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## Pliocene nassariids (Mollusca : Neogastropoda) of central-west Portugal

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**Abstract:** The study describes the stratigraphy, taphonomy and palaeoecology of the Pliocene outcrop at Vale de Freixo (Pombal area, central-west Portugal). A systematic study is carried out of the rich fauna of the Nassariidae gastropods which are found here. A comparative study is made of this fauna and those found in other adjacent Pliocene outcrops studied by other authors. *N. rideli* (Dollfus), *N. holasticus* (Beyrich) and *N. kennardi* (Harmer) are cited for the first time in the Portuguese Pliocene. The presence of typical North Atlantic species, together with the existence of certain phenotypes only previously described in more northern outcrops, suggests a possible migration towards the south of these species, following the thermic shift provoked by the climatic cooling which took place during the Upper Pliocene.

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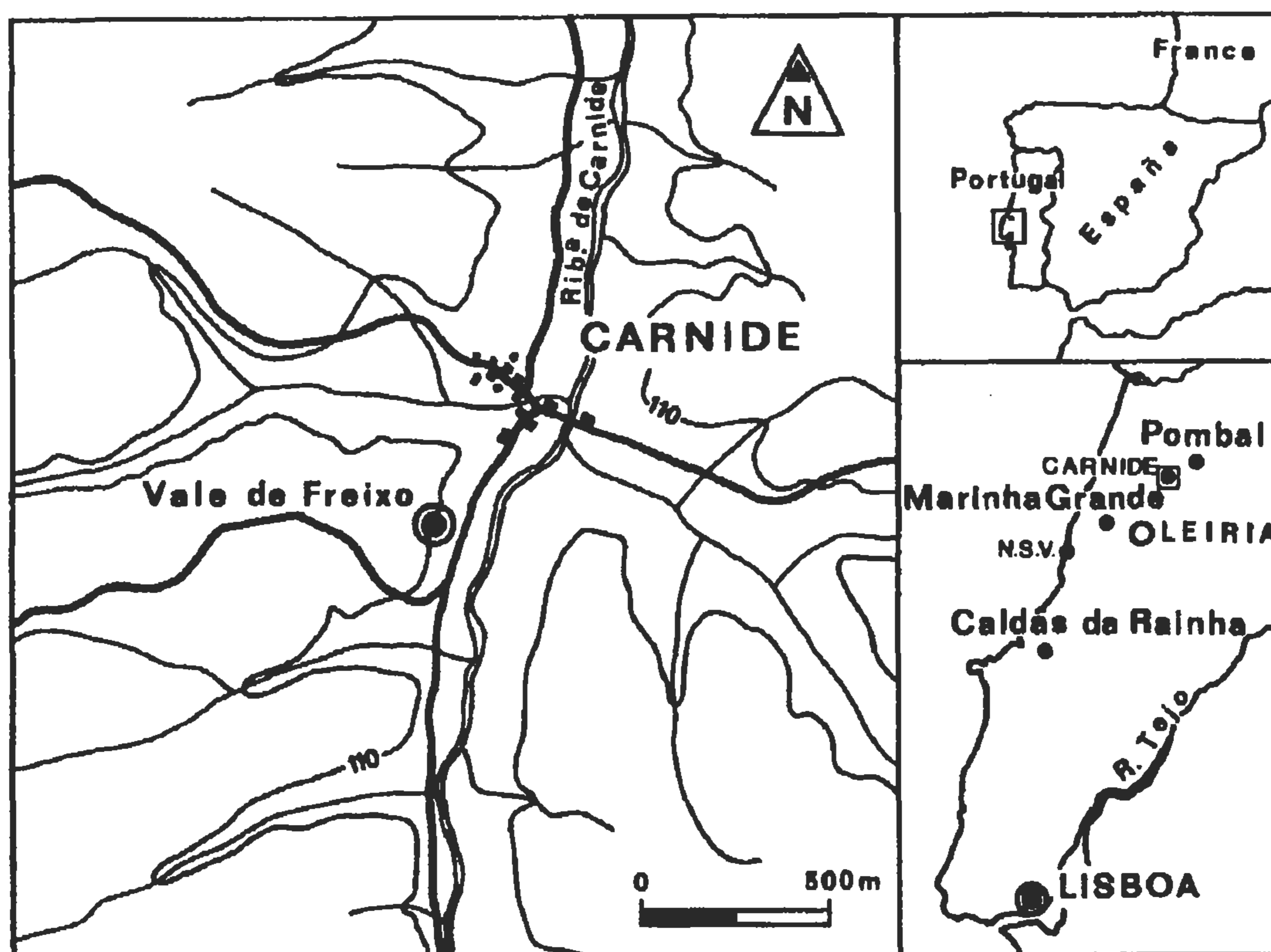
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### INTRODUCTION

The first notice of marine mollusc fossils in the Caldas da Rainha - Marinha Grande - Pombal Pliocene goes back to Choffat (1889). This author reported the discovery of fossil mollusc shells at Salir do Porto, and Águas Santas (Caldas da Rainha region), at Monte Real, and at a locality later known as Nossa Senhora da Vitória -- Marinha Grande region -- (Choffat, 1903).

Early in this century, Morais (1936) reported the finding of the Mina outcrop and, later (Morais, 1941) the discovery of Pliocene fossils at Guarda Nova and Matos (all in the Marinha Grande region). He collected some fossil molluscs, later studied by Cox (1936, 1941).

The existence of Pliocene marine fossiliferous sediments in the Pombal region was recognized for the first time by Teixeira & Zbyszewsky (1951). The Pliocene mollusc fossils from these outcrops, as well as from the remaining outcrops of this region, were studied by Zbyszewsky (1959), following the pioneering study of the



Text-fig. 1. Study area. Location of Vale de Freixo outcrop. central-west Portugal.

Pliocene Bivalvia in the Northern Tagus region (Caldas da Rainha - Marinha Grande) carried out by Dollfus & Cotter (1909).

Despite their importance and diversity, the Pliocene molluscan fauna from the Caldas da Rainha - Marinha Grande - Pombal region has never been studied in depth nor in a consistent manner. In fact, after the publication of Zbyszewsky's thesis in 1959, it was not until the 1970's that the Portuguese Pliocene molluscs were re-examined, this time by Brébion (1971, 1974). After Brébion's papers, the study of Pliocene malacofauna almost completely ceased.

The discovery, in the beginning of the 1980's, of a new Pliocene fossiliferous outcrop at Vale de Freixo (Pombal region), revealed by sand exploitation operations (today abandoned), gave new life to the study of the fossil molluscs from this region. The diversity and good preservation of the Vale de Freixo molluscan fauna has enabled the reinstatement of molluscan studies and revision of the work published around the beginning of the century (Silva, 1990, 1991, 1992).

Series	Stage	Formation	Bed	Thickness	Graphic columnar section	Description
PLIOCENE	Piacenzian	Arenito de Carnide	5	> 5 m		Sand, yellow, well graded, barren
			4	0.3 m		Sand, brown-yellow well graded, fossiliferous
			3	0.4 m		Sand, dark grey, fine, moderately graded, fossiliferous
			2	0.25 m		Conglomerate, dark grey, with fine to medium sand matrix, fossiliferous
			1	> 10 m		Silt, light grey, clayey, with some coarse sand, barren
MIOCENE		Arg. de Amor			contact undulating due to erosion, burrowing and channeling	

Text-fig. 2. Stratigraphic column of Vale de Freixo outcrop. Lowermost section of the Pliocene sequence.



## THE VALE DE FREIXO OUTCROP

### Stratigraphy

The Vale de Freixo outcrop is situated in the central-west part of Portugal (UTM - Universal Transversal of Mercator - coordinates: 29SNE23150151775), near the locality of Carnide (Pombal region). The outcrop lies nearly 20km away from the present day Atlantic shoreline (Text-fig. 1).

From a geological point of view, the Pliocene formations of the Caldas da Rainha - Marinha Grande - Pombal region are part of a broader Mesozoic-Cenozoic morphostructural unit known as the West or Lusitanian Margin - Bordadura Ocidental ou Lusitânica - (Ribeiro *et al.*, 1979). In this region, Pliocene formations overlie Mesozoic-Cenozoic sediments (lower Jurassic to middle Miocene), over an extended erosional marine platform.

The Pliocene stratigraphic sequence in the Pombal region is, in ascending order: Arenito de Carnide Formation (Formação Arenito de Carnide), and Arenito de Paredes/Roussa Formation (Formação Arenito de Paredes/Roussa). The Arenito de Carnide Formation consists of barren fine silty micaceous sand. Locally, the lowermost section of Arenito de Carnide contains a short fossiliferous sequence consisting of a basal conglomerate and a sand rich in marine shells (Cachão, 1989). The Arenito de Paredes/Roussa Formation consists of coarser siliciclastic sediments, containing, in the top of the unit, intercalated continental organic clayey layers (Argilitos de Barracão) rich in plant remains (Diniz, 1984).

In the Pombal region (Vale de Freixo outcrop) the fossiliferous marine Pliocene sequence lies sub-horizontally, overlying the Argilitos de Amor Formation (Formação Argilitos de Amor) considered to be middle Miocene. The Argilitos de Amor consists of barren clayey silt beds, the top being an erosional surface (Text-fig. 2).

The calcareous nannofossil assemblage in the fossiliferous lowermost beds of the Pliocene sequence, at Vale de Freixo, indicates placement in Okada & Bukry's (1980) biozone CN12a. This zone, which lasted from about 3.5 to 2.65 Ma, corresponds to the lowermost part of Martini's (1971) biozone NN16 - Piacenzian; upper Pliocene (Cachão, 1990).

The fossiliferous beds in the Vale de Freixo outcrop (lowermost Pliocene sequence) have a maximum thickness of approximately 1 metre. These beds are remarkable for their relatively abundant, well-preserved macrofossils, consisting largely of bivalves and gastropods. The mollusc fossils studied were collected from bed 3.

The sedimentological analysis of bed 3 revealed that the carbonate fraction makes up about 49% of the sediment (largely bioclasts) and organic matter about 7% (largely plant detritus). The coarse fraction (after carbonate dissolution) makes up about 1%, and the sand fraction about 35% of the whole sediment. The sand fraction is characterized as very fine sand, moderately graded, with very negative symmetry, mesocurtic.

### TAPHONOMY AND PALAEOECOLOGY

Taphonomic analysis of bed 3 of Vale de Freixo was mainly concentrated on the mollusc remains since they are both the dominant faunal constituents and the object of study. In bed 3, fossils are evenly scattered in the sediment, rarely forming concentrations. The abundance of mollusc fossils is relatively low (there are no shell beds). The most abundant molluscs are the gastropods *Bittium reticulatum* (Da Costa), *Petalonchus intortus* (Lamarck), *Calyptrea chinensis* (Linnaeus), *Alvania cancellata* (Da Costa) and *Triphora perversa* (Linnaeus); and the larger bivalves *Striarca lactea* (Linnaeus), *Spisula subtruncata* (Da Costa), *Chlamys multistriata* (Poli), ?*Cyclocardia scalaris* (Sowerby) and *Timoclea ovata* (Pennant).

The preservational condition of the fossils is normally good; they are largely unworn and some show traces of original coloration. Many bivalve and gastropod shells with delicate ornamentation and/or morphological features are complete - e.g. *Circomphalus foliaceolamellosus* (Dillwyn), *Tellina corbis* (Bronn) and *Calyptrea chinensis* (Linnaeus), with the bivalves sometimes articulated. This and the presence of delicate, thin-shelled clams such as *Pharus legumen* (Linnaeus) and *Tellina* spp. (often in life position) and small echinoids *Echinocyamus pusillus* (Müller), which are especially vulnerable to mechanical destruction, indicate moderate transportation and/or exposure to wave action following death. No post-mortem orientation by fluid flow was associated with *Turritella*, *Scaphopoda* or other elongated shells.

A broad range of size classes is present for the abundant species. The presence of many specimens of different sizes suggests that post-mortem size-selective winnowing processes did not occur.

Many shells show evidence of encrusting organisms, such as bryozoans, vermetid gastropods and above all, barnacles. They also show borings (ichnospecies *Oichnus simplex* Bromley and *O. paraboloides* Bromley), predation marks of crabs and the strong effects of those other marine bioeroders, which normally attack molluscan shells exposed on the sea floor (e.g. boring bryozoans, clionid sponges, polychaetes, and



thallophytes). Apart from gastropods and bivalves other fossil remains are present in bed 3 of Vale de Freixo, namely: scaphopods, chitons (rare), forams, ostracodes, bryozoans, barnacles, echinoids, asteroids (rare isolated skeletal elements), corals (rare), crabs (rare claws), fish otoliths and teeth (rare), calcareous nannofossils (rare discoasterids, coccolithophorids and ascidian spicules), pollen and macroplant remains (rare).

The combination of the above mentioned factors indicate that the molluscan fauna of bed 3 of Vale de Freixo has suffered little post-mortem transportation. Thus, this molluscan fauna may be characterized as sub-autochthonous, in the sense of Yanin (1983), i.e. the organisms were buried in the place they lived or near to it, but were not normally preserved in life position; the place of death (thanatotope) partially or totally corresponds to the biotope; the shells were reworked and reorientated following the death of the molluscs but these processes were relatively unimportant.

The mollusc assemblage from Vale de Freixo (bed 3) indicates a shallow marine infralittoral environment of normal salinity, less than 30 metres deep, with relatively warm temperature conditions, warmer than today at that latitude (Cachão & Silva, 1990; Silva, 1991).

#### THE NASSARIIDAE OF VALE DE FREIXO

The first papers concerning Portuguese Pliocene gastropods are those of Cox (1936, 1941). In his first paper, dealing "[...] with a small series of fossil marine shells collected [...] from a deposit on the coast of Portugal [...]" Cox (1936: 47) described a new species of Nassariidae from the Mina outcrop (Marinha Grande): *Nassarius (Hima) pontis-novi* Cox, 1936. In his second one he described another new *Nassarius* Duméril species belonging "[...] to a series of well preserved fossil shells collected by Professor J. C. de Morais from a well-sinking at Matos (Marinha Grande), a locality situated about 8km. from Mina [...]" (Cox, 1941: 7): *Nassarius (Uzita) malachiasi* Cox, 1941. Eighteen years later, Zbyszewsky (1959) listed 17 species of Nassariidae from Caldas da Rainha - Marinha Grande - Pombal region; he included 15 in the genus *Nassa* Lamarck and 2 in the genus *Nassarius* Duméril (the species previously described by Cox). Later, Brébion (1971) revised the Portuguese Pliocene gastropods recognising 26 Nassariidae, of which 9 were identified to only generic or subgeneric level. According to Brébion (1971) the 26 species of Nassariidae were distributed in this way: 22 *Nassarius* (2 *Sphaeronassa* Locard, 16 *Hinia* Gray, 1 *Arcularia* Link and 3 *Nassa* Lamarck); 1 *Cyclope* Risso, 1 *Desmoulea* Gray and 2 *Dorsanum* Gray. The study of the Vale de Freixo outcrop has so far revealed the presence of 15 species of Nassariidae: 14 *Nassarius* Duméril s.l., and 1 *Demoulia* Gray (= *Desmoulea* Gray). Neither *Dorsanum* nor *Cyclope* were found.

The complete list of Nassariidae species identified in Vale de Freixo is as follows:

Genus *Demoulia* Gray.

*D. conglobata* (Brocchi, 1814)

Genus *Nassarius* s.l. Duméril.

*N. pliomagnus* (Sacco, 1904)

*N. companyoi* (Fontannes, 1879)

*N. clathratus* (Born, 1788)

*N. prismaticus* (Brocchi, 1814)

*N. strobelianus* (Cocconi, 1873)

*N. semistriatus* (Brocchi, 1814)

*N. reticulatus* aff. *musivus* (Brocchi, 1814)

*N. rideli* (Dollfus, 1889)

*N. holasticus* (Beyrich, 1854)

*N. kennardi* (Harmer, 1914)

*N. serraticosta* (Bronn, 1830)

*N. pyrenaicus* (Fontannes, 1879)

*N. gibbosulus* (Linnaeus, 1758)

*N. turritus* (Borson, 1820)

The study of this material has led to a number of biogeographic considerations, as well as enabling some corrections to be made to earlier works, thanks to the geographic proximity of the outcrop studied here to previously described ones.

**Erratum:** Throughout the text, where it reads "*N. holasticus*" it should read "*N. holsaticus*".

The following abbreviations are used: H : height of the specimen; D : diameter of the last whorl; Hv : height of the last whorl on the apertural plane; vol : whorls of protoconch; dp : diameter of protoconch; hp : height of protoconch.

**SYSTEMATIC PALAEONTOLOGY**  
**CLASS GASTROPODA**  
**SUBCLASS PROSOBRANCHIA**  
**ORDER NEOGASTROPODA**  
**FAMILY NASSARIIDAE**

**GENUS *Demoulia* Gray.**

***Demoulia conglobata* (Brocchi, 1814)**

Pl. 1, figs 1a - b

- 1814 *Buccinum conglobatum* Brocchi, p. 334, tav. IV, fig. 15.  
1882 *Nassa conglobata* (Brocchi) Bellardi, p. 83, tav. V, fig. 17 (a-b).  
1918 *Desmoulea conglobata* (Brocchi) Harmer, p. 333, pl. 34, fig. 27.  
1927 *Desmoulea conglobata* (Brocchi) Peyrot, p. 53, pl. III, figs 112-114.  
1959 *Nassa (Desmoulea) conglobata* (Brocchi) Zbyszewsky, p. 95, pl XI, figs 59, 65.

**Material:** One adult specimen with the apex and part of the last whorl broken.

**Remarks:** The presence of this species in the Atlantic upper Pliocene from Portugal has been reported by Zbyszewsky (1959). Brébion (1971) included, probably by error, *Desmoulea pinguis* (A. Adams) that corresponds to an extant species. During Pliocene times this species was widely distributed in the Atlantic, north of Gibraltar, from Spain (Landau, 1984) to Great Britain (Harmer, 1914, 1918). It is unknown south of this limit; neither Chavan (1940) nor Lecointre (1952) nor Brébion (1979) have reported it from western Morocco.

**GENUS *Nassarius* Duméril.**

***Nassarius clathratus* (Born, 1788)**

Pl. 1, figs 2a - b

- 1788 *Buccinum clathratum* Born, p. 255.  
1879 *Nassa clathrata* (Born); Fontannes p.57, pl. V, fig. 2.  
1904 *Nassa (Niotha) clathrata* (Born) var. *obtusepercostata*; Sacco p. 66.  
1959 *Nassa clathrata* Born; Zbyszewsky, p. 95.  
1971 *Hinia clathrata obtusepercostata* (Sacco); Brébion, p. 136.  
1975 *Niotha clathrata* (Born) *obtusepercostata* (Sacco); Di Geronimo, p. 124, tav. I, figs 11, 13-14.  
1976 *Nassarius clathratus* (Born); Adam & Glibert, p. 5, pl. III, figs 1-3.  
1991 *Nassarius clathratus* (Born); Gili, p. 167, lam. 5, figs a-i (synonymy).

**Material:** Three adult specimens well preserved.

**Remarks:** The collected specimens display the typical species morphology and sculpture: a well developed shoulder; and tubercles at the intersection of axial ribs with prominent adapical threads. Brébion (1971) reported the presence of *Hinia clathrata obtusepercostata* (Sacco, 1904), which corresponds to specimens with smaller D/H than average, and a less prominent shoulder. These features, bearing in mind the similarity of the protoconch and teleoconch and the fact of its overlapping geographical distribution, are not enough to separate the two forms at subspecific level (Di Geronimo, 1975; Gili, 1991).

***Nassarius prismaticus* (Brocchi, 1814)**

Pl. 1, fig. 3a - b

- 1814 *Buccinum prismaticum* Brocchi, p. 337, tav. V, fig. 7.  
1879 *Nassa limata* (Chemnitz); Fontannes, p. 59, pl. V, figs 3-4.  
1976 *Nassarius prismaticus* (Brocchi); Adam & Glibert, p. 51, pl. II, fig. 8, pl. V, fig. 9, pl. VI, figs 2-5.



1991 *Nassarius prismaticus* (Brocchi); Gili, p. 176, Lam. 6, figs a-j (synonymy).

**Material:** One adult specimen well preserved and two parts of spire with its apex.

**Remarks:** These specimens have faint ribbing on the whorls. The report, by Zbyszewsky (1959), of *Nassa (Uzita) limata* (Chemnitz) is probably due to confusion with Brocchi's species, as often occurs in other palaeontological papers as Adam & Glibert (1976) have pointed out.

#### *Nassarius strobelianus* (Cocconi, 1873)

Pl. 1, fig. 4a - b

1873 *Nassa strobaliana*. Cocconi, p. 85, tav. II, figs 5-6.

1882 *Nassa strobaliana* Cocconi; Bellardi, p. 95, tav. VI, fig. 10 (a-b).

1959 *Nassa strobaliana* Cocconi; Zbyszewsky; p. 97, pl. XI, fig. 51.

1971 *Hinia (Trironella) strobaliana* (Cocconi); Brébion, p. 136.

**Material:** One almost complete specimen and one fragment of the last whorl.

**Remarks:** These specimens correspond quite well to the original description, but in comparison with the illustration in Cocconi (1873, tav. II, fig. 5-6) show some differences. They present fewer axial ribs and the spiral threads are only visible in the interspaces. The adapical concavity of the whorls (more deeply in the last whorls) is a distinguishing characteristic of this species.

#### *Nassarius pyrenaicus* (Fontannes, 1879)

Pl. 1, fig. 5a - b

1879 *Nassa pyrenaica*. Fontannes, p. 72, pl. V, figs 17-18.

1879 *Nassa pyrenaica* var. *compacta*. Fontannes, p. 73, pl. V, fig. 19.

1882 *Nassa tersa*. Bellardi, p. 155, tav. X, fig. 1.

1904 *Nassa (Amycla) tersa* Bellardi var. *abbreviatula* Sacco, p. 72, tav. XVI, fig. 71.

1959 *Nassa pyrenaica* Fontannes var. *compacta* Fontannes; Zbyszewsky, p. 96, pl. XI, fig. 57.

1971 *Nassa (Amyclina) tersa abbreviatula* Sacco.; Brébion, p. 136.

1991 *Nassarius pyrenaicus* (Fontannes); Gili, p. 456, lam. 34, figs a-g (synonymy).

**Material:** Four adult well preserved specimens.

**Remarks:** The Vale de Freixo specimens assigned to this species present some peculiar morphological features when compared with the Mediterranean specimens studied by Gili (1991). These Portuguese specimens have more prominent spiral threads (they can be seen with the naked eye) and are always present on the adapical part of last whorl. The protoconch presents 3.5 whorls or a few more, but does not reach four whorls, and the diameter and height averages are smaller (0.89 and 0.74mm, respectively). In this species specimens were also found with larger measurements than usual. The largest specimen has six whorls of teleoconch, a height of

**PLATE 1.** Nassariids from the Upper Pliocene of the Vale de Freixo (Pombal) Portugal in the collections of the Museu Nacional de História Natural (Museu de Geologia), University of Lisbon, unless otherwise indicated.

Fig. 1 a-b. *Demoulia conglobata* (Brocchi, 1814). H = 31.7mm.

Fig. 2 a-b. *Nassarius clathratus* (Born, 1788). H = 23.0mm.

Fig. 3 a-b. *Nassarius prismaticus* (Brocchi, 1814). H = 20.0mm.

Fig. 4 a-b. *Nassarius strobelianus* (Cocconi, 1873). H = 26.2mm, coll. B. Landau.

Fig. 5 a-b. *Nassarius pyrenaicus* (Fontannes, 1879). H = 23.3mm.

Fig. 6 a-b. *Nassarius turritus* (Borson, 1820). H = 23.3mm.

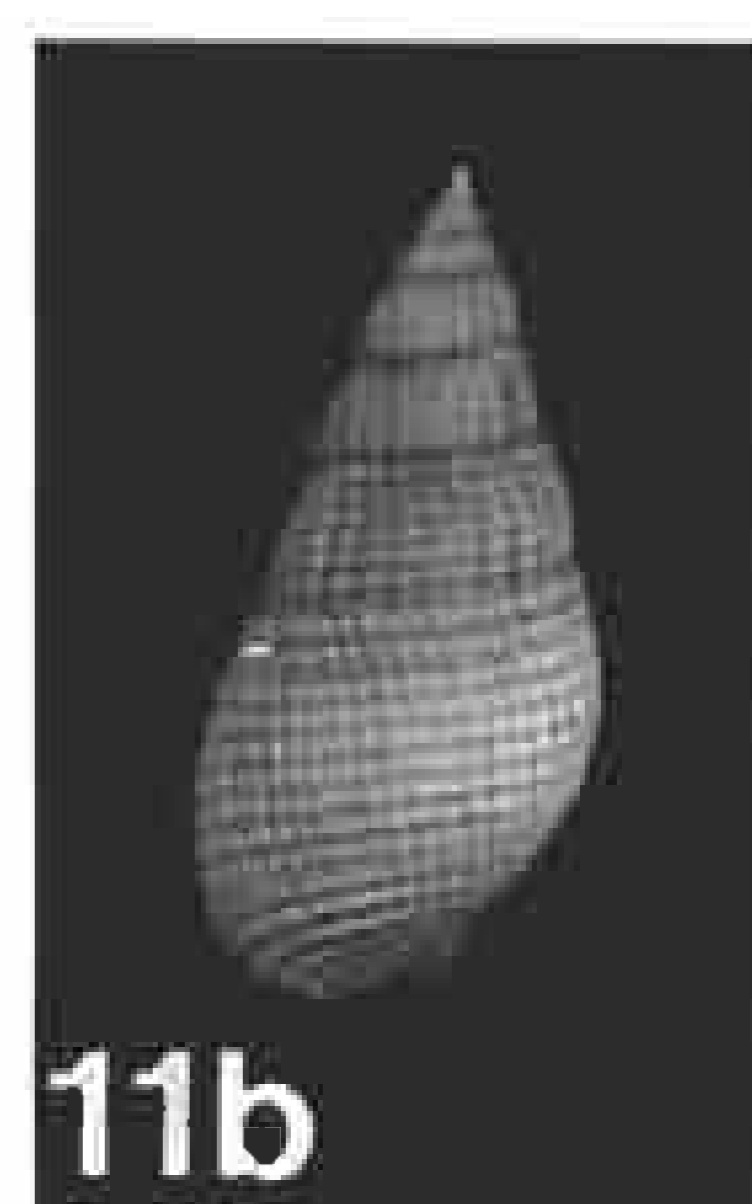
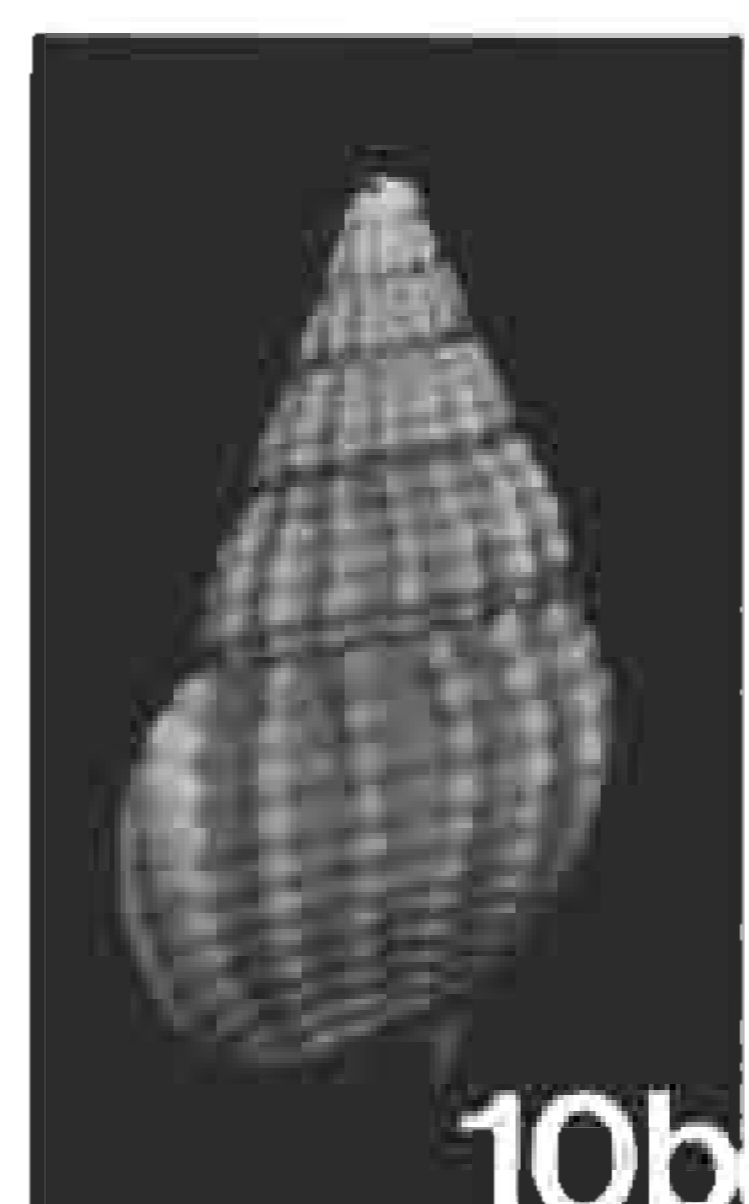
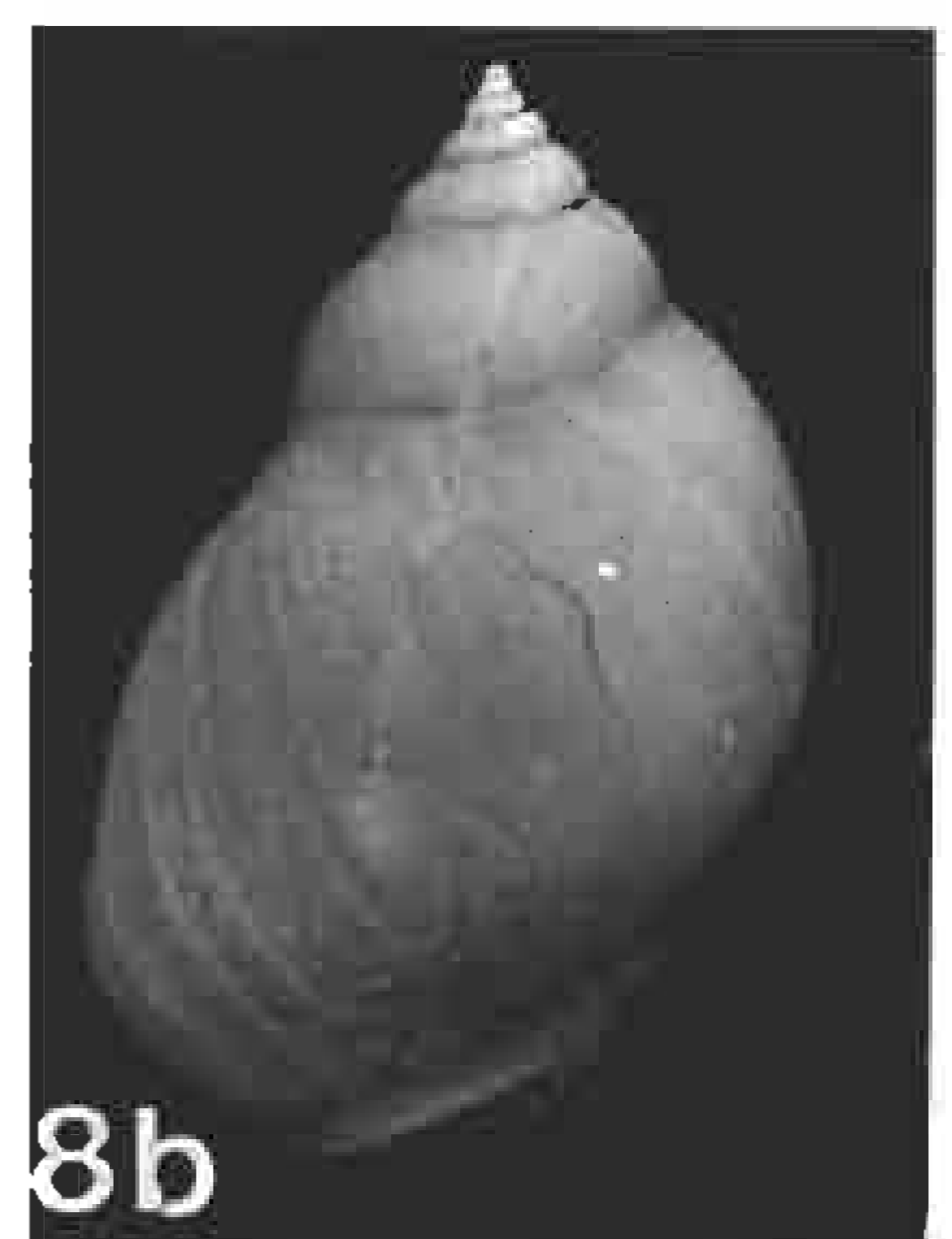
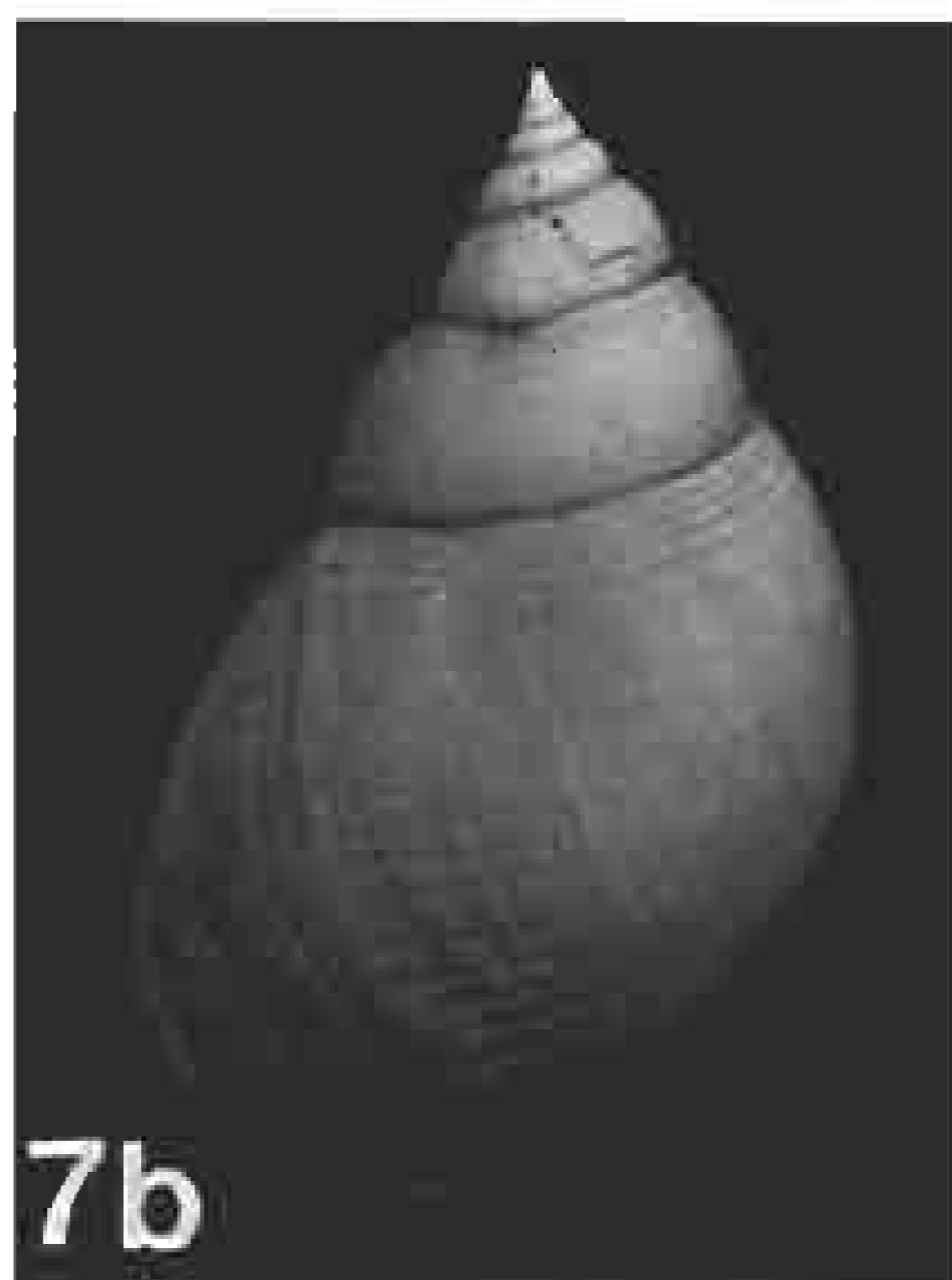
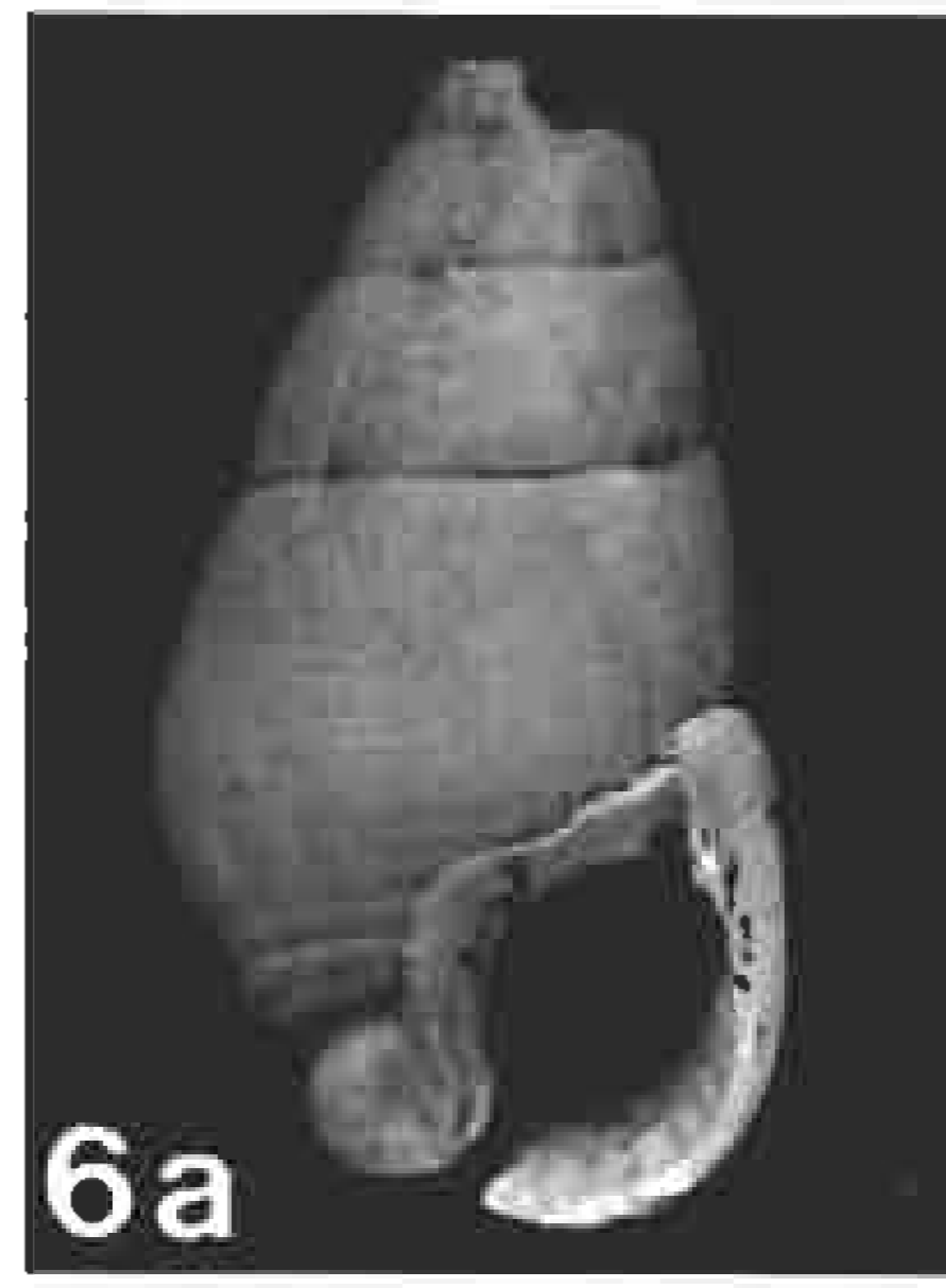
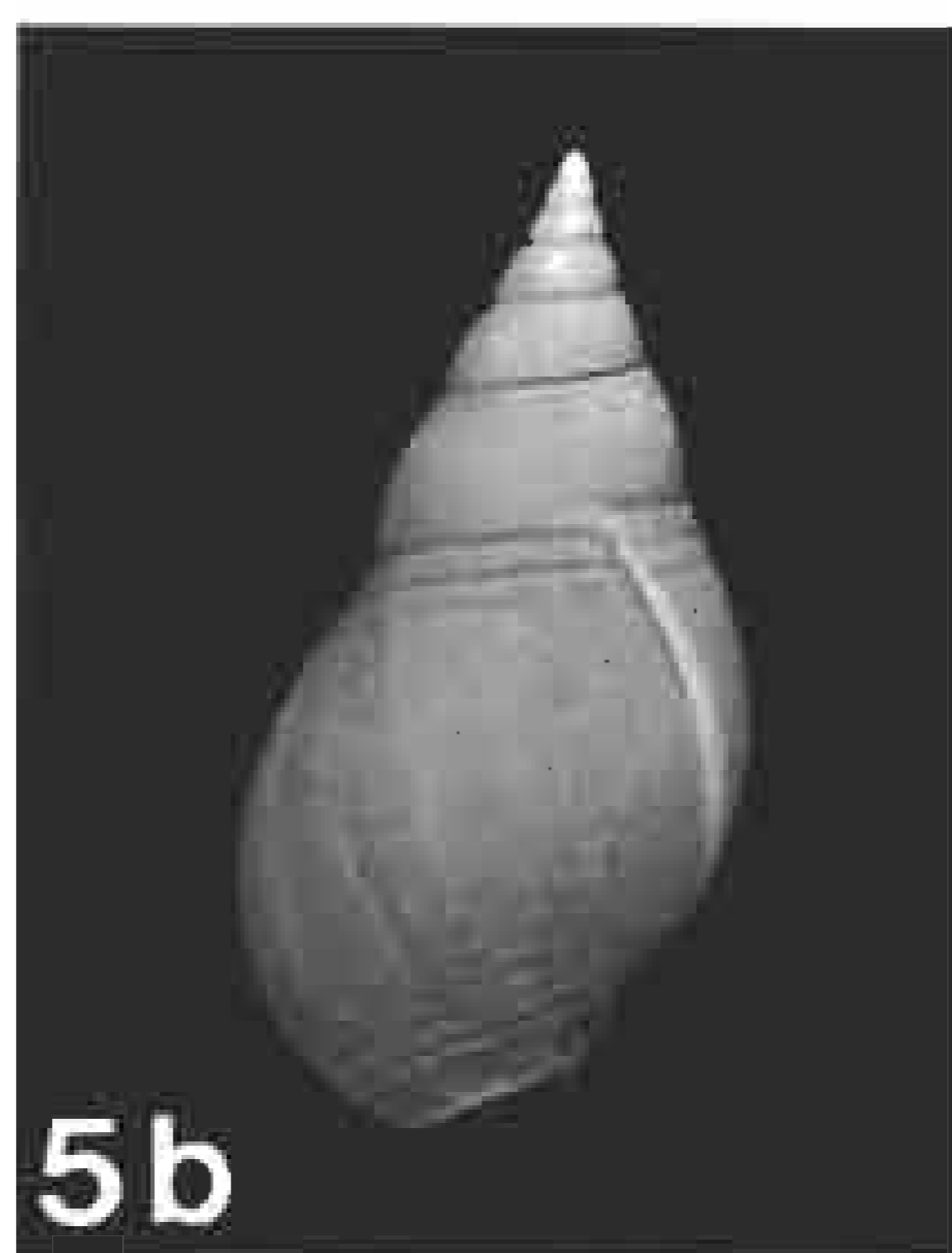
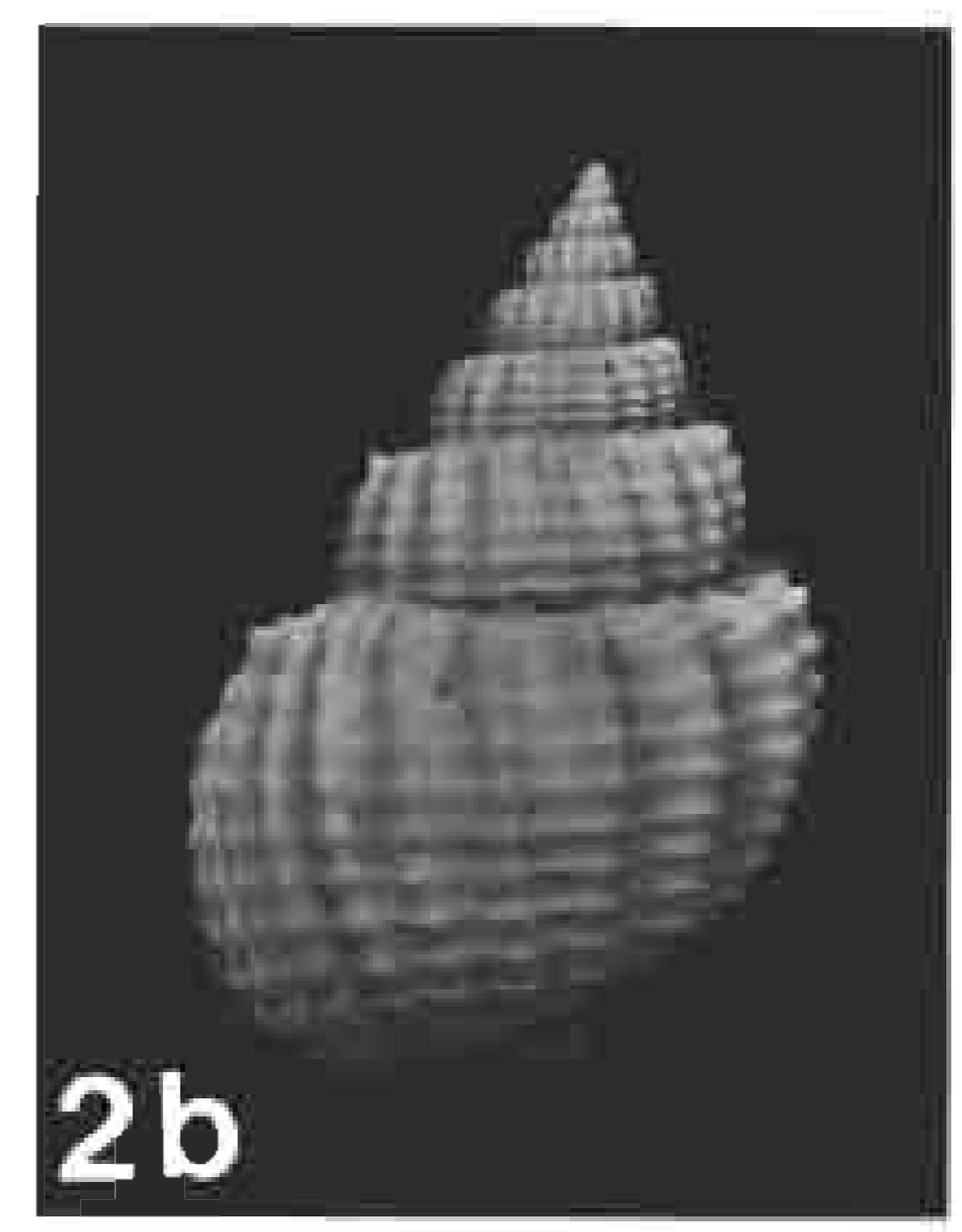
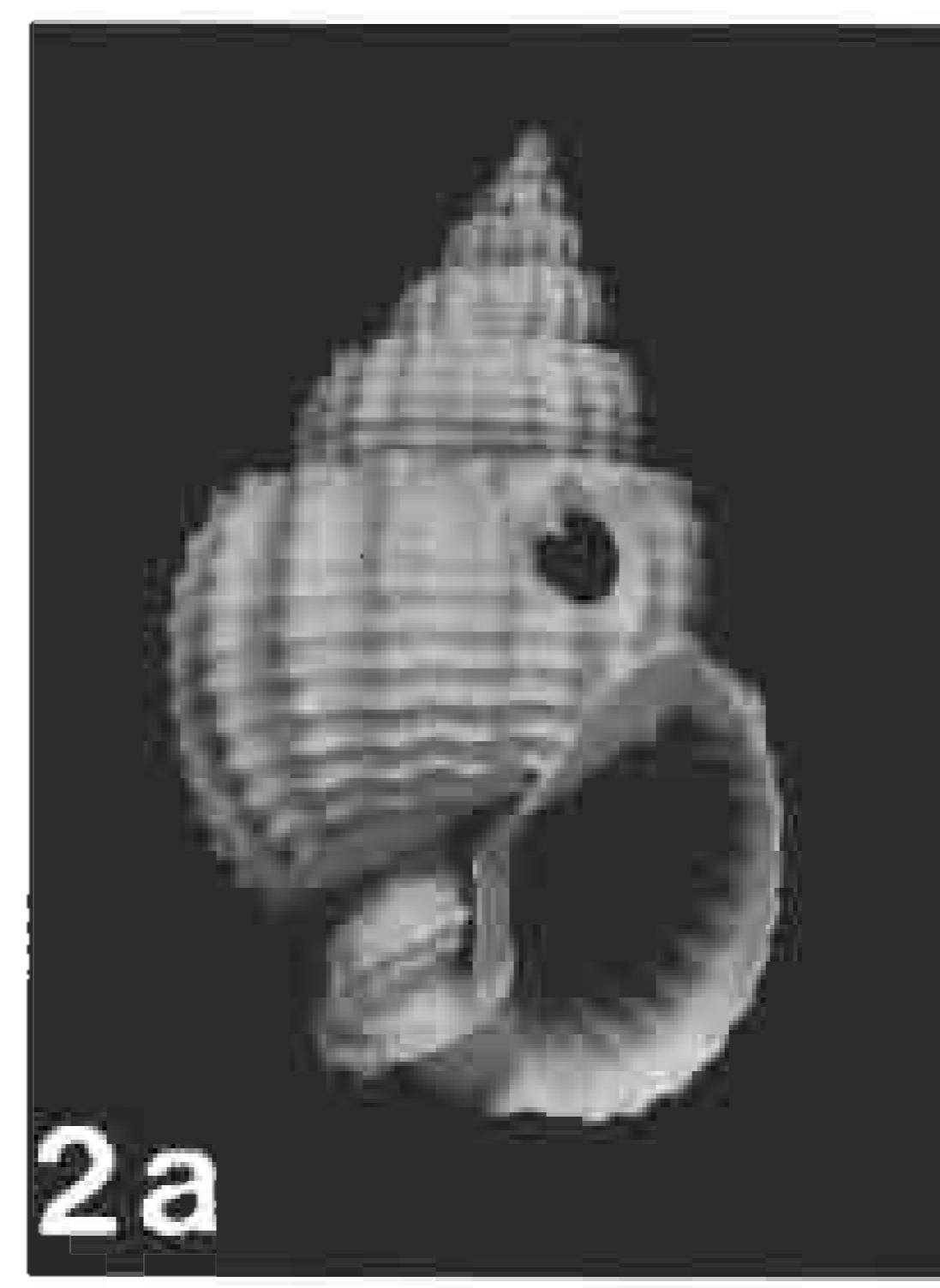
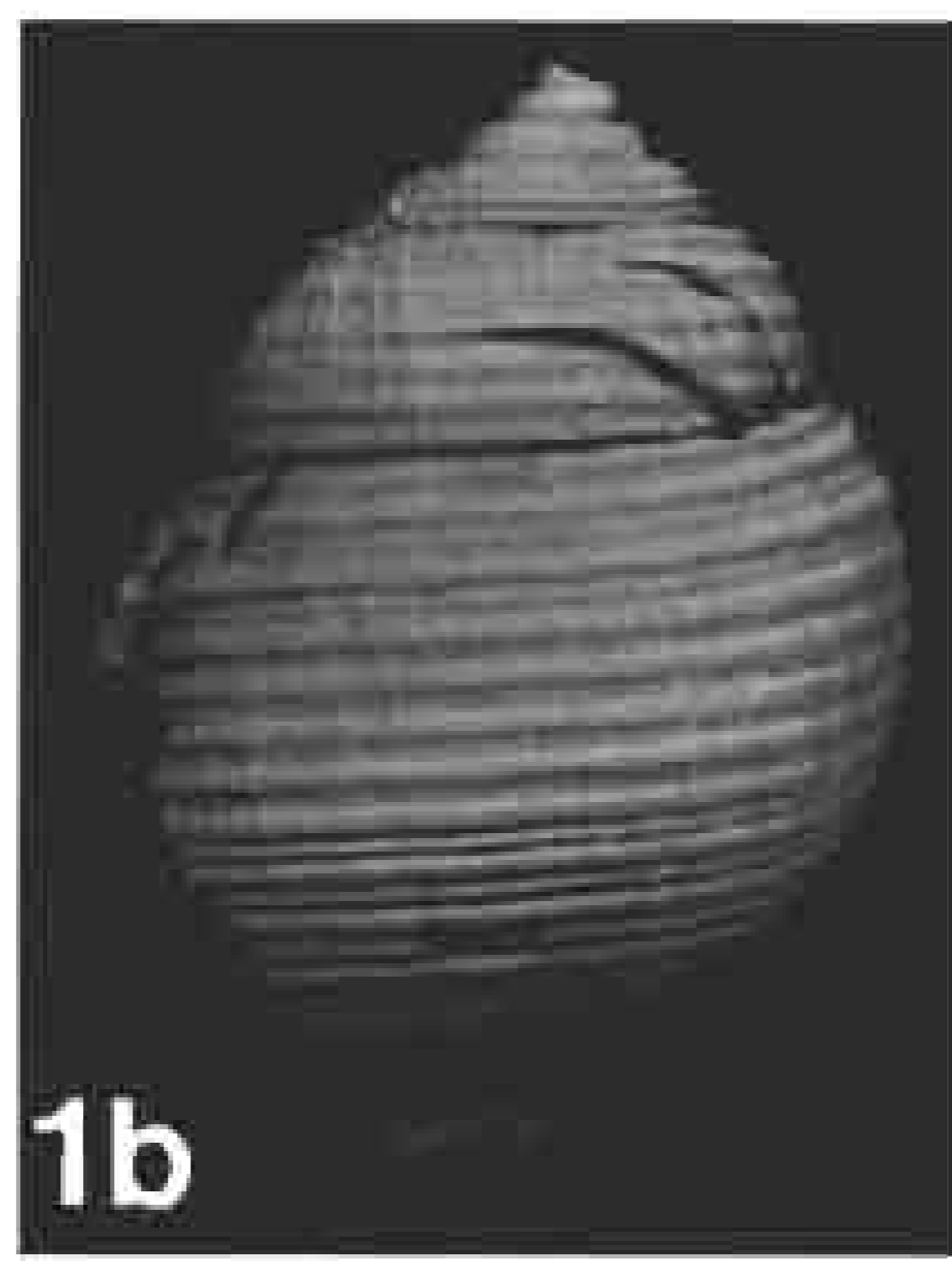
Fig. 7 a-b. *Nassarius pliomagnus* (Sacco, 1904). H = 44.2mm

Fig. 8 a-b. *Nassarius companyoi* (Fontannes, 1879). H = 43.1mm

Fig. 9 a-b. *Nassarius gibbosulus* (Linnaeus, 1758). H = 13.7mm

Fig. 10 a-b. *Nassarius rideli* (Dollfus, 1889). H = 18.4mm,

Fig. 11 a-b. *Nassarius* aff. *musivus* (Brocchi, 1814). H = 17.0mm,





23.3mm and a width of 11.8mm, thus larger than the specimens studied by Gili (1991). The specimen considered here has spiral threads on all the whorls of the spire, and five adapical threads on the last whorl.

The authors believe that these forms of Vale de Freixo correspond to those named *Hinia (Amyclina) tersa abbreviatula* (Sacco) by Brébion (1971) and *Nassa pyrenaica* var. *compacta* Fontannes by Zbyszewsky (1959). Gili (1991) justified considering *Nassa tersa* Bellardi, 1882 as a synonym of *Nassa pyrenaica* Fontannes, 1879; the varieties *compacta* Fontannes, and *abbreviatula* Sacco, apply to specimens less slender than the type specimen, like the ones found in this Portuguese outcrop (average D/H = 0.54).

This is the first report of the species in sandy sediments from a taphonomically well-documented outcrop. Up to now all specimens of this species were collected in clayey sediments or in sediments with a weak sandy component.

### ***Nassarius turritus* (Borson, 1820)**

Pl. 1, figs 6a - b

1820 *Nassa turrita*. Borson, p. 218, t. 5, fig. 11.

1879 *Nassa eurosta*. Fontannes, p. 62, pl. V, fig. 6.

1941 *Nassarius (Uzita) malachiasi*. Cox, p. 7, pl. 1, fig. 1 (a-b).

1959 *Nassa (Uzita) malachiasi* Cox; Zbyszewsky, p. 97, pl. XI, figs 56, 66.

1971 *Hinia (Uzita) eurosta* (Fontannes); Brébion, p. 136.

1975 *Alectrion (Zeuxis) eurostus* (Fontannes); Pavia, p. 144, tav. VI, fig. 28, tav. 7, figs 10-14.

1976 *Alectrion (Zeuxis) turritus* (Borson); Pavia, p. 156, tav. 2, fig. 10.

1982 *Nassarius eurostus* (Fontannes); Martinell, p. 87, lam 2, figs 11-12.

1991 *Nassarius turritus* (Borson); Gili, p. 468, lam. 34, figs h-k (synonymy).

**Material:** Two eroded adult specimens.

**Remarks:** *Nassarius (Uzita) malachiasi* Cox, 1941, as well as the specimens assigned to *Hinia (Uzita) eurosta* (Fontannes) by Brébion (1971), should be included in Borson's species (Gili, 1991). In fact, the basic difference between *malachiasi*, *eurosta*, *turritus* and some other closely related species (see Gili, 1991), is the number of ribbed whorls and some slight variations in the proportions of the shell (Pavia, 1975). The Vale de Freixo specimens are differently costated and also present some variation in the extent of spiral threads. Their size is not very large for this species.

### ***Nassarius gibbosulus* (Linnaeus, 1758)**

Pl. 1, figs 9a - b

1758 *Buccinum gibbosulum* Linnaeus, p. 737.

1873 *Eione affinis*. Cocconi, p. 89, tav. II, fig. 9-10.

1991 *Nassarius gibbosulus* (Linnaeus); Gili, p. 442, lam. 33, figs a-j (synonymy).

**Material:** Three adult specimens, very well preserved.

**Remarks:** This material presents a more slender general form, a weaker gibbosity and a narrower aperture than typical modern specimens of *N. gibbosulus*. The features of the species *Eione affinis*, established by Cocconi (1873) for Pliocene material, coincides with the morphotype of these Portuguese specimens. On the other hand, this particular morphology is closely similar to that of *N. circumcinctus* (A. Adams), a modern species very similar to *N. gibbosulus*. However, in literature concerning fossil molluscs, these two taxa are commonly considered to be conspecific and therefore *E. affinis* is regarded as a junior synonym of *N. gibbosulus*. The existence of *N. circumcinctus* in Pliocene times is currently uncertain and worthy of future investigation.

### ***N. mutabilis* (Linnaeus, 1758) group**

Fossil Nassariidae related to the modern species *N. mutabilis* (Linnaeus) collected in Vale de Freixo are assigned to two common Pliocene morphotypes: 1) specimens with a continuously sulcate surface sculpture (from suture to suture), and 2) specimens presenting grooves only on the adapical part of spire whorls and on the abapical half of the last whorl. The Pliocene specimens corresponding to these morphotypes do not belong to the



modern species *N. mutabilis*, as demonstrated by Martinell & Cuadras, (1977), Gili & Martinell (1990), and Gili (1991), but are referred to the two taxa below:

***Nassarius pliomagnus* (Sacco, 1904)**

Pl. 1, figs 7a - b

1904 *Nassa mutabilis* (Linnaeus) var. *pliomagna*. Sacco, p. 67, tav. XV, figs 27-28.

1918 *Nassa mutabilis* (Linnaeus) var. *erthensis* Wood; Harmer, p. 14, t. 33, fig. 26.

1959 *Nassa mutabilis* (Linnaeus) var. *pliomagna* Sacco.; Zbyszewsky, p. 95, pl. XI, figs 82-83.

1990 *Nassarius (Sphaeronassa) pliomagna* Sacco; Gili & Martinell, p. 21, lam. 1, figs 1-6, lam. 2, figs 5-6, lam. 3, figs 1-9, lam. 4, figs 7-9.

1991 *Nassarius pliomagnus* Sacco; Gili, p. 133, lam. 1, figs a-g, lam. 2, figs a-e (synonymy).

**Material:** Five well preserved specimens, two of them juvenile.

**Remarks:** These are the totally grooved specimens. The Vale de Freixo specimens have some peculiar morphological features. They present quite flat spiral threads often subdivided by a shallow furrow, separated by very thin grooves. However, their most remarkable feature is size. The largest specimen collected has seven whorls of teleoconch, reaches a height of 44.4mm and a diameter of 26.9mm. Very large specimens of this species are known to exist in northern Italian Pliocene outcrops, but none of them reach the size recorded here (personal observations). This "gigantism" corresponds to the specimens assigned by Harmer (1918) to *Nassa mutabilis* var. *erthensis* Wood, which should, in turn, be assimilated in the species *N. pliomagnus* Sacco. It seems that these large specimens are characteristic of more northern Atlantic faunas, since the Atlantic specimens from the vicinity of the Strait of Gibraltar (Southern Spain - Huelva - and Morocco) and those from the western Mediterranean are always smaller (Gili & Martinell, 1990). No doubt Zbyszewsky (1959) was referring to this species when he reported the presence of *Nassa mutabilis pliomagna* in the Portuguese Pliocene, as probably was Brébion (1971) when he referred to *Sphaeronassa* sp.

***Nassarius companyoi* (Fontannes, 1879)**

Pl. 1, figs 8a - b

1879 *Nassa mutabilis* (Linnaeus) var. *companyoi*. Fontannes, p. 71, tav. V, fig. 16.

1959 *Nassa mutabilis* (Linnaeus); Zbyszewsky, p. 95, pl. XI, figs 67, 73.

1990 *Nassarius (Sphaeronassa) aff. mutabilis* (Linnaeus); Gili & Martinell, p. 30, lam. 4, figs 5-6.

1991 *Nassarius companyoi* (Fontannes); Gili, p. 148, lam. 3, figs a-g (synonymy).

**Material:** Thirty specimens in diverse growth stages, well preserved.

**Remarks:** These are the specimens with grooves covering only part of their surface. The species name selected here corresponds to the first Pliocene varietal name applied to *N. mutabilis* found in the literature, which refers to this particular morphotype (Gili, 1991). The diversity of shell profile, as well as the variability in ornamentation (presence and number of adapical threads), in Vale de Freixo specimens is very wide. This variability has also been observed in specimens from other localities. In previous papers concerning Pliocene molluscs from Portugal the species *N. companyoi* was probably identified as *Nassa mutabilis* by Zbyszewsky (1959) and as *Sphaeronassa mutabilis* by Brébion (1971).

***N. reticulatus* (Linnaeus, 1758) group**

The variability assigned to the modern species *N. reticulatus* (Linnaeus) is very broad. Between specimens with a conical spire, numerous thin axial ribs and spiral threads - *N. reticulatus* s.s. - and specimens with a turriculate spire and a few thick axial ribs - *N. reticulatus nitidus* (Jeffreys) - a complete series of intermediates has been described, sometimes under different specific names (see Monterosato, 1911). So far, clear evidence of discontinuous variation, permitting the separation of *N. reticulatus* s.l. into different species, has not been found.

As regards Miocene and Pliocene fossils the situation is similar. Under the name of *N. reticulatus* specimens with a morphology corresponding, more or less, to the variability of the modern species have been grouped. On the other hand, specimens also presenting similar characteristics to the recent forms have been assigned to



different species. Specimens corresponding to two different phenotypes were collected in Vale de Freixo: one resembling *N. reticulatus nitidus* and the other closer to *N. reticulatus* s.s.

***Nassarius rideli* (Dollfus, 1889)**

Pl. 1, figs 10a - b

1889 *Nassa rideli*. Dollfus, p. 11, fig. 4.

1927 *Nassa (Hinia) rideli* Dollfus; Peyrot, p. 47, pl. II, figs 123-125.

**Material:** Three adult well preserved specimens.

**Remarks:** Specimens grouped under this specific name, established on Miocene material, present some apertural features that separate them from *N. reticulatus*. The aperture of *N. rideli* is more circular, with a well marked columellar concavity and an adapical sinus clearly delimited by an adapical columellar fold. The outer lip is thick and strongly curved, presenting an abapical toothlet which delimits, with the columellar fold, a narrow siphonal canal. The abapical end of the columellar callus extends laterally, regularly curving to the adapical end of the outer lip, without expanding vertically over the whorl. These features are very constant in these Vale de Freixo specimens. They closely resemble those described and illustrated by Peyrot (1927: 47, pl. II, figs 123-125) as *Nassa (Hinia) rideli*. These forms were probably the ones identified by Brébion (1971) as *Hinia recta* Dollfus & Dautzenberg. However, the material from Vale de Freixo does not coincide with the illustration of the above-mentioned species in Glibert (1952), namely in spire and apertural morphology. On the other hand, the sculpture of ribs and threads is very similar to that of *N. reticulatus*, which may have led Zbyszewsky (1959) to identify these forms as *Nassa reticulata nitida*.

According to available data *N. rideli* is an exclusively Atlantic species. It would be important to confirm this specific identification by comparing Vale de Freixo shells with type specimens of *N. rideli*. If the presence of *N. rideli* in Vale de Freixo is confirmed this will be its first reported Pliocene occurrence.

***Nassarius reticulatus* aff. *musivus* (Brocchi, 1814)**

Pl. 1, figs 11a - b

1882 *Nassa reticulata* (Linnaeus); Bellardi, p. 47, tav. III, fig. 7 (a-b).

1901 *Nassa (Hinia) reticulata* (Linnaeus); Cossmann, p. 204, pl. IX, fig. 8.

1983 *Hinia (Hinia)* cf. *restitutiana* (Fontannes); González-Delgado, p. 291, lam. 15, figs 1-2.

1991 *Nassarius reticulatus* (Linnaeus); Gili, p. 319, lam. 19, figs i-j (synonymy).

**Material:** Twenty well preserved specimens, in diverse growth stages.

**Remarks:** The general shell shape of *N. musivus* (Brocchi, 1814), the morphology of its aperture and associated structures, as well as its sculpture, consisting of axial ribs and closely packed thin spiral threads, is very similar to that of *N. reticulatus* s.s. *N. musivus* differs from *N. reticulatus* in having less prominent axial ribs, lacking raised knobs in the intersection of the ribs with the spiral threads and having less convex whorls (see Rossi-Ronchetti, 1955 and Pinna & Spezia, 1978 for holotype description and illustrations). It is not clear that these differences in themselves are enough to separate these two forms at the species level. In addition, the protoconch of *N. musivus* shows no important differences in comparison with that of *N. reticulatus* s.s. (Gili, 1991). It would be essential to study a large number of *N. musivus* specimens to characterize this species correctly.

The specimens found in Vale de Freixo do not exhibit the exact features typical of *N. musivus*, but they come very close. The specimens are very well preserved; protoconch consisting of 3.0 whorls with a maximum

**PLATE 2.** Nassariids from the Upper Pliocene of the Vale de Freixo (Pombal) Portugal in the collections of the Museu Nacional de História Natural (Museu de Geologia), University of Lisbon.

Fig. 1-3. Protoconch of *Nassarius holasticus* (Beyrich, 1854).

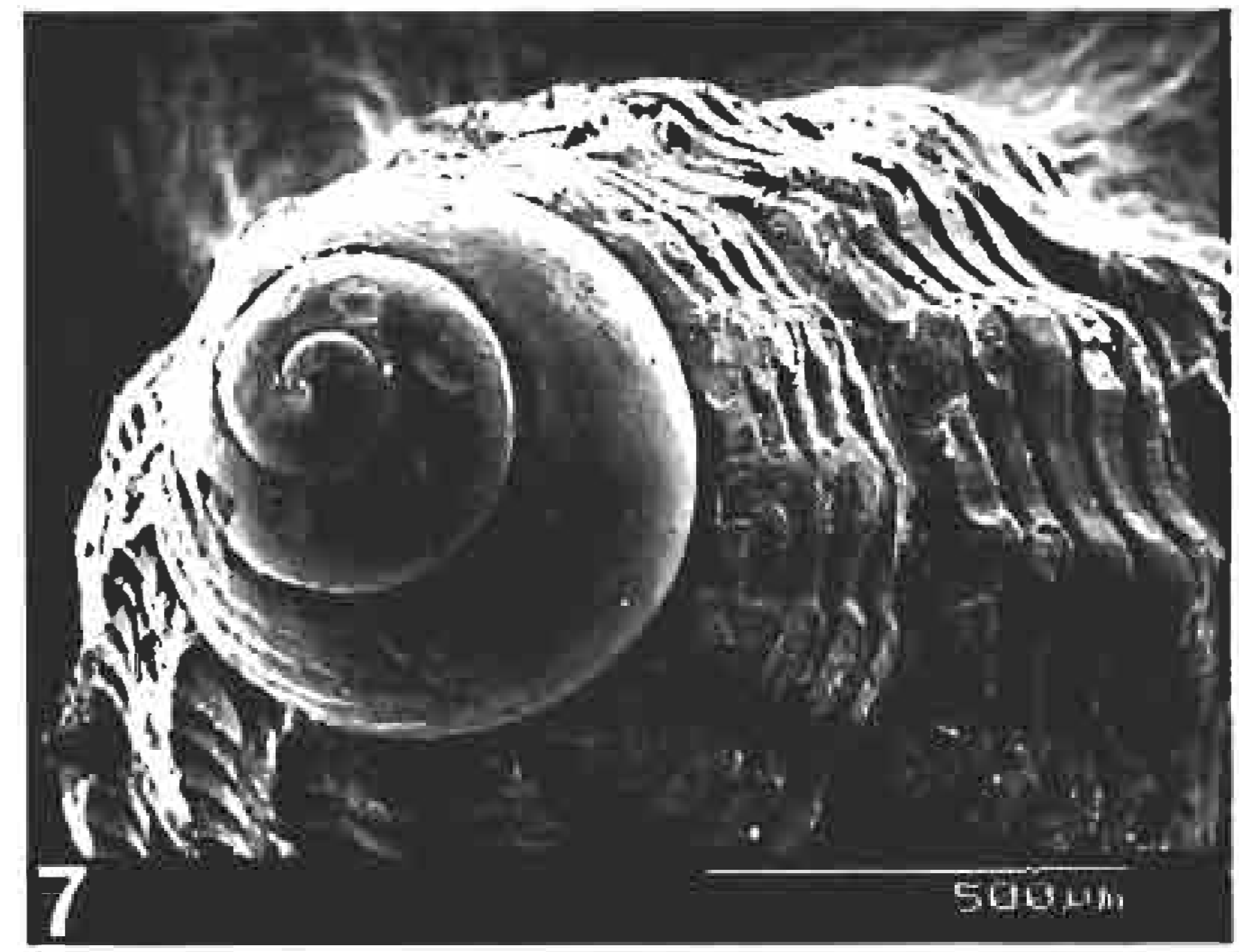
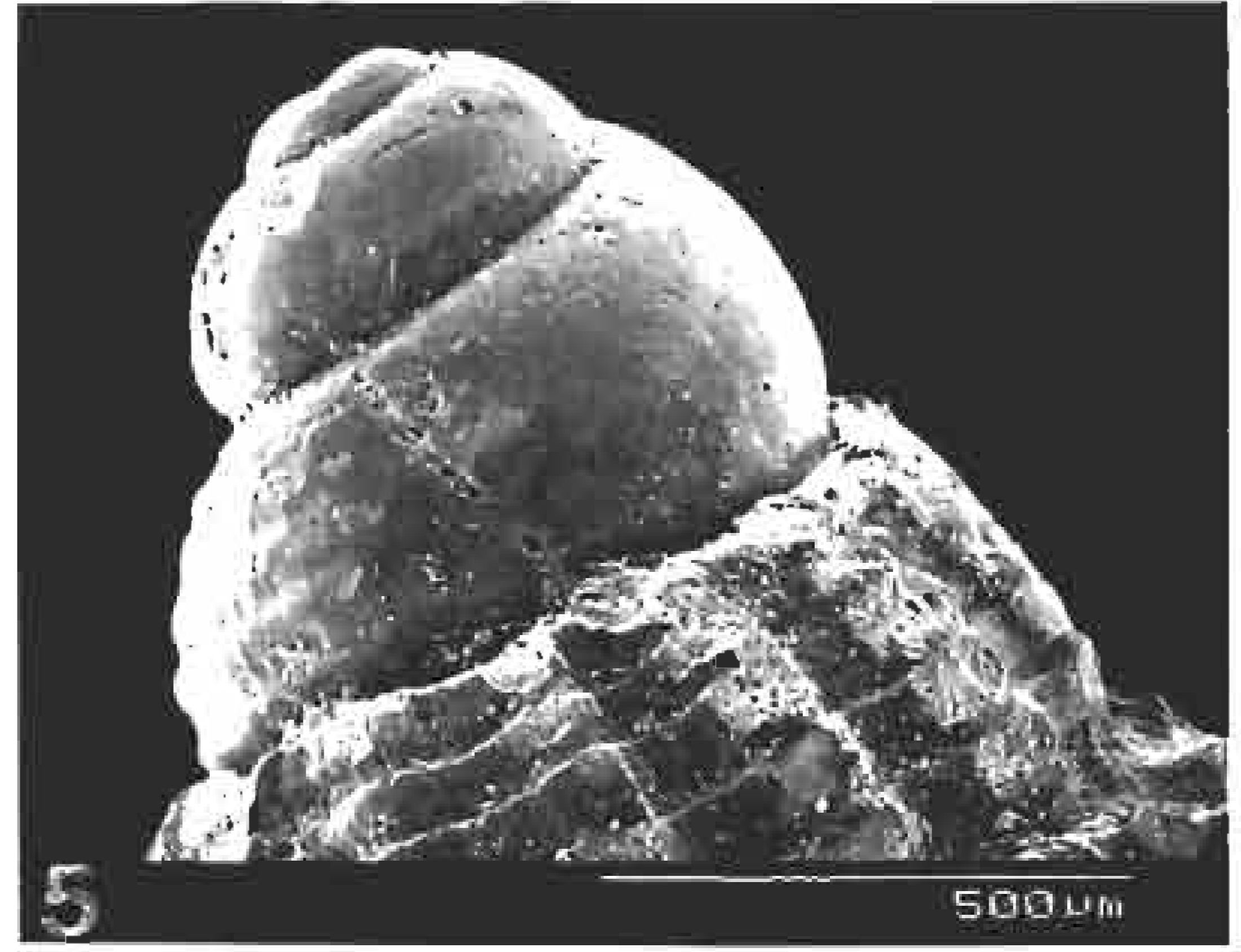
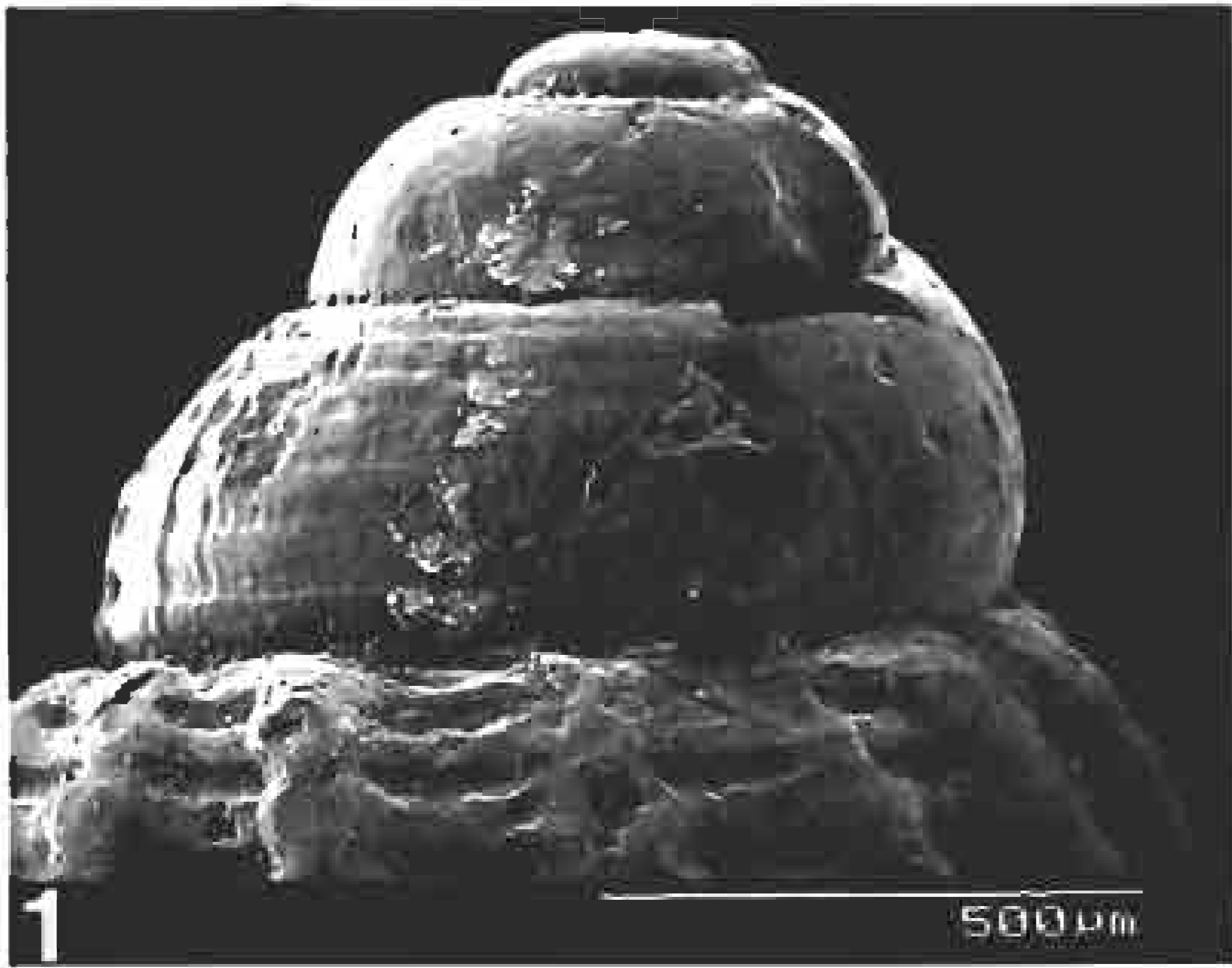
Fig. 4. *Nassarius holasticus* (Beyrich, 1854).

Figs 5, 7. Protoconch of *Nassarius kennardi* (Harmer, 1914).

Fig. 6. *Nassarius kennardi* (Harmer, 1914).

**Erratum:** Throughout the text, where it reads "*N. holasticus*" it should read "*N. holsaticus*".





diameter of 0.6 to 0.7mm. These measurements coincide with measurements made by Gili (1991) in *N. reticulatus* shells of a similar morphology from other Atlantic and Mediterranean outcrops.

Both Zbyszewsky (1959) and Brébion (1971) reported the occurrence of *N. musivus* in the Portuguese Pliocene, so the authors have decided to refer the Portuguese Pliocene specimens to *N. reticulatus* aff. *musivus* in order to allow clear future reference to the specimens.

With the exception of *N. rideli*, all previously discussed species, as well as *N. semistriatus* (20 specimens) and *N. serraticosta* (3 specimens), existed both in the Atlantic and in the Mediterranean during Pliocene times. However, in Vale de Freixo other small-sized Nassariidae were found that seem exclusive of Atlantic Neogene faunas: *N. holasticus* (Beyrich, 1854) and *N. kennardi* (Harmer, 1914). Portugal may have been their southern distribution limit, since their occurrence has not been reported from other Atlantic localities farther south, or from the Mediterranean. The small number of specimens collected and their, sometimes, poor preservation were an obstacle to their definite identification. Since these species are rarely mentioned in the literature and some doubt persists as to their specific identification the authors considered it useful to describe the specimens assigned to these two species.

### *Nassarius holasticus* (Beyrich, 1854)

Pl. 2, figs 1- 4

1958 *Nassa holastica* (Beyrich); Sorgenfrei, p. 219, pl. 48, fig. 149.

1964 *Hinia (Hinia) holastica* (Beyrich); Anderson & Chevalier, p. 258, pl. 25, fig. 195.

1968 *Hinia holastica* (Beyrich); Rasmussen, p. 138, pl. XI, figs 3, 5-7.

1972 *Hinia (Miohinia) holastica* (Beyrich); Nordsieck, p. 80, pl. XIX, fig. 113.

**Material:** Two specimens, one complete (teleoconch = 3.75 whorls; H = 5.27mm, D = 3.23mm Hv = 3.71mm), the other slightly damaged. Arenito de Carnide Formation, Vale de Freixo outcrop (Pombal region). Pliocene, Piacenzian.

**Description:** Shell of small size, moderately high. Protoconch consisting of 3.0 to 3.5 whorls, in both cases with the same morphology: small nucleus, spire developing regularly both in height and diameter, whorls smooth and strongly convex, suture deep (measurements: first specimen [3 whorls] hp = 0.53mm, dp = 0.7mm; second specimen [3.5 whorls] hp = 0.55mm, dp = 0.8mm). Teleoconch consisting of three and three quarter whorls. Beginning of teleoconch marked by the appearance of six spiral threads; first axial ribs appear one quarter of a whorl later. Suture superficial and undulates slightly near axial ribs. Sculpture consisting of axial ribs and spiral threads. Axial ribs tightly packed, low, with a rounded top, prosocline; axials vary from 16 to 17 on penultimate whorl, on later whorls become weaker and, towards the end of the last whorl, almost disappear; last axial rib developing as a labial varix. Spiral threads initially convex, becoming flat and tightly packed on later whorls; interspaces (grooves between spiral threads) of same width as threads on the beginning of teleoconch, becoming much narrower on later whorls, especially on the last two. Spire whorls smoothly convex, last whorl more strongly curved in abapical area. Base of shell featuring a narrow, concave, spiral band delimiting the siphonal canal. Aperture elliptical, tending towards sub-circular, wide. Outer lip slightly convex adapically, becoming more convex abapically, ending perpendicularly to shell axis, crenulated within. Teeth six, small, low. Columellar lip slightly convex adapically, becoming concave, ending parallel to shell axis. Callus thin, apparently restricted to aperture. Siphonal canal short, broad, straight.

**Remarks:** None of the studied specimens has a well preserved aperture. The aperture of the best preserved specimen has a gastropod drill hole on the siphonal canal which has obliterated all the columellar area.

The descriptions and the illustrations in the above cited papers coincide largely with our specimens. As to protoconch measurements a certain degree of variation has been found:

	Sorgenfrei (1958)	Rasmussen (1968)	Herein
dp	0.93 to 1.05mm	1.2 to 1.3mm	0.7 to 0.8mm
hp	-	0.7 to 0.9mm	0.53 to 0.55mm
dp/vol	0.3	-	0.23 to 0.25mm

It is difficult to ascertain the real meaning of these differences, given the small number of measured specimens. However, the specimens described by Sorgenfrei (1958) have a greater number of axial ribs (20 - 25), and the

**Erratum:** Throughout the text, where it reads "*N. holasticus*", it should read "*N. holsaticus*".



specimens illustrated both by Rasmussen (1968) and Anderson & Chevalier (1964) have two small adapical columellar tubercles on the aperture (not seen in Sorgenfrei's illustration). Since the specimens herein show incomplete aperture preservation, it is impossible to determine if they were present or not.

Sorgenfrei (1958) noted that *Nassa clathurella* Bellardi, 1882 is probably identical to *N. holasticus*. However, regardless of sculpture and shell shape similarities, the shells belonging to Bellardi's species are more than twice the size of *N. holasticus*. The studied material represents the first reported Pliocene occurrence of *N. holasticus*, since it has previously only been reported from the Miocene.

### *Nassarius kennardi* (Harmer, 1914)

Pl. 2, figs 5-8

1914 *Nassa kennardi*. Harmer, p. 87, pl. V, fig. 11.

1914 *Nassa kennardi* var. *elongata*. Harmer, p. 87, pl. V, figs 12 - 13.

1916 *Nassa kennardi*. Harmer, p. 316, pl. XXXV, figs 4 - 5.

1959 *Nassarius (Phrontis) kennardi* (Harmer); Glibert, p.18, pl. III, fig. 14.

**Material:** Three specimens. Average measurements: H = 3.14mm, D = 1.76mm, Hv = 2mm. Arenito de Carnide Formation, Vale de Freixo outcrop (Marinha Grande region). Pliocene, Piacenzian.

**Description:** Shell of very small size, spire low. Protoconch consisting of 3.0 to 3.25, very convex, smooth, regularly increasing whorls; suture becoming deeper on later whorls; nucleus small, low (average measurements: dp = 0.63mm, hp = 0.56mm). Three teleoconch whorls. Beginning of teleoconch marked by the appearance of five spiral threads; first axial ribs appear one quarter of a whorl later. Whorls only slightly convex, hardly distinguishable from one other; spire almost conical. Suture straight, linear, shallow. Sculpture consisting of axial ribs and spiral threads. Axial ribs neither sharp nor prominent, widening with growth whorls to become very faint on last whorl. Interspaces of same width as ribs, 13 - 14 in penultimate, 11 - 12 in last whorl; last axial rib developing as labial varix. Spiral threads overlying axial ribs do not form prominent nodes. Six initially slightly rounded, uniform, spiral threads, (interspaces of same width as threads), becoming flat on later whorls, interspaces very narrow; on the last whorl the abapical threads and those on the siphonal canal become thinner. Last whorl adapically flattened, with sharp convexity in median area. Neck slightly concave, without clear separation between the base of last whorl and siphonal canal. Aperture elliptical very narrow, low. Outer lip regularly and smoothly curved, crenulate within. Six, thick, low teeth. An adapical labial tooth, together with an adapical columellar tubercle, delimit a small anal canal. Columellar lip slightly convex. Callus thin, restricted to the aperture, along the columellar lip. Siphonal canal short, broad, straight, externally covered by threads.

**Remarks:** A comparison of specimens described by Harmer (1914) with Vale de Freixo specimens shows some differences. The Portuguese specimens lack flexuous axial ribs and are much smaller. The Belgian Pliocene specimens reported by Glibert (1959) seem to correspond to var. *elongata* Harmer, are wider than the type specimens, and larger than the material studied here. The specimens described by Glibert (1959) present eight axial ribs per whorl, fewer than in the Portuguese specimens. On the other hand, the specimens described and illustrated by Harmer (1914, 1916) and Glibert (1959) lack the adapical columellar tooth seen in Vale de Freixo specimens.

*N. kennardi* compares closely with *Nassa woodwardi* Harmer, 1914. Whorls and aperture shape are very similar. However, both Harmer (1914) and Sorgenfrei (1958, pl. 49, fig. 153) state that this species has well-defined nodes resulting from spiral threads interacting with axial ribs. *Nassa (Hima) turonensis* (Deshayes), illustrated by Peyrot (1927), also bears a close resemblance to *N. kennardi* and, when compared with the specimens described here, shows the same differences as *N. woodwardi* does. In the literature, *N. kennardi* is only cited from the Pliocene. It is possible that *N. turonensis* could be its Miocene ancestor, but without an exhaustive comparative study of specimens assigned to these two named species (outside the scope of the present paper) it is impossible to decide whether or not they are conspecific.

### CONCLUSIONS

The Nassariidae fauna from Vale de Freixo, 15 species, should be considered as very rich. Only in the outcrops from the Malaga area (Spain) has a higher number of species been found (study underway); of the outcrops studied by Gili (1991), in the Atlantic region and in the Western Mediterranean, none contain such a high number of nassariids.

In a previous study (Gili & Martinell, 1993) the similarity between the Nassariidae faunas from the Mediterranean and from the Atlantic around Gibraltar during the Lower Pliocene (Zanclean) was clearly demonstrated, although



no species was found which belonged exclusively to the Atlantic area. This similarity is also seen in the assemblage of species discussed here, but among these species of the Portuguese Upper Pliocene (Piacenzian) two groups may be distinguished. The first, and more numerous group, consists of 12 species which are also found in the Mediterranean Pliocene; the second group is made up of only 3 species (*N. rideli*, *N. holasticus* and *N. kennardi*), which up to now have only been found in the North European Atlantic Neogene. Among the species of the first group, *N. pliomagnus* presents the typical dimensions of the most northern specimens. The species in the second group presents its known southern distribution limit in the area under study.

Certain palaeobiogeographical considerations arise from the characteristics of the Nassariid fauna from the Pombal region. The molluscan assemblage of the Vale de Freixo fossiliferous beds indicates placement in the upper Pliocene, after the intra-Piacenzian cooling event had taken place *circa* 3.0-3.2 Ma (Silva, 1993). This event, evidenced by other proxy data, is responsible for the ecobiostratigraphic event characterised by the disappearance, from the Mediterranean, of several taxa of benthic molluscs of tropical affinity (Raffi *et al.*, 1989). The nassariid fauna used for the comparison (Gili & Martinell, 1993) corresponds to the Lower Pliocene (Zanclean), which precedes the above mentioned cooling period and occurs more to the south. In the light of this, the environmental characteristics of the Pliocene in Vale de Freixo and surrounding areas correspond to colder thermic conditions than those recorded in the Huelva area and in the Moroccan Atlantic (Gibraltar area).

The existence of species and phenotypes in the Portuguese Pliocene normally associated with more northern regions, must correspond to a migratory shift towards the south of these species induced by the progressive cooling event recorded during the Upper Pliocene. It is possible that the species which were exclusive to the Atlantic regions, found in Vale de Freixo, show the existence of a thermic barrier which moved south progressively as the climatic cooling became more intense. It would be interesting to determine if such a distribution pattern exist for other mollusc Families in this same region.

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