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Cretaceous rudist-bearing platform carbonates from the Lycian Nappes (SW Turkey): Rudist associations and depositional setting

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ABSTRACT

Lycian Nappes (in SW Turkey) lie between the Menderes Massif and Bey Dağları carbonates and comprise thrust sheets (nappes piles) of Paleozoic-Cenozoic rocks, ophiolitic and tectonic mélanges and serpentinized peridodites. This study focuses on identification of rudists and their palaeoenvironmental features observed within the Cretaceous low grade metamorphic successions (dominated by recrystallized limestones) from the Tavas and Bodrum nappes. The study is based on fifteen stratigraphic sections measured from Tavas, Fethiye, Köyceğiz, Bodrum, Ören and Bozburun areas. The Lower Cretaceous successions with rudists are very sparse in the Lycian Nappes and a unique locality including a Berriasian epidiceratid-requieniid assemblage is reported so far. A new requieniid-radiolitid assemblage was found within the pre-Turonian (?Albian-?Cenomanian) limestones. Four different Late Cretaceous rudist assemblages were firstly identified as well: 1) Caprinid-Ichthyosarcolitid assemblage (middle-late Cenomanian); 2) Distefanellid assemblage (late Turonian); 3) Hippuritid-Radiolitid assemblage (late Coniacian-Santonian-Campanian); 4) Radiolitid-Hippuritid assemblage ('middle'-late Maastrichtian). Microfacies data and field observations indicate that the rudists lived in the inner and outer shelves of the Cretaceous carbonate platform(s) in this critical part of the Neotethys Ocean. Rudists formed isolated patchy aggregations in very shallow palaeoenvironments and deposited as shell fragments particularly on the outer shelf environment, which is characterized by higher energy and platform slope characteristics.

1. Introduction

The Late Cretaceous rudist faunas are a typical constituent of the Cenomanian-Maastrichtian formations and distributed widely in various tectono-stratigraphic units of Turkey (Fig. 1A) such as the İstanbul Zone, central Anatolia, central and eastern Pontides of the Sakarya Zone, Bornova Flysch Zone, metamorphic massifs (Menderes Massif, Tavşanlı and Afyon zones), Bey Dağları Autochthon and eastern Anatolia of the Anatolide-Tauride Block and southeastern Anatolia of the northernmost part of the Arabian Platform/Plate (see Steuber, 2002 for complete list; Özer, 2002, 2010a,b; Özer et al., 2008, 2009; Sarı, 2006a,b; Sarı and Özer, 2002, 2009; Sarı et al., 2004; Steuber et al., 2009). The Early Cretaceous rudist faunas are only known from the Zonguldak-Amasra area in the western Pontides, the Karaburun Peninsula in the western Turkey and Bey Dağları in the western Taurides until now (Douvillé, 1896; Fenerci-Masse, 2006; Masse et al., 2002, 2004, 2008, 2009). Although there is much information about the stratigraphic and geographic distribution of rudists in Turkey, we have almost no data on the rudists in the Lycian Nappes, which is one of the important tectono-stratigraphic units in the western Anatolia. The presence of the rudists and/or their fragments was reported from the platform-type carbonates of the Lycian Nappes (Akdeniz, 2011a,b; Bernoulli et al., 1974; Collins and Robertson, 1997, 1998, 1999, 2003; de Graciansky, 1968, 1972; de Graciansky et al., 1967; Gutnic et al., 1979; Kaaden and Metz, 1954; Konak, 2007; Konak et al., 1987;

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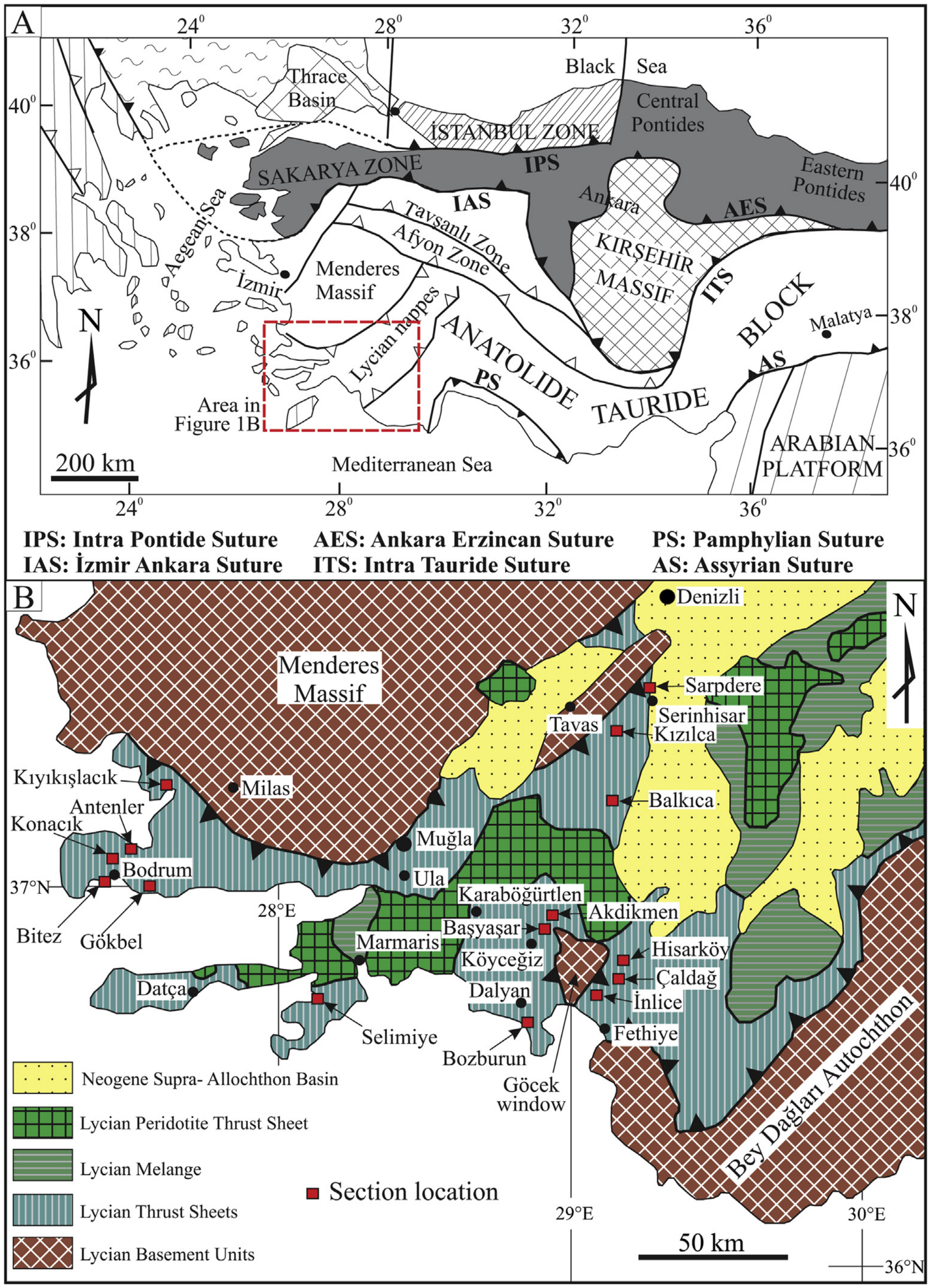


Fig. 1. A-Tectonic map showing the studied area and location of the Lycian Nappes in the tectono-stratigraphic units of Turkey and surroundings (after Okay and Tüysüz, 1999). B-Map showing localities of the measured-stratigraphic sections (red squares) with rudists in the tectonic units of the Lycian Nappes (simplified from Collins and Robertson, 1998). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Özkaya, 1990; Poisson, 1977; Şenel, 1997a,b,c). However, none of the studies above focused on the rudists. Some rudists were described from the Cenomanian monotonous, platform-type marbles in a single locality (Serinhisar, Tavas, Denizli) by Özer (1998, 1999) and Özer et al. (2001) and from the Berriasian limestone megablock in the Bodrum area by Masse et al. (2015). The platform carbonates of the Serinhisar area were attributed to the cover rocks of the Menderes Massif in studies of the 1980's and the 1990's (Collins and Robertson, 1999; Çağlayan et al., 1980; Okay, 1989; Özkaya, 1990, 1991). Later, they were included into the Lycian Nappes (Akdeniz, 2011a,b; Konak, 2007; Şenel, 1997a,b,c).

This study deals with the presence of the Cenomanian-Maastrichtian and the Early Cretaceous rudist bivalves (radiolitid, hippuritid, canaliculate rudists) from the Lycian Nappes. So, the aims of this study are to present the Cretaceous rudist associations from several localities such as Tavas-Denizli, Köyceğiz, Fethiye, Bodrum, Ören and Bozburun-Muğla areas through the Lycian Nappes (Fig. 1B) and emphasize the depositional environments characteristics of rudist-bearing platform carbonates of the nappe piles.

2. Material and methods

The rudist material described and interpreted herein comes from the fifteen measured-stratigraphic sections (Figs. 1B, 2–4). The coordinates and explain better of these sections are given in Table 1.

As the rudists are mostly embedded within the pure, indurated limestones, it was impossible to collect matrix-free, loose specimens. We prepared transverse sections of rudists from the collected limestone samples to determine their internal features. The main problem in studying rudist-bearing limestones is recrystallization due to metamorphism during transportation of the nappe piles and internal tectonic movements. Fortunately, we have found stratigraphic intervals including 'preserved' rudist shells from several localities. We studied thin sections of the numerous limestone samples collected through the stratigraphic sections to describe the microfacies characteristics and microfossils as well. All the micropalaeontologic data will be presented in separate papers.

The rock samples with rudists (nos S 92 01/M, 14-108 A-I, 14-149R, 15-57 A, 15-58 A, B, C, 15-59 A, B, 15-60 A, B, 15-168 A, B, C, D) are displayed in the museum showcases of the Geological Engineering Department of Dokuz Eylul University, İzmir, Turkey. Thin sections (nos 14-27, 14-29, 14-109, 14-151 A, B, 14-209, 14-266, 14-426, 15-02, 15-13, 15-57, 15-99, 15-118, 15-167, 15-176) are deposited in the palaeontology laboratory of the same department.

3. Geological setting

Lycian Belt is located between the Menderes Massif and the Bey Dağları Autochthon in the western Turkey (Fig. 1B). Various tectonic models have been proposed for the origin of the Lycian Belt. According to the most favored tectonical concepts, the nappes originated from the north of the Menderes Massif and thrusted southward during the Late Cretaceous to Burdigalian/Langhian interval (de Graciansky, 1972; Dürr, 1975; Dürr et al., 1978; Gutnic et al., 1979; Ricou et al., 1979; Şengör and Yılmaz, 1981; Okay, 1989; Collins and Robertson, 1997, 1998, 1999, 2003; Güngör and Erdoğan, 2001; Oberhänsli et al., 2001; Rimmelé et al., 2006; Okay et al., 2012; Pourtaeu et al., 2016). But, some alternative studies considered a dual origin for the Lycian Nappes. Poisson (1985) proposed that the sedimentary thrust sheets originated from an intra-continental rift basin (the Kızılca-Çorakgöl basin, which corresponds to the eastern prolongation of the Ionian Zone of Greece) between the Menderes and the Bey Dağları platforms, except the peridodite nappes drifting from the north of the Menderes Massif. Özkaya (1990, 1991) suggested that the thrust slices of the Lycian Nappes were derived from the İzmir-Ankara Zone to the north and the Alakaya Basin to the south of the Menderes Massif. Ersoy (1993a) accepted the dual origin concept of Poisson (1985). The tectonic klippe of the Lycian Nappes are very

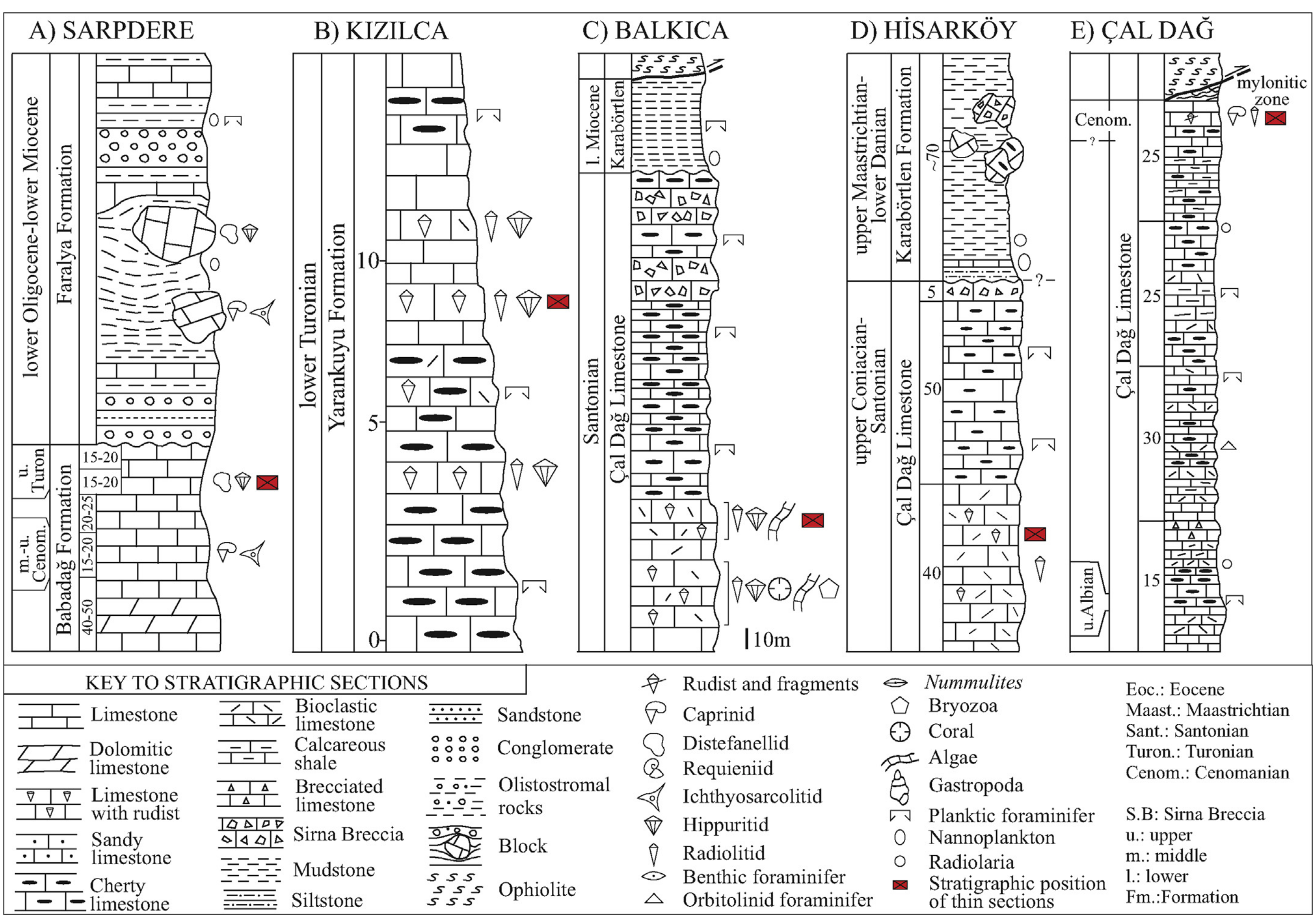


Fig. 2. Measured-stratigraphic sections and key to the stratigraphic sections (see Fig. 1B for locations of the sections). Numbers show meters.

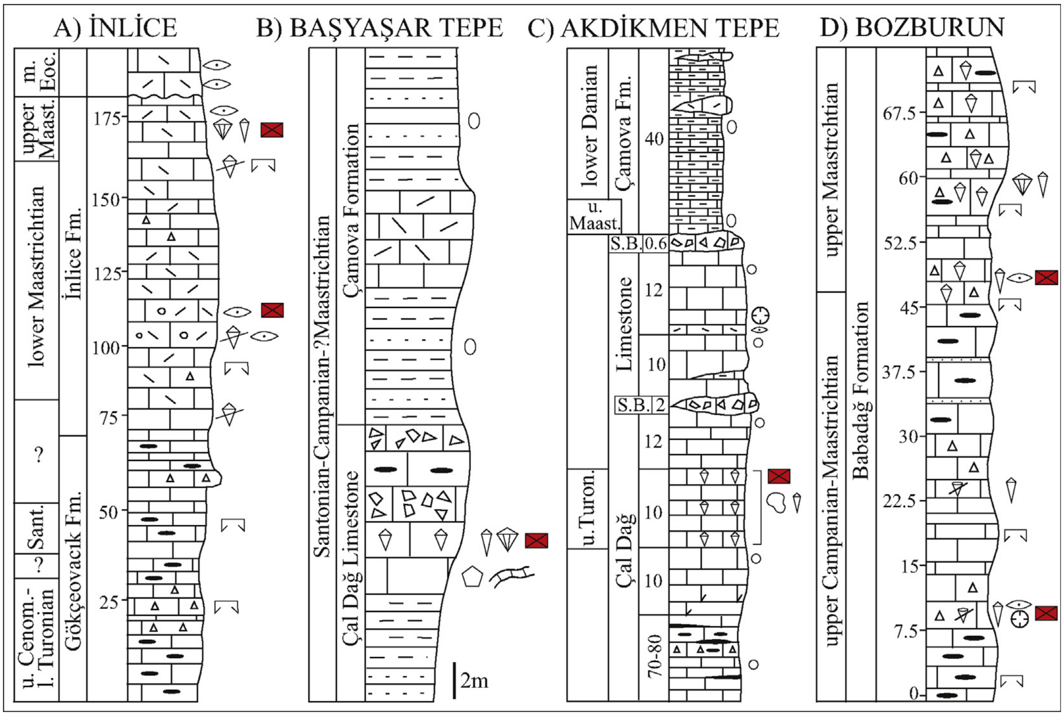


Fig. 3. Measured-stratigraphic sections (see Fig. 1B for locations of the sections and Fig. 2 for explanations). Numbers show meters.

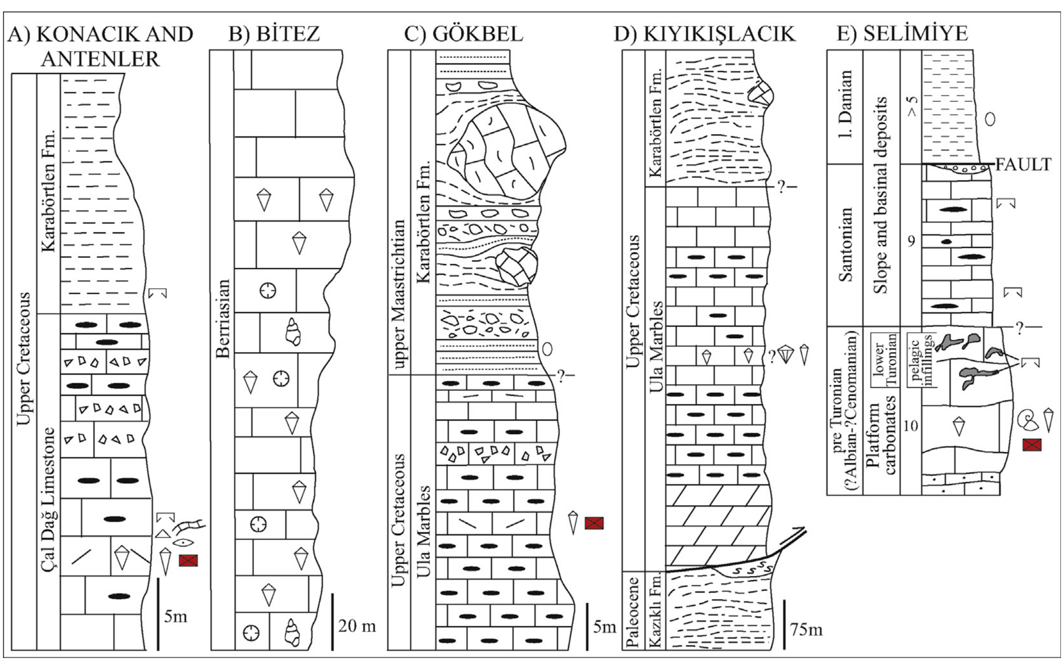


Fig. 4. Measured-stratigraphic sections (see Fig. 1B for locations of the sections and Fig. 2 for explanations). Numbers show meters.

sparse above the Menderes Massif and only found in the Söke-Selçuk area (the Dilek Peninsula) to the west (Güngör and Erdoğan, 2001), around the Borlu area to the north (Rimmelé et al., 2006) and in the surroundings of Çal-Çivril area to the east (Sözbilir, 1997; Özer et al., 2001; Rimmelé et al., 2006).

In the early studies the Lycian Nappes were firstly subdivided into three main tectonic units such as: (i) the autochthonous series, (ii) the intermediate complex consisting of imbricated thrust sheets (the Karadağ, the Teke Dere, the Köyceğiz, the Haticeana Dağ and the İnlice series) and (iii) the peridotite nappe (de Graciansky et al., 1967; de Graciansky, 1968, 1972; Bernoulli et al., 1974). Later, the Lycian Nappes were separated into eight units (i.e. the Tavas, the Bozdağ, the Domuzdağ, the Yavuz and Yeleme, the Gümüşlü, the Gülbahar, the ophiolitic nappe, the Kızılcadağ mélange) by Poisson (1977), four major units (i.e. the Elmalı, the Köyceğiz, the Tavas, the Tefenni units) by Özkaya (1990), eight structural units (i.e. the Beydağları Autochthon, the Marmaris Ophiolitic Nappe, the Yeşilbarak, the Tavas, the Bodrum, the Dumanlıdağ, the Domuz Dağ,

Table 1
Table showing the locations, UTM coordinates and corresponding figures of the measured-stratigraphic sections in the Lycian Nappes.

No	Section	Location	UTM Coordinates (35S)	Fig.
1	Sarpdere	1 km north of Serinhisar town (formerly Kızılhisar)-Tavas	0700210/4163554; 0700259/4163524	2A
2	Kızılca	10 km southwest of Serinhisar town, near Kızılca village	0688930/4152406	2B
3	Balkıca	25 km south of Tavas town, 1 km east of Balkıca village	0687620/4133297; 0687744/4133476	2C
4	Hisarköy	64 km northeast of Fethiye, southeast of Ürmük Dağ, around Hisarköy village	0691733/4115105; 0690475/4115850	2D
5	Çal Dağ	22 km northwest of Fethiye, 6 km northwest of Arpacık (formerly Nif) village	0688880/4082227; 0691755/4081569	2E
6	İnlice	4 km east of Göcek town, north of İnnice village	0677407/4070017; 0677044/4069119	3A
7	Başyaşar Tepe	18 km northeast of Köyceğiz town, 7 km west of Otmanlar village	0666170/4100742; 0666156/4100578	3B
8	Akdikmen Tepe	15 km northeast of Köyceğiz town	0659450/4097855; 0659157/4098570	3C
9	Bozburun Tepe	23 km southeast of Köyceğiz town	0646207/4070449; 0646052/4070553	3D
10	Konacık	3 km northwest of Bodrum town, northeast of Konacık village	0536816/4101635; 0536731/4102034	4A
11	Antenler	3 km northeast of Bodrum town	0539343/4102445; 0539340/4102230	4A
12	Bitez	3 km southwest of Bodrum town, near Bitez	0533821/4097382; 0533808/4095944	4B
13	Gökbel	Between YukarıMazıköy and Gökbel villages, 2 km northwest of Gökbel village	0567365/4099593; 0567359/4098273	4C
14	Kıyıkışlacık	5 km southwest of Kıyıkışlacık village	0551076/4126024; 0549298/4125720	4D
15	Selimiye	10 km northeast of Bozburun town, 6 km northeast of Selimiye village	0599527/4065148; 0599525/4065140	4E

the Gülbahar nappes) by Şenel (1997a,b,c) and three tectono-stratigraphic units (i.e. the Lycian thrust sheets consisting of Yavuz, Karadağ, Teke and Köyceğiz units, the Lycian mélange and the Lycian peridodite thrust sheet) by Collins and Robertson (1997, 1998, 1999).

The rudists examined in this study come from the Köyceğiz and the İnlice Series of de Graciansky (1972), the Tavas and the Bozdağ massifs of Poisson (1977), the Köyceğiz and the Tavas units of Özkaya (1990), the Tavas and the Bodrum nappes of Şenel (1997a,b,c) and the Köyceğiz thrust sheet of Collins and Robertson (1997, 1998). The tectono-stratigraphic nomenclature (the Tavas and the Bodrum nappes) followed here is that of Şenel (1997a,b,c).

When examining previous studies, we can suggest that the Tavas and the Bodrum nappes show almost the same lithologic succession consisting of alternation of limestones and cherty limestones. However, dolomitic limestones, cherty limestones and calciturbiditic limestones are more dominant in the Bodrum nappe, which tectonically overlies the Tavas nappe. The main difference between the Tavas and the Bodrum nappes is the presence of chert breccias named as 'Sirna breccia' in the uppermost part of the Upper Cretaceous succession of the Bodrum nappe, separating the platform-type carbonates from the turbidites. The Sirna breccia does not exist in the Tavas Nappe and the coeval stratigraphic interval is represented by an unconformity.

4. Stratigraphy and comparison

The rudists are found in the slightly metamorphic limestones of the Tavas, Fethiye, Köyceğiz, Ören, Bodrum and Bozburun areas. Location of the rudist-bearing measured-stratigraphic sections are given in Fig. 1B and the sections are presented in Figs. 2–4. The rudist contents of the measured-stratigraphic sections are presented in the following chapter.

4.1. Tavas area

Mesozoic monotonous platform-type limestones, showing low-grade metamorphism, have widespread outcrops between Tavas and Denizli (Fig. 1B). Previous studies suggest an imbricated internal structure for these carbonates (Collins and Robertson, 1999; Okay, 1989; Özkaya, 1990; Poisson, 1977, 1985). Microfossils are very poor or absent in these limestones due to the metamorphism. However, the rudist-bearing limestones can be found in the topmost part of the sequence, as explained below in Sarpdere (Serinhisar) section (Fig. 2A). They are the unique and important palaeontologic data for the recrystallized carbonate sequence in the area (Çağlayan et al., 1980; Özkaya, 1990; Özer, 1998; Özer et al., 2001; Özer and Sarı, 2008). Three stratigraphic sections with rudists were measured in this area (Fig. 2A–C); Sarpdere section belongs to Tavas nappe, Kızılca and Balkıca sections to Bodrum nappe (Akdeniz, 2011a,b; Şenel, 1997a,b,c). The details of the sections are given below;

4.1.1. Sarpdere section

Sarpdere is located to the north of Serinhisar town (formerly Kızılhisar) in the Tavas area (Fig. 1B) and represents an excellent outcrop of rudist-bearing limestone that allowed us to understand the stratigraphy of the carbonate sequence. Our new observations show that the uppermost part of the Babadağ Formation consists of, in ascending order (Fig. 2A), (i) a 40–50-m-thick, intercalation of grey, massive dolomitic limestones and dark grey, unfossiliferous massive limestones, (ii) a 15–20-m-thick, dark grey, bituminous, thick-bedded limestones with canaliculate rudists indicating a middle-late Cenomanian age. Some radiolitids, requieniids and *Chondrodonta* sp. are also present (Fig. 5A–E). (iii) a 20–25-m-thick, grey, unfossiliferous massive limestones, (iv) a 15–20-m-thick, light grey, thick-bedded limestones characterized mainly by *Distefanella*, but radiolitids and hippuritids are also present (Fig. 5F–N). The rudists indicate a late Turonian age, (v) a 15–20-m thick, grey, unfossiliferous thick-bedded limestones. This succession shows low grade metamorphism effects and so the microfossils are totally masked due to the recrystallization. The depositional texture can be only observed in upper Turonian limestones. Internal structure of the rudists can be distinguished despite the recrystallization.

Rudist-bearing limestones are unconformably overlain by megabreccias consisting mainly of serpentinites and limestone clasts and also limestone blocks with middle-upper Cenomanian and upper Turonian rudists in the reddish-metaclastic matrix of the Faralya Formation (Fig. 2A). These megabreccias rest on the various stratigraphic levels of the rudist-bearing platform-type limestones and continue with intercalation of reddish, cherty and laminated micritic limestones, mudstones, conglomerates and sandstones to the top. The matrix of the Faralya Formation yields nannofossils suggesting an early Oligocene-early Miocene age (Özer et al., 2016).

Previous studies suggested Late Cretaceous or Cenomanian and Santonian ages for the rudist-bearing limestones in this section (Çağlayan et al., 1980; Okay, 1989; Özkaya, 1990; Özer, 1998; Özer et al., 2001, 2008; Akdeniz, 2011a). But, the new data obtained from the Late Cretaceous rudist fauna in the Sarpdere section indicate middle-late Cenomanian and late Turonian ages for the limestones. The Cenomanian-Turonian succession of the Sarpdere section shows clear similarity with the rudist-bearing limestones of the Bey Dağları Carbonate Platform (Özer, 1988; Sarı, 2006a; Sarı

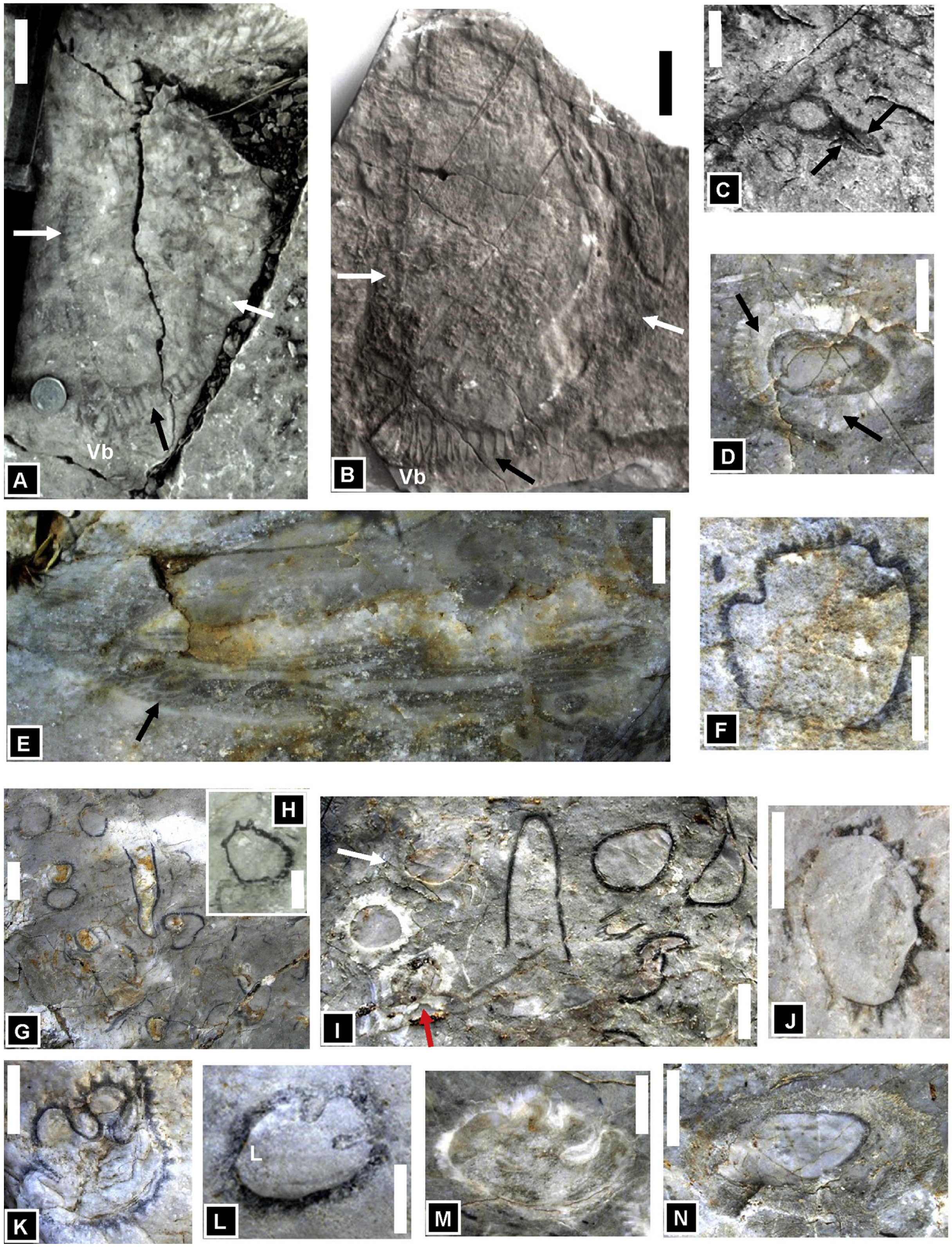


Fig. 5. Rudists of the Sarpdere section (C–N are the outcrop photographs): A–E-middle-upper Cenomanian rudists (A and C from Özer, 1988), A–B-*Neocaprina gigantea* Pleničar, the natural transverse sections of the right valve, sample nos S 92 01/M and 14-149R, the ventral canals (black arrow), the accessory cavities (white arrows) and the external carina (Vb) can be observed. Note the ghost appearances of the accessory cavities (white arrows) in B, C-*Ichthyosarcolites poljaki* Polšak, the transverse section of the right valve. Note the well-developed ridges and small round or oval canals (black arrows). D-*Durania* sp., the right valve transverse section with thick outer shell layer showing partially preserved polygonal prisms (black arrows). E-*Caprinula* aff. *boisyyi* d'Orbigny, the oblique section of the right valve showing a row of large canals on inner side following one or three rows of small, round and may be sparse piriform pallial canals (black arrow), F–N-upper Turonian rudists, F-*Distefanella montagnei* Slišković, the transverse section of the right valve showing the concave radial bands characteristic of the species, G-*Distefanella salmojraghii* Parona, the transverse and radial sections of the right valves. Note the different shape of valve sections (round, oval or subtriangulary), H-*Distefanella salmojraghii* Parona (=*Distefanella tavassiana* Özer), the transverse section of the right valve, note the concave radial bands, I-the

and Özer, 2009; Sarı et al., 2009). The succession should be compared to sequences of southern Apennines-Italy (Cestari and Laviano, 2012) and of island of Cres-Croatia (Korbar et al., 2001) due to similarities of both lithologic aspects and faunal contents and also having recrystallization.

4.1.2. Kızılca section

Kızılca village is located to the southeast of Tavas town (Fig. 1B), where the first detailed Liassic-uppermost Cretaceous stratigraphic section was presented by Poisson (1977) and Poisson and Sarp (1985). Later, Lower Liassic algal limestones (Ağaçlı Formation), overlying Upper Liassic-Cenomanian reddish mudstones (Babadağ Formation) and uppermost Cretaceous cherty limestones comprising limestone lenses with rudists (Yarankuyu Formation) were reported by Akdeniz (2011a) and Çakmakoğlu (1986). Kızılca section is measured in the ancient marble quarry located approximately 1 km north to the Kızılca village. The base of the approximately 15-m-thick section consists of a 3-m-thick, pinkish cherty and laminated limestones (Fig. 2B). A 0.15–0.40-m-thick chert bands are parallel to the strike of the limestones. The cherty limestones are intercalated with rudist-bearing bioclastic limestones at the lower half of the section. Upward in the section, intercalations of the grey limestones and bioclastic limestones with rudists are seen. Cherty limestones appear at the top of the section again. The rudists are the main components of the bioclastic limestones and are observed as generally shell fragments. Many right valve sections of Radiolitidae show the prismatic cellular structure of the outer shell layer and acute costae (Fig. 6A, B). The cherty limestones comprise well-preserved planktic foraminifera indicating an early Turonian age for the Yarankuyu Formation (Özer et al., 2016). Similar pelagic successions are reported from the lower Turonian of Brac Island (Sveti Duh Formation) by Davey and Jenkyns (1999) and Moro et al. (2002). However, the Sveti Duh Formation includes only calcispheres, possibly as a result of reduced water depth. Lower Turonian pelagic cherty limestones (without bioclastic limestones with rudists) are also found in the İnlice section (Fethiye area) as explained below, which may be compared with the Kızılca section.

Poisson (1977) and Poisson and Sarp (1985) suggested a Cretaceous age for the rudist fragments-bearing brecciated limestones. Akdeniz (2011a) and Çakmakoğlu (1986) inferred a latest Cretaceous age for the formation and separated rudist–bearing limestones as a rock unit. However, our data indicate that the bioclastic limestones consist of reworked rudist shell fragments within the lower Turonian 'deep water' limestone sequence.

4.1.3. Balkıca section

Balkıca section was measured to the southernmost of Tavas town (Fig. 1B). This section consists of platform-type carbonates (Çal Dağ Limestone), which are overlain by turbidites (Karabörtlen Formation) (Fig. 2C). The peridodites overthrust the Karabörtlen Formation. The lower boundary of the carbonate succession is not seen in the section. The succession is characterized by a 40–45-m-thick, grey, bioclastic limestones at the base. The rudists are the main components of these bioclastic limestones. Although they are mostly fragmented, some of them could be determined and may be suggested a Santonian age (Fig. 6C–F). Hermatypic corals, red algae, gastropods and some reworked benthic foraminifers are also present (Fig. 6H). These bioclastic limestones do not include any index microfossils. The bioclastic limestones continue with a 130-m-thick, unfossiliferous dark grey, massive limestones and cherty limestones, which are intercalated with chert breccias (Sirna breccia). The limestone clasts including the prismatic outer shell layer fragments of radiolitids are observed within the chert breccias (Fig. 6G). The cherty limestones yield some planktic foraminifera suggesting a middle Turonian-Santonian age (Özer et al., 2016). According to the rudist fauna and planktic foraminifera a Santonian age may be suggested for the limestone succession. The pinkish calcareous shales and mudstones intercalated with greenish-grey sandstones and siltstones of the Karabörtlen Formation rest unconformably over the cherty limestones. Nannofossil data indicate an early Miocene age for the Karabörtlen Formation (Özer et al., 2016).

Previous studies suggest a latest Cretaceous age for the limestones of the Balkıca section based on very limited palaeontologic data such as some foraminifera (Poisson, 1977; Göktaş, 1988; Akdeniz, 2011a,b). However, a Santonian age is suggested for the limestones in this study.

4.2. Fethiye area

Compiled stratigraphy of the Nif Mountain (Çal Dağ) and Hisarköy area to the north of the Fethiye town (Fig. 1B) comprises from old to young; the Lower Jurassic dolomitic limestones, the Middle Jurassic-Cenomanian limestones and calcarenites, and overlying uppermost Cretaceous-Paleocene turbidites (Colin, 1962; de Graciansky et al., 1967; de Graciansky, 1972; Akdeniz, 2011a). The Çal Dağ section first presented by de Graciansky (1972, fig. 56) was a reference section for the Çal Dağ Limestone unit, which has been referenced in several studies (Akdeniz, 2011a; Bernoulli et al., 1974; Poisson, 1977; Şenel, 1997a,b,c). de Graciansky (1972) reported occurrences of some planktic and benthic foraminifera in the Cretaceous limestones and also rudist debris in the Albian-upper Cenomanian limestones from the Çal Dağ section. The İnlice Series (İnlice-Göcek, NW Fethiye) comprise from bottom to top, unfossiliferous cherty limestones, Maastrichtian limestones with benthic foraminifera and Eocene limestones and detritic rocks with *Nummulites*, which was recorded by de Graciansky (1972), Poisson (1977) and Şenel (1997a,b,c) as well. According to de Graciansky (1972) and Poisson (1977), İnlice Series belong to "intermediate complex" showing some stratigraphic differences from the other sections of the Lycian Nappes. The Çal Dağ and Hisarköy sections belong to the Bodrum nappe (Akdeniz, 2011a,b; Şenel, 1997a,b,c).

4.2.1. Hisarköy section

This section comprises the Çal Dağ Limestone, which is overlain unconformably by the Karabörtlen Formation (Fig. 2D). The lower boundary of the carbonate succession is absent in the section. The Çal Dağ Limestone can be divided into two parts: a 40-m-thick basal part consists mainly of grey, thick-bedded bioclastic limestones with rudists. Rudists are generally observed as shell fragment and may be occur from Coniacian to Maastrichtian (Fig. 6I–K). Gastropods, corals, algae and indeterminable bivalvia fragments are also present

transverse and radial sections of the right valves of *Distefanella salmojraghii* Parona and the transverse sections of the right valves of *Durania* cf. *gaensis* (Dacqué) and *Durania* sp. (in the left side). Note one of *Durania* sections has a wide and depressed ventral radial band (red arrow) of *D. gaensis* (Dacqué) showing typical character of the species and the ghost of this genus (white arrow). J-*Distefanella salmojraghii* Parona, the transverse section of the right valve. Note the well-developed costae. K-*Vaccinites* cf. *praegiganteus* (Toucas), the transverse section of the right valve, L-*Hippurites* cf. *socialis* Douvillé, the transverse section of the right valve, the slightly developed rounded L is marked. M-*Vaccinites* cf. *rousseli* Douvillé, the transverse section of the right valve, N-*Durania* sp. (*Durania* aff. *laevis* Douvillé), the transverse section of the right valve. Note distinct closely spaced radial ribs. Scale bars are equal to 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

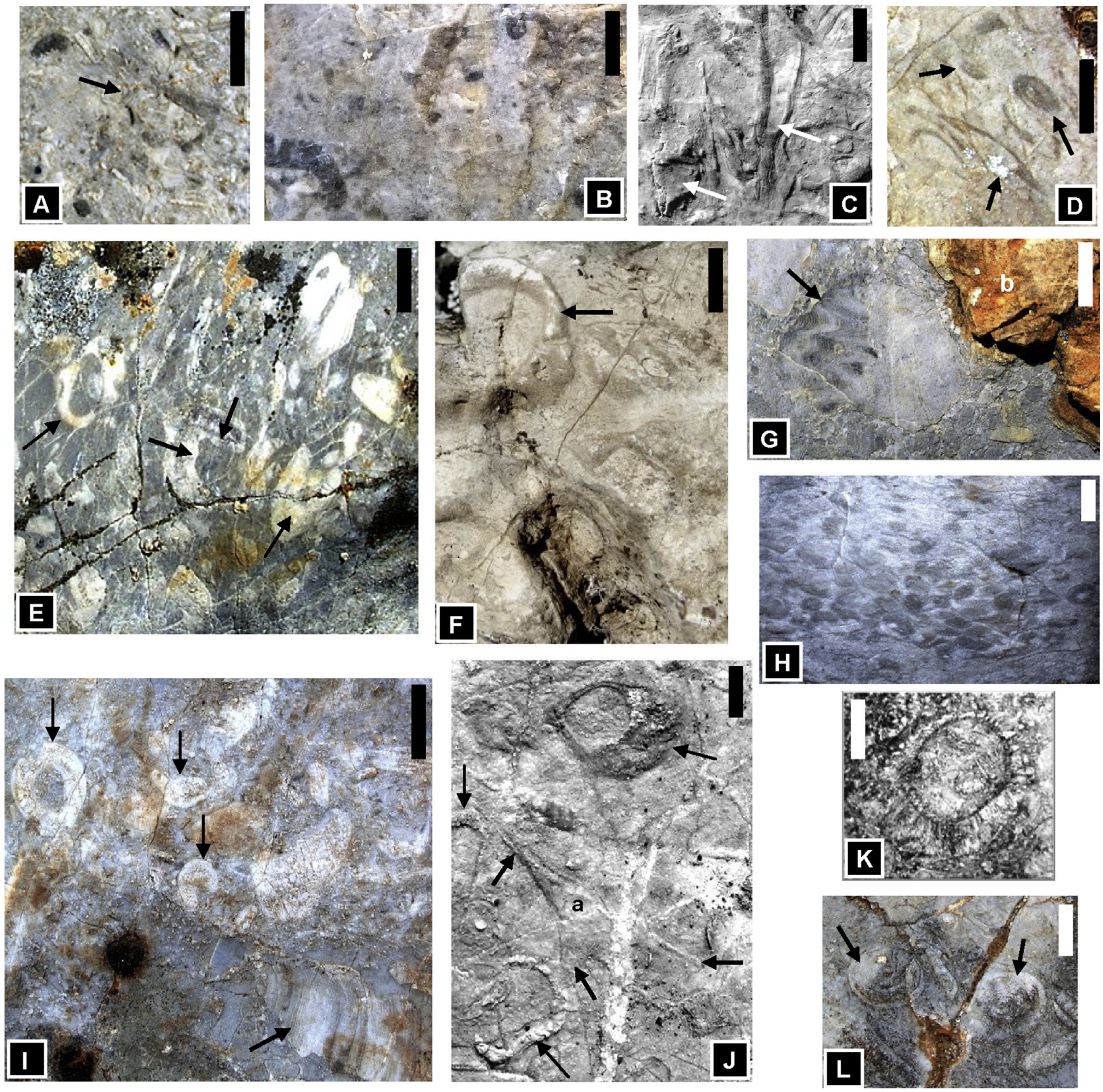


Fig. 6. Outcrop photographs of rudist sections from several stratigraphic sections, A–B-rudists of the Kızılca section, lower Turonian: A-a transverse section of the right valve (black arrow) of radiolitid fragment, B-the general view of the bioclastic limestone showing transverse sections of the right valves fragments of undeterminable radiolitids, C–G-rudists of the Balkıca section, Santonian, C-the general view of the bioclastic limestone showing the fragments of indeterminate small tubular radiolitids (arrows), D-the sections of indeterminable radiolitids (black arrows) within the bioclastic limestones, E-some sections probably belong to tubular rudists (thin black arrows). Two concave structures (thick black arrows) may be belong to pillars of hippuritids, F-right valve transverse sections of indeterminable radiolitid sections. One of the sections (arrow) may be compared with *Bournonia* aff. *hvarensis* Pejović. G-a limestone clast including the prismatic outer shell layer fragments of radiolitids (black arrow) within the chert breccias (b), H-hermatypic corals, Balkıca section, I–K-rudists of the Hisarköy section, upper Coniacian-Santonian-Campanian, I-small tubular (indeterminate) radiolitid sections (thin black arrows) and a radiolitid fragment (thick black arrow) showing the cellular structure, J-the general view of the bioclastic limestone consisting of indeterminable right valve transverse sections of Radiolitidae (thin black arrows), K-the right valve transverse section of indeterminate radiolitid. The radial ridges (arrows) of the one of these sections (a) may be compared with *Bournonia wiontzeki* Pejović. L-gastropod sections (?acteonellid), Hisarköy section. Scale bars indicate 10 mm.

(Fig. 6L). Microfossils are not seen in the rudist-bearing limestones. A 50-m-thick upper part of the succession is characterized by thick-bedded, grey, cherty limestones. A 5-m-thick Sirna breccia consists of angular chert fragments and is observed at the uppermost part of the section. The planktic foraminifera suggesting a late Coniacian-Santonian age were described from the cherty limestones (Özer et al., 2016). So, the late Coniacian-Santonian age can be suggested for the Çal Dağ Limestone. The Karabörtlen Formation consists of mudstones, sandstones, thin calcareous shale lens and limestone blocks. Nannofossil assemblages in fine-grained rocks indicate a late Maastrichtian-early Danian age (Özer et al., 2016).

Akdeniz (2011a) named limestones with rudist fragments as Ürmükdağı Limestone and reported that age of the formation is Berriasian-Cenomanian according to the stratigraphic relations. However, our data show that the lower part of the section comprises bioclastic limestones with some determinable rudists and the upper part includes cherty limestone with planktic foraminifera showing a late Coniacian-Santonian age.

4.2.2. *Çal Dağ section*

The Çal Dağ section comprises a 180-m-thick pelagic limestone succession (Fig. 2E). A 95-m-thick middle and upper parts of the section are mainly made up cherty and bioclastic limestone alternations. The Radiolaria, orbitolinids and bivalvia fragments are abundant in the limestones. But, it was impossible to describe the species due to bad preservation. Planktic foraminifera are very rare throughout the succession, only a few samples from the middle of the section yield planktonic foraminifera of late Albian age (Özer et al., 2016). The uppermost part of the section, around the peak (2.184 m) of the Çal Dağ, is characterized by the presence of the bioclastic limestones with rudist fragments intercalated with cherty limestones. The rudist shells within the bioclastic limestone interlayers (at the top of the section) are represented by canaliculated rudists and radiolitids (Fig. 7A–D). The identified canaliculated rudists suggest a Cenomanian (mostly middle-late) age. Besides, indeterminable radiolitid fragments also occur. These limestones do not yield foraminifera.

de Graciansky et al. (1967) reported a canaliculated rudist *Caprina choffati* Douvillé suggesting Cenomanian age from the Nif écaille zone, without illustration and exact location. This species is well-known from the upper Albian in Spain and Portugal (Steuber, 2002). The discrepancy between the stratigraphic distribution of the species and the age of the Çal Dağ succession may arise from wrong identification. According to de Graciansky (1972), the rudist sections are seen in the upper Albian-upper Cenomanian limestones from the top of the sequence. But, this study reveals that they are only present in the Cenomanian bioclastic limestones towards the uppermost part of the section.

4.2.3. İnlice section

This section consists mainly of approximately 190-m-thick platform-type carbonates (Fig. 3A). The carbonates comprise three different lithologic succession from bottom to top: (i) a 50-m-thick basal part is made of cherty limestones. Planktic foraminifera in this interval suggest latest Cenomanian-early Turonian and Santonian ages, (ii) a 45–50-m-thick middle part consists of thick bedded, bioclastic limestones with abundant larger benthic foraminifera and rudist, bivalve and coral fragments. Benthic foraminifera show an early-'middle' Maastrichtian age for this interval, (iii) a 80–85-m-thick upper part is composed of calciturbiditic and bioclastic limestones with larger benthic and planktic foraminifera suggesting a 'middle'-late Maastrichtian age. The rudist fragments are the main components in the upper part of these limestones and are mainly represented by radiolitid shells with prismatic cells, some hippuritid and canaliculate shell sections are also observed (Fig. 7E–F). Despite that all the rudists are observed as shell fragments, some taxa suggesting a 'middle'-late Maastrichtian age can be identified. Middle Eocene pinkish-red micritic limestones and grey, massive limestones with nummulitid and planktic foraminifera rest unconformably over the rudist-bearing bioclastic limestones.

The limestones with rudists and benthic foraminifera of the İnlice section were reported as Maastrichtian calcarenites by de Graciansky (1972), de Graciansky et al. (1967) and Poisson (1977). This study shows that the bioclastic limestones with rudists and benthic fossils and calciturbiditic limestones with planktic foraminifera are intercalated at the upper part of the carbonate succession. Foraminiferal assemblages indicate an early-'middle'-late Maastrichtian age. The presence of some rudist taxa suggesting 'middle'-late Maastrichtian age are very important for comparison İnlice section with other localities in the Köyceğiz area.

4.3. Köyceğiz area

Mesozoic rocks show a wide distribution in the Köyceğiz area and consist mainly of cherty limestones and are overlain by turbidites (Akdeniz, 2011a,b; Bernoulli et al., 1974; de Graciansky, 1968, 1972; de Graciansky et al., 1967; Şenel, 1997a,b,c). Previous studies have some information on the presence of rudist bivalves. Only some rudist fragments were reported from the cherty limestones, without any detailed information and description. However, our studies reveal that rudist exist and yield important biostratigraphic data as explained below. Başyaşar Tepe and Akdikmen Tepe sections belong to the Bodrum nappe, Bozburun Tepe section belongs to the Tavas nappe (Fig. 1B) (Akdeniz, 2011a,b; Şenel, 1997a,b,c).

4.3.1. Başyaşar Tepe section

Platform-type carbonates (Çal Dağ Limestone) consist mainly of a 10-m-thick cherty limestones in this section (Fig. 3B). They are intercalated with rudist-bearing limestones towards to top of the section. The rudist sections are mostly recrystallized as a result of low-grade metamorphism. Despite recrystallization some hippuritid sections suggesting a Santonian-Campanian age could be identified (Fig. 7G–N). The topmost part of the Çal Dağ limestone is characterized by chert breccias (Sirna breccia), which are alternated with cherty limestones. The carbonate-dominated succession passes into sandstone and mudstone alternations with bioclastic limestone lenses of Çamova Formation, which include Maastrichtian-early Danian nannofossils (Özer et al., 2016).

Akdeniz (2011b) and Şenel (1997a,b,c) described the rudist-bearing limestones as Gökçegediği Formation and suggested an Early Cretaceous-Cenomanian age. However, the rudist fauna described in this study suggests a Santonian-Campanian age for these limestones.

4.3.2. Akdikmen Tepe section

The platform-type carbonates (Çal Dağ Limestone) of the Akdikmen Tepe section are represented by thick-bedded limestones and consist of from bottom to top (Fig. 3C), (i) alternation of a 70–80-m-thick, allodapic nodular cherty limestones, (ii) a 10-m-thick dolomitic limestones and (iii) a 40–45-m-thick recrystallized limestones. The latter includes approximately 10-m-thick rudist-bearing limestones at the base, which comprises three levels of patchy aggregations of rudist bivalves indicating a late Turonian age (Fig. 8A–I). Calcareous mudstones with very rare planktic foraminifera, some branching coral and gastropod sections between two chert breccia (Sirna breccia) levels (0,6–2-m-thick) were also found towards the upper part of the massive recrystallized limestones (Fig. 8J–K). The same limestones with coral and gastropod sections are seen at the uppermost part of the carbonate succession to the north of Köyceğiz, around Çakmak Tepe and Çamova. Platform-type carbonates can be traced laterally to the west in that area. A 0,6-m-thick chert breccia level (Sirna breccia) separates the massive carbonates (Çal Dağ Limestone) from the calcareous shales (Çamova Formation). The latter consists of mudstones and siltstones including bioclastic limestone lenses and blocks of various origin. Nannofossils obtained from the fine-grained rock samples indicate a late Maastrichtian and early Danian age for the Çamova Formation (Özer et al., 2016).

Akdikmen Tepe section was first reported by de Graciansky (1972) and later accepted as a reference section for the Çal Dağ Limestone, Sirna breccia, Çamova and Karabörtlen formations in many subsequent studies (Akdeniz, 2011b; Bernoulli et al., 1974; Ersoy, 1989, 1993b; Konak, 2007; Poisson, 1977; Şenel, 1997a,b). However, Akdeniz (2011b) and Şenel (1997a,b,c) proposed the name Gökçegediği Formation for the rudist-bearing limestones. The section is important for the Upper Cretaceous stratigraphy of the Lycian Nappes. de Graciansky (1972) presented only 20-m-thick uppermost part of the platform limestones (Çal Dağ Limestone) in his section, probably due to harsh topography. de Graciansky (1972) and other previous studies (Akdeniz, 2011b; Bernoulli et al., 1974;

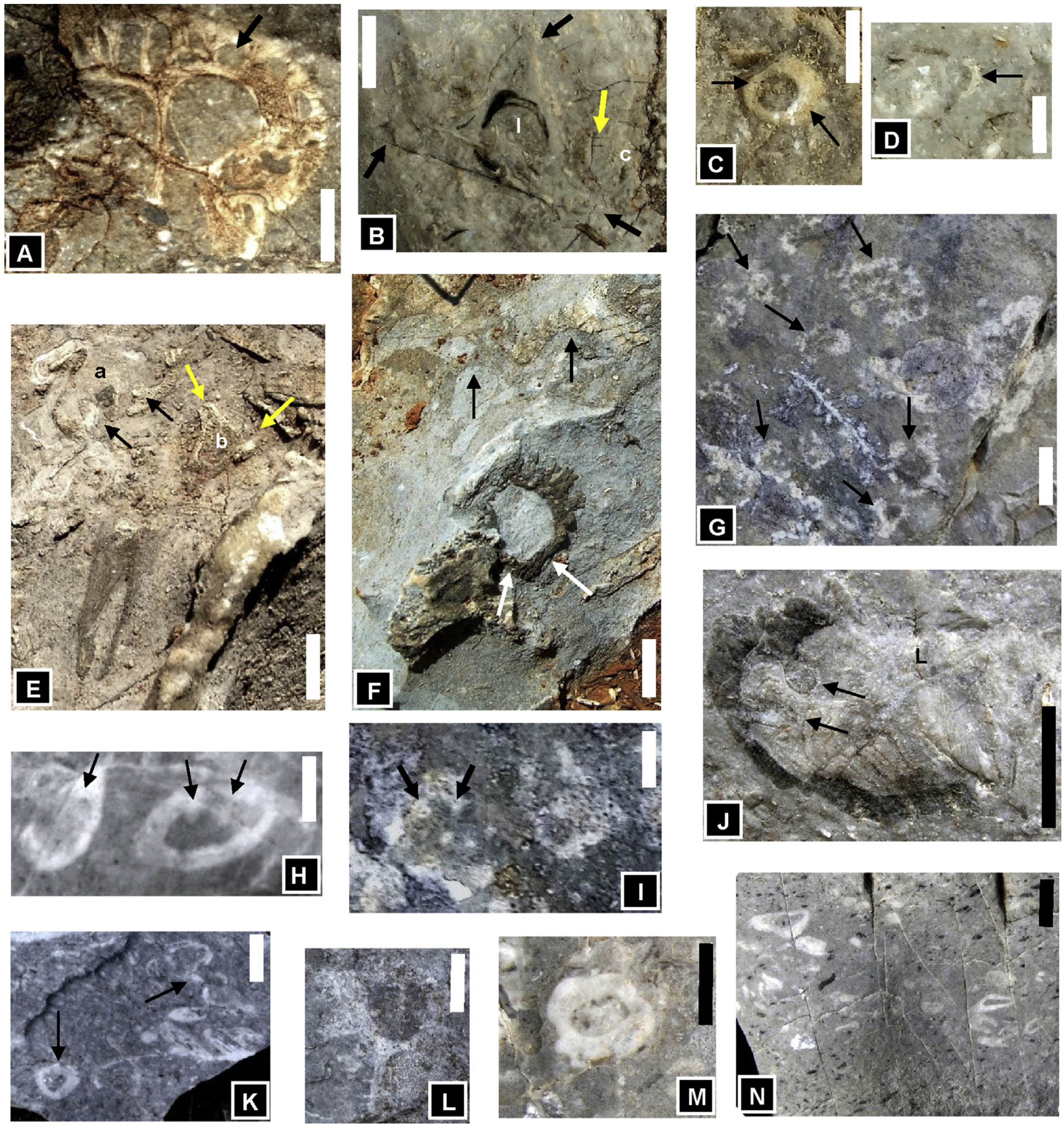


Fig. 7. A–E-rudists of the Çal Dağ section, middle-upper Cenomanian: A-*Caprina* cf. *schiosensis* Boehm, the natural transverse section of the left valve fragment showing the rectangular accessory cavities (arrow), sample no 15-168A, B-the right valve section of *Ichthyosarcolites* cf. *poljaki* Polšak (I). A fragment of canaliculated rudist (c) can be also observed. Note the fusiform canals (yellow arrows) of canaliculated rudist and the ridges (black arrows) of *I. poljaki*, sample no 15-168B, C-*Ichthyosarcolites* cf. *monocarinatus* Sliškovic, the transverse section of the right valve, some rounded canals can be observed (arrows), sample no 15-168D, D-indeterminable small radiolitid fragment, the transverse section of the right valve, may be *Durania* sp. (arrow), sample no 15-168C, E–F-rudists of the İnlice section, 'middle'-upper Maastrichtian, outcrop photographs. E–hippuritid and radiolitid right valve sections. Note the pillars (arrows) of the hippuritid section (a) showing similarity with those of *Hippurites cornucopiae* Defrance. The radial ribbings in the outer shell layer of hippuritid section can partly preserved. (b) *Bournonia* aff. *adriatica* Pejović, note the radial bands (yellow arrows), F-*Sauvagesia* sp., the transverse section of the right valve, the ligamental ridge is very little and the radial bands seem to straight or slightly concave (white arrows) separated by bulge interband. Radiolitid sections (black arrows) are also present in the bioclastic limestone, G–N-rudists of the Başyaşar Tepe section, Santonian-Campanian, sample nos 14-108 A–I, G–K-the transverse sections of the right valves of hippuritids, G-the general view of the limestone showing the ghost of hippuritid transverse sections (arrows), H–I-*Hippurites* aff. *nabresinensis* Futterer, the pillars seem to be more developed than previous figure. The elongation of the pillars in figure I may be due to oblique section, J-*Vaccinites* sp., the first pillar is slightly pinched at the base, but second one is more pinched (black arrows), the L is partly shown by the incurved black lines in the upper right part of the section. K-small transverse sections of hippuritids, may be compare with *Hippuritella* aff. *lapeirousei* (Goldfuss), showing the slightly developed pillars (arrows), L-*Biradiolites* sp. (*Biradiolites* aff. *fissicostatus* d'Orbigny), M-*Durania/Sauvagesia* sp., a transverse section of the right valve, note the thick outer shell layer, N-the transverse sections of the right valves of indeterminate radiolitids, sections of the valve are very small and elongated. Scale bars indicate 10 mm. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Ersoy, 1989; Konak, 2007; Poisson, 1977; Şenel, 1997a,b) suggest that the ages of the Çal Dağ Limestone and overlying Sirna breccia are Berriasian-Cenomanian and Cenomanian respectively. Akdeniz (2011b) and Şenel (1997a,b,c) cautiously attributed Turonian age for the Çal Dağ Limestone. Our data come from an approximately 135 m thick upper part of the Çal Dağ Limestone. The late Turonian rudists and two levels of the Sirna breccia in the succession are first described in this study for the Köyceğiz area.

4.3.3. Bozburun Tepe section

The base of the platform-type carbonates (Babadağ Formation) comprises 40–50-m-thick cherty limestones, which are intercalated with brecciated limestones with some rudist, benthic foraminifera and coral sections (Fig. 3D). These limestones yield planktic foraminifera suggesting a late Campanian-Maastrichtian age (Özer et al., 2016). The top of the section is characterized by a 30–40-m thick, calciturbiditic massive limestones including abundant rudist sections and intercalated thin bedded pelagic limestones. Rudist fauna suggests a 'middle'-late Maastrichtian age (Fig. 9A–J). The planktic foraminifera assemblages within the pelagic limestones confirm the late Maastrichtian age (Özer et al., 2016).

The limestones cropping out in the BozburunTepe and surrounding area were named as the Babadağ Formation by Şenel (1997a). The age of the formation was accepted as Toarcian-Maastrichtian based on the previous studies around Fethiye, Çameli and Elmalı (Şenel, 1991; Şenel et al., 1994). The same author indicated that the uppermost part of the limestone sequence contains abundant rudist fragments. Recently, the origin of the cherts in the calciturbiditic limestones of the Bozburun Tepe was studied by Gül (2015). Our study suggests a 'middle'-late Maastrichtian age, based on the rudist fauna, for the first time for the succession.

4.4. Bodrum area

The carbonate succession of the Bodrum area is characterized from bottom to top, by thick Jurassic-Cretaceous cherty limestones (Çal Dağ Limestone), chert breccias (Sirna breccia) and turbidites (Karabörtlen Formation) (Bernoulli et al., 1974; Çakmakoğlu, 1985; Ercan et al., 1982, 1984; de Graciansky, 1972; Phillippson, 1910–1915). Rudist occurrences of the area have been reported in a few studies so far (Özer et al., 2014; Masse et al., 2015). Konacık and Antenler and Bitez stratigraphic sections (Fig. 1B) in this area belonging to the Bodrum nappe (Şenel, 1997a,b,c) are summarized below:

4.4.1. Konacık and Antenler sections

Cretaceous carbonate successions show similar characteristics in two sections and consist mainly of thick-bedded, folded cherty limestones (Figs. 1B, 4A). Bioclastic limestones include rudist shell fragments (Fig. 10A–B) and are alternated with cherty limestones at the uppermost part of the carbonate sequence in these sections. Although, some radiolitid and hippuritid fragments are observed in two localities, descriptions of these rudist fragments were impossible due to recrystallization caused by low grade metamorphism. The rudist fragments-bearing bioclastic limestones contain reworked (probably contemporaneous current reworking) benthic and planktic foraminifera such as *Orbitolina* sp., *Orbitoides* sp. and *Rugoglobigerina* sp. and also algae and bryozoa.

The top of the section characterized by alternation of cherty limestones with some planktic foraminifera (*Globotruncana* sp.) and Sirna breccia is overlain by turbidites (Karabörtlen Formation), which comprise mudstone-siltstone-sandstone alternations at the base and various type small and megablocks at the upper part. The planktic foraminifera in the matrix of the Karabörtlen Formation indicate a late Campanian age (Özer et al., 2016).

A latest Cenomanian age was attributed to the cherty limestones and Sirna breccia in the Bodrum area based on stratigraphic data from the Köyceğiz area (Bernoulli et al., 1974; Çakmakoğlu, 1985; Ercan et al., 1982, 1984; de Graciansky, 1972; Moix et al., 2013; Rimmelé et al., 2003, 2004, 2006). However, the microfossils (especially the Orbitoididae) and may be the biradiolitid section show a latest Cretaceous age for the cherty limestones. The presence of the late Campanian planktic foraminifera in the matrix of the Karabörtlen Formation supports this interpretation for the Bodrum area.

4.4.2. Bitez section

The Karabörtlen Formation have megablocks of limestones as explained above in the Bodrum area. One of the limestone megablocks recently labelled as "Bitez block" by Masse et al. (2015) shows different lithological characteristics when compared with the classical Cretaceous limestone sequences of the Lycian Nappes. This block is characterized by absence of the cherty limestones, and presence of abundant rudist and coral sections (Figs. 4B, 10D–G). The lithologic characteristics and micro- and macrofossil content (i.e. benthic foraminifera, calcareous algae, calpionellids, chondrodontids and rudists) are recently presented by Masse et al. (2015). The rudist fauna, consisting of epidiceratids and requieniids, suggests a late Tithonian-Berriasian age (Fig. 10D–F). The micropalaeontological data indicate a Berriasian age for the rudist-bearing limestones of the Bitez block (Masse et al., 2015).

The Lower Cretaceous limestones are widely reported from the Lycian Nappes (Akdeniz, 2011a, b; Bernoulli et al., 1974; Ersoy, 1989, 1993b; de Graciansky, 1972; de Graciansky et al., 1967; Konak, 2007; Poisson, 1977; Şenel, 1997a,b,c), but, there is no information on the presence of rudists in these studies. Although palaeogeographic origin of the "Bitez block" is unclear, the first report of Berriasian rudists in Turkey presents important palaeobiogeographic data regarding their geographic distribution towards the eastern part of the Mediterranean Tethys (Masse et al., 2015).

4.5. Ören area

The low grade metamorphic rocks outcropping around the Ören area were named as Ören Unit by Konak et al. (1987) and included to the Bodrum nappe by Konak and Çakmakoğlu (2007). The platform-type carbonates (Ula Marbles) consist of thick-bedded dolomitic limestones/marbles, thin to medium bedded cherty limestones/marbles with calcite forming rosetta structures and chert breccias (Sirna breccia). The Karabörtlen Formation overlies these carbonate succession (Çakmakoğlu, 1985; Rimmelé et al., 2004; Konak and Çakmakoğlu, 2007; Özer et al., 2016). Although these rocks show a wide distribution in the Ören area, around Aşağı-Yukarı Mazıköy, Gökbel and between Çamlıköy and Kıyıkışlacık, no palaeontologic data (both rudist and microfossil) have been presented by previous studies so far. Nine stratigraphic sections were measured in this area. Two of them will be presented below as only the two includes information on rudists. The Gökbel section belongs to the Bodrum nappe and the Kıyıkışlacık section belongs to the Tavas nappe (Fig. 1B).

4.5.1. Gökbel section

Cherty limestones of the Ula Marbles are thicker than 100 m and are folded in this locality. Bioclastic limestones consisting mainly of rudist fragments are observed in the uppermost part of the sequence (Fig. 4C). Description of rudists is impossible due to the intense fragmentation. However, some transverse sections of radiolitids and many right valve fragments showing cellular structure of the radiolitids and dark-grey calcitic outer shell layer of hippuritids can be recognized in the bioclastic limestone horizons (Fig. 10C). The top of the section is characterized by a 10–15-m-thick alternation of cherty limestones and brecciated limestones (Sirna breccia). The Karabörtlen Formation comprising sandstones, siltstones and mudstones with limestone blocks and olistostromal levels rests over the Ula Marbles. Some late Maastrichtian nannofossils were described from the Karabörtlen Formation (Özer et al., 2016).

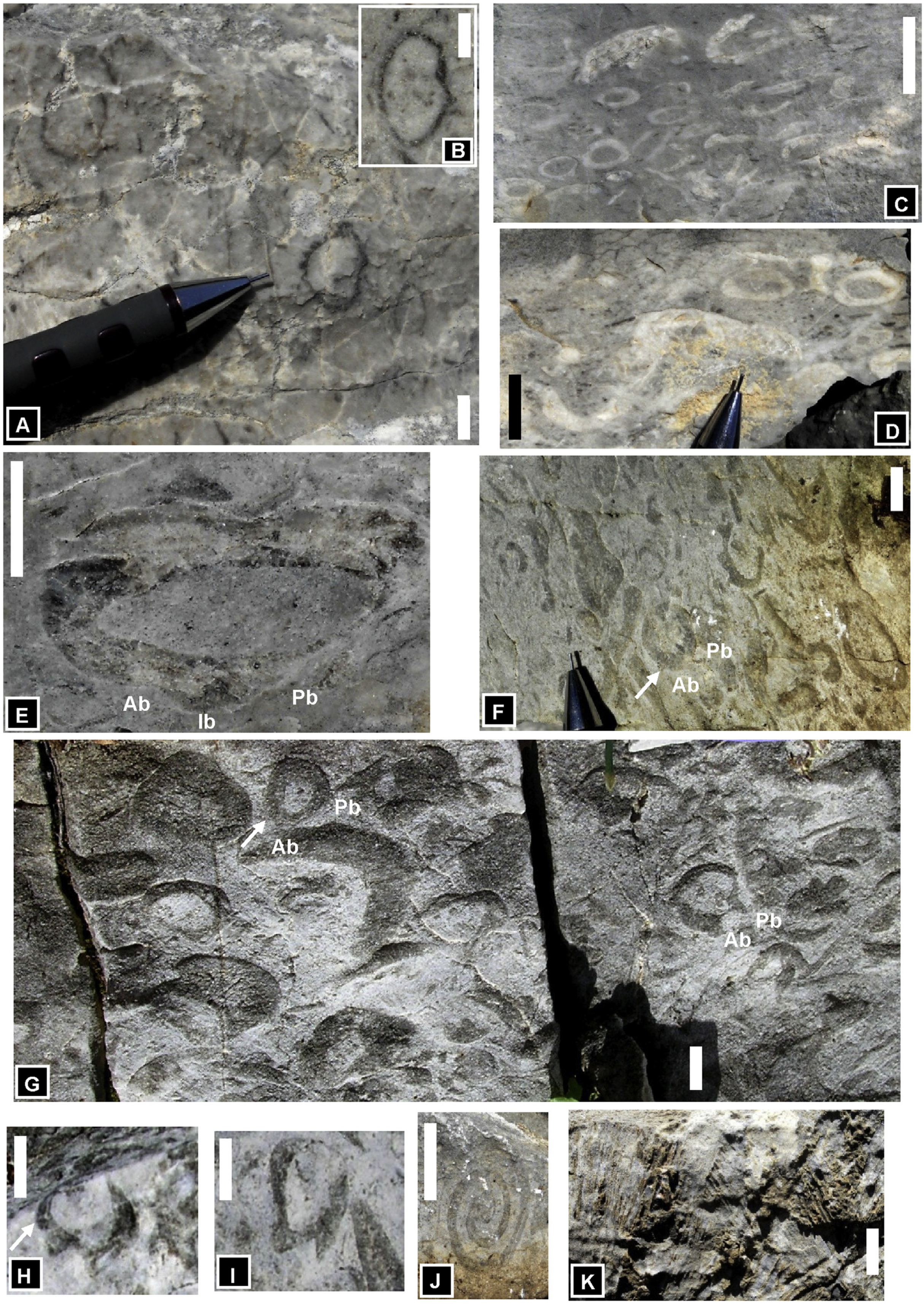


Fig. 8. A–I-rudists of the Akdikmen Tepe section, middle-upper Turonian, the transverse sections of the right valve, A–B-*Distefanella salmojraghii* Parona, A-outcrop photograph of the *Distefanella*-bearing recrystallised limestones, B-sample no 15-57, C–D-*Durania* sp. (*D.* aff. *arnaudi* (Choffat)), many small right valve transverse sections, sample nos 15-58 B and 15-59 A, E-*Durania arnaudi* (Choffat), the transverse section of the right valve showing fine ribbing on the intended radial bands, the L is absent. It is a large form than previous

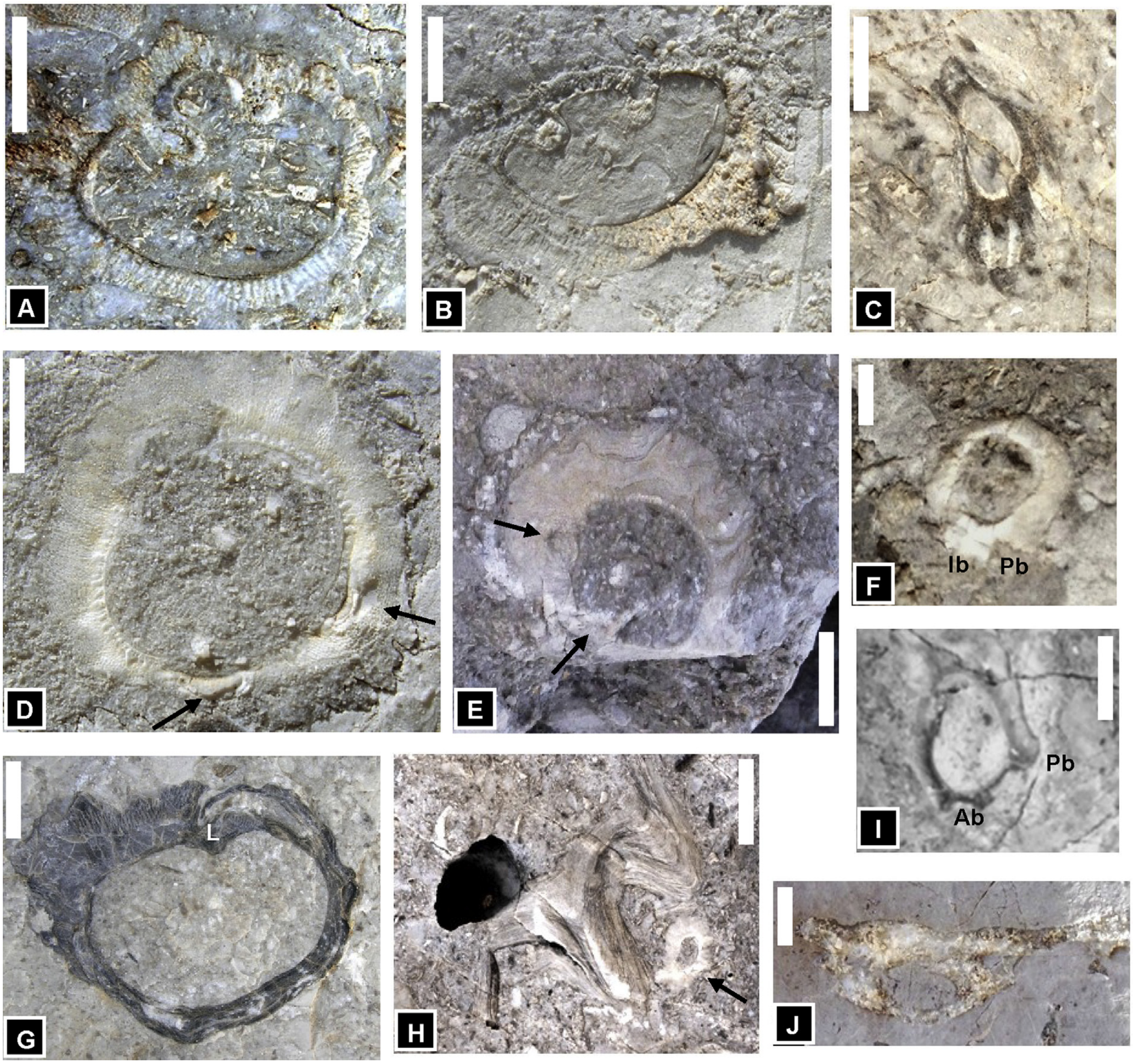


Fig. 9. A–J-rudists of the Bozburun Tepe section, 'middle'-upper Maastrichtian, outcrop photographs, A–B-*Hippurites cornucopiae* Defrance, the transverse sections of the right valve, the first pillar is open at the base, but the second one is slightly pinched, note the radial ribbings in the outer shell layer, C-*Biradiolites* sp., the transverse section of the right valve, D–E-*Lapeirousia* sp., the transverse sections of the right valves, note the pseudopillars (arrows) and the preserved cellular structure of the outer shell layer, F-*Durania* sp., the transverse section of the right valve, the Pb and Ib are well-observed, but Ab seems to be obscured in the left side, G-*Prareradiolites* sp., the transverse section of the right valve, the ligamental ridge (L) is open at the base and slowly developed, note the partially preserved cellular structure of the outer shell layer, H-a fragment of a radiolitid with well-developed ribs reminiscent those of *Biradiolites* sp. (*Biradiolites* aff. *chaperi* Toucas) and small right valve transverse section of *Durania* sp. (arrow), I-*Bournonia* aff. *fascicularis* (Pirona), the transverse section of the right valve, J-*Bournonia*/*Biradiolites* sp., the transverse section of the right valve showing two radial ribs, the posterior one is more developed than the other, Scale bars are equal to 10 mm.

Stratigraphic characteristics of the uppermost part of the carbonate succession of the Ula Marbles show clear similarity with those of Konacık-Antenler sections in the Bodrum area (Figs. 1B, 4A). Although, it was not possible to obtain detailed faunal composition of the rudists in these sections, documenting of distribution of the bioclastic limestones with rudist fragments could be important if they are a meaningful level at the uppermost part of the carbonate successions between the Bodrum and Ören areas.

4.5.2. Kıyıkışlacık section

The Ula Marbles, consisting mainly of grey, thick-bedded dolomitic and cherty marbles, have widespread distribution to the northwest of Ören village, around Akbük, Bozbük, Gürçamlar and Kıyıkışlacık villages and tectonically overlie the metamorphic rocks of the Menderes Massif (Brinkmann, 1967; Dürr, 1975; Arslan et al., 2013; Özer et al., 2016). The Kıyıkışlacık stratigraphic section consists, from bottom to top, of thick-bedded dolomitic marbles,

figures, sample no 15-60A, F–I-*Bournonia africana* Douvillé, many small right valve transverse sections show broadly truncated anterior radial band (Ab) and narrower or slightly depressed posterior radial band (Pb). The length of the radial bands is approximately equal. The valve is generally smooth, but one small rib (white arrows) can be observed in the anterior part of the valve in some sections. The outer shell layer seems to be compact. Note the variability of the radial bands in the same association G, sample nos 15-58 C, 15-59 B, C, 15-60 B, J-gastropod section (?acteonellid), outcrop photograph, Akdikmen Tepe section, K-branching coral-bearing recrystallized limestones, outcrop photograph, Akdikmen Tepe section, Scale bars are equal to 10 mm.

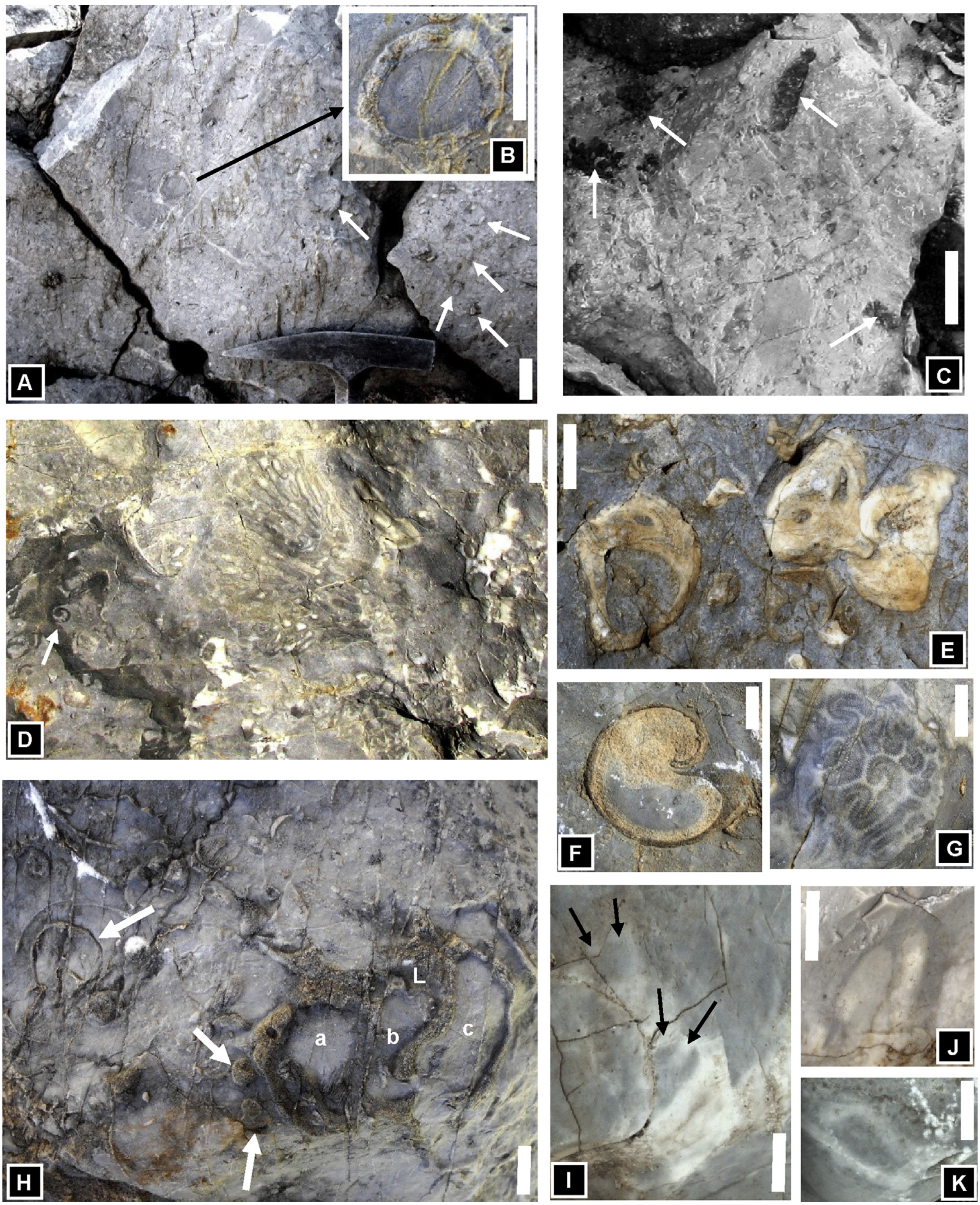


Fig. 10. Rudists of the Bodrum and Bozburun peninsulas and Ören area: outcrop photographs. A–B-Bodrum Peninsula, uppermost Cretaceous, Antenler locality. A-the general view of the bioclastic limestones with rudist fragments and sections (white arrows). Black arrow shows enlarged rudist section in the next figure. B-radiolitid indet (?*Biradiolites* sp.), C-the bioclastic limestones characterized mainly by small and large (arrows) rudist fragments, uppermost Cretaceous, Ören area, Gökbel locality, D–G-Bodrum Peninsula, Bitez locality, Berriasian, D-the facies characteristics of the Bitez limestone block showing the gastropod sections (white arrow), branching coral colony (in the middle of the photo) and rudist sections, E–F-a longitudinal bivalve section of *Heterodiceras luci* (Defrance) and the left valve section of *Hypelasma salevensis* (Joukowsky and Favre), respectively, G-coral, H-limestone showing requieniid rudist sections (white arrows) and radiolitid sections (a–c) with very little ligamental ridge (L), pre Turonian (?Albian-?Cenomanian), Bozburun Peninsula, Selimiye locality, I–K-some badly preserved rudist sections due to metamorphism in the marbles, Ören area, Kıyıkışlacık section, uppermost part of the Upper Cretaceous, I-hippuritid right valve transverse sections showing the pillars (arrows), J–K-radiolitid indet (?*Durania* sp.) Scale bar indicates 10 mm.

approximately 300-m-thick, usually folded, thin to medium bedded cherty marbles and 50-m-thick, massive marbles without cherts (Fig. 4D). This levels include some 'ghost' rudist sections (Fig. 10I–K). These rudist sections show similarities with those of described from the marbles of southern and northern sectors of the Menderes Massif by Özer (1993, 1998) and Özer et al. (2001). Alternations of sandstones, mudstones and siltstones with rare recrystallized limestone blocks of the Karabörtlen Formation overlies the carbonate succession along a questionable contact.

Previous studies suggest that the Lycian Nappes consist mainly of dolomitic marbles and cherty marbles without fossils between Çamlıköy and Kıyıkışlacık (Brinkmann, 1967; Dürr, 1975; Arslan et al., 2013). The rudist sections from the Kıyıkışlacık section are the first palaeontologic data from this area.

4.6. *Bozburun area*

A few geological studies in the Bozburun Peninsula record the presence of the Upper Triassic-Cretaceous platform-type carbonates and Upper Cretaceous-Palaeocene blocky flysch (i.e. Ersoy, 1993b; Şenel and Bilgin, 1997). The age of these units was based on limited palaeontologic data. Five stratigraphical sections were measured from the Bozburun Peninsula. One of them is presented below as the platform-type carbonates include rudist bivalves.

4.6.1. *Selimiye section*

This section is located to the northeast of the Bozburun town (Fig. 1B), where platform-type carbonates are widely exposed. Rudist, gastropod and coral sections are observed within the uppermost part of the grey, 10-m-thick massive platform-type carbonates (Fig. 4E). Rudist sections observed belong to Requieniidae and Radiolitidae (Fig. 10H). Some orbitolinids and indeterminable benthic foraminifera are observed in these limestones. Pinkish pelagic infillings (i.e. neptunian dykes) within the upper part of the rudist-bearing limestones yield a planktic foraminifera assemblages of early Turonian age (Özer et al., 2016). A 9-m-thick pinkish-reddish cherty limestones with planktic foraminifera, suggesting a Santonian age, rest over the rudist-bearing limestones. Siltstones and mudstones overlie the pinkish-reddish cherty limestones and yield some early Danian nannofossils (Özer et al., 2016).

A few studies carried out in the platform-type carbonates of the Bozburun area did not yield any information on the rudists (Ersoy, 1993b; Şenel and Bilgin, 1997). The current study presents information on the rudist for the first time within the uppermost part of the carbonate succession, which has widespread geographic distribution in the Bozburun Peninsula. The facies characteristics of the rudist-bearing limestones may be comparable with the Albian (Lower Cretaceous) limestones with *Eoradiolites* in the Mediterranean Tethys (Masse et al., 1998, 2010). Further detailed palaeontological data are required for precise determination of the Lower Cretaceous stages and correlations. The pinkish infillings of the neptunian dykes of early Turonian age indicate that the rudist-bearing platform limestones in the Bozburun area are older than the Turonian (?Cenomanian or older). Lower Cretaceous calcarenites and calcirudites with *Orbitolina* were reported by Orombelli et al. (1967) from the Datça Peninsula. So, the limestones with orbitolinid foraminifera of the Selimiye section may be compared with that of Orombelli et al. (1967). The Cretaceous sequences in the Lycian Nappes are mainly characterized by cherty limestones. As the rudist-bearing limestones of the Selimiye section do not contain cherts, they could be compared with the Berriasian Bitez block of the Bodrum area.

5. Rudist associations

The previous studies suggest that the Cretaceous sequences consist mainly of the platform-type cherty limestones without siliciclastic input in the Lycian Nappes. Limited studies suggest only rudist fragments from the Upper Cretaceous carbonate successions (Akdeniz, 2011a, b; de Graciansky et al., 1967; Şenel, 1997a,b,c). However, this study reveals the presence of the rudist associations in the recrystallized limestones and/or bioclastic limestones of the Tavas and the Bodrum nappes as explained below:

5.1. *Lower Cretaceous*

The Lower Cretaceous successions with rudists are very sparse in the Lycian Nappes. Rudists were recently described by Masse et al. (2015) from the Bitez limestone block in the Bodrum area. A Berriasian age was obtained based on the benthic foraminifera, calcareous green algae, problematica, rudists and *Chondrodonta* sp. in Bitez section (Fig. 4B). The epidiceratid-requieniid assemblage of the Bitez limestone block has a low density and consists of *Heterodiceras luci* (Defrance), *Heterodiceras* sp.1, *Heterodiceras*? sp. and *Hypelasma salevensis* (Joukowsky and Favre). This rudist assemblage, associated with corals and non rudist bivalves (Fig. 10D–G), shows similarity with the Berriasian successions of France (Masse et al., 2015). The rudist-bearing Bitez limestone block shows different characteristics concerning both lithology and age when compared with the Lower Cretaceous of the Lycian Nappes. There has been no information on the Berriasian neritic fauna (rudists, corals, benthic foraminifera etc.) from the Lower Cretaceous limestones (without chert) in the Lycian Nappes so far. So, the origin of the Bitez limestone block is enigmatic at the moment.

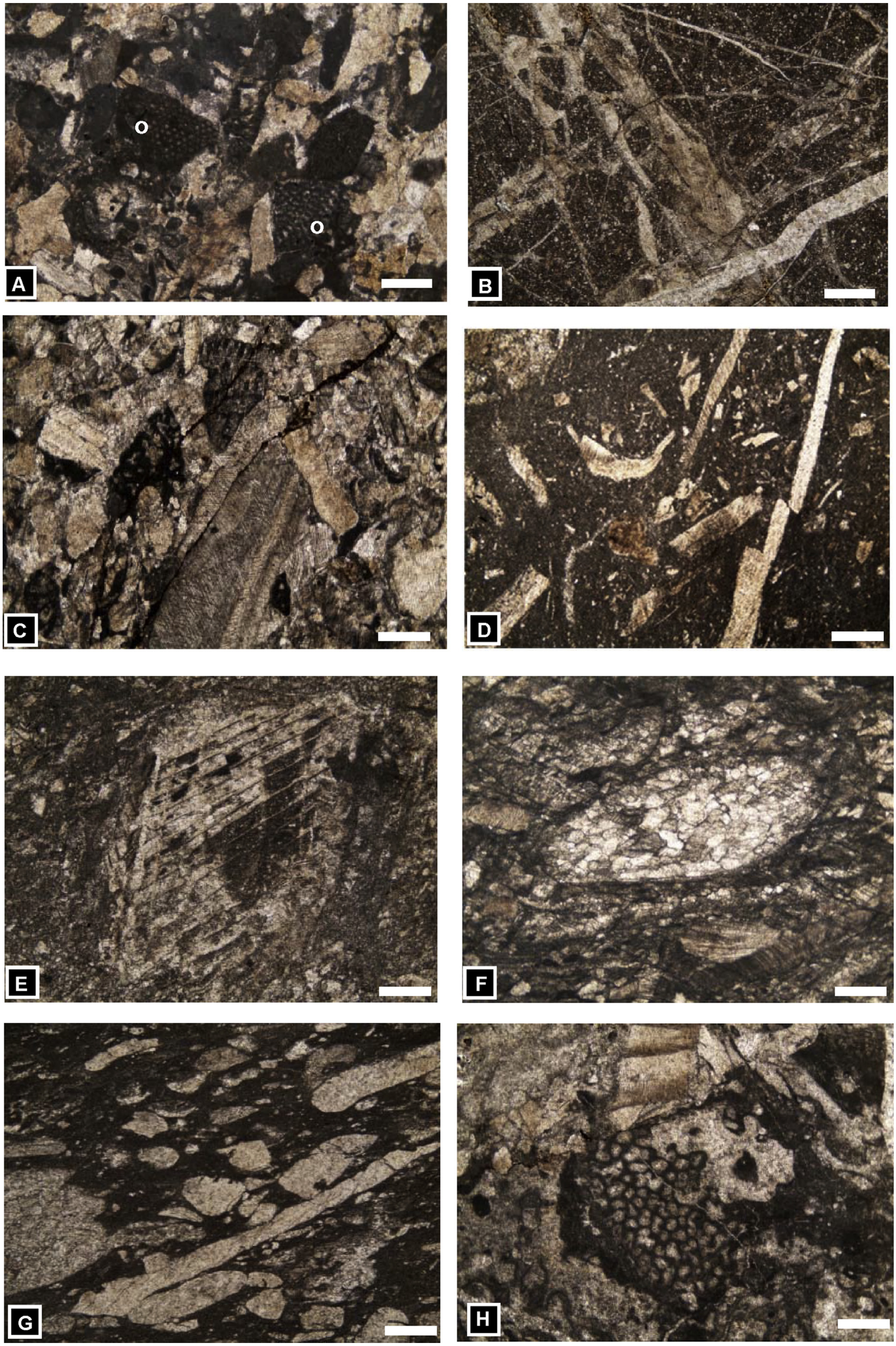
Rudist-bearing platform-type limestones with requieniids and radiolitids are found in the Bozburun area (Fig. 4E: Selimiye section). The radiolitid-requieniid association is represented by low density (Fig. 10H). The age of this association is clearly older than Turonian (?Cenomanian or older). Although the facies characteristics of these limestones show similarity with the Albian (Lower Cretaceous) limestones of the Mediterranean Tethys, new precise palaeontological data are required for the area for finer evaluations.

Although, the origin of the Bitez block is unclear at the moment and the palaeontological data from the Selimiye section are not enough to compare this succession with the rest of the Lycian Nappes, these preliminary data could be later useful for uncover the Lower Cretaceous stratigraphy of the Lycian Nappes when combined with the forthcoming data.

5.2. *Upper Cretaceous*

The Upper Cretaceous sequences with rudist have wider distribution in the Lycian Nappes than the Lower Cretaceous. Four main rudist assemblages were distinguished within the Upper Cretaceous sequences of the Lycian Nappes:

a) the middle-late Cenomanian caprinid-ichthyosarcolitid assemblage is observed in the Tavas and Fethiye areas, which belong to the Tavas and Bodrum nappes, respectively.
b) the late Turonian distefanellid assemblage is determined from the Tavas area in the Tavas nappe and the Köyceğiz area in the Bodrum nappe.
c) the late Coniacian-Santonian-Campanian hippuritid-radiolitid assemblage is widely represented in the Bodrum nappe.
d) the 'middle'-late Maastrichtian radiolitid-hippuritid assemblage is observed in the Köyceğiz and Fethiye areas in the Tavas nappe.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Details of the four assemblages are given below from old to young:

5.2.1. Caprinid-ichthyosarcolitid assemblage

This assemblage is observed in the Sarpdere and Çal Dağ sections. The assemblage is characteristically represented by abundant canaliculated rudists (caprinids and ichthyosarcolitids) in the Sarpdere section. The rudist sections appear mostly as ghost due to the slight metamorphism. Despite the metamorphism, the rudist sections could be described thanks to the protected canal structures. The assemblage comprises *Neocaprina gigantea* Pleničar, *Caprina schiosensis* Boehm, *Schiosia* cf. *schiosensis* Boehm, *Sphaerucaprina* cf. *woodwardi* Gemmellaro, *Ichthyosarcolites bicarinatus* (Gemmellaro), *I. triangularis* Desmarest, *I. monocarinatus* Slišković (synonymous with *Ichthyosarcolites rotundus* Polšak, see Cestari et al., 1998), *I. poljaki* Polšak, *Eoradiolites* sp., *Durania* sp., and requieniids (*Apricardia* sp.) and is presented so far by Özer (1998) and Özer et al. (2001). *Chondrodonta* sp. is associated to this fauna. The right valve transverse sections of *N. gigantea* is remarkably similar to that of the species determined by Pleničar and Jurkovšek (2000, pl. 4, fig. 2) (Fig. 5A, B). *I. poljaki* presents the well-developed ridges and small round or oval canals in the transverse section of the right valve (Fig. 5C). The additional sections are obtained from the new field observations: *Caprinula* aff. *boisyyi* d'Orbigny and *Durania* sp (Fig. 5E, D). The oblique section of the first species presents a single row of large canals on the inner side following one or three small, round and piriform pallial canals may be compared with those of *C. boissyi* described by Douvillé (1888, pl. 22). This species is first found in Turkey. The second one have a thick outer shell layer with partially preserved polygonal prisms.

The Çal Dağ section shows a poor rudist fauna than Sarpdere section, but some canaliculated rudists like *Caprina* cf. *schiosensis* Boehm, *Caprina* sp., *Ichthyosarcolites* cf. *poljaki* Polšak and *Ichthyosarcolites* cf. *monocarinatus* Sliškovic and radiolitid can be identified (Fig. 7A–D).

This assemblage is well known from the middle-upper Cenomanian of the northern (especially central and eastern) and also from the southern sides of the Mediterranean Tethys (Steuber, 2002). In Turkey, the similar assemblage is well documented from the middle-upper Cenomanian of the Bey Dağları Carbonate Platform by Özer (1988), Sarı (2006b) and Sarı and Özer (2009).

5.2.2. Distefanellid assemblage

This assemblage is observed in the Sarpdere and Akdikmen Tepe sections. It is mainly characterized by the abundance of *Distefanella salmojraghii* Parona in the Sarpdere section. The right valve transverse sections of this species show close similarities with *D. bassanii* Parona. Özer (1998) and Özer et al. (2001) identified these type of sections as *D. bassanii* and Özer (1999) also described a new species *Distefanella tavassiana* showing concave radial bands (Fig. 5H) as well. However, Cestari (2008) showed that all the sections described as *D. bassanii* Parona and the new species indicated above are synonymous with *Distefanella salmojraghii* Parona, which is accepted in this study. *D. montagnei* Slišković is rare (Fig. 5H). Moreover, some hippuritids and radiolitids are newly found in the Sarpdere section: *Hippurites* cf. *socialis* Douvillé, *Vaccinites* cf. *praegiganteus* (Toucas), *V.* cf. *rousseli* Douvillé, *Durania* cf. *gaensis* Dacqué, *Durania* sp. (*Durania* aff. *laevis* Douvillé) and *Sauvagesia*/*Durania* sp (Fig. 5F–N).

The shape of the siphonal pillars of *Hippurites* cf. *socialis* Douvillé may be compared with the specimens of Douvillé (1893), Toucas (1903) and Sarı and Özer (2009). The ligamental ridge and the siphonal pillars of *Vaccinites* cf. *praegiganteus* (Toucas) present typical characters of the species of Chikhi-Aouimeur (2010), Sarı and Özer (2009), Sarı et al. (2004), Simonpiètri (1999), Steuber (1999) and Toucas (1904). The shape of the ligamental ridge of *Vaccinites* cf. *rousseli* Douvillé shows similarities with that of determined by Chikhi-Aouimeur (2010), Douvilé (1894, 1897), Özer and Ahmad (2015) and Simonpiétri (1999). It can also be comparable with *Hippuritella libanus* Douvillé, however the latter seems to be synonymous with *V. rousseli* (see Chikhi-Aouimeur, 2010; Özer and Fayez, 2015). The wide and depressed ventral radial band of *Durania* cf. *gaensis* Dacqué shows typical character of the species of Abdelgawad et al. (2011), Douvilé (1910) and Polšak (1967). The shape of the transverse section of the right valve and the radial bands of *Durania* sp. (*Durania* aff. *laevis* Douvillé) show some similarities with specimen of Douvilé (1910).

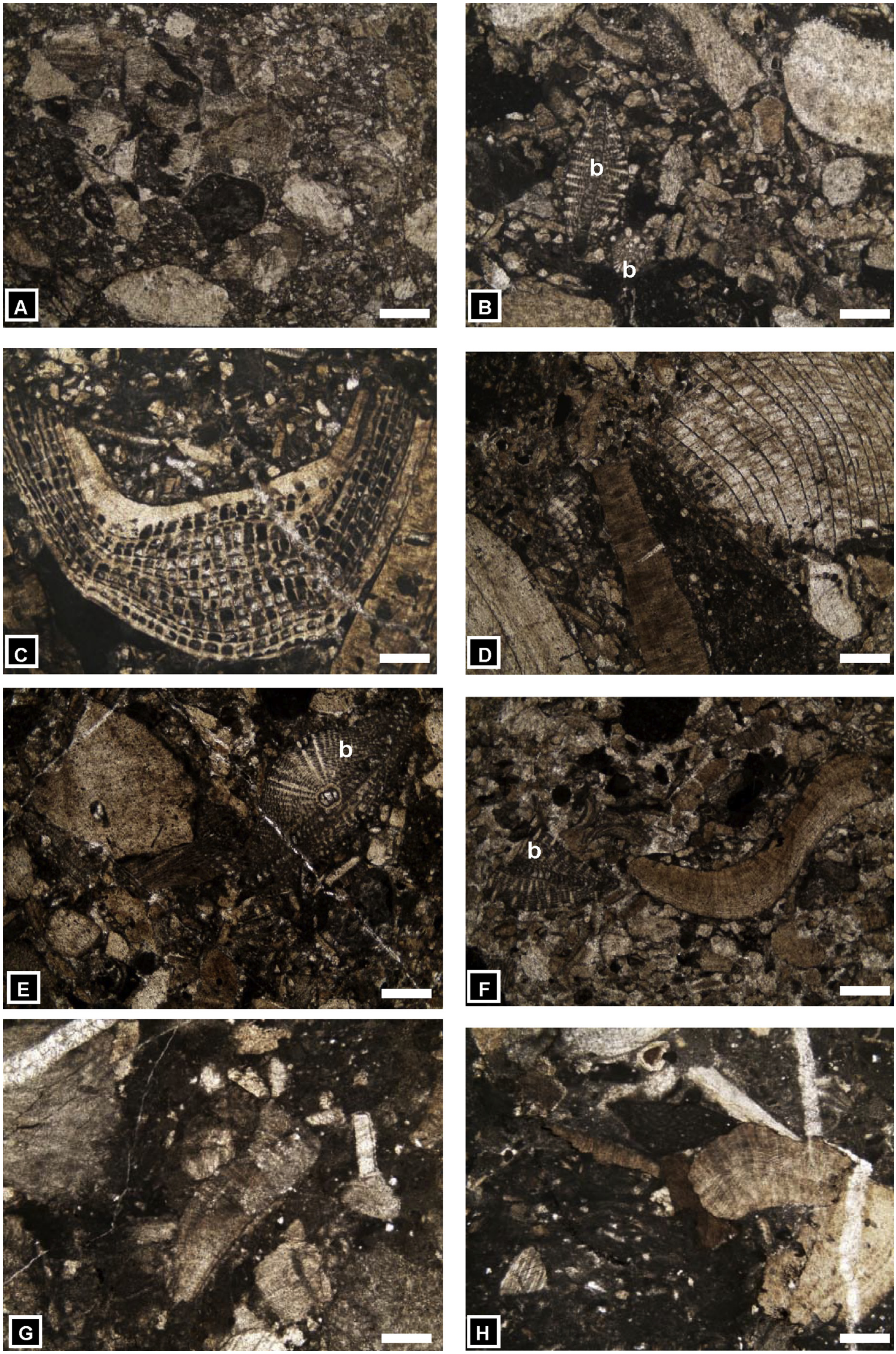
Many sections of *Distefanella salmojraghii* Parona and small forms of *Bournonia africana* Douvillé, *Durania arnaudi* (Choffat) and *Durania* sp. are observed in the Akdikmen Tepe section. The developed radial bands of *Bournonia africana* Douvillé can be compared with those of *Bournonia excavata* d'Orbigny, however the anterior radial band of the latter species is always more developed than the other (Cestari and Sirna, 1989; Cestari, 2008; Pons and Vicens, 2008; Santiago, 2014). The radial bands of *Bournonia africana* Douvillé show variability in same association (Fig. 8F–G). This variability and also the oval or round shape of the inner shell margin may be compared with specimens from Gafsa region (Tunisia) and Dionysos (Greece) described by Chikhi-Aouimeur et al. (2006) and Steuber (1999), respectively.

This association indicates a late Turonian age, well-known and shows a wide distribution within the upper Turonian formations of the Mediterranean Tethys (Steuber, 2002).

5.2.3. Hippuritid-radiolitid assemblage

This assemblage has wider distributions than the others through the Lycian Nappes. Despite wider distribution, it can be described from the right valve sections within the bioclastic limestones of the Balkıca, Hisarköy, Başyaşar Tepe and Kıyıkışlacık sections. Some hippuritid and radiolitid species were described as *Hippurites* cf. *nabresinensis* Futterer, *Hippuritella* aff. *lapeirousei* (Goldfuss), *Vaccinites* sp., *Hippurites* sp. and *Bournonia* sp. (*Bournonia* aff. *wiontzeki* Pejović), *Bournonia* sp. (*Bournonia* aff. *hvarensis* Pejović), *Biradiolites* sp. (*Biradiolites* aff. *fissicostatus* d'Orbigny), ?*Biradiolites* sp., *Sauvagesia* sp. and *Durania* sp (Figs. 6C–K, 7G–N, 10I–K). The taxa show a wide stratigraphic distribution within the upper Coniacian-Santonian-Campanian successions in the Mediterranean Tethys (Steuber, 2002). *Hippurites nabresinensis* is reported from the upper Coniacian-middle Santonian, uppermost Santonian-lower Campanian and middle Campanian, and *Hippuritella lapeirousei* from the upper Campanian-lowermost Maastrichtian rudist biozones in the

Fig. 11. A-packstone/grainstone with abundant rudist and bivalve debris and benthic foraminifers (o:orbitolinid foraminifera), Selimiye section, sample no. 14-426, B-wackestone/packstone with radiolarians, calcispheres and canaliculated rudist debris, Çal Dağ section, sample no. 15-167, C-grainstone/rudstone consists mainly of rudist debris showing intense fragmentation, Kızılca section, sample no. 15-176, D–E-packstone with rudist debris, Sarpdere section, sample no. 14-151 B and A. Note compaction of the shell and sparry (equant) calcite cement and fine-grained carbonate sediments entirely or partially filled the cellular outer shell layer of the radiolitid. The breaking up of the cell walls are also observed suggesting the mechanical compaction in E. The microfossils are masked due to the recrystallization, F-grainstone/packstone showing oval section of *Distefanella* (in the center) and rudist debris, Akdikmen Tepe section, sample no. 15-57. Note the collapse of the internal part of *Distefanella* valve section filled totally with calcite. The recrystallization affected the outer shell layer of the valve and masked the microfossils as well, G-packstone/floatstone showing orientation of rudist debris, Balkıca section, sample no. 14-209, H-grainstone/packstone with rudist, coral and algae debris, Hisarköy section, sample no. 15-118. Scale bars are equal to 1 mm. See figures 2–4 for the stratigraphic positions of the thin sections.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central-eastern Mediterranean provinces by Steuber and Schlüter (2012). Radiolitids are described from the Coniacian-Santonian, Santonian-Maastrichtian and Campanian-Maastrichtian of the northern side of the Mediterranean Tethys (Steuber, 2002). Therefore, a late Coniacian-Santonian-Campanian age could be attributed to this assemblage.

5.2.4. Radiolitid-Hippuritid assemblage

This assemblage shows very limited distribution in the Lycian Nappes, it is only observed from the Bozburun and İnlice sections. The Bozburun section comprises well preserved and rich rudist fauna than the İnlice section. This assemblage is characterized by the abundance of radiolitids such as *Bournonia* aff. *adriatica* Pejović, *Bournonia* aff. *fascicularis* (Pirona), *Bournonia* sp., *Biradiolites* sp. (*Biradiolites* aff. *chaperi* Toucas, pro *Rajka spinosa* Milovanović and Grubič according to Pons and Vicens, 1986), *Lapeirousia* sp., *Durania* sp., *Praeradiolites* sp. and *Sauvagesia* sp. Hippuritids are represented by only a single species: *Hippurites cornucopiae* Defrance, which is abundantly observed through the Bozburun stratigraphic section (Figs. 7E–F, 9). *Hippurites cornucopiae* is well-known from the 'middle'-upper Maastrichtian deposits in the northern and southern sides of the Mediterranean Tethys (Steuber, 2002). *Hippurites cornucopiae* Interval Zone is determined in the central-eastern Mediterranean provinces and Arabian Plate chronostratigraphically indicating a 'middle'-late Maastrichtian age (Steuber and Schlüter, 2012). *Bournonia adriatica* is well-known from the 'middle'-late Maastrichtian of the central Mediterranean Tethys (Steuber, 2002). *Biradiolites chaperi* shows a wide distribution in the upper Campanian-Maastrichtian and also 'middle'-upper Maastrichtian formations of the Mediterranean Tethys (Steuber, 2002). This association suggests a 'middle'-late Maastrichtian age.

6. Depositional setting and correlation

Obtained lithologic, biotic and microfacies data emphasize distinct depositional settings, where the rudists were flourished, fragmented or reworked through the Cretaceous time in the Lycian platform(s) (Figs. 11–13).

The rudists of the Lower Cretaceous successions are still less known than those of the Upper Cretaceous as explained above. We found Berriasian rudists (essentially epidiceratids and requieniids) together with corals, benthic foraminifera, calcareous algae and calpionellids only in the Bitez massive limestone block of the Bodrum Peninsula (Fig. 10D–G), indicating a shallow water settings in the distal, marginal parts of the carbonate platform (Masse et al., 2015; Özer et al., 2014, 2016). These limestones have been recently determined as "Stramberk type limestones" by Masse et al. (2015). In the Bozburun Peninsula, Selimiye stratigraphic section show some requieniid and radiolitid sections and associated corals, gastropods and benthic foraminifera (orbitolinids) within the limestones suggest a very shallow marine conditions. Corals are generally thrived in outer platform conditions (Fenerci-Masse, 2006; Moro et al., 2016; Scott, 1988, 1995). Depositional texture of the limestones is packstone/grainstone with abundant bivalvia debris and orbitolinid foraminifera. Intense fragmentation and micritization are observed (Fig. 11A).

The Upper Cretaceous rudist-bearing limestones present much more data than the Lower Cretaceous concerning depositional characteristics.

The middle-late Cenomanian canaliculated rudist-bearing limestones of the Sarpdere section should have been deposited mostly in a restricted, low-energy, inner platform conditions due to the features of the limestones (dark grey, bituminous) and also low diversity of rudist fauna. There are no other macrofossils accompanying rudists. Autochthonous rudist aggregations and small isolated rudist patches are observed. Besides, accumulations of broken debris of rudists, indicative of an agitated environment caused by constant or ephemeral wave action, are also present. The rudist-bearing limestones are recrystallized and depositional textures are always masked by recrystallization, and so, it is impossible to determine their microfacies characteristics and depositional texture. We have to rely on macroscopic features of rudists to infer depositional environment. High-energy platform margin environment has been proposed for many canaliculate rudist-bearing Cenomanian carbonate platform successions in the northern side (especially center and eastern regions) (Carbone et al., 1971; Philip and Mermigis, 1989; Sartorio et al., 1992; Carbone, 1993; Cestari and Sartorio, 1995; Laviano et al., 1998b; Stefano and Ruberti, 2000; Stössel and Bernoulli, 2000; Korbar et al., 2001; Sarı and Özer, 2009; Cestari and Laviano, 2012), in the southern side (Chikhi-Aouimeur et al., 2006; Schulze et al., 2003, 2004) of the Mediterranean Province and in the Gulf of Mexico (Scott, 1990). Cenomanian (mostly upper) low-energy inner shelf environment with canaliculate and radiolitid rudists has been also reported from Apennines of Italy (Cestari and Laviano, 2012), from Provence-France (Philip and Auiraud-Crumiere, 1991), from Prebetic Domain (Martin-Chivelet et al., 1990), from south Pyrenees of Spain (Caus et al., 1993), from Egypt (Bauer et al., 2002, 2003; Bachmann et al., 2003), from Oman (Philip et al., 1995) and from Jordan (Schulze et al., 2003; Özer and Ahmad, 2015).

The middle-upper Cenomanian limestones of the Çal Dağ section show different facies characteristics from the Sarpdere section. The canaliculate rudist and radiolitid fragments are embedded within the wackestone/packstone beds with abundant radiolarians and calcispheres, which are intercalated with the cherty limestones (Fig. 11B). This data suggests that the rudist debris were transported from the high energy platform edge environment to the adjacent pelagic environment along the platform slope.

The lower Turonian cherty pelagic limestones of the Kızılca section are intercalated with abundant rudist debris-bearing bioclastic limestones, which show grainstone/rudstone depositional texture. Presence of abundant rudist fragments indicates reworking and intense fragmentation (Fig. 11C), which is explained by transportation of rudists from probably a Cenomanian shallow-marine carbonate platform. These data indicate mainly slope depositional settings.

Light grey, massive recrystallized limestones characterized by abundant distefanellids suggest presence of a shallow platform environment for the late Turonian. Small rudist patches and limited fragmentation of rudist shells are present in the limestones of the Sarpdere section. In thin sections, sparry (equant) calcite cement and fine-grained carbonate sediments entirely or partially filled the voids of cellular outer shell layer of radiolitid fragments within the

Fig. 12. Microfacies photographs of the rudist-bearing limestones. Note intense fragmentation of rudists, micritization around the fragments, bioerosional features and sparry (equant) calcite cement and fine-grained carbonate sediments entirely or partially filled the cellular outer shell layers of radiolitids. A-packstone with rudist debris, Başyaşar Tepe section, sample no. 14-109, B–C-packstone/rudstone with abundant rudist debris and benthic foraminifera (b), İnlice section, sample nos. 14-266 and 15-99 respectively, D–E-rudstone/packstone/grainstone with abundant rudist debris and benthic foraminifera, Bozburun section, sample no. 15-13, F-grainstone with rudist debris and benthic foraminifers, Bozburun section, sample no. 15-02, G-floatstone/packstone with rudist and bivalve debris, Konacık section, sample no. 14-29, H-packstone with rudist debris, Gökbel section, sample no. 14-27. Scale bars are equal to 1 mm. See figures 2–4 for the stratigraphic positions of the thin sections.

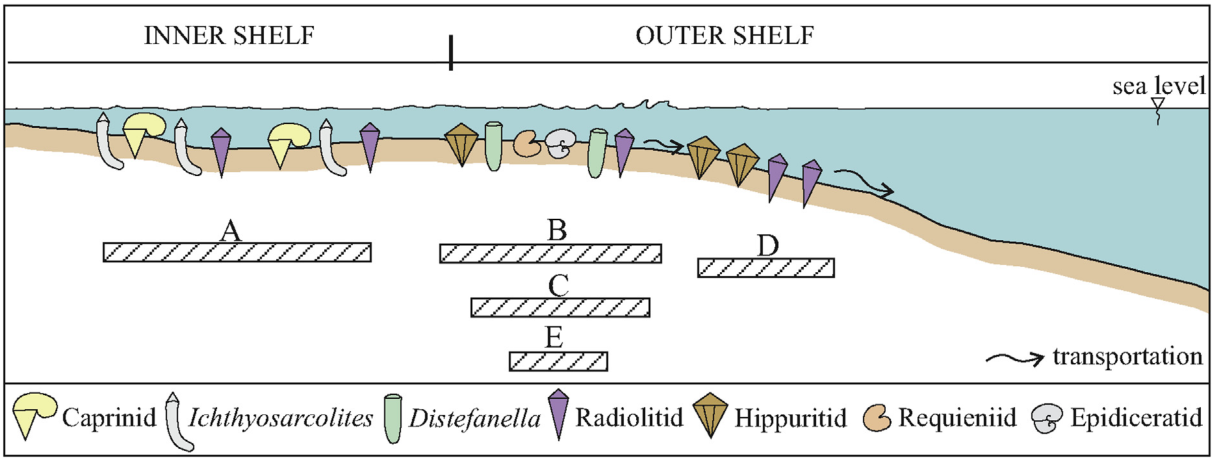

Fig. 13. Schematic carbonate platform model showing depositional settings of rudists and distribution of the rudist associations. A-caprinid-ichthyosarcolitid, B-distefanellid, C-hippurtid-radiolitid, D-radiolitid-hippuritid and E-epidiceratid-requieniid and radiolitid-requieniid assemblages. Not to scale.

packstone (Fig. 11D, E). Occurence of highly diversified rudist fauna, lithologic and microfacies characteristics of the succession indicate that the limestones were deposited under moderate to sometimes high hydrodynamic conditions in an outer platform environment.

The upper Turonian neritic recrystallized limestones comprise small patches of *Distefanella*, *Durania* and *Bournonia* and their fragments in the Akdikmen Tepe section. Rudist composition suggests an outer platform setting with moderate to high-energy conditions. The grainstone/packstone depositional texture shows collapse of the internal part of the rudist valve sections filled with totally calcite cement and intense recrystallization affected the outer shell layer of the valve and masked the microfossils (Fig. 11F). Presence of chert breccias and coral fragments at the upper part of the succession may indicate development of a gently dipping carbonate ramp depositional settings. Existence of rare planktonic foraminifera in a calcareous mudstone interbed and overlying turbidites indicates development of pelagic conditions in depositional environment. The rudist-bearing Turonian limestones with rudists are mostly deposited in outer platform, shelf margin and ramp settings in the circum Mediterranean Tethys, but inner platform records are also present (Moro, 1997; Moro et al., 2002; Bauer et al., 2002, 2003; Bachmann et al., 2003; Abdelgawad et al., 2011; Hennhöfer et al., 2014). Cestari (2005) indicates that the species of *Distefanella* are found in the outer platform of a shelf margin settings. Cestari and Pons (2007, 2008) suggest that the genus *Distefanella* lived in moderate to high-energy conditions. They also noted that the genus specifically lived in the shelf margin environments with a high sediment accumulation rate, which may be adapted for the Sarpdere and Akdikmen Tepe limestones with *Distefanella*.

The rudist-bearing upper Coniacian-Santonian-Campanian massive and bioclastic limestones are widely observed in the Lycian Nappes when compared with those of Cenomanian and Turonian. Some rudist sections observed in the massive marbles of the Kıyıkışlacık section may suggest a shallow-marine conditions. The marbles do not yield information for microfacies characteristics as the Cenomanian-Turonian strata.

The bioclastic limestones are also observed in the Balkıca, Hisarköy and Başyaşar Tepe stratigraphic sections. They are grey, light grey, thick bedded with small rudist patches and/or accumulations of radiolitids and hippuritids, which are associated with hermatypic corals and gastropods. Depositional texture is mainly represented by packstone/floatstone/grainstone and locally grainstone, which comprise mainly rudist fragments. Besides, benthic foraminifera, red algae and sponge are also observed. The oriented rudist fragments commonly have micritic envelopes (Figs. 11G, H, 12A). These features suggest an outer platform settings for the rudist-bearing limestones. Increasing of the amount of transported rudist debris (i.e. floatstone and grainstone textures) especially in the uppermost part of sequence indicates development of the high energy marginal slope conditions in the depositional environment. The grading upward of these bioclastic limestones to the pelagic, cherty thin bedded, laminated limestones with chert breccias confirms the slope environment. Existence of rudist debris and neritic limestone clasts within the cherty limestones indicates an intense transportation from outer platform through the slope. The facies characteristics of the succession suggest a moderate to high energy shallow-marine environment for the initial stages and a deeper-water setting for the later stages of the Coniacian-Campanian interval. Several studies have reported similar Coniacian-Santonian-Campanian rudist-bearing limestones reflecting an outer platform settings with marginal slope influenced by the pelagic conditions (Carbone, 1993; Carannante et al., 1998; Laviano et al., 1998b; Moro and Cósović, 2000; Stössel and Bernoulli, 2000; Moro et al., 2002, 2016; Simone et al., 2003; Steuber et al., 2005; Sarı, 2006b; Sarı and Özer, 2009; Cestari and Laviano, 2012).

The Maastrichtian rudist-bearing limestones present two types of facies: (i) bioclastic limestones and (ii) calciturbiditic (allodapic) limestones. The first facies is observed in the İnlice section, which is mainly characterized by bioclastic limestones overlying the uppermost Cenomanian-Santonian pelagic cherty limestones. The basal part of the bioclastic limestones consists of packstone/rudstone depositional textures with abundant benthic foraminifera and rudist debris showing intense fragmentation, micritization and bioerosional features (Fig. 12B). Coral and red algae debris accompany the rudists and benthic foraminifera. Planktic foraminifera are generally rare throughout the section, but abundantly present at some levels. Several limestone breccia levels are observed within the succession and rudist debris are abundantly presented in the upper part of the succession. These levels are represented by rudstone/grainstone/packstone depositional textures with abundant rudist debris showing intense fragmentation, micritization, bioerosional features. Sparry (equant) calcite cement and fine-grained carbonate sediments entirely or partially filled the cellular outer shell layer of radiolitid fragments (Fig. 12C). These data reflect margin of an outer platform environment. Here, the bioclastic limestones were deposited under high to moderate energy conditions. Sometimes, pelagic incursions occurred probably in that gently slope settings, where transported rudist debris abundantly deposited. The second facies is detected in the Bozburun section, which is characterized by cherty limestones, calciturbiditic (allodapic) limestones with rich planktic foraminifera, and some benthic foraminifera. Rudists are observed in the limestones without cherts and they are commonly fragmented due to mechanical compaction, but determinable rudist sections were found towards the upper part of the section. These rudist fragments could have been derived from small patches of rudist aggregations from adjacent environments. The rudstone/packstone/grainstone depositional textures with abundant rudist debris showing micritization, bioerosional features and sparry (equant) calcite cement entirely filled the cellular outer shell layer of radiolitid, are described (Fig. 12D–F). The bioclastic limestones of Konacık and Gökbel sections consist of packstone/floatstone depositional textures with abundant rudist debris showing intense fragmentation and micritization (Fig. 12G–H). These data indicate outer platform, slope depositional settings. The Maastrichtian facies and depositional environment features of the limestones with rudists of our study are comparable with those of Mediterranean Tethys (mostly central) presented by Accordi et al. (1982, 1988, 1989), Carbone (1993), Gallemi et al. (1997), Laviano (1996) and Steuber et al. (2005, 2007).

The facies and depositional features of the rudist-bearing limestones of the Lycian Nappes show that the rudists lived and formed associations in the inner and outer shelfs of the carbonate platforms (Fig. 13).

7. Conclusions

The Cretaceous rudist associations and the depositional settings are first described from the low grade metamorphic successions (dominated by recrystallized limestones) of Lycian Nappes. The rudist data was obtained from fifteen measured-stratigraphic sections in Tavas, Fethiye, Köyceğiz, Ören, Bodrum and Bozburun areas.

The Lower Cretaceous with rudists is very sparse in the Lycian Nappes and a epidiceratid-requieniid assemblage (Berriasian) is only reported from the Bitez limestone block in the Bodrum Peninsula (Masse et al., 2015). It has a low density and consists of *Heterodiceras luci* (Defrance), *Heterodiceras* sp.1, *Heterodiceras*? sp. and *Hypelasma salevensis* (Joukowsky and Favre). A requieniid-radiolitid assemblage showing a low density is first found in the platform-type limestones of the Bozburun Peninsula. The age of this association is clearly older than Turonian (?Albian-?Cenomanian), due to the presence of the lower Turonian pelagic infillings within the upper part of the rudist-bearing limestones. But, further detailed palaeontological data are required for precise determination of the Lower Cretaceous stages.

The Upper Cretaceous sequences have widespread distribution in the Lycian Nappes than the Lower Cretaceous. Four main rudist assemblages are distinguished within the Upper Cretaceous sequences of the Lycian Nappes:

1) Caprinid-Ichthyosarcolitid assemblage (middle-late Cenomanian; Sarpdere, Serinhisar-Tavas and Çal Dağ-Fethiye) comprises *Neocaprina gigantea* Pleničar, *Caprina schiosensis* Boehm, *Schiosia* cf. *schiosensis* Boehm, *Sphaerucaprina* cf. *woodwardi* Gemmellaro, *Ichthyosarcolites bicarinatus* (Gemmellaro), *I. triangularis* Desmarest, *I. monocarinatus* Slišković, *I. poljaki* Polšak, *Caprinula* aff. *boisyyi* d'Orbigny, *Eoradiolites* sp., *Durania* sp. and requieniids (*Apricardia* sp.).
2) Distefanellid assemblage (late Turonian; Sarpdere, Serinhisar-Tavas and Akdikmen Tepe-Köyceğiz) is represented by *Distefanella salmojraghii* Parona, *D. montagnei* Slišković, *Hippurites* cf. *socialis* Douvillé, *Vaccinites* cf. *praegiganteus* (Toucas), *V.* cf. *rousseli* Douvillé, *Durania arnaudi* (Choffat), *Durania* cf. *gaensis* Dacqué, *Durania* sp. (*Durania* aff. *laevis* Douvillé), *Bournonia africana* Douvillé and *Sauvagesia/Durania* sp.
3) Hippuritid-Radiolitid assemblage (late Coniacian-Santonian-Campanian; Balkıca-Tavas, Hisarköy-Fethiye, Başyaşar Tepe-Köyceğiz, Gökbel and Kıyıkışlacık-Ören-Ula, Konacık and Antenler-Bodrum) consists of *Hippurites* cf. *nabresinensis* Futterer, *Hippuritella* aff. *lapeirousei* (Goldfuss), *Vaccinites* sp., *Hippurites* sp., *Bournonia* aff. *hvarensis* Pejović, *Bournonia* aff. *wiontzeki* Pejović, *Biradiolites* sp. (*Biradiolites* aff. *fissicostatus* d'Orbigny), *Biradiolites* sp., *Sauvagesia* sp. and *Durania* sp.
4) Radiolitid-Hippuritid assemblage ('middle'-late Maastrichtian; İnlice-Fethiye and Bozburun Tepe-Köyceğiz) comprises *Bournonia* aff. *adriatica* Pejović, *Bournonia* cf. *fascicularis* (Pirona), *Bournonia* sp., *Biradiolites* sp. (*Biradiolites* aff. *chaperi* Toucas), *Lapeirousia* sp., *Durania* sp., *Sauvagesia* sp. and *Hippurites cornucopiae* Defrance.

This study reveals for the first time that the rudists, which were regarded as shell fragments in previous studies comprise assemblages indicating different ages in the Lycian Nappes. The biostratigraphic data obtained from rudists provide valuable contribution to better understand the Upper Cretaceous stratigraphy of the Lycian nappe piles.

The rudists and the microfacies characteristics of the limestones provide information on the depositional environments of the Cretaceous successions. The data obtained reveal that the limestones were deposited in the inner and outer shelves of the Cretaceous carbonate platform(s). Rudists formed small isolated patches and aggregations in these environments and commonly deposited as shell fragments particularly on the outer shelf in response to increasing energy and platform slope characteristics.

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