

First record of Upper Turonian rudists (Mollusca, Hippuritoidea) in the Bey Dağları carbonate platform, Western Taurides (Turkey): taxonomy and strontium isotope stratigraphy of *Vaccinites praegiganteus* (Toucas, 1904)

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Abstract

The uppermost part of the Upper Cretaceous platform carbonates of the Bey Dağları Autochthon in the Korkuteli, Turkey, area is characterised by an association of hippuritid and radiolitid rudist bivalves dominated by *Vaccinites praegiganteus* (Toucas). A Late Turonian age is indicated by ⁸⁷Sr/⁸⁶Sr values of well-preserved low-Mg calcite of the shells and agrees with the stratigraphical range of the species in the western and central Mediterranean region. This is the first record of Upper Turonian rudists from Turkey. Right valves of 17 specimens of *V. praegiganteus* from Bey Dağları have been analysed morphometrically and are compared with previously reported specimens from the central and western Mediterranean. Most of the specimens from Turkey differ in having fused posterior pillars.

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1. Introduction

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). The widespread Late Cretaceous carbonate platforms of the Tethyan Realm hosted congregations of elevator rudist bivalves (mainly hippuritids and radiolitids) (Ross and Skelton, 1993; Philip et al., 1995; Gili et al., 1995), which are regarded as good palaeobiogeographic indicators as they showed broad geographical extent, rapid evolutionary rate and relatively wide ecological diversity (Philip, 1982).

A precise Upper Cretaceous biostratigraphy based on hippuritid rudists was established in the western

Mediterranean region (Philip et al., 1983; Pascual et al., 1989; Philip, 1998; Vicens et al., 1998; Simonpiétri and Philip, 2000). Pronounced endemism of rudist faunas of this region (Pons and Sirna, 1992) does not permit application of this zonation to the central and eastern Mediterranean, where the biostratigraphy of post-Cenomanian Cretaceous carbonate platforms is generally difficult due to long ranges of benthic microfossils and the lack of fossils that provide a precise biostratigraphy in other depositional settings. After initial attempts at strontium isotope stratigraphy (SIS) of Late Cretaceous rudist shells (Swinburne et al., 1992; Swinburne and Noacco, 1993), the method has been improved by modern data on the evolution of the ⁸⁷Sr/⁸⁶Sr ratio of seawater (McArthur et al., 1994, 2001) and rigorous assessment of diagenetic alteration (McArthur, 1994) so that precise numerical ages were obtained recently for rudist formations of Germany and Austria (Gosau-type rudist formations; Steuber, 2001), Spain, Greece, Turkey and United Arab Emirates (Steuber,

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2003), and the Caribbean (Steuber et al., 2002). This resulted in a revision of stratigraphical ranges of numerous species and suggests that the history of many Late Cretaceous carbonate platforms must be re-evaluated.

Late Cretaceous platform carbonates of the Bey Dağları autochthonous unit (Fig. 1) have been the subject of many stratigraphic and tectonic studies (Özgül, 1976; Poisson, 1977; Gutnic et al., 1979; Farinacci and Köylüoğlu, 1982; Farinacci and Yeniay, 1986; Özkan and Köylüoğlu, 1988; Naz et al., 1992; Robertson, 1993; Sari and Özer, 2001, 2002). The biostratigraphy of the Cenomanian part of the sequence is well established (Bignot and Poisson, 1974; Farinacci and Yeniay, 1986; Özer, 1988; Sari and Özer, 2001, 2002) from the comparison of rudists and benthic foraminiferal faunas which are widely distributed on the extensive carbonate platforms along the northern and southern borders of the Tethyan Realm (Philip,

1982; Floquet et al., 1987; Philip and Airaud-Crumière, 1991). However, only very limited biostratigraphical data are available concerning the post-Cenomanian neritic carbonates of the platform (Poisson, 1967, 1977; Sari and Özer, 2001, 2002) and interpretations of the evolution of the platform have been largely based on planktonic foraminifera from overlying pelagic carbonates.

2. Regional geological setting

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

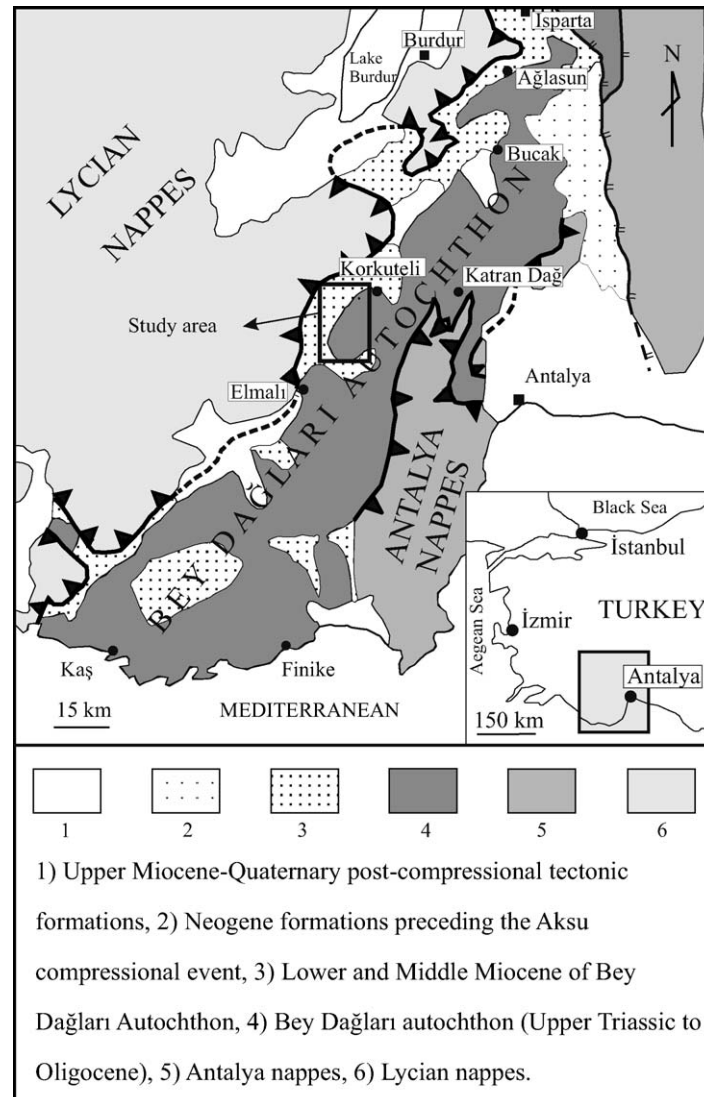


Fig. 1. Main tectonic belts of the western Taurides (simplified from Poisson et al., 1983) and the location of the study area.

in the northwest, and is partially exposed in the Göcek window (Özgül, 1976; Poisson, 1977; Farinacci and Köylüoğlu, 1982; Naz et al., 1992; Robertson, 1993) (Fig. 1). During the Mesozoic, 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 (Farinacci and Köylüoğlu, 1982; Farinacci and Yeniay, 1986).

The Bey Dağları autochthon was under the effect of different tectonic regimes during the Late Cretaceous (Poisson, 1977; Poisson et al., 1983; Robertson, 1993). Many published and unpublished studies have shown that the Upper Cretaceous sequences are characterised by breaks in deposition and important facies variations in both neritic and pelagic carbonates. Therefore, each individual area has its own characteristics and should be studied in detail to shed light on the overall Late Cretaceous evolution of the Bey Dağları carbonate platform. The Korkuteli area, which is the focus of the present study, corresponds to the middle part of this autochthonous unit (Figs. 1, 2).

3. Stratigraphy of the Korkuteli area

In the Korkuteli area (Fig. 2), important sedimentary breaks and facies changes relating to the evolution and drowning of the Late Cretaceous carbonate platform are recognized.

The Middle Cenomanian–Upper Santonian Bey Dağları Formation forms the base of the sequence and is disconformably overlain by the Middle Campanian–Lower Maastrichtian pelagic Akdağ Formation above an erosional surface. Palaeogene pelagic marls disconformably overlie the different stratigraphic levels of the Upper Cretaceous succession (Fig. 3).

The Bey Dağları Formation is made up of neritic and hemipelagic limestones. The neritic part accumulated in a peritidal environment that prevailed from the Middle Cenomanian to the Late Turonian and constitutes an approximately 600-m-thick sequence. The facies characteristics of the monotonous neritic limestones were discussed in detail elsewhere (Sarı and Özer, 2001). Two main rudist formations are of Middle Cenomanian and Late Turonian age, respectively (Figs. 2–4). The older level is made up of scattered caprinids and radiolitids (caprinid–radiolitid lithosomes) and occurs very close to the bottom of the sequence.

Benthonic foraminifers such as *Chrysalidina gradata* d'Orbigny, *Pseudolituonella reicheli* Marie, *Pseudorhapydionina dubia* (de Castro), *P.* cf. *laurinensis* (de Castro), *Sellialveolina viallii* (Colalongo), *Nummoloculina* sp., *Nezzazata* sp. and *Cuneolina* sp., accompany the rudists and indicate the Middle–Late Cenomanian. The lower level with *S. viallii* (Colalongo) corresponds

to the Middle Cenomanian, and the upper level with *P. laurinensis* (de Castro) is of Late Cenomanian age (Bignot and Poisson, 1974). While the Cenomanian can be recognized and subdivided by means of benthic foraminifera, this is not possible for the Turonian, and biostratigraphy has to rely on rudist bivalves. Özer (1988) described Cenomanian rudist associations from Katran Dağ (formerly Sam Dağ). Poisson (1967) determined *H. gr. sulcatus* (Douvillè), *Sauvagesia* cf. *sharpei* (Bayle), *V. atheniensis* (Ktenas), *V. cf. boehmi* (Douvillè), and *V. cf. sulcatus* (Defrance) from the region of Korkuteli (Fedil dere), and suggested that the fauna indicates a Santonian–Early Campanian age. Recently, Sarı and Özer (2002) described a rudist fauna from the same locality and mentioned *V. taburni* (Guiscardi), *Hippurites nabresinensis* Futterer and *H. colliciatius* Woodward, suggesting a Santonian–Campanian age. The fauna has now been restudied here with the result that *V. atheniensis* (Ktenas) of Poisson (1967) and *V. taburni* (Guiscardi) of Sarı (1999) and Sarı and Özer (2002) are re-assigned to, and fall within the range of variability of *V. praegiganteus*. A few small hippuritids and some radiolitids accompany *V. praegiganteus* in the upper rudist level (hippuritid–radiolitid lithosomes).

Massive hemipelagic limestones gradationally overlie the Upper Turonian neritic rudist limestones. The limestones include a planktonic foraminifera fauna which indicates the *Dicarinella concavata* and *Dicarinella asymetrica* zones, and thus suggests a period of platform drowning during the latest Turonian or earliest Coniacian according to the zonal schemes of Robaszynski and Caron (1995).

4. Strontium-isotope stratigraphy

4.1. Methods

Samples were drilled with tungsten instruments (0.6 mm diameter) from polished transverse sections of the outer-shell layer of *V. praegiganteus*. Element concentrations were analysed with ICP-AES (inductively coupled plasma-atomic emission spectrometry) on 1 mg of split samples, and the remaining sample powder was used for Sr isotope analyses. Sr was separated by standard ion-exchange methods, and isotope ratios were analysed on a Finnigan MAT 262 thermal-ionisation mass spectrometer. Isotope ratios were normalized to an $^{86}\text{Sr}/^{88}\text{Sr}$ value of 0.1194. The mean of $^{87}\text{Sr}/^{86}\text{Sr}$ of modern seawater (USGS EN-1) measured in 2002 at the Bochum isotope lab is 0.709143 ($n=34$, 2 s.e. [standard error]= 13×10^{-7}), and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of samples are adjusted by $+32 \times 10^{-6}$ to a value of 0.709175 of USGS EN-1, to derive numerical ages from the “look-up” table of McArthur et al. (2001). Interlaboratory comparison has proven the correctness of this approach. The value

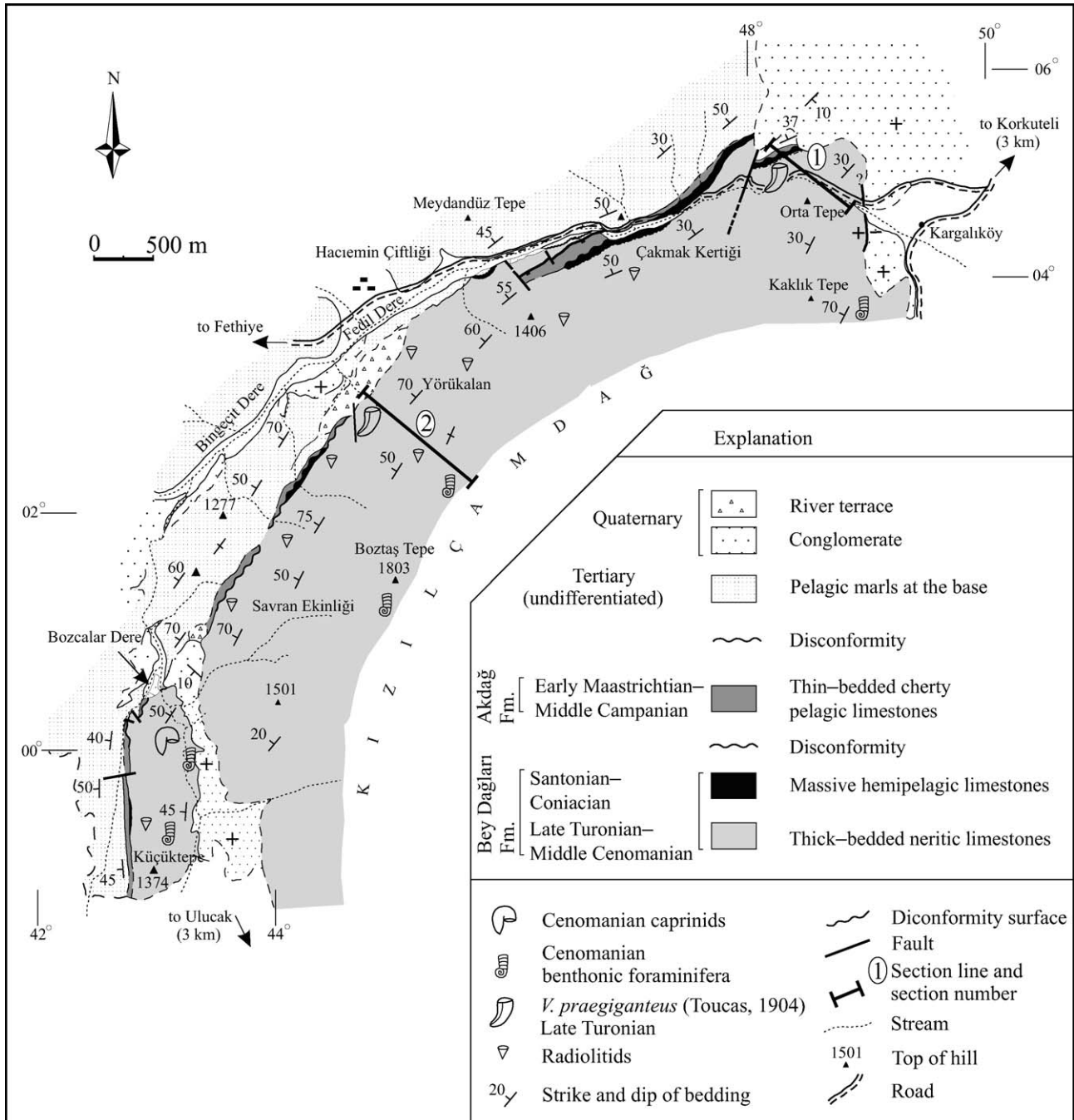


Fig. 2. Geological map of the Korkuteli area (between Korkuteli and Ulucak).

of a single standard run together with samples analysed for the present study is 0.709141 (2 s.e. = 7×10^{-6}). Numerical ages are derived from McArthur et al. (2001).

4.2. Preservation of seawater $^{87}\text{Sr}/^{86}\text{Sr}$ values

High Mn and Fe concentrations in biological calcite are generally considered to indicate diagenetic alteration of original chemical and isotopic composition (McArthur, 1994). While all analysed samples match this criterion of being well preserved, only two samples have

Sr concentrations of more than 1000 $\mu\text{g/g}$ (Table 1), which are characteristic of unaltered low-Mg calcite of Late Cretaceous rudist shells (Steuber, 2002a; Steuber and Veizer, 2002). This indicates that alteration involved equilibration with diagenetic waters under oxic conditions, without gain of Mn and Fe, but with a loss of Sr. There is a clear trend of increasing $^{87}\text{Sr}/^{86}\text{Sr}$ values with decreasing Sr concentrations (Fig. 5), indicating the typical pattern of a diagenetic shift to more radiogenic Sr isotopic compositions than that of seawater (McArthur, 1994; Jones and Jenkyns, 2001).

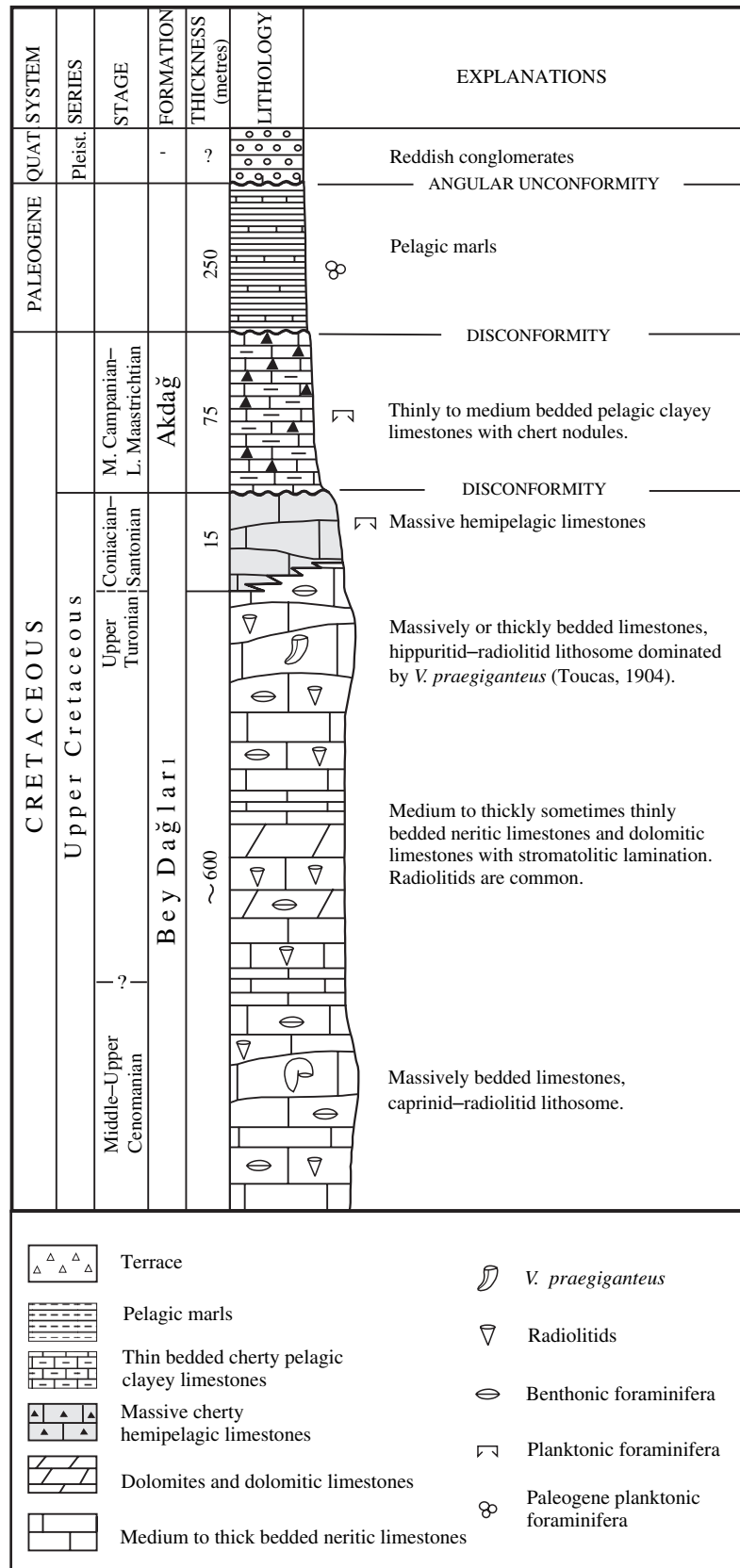


Fig. 3. Generalized columnar section of the study area (see Fig. 2 for rudists).

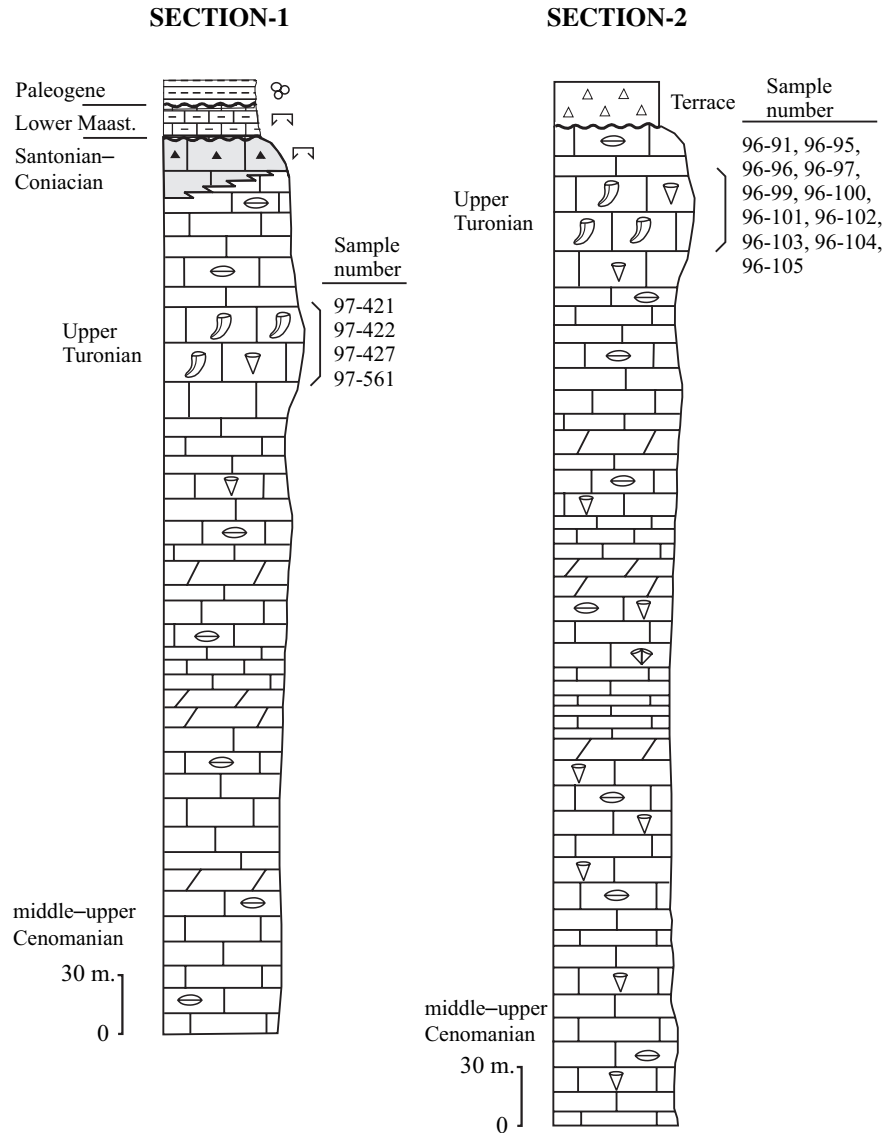


Fig. 4. Measured sections showing the stratigraphic level of the hippuritid–radiolitid lithosome with *Vaccinites praegiganteus* (Toucas, 1904). See Fig. 2 for the location of the sections and Fig. 3 for key.

4.3. Numerical age

The mean ⁸⁷Sr/⁸⁶Sr value of the two samples that are considered to be least diagenetically altered (0.707293; Table 1) is slightly lower than the Upper Cretaceous

minimum of 0.707294 (Fig. 6) which is reported from the Upper Turonian (McArthur et al., 2001), and constrained by relatively few data from the US Western Interior (McArthur et al., 1994). The numerical age range of 89.11–90.10 Ma (Table 1) for specimen no.

Table 1 Analytical results of low-Mg calcite in samples from outer shell layers of *V. praegiganteus*

Locality sample no.	⁸⁷ Sr/ ⁸⁶ Sr	± 2 s.e. (× 10 ⁻⁶)	⁸⁷ Sr/ ⁸⁶ Sr (mean)	Age (Ma)	Sr (µg/g)	Mg (µg/g)	Fe (µg/g)	Mn (µg/g)
96-97/1	0.707292	7			1343	1418	8	0
96-97/2	0.707294	7	0.707293	> 89.11 < 90.10	1442	2373	0	0
96-98/1	0.707400	7			244	2285	0	0
96-98/2	0.707322	7			517	4981	0	0
96-100/2	0.707340	7			332	3697	0	0

Numerical age derived after Howarth and McArthur (1997, version 3:10/99; McArthur et al., 2001) from mean value of two samples with high Sr concentrations which are believed to have retained the original Sr-isotopic composition.

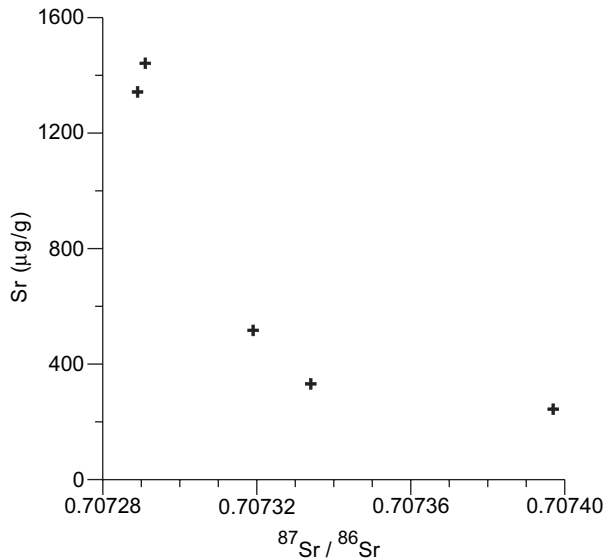


Fig. 5. Sr concentration and $^{87}\text{Sr}/^{86}\text{Sr}$ values in samples of low-Mg calcite of shells of *Vaccinites praegiganteus* (cf. Table 1).

96–97 from section two (Figs. 2, 4) is obtained from the “look-up” table from the mean $^{87}\text{Sr}/^{86}\text{Sr}$ value disregarding analytical uncertainty. As diagenesis shifts the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio to higher values (Fig. 5), a Late Turonian age, i.e. a stratigraphic position near the Upper Cretaceous minimum is well constrained (Fig. 6). Slightly lower $^{87}\text{Sr}/^{86}\text{Sr}$ values than those given for the Upper Cretaceous minimum by McArthur et al. (2001) have also been reported from Late Turonian rudist formations of the Northern Calcareous Alps (Steuber, 2001).

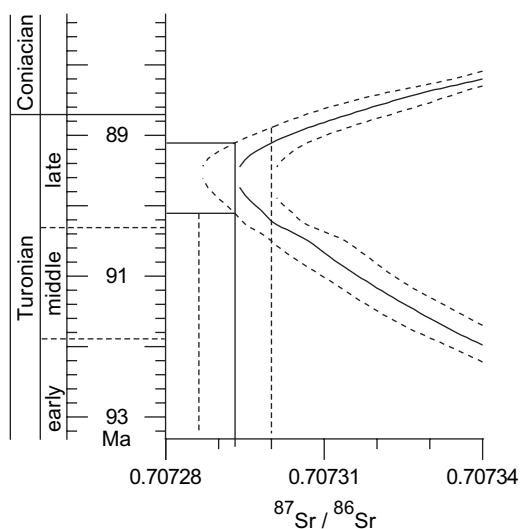


Fig. 6. Variations in $^{87}\text{Sr}/^{86}\text{Sr}$ values of Turonian–Coniacian seawater (from McArthur et al., 2001). Bold curve indicates mean value and broken lines the 95% confidence limits. Bold vertical line is mean value of two well-preserved samples (Table 1), and dashed vertical lines are 2 s.e. of mean value.

5. Systematic palaeontology

The repository of the specimens is the Geological Engineering Department, Dokuz Eylül University, İzmir, Turkey.

Family: Hippuritidae Gray, 1848

Genus: *Vaccinites* Fischer, 1887

Type species: *Hippurites cornuvaccinum* Bronn, 1831

Vaccinites praegiganteus (Toucas, 1904)

Figs. 12–14

- 1904 *Vaccinites praegiganteus* Toucas, p. 91, pl. 13, fig. 2, 2a, text-figs. 142, 144, 145.
- 1926 *Hippurites* (*Vaccinites*) *praegiganteus* Parona, p. 23, pl. 1, fig. 5a, b; pl. 2, fig. 2.
- 1933 *Vaccinites inferus* var. *praegiganteus* Toucas; Antonini, p. 88.
- 1933 *Vaccinites* cf. *praegiganteus* Toucas; Antonini, p. 88, pl. 8, figs. 5, 6.
- 1959 *Hippurites* (*Vaccinites*) *praegiganteus* Toucas; Polšak, pp. 61, 73, pl. 3, figs. 2, 3.
- ? 1975 *Hippurites* (*Vaccinites*) *praegiganteus* Toucas; Plenar, pp. 93, 109, pl. 4, figs. 1, 2; pl. 5, figs. 1, 2.
- 1984 *Pseudovaccinites inferus* (Douvillé) var. *praegiganteus* Toucas; Bilotte, pl. 41, fig. 1.
- 1993 *Vaccinites praegiganteus* (Toucas) var. *glaensis* n. var. Steuber, p. 46, text-figs. 6g–h, 8/8.
- 1993 *Vaccinites praegiganteus* (Toucas); Steuber, p. 46, text-figs. 6a–h, 8/6.
- 1999 *Vaccinites praegiganteus* (Toucas); Steuber, p. 178, pl. 21, fig. 3.
- 1999 *V. praegiganteus* Toucas; Simonpiétri, fig. 23, LA 14, LA 19, pl. 5, figs. 1–12; pl. 6, figs. 1–6.
- 2000 *V. praegiganteus* Toucas; Simonpiétri and Philip, p. 722, text-figs. 2, 3.

Material. Seventeen incomplete right valves from three different localities in the Korkuteli area. Four from the west of Kargalköy (97-421, 97-422, 97-427, 97-561), 11 from Yörükalan locality (96-91, 96-95–96-97, 96-99–96-105) and two from the east of Ulucak village (U-4, U-5) (Figs. 2, 4).

Left valves could not be studied and the length of the complete right valves could only be estimated because all the specimens are incomplete.

Morphometric analysis. Explanations of measurements applied to the transverse sections of the *V. praegiganteus* are given in Fig. 7. Many different measurement techniques have been applied to the Hippuritidae (van Dommelen, 1971; Skelton and Wright, 1987; Laviano and Guarnieri, 1989; Reali, 1992; Vicens, 1992).

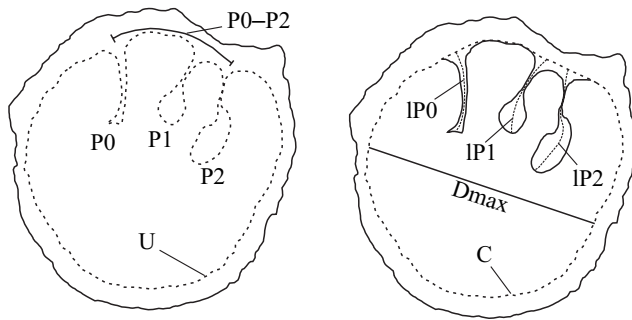


Fig. 7. Explanation of measurements on transverse sections of right valves of *Vaccinites praegiganteus* (Toucas, 1904). P0, ligamentary pillar; P1, first pillar; P2, second pillar; IP0, IP1, IP2, lengths of pillars; P0–P2, distance between P0 and P2; U, contour of the inner margin of the outer shell layer (dotted line); C, circumference of the inner margin of the outer shell layer (dotted line); Dmax, maximum diameter.

The most reliable and comprehensive approaches were made by Steuber (1999), Simonpiétri (1999) and Simonpiétri and Philip (2000). The approach of Steuber (1999) is followed herein.

All measurements have been made from polished transverse sections of the right valves. Transverse sections were cut exactly perpendicular to the growth axis. Because all specimens are broken, only four shells are available to observe the ontogenetic development by cutting successive growth stages (Fig. 8). The contour (U) reflects the original length of the mantle margin and is considered to be a more precise parameter of size than the diameter of shells (Steuber, 1999). When the distance between the sutures of P0 and P2 (P0–P2) is compared with the length of the contour (U) of the inner margin of the outer shell layer (Fig. 9), environmentally driven morphological variations, e.g. due to a departure of the outline of the shell from circularity, can be excluded (Steuber, 1999).

Because the outer shell layer of many specimens is broken or eroded, the lengths of the pillars were measured as a line from the intersection of (C) and the suture to the tip of the pillar (Fig. 7). The relative lengths of P0, P1 and P2 are expressed in the ternary diagram (Fig. 10). This method allows for a comparison of closely related species (Steuber, 1999). In this diagram, change of the relative lengths of the pillars during ontogeny can be clearly seen and the population sample investigated can be compared with previously published figures (Figs. 10, 11).

Description. The right valve is elongated-conical, more than 200 mm high, and ornamented with longitudinal ribs 1–4 mm wide. Dmax ranges from 41 mm (96-96) to 76 mm (U-5). Thickness of the outer shell layer is commonly 4–5 mm, but may be up to 10 mm, and increases with increasing diameter. Inner margin of the outer shell layer smooth or slightly undulating.

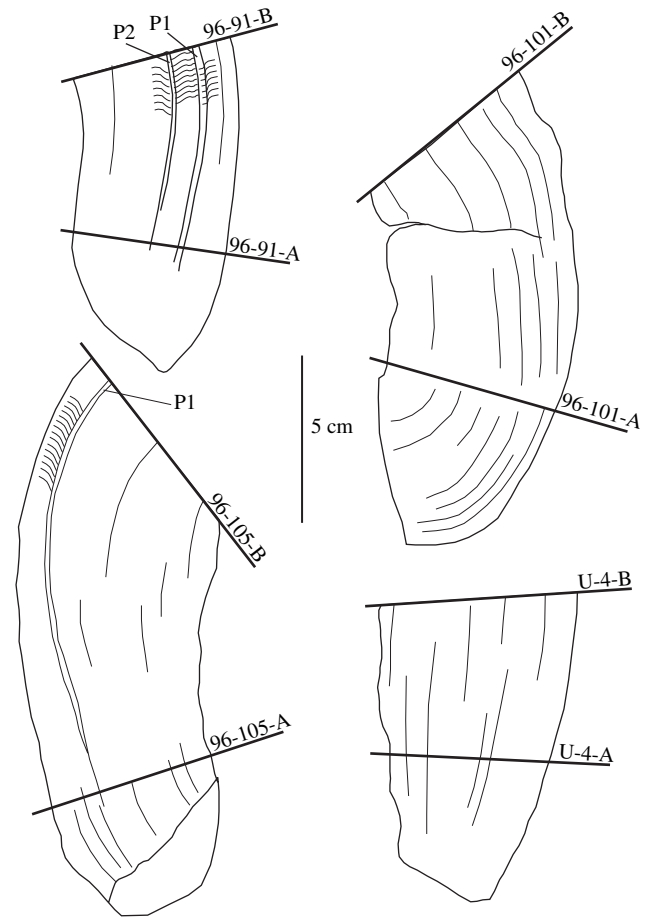


Fig. 8. Position of transverse sections of different ontogenetic stages of four right valves of *Vaccinites praegiganteus* (Toucas, 1904). Sections A and B represent early and late ontogenetic stages, respectively.

P0 (ligamentary pillar) is strongly developed and rather long (10–21 mm), commonly with undulating anterior and posterior margins. Its inner termination is generally widened and rectangularly or obliquely truncated, rarely with preserved ligamental remains. It is straight or slightly anteriorly curved at its tip.

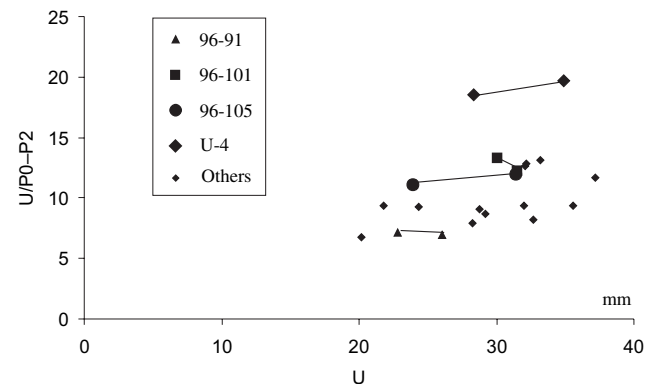


Fig. 9. Arrangements of pillars plotted against the length of contour of inner margin of outer shell layer (U) in *Vaccinites praegiganteus* (Toucas, 1904) from Bey Dağları. Different ontogenetic levels of individual shells are connected by lines.

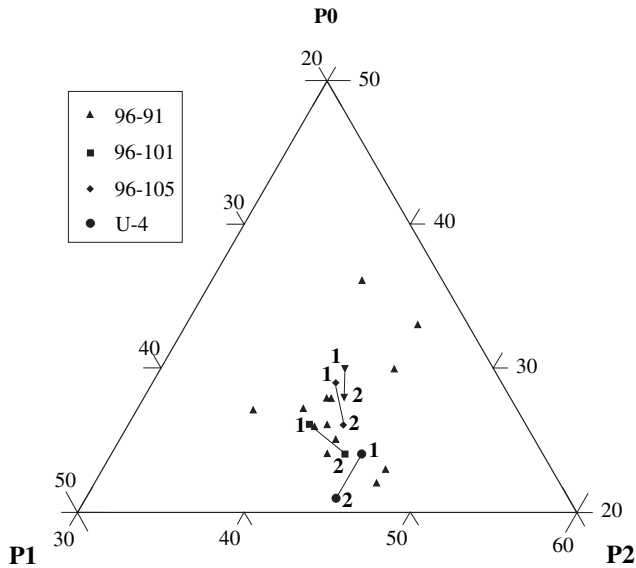


Fig. 10. Relative length of pillars (P0, P1 and P2) in *Vaccinites praegiganteus* (Toucas, 1904). [$P0/(P0+P1+P2) \times 100$]; [$P1/(P0+P1+P2) \times 100$]; [$P2/(P0+P1+P2) \times 100$]. Ontogenetic stages of individual shells are connected by lines. 1, represents early and 2, late ontogenetic stages.

P1 (first pillar) is pinched at the base in three specimens and tends to be more pinched and/or pedunculated with increasing diameter of the RV. P1 of the other specimens is long (up to 29 mm), pedunculated, the head being oval.

P2 (second pillar) is up to 38 mm long and pedunculated even in early ontogenetic growth stages. Shape of P2 varies from kidney or sickle-shaped to crescentic; it is always more or less inflected anteriorly, anterodorsally or dorsally.

P2 is always longer than P0 and P1. $IP0/IP1$ ranges from 0.60 to 1.48, $IP0/IP2$ from 0.46 to 0.93 and $IP1/IP2$ from 0.53 to 1.0 (Table 2). The relative length of P0 decreased during ontogeny (Fig. 10).

Twelve of the 17 specimens studied (71%) have fused pillars (P1 and P2; Figs. 12–14). Fusing of two pillars can be traced through successive growth stages (Fig. 13C, D), although fused pillars also occur in early growth stages (Fig. 14A).

Distance between P0 and P2 (P0–P2) is longer in specimens that have separate pillars, and the ratio of $U/P0-P2$ ranges between 6.73 and 9.37 in these specimens (Table 2). P0 and P2 are closely located in specimens which have fused pillars and their ratio of $U/P0-P2$ varies from 8.59 to 19.39. There is only a minor change in $U/P0-P2$ ratio during ontogeny (Table 2, Fig. 9).

The myocardinal elements are preserved only in two specimens (Figs. 12D, 14D). The anterior tooth of the left valve is oval or pear-shaped in transverse section and anteroventral to P0. The single tooth of the right valve is not preserved. The posterior tooth of the left valve is oval to subrectangular in transverse section and located closely posterior or posterodorsal to P0. The transverse section of the posterior myophore is triangular and found between P0 and P1, more or less closely located to the dorsal shell wall.

Remarks, comparison and discussion. The collection from Bey Dağları can be grouped into specimens with separate pillars and specimens that have fused middle and posterior pillars. The latter group is rather different from the previously described and figured specimens while the first group compares well with the type material and subsequent records. The specimens of Toucas (1904) are very similar to the present specimens with respect to the morphology of pillars, distance between pillars and the location of the myocardinal elements. *V. praegiganteus* of Parona (1926, pl. 1, fig. 5b) differs from the Turkish specimens in having more closely spaced pillars and extremely pedunculated and oval-headed pillars.

Philip (1981, fig. 5e) gave five successive ontogenetic transverse sections of *V. praegiganteus*. These sections seem to show a rounded ligamentary ridge, while the morphology and spacing of pillars are almost the same as in the specimens from Bey Dağları.

Simonpiétri (1999) illustrated a large number of specimens belonging to *V. praegiganteus* and regarded *V. inferus* as the common ancestor of three phyletic lineages (see also Simonpiétri and Philip, 2000), *V. praegiganteus* being the oldest member of the lineage of *Vaccinites giganteus*. Two sets of drawings of successive ontogenetic transverse sections (Simonpiétri, 1999, fig. 23, LA 14 and LA 19) and photographs of 18 transverse sections (pl. 5, figs. 1–12 and pl. 6, figs. 1–6) illustrate the intraspecific variability of the species in the type region. Only one specimen of Simonpiétri (1999, pl. 6,

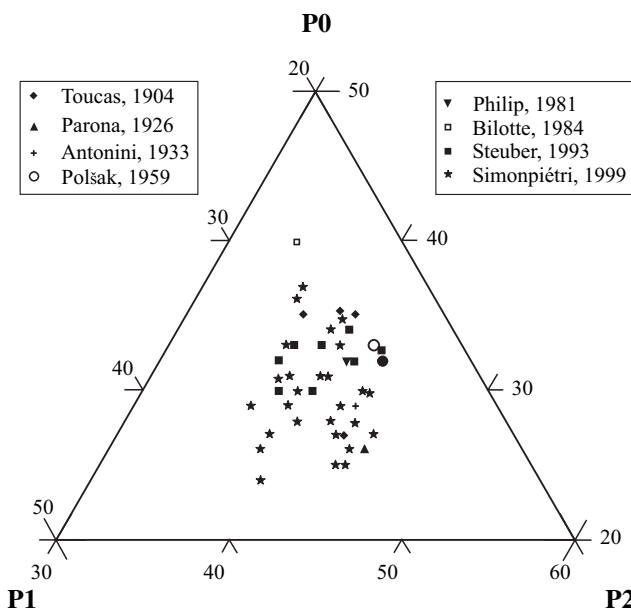


Fig. 11. Relative length of pillars (P0, P1 and P2) in *Vaccinites praegiganteus* (Toucas, 1904) from previous studies.

Table 2

Measurements (mm) of transverse sections of right valves of *Vaccinites praegiganteus* (Toucas, 1904) (see Fig. 7 for explanation of measurements)

Sample no.	C	Dmax	U	P0–P2	IP0	IP1	IP2	IP0/IP1	IP0/IP2	IP1/IP2	U/P0–P2
96-91-A	155	50	228	32	12	11	16	1.01	0.71	0.7	7.13
96-91-B	174	56	260	37	13	14	19	0.93	0.65	0.7	7.03
96-95	193	62	321	25	16	23	34	0.69	0.46	0.89	12.84
96-96	129	41	202	30	10	11	15	0.88	0.67	0.76	6.73
96-97	196	59	320	34	17	24	24	0.74	0.73	1	9.41
96-99	196	63	322	25	17	21	33	0.78	0.5	0.64	12.88
96-100	223	65	327	40	19	13	20	1.48	0.93	0.63	8.18
96-101-A	179	54	300	23	18	22	28	0.79	0.63	0.8	13.04
96-101-B	188	60	315	26	17	22	30	0.78	0.56	0.72	12.12
96-102	233	74	356	38	19	17	27	1.14	0.69	0.61	9.37
96-103	198	63	282	36	15	10	20	1.42	0.75	0.53	7.83
96-104	191	44	218	23	10	13	17	0.77	0.58	0.75	9.48
96-105-A	145	46	241	22	14	15	20	0.96	0.72	0.75	10.95
96-105-B	181	56	314	26	18	22	29	0.82	0.61	0.73	12.08
97-421	178	56	292	34	16	18	23	0.94	0.7	0.75	8.59
97-422	155	49	244	26	13	16	20	0.79	0.65	0.82	9.38
97-427	198	62	332	25	20	24	30	0.83	0.68	0.82	13.28
97-561	171	57	288	32	17	21	27	0.83	0.63	0.76	9
U-4-A	178	60	284	15	15	20	29	0.78	0.53	0.68	18.93
U-4-B	210	62	349	18	17	28	36	0.6	0.46	0.76	19.39
U-5	223	76	372	32	21	29	38	0.73	0.56	0.77	11.63

fig. 4) has very closely spaced P1 and P2, which became fused during ontogeny, similar to specimen 96-105 from Bey Dağları (Fig. 13C, D).

Although Toucas (1904) emphasized a truncated ligamentary pillar as a characteristic feature of the species,

some of the specimens of Simonpiétri (1999) have a P0 with a rounded inner termination. Simonpiétri (1999) noted that the tip of the ligamentary crest should not be considered a characteristic feature because, in one specimen, P0 can be rounded or truncated in different

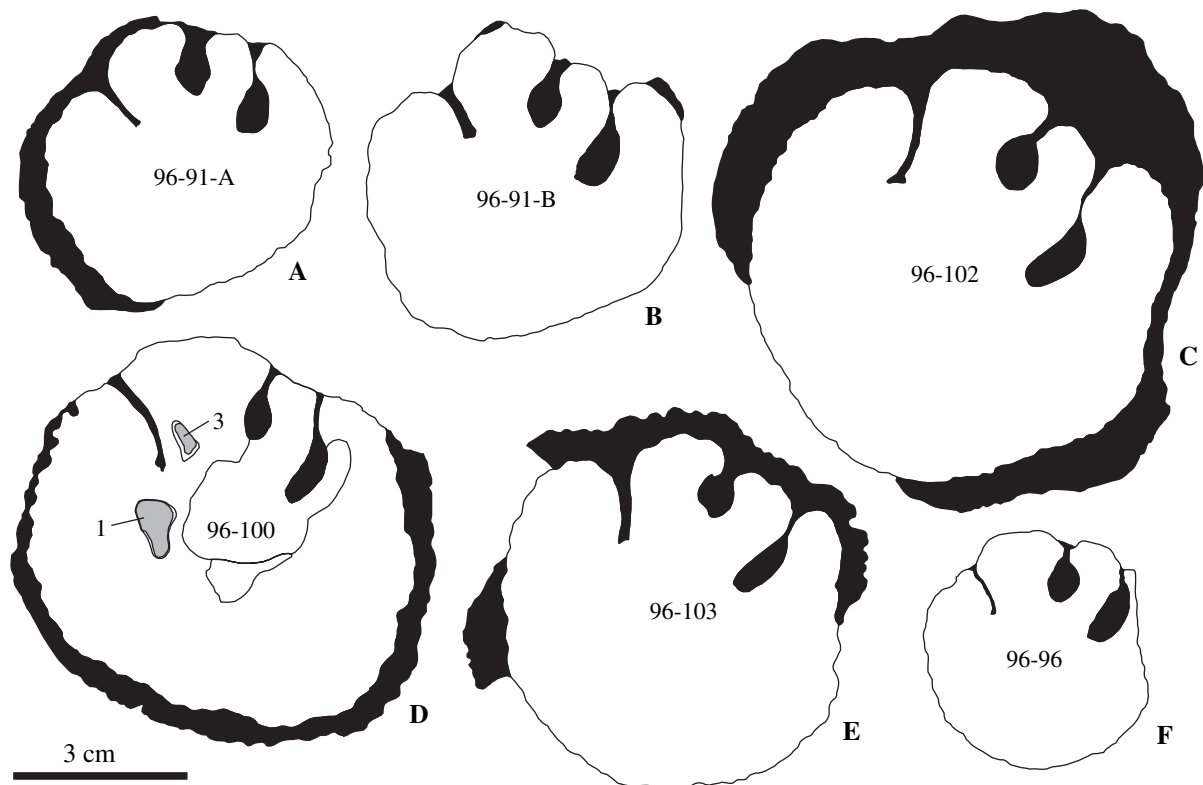


Fig. 12. Transverse sections through right valves of *Vaccinites praegiganteus* (Toucas, 1904). First and second pillars (P1, P2) are close to each other but not fused. A and B represent successive growth stages of one shell. Shaded areas represent myocardial elements. 1, anterior tooth; 2, posterior tooth; mp, posterior myophore.

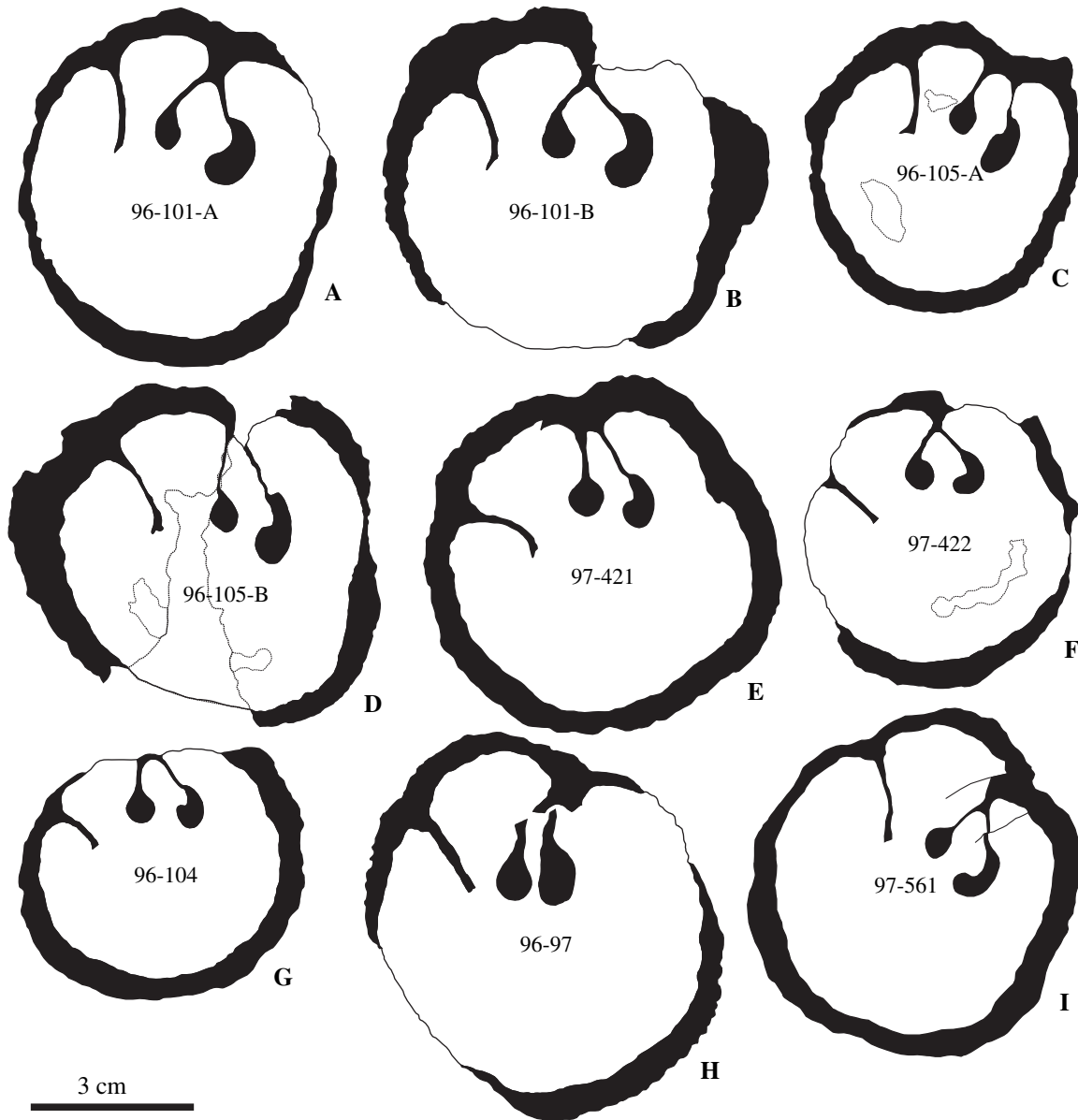


Fig. 13. Transverse sections through right valves of *Vaccinites praegiganteus* (Toucas, 1904). First and second pillars (P1, P2) are fused near the inner margin of the shells. A, B and C, D represent successive growth stages of single shells. The pillars (P1, P2) tend to become fused during ontogeny.

ontogenetic stages. All of the present specimens have a truncated ligamentary pillar.

Relative lengths of the three infolds were evaluated from previously figured specimens mentioned above, and measurements were compared with those of the Turkish shells. Relative lengths of P1 and P2 of the Turkish specimens are similar to values of previously figured shells, but the mean relative lengths of P0 are smaller in the specimens from Bey Dağları (Figs. 10, 11).

Stratigraphical and geographical distribution. *V. praegiganteus* is well-known from many Upper Turonian outcrops of the western and central Mediterranean

region. Steuber (2002b) summarized the stratigraphic and geographic distribution of the species, which was reported from the Middle Turonian–Coniacian of France, Santonian of Croatia, Middle Turonian–Coniacian of Bosnia-Herzegovina, Middle Turonian–Lower Santonian of Yugoslavia and Upper Turonian of Greece. In the eastern Mediterranean region, *V. praegiganteus* is known from the Coniacian of Israel (Bartov et al., 1972) and a single specimen has been collected by one of us (TS) from the Upper Turonian of Abu Roash, Egypt. The occurrence of the species in the Upper Turonian of the Bey Dağları carbonate platform closes a gap in its geographical distribution.

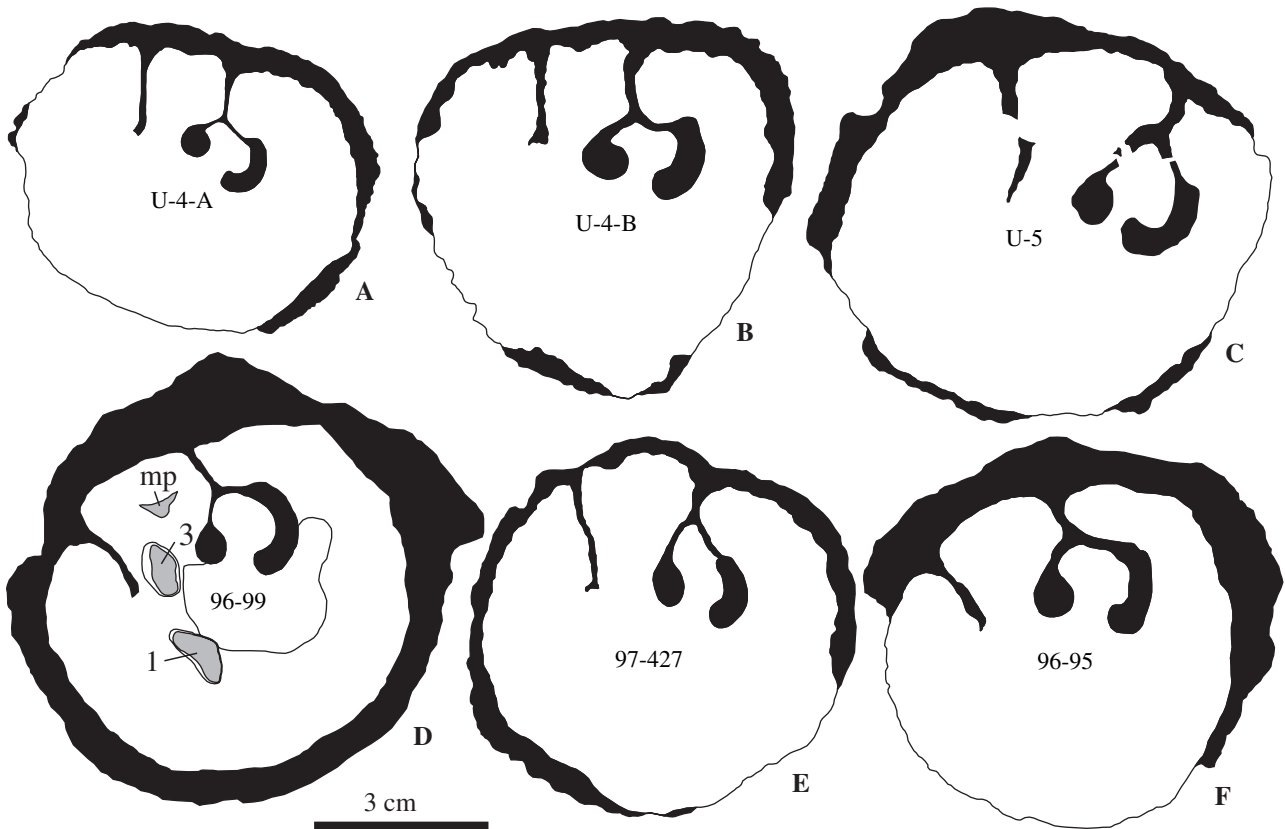


Fig. 14. Transverse sections through right valves of *Vaccinites praegiganteus* (Toucas, 1904). First and second pillars (P1, P2) are fused and connected to the shell wall by a seam of infolded outer shell layer. A and B represent successive growth stages of a single shell. The pillars (P1, P2) are fused even in the early ontogenetic stage (A). Shaded areas represent myocardinal elements. 1, anterior tooth; 2, posterior tooth; mp, posterior myophore.

6. Conclusions

In the Korkuteli area of the Bey Dağları Autochthon, neritic limestones of the carbonate platform corresponding to the lower part of the Bey Dağları Formation, constitute an approximately 600-m-thick monotonous sequence of Middle Cenomanian–Late Turonian age. The uppermost level of the shallow-water limestones include a hippuritid–radiolitid association, which is dominated by *V. praegiganteus*. Analysis of geochemically well-preserved low-Mg calcite of shells of *V. praegiganteus* for $^{87}\text{Sr}/^{86}\text{Sr}$ values has yielded a Late Turonian age. These chemostratigraphical data are important as the biostratigraphy of Upper Cretaceous carbonate platforms is generally difficult in the absence of precise biostratigraphical markers. The Late Turonian age obtained by strontium isotope stratigraphy is consistent with the biostratigraphically confirmed occurrences of the species in the central and western Mediterranean. *V. praegiganteus* is the first rudist bivalve to be described from the Upper Turonian of Turkey.

Most (71%) of the studied specimens of *V. praegiganteus* from Bey Dağları have fused first and second pillars and differ in this character from specimens of the central and western Mediterranean region. Morphometrical

analysis of ontogenetic changes in diagnostic characters of right valves has shown that the spacing of the pillars (U/P0–P2 values) remained rather constant, and that the relative length of ligamentary pillar (IP0) decreased during ontogeny. This contrasts with typical ontogenetic patterns observed in other species of the Hippuritidae (Steuber, 1999; Simonpiétri and Philip, 2000).

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