

Taxonomic revision of the Indo-Pacific *Vasticardium assimile* species group (Mollusca, Cardiidae)

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SUMMARY. Several forms of Indo-Pacific *Vasticardium* of medium size, are here grouped as the *Vasticardium assimile* species group. Three of these forms, mainly from the Indian Ocean and previously described as three different species, *V. assimile*, *V. lacunosum* and *V. rubicundum*, share many characters and have often been confused. They are considered here to represent only two species, *V. assimile* and *V. rubicundum*, while *V. assimile lacunosum* is treated as a subspecies restricted to the Persian Gulf. *V. assimile* is restricted to the western Indian Ocean, southernmost Red Sea and Persian Gulf, whereas *V. rubicundum*, although more abundant in the southeastern Indian Ocean, extends also into a large part of the western Pacific, where it has been described as *mindanense*, *compunctum*, and *kengaluorum*. Two rare additional species, *Vasticardium rhegminum*, from the Masirah area (Oman), and *Vasticardium thomassini* sp. nov., from southeastern Africa and Madagascar, are treated.

MATERIAL, METHODS AND TEXT CONVENTIONS

The material comes from the following museums:

AMS: Australian Museum, Sydney.

ANSP: Academy of Natural Sciences, Philadelphia.

BMNH: The National History Museum, London.

IRSNB: Institut Royal des Sciences Naturelles de Belgique, Brussels.

LACM: Los Angeles County Museum of Natural History, Los Angeles.

MHNG: Museum d'Histoire Naturelle de Genève, Geneva.

MNHN: Museum National d'Histoire Naturelle, Paris.

NHMW: Naturhistorisches Museum, Vienna.

NMW: National Museum of Wales, Cardiff.

RMNH: Nationaal Natuurhistorisch Museum, Leiden.

USNM: National Museum of Natural History, Washington.

ZMA: Zoologisch Museum, Amsterdam.

ZMUC: Zoologisk Museum, Copenhagen.

In the description of the shells, particular attention was devoted to the rib morphology (structure and ornamentation of the ribs), this in an ontogenic perspective, by taking into account these elements in the earliest parts of the shell and their variations towards the adult parts, in the various "quarters".

For examination purposes, the shells are divided externally into four radial "quarters": **AQ**: Anterior Quarter; **MAQ**: Medio-Anterior Quarter; **MPQ**: Medio-Posterior Quarter; **PQ**: Posterior Quarter. Longitudinally, shells are divided schematically into two parts, a "juvenile" (or umbonal) part and an "adult"

(or marginal) part. In the description of the hinges, angle **A** is the angle formed by the two lines joining the tip of the main cardinal tooth to the tips of the laterals respectively. Ratio **D** is determined by dividing the length of the line from the tip of the umbo to the tip of the posterior lateral by the corresponding distance from the umbo to the tip of the anterior lateral.

SYSTEMATICS

Family **CARDIIDAE** Lamarck, 1809

Genus *Vasticardium* Iredale, 1927.

Type species: *Cardium elongatum* Bruguière, 1789, by original designation, Iredale 1927: 75.

Diagnosis. Shells medium to large, generally elongated and variably inflated. Shape ovoid and symmetrical or posteriorly expanded, obliquely or not, "winged" or truncated. Mean rib number ranges from 30-40, exceptionally 45. Hinge line moderately angled (Angle A circa 130°). Cardinal teeth in right valve separated or merely touching at their base and never connected by a high and narrow dorsal saddle.

In juvenile median and anterior parts, ribs quickly become high, square-sided and fully ornamented, directly following millimetric smooth, very primitive shell. In PQ, ribs always high and square-sided, always simple, not longitudinally divided into two parts; top scales or nodules always arranged in a single row along apex. In other quarters of adult shells, ribs generally high, often squared and overhanging interstices, rarely

triangular; in MPQ they often bear scales or tubercles with crenulated margins, cross-bars in the anterior half. Interstices moderately deep and wide, with a smooth or finely striated flat bottom, independent from flanks of ribs.

Remark. In previous papers (VIDAL, 1992, 1993), I provisionally used *Acrosterigma* Dall, 1900, for species belonging to the same genus as the one described here. I currently consider the genus *Vasticardium*, as defined above, to be more appropriate.

DIAGNOSIS OF THE *VASTICARDIUM ASSIMILE* SPECIES GROUP

Species of the group, all of medium size, share several similar macroscopic characters such as shape, hinge structure, rib number, and above all color. In addition, the young shells (up to one or two cm in height or slightly more) are somewhat similar as far as rib sculpture is concerned: in PQ, rather low, asymmetrical ribs bearing top oblique scales, with a sharp anterior margin overhanging interstices (Fig. 8) and, in other parts of shell, high ribs with a roundly triangular top zone crenulated on margins which often overhang smooth and flat-bottomed interstices (Figs 6-7).

Another significant similarity is that the carbonates which form the shell seem to have a characteristic thin microscopic structure which makes the shell fragile, and easily faded, worn or notched, and gives it lustreless colorations. In addition, ribs are constituted of several carbonaceous laminae, longitudinally juxtaposed, some of them with pink coloration visible when ribs are worn.

Vasticardium assimile (Reeve, 1844)

Figs 1-11, 25-26.

Cardium assimile Reeve, 1844, Sp. 45, pl. 9, fig. 45.

Cardium lacunosum Reeve, 1845, Sp. 81, pl. 16, fig. 81.

Selected references.

- Cardium assimile*: Römer, 1869, pl. 11, fig. 11.
Cardium assimile: Braga, 1952: 49, pl. 10, fig. 2.
Laevicardium (Trachycardium) rubicundum:
 Fischer-Piette, 1977: 65 [Partly].
Trachycardium lacunosum: Bosch, 1982: 172.

Trachycardium lacunosum: Smythe, 1982: 100, pl. 18, fig. c.

Trachycardium elongatum: Drivas & Jay, 1988: 140, pl. 55, fig. 1.

Trachycardium lacunosum: Oliver, 1992: 126, pl. 23, fig. 8a-b.

Acrosterigma assimile: Oliver, 1995: 246, fig. 1091.

NOT *Trachycardium lacunosum*: Keen, 1945: 36 [= probably *rubicundum*].

Type material.

Cardium assimile: Three syntypes in BMNH Reg. N° 1978-129, from Zanzibar. The largest is figured here (Figs 1-3). Another specimen corresponds exactly to the dimensions of Reeve's figure (H= 56.0, L= 42.7 mm), but looks different because the illustration is of poor quality.

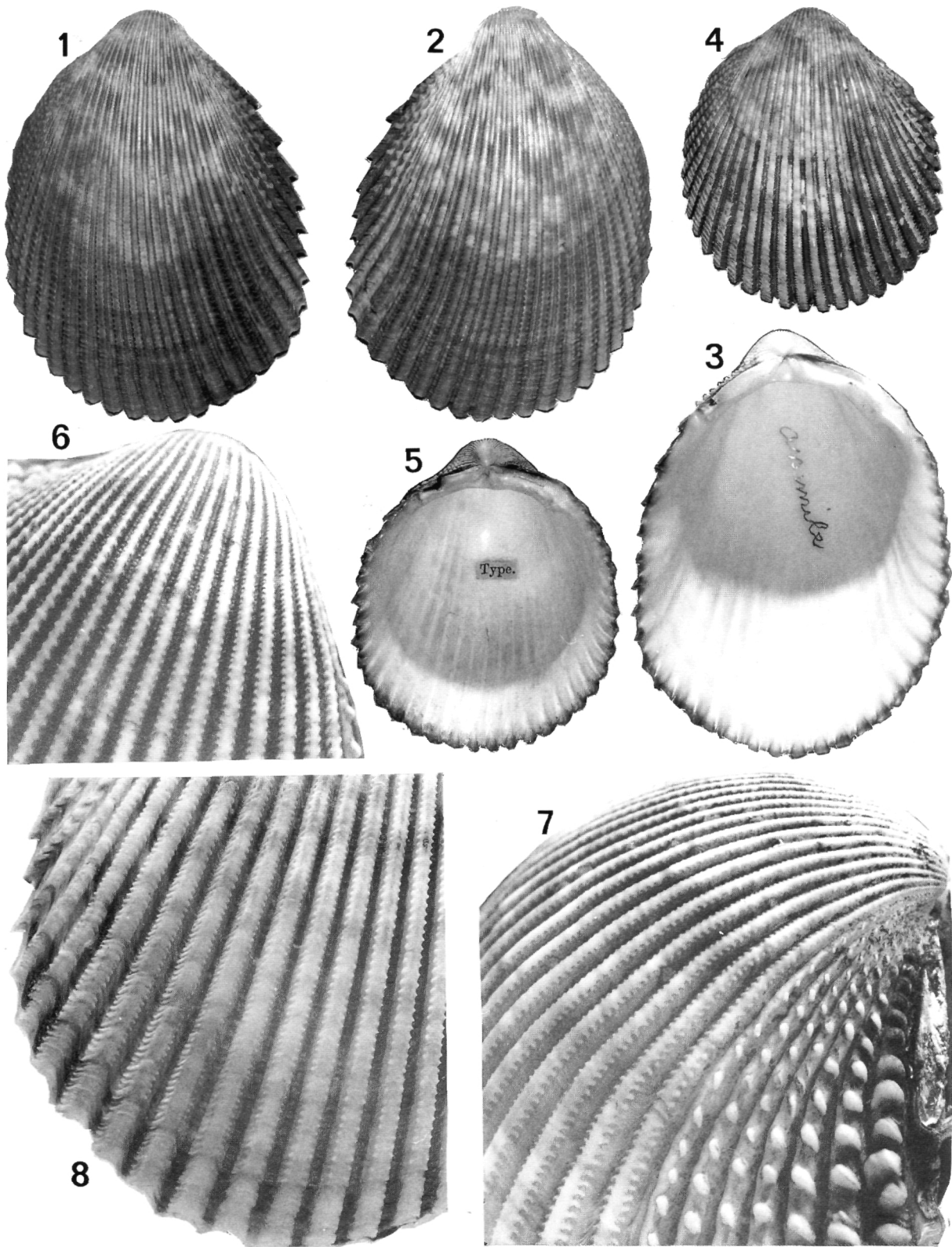
Cardium lacunosum: One shell considered as holotype in BMNH Reg. N° 1978-133 locality unknown (Figs 4-5). The right valve fits the figured one as far as dimensions and rib number are concerned, but several other characters do not match Reeve's figure and description. For example, ribs are curved backwards in projection with thin numerous marginal crenulations (at least 40: see definition p. 11-2) in the supposed "holotype", as opposed to perfectly straight ribs with strong rarer crenulations (barely 20 in number) in Reeve's specimen. For these reasons I think that the shell in the BMNH, which is a "common" form of *V. assimile*, is not the shell described and figured by Reeve as *lacunosum* [which means "hollowed", an allusion to the strong marginal crenulations of the ribs; Reeves writes "laterally hollowed"], and a neotype will be selected for these special forms from the Persian Gulf considered as a subspecies: *V. assimile lacunosum* (see below).

Description.

Shells medium to large. Shape regularly subovoid, almost equilateral but somewhat posteriorly truncated, with ribs sometimes slightly curved backwards in projection. Generally elongated in the adult stage (mean L/H= 0.77; range 0.71-0.92), and relatively tumid (mean W/L= 0.87; range 0.79-1.02).

Lunule narrow but well marked, and purple in color. *V. assimile* is always externally colored with stripes and/or splashes of vivid but lusterless brown or purple, more rarely orange or pink; interior white, sometimes with a double colored ray in umbonal area, and purple margin.

Figs 1-3. *Vasticardium assimile*, Syntype, BMNH 1978-129, L= 47.0 mm. **Figs 4-5.** *Vasticardium assimile*, specimen erroneously considered as holotype of *Cardium lacunosum* Reeve, BMNH 1978-133, L= 40.5 mm. **Figs 6-7.** *Vasticardium assimile*, specimen from Magaruque Is, Mozambique, MNHN. Fig. 6: left valve; detail of juvenile median part of shell; scale x 5. Fig. 7: right valve; detail of juvenile PQ and MPQ; scale x 5. **Fig. 8.** *Vasticardium assimile*, right valve, specimen from Zanzibar, MNHN; detail of juvenile MPQ and MAQ, particularly thin and numerous marginal crenulations on the ribs (50 per two cm); scale x 2.5.



Hinge moderately arched (mean $\angle A = 130^\circ$, range 120-135°) and rather asymmetrical (mean ratio $D = 1.20$, range 1.00-1.45). Posterior cardinal tooth in left valve long (2/3 of the width of the hinge area) and high (almost as high as main cardinal), relatively narrow and often with an acute summit. Foundation of anterior lateral (mainly in left valve, tooth PII) very moderately "hook-shaped". A medial short weak rib (umbonal support) present in umbonal cavity of many shells.

Mean rib number 33.4 (range 31-37).

Rib morphology:

In juvenile PQ (Fig. 8) ribs rather low and asymmetrical, with anterior edge overhanging interstice, with a sharp continuous margin jutting in front of scales. Rib tops set with large, more or less tubercular, slightly twisted oblique scales; no secondary small scales occur on edges of ribs as in some other species groups of *Vasticardium*; interstices as wide as ribs. In adult PQ, scales on rib tops can become more or less rounded tubercles, often irregular in shape and degenerate.

The juvenile median part of shell (Fig. 6) bears high ribs, of trapezoidal section with wide sloping flanks and a slightly rounded smooth top zone, bordered on both sides by crenulations which overhang the flanks; tops sometimes regularly swollen by extension of marginal crenulations. Interstices also trapezoidal in section, and almost as large as ribs; their bottoms are flat and clearly separated from flanks of ribs by a break line. This bottom often transversely very finely notched and flanks sometimes distinctly grooved, mainly posteriorly. In adults, a significant change from the juvenile sculpture occurs in MPQ (Fig. 25): the last ribs of this quarter (close to PQ) become very asymmetrical with anterior flank shorter and more abrupt; on anterior margins of ribs, the crenulated projecting edge does not change, but on the wider posterior side, marginal crenulations progressively join the flank ridgelets which become stronger, and overhanging disappears. Posterior parts of ribs form a wide dipping flank, entirely strongly ridged, ridges and furrows becoming more and more irregular with age; this evolution (illustrated in Fig. 25) is very characteristic of *Vasticardium assimile* and examining it always allows to separate this species. The reduced rib tops remain smooth or become regularly ridged in the most adult part, rarely with a herringbone structure. In anterior part of adult MPQ and MAQ, ribs remain crenulated on both overhanging margins.

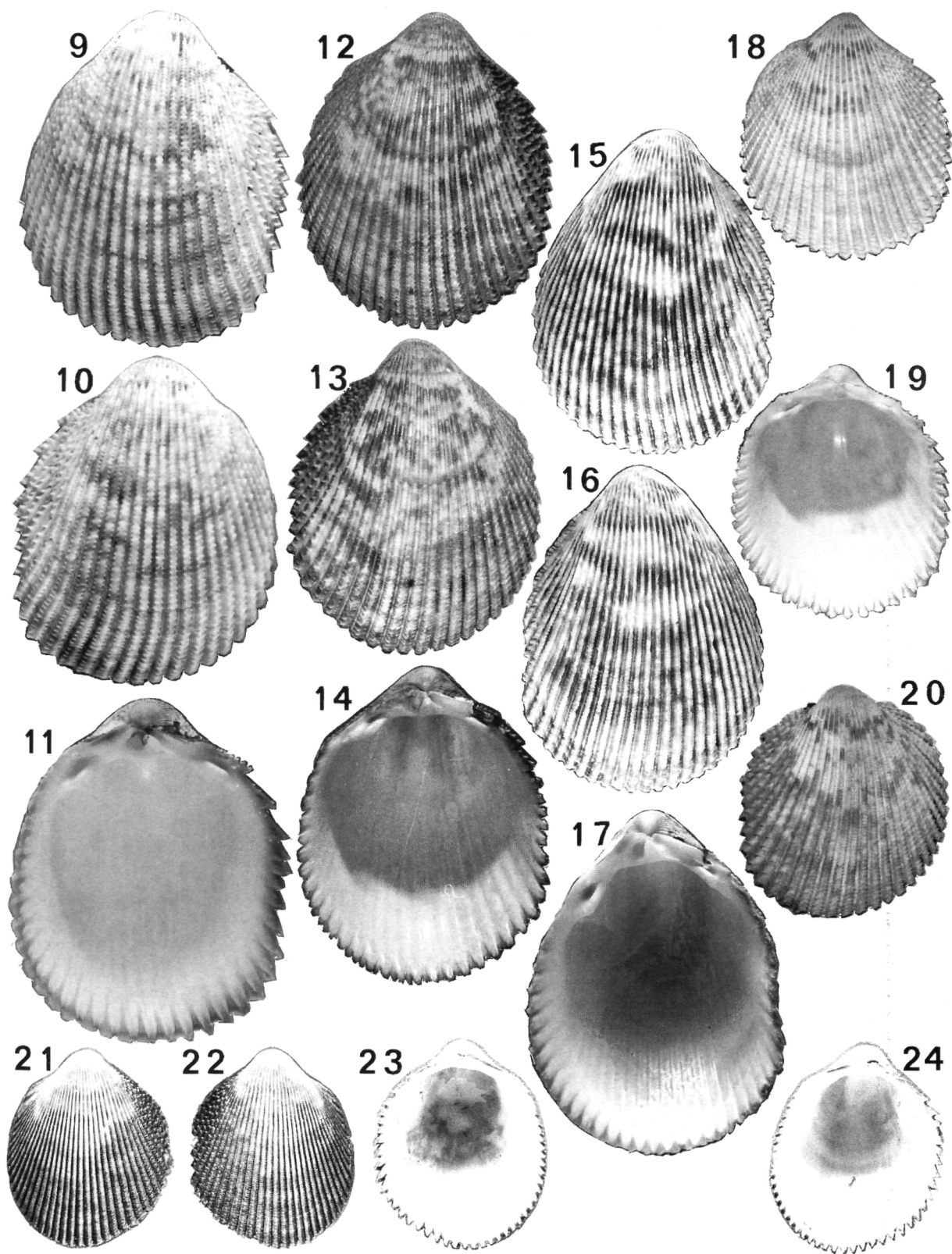
In juvenile AQ, ribs more square-sided, and slightly asymmetrical, with transverse ridges on their top (Fig. 6); interstices rounded, without any discontinuity with rib flanks, both being slightly striated by fine growth lines. In adult AQ, tops of ribs become flat and depressed anteriorly and are ornamented with slightly curved, strong imbricated cross-bars.

Material examined.

The following lots in addition to the type material:

- A) South Africa: East London: 1(MNHN); Port Shepstone: 1(MNHN), 1(ANSP)
 B) Mozambique: Magaruque Island: 1(MNHN); Santa Carolina Island: 2(MNHN); no specific location: 1(MNHN)
 C) Madagascar: Tulear: 2(MNHN); no specific location: 1(MNHN), 1(BMNH)
 D) TANZANIA: Zanzibar: 5(MNHN), 2(BMNH), 1(ANSP), 1(USNM), 1(LACM); M'Boa Maji: 1(USNM)
 E) Kenya: Shimoni: 1(BMNH); no specific location: 1(MNHN)
 F) Somalia: Eil: 1(MNHN); Beidi: 1(MNHN); Mogadishu: 1(MNHN), 1(ANSP); S. Cape Guardafui: 1(MNHN); Bender Kassim: 1(MNHN); W. Elayu: 1(MNHN); E. Sugra: 1(MNHN); Mait: 1(MNHN); Candara: 1(ANSP)
 G) Aden: 1(MNHN); 1(BMNH)
 H) Djibouti: 2(MNHN)
 I) Yemen: Abd el Kuri Island: 1(MNHN); Socotra Island: 1(MNHN); Mocha: 1(MNHN); Hodeida: 2(MNHN), 2(USNM); N. Hodeida: 1(MNHN)
 J) Oman: Masirah: 1(MNHN); Musqat: 1(MNHN); 1(BMNH)
 K) Persian Gulf: Bender Abbas: 1(MNHN); Khassab: 1(BMNH); Trucial Coast: 2(BMNH); Lavan Is: 1(MNHN); Al Hamra: 1(MNHN); Doha: 1(MNHN); Dammam: 1(USNM); Ras Tannurah: 2(ANSP), 1(USNM); Kuwait, Al Fintas: 1(MNHN); Kuwait: 1(USNM); not localized: Tarut Bay: 1(ANSP), 1(USNM); Chaschuse Is 1(USNM); no specific location: 1(BMNH); 1(LACM)
 L) Pakistan: Karachi: 1(BMNH), 1(USNM)
 M) India: Tuticorin: 1(MNHN); Gulf of Manaar: 2(ANSP), 1(BMNH)
 N) Sri Lanka, Trincomalee: 1 (BMNH); no specific location: 2(BMNH); 2(USNM); 1(LACM)
 O) No locality: 3(MNHN).

Figs 9-11. *Vasticardium assimile* lacunosum, Neotype, MNHN, ex coll. Vidal, L= 46.0 mm. **Figs 12-14.** *Vasticardium rubicundum*, Syntype, BMNH ex coll. Cuming, L= 49.0 mm. **Figs 15-17.** *Vasticardium rhegminum*, bivalved specimen, MNHN ex coll. Sue Hobbs, L= 39.4 mm. **Figs 18-19.** *Vasticardium rubicundum*, Lectotype of *Cardium mindanense*, BMNH 1070-124, L= 34.7 mm. **Fig. 20.** *Vasticardium rubicundum*, Paralectotype of *Cardium mindanense*, BMNH 1070-124, L= 34.0 mm. **Figs 21-24.** *Vasticardium thomassini*, Holotype, MNHN ex coll. Thomassin, L= 27.7 mm.



Measurements of *V. assimile* ss, excluding Persian Gulf forms.

	Height	Length	Width	L/H	W/L	ratio D	angle A	Ribs
	(mm)	(mm)	(mm)				°	
Syntype	63.3	47.0	40.0	0.74	0.85	1.15	120	33
Syntype	56.0	42.7	35.3	0.76	0.83	1.20	120	34
Mozambique	53.7	40.0	34.4	0.74	0.86	1.27	125	35
Madagascar	57.0	47.0	41.3	0.82	0.88	1.05	130	34
Zanzibar	59.4	44.3	37.2	0.75	0.84	1.15	120	34
Kenya	47.4	35.5	30.6	0.75	0.86	1.25	125	34
Socotra Is.	53.2	40.6	34.0	0.77	0.84	1.14	125	34
N Somalia	42.1	30.2	28.2	0.72	0.93	1.17	125	36
Aden	44.0	35.8	29.3	0.81	0.82	1.31	125	33
Djibouti	39.0	31.0	24.6	0.79	0.79	1.15	130	32
N Yemen	48.9	34.5	32.1	0.71	0.93	1.26	120	32
Masirah Is	55.8	43.8	36.4	0.78	0.83	1.09	125	32
S India	44.9	36.5	31.2	0.81	0.85	1.60	135	33

The maximum size observed in the "nominal" form is a right valve from Madagascar, in MNHN (H= 68.8 mm, L= 49.0 mm).

Distribution.

Because of the possible confusion with *V. rubicundum*, it is impossible to accept literature records uncritically. From material examined, I have ascertained the following distribution: east coast of Africa from East London (Natal) to the Gulf of Aden, Madagascar, Seychelles, southernmost part of the Red Sea (Yemen), Oman (Masirah, Muscat), Persian Gulf (from Strait of Hormuz as far as Kuwait), Pakistan (Karachi), south India (Gulf of Mannar), and Sri Lanka.

It is also present in Réunion and Mauritius (DRIVAS & JAY, 1988, pl. 55, fig. 1, under the name *elongatum*). The only record in the literature of *V. assimile* outside these areas is from Java (ALTENA, 1945: 150). There are records of *V. lacunosum* from Torres Strait (MELVILL & STANDEN, 1899: 190) and New Guinea (KEEN, 1945: 36). I consider all these records to probably refer to *V. rubicundum* which has a western Pacific extension.

Remarks.

Differences from *V. rubicundum*: *V. assimile* is very close to *V. rubicundum*, mainly in the juvenile shells. For differences see under *V. rubicundum*.

Variability of *V. assimile*: This species has many constant characters always allowing one to separate it from the others, both within the present group and outside it [It is, particularly, easily separable from *Acrosterigma magnum* (Linné), although it is considered by Reeve "quite similar" (= *assimile*) to this species]. Nevertheless some characters can vary according to populations and/or individuals. The most significant of these variations are:

1- Elongation in adult specimens (L/H range 0.71-

0.92).

2- Size and number of the marginal crenulations of the ribs: These are very variable mainly in the median part of the shell, from very small and reduced to thin scales [in which case the ribs in the median part remain roughly triangular and the interstices opened and wide (Figs 8, 25)], to as wide as about half the width of the rib [in which cases the crenulations overhang the flanks of the ribs which are nearly "vertical", and the interstices are reduced in width (Fig. 26)]. Apparently in relation to the size, the number of the crenulations is also variable: in the middle of the shell, in a band between 3 and 5 cm from the tip of the umbo (curved distance), this number varies from 21 to 52.

3- Regular swelling or ridging of the tops of the ribs in the median part of the shell: In the anterior part of the shell, the rib tops always bear cross bars joining the lateral crenulations; this phenomenon gradually disappears backwards and, in the medial part of the shell, the tops can either still be swollen or become flat and smooth. This character varies also with the age of the shell, and the swelling of the tops is variable according to individuals, the young shells developing it relatively late.

4- Shape and size of the top ornaments of the ribs in PQ: These ornaments can vary in the same individual, and also become locally irregular and degenerate; they vary from nodular or elongated tubercles to thin, variably twisted, oblique lamellar scales.

These variations generally occur at random and separately according to populations and/or individuals. However a geographical group with constant simultaneous variations is present in the Persian Gulf, and is here defined as a subspecies: *V. assimile lacunosum*.

Vasticardium assimile lacunosum

(Reeve, 1845)

Figs 9-11, 26.

Cardium lacunosum Reeve, 1845, Sp. 81, pl. 16, fig. 81.*Acrosterigma lacunosa*: Oliver, 1995: 246, fig. 1090.**Type material.**

As seen above, the specimen BMNH 1978-133 is closer to the nominal subspecies of *V. assimile* and is certainly not the holotype of *C. lacunosum* figured and described by Reeve. Considering that this latter shell is not traced, a neotype of *Cardium lacunosum* is selected here (Figs 9-11), a shell from Al Fintas, Kuwait, in MNHN, measuring 57.7 x 46.0 x 41.3 mm, with 33 ribs. Ratio D= 1.27, < A= 130°; number of crenulations 27.

Description.

Shells medium to large. Shape regularly subovoid, almost equilateral but somewhat posteriorly truncated, with ribs sometimes slightly curved backwards in projection. Generally moderately elongated in adult stage (mean L/H= 0.81; range 0.73-0.89), and relatively tumid (mean W/L= 0.90; range 0.84-1.02).

Lunule, colour, hinge, rib number in agreement with general description of species. No umbonal support observed.

Rib morphology:

In PQ, thin, lamellar, homogeneous and regularly set oblique scales on top of ribs (Fig. 26).

In median and anterior parts, few and strong marginal crenulations of ribs, and lack of smoothness of ribs tops.

Material examined and distribution.

Persian gulf (see above).

Measurements of *V. assimile lacunosum*

	Height	Length	Width	L/H	W/L	ratio D	angle A	Ribs
	(mm)	(mm)	(mm)				°	
Neotype	57.7	46.0	41.3	0.80	0.90	1.27	130	33
Kuwait	58.1	44.0	43.0	0.76	0.98	1.10	130	32
Dubai	47.0	38.1	32.1	0.81	0.84	1.00	130	34
Bandar Abbas	64.0	47.0	47.8	0.73	1.02	1.21	120	35

Maximum record in literature, a height of 90 mm (Smythe, 1982).

Remarks.

The uniqueness of the subspecies *lacunosum* is the constant conjunction of two characters which can sporadically exist in the nominal subspecies:

1- Thin, lamellar, homogeneous and regularly set transverse scales on top of ribs in PQ (Fig. 26), rather than the globular, somewhat elongated variable tubercles which are generally present in the nominal subspecies (where comparable lamellar scales can also sporadically exist, Figs 7, 25).

2- Strong marginal crenulations of the ribs, and lack of smoothness of rib tops: In the median part of the shell the lateral crenulations proceed up to the top zone, forming cross-bars or partially joined rugae, all of which gives the ribs a "plaited-like structure" as Smythe says (1982: 100), figuring a good example of this special form (1982, pl. 18, fig. c). This character already appears in very young shells: in the umbonal area the crenulations of the ribs become regularly swollen very early, unlike those in the nominal subspecies. The number of crenulations is smaller: 21 to 37 crenulations (as defined above) versus 35 to 52 in the nominal subspecies.

Besides the two fundamental elements of distinction above, some other more statistical elements seem to characterize *lacunosum*. It is less elongated (average L/H= 0.81, vs general average= 0.77), more tumid (average W/L= 0.90, vs general average= 0.87), and larger (in the largest specimen H= 90 mm, as opposed to 68.8).

Vasticardium rubicundum

(Reeve 1844.)

Figs 12-14, 18-20, 27, 31.

Cardium rubicundum Reeve, 1844, Sp. 44, pl. 9, fig. 44.*Cardium mindanense* Reeve, 1844, Sp. 19 [excluding the syntype figured pl. 9, fig. 19 = *Trachycardium egmontianum* Shuttleworth, 1856, 5: 172].*Vasticardium compunctum* Kira, 1959: 137, pl. 55, fig. 9.*Acrosterigma kengaluorum* Voskuil & Onverwagt 1992: 33, pls 1-2.

Selected references.

- Vasticardium rubicundum*: Keen, 1945: 36.
Cardium rubicundum: Braga, 1952: 49, pl. 10, fig. 2.
 NOT *Laevicardium* (*Trachycardium*) *rubicundum*:
 Fischer-Piette, 1977: 65 [= partly *Vasticardium*
assimile].
Trachycardium rubicundum: Oliver, 1992: 126, pl.
 23, Figs 7a-b.
Trachycardium (*Vasticardium*) *mindanense*:
 Springsteen & Leobrera, 1986: 306, pl. 87, fig. 2.

Type material.

Cardium rubicundum : Three syntypes from Zanzibar in BMNH, coll. Cuming, all larger than Reeve's figure; the largest (Figs 12-14) measures 60.0 x 49.0 x 41.3 mm.

Cardium mindanense : The name of this taxon is not to be confused with *C. mendanaense* Sowerby, 1897, which is another Indo-Pacific shell belonging to the group of *Vasticardium orbita* (see VIDAL, 1997a). There are three syntypes of *Cardium mindanense* Reeve in BMNH (ex Cuming) said to have come from Mindanao (Philippines). As indicated by pencilled notes, these three specimens were initially set on the same board. They are now separated into two boxes :

- one box with the specimen figured by Reeve, subsequently erroneously labelled "holotype". Reg. N° 1978-124, measuring 41.0 x 35.2 x 29.0 mm, with 30 ribs. This shell is *Trachycardium egmontianum* Shuttleworth, 1850, from the Atlantic coast of North America. This shell was probably placed with the others by Cuming, in error, because of a certain superficial resemblance between them. Further, it was probably chosen by Reeve for the figure because it was the largest.

- a second box with two specimens of *V. rubicundum*, respective dimensions: H= 40.1 mm, 37.6 mm; L= 34.7 mm, 34.0 mm; W= 30.6 mm, 25.3 mm; the number of ribs is 36 in both specimens. These last two shells are very probably those which come from Mindanao and from which the name *mindanense* originates. In order to avoid possible confusion and to preserve the legitimate Indo-Pacific origin of this taxon, I have selected as lectotype of *Cardium mindanense* the largest of these (Figs 18-19); the remaining syntype, becomes the paralectotype (Fig. 20).

Acrosterigma kengaluorum: The holotype is in RMNH (56769) from Honiara, Guadalcanal Is, the Solomons, a shell measuring 30.7 x 27.8 x 21.0 mm, with 34 ribs. Twenty paratypes, all in private collections, are from the same area; their dimensions are as follows: H= 24.1 to 37.4 mm, L= 19.6 to 34.5 mm, W= 15.2 to 25.6 mm. Mean rib number 35.4 (range 32-38). Mean L/H= 0.90 (range 0.86-0.96); mean W/L= 0.75 (range 0.69-0.82).

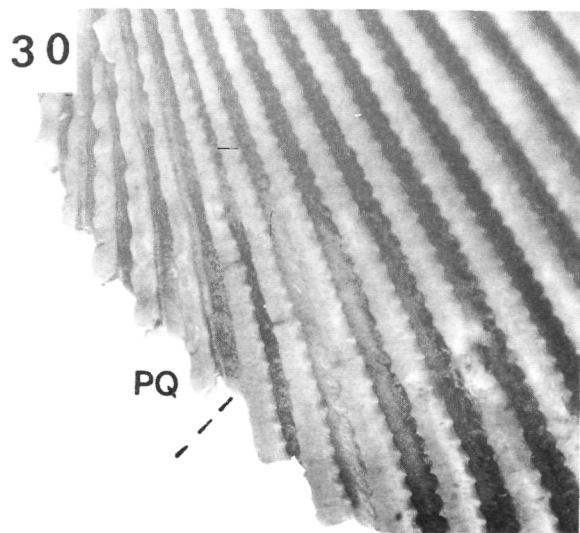
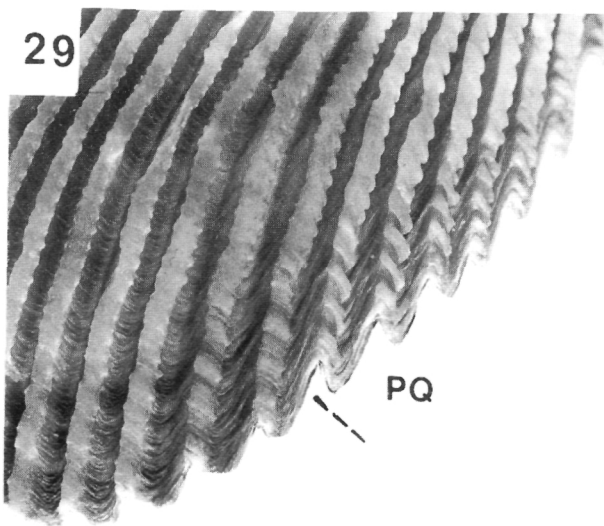
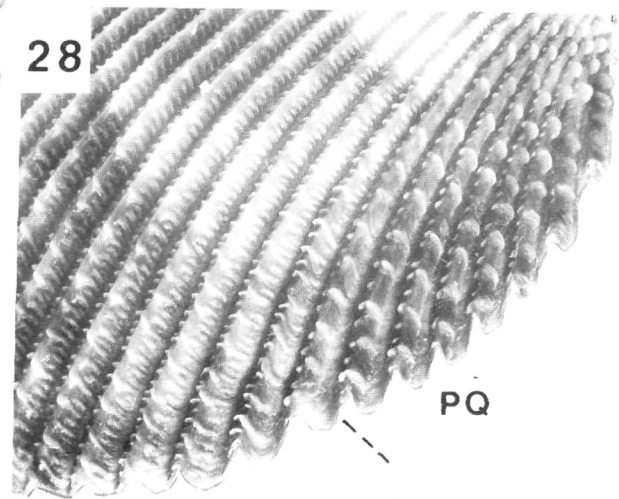
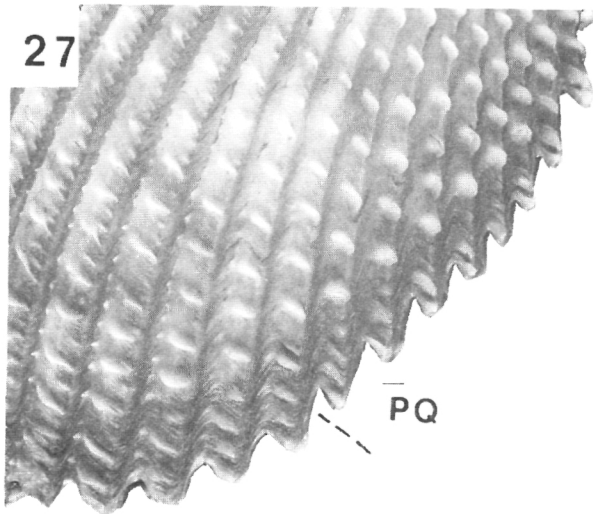
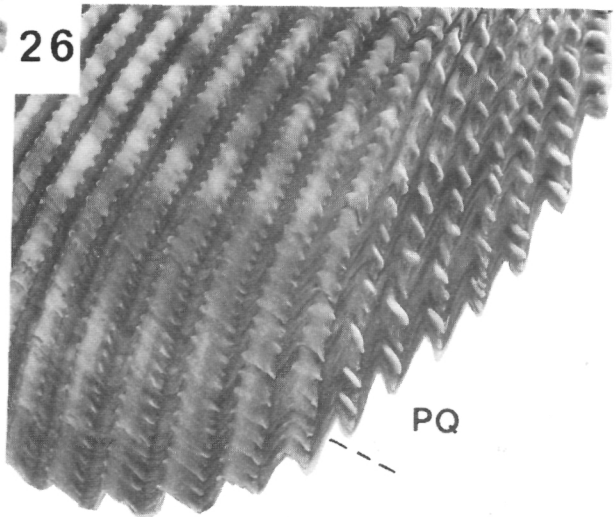
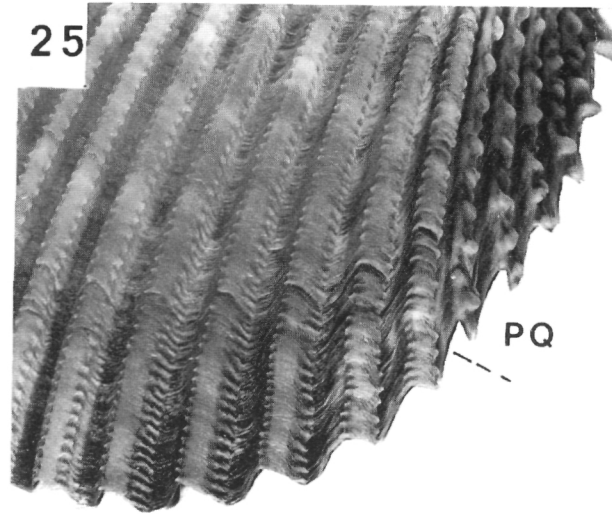
Vasticardium compunctum: This name first appears as a Kuroda M.S. name in HABE (1951: 145). KIRA (1955) gives a figure and still credits the name to Kuroda M.S., but this figure is not accompanied by a description. The name is first validated by KIRA (1959: 139) who gives a diagnosis of the species in Japanese, using the same figure. In 1962 (p. 156), KIRA gives a description in English. The shell figured by KIRA (1955 and 1959, pl. 55, fig. 9, and 1962, pl. 56, fig. 9) is considered as the holotype, with dimensions of 41.5 x 32.9 x 31.5 mm. According to a personal communication from A. Matsukuma, Kira's illustrated material is stored in Osaka City Museum (Natural History) and is not available for loan. The localities for the species given by KIRA, in 1962, are the Amami and the Ryukyu Islands (Japan). Only photographs of Kira's type of *V. compunctum* have been examined but one lot in MNHN comes from the type locality, the Amami Islands, Japan.

Description.

Shells regularly subovoid, almost ellipsoidal in shape and almost equilateral, except for a small truncation in posterior margin. PQ is somewhat flat or slightly depressed and forms an obtuse angle with rest of shell. Ribs generally straight, rarely slightly curved backwards in projection; adult state little elongated (mean L/H= 0.81; range 0.77-0.86) and relatively tumid (mean W/L= 0.84; range 0.78-0.84).

Exterior splashed or striped with red-purple, or sometimes brown; yellow or light orange markings can occur and predominate in specimens from southern Japan, and brown markings predominate in rest of Pacific; entirely white specimens are rare. Interior white with a colored margin and an umbonal area with two rays. Lunular area narrow, generally purple colored.

Fig. 25. *Vasticardium assimile*, left valve, specimen from Magaruque Is, Mozambique, MNHN (same as Figs 6 and 7); detail of PQ and MPQ showing particularly the ontogenic change towards the shell margin of the small posterior marginal crenulations into elongated ridges on the flank of the ribs in last ribs of MPQ; scale x 2.5. **Fig. 26.** *Vasticardium assimile lacunosum*, left valve, specimen from the Persian Gulf, detail of PQ and MPQ; scale x 2.5. **Fig. 27.** *Vasticardium rubicundum*, left valve, specimen from Zanzibar, MNHN; detail of PQ and MPQ showing particularly the additional scales in MPQ, superposed on the thin marginal crenulations; scale x 2.5. **Fig. 28.** *Vasticardium thomassini*, Holotype; detail of PQ and MPQ; scale x 4. **Fig. 29.** *Vasticardium rhegminum* left valve, same specimen as in Figs 15-17; detail of PQ and MPQ; scale x 2.5. **Fig. 30.** *Vasticardium rhegminum*, small right valve, MNHN coll. Day; detail of juvenile PQ and MPQ showing particularly in PQ the anterior edge of ribs with a thin longitudinal furrow; scale x 5.



Hinge moderately arched ($< A$ range 125-140°) and rather asymmetrical (mean ratio $D = 1.15$; range 1.0-1.43). Posterior cardinal in left valve (4b) rather long and high, sometimes with a sharp top; foundation of anterior laterals, mainly in right valve, moderately projecting and more hook-shaped than in *V. assimile*. No medial rib in umbonal cavity.

Mean rib number 36.0 (range 33-39).

Rib morphology:

In juvenile PQ, ribs rather low, and asymmetrical, with anterior edge overhanging interstice with a sharp continuous rib margin juttied in front of scales or rarely dividing into successive transverse bent lamellae; rib tops bear large somewhat tubercular, slightly twisted scales, obliquely set; interstices are as wide as ribs. In adult PQ, anterior edge of ribs generally becomes less sharp and often does not overhang interstices which become narrower than ribs; scales become tubercular (Fig. 27).

In juvenile median part of shell, ribs trapezoidal with rounded, narrow, almost flat tops, which are always smooth; flanks of ribs strongly ridged and furrowed, with furrows generally straight except for anterior flanks of MPQ, where they are very bent. These ornaments disappear near base of flanks, leaving a smooth basal zone. Before disappearing, these ridges thicken, forming small tubercles on their lower extremity; these tubercles, being always aligned at lower 1/3 of ribs, form regular beaded longitudinal lines along flanks of ribs; these "beads" extend into interstices, sometimes almost touching; in that latter case, the smooth inferior part of ribs and bottom of interstices form "tunnels." Bottom of interstices flat and weakly notched. Margin of top zone very variable, with respect to crenulations, from one population to another; these crenulations may or may not be present, on one or on both sides of ribs, but in anterior half of shell crenulations are always in continuity with the flank ridges which are strongly furrowed but not beaded. When these crenulations are present, flanks bear two longitudinal lines of tubercles: crenulations in the upper part, and "beads" in lower part. In adult MPQ, ribs remain or become very asymmetrical; on anterior part of ribs the finely crenulated projecting edge remains the same, but furrowing of the reduced flank lessens; in the wider posterior part, crenulations and flank furrows progressively disappear, and strong oblique straight scales develop on top and flank of rib. These scales, which are a continuation of main scales of adjacent PQ, superpose on pre-existing

ornamentation and entirely replace it in the most aged part of shell (Fig. 27). In adult MAQ, and sometimes as early as in anterior part of MPQ, ribs become very asymmetrical; upper anterior part of rib flanks lowers forming a gently sloping ridged plane with the anterior part of top zone; long ridges of these planes form typical asymmetrical herringbone patterns with posterior crenulations or ridges; these herringbone-shaped ridges, first open then closed on all ribs, are often of a light color and contrast strongly with the darker color of ribs.

In juvenile AQ, flanks of ribs not beaded, interstices only finely striated by growth lines, and crenulations tend to join to form imbricated transverse ridges with a quasi-herringbone pattern. In adult AQ, these patterns evolve into imbricated continuous cross bars on top and anterior flank of ribs; tops retain a generally asymmetrical herringbone aspect.

Material examined.

Type material: Syntypes of *C. rubicundum* and *C. mindanense*, Holotype and paratype N° 1 of *A. kengaluorum*, and the following lots:

- A) South Africa: East London: 1(MNHN), 1(USNM); Port Shepstone: 1(MNHN) 1(ANSP); S. Durban: 1(MNHN); N. Durban: 1(MNHN); Brighton: 1(MNHN); no specific location: 1(BMNH)
- B) Mozambique: Joao Belo: 1(MNHN); Inhambane: 1(MNHN); Chidenguele: 1(MNHN); Ponta da Barra: 1(USNM)
- C) Madagascar: Tulear: 5(MNHN)
- D) Tanzania: Dar es Salaam: 1(AMS); Zanzibar: 4(MNHN), 1(BMNH), 2(ANSP)
- E) Kenya: Shimoni: 4(BMNH)
- F) Somalia: N. Mogadishu: 1(MNHN), 1(ANSP)
- G) "Indian Seas": 1(MNHN)
- H) Sri Lanka: no specific location: 1(MNHN), 1(AMS)
- I) Singapore: 1(AMS)
- J) Indonesia-Java: Batavia Bay: 1(ZMA); Bantan: 2(USNM)
- K) Indonesia-Bali: Nusa-Dua 1(LACM)
- L) Philippines: Mindanao, Zamboanga: 1(MNHN); Luzon, Tabangao: 1(AMS); Luzon, Corregidor: 1(AMS)
- M) Indonesia-Sulawesi: N. Paleleh: 1(RMNH)
- N) Indonesia-Moluccas: no specific location: 1(ZMA)
- O) Papua New Guinea: Oro Bay: 1(MNHN)
- P) Japan: Amami Islands: 1(MNHN), 1(ANSP); Okinawa: 2(USNM), 1(LACM).

Fig. 31. *Vasticardium rubicundum*, left valve, specimen from Zanzibar, MNHN; detail of median part (MPQ and MAQ). Scale x 3.5. **Fig. 32.** *Vasticardium thomassini*, left valve, holotype; detail of median part (MPQ and MAQ), scale x 4.0.

Measurements of *V. rubicundum*

	Height	Length	Width	L/H	W/L	ratio D	angle A	Ribs
	(mm)	(mm)	(mm)				°	
Syntype	60.0	49.0	41.3	0.82	0.84	1.30	130°	35
Syntype	51.7	41.3	34.6	0.80	0.84	1.18	125°	37
Syntype	50.3	40.4	33.1	0.80	0.82	1.24	125°	37
Zanzibar	54.6	42.8	37.5	0.84	0.88	1.16	125°	34
Indian Seas	43.4	35.4	28.7	0.82	0.81	1.04	130°	36
Sri Lanka	40.8	33.1	26.6	0.81	0.80	1.17	135°	35
Papua N G	34.0	29.1	23.5	0.86	0.81	1.43	140°	34
Japan, Amami	46.0	35.4	33.3	0.77	0.94	1.30	130°	35

Largest specimen observed is the above syntype (H= 60.0 mm).

Distribution.

Because of the frequent confusion of *V. rubicundum* with *V. assimile*, the distribution derived from the literature is unreliable, and here only the verified localities are taken into account. Its extension into the western Indian ocean is smaller than the one of *V. assimile*, and it is not recorded from the Gulf of Aden or Arabian Sea. But *V. rubicundum* has a larger Pacific distribution, and is sporadically found as far as in Japan and the Solomons. However, it is undoubtedly locally rarer outside the southwestern zone of the Indian Ocean where it is sympatric with *V. assimile*.

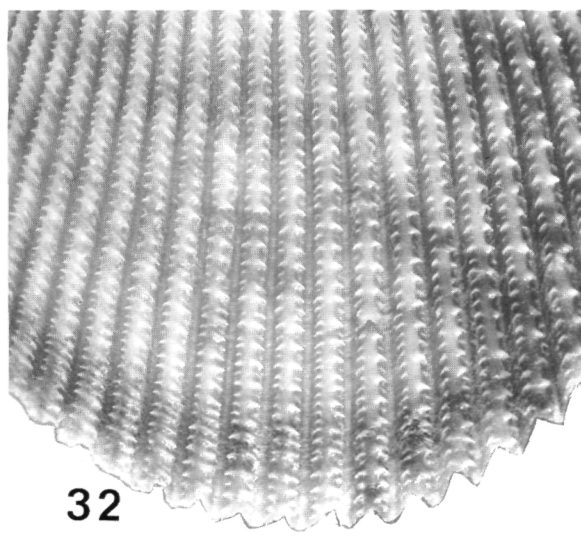
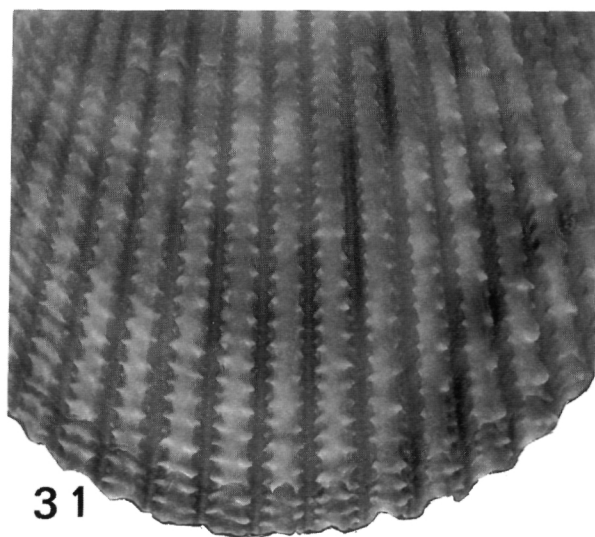
Remarks.

Variability of *V. rubicundum*: Unlike *V. assimile*, *V. rubicundum* is stable in shape and rib ornamentation. The only variable element is color. The specimens from the southwestern Indian Ocean are rather colored

with purple or pink (like *V. assimile*). In the westernmost Pacific, the colors are rather brown, and in Japan they are entirely yellow to light orange, sometimes almost white. Two specimens from Singapore, in AMS, are entirely white.

Differences from *V. assimile*: Three easily observed main characters of *V. rubicundum*, among others, separate it from *V. assimile*:

- 1) Beaded structure of the ribs in the young specimens; flanks of ribs are smooth in *V. assimile*.
- 2) Large oblique scales on top of ribs in MPQ in adult specimens; tops smooth in *V. assimile* (compare Fig. 25 and Fig. 27).
- 3) Strongly marked asymmetrical herringbone patterns on the ribs in the median and anterior parts of the shells in adult specimens (no herringbone in *V. assimile*).



Differences from *V. vertebratum*: A beaded double ornamentation readily comparable to the one in *V. rubicundum* also exists in the Australian *V. vertebratum* (Jonas, 1844) [*V. reeveanum* (Dunker, 1852)], which is also of a comparable reddish color. However this species belongs to the species-group of *V. flavum* (Linné) (see VIDAL 1997b) and significant characters separate the two shells. *V. vertebratum* is characterized by:

- 1) Average number of ribs: 29, instead of 36.
- 2) Juvenile ribs in PQ rather symmetrical, without any anterior sharp edge, but with secondary ornaments (small scales and ridges, in addition to the main scales, on the margins of top).
- 3) Ribs always rather symmetrical.
- 4) Interstices much more strongly striated.
- 5) Double beaded ornamentation regular and constant, not limited to the young parts of the shell.
- 6) Herringbone pattern on the ribs rare.

Vasticardium rhegminum
(Oliver & Chesney, 1997).

Figs 15-17, 29-30

Acrosterigma n. sp. (b) Oliver, 1995: 246, fig. 1092.

Trachycardium (Acrosterigma) rhegminum Oliver & Chesney, 1997: 69, Figs 39-42.

Type material.

Five immature bivalved shells, live collected from off Ras Madrasah, Gulf of Masirah, Oman, coll. "John Murray" Expedition Sta. 53, 19°22'36"N-57°53'00"E, 13.5 m. Holotype in BMNH. Four paratypes, three in BMNH, one in NMW reg. NMW.Z.1994.

Description.

Shell medium-sized, solid, and rather heavy, nearly equilateral, and only very slightly oblique (ribs only slightly curved backwards in projection). Outline ovate, generally elongated (mean L/H= 0.83; range 0.77-0.87) and moderately tumid (mean W/L= 0.84; range 0.80-0.90). Anterior dorsal slope longer and steeper than posterior, and posterior margin slightly straightened. Lunular area small, elongate and purple colored.

External color white to beige with an irregular pattern of pink (generally dominant) to light purple-brown; internally, margin tinged orange-pink along posterior edge and lightly suffused pink or orange-pink over umbonal cavity, with two umbonal rays.

Hinge wide and strong in adult shells, markedly acutely angled compared to other species of group (< A range 105-115°) and of different asymmetry (ratio D about 0.95). Foundation of anterior laterals not hook-shaped, and a long, elevated medial rib (umbonal support) occurs in umbonal cavity of all shells.

Mean rib number 40.2, range 38-43.

Rib morphology:

In juvenile PQ, initial rib morphology conforms that of other species of this group: ribs asymmetrical, with anterior edge overhanging interstice, and a sharp continuous margin jutting in front of scales; rib tops bear large somewhat tubercular, slightly twisted scales obliquely set; interstices are as wide as ribs. In adult PQ, scales flatten with growth, become round and widen, occupying all the top area, and forming successive oblique "waves", touching one another; these waves form crenulations on posterior margin of ribs, but on anterior margin they gradually disappear, forming a straight line which progressively overhangs interstice above original rib margin (Fig. 29). This results, on anterior margin, in a double overhanging edge divided by a well delineated thin furrow (Fig. 30).

In juvenile median part of shell, high ribs with roundly triangular top zones and crenulated margins overhang smooth and flat-bottomed interstices; flanks smooth, not separated from interstices. In adults (Fig. 29), ribs become very high, and progressively asymmetrical, with vertical smooth flanks, and smooth flat tops with more or less regularly crenulated margins overhanging interstices. Interstices deep, with flat, smooth bottoms, as wide as or wider than ribs.

In AQ, and as early as in anterior part of MAQ in very adult shells, marginal crenulations join from one side to other of rib tops, forming transverse oblique ridges, rarely with a herringbone pattern.

Material examined.

In addition to the type specimens, the following lots:

- A) 43 valves, as type series, BMNH.
- B) 15 valves, from storm beach opposite the British Eastern Relay Station camp, Masirah Island, in NMW coll. Oliver & Chesney Nov 1992 Reg. NMWZ.1993.X.Z.
- C) 1 valve from Masirah area, in BMNH coll. Biggs 1967.
- D) 3 small valves from Masirah Island, in MNHN coll. Day 1994.
- E) 4 valves from Masirah Island, in MNHN coll. Fuller 1968.
- F) 1 bivalved specimen from Masirah area, in MNHN leg Sue Hobbs 1995 (Figs 15-17).
- G) 1 bivalved specimen from Masirah area, in Sue Hobbs' private coll.

Measurements of *V. rhegminum*

	Height (mm)	Length (mm)	Width (mm)	L/H	W/L	ratio D	angle A °	Ribs
Holotype	34.7	28.9	24.4	0.84	0.84			38
MNHN (Hobbs)	53.6	39.4	36.4	0.73	0.92	0.94	105	39
Hobbs coll.	52.0	38.9	34.5	0.75	0.89	0.95	105	41
MNHN (Fuller)	63.5	46.9	(42.0)	0.74	0.90		110	42
MNHN (Fuller)	45.0	34.6	(32.4)	0.77	0.94		115	39
MNHN (Fuller)	27.0	22.6	(20.0)	0.84	0.88	1.00		38

Largest specimen observed, the above right valve from Masirah Island, in MNHN coll. Fuller (H= 63.4 mm).

Distribution.

To date, this species is known only from the Bay of Khalij (Masirah), on the southern coast of Oman, where it is sympatric with *V. assimile*.

Remarks.

Variability of *V. rhegminum*: This species is remarkably constant from one specimen to another, in all growth stages.

Differences from the three other species of the group: The average rib number of *V. rhegminum* is higher than in *V. assimile* and *V. rubicundum* (40.2 vs 33.4 and 35.6). This species differs also from the three other species of the species group by its very much smaller angle A, its characteristic "wavy" posterior zone with a furrowed anterior edge, and also by its very high regular ribs with smooth flanks and wide smooth interstices in the other parts of the shell.

Differences from some other species of *Vasticardium* with high ribs and wide interstices: The very special character of PQ is sufficient to separate *V. rhegminum* from several other forms which also have very high ribs and wide interstices, such as some subspecies of *V. elongatum* (see VIDAL 1993), *V. fidele* (see VIDAL 1992), and some subspecies of *V. orbita* (see VIDAL 1997a).

Vasticardium thomassini sp. nov.

Figs 21-24, 28, 32.

Type material.

Holotype (Figs 21-24, 28, 32), a shell from Tulear area (Madagascar), Thomassin's sta. D21, 43°49'E-23°31'S, 45m, in MNHN. Paratype 1, a left valve from the same station, in MNHN. Paratype 2, a left valve from Tulear area, Thomassin's sta. 211, 43°37'E-23°31'S, 12m, in MNHN. Paratype 3, a shell from south side of Pwakuun Is, W.Zanzibar, ca. 25 m, in ANSP 213809. Paratype 4, a right valve from between Port Shepstone and Port Edward, Natal (South Africa), in MNHN, leg Lavranos ex Polak.

Description.

Shell small to medium, regularly subovoid, almost ellipsoidal in shape an almost equilateral, except for a small truncation in PQ; holotype has also a small truncation in MPQ. Ribs generally straight, rarely slightly curved in projection. Adult shell little elongated (L/H range in the three largest shells 0.81-0.83) and relatively tumid (W/L range in the same shells 0.82-0.87). Lunular area well delineated, rather narrow, dark purple colored.

Exterior splashed with yellow to orange, with darker irregular stripes; interior white with an umbonal area yellow to orange, sometimes with two darker rays; margin not colored.

Hinge moderately arched (<A circa 135°) and almost symmetrical (ratio D circa 1.0 or a little more). Posterior cardinal in left valve (4b) rather long and high, with a pointed top. Foundation of anterior lateral in right valve moderately hook-shaped. No medial ridge in umbonal cavity.

Rib number ranges 42-45.

Rib morphology:

In juvenile PQ, ribs rather low and assymetrical with anterior edge overhanging interstice with a sharp continuous margin juttet in front of scales or dividing into successive transverse bent lamellae; rib tops bear large, somewhat tubercular, slightly twisted scales, obliquely set. Except for the two last ones, interstices are narrow. In adult PQ (Fig. 28), anterior edge of ribs becomes less sharp and does not overhang interstice: the previous thin bent lamellae of anterior edge become small flank scales with a different obliquity from the one of the main scales, forming an angle with them, and being about twice more numerous.

In juvenile median part of shell, ribs are, at first, flatly rounded, smooth, with progressive appearance of small serrations at their lower part, separated from interstice which is finely striated or notched. Then basal serrations enlarge, become overhanging and ribs progressively become roundly triangular. In adult MPQ (Fig. 28), ribs remain about same as in PQ with same assymetry (anterior flank shorter and steeper), but posterior flank becomes finely ridged, when anterior

small scales become more numerous and progressively change, onwards, into small, thin flank ridges; the equivalent of PQ main scales change into tubercles on top of ribs. In adult middle of shell (anterior part of MPQ and posterior part of MAQ, Fig. 32), ribs become about symmetrical and triangular, with both flanks bearing numerous thin ridges not reaching interstice, shorter and more numerous in anterior flank, forming an herringbone pattern with the posterior ones. Top zone progressively loses, onwards, its tubercles and becomes smooth.

In AQ, ribs become more asymmetrical (posterior flank shorter) and slightly overhanging and lateral ridges progressively join together to form top imbricated rugae.

Material examined and distribution.

The type series, consisting only of 1 valve from S. Natal, 1 specimen and 2 valves from S.W. Madagascar, 1 specimen from Zanzibar. In these three localities it is sympatric with *V. assimile* and *V. rubicundum*.

Measurements of *V. thomassini*

	Height	Length	Width	L/H	W/L	ratio D	angle A	Ribs
	(mm)	(mm)	(mm)				°	
Holotype	34.0	27.7	23.5	0.81	0.85	0.95	130	43
Paratype1	28.2	23.4	(20.4)	0.83	0.87	1.0		42
Paratype2	32.7	26.7	(22.0)	0.82	0.82	1.0		44
Paratype3	23.0	20.2	15.4	0.88	0.76	1.10	135	45
Paratype4	18.5	16.1	12.0	0.93	0.75		135	44

Etymology.

Bernard A. Thomassin conducted extensive field work in Tulear area (S.W. coast of Madagascar), between 1963 and 1972, for ecological studies (see THOMASSIN, 1978).

Remarks.

Differences from *V. rubicundum*: *V. thomassini* is very close to *V. rubicundum* as far as shape, morphometric data, lunule, hinge are concerned; it differs from the specimens from Africa in absence of purple coloring in the exterior, and is closer, in that domain, to the yellow-orange forms of Japan (*compunctum*). It differs from all the forms of *V. rubicundum* in:

(1) Number of ribs ranging 42-45, when the maximum in *V. rubicundum* is 39.

(2) Rib morphology (compare Figs 28 and 32 with Figs 27 and 31): presence in *V. thomassini* of secondary anterior small scales in PQ and much more numerous lateral serrations or ridges in the rest of the shell; in *V. thomassini* the interstices in the median part of the shell are much narrower (see Fig. 32); in this median part, the small lateral ridges are much more numerous and form a better herringbone pattern in *V. thomassini*; absence also of the "double-beading" of the ribs in the median part of the juvenile shell which characterizes *V. rubicundum*.

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