

Five new species of Cypraeidae from the Middle Miocene („Vindobonian“) of Porto Santo, Madeira Archipelago *)

(Gastropoda: Prosobranchia)

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With 7 figures

Abstract

Five new species of Cypraeidae from the Middle Miocene of Porto Santo (Madeira archipelago) are described, the present knowledge of the Cypraeid fauna is summarized. Of *Cypraea stenostoma* MAYER-EYMAR 1864 a lectotype is designated, all other available material critically revised.

Key words: Taxonomy, fossil Cypraeidae, new species, Miocene, Madeira archipelago.

Kurzfassung

Fünf neue Cypraeidae-Taxa aus dem Mittel-Miozän von Porto Santo (Madeira-Archipel) werden beschrieben und die gegenwärtigen Kenntnisse über die fossilen Cypraeiden des Archipels werden zusammengefaßt. Von *Cypraea stenostoma* MAYER-EYMAR 1864 wird ein Lectotyp festgelegt, das übrige Material von MAYER-EYMAR wird kritisch revidiert.

Schlüsselwörter: Taxonomie, fossile Cypraeidae, neue Arten, Miozän, Madeira-Archipel.

Introduction

More than one decade ago CHRISTA and JENS HEMMEN from Wiesbaden (Germany) and the co-author with his wife CHRISTINA collected a number of fossils from Miocene deposits on the island of Porto Santo and its outlayers Ilheu de Cima and Ilheu de Baixo (cfr. GROH 1985). Closer examination of this collection started only two years ago, however. Amongst the material there were eleven specimens or fragments of Cypraeidae, belonging to four different species. The literature available was poor and determination turned out an impossible task. We saw the necessity to revise all material from the archipelago, including that of the German geographer W. REISS, collected in autumn 1861 and later

studied by the Swiss geologist K. MAYER-EYMAR (1864 a, b). This was possible due to the rediscovery of a part of this historic material of fossil Cypraeidae in the geological collection of the Naturhistorisches Museum Basel (Switzerland).

Tools and Methods

To gain the best possible results from the partly poor material available we used a photographic scanning-system to recover and enhance important features of shell-morphology. The hardware consisted of an APPLE MACINTOSH Performa 630

*) Beiträge zur Molluskenfauna des Madeira-Archipels, Nr. 14; Nr. 13: A review of Macaronesian *Truncatellina* (Gastropoda: Vertiginidae) with descriptions of four new species. – *Bocagiana*, 151: 19 pp., 10 figs., 2 tables; Funchal.

with Video-Card, photos were taken with the aid of a CANON Still-Video-Camera and a MICROTECH SCANMAKER II (600 dpi), as software for photographic processing we used ADOBE PHOTOSHOP 2.5 and MACDRAW PRO. Reconstructions were made on the basis of fragments from different specimens of the same species. The available data on dentition, shape and proportion was combined to a hypothetical specimen by simply scaling and linking the images of the fragments available.

Following abbreviations are used:

CHW = Private collection of JENS HEMMEN, Wiesbaden (Germany)
 CLL = Private collection of FELIX LORENZ jr., Lauenburg (Germany)
 H = Height
 L = Length
 MSL = Medium sea level
 NHB = Naturhistorisches Museum Basel (Switzerland)
 SMF = Senckenberg-Museum, Frankfurt/M. (Germany)
 W = Width

Notes on the already published works on the fossil Cypraeidae from Porto Santo

The basis of the present article was laid by MAYER-EYMAR (1864a, b). In his papers six species of fossil Cypraeidae from Porto Santo are listed, the author assigns most of them to recent species. Only one (*Cypraea stenostoma*; 1864b: no. 200 p. 84; pl. 7 figs. 63, 63a) is described as being new to science. Only F. A. SCHILDER picked up this work (1928: 273, footnotes 15+17), but apparently he had never studied the material himself – he bases his opinion on mere guesses.

In other works on the Miocene of Porto Santo (JOKSIMOWITSCH 1911, SILVA 1959, LIETZ & SCHWARZBACH 1970, GROH 1985) no further Cypraeidae are mentioned; from other Miocene localities in the archipelago no Cypraeidae are known. The geological, stratigraphical and paleontological knowledge of the Tertiary sedimentary rocks of Porto Santo is first described by HARTUNG (1864) and MAYER-EYMAR (1864a, b) and last summarized by MITCHELL-THOMÉ (1976: 127–136). The exact age of the Tertiary sediments is still not known and only referred to the Vindobonian by MITCHELL-THOMÉ (1974: 1208) or LIETZ & SCHWARZBACH (1970: 280) which ranges from 20 to 13 Mio. years B. P.

Due to the courtesy of DR. RENÉ PANCHAUD and ANTOINE HEITZ, both from the Geological Department of the Naturhistorisches Museum Basel (Switzerland) we have had the opportunity to study a good part of MAYER-EYMAR's fossil Cypraeid specimens from Porto Santo, stored in Basel as a unlimited loan of the Eidgenössische Technische Hochschule Zürich (Switzerland). Those specimens not mentioned in the last column of following table must be considered lost forever – their identity will remain uncertain.

Systematics

Revision of the fossil Cypraeid specimens from Porto Santo in the MAYER-EYMAR-collection

„*Cypraea argus*“

Fig. 1

Material studied: 1 stonycast [NHB: H 17546 = MAYER-EYMAR-collection no. Po. 6230–GS–1].



Fig. 1. Stonycast of a bivalve, identified by MAYER-EYMAR as „*Cypraea argus*“.

Measurements: L = 33 mm, W = approx. 15 mm, H = approx. 8 mm.

Discussion: According to MAYER-EYMAR (1864b) there were two stonycasts from the Ilheu de Baixo which he identified as the recent Indo-Pacific *Cypraea [Lyncina] argus* LINNÉ 1758 – without doubt – as he stated „deren Form mit der ausgezeichneten Gestalt dieser schönen Art auf's Genaueste übereinstimmt.“ We had the opportunity to study one of these stonycasts which resembles neither *Lyncina argus* nor any Cypraeid at all. Most probably we are dealing with the stonycast of an elongated bivalve, e.g. *Lithodomus*, a genus that is represented with twospecies from these layers (cfr. MAYER-EYMAR 1864b, MITCHELL-THOMÉ 1976).

„*Cypraea Brocchii*“

Material studied: None.

Discussion: MAYER-EYMAR (1864b) notes two specimens from the Pico de Juliana and states that at least one of these is without any doubt identical with *Cypraea [Prozonaria] brocchii* DESHAYES 1844. In respect to the zoogeographical and stratigraphical circumstances this determination is for sure incorrect: *P. brocchii* disappeared already in the lower Miocene (Burdigal). Nevertheless, as the specimens are lost, clarification is not possible.

„*Cypraea pyrum*“

See under description of *Proadusta pygodentata* n. sp.

„*Cypraea sanguinolenta*“

See under description of *Luria palmula* n. sp.

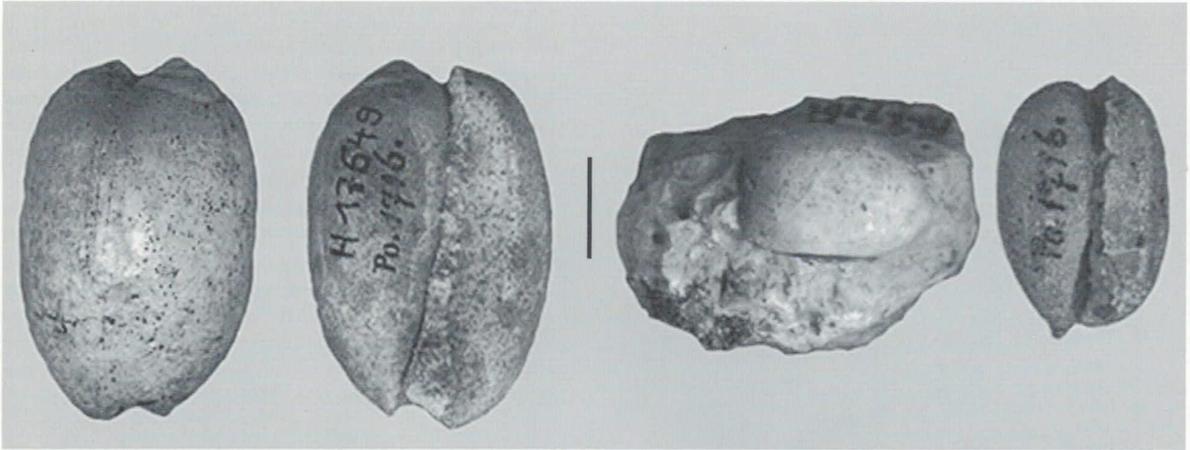


Fig. 2. *Cypraea stenostoma* MAYER-EYMAR

- a) stonecast of lectotype in dorsal and ventral view (= specimen figured 1864b on pl. 7 figs. 63, 63a.)
 b) stonecast of paralectotype 1, not conspecific with the lectotype, dorsal view.
 c) stonecast of paralectotype 2, not conspecific with the lectotype, ventral view.

Cypraea stenostoma MAYER-EYMAR 1884

Figs. 2a, 2b, 2c

Material studied: Three syntypes, all stonecasts, of which the largest [NHB: H 17549 = MAYER-EYMAR-collection no. Po 1716-P] is figured (MAYER-EYMAR 1864b: pl. 7 figs. 63, 63a) and herewith designated as lectotype. Both paralectotypes [NHB: H17550/1+2 = MAYER-EYMAR-collection no. Po 1716-GS-2] are not conspecific with the lectotype. All had been collected by W. REISS in autumn 1861. Both original labels state: „*Cypraea stenostoma*, M-E.; Helv. II, B; Ilheo de Baixo, Porto Sto; (3); -P -; 1 Ex“ respectively „Po. 1716.; Ilheo de Baixo, Porto Sto; (3); *Cypraea stenostoma* My.; 1 Ex.“.

Locus typicus: Madeira archipelago, Porto Santo, Ilheo de Baixo [SE-coast, environments of Portinho].

Stratum typicum: Not exactly known, but most probably the third layer of breccia above MSL, cut by a fault. A description of the existing four layers of calcareous fossilized breccia near Portinho is given by SILVA (1959).

Measurements: Lectotype: L = 35.1 mm, W = 23.5 mm, H = 18.1 mm. Paralectotype 1 [H 17550/1]: L = approx. 19.5 mm, W = 13.2 mm, H = approx. 9.5 mm; paralectotype 2 [H 17550/2]: L = 19.2 mm, W = 13.1 mm, H = 9.5 mm.

Number of teeth: Lectotype: Labral 16 impressions at a length of 22 mm preserved. In both paralectotypes teeth are either not visible (paralectotype 1) or lacking (paralectotype 2).

Discussion: From the four stonecasts mentioned by MAYER-EYMAR (1864b: 84) for the type-series three are preserved and could be studied. The designated lectotype is the stonecast of a medium-sized subcylindrical, denticulated species with a prominent projecting spire. Dentition was present only on the labrum, 16 impressions of fine, narrow teeth can be counted on a length of 22 mm. No traces of teeth can be found on the columellar side, suggesting that the shell was possibly subadult. A generic assignment of the species is not possible with certainty, but the data on age and origin, size, shape, the density of the labral dentition as well as the projecting spire allow an assignment to a smaller species of Cypraeidae, genus *Trona* is a possibility.

Both paralectotypes seem to represent one or even two smaller short-cylindrical species. MAYER-EYMAR's assignment of these to the same species as the lectotype was probably based on a misinterpretation: MAYER-EYMAR apparently searched for an equivalent to his shells in the Cypraeid fauna already known to science. This, for instance, led to the identification of the above mentioned cast of a bivalve as *Cypraea argus* (he must have taken the dome of the bivalve-shell as a dorsal profile). The reason why he assigned the three fossil casts to a new species was because these did not resemble any species he knew. We are certain that MAYER-EYMAR at his time did not realize that what he was dealing with were merely the casts of the interior of two or more species of Cypraeidae. SCHILDER & SCHILDER (1971: 32) treat *stenostoma* as the youngest and only Lusitanian chrono-subspecies of *Trona lyncoides* (BRONGNIART 1823), a very elaborate conclusion which to draw seems impossible to us, especially when taking into account the fact that the SCHILDER's never could study the specimens.

„*Cypraea stercoraria*“

Material studied: None.

Discussion: MAYER-EYMAR (1864b) mentions three specimens from the Pico de Juliana which he believes to be identical with the recent West African *Cypraea* [*Trona*] *stercoraria* LINNÉ 1758. These specimens are lost, so that no evaluation is possible.

Descriptions of five new species from the Middle Miocene of Porto Santo

Cypraeidae GRAY 1824
 Cypraeinae GRAY 1824

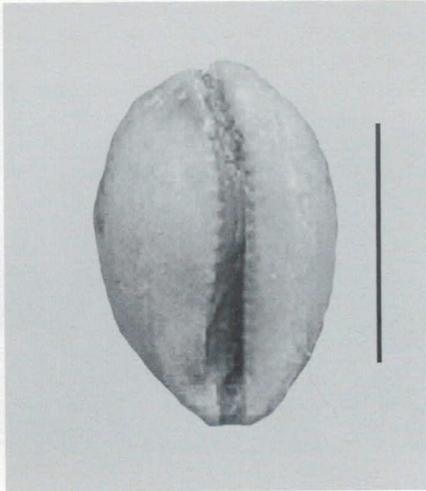


Fig. 3: Holotype of *Luria santoensis* n. sp. in ventral view.

Luria JOUSSEAUME 1884

Luria santoensis n. sp.

Fig. 3

Type material: A single, very well preserved specimen, the holotype (SMF 310 773), collected by CHRISTINA GROH in June 1983.

Locus typicus: Madeiran archipelago, Porto Santo, Ilheu de Cima, SSW-coast near Portinha, approx. 400 m NW Porto do Cais, approx. 20 m above MSL.

Stratum typicum: Light grey to ochrous, marmorized breccoidal limestones with fine to medium-sized inclusions of tuff-particles, approx 10 cm thick, with few fossil remains of marine molluscs and a single stonecast of a landshell (cf. GROH 1985: 227; KREJCI-GRAF 1961: 104).

Etymology: The name refers to the island of Porto Santo, the terra typica of the species.

Measurements: L = 15.4 mm, W = 10.3 mm, H = 8.0 mm.

Number of teeth: Labral 24, columellar 18.

Description: Flattened, oval, with blunt extremities. The spire is exposed, small, slightly pointed (the protoconch is broken off). The aperture is narrow throughout, bordered by very fine, regular and distinct teeth which are restricted to the edges of the lips. The labrum is slightly concave anteriorly. There is a well developed, smooth, spoonlike fossula.

Discussion: At first glance the general shape of the unique specimen resembles an inflated miniature of a recent Indo-Pacific *Luria isabella* (LINNÉ 1758). On the other hand the smooth fossula combined with the small size resemble the recent Caribbean *Luria cinerea* (GMELIN 1791). The new species may represent an ancestral form inbetween the Mediterranean-West African branch of the genus and the isolated living western Atlantic species.

Luria palmula n. sp.

Figs. 4a, 4b

Type material: A single, well preserved specimen, the holotype [NHB H 17548 = MAYER-EYMAR-collection no. Po 6223-GS-1], collected by W. REISS in autumn 1861.

Locus typicus: The original label states: „*Cypraea sanguinolenta*, Gmel.; Helvétien; Pico de Juliana auf Porto Santo b. Madeira; (3), Po. 6223.-GS.-1 Ex“. Referring to LIETZ & SCHWARZBACH (1970) the altitude was between 340 and 350 m above MSL.

Stratum typicum: No longer discoverable, as JENS HEMMEN and the second author could prove in summer 1983; probably the only few meters stretching layer is hidden under recent slope deposits. There is a description by LIETZ & SCHWARZBACH (1970: 280, locality 16).

Etymology: The name refers to the shape of the fruit of the date palm, in Latin „palmula“.

Measurements: L = 32.5 mm, W = approx. 16.0 mm, H = approx. 13.3 mm.

Number of teeth: Labral 28, columellar 30.

Description: Elongate-oval, narrow. Extremities callous, slightly produced. Spire pointed, covered with callus, exceeding the left side of the posterior extremity. The aperture is very narrow, hardly curved, widening slightly towards the anterior. The fossula is steep and smooth. There are fine, equally thick columellar and labral teeth which are restricted

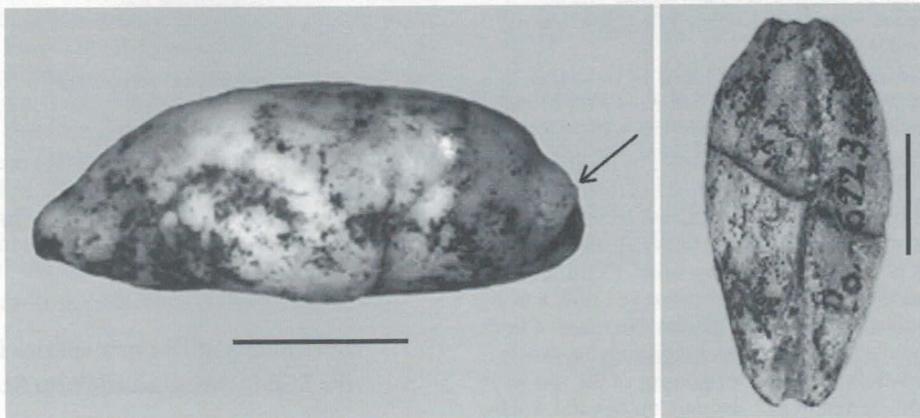


Fig. 4. *Luria palmula* n. sp., holotype
a) lateral view, note the pointed spire, b) ventral view.

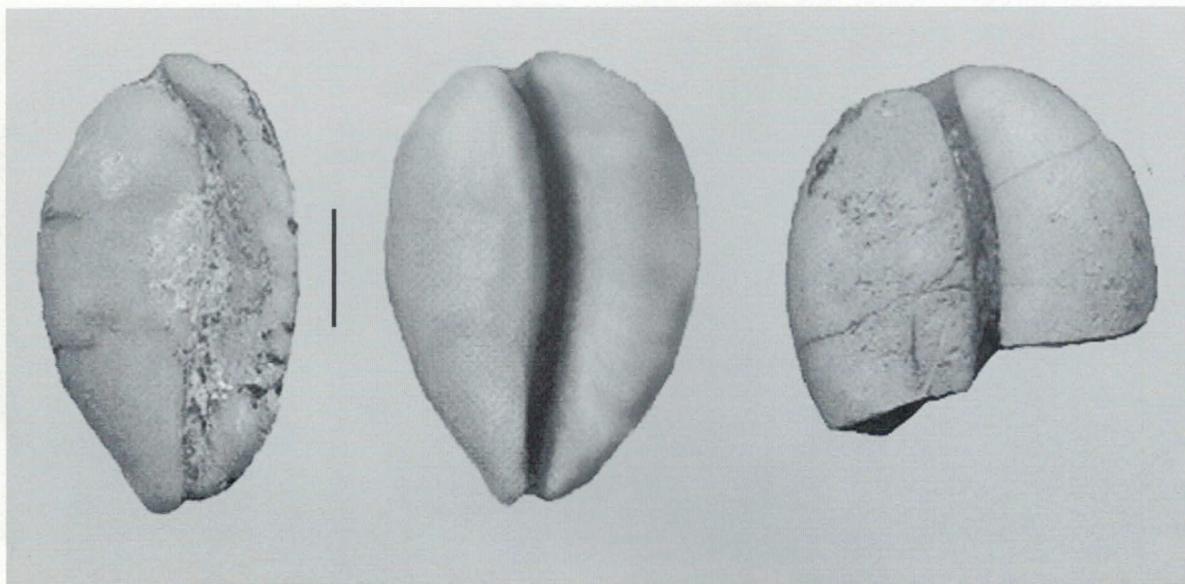


Fig. 5. *Zonaria sorrira* n. sp.

a) holotype, b) reconstruction gained from both types, c) paratype.

to the border of the aperture and do not extend onto base or labrum.

Comparison: The assignment of the new species to *LURIA* is well justified considering the structure of teeth and the elongate shape, similar to recent Indo-Pacific *Luria isabella* (LINNÉ 1758). The distinguishing feature, also to other living and fossil members of the genus is the pointed, well visible spire, which resembles the recent Indo-Pacific *Mauritia scurra* (GMELIN 1791).

Remarks: According to MAYER-EYMAR (1864b) there were two specimens (one now lost) of that species, which he assigned erroneously to recent West-African *Cypraea* [*Zonaria*] *sanguinolenta* GMELIN 1791. F. A. SCHILDER (1928) guessed that this might be the Helvetian „*Zonaria*“ *columbaria* LAMARCK 1822 [later by SCHILDER & SCHILDER (1971: 43) transferred to the genus *Schilderia*] or Mid-Miocene Lusitanian *Luria fortunatarum* SCHILDER 1928. As stated above, he had never seen any of the specimens discussed herein, all his assignments must have been made on a random basis. In this case the taxa he picked to compare the new taxon with are indeed similar in size, but these belong to the Mediterranean branch of their genera, both of whose species normally have a flat or umbilicate spire and a different dental structure.

Cypraeovulinae SCHILDER 1927

Zonaria JOUSSEAUME 1884

Zonaria sorrira n. sp.

Fig. 5

Type material: The holotype (SMF 310 771) is a completely fossilized shell which has been flattened by the pressure of the embedding limestone. The basal aspect however is well preserved. The para-

type (CHW) is merely a posterior half of a larger specimen. Both types have been collected by J. HEMMEN and K. GROH in June 1993.

Locus typicus: Madeiran archipelago, Porto Santo, Ilheu de Baixo, SE-coast N Portinho, approx. 40 m above MSL.

Stratum typicum: Light grey, finely grained, hardly cemented calcareous breccia with inclusions of few fossil marine gastropod shells, 1 to 3 m thick, above pyroclastics (cf. SILVA 1959: layer 3 above MSL).

Etymology: „Sorrira“ is the Portuguese word for smile, which refers to the impression of a smiling mouth seen on the basal aspect of the holotype.

Measurements: Holotype: L = 38.8 mm, W = 23.4 mm, H = 11.8 mm. Paratype: L = 29.2 (estimated 45 to 48 mm), W = 32.2, H = 19.8 (estimated 21 to 22 mm). Thickness of last whorl at the mid of the columellar side maximum 6.8 mm!

Number of teeth: Both specimens edentate.

Description: Oval to pyriform, depressed and very callous. The extremities are blunt and not projecting, the spire is completely obscured by the callus. The columellar side is absolutely edentate, lacking also a terminal ridge. There is a callous edge bordering the aperture. The labrum is slightly corroded in the holotype, but the paratype specimen shows slight irregularities along the inner edge, possibly a rudimentary dentition; from basal view the labrum as well appears edentate. Because of this characteristic feature both specimens can be assigned to the same species despite the difference in size.

Comparisons: The new species resembles the *Zonaria maxima*-complex to which belong several very callous and inflated species from the Miocene of the Mediterranean. The new species however is striking because of the complete absence of exteriorly visible teeth on either side of the aperture. A certain similarity to partly edentate species of *SCHILDERIA* does exist, a complete specimen might display more features to assure the here chosen assignment.



Fig. 6. *Zonaria bemmenorum* n. sp.
a) holotype, b) paratype 1.

***Zonaria bemmenorum* n. sp.**

Fig. 6

Type material: Three quite well preserved specimens, of which the holotype (SMF 310 772) is complete; the two others and further three fragments (one anterior part and two labial sides) are paratypes. All specimens have been collected in June 1983 by C. & J. HEMMEN and C. & K. GROH.

Other material: Two stonecasts of juvenile shells, probably also belonging to that species, are excluded from the types series.

Locus typicus: Madeiran archipelago, Porto Santo, Ilheu de Cima, SSW-coast near Portinha, approx. 400 m NW Porto do Cais, approx. 20 m above MSL.

Stratum typicum: Light grey to ochrous, marmorized breccoidal limestones with fine to medium-sized inclusions of tuff-particles, approx. 10 cm thick, with few fossil remains of marine molluscs and a single stonecast of a landshell (cfr. GROH 1985: 227; KREIJCI-GRAF 1961: 104).

Etymology: Named for CHRISTA and JENS HEMMEN, Wiesbaden (Germany) who collected part of the Cypraeaidae at our disposal.

Measurements: (* Columellar side partly chipped off)
Holotype: L = 19.2 mm, W = 10.8 mm, H = 8.8 mm. Paratype 1* (CHW): L = 19.5 mm, W = 12.6 mm (estimated approx. 13.5 mm), H = 8.7 mm (estimated approx. 9.5 mm); paratype 2* (CLL): L = 23.5 mm, W = 13.3 mm (estimated approx. 13.8 mm), H = 10.4 mm (estimated approx. 10.8 mm).

Number of teeth: Holotype: Labial 20, columellar 16. Paratype 1*: Labial 18, paratype 2*: Labial 21.

Description: Elegantly pyriform, elongate with produced, slightly rostrate extremities. The spire is slightly projecting and pointed. The anterior extremities are slightly bordered, showing a callus-accumulation dorsally. The dentition is fine, distinct and regular, restricted to the edges along the aperture on both lips. The first four anterior columellar teeth extend into the aperture but do not form a distinct fossula. There is a terminal ridge rather weakly produced.

Comparisons: The shell is similar in general appearance to the recent *Zonaria picta* (GRAY 1824) from Cape Verde Islands, which however has a different dental formation, especially anteriorly on columellar side. Additionally the margins of *Z. picta* are less pronounced. Also the variable *Zonaria pyrum* (LINNÉ 1758) can be very similar in general shape and dentition. It is possible that *Z. bemmenorum* belonged to an ancestral stage of *Z. pyrum*.

Erosariinae F. A. SCHILDER 1924

***Proadusta* SACCO 1894**

***Proadusta pygodentata* n. sp.**

Figs. 7a, 7b

Type material: The holotype (SMF 310 774) is a single fragment of the columellar side, while the labral side is present only as stonecast. It was collected in June 1983 by K. GROH. In addition there is one paratype, a plaster-cast of a core-negative [NHB H 17547 = MAYER-EYMAR-collection no. t. 2744-P-1]. This was taken by W. REISS in autumn 1861. The original label states: „*Cypraea pyrum*, Gm.; Helv. II, b; Ilheu de Baixo, Porto Santo, Mad.; (2); t. 2744 - P - 1 Ex., 1 Abg.“.

Locus typicus: Madeiran archipelago, Porto Santo, Ilheu de Baixo, SE-coast N Portinho, approx. 40 m above MSL.

Stratum typicum: Light grey, finely grained, hardly cemented calcareous breccia with inclusions of few fossil marine gastropod shells, 1 to 3 m thick, above pyroclastics (cfr. SILVA 1959: layer 3 above MSL).

Etymology: The denticulate posterior is most characteristic for this species, the name is derived from Greek „pygos“ = backside and Latin „dentata“ = toothed.

Measurements: Holotype: L = 17.6 mm (estimated approx. 20 to 22 mm), W = 11.2 mm (estimated approx. 12 mm), H = 9.6 mm

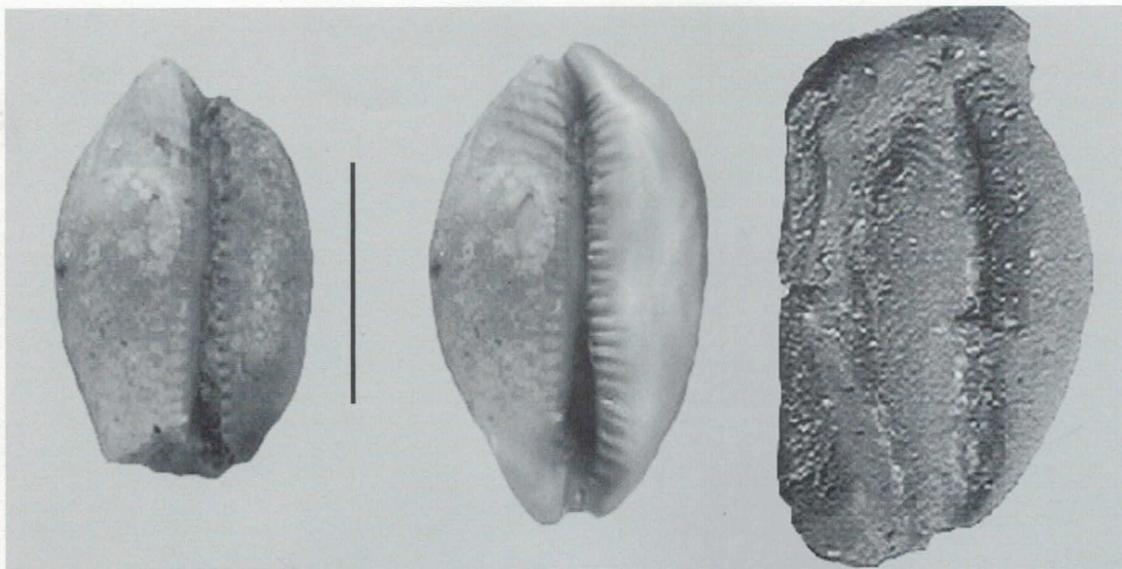


Fig. 7. *Proadusta pygodentata* n. sp.
a) holotype, b) reconstruction, c) paratype, plaster-cast from negative core.

(estimated approx. 10.5 mm). Paratype: L = 24.5 mm, W = approx. 15 mm, H = approx. 12.5 mm.

Number of teeth: Holotype: Labral impressions of 16 (estimated 25), columellar 22 (estimated 25 to 27) preserved. Paratypoid: Labral 8 on the anterior 11.5 mm, columellar 22.

Description: Elongate-ovate to oval-pyriform with rostrated extremities. A smooth labral margin is present. The pointed spire was covered by enamel. The holotype exhibits numerous sharply cut columellar teeth which become longer and coarser towards the posterior end to form six distinct riblets. On labral side there was equally fine dentition judging from the depressions formed into the cast. There are traces of a smooth, spoonlike fossula.

Comparisons: The feature of ribbing on the posterior end on columellar side, combined with a smooth distinct labral margin and a produced fossula is seen in very few recent species of Cypraeidae. There are few species in *Palaeocypraea* from the Cretaceous of Europe and *Proadusta*, a widespread genus in the Miocene, still represented by one recent species in the Caribbean [*P. surinamensis* (PERRY 1811), in which the posterior end on columellar side is also ribbed]. Therefore the placement of the new species in *Proadusta* seems most appropriate.

Remarks: MAYER-EYMAR (1864b) referred the plaster-cast to *Cypraea* [*Zonaria*] *pyrum* GMELIN 1771, and F. A. SCHILDER (1928) guessed that this might be the *Ovulid* *Apiocypraea michaudiana* (GRATELOUP 1847).

Aspects of the fossil Cypraeid fauna of Porto Santo

The fauna described herein seems closely related to the living Cypraeid fauna encountered in this part of the Atlantic

today (cf. LORENZ & HUBERT 1993), although none of the new species can be directly referred to a still living species of this area. However, it is interesting to find that the genus-constellation since the Middle Miocene has not changed much until today, suggesting that the biotope of this part of the Atlantic has been rather stable throughout the past 20 to 13 million years. With the exception of the conchologically extreme *Z. sorrira* n. sp. all fossil species have equivalents among the living representatives. This is especially striking in *Zonaria hemmenorum* n. sp. when compared to the recent *Z. pyrum* and its subspecies. The ancient *Proadusta pygodentata* n. sp. shows certain resemblance to the sole living survivor of the genus, *P. surinamensis* of the Caribbean. The two Luria-species, *L. santoensis* n. sp. and *L. palmula* n. sp., confirm that *Luria* is an old genus, well represented from the Miocene of Europe and the Caribbean. Another parallel of the fossil species described herein and the living Cypraeid fauna of the Atlantic may be that there was and is a smaller oval species (fossil: *L. santoensis* n. sp., recent: *L. cinerea*) and a larger, elongate species (fossil: *L. palmula* n. sp., recent: *L. lurida*) in the genus *Luria* in the Atlantic; the main concept of shell-features has not changed much since the Miocene.

Acknowledgements

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References

- GROH, K. (1985): Erstnachweis einer Geomitrine aus dem atlantischen Jungtertiär – Arch. Molluskenkunde, **115** (4/6): 225–229; Frankfurt/M.
- HARTUNG, G. (1864): Geologische Beschreibungen der Inseln Madeira und Porto Santo., mit dem systematischen Verzeichniss der fossilen Reste dieser Inseln und den Azoren von KARL MAYER. – 299 pp., 15 pls., 1 map; Leipzig (ENGELMANN).
- JOKSIMOWITSCH, L. (1911): Die zweite Mediterran-Stufe von Porto Santo und Salvagem. – Z. dtsh. geol. Ges., **62**: 43–96; Berlin.
- KREJCI-GRAF, K. (1961): Vertikal-Bewegungen der Makaronesen. – Geol. Rundschau, **51**: 73–122; Stuttgart.
- LIETZ, J. & SCHWARZBACH, M. (1970): Neue Fundpunkte von marinem Tertiär auf der Atlantik-Insel Porto Santo (Madeira-Archipel). – N. Jb. Geol. Paläontol., 1970 (5): 270–282; Stuttgart.
- LORENZ, F. jr. & HUBERT, A. (1993): A guide to worldwide cowries. – 571 pp.; Wiesbaden (CHRISTA HEMMEN).
- MAYER [EYMAR], K. (1864a): Paläontologische Verhältnisse, systematisches Verzeichniss der fossilen Reste von Madeira, Porto Santo und Santa Maria nebst Beschreibung der Inseln Madeira und Porto Santo. – In: G. HARTUNG (see above).
- – – (1864b): Systematisches Verzeichniss der fossilen Reste von Madeira, Porto Santo und Santa Maria nebst Beschreibung der neuen Arten. – 107 pp., 7 pls.; Zürich (MAYER-EYMAR).
- MITCHELL-THOMÉ, R. C. (1974): The sedimentary rocks of Macaronesia. – Geol. Rundschau, **63**: 1179–1216; Stuttgart.
- – – (1976): Geology of the Middle Atlantic Islands. – In: F. BENDER, V. JACOBSHAGEN, J. D. DE JONG & G. LÜTTING (eds.) Beiträge zur regionalen Geologie der Erde, **12**: IX + 382 pp.; Berlin & Stuttgart (BORNTAEGER).
- SCHILDER, F. A. (1928): Synopsis der Cypraeacea fossiler Lokalfaunen. – 4. Das Jungtertiär von Gran Canaria. – Senckenbergiana, **10**: 273–285; Frankfurt/M.
- SCHILDER, M. & SCHILDER, F. A. (1971): A catalogue of living and fossil cowries. Taxonomy and bibliography of Triviacea and Cypraeacea (Gastropoda Prosobranchia). – Mém. Inst. roy. Sci. nat. Belg., (2) **85**: 246 pp; Bruxelles.
- SILVA, G. H. (1959): Fosséis do Mioceno marinha da Ilha de Porto Santo. – Mem. Not. Publ. Mus. Lab. Mineral. Geol. Univ. Coimbra, **48**: 1–22; Coimbra.