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Original article

Upper Cretaceous rudist biostratigraphy of the Bey Dağları Carbonate Platform, Western Taurides, SW Turkey ☆

Biostratigraphie des rudistes du Crétacé supérieur de la plate-forme carbonatée de Bey Dağları, Taurides occidentales, SO de la Turquie

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Abstract

The Upper Cretaceous (Middle Cenomanian-Coniacian) successions of the Bey Dağları Carbonate Platform (Western Taurides, SW Turkey) are represented by rudist-bearing shallow-water limestones. Four rudist lithosomes are distinguished for the first time from the Eastern, Northern and Southern Areas of the Bey Dağları Autochthon. The oldest rudist assemblages dominated by caprinids are observed in the Eastern (Katran Dağ) Area (caprinid lithosomes) and suggest a Middle-Late Cenomanian age. The uppermost part of the platform carbonates in the Northern Area is characterized by an association of hippuritid and radiolitid rudist bivalves dominated by *Vaccinites praegiganteus* (Toucas) (hippuritid lithosomes). The rudist fauna indicates the Late Turonian age, which is confirmed by the previously obtained $^{87}Sr/^{86}Sr$ values of well-preserved low-Mg calcite of *Vaccinites praegiganteus* (Toucas) shells. The rudist associations of the Southern (Susuzdağ) Area are represented by two rudist formations. The lower lithosomes are mainly made up of hippuritids and radiolitids (hippuritid-radiolitid lithosomes). The stratigraphical distributions of the species of the assemblage indicate a Santonian-Early Campanian age. The rudist associations of the upper lithosomes are dominated by species of *Joufia* and *Gorjanovicia* (*Joufia-Gorjanovicia* lithosomes), which suggest a Late Campanian-Maastrichtian age. Identification of the rudist lithosomes yields information on the palaeobiogeographic distribution of the rudist species in the eastern Mediterranean region and also on the biostratigraphic frame of the Upper Cretaceous successions of the Bey Dağları Carbonate Platform.

Keywords: Rudist lithosome; Upper Cretaceous; Biostratigraphy; Bey Dağları Carbonate Platform; Western Taurides

Résumé

Les séries d'âge crétacé supérieur (Cénomanien moyen-Coniacien) de la plate-forme carbonatée de Bey Dağları (Taurides occidentales, SO de la Turquie) sont représentées par des calcaires peu profonds à rudistes. Quatre lithosomes à rudistes sont distingués pour la première fois dans les régions autochtones Est, Nord et Sud de Bey Dağları. Les plus anciens assemblages à rudistes dominés par les caprinidés (lithosomes à caprinidés) sont observés dans la région Est (Katran Dağ) et suggèrent un âge cénomanien moyen à supérieur. La partie la plus supérieure des carbonates de plate-forme est caractérisée dans la région Nord par une association à bivalves rudistes hippuritidés et radiolitidés (lithosomes à hippuritidés) dominés par *Vaccinites praegiganteus* (Toucas). La faune à rudistes indique un âge turonien supérieur, confirmé par les valeurs $^{87}Sr/^{86}Sr$ obtenues précédemment sur des coquilles bien préservées en calcite faiblement magnésienne de *Vaccinites praegiganteus* (Toucas). Les associations à rudistes de la région Sud (Susuzdağ) sont représentées par deux formations à rudistes. Les lithosomes inférieurs sont principalement caractérisés par des hippuritidés et des radiolitidés (lithosomes à hippuritidé-radiolitidé). La distribution stratigraphique des espèces de l'assemblage indique un âge santonien à campanien inférieur. L'association à rudistes du lithosome supérieur est dominée par les espèces des genres *Joufia* et *Gorjanovicia* (lithosomes à *Joufia-Gorjanovicia*), ce qui suggère un âge campanien supérieur à maestrichtien. L'identification des lithosomes à rudistes fournit des informations sur la distribution paléobiogéographique des espèces de rudistes en Méditerranée occidentale et sur le canevas biostratigraphique des successions du Crétacé supérieur de la plate-forme carbonatée de Bey Dağları.

Mots clés : Lithosome à rudistes ; Crétacé supérieur ; Biostratigraphie ; Plate-forme carbonatée de Bey Dağları ; Taurides occidentales

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1. Introduction

The Bey Dağları Carbonate Platform was one of the many isolated Tethyan carbonate platforms surrounded by pelagic basins during Cretaceous times (Dercourt et al., 2000; Robertson et al., 2003; Poisson et al., 2003). The Upper Cretaceous successions of the carbonate platform are represented mainly by rudist-bearing (mainly caprinids, hippuritids

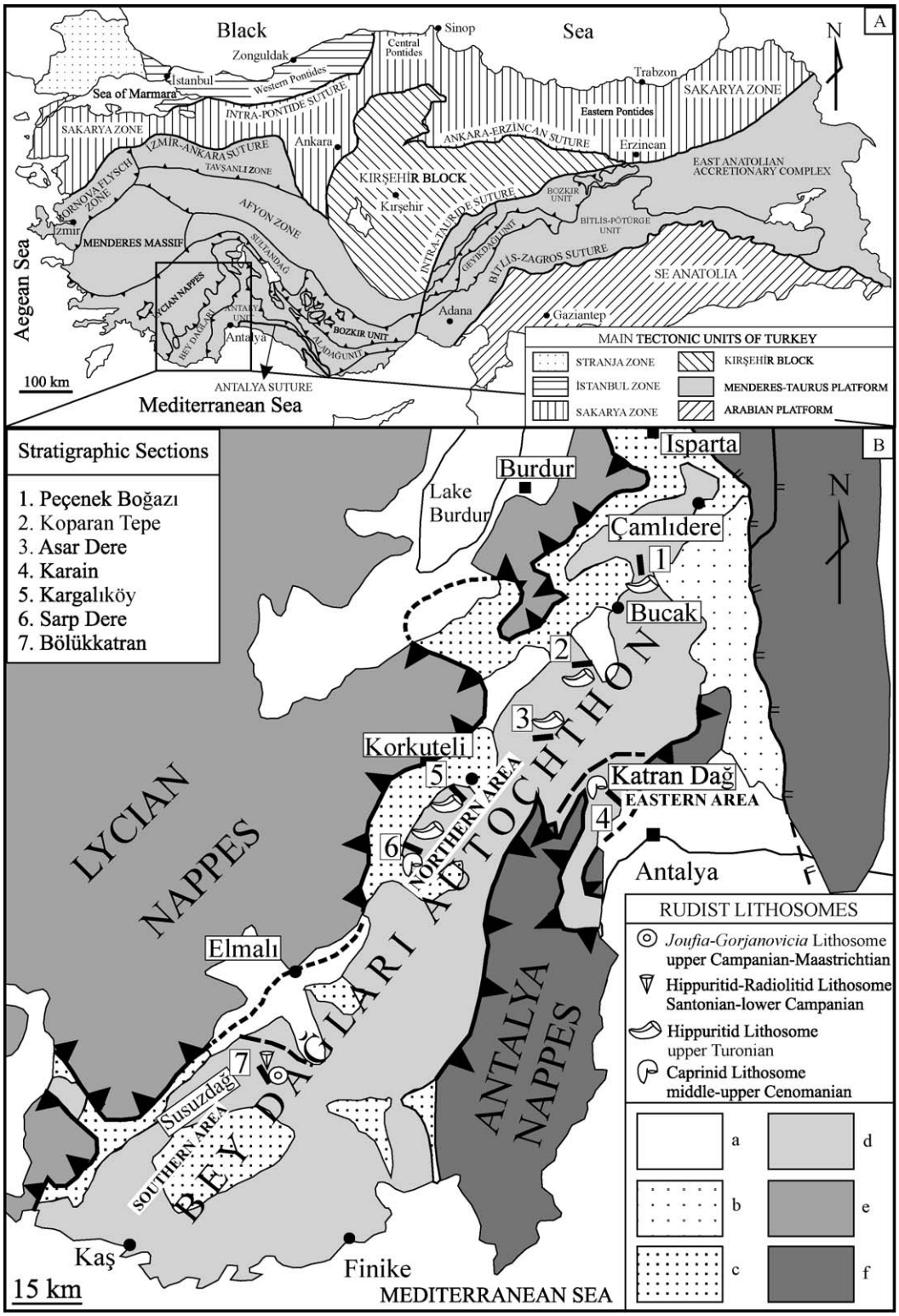

Fig. 1. **A**. Main tectonic units of Turkey (after Görür and Tüysüz, 2001). **B**. Main tectonic belts of the Western Taurides (simplified from Poisson et al., 1984) and the location of the measured stratigraphic sections. a: Upper Miocene-Quaternary post-compressional tectonic formations; b: Neogene formations preceding the Aksu compressional event; c: Lower and Middle Miocene of the Bey Dağları Autochthon; d: Bey Dağları Autochthon (Upper Triassic to Oligocene); e: Antalya nappes; f: Lycian nappes.

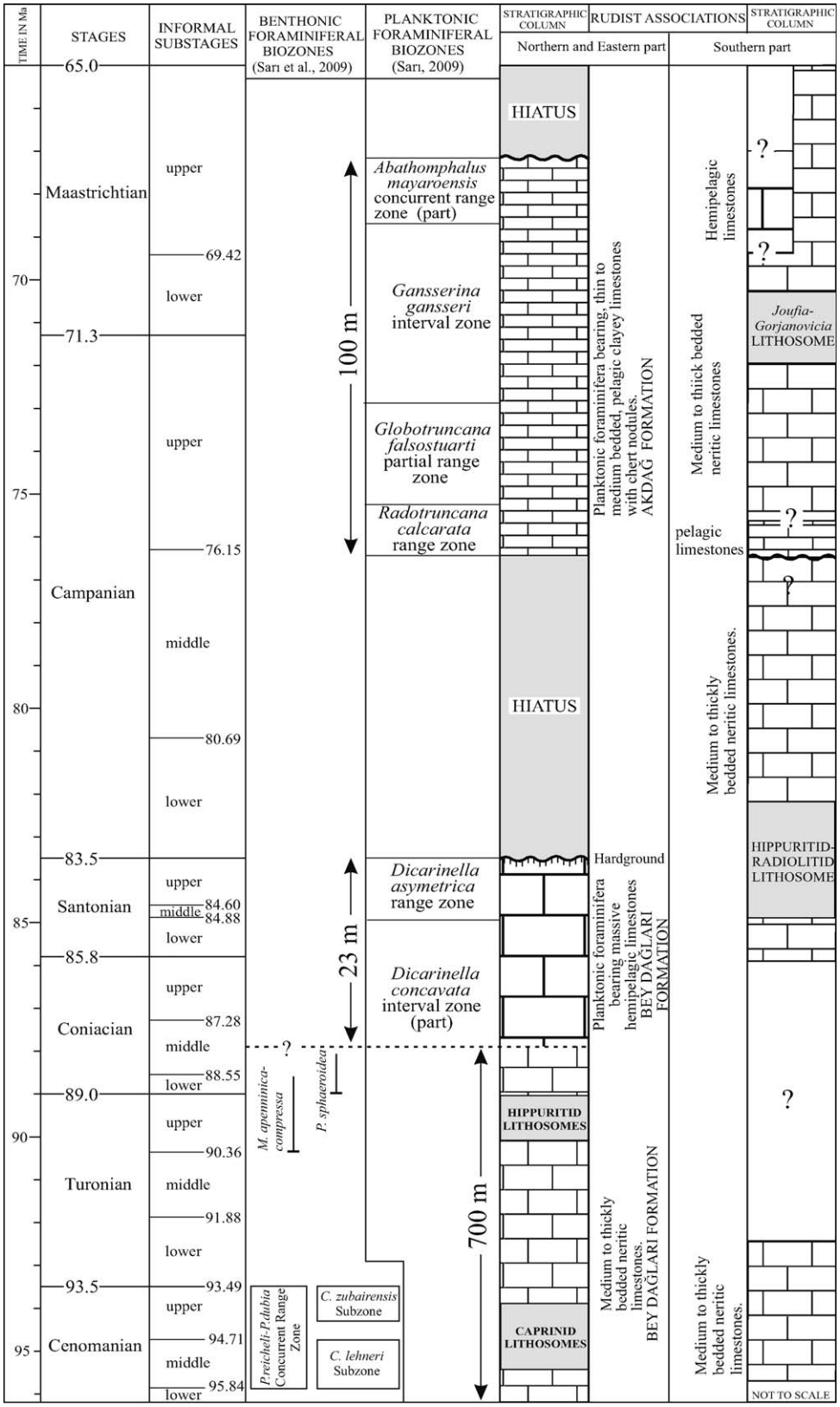

Fig. 2. Synthesized lithostratigraphic column of the Upper Cretaceous sequences of the Bey Dağları Carbonate Platform, plotted against the planktonic foraminiferal and benthonic foraminiferal biozonation and rudist associations (After Sarı, 2006b, 2009; Sarı et al., 2009). Time table adapted from Gradstein et al. (1994).

and radiolitids) shallow-water limestones without any siliciclastic input (Poisson, 1977; Özer, 1988; Sarı, 1999, 2006a, b; Sarı and Özer, 2001, 2002; Sarı et al., 2004). The rudist bivalves (superfamily Hippuritoidea) were sessile epifaunal suspension feeders, which flourished on carbonate-dominated substrata of shallow marine settings at low latitudes, from the Jurassic to the Late Cretaceous (Skelton, 1979; Philip, 1981, 1982; Ross and Skelton, 1993). They are regarded as good palaeobiogeographic indicators as they showed broad geographical extent, high evolutionary rate and relatively wide ecological diversity (Philip, 1982; Ross and Skelton, 1993; Philip et al., 1995; Gili et al., 1995).

Occurrences of rudist bivalves are important, as the biostratigraphy of post-Cenomanian Cretaceous carbonate platforms is generally difficult due to long ranges of benthonic microfossils and the lack of fossils that provide a precise biostratigraphy. While the Cenomanian can be recognized and subdivided by means of benthonic foraminifera, this is not possible for the Turonian, and biostratigraphy commonly has to rely on rudist bivalves. A precise Upper Cretaceous biostratigraphy based on caprinid and hippuritid rudists was established in the western Mediterranean region (Philip et al., 1983; Pascual et al., 1989; Philip, 1998; Vicens et al., 1998; Simonpiétri et Philip, 2000). Pronounced endemism of rudist faunas of the western Mediterranean region (Pons and Sirna, 1992) does not permit application of the biozonation to the central and eastern Mediterranean. Recent works mainly based on strontium isotope stratigraphy of rudist shells suggest that the ranges of most rudist species in the whole mediterranean region need to be revised (Steuber, 2003; Steuber et al., 2005).

Despite the existence of many rudist localities throughout the autochthon, there have been rather scarce studies dealing with the rudist biostratigraphy. The first data on the rudists of the Bey Dağları Autochthon were reported by Poisson (1967, 1977) and there have been few studies since then (Özer, 1988, 2002; Sarı, 1999; Sarı and Özer, 2001, 2002; Sarı et al., 2004). Two systematic studies concerning the caprinids of the Middle-Upper Cenomanian of Katran Dağ and hippuritids of the Upper Turonian of the Korkuteli area were carried out by Özer (1988) and Sarı et al. (2004), respectively. As only very limited biostratigraphical data were available within the post-Cenomanian neritic limestones (for both rudists and benthonic foraminifera), interpretations of the evolution of the platform have been largely based on planktonic foraminifera from overlying pelagic limestones so far.

The aim of this study is mainly to present the rudist assemblages of the four rudist lithosomes observed in seven stratigraphic sections logged from the Upper Cretaceous platform limestones of the Bey Dağları Autochthon (Fig. 1). The geographic and stratigraphic distribution of the species from the rudist lithosomes is also demonstrated.

2. Regional geological setting

The Bey Dağları Autochthon, which is approximately 150 km long and oriented NE-SW from Kaş to Isparta (Fig. 1), represents a segment of a Mesozoic Tethyan platform on which carbonate accumulation persisted from the Triassic to the Early Miocene. This segment was overthrusted by the Antalya nappes in the east and by the Lycian nappes in the northwest, and is

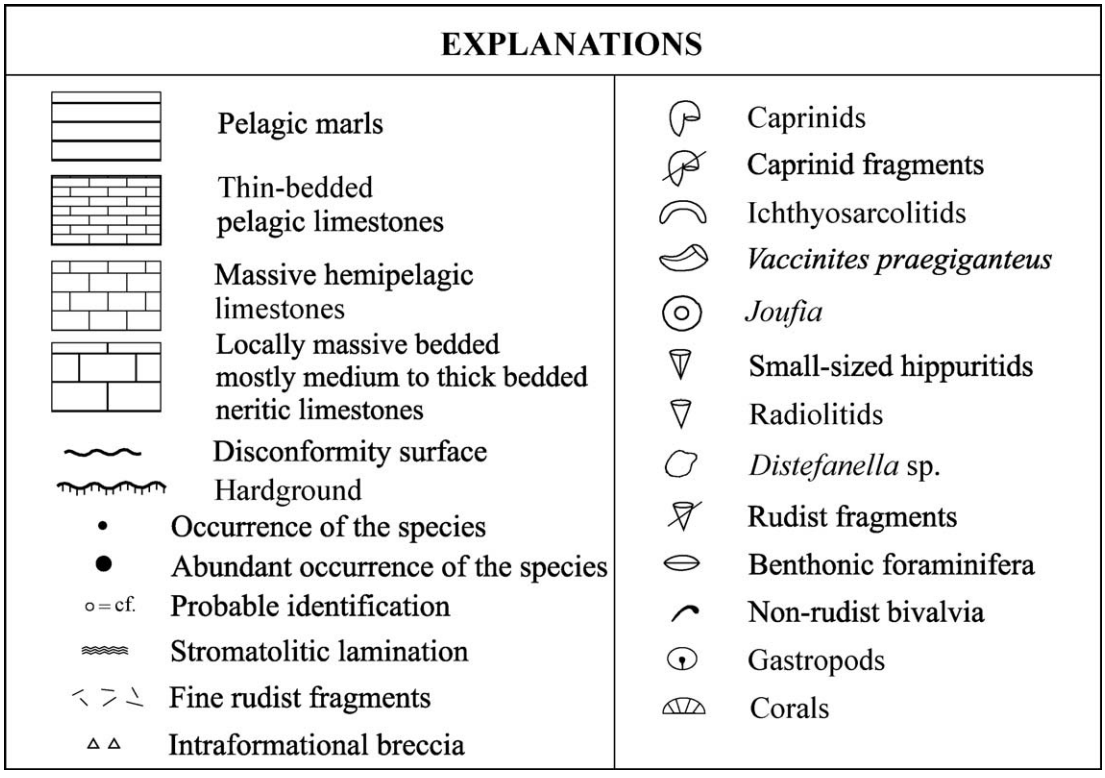

Fig. 3. Explanation for all measured stratigraphic sections.

partially exposed in the Göcek window (Özgül, 1976; Poisson, 1977; Farinacci and Köylüoğlu, 1982; Naz et al., 1992; Robertson, 1993). During Mesozoic times, the autochthonous unit was part of a larger crustal fragment of the African palaeomargin which can be traced in the Taurides and Zagrides to the east, and the Hellenides, Dinarides and Apennines to the west (Şengör and Yılmaz, 1981; Farinacci and Köylüoğlu, 1982; Poisson et al., 1984, 2003; Özgül, 1984; Robertson and Dixon, 1984; Farinacci and Yeniay, 1986; Robertson et al., 1991, 2003; Robertson, 1993, 2002).

The Bey Dağları Carbonate Platform was one of the many Mesozoic Tethyan carbonate platforms initiated as a result of flooding of blocks, which had rifted from the northern margin of Gondwana during Mid-Late Triassic (following Late Permian-Early Triassic rifting) throughout the southern part of the Eastern Mediterranean region (Robertson, 2002). The Bey Dağları Carbonate Platform passed through the entire predictible geodynamic spectrum of the Wilson cycle: rifting, drifting, transtension, transpression, and collision (Bosellini, 1989); it is reconstructed as an isolated carbonate platform, which was the southernmost representative of the girdle of intraoceanic platforms extending from the western Mediterranean to the eastern Mediterranean Neotethys during the Late Cenomanian (Dercourt et al., 2000).

The Bey Dağları Autochthon was under the effect of different tectonic regimes during the Late Cretaceous, which is time of intense tectonic movements in this critical area of eastern Mediterranean. Late Cretaceous tectonic activities are thought to be responsible for the drowning of carbonate platforms, opening of small oceanic basins and collision of different tectonic units. Many studies have shown that the Upper Cretaceous sequences are characterized by breaks in deposition and important facies variations in both neritic and pelagic carbonates (Poisson, 1977; Gutnic et al., 1979; Farinacci and Köylüoğlu, 1982; Farinacci and Yeniay, 1986; Özkan and Köylüoğlu, 1988; Naz et al., 1992; Sarı, 1999, 2006a, b, 2009; Sarı and Özer, 2001, 2002; Sarı et al., 2004, 2009).

3. Upper Cretaceous rudist biostratigraphy

The Upper Cretaceous sequences of the Bey Dağları Autochthon are divided into three geographical areas (Eastern, Northern and Southern Areas) as they show different biotic and sedimentary characteristics possibly related to different evolutionary histories (Fig. 1). They present important biotic and facies changes and include sedimentary breaks related to the evolution of the platform. Four main rudist lithosomes are observed throughout the Upper Cretaceous platform limestones of the Bey Dağları Autochthon (Figs.2 and 3Figs. 1-3):

- the Middle-Late Cenomanian caprinid lithosomes are observed in the Eastern (Katran Dağ) Area;
- the Late Turonian hippuritid lithosomes are mainly detected in the Korkuteli part of the Northern Area and can be traced patchily throughout the northernmost part of the autochthon as a key marker level;

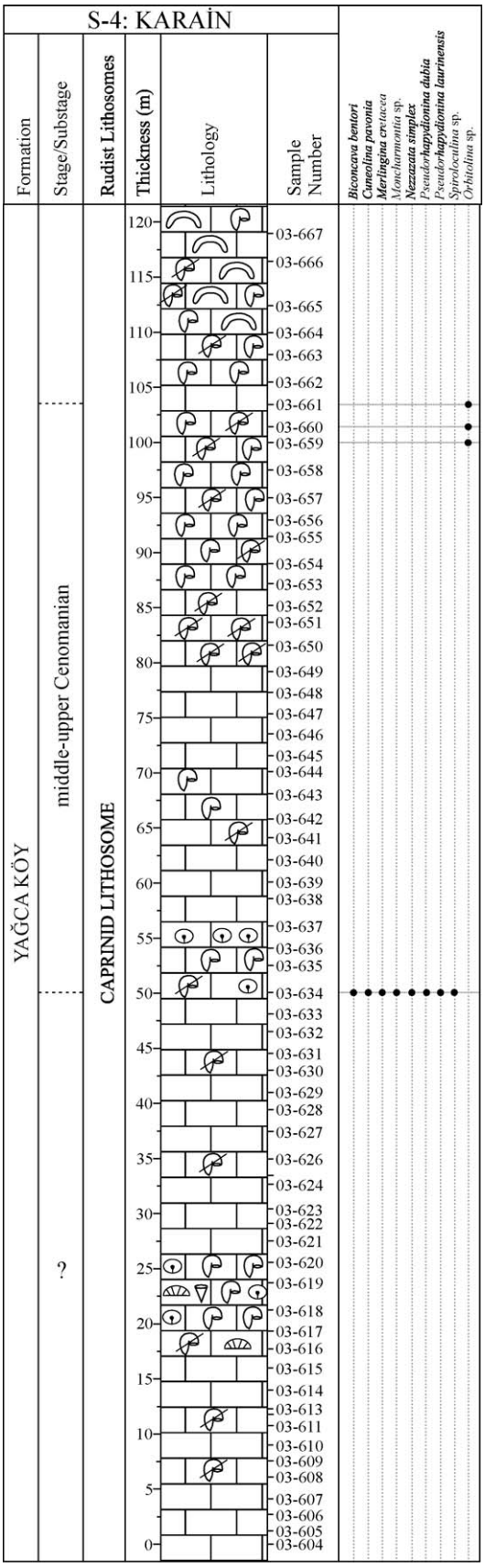

Fig. 4. Karain measured stratigraphic section (see Fig. 1B for location of the section and Fig. 3 for explanations).

- the Santonian-Early Campanian hippuritid-radiolitid lithosomes;
- the Late Campanian-Maastrichtian *Joufia-Gorjanovicia* lithosomes are determined from the Southern (Susuzdağ) Area.

Details of the four main rudist lithosomes, associated benthic microfossils and depositional environments of related limestones, are described below.

3.1. Caprinid lithosomes

The unique outcrops of the caprinid lithosomes are observed in the neritic limestones of the Yağca Köy Formation in the Eastern Area (Katran Dağ), which is represented by abundant occurrences of caprinids and ichthyosarcolitids. The Karain section in this area includes rich caprinid assemblages throughout the 120 m-thick succession (Fig. 4). The lower

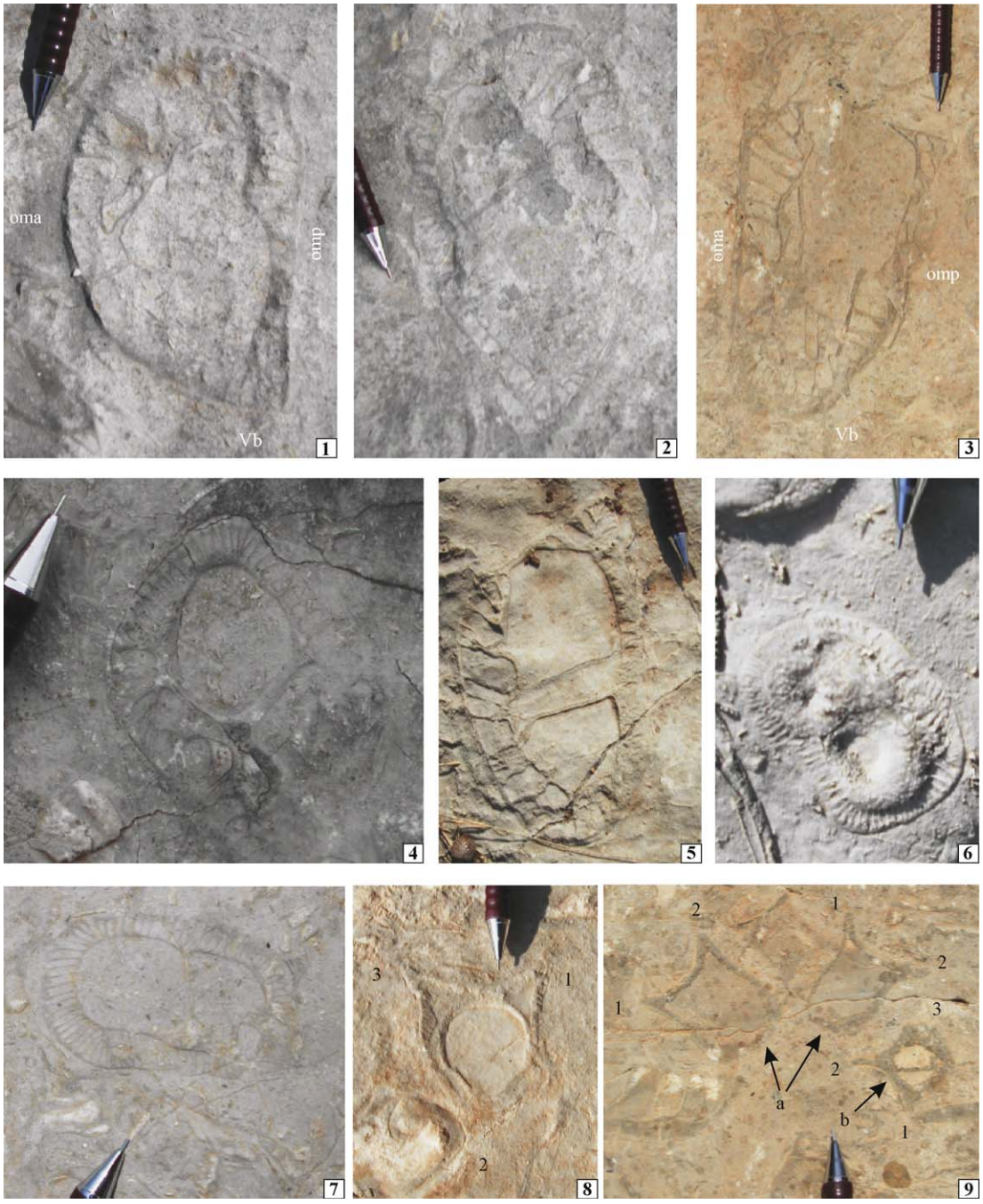

Fig. 5. Outcrop photographs of the caprinid lithosomes in the Karain section. **1–3**. Transverse sections of the right valves of *Neocaprina gigantea* Plenicăr. Note the anterior (oma) and posterior (omp) accessory cavities and canals and also the development of external carina (Vb). **4**. *Caprina schiosensis* Boehm. Transverse section of the left valve. Note the pallial canals observed as one row of canals comprising fusiform-type canals. **5, 6**. *Schiosia* cf. *schiosensis* Boehm. Transverse sections of the left valves. Note the small rounded and fusiform canals. **7**. *Caprina schiosensis* Boehm. Transverse section of the left valve. The fusiform canals are typical for the species. **8**. *Ichthyosarcolites triangularis* Desmarest. Transverse section of the right valve. **9**. **a**: *Ichthyosarcolites bicarinatus* (Gemmellaro). Transverse section of the right valve. Note the presence of two ridges (1, 2), which are characteristic features of the species; **b**: *Ichthyosarcolites triangularis* Desmarest. Transverse section of the right valve.

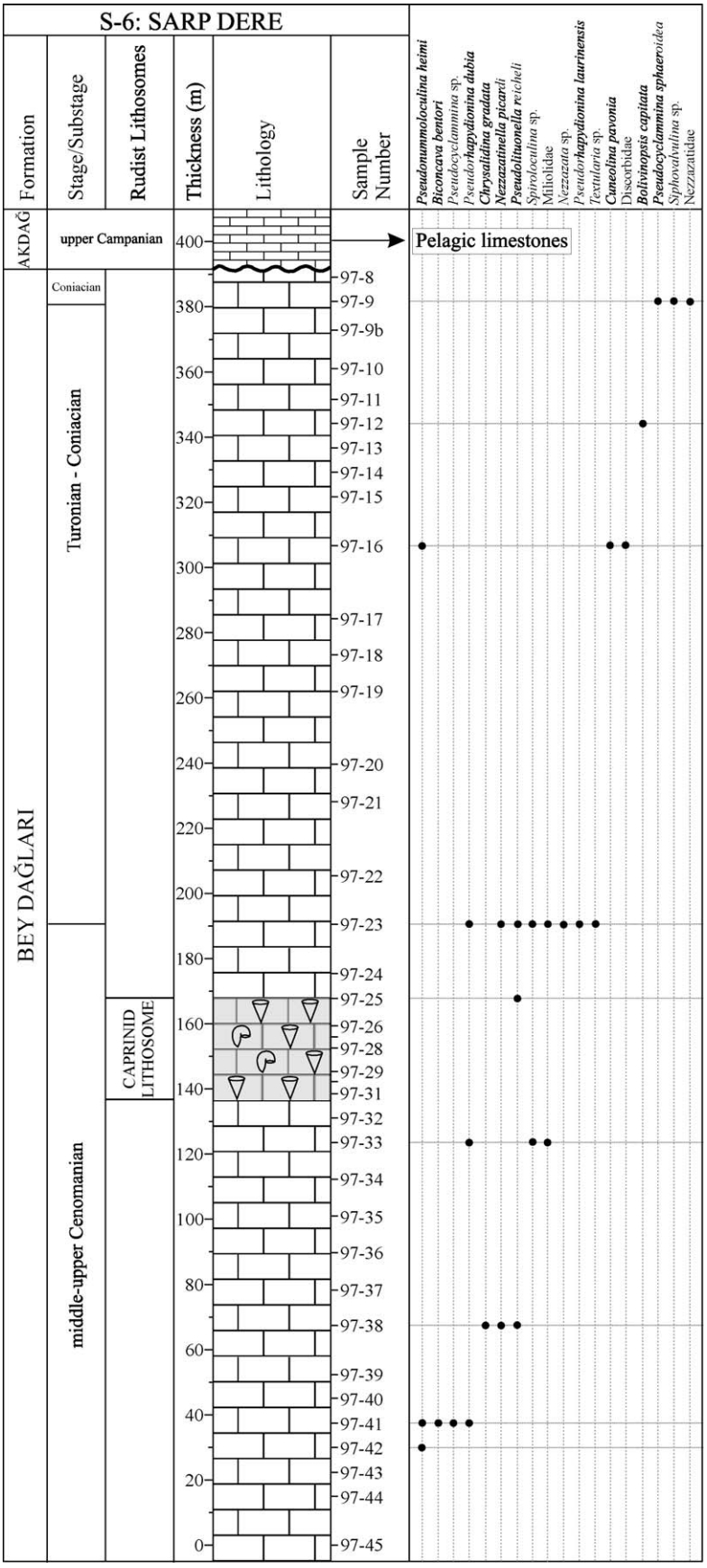

Fig. 6. Measured section at Sarp Dere (see Fig. 1B for location of the section and Fig. 3 for explanations).

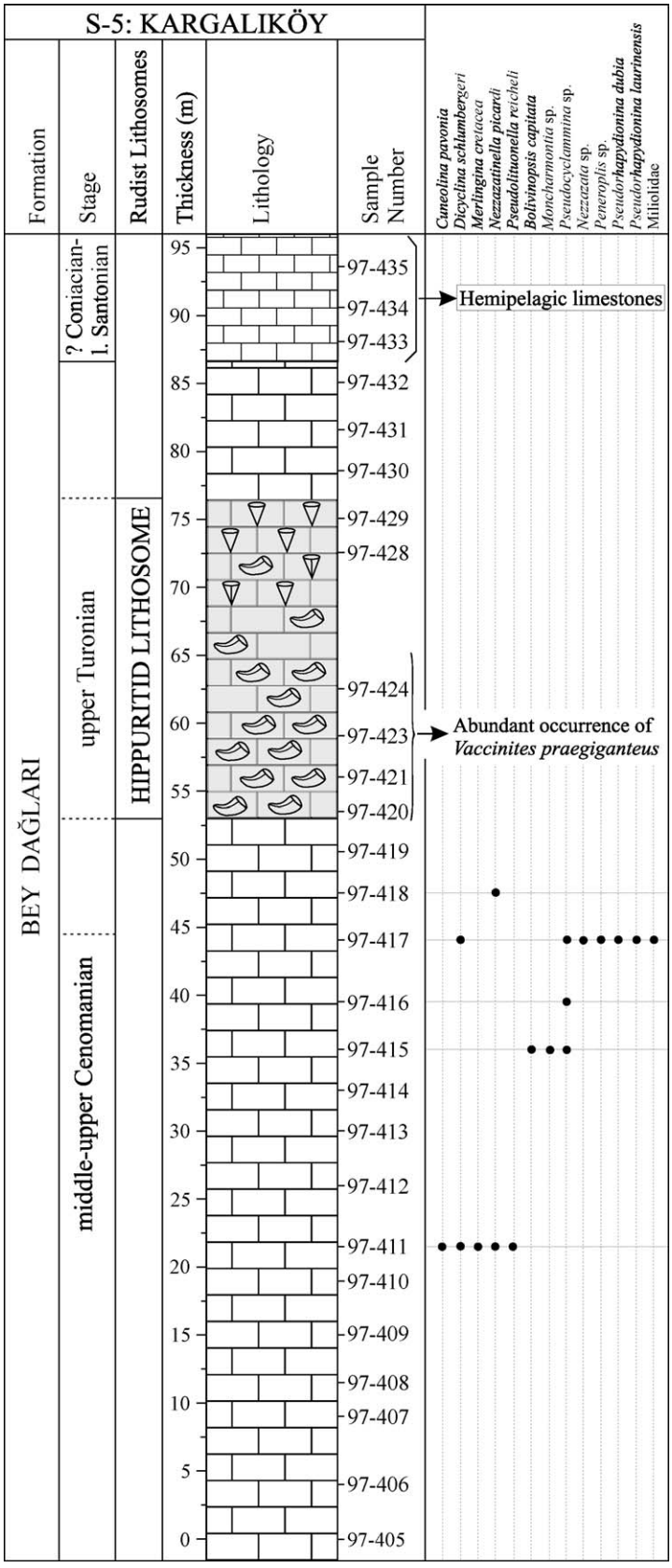

Fig. 7. Measured section at Kargalıköy (see Fig. 1B for location of the section and Fig. 3 for explanations).

part of the sequence is dominated by caprinids, which are accompanied by gastropods, corals and non-rudist bivalves, while the upper part is dominated by ichthyosarcolitids. Many rudists are observed as transported and broken shell fragments, which indicate intermittent wave action. The rudist assemblages of the Karain section comprise *Ichthyosarcolites bicarinatus* (Gemmellaro), *Ichthyosarcolites triangularis* Desmarest, *Caprina schiosensis* Boehm, *Neocaprina gigantea* Plenicăr, *Schiosia* cf. *schiosensis* Boehm, *Sphaerucaprina woodwardi* Gemmellaro, *Durania* sp., *Radiolites* sp. and *Sauvagesia* sp. (Fig. 5). Similar associations are widespread in the Mediterranean region and were reported from the Cenomanian and the Upper Cenomanian of Bosnia-Herzegovina (Sliškovic, 1968), the Cenomanian of Croatia (Polšak and Mamužic, 1969), the Lower Cenomanian of France (Bilotte, 1985), the Cenomanian of Greece (Accordi et al., 1989), the Cenomanian and the Upper Cenomanian of Italy (Cherchi et al., 1993), the Cenomanian of Romania (Lupu, 1992) and Slovenia (Plenicăr, 1963). Similar assemblages are also documented in Turkey from the Middle-Upper Cenomanian of Katran Dağ (Özer, 1988) and Serinhisar (Özer, 1998). The obtained rudist fauna suggests a Middle-Late Cenomanian age, which is consistent with the assemblages of benthonic foraminifera that suggest a Middle-Late Cenomanian age for the Middle-Upper parts of the succession (Sarı et al., 2009).

The neritic limestones of the Eastern Area (Katran Dağ) have different facies characteristics from the other stratigraphic sections probably as a result of a different palaeogeographic evolution. The sequence in this area is dominated by the winnowed bioclastic rudstone/grainstone microfacies with rich

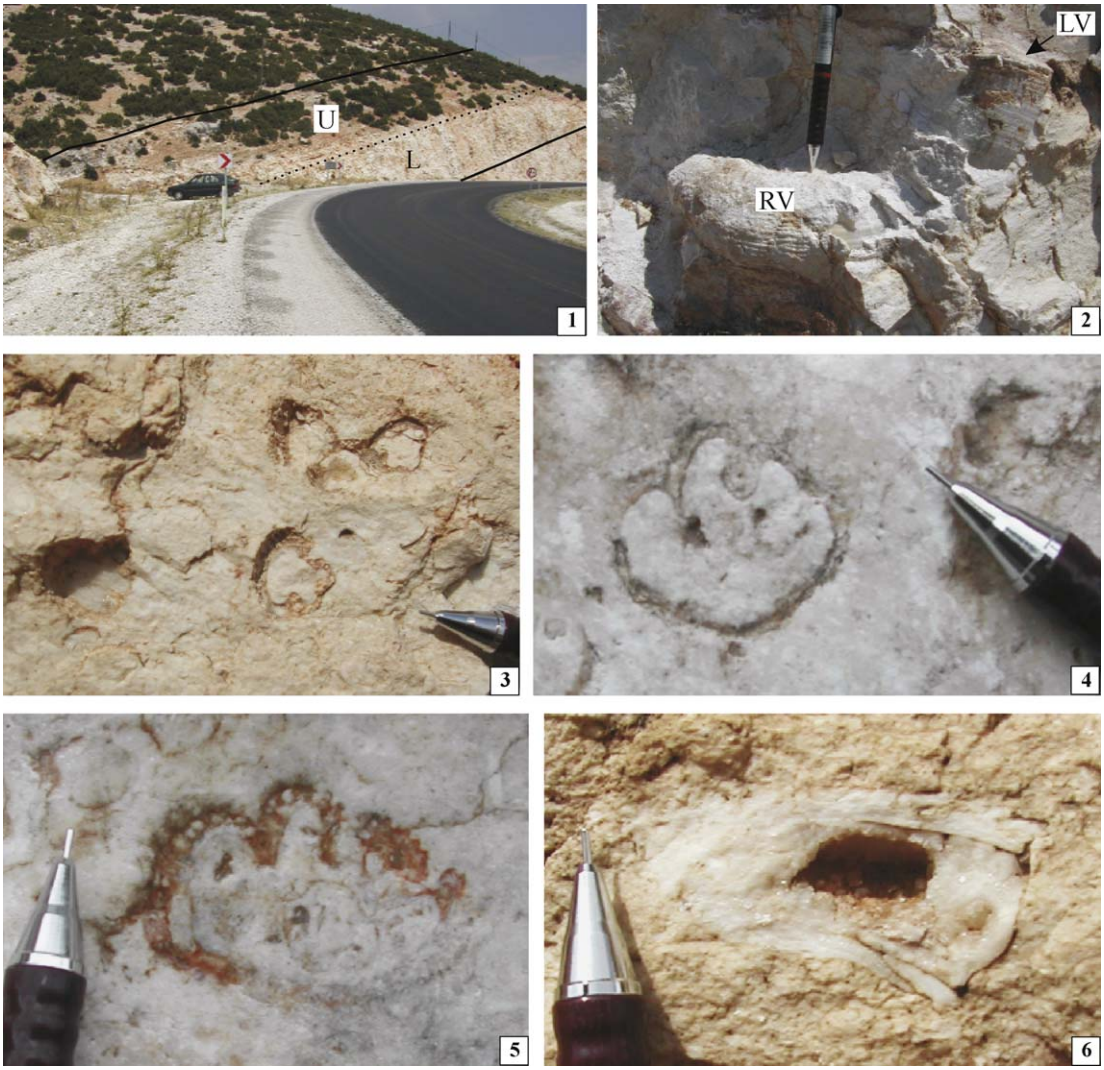

Fig. 8. The hippuritid lithosome in the Kargalıköy section. (Korkuteli-Fethiye road cut, Coordinates : 04950/48500, see Fig. 1B for location of the section and Fig. 7 for stratigraphic level of the lithosome). **1**. Outcrop photograph of the hippuritid lithosome in the Kargalıköy section (Korkuteli) The lower part of the lithosome (L) is dominated by *Vaccinites praegiganteus* (Toucas), while the upper part (U) is represented by small-sized hippuritids and radiolitids. **2**. An individual of *Vaccinites praegiganteus* (Toucas) in growth position in the lower part of the lithosome. Note that the right (RV) and left valves (LV) are preserved. Many of the specimens have curved right valve. **3**. Scattered sections of small-sized hippuritids (*Hippuritella* cf. *resecta* [Defrance]) in the upper part of the lithosome. **4, 5**. Transverse sections of the right valves of *Hippuritella resecta* (Defrance) in the upper part of the lithosome. **6**. Longitudinal section of a small radiolitid in the upper part of the lithosome. The length of the pencil is 14 cm and the length of the metal part of the pencil is 1.7 cm.

rudist fragments and rare corals and gastropods. Coarse bioclastic grains are well-rounded, coated with micrite envelopes and replaced by sparry calcite. The microfacies indicate the dominance of winnowed platform edge environments, where lime mud is removed because of constant wave action, at or above wave base (Wilson, 1975; Flügel, 2004). The rudstone/grainstone microfacies rarely alternates with the 'coral framestone', 'floatstone with rudist fragments and intraclasts' and 'packstone with benthonic foraminifera and rare intraclasts' microfacies (Sarı, 2006b).

3.2. Hippuritid lithosomes

The hippuritid lithosomes are observed within the uppermost part of the approximately 700 m-thick, Middle Cenomanian-Coniacian platform limestones of the Bey Dağları Formation in the Northern Area of the autochthon (Figs. 1 and 2).

Benthonic foraminifera and rudists are the unique fossil components to date the neritic limestones of the Bey Dağları Carbonate Platform in the northern part. The lower part of the neritic limestones, corresponding to the Middle-Upper Cenomanian, is relatively rich in benthonic foraminifera. They are rich in number of individuals but poor in diversity because of the restriction of the environmental conditions. However, the upper part, which corresponds to the Turonian-Coniacian interval, has poor assemblages. *Pseudolituonella reicheli-Pseudorhapydionina dubia* Concurrent Range Zone is defined from the Middle-Upper Cenomanian platform limestones. The biozone includes *Cisalveolina lehneri* Subzone and *Coxites zubairensis* Subzone, which correspond to the Middle Cenomanian and Upper Cenomanian, respectively. The first occurrences of *Moncharmontia apenninica-compressa* and *Pseudocyclammina sphaeroidea* indicate the Late Turonian and the Coniacian, respectively (Sarı et al., 2009).

The Middle Cenomanian-Coniacian neritic limestones of the northern part of the Bey Dağları Autochthon include two main rudist formations. The unique outcrop of the lower rudist formation, which is made up of scarce unidentifiable caprinids and radiolitids, is observed in Sarp Dere (Figs. 1 and 6). The accompanied benthonic foraminifera assemblages suggest a Middle-Late Cenomanian age (Sarı et al., 2009). The level may correspond to the caprinid-bearing neritic limestones of the Karain section.

The best outcrops of the hippuritid lithosomes are observed in the Korkuteli area (i.e. Kargalıköy and Yörükalan sections; Fig. 1). The area was first studied by Poisson (1967) who found *Hippurites* gr. *sulcatus* (Douvillé), *Sauvagesia* cf. *sharpei* (Bayle), *Vaccinites atheniensis* (Ktenas), *Vaccinites* cf. *boehmi* (Douvillé), *Vaccinites* cf. *sulcatus* (Defrance), and suggested that the fauna indicates a Santonian-Early Campanian age. However, our studies show that the level is dominated by *Vaccinites praegiganteus* (Toucas), which is associated with small hippuritids and radiolitids. The 20 m-thick lithosome is separated from the underlying well-bedded limestones by its massive structure. Numerous sections of *Vaccinites praegiganteus* (Toucas) are seen in the lower part of the lithosome,

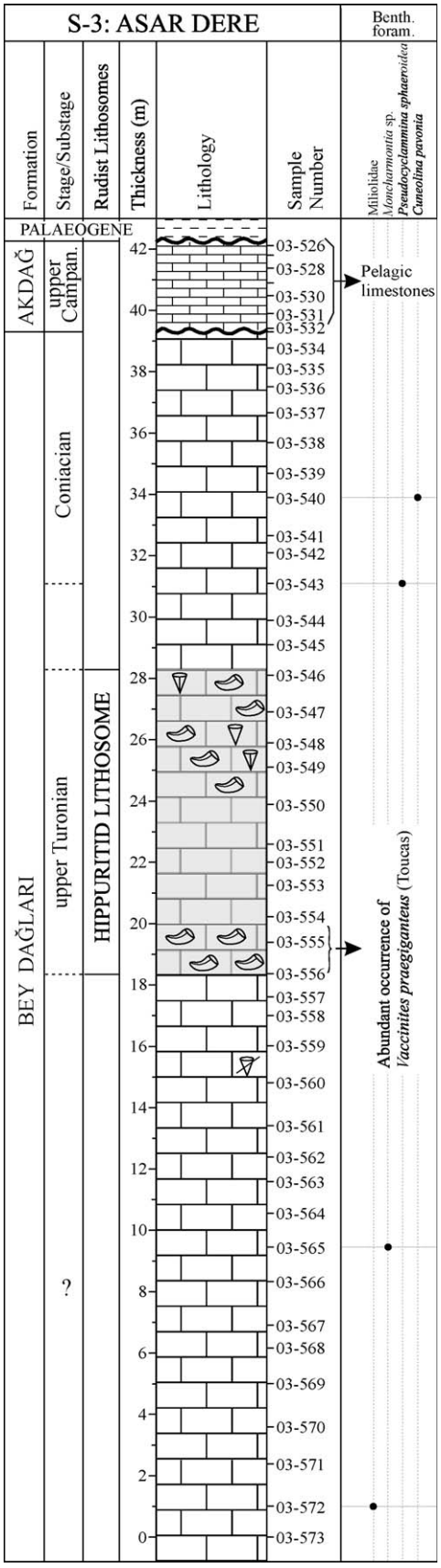

Fig. 9. Measured section at Asar Dere (see Fig. 1B for location of the section and Fig. 3 for explanations).

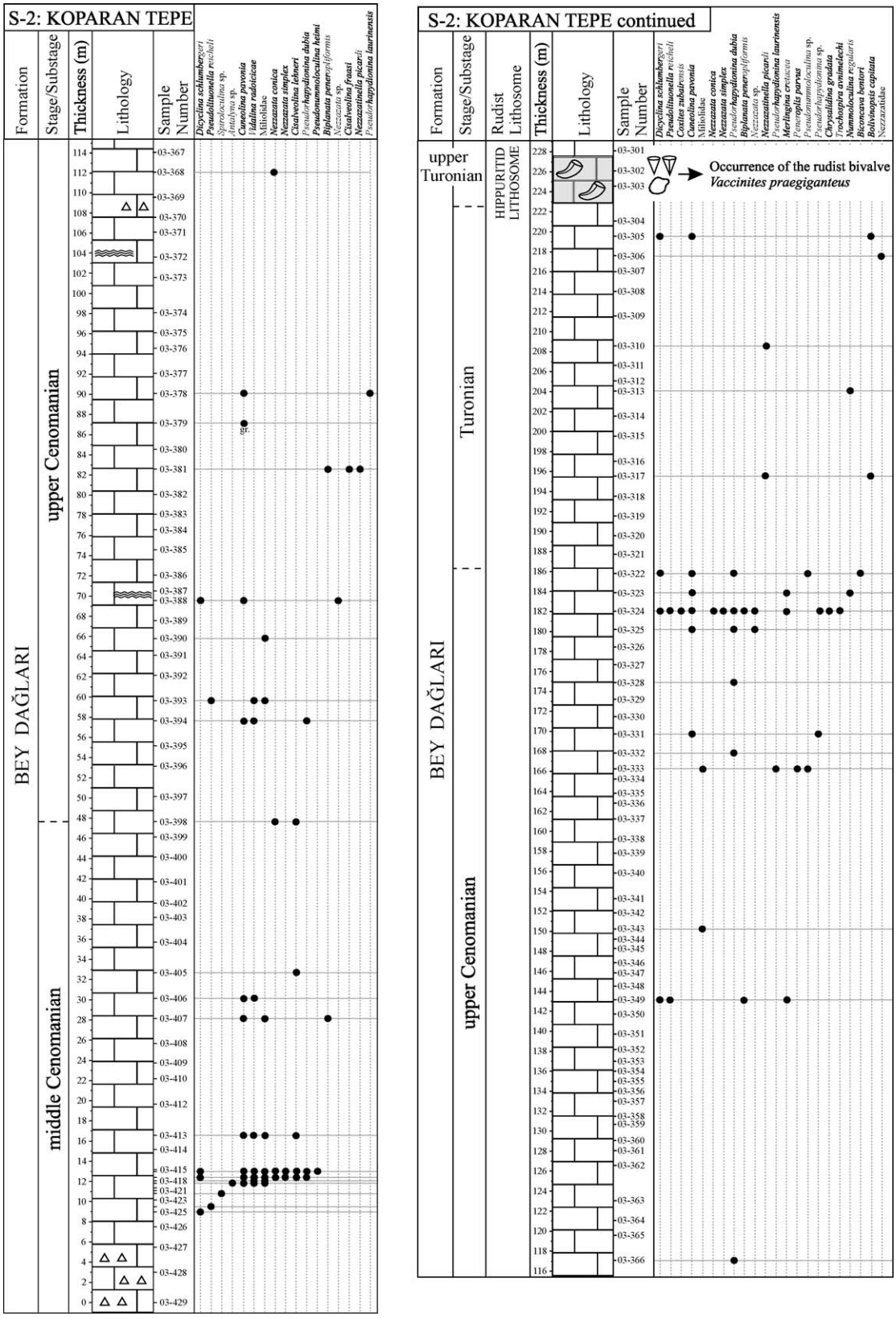

Fig. 10. Measured section at Koparan Tepe (see Fig. 1B for location of the section and Fig. 3 for explanations).

many in growth position in the Kargalıköy section (Figs. 7 and 8). The abundance of *Vaccinites praegiganteus* (Toucas) decreases towards the top of the lithosome, where radiolitids and sparse small hippuritids such as *Hippurites socialis* Douvillé, *Hippuritella resecta* (Defrance) and *Vaccinites inferus* (Douvillé) are observed (Figs. 7 and 8). The lithosome is also observed in the Yörükalan section and east of Ulucak in the Korkuteli area (Fig. 1).

The hippuritid lithosomes were also detected in the Asar Dere, Koparan Tepe and Peçenek Boğazı sections in the northern part of the autochthon (Fig. 1). The 10 m-thick massive lithosome in the Asar Dere section is very similar to that of the Korkuteli area (Fig. 9). The hippuritid lithosomes of the Koparan Tepe and Peçenek Boğazı sections are different in terms of abundance of *Vaccinites praegiganteus* (Toucas), the thickness of the lithosome and the individuals constructing the lithosomes. *Vaccinites praegiganteus* (Toucas) and small-sized hippuritids are scarce in the Koparan Tepe section, where radiolitids and *Distefanella* species are common. The rudist fauna comprising *Vaccinites praegiganteus* (Toucas), *Milovanovicia heraki* Polšak, *Distefanella bassanii* Parona, *Biradiolites angulosus* d'Orbigny, *Hippurites socialis* Douvillé and *Hippuritella resecta* (Defrance) indicates the Late Turonian (Figs. 10 and 11). A similar lithosome was also observed in the middle part of the Peçenek Boğazı section, where a few individuals of *Vaccinites praegiganteus* (Toucas) are associated with a rudist assemblage comprising *Milovanovicia heraki* Polšak, *Distefanella bassanii* Parona, *Biradiolites angulosus* d'Orbigny, *Hippurites socialis* Douvillé and *Hippuritella resecta* (Defrance), which indicates the Late Turonian (Figs. 12 and 13). Correlation of the rudist lithosomes observed in the eastern and northern part of the autochthon is given in Fig. 14.

The species of the hippuritid lithosome, specifically *Vaccinites praegiganteus* (Toucas), *Vaccinites inferus* (Douvillé), *Hippuritella resecta* (Defrance), *Milovanovicia heraki* Polšak, *Distefanella bassanii* Parona and *Biradiolites angulosus* d'Orbigny are characteristic of the Middle-Upper Turonian of the Mediterranean region (Parona, 1901; Toucas, 1903; Douvillé, 1910; Astre, 1954; Plenicăr, 1961; Polšak, 1967;

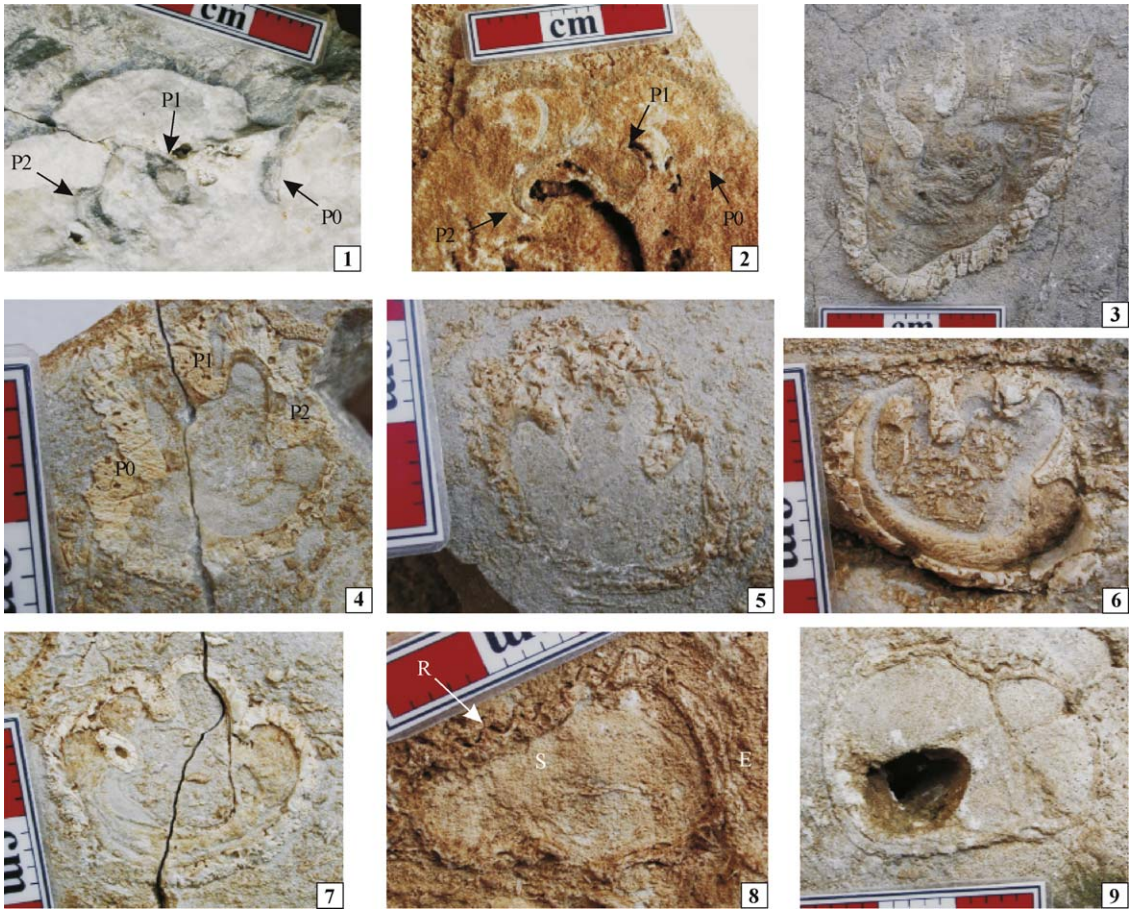

Fig. 11. The hippuritid lithosome in the Koparan Tepe section. **1, 2**. Transverse sections of the right valves of *Vaccinites praegiganteus* (Toucas). The species is characterized by its fused first and second pillars (P1 and P2). Samples no. KO-1 and KO-18 from the same level, respectively. **3**. An oblique section of the right valve of *Vaccinites* sp. Sample no. KO-19. **4**. Transverse section of the right valve of *Hippurites socialis* Douvillé. Note the wide V-shape ligamentary pillar. Sample no. KO-9. **5–7**. Transverse sections of the right valves of *Hippuritella resecta* (Defrance). The ligamentary pillar is short and truncated at its tip. The second pillar is slightly pinched at the base. Samples no. KO-26, KO-17 and KO-10, respectively. **8, 9**. Transverse sections of the right valves of *Distefanella bassanii* Parona. Note the subrectangular section of the valve, the irregular sections of the ridges (R) and flat and/or slightly concave shape of the siphonal bands (S, E), which are characteristic features of the species. Samples no. KO-21 and KO-3, respectively. The total length of the scale is 3 cm; the red/black part of the scale is 1 cm.

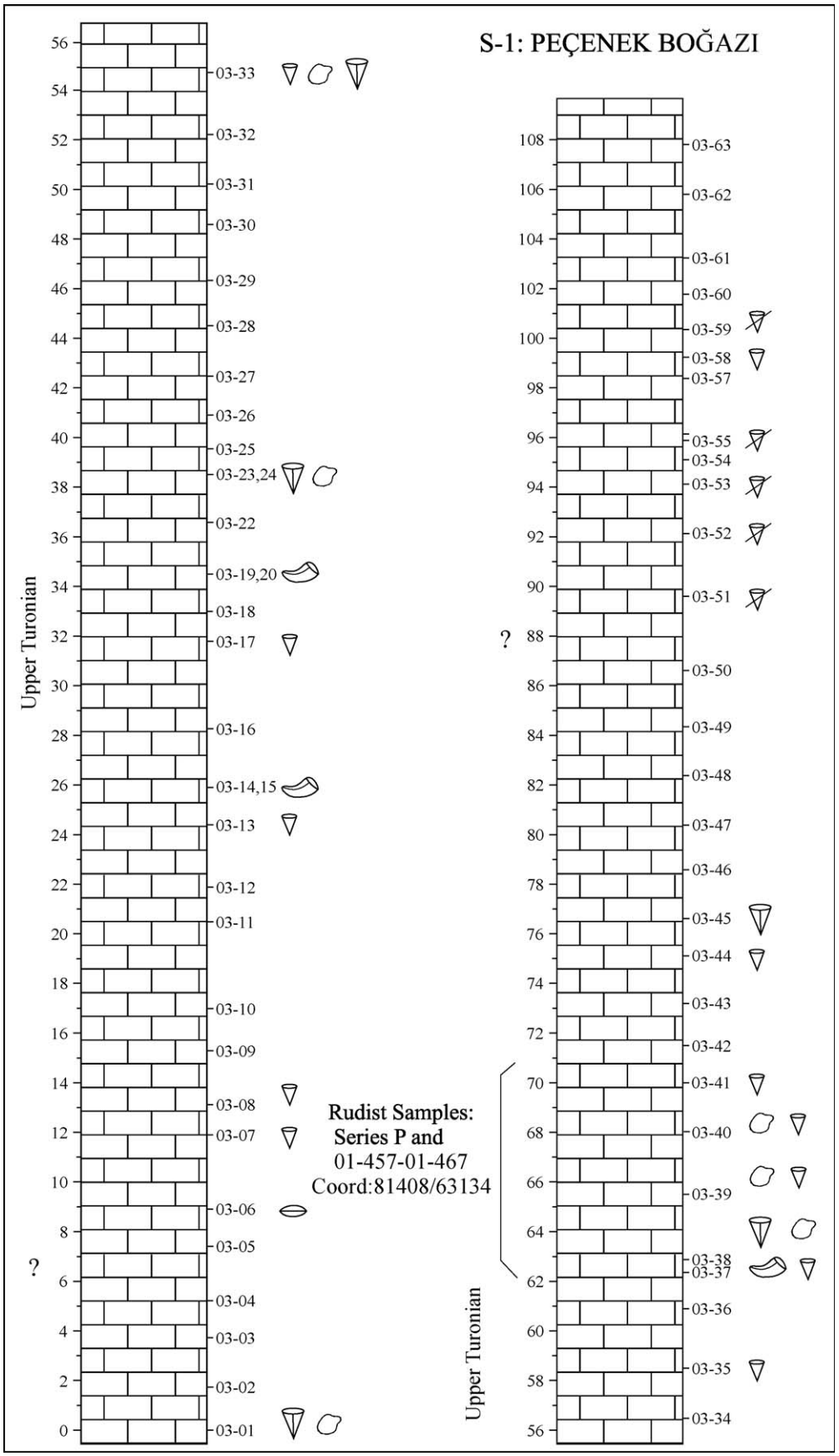

Fig. 12. Measured section at Peçenek Boğazı. The numbers on the left of the lithological column represent thickness in meters (see Fig. 1B for location of the section and Fig. 3 for explanations).

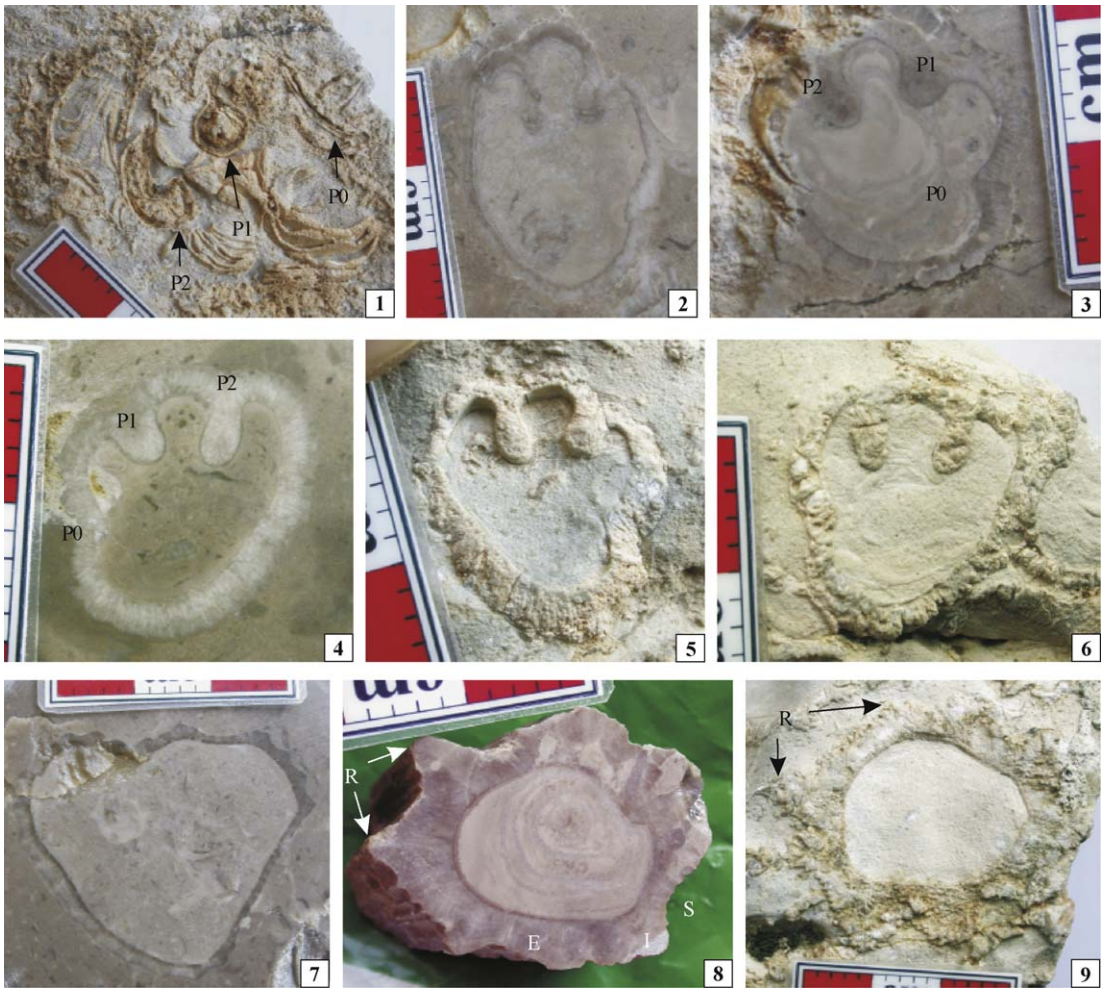

Fig. 13. The hippuritid lithosomes in the Peçenek Boğazı section. **1**. Transverse section of the right valve of *Vaccinites* cf. *praegiganteus* (Toucas). The species is characterized by its pinched first and second pillars (P1 and P2), which tend to be fused, the position of ligamentary pillar (P0) is not clear because of erosion. Sample no. P-100. **2–6**. Transverse sections of the right valves of *Hippurites socialis* Douvillé. Samples no. 01-460, 01-459, P-47, P-5 and P-15, respectively. **7**. Transverse section of the right valve of *Distefanella bassanii* Parona. Sample no. P-44. **8**. Transverse sections of the right valve of *Milovanovicia heraki* Polšak. Note the well-developed rib sections (R), the shape of the siphonal bands (E, S, I), and the compact outer shell layer, which are the characteristic features of the species. **9**. Transverse section of the right valve of *Milovanovicia* sp. Note the rib sections (R). The siphonal bands cannot be observed. Sample no. P-14. The total length of the scale is 3 cm; the red/black part of the scale is 1 cm.

Sliškovic, 1968; Campobasso, 1972; Bilotte and Philip, 1985; Caffau and Plenicăr, 1992; Steuber, 1993a, 1993b, 1999, 2001; Steuber and Höfling, 1999; Simonpiétri et Philip, 2000; see Steuber, 2002 for further occurrences). However, they were also found in Turonian, Coniacian, Santonian and Campanian beds (Toucas, 1907; Astre, 1954; Sliškovic, 1968; Bartov et al., 1972; Bilotte, 1985; Ruberti, 1997; Plenicăr and Jurkovsek, 1998; Carannante et al., 2000; see Steuber, 2002 for further occurrences).

Numerous specimens of *Vaccinites praegiganteus* (Toucas) have been collected from the hippuritid lithosomes of the Korkuteli area (i.e. Kargalıköy and Yörükalan sections). Analysis of geochemically well-preserved low-Mg calcite of shells of *Vaccinites praegiganteus* (Toucas) for $^{87}Sr/^{86}Sr$ values yielded a Late Turonian age (Sarı et al., 2004).

Neritic limestones of the Bey Dağları Formation are mainly accumulated in a platform interior environment that existed from Middle Cenomanian to Coniacian. Microfacies analysis of the neritic limestones indicates peritidal (tidal flat, ponds and channels), subtidal, shelf (restricted circulation), shelf lagoon (open circulation), winnowed edge, organic build up and foreslope environments. The following microfacies have been distinguished belonging to the mentioned environments. These are the main microfacies and they are transitional and intercalated (Sarı and Özer, 2001; Sarı, 2006b):

- laminated peloidal packstone and fenestral mudstone microfacies;
- alternating cryptalgal and laminated peloidal packstone microfacies;
- sparse benthonic foraminifera-bearing non-laminated peloidal packstone/grainstone microfacies;
- rich benthonic foraminifera-bearing wackestone/packstone microfacies;
- rudist fragments-bearing packstone microfacies.

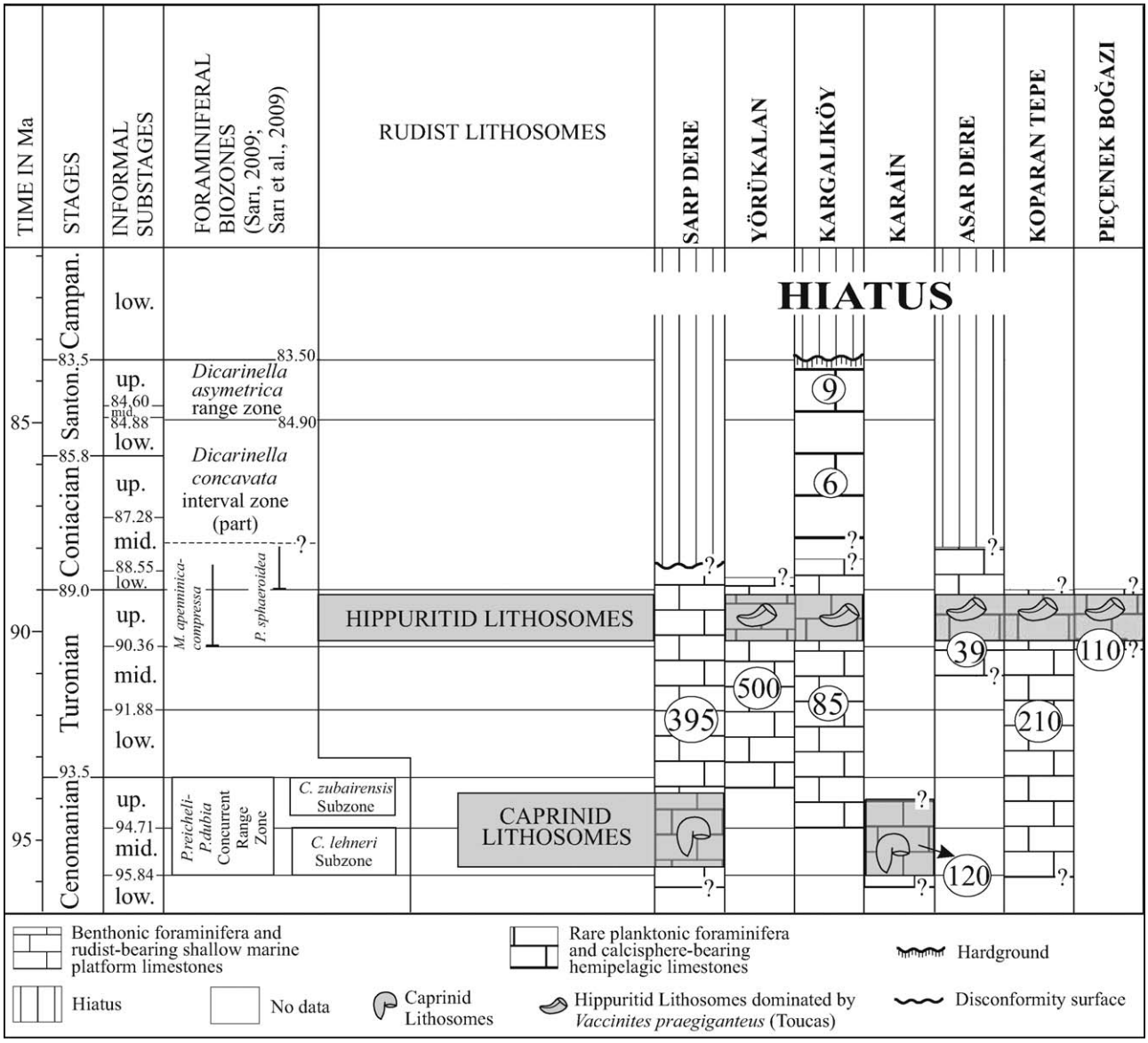

Fig. 14. Chart showing the correlation of the Upper Cretaceous stratigraphic sections measured from the eastern and northern parts of the Bey Dağları Autochthon (between Korkuteli and Çamlıdere). The numbers in circles indicate thickness of the sequence (see Fig. 1B for location of the sections and Fig. 3 for explanations).

The rudist-bearing neritic limestones are capped with 23 m-thick, Coniacian-Santonian hemipelagic limestones. The faunal change after the Late Turonian (probably in the Coniacian) from rudist and benthonic foraminifera to planktonic foraminifera on the northern part of the platform indicates an incipient drowning of the platform. The limestones deposited in hemipelagic conditions are massive, cream-coloured, fractured and contain rare planktonic foraminifera and abundant calcispheres. The neritic and hemipelagic limestones are both massive and cream-coloured and the same in appearance (i.e., textures on broken, fresh surface are the same), hence they are indistinguishable in the field. The maximum thickness of the hemipelagic levels was measured in the Kocaboğaz Dere section and is 23 m. Thin to medium-bedded cherty pelagic limestones of the Late Campanian-Late Maastrichtian Akdağ Formation reach a total thickness of 100 m and disconformably overlie the different stratigraphic levels of the underlying Bey Dağları Formation (Fig. 2).

3.3. Hippuritid-Radiolitid lithosomes

Two rudist associations are present in the Southern Area (Susuzdağ; Bölükkatran section; Figs. 1 and 15–17). The 20 m-thick hippuritid-radiolitid lithosomes are observed at the lowermost part of the 350 m-thick succession and are made up of *Hippuritella variabilis* Munier-Chalmas, *Vaccinites* cf. *chaperi* Douvillé, *Rajka spinosa* Milovanović-Grubic, *Praeradiolites* aff. *subtoucasi* Toucas and unidentifiable radiolitids (Fig. 16). *Rajka spinosa* Milovanović-Grubic has been considered a junior synonym of *Biradiolites chaperi* Douvillé by Pons and Vicens (1986) and according to its shell structure, *Rajka* is certainly a biradiolitid. It is widespread in the

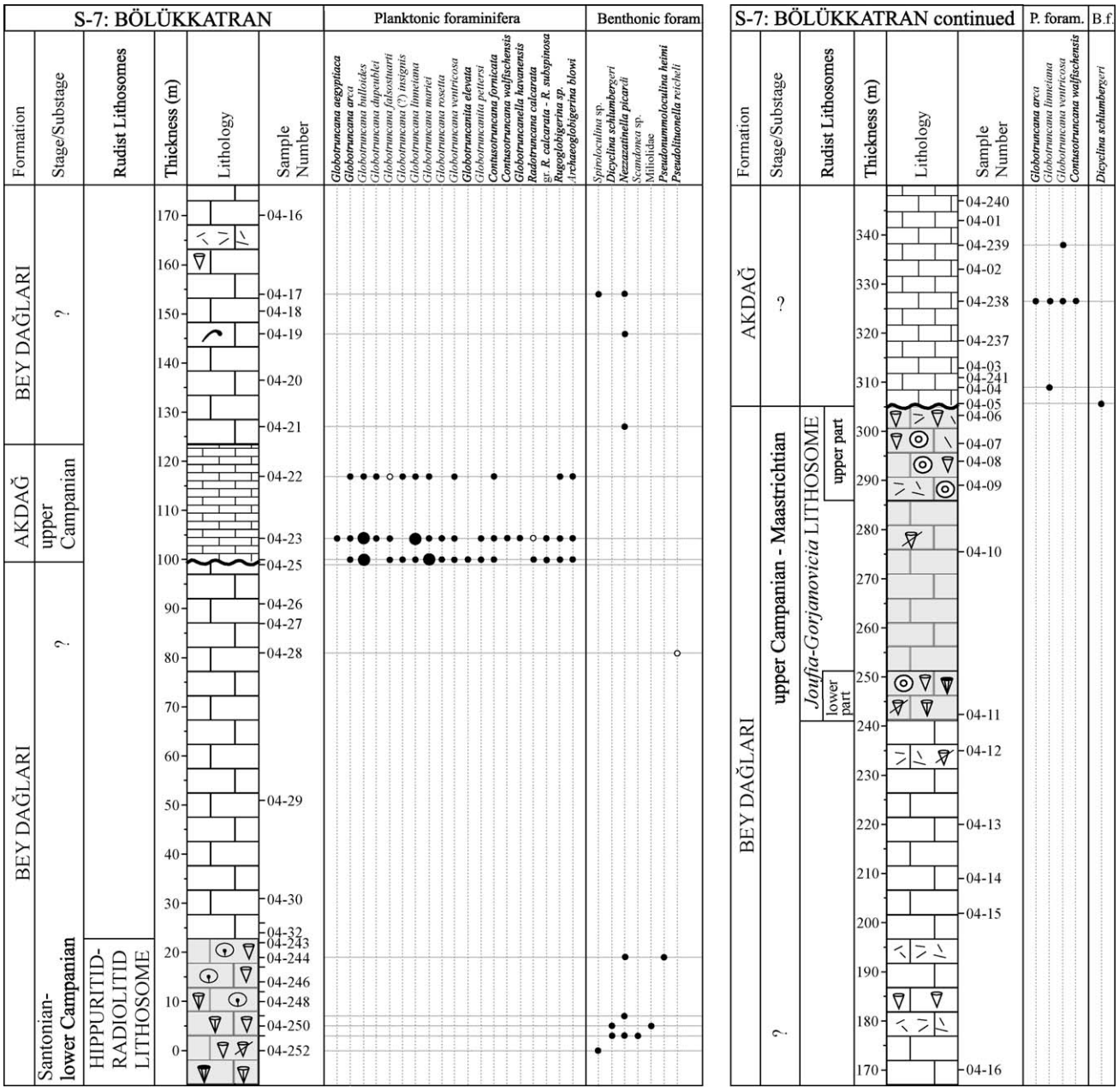

Fig. 15. Measured section at Bölükkatran (see Fig. 1B for location of the section and Fig. 3 for explanations).

Campanian-Maastrichtian successions of Europe and was reported from the Santonian of Greece and Slovenia as well (Milovanović, 1984; Ruberti, 1993; Cherchi et al., 1993; Plenicăr and Jurkovsek, 1996, 1998). *Praeradiolites subtoucasi* Toucas was documented from the Lower Campanian of many European countries (Toucas, 1907; Astre, 1954; Pamouktchiev, 1965; Lupu, 1976; Pons, 1977; Czabalay, 1982; Vicens, 1992) and also from the Upper Campanian-Maastrichtian of the Kocaeli Peninsula, Turkey (Fenerci, 1999a). *Hippuritella variabilis* Munier-Chalmas abundantly occurs in the Campanian of Europe and was also reported from the Coniacian-Maastrichtian (Douvillé, 1892; Pons, 1977; Steuber et al., 1993; Steuber, 1999). *Vaccinites cornuvaccinum-Vaccinites chaperi* lineage is clearly tied to chronostratigraphy by strontium isotope stratigraphy by Steuber (2003), who noted that the range of *Vaccinites chaperi* Douvillé is Late Coniacian-Early Campanian. The stratigraphical distributions of the species of the assemblage from the hippuritid-radiolitid lithosomes suggest a Santonian-Early Campanian age.

3.4. Joufia-Gorjanovicia *lithosomes*

The upper rudist associations (*Joufia-Gorjanovicia* lithosomes) of the Bölükkatran section are observed at the top of the neritic succession and constitute two parts (Fig. 15). The 3 m-thick massive lower part comprises abundant shell fragments of *Joufia reticulata* Boehm, rare *Hippurites heritschi* (Kühn), *Vaccinites* sp. and radiolitids (Figs. 15 and 17). The 10 m-thick

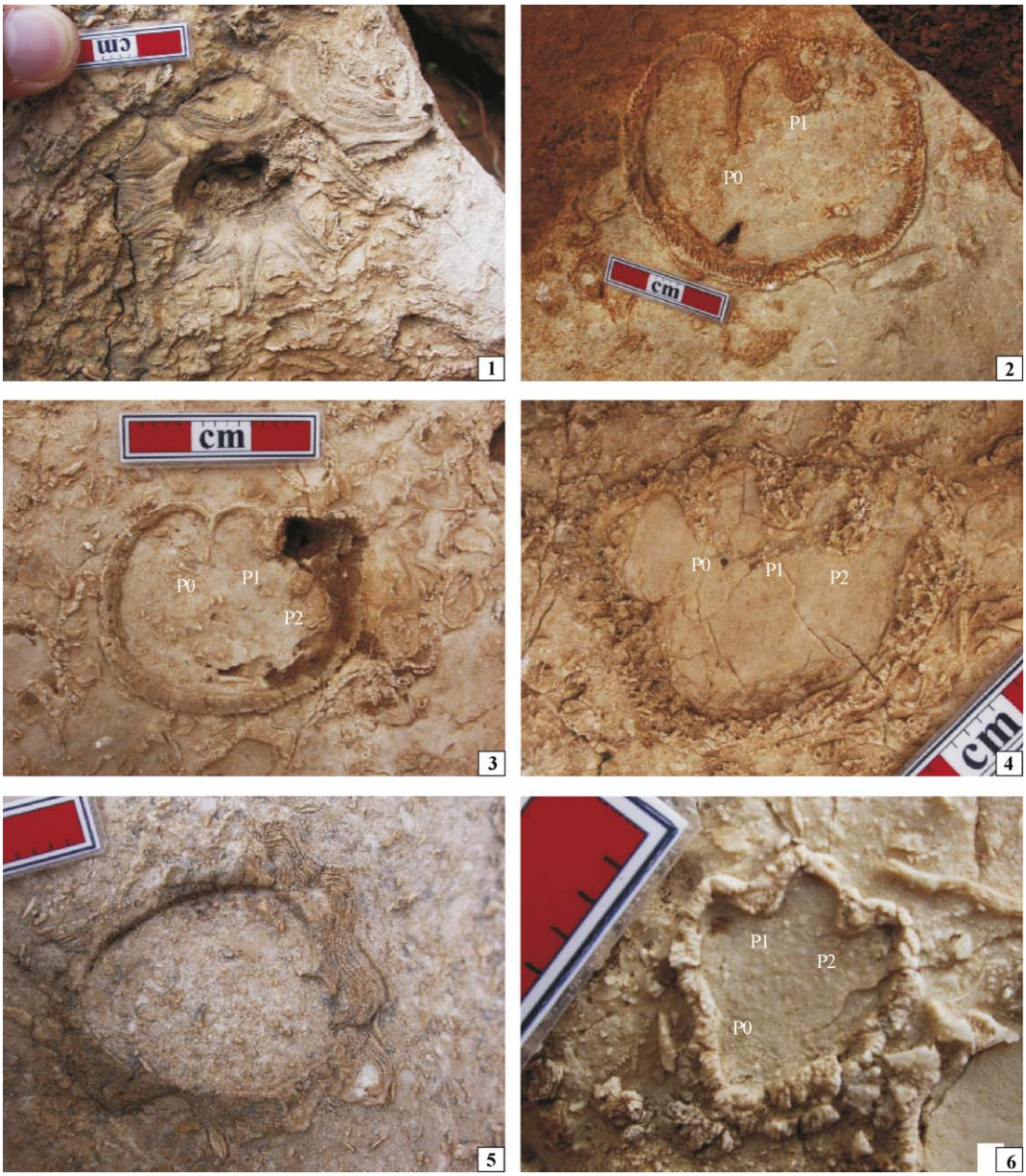

Fig. 16. Rudist assemblages of the hippuritid-radiolitid lithosomes in the Bölükkatran section (see Fig. 15 for the levels where the photographs were taken). **1**. *Rajka spinosa* Milovanović-Grubic. Transverse section of the right valve. Note the strongly developed ridges, which is the characteristic feature of the species. **2, 3**. *Vaccinites* cf. *chaperi* Douvillé. Transverse sections of the right valves. **4**. *Vaccinites* sp. Transverse section of the right valve. **5**. *Praeradiolites* aff. *subtoucasi* Toucas. Transverse section of the right valve. Note the outer shell layer, which is made up of rectangular cells. **6**. *Hippuritella variabilis* Munier-Chalmas. Transverse section of the right valve. Ligamentary pillar (P0) is simple and wide. The first and second pillars (P1 and P2) are slightly developed. Note the scale: the diameter of the right valves of the species is about 1–1.5 cm. The total length of the scale is 3 cm; the red/black part of the scale is 1 cm.

upper part of the lithosomes is dominated by species of *Joufia* and *Gorjanovicia*. The rudist association comprises *Joufia reticulata* Boehm, *Gorjanovicia akyolii* Özer, *Gorjanovicia* cf. *costata* Polšak and *Gorjanovicia lipparinii* Polšak, which suggest a Middle Campanian-Maastrichtian age (Fig. 17). The species of *Gorjanovicia* are observed in the Coniacian-Maastrichtian successions (Polšak, 1967; Özer, 1982, 1988; Sribar and Plenicăr, 1991; Caffau and Plenicăr, 1995; Plenicăr and Jurkovsek, 1998; Fenerci, 1999b). *Hippurites heritschi* (Kühn) was reported from the Campanian-Maastrichtian (Pejović and Kühn, 1960; Pamouktchiev, 1982; Camoin, 1983; Accordi et al., 1989; Plenicăr and Jurkovsek, 1998). *Joufia reticulata* Boehm was also documented from the Campanian-Maastrichtian successions (Tavani, 1958; Pamouktchiev, 1965; Camoin, 1983) and is especially widespread in the Maastrichtian of Turkey (Karacabey, 1972; Özer, 1988). The rudist assemblage suggests that the age of the *Joufia-Gorjanovicia* lithosomes should be Late Campanian-

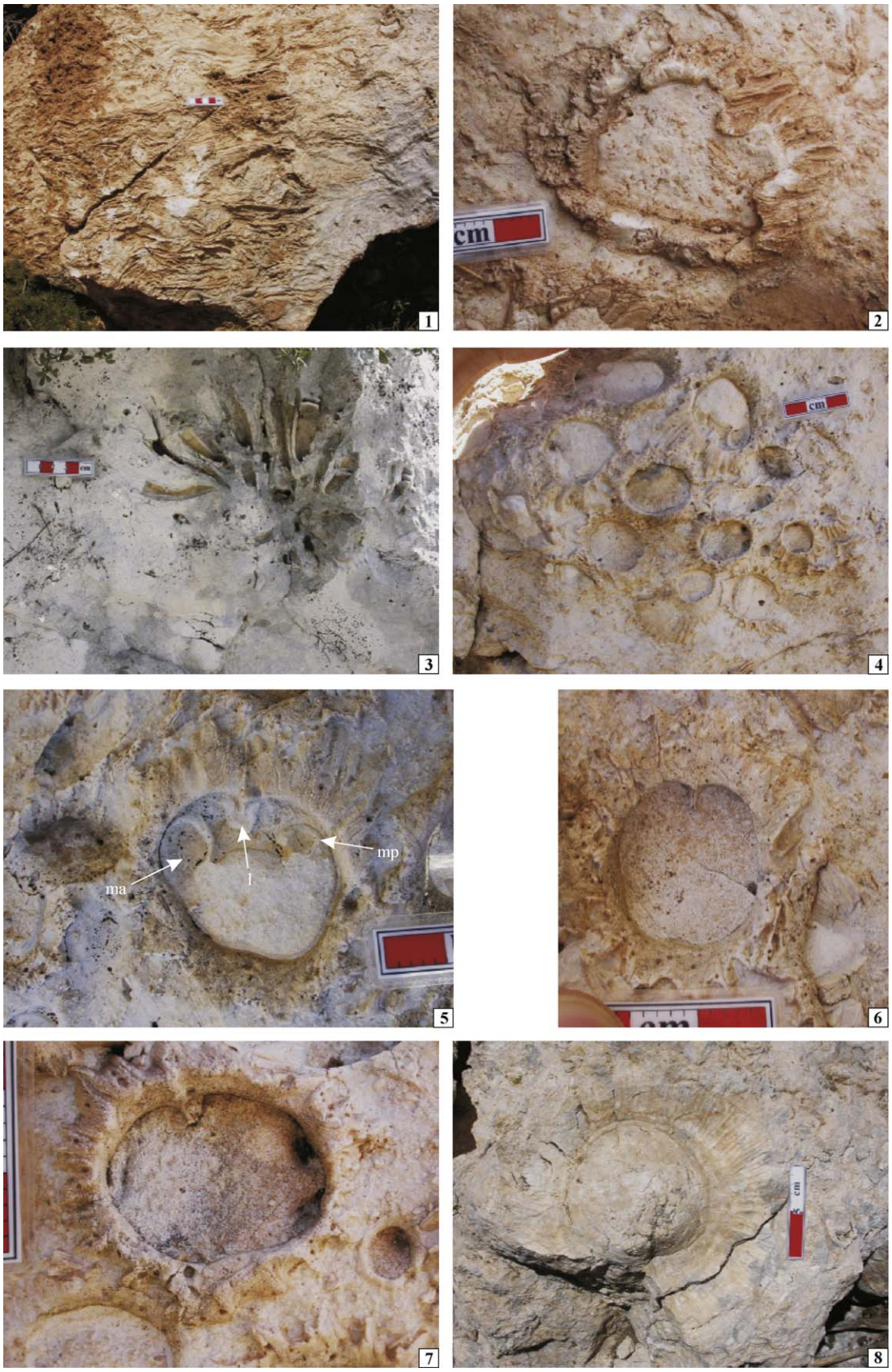

Fig. 17. Outcrop photographs of the *Joufia-Gorjanovicia* lithosomes in the uppermost part of the Bölükkatran section (see Fig. 15 for the levels where the photographs were taken). **1**. Massive bed comprising abundant shell fragments of *Joufia* (lower part of the lithosomes). The total length of the scale is 5 cm. **2**. *Hippurites heritschi* (Kühn) (lower part of the lithosomes). Transverse section of the right valve. The length of the red/black part of the scale is 1 cm. **3**. A "bouquet" of *Gorjanovicia* in growth position (upper part of the lithosomes). The total length of the scale is 5 cm. **4**. Monospecific community consisting of individuals of

Maastrichtian. This age is confirmed by the Upper Campanian pelagic level, which underlies the rudist-bearing neritic limestones (Fig. 15).

The platform limestones in the Southern Area (Susuzdağ) are mainly represented by calcarenites with poor long-ranged benthonic foraminiferal associations. Field observations and microscopic studies on the neritic limestones of the Bölükkatran section suggest peritidal, subtidal, shelf (restricted circulation), shelf lagoon (open circulation), winnowed edge, organic build up and foreslope environments from Santonian to the Maastrichtian. The main microfacies observed in the Susuzdağ area are (Sarı, 2006b):

- ostracod mudstone with loferites;
- mudstone with algal stromatolites and loferites. This microfacies sometimes shows alternations with rare ostracod mudstone with abundant patchy cyanobacterial mats;
- peloidal packstone/wackestone with loferites. This microfacies sometimes grades into alternation of peloidal packstone/mudstone with cryptalgal laminae and rare thin-shelled ostracods;
- oncoid wackestone with abundant thin shells;
- peloidal packstone/grainstone with rare ostracods;
- wackestone/packstone with benthonic foraminifera, dasycladacean algae and *Thaumatoporella* sp.;
- floatstone with abundant rudist and non-rudist bivalve fragments;
- laminated, cross-bedded or unlaminated rudstone/grainstone/packstone with abundant rudist fragments and intraclasts;
- packstone to rudstone with *in situ* rudists. The widespread occurrence of loferites and laminated, cross-bedded or unlaminated grainstone and rudstone microfacies with abundant rudist fragments indicates the dominance of intertidal and winnowed edge environments.

4. Conclusions

Despite numerous rudist occurrences throughout the Bey Dağları Autochthon, there have been rather scarce studies dealing with the rudist biostratigraphy. As the benthonic foraminiferal assemblages within the Upper Cretaceous platform limestones (especially the post Cenomanian part) are generally poor in the Bey Dağları Autochthon, the biostratigraphy has to rely on rudist bivalves. This study reveals the presence of four rudist lithosomes from three geographical areas of the Bey Dağları Autochthon. The oldest rudist assemblages (caprinid lithosomes) have been observed in the Eastern Area (Katran Dağ). The lithosomes are represented by the abundance of caprinids, which suggest a Middle-Late Cenomanian age. The accompanying benthonic foraminiferal assemblages confirm the Middle-Late Cenomanian age. The Upper Turonian hippuritid lithosomes are characterised by dominance of *Vaccinites praegiganteus* (Toucas) determined from the Northern Area. The best outcrops of the lithosomes are observed in the Korkuteli area; they patchily occur throughout the northernmost part of the autochthon between Korkuteli and Çamlıdere as a key marker level. Two of the lithosomes are detected in the Southern Area (Susuzdağ), where the Upper Cretaceous successions are represented by shallow-water platform limestones. The hippuritid-radiolitid lithosomes from the lowermost part of the sequence is represented by mainly hippuritids and radiolitids, which yield a Santonian-Early Campanian age. The uppermost part of the section is characterized by the presence of the *Joufia-Gorjanovicia* lithosomes. The rudist fauna and the underlying pelagic incursion suggests a Late Campanian-Maastrichtian age for the youngest rudist lithosomes.

Presence of rudist-bearing Santonian-Early Campanian and Late Campanian-Maastrichtian neritic limestones in the Southern Area shows that the platform conditions are dominant throughout the Late Cretaceous in the southern part of the platform while the northern part drowned after the Turonian (during the Coniacian).

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Gorjanovicia akyolii Özer (upper part of the lithosomes). The total length of the scale is 3 cm. **5**. *Gorjanovicia akyolii* Özer (upper part of the lithosomes). Transverse section of lower valve. Ligamentary pillar (l) and myocardinal elements (ma, mp) are clearly observed. The length of the red/black part of the scale is 1 cm. **6**. *Gorjanovicia lipparinii* Polšak (upper part of the lithosomes). Transverse section of the right valve. The length of the red/black part of the scale is 1 cm. **7**. *Gorjanovicia* cf. *costata* Polšak (upper part of the lithosomes). Transverse section of the right valve. The length of the red/black part of the scale is 1 cm. **8**. *Joufia reticulata* Boehm (upper part of the lithosomes). Upper view of the left valve of the species. Radial canals of the left valve can be observed beneath the eroded parts of the left valve. The total length of the scale is 10 cm.

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