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HOLOPLANKTONIC GASTROPODS FROM THE EARLY MESSINIAN OF THE HERAKLION BASIN (CRETE, GREECE)

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The first finds of planktonic gastropods from the Messinian (Late Miocene) of the Aegean area are described. They originate from Early Messinian marls of the Heraklion Basin of Crete (Greece). Representatives of euthecosomatous pteropods [*Limacina* sp., *Bowdenatheca jamaicensis* Collins, 1934, *Diacria trispinosa* (de Blainville, 1821) and *Cavolinia gypsorum* (Bellardi, 1873)] and of heteropods (*Protatlanta* sp., *Atlanta* sp. and *Carinaria lamarcki* Péron & Lesueur, 1810) have been identified. Material assigned to *Carinaria* and *Bowdenatheca* represents the first Messinian record of these genera. The occurrence of holoplanktonic gastropods indicates a normal marine salinity during the Early Messinian.

Key words — Mollusca, Pteropoda, Heteropoda, Miocene, Messinian, Crete, taxonomy, palaeoecology.

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INTRODUCTION

The holoplanktonic gastropods (euthecosomatous pteropods and heteropods) described in the present paper have been collected by Mrs Sophia Tsagaris and Mr Bruno Delrieu (Paris) during field work for the preparation of geological memoirs on the Neogene of the Heraklion Basin (Crete). The marls in the outcrops studied which yielded these holoplanktonic gastropods have been dated by Mrs G. Bizon (Paris) using planktonic foraminifera as Early Messinian, corresponding to Zone N 17.

Holoplanktonic gastropods are here recorded from the Messinian of Crete for the first time. They are therefore discussed in detail, although a palaeoecological study of the entire faunal assemblages will be published elsewhere (Gaudant *et al.*, in prep.). The material described in the present contribution is housed in the Palaeontological Institute of the Muséum national d'Histoire naturelle at Paris (MNHNP), where the illustrated specimens bear the registration numbers R.62678 to R.62687. All specimens are preserved as internal or external moulds lacking shell material. The letters and numbers cited in the 'Systematic part' below [Material studied] refer to sample numbers used by the collectors.

MESSINIAN HOLOPLANKTONIC GASTROPODS FROM THE MEDITERRANEAN AREA

Records of holoplanktonic gastropods from the Messinian of the Mediterranean area are scant, all documented occurrences being restricted to the Piedmont Basin in northern Italy.

The most diverse fauna of Messinian pteropods was described by Pavia & Robba (1979) from the Late Messinian (S. Agata Fossili Formation, Montaldo Member) of Tetti Borelli near Torino. These authors recorded *Vaginella caribbeana* Collins, 1934, *Cuvierina intermedia* (Bellardi, 1873), *Cuvierina* aff. *tubulata* Collins, 1934, *Cuvierina* sp. 1 and *Diacria sangiorgii* Scarsella, 1934. Janssen (1995) revised this material; specimens referred to as *C. intermedia* proved to be *C.*

inflata (Bellardi, 1873), and *Cuvierina jagti* Janssen, 1995 was erected to include Pavia & Robba's *Cuvierina* sp. 1 and *C.* aff. *tubulata*. Janssen (1995) assigned *Vaginella caribbeana* to a new genus, *Edithinella*. New records for Borelli are *Clio giulioi* Janssen, 1995 and ? *Diacrolinia elioi* Janssen, 1995. The latter genus was also introduced by Janssen (1995).

Sturani (1973) mentioned *Cavolinia gypsorum* (Bellardi, 1873) from the Early Messinian from the environs of Alba from where it had already been collected by Bellardi (at Guarene d'Alba). Nannoplankton dating of the type lot of *C. gypsorum* from Guarene d'Alba has shown it to be of Tortonian age (nannoplankton Zone NN 10, identifications by E. Martini; see Janssen, 1995). Subsequent preparation of the type lot by Janssen (1995) also yielded the following species: *Atlanta* sp., *Limacina atlanta*, *Limacina* sp. indet. and *Diacria trispinosa* (de Blainville, 1821).

In the following literature sources references to the Early Messinian can be found: Sturani & Sampó (1973) collected *Cavolinia gypsorum* and the heteropod *Atlanta* or *Protatlanta* sp. indet. at Pecetto di Valenza near Alessandria and at Mussotto near Alba, and *C. gypsorum* at Collina di La Morra. The diatomitic marls from Pecetto di Valenza were considered to be of Tortonian age by Fourtanier *in* Fourtanier *et al.* (1991) on the basis of diatom assemblages. The sample from Collina di La Morra (Sturani & Sampó, 1973) contained also Creseinae sp. ? nov. (see Janssen, 1995).

Sturani (1978) illustrated *Atlanta* sp. from Biglini near Alba and *Diacria trispinosa* from S. Maria, northeast of La Morra. Janssen (1995) identified the *Atlanta* sp. of Sturani (1978) and Sturani & Sampó (1973) as *Limacina atlanta* (Mörch, 1874). In Sturani's (1978) sample Janssen additionally found *Styliola subula*, Creseinae sp. ? nov. and *Cavolinia gypsorum*; he also recorded *Limacina ? atlanta* and *Diacria sangiorgii* from the Early Messinian at Roddi (Alba).

Amongst the taxa mentioned above, *Diacria trispinosa* and *Styliola subula* are the only species which are still extant in the Mediterranean Sea. *Cavolinia gypsorum* appears to be the most characteristic pteropod species for the Early Messinian but it is not restricted to it.

MESSINIAN HOLOPLANKTONIC GASTROPODS FROM CRETE

In the present contribution the first Messinian holoplanktonic gastropods of the Aegean area are recorded from four localities in the Heraklion Basin in Crete. Neogene and Pleistocene sediments uncon-formably rest on pre-Neogene rocks in Crete. Latest Tortonian to earliest Late Messinian sediments (the Vrysses Group in Meulenkamp *et al.*, 1979) are known from the entire island. In the Heraklion Basin the Aghia Varvara Formation consisting of marls and limestones can be found; the marl sequences often contain evaporites. Holoplanktonic gastropods are preserved in the laminated yellowish marls and in the diatomitic intercalations of the pre-evaporitic Messinian. For further details and relevant literature the reader is referred to Meulenkamp *et al.* (1979) (in particular the Neogene of Crete) and to Rouchy (1982) for the Messinian in the Mediterranean area.

The localities from which holoplanktonic gastropods have been collected are: Mires (Aghios Ioannis), Psalidha, Tsangaraki and Keramoutsi. The first two are situated in the southwest and the last two in the north of the Heraklion Basin (Fig. 1).

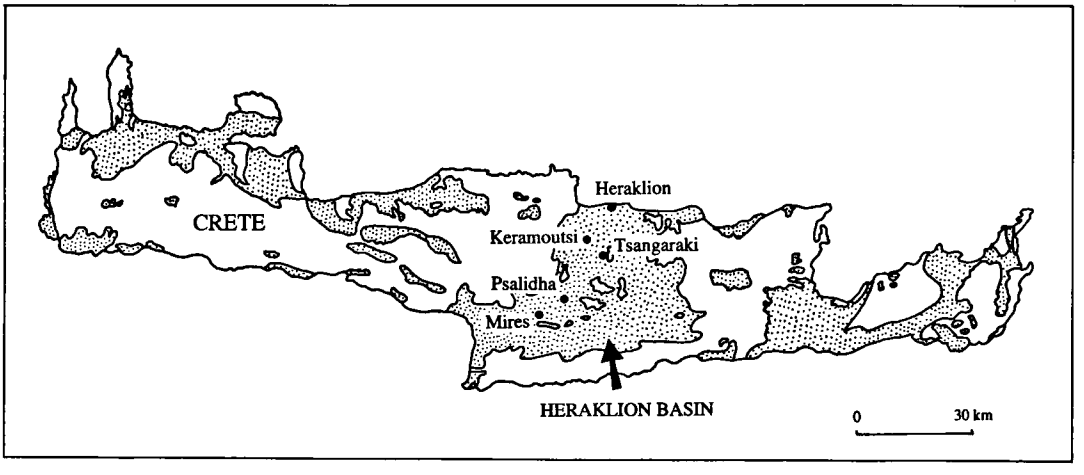


Fig. 1. Schematic map of Crete showing the location of outcrops discussed in the text. Neogene and Quaternary formations are dotted, pre-Neogene formations are white (modified after Dermitzakis, 1987).

With the exception of Psalidha, where holoplanktonic gastropods have been collected from diatomitic intercalations, the pteropods originate from the yellowish laminated marls. A detailed description of the first three outcrops and their faunal and floral contents will be presented by Gaudant *et al.* (in prep.). Except for Keramoutsi the samples have been dated by means of planktonic foraminifera. At Keramoutsi, stratigraphic assignment was based solely on facies. The sequence exposed there is similar to that outcropping at Tsangaraki.

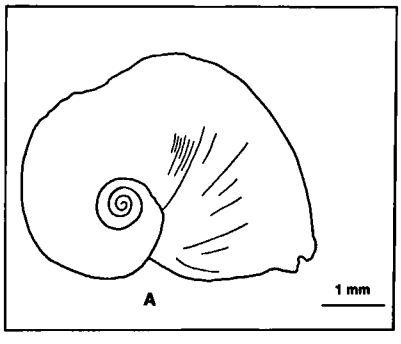
In the Heraklion Basin seven species of holoplanktonic gastropods have so far been collected. Four of these are euthecosomatous pteropods, *viz. Limacina* sp., *Cavolinia gypsorum*, *Diacria trispinosa* and *Bowdenatheca jamaicensis* and three are heteropods, viz. *Protatlanta* sp, *Atlanta* sp. and *Carinaria lamarcki* Péron & Lesueur, 1810, with the latter species extending to the present.

SYSTEMATIC PART

Phylum	Mollusca
Class	Gastropoda
Order	Mesogastropoda
Superfamily	Heteropoda
Family	Atlantidae Wiegmann & Ruthe, 1832
Genus	*Protatlanta* Tesch, 1908

Protatlanta sp.

Text-fig. 2a



Text-fig. 2a. Schematic illustration of *Protatlanta* sp., spiral side.

Material studied — Mires, coupe 4: 1 specimen; coupe 7: 1 specimen; J. Gaudant Coll.

Description — Shell dextral, flattened and smooth. The larger specimen shows approximately four whorls, the ultimate whorl expanding rapidly in width and lacking a carina. Because the specimens are distorted, observations on the kind of elevation of the early whorls are impossible. Growth lines are barely visible on the youngest part of the ultimate whorl. The second specimen shows the umbilical side.

Dimensions — Maximum shell diameter of the specimens: 1.08 mm; 2.48 mm.

Discussion — The carina of *Protatlanta* consists of conchiolin, which explains why it is not preserved in fossils, in contrast to that of *Atlanta* which is aragonitic. The only extant species known is *Protatlanta souleyeti* (Smith, 1888), which has 3¼ whorls and a slightly elevated spire. The maximum diameter reaches 1.9 mm (Seapy, 1990).

Genus *Atlanta* Lesueur, 1817

Atlanta sp.

Material studied — Tsangaraki (CR 91-315/3: 1 specimen, CR 91-317/1: 2 specimens, CR 91-317/2: 2 specimens; B. Delrieu Coll.).

Description — Shell flattened, dextral. The number of whorls is approximately three, lying more or less in one plane. The last whorl rapidly increases in width and shows a peripheral carina in mid-whorl position over almost its entire length. The carina becomes very wide in apertural direction. Its width equals half the width of the body whorl. The surface is smooth.

Dimensions — Maximum shell diameter (inclusive of carina): 1.4 mm.

Discussion — There are six extant species of *Atlanta* in the Mediterranean Sea, *viz. Atlanta peroni* Lesueur, 1817, *A. lesueuri* Souleyet, 1852 (see Richter, 1986), *A. helicinoides* Souleyet, 1852, *A. fusca* Souleyet, 1852, *A. inclinata* Souleyet, 1852 and *A. inflata* Souleyet, 1852 (see van der Spoel, 1976). *Atlanta lesueuri* is the species with three whorls; it is closely similar to the specimens before me, but in view of poor preservation and the limited number of specimens available open nomenclature is preferred.

Sturani & Sampó (1973) found *Atlanta* sp. at Pecetto di Valenza (Tortonian, see above) and Musotto & Sturani (1976) recorded it from Biglini. These records have now been re-identified as *Limacina atlanta* by Janssen (1995). That author encountered *Atlanta* sp. during preparation of the type lot of *Cavolinia gypsorum*. This sample is also dated as Tortonian (see Janssen, 1995).

Family Carinariidae Fischer, 1883
Genus *Carinaria* Lamarck, 1801

Carinaria lamarcki Péron & Lesueur, 1810
Pl. 3, Figs 2, 3

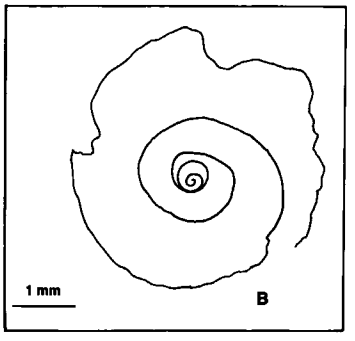
* 1810 *Carinaria lamarcki* Péron & Lesueur, p. 69, pl. 3, fig. 15.
. 1949 *Carinaria lamarcki* Péron et Lesueur 1810 — Tesch, p. 26, pl. 1, fig. 1.
. 1976 *Carinaria lamarcki* Peron & Lesueur, 1810 — van der Spoel, p. 152, fig. 152.

Material studied — Mires: two specimens on a slab of marl (KAP 133/1) and one fragment (KAP 132/2), reg. no. R.62678; S. Tsagaris Coll.
Description — The shell is dextral and is shaped like a Phrygian cap. The juvenile shell part is not well preserved, which makes determination of how many whorls there are difficult. Recent specimens are known to have four whorls (van der Spoel, 1976). The body whorl is very large, increases rapidly in width and shows coarse transverse ribbing. About 15 ribs are visible, but probably there were a few more ribs in the older part, where the boundary between juvenile and adult shell cannot be made out due to poor preservation. The ribs are slightly flexuous and most of them persist to the upper suture but some fuse with adjacent ribs near the umbilicus. The carina is developed along the periphery of the entire body whorl. The ribs continue on the carina, flatten towards its outer margin and become very weak and strongly curved in the direction of the apex.
Dimensions — Maximum shell diameter (inclusive of carina): 5 mm.
Discussion — This is the first record of a species of the Carinariidae, not only from strata of Messinian age but also from the entire Late Miocene of the Mediterranean area. Several species, *viz. Striocarinaria striata* Di-Geronimo, 1974, *S. hugardi* (Pictet, 1855), *S. rutschi* (Robba, 1972) and *Carinaria paretoi* Mayer, 1868, have been recorded from the Middle Miocene and a single taxon (*Carinaria peloritana* Seguenza, 1867) from Pliocene deposits in Italy.

Whether the specimens from Mires belong to *Striocarinaria* or *Carinaria* cannot be determined, because the lack of shell material precludes recognition of the fine longitudinal striae, which occur in the former and which are the only feature distinguishing these genera. However, the general shape and radial ornament show the specimens from Crete to be assignable to the Recent species *Carinaria lamarcki.*

Order Thecosomata
Suborder Euthecosomata
Family Limacinidae Gray, 1847
Genus *Limacina* Bosc, 1817

Limacina sp.
Pl. 1, Fig. 1
Text-fig. 2b



Text-fig. 2b. Schematic illustration of *Limacina* sp., inner aspect of the spiral side.

Material studied — Many specimens from Mires (KAP 132/1-2, KAP 133/1-2, KAP 134/1-3, 5; S. Tsagaris Coll.; coupe 4, 5, 6, 9; J. Gaudant Coll.), a few specimens from Tsangaraki (CR 91-302/1-2, 4-5, CR 91-315/1, CR 91-317/2; B. Delrieu Coll.) and from Keramoutsi (KE 92-063; B. Delrieu Coll.).
Description — The specimens are sinistral and almost planispiral. The surface is smooth and the umbilicus wide. The diameter varies between 1 and 2.5 mm in most of the specimens.
Discussion — The specimens are poorly preserved and the spire is often crushed. Apparently dextral specimens of the same size occur in several samples; they appear to reveal the umbilical side of a *Limacina*, but this cannot be proved beyond doubt in every case. Alternatively, these specimens may show the spiral side of dextral gastropods, which in many cases are also crushed.

A mass occurrence with many specimens of larger size, up to almost 2 mm (Pl. 1, Fig. 1), is preserved in a sample from Mires (KAP 134). In these specimens the umbilicus appears to be relatively wider.

The spiral side of this *Limacina* species resembles that of *Limacina inflata* d'Orbigny, 1836 in some specimens, but the umbilicus is much wider. The sole record of *Limacina* from the Messinian strata is *Limacina atlanta* (see Janssen, 1995), from Biglini and Roddi in the Piedmont Basin. It is very probable that the

specimens from Crete belong to this species, but the poor state of preservation precludes a definite assignment. Only in one specimen could the typical asymmetrical coiling be recognised (Text-fig. 2b).

Family	Cavoliniidae Fischer, 1883
Subfamily	Cuvierininae van der Spoel, 1967 ?
Genus	*Bowdenatheca* Collins, 1934

Bowdenatheca jamaicensis Collins, 1934
Pl. 4, Figs 1-4

* 1934 *Bowdenatheca jamaicensis* Collins, p. 221, pl. 13, figs. 13-15.
1995 Creseinae sp. ? nov. Janssen, p. 30, pl. 2, fig. 3a-d.

Material studied — Mires: many specimens on four slabs of marl (KAP 132/1, 133/1, 134/1-3; S. Tsagaris Coll.) and more than 50 specimens on nine slabs of marl (coupe 4, 5, 7, 8; J. Gaudant Coll.), Psalidha: a single specimen in diatomitic marl (PSA 3; S. Tsagaris Coll.), Tsangaraki: many specimens on ten slabs of marl (CR 91-302/1-3, CR 91-315/1, CR 91-317/1-2, CR 91-333/1-4; B. Delrieu Coll.).
Description — The shell is slender, elongated, slightly and regularly widening towards the aperture. Only in the very posterior part of some specimens is the increase in width somewhat more pronounced. The teleoconch is flattened dorsoventrally, which may be the result of sediment compaction to some degree. The shell surface is smooth in most specimens; in a few specimens growth lines are visible in the anterior part. In a single specimen (Pl. 4, Fig. 2) weak and narrow transverse ribs are developed.
Dimensions (in mm) —

— maximum length	Mires:	4.27-14.40
	Tsangaraki:	4.84-11.40
— maximum width	Mires:	1.21-4.00
	Tsangaraki:	1.00-3.85

Discussion — With regard to the general outline these specimens are very similar to *Creseis*. They show a dorsoventrally flattened teleoconch, whereas the cross-section in *Creseis* is circular. Sediment compaction may have caused this flattening, but it is also possible that to some degree the original shape may have been flattened dorsoventrally.

These specimens might be conspecific with Italian coeval material referred to as Creseinae sp. ? nov. from Collina di La Morra and Biglini (Piedmont Basin) by Janssen (1995), who also recorded this form from Zinola near Savona (occurring in Pliocene [Late Zanclean] strata) and from other localities in northern Italy and southern France. Janssen (1995) described a well-preserved specimen from Zinola as flattened dorsoventrally except for the earliest shell part, mentioning growth lines, but not transverse ribs.

After finishing his 1995 manuscript Janssen had the possibility to study topotypes from *Bowdenatheca jamaicensis*. This material led him to the conclusion that it is conspecific with the Mediterranean pteropod material mentioned above. These new results will be discussed in one of his forthcoming papers. Here I would like to thank Arie Janssen for informing me about his preliminary results.

Subfamily	Cavoliniinae van der Spoel, 1967
Genus	*Cavolinia* Abildgaard, 1791

Cavolinia gypsorum (Bellardi, 1873)
Pl. 1, Figs 1, 2; Pl. 2, Figs 1-4; Pl. 3, Figs 1, 3

v* 1873 *Hyalaea gypsorum* Bell. — Bellardi, p. 25, pl. 3, fig. 5.
. 1880 *Cavolinia gypsorum* (*Hyalaea*), Bellardi — Tiberi, p. 30.
v. 1904 *Cavolinia gypsorum* (Bell.) — Sacco, p. 12.
. 1905 *C. gypsorum*, Bellardi sp. (*Hyalaea*) — Bellini, p. 33, fig. 19.
1973 *Cavolinia gypsorum* Bell. — Sturani, p. 244, fig. 1.
1973 *Cavolinia gypsorum* Bell. — Sturani & Sampò, pp. 340, 349, 352.
v. 1983 *Cavolinia gypsorum* Bellardi, 1872 — Ferrero Mortara *et al.*, p. 27.
1990 *Cavolinia* cf. *gypsorum* Bellardi — Shibata & Ujihara, pp. 68, 69, 70, 79, figs 4, 5, 9.
. 1992 *Cavolinia gypsorum* Bellardi, 1872 — Cavallo & Repetto, p. 170, fig. 492.
v. 1995 *Cavolinia gypsorum* (Bellardi, 1873) — Janssen, p. 99, pl. 8, figs 9-12 (with additional synonymy).
. in pr. *Cavolinia gypsorum* (Bellardi, 1873) — Janssen, pl. 4, figs 1-3.

Type material — Many syntypes in the collections of the 'Museo Regionale di Scienze Naturali' at Torino, registration no. BS.007.01.002 (Ferrero Mortara *et al.*, 1981). Janssen (1995, pl. 8, fig. 9a, b) designated a lectotype.
Locus typicus — Guarene d'Alba (Piedmont, Italy).
Stratum typicum — Marls which accompany the gypsum, Tortonian (on the basis of nannoplankton analysis by E. Martini, Zone NN 10; see Janssen, 1995).
Material studied — Mires: many specimens on eleven

slabs of marl (KAP 039, KAP 132/1-2, KAP 133/1-3 and KAP 134/1-5; S. Tsagaris Coll.) and 24 specimens on ten slabs of marl (coupe 3, 5, 6, 7, 8; J. Gaudant Coll.). Psalidha: 13 specimens on five slabs of diatomitic marl (PSA 1-5); S. Tsagaris Coll.; Tsangaraki: many specimens on fourteen slabs of marl (CR 91-302/1, 3-6, CR 91-315/1-5, CR 91-317/1-2, CR 91-333/1, 5); B. Delrieu Coll.; Keramoutsi: 2 specimens (KE 92-063); B. Delrieu Coll.

Description — The dorsal and ventral side of the shell are both rather convex giving the shell a somewhat globular shape. The dorsal side has five radial ribs, which are very prominent in the anterior part of the shell and extend from the aperture in the direction of the apex with decreasing width. The middle rib and the two ribs next to it are of equal size and flatten in the posterior third of the shell. The two ribs in the outer part of the shell are narrower than the other ribs and disappear at mid-height. Latero-posteriorly of these ribs the shell is slightly extended on each side by a flat triangular area. The maximum width of the shell is found in this part. The protoconch, which is slightly curved dorsally, is located between these areas.

The ventral side is one third less high than the dorsal side. The surface is smooth except for the presence of a distinct fine transverse striation, which may represent growth lines. Viewed from the ventral side, the anterior apertural lip of the dorsal side expands over the ventral part of the shell. It may reach a length of 2.42 mm. In a specimen from Keramoutsi (Pl. 2, Fig. 3), which also shows the striation of the ventral side, this lip is well preserved. The two oblique radial folds on the ventral side as documented by Janssen (1995) are not preserved in most of the specimens, but the specimen from Keramoutsi bears a weak impression of one of them. It is situated in the area where the striation reaches its maximum convexity in apertural direction.

Dimensions (in mm) —

— Height (exclusive of protoconch):

Mires	5.70-8.20
Psalidha	6.13-7.41
Tsangaraki	4.56-6.27
Keramoutsi	7.55-10.12

— maximum width:

Mires	5.00-7.90
Psalidha	4.56-5.98
Tsangaraki	4.56-5.70
Keramoutsi	6.98-8.83

Discussion — *Cavolinia uncinata* (Rang, 1829) is the Recent species most closely related to the specimens before me. It differs from *C. gypsorum* in having a flatter dorsal side. In addition, the two outer ribs of each side are of equal width and length and are very close to each other. *Cavolinia uncinata* is assumed to be the descendant of the Japanese finds of *C.* cf. *gypsorum* as described by Shibata & Ujihara (1990).

Juvenile shells of *C. gypsorum*, which have been found in all outcrops except Keramoutsi, are not only smaller in size but also less globular and with a less distinct ornament. The smallest amongst them show no ornament at all.

Up to now, *Cavolinia gypsorum* was mainly recorded from the Early Messinian (planktonic foraminifera Zone N 17) and Tortonian of the Piedmont Basin (Italy). Bellardi (1873) listed this species from Guarene d'Alba (Tortonian), where it occurred abundantly in the marls accompanying the gypsum. A hundred years later, Sturani (1973) was the first to rediscover the occurrence of *C. gypsorum* northwest of Alba in euxinic clays below the gypsum horizon at the base of the Messinian. Sturani & Sampó (1973) also recorded the species from Collina di La Morra and from Mussotto near Alba in clays of the same age and from Pecetto di Valenza (Tortonian, see above). Janssen (1995) has collected it from Tortonian clays near S. Agata Fossili. Recently Janssen (in press) identified *C. gypsorum* among material from the Dominican Republic (Late Miocene, Cercado Formation, ? Lower Pliocene, Gurabo Formation).

The only other related record is that of *C.* cf. *gypsorum* from the Early Pliocene (planktonic foraminifera zones N 18-20) of Japan (Shibata & Ujihara, 1990).

Genus *Diacria* Gray, 1847

Diacria trispinosa (de Blainville, 1821)

* 1821 *Hyaloea trispinosa*, Lesueur — de Blainville, p. 82.
1978 *Diacria* cf. *trispinosa* (Lesueur) — Sturani, p. 12, fig. 1f.
1978 *Diacria trispinosa* — Sturani, p. 12.
v. 1995 *Diacria trispinosa* (de Blainville, 1821) — Janssen, p. 107, pl. 9, figs 3-5 (with additional synonymy).
in pr. *Diacria trispinosa* (de Blainville, 1821) — Janssen, pl. 5, figs 4-8 (with additional synonymy).

Material studied — Mires, coupe 5: 34 specimens; coupe 6: 5 specimens; coupe 7: 11 specimens; coupe 8: 3 specimens, and many fragments (J. Gaudant Coll.).

Description — *Diacria* with elongated posterior and

rapidly expanding anterior shell portion. Greatest width is there where the highly curved aperture expands into lateral spines. These project horizontally to the shell axis, and are occasionally slightly curved posteriorly. Dorsal side with wide longitudinal median lobe and adjacent narrow riblets on both sides of this lobe. A subdivision of the median lobe into three longitudinal riblets is clearly visible on one specimen showing the internal aspect of the dorsal side. Apertural lip somewhat overlaps the ventral side anteriorly.

Ventral side less high with short backward folded apertural lip. Median lobe wider than the one of the dorsal side, without subdivision but with adjacent riblets. Horizontal growth lines are weakly visible on one specimen.

Dimensions (in mm) — width varying between 4.68 and 5.72, the height of the two most complete specimens being 6.39 and 6.47.

Discussion — Most of the specimens do not show the three longitudinal ribs in the middle of the dorsal side. This may be a matter of preservation. Janssen (1995 and in press) noted a reduction in this ornament in specimens from Italy and the Dominican Republic. The latter material has been referred to as *Diacria bisulcata* Gabb, 1873. Janssen (in press) synonymises *D. bisulcata* with *D. trispinosa*, with the former representing a forma at best.

Diacria trispinosa is known from the late Miocene to the present day, being distributed worldwide now. During the late Miocene its occurrence is restricted to the Mediterranean area (Tortonian and Messinian) and the Dominican Republic (Janssen, in press: Cercado Formation). The earliest occurrence in the Mediterranean area is from Italy, viz. the Tortonian in Guarene d'Alba (Janssen, 1995). The species has been recorded from the Messinian from northeast of La Morra (Sturani, 1978). Janssen (1995) expressed doubts over this identification.

CONCLUSIONS

In the Early Messinian of the Heraklion Basin two groups of holoplanktonic gastropods occur, namely euthecosomatous pteropods and heteropods. They have been collected at Mires, Psalidha, Tsangaraki and Keramoutsi. Just as in the Italian Piedmont Basin the pteropod *Cavolinia gypsorum* is the most characteristic species in the Early Messinian, being known from all four localities, but most abundant at Mires and Tsangaraki.

At Mires, *C. gypsorum* co-occurs with three other pteropods, *Diacria trispinosa*, *Bowdenatheca jamaicensis* and *Limacina* sp., and two heteropods, *Carinaria lamarcki* and *Protalanta* sp. At Tsangaraki the last two pteropods occur, but *Bowdenatheca* is commoner and instead of *C. lamarcki* and *Protatlanta* sp. another heteropod has been found, *Atlanta* sp. At Psalidha and Keramoutsi no heteropods have been collected. In addition to *C. gypsorum*, single specimens of *Bowdenatheca jamaicensis* and *Limacina* sp. have been collected at these localities, respectively.

The discovery of holoplanktonic gastropods in the pre-evaporitic Early Messinian of the Heraklion Basin confirms the persistence of a normal marine salinity at that time, which observation is confirmed by records of marine fishes (Gaudant *et al.*, in prep.). Recent representatives of *Diacria* and *Cavolinia* all occur in the circumglobal warm-water region (Bé & Gilmer, 1977).

The Recent *Diacria trispinosa* is a 'warmwater cosmopolitan species which occurs abundantly in the tropical regions, warm boundary currents and areas bordering land masses and islands' (Bé & Gilmer, 1977, p. 785. It occurs worldwide between 65°N and 50°S and is most abundant between 45°N and 35°S, its temperature range being between 9.1 and 28°C and salinity ranging from 34.98 to 36.68 ‰. The cosmopolitan *Carinaria lamarcki* occurs between 60°N and 45°S and is most abundant in the Atlantic and the Mediterranean Sea (Tesch, 1949). *Protatlanta* is distributed between 50°N and 35°S (van der Spoel, 1976).

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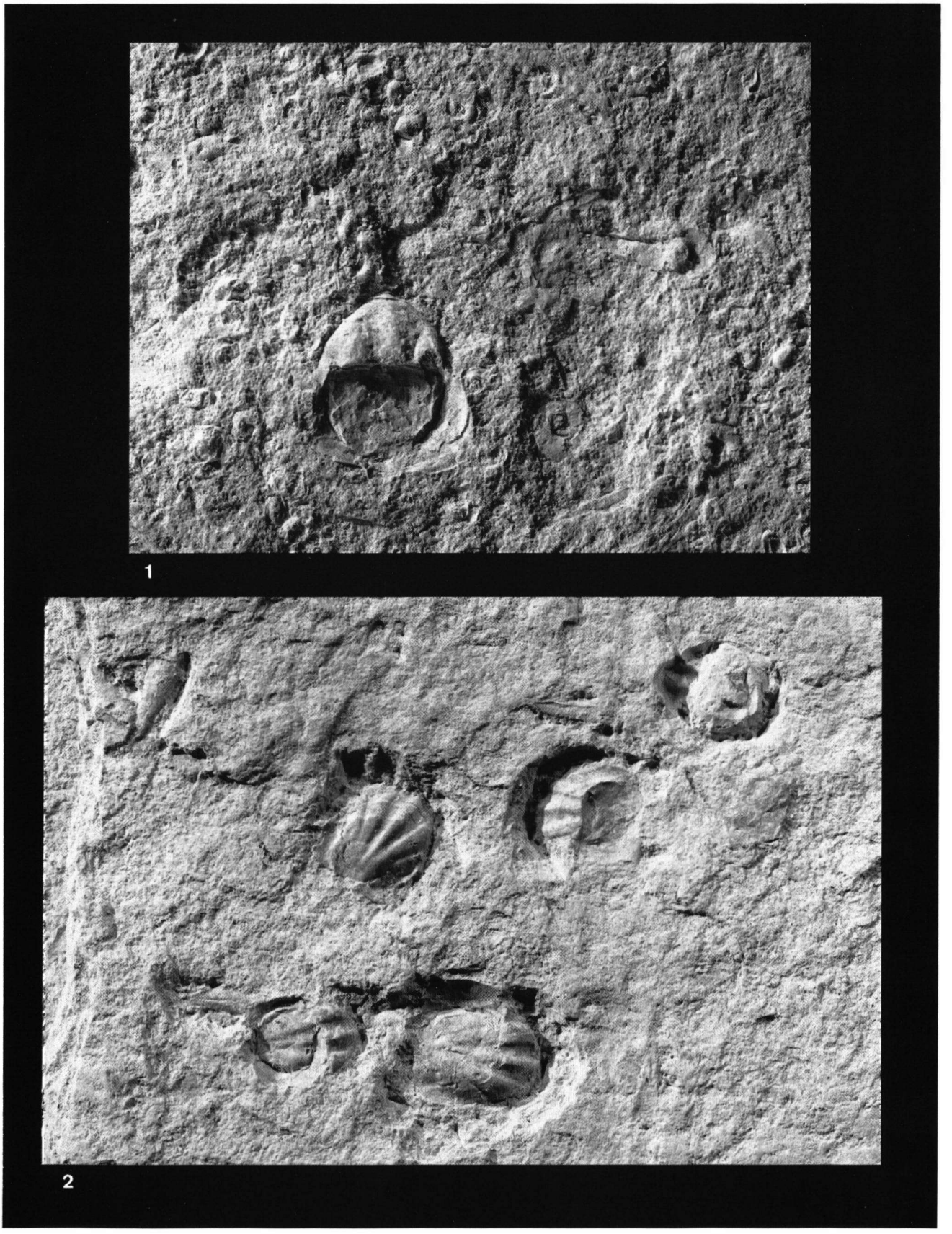
PLATE 1

Fig. 1. *Cavolinia gypsorum* (Bellardi, 1873) and a mass occurrence of *Limacina* sp.; Mires, KAP 134/3 (reg. no. R.62681), x 6

Fig. 2. *Cavolinia gypsorum* (Bellardi, 1873); Mires, KAP 133/1 (reg. no. R.62678), x 3.

PLATE 1



1

2

PLATE 2

Figs 1-4. *Cavolinia gypsorum* (Bellardi, 1873); 1 - Mires, KAP 134/5 (reg. no. R.62682), x 9; 2 - Psalidha, PSA 3 (reg. no. R.62683), x 9; 3 -Keramoutsi, KE 92-063 (reg. no. R.62685), x 6; 4 - Keramoutsi, KE 92-063 (reg. no. R.62685), x 8.

PLATE 2

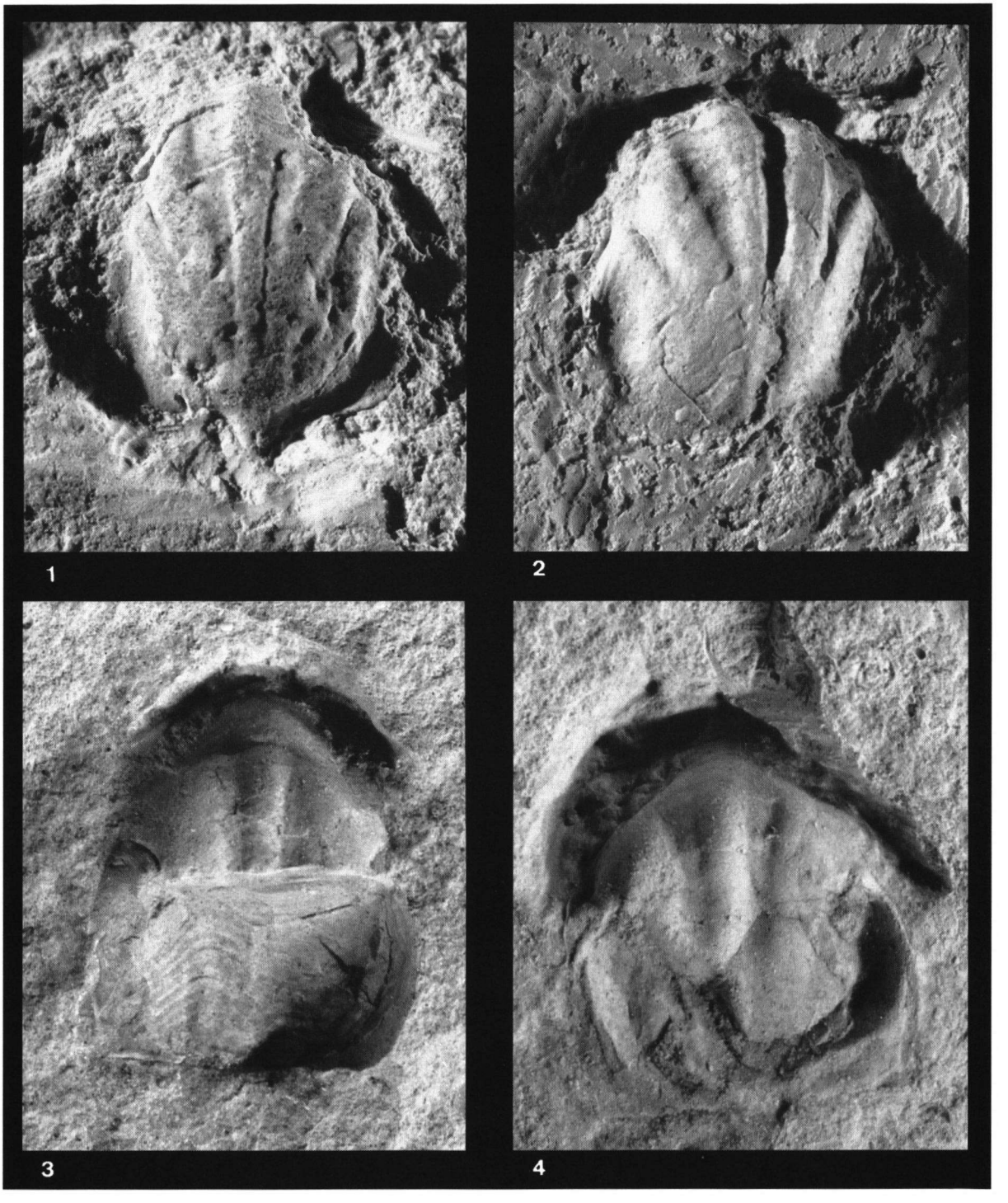


PLATE 3

Fig. 1. *Cavolinia gypsorum* (Bellardi, 1873); Psalidha, PSA 5 (reg. no. R.62684), x 9.
Fig. 2. *Carinaria lamarcki* Péron & Lesueur, 1873; Mires, KAP 133/1 (reg. no. R.62678), x 9.
Fig. 3. *Carinaria lamarcki* Péron & Lesueur, 1873 and *Cavolinia gypsorum* (Bellardi, 1873); Mires, KAP 133/1 (reg. no. R.62678), x 12.

PLATE 3

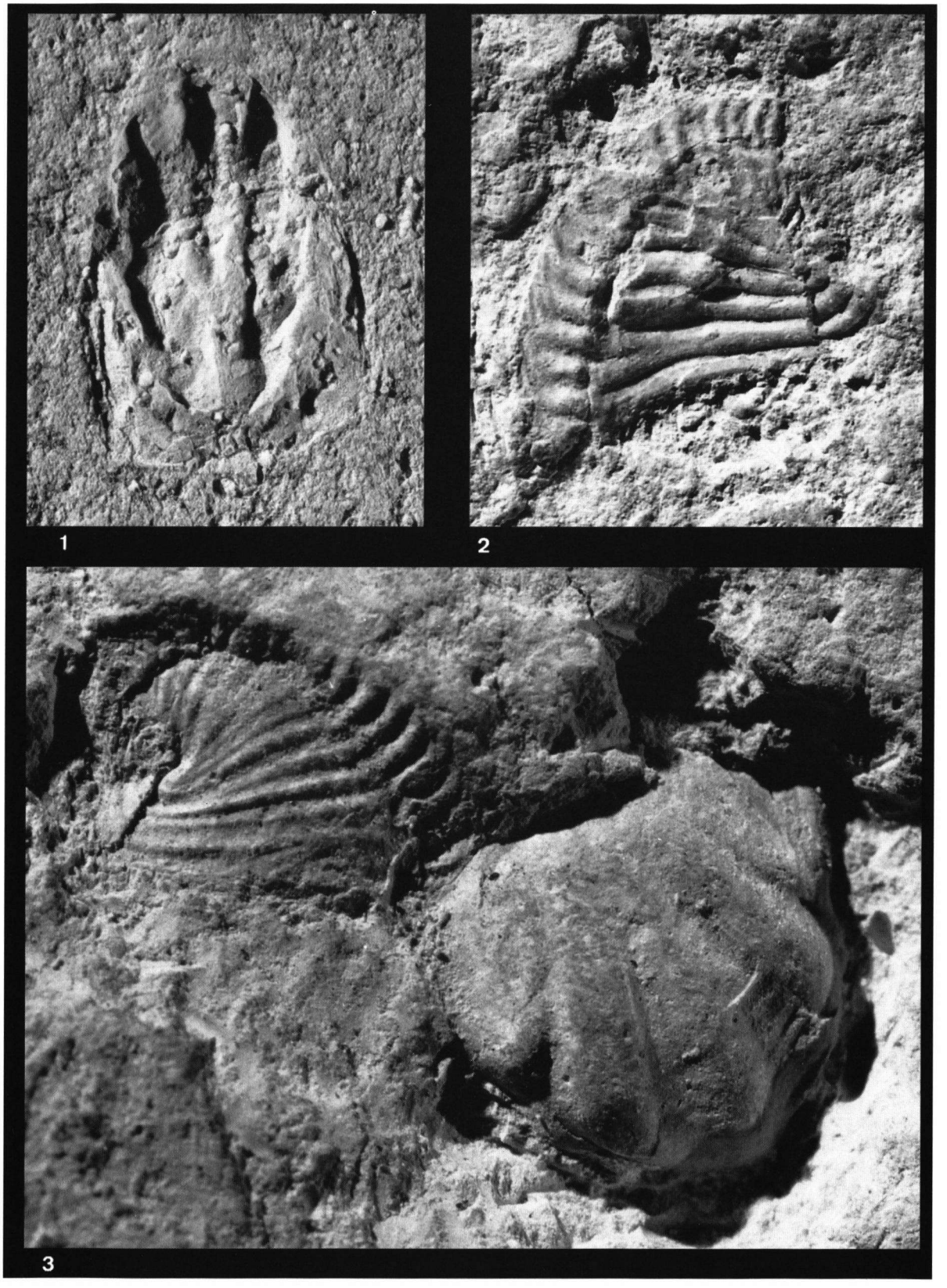


PLATE 4

Figs 1-4. *Bowdenatheca jamaicensis* Collins, 1934; 1 - Mires, KAP 134/1 (reg. no. R.62680), x 8; 2 - Mires, KAP 133/1 (reg. no. R.62678), x 4; 3 - Tsangaraki, CR 91-333/2 (reg. no. R.62686), x 4; 4 - Tsangaraki, CR 91-333/4 (reg. no. R.62687), x 4.

PLATE 4