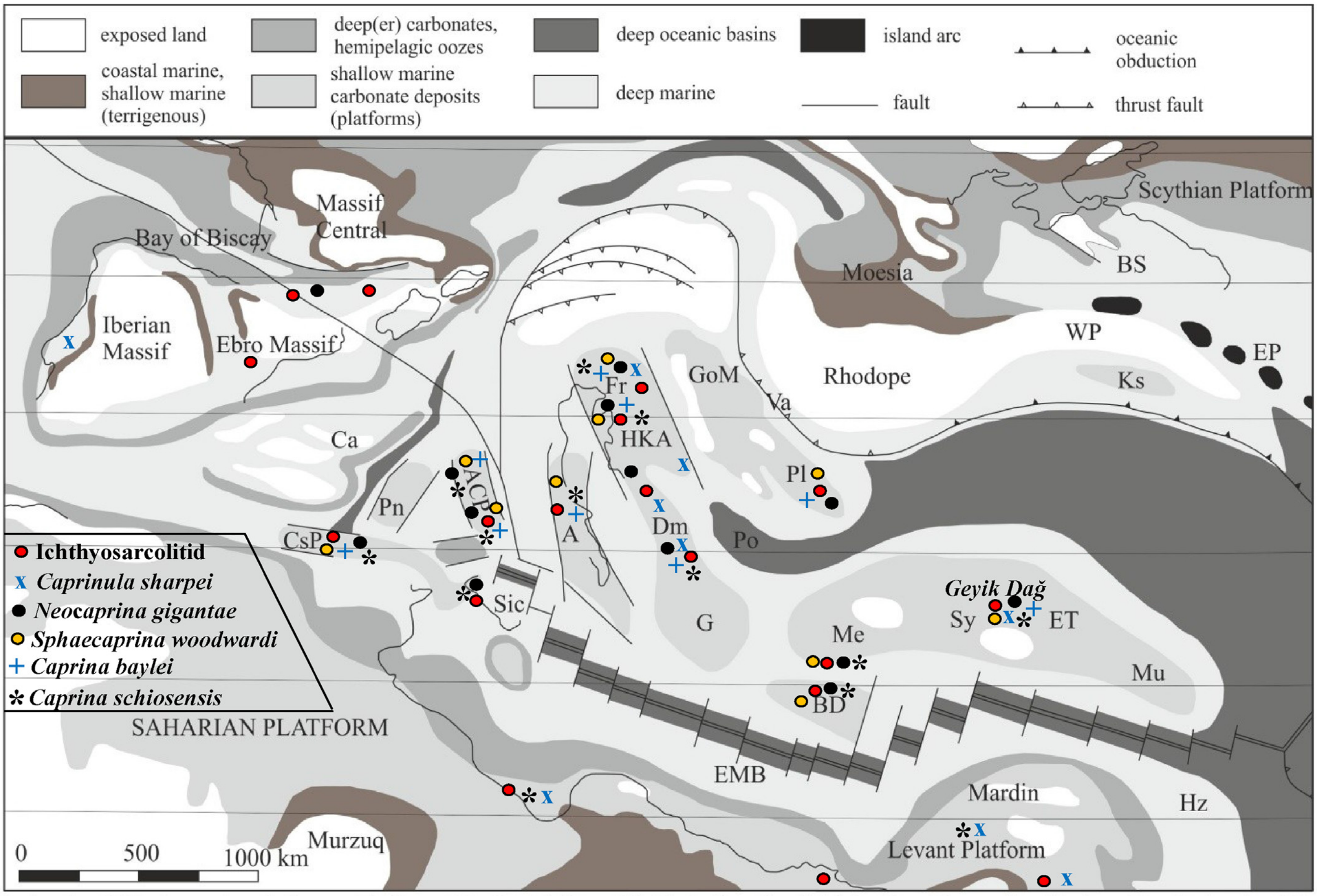
Material. Two LV transverse sections, two slightly oblique sections and many LV section fragments.
Description. The LV is curved and the pallial canals of the il can be seen in the eroded parts of the ol (Fig. 13G). The transverse section of the LV is sub-oval. The ol is very thin or eroded, the il is 5–10 mm thick and consists of a single row of fusiform pallial canals separated by thin lamellae (Fig. 13H-I). The bc is subcircular, large and separated by a lamina from the pc. This lamina is connected with the ats. The L is invaginated, the at, the pt and the ct are small and the am is better preserved than the pm. The anterior side of the valve is generally crushed, however some large ectomyophoral accessory cavities/canals are observed in this part of the valve.
Discussion and remarks. A simple and single row of pallilal canals shows similarities with that of *Caprina schiosensis* described by many authors. Poor preservation of the dorsal and the anterior sides of the LV precludes a definitive assignment to *Caprina schiosensis*.

5. Distribution and age of the rudist fauna

The rudist fauna of the studied area is characterized by the abundance of ichthyosarcolitids. All species of this family, following the recent revision of Rineau and Villier (2018), are represented in the studied fauna. *Caprinula sharpei* is relatively abundant among the caprinulids and *Neocaprina gigantea* is very rare. Caprinids are also relatively abundant. The rudists form a rich fauna, which is found for the first time in the Central Taurides allowing us to examine their distributions in Turkey and also along the Mediterranean Province (Fig. 14).

Many studies on rudists show that they are widely distributed in the Upper Cretaceous strata of the various tectonostratigraphic units in Turkey, but the Cenomanian rudists have only been described from the western Taurides and Lycian nappes in the SW of Turkey (Özer, 2002; Özer et al., 2009, 2017). Some canaliculate rudists have been first described from the middle-upper Cenomanian limestones of a single locality (Karain) in the Bey Dağları (western Taurids) by Özer (1988). Our ongoing studies on rudists show that the ichthyosarcolitids, caprinulids and caprinids are accompanied in many localities by benthic foraminifers which indicate a middle-late Cenomanian age in the Bey Dağları carbonate platform (Sarı, 2006a, b; Sarı and Özer, 2002, 2009; Özer and Sarı, 2008; Sarı et al., 2009). The Geyik Dağı rudist fauna, except *Caprinula sharpei* and *Caprina baylei*, is also present in the Bey Dağları. The Lycian nappes are located between the Bey Dağları Carbonate Platform and Menderes Metamorphic Massif in the SW Turkey. The middle-upper Cenomanian caprinid-ichthyosarcolitid rudist association was recently described from two localities in the Lycian nappes by Özer et al. (2017). This association shows similarity with that of the Geyik Dağı, but *Caprinula sharpei* and *Caprina baylei* are absent, like in the Bey Dağları (Fig. 14).

Fig. 13. A-F. *Caprina baylei* (Gemmellaro, 1865). Outcrop photographs of the LV. A. The pallial canals of the il, some small fusiform pallial canals in the transverse section (black arrow) and a thick lamina (yellow arrow) separating the bc from the pc. B–F. The adumbonal view of the transverse sections. The antero-dorsal side of the valve is usually crushed, however some big ectomyophoral accessory cavities/canals are observed in C (white arrows). Note the presence of a subsquare cavity between the pts and the il in C, E and F (yellow arrows). G-I. *Caprina* cf. *schiosensis* Boehm (1892). Outcrop photographs of the LV. G. Curved beak (white arrow) showing the pallial canals of the il. H. Slightly oblique section, adumbonal view. The white arrow indicates a lamina separating the pc from pc. I. A fragment showing a single row of fusiform pallial canals. Scale bar indicates 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)



A: Apulia, ACP: Appennine Carbonate Platform, BD: Bey Dağları, BS: Black Sea, Ca: Calabria, Csp: Constantine Platform, Dm: Dalmatia, EMB: Eastern Mediterranean Basin, EP: Eastern Pontides, **ET: Eastern Taurus**, Fr: Friuli, G: Gavrovo, GoM: Golija Massif, HKA: High Karst, Hz: Hezan, Ks: Kırşehir, **Me: Menderes**, Mu: Munzur, Pl: Pelagonian, Pn: Panormides, PO: Pindos-Olonos, Sy: Seydişehir, WP: Western Pontides.

Fig. 14. Cenomanian paleogeographic map (Dercourt et al., 2000) showing the distributions of the studied canaliculate rudists (symbols are given in the left of the figure). Note the ichthyosarcolitids show a vast geographic distribution in Mediterranean Tethys, while caprinids and caprinulids seem to be localized in the Central and Eastern part of the province.

Ichthyosarcolitids show a wide distribution from Spain to Turkey in the northern side of the Mediterranean Tethys (Fig. 14). They were considered to be fundamentally of Cenomanian age by many authors in the Old World, but occur also in the uppermost Albian of Slovenia (Steuber, 2002). Ichthyosarcolitids are also found in the Albian of the New World (see Rineau and Villier, 2018). They were described from the lower Cenomanian (Moreau, 1976), the middle Cenomanian (Moreau, 1976; Bilotte, 1985; Bilotte and Philip, 1985; Husinec et al., 2000; DiStefano and Ruberti, 2000), the lower-middle Cenomanian (Polšak et al., 1982; Cestari and Sartorio, 1995; Cestari and Laviano, 2012), the middle-upper Cenomanian (Fabre, 1940; Ruberti, 1993) and from the upper Cenomanian (Parona, 1921; Slišković, 1968, 1983; Carbone et al., 1971; Praturlon and Sirna, 1976; Moreau, 1976; Sirna, 1982; Polšak et al., 1982; Mainelli, 1992; Cherchi et al., 1993; Cestari et al., 1998; Pleničar et al., 1999; Di Stefano and Ruberti, 2000). Ichthyosarcolitids are reported from Algeria, Libya and Tunisia, and as rare finds from Egypt at the southern margin of the Mediterranean Tethys. They were accepted mostly as Cenomanian in age (Steuber, 2002), and rarely late Cenomanian (Razgallah et al., 1994; Bauer et al., 2001) and early Cenomanian (Philip et al., 1995).

The distributions of caprinulids and caprinids show that they are localized in the central and eastern parts of the Mediterranean Tethys (Fig. 14). The Cenomanian age was mostly considered for these canaliculate rudists in the northern side of the Mediterranean Tethys (Steuber, 2002). However, an early Cenomanian age (Steuber, 1999), early-middle Cenomanian age (Cestari and Sartorio, 1995; Di Stefano and Ruberti, 2000; Cestari and Laviano, 2012) and late Cenomanian age (Slišković, 1968; Carbone et al., 1971; Praturlon and Sirna, 1976; Sirna, 1982; Cherchi et al., 1993; Pleničar et al., 1999; Di Stefano and Ruberti, 2000; Cestari and Laviano, 2012) were also considered for these canaliculate rudists. In the northern part of Africa, they were mostly described from Cenomanian formations (Steuber, 2012), but also rarely from the lower and/or middle-upper Cenomanian (Chikhi-Aouimeur, 2010) and recently from the upper Cenomanian (Aouissi et al., 2018) in the northern part of Africa. Some of them were described from the upper Cenomanian of northwestern of Jordan (Özer and Ahmad, 2015, 2016) in the easternmost part of the southern Mediterranean Tethys.

The rudist association of the Geyik Dağı thus indicates a Cenomanian age. The rudist-bearing limestones in the Geyik Dağı area abundantly contain *Conicorbitolina conica* (Archiac, 1837) indicating an early-middle Cenomanian age (Schroeder and Neumann, 1985). This benthic foraminifer was recorded together with canaliculate rudists described here, in the central and eastern of the Mediterranean Tethys. *Conicorbitolina conica* was found together with *Caprina baylei*, *Caprina schiosensis* and *Ichthyosarcolites* species in the Periadriatic domain, Italy and early-middle Cenomanian age is suggested for this fauna by Cestari and Sartorio (1995). *Caprina baylei* and *Sphaerucaprina woodwardi* were described from Boeotia, central Greece and an early Cenomanian age was attributed to them due to the presence of *Conicorbitolina conica* by Steuber (1999). The latter species was described from the rudist-bearing limestones characterized mainly by ichthyosarcolitids from the Baldarin locality in the Cres island of Croatia and a late middle Cenomanian age was suggested for these deposits by Husinec et al. (2000). According to Di Stefano and Ruberti (2000), foraminifer grainstone/packstone with *Conicorbitolina conica* pass laterally to middle Cenomanian ichthyosarcolitid and gastropod-bearing floatstone and reworked skeletal beds. *Conicorbitolina conica* was also found together with *Sphaerucaprina woodwardi* and *Ichthyosarcolites bicarinatus* in the lower-middle Cenomanian of the southern Apennines (Italy) by Cestari and Laviano (2012).

According to these data, we conclude on an early-middle Cenomanian age for the Geyik Dağı rudist association.

6. Conclusions

Lower-middle Cenomanian canaliculate rudist fauna is described for the first time from the Geyik Dağı area in the Central Taurides of Turkey. The rudists are found in the uppermost part of the Bajocian-Cenomanian neritic carbonates of the Polat Limestone. The rudists are abundant, however gastropods (especially nerineids), corals and *Conicorbitolina conica* (d'Archiac, 1837) are also present. The pelagic Maastrichtian-Lutetian Kuşça Limestone disconformably overlies the rudist-bearing limestones.

The rudist fauna consists of *Ichthyosarcolites triangularis* Desmarest, 1817, *I. monocarinatus* Slišković, 1966, *I. bicarinatus* (Gemmellaro, 1865), *I. rotundus* Polšak, 1967, *Caprina baylei* (Gemmellaro, 1865), *Caprina* cf. *schiosensis* Boehm, 1892, *Sphaerucaprina woodwardi* Gemmellaro, 1865, *Caprinula sharpei* (Choffat, 1885) and *Neocaprina gigantea* Pleničar, 1961. Ichthyosarcolitids are more abundant than caprinids and caprinulids. The distribution both of canaliculate rudists and *Conicorbitolina conica* are compared with those of the Mediterranean Tethys and an early-middle Cenomanian age is concluded for the rudist-bearing limestones in the Geyik Dağı area.

Four main lithofacies that have been recognized within the Polat Limestone show that the rudist-bearing limestones were deposited in a carbonate ramp environment: (1) scarce ichthyosarcolitid-gastropod packstone contains very limited canaliculate rudists, gastropods, (2) canaliculate rudist packstone-floatstone-rudstone mainly characterized by well preserved canaliculate rudist sections, (3) packstone-grainstone-rudstone with canaliculate rudist-gastropod-coral fragments and whole shells and (4) mixed canaliculate rudist-gastropod-coral fragments rudstone-grainstone and rudstone consists entirely of shell fragments. The facies characteristics indicate a middle carbonate ramp depositional environment with varying hydrodynamics.

The faunal and facies characteristcs of the rudist-bearing limestones show similarities with those of the central region of the Mediterranean Tethys.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cretres.2019.06.007.