

Late Aptian rudist faunas from the Zonguldak region, western Black Sea, Turkey (taxonomy, biostratigraphy, palaeoenvironment and palaeobiogeography)



*Jean-Pierre Masse, *Mükerrem Fenerci-Masse and †Sacit Özer

*Centre de sédimentologie-paléontologie, laboratoire associé au CNRS 6019, Université de Provence, 13331 Marseille Cedex 03, France.

†Dokuz Eylül Üniversitesi, Mühendislik Fakültesi, Jeoloji Mühendisliği Bölümü, 35100 Bornova, İzmir, Turkey

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In the western Black Sea region of Turkey (Zonguldak area), Late Aptian rudist-bearing carbonates (the Cengellidere Formation) yielded the following fauna: *Toucasia* gr. *carinata-lonsdalei*, *Pseudotoucasia catalaunica*, *Polyconites verneuili*, *Horiopleura almerae*, *Eoradiolites plicatus* and *Eoradiolites* sp. This assemblage dates the Gargasian and has a broad Mediterranean palaeobiogeographical significance. Because typical African elements are lacking, it is ascribed to the European Province, in agreement with palaeotectonic regional reconstructions. The rudist communities thrived on a mixed, carbonate-siliciclastic, coastal ramp facing a basin corresponding to the modern Black Sea. This mode of occurrence contrasts with the classical Urgonian-type flat, platform settings of wide extent. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Rudist-bearing limestones pertaining to the so-called Early Cretaceous Urgonian complexes are well represented in the Carpatho-Balkan regions as well as in northern Anatolia, in areas belonging to the East European, northern Tethyan margin or to the so-called Preapulian domain *sensu* Tollman (1990) (=regions situated between the Periadriatic, i.e., Apulia or Adria, and European domains *s.s.*). Carbonate platforms with requieniid and monopleurid rudists have been documented from Romania (Masse *et al.*, 1999), eastern Serbia (Paquier, 1908; Jankicevic, 1978), Bulgaria (Zlatarski, 1886; Toulou, 1902; Paquier, 1903, 1905; Tzankov, 1960; Atanassova-Deltcheva, 1978) and from the Black Sea region of Turkey (Charles & Flandrin, 1929; Astre & Charles, 1931; Özer, 1986; Masse *et al.*, in press). The corresponding faunas are essentially Barremian–early Aptian in age.

By contrast, late Aptian faunas are rare in these regions and hitherto have been documented only from two areas: (1) eastern Serbia where *Eoradiolites plicatus* (Conrad) was identified (Danilova & Pejovic, 1981);

and (2) Zonguldak in the Western Black sea region, Turkey, where Douvillé (1896) mentioned *Polyconites verneuili* (Bayle), and *Pseudotoucasia santanderensis* (Douvillé) (*pro* *Toucasia* in Douvillé 1896).

Moreover, Late Aptian rudists (*Polyconites* cf. *verneuili* and *Eoradiolites* sp.) have been reported recently from the Apuseni Mountains (Romania) (Masse *et al.*, 1999). The aim of the present paper is to reappraise the Late Aptian rudist faunas from the Zonguldak area. This study is based upon a collection of specimens obtained during a regional field survey. The systematic description of the faunas is complemented by biostratigraphical and sedimentological data of the section investigated. The stratigraphical and palaeobiogeographical significance of the rudist fauna is discussed and its regional meaning emphasised.

2. Geographical and stratigraphical setting

The Zonguldak region belongs to the Western Outer Pontides, i.e., the eastern part of the

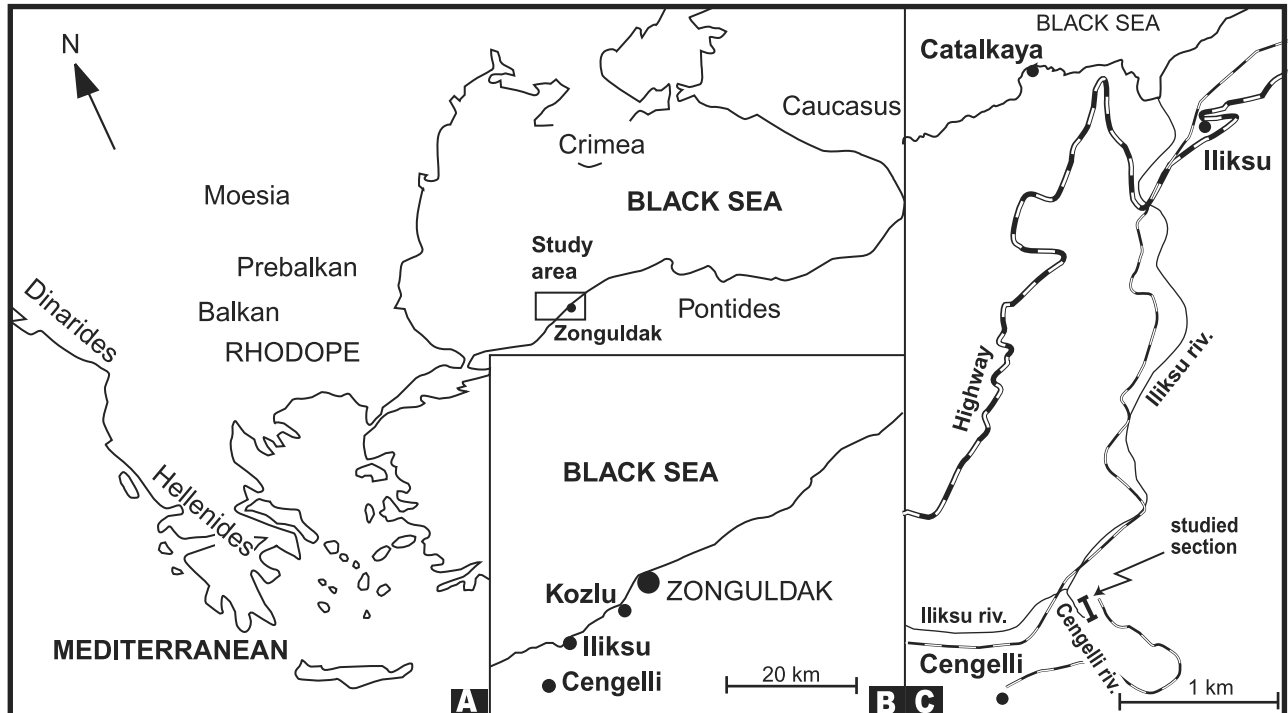


Figure 1. Geographic setting of the study area (A); location of the sector investigated in the western Black Sea region (B); and situation of the section studied near Cengelli (C).

Rhodope-Pontide segment of the East European Platform (Görür, 1988). The section studied, first described by Derman (1990), crops out at Cengellidere, southwest of Zonguldak, near the village of Cengelli south of Iliksu (Figure 1). After Derman (1990) it consists of the following stratigraphical units (from bottom to top): (1), interbedded sandstones and limestones containing rudists, named the 'Cengellidere Formation' by Derman (1990), who suggested that it is Barremian–early Albian in age and in stratigraphically disconformable contact with the underlying Carboniferous rocks; (2), sandstones and sands corresponding to the Velibey Kumtasi Formation, ascribed to the Upper Albian. This unit, equivalent to the Grès de Velibey *sensu* Charles & Flandrin (1929), is overlain by bioturbated sands and sandstones of the Sapça Formation, and finally capped by marls of the Tasmaca Formation. The last two formations were attributed to the Senonian.

Our investigations show that the Cengellidere Formation is nearly 90 m thick at its type locality and consists of five carbonate beds or bed-sets, numbered in stratigraphic order from 1 to 5 (bed-set 4 is the thickest, at 20 m), interbedded with sands, sandstones or gravelly sandstones (Figure 2).

The micropalaeontological assemblage identified in the carbonates consists of the benthic foraminifera

Sabaudia minuta (Hofker), *S. briacensis* Arnaud-Vanneau, *S. auruncensis* (Chiocchini & Di Napoli), *Vercorsella scarcellai* (De Castro), *Orbitolina* (*Mesorbitolina*) *texana* (Roemer) (Figure 3) and *Buccirenata hedbergi* (Maync). Dasycladalean algae are represented by *Neomeris* and *Terquemella*, associated with *Polystrata alba* (Pfender) (a red alga). Because typical Albian taxa are lacking, this assemblage is ascribed to the Late Aptian, an assignment based on the following references: Peybernès (1976), Arias *et al.* (1989), Masse *et al.* (1992) [in these papers *Orbitolina* (*Mesorbitolina*) *texana* is named *O. (M.) minuta* (Douglass)], Schroeder (1985), Azema *et al.* (1979) and Chiocchini (1984). Associated rudists corroborate this dating (see biostratigraphy below).

Limestones are in general rudist-rich, whereas some are dominated by *Chondrodonta*. Radiolitics predominate; nevertheless some beds contain abundant requieniids, while polyconitids are subordinate.

We assume that the specimens of *Polyconites vermeuili* and *Pseudotoucasia santanderensis*, given to Douvillé by M. Ralli (a mining engineer at Kozlu), from the vicinity of Iliksu (Illi-Sou in Douvillé, 1896) were probably collected from Cengellidere, because at present, in the regional context, this rudist-bearing locality appears to be unique to the region.

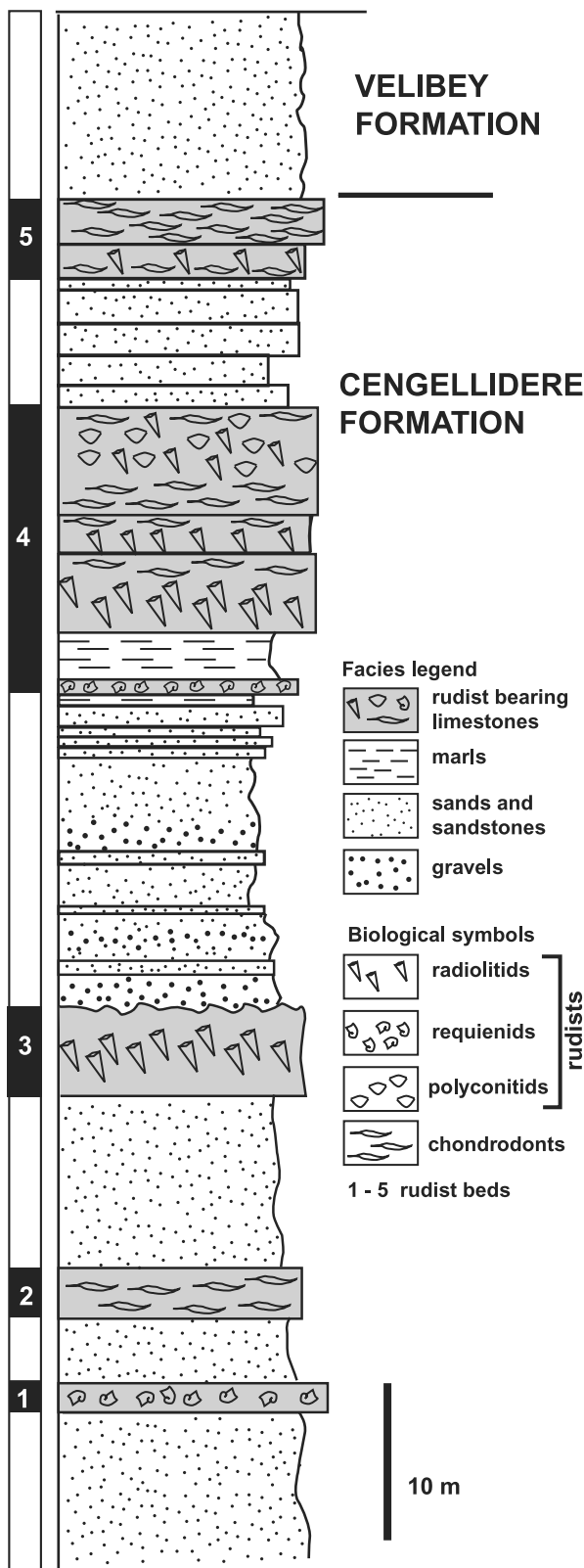


Figure 2. Stratigraphic section of the rudist-bearing Cengellidere Formation.

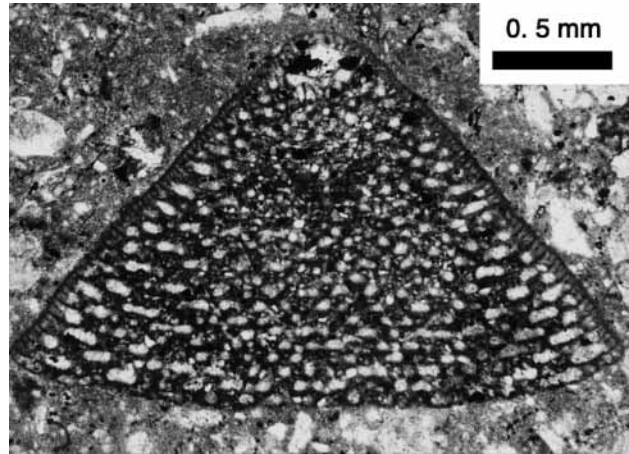


Figure 3. *Orbitolina (Mesorbitolina) texana* (Roemer). Axial section showing the macrospheric embryo (thin section 14136).

3. Systematic palaeontology

The repository of specimens is the Centre de Sédimentologie-Paléontologie, Université de Provence, Marseille. The symbols used for descriptions are as follows: UV, upper valve; LV, lower valve; Dors, dorsal side; Vent, ventral side; Ant, anterior side; Post, posterior side; pmp, posterior myophoral plate; mp, posterior myophore; am, anterior myophore; at, anterior tooth; as, anterior socket; ct, central tooth; pt, posterior tooth; ps, posterior socket; pc, posterior cavity; tb, tabulae-like structure; L, ligament crest; Ar, anterior ridge; Pr, posterior ridge; Ab, anterior band; Pb, posterior band; Ib, interband; ca, coiling axis.

Class: Bivalvia Linnaeus, 1758
 Order: Hippuritoida Newell, 1965
 Superfamily: Hippuritoidea Gray, 1848
 Family: Requieniidae Douvillé, 1915
 Genus *Toucasia* Munier-Chalmas, 1873

Type species. Requiencia carinata Matheron, 1842

Toucasia gr. *carinata* (Matheron, 1842), *lonsdalei* (Sowerby, 1837)
 Figure 4A, B

Material. Two upper and two lower valves.

Description. We ascribe to this genus toucasiform shells, i.e., those having a relatively compressed, carinate lower valve and an elongate, asymmetric upper valve, the posterior side of which is elevated above the commissure. The diameter of specimens fluctuates

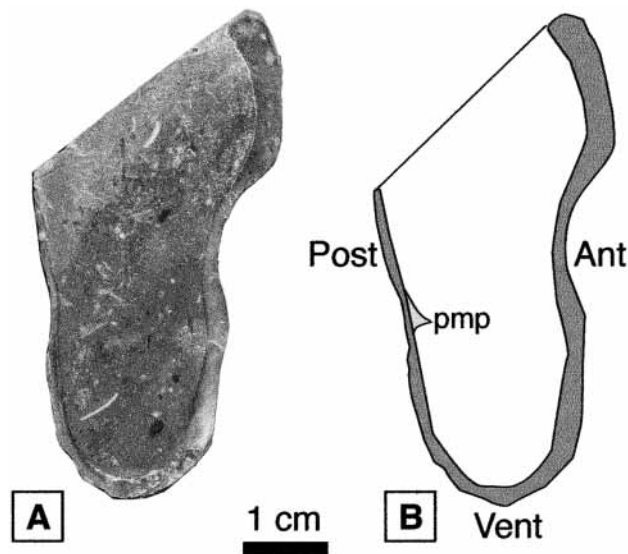


Figure 4. *Toucasia* gr. *carinata* (Matheron) *lonsdalei* (Sowerby). Transverse section of a lower valve showing the triangular cross-sectional shape of the posterior myophoral plate, thickness differences between the anterior and posterior sides, and the absence of ventral carina. A, section; B, interpretation.

from 4 to 10 cm. The length/width ratio of the upper valve is nearly constant at 0.6. This value is the expression of a significant lateral compression of the test. Internal myophoral structures were in general not preserved, except in one specimen which shows the posterior myophore of the lower valve. Myophoral grooves are similarly not preserved on the outer shell surface except in one specimen showing the track of the posterior myophore of the upper valve.

Discussion. Whether these forms belong to *Toucasia* or *Pseudotoucasia* is problematical. Because of the low triangular shape of the posterior myophore of the lower valve, *Toucasia* appears more appropriate. In *Pseudotoucasia* this triangle tapers distally and is slightly curved. This shape is clearly documented for *P. santanderensis* and also known for large specimens of *P. catalaunica* Astre (see Figure 5; Malchus, 1998; Masse, pers. obs.), whereas it is more variable on small specimens of this taxon. Assuming that our material belongs to *Toucasia*, the length/width ratio of the upper valve suggests some affinities with *Toucasia carinata* (Matheron) or *Toucasia lonsdalei* (Sowerby).

Toucasia carinata is known from the Barremian–Albian interval (Masse, 1995) while *T. lonsdalei*, the identification of which has been frequently mistaken, seems to be a Late Aptian taxon.

Genus *Pseudotoucasia* Douvillé, 1911

Type species. *Toucasia santanderensis* Douvillé, 1889

Pseudotoucasia catalaunica Astre, 1932

Figure 5A–D

Material. One upper and one lower valve.

Description. This species is characterised by the shape of the posterior myophoral plate of the upper valve, which has a significant bend towards the commissure but lacks the geniculate and pediculate aspect found in *Pseudotoucasia santanderensis*. It also differs from the latter by the acute posterior margin of the upper valve (Astre, 1932).

Our material displays: (1) an isolated upper valve showing the posterior myophoral plate conforming to the foregoing description; the length from commissure to apex is 3.5 cm (Figure 5C). (2) a transverse section of a lower valve, cut in one whorl, showing the myophoral plate, triangular, tapering and slightly curved ventrally (Figure 5A, B); this section also shows that the length/width shell ratio is close to 1, a value that conforms to those of the Spanish material (Masse, pers. obs.).

Discussion. *Pseudotoucasia catalaunica* is essentially known from the Late Aptian (Astre, 1932, 1935; Malchus, 1998; Masse *et al.*, 1998) and has not been documented hitherto outside northwest Europe (Spain and France), whereas van de Fliert (1952) mentioned this taxon from Algeria without illustrating it.

In his paper on the Koslu fauna, Douvillé (1896) recorded the presence of ‘*Toucasia santanderensis*’. This taxon, first described from northern Spain (Douvillé, 1889), was subsequently regarded as the type species of the genus *Pseudotoucasia* (Douvillé, 1911). Therefore, when Douvillé studied the Koslu specimens the genus *Pseudotoucasia* was not yet defined. This description of *Pseudotoucasia catalaunica*, subsequently described by Astre (1932), post-dates Douvillé’s identification. With little doubt, then, ‘*Toucasia santanderensis*’ from Koslu (in Douvillé, 1896), must be ascribed to *Pseudotoucasia catalaunica*.

Family: Polyconitidae Mac Gillavry, 1937

Genus *Polyconites* Roulland, 1830

Type species. *Polyconites operculatus* Douvillé, 1887

Polyconites verneuili (Bayle, 1860)

Figure 6A–C

Description and taxonomic interpretation. Our material is represented by two bivalve specimens with a relatively

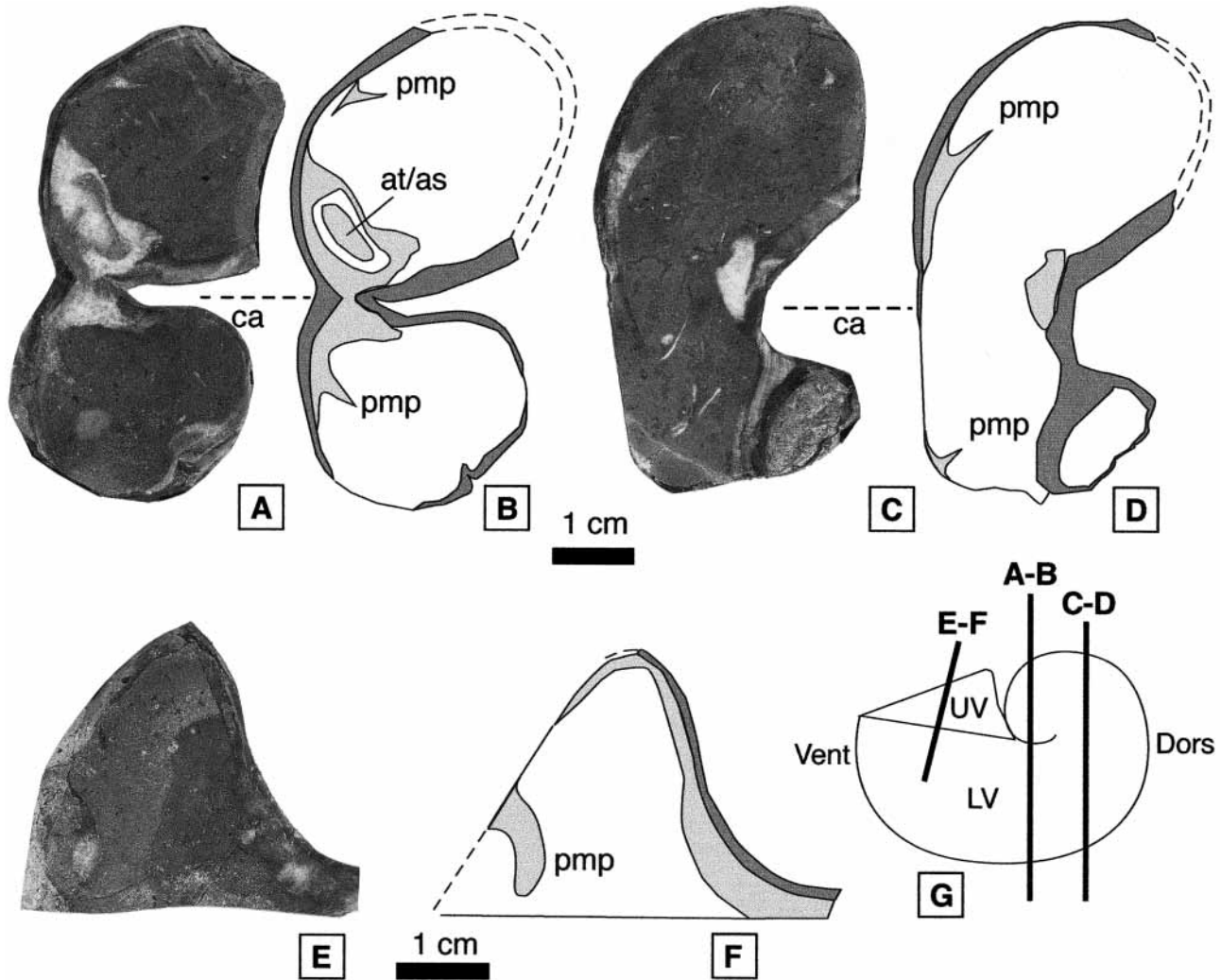


Figure 5. *Pseudotoucasia catalaunica* Astre. A–D, transverse sections of a lower valve (same specimen) showing the myocardinal organisation; note the distal tapering of the posterior myophoral plate. A, C, sections; B, D, interpretation. E, F, transverse section of an upper valve showing the characteristic shape of the posterior myophoral plate. E, section; F, interpretation. G, schematic drawing to display the position of sections A, D and F.

low conical lower valve and a flat upper valve. For the larger, better preserved specimen, the antero-posterior diameter of the upper valve is 8 cm, the dorso-ventral diameter is 5.5 cm, and the height of the lower valve is 4 cm. Therefore, the overall shape and dimensions closely resemble the type figures given by Douvillé (1889) for *Polyconites verneuili*. This similarity is reinforced by the deformation of the anterior side of the lower valve caused by the adhesion to a requieniid valve.

The internal characters, observed on an oblique antero-posterior longitudinal section, are poorly preserved but allow us to make the following observations: (1) the upper valve shows the anterior myophoral crest and the posterior dorsal teeth zone

with a well-defined posterior cavity; (2) on the lower valve, the anterior side of the inner shell layer is very thin (it is far thicker in *Horiopleura*); the dorsal posterior side shows the cardinal zone. The internal characters consequently match the external ones, enabling us to ascribe our specimens to *Polyconites verneuili*, in agreement with Douvillé's former identifications from 'Illi-Sou'.

Geographical and stratigraphical distribution. *Polyconites verneuili* has been documented from France and Spain (Douvillé, 1889; Astre, 1932; Bataller-Calatayud, 1947; Malchus, 1998; Masse *et al.*, 1998) but has also been found in North Africa (Chikhi-Aouimeur, 1980; Masse & Chikhi-Aouimeur, 1982; Masse,

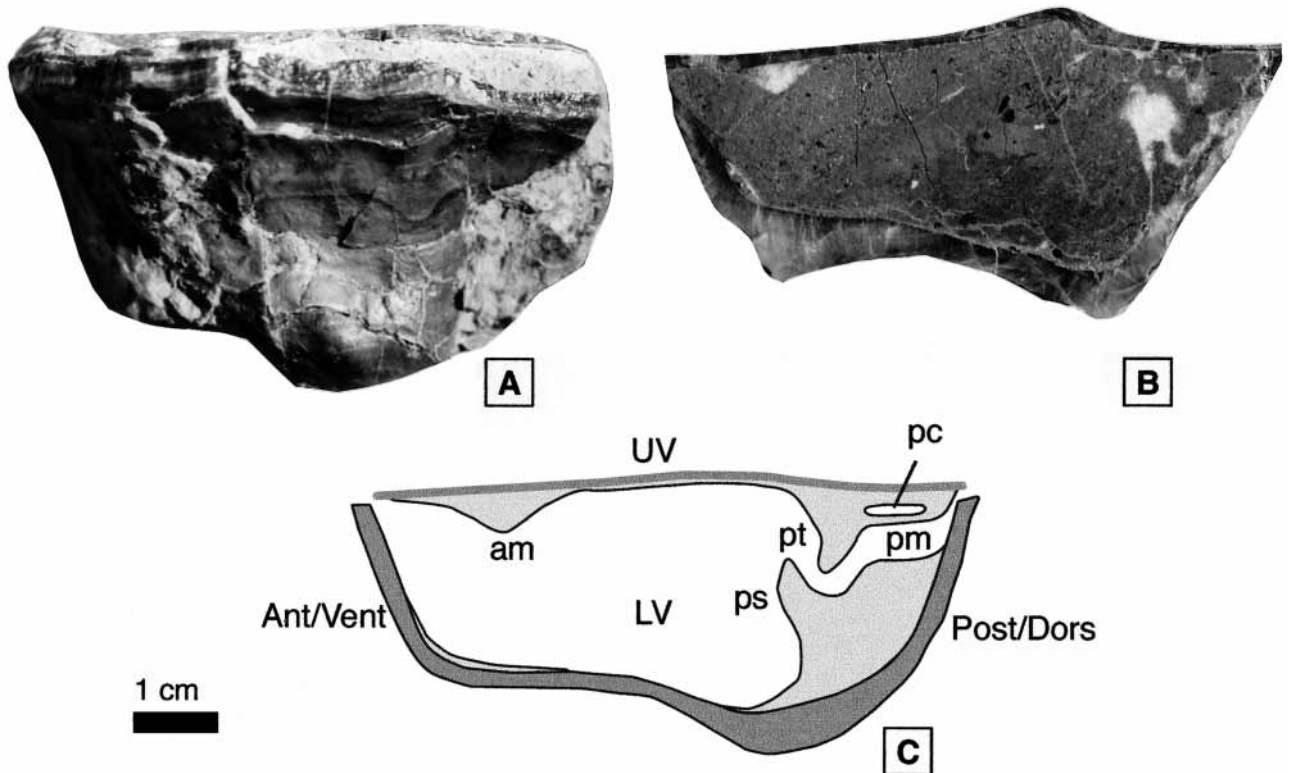


Figure 6. *Polyconites verneuili* (Bayle). A, ventral view of a bivalve specimen showing the low conical lower valve and flat upper valve. B, oblique cross section of the same specimen (myocardinal attributes partly modified by sponge borings). C, interpretation of section in B, showing the myocardinal attributes: anterior myophore, posterior tooth flanked by a posterior cavity overlying the posterior myophore.

unpublished) and Italy (di Stefano, 1898). Closely related forms have also been reported recently from Romania (Masse *et al.*, 1999). From the foregoing it is apparent that the age range of *Polyconites verneuili* is Late Aptian–Albian *p.p.*

Genus *Horiopleura* Douvillé, 1889

Type species. *Horiopleura lamberti* Douvillé, 1889

Horiopleura almerae Paquier, 1905

Figure 7A–F

Material. About ten randomly oriented sections in four blocks and numerous fragments.

Description. This form is represented by various sections showing the following characters. (1) Conical, short lower valve with a thick inner layer (up to 1 cm) and a thin outer calcitic layer (about 1 mm on average). There is a short, triangular (in transverse section) ligament crest marked externally by a groove. The myophores are nearly parallel to the commissure and are produced by an enlargement of the inner shell

layer which thins ventrally. The posterior myophore is slightly depressed dorsally and becomes horizontal ventrally or slightly inclined inward. (2) Moderately inflated upper valve with a slightly depressed ventral side. The posterior myophoral plate is gently inclined outward and pediculate. The anterior myophore is less developed and limited inward by a crest normal to the valve. The anterior tooth has a bulbous end.

The anterior–posterior diameter fluctuates from 3 to 5 cm, whereas the dorso–ventral diameter does not exceed 3–4 cm. The height of the lower valve is also 3–4 cm on average, that of the upper valve being less than 1 cm. The inner shell layer of the lower valve, originally aragonitic, often shows growth structures closely resembling tabulae, especially in the body cavity (Figure 7E). This pattern is also expressed in the central tooth (Figure 7A).

Discussion. The myophoral organisation and the morphological traits conform to those of the genus *Horiopleura* as defined by Douvillé (1889). The slightly depressed posterior right myophore departs from that of *Horiopleura lamberti* (Munier-Chalmas), which is deeper and flanked inwardly by an erect lamina; the

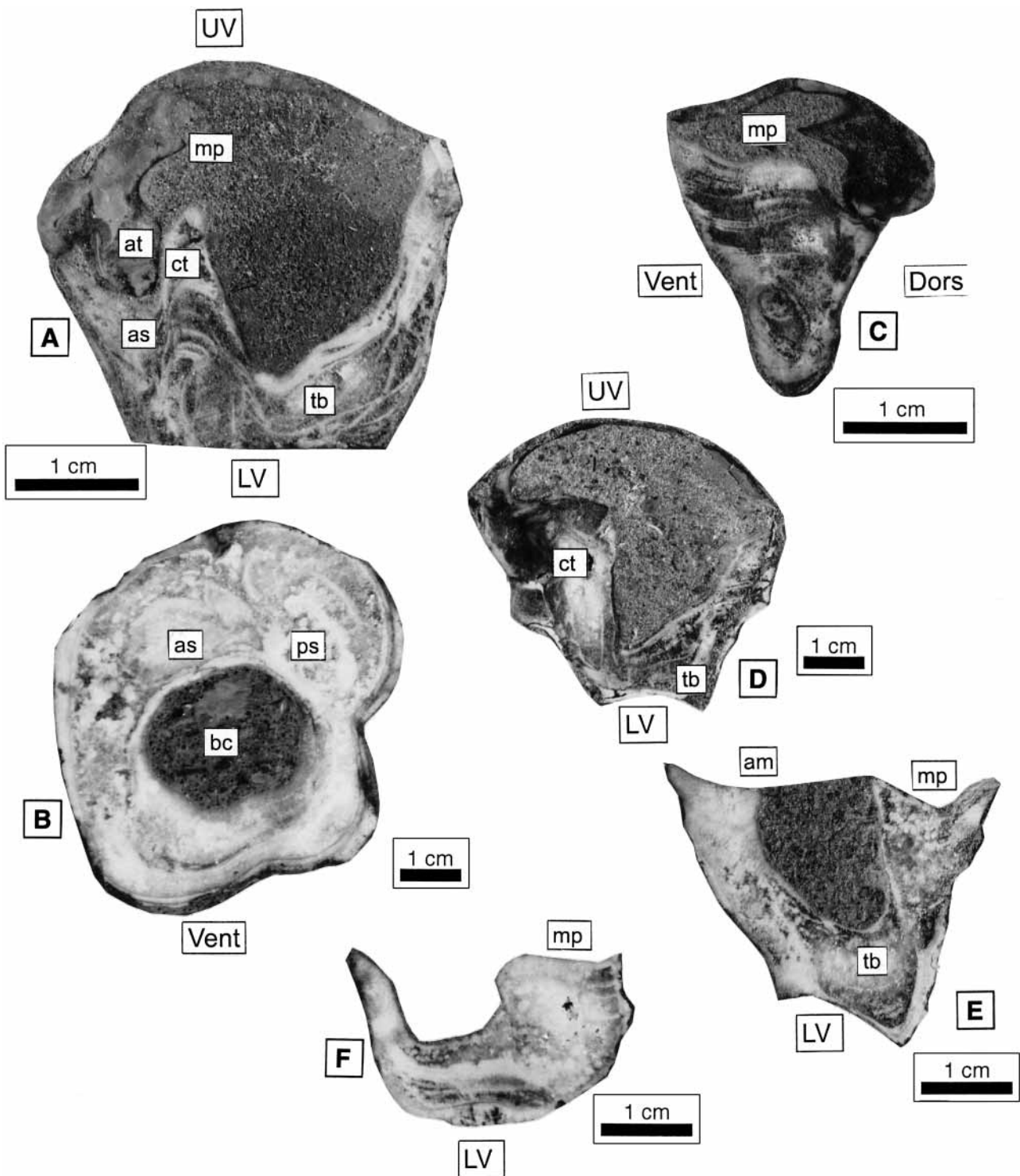


Figure 7. *Horiopleura almerae* Paquier (block sample 14141). A, longitudinal dorso-ventral section of a bivalve specimen showing the cardinal organisation: anterior tooth with a bulbous end and the convex habit of the upper valve. Inner shell layer of the lower valve with growth structures. B, transverse section of the lower valve showing the thick inner shell layer and the cardinal zone. C, longitudinal oblique section of a bivalve specimen showing the dorsally salient upper valve. D, longitudinal oblique section of a lower valve showing the myocardial elements. E, longitudinal section of a lower valve showing the myophoral thickening; the posterior myophore is depressed. F, longitudinal oblique section of a lower valve showing the shell thickening corresponding to the posterior myophore.

size is also smaller, the ornamentation more reduced, and the radial bands inconspicuous. By its inflated upper valve it differs from *Horiopleura baylei* (Coquand), although the overall dimensions are similar. The size and shape also contrast with those of *Horiopleura dumortieri* (Matheron). The limited development of the posterior accessory cavity of the upper valve, the absence of a conical depression underlying the posterior myophore of this valve, the lack of an erect lamina on the posterior myophore of the lower valve, the bulbous habit of the anterior tooth, and the external shape of the upper valve, conform to those of *Horiopleura almerae* Paquier. The overall dimensions are, nevertheless, reduced relative to those of the Spanish form.

Besides its Late Aptian type locality this species has been recorded from southwestern France (Masse, 1995), also in Late Aptian beds. Closely related forms were mentioned from the same stratigraphic interval in Algeria (Chikhi-Aouimeur, 1980), while *Horiopleura* figured by Masse *et al.* (1998) from Albian beds in southern Italy, also belongs to this group.

Family: Radiolitidae d'Orbigny, 1847

Genus *Eoradiolites* Douvillé, 1909

Type species. *Radiolites davidsoni* Hill, 1893

Eoradiolites plicatus (Conrad, 1852)

Figure 8A–E

Material. One isolated specimen and numerous randomly oriented sections in rock slabs.

Description and taxonomic interpretation. This form is characterised by a significant dorso-ventrally contrasting shell structure: the dorsal side of the shell is thick, with a well-defined radial (more or less branching-meandriiform) structure, while the ventral side is mainly compact and relatively thin. The 'cellular structure', actually radial, tends to be confined to the radial bands (Douvillé, 1910, 1913). The subrectangular transverse outline, the bilateral symmetry (relative to the line running from the ligament crest ventrally to the interband) and the shape of the bands are also diagnostic characters for this species.

The specimens collected at Cengellidere conform to the foregoing description. The average values ($n=6$) are 2.0 cm for the antero-posterior and 2.4 cm for the dorso-ventral diameters. These values are smaller than the average values given for the species by Gallo-Maresca (1993), namely 2.7 cm and 3.1 cm respectively. Because the relationships between the

size and stratigraphic age of the representatives of *E. plicatus* are not well established (Gallo Maresca, 1993) the meaning of these relatively small dimensions of the Cengellidere specimens is unclear. A possible explanation is that our measurements (performed on slabs) did not deal with commissural or nearly axial longitudinal sections, leading to some underestimation of the actual dimensions.

Discussion. This species was first described from Lebanon (Conrad, 1852 and Fraas, 1878, in Douvillé, 1910, 1913). It has been documented from the European (mainly Spain) and African margins (Italy, North Africa, Levant, Sinai) of the Mediterranean Tethys, as well as from central Iran (Masse & Gallo Maresca, 1997; Steuber & Bachmann, 2002). The Zonguldak record fills a palaeogeographic gap between the Mediterranean and the Asiatic distributional area of this species.

The stratigraphical first occurrence of *Eoradiolites plicatus* is Gargasian, probably middle Gargasian, whereas the species extends to the Albian (Gallo-Maresca, 1993; Masse, 1995; Masse *et al.*, 1998).

Eoradiolites sp.

Figure 9A, B

Material. One lower valve cut into three slices, including one thin section.

Description. This form is characterised by a triangular cross-sectional shape, with a wide ventral zone. As for *Eoradiolites plicatus*, the dorsal side of the shell has a well-defined radial pattern, while the ventral side is compact. The distribution of the radial structure shows the following traits: (1) the antero-ventral side has relatively thick and short radial walls (i.e., the thickness of walls is nearly equal to the open space between them), and radial walls are present within the salient, ventral ridge; (2) thin walls have an irregular, slightly undulating branching pattern that tends to be localised in the antero-dorsal zone; (3) the postero-dorsal zone contains thick, short walls which do not run to the postero-ventral ridge; (4) the radial pattern tends to be localised in the outer part of the calcitic shell layer, the inner part being compact.

We regard as radial bands two bulges found in the middle part of the ventral zone, separated by a small depression ascribed to the interband. The ligamental crest is subtriangular and somewhat asymmetric.

Discussion. Owing to the distribution of the radial structure this form is close to *Eoradiolites plicatus*, whereas the cross-sectional shape, radial bands and

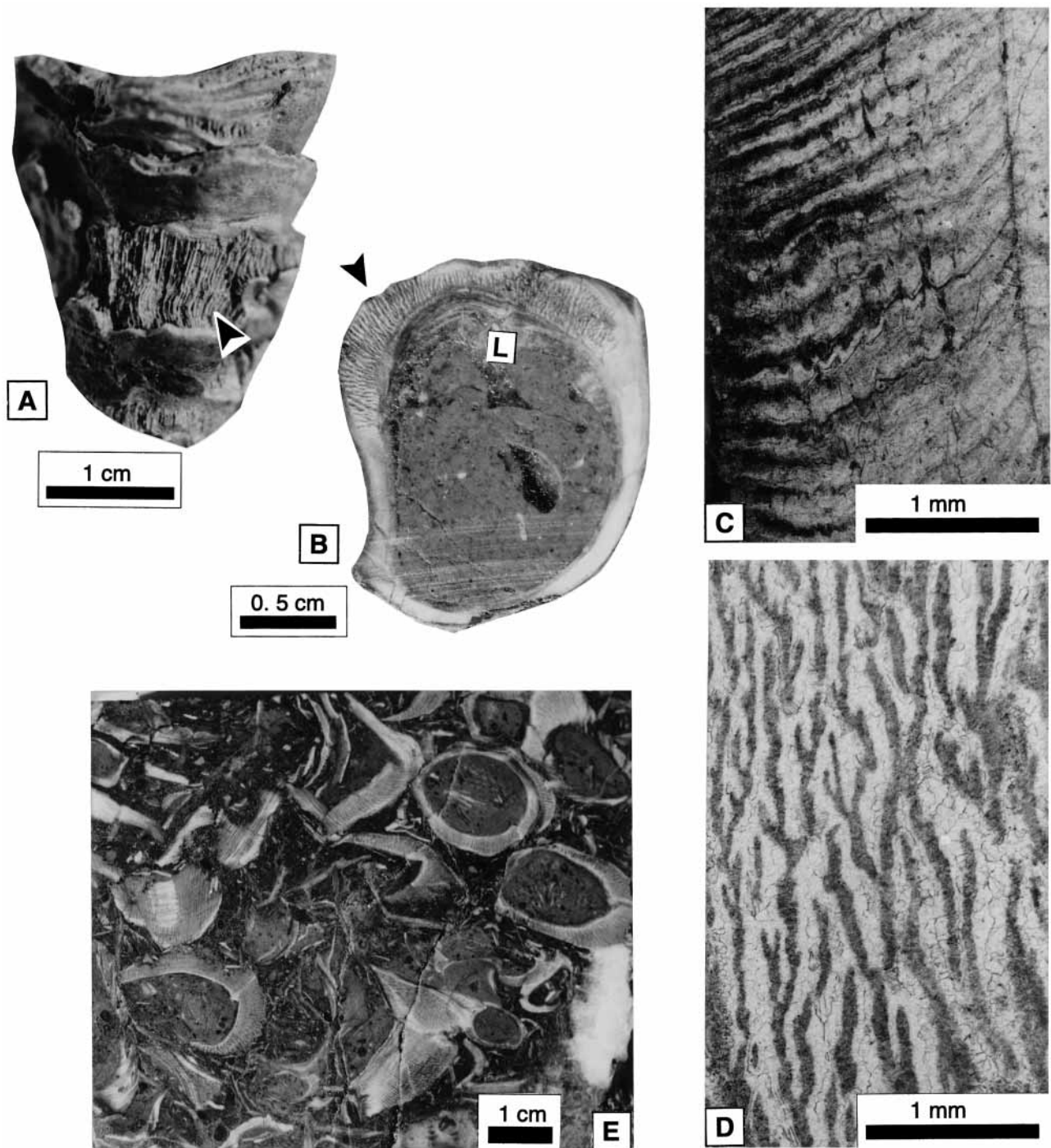


Figure 8. *Eoradiolites plicatus* (Conrad). A, dorsal view of an isolated specimen showing the radial outer shell structure (arrow). B, transverse section of a lower valve showing the radial structure of the dorsal side and the compact structure of the ventral side. C, longitudinal section of the outer shell layer showing the compact shell and banded structure with crenellations. D, transverse section of the dorsal radial zone, showing the irregular, somewhat branching, pattern of the walls. E, polished slab showing a 'radiolitic facies' with *Eoradiolites plicatus* (sample 14136).

radial wall habits are different. Affinities with *Eoradiolites* sp. 1 Gallo-Maresca (Gallo-Maresca, 1993), subsequently named *Eoradiolites* sp. (aff. *metohiensis*

Pejovic) (Masse & Gallo-Maresca, 1997), must be acknowledged. The juveniles of *Eoradiolites metohiensis* (see in Pejovic, 1974, pl. I, fig. 1, right section, and

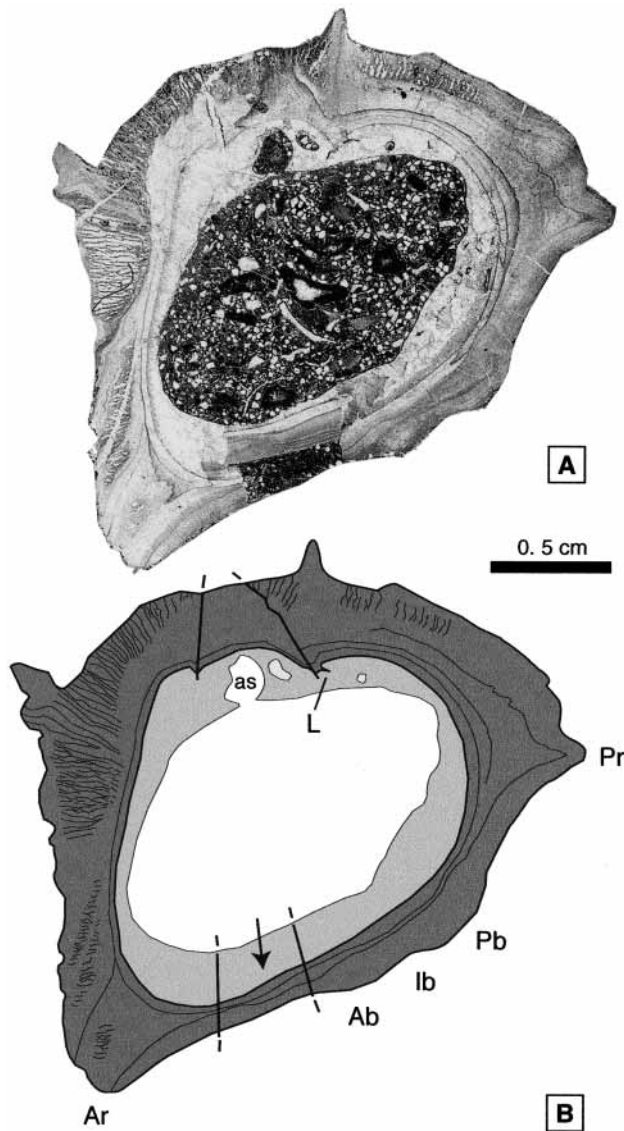


Figure 9. *Eoradiolites* sp. A, transverse section (thin section 14138) and B, its interpretation. Black lines correspond to fractures; the arrow points to the reconstruction of the broken anterior side of the ventral zone; note the radial pattern of the dorsal part and the compact structure of the ventral (between the anterior and posterior ridges) and posterior parts of the outer shell layer.

fig. 2) show an acellular ventral zone and radially arranged walls, even if the overall organisation tends to be cellular. *Eoradiolites metohiensis* is a Cenomanian species while *Eoradiolites* sp. aff. *metohiensis* was found in the Upper Aptian of central Italy (Gallo-Maresca, 1993). Whereas *Eoradiolites* sp. appears to be a new taxon, more abundant material, including bivalve specimens, is required before the species can be formally described.

4. Biostratigraphical and palaeogeographical significance of the rudist fauna

The assemblage of *Pseudotoucasia catalaunica*, *Polyconites verneuili*, *Horiopleura almerae* and *Eoradiolites plicatus* is well known from northeast and southeast Spain (Astre, 1932; Masse *et al.*, 1998; Malchus, 1998). The corresponding age is Gargasian. Because *Pseudotoucasia catalaunica* was essentially documented from Iberia and southwest France, the record of this species in Anatolia is exceptional and broadens considerably the palaeobiogeographical distribution of this requieniid. *Polyconites verneuili* and *Eoradiolites plicatus* were described from Lebanon by Douvillé (1913) in beds dated as Albian, and were subsequently also found in Late Aptian deposits (Saint-Marc, 1970). *Polyconites verneuili*, *Horiopleura* sp., close to the above-mentioned species, and *Eoradiolites plicatus* have also been recovered from sequences of Late Aptian age in northeastern Algeria (Chikhi-Aouimeur, 1980, 1983). Moreover, *Eoradiolites* sp., as illustrated herein, has been reported from the Upper Aptian of central Italy (Gallo-Maresca, 1993). The *Pseudotoucasia-Eoradiolites-Polyconites-Horiopleura* group is a key association of the Upper Aptian of southwest France (Masse, 1995). In the uppermost Aptian (Clansayesian) and in the Albian this group is still present but with some additional forms: namely *Praeradiolites* and *Agriopleura? darderi* (Astre). However, Late Aptian and Albian faunas record significant differences at species level. All of these taxa have a wide palaeobiogeographical distribution in the Mediterranean region (Figure 10).

From the foregoing we conclude that the Cengellidere fauna has a cosmopolitan distribution in the Mediterranean context. Nevertheless, owing to the absence of *Himeraelites* (an Aptian–Albian form typical of the Mediterranean, south Tethyan, margin: di Stefano, 1889; Chikhi-Aouimeur, 1980; Masse, 1985; Cestari & Sartorio, 1995; Baron-Szabo & Steuber, 1996; Skelton & Masse, 1998), the Cengellidere fauna is more European than Mediterranean *s.l.* Moreover, given the presence of *Eoradiolites plicatus* and the absence of any true ‘acellular’ radiolitid, this fauna belongs to the Mediterranean instead of the Asiatic domain (Masse & Gallo-Maresca, 1997). The finding of *E. plicatus* in the Western Pontides provides a link between the Mediterranean and Asiatic palaeobiogeographic entities, notably central Iran where, besides typical Asiatic radiolitid forms, *E. plicatus* is also present (Masse & Gallo-Maresca, 1997).

The European meaning of the Cengellidere fauna fits with the palaeostructural reconstruction of the Pontides, which are considered to be a part of

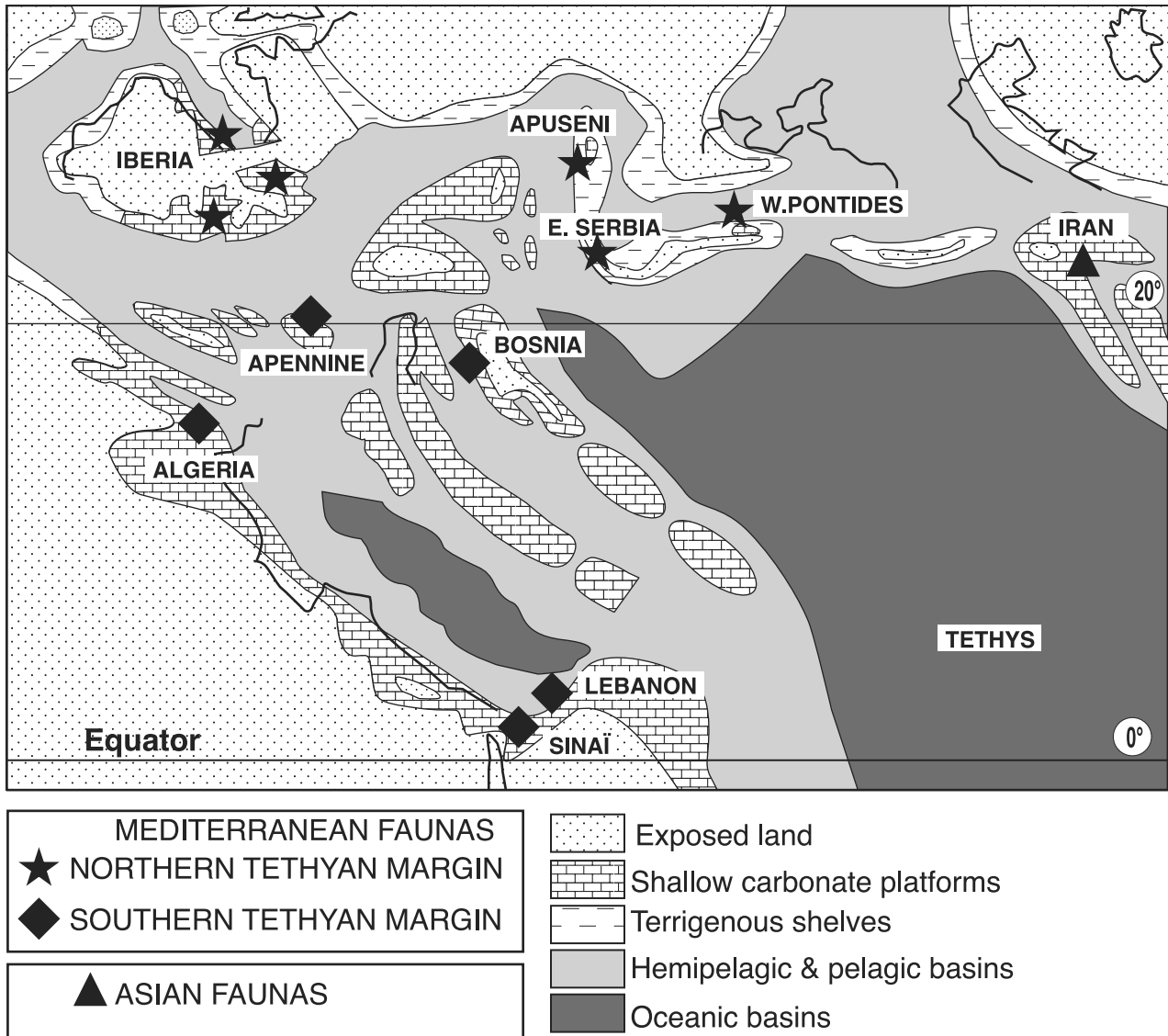


Figure 10. Palaeobiogeographic distribution of Upper Aptian rudist faunas from the Mediterranean region (modified from Masse *et al.*, 1993 and Masse & Gallo-Maresca, 1997).

the northern margin of Tethyan Eurasia (Fourquin, 1975; Bergougnan, 1975; Görür, 1988). Placing this rudist fauna in the European Province also fits with the palaeobiogeographical meaning ascribed to the antecedent Barremian–Lower Aptian rudist faunas from the Zonguldak–Amasra region (Masse *et al.*, *in press*).

5. Palaeoenvironments

The mode of occurrence of the Late Aptian rudist assemblages, in relatively thin limestone beds interbedded in fluvio-deltaic sandstones, suggests coastal settings under a pronounced siliciclastic influence.

The siliciclastic material is not only found in the sandstones but is also significantly present in the limestones. The rudists were, therefore, thriving in mixed carbonate-terrigenous settings. These conditions are rather different from those of typical ‘offshore’ or epicontinental Late Aptian carbonate platforms known, for example, in southwest France (Masse, 1995), North Africa (Chikhi-Aouimeur, 1980; Masse & Chikhi-Aouimeur, 1982; Masse & Thieuloy, 1979) and southern Spain (Masse *et al.*, 1998a), even if terrigenous runoff was locally significant in these regions. The Late Aptian Cengellidere coastal settings were bordering a continental domain located south of the present Black Sea shore.

Intermittent subaerial exposure or freshwater influence is evident from frequent early dissolution features observed on top of, or even within, rudist beds. These features and the high siliciclastic influence suggest an unstable coastal zone where rudist communities were developing in more or less isolated patches, in close association with chondrodontid banks. By contrast with the former hypothesis, the Cengellidere coastal ramp system documents the presence of shallow water conditions instead of deep water settings (Charles & Flandrin, 1929) during the Late Aptian. This ramp clearly opened towards the north, i.e., towards the present Black Sea depression.

6. Conclusions

In the western Black Sea region of Turkey Late Aptian shallow-water carbonates in the Zonguldak region, corresponding to the Cengellidere Formation, are associated with siliciclastics, and contain stratigraphically diagnostic benthic foraminifera. Their rudist content is dominated by Radiolitidae, the Polyconitidae and Requiieniidae being subordinate. The fauna consists of *Toucasia* gr. *carinata-lonsdalei*, *Pseudotoucasia catalaunica*, *Polyconites verneuili*, *Horiopleura almerae*, *Eoradiolites plicatus* and *Eoradiolites* sp. This assemblage has biostratigraphical significance. The Late Aptian age assignment is corroborated by the associated micropalaeontological assemblage, especially orbitolinids.

This fauna is well known from southwest France and Spain but many of its components are also documented from the Levant and North Africa. Nevertheless the lack of typical African elements, such as *Himeraelites*, shows that, from the palaeogeographic viewpoint, it has essentially a European aspect. This interpretation fits with palaeotectonic reconstructions that show the Western Pontides as a part of the Eurasian, north Tethyan margin during the Early Cretaceous.

Based on the Radiolitidae the region studied pertains to the Mediterranean Province. Palaeobiogeographic and/or palaeoenvironmental connections with Late Aptian carbonate platforms of the Eastern Mediterranean are problematic because rudist-bearing carbonates are absent from the Prebalkan and Moesia and are only locally recognised in some Carpathian areas, including eastern Serbia. By contrast with Urgonian-type carbonate platform successions corresponding to widespread, siliciclastic free, nearly horizontal sedimentary systems, the Cengellidere Formation represents coastal settings of a mixed carbonate siliciclastic ramp facing a basinal area presently located in the Black Sea depression.

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