

# The bivalve *Pinna cretacea* (Schlotheim, 1813) from the Cretaceous of Brazil

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The bivalve *Pinna cretacea* (Schlotheim, 1813) is described from the Cenomanian–Coniacian Cotinguiba Formation of the Sergipe Basin, north-eastern Brazil, and its mode of life and palaeobiogeographic distribution discussed. The specimens are generally found in life position with their articulated anterior (umbonal) end embedded vertically in the substrate, in analogy with Recent forms. Two representatives of the family Pinnidae Leach, 1819, are recognized in the Cretaceous of Brazil; besides *P. cretacea*, which is also known from the Albian of the Camamu Basin (Bahia), *Atrina reginamaris* (Maury, 1930) occurs in the Maastrichtian of the Pernambuco-Paraíba Basin.

Key words: Bivalvia, *Pinna*, taxonomy, Cretaceous, Brazil.

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## Introduction

The Cretaceous rocks exposed in the Sergipe Basin in north-eastern Brazil (Fig. 1) contain a rich macroinvertebrate fauna dominated by ammonites, bivalves, gastropods and echinoids. With their large size and distinct shape, representatives of the bivalve genus *Pinna* form a conspicuous element of the fauna, and are particularly well represented in upper Turonian–lower Coniacian beds. Until now, pinnids from Sergipe were only mentioned in passing by a few authors (Wanderley 1938; Beurlen 1964; Brito 1981; Bengtson 1983). Here we describe *Pinna cretacea* (Schlotheim, 1813) from Sergipe and discuss its mode of life and biogeographical distribution. Previous descriptions and reports of pinnids from the Camamu and Pernambuco-Paraíba basins (Maury 1930; Beurlen 1961; Brito 1967; Muniz 1993) are also discussed.

## Geographical and geological setting

The Sergipe Basin is located in the coastal and contiguous offshore part of the state of Sergipe in north-eastern Brazil (Fig. 1). It forms a sub-basin of the Sergipe-Alagoas Basin which comprises, from north to south, the Cabo, Alagoas, Sergipe and Jacuípe sub-basins. The Sergipe Basin is one of the numerous South Atlantic continental margin basins that were formed as a result of rifting and separation of South America from Africa in the late Mesozoic. Structurally it forms a half-graben, which is limited to the south-east by the continental slope and to the north-west by a system of normal faults. The sedimentary fill comprises a basal, non-marine succession and an Aptian–Miocene marine succession, which together

represent one of the most complete Cretaceous successions among those recorded in the South Atlantic marginal basins.

The geological evolution and the development of the marine Cretaceous of the Sergipe Basin have been discussed at length by several authors. For more detailed information the reader is referred to, e.g., Ojeda and Fugita (1976), Ojeda (1982), Bengtson (1983), Koutsoukos and Bengtson (1993), Koutsoukos et al. (1993) and Feijó (1995a).

## Material

This study is based on 37 specimens from eight localities in the Sergipe Basin (Fig. 1). For locality descriptions, see Bengtson (1983: appendix 1). The material consists of poorly to moderately well-preserved internal moulds. In ten specimens fragments of shell material are preserved. All specimens lack the posterior end and some have been deformed by diagenetic processes.

The specimens are housed in the collections of the Geologisch-Paläontologisches Institut, Universität Heidelberg, Germany (GPIH), with plaster casts of the figured specimens deposited in the Museu Nacional, Rio de Janeiro, Brazil.

## Mode of life and biogeography

Recent Pinnidae occur mainly in water depths ranging from a few metres down to ca. 50 m. In sheltered areas they can also be found in very shallow waters, even intertidally (Yonge 1953; Stanley 1970; Butler et al. 1993). They are suspension feeders that inhale water at the posterior end of the shell.

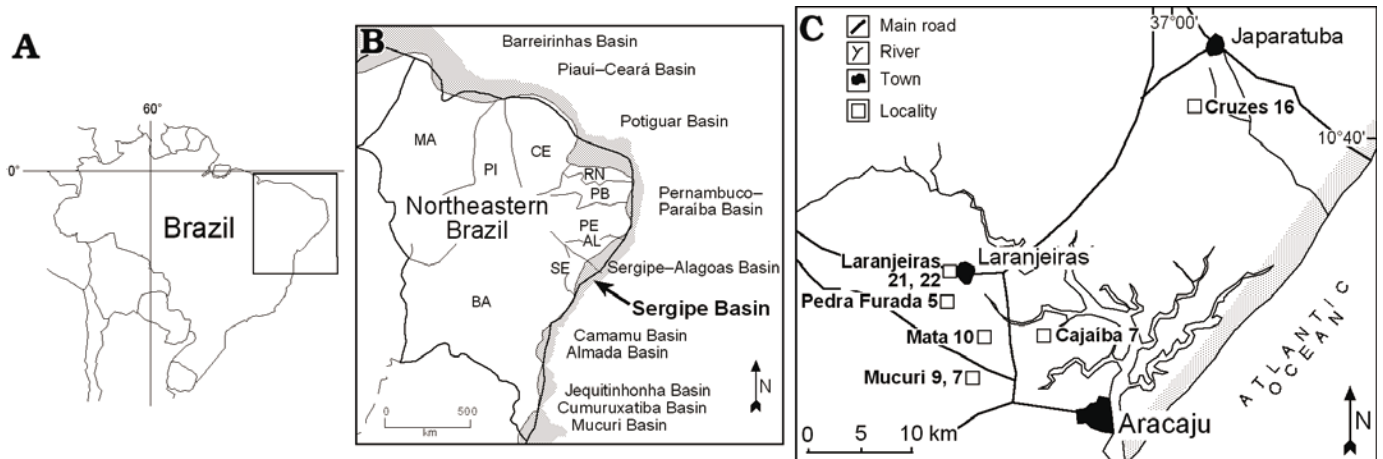


Fig. 1. Sedimentary basins along the north-eastern coast of Brazil (A, B) with locality map for the Sergipe Basin (C). Abbreviations of state names: AL, Alagoas; BA, Bahia; CE, Ceará; MA, Maranhão; PB, Paraíba; PE, Pernambuco; PI, Piauí; RN, Rio Grande do Norte; SE, Sergipe.

Attached to coarser particles in the substratum by their strong, exceptionally long and numerous byssus threads they maintain a vertical position in sandy or muddy sediments. Seilacher (1984) remarked that the majority of Recent tropical *Pinna* and *Atrina* species live completely buried in muddy substrates with their posterior end level with the sediment surface. However, many Recent pinnids live with their broad posterior part elevated well above the sea floor (e.g. Stanley 1970; Richardson et al. 1999). This mode of life is seen, for example, in the Mediterranean sand-living *P. nobilis* Linné, 1758, in which only the anterior fifth to third of the shell is buried (e.g., Yonge 1953; Richardson et al. 1999). For the Cretaceous *P. cretacea* described here we assume a similar, semi-infaunal mode of life (Fig. 2). All the Sergipe specimens are incomplete with only the anterior (umbonal) part of the shell preserved. However, the preserved portions are articulated and generally found in life position, as indicated by the orientation of the shells perpendicular to bedding. For more information on the mode of life, in particular of Recent pinnids, the reader is referred to, for ex-

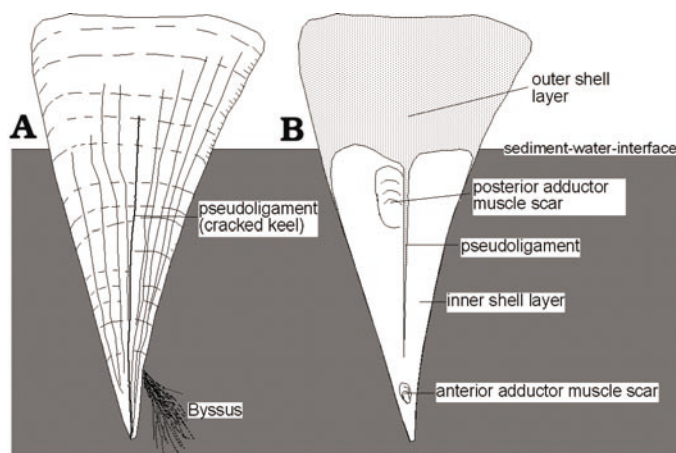


Fig. 2. Inferred mode of life of *Pinna cretacea* (Schlotheim, 1813). A. External view of left valve. B. Internal view of right valve (modified from Seilacher 1984).

ample, Yonge (1953), Stanley (1970), Butler et al. (1993), and Richardson et al. (1999), and references therein. The functional morphology of pinnid bivalves was discussed in detail in a series of studies by Seilacher (1981, 1982, 1984).

*Pinna cretacea* is a stratigraphically and geographically widely distributed species (Fig. 3). In Brazil it occurs in the Albian of the Camamu Basin (see below) and from the Cenomanian (or possibly Albian) to lower Coniacian of the Sergipe Basin (descriptions herein). It is also described from the Albian to upper Maastrichtian of Europe, for example England, Denmark, Germany, Austria, Czech Republic, Poland, Russia (e.g., Geinitz 1875; Wegner 1905; Andert 1934; Kríž and Soukup 1975; Abdel-Gawad 1986; Dhondt 1987), the Cenomanian to Campanian of the eastern Mediterranean and the Near East, for example Turkey, Syria, Palestine (e.g., Stchepinsky 1942), the Albian to ?Campanian of Africa, for example Tunisia, Somalia, Gabon, Congo, Angola, South Africa (e.g., Pervinquièrre 1912; Rennie 1930; Darteville et al. 1957; Freneix 1966), and the Upper Cretaceous of southern India (Stoliczka 1871). A number of very similar species have also been described from the Cretaceous of North America (e.g., Stephenson 1955; Packard and Jones 1965).

Many Recent pinnids possess teleplanic larvae, capable of being transported over long distances (e.g., Scheltema 1977; Butler et al. 1993). Such larvae might have been also present in *P. cretacea* and, along with external factors, such as climatic and palaeoceanographic conditions, controlled its wide distribution. The Late Cretaceous was characterised by globally warm climates and very high sea-levels. The relatively low temperature gradients between polar and equatorial regions (e.g., Huber et al. 1995) and the development of extensive shallow-marine shelf areas apparently favoured rapid and wide dispersal of taxa. This is reflected in the overall composition of marine macroinvertebrate faunas in the Cretaceous of Brazil, both benthic and nektic. In general, these faunas show low degrees of endemism. All macroinvertebrate groups, e.g., ammonites, bivalves, gastropods, and echinoids, show strong affinities with faunas described

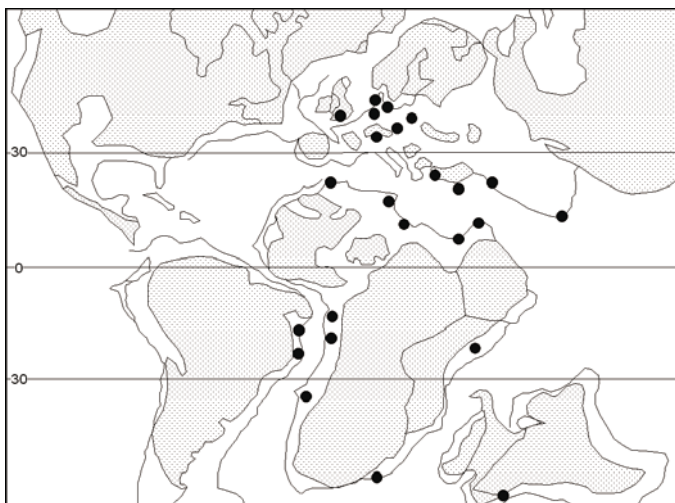


Fig. 3. Palaeobiogeographical distribution of *Pinna cretacea* (Schlotheim, 1813) in the Late Cretaceous. For sources see text. Map for the Turonian based on Barron et al. (1981), Barron (1987), and Funnell (1990).

from other areas, in particular the southern Tethys (e.g., Smith and Bengtson 1991; Smith 1992; Bengtson 1996; Seeling and Bengtson 1999, 2002, 2003).

## Pinnidae in the Cretaceous of Brazil

The first report of *Pinna* from the Cretaceous of Brazil was by Wanderley (1938), who reported "Pinas" from Jiquy, near Socorro (= Cajaíba 3 area of Bengtson 1983, lower Coniacian). This is the same area and stratigraphic interval from where the majority of the specimens studied here derive. Beurlen (1964) briefly noted the presence of a species of *Pinna* in the Riachuelo Formation (Aptian–Albian), without providing further details. From the overlying Cotinguiba Formation (Cenomanian–Coniacian) Brito (1981) remarked on the abundance of *Pinna* in the Jiqui quarry and Bengtson (1983) regarded the genus as a characteristic component of the lower Coniacian.

*Pinna* has also been reported from northern Sergipe (from Morro do Chaves, near Propriá on the São Francisco River) and originally said to be Triassic (Duarte 1936). The age was subsequently revised (see history in Petri 1962) and is now considered to be early Cretaceous (Coqueiro Seco Formation) on the basis of ostracodes and palynomorphs. Duarte's (1936) specimens were small, poorly preserved external moulds and left undescribed. As the co-occurring bivalves and other fossils such as ostracodes are non-marine (E.A.M. Koutsoukos, Petrobras, Rio de Janeiro, and W. Souza-Lima, Petrobras, Aracaju, *in litt.*) it can be safely assumed that Duarte's (1936) report of *Pinna* was based on a misidentification.

From outside Sergipe only two Cretaceous pinnid species have been described: *Pinna* aff. *decussata* Goldfuss, 1837

from the Albian of the Camamu Basin (Brito 1967), and *Atrina reginamaris* (Maury, 1930) from the Maastrichtian of the Pernambuco-Paraíba Basin (Maury 1930; Muniz 1993).

Brito (1967) remarked on the great similarities between his specimens from Camamu and the *P. decussata* described by Rennie (1930) and Darteville et al. (1957) from South Africa and the west African basins. He left the specimens in open nomenclature owing to their poor preservation. In our view, even if the specimens are not well preserved, the description and the figures of Brito (1967) clearly show that they fall within the variability of *P. cretacea*. The specimens were assigned a late Albian age, based on the occurrence of the ammonite *Elobiceras* in the same beds (Algodões Formation) (Brito 1967). In Sergipe the oldest confirmed specimen of *Pinna* appears in beds inferred to be Cenomanian (locality Cruzes 16, see Bengtson 1983, Appendix 1), although a late Albian age cannot be excluded. The great majority, however, occur in the upper Turonian–lower Coniacian. The Camamu species as well as all our specimens from Sergipe are here referred to *Pinna cretacea* (Schlotheim, 1813).

*Atrina reginamaris* (Maury, 1930) from the Pernambuco-Paraíba Basin, originally described as a *Pinna*, was redescribed by Muniz (1993) and placed in *Atrina* on the basis of the absence of a bilobate internal nacre. *A. reginamaris* shows some similarities with *P. laqueata* Conrad, 1858 from the Campanian of the Gulf Coast and Texas (USA) but has fewer radial ribs.

A report by Beurlen (1961) of *Atrina laticostata* (Stoliczka, 1871) from the Beberibe Formation (Turonian–Campanian, *vide* Feijó 1995b) of the Pernambuco-Paraíba Basin is difficult to assess without description or figures of the specimens. However, *A. laticostata* is very similar to *P. cretacea*, and poorly preserved specimens are easily confused.

## Systematic palaeontology

Family Pinnidae Leach, 1819

Genus *Pinna* Linné, 1758

*Remarks.*—*Pinna* shows strong morphological similarity with *Atrina* Gray, 1842. The principal distinguishing character is the interior nacre, which in *Pinna* is divided medially into two lobes, and the presence of a median carina in this genus.

*Pinna cretacea* (Schlotheim, 1813)

Fig. 4A–C.

*Pinnites cretaceus* Fauj.; Schlotheim 1813: 113.

*Pinna decussata nobis*; Goldfuss 1837: 166, pl. 128: 1, 2.

*Pinna arata*, Forbes; Stoliczka 1871: 384, pl. 24: 5, pl. 25: 1, pl. 26: 5.

*P. cretacea* Schloth.; Geinitz 1875: 54, pl. 14: 2, 3.

*P. decussata* Goldf.; Geinitz 1875: 53, pl. 15: 2, 3, pl. 16: 1.

*Pinna cretacea* Schlotheim; Wegner 1905: 157, 156.

*Pinna decussata* Goldfuss; Pervinquier 1912: 130.

*Pinna* cf. *decussata* Goldfuss; Rennie 1930: 174, text-figs. 2, 3, pl. 19: 9.

*Pinna cretacea* Schloth. sp.; Andert 1934: 88–90.

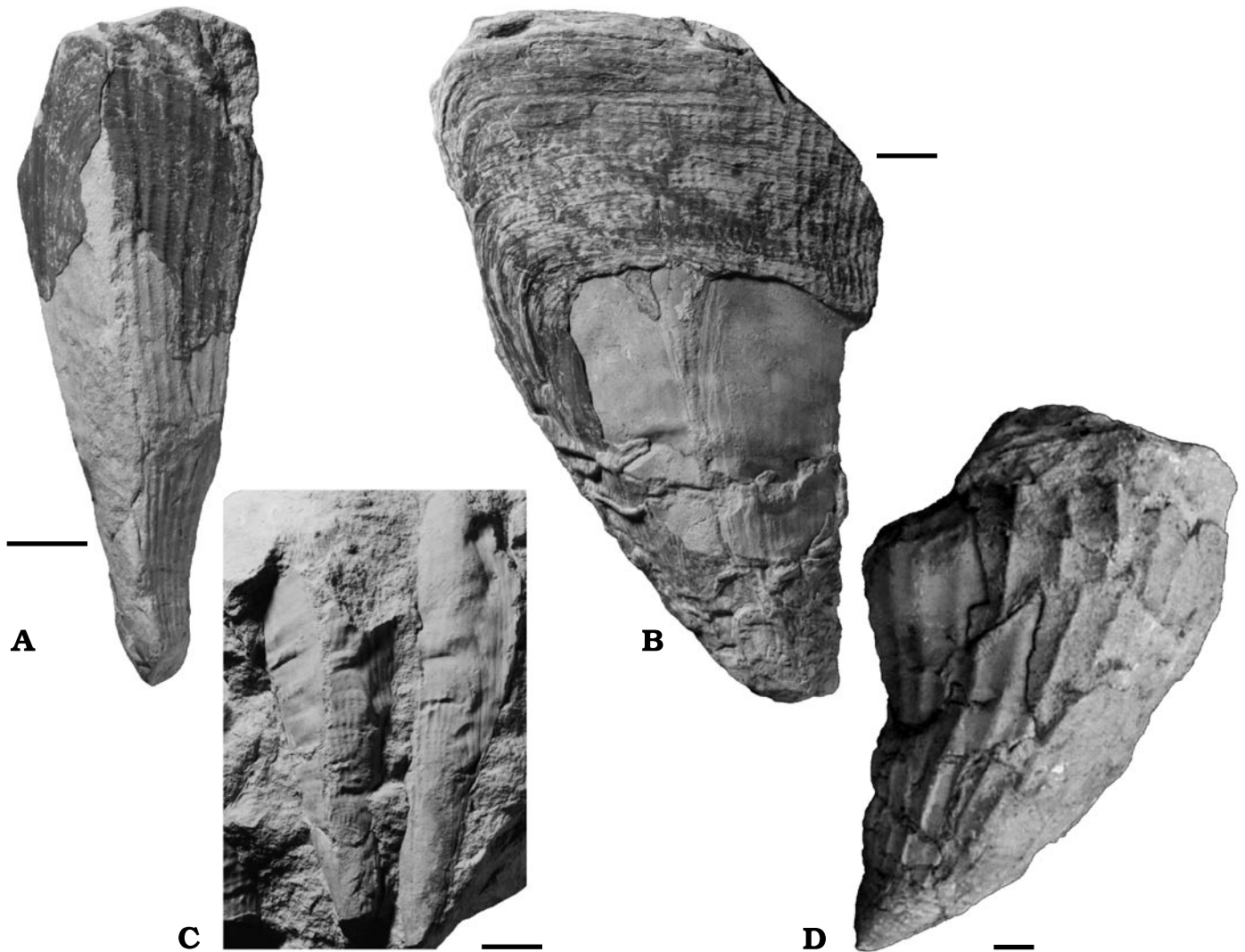


Fig. 4. *Pinna cretacea* (Schlotheim, 1813) from Sergipe. **A.** Right valve (no. GPIH-BR C37.192), from Cajaíba 7, Cotinguiba Formation, upper Turonian or lower Coniacian. **B.** Right valve, internal mould with trace of bilobate internal nacreous layer (no. GPIH-BR C26.14), from Mucuri 7, Cotinguiba Formation, upper Turonian. **C.** *Pinna cretacea* (Schlotheim, 1813) from Sergipe; internal moulds of two left valves preserved in life position (nos GPIH-BR C37.716, 717), from Cajaíba 7, Cotinguiba Formation, upper Turonian or lower Coniacian. **D.** *Atrina reginamaris* (Maury, 1930) from the Pernambuco-Paraíba Basin (no. DG-CT-UFPE 3232), from “Pedreiras do Roger”, João Pessoa, Paraíba (“locality 5” of Muniz 1993), Gramame Formation, Maastrichtian; specimen housed in the collections of the Department of Geology of the Universidade Federal de Pernambuco, Recife, Brazil. Scale bars 2 cm.

*Pinna decussata* Goldfuss; Stchepinsky 1942: 21, 55, pl. 4: 3.

*Pinna decussata* Goldfuss; Darteville et al. 1957: 68, pl. 9: 1a–c.

*Pinna* aff. *P. decussata* Goldfuss; Brito 1967: 7, 8, pl. 1: 7–9.

*Pinna decussata*; Križ and Soukup 1975: 47–49, pl. 2: 1–5.

*Pinna cretacea* (v. Schlotheim, 1813); Abdel-Gawad 1986: 140, 141, pl. 30: 1; with extensive synonymy for northern and eastern European occurrences.

**Material.**—37 internal moulds of the anterior end of the shell, from eight localities in the Cenomanian (Cruzes 16: no. C380.6), lower Turonian (Laranjeiras 21: no. C61.38; Laranjeiras 22: no. C62.38; Pedra Furada 5: no. C96.4), upper Turonian (Mata 10: nos C367.3, 4, 39), upper Turonian or lower Coniacian (Cajaíba 7: nos C37.7, 8, 17, 18, 55, 129–133, 189–192, 588, 598, 716–720; Mucuri 7: nos. C26.4, 5, 14, 15, 51, 53, 77, 78; Mucuri 9: no. C32.1) of the

Cotinguiba Formation, Sergipe Basin, Brazil (specimen numbers prefixed by GPIH-BR).

**Description.**—Large, maximum length of preserved, anterior part 250 mm; equivalve, narrow, very elongate, triangular, wedge-shaped shell; dorsal margin straight to slightly concave, ventral margin straight to slightly convex; median carina running from umbo towards posterior margin dividing valves into two nearly equal parts; each part covered with six to nine strong radial ribs separated by broad interspaces, in some specimens posterior portions of dorsal part with weaker intercalary ribs; radial ribs crossed by concentric growth lines forming net-like structure on internal moulds, strong ridges or folds near postero-ventral margin, forming acute angle with last radial rib and curving slightly towards the umbo; internal nacre divided medially into two lobes; cross-section of valves



quadrate near the umbo, rhombic to diamond-shaped at mid-length and flattened, lenticular towards the posterior end. Fragments of shell material is preserved in ten specimens (nos C26.14, 15, 77, 78; C37.8, 131, 133, 192, 598; C62.38).

*Discussion.*—Most of the European Upper Cretaceous pinnids have been assigned to *Pinna cretacea* (Schlotheim, 1813) or *Pinna decussata* Goldfuss, 1837. The main distinguishing character between these species is the more elongate shape of *P. cretacea* and its less distinctly curved ridges on the ventral part of the shell. However, their morphological differences are minor and have never been clearly defined (Dhondt 1987). Also in Recent *Pinna* there is considerable variation in the width of the shell between different localities and even within the same area (C.A. Richardson, Anglesey, written communication, 2002). Moreover, most European Cretaceous pinnids are poorly preserved and commonly deformed. The width of the shell is therefore not a useful taxonomic character. The two species were synonymised by Wegner (1905), a view followed by a number of subsequent authors (e.g., Andert 1934; Abdel-Gawad 1986; Dhondt 1987) and also by us. There are also less elongate, broader specimens in the Sergipe material but the difference in shape is probably a result of post-depositional deformation. Thus, all specimens from Sergipe are assigned to *P. cretacea*.

*P. arata* Forbes, 1846 was originally based on the presence of secondary ribs on the dorsal part of the shell. In all other respects it is similar to *P. cretacea*, as already discussed by Stoliczka (1871). Secondary ribs are also seen in some of the specimens from Sergipe and we consider this feature to fall within the variability of *P. cretacea*.

The North American species *Pinna laqueata* Conrad, 1858 (see Stephenson 1955) and *Pinna calamitoides* Shumard, 1858 (see Packard and Jones 1965) closely resemble *P. cretacea*. This applies to their general outline and ornamentation as well as to the internal characteristics of the shell (Abdel-Gawad 1986).

*Atrina laticostata* (Stoliczka, 1871) is a very similar species described from the Albian to Campanian of West Africa (Nigeria, Gabon, Cameroon) (e.g., Solger 1904; Riedel 1932; Darteville et al. 1957; Barber 1958) and southern India (Stoliczka 1871). It is differentiated from *P. cretacea* by having fewer ribs and by the lack of a median carina. In all other respects the species are similar and poorly preserved specimens may be easily confused.

*Atrina reginamaris* (Maury, 1930) from the Maastrichtian of the Pernambuco-Paraíba Basin is distinguished by its broader posterior end, more concave dorsal margin and more convex ventral margin, its smaller number of radial ribs, which are separated by much broader interspaces, and by the absence of a nacreous inner layer (Fig. 4D).

*Occurrence.*—Widely distributed in the Albian to Maastrichtian of Europe, Africa and southern India; in Brazil the species occurs in the Albian of the Camamu Basin and the Cenomanian to lower Coniacian of the Sergipe Basin.

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