

# Bivalves (Mollusca) from the Coniacian-Santonian Anguille Formation from Cap Esterias, Northern Gabon, with notes on paleoecology and paleobiogeography

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## ABSTRACT

The Anguille Formation (Coniacian-Santonian) of North of Gabonese coastal basin has been analysed from the 'Cap Esterias' section. Palaeoecologic and paleogeographic aspects of the bivalves were taken into account. Twelve bivalve species representing 9 genera have been identified from 'Cap Esterias' section. Among these *Acanthocardia* cf. *denticula* (Baily, 1855), *Aphrodina dutrugei* (Coquand, 1862) and *Protocardia* cf. *pauli* (Coquand, 1862) are found for the first time in the 'Cap Esterias' region. A large part (66.67%) of the identified bivalve species occur over a wide geographical area: from Brazil to Central Africa, eastern Mediterranean region, Madagascar, Nigeria, northwestern Africa, South Africa, southern India and southern Europe. The fauna is composed only of suspension-feeders indicating that food resources were dominantly in suspension. The assemblage of bivalves is dominated by shallow burrowing infaunal bivalves and indicates the existence of an unstable and soft substrate. This assemblage can be regarded as parautochthonous.

## KEY WORDS

Palaeoecology,  
paleogeography,  
Gabonese coastal basin,  
bivalves,  
Cap Esterias.

## RÉSUMÉ

*Les Bivalves (Mollusques) du Coniacien-Santonien de la Formation de l'Anguille du Cap Estérias, nord du Bassin Gabonais; notes sur la paléoécologie et paléogéographie.*

Les aspects paléoécologiques et paléogéographiques des bivalves de la Formation de l'Anguille (Coniacien-Santonien), au nord du bassin côtier gabonais, ont été analysés à partir de la coupe du « Cap Estérias ». Douze espèces de bivalves représentant neuf genres ont été identifiées au niveau de cette coupe. Parmi elles, *Acanthocardia* cf. *denticula* (Baily, 1855), *Aphrodina dutrugei* (Coquand, 1862) et *Protocardia* cf. *pauli* (Coquand, 1862) sont signalés pour la première fois dans la région du « Cap Estérias ». Une grande partie (66,67 %) des espèces identifiées ont une large distribution géographique. Elles sont connues au Brésil, en Afrique centrale, à l'Est de la région méditerranéenne, à Madagascar, au Nigéria, au Nord-Ouest de l'Afrique, en Afrique du Sud, au sud de l'Inde et au sud de l'Europe. La faune est composée seulement des suspensivores. Ceci est l'indice de l'abondance de la nourriture en suspension. L'assemblage des bivalves est dominé par les épibiontes enfouis, ce qui indique un substratum instable et meuble. L'assemblage peut être regardé comme para autochtone.

## MOTS CLÉS

Paléoécologie,  
Paléogéographie,  
Bassin côtier gabonais,  
bivalves,  
Cap Estérias.

## INTRODUCTION

The history of the Gabonese coastal basin (Fig. 1) is connected to opening of the South Atlantic Ocean (Klasz 1965; Reyre 1989; Teisserenc & Villemin 1990). The tectonic and sedimentary evolution (Mbina Mounquengui 1998; Mbina Mounquengui *et al.* 2002; Mbina Mounquengui & Lang 2003) permit three phases to be distinguished: prerift phase (Precambrian-Jurassic), rift phase (Neocomian-Barremian) and postrift phase (Aptian-present). Prerift and rift phases are characterized mainly by continental, lacustrine and fluvial sediments whereas postrift phase is characterized by marine sediments.

The postrift phase contains several formations. Among these, there is the Anguille Formation which occurs in the Cap Esterias region. The stratigraphical framework, together with the palaeontological value of the Anguille Formation has been discussed by several authors (Hourcq & Hausknecht 1954; Darteville & Brébion 1956; Darteville & Freneix 1957; Gérard 1958; Klasz 1965; Hudeley & Belmonte 1970; Vidal *et al.* 1975; Moussodou 1984; Reyre 1989; Teisserenc & Villemin 1990; Dupont 1996; Volat *et al.* 1996; Chevalier *et al.* 2002; Mbina Mounquengui *et al.* 2008). Unfortunately, references to the marine bivalves exist in the form of species list, without taxonomic descriptions or illustrations. Only Darteville & Freneix (1957) provide information on taxonomy and paleogeography. There are no known works on the paleoecology of the Anguille Formation. Therefore the marine bivalve fauna and its ecology in the Anguille Formation are still unknown, despite the abundance and often dominance of bivalve fossils in the deposits.

This paper is an attempt to improve this situation based on bivalve mollusks collected from the so-called 'Cap Esterias' section, North subbasin of Gabonese coastal basin.

## GEOLOGICAL SETTING

The Anguille Formation was deposited on the continental shelf and shows two sedimentary cycles (Klasz 1965; Vidal *et al.* 1975; Logar 1983; Moussodou 1984; Reyre 1989; Teisserenc & Villemin 1990; Dupont 1996; Volat *et al.* 1996; Chevalier *et al.* 2002). The base of the first cycle is composed of silty clays with chert layers. The rest of the first cycle is silty. The second cycle is more sandy. The first and second cycle are assigned respectively to Coniacian and Santonian by microfossils and ammonites (Hudeley & Belmonte 1970; Klasz & Michelot 1971). In the western part of the basin, the Anguille formation has clay at the base, overlain by thick turbiditic sand deposits.

The Anguille Formation overlies the Azilé Formation (Turonian) and is overlain by the Pointe Clairette Formation (Campanian) (Fig. 2). Total thickness of the Anguille Formation is about 650 to 800 m (Teisserenc & Villemin 1990).

Fossils of the Anguille Formation include foraminifera, ostracods, gastropods, ammonites, pollen and bivalves (Darteville & Brébion 1956; Darteville & Freneix 1957; Hudeley & Belmonte 1970; Klasz & Micholet 1971; Boltenhagen 1975a, b; Klasz 1965; Dupont 1996; Volat *et al.* 1996).

The measured section (Fig. 1C) is located at 'Cap Esterias' region in North of Libreville within North subbasin at GPS coordinates 0°36'50.3"N, 9°19'07.0"E (Fig. 1). It consists of clay, sandstone, silt to argillaceous sandstone and silty clay. The section was subdivided into five units, based on lithology. From the bottom to the top, these units are: Unit 1 is composed of 1.8 m thick of dark clay with medium bioturbation. Unit 2 made of 1.2 m of bioclastic, indurated, medium to coarse sandstone. This unit is highly bioturbated towards the top and contains bivalves, rare ammonites and rare gastropods. Some articulated bivalves specimens were found in live position. The upper 3.10 m represents Unit 3 which is consisting of silt to argillaceous sandstone with low bioturbation. Above there is 50 cm (Unit 4) of Breccia. Higher up in the section is Unit 5 composed of 90 cm of highly bioturbated silty clay.

## MATERIAL

The study was conducted based on 86 specimens from Cap Esterias section. All specimens are collected only within Unit 2. From the collected specimens, 54 are disarticulated and 32 are articulated. Most of the specimens are preserved as internal or external mould like *Agelasina plenodonta* Riedel, 1932 and *Aphrodina gabonensis* Darteville & Freneix, 1957. Some specimens have shell preserved as *Granocardium productum* (Sowerby, 1832) and *Granocardium* sp.

The material is deposited at the collection of the Geology Department, Faculty of Sciences Masuku University of Franceville (Gabon), under collection number MDG/CEs/Lm.

## BIVALVE FAUNA

Identification of material has relied on various sources, inclusive of Sowerby (1832), Sharpe (1850), Baily (1855), Coquand (1862), Stoliczka (1871), Woods (1906), Pervinquier (1912), Barber (1958), Riedel (1932), Darteville & Freneix (1957), Dhondt & Dieni (1993), Abdel-Gawad *et al.* (2004), El Qot (2006), Ayoub-Hannaa (2011), Benyoucef *et al.* (2012). In the descriptions, the terms small, medium and large are defined by the following size ranges: small, up to 10.0 mm long; medium, 10.1 mm to 30 mm; large 30.1 mm and over.

Family ARCTICIDAE Newton, 1891

1. *Agelasina plenodonta* Riedel, 1932  
(Fig. 4F, H, L, P)

## DESCRIPTION

Shell large, equivalve, inequilateral subtrigonal to subtrapezoidal in outline; umbo prosogyrate; valves inflated; outer surface with or without fine concentric growth line; anterior and ventral margins well rounded; posterior margin evenly rounded; carina in both valves.

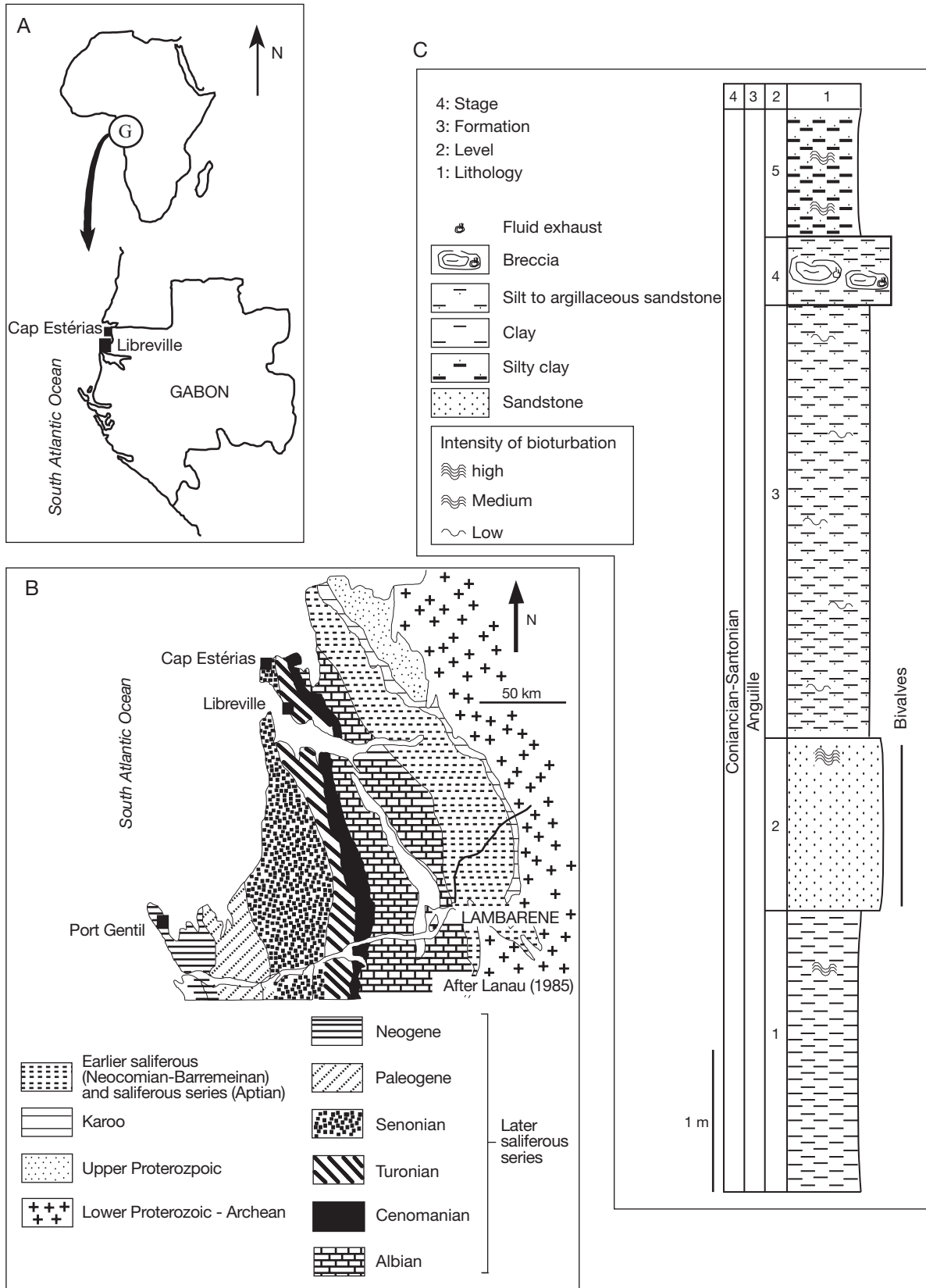


FIG. 1. — **A**, Location map of Gabon and Cap Estérias; **B**, geological map of north Gabonese coastal basin; **C**, lithostratigraphy of the 'Cap Estérias' section. Geological map after Lanau (1985).

TECTONIC ASSEMBLAGE	SALIFEROUS PHASE	BIOZONATION Ostracods, spores and pollens, foraminifers				FORMATIONS	EQUIVALENCE		
		EW	M6	C16					
Post-Rift	Post saliferous phase					Ewongue	MAASTRICHTIAN	SENONIAN	
		PC	M5		2 1	Pointe Clairette	CAMPANIAN		
		AG	M4			2 1	Anguille		SANTONIAN
				C15					CONIACIAN
				AZ			Azile	TURONIAN	
				LO			Cap-Lopez	CENOMNIAN	
				MD			Madiela	ALBIAN	
	Saliferous phase				Ezanga	APTIAN			
		AP			Como				
Syn-Rift	Pre saliferous phase				Série des Shistes		BARREMIAN		
				BA					
				NE			HAUTERIVIAN		
Pre-Rift					Grès de N'dombo				

Fig. 2. — Cretaceous stratigraphic nomenclature of the Gabonese sedimentary basin and place of the Coniacian-Santonian (after Mbina Mounguengui & Lang, 2003, modified).

Family CARDIIDAE Lamarck, 1809

2. *Acanthocardia* cf. *denticulata* (Baily, 1855) (Fig. 4B)

DESCRIPTION

Shell medium, triangular in outline; umbo prosogyrate; valves weakly inflated; outer surface with radial ribs; anterior and posterior margins straight, ventral margin weakly rounded.

3. *Granocardium productum* (Sowerby, 1832) (Fig. 4C)

DESCRIPTION

Shell large, equivalve, subequilateral, subtrigonal to suborbicular in outline; umbo prominent; valves inflated; outer surface with radial ribs; anterior margin slightly rostrate, rounded in outline; posterior margin straight, rounded into ventral margin.

4. *Granocardium* sp. 1 (Fig. 4D)

DESCRIPTION

Shell large, equivalve, inequilateral, subtrigonal to elongate in outline; umbo prosogyrate, valve inflated; outer surface with radial ribs which have pearls; anterior margin rostrate, rounded in outline; posterior margin rounded.

5. *Granocardium?* sp. 2 (Fig. 4A, Q?)

DESCRIPTION

Shell large, inequilateral subtrigonal to elongate in outline; umbo breacked, valve slightly inflated, outer surface with

big radial ribs. Anterior margin rounded; posterior margin straight, rounded into ventral margin.

6. *Protocardia* cf. *pauli* (Coquand, 1862) (Fig. 4G, J)

DESCRIPTION

Shell large, equivalve, inequilateral, elongate in outline; umbo prosogyrate, valves inflated, anterior margin straight, subrounded into ventral margin; posterior margin cruved; no ornament preserved.

7. *Protocardia?* sp. (Fig. 4E)

DESCRIPTION

Shell medium, equal, inequilateral, diamond-shaped in outline; umbo prosogyrate, valves inflated; anterior margin more rostrate than posterior margin; no ornament preserved.

Family LIMIDAE Rafinesque, 1815

8. *Plagiostoma pseudohernesi* (Riedel, 1932) (Fig. 4N)

DESCRIPTION

Shell large, subequivalve, suborbicular in outline; umbo prominent; valves slightly inflated; outer surface with ten ribs (five in each part) anterior and posterior margins straight, rounded into ventral margin.



FIG. 3. — Palaeobiogeographical distribution of bivalves fauna of 'Cap Estérias' in the Late Cretaceous. Geological map modified after Vrielynck & Bouysse (2003).

Family VENERIDAE Rafinesque, 1815

9. *Anofia?* sp. (Fig. 4M)

DESCRIPTION

Shell large, suborbicular in outline; umbo prosogyrate; outer surface with fine concentric line toward ventral margin; anterior and posterior margins straight, rounded into ventral margin.

10. *Aphrodina dutruegi* (Coquand, 1862) (Fig. 4I)

DESCRIPTION

Shell medium to large, equivalve, inequilateral, subtrigonal in outline; umbo prosogyrate; valve inflated; anterior margin slightly rostrate, rounded in outline; posterior margin evenly rounded, passing smoothly into the weakly convex ventral margin, no ornament preserved.

11. *Aphrodina gabonensis* Darteville & Freneix, 1957 (Fig. 4O)

DESCRIPTION

Shell large, equivalve, inequilateral, subtrigonal in outline; umbo prosogyrate; valves slightly inflated; outer surface with

concentric fine line; anterior margin slightly rounded; posterior margin curved.

Family PINNIDAE Leach, 1819

12. *Atrina laticostata* (Stoliczka, 1871) (Fig. 4K)

DESCRIPTION

Shell large, equivalve, inequilateral, elongate triangular in outline; umbo breacked; outer line with radial ribs; anterior and posterior margins straight; ventral margin straight to slightly round.

DESCRIPTION OF BIVALVE ASSEMBLAGE

The fossil bivalve assemblages from the unit 2 of the 'Cap Estérias' section consist of 12 species belonging to 9 genera. These species are *Acanthocardia* cf. *denticulata*, *Agelasma plenodonta*, *Anofia?* sp., *Aphrodina dutruegi*, *Aphrodina gabonensis*, *Atrina laticostata*, *Granocardium productum*, *Granocardium* sp. 1, *Granocardium?* sp. 2, *Plagiostoma pseudohoernesii* (Riedel, 1932), *Protocardia* cf. *pauli*, *Protocardia?* sp.

The bivalve assemblage from 'Cap Esterias' section is dominated by genera *Aphrodina* Conrad, 1869 (22 specimens)

TABLE 1. — Summary of life-habit and trophic groups of the bivalves identified in this study.

Families	Species	Life-Habit							Trophic-Groups	
		free and mobile	cemented	byssate	semi-infaunal-byssate	shallow-burrower	deep-burrower	mobile	Suspensions-feeders	deposit-feeders
		Epifaunal			Infaunal					
Arctiidae	<i>Agelasina plenodonta</i> Riedel, 1932					×			×	
Cardiidae	<i>Acanthocardia cf. denticulata</i> (Baily, 1855)					×			×	
	<i>Granocardium productum</i> Sowerby, 1832					×			×	
	<i>Granocardium</i> sp. 1					×			×	
	<i>Granocardium?</i> sp. 2					×			×	
	<i>Protocardia cf. pauli</i> (Coquand, 1862)					×			×	
	<i>Protocardia?</i>					×			×	
Limidae	<i>Plagiostoma pseudohoernesii</i> (Riedel, 1932)			×						×
Veneridae	<i>Anofia?</i> sp.					×				×
	<i>Aphrodina dutrugei</i> (Coquand, 1862)					×				×
	<i>Aphrodina gabonensis</i> Darteville & Freneix, 1957					×				×
Pinnidae	<i>Atrina laticostata</i> (Stoliczka, 1871)				×					×

and *Agelasina* Riedel, 1932 (24 specimens). At the family level, it is dominated by the family Cardiidae with six species (Table 1). The others families are represented by one or three species (Table 1).

With respect to life habits (Table 1), the bivalve assemblage from ‘Cap Esterias is dominated by shallow infaunal burrowers (96.82%). These are *Agelasina plenodonta* (40.68%), *Aphrodina gabonensis* (22.22%) and *Aphrodina dutrugei* (11.11%). *Plagiostoma pseudohoernesii* and *Atrina laticostata* are the only representatives respectively of epifaunal byssate (1.59%) and semi-infaunal-byssate (1.59%) bivalves. The assemblage is characterized by the absence of deep-burrower and mobile infaunal elements one one hand and by absence of free, mobile and cemented epifaunal on the other.

According to their trophic-group (Fig. 4), all bivalves are suspension-feeders. The representatives of *Aphrodina* and *Agelasina*, together comprising 74.01% of the fauna, are suspension-feeders bivalve that dominate the assemblage. They others bivalves are represented by 2.33% such *Granocardium* and *Protocardia* or 1.59% such as *Acanthocardia* Gray, 1851, *Anofia* Reymont, 1955, *Atrina* Gray, 1842 and *Plagiostoma* Sowerby, 1814. No deposit feeders were found in the assemblage.

## DISCUSSION

### PALEOBIGEOGRAPHY

Of the nine identified species, eight (88.89%) occur over a broad geographical area, ranging from Brazil to Central Africa (Angola, Cameroon, Congo, Gabon, RDC) (Riedel 1932; Darteville & Freneix 1957; Ricardo Lopes De Simone & Mezzalira 1994; Musavu Moussavou *et al.* 2013, 2014), eastern Mediterranean region (Jordan, Palestine) (Berndt 2002; Ahmad 2005), Madagascar (Basse 1933), Nigeria (Barber

1958), northwestern Africa (Egypt, Tunisia, Algeria, Morocco) (Pervinquier 1912; Abbass 1962; Fawzi 1963; Abdel-Gawad *et al.* 2004; El Qot 2006; Benyoucef *et al.* 2012), South Africa (Baily 1855; Woods 1906), southern India (Stoliczka 1871), and southern Europe (Italy, Portugal) (Sharpe 1850; Dhondt & Dieni 1993) (Fig. 3). Species with such broad distributions include: *Acanthocardia cf. denticulata* (Fig. 4B), *Agelasina plenodonta* (Fig. 4F, H, L), *Aphrodina dutrugei* (Fig. 4I), *Atrina laticostata* (Fig. 4K), *Granocardium productum* (Fig. 4C), *Plagiostoma pseudohoernesii* (Fig. 4N) and *Protocardia cf. pauli* (Fig. 4G, J), *Protocardia?* sp. (Fig. 4E). Among taxa identified, *Aphrodina gabonensis* (Fig. 4O) (8.33%) represents the only endemic species to the gabonese coastal basin during Coniacian-Santonian interval. This means that open marine connections were established between north of Gabon, the mediterranean province, Central Africa, South Africa, southern India and southern Europe in Coniacian-Santonian.

### PALAEOECOLOGY

The palaeoautecology of bivalves is summarised in Table 1. It is based on information by Yonge (1953), Duff (1978), Pugaczewska (1986), Berndt (2002), Delvene (2003), Ayoub-Hannaa (2011), Ayoub-Hannaa & Fürsich (2012). Most of the bivalve taxa encountered have been previously recorded from ‘Cap Estérias’ region (Darteville & Freneix 1957) excepted for *Acanthocardia cf. denticulata*, *Aphrodina dutrugei* and *Protocardia cf. pauli* which are recorded here for the first time.

Many studies have treated the distribution patterns of marine macroinvertebrates (e.g., Fürsich 1984, 1994; Berndt 2002; Delvene 2003; Fürsich *et al.* 2004; Harzhauser & Mandic 2004; Zuschin *et al.* 2004a, b; Fürsich & Thomsen 2005; Schneider *et al.* 2009; Ayoub-Hannaa 2011; Ayoub-Hannaa & Fürsich 2012; Bengtson *et al.* 2014). The parameters controlling faunal distribution are substrate, water energy, salinity, temperature, nutrient supply and oxygen availability.



FIG. 4. — **A, Q**, *Granocardium?* sp. 2; **B**, *Acanthocardia* cf. *denticulata* (Baily, 1855); **C**, *Granocardium productum* (Sowerby, 1832); **D**, *Granocardium* sp. 1; **E**, *Protocardia?* sp.; **F, H, L, P**, *Agelasma plenodonta* Riedel, 1932; **G, J**, *Protocardia* cf. *pauli* (Coquand, 1862); **I**, *Aphrodina dutrugei* (Coquand, 1862); **K**, *Atrina laticostata* (Stoliczka, 1871); **M**, *Anofia?* sp.; **N**, *Plagiostoma pseudohoernesii* (Riedel, 1932); **O**, *Aphrodina gabonensis* Darteville & Freneix, 1957. Scale bar: 2 cm.

The bivalve assemblage of 'Cap Estérias' section is dominated by shallow burrower infaunal bivalve. This indicates the existence of soft substrate (Delvene 2003; Fürsich & Tomsen 2005; Ayoub-Hannaa 2011; Ayoub-Hannaa & Fürsich 2012; Bengtson *et al.* 2014). Deep-burrower infaunal bivalves are absent. This may be related to the dissolution of aragonitic shell during early diagenesis and/or to low oxygen condition in deeper layers of the substrate.

All bivalves are suspension-feeders. This means that the water energy level was sufficiently high to keep organic matter in suspension (Berndt 2002; Delvene 2003; Fürsich & Tomsen 2005; Ayoub-Hannaa 2011; Ayoub-Hannaa & Fürsich 2012). The absence of deposit feeders suggests probably a very small amount of organic matter in the sediment or organics in the water column (Ayoub-Hannaa & Fürsich 2012). This, suggests also an environment at least intermittently influenced by waves and/or currents (Fürsich & Heinberg 1983).

According to Boucot *et al.* (1958), the degree of disarticulation is a reliable means of determining the relative amount of taphonomic reworking. In 'Cap Estérias' section, 54 disarticulated and 32 articulated specimens are collected. Moreover abrasion and breakage of shells are low. Large-sized *Agelasina* shells are common (10 articulated specimens versus 13 disarticulated specimens). This suggests that bivalve community from 'Cap Estérias' section is transported under high-energy conditions, but of short duration and a short distance after death (Boucot *et al.* 1958; Seeling & Bengtson 1999). Therefore the assemblage of bivalves can be regarded as parautochthonous.

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