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A new species of *Fusivoluta* Martens, 1902 (Gastropoda: Volutidae) from Mozambique

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ABSTRACT

During a recent expedition to Mozambique, several specimens attributed to the genus *Fusivoluta* von Martens, 1902 were collected between 1100 and 1820 m deep. Among them, a new species has been found and is here described and compared with the other East African *Fusivoluta*. Several live-collected specimens, belonging to the newly described species and to *Fusivoluta clarkei* Rehder, 1969 were sequenced for a nuclear gene (28S), revealing fixed differences between the two species.

Additional keywords: Molecular taxonomy, 28S gene, *Fusivoluta profundorum* nov. sp., Gastropoda, Mozambique, Volutidae

INTRODUCTION

The MAINBAZA expedition took place in April 2009 on board R/V VIZCONDE DE EZA, a research vessel from the Secretaria del Mar of the Spanish Ministerio de Medio Ambiente, Medio Rural y Marino, as part of a joint project between Muséum National d'Histoire Naturelle (MNHN) and Instituto Español de Oceanografía (IOE). Forty-six hauls were conducted at depths between 100 and 1820 meters on four transects off Maputo, Inhambane, Bazaruto, and the mouth of the Zambezi River. The expedition discovered many new species of benthic invertebrates, several of which have already been named (Alf et al., 2010; Cabezas et al., 2010; Komai and Chan, 2010; Richer de Forges, 2010). Among them, a new bathyal Volutidae has been identified, and is described as new in this article. Morphological differences clearly separate it from other *Fusivoluta* species. Additionally, several live-collected specimens of this new species and of *F. clarkei* were sequenced for the 28S gene to molecularly confirm the validity of the two species.

MATERIALS AND METHODS

Study Material: The studied material identified as *Fusivoluta* spp. was collected in six different stations

(details are provided below) during the Mainbaza expedition. Three of them (CP3139, CP3141, and CP3154) provided live material (five specimens in total) that was used for molecular analyses (Table 1). Two of them were morphologically identified as *Fusivoluta clarkei*; the three others were assigned to the new species. All vouchers are deposited in the MNHN; specimen data are also recorded in BOLD and sequences are published in GenBank (accession numbers are given in Table 1). Another species, *Athleta mozambicana* (Rehder, 1972), also belonging to the family Volutidae, was collected during the same expedition; it was added to the analysis as closely related outgroup. Two other Volutidae species were available in GenBank (*Amoria hunteri* – accession number DQ916584.1 and *Alcithoe aillaudorum* – accession number GU440153.1). A distant outgroup belonging to the family Muricidae was used to artificially root the phylogenetic tree (*Chicoreus subpalmatus*, accession number GU440174.1).

DNA Analysis: Live-collected specimens were preserved in alcohol and their DNA was extracted following the same protocol as in Puillandre et al. (2011). A fragment of the 28S gene was amplified using the primer C1' (ACC CGC TGA ATT TAA GCA T) and D2 (TCC GTG TTT CAA GAC GGG) (Jovelín and Justine 2001). PCR reactions were performed in 25 µL final volume, containing approximately 3 ng template DNA, 1.5 mM MgCl₂, 0.26 mM of each nucleotide, 0.3 µM of each primer, 5% DMSO and 0.75 U of Taq Polymerase (Qbiogene). Amplification products were generated by an initial denaturation step of 5 min at 94 °C followed by 35 cycles at 94 °C for 40 s, annealing at 52 °C and by an extension at 72 °C for 1 min. The final extension was at 72 °C for 5 min. PCR products were purified and sequenced by a sequencing facility (Eurofins). All genes were sequenced in both directions for increased accuracy. Sequences were manually aligned, and phylogenetic analyses were performed using the bayesian approach implemented in MrBayes (Huelsenbeck et al. 2001). Two parallel analyses were run, consisting each of

Table 1. List of specimens used for the phylogenetic analysis

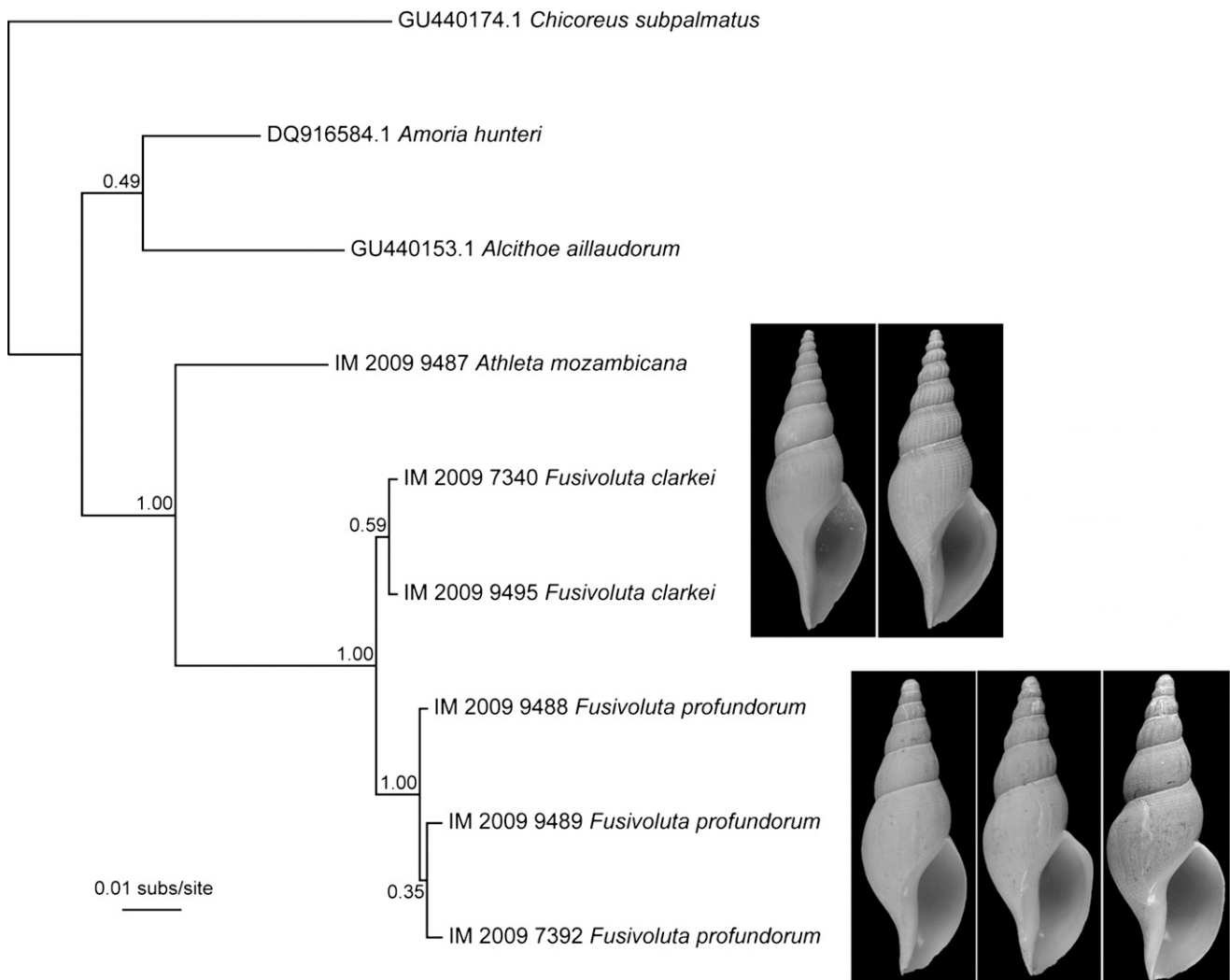
MNHN Number	Family	Genus	Species	Station	BOLD ID	GenBank number
IM-2009-7340	Volutidae	<i>Fusivoluta</i>	<i>clarkei</i>	CP3141	NEOGA1168-12	JQ775166
IM-2009-7392	Volutidae	<i>Fusivoluta</i>	<i>profundorum</i>	CP3139	NEOGA1170-12	JQ775169
IM-2009-9488	Volutidae	<i>Fusivoluta</i>	<i>profundorum</i>	CP3139	NEOGA1166-12	JQ775167
IM-2009-9489	Volutidae	<i>Fusivoluta</i>	<i>profundorum</i>	CP3139	NEOGA1165-12	JQ775168
IM-2009-9495	Volutidae	<i>Fusivoluta</i>	<i>clarkei</i>	CC3154	NEOGA1169-12	JQ775165
IM-2009-9487	Volutidae	<i>Athleta</i>	<i>mozambicana</i>	CP3146	NEOGA1167-12	JQ775164
	Volutidae	<i>Amoria</i>	<i>hunteri</i>			DQ916584.1
	Volutidae	<i>Alcithoe</i>	<i>aillaudorum</i>			GU440153.1
	Muricidae	<i>Chicoreus</i>	<i>subpalmatus</i>			GU440174.1

eight Markov chains of 5,000,000 generations. All other parameters were set to default.

Abbreviations: DNMH: Delaware Museum of Natural History, Greenville, Delaware; MNHN: Muséum National d'Histoire Naturelle, Paris; RSA: Republic of South Africa; Stn: station.

RESULTS

Phylogenetic Analysis: The phylogenetic tree (Figure 1) clearly shows that all the specimens identified as *Fusivoluta* belong to a single well-supported clade (Posterior Probability PP = 1). Within this clade, two reciprocally monophyletic groups are defined, one corresponding

**Figure 1.** Phylogenetic tree.

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461
IM_2009-7340 GGCAGGAGA TCTTCAACGA --CTCTCCCG GCGC-GGGGA CGCGTGCCGG
IM_2009-9495 GGCAGGAGA TCTTCAACGA --CTCTCCCG GCGC-GGGGA CGCGTGCCGG
IM_2009-9489 GGCAGGAGA TCTTCAACGA GACTCTCCCG GCGCTGGGGA CGCGTGCCGG
IM_2009-7392 GGCAGGAGA TCTTCAACGA GACTCTCCCG GCGCTGGGGA CGCGTGCCGG
IM_2009-9488 GGCAGGAGA TCTTCAACGA GACTCTCCCG GCGCTGGGGA CGCGTGCCGG
511
CCGTGTGCAC TTTCCGCGGG CAGAGCGCCA CGACCGGTTT TTGGGCGGTC
CCGTGTGCAC TTTCCGCGGG CAGAGCGCCA CGACCGGTTT TTGGGCGGTC
CCGTGTGCAC TTTCCGCGGG CAGAGCGCCA CGACCGGTTT TTGGGCGGTC
CCGTGTGCAC TTTCCGCGGG CAGAGCGCCA CGACCGGTTT TTGGGCGGTC
CCGTGTGCAC TTTCCGCGGG CAGAGCGCCA CGACCGGTTT TTGGGCGGTC
561
AGAAGCTGGC -GAGGATGGT AGGCGCGC-G TCTCCGCGCG TGCCTGGTA
AGAAGCTGGC -GAGGATGGT AGGCGCGC-G TCTCCGCGCG TGCCTGGTA
AGAAGCTGGC -GAGGATGGT AGGCGCGTTG TCTCCGCGCG TGCCTGGTA
AGAAGCTGGC -GAGGATGGT AGGCGCGTTG TCTCCGCGCG TGCCTGGTA
AGAAGCTGGC -GAGGATGGT AGGCGCGTTG TCTCCGCGCG TGCCTGGTA
611
CAGCCTC-GC CTGTCCCGAT CCGCCC-GGG GACCGAGGAG CCGCCGCTGG
CAGCCTC-GC CTGTCCCGAT CCGCCC-GGG GACCGAGGAG CCGCCGCTGG
CAGCCTC-GC CTGTCCCGAT CCGCCC-GGG GACCGAGGAG CCGCCGCTGG
CAGCCTC-GC CTGTCCCGAT CCGCCC-GGG GACCGAGGAG CCGCCGCTGG
CAGCCTC-GC CTGTCCCGAT CCGCCC-GGG GACCGAGGAG CCGCCGCTGG
661
T-G-TAGGCC GCCCGGCC TCCTGGGATG TTCGACTGGC AGAGACTGGG
T-G-TAGGCC GCCCGGCC TCCTGGGATG TTCGACTGGC AGAGACTGGG
T-G-TAGGCC GCCCGGCC TCCTGGGATG TTCGACTGGC AGAGACTGGG
T-G-TAGGCC GCCCGGCC TCCTGGGATG TTCGACTGGC AGAGACTGGG
T-G-TAGGCC GCCCGGCC TCCTGGGATG TTCGACTGGC AGAGACTGGG
711
CAACCGTGTC TGCTGACCGC TTCCTTGAC GGCAAAAACC AAGGGG---T
CAACCGTGTC TGCTGACCGC TTCCTTGAC GGCAAAAACC AAGGGG---T
CAACCGTGTC TGCTGACCGC TTCCTTGAC GGCAAAAACC AAGGGGCTGT
CAACCGTGTC TGCTGACCGC TTCCTTGAC GGCAAAAACC AAGGGGCTGT
CAACCGTGTC TGCTGACCGC TTCCTTGAC GGCAAAAACC AAGGGGCTGT
761
GGGCC--GC CGGCACAGGG TCGGTGGCGA ATCGGTCGGC CCTCCACCTG
GGGCC--GC CGGCACAGGG TCGGTGGCGA ATCGGTCGGC CCTCCACCTG
GGGCT--GC CGGCACAGGG TCGGTGGCGA ATCGGTCGGC CCTCCACCTG
GGGCT--GC CGGCACAGGG TCGGTGGCGA ATCGGTCGGC CCTCCACCTG
GGGCT--GC CGGCACAGGG TCGGTGGCGA ATCGGTCGGC CCTCCACCTG

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Figure 2. 28S alignment of the two specimens of *Fusivoluta clarkei* (above) and three specimens of *F. profundorum* (below) showing the diagnostic characters that discriminate the two species.

to *Fusivoluta clarkei*, with low statistical support (Posterior Probability PP = 0.59), the second to *Fusivoluta profundorum* with a high statistical support (PP = 1). Furthermore, the analysis of the 28S alignment reveals the existence of several fixed mutations and insertions (10 in total, shown on figure 2) that distinguish the two species. These results thus confirm the morphological identifications and support the validity of the two species.

In this partial tree, the relative closeness of *Fusivoluta* to *Athleta* is noticeable. Nevertheless, no conclusion must be drawn yet, pending the construction of a complete phylogenetic tree of the Volutidae.

SYSTEMATICS

Family Volutidae Rafinesque, 1815

Subfamily Calliotectinae Pilsbry and Olsson, 1954.

Genus *Fusivoluta* Von Martens, 1904.

Type Species: *Fusivoluta anomala* von Martens, 1902

***Fusivoluta profundorum* new species** (Figures 3–21)

Diagnosis: Shell of moderate size, fusiform, with high spire. Protoconch bulbous, with 2–3 whorls. Teleoconch sculptured with axial ribs. Columella without plaits. Aperture with flared outer lip when adult. Fasciole indistinct. Siphonal notch absent. Thin periostracum and horny operculum present.

Description: Adult shell of moderate size for genus (length 45–55 mm), light, fusiform. Surface dull covered by thin, adherent, gray periostracum. Protoconch small (average width: 2 mm), with 2 whorls, first whorl flattened, subsequent very convex. Transition protoconch–teleoconch sharp. Spire moderately high, forming average of 48% of total length of shell. Protoconch and abapical part of spire usually eroded. Teleoconch of 5 whorls, last slightly inflated. Suture indented. Sculpture of axial ribs

(14–15 on antepenultimate whorl), blunt or knobbed on some specimens, prominent onto spire, then becoming obsolete on half abapical part of penultimate whorl and on whole last whorl. Spiral sculpture of numerous, regularly spaced, minute cords covering whole teleoconch, becoming weaker on last whorl, crossed by faint axial lirae giving cancellate appearance (Figure 40, left). Aperture large, semi-circular, with outer lip thin and anteriorly flared. Columella slightly sigmoid without plaits. Anterior canal very short without siphonal notch. Surface of teleoconch and aperture gray-white, anterior part of columella and inner edge of outer lip slightly tinged with orange.

Type Material: Holotype MNHN 22816 (=IM-2009-7392), 49.0×18.5 mm (Figures 3–5); paratype I, IM-2009-9489, Stn CP3139, 1195 m, 45.7×17.5 mm (Figures 6–7); paratype II IM-2009-9488, Stn CP3139, 1195 m, 44.6×16.3 mm (Figures 8–9); paratype III, stn CC3158, 1220–1248 m, 43.3×17.7 mm (Figures 10–11).

Other Material Examined: Station CP3139, 23°35' S, 36°06' E, 1100–1200m, 8 specimens: 49.5×17.4 mm, 48.0×17.8 mm, 48.0×17.3 mm, 47.2×18.2 mm, 44.5×19.8 mm, 42.9×18.3 mm, 42.7×16.0 mm, 43.0×17.2 mm. Station CC3158, 21°46' S, 36°12' E, 1220–1248 m, 2 specimens: 43.3×17.6 mm (live), 39.6×16.7 mm. Station CC3156, 21°40' S, 36°35' E, 1810–1820 m, 1 specimen: 56.3×21.3 mm. Station CP3145, 21°47' S, 36°24' E, 1408–1421 m, 2 specimens: 55.5×40.0 mm, 50.8×18.0 mm.

Type Locality: 23°35' S, 36°06' E, 1100–1200 m, station CP3139.

Etymology: Specific epithet refers to the deep-sea habitat of the new species.

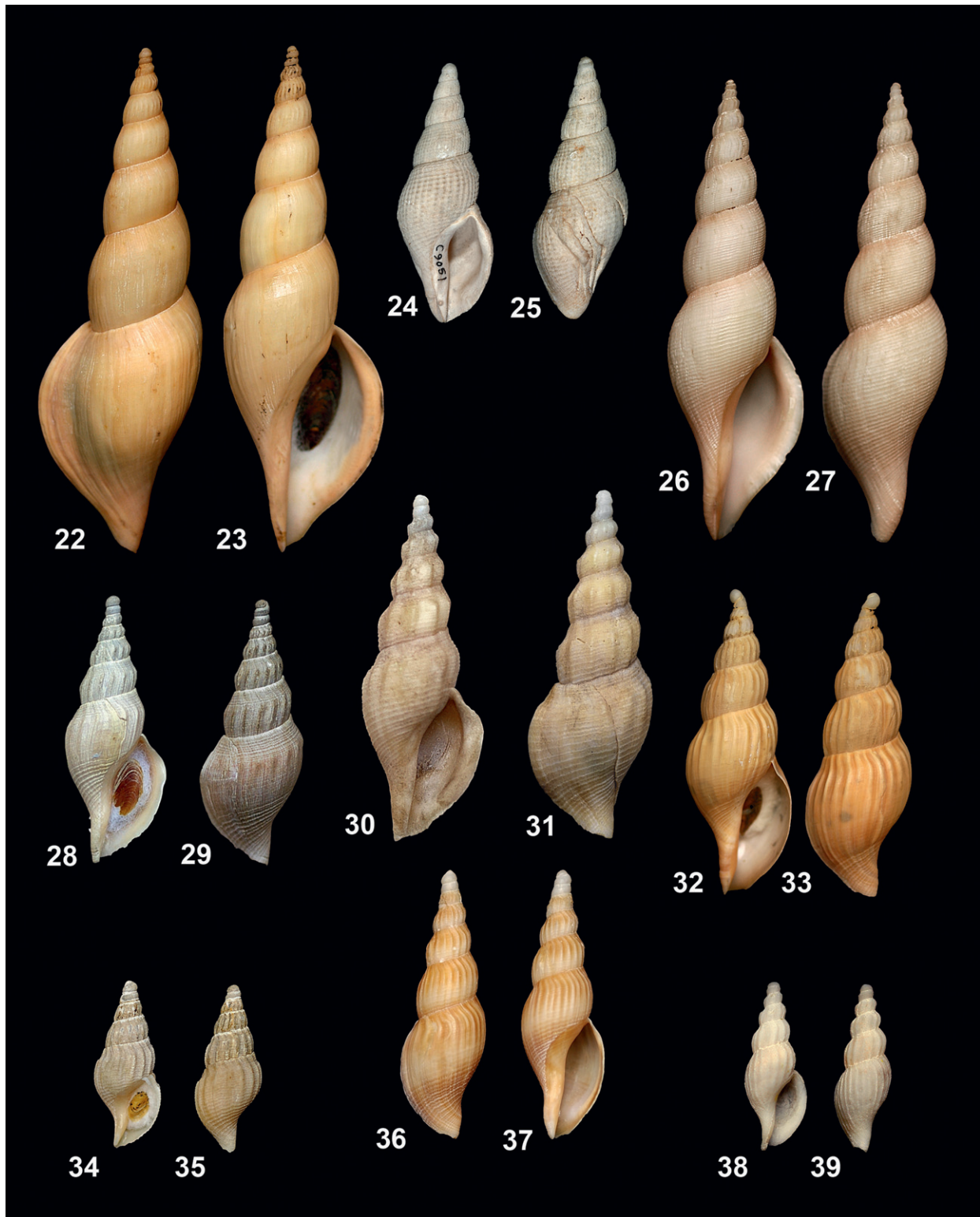
Distribution: Endemic in waters off Mozambique. A distribution between latitudes 21–23° S, in 1100–1500 m deep is revealed by the trawling operations, but the southern and northern limits are still imprecise because of lack of exploration beyond the explored range (see map, Figure 48).

Table 2. Summary of conchological differences between the five comparable *Fusivoluta*.

	<i>profundorum</i>	<i>clarkei</i>	<i>barnardi</i>	<i>decussata</i>	aff. <i>anomala</i>	<i>anomala</i>
Protoconch	bulbous, 2 whorls, the first flattened	rounded, 1.5 whorl, the first immersed	raised, bulbous, 1.25 whorl	mamillate of 1.5 whorl	turreted, of 2 very convex whorl	raised, 1.5 whorl, the first flattened
axial ribs	14–15 often knobbed	19–20 moderately angulate	22–23 very faint	absent	14–15 slightly angulate	12–13 strongly angulate
sculpture of last whorl	cancellate, no knobs	dominant spiral threads, no knobs	almost smooth	strongly cancellate, nodulose,	prominent subsutural and anterior spiral cord, faint spiral knobs	extended strong spiral cords, marked spiral knobs
Coloration	grayish	tan	orange-yellow	whitish	grayish	deep yellow
Distribution	southern Mozambique	Natal, southern Mozambique	Natal	Transkei, South Africa	Zanzibar Channel	Somalia



Figures 3–21. *Fusivoluta profundorum*. **3–5.** Holotype. MNHN 22816, Stn CP 3139, 1194 m, 49.0 mm. **6–7:** Paratype I, IM-2009-9489, Stn CP3139, 45.7 mm. **8–9:** Paratype II, IM-2009-9488, Stn CP3139, 44.6 mm. **10–11.** Paratype III, stn CC3158, 1220–1248m, 43.3 mm. **12–13.** Stn CP3139, 42.9 mm. **14–15.** Stn CP3139, 43.0 mm. **16–17.** Stn CP3139, 44.5 mm. **18–19.** Stn CP3145, 1408–1421 m, 55.5 mm. **20–21.** Stn CC3158, 1220–1248 m, 43.3 mm (live taken).



Figures 22–39. Living species of *Fusivoluta* (except for *F. decussata*, all the shells illustrated here are from the first author's collection). **22–23.** *F. barnardi*, off Tugela Bank, Natal, RSA, 320 m, 135 mm. **24–25.** *F. decussata*, off Mashbe River, Transkei, 700 m, 47 mm, Natal Museum (Photo D. Herbert). **26–27.** *F. clarkei*, off Maputo, Mozambique, 450–510 m, 122.3 mm. **28–29.** *F. aff. anomala*, Zanzibar Channel, 850 m, 47.5 mm. **30–31.** *F. anomala*, South of Ras Afun, Somalia, 420–450 m, 61.8 mm. **32–33.** *F. pyrrhostoma*, Agulhas Bank, RSA 400 m, 78.1mm. **34–35.** *F. sculpturata*, Capetown, no depth given, 27.5 mm. **36–37.** *F. blaitzei*, off Cape St Blaize, RSA, circa 250 m, 48.2 mm. **38–39.** *F. wesselsi* Tugela Bank, Natal, RSA, 50 m, 24.6 mm.

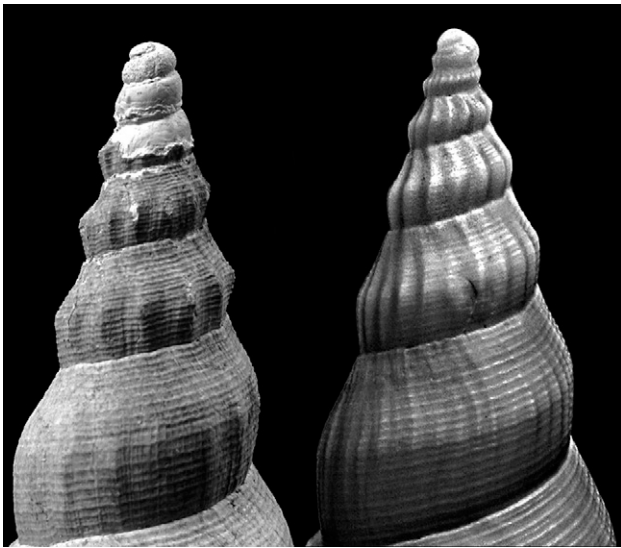


Figure 40. Comparison between the early spires of *Fusivoluta profundorum* (left) and *F. clarkei* (right).

Discussion: *Fusivoluta profundorum* shows very few variants, differing only by the strength of the axial ribs, knobbed specimens occurring mainly below 1400 m.

The genus *Fusivoluta* comprises ten East African species, of which five species, rising in successive ranges all along the east coast of Africa, must be compared with *F. profundorum*:

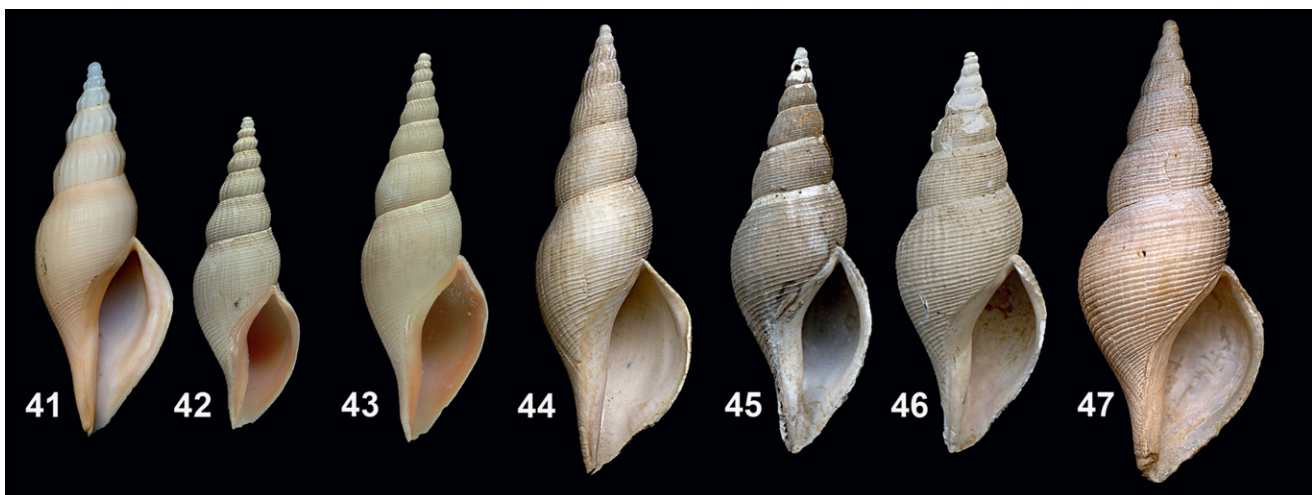
Fusivoluta barnardi Rehder, 1969 (Figures 22–23) from the coast off Natal, is a large shell (up to 145 mm long) with 7–8 teleoconch whorls, a high spire, axial ribs forming small nodules on the three early whorls, crossed

by fine spiral lirae, becoming obsolete on the subsequent whorls giving a smooth surface. Background colour and aperture deep beige-orange.

Fusivoluta decussata Barnard, 1959 (Figures 24–25), from Transkei, is a rare species, with only 5 specimens known. It is a medium-sized, solid species (approx. 50 mm) bearing a strong cancellate sculpture, the intersection between spiral and axial cords forming nodules. The thickness of this shell, the lack of true axial ribs and its notched suture contrast with the other members of the genus. Barnard himself placed this distinctive shell provisionally in *Fusivoluta*, pending studies of its anatomy.

Fusivoluta clarkei Rehder, 1969 (Figures 26–27) from off Mozambique, is a parapatric species occurring all along the same range as *F. profundorum*, but at lesser depth, from 450 to 900 m. It is a highly polymorphic species varying in size, shape and sculpture, according to depth. The type locality (holotype DNMN 12833) is off João Belo, Gaza district in 440 m. This typical form (Figures 41–43) the closest to *F. profundorum*, thrives between 450–650 m. It differs from the latter by a large size, 75–125 mm long, an elongate-fusiform shape with high spire and relatively long anterior canal. The 2–3 first post-nuclear whorls are made angulate by nodulose axial ribs, reduced to weak axial plicae on the rest of the spire, absent on the last whorl. Numerous strong spiral cords extending onto the whole teleoconch. Columella straight or weakly concave. Background color yellowish pink, the subsutural zone slightly darker.

Between 600 to 900 m, *F. clarkei* tends to be broader, with more pronounced spiral cords (Figures 44–45). Some shells are very squat, with reduced axial ribs, and very prominent spiral sculpture, which imparts the shell a rough



Figures 41–47. Variations of *Fusivoluta clarkei*. **41.** North Natal, RSA, 350–400 m, P. Bail collection (ex Meyer collection) 70.0 mm. **42.** Mozambique, IM-2009-9495, Stn CC3154, 19°36' S, 36°47' E, 636 m, MNHN, 58.2 mm. **43.** Mozambique, IM-2009-7340, Stn CP3141, 23°33' S, 35°55' E, 684–698 m, MNHN, 72.8 mm. **44.** Mozambique, 750–800 m, P. Bail collection, 84.6 mm. **45.** Mozambique, Stn CP3140, 23°33' S, 36°07' S, 890–900 m, MNHN, 77.1 mm. **46.** Mozambique, Stn CP3148, 21°32' S, 35°47' E, 768–787 m, MNHN, 75.3 mm. **47.** South Mozambique, 750–800 m, P. Bail collection (ex Meyer collection), 86.8 mm.



Figure 48. Map of the estimated range of *Fusivoluta profundorum*.

cancellate surface, very similar to that of *F. decussata* (Figures 46–47). No live-taken specimens of this form have been found until now. From 900 m to 1200 m, no *Fusivoluta* have been brought up by the few dredgings operated by Mainbaza expedition, suggesting a possible depth gap between the habitat of *F. clarkei* and *F. profundorum*, subject to confirmation by future expeditions.

Fusivoluta aff. *anomala* (Figures 28–29), from off Zanzibar, is a rare species discovered during the 1980s by Russian boats operating along the Zanzibar Channel in deep water (600–800 m). Sharing the same medium size (circa 45 mm) and light structure with *F. profundorum*, it differs by a turreted protoconch of 3 whorls and a very tapered spire. Sculpture of strong axial ribs, adapically attenuated, numbering 14–15 on the penultimate whorl, crossed by spiral cords divided into two parts: one sub-sutural, the other on the anterior third part of the body whorl, delimiting a smooth central part. Its relationship to the species below is problematic.

Fusivoluta anomala (Martens, 1902) (Figures 30–31) from off Somalia, is also a very rare species, known only from the holotype. It differs from *F. profundorum* by its solid, heavy structure, a very elongate-fusiform shape with a high narrow spire, made angulate by axial nodules (13 on the penultimate whorl), crossed by raised spiral cords. Both spiral and axial sculptures extend onto the whole teleoconch. Aperture large with the outer lip very flared. Base color yellowish-beige.

Four species are too different to warrant extensive comparison: *Fusivoluta pyrrostoma* (Watson, 1882) (Figures 32–33) from Western Cape differs by a rough surface and its tilted raised protoconch; *Fusivoluta sculpturata* (Tomlin, 1945) (Figures 34–35) from Western Cape is a small species, under 30 mm long, with heavily sculptured surface; *Fusivoluta blazei* (Barnard, 1959) (Figures 36–37) from Western Cape is a rather small, elongate, bicoloured shell with very high spire; *Fusivoluta wesselsi* Kilburn, 1980 (Figures 38–39) from Natal is a narrow, fusiform, small-sized species, under 25 mm when adult.

ACKNOWLEDGMENTS

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