

Revision and morphometric characteristics of the *Vasticardium fidele* group (Bivalvia: Cardiidae) in the Indo-Pacific with description of three new species

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ABSTRACT. Ter Poorten replaced living *Vasticardium fidele* (Vidal, 1992) with the fossil *V. kenyanum* (Cox, 1930) referring to the rules of priority. The synonymy is based on the assumption that *V. fidele* is the only living species distributed in the Indo-Pacific oceans. In this study I provide evidence that five extant species, of which three new, can be distinguished, in addition to the Pleistocene *V. kenyanum* from Kenya. I describe living *V. neokenyanum* n. sp. from the Indian Ocean (Mozambique), *V. terpoorteni* n. sp. from the Bay of Bengal (SE India), *V. somnueki* n. sp. from the western Andaman Sea (off North Sumatra), *V. fidele* (Vidal, 1992) from the eastern Andaman Sea and the Gulf of Thailand, and *V. hullebergi* Thach, 2014 from the South China Sea (Vietnam). Erection of the new species is supported by pairwise comparisons of the five living species by ANOVA analyses of adult specimens ($L > 40$ mm). Juvenile specimens are not included because juvenile and adult individuals show significant differences when the two size classes are compared.

Dedication

This paper is dedicated to the memory of the extremely skilled morphologist Jacques Vidal who contributed significantly to the taxonomy of cardiids. He is remembered as a dear colleague, always ready to help whenever needed.

INTRODUCTION

Vidal (1992) used the specific name *fidele* (the faithful). He found that the species displayed very little variation from juvenile to adult size. However, shell dimensions of juveniles < 40 mm in length differ significantly from adults in my studies. Ideally measurements should be made on specimens of the same age, but this is impossible to achieve in practice. Vidal identified specimens from the Indo-Pacific and referred them to *V. fidele*. Ter Poorten (2005) concluded that fossil *Vasticardium kenyanum* (Cox, 1930) is identical with *Vasticardium fidele*. At that time only one living species of the fidele-group was recognized. Now, 5 living species in the group it is increasingly difficult to state, which one should be identical with the fossil species. Hence, I remove *V. fidele* from synonymy with *V. kenyanum*. Details and

certain measurements for comparisons cannot be obtained with a distorted impression (Hulleberg 2014).

MATERIAL AND METHODS

Adult and juvenile specimens of *Vasticardium fidele* from Thailand are from 3 sources: the PMBC (courtesy of Dr C. Aungtonya), a shell shop on Phuket Island (courtesy of Somnuek Patamakanthin), and the private collection of J.J. ter Poorten. Shells from the Andaman Sea off northern Sumatra are from one batch landed by Thai fishermen (courtesy of Somnuek Patamakanthin). Shells from India landed by local fishermen (shell dealer near Tuticorin). Vietnamese shells landed by local fishermen (courtesy of Dr. Thach). The holotype of *V. fidele* in Paris (courtesy of Dr. Philippe Bouchet). A topotype of *V. fidele* from Japan (courtesy of J.J. ter Poorten). He put his private collection at my disposal, including a specimen of dubious origin from a shell dealer in the Philippines.

Shells from Mozambique are all from local fishermen (courtesy of J.J. ter Poorten).

Methods. Numbered dents start at the first rib on the posterior side of shells. Interior views of shells are scanned on a high-resolution flatbed scanner to ensure that images are horizontal. Shell dimensions are analysed according to Hylleberg (2014) and referred to as SQ analysis. The nymph is turned into horizontal position and the image reduced to fit into a 10 x 10 cm square. Horizontal and vertical lines are drawn. The bottom part of the square is extended to accommodate the elongated ventral part of the valve. A line touching the anterior and posterior laterals marks the inclination relative to the horizontal nymph line. Inclination of the anterior right valve is always downward in *Vasticardium*. Horizontal and vertical dimensions are measured on hard copies. One mm corresponds to 1% of the measurement. SQ scanned specimens are converted to "find edges" in Photoshop. Rib flanks are coloured in Photoshop.

Statistical data. Means and standard deviations according to (https://www.easycalculation.com/statistics/standard-deviation.php). Analysis of variance between groups (ANOVA) and box plots according to (http://www.physics.csbsju.edu/stats/anova.html).

Abbreviations

JJTP: collection of Jan Johan ter Poorten.
 JH: collection of Jorgen Hylleberg.
 L: length of shell from umbo to ventral edge = height
 MNHN: Muséum national d'Histoire naturelle, Paris, France.
 PMBC: Phuket Marine Biological Center, Thailand.
 RC: Reference Collection
 s.d.: standard deviation.
 Spcm(s): specimen(s)
 SQ: standard square analysis.
 ZMA: Zoological Museum Amsterdam, the Netherlands (now NBC Naturalis: Naturalis Biodiversity Center, Leiden, The Netherlands).

Horizontal pivot axis analysis. **Ral**: anterior laterals of the right valve. **Ral 1**: tooth close to the shell margin. **Ral 2**: small tooth or swelling at the base of the junction of Ral 1 and Ral 3. **Ral 3**: large posterior tooth. Horizontal dimensions. **AK**: anterior side of shell to umbo. **KL**: umbo to end of the nymph. **LB**: end of the nymph to posterior side of shell. Vertical dimensions: **BI**: top of shell to horizontal nymph line. **BD**: horizontal nymph to bottom line of the standard square. **DF**: part of shell outside the standard square. **SQ**: ratio of vertical dimension divided by width of square. **TT°** = inclination of anterior shell part.

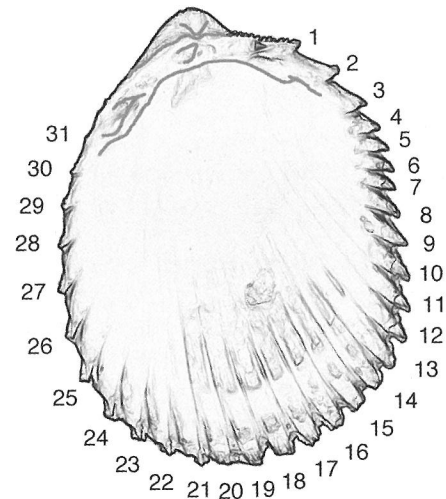


Fig. 1. *Vasticardium fidele* (Vidal, 1992). Numbering of dents, right valve, interior view.

SYSTEMATIC ACCOUNT

Vasticardium fidele (Vidal, 1992)
 Figs 1; 2A-N; 7D; 8D

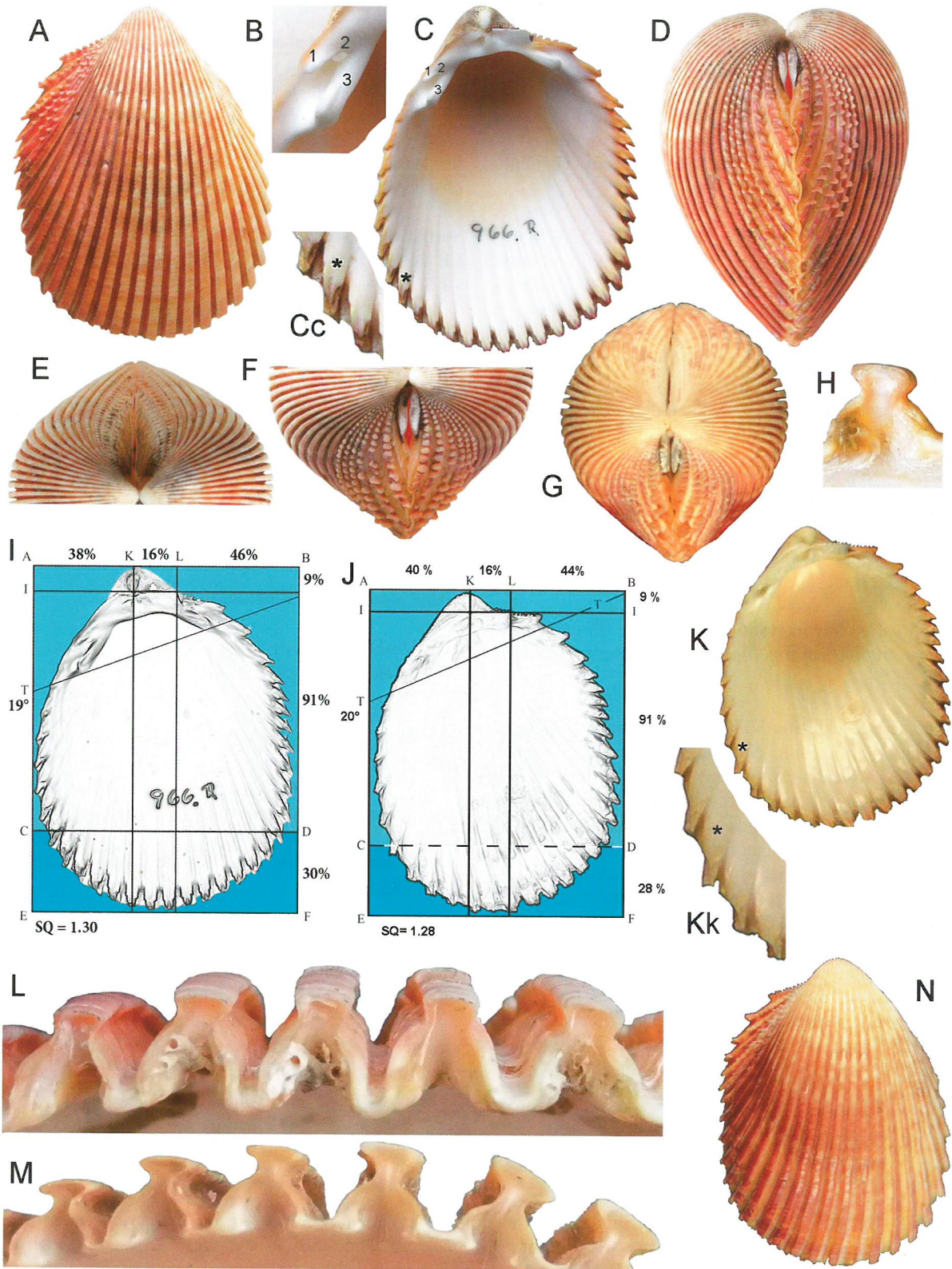
Acrosterigma fidele Vidal, 1992: 24, figs 1-5.

Holotype. MNHN IM-2000-3985 (Hylleberg, 2004 p. 861).

Type locality. Okinawa, Japan, but locality doubtful.

Figure 2. *Vasticardium fidele* (Vidal, 1992)

A. Exterior, right valve; **B.** Right anterior laterals enlarged; **C.** Interior, right valve, Ral 1-3 marked; **Cc.** dent 25 enlarged (star); **D.** Posterior slope; **E.** Apical view, anterior part; **F.** Apical view, posterior part; **G.** Holotype MNHN IM-2000-3985, apical view; **H.** Enlarged central rib, vertical view; **I & J.** Right valves in standardized squares (J holotype MNHN); **K.** Interior right valve; **Kk** dent 25 enlarged (star); **L.** Overhanging central ribs, vertical view; **N.** Exterior, right valve. - Figs. A, B, C, Cc, D, E, F, I: JH 966, Phuket, Thailand, 55.0 mm. Figs G, J, K, Kk: holotype MNHN IM-2000-3985, Okinawa but doubtful loc., 75.3 mm. Fig. L: JJTP 2184, topotype, Okinawa but doubtful loc., 83.0 mm. Figs H, M: JJTP 1048, Gulf of Thailand, 47.2 mm.



Other material examined. JJTP 722 Philippines [doubtful locality]. 41.5 mm - JJTP 2184 Japan, Okinawa Isl. [doubtful topotype of *V. fidele*], trawled offshore, 1 spcm., 83.0 mm - JJTP 1578 Thailand, Andaman Sea, Raya Isl. Dived at 25–30 m. 1 spcm., 49.5 mm - JJTP 2538 Thailand, Andaman Sea, 1 spcm., 41.5 mm - JJTP 2569 *idem*, 1 spcm., 79.1 mm - JJTP 1052 Thailand, Gulf of Thailand. 1 spcm., 57.7 mm - JJTP 1048 Thailand, Gulf of Thailand, Pattani, harbour, fishery in Indonesian waters. 2 spcms, 47.2; 41.9 mm - JJTP 3611 Thailand, Gulf of Thailand, Pattani. 1 spcm., 69.5 mm.

JH 966 Thailand, Andaman Sea, 1 spcm., 55.0 mm - JH 967 Thailand, *idem*, 1 spcm., 71.9 mm - JH 968 Thailand, *idem*, 1 spcm., 53.0 mm - JH 890 Thailand, *idem*, 1 spcm., 81.2 mm - JH 891 Thailand, *idem*, 1 spcm., 78.5 mm - JH 892 Thailand, *idem*, 1 spcm., 61.6 mm - JH 893 Thailand, Andaman Sea, 1 spcm., 72.7 mm - JH 2788 Thailand, Gulf of Thailand. 1 spcm., 58.7 mm - JH 2827 Thailand, *idem*, 1 spcm., 54.1 mm - JH 3001 Thailand, *idem*, 1 spcm., 41.1 mm - JH 3002 Thailand, *idem*, 1 spcm., 69.0 mm - JH 3003 Thailand, *idem*, 1 spcm., 70.0 mm - JH 3004 Thailand, *idem*, 1 spcm., 76.0 mm.

PMBC: 19461 Thailand, Andaman Sea. 3 valves. 45.5, 58.3, 82.3 mm.

Diagnostic characters. Outline of dent 25 created by the protruding rib together with the anterior rib flank (Fig. 2Cc).

Original description Vidal 1992 (extract). Length (L = height) 75.3 mm. Subovoid, rather inequilateral, with the posterior part flaring out but truncated. The truncation gives the shell a subrectangular outline and shortens the posterior end, which is slightly depressed, giving it the appearance of a "wing". A total of 31 ribs. Posterior ribs number 6-7, rather square-sided, with top zones bending onwards, large helical scales on their posterior side. Central ribs extremely high, flat smooth top, edges finely crenulated overhanging wide leaning sides. Rib profile in the lower shell part resembles an overturned stem glass (see Fig. 2 H). Interstices constitute the longest parts of the shell. The ventral edges of the two valves do not interlock entirely. Colour: pinkish yellow to orange.

My additions. Holotype colours are without periostracum. Interior view of right valve. SQ orientation (Fig. 2 J-K, Kk), dents in 5 segments starting on the posterior side of right shell (Fig. 1). Dents **1-3**: Cone-shaped with broad bases and tapering tips. **4-7**: uniform shape and gradually smaller bases. **8-18**: interribs 15-18 joined by equally strong anterior and posterior flanks of neighbouring ribs (Fig. 7D). **19-29**: Rib 25 has a characteristic rectangular outline created by the protruding rib together with the anterior rib flank (Fig. 2 Kk, L). **30-31**: gradually smaller, obscure on the shell edge in interior view.

Statistics. SQ analysis (Fig. 2J): AK 40% - KL 16% - LB 44% - BI 9% - BD 91% - DF 28% - SQ value 1.28 - TT 20°.

Remarks. Vidal (1992) questioned Japan as the type locality. In addition to the type material, there is one shell (topotype) in the JJTP coll. provided by a Japanese shell dealer. However, literature data with a Japanese origin are lacking. Japanese fishermen may have fished far away from Japan or shell dealers exchanged material. Based on the present morphological analysis of the *V. fidele* specimens, I suggest that the type material should come from the eastern Andaman Sea or the Gulf of Thailand.

Other material of *Vasticardium fidele*

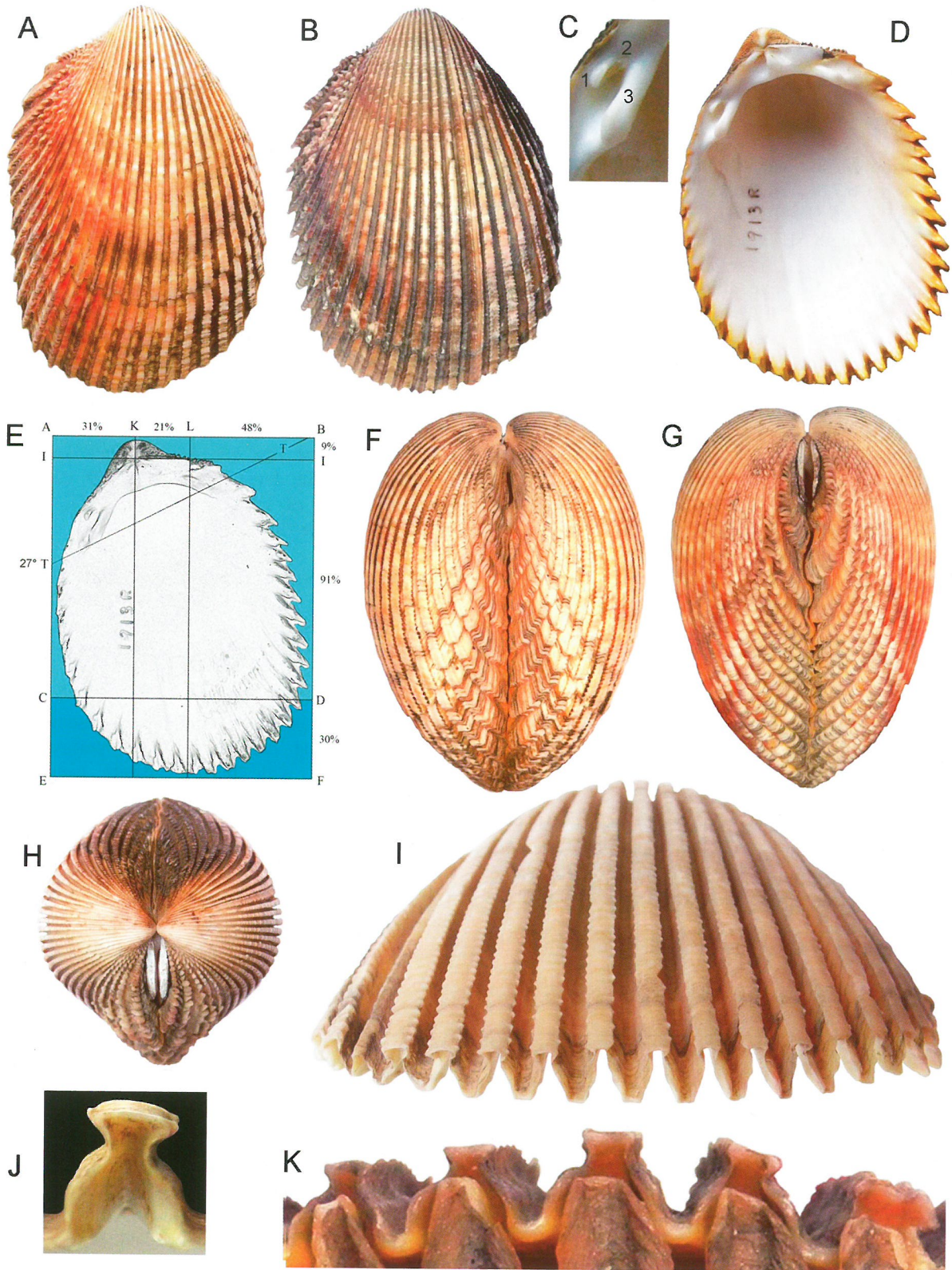
Distribution. Eastern Andaman Sea, Myanmar. Gulf of Thailand, Singapore.

Description. Colour with periostracum: Light brown with darker bands across surface. Posterior slope light rose when periostracum has peeled off (Fig. 2A, D). Inside yellow blotch under umbo. Colour without periostracum: Interstices of posterior slope pink-rose, posterior half of shell light brown with darker brown bands. Inside yellow blotch under umbo. Maximum length 83 mm.

Exterior: ribs **1-3**: broad interribs, large scales. **4-7**: narrow interribs, small scales. **8-18**: very small scales on rib 8. Rounded rib tops on 8-11, slightly rounded on 12-19, low crossbars, laterally as small knobs. **19-30**: rib tops slightly curved, crossbars larger. **31-32**: strong crossbars. Low, not overhanging ribs, diminutive rib 33 present.

Figure 3. *Vasticardium hyllebergi* Thach, 2014

A & B. Exterior of right valves; **C.** Right anterior laterals enlarged. Ral 1-3 marked; **D.** Right valve interior; **E.** Right valve in standardized square; **F, G.** Anterior and posterior slopes; **H.** Apical view; **I.** Lateral view, left valve; **J.** Vertical view of isolated rib; **K.** Vertical view of flat central ribs with strong, overhanging cross bars. - Figs A, F, G: JH 1911, Nha Trang, Vietnam, 93.3 mm, Figs B, C, D, E, H, I, J, K: JH 1913, Nha Trang, Vietnam, 80.9 mm.



Interior: Hinge: small Ral 2 (Fig. 2B). Dents **1-3**: cone-shaped with broad bases and tapering tips. **4-7**: uniform shape and gradually smaller bases. **8-18**: longer, point more downward. Dents 16-19, ribs of neighbouring anterior and posterior flanks are equally strong (Fig. 7). **19-30**: rib 25 with marked outline created by the protruding rib together with the anterior rib flank (Fig. 2). **31-32**: gradually smaller, obscure on the shell edge.

Statistics. Means and standard deviations (n = 29): AK 39.8 ± 6.7 % - KL 16.6 ± 3.1 % - BI 8.7 ± 1.1 % - DF 25.8 ± 3.6 % - TT $20.6^\circ \pm 4.6$ - total ribs 31.0 ± 1.3 - total length 61.7 ± 14.5 mm.

Remarks. PMBC expedition material collected at depths from 28 to 173 m comprises only juvenile specimens without periostracum. The 5th Thai-Danish Expedition to the Andaman Sea only caught 1 juv. from the Andaman Sea (Hylleberg, 2009: 304). One specimen has dents 10-11 chipped away on left and right valves respectively, creating a 4-5 mm hole (JH 967). Same appearance and position as holes in *V. terpoorteni*.

Vasticardium hyllebergi Thach, 2014
Figs 3A-K; 7G; 8E

Vasticardium hyllebergi Thach, 2014: 115, figs 1-9.

Holotype. PMBC n° 16310 (Thach, 2014: 115-116, figs 1 & 2, 84.0 mm).

Other material examined. JJTP 4077 Vietnam, Nha Trang, offshore, trawled by local person. 1 spcm., 94.1 mm.

JH 171 Vietnam, Nha Trang. 74.1 mm - JH 1911 Vietnam, Nha Trang. 93.3 mm - JH 1912, Vietnam, Nha Trang. 67.8 mm - JH 1913 Vietnam, Nha Trang. 80.9 mm - JH 2925 Vietnam, Nha Trang. 81.0 mm.

Type locality. Vietnam, Phan Thiet, depth 15 m.

Diagnostic characters. All ribs with flat surface. Very oblong shell form. Largest species, maximum length 97.0 mm. Lowest % AK and BI. Highest % DF (Fig. 8).

Description. Colour with periostracum: red-brown to light grey-brown with darker brown bands across shells. Faintly yellow on the inside below umbo. Colour without periostracum: posterior half orange with narrow, darker bands fading away on the anterior whitish-yellow half.

Exterior: Ribs **1-3**: cone-shaped with broad interspaces and rounded tips. **4-7**: interribs narrow, uniform shape. **8-18**: flat tops, distinct crossbars terminating with lateral knobs on both sides (Fig. 3J-K). **19-29**: posterior ribs: flat tops of ribs, few small lateral knobs. **30-32**: anterior ribs flat or gently curved surfaces of ribs, distinct crossbars (Fig. 3F, I).

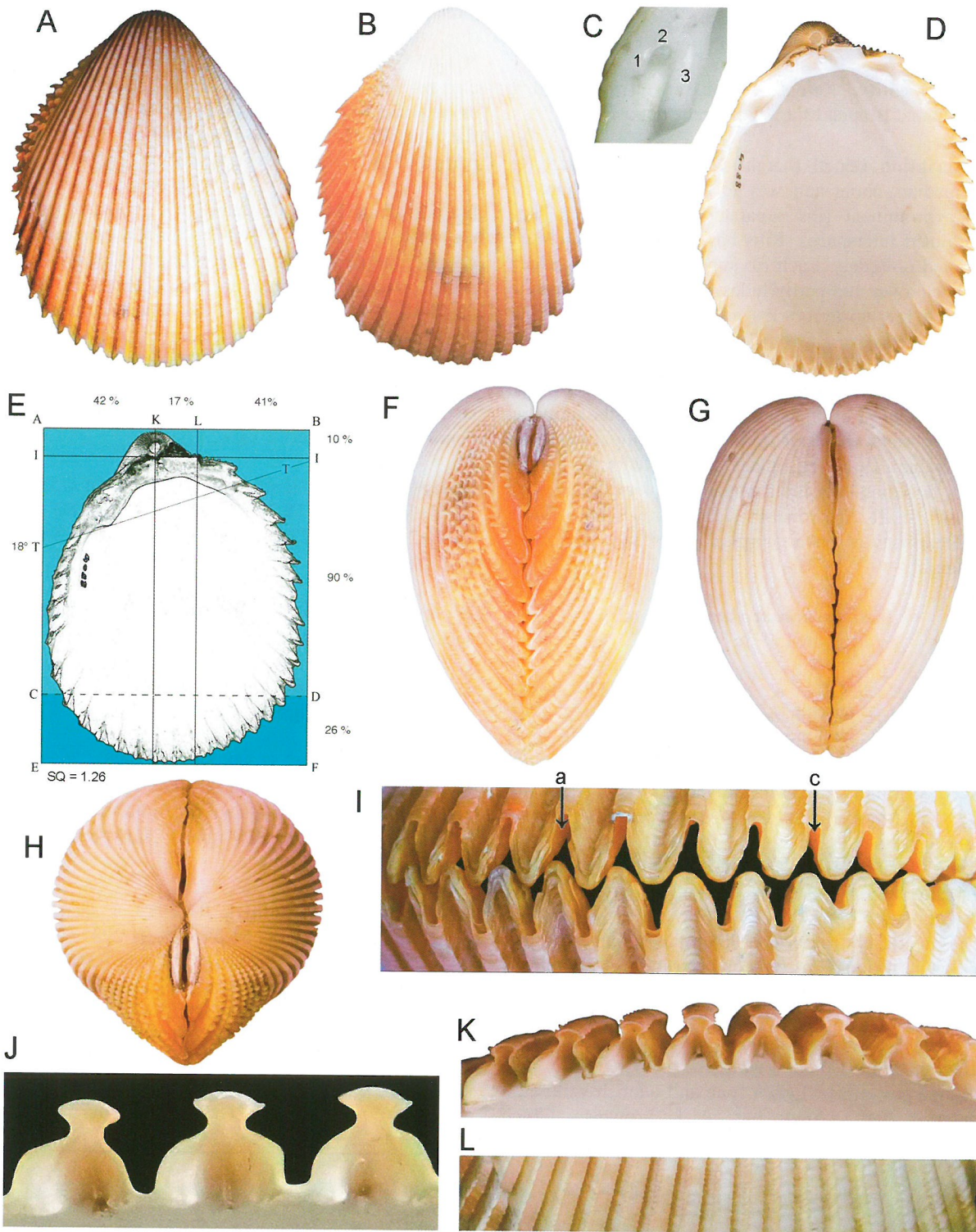
Interior: Dents **1-3**: cones with broad bases. **4-7**: smaller cones, tight together. **8-18**: dentation similar but left flanks of ribs are stronger and contribute significantly to the dents (Fig. 7G). **19-29**: dents 19-20: both flanks of same length (Fig. 7G). **30-32**: obscure in interior view.

Statistics. Means and standard deviations: SQ (n = 16): - AK 32.5 ± 5.0 % - KL 19.6 ± 2.2 % - BI 7.8 ± 1.2 % - DF 29.5 ± 3.9 % - TT° 23.3 ± 4.0 , - total ribs 32 ± 2.0 - total length (n=7) 78.9 ± 11.1 mm (Fig. 3 E; Fig. 7 G).

Remarks. The holotype is without periostracum. Four specimens in JH coll. have intact periostracum. Anterior slopes with black deposits caused by anaerobic conditions in the sediment. Such deposits highlight rib structure and growth stages (Fig. 3). Shell proportions are slightly size dependent. Values of AK % decrease with increasing size. Relative values of KL, LB, DF and °TT increase with increasing size.

Figure 4. *Vasticardium neokenyanum* n. sp.

A & B. Holotype and paratype, right valves; **C.** Right anterior laterals enlarged. Ral 1-3 marked; **D.** Right valve, interior; **E.** Right valve in standardized square; **F-G.** posterior and anterior slopes; **H.** apical view; **I.** interlocking dents, vertical view. Arrows point at rib flanks, a = anterior and c = posterior; **J.** vertical view of central ribs, curved surfaces, pointed edges created by crossbars; **K.** overhanging ribs with blunt or pointed edges created by crossbars; **L.** enlarged section of central rib surfaces. - Figs A, C, D, E, J, K, L: holotype PMBC 9115, Mozambique, 67.8 mm., Fig. H: 82.5 mm, JJTP 4521. Figs B, F, G, I: paratype JJTP 4521-2, Mozambique, 61.0 mm,



***Vasticardium kenyanum* (Cox, 1930)**

Fossil species.

Cardium (*Trachycardium*) *kenyanum* Cox, 1930: 159, pl. 15 figs. 13a-b.**Type material.** Cast of holotype ZMA 138643.**Type locality.** Kenya, Mombasa, railway cutting Schimanzi Branch Line, Pleistocene deposits.**Description.** Length (height) 65.7 mm. Umbo anterior to median, about half way to the ventral margin. 32 very prominent ribs separated by very deep flat-bottomed interspaces. Ribs have flat sides which are striated obliquely. Each rib supports a capping which projects over and partly hides the interspaces on each side. A few posterior ribs on the posterior side bear short spines (extract from Ter Poorten, 2005).**Remarks.** The description puts emphasis on position of the umbo. I have also used position of the umbo as an important character defining each population (the AK-value). However, I place the shell with the nymph in a horizontal position, a possibility excluded with most fossil impressions and preventing direct comparisons of shell morphology of live and fossil material.***Vasticardium neokenyanum* n. sp.**

Figs 4A-L; Fig.7 A; Fig. 8A.

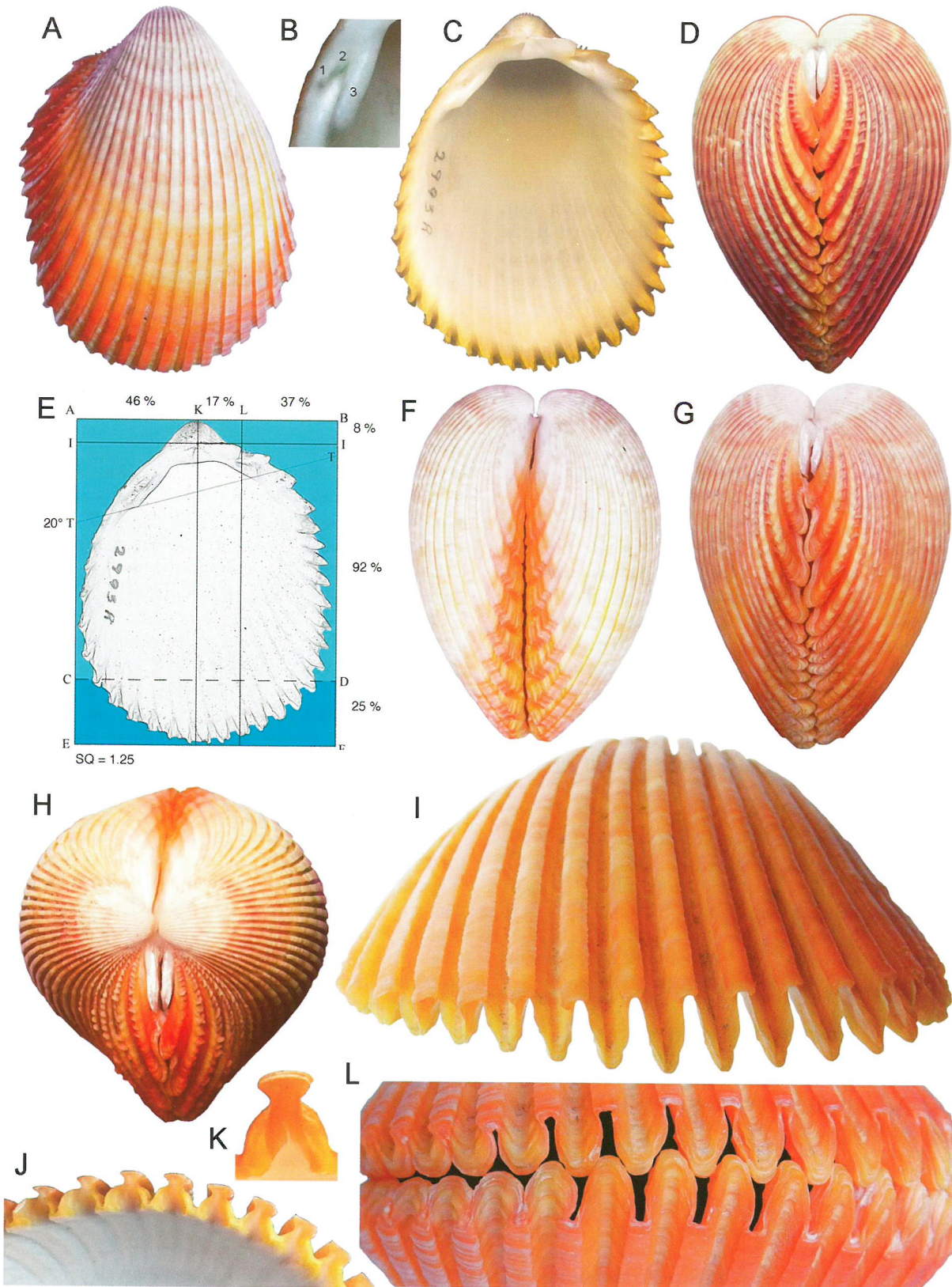
Holotype. PMBC n° 9115 (ex JJTP 4088), Mozambique, Inhambane district, Jangamo area, dived at 10–15 m, 67.9 mm - Paratypes 1-4: JJTP 4521 Mozambique, Nacala Bay, dived at 10–15 m, 2 spcms, 82.2; 81.8 mm - 4522 *idem*, dived at 8–10 m. 2 spcms, 61.8; 58.3 mm.**Type locality.** Mozambique, Inhambane district, Jangamo area,**Diagnostic characters.** Colours pale orange outside, all white inside. Crossbars on central ribs with pointed tips resembling pointed horns or small thorns of a rose in vertical view (Fig. 4J). Maximum size 82.5 mm.**Description.** Colour without periostracum: pale orange posteriorly, lighter tone and whitish yellow on anterior half. Large, but weak brownish blotch

stretches across the posterior shell and slope (Fig. 4B, F). Inside white.

Exterior: ribs straight in small specimen (Fig. 4A), curved in large specimen (Fig. 4B). Ribs **1-3**: scales increase in size from 1-3. **4-7**: similar size of scales (Fig. 4F). **8-18**: small vertical scales on posterior side of ribs 8-10. Pointed crossbars on ribs 11-18. **19-29**: crossbars terminate laterally in small knobs, stronger on posterior side of ribs. Posterior ribs with curved or flat tops. **30-32**: small, not overhanging. The anterior parts tend to be rounded in apical view (Fig. 4H).Interior: dents **1-3**: cone-shaped with broad bases and tapering tips (Fig. 4D). **4-7**: slender cone-shaped, pointed interribs and gaps between teeth with distinct posterior flanks and small anterior flanks of ribs (Fig. 4I). **8-18**: dent 8, ventral rib flank longer, conspicuous on dents 9-12, gradually decreasing in length from 13-15. Dents 16-18 with rib flanks of similar length (Fig. 7A, cf. Fig. 4I). **19-29**: dorsal rib flanks increase in size (Fig. 7A). Dents 27-28 rib flanks smaller. **30-32**: dents obscure in interior view.**Statistics.** Means and standard deviations (n = 5): AK 36.6 ±5.0 % - KL 18.2 ±2.3 % - BI 9.2 ±0.8% - DF 25.0 ±2.5% - TT° 22.2 ±2.4° - length 57.4 ±9.3 mm - total ribs 32.4 ±1.1**Etymology.** Neo = new, with reference to the fossil species *V. kenyanum****Vasticardium somnueki* n. sp.**

Figs 5A-L; 7C; 8C

Holotype. PMBC n° 16348 (ex JH 2993), 76.7 mm, Andaman Sea, off N. Sumatra - Paratype no. 1: in the JJTP Coll. (JH 2994) 1 spcm., 86.1 mm - Paratype no. 2: JH 2983. 1 spcm., 59.0 mm - Paratype no. 3: JH 2989. 1 spcm., 82.0 mm.**Other material examined.** JH 2982. 1 spcm., 64.5 mm - JH 2984. 1 spcm., 71.2 mm - JH 2985. 1 spcm., 77.3 mm - JH 2986. 1 spcm., 79.0 mm - JH 2987. 1 spcm., 83.3 mm - JH 2988. 1 spcm., 62.0 mm - JH 2990. 1 spcm., 78.3 mm - JH 2991. 1 spcm., 66.0 mm - JH 2992. 1 spcm., 77.2 mm - JH 2995. 1 spcm., 71.2 mm - JH 2996. 1 valve 66.3 mm - JH 2997. 1 valve 73.7 mm - JH 2998. 1 valve 71.6 mm - JH 2999. 1 valve 74.6 mm - JH 3000. 1 valve 77.8 mm.**Figure 5.** *Vasticardium somnueki* n. sp.**A.** exterior, right valve; **B.** Right anterior laterals enlarged. RAL 1-3 marked; **C.** Right valve interior; **D.** posterior slope; **E.** Right valve in standardized square; **F, G.** Anterior and posterior slopes; **H.** Apical view; **I.** Vertical view of long dents, left valve; **J.** Overhanging ribs with knobby edges created by weak crossbars; **J.** row of overhanging ribs, slightly curved surfaces, vertical view; **K.** Isolated rib, vertical view; **L.** interlocking dents, vertical view. - Figs B-E, H-K: holotype PMBC 16348, Andaman Sea off N Sumatra, 76.7 mm. Figs A, F-G, L: JH 2994, paratype 1, JJTP 4584 (ex JH 2994), 86.1 mm.



Type locality. All shells trawled on the shelf of the Andaman Sea, off N. Sumatra.

Diagnostic characters. Maximum length 76.7 mm. Minute crossbars with very small lateral knobs on both sides (Fig. 5J-K). Longest dents in the *fidele* group (Fig. 5I). Scales on ribs 4-7 become gradually smaller and oriented parallel with the posterior ribs (Fig. 5D, G).

Description. Colour: all specimens without periostracum. Dark red-orange on the posterior half, orange interspaces, increasingly yellowish-white on the anterior half (Fig. 5F). Darker red-violet bands across shell surface. Interior shell below umbo stained deep yellow with orange hue.

Exterior (Fig. 5A): ribs **1-3**: Distinct scales on ribs (Fig. 5H). **4-7**: scales increasingly smaller and turning parallel with the ribs (Fig. 5D). **8-18**: ribs slightly curved (Fig. 5A). Ribs appear smooth but carry very small lateral knobs on both sides (Fig. 5J, K). Top of ribs slightly rounded. **19-28**: increasingly flat tops of ribs. **29-30**: strong crossbars.

Interior (Fig. 5C, E): Ral 2 obscure or small (Fig. 5B). Dents **1-3**: strong, broad bases, and tapering tips. **4-7**: cone-shaped, pointed interribs. **8-18**: similar but the posterior (left) flanks of ribs are stronger and contribute significantly to dents (Fig. 7C). Dents 16-18: Left and right flanks of ribs about same strength on each side of the rib. **19-29** (Fig. 5C): right flanks increase in size compared to left flanks. Dents 24 & 25: ribs are distinct (Fig. 7C). Dents 26-29: small dents, gradually disappearing. **30-32**: small knobs on the shell edge.

Statistics. Means and standard deviations (n = 19): AK 36 ±5.3 % - KL 18.4 ±3.3 % - BI 9.4 ±1 % - DF 27.2 ±3.4 % - TT° 22.7, ±5° - total ribs 31.2 ±0.8 - total length 73.4, ±7.4 mm (Figs 5E; 8C).

Etymology. Named in honour of Mr Somnuek Patamakanthin, Rawai, Phuket Island, Thailand.

Vasticardium terpoorteni n. sp.
Fig 6A-K; 7B; 8B

Holotype. PMBC n° 16332 (ex JH 105), 69.5 mm, Bay of Bengal, SE India. **Paratype 1.** JJTP 1543.

India, Rameswaram, 1 spcm., 61.1 mm. - **Paratype 2.** JJTP 2537 India, Gulf of Mannar, Tuticorin, 1 spcm., 52.8 mm.

Other material examined. JJTP 825 India, Chennai, 2 valves. 44.8; 43 mm - JJTP 972 SE India, Cuddalore. 1 spcm 62.7 mm figured by ter Poorten (2005) - JJTP 1732 India, Chennai, 8 valves 54.1–49.1 mm. JH 106 India, Rameswaram 1 valve. 66.5 mm - JH 107 India, *idem*, 1 valve. 63.6 mm - JH 108 India, *idem*, 1 valve. 62.8 mm - JH 109 India, *idem*, 1 valve 47.6 mm - JH 110 India, *idem*, 1 spcm., 65.0 mm - JH 111 India, *idem*, 1 spcm., 50.6 mm.

Type locality. Bay of Bengal, SE India.

Diagnostic characters. Maximum length 69.5 mm. Smallest species in the *V. fidele* group. Highest average number of ribs of the 5 living species. Highest relative AK & BI values, lowest inclination TT° (Fig. 8B).

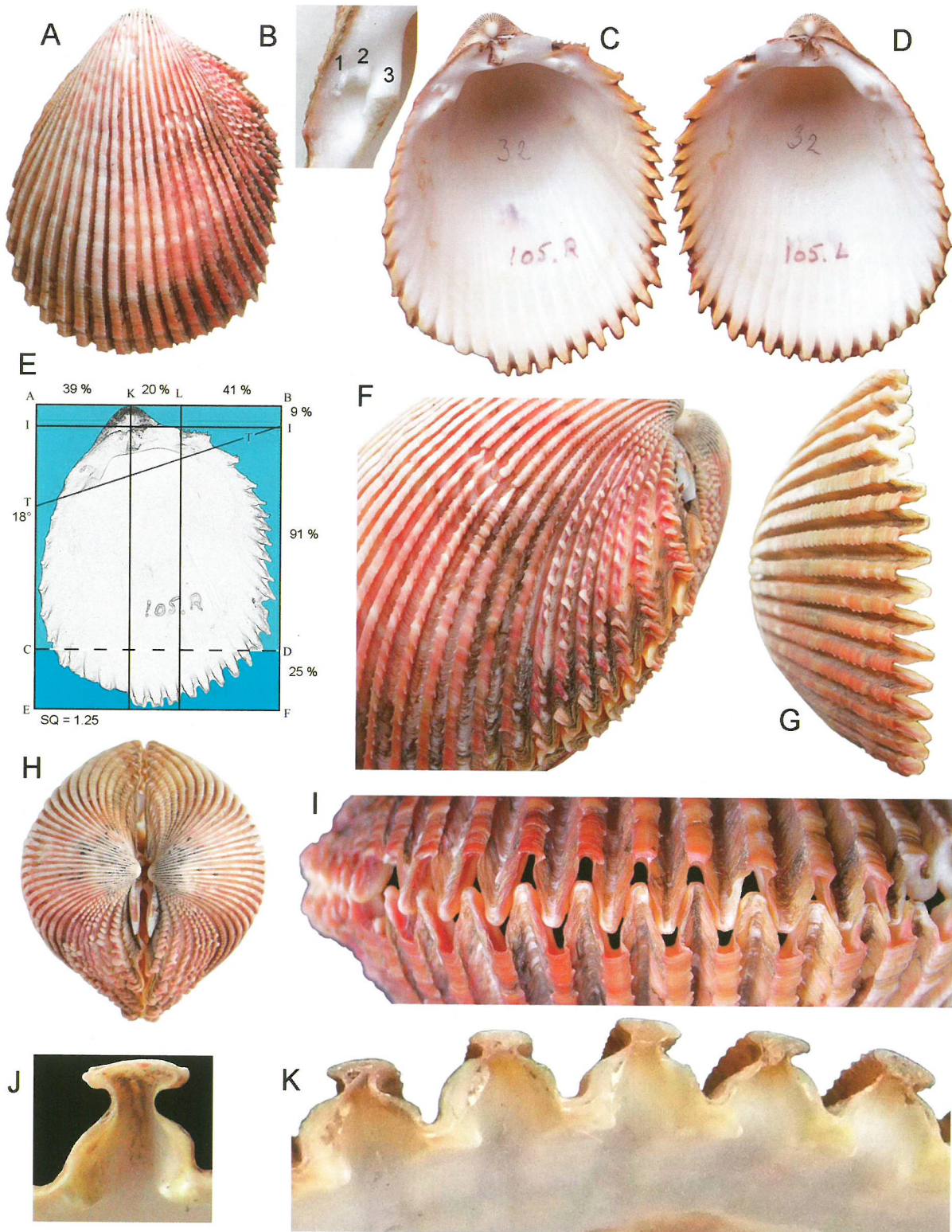
Description. Colour with periostracum: Ribs on posterior part pink-violet, anteriorly faintly coloured, light-brown periostracum, surface with darker blotches and bands. Colour without periostracum: Orange, more intensely coloured posteriorly. Interior shell below umbo stained yellow or orange-yellow.

Exterior: ribs **1-3**: posterior slope with large scales (Fig. 6F). **4-7**: smaller scales. **8-19**, small scales on posterior side of ribs 8-9. Rib tops flat, or slightly curved (Fig. 6J-K). Crossbars weak on surface, distinct knobs laterally. **20-30**: crossbars and lateral knobs increasingly stronger (Fig. 7J-K). **31-33**: not overhanging, strong crossbars (Fig. 6H). Central ribs slightly curved (Fig. 6A).

Interior: dents **1-3**: broad and strong. **4-7**: cone-shaped, pointed. **8-19**: slightly longer on 9-12. Similar dent size on 15-19, left & right rib flanks contribute to dent formation on left and right sides of each dent (Fig. 7B). **20-30**: left flanks reduced (Fig. 7B). Dents 26-30, anterior and posterior flanks contribute similar to dent formation, size of dents gradually decreasing. Interribs become wider and ribs protrude to a level short of tips of dents. Edges of ribs smooth. **31-33**: dents very small, disappearing from shell edge.

Figure 6. *Vasticardium terpoorteni* n. sp.

A. exterior, right valve; **B.** Right anterior laterals enlarged. RAL 1-3 marked; **C-D.** Right and left valve, interior. Four dents broken in the right valve; **E.** Right valve in standardized square; **F.** posterior slope, left valve; **G.** vertical view of dents; **H.** apical view; **I.** interlocking dents, vertical view; **J.** single rib, vertical view; **K.** overhanging ribs with knobby edges created by strong crossbars. - Figs A-K: holotype PMBC 16332, India, Bay of Bengal, 69.5 mm.



Statistics.

Means and standard deviations (n = 16): AK 41.6 ±4.5% - KL 17.8 ±3.3 % - BI 10.2 ±0.8 % - DF 24.8 ±4.4 % - TT° 19.2 ±3.9 - total ribs 33.1 ±0.9 - length 56.0 ±8.4 mm (Fig. 8B).

Remarks. Dents 9-10 are chipped away on left and right valves respectively (Fig. 6C-D) creating a 4-5 mm hole. Similar holes are present in 4 other specimens from India, but only one complete specimen from Thailand carry the same predator mark on the shell.

Etymology. The species is named after Jan Johan ter Poorten in appreciation of his many significant contributions to taxonomy of cardiids.

DISCUSSION

The Pleistocene period involved several glacial cycles and rapid sea level and temperature fluctuations. Huge areas of present day sea bottoms were exposed and open for colonization when the last glaciation finally terminated and sea water again filled the Gulf of Thailand about 10,000 years ago. During the glaciation, sea levels were up to 200 m lower than the present day situation and dry land barriers prevented exchange of genes between populations in the Pacific to the Indian Ocean. The marine life in the Gulf of Thailand is therefore rather recent.

Ter Poorten (2005) concluded that the fossil *Vasticardium kenyanum* (Cox, 1930) is identical with *Vasticardium fidele* (Vidal, 1992). *V. kenyanum* stems from the Pleistocene with an age spanning from 2.6 million to about 12 thousand years ago. The material of *V. kenyanum* is estimated to be late Pleistocene, i.e. about 125,000 years BC (ter Poorten pers. com.). *V. kenyanum* could be a senior synonym of *V. fidele*. However, many important morphological characters cannot be studied on a fossil imprint. Furthermore, it is unknown how *V. kenyanum* has reacted to the late Pleistocene period encompassing a glacial cycle with likely extinctions caused by rapid sea level- and temperature fluctuations. That is the reason why I named the specimens from Mozambique *V. neokenyanum*.

Land areas in the Malayan, Indonesian, southern New Guinea-northern Australian region increased during glacial periods. Springer & Williams (1990) proposed that loss of marine habitats and cooler seawater temperatures resulted in extinction of populations and contributed to the existence of widely distributed plate endemics. It is apparent from fish and mollusc examples.

The reproduction period and spreading potential of larvae is unknown for the species of *Vasticardium* described here. It remains speculative if they live isolated or are able to interact. The present material landed by fishermen suggests that the species occurs in more or less isolated patches preventing gene flow

over larger distances, but conditions may be difficult to predict. Macaranas *et al.*, 1992 found that large genetic differences occurred among the Great Barrier Reef, Fiji and Philippine populations of *Tridacna derasa* (Röding). This result contrasted strongly with low genetic distance reported previously for giant clam *T. maxima* over similar geographical scales. (Macaranas *et al.*, 1992). Significant genetic structuring was reported for crown-of-thorns starfish *Acanthaster planci* (L.) populations within Australia, with Eastern Australian and Western Australian populations forming different groups. (Benzie & Stoddart 1992).

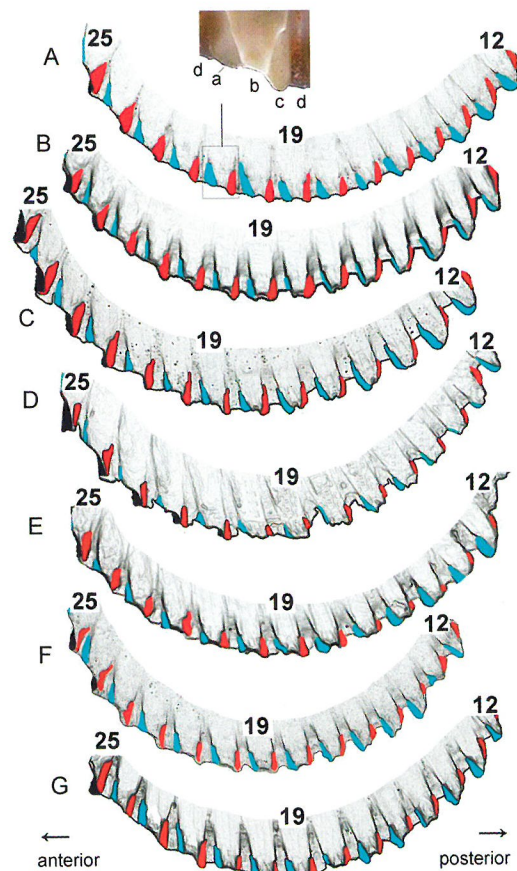


Figure 7. Ventral shell edge, interior view, horizontal pivot axis orientation. Dents #12, 19, 25 numbered A, C-F = right valves. B = left valve flipped horizontally to show all dents because the right valve is damaged (Fig. 6). Rib flanks coloured: Red: anterior flank. Blue: posterior flank. Black: protruding rib.

A. *Vasticardium neokenyanum* n. sp., Mozambique, Holotype PMBC, 67.8 mm. Inset: photo of dent 21 : a = posterior flank, b = interspace, c = anterior flank, d = rib; **B.** *V. terpoorteni* n. sp., JH 105 holotype PMBC, India, Bay of Bengal, 69.5 mm; **C.** *V. somnueki* n. sp., holotype PMBC, Andaman Sea off N Sumatra, 76.7 mm; **D.** *V. fidele*, holotype MNHN, Okinawa, but doubtful loc., 75.3 mm; **E.** *V. fidele*, juvenile, JH 2835, Gulf of Thailand, 36.9 mm; **F.** *V. fidele*, JH 2788, Gulf of Thailand, 58.7 mm; **G.** *V. hyllebergi*, JH 1912, 67.8 mm.

In addition to the unknown dispersal potential we have to consider the past and present physical barriers created by the big rivers in India, Myanmar and

Thailand. River runoff from the landmasses creates a barrier for stenohaline species by creating turbid, hyposaline conditions.

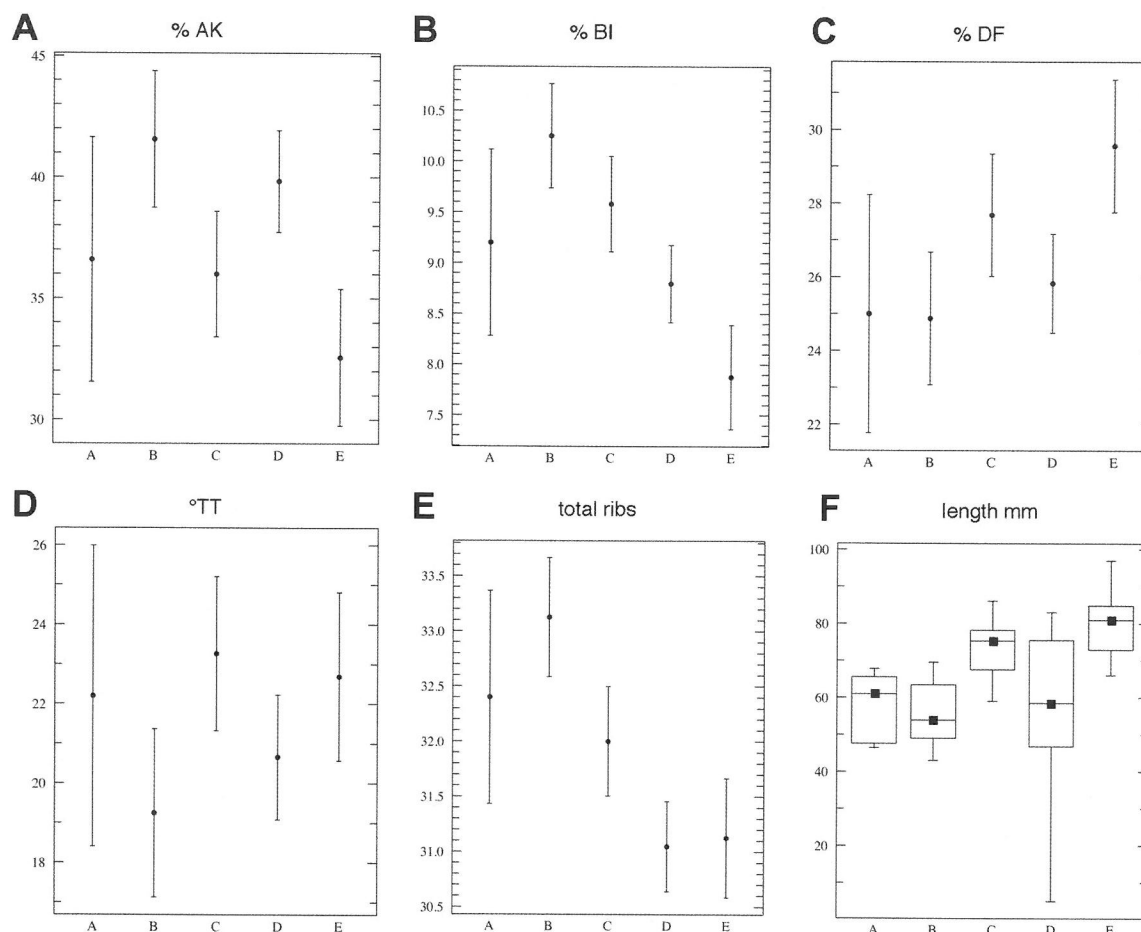


Figure 8. ANOVA analysis. X-coordinate

A. *Vasticardium neokenyanum* n. sp., Mozambique (n=5); **B.** *V. terpoorteni* n. sp., India (n=16); **C.** *V. somnueki* n. sp., off Sumatra (n=19); **D.** *V. fidele* (Vidal, 1992), Thailand (n=29); **E.** *V. hyllebergi* Thach, 2014, Vietnam (n=16). Y-coordinate: means and standard deviations.

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