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A REVISION OF THE SPECIES OF *BOLMA* RISSO, 1826 (Gastropoda: Turbinidae)

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ABSTRACT

All Australian and New Zealand fossil taxa and all world living taxa are revised in the genus *Bolma* Risso (= *Oobolma* Sacco, = *Ormastraliium* Sacco, = *Tylastraliium* Sacco, = *Pseudastraliium* Schepman, = *Incilaster* Finlay, = *Galeoastraea* Habe, = *Hirasazaea* Habe). The genus is contrasted with related genera using shell and radular characters, and all recognised taxa in *Bolma* are diagnosed and figured. New taxa named are *Bolma anacanthos* n. sp., Oligocene, Victoria; *B. austroconica* n. sp., Oligocene, Victoria; *B. flindersi darraghi* n. subsp., Upper Eocene, Victoria; *B. kermadecensis* n. sp., Recent, Kermadec Islands; *B. somaliensis* n.sp., Recent, East Africa; and *B. tamikoana flava* n. subsp., Recent, Malagasy Republic. *Senobolma* Okutani, 1964 is ranked as a subgenus of *Bolma* Risso. Living taxa newly recorded from Australia are *B. guttata millegranosa* (Kuroda & Habe), *B. guttata* subsp?, *B. henica* (Watson), and *B. tamikoana tamikoana* (Shikama).

INTRODUCTION

The gastropod genera related to *Astraea* Röding (*Bolma* Risso, *Astraliium* Link, *Guildfordia* Gray, *Lithopoma* Gray, *Pomaulax* Gray, etc.) have smooth surfaces or finely to coarsely gemmate sculpture, a very low to very prominent row (or rows) of peripheral spines that in many species are situated on a weak to marked peripheral angulation, and heavy calcareous opercula that place them in the family Turbinidae. They are often included in a separate subfamily *Astraeinae* (= *Bolmidae* Delpy, 1942, p. 181) but several typical turbinids have granular sculpture (e.g., *Modelia granosa* (Martyn), New Zealand; *Euninella gruneri* (Philippi), South and south Western Australia) and some species of *Turbo* Linné have a row of peripheral spines (e.g., *Turbo (Batillus) cornutus* (Solander in Lightfoot), in which peripheral spines may be absent or small to very large). The opercula of most "Astraeinae" are oval, whereas most Turbininae have circular opercula. The opercula of species of *Bolma* are oval, circular or intermediate in shape. Apart from the enigmatic Triassic genus *Rothpletzella* Bohm, 1895, (Knight *et al.* 1960, p.1264, fig. 170, 1) both the "subfamilies" Turbininae and *Astraeinae* are known earliest in Upper Cretaceous rocks (Knight *et al.* 1960). In the absence of any distinguishing shell characters other than that many members have a peripheral angulation, and of any difference in stratigraphic range, and because of the intergrading opercula features, we do not recognise a subfamily for the genera related to *Astraea*.

The genera related to *Astraea* are difficult to diagnose on shell and opercular features alone. Fortunately the radulae have been described for a number of species. Radulae of several further species are described below, and all these help to clarify the generic groupings. The most recent reviewers, Knight *et al.* (1960), oversimplified the situation by reducing nearly all of the proposed genera to subgenera of *Astraea*. They allowed *Guildfordia* Gray as a separate genus, of which they ranked *Pseudastraliium* Schepman as a subgenus, following Habe (1957, p. 208).

Species of *Bolma* are sometimes difficult to define because usually few specimens from any one population have been available for study. Consequently the limits of both population and geographic variation have been difficult to assess. For this study, material of *Bolma* in many world museums has been either studied at the museums or borrowed.

Almost nothing is known of the biology of species of *Bolma* although it is assumed that they have at least a short planktonic larval life and probably do not graze on attached algae because most species live well below the limits of algal growth. Wide distribution might be expected in animals exhibiting a free-swimming larval stage and inhabiting a subtidal environment, but this is apparent in only a few species. Two species as here interpreted, *B. henica* (Watson) and *B. guttata* (A. Adams), range from Japan to South Africa and Australia but the latter species shows a number of geographical forms over its range which are here regarded as subspecies.

Some details of the anatomy of the type species of *Bolma*, *B. rugosa* (Linné), have been published by Haller (1883) and Simroth (1892-1907).

Abbreviations

In the lists of localities, the following abbreviations have been used for some institutions holding the listed specimens:

AM	— Australian Museum, Sydney.
AMNH	— American Museum of Natural History, New York.
ANSP	— Academy of Natural Sciences, Philadelphia
BMNH	— British Museum (Natural History), London
DMNH	— Delaware Museum of Natural History, Greenville
NM	— Natal Museum, Durban
NMV	— National Museum of Victoria, Melbourne
NMW	— National Museum of Wales, Cardiff
NSMT	— National Science Museum, Tokyo
NZGS	— New Zealand Geological Survey, Lower Hutt
NZOI	— New Zealand Oceanographic Institute, Wellington.
SAM	— South African Museum, Cape Town.
USNM	— United States National Museum, Washington, D.C.
WAM	— Western Australian Museum, Perth

TAXONOMY

Family **Turbinidae**

In order that our concept of *Bolma* may be more fully appreciated the diagnostic features of the genus are contrasted with those of the other taxa of the *Astraea* group that are here considered to be of generic rank.

Astraea Röding, 1798, p. 69 (type species (subsequent designation, Suter, 1913): *Trochus imperialis* Gmelin, 1791 = *Trochus heliotropium* Martyn, 1784, valid I.C.Z.N. Opin. 479) is a distinctive group of Turbinidae with a low spire, a widely open umbilicus, a narrowly reflected inner-lip callus, and a relatively thin, flat operculum. In New Zealand, the living *A. heliotropium* (Martyn) has a fossil history in late Lower Miocene to Pleistocene rocks, *A. bicarinata* Suter, 1917 occurs in Lower Miocene rocks, and 3 unnamed species occur in Upper Eocene, Oligocene, and early Miocene rocks. In Australia, *A. johnstoni* (Pritchard, 1896) occurs in Upper Eocene rocks, *A. hudsoniana* (Johnston, 1888) occurs in early Miocene rocks, and a species from Upper Miocene rocks is unnamed. Only these eight species belong in *Astraea* (sensu stricto).

Astraliium Link, 1807, p. 135 (type species (monotypy): *Astraliium deplanatum* Link, 1807 = *Turbo calcar* Linné, 1758) is a low-spired to very high-spired group having sculpture of major radial folds or ribs which are sometimes produced into short spines, a completely closed umbilicus, a flat, smooth operculum, and the basal callus usually narrow and separated from the columella. Genus-group names that may be synonyms of *Astraliium* or may in some cases prove to be subgenera are: *Calcar* Montfort, 1810, p. 135 (type species (by monotypy): *Calcar sporio* Montfort, 1810 = *Turbo calcar* Linné, 1758); *Cyclocantha* Swainson, 1840, p. 348 (type species (by subsequent designation, herein): *Turbo calcar* Linné, 1758); *Stella* Herrmannsen, 1849, p. 501 (type species (by original designation): *Trochus stella* Lamarck, 1822); *Distellifer* Iredale, 1937, p. 249 (type species (by original designation): *Distellifer wallisi* Iredale, 1937, = *Trochus rhodostomus* Lamarck, 1822); *Pagocalcar* Iredale, 1937, p. 249 (type species (by original designation): *Trochus pileolum* Reeve, 1842, ? = *Trochus limbiferus* Kiener, 1850); *Rugastella* Iredale, 1937, p. 249 (type species (by original designation): *Trochus rotularius* Lamarck 1822); *Bellastraea* Iredale, 1924, p. 232 (type species (by original designation): *Bellastraea kesteveni* Iredale, 1924); *Micrastraea* Cotton, 1939, p. 169 (type species (by original designation): *Trochus aureus* Jonas, 1844).

Another distinctive group is the American and Japanese genera or subgenera closely related to *Lithopoma* Gray, 1850, p. 88 (type species (monotypy): *Trochus tuber* Linné, 1767). Included in the group are *Pachypoma* Gray, 1850, p. 88 (type species (subsequent designation, Fischer, 1873): *Trochus caelatus* Gmelin, 1791); *Pomaulax* Gray, 1850, p. 87 (type species (subsequent designation, Fischer, 1873): *Trochus japonicus* Dunker, 1845); *Uvanilla* Gray, 1850, p. 87 (type species (subsequent designation, Fischer, 1873): *Trochus unguis* Wood, 1828); and *Megastraea* McLean, 1970, p. 71 (type species (original designation): *Trochus undosus* Wood, 1828). They are similar in their medium to large size, moderate to tall spires with conic to markedly convex-whorled spire outlines, smooth or only weakly folded shell surface, relatively low, rounded peripheral folds to almost absent peripheral sculpture, and inflated or spirally sculptured opercula. The spirally ridged opercula bear granules or spines. They do not seem closely related to other genera of the *Astraea* group, and are separated from them by their relatively smooth surfaces, lack of a spreading basal callus, separation of callus from columella, and distinctive opercula.

Cookia Lesson, 1832, pl. 15 (type species (monotypy): *Trochus sulcatus* Martyn, 1784; valid I.C.Z.N. Opin. 479) has some similarity to *Pachypoma* and *Pomaulax* in shell and radular features but differs in having a smooth operculum with a strong spiral margining rib, and with a second short rib emerging from the nucleus. The radula differs from that of *Bolma* in having more massive marginal teeth and a relatively smaller central tooth with a central peg extending markedly beyond the upper margin of the tooth (Hutton, 1883, p. 125, pl. 14, fig. P; see also below and fig. 16g-i). This closely resembles the radula of *Lithopoma* figured by Pilsbry (1888, p. 61, fig. 11). Some species of *Bolma*

(e.g. *B. aureola* (Hedley)) approach *Cookia sulcata* in form and sculpture, and the uncoloured basal callus pad of *Cookia* is very similar to that of *Bolma*. Because of the radular and shell similarities to the *Lithopoma* group, we regard *Cookia* as a subgenus of *Lithopoma*.

Guildfordia Gray, 1850, p. 87 (type species (monotypy): *Astralium triumphans* Philippi, 1841) has a relatively low spire, sculpture of fine, low, closely spaced gemmae ending immediately above the row of peripheral nodules or spines, a very finely sculptured to smooth base, the centre of which is covered by a callus pad with a marked central depression, and a flat, relatively thin operculum. Some relatively short-spined species such as *Astralium* (*Guildfordia*) *moniliferum* Hedley and Willey, 1896 from New Britain (Hedley and Willey, 1896) have all the features of *Guildfordia* except long spines, and we can see no reason why they should not be placed there.

Opella Finlay, 1926, p. 368 (type species (original designation): *Astraea subfimbriata* Suter, 1917) is a highly distinctive group with a moderate to tall, conical, flat-sided spire, low nodular sculpture and a closed umbilicus as in *Guildfordia*, although there is no basal depression, and a marginal row of nodules protrudes down from the edge of the base below the peripheral keel. Protrusion of the nodules from the base seems to be foreshadowed in *Guildfordia* by the cessation of the nodular sculpture above the peripheral row of spines, and we regard *Opella* as a subgenus of *Guildfordia*. *Fractopella* Beu, 1970, p. 123 (type species (original designation): *Fractopella megapex* Beu, 1970) seems best regarded as another subgenus of *Guildfordia*, distinguished by its smooth, trochoid, bulbous protoconch, unlike the low, prominently carinate one of all other Turbininae.

Vitiastraea Ladd, 1966, p. 45 (type species (original designation): *Astraea* (*Vitiastraea*) *holmesi* Ladd, 1966, Upper Eocene, Tonga) known only from the unique holotype, is a minute (2.4 x 3.0 mm) round-whorled shell superficially resembling the much larger *Lunella* Röding, with two prominently nodular angulations around the last whorl. Only 1½ whorls of the teleoconch are developed, and it is a juvenile specimen that could belong in either *Turbo* (s.l.) or *Astraea* (s.l.). Clarification of its relationships must await the collection of adult material.

Bolma Risso, 1826. Species here placed in *Bolma* are similar in having a turbinated shell; one or, in most species, two angulations on the last whorl (and one on spire whorls) that bear nodules or spines on most species; a simple columellar callus which, in mature shells of most species, spreads over much of the base adjacent to the columella, and is coloured yellow or orange in some species. The operculum is simple, markedly convex, and smooth or with a granular, in some species depressed, central area. The position of angulations on whorls, length of spines, and details of fine nodular ornament and opercular sculpture, features that have been used to define several genera or subgenera, seem to us to be specific characters within this group and we propose to place all species in the genus *Bolma*, recognising as a separate subgenus only *Senobolma* Okutani, 1964.

Two species groups can conveniently be recognised within *Bolma* s.s. One, the "*Bolma rugosa* group" is composed of species with generally rather solid, larger shells, usually with distinct, irregular axial folds dorsally and an oval, often coloured operculum. The other group, the "*Bolma guttata* group" is composed of species with generally smaller shells of lighter build and usually with a white, circular operculum and regular gemmate sculpture. Some species share some features of both groups and consequently the groups are not considered to be of subgeneric status. Species are classified in one or other of these two species groups in the taxonomic section below, and a list of all the Recent taxa of *Bolma* is presented at the end of this report.

Radulae

The radulae of the following species of *Bolma* have previously been figured: *B. rugosa* (Linné) Troschel and Thiele, 1879, p. 217, pl. 21, fig. 1; *B. henica* (Watson) Thiele, 1903, p. 121, 163, pl. 8, fig. 45; *B. recens* (Dell) Dell, 1967, p. 306, fig. 8; *B. guttata millegranosa* (Kuroda and Habe) Habe, 1958, p. 45, pl. 3, fig. 1; *B. modesta* (Reeve) Habe, 1958, p. 46, pl. 3, fig. 13; *B. tayloriana* (Smith) Barnard, 1963, p. 217, text-fig. 5d.

Habe (1958) separated *Hirasazaea*, *Galeoastraea* and *Bolma* on minor shell characters, and also figured the radulae of *Galeoastraea* (*Galeoastraea*) *millegranosa* and *G. (Hirasazaea) modesta*. The radulae are not clearly drawn and show a peculiar peg-like "cusp" on the central tooth which was referred to by Dell (1967, p. 307).

This peg-like "cusp" is apparently present on the central teeth of all of the examined species of *Bolma*. It is a flat peg on the ventral (inside) surface of the tooth and is attached to the radular membrane. It has been misinterpreted as a true cusp by some authors and is usually shown in illustrations as appearing on the upper face of the tooth. Apparently the central teeth are so transparent that the peg shows through clearly. Depending on the length of the peg and the angle of the tooth it has been shown to extend beyond the cutting edge of the central tooth or as lying well within it. Such a comparison can be made between Troschel and Thiele's (1879) figure of the central tooth of *Bolma rugosa* and of Barnard's (1963) figures of the central tooth of "*Astraea*" *tayloriana*. A similar peg or basal plate occurs in most other genera of Turbinidae and presumably has a supportive function.

Because of the difficulty in comparing the published illustrations of turbinid radulae, an examination of the radulae of species belonging to several genera of the Turbinidae was undertaken to provide a basis for comparison with those of *Bolma* species (figs 15-19).

For the purposes of the following discussion only the generic names will be used. Full details of the species names and their data can be found in the captions to the figures referred to.

The radula of the type species of *Astralium* has very distinctive central teeth (figs 15e, f), and the lateral teeth of this and other species of the genus show a highly advanced type of articulation (figs 15a, b). The radulae of the type species of *Bellastraea*, *Astralium*, and *Micrastraea* (here considered to be synonyms) are virtually identical (figs 15b-f). This type of central tooth is in marked contrast to those seen in the other genera examined where any articulation of the lateral teeth was not associated with any significant change in the shape of the teeth.

The radulae of species of *Astraea*, *Bolma*, *Bolma (Senobolma)*, and *Guildfordia* all show a general similarity, with roughly oval or pentagonal central teeth, each having a short peg which hardly projects, or does not project, above the slightly curved or straight, simple cutting edge when the tooth is horizontal. The peg is flat, short, blunt, broad, and usually expanded distally (figs 16k, 17f, 18c, g, i, k).

There is some variation in the central teeth of the few species of *Bolma* examined to date. Some species in the "*Bolma rugosa* group," as here recognised, have central teeth with a pair of short latero-basal projections on each tooth (figs 18b, d, e, h, k) and tend to have a stronger, more recurved cutting edge than species in the "*Bolma guttata* group" (figs 19a, d, f). In other characteristics they closely resemble one another and some (figs 19d, e) are somewhat intermediate in shape. The central teeth of *Guildfordia* (fig. 17h) and *Bolma (Senobolma)* (fig. 17j) agree well with those of the "*Bolma guttata* group" and

those of *Astraea* (figs 16j-l) agree well with those of the “*Bolma rugosa* group”, although we do not consider that all these similarities necessarily indicate close phylogenetic relationship.

The median and outer marginal teeth of the *Bolma-Astraea* group are relatively simple and appear to be of little value at the generic level. They are sometimes rather heavily serrated as in some species of *Bolma*, such as *B. rugosa* (fig. 18a) and *B. jacquelineae* (fig. 18f), *Bolma (Senobolma)* (fig. 17i) and *Guildfordia* (fig. 17g).

The radulae of species of *Turbo*, involving several subgenera (figs 16a-c; 17a-e), and that of *Cookia* (figs 16f-i), show a close similarity and differ from those of other Turbinidae examined. The central tooth is pentagonal to almost triangular in shape with a long, very thick peg which consists of 2 layers, the upper layer being shorter than the lower (figs 16a; 17c-e). The inner marginal teeth, with the exception of the innermost pair of marginals in each row, have a peculiar cusp pattern (figs 16a, f, 17a) quite unlike the simple cusps seen in all the other groups examined, with the exception of *Lithopoma*. The main difference between the central teeth of *Cookia* and those of *Turbo* is that the depression on the outer face of each tooth which indicates the point of attachment of the peg is placed high up in *Cookia* (fig. 16i) but is often near the base of the tooth in *Turbo* species (fig. 16l; 17e), although at least two *Turbo* species (placed in different subgenera) show an intermediate condition (fig. 17a, b).

Lithopoma has a central tooth that is much more elongate than those of any of the other genera examined and the short cutting edge is strongly recurved to form a powerful, square cusp (fig. 16d). The marginal teeth (fig. 16e) are like those of *Turbo*, and its relationships, and those of *Cookia*, are probably with that group rather than with *Astraea* under which they were placed by Knight *et al.* (1960) as subgenera.

In summary, the morphology of the radula, and in particular of the central teeth, shows that three fairly distinct groups can be recognised. The genus-group taxa having similar radulae to those of *Bolma* species are *Astraea*, *Guildfordia* and *Senobolma*. Both *Astraea* and *Guildfordia* are easily differentiated from *Bolma* on shell characters, and *Senobolma* is here regarded as a subgenus of *Bolma*. The *Turbo* group includes *Cookia* and *Lithopoma*, and *Astralium* forms the third and most distinctive group.

Fossil *Bolma*

The earliest record of *Bolma* is a 5 mm-high, fragmentary external mould in Teurian (Paleocene) cemented siliceous sandstone (Kauru Formation) from GS3773, Raupo Creek, near Five Forks, inland from Oamaru, New Zealand. Apart from this specimen, the genus is first known in Upper Eocene rocks of New Zealand, Australia and Tonga. Paleocene and Eocene species are all small, rather low spired, with channelled sutures and granulate or scaly sculpture. They closely resemble some living species, particularly *B. guttata* (Adams) and *B. recens* (Dell). The Miocene species *B. granifer* (Martin) from Java also falls into this group. The genus probably migrated into the Tethyan region from the Indian Ocean in the early Oligocene as the first Tethyan record is from the upper Oligocene. The genus also reached the Atlantic in the Miocene and evolved into several species, thus enabling a Pliocene recolonization of the Mediterranean following the dessication of that sea in the late Miocene. The Atlantic fauna is now reduced to only 3 species, one of which, *B. rugosa* (Linné), is the sole surviving member of the genus in the Mediterranean. It is possible that some species of *Bolma* may have re-entered the Indian Ocean around South Africa but there is no fossil evidence to support this view. Strangely, for a genus with several Tethyan Atlantic species, there are no fossil or living records of *Bolma* from the Americas.

This review is concerned primarily with the world Recent species of *Bolma*, and with the fossil species of Australia and New Zealand. We have made no attempt to list in their entirety the very numerous species of *Bolma* recorded in the voluminous literature on European Tertiary Mollusca. We list here fossil species from non-European localities that we include in *Bolma*. Original assignments follow the species names and references are given to species not diagnosed elsewhere in the paper. This is followed by a brief summary of the major works in which European Tertiary species are described.

Non-European fossil *Bolma*:

anacanthos n. sp., Oligocene, Victoria.

amabilis, *Turbo* (*Modelia*), Ozaki, 1954, Pliocene, Japan (synonym of *B. guttata guttata* A. Adams).

austronica n. sp., Oligocene, Victoria.

?*brasiliensis*, *Astraea*, Ferriera and da Cunha, 1957, p. 14, pl. 2, fig. 3, 4, Miocene of Para, Brazil (may belong in *Bolma* but resembles more a distorted mould of *Turbo*).

crassigranosa, *Gibbula*, T. Woods, 1877, Lower Miocene, Tasmania.

flindersi, *Astralium* (*Calcar*), T. Woods, 1877, Lower Miocene, Tasmania.

flindersi darraghi n. subsp., Eocene, Victoria.

girgylla, *Astralium* (Reeve), Altena, 1939, p. 46, fig. 1a, b, c — Pliocene of Cheribon, Java, and Pleistocene, New Hebrides.

granifer, *Turbo* (*Callopoma*), Martin, 1883, p. 184, pl. 9, fig. 178, Upper Miocene of Java; figured by Pannekoek, 1936, p. 60, pl. 3, fig. 40.

hataii, *Bolma*, McNeil, 1960, p. 34, pl. 7, fig. 5, 9, 14, Miocene or Pliocene Shinzato Tuff, Okinawa (see under *B. modesta* below).

kendengensis, *Astralium* (*Bolma*), Altena, 1938, p. 291, fig. 14a-c, 15a, b, Pliocene, Java (similar to *B. guttata guttata* (A. Adams)).

marshalli, *Turbo*, Thomson, 1908, Upper Eocene and Oligocene, New Zealand.

ornatissimum, *Astralium* (*Calcar*), T. Woods, 1877 (synonym of *B. crassigranosa* (T. Woods)).

pseudomodesta, *Astraea*, Nomura, 1935, p. 208, pl. 10, fig. 1a-c, Pliocene Byoritzu beds of Taiwan (see under *B. modesta* below).

cf. *pseudomodesta*, *Bolma*, McNeil, 1960, p. 33, pl. 16, fig. 10, 23, Pliocene Naha Limestone of Okinawa.

stearnsi, *Astraea* (*Bolma*), Ladd, 1970, C4, pl. 3, fig. 6, 7, Upper Eocene, Eua Is., Tonga (possibly related to *B. tamikoana* (Shikama)).

takitai, *Pachypoma*, Ozaki, 1954, p. 12, text-fig. 1, 2, Pliocene, Japan.

virgata, *Astraea*, Ozaki, 1954, p. 12, pl. 6, fig. 1-6, Pliocene, Japan (similar to *B. guttata millegranosa* (Kuroda and Habe)).

n. sp. ?, *Bolma*, McNeil, 1960, p. 34, pl. 2, fig. 7, Miocene Yonobaru Clay, Okinawa (see under *B. modesta* below).

sp. ind., *Bolma*, McNeil, 1960, p. 33, pl. 7, fig. 15, Miocene or Pliocene Shinzato Tuff, Okinawa (see under *B. modesta* below).

European fossil *Bolma*:

In his revision of Italian Miocene and Pliocene species of *Bolma*, Sacco (1896, pp. 9-19) included seven species in *Bolma (sensu stricto)*: *B. rugosa* Linné with 10 varieties; *B. meynardi* (Michelotti, 1847); *B. taurinensis* Sacco, 1896, with two varieties; *B. granosa* (Borson, 1821) with one variety; *B. muricata* (Dujardin, 1835) with three varieties; *B. borsoni* (Michelotti, 1847) with three varieties; and *B. proborsoni* Sacco, 1896, with one variety. In addition, he included the following six species in *Ormastraliium* Sacco and related groups: *Bolma (Oobolma) castrocarenis* (Foresti, 1876) with one variety; *Ormastraliium fimbriatum* (Borson, 1821) with 13 varieties; *O. subspinosum* Rovereto in Sacco, 1896, with one variety; *O. (Tylastraliium) speciosum* (Michelotti, 1847) with one variety; *O. (T.) taurospeciosum* Sacco, 1896 (a total of 13 species and 43 varieties, not including typical varieties). He compared *Ormastraliium carinatum* (Borson) var. *prohenica* Sacco, 1896 closely with "*Ormastraliium*" *henicum* (Watson), indicating that he thought Italian Pliocene and Indo-Pacific Recent species are congeneric, as we conclude here.

Cossmann (1918, pp. 152-6) synonymised *Oobolma* Sacco with *Bolma* Risso, and included 13 Miocene species and three Pliocene species and four varieties in *Bolma*. He synonymised *Tylastraliium* Sacco with *Ormastraliium* Sacco, ranked *Ormastraliium* as a subgenus of *Bolma*, and included in *Bolma (Ormastraliium)* five Miocene species and the Pliocene species previously included by Sacco (1896). Most of the Miocene species placed in *Bolma* and *Ormastraliium* by Cossmann (1918) had previously been fully documented by Cossmann and Peyrot (1918, pls. 5, 6). More recently a further European fossil, *Bolma belgica*, was included in the genus by Glibert (1952, p. 14, pl. 1, fig. 8) and the Aquitaine relatives were revised and some new species named by Magne and Vergneau-Saubade (1971). Most recently, Baluk (1975, p. 43-6, pl. 6) provided good figures of three species of *Bolma* from the Upper Miocene Korytnica Clay of Poland.

Systematic Descriptions

Genus **Bolma** Risso, 1826

- Bolma* Risso, 1826, p. 117. Type species (monotypy): *Bolma rugosa* Risso (= *Turbo rugosus* Linné, 1767), Miocene to Recent, Europe — Mediterranean.
- Oobolma* Sacco, 1896, p. 14. Type species (monotypy): *Turbo rugosus* var. *castrocarenis* Foresti, 1876, Pliocene, Italy.
- Ormastraliium* Sacco, 1896, p. 15. Type species (original designation): *Trochus fimbriatus* Borson, 1821, Pliocene, Italy.
- Tylastraliium* Sacco, 1896, p. 19. Type species (subsequent designation, Sacco in Cossmann, 1918: 155): "*Turbo michelotti*" Cossmann, 1918 (err. pro *Turbo speciosa* Michelotti, 1847), Pliocene, Italy.
- Pseudastraliium* Schepman, 1908, p. 27. Type species (monotypy): *Astraliium (Pseudastraliium) abyssorum* Schepman, 1908, Recent, Indonesia.
- Incilaster* Finlay, 1926, p. 367. Type species (original designation): *Turbo marshalli* Thomson, 1908, Oligocene and late Eocene, New Zealand.
- Galeoastraea* Habe, 1958, p. 45. Type species (original designation): *Galeoastraea millegranosa* Kuroda & Habe (*nomen nudum*, = *Galeoastraea millegranosa* Kuroda & Habe in Habe, 1958).

Hirasazaea Habe, 1958, p. 46. Type species (original designation): *Trochus modestus* Reeve, 1842, Recent, Japan.

Barnard (1963, p. 217) noted that Watson (1886, p. 131) commented that Risso had spelled the generic name *Bolina*, which is twice pre-occupied. However, reference to Risso (1826, p. 117) showed that the name was originally spelled *Bolma*.

A KEY TO THE RECENT SPECIES OF *BOLMA* (*BOLMA*)
BASED ON THE ADULT SHELL AND OPERCULAR CHARACTERS

1. Shell with axial folds on shoulder 2
Shell without axial folds on shoulder 7
2. Shell with peripheral and basal angles equal to subequal in strength (and in development of spines if present) 3
Shell with peripheral and basal angles unequal in strength and spine development 6
3. Shell large (40-60 mm in height) with broad basal callus 4
Shell small (20-40 mm in height) with narrow basal callus 5
4. Colour of shell greenish, operculum orange *rugosa* (Linné).
Colour of shell pink, operculum white *modesta* (Reeve).
5. Shell with coarsely beaded sculpture, peripheral and basal angles about equal in strength *jacquelineae* (Marche-Marchad).
Shell with fine sculpture, basal angle slightly stronger than peripheral angle *andersoni* (Smith).
6. Shell with wide basal callus occupying about $\frac{2}{3}$ of base *johnstoni* (Odhner).
Shell with narrow basal callus occupying about $\frac{1}{4}$ of base *aureola* (Hedley).
7. Shell with peripheral angulation of penultimate whorl not separated from shoulder of body whorl 8
Shell with peripheral angulation of penultimate whorl separated from shoulder of body whorl 13
8. Shell large (greater than 38 mm in height) *tayloriana* (Smith)
Shell small to medium (less than 35 mm in height) 9
9. Shell with spinose or subspinose peripheral angle, basal angle weak to strong 10
Shell lacking distinct peripheral or basal angles, sculpture undifferentiated *midwayensis* (Habe & Kosuge).
10. Shell with very short spines on peripheral angle, height of spire usually greater than maximum width of shell, no trace of sutural channel, basal callus pale yellow *somaliensis* nov.
Shell with very short to long spines on peripheral angle, height of spire usually less than, or about equal to, maximum width of shell, basal callus white ... 11

11. Shell with long spines (about equal to width of shoulder) on peripheral angle *persica* (Dall).
 Shell with short spines (equal to ½ width of shoulder or less), or none, on peripheral angle 12
12. Shell with orange or yellow basal callus, no sutural channel
 *tamikoana* (Shikama).
 Shell with white basal callus, with narrow to moderate sutural channel
 *guttata* (Adams).
13. Shell with 1-3 spiral rows of gemmules or scales between peripheral and basal angles 14
 Shell with 4 or more rows of gemmules or scales between peripheral and basal angles 17
14. Shell with wide sutural channel bordered below by a row of nodules much stronger than those on remainder of shoulder *henica* (Watson).
 Shell with moderate to very narrow sutural channel bordered below by a row of gemmules only slightly stronger than those on remainder of shoulder 15
15. Shell with long spines (about equal to width of shoulder) *persica* (Dall).
 Shell with short spines (equal to ½ width of shoulder or less) or spines absent 16
16. Shell with basal and peripheral rows of spines subequal and visible on spire whorls *girgyllus* (Reeve).
 Shell with peripheral rows of spines and basal row of gemmules or scales, peripheral row only visible on spire whorl *guttata* (Adams).
17. Shell with distinct peripheral and basal angles, more than 10 spines on body whorl 18
 Shell with distinct peripheral angle and weak basal angle, less than 8 spines on body whorl *kermadecensis* nov.
18. Shell with 4-5 spirals between basal and peripheral angles, spines moderate to long *henica* (Watson).
 Shell with more than 10 spirals between basal and peripheral angles, spines short to rudimentary 19
19. Base with axial rugae, shell fawn *recens* (Dell).
 Base mostly smooth, with no axial rugae, shell pink and white
 *bartschi* Dall.

Subgenus *Bolma* (sensu stricto)A. ***Bolma rugosa* group*****Bolma andersoni*** (Smith, 1902)

Fig. 1j-n

Astralium (Bolma) andersoni E. A. Smith, 1902: 248, pl. 4, fig. 7.

Astralium (?Bolma) andersoni. — G. B. Sowerby 3rd, 1903: 230, pl. 5, fig. 5.

Astraea andersoni. — Barnard, 1963: 219.

DIAGNOSIS. Shell: height about equal to diameter, base almost flat, whorls strongly angled but concave between angulations. Peripheral angulation margining base, bearing 12 large, rounded, hollow, scale-like spines per whorl; upper angulation at half whorl height, bearing 9 to 14 large nodules, expanded laterally into prominent spines on juvenile shell but reduced to rounded, scale-tipped nodules on last few whorls of sub-adult specimen. A weak basal angulation represented by weakly gemmate spiral cord near margin of base of juvenile shell, and by weakly defined cord and marked colour change in sub-adult. Upper surface of whorls sculptured with low, narrow-crested axial folds extending from upper suture to each nodule of upper angulation, and entire surface densely covered with fine, wavy spiral lirae, more prominent on nodules than elsewhere; one cord between upper and peripheral angulations slightly more prominent than other spiral lirae. Base bearing narrow, smooth callus in central fifth of radius, remainder sculptured with about 10 low, narrow, finely scaled spiral cords and many fine interstitial lirae. Nodule rows and lower half of whorls bright purplish pink, shading to a more yellow tinge on upper half of whorls and to pinkish yellow on base; basal callus pale yellow.

Operculum: Not seen.

DIMENSIONS. Holotype: height 27 mm, diameter 31 mm (Smith, 1902); figured subadult: height 31.6 mm, diameter 34.3 mm; figured juvenile: height 12.1 mm, diameter 14.0 mm. Maximum size recorded 85 mm in height (Barnard, 1963, p. 220).

TYPE LOCALITY. Off Durban, South Africa, ex stomach of fish.

HOLOTYPE. Smith (1902, p. 249) stated that the holotype was in the collection of "Mr. Anderson, junr., of Durban." Its present location is unknown.

MATERIAL EXAMINED. Off Natal (NM, 3729) (figured sub-adult); off Durban, ex gut loggerhead turtle, 1973 (NM, A235) (2 juveniles).

OTHER LOCALITIES. South Africa; 32°45'S, 28°26'E, near Cape Morgan, 66 m; off Port Shepstone, 44 m; off Itongazi River, 46 m (all from Barnard 1963, p. 220).

Bolma andersoni is similar in shape, type of sculpture, and coloration to *B. jacquelineae* (Marche-Marchad), *B. modesta* (Reeve) and *B. girgylla* (Reeve), but differs from all related species in its flatter and more finely sculptured base, in its single row of relatively large, rounded nodules above the peripheral row, and in its very reduced basal angulation. The larger of the two juvenile specimens available bears long spines on the nodules of the upper angulation (fig. 1j-k), but these have been broken off the sub-adult specimen examined. Barnard (1963, p. 220) assigned shells up to 85 mm high to *B. andersoni*. The unidentified juvenile specimen figured by Barnard (1963, fig. 7 f, g,) is similar to available juveniles of *B. andersoni*, and probably belongs in this species; it is from off Unkomaas, Natal, in 73 m (SAM, A9236).

***Bolma aureola* (Hedley, 1907)**

Figs 1a-c, 18h, i

Astrarium (*Cookia*) *aureolum* Hedley, 1907: 491, pl. 21, figs 56-58.

Cookia aureolum. — Ripplingale & McMichael, 1966: 37, pl. 2, fig. 16; Habe & Kosuge, 1966: 13, pl. 4, fig. 8.

DIAGNOSIS. Shell: Whorls convex, with scaly, nodular sculpture and medium to short peripheral spines. Peripheral angulation spinose, sharp in early spire whorls, at lower

$\frac{1}{3}$ - $\frac{1}{4}$, becomes rounded on later whorls, weak and rounded in large shells. About 10-15 short spines on last whorl of medium sized shells; up to 22 in large shells (such as the holotype). Spines relatively long in juveniles. A second angle just below periphery also becomes rounded on large shells. Eight-nine squamose spiral ribs on base and 10 on side of penultimate whorl; lower spirals on sides of whorls very oblique and pass laterally on to the peripheral spines. One spiral between peripheral and basal angles, the latter having an additional spiral cord. Basal callus narrow, covering about a quarter of base, bright orange; columella white. Surface purplish-red, brick-red or dull orange, often with a white and pale olive marbled band in the centre of the upper surface of the whorls of immature shells.

Operculum: Oval, with large marginal rib and central spiral depression as in *B. rugosa*, but more elongate than that species. Very similar to that of *Lithopoma (Cookia) sulcata*, which, however, is white, not pinkish-orange as in *aureola*.

DIMENSIONS. Largest shell seen (C. 37246): height 88 mm, diameter 98 mm. Holotype: height 87 mm, diameter 92 mm.

TYPE LOCALITY. S. of Masthead Island, Capricorn Group, Queensland, 37 m.

HOLOTYPE. AM, C. 18807.

OTHER MATERIAL EXAMINED. (all AM; numbers in brackets show number of specimens). *Queensland*: Gillett Cay, Swain Reefs, 69 m, C. 72698 (1); Northwest Is., Capricorn Group, C. 72695 (1); Heron Is., C. 72693 (1); 27 km E. of Heron Is., 55 m, C. 72690 (1); Masthead Reef, C. 37246 (1); off Bundaberg, C. 72697 (2); off Burnett Heads, C. 72694 (4); prawn trawl south of Fraser Is., C. 72693 (3); Tin Can Bay, C. 62499 (3); Off Wide Bay, 46 m, C. 72692 (2), 55 m, C. 72703 (1); trawled in Wide Bay, C. 81962 (2); Off Jumpin Pin Bar, near Southport, 31 m, C. 63161 (2); off Southport, C. 72689 (1); *New South Wales*: off Tweed Heads, northern N.S.W., 55 m, C. 72691 (3).

Small and medium-sized shells are similar to *B. modesta* (Reeve), from which they differ in their brighter colour, longer spines, narrower callus pad, and more strongly sculptured operculum. Still more alike is *B. johnstoni* (Odhner), which has closely similar spination, but has a widely spread basal callus and a convex, centrally granular operculum.

***Bolma girgylla* (Reeve, 1843)**

Fig. 2a-c

Trochus girgyllus Reeve, 1843: 185; Reeve, 1848, *Trochus*, pl. 10, fig. 53.

Turbo (Bolma) gyrillus (sic). — G. B. Sowerby 3rd, 1886: 208, pl. 499, fig. 73.

Astraea (Bolma) modesta girgyllus. — Hirase, 1938: 41, pl. 74, fig. 8.

Astraliium girgyllus. — Altena, 1939: 46, pl. 3, fig. 1a-c.

Astraea modesta girgyllus. — Yen, 1942: 182, pl. 12, fig. 24 (type figured).

Astraea girgyllus. — Kuroda & Habe, 1952: 39.

Galeoastraea (Hirasazaea) girgyllus. — Habe, 1958: 55; Okutani, 1972: 79, pl. 1, fig. 3, 4.

Bolma girgyllus. — Oyama & Takemura, 1960: *Bolma*, fig. 5, 6.

DIAGNOSIS. Shell: Whorls rounded, sculpture nodulose. Peripheral angle at middle of whorls on spire and body whorl, with 2 rows of long spines; spines on uppermost row sometimes very long and heavy, about 11-14 on body whorl. Subsutural zone lightly convex, with 2 rows of gemmules slightly stronger than the 7 rows on the remainder of convex shoulder. Peripheral angulation and zone between it and prominent basal angulation with about 3 irregular rows of gemmules equal in size to those on shoulder and outer base. Base with 10-12 rows of beaded spines, enlarging towards the umbilical area. Basal callus narrow, orange, columella white. Outer lip expanded when mature. Colour pinkish fawn, sometimes with dark purplish dorsal surface, or a series of dark purple spots on the upper shoulder (description mainly based on specimen from Moluccas, Indonesia).

Operculum: White, with convex surface, central area with a slight depression.

DIMENSIONS. Lectotype (here chosen): height 57.4 mm, diameter 57.2 mm. Zenisu Bank, Japan: height 42.9 mm, diameter 41.6 mm.

TYPE LOCALITY. "China."

TYPES. Lectotype (1968673/1) and paralectotype (1968673/2) in BMNH. The lectotype, chosen here, is the specimen figured by Yen (1942).

OTHER MATERIAL EXAMINED. "Mollukken, Indonesie," coll. Schepman, 1 spec. (Zoologisch Museum, Amsterdam; not the "Siboga" specimen recorded as *Astraliium girgyllus* by Schepman (1908), which is *B. tamikoana* (Shikama)); Zenisu Bank, S. of Izu Peninsula, Japan, 34°00.1'N, 138°51.0'E, 90 m (Tokai Regional Fisheries Lab.) (1), recorded by Okutani (1972, p. 79); Stn 438A, Upper Kere River, 166°56'74"E, 15°34'S, Espirito Santo, New Hebrides, Pleistocene (U.S. Geological Survey, Washington, D.C.) (1).

OTHER LOCALITIES. Tosa Bay, Shikoku, Japan (Oyama & Takemura, 1960); rare on rocky bottom in 50-100 m, from Kochi Pref., Japan, and the China Sea (Habe, 1964).

FOSSILS. Recorded fossil from the Pliocene of Cheribon, Java (Altena, 1939), but the identification was questioned by McNeil (1960, p. 34). We have not seen the specimen but the figures given by Altena (pl. 3, fig. 1a-c) closely resemble *B. girgylla*.

Bolma girgylla superficially resembles *B. modesta* (Reeve) but differs in the minor spiral sculpture consisting of rounded gemmae rather than scales, in there being consistently two rows of longer spines on the last whorl, in lacking any axial folds on the shoulder and in the narrower basal callus.

This species shows intermediate characters between the *B. rugosa* and *B. guttata* groups but is placed here because of its large size and because it has been frequently associated with *B. modesta*.

Bolma jacquelineae (Marche-Marchad, 1957)
Figs 2f-j; 18e-g

Astraea (Bolma) jacquelineae Marche-Marchad, 1957: 200, pl. 1, figs 1, 2.

DIAGNOSIS. Shell: Whorls prominently and equally bi-angled, strongly sculptured. Peripheral angulation and basal angulation equal in strength, separated by a concave area. Spines and spiral cords rather weakly developed; 15 low, rounded nodules on each angulation on last whorl, and 6 weak, gemmate cords on sides of whorls. Basal callus narrow. Surface red tinged with violet, early whorls white.

Operculum: Nearly circular, with central depression and outer concentric ridge as in *B. rugosa*; surface pustulose; wine-red with white edges.

DIMENSIONS. Holotype: height 31 mm, diameter 30 mm; figured specimen: height 20.9 mm, diameter 22.8 mm; largest specimen seen: height 37 mm, diameter 33 mm.

TYPE LOCALITY. 32 km W. of Freetown, Sierra Leone, 25 m.

HOLOTYPE. In Muséum National d'Histoire Naturelle, Paris.

MATERIAL EXAMINED. Off Tema, Ghana, W. Africa (NMW; AM; DMNH) (several).

OTHER LOCALITIES. Île du Prince, Guinea-Bissau (Portuguese West Africa), 75 m (Marche-Marchad, 1957). Tomlin & Shackelford (1915, p. 267) recorded *B. rugosa* from the island of São Thomé in the Gulf of Guinea. Mr. Peter Dance (*in litt.*) informed us that this specimen (Fig. 2j), now in NMW is *B. jacquelineae*.

Marche-Marchad (1957, p. 201) compared the shell closely with *B. johnstoni* (Odhner), noting that *B. jacquelineae* "differs by its much straighter and shorter spines, its finer and more regular spiral sculpture" (free translation). It is also smaller and taller spired than *B. johnstoni*.

Bolma johnstoni (Odhner, 1923)

Fig. 2k-n

Astraea (Bolma) johnstoni Odhner, 1923: 9, pl. 1, figs. 15-17.

Astraea johnstoni. — Nicklès, 1950: 45, text-fig. 31.

Astraea (Astralium) johnstoni. — Anon., 1972: 13, 3 figures.

DIAGNOSIS. Shell: Whorls convex, with scaly, nodular sculpture and moderately long peripheral spines. Peripheral angulation on lower 1/3 of spire whorls, somewhat rounded on last whorl. Twelve spines on body whorl. A second angle below periphery is rather indistinct on body whorl. Five coarsely squamose, oblique cords below, the lowest at the basal angulation. Five sparsely nodulose basal cords. Basal callus broad, extending over much of base, reddish brown, columella white. Surface light red.

Operculum: Quadrately oval, smooth and convex with granular central area; reddish-brown with white margins.

DIMENSIONS. Not known.

TYPE LOCALITY. Porto Alexander, Angola, 60 fathoms (110 m).

HOLOTYPE. Natural History Museum, Stockholm.

OTHER LOCALITIES. Apart from the three specimens from the type locality, the only recorded specimens are two from off Orstom, Gulf of Guinea, in 85 m (Anon. 1972, p. 13).

Odhner (1923, p. 10) compared this species only with *B. rugosa*, but it is more similar to *B. modesta* and *B. aureola* than to *B. rugosa*. It differs from *B. modesta* in the more regularly squamose upper surface, in developing a single peripheral row (rather than two or three rows) of spines, and in the reddish brown (rather than white) operculum; and from *B. aureola* in its markedly smaller size (assuming Odhner's figure is natural size; he did not publish dimensions), the more widely spread basal callus, the lack of a spiral groove in the operculum and the markedly fewer rows of granules; and from both in its reddish-brown, rather than orange, basal callus.

Bolma modesta (Reeve, 1842)

Figs 1d-f; 2d, e; 18c, d

Trochus modestus Reeve, 1842: 165, pl. 218, fig. 14; Reeve, 1843: 185; Reeve, 1848: 139, pl. 13, fig. 67; Reeve, 1861: *Trochus*, pl. 10, fig. 56.

Turbo (Bolma) modestus. — G. B. Sowerby 3rd, 1886: 208, pl. 505, fig. 150.

Bolma modesta. — Kuroda, 1941: 77; Kira, 1955: 20, pl. 10, fig. 5; Oyama & Takemura, 1960: *Bolma*, fig. 3, 4.

Astraea modesta. — Yen, 1942: 182; Kuroda & Habe, 1952: 39.

Astraea (Bolma) modesta. — Nomura & Zinbo, 1934: 146, pl. 5, fig. 37; Hirase, 1938: 41, pl. 74, fig. 6.

Galeoastraea (Hirasazaea) modesta. — Habe, 1958: 55, pl. 3, fig. 13; Kira, 1961: 20, pl. 10, fig. 5; Kira, 1962: 18, pl. 11, fig. 5; Kuroda *et al.*, 1971: 49, pl. 14, fig. 2; Okutani, 1972: 79.

DIAGNOSIS. Shell: Whorls rounded, sculpture mostly scaly. Peripheral angle at middle of whorls on spire, with 1-2 (3 in a few specimens) rows of short to relatively long spines on the rounded body whorl. Sculpture very variable. Subsutural zone concave, sometimes bearing strongly prosocline, high, thin growth lamellae. Upper surface of whorls bearing 4-8 rows of hollow scales, and in some specimens short, low, rounded axial folds below suture. Peripheral angulation and zone between it and weak basal angulation bears row of small to large, hollow, scale-like spines, and on most specimens a further row of spines forms weak third angulation between other angulations. Up to 3 secondary rows of spines present, and 2-6 peripheral rows of minute scales. Base with 8-9 spiral rows of low, hollow scales. Basal callus broad, bright orange-yellow; columella white. Outer lip expanded when mature. Surface pinkish mauve, with a nacreous gleam.

Operculum: Slightly oval, with a prominent marginal ridge; central area almost flat, surface irregularly and minutely granular; white.

DIMENSIONS. Figured specimens: height 50 mm, diameter 56 mm; height 45.7 mm, diameter 49 mm.

TYPE LOCALITY: Japan.

TYPES: Reeve's (1842) figured specimen was not found in the BMNH, but the specimen in fig. 2d-e was identified as this species by Reeve (BMNH, 19782).

OTHER MATERIAL EXAMINED. Japan: Honshu (AM) (1); off Kii, Honshu, 90 m (AMNH) (3), (USNM) (2), (AM) (2); Nagasaki, Kyushu (ANSP) (2), (USNM) (2) (S. Australian Museum) (2); Boshu (USNM) (4); Hizen, Kyushu (AMNH) (2); Sagami Bay (ANSP) (3), 18-37 m (AMNH) (3); Tosa Bay, Shikoku (ANSP) (5); off Honshu Is., U.S. Fisheries Commission Stn 3727, 62 m and Stn 3734, 66-88 m (USNM) (3 and 2); Miara (USNM) (1); Mikawa (USNM) (2); Hashimoto (USNM) (1); off Hondo, S. coast, U.S. Fisheries Bureau Stn 3703, 57 m (USNM) (1); off Pratas Is., China Sea, 274 m, U.S. Bureau of Fisheries (USNM) (1); Loo Choo Ids (= Ryukyu Ids) (ANSP) (31); Iagashima Is., 91-146 m (Bishop Museum, Honolulu) (7).

OTHER LOCALITIES. Off Cape Ashizuri, Kochi Peninsula (Oyama & Takemura, 1960); "South of central Japan at 10-20 fathoms (= 18-36 m) deep" (Kira, 1962, p. 18); seven localities in Sagami Bay, and "Honshu (Boso Peninsula as northern limit), Shikoku, Kyushu, Formosa and China. On rocks and gravels of 20-100 m deep" (Kuroda *et al.*, 1971, p. 49).

Recorded as a fossil from the Pliocene Ryukyu Limestone of Kikaizima, Ryukyu Islands, by Nomura & Zinbo (1934, p. 146, pl. 5, fig. 37).

Several Miocene and Pliocene fossil species from Taiwan and Okinawa appear to fall within the variation of Recent *Bolma modesta* to judge from figures given by McNeil (1960): *Astraea pseudomodesta* Nomura, 1935, p. 208, pl. 10, figs. 1a-c; *Bolma* cf. *pseudomodesta* McNeil, 1960, p. 33, pl. 16, figs. 10, 23; *Bolma* sp. ind. McNeil, 1960, p. 33, pl. 7, fig. 15; *Bolma hataii* McNeil, 1960, p. 34, pl. 7, figs 5, 9, 14; *Bolma* n. sp.? McNeil, 1960, p. 34, pl. 1, fig. 7.

***Bolma rugosa* (Linné, 1767)**

Figs 1g-i; 18 a, b, j-l

Turbo rugosus Linné, 1767: 1234; Gmelin, 1791: 3592, sp. 14; Link, 1807: 132; Brocchi, 1814: 362; Borson, 1821: 90; Dillwyn, 1817, vol. 2, p. 829, sp. 33; Lamarck, 1822: 46; Deshayes, 1843: 197; Reeve, 1848: *Turbo*, pl. 6, sp. 25, fig. 26; Locard, 1892: 203, fig. 179; Nobre, 1931: 215, pl. 25, fig. 1.

Turbo calcar var. B. Gmelin, 1791: 3592.

Trochus rugosus. — Röding, 1798: 82; Philippi, 1836: 178; Philippi, 1844: 151.

Turbo armatus Dillwyn, 1817, vol. 2: 829, sp. 32 (immature).

Turbo (Bolma) rugosus. — Bucquoy, Dautzenburg & Dollfus, 1884: 332, pl. 38, figs 1-11 (very full synonymy and excellent figs); G. B. Sowerby 3rd, 1886: 208, p. 498, fig. 60.

Bolma rugosa. — Risso, 1826: 117; Troschel & Thiele, 1879: 217, pl. 21, fig. 9 (radula); Sacco, 1896: 9-11, pl. 1, figs 16-22 (with long synonymy and 10 varieties); Cossmann, 1918: 153, pl. 4, figs 24, 25.

Astraea (Bolma) rugosa var. *turboides* and *delphinoides* Coen, 1937: 145.

Astraea (Bolma) rugosa. — Nordsieck, 1968: 33, pl. 6, figs 17. 40.

DIAGNOSIS. Shell: Spire turbinata, with strongly convex whorls and nodulose sculpture. Spire whorls angled in middle, last whorl with moderate basal angle at lower $\frac{1}{3}$. Upper angulation with medium to long spines on early spire whorls, extending to body whorl in some specimens. Spines on basal angulation of a few specimens. Sculpture of low spiral cords, crossing low, widely spaced nodules below the suture; subsutural nodules taper off towards periphery as low, rounded, slightly opisthocline radial ribs spaced their own width apart. Surface covered with high, thin, widely spaced, markedly prosocline, axial growth lamellae which are raised into hollow scales where they cross the spiral cords. 4-5 rather weak spirals on upper surface of penultimate whorl, 1 strong and usually 2 weak spirals between the peripheral and basal angulation and 4-5 spirals on base. Basal callus broad, covering up to half of base, brownish-orange; columella nacreous white. Outer lip slightly expanded when fully mature. Surface olive green, with white or orange patches on some specimens.

Operculum: Oval with thick, rounded, spiral marginal rib around a shallow central depression, its initial spiral hidden by a small swelling, smooth; bright brownish-orange, columellar edge and central swelling white.

DIMENSIONS. Figured specimen: height 47.5 mm, diameter 48 mm.

TYPE: Dance (1967: 22) stated that there is a specimen of *B. rugosa* in the Linnean Collection, housed by the Linnean Society of London, available for designation as a lectotype.

MATERIAL EXAMINED. Many specimens in several museums.

LOCALITIES. Recorded by many authors from a large number of localities from the Mediterranean Sea and the central eastern Atlantic south to the Canary Islands, to at least 200 m deep.

This species has been listed or figured in so many works since 1767 that we have not attempted to compile a complete synonymy. *Bolma rugosa* occurs commonly also in the Miocene, Pliocene and Quaternary of countries around the Mediterranean (see synonymy in Sacco, 1896). The variable sculpture has led to recognition of numerous varieties by both paleontologists (notably Sacco, 1896) and neontologists, and probably several southern European nominal species of fossil *Bolma* will be found to be part of the variation of *B. rugosa*.

B. *Bolma guttata* group.

***Bolma anacanthos* n. sp.**

Fig. 3j-l

DIAGNOSIS. Shell: Moderately large, with relatively low spire, sculptured with numerous spiral cords bearing granules or scales. Protoconch typical, of 2½ whorls, teleoconch of 4½ whorls. Peripheral angle at lower quarter of spire whorls, forming a sutural channel that becomes progressively shallower down the spire. Spire whorls flat above periphery, last whorl weakly convex with periphery at centre and a second weak angulation at upper third of height. Below periphery a weak basal angulation is defined by two slightly raised cords; all angulations become progressively weaker over last whorl so that last quarter is evenly rounded. Sculpture of approximately equally strong spiral cords over whole surface which, on upper part of whorls bear small, low, closely spaced, sharply rounded granules; on progressively lower cords the granules become progressively more scale-like. Subsutural spiral cord with rounded granules about twice size of others. About 20 spirals on last whorl and base, 5-7 on penultimate whorl above periphery. Base with a thin callus spread over about a third of its area, separated from columella by a groove.

Operculum: Unknown.

DIMENSIONS. Holotype: height 21.45 mm, diameter 20.76 mm.

TYPE LOCALITY. Jan Juc Formation, Zone 3 (Bird Rock ledge), Bird Rock Cliffs, Torquay, Victoria; F. A. Cudmore Colln.

HOLOTYPE. NMV, P. 31183.

OTHER MATERIAL EXAMINED. Bird Rock Cliffs, Torquay, G. B. Pritchard Colln, coll. J. T. Jutson, P.31186, NMV (2 paratypes).

AGE. Janjukian (Oligocene Australian local stage).

The new species is similar to *Bolma guttata millegranosa* (Kuroda & Habe) in general appearance, but differs in its smaller size, in having a weaker sutural channel, in lacking a marked basal angulation, in having a very much less marked peripheral angulation lacking spines, and in having a more closely sculptured base. It also closely resembles *B. tamikoana* (Shikama), from which it differs in its smaller size, in lacking all spines, in its wider basal callus, and in having a narrow sutural channel.

***Bolma austroconica* n. sp.**

Fig. 3a, b

DIAGNOSIS. Shell: Small, tall spired, with spiral rows of relatively coarse gemmae and a sharply angled periphery. Protoconch typical, of 3 whorls, teleoconch of 4¼ whorls. Whorls flat-sided, spire outline slightly convex for most of its height but strongly convex near apex. Suture simple. Periphery at basal angulation, i.e. at lower suture of spire whorls, sharply angled on last whorl. Sculpture of 4 spiral rows of rounded gemmae on penultimate whorl, the uppermost, third and fourth rows equally large, the second row weaker but becoming progressively stronger down the spire to be of equal strength to other rows on last half of last whorl. The third cord from upper suture bears short spines on first 2½ teleoconch whorls, the spines becoming progressively stronger over first half-whorl and then progressively weaker, merely rounded gemmae over last 1½ whorls. Fourth spiral forms basal angle of last whorl. Base flat, with 4 rows of gemmae smaller than those above periphery. Columella simple, no basal callus in material examined.

Operculum: Unknown.

DIMENSIONS. Holotype: height 15.45 mm, diameter 11.30 mm.

TYPE LOCALITY. Jan Juc Formation, "Spring Creek" = Bird Rock Cliffs, Torquay, Victoria.

HOLOTYPE. NMV P.31184, ex Mrs. M. Robertson Colln.

OTHER MATERIAL EXAMINED. Bird Rock Cliffs, Torquay, G. B. Pritchard Colln, P.31180, NMV (1 paratype); same locality, F. A. Cudmore Colln, coll. T. S. Hall, NMV (1 paratype); Jan Juc Formation, zone 4 (above Bird Rock ledge), Bird Rock Cliffs, Torquay, F. A. Cudmore Colln, P.31185, NMV (1 paratype).

AGE. Janjukian (Oligocene Australian local stage).

This new species is similar to *Bolma crassigranosa* (T. Woods) but differs in its flat-sided whorls, its more sharply angled periphery and its more equal rows of gemmae lacking marked spines. It is also similar to *B. flindersi* (T. Woods) but differs in its smaller size, taller and narrower form, its less numerous and more widely spaced spiral cords, and its lack of spines and sutural channel on the adult whorls.

***Bolma crassigranosa* (T. Woods, 1877)**

Fig. 3d-f

Gibbula crassigranosa T. Woods, 1877: 98; May, 1919: 70, pl. 8, fig. 4; Ludbrook, 1967: 66, pl. 2, fig. 18.

Astralium (Calcar) ornatissimum T. Woods, 1877: 98.

Astralium (Bellastraea) ornatissimum. — Ludbrook, 1967: 66, pl. 2, fig. 16.

DIAGNOSIS. Shell: Small, with tall to moderately tall spire, simple sutures, and convex whorls bearing spiral rows of large gemmae. Periphery weakly to strongly angled, prominent basal angle formed by protruding row of gemmae. Spire whorls with two major spiral cords, the upper bearing relatively large, axially elongated gemmae; the lower, at whorl centre, forms the peripheral angle and bears spines that are moderately

large to rudimentary in different individuals, and become progressively smaller down the last two teleoconch whorls. A weak third row of low gemmae lies immediately above the suture of spire whorls and forms the basal angulation on the last whorl; a weak interstitial row of gemmae lies between each pair of major ones on upper surfaces of whorls. Base flat or slightly convex, bearing three widely spaced rows of low gemmae, the innermost close to the columella. Columella narrow, not expanded into a basal callus.

Operculum: Unknown.

DIMENSIONS. Figured specimen, P. 31189: height 19.5 mm, diameter 13.4mm; P. 31188: height 11.8 mm, diameter 11.5 mm; largest fragment observed is 16.5 mm in diameter.

TYPE LOCALITY. Both *Gibbula crassigranosa* and *Astralium ornatissimum* were described from "Table Cape" (= Fossil Bluff and Freestone Cove, near Wynyard), northern Tasmania.

HOLOTYPE. Tasmanian Museum, Hobart.

MATERIAL EXAMINED. Freestone Cove Sandstone (= Lower bed), Freestone Cove, near Wynyard, northern Tasmania; F. A. Cudmore Colln., NMV, P.31189 (10); Atkinson Colln., NMV, P.31188 (1).

AGE. Longfordian (basal Miocene Australian local stage).

Ludbrook (1967, pl. 2, figs. 16, 18) figured the holotypes of *Astralium ornatissimum* and *Gibbula crassigranosa*. Later photographs of the holotype of *Astralium ornatissimum* show it to be a worn, broken, juvenile specimen of *Bolma crassigranosa*. The two names were proposed at the same time and, although the name *ornatissimum* has page priority, as first revisers we choose the name *Astralium crassigranosum* as the valid name to be used for the taxon because it is based on a better specimen. May (1919, p. 70) also noted that, from comparison of "cotypes", *G. ornatissima* and *A. crassigranosa* are "scarcely distinct." *Bolma crassigranosa* is easily distinguishable from all other Australian fossil species of *Bolma* by its tall spire and its coarse sculpture of two main rows of large gemmae.

***Bolma bartschi* Dall, 1913**

Fig. 6a-h

Bolma bartschi Dall, 1913: 591; Dall, 1925: 6, pl. 36, fig. 9; Kosuge, 1972: pl. 4, figs 8, 9.

Turbo asteriola Dall, 1925: 28, pl. 36, figs 1, 7; Kosuge, 1972: pl. 4, figs. 6, 7.

Astraea (?) *asteriola*. — Kuroda & Habe, 1952: 39.

DIAGNOSIS. Shell: Relatively tall spired, with convex shoulders, a wide flat area between basal and peripheral angulations, peripheral spines long in juvenile and very short in adult. Moderately prominent peripheral angulation in centre of spire whorls and at upper third of last whorl, bearing moderately long, narrow, ventrally directed spines (12 on last whorl) in juvenile but, as usual in *Bolma*, spines become progressively smaller during growth so that last whorl of adult bears 15 low, scale-like nodules. Basal angulation prominent, bordered by a narrow, squamose cord. Sculpture of whorl upper surfaces consisting mainly of a prominent subsutural row of rounded, closely spaced gemmae, approximately 27 on last whorl of juvenile and 29 on last whorl of adult, with a few sparse rows of low, rounded gemmae developing down the spire on the gleaming, weakly

spirally lirata area between subsutural cord and periphery; row below subsutural cord develops on second whorl of juvenile specimen and fifth row of adult specimen; adult develops progressively more cords to bear three intermediates on this area on last part of last whorl. Area between angulations weakly spirally lirata in juvenile, bearing fine, regular, smooth, spiral threads in adult, about 17 on last whorl of holotype. Base shining and faintly spirally lirata in juvenile, with about 15 weak, smooth, spiral threads in adults, the six near the margin regular and close as on lateral area, the rest low, widely spaced and ill-defined. Basal callus very thin, transparent, polished, spread over about $\frac{1}{8}$ of base near inner lip in juvenile, $\frac{1}{3}$ of base in adult. Surface between suture and periphery marked light and dark purplish red to magenta, peripheral and basal angulation cords light magenta red between white or pink nodules and spines, a few light magenta red axial flames on vertical lateral areas, rest of shell pale cream; parietal wall and narrow basal area near columella white, inner edge of columella nacreous, outer edge of columella white; entire surface with a nacreous gleam.

Operculum: White, thick and strongly convex with a weakly granular, very slightly depressed centre in juvenile; relatively thin and weakly convex with very weakly defined spiral groove in centre and faint, concentric, marginal striations in adult.

DIMENSIONS. Holotype of *B. bartschi*: height 30 mm, diameter 35 mm; holotype of *B. asteriolo*: height 14 mm, diameter 20 mm (including spines).

TYPE LOCALITIES. *Bolma bartschi*: Albatross Stn 5629, off Dowarra Is., near Ternate, Moluccas, 375 m; *B. asteriolo*: Albatross Stn 4924, Colnett Strait, eastern Sea of Japan, 291 m.

HOLOTYPES. Both in USNM; *B. bartschi*, 214444; *B. asteriolo* 205733.

Examination of the holotypes of *Bolma bartschi* and *Turbo asteriolo* suggests that the specimen of *T. asteriolo* is a juvenile specimen of *B. bartschi*. It agrees with the much larger holotype of *B. bartschi* in its cream and red colour, its shape and its sculpture, but differs in having longer spines, pink (instead of white) subsutural nodules without the reddish purple between them, with secondary gemmules commencing after $2\frac{1}{4}$ whorls (compared with after $4\frac{3}{4}$ whorls (i.e. first $\frac{1}{4}$ of body whorl) in *bartschi*) and a markedly more convex operculum. The apical spines are obviously broken off the holotype of *B. bartschi* and the spines presumably decrease in length down the shell as happens in other species of *Bolma*, so that this feature is presumably correlated with the small size of the holotype of *B. asteriolo*. The differences observed in the operculum are probably due to a change with growth; as it becomes more flattened it develops a weak central spiral groove in the larger specimen. Only these two specimens of *B. bartschi* are known to us.

The other differences noted above between the 2 holotypes do not seem to us to be of sufficient magnitude to separate them as different species.

***Bolma flindersi* (T. Woods)**

We consider the following two Australian Tertiary taxa to be subspecies in the lineage of *Bolma flindersi*.

***Bolma flindersi darraghi* n. subsp.**

Fig. 5a-h

DIAGNOSIS. Shell: Small, spire moderately tall, depressed pagodiform, with narrowly channelled sutures, usually with 3 rows of short spines on body whorl. Peripheral angle at about lower $\frac{1}{3}$ on spire whorls and about middle of body whorl;

bearing moderate to short, hollow, forwardly directed, horizontal to slightly upwardly directed spines, 15-18 on body whorl. A row of short spines, intermediate in size between the peripheral spines and the scales on the basal angulation, lies in the lightly convex space between the two angulations. Base with 5-6 close, scaly spiral cords and upper surface of body whorl with 4 well-spaced, gemmate, spiral rows of granules, the uppermost (subsutural) strongest, the remainder decreasing in strength towards the periphery. Fine growth lamellae strongly prosocline. Mature aperture and basal callus not seen. Basal callus very narrow; separated from columella by a weak depression in subadult.

Operculum: Unknown.

DIMENSIONS. Holotype: height 13.00 mm, diameter 14.02 mm; figured paratype: height 11.96 mm, diameter 12.94 mm.

TYPE LOCALITY. Brown's Creek Clay, below *Notostrea* greensand, Washout 1, nearest Brown's Creek, Johanna, coast west of Cape Otway, Victoria. Coll. T. A. Darragh, 20 Nov. 1970, holotype and 7 paratypes.

HOLOTYPE. NMV, P.30767.

OTHER MATERIAL EXAMINED. As above, 9.4 m below *Notostrea* greensand, Washout 1, nearest Brown's Creek, Johanna, coast west of Cape Otway, Victoria. Coll. T. A. Darragh, 24 Feb. 1971, 4 paratypes (NMV, P.30768). Pallinup Formation, 25 km N. of Walpole townsite along Thomson Highway, Western Australia. Coll. T. A. Darragh and G. W. Kendrick, 30-31 August, 1973 (4) (WAM 78.922); (3) (NMV, P. 4775-6).

AGE. Aldingan (Upper Eocene Australian local stage).

The new subspecies differs from *B. flindersi flindersi* in having a more pagodiform whorl outline, a shorter spire, a much stronger basal angulation, narrower spines, and sculpture of more numerous rows of finer gemmae. It seems likely that *B. flindersi darraghi* is the direct ancestor of *B. flindersi flindersi*. Three specimens (NMV, F.30747 (2 specimens) and NZGS, WM11742 (1 specimen)) from the Jan Juc Formation at Bird Rock Cliffs, Torquay, Victoria (Janjukian Stage, Oligocene) are slightly smaller than *flindersi flindersi*, are of similar outline and resemble in most details the Eocene shells from Johanna, but have very markedly longer peripheral spines (fig. 3c). They are interpreted as a long-spined form intermediate between *B. flindersi darraghi* and *B. flindersi flindersi* in an evolutionary lineage. The Western Australian Eocene specimens have no spines, probably due to wear, and up to 6 (instead of 4) rows of gemmules on the shoulder (fig. 5f-h). They probably represent a geographic form of *B. flindersi darraghi* but are not named because of the poor condition of the material.

The new subspecies is named for Mr T. A. Darragh, Deputy Director, National Museum of Victoria, who recognised the subspecies as new and generously consented to our naming it, and who has kindly made available to us most of the Australian fossil material we have examined.

Bolma flindersi flindersi (T. Woods, 1877)

Fig. 4d-j

Astralium (Calcar) flindersi T. Woods, 1877: 95; May, 1919: 71, pl. 10, fig. 11.

Calcar flindersi. — Cossmann, 1918: 145.

Astralium flindersi. — Pritchard, 1896: 116; Darragh, 1970: 169.

DIAGNOSIS. Shell: Relatively tall spire, small, with narrowly channelled suture, flat whorls with granulose to scaly sculpture and rudimentary or short peripheral spines. Peripheral angulation sharp on all whorls, very low on spire whorls, a narrow channel usually present below. Spines short or reduced to nodules and very variable in size and number (the extent of variation is shown in fig. 4d-j). Basal angle usually poorly defined or absent, in some specimens represented by a spiral row of short scales or gemmules larger than in other rows. Two spirals immediately below periphery may form a weak basal angulation, are equally prominent in some specimens or are both indistinguishable from remainder of basal spirals in some specimens. Base bearing 5 gemmate cords. One cord (sometimes 2) immediately below sutural channel more strongly gemmate than the 4-6 others on upper surface of penultimate whorl. Body whorl with up to 10 spirals. Ornament on spiral ribs varies from rounded gemmae to short scales. Whole surface crowded with fine, strongly prosocline growth lines. Basal callus very thin, spread over about $\frac{1}{3}$ of base, separated from columella by a shallow groove.

Operculum: Slightly oval, with strong spiral ridge about midway between outer edge and centre, a shallow groove above and below ridge (3 specimens in NMV, P.30772).

DIMENSIONS. Holotype: height 17 mm, diameter 13 mm.

TYPE LOCALITY. "Table Cape" (= Fossil Bluff, Wynyard), Tasmania.

HOLOTYPE. Apparently lost (not recorded by Ludbrook, 1967).

OTHER MATERIAL EXAMINED. "Table Cape" (Freestone Cove Sandstone, Fossil Bluff and Freestone Cove, near Wynyard), north coast of Tasmania, AM (5), NMV (many).

AGE. Longfordian (basal Miocene Australian local stage).

Bolma flindersi is similar to, but smaller than, both *B. guttata bathyraphis* (Smith) and the Italian Pliocene *B. castrocarensis* (Foresti) (Sacco, 1898, pl. 1, fig. 39, 40). The basal angulation is weak or absent in *B. flindersi* although the periphery is sharply angled, whereas there is a marked lower basal angulation in *B. guttata bathyraphis* and a regularly rounded periphery and base in *B. castrocarensis*. *Bolma castrocarensis* has even more poorly developed peripheral spines than *B. flindersi*. The basal callus is more weakly developed in *B. flindersi* than in either similar species. *B. somaliensis* sp. nov. is similar to *B. flindersi* and is contrasted below.

***Bolma guttata* (A. Adams, 1863)**

Three geographic subspecies are recognised as comprising this species. The overall features of similarity are a prominent sutural channel, numerous, short peripheral spines and a rather weak basal angle. Only 1-3 spiral cords lie between the basal and peripheral angles. The basal callus is very thin and transparent, white, and separated from the columella by a shallow groove. The operculum is subcircular and has weak concentric striae around the edges of the central area which is weakly pustulose. The colour in all forms is mauve-pink, usually with a few purple blotches.

This species is very similar to *B. marshalli* (Thomson), which differs mainly in its stronger basal angle, finer sculpture and thicker and wider basal callus which is not separated from the columella by a groove. The operculum is also flatter and thinner. It also closely resembles *B. persica* (Dall) which, however, has a relatively shorter spire, much longer peripheral spines, weaker sculpture and no sutural channel.

Bolma guttata bathyraphis (E. A. Smith, 1899)

Figs 7a-g; 8a-m; 19c-d

Astralium bathyraphe E. A. Smith, 1899: 247; E. A. Smith, 1901: pl. 12, figs. 4-4c.*Astralium (Cyclocantha) gilchristi* G. B. Sowerby 3rd, 1903: 221, pl. 5, fig. 6.*Astraea gilchristi*. — Barnard, 1963: 221, fig. 7c.

DIAGNOSIS. Shell: Spire moderately tall; sutures channelled, with flat-sided to lightly convex whorls and finely to rather coarsely gemmate sculpture. Peripheral angulation sharp on spire, where it is near base of whorls; last whorl sometimes rounded. Body whorl with 4-7 spiral rows of rounded to weakly scaled gemmae below suture, uppermost slightly stronger than others; peripheral sculpture subspinose to spinose, 20-30 spines when present; spines short, hollow, triangular. 1-3 rows of gemmae below peripheral angle and a third, heavier row of smooth or weakly scabrous nodules on rather weak basal angulation. About 4-8 rows of smaller gemmae on base. Entire surface crossed by prosocline axial lamellae, sometimes very distinct. Basal callus moderately expanded, thin, transparent, whitish, separated from white columella by a groove. Outer lip slightly reflected above. Surface pale fawn to pinkish-mauve sometimes with darker mauve blotches.

Operculum: Nearly circular, thickly convex, with faint, closely spaced spiral grooves around the margin; central area somewhat flattened with a few indistinct wrinkles, white.

DIMENSIONS. *A. bathyraphe*, holotype: height 34 mm, diameter, 33.7 mm. *A. gilchristi*, holotype: height 26.9 mm, diameter (including spines) 29.4 mm. Squamose specimens from Maldive Ids, 229 m: height 38.6 mm, diameter 35.7 mm; height 35.8 mm, diameter 31.7 mm.

TYPE LOCALITIES. *A. bathyraphe*: N. Maldive Atoll, N. Indian Ocean, 384 m ("Investigator" Stn 218). *A. gilchristi*: Bearing N.W. $\frac{1}{4}$ W, 15 km from O'Neil Peak, Natal, 165 m.

HOLOTYPES. *A. bathyraphe*: Zoological Survey, Calcutta, M579. *A. gilchristi*: SAM, A.5219.

OTHER MATERIAL EXAMINED. 23°36.3'S, 43°32.5'E, off Tuléar, S. W. Malagasy Republic, 250 m, 28 Feb., 1973, A. Crosnier Colln (AMS) (3); as last, 23°35.9'S, 43°32.7'E, 285-305 m, 27 Feb., 1973 (AMS) (1 broken); 12°41.3'S, 48°16'E, off Nossi Bé, N. W. Malagasy Republic, 308-314 m, 15 April, 1971, A. Crosnier Colln (AMS) (2); as last, 12°51.0'S, 48°06.3'E, 675-705 m, 14 Sept. 1972 (AMS, NM) (5); Bay of Bengal, "Investigator" Stn (no other data), Melvill — Tomlin Colln (NMW) (1); John Murray Expedition, Stn 157, 4°43'48" N to 4°44'00" N, 72°55'24" E to 72°54' 18" E, 229 m, coral rubble bottom, Maldive Ids, Indian Ocean, 6 April, 1934 (BMNH) (3).

OTHER LOCALITIES. *South Africa*: Scottsburg Lighthouse, Natal, bearing N.W. by N., distant 12.8 km, 168 m; off Port Shepstone, 457 m; off Cape Natal, 99 m; off Cape Vidal, 146-183 m; off Durnford Point, 165 m; all from Barnard (1963, p. 221).

An examination of the small amount of material available to the writers has indicated that one rather variable subspecies of the *guttata* group can be recognized in the western and northern Indian Ocean. Specimens from S. W. Malagasy Republic and S.E. Africa (including the type of *Astralium gilchristi*) are similar in having a distinctly spinose periphery, flat whorls, and a colour pattern of dark blotches (figs. 7a-g; 8a-m). Of the two

lots available from N. W. Malagasy Republic, one is like *gilchristi* and the other 5 specimens from deeper water are more heavily beaded, non-spinose, have a uniform colour pattern, develop weak spiral striae over the closely packed gemmae and have a yellowish edge to the basal callus (figs. 8d-f). These latter specimens are somewhat similar to the type of *B. guttata bathyraphis* (figs. 7e-g) from the Maldive Islands in general form but that specimen is a little larger, has stronger gemmae and lacks the secondary spiral striae and yellow-edged callus. In most respects the holotype of *bathyraphis* shows intermediate shell characters between *gilchristi* and the non-spinose shells from N.W. Malagasy Republic. A lot of 3 specimens, also from the Maldive Islands, have weakly convex whorls and distinctly scaly sculpture (figs. 8g-m). A single specimen from the Bay of Bengal has a weak subsutural channel and is, in this respect, and in having a lightly convex shoulder on the body whorl, similar to *B. guttata millegranosa*. It is, however, like *B. guttata bathyraphis* in other characters.

Finlay (1926, p. 367) commented that *B. guttata bathyraphis* is similar to "*Incilaster*" *marshalli* (Thomson) but the similarity of *B. guttata bathyraphis* is much greater to *B. flindersi flindersi* (T. Woods) and the Italian Pliocene *B. castrocarensis* (Foresti) (Sacco 1896, pl. 1, fig. 39, 40), although *B. flindersi* is much smaller and not closely related. *B. guttata bathyraphis* has fewer rows of more rounded nodules, a more clearly differentiated row of peripheral nodules, a more marked sutural channel and a more marked basal angulation than those of *B. flindersi*. *Bolma castrocarensis* does not have differentiated peripheral nodules and has more convex whorls than *B. guttata bathyraphis*, its sculpture consisting of seven or eight lateral rows of large, rounded, slightly laterally compressed nodules and five or six basal rows of slightly smaller nodules. The basal callus is broad and thick in *B. castrocarensis*, but narrow in *B. guttata bathyraphis*, and the two forms are probably not closely related.

Bolma guttata guttata (A. Adams, 1863)

Figs 9i-m; 19 e-f

Modelia guttata A. Adams, 1863: 507

Turbo (Modelia) guttata. — G. B. Sowerby 3rd, 1886: 206, pl. 499, fig. 68.

Turbo (Modelia) amabilis Ozaki, 1954: 11, pl. 4, figs. 1-3.

Turbo guttatus. — Kuroda & Habe, 1952: 93.

Bolma guttata. — Oyama & Takemura, 1960: *Bolma*, figs. 9-11.

Galeoastraea guttata. — Habe, 1961: 14, pl. 7, fig. 17; Habe, 1964: 21, pl. 7, fig. 17; Kuroda *et al.*, 1971: 48, pl. 14, fig. 3, 4; Okutani, 1972: 78, pl. 1, figs. 5, 6.

DIAGNOSIS. Shell: Solid, with rounded body whorl and weakly convex spire whorls, weakly channelled suture, short spines and heavy, gemmate spiral cords. Peripheral angle low on whorls of spire, rounded on body whorl, with short, hollow spines, about 26 on body whorl. Basal angulation represented by the second basal spiral cord which is very slightly more prominent than the first. Five additional cords on base and 5 above periphery, the uppermost strongest. Growth lamellae fine and weak, strongly prosocline. Basal callus expands over $\frac{1}{4}$ of base, very thin, transparent, colourless, separated from the white columella by crescent-shaped depression. Outer lip slightly reflected and expanded. Surface pinkish-mauve, with small dark reddish-mauve blotches.

Operculum: Oval, white, with a slight depression off centre in adult, juvenile with marked central depression. Marginal area a narrow flattened rim, central area rather flat-topped, weakly pitted, sides of central area with few irregular concentric striae.

DIMENSIONS. Holotype: height 40 mm, diameter 39.4 mm; figured specimen: height 31 mm, diameter 33 mm.

TYPE LOCALITY. "Tatiyama", Japan (= Tateyama, Sagami Bay).

HOLOTYPE. BMNH, 1968210.

OTHER MATERIAL EXAMINED. Several of the specimens recorded by Okutani (1972) from three submarine banks near the Izu-Shichito Ids (Tokai Regional Fisheries Laboratory); Okinose Bank, off Sagami Bay, central Honshu, 48 m (NSMT) (1).

OTHER LOCALITIES. "Mainly found in Sagami Bay, Honshu at depths of 50-200 m" (Habe 1964, p. 21); Okutani (1972) noted that this subspecies may be one of the most common prosobranchs on the submarine banks near the Izu-Shichito Islands; six localities in Sagami Bay (Kuroda *et al.*, 1971, p. 48). The geographic range is Honshu (Sagami Bay to off Choshi City) and around the Izu Islands, on fine sandy and gravelly substrates in depths of 50-200 m (Kuroda *et al.*, 1971). Recorded as a Pliocene fossil (*B. amabilis*) from Tyosi, Japan, by Ozaki (1954, p. 11); as noted by Habe (1958, p. 55) this name appears to be based on fossil specimens of *B. guttata guttata*.

Bolma guttata guttata differs from the other subspecies in its shorter spines and much coarser sculpture. Dr. Tadashige Habe noted (*in litt.*, 8 Nov. 1975) that *B. guttata millegranosa* seems to be a subspecies of *B. guttata* "from Sagami Bay", having a different operculum.

Bolma guttata millegranosa (Kuroda and Habe, *in* Habe, 1958)

Fig. 9a-d

Astraea (Bolma?) persica. — Hirase, 1938: 41, pl. 74, fig. 7 (not *Bolma persica* Dall, 1907).

Bolma? millegranosa (Kuroda & Habe, MS) Kira, 1955: 20, pl. 10, fig. 3 (*nomen nudum*).

Bolma millegranosa. — Oyama & Takemura, 1960: *Bolma*, fig. 1-3.

Galeoastraea millegranosa. — Kuroda & Habe *in* Habe, 1958: 45, pl. 3, fig. 1 (radula); Kira, 1962: 18, pl. 11, fig. 3.

Galeoastraea (Hirasazea) millegranosa. — Kira, 1961: 20, pl. 10, fig. 3.

DIAGNOSIS. Shell: Whorls slightly convex, sutures weakly to moderately channelled, spines rather long for species, sculpture of moderately strong, gemmate spiral cords. Peripheral angle sharp on early whorls, slightly overhanging later whorls. Periphery bluntly angled on body whorl, with about 22-28 hollow, rather short, slightly downwardly directed spines on body whorl. Basal angle distinct, granulate, the space between basal and peripheral angles flat, with 1 weakly gemmate spiral thread. Base with 6 weakly gemmate threads, becoming stronger towards the columella. Upper surface of whorls with a moderately strong row of granules a little below the suture, followed by 5-7 gemmate spirals on penultimate whorl, 6-8 on body whorl. Basal callus very thin, white near columella, remainder transparent, separated from columella by a groove, extending over about $\frac{1}{3}$ of base. Surface pinkish-fawn, with purplish-brown blotches on upper surface. Outer lip reflected when mature.

Operculum: Oval, almost circular, with steep concentrically striated sides and flattened pustulose central area. Central area higher opposite nucleus than above nucleus.

DIMENSIONS. Holotype: height 23.5 mm, diameter 26.5 mm (Dr. T. Habe, *in litt.*); paratype: height 40.0 mm, diameter 41.9 mm (Dr. T. Habe, *in litt.*). Figured specimens: height 29.5 mm, diameter 31.3 mm; height 41.0 mm diameter 39.1 mm; large specimen: height 46.3 mm, diameter 44.2 mm.

TYPE LOCALITY. Tosa Bay, Shikoku, Japan, ca. 100 m (Dr. T. Habe, *in litt.*).

TYPES. NSMT, 59903; single paratype, NSMT, 59904.

MATERIAL EXAMINED. Tosa, Japan (ANSP) (4); (Bishop Mus., Honolulu) (2); Japan (ANSP) (2); Kii, Japan, (AMNH) (2); (Bishop Mus., Honolulu) (2); Off S. end of Frazer Is., Queensland, 25°57.8'S, 153°51.3'E, 201 m, (AM) (2 + fragments); same data as last, 25°58.8'S, 153°51.0'E, 210-219 m (AM) (4 juveniles).

OTHER LOCALITIES. Japan: Southern part of Honshu and Shikoku in 91-146 m (Kira, 1962, p. 18); Tosa Bay, Shikoku (Oyama & Takemura, 1960: *Bolma* pl. 1). The subspecies does not overlap the geographic range of *B. guttata guttata* (A. Adams), which occurs further north around Sagami Bay.

Bolma guttata millegranosa differs from *B. guttata guttata* in its finer sculpture of more numerous rows of gemmae, in having a flattened, steep-sided rather than convex operculum and in its longer spines; from *B. guttata bathyraphis* in its more inflated whorls, its slightly coarser sculpture and its downwardly directed peripheral spines, and from *B. persica* (Dall) in its coarser gemmae, its much shorter peripheral spines, and its more inflated whorls. The eastern Australian specimens agree in nearly every respect with Japanese material and it is surprising that no other records from the rest of the western Pacific are available.

As with several other species of Japanese molluscs, the manuscript name *millegranosa* of Kuroda and Habe was first introduced as a *nomen nudum* when it was published by Kira (1955, p. 20) as no statement was given to differentiate the taxon (International Code of Zoological Nomenclature, Art. 13a). As Habe (1958, p. 45) was the first to associate a statement of differentiation with the name (International Code of Zoological Nomenclature, Art. 24b) when he distinguished the radula from that of *Bolma modesta* (Reeve) and as he attributed the name to Kuroda & Habe, we agree with Dr. Habe (*in litt.*, 8 Nov. 1975) that the name should be attributed to Kuroda & Habe *in* Habe (1958, p. 45). Dr. Habe has noted that the holotype (details above) is the specimen from which his illustrated radula was removed.

***Bolma guttata* subsp.?**

Fig. 9e-h

DIAGNOSIS. Shell: Two immature specimens resembling *B. guttata millegranosa* in most features (larger described). Peripheral spines longer than on *B. guttata millegranosa*, with 12 on last whorl (about 17 per whorl at equivalent stage of *B. guttata millegranosa*), whorls more flat-sided and spiral sculpture weaker than in *B. guttata millegranosa*. In the last two features it resembles *B. guttata bathyraphis* but differs in its fewer, longer, downwardly directed spines (21-25 per whorl at same stage in *B. guttata bathyraphis*). A prominent basal angulation bears a strongly gemmate cord. Concave area

between peripheral and basal angulations bears a single, weakly gemmate spiral thread, base bears 5 weak, gemmate cords. Whole surface crossed by conspicuous, strongly prosocline growth lamellae. Basal callus white, narrow. Surface pinkish fawn with small, irregular, pale purplish blotches on upper surface and on spines.

Operculum: Almost circular, thick, slightly flattened in centre, coarsely and irregularly granulate over most of surface, with narrow marginal zone of irregular concentric grooves; white.

DIMENSIONS. Larger: height 15.73 mm, diameter (including spines) 22.35 mm; smaller: height 5.23 mm, diameter 8.45 mm.

MATERIAL EXAMINED. Between Shark Bay and Onslow, Western Australia (WAM 603-70, 1 juvenile, larger); approx. 274 km W. of Port Hedland, Western Australia, 19°29'S, 116°01'E, 137 m (AM, C.96325, 1 juvenile, smaller).

This form possibly represents an unnamed subspecies, but adult material is needed to confirm its features.

Bolma henica (Watson, 1885)
Figs 10a-h; 19a,b

Turbo (Calcar) henicus Watson, 1885: 73; Watson, 1886: 130, pl. 6, fig. 11.

Astraliium henicum. — Thiele, 1903: 121, 163, pl. 8, fig. 45 (radula).

Calcar henicum. — Martens, 1903: 46.

Astraliium (Pseudastraliium) abyssorum Schepman, 1908: 27, pl. 2, fig. 1.

Astraea (Calcar) henica. — Nomura & Zinbo, 1934: 146.

Astraea (Pseudastraliium) abyssorum. — Hirase, 1938: 42, pl. 74, fig. 10.

Guildfordia abyssorum var. — Taki, 1951: pl. 74, fig. 10.

Guildfordia henicus var. — Kuroda & Habe, 1952: 59.

Pseudastraliium henicus gloriosum Kuroda & Habe in Kira, 1955: 20, pl. 10, fig. 2 (*nomen nudum*).

Guilfordia (Pseudastraliium) henicus gloriosa. — Oyama & Takemura, 1957: *Guildfordia*, fig. 1-4 (*nomen nudum*).

Pseudastraliium cf. *henicus*. — McNeil, 1960: 33, pl. 11, fig. 9, 10.

Guildfordia (Pseudastraliium) gloriosa. — Kuroda & Habe in Kira, 1961: 20, pl. 10, fig. 2; Kira, 1962: 19, pl. 11, fig. 2.

DIAGNOSIS. Shell: Spire moderate to low, whorls flat, sculpture of rather short spines and scaly (sometimes gemmate) spirals; sutures strongly channelled. Shoulder flat, to slightly concave, edge bordered by a row of large, white beads between which and periphery are up to 7 rows of small beaded spirals which often do not commence for 2-3 whorls. Periphery sharply angled, bearing up to about 17 rather long, curved, hollow spines on body whorl. Basal angulation prominent, weakly to strongly gemmate or scaly. Space between peripheral and basal angulation flat, bearing 0-5 scaled (or sometimes beaded) spirals. Base with up to 10 scaled (or sometimes beaded) spirals, smooth in small specimens. Growth lamellae fine, strongly prosocline. Basal callus narrow, white, not separated from columella. Colour light yellowish-pink, base paler than upper surface.

Operculum: Oval, rather flattened in centre, with steep edges and a very slight flange on outer lower margin, weakly granulose in centre, with faint concentric marginal striae; white.

DIMENSIONS. Lectotype of *T. henicus*: height 21.6 mm, diameter 26.5 mm (including spines), 22.2 mm (excluding spines). Lectotype of *A. abyssorum* (from original description): height 17 mm, diameter (excluding spines) 24 mm. Large specimen: height 28.4 mm, diameter (including spines) 26.5 mm, diameter (excluding spines) 21.0 mm.

TYPE LOCALITIES. *T. henicus*: 19°9'35" S, 179°41'50" E, off Matuku, Fiji Ids, 576 m, H.M.S. "Challenger" Stn 173. *A. abyssorum*: not specified by Schepman (1908, p. 27), who listed 7 localities in depths of 189 to 520 m, in and around the Straits of Samau, Indonesia, taken by the "Siboga" Expedition. His figured specimen is from "Siboga" Stn 59, western entrance to Samau Strait, Indonesia, 10°22.7'S, 123°16.5'E, 390 m, and this specimen is here designated the lectotype of *Astraliium* (*Pseudastraliium*) *abyssorum* Schepman, 1908 (fig. 10a-c). *P. gloriosum*: Southern parts of Honshu and Shikoku, as deep as 91-146 m (Kira 1961; Kira 1962); exact locality not known to us.

TYPES. *T. henicus*: lectotype (here designated), the larger of 2 syntypes in BMNH, 87.2.9. 453, paralectotype 87.2.9.454. 3rd syntype (i.e. paralectotype) in NMW, ex. McAndrew Colln. *A. abyssorum*: lectotype (here designated), Zoölogisch Museum Amsterdam, 2532. *P. gloriosum*: not known to us.

OTHER MATERIAL EXAMINED. Tosa Bay, Japan, 146 m (3), 220 m (2), 274 m (2) (AMNH); Tanabe, Japan (Bishop Museum, Honolulu) (1); Tosa Bay, 220 m (1), depth not known (11) (ANSP), (2 lots, each 1 spec.) (USNM); Shikoku, Japan (ANSP) (2); Molucca Passage, between Gillolo Is. and Makyan Is., 498 m (USNM) (3); Sibuko Bay, Borneo, S.E. of Mabul Is., 597 m (USNM) (3); Sibuko Bay, Borneo, S. of Silungau Is., 588 m (USNM) (1); "Valdivia" Stn 192, 0°43'S, 98°34'E, off Pandang, Sumatra, Indonesia, 371 m; Stn 193, 0°30'S, 98°0'E, off Sumatra, Indonesia, 132 m (1 juvenile, possibly this species); Stn 209, 6°56'S, 93°33'E, off Sumatra, Indonesia, 362 m (2) and Agulhas Bank, South Africa (1) (all Humboldt University Museum, E. Berlin); "Siboga" Expedition Stns 12, 7°15'S; 115°15.6'E, Java Sea, 289 m (4); Stn 89, Pulu Kaniungun Ketjil, Indonesia, 11 m (1); Stn 139, 0°11'S, 127°25'E, Molucca Sea, 397 m (Schepman's illustrated radula removed from this specimen); Stn 156, 0°29.2'S, 130°5.3'E, Halmahera Sea, 469 m (3); Stn 159, 0°59.1'S, 129°48.8'E, Halmahera Sea, 411 m (1); Stn 279 Rumah-Kuda Bay, Roma Is., Indonesia, 36 m (1) (all Zoölogisch Museum, Amsterdam); 3 km off Laulasi Village, S. of Aoki, N.W. coast of Malaita Is., Solomon Ids, 365 m (1 juvenile, probably this species) (AM); Great Barrier Reef Expedition dredge Stn 15, 384 m, 0.8 km outside Cook's Passage, Queensland (AM, C77149) (1); E.N.E. of Clarence River mouth, northern New South Wales, 457 m, F.R.V. "Kapala" Stn K75-09-08, 29°26'S, 153°49'-50'E (ca. 100, most in AM, 3 in NZGS).

OTHER LOCALITIES. Southern parts of Honshu and Shikoku, Japan, as deep as 91-146 m (Kira, 1961; Kira, 1962). Recorded as a fossil from the Pliocene Chinen Sand of Okinawa and Ryukyus Limestone of Kikaiga-shima, Ryukyu Islands, by McNeil (1960) and Nomura & Zinbo (1934).

This species exhibits variation in the degree of spiral sculpturing, some specimens being almost smooth (except for the subsutural and subperipheral cords and the peripheral spines). Intergrading sculptural forms have, however, been observed from several localities. The observed shell variation encompasses the forms included in the synonymy.

Barnard (1963, p. 219) suggested that von Martens' (1903) record of *henica* from South Africa was probably *B. tayloriana* or possibly *B. gilchristi* (= *B. guttata bathyraphis*

herein). Examination of the "Valdivia" specimens has shown that von Martens' identification is the correct one.

The species name *gloriosum* of Kuroda & Habe, MS, first published by Kira (1955, p. 20), is a *nomen nudum* as no statement was given to distinguish it from related taxa (International Code of Zoological Nomenclature, Art. 13a). A description was first associated with the name by Kira (1961, p. 20) and, as with several other Japanese mollusc names, we consider the authorship should be attributed to Kuroda & Habe *in* Kira, 1961.

***Bolma kermadecensis* n. sp.**

Fig. 12h-j

DIAGNOSIS. Shell: With rounded whorls, deeply incised suture and few, long peripheral spines. Teleoconch of 5½ whorls; peripheral angle slightly below middle of whorls with 1 row of 7 long, heavy spines on body whorl, 11 (all but one broken) on penultimate whorl. Spines directed forwards and slightly downwards, very small on upper spire whorls. Shoulder convex, with 10 spiral rows of rather widely spaced small gemmae on body and penultimate whorls, subsutural row not stronger than others. Basal angle very weak, marked by a gemmate spiral cord slightly stronger than the other basal spirals; 5 weak spirals above "basal angle" and 9 below. Whole surface crossed by prosocline growth rugae. Basal callus thin (slightly immature), spread over approximately ⅓ of base, white, with pale yellow tinge near columella. Columella with shallow, longitudinal groove. Colour rather dark pinkish-fawn, with diffuse dark purple blotches on shoulder.

Operculum: Not known.

DIMENSIONS. Holotype: height 36.0 mm, diameter (including spines) 47.0 mm, (excluding spines) 34.5 mm.

TYPE LOCALITY. NZOI Stn K854, 30°33.0'S, 178°31.7'W, east of Curtis Is., Kermadec Ids, 165-135 m, M.V. "Tangaroa", 30th July 1974.

HOLOTYPE. NZOI, H235.

OTHER MATERIAL EXAMINED. NZOI Stn K826, 28°48'S, 177°48'W, N.E. of Raoul Is., Kermadec Ids., 160-210 m (paratype (fragment of body whorl), NZOI, P336).

This species, known only from 1 complete subadult specimen and one large fragment, is very distinctive. The small number of spines on the last whorl, the finely sculptured base, the lack of differentiation of the subsutural row of gemmules, and the very weak basal angulation are a combination of features not observed in any other species. It is superficially similar to *B. girgylla* (Reeve) but differs from that species in its smaller size, the single row of spines on the last whorl, and the finer sculpture. It is probably allied to *B. guttata* (Adams) but it differs in its finer sculpture, strongly convex whorls, the small number of long spines on the body whorl, and the very weak basal angle. *B. tamikoana flava* nov. is similar in having a weak basal angle but does not have a well-developed sutural channel, has only a weakly convex body whorl, has more numerous, small spines, and has coarser and more numerous gemmate spirals.

***Bolma marshalli* (Thomson, 1908)**

Fig. 11a-d

Turbo marshalli Thomson, 1908: 103, pl. 14, fig. 6; Suter 1915: 3.

Incilaster marshalli. — Finlay, 1926: 367, pl. 18, figs 20-23; Olson *in* Gage, 1957: 116; Fleming, 1966: 40.

DIAGNOSIS. Shell: Spire of medium height, suture broadly channelled, peripheral spines short, and spiral sculpture relatively weak. Peripheral and basal angulations both prominent, and separated by a relatively wide, flat area. Subsutural shoulder area relatively wide, weakly concave. Sculpture, in descending order: two horizontal, closely spaced rows of rounded gemmae, the outer the larger and at the subsutural angulation; five rows of small pointed nodules, developed from two rows and their interstitial threads of early spire whorls; a row of 12 low, spinose, peripheral nodules; three closely spaced rows of scale-tipped nodules; a single row of slightly larger, scale-tipped nodules at the basal angulation; and five closely spaced basal rows of scale-tipped nodules. Growth lamellae thin, strongly prosocline. Basal callus thick, spreading over half of base. Outer lip slightly expanded and reflected in mature shells.

Operculum: Convex, with finely granular central area and faint concentric marginal striae.

DIMENSIONS. Figured specimen: height 28.3 mm, diameter 30.3 mm (including spines).

TYPE LOCALITY. Thomson (1908, p. 103) gave no locality for *Turbo marshalli*, other than the area near Kakanui, south of Oamaru, New Zealand, implied by the title of his paper. However, he referred the reader to his earlier paper (Thomson 1906) on the geology of Kakanui district, in which fossils were listed. "*Turbo* n. sp." was recorded on p. 488, in a list of fossils collected from the top, hard, fossiliferous layer of "barren breccia," beneath limestone in a cliff section north of Kakanui North Head (Thomson 1906, p. 487). In modern stratigraphic terminology, these are the Deborah Volcanic Formation and McDonald Limestone, both of Whaingaroan age (lower Oligocene) (Gage 1957, map sheet S136). The locality is that known to present day geologists as "cliffs below Everett's Quarry, Kakanui," where excellent specimens of the fossils listed by Thomson (1906, p. 488) can be collected from the hard, red tuff bed underlying McDonald Limestone in the cliff face below the disused lime quarry. The crystal tuff of the Deborah Volcanic Formation, known to Thomson (1906) as the "mineral breccia," source of the "gem gravels" of Kakanui Beach, is fossiliferous where it crops out at Gees Point, north of Kakanui North Head, but specimens of *Bolma marshalli* have not been collected there, and there is little doubt that the cliff below Everett's Quarry is the type locality.

TYPES. Holotype in Otago Museum, Dunedin, C.03.13, with 2 juvenile paratypes. Suter (1915, p. 4) listed "Primary types (6 shells, 1 operculum)" and the fate of the other specimens is unknown.

OTHER MATERIAL EXAMINED. NZGS fossil locality GS9535, red tuff below McDonald Limestone, cliffs below Everett's (disused) Quarry, Kakanui, south of Oamaru, New Zealand, coll. P. A. Maxwell (3 shells and a number of associated opercula); GS3881, red tuff below Everett's Quarry (1); all NZGS.

AGE. Whaingaroan New Zealand local stage (lower Oligocene).

Specimens from the green tuff at Lorne, Kaiatan Stage (upper Eocene) (GS9481, fallen block of green tuff of Waiareka Volcanic Formation (Gage, 1957, p. 33) in slump at base of William's Bluff, near abandoned Lorne railway station, Waiareka Valley, near Oamaru, New Zealand, coll. P. A. Maxwell, NZGS) (Figs 11e-g) are slightly different from typical *marshalli* in having slightly shorter peripheral spines, less markedly channelled sutures, and a stronger second subsutural row of gemmae which tends to make the shoulder angulation more prominent. This form is tentatively retained in *B. marshalli*.

Bolma marshalli is most similar to *B. guttata bathyraphis*, from which it differs in its shorter spire, thicker basal callus, and different numbers of spiral cords. *B. marshalli* may be ancestral to the Recent *B. guttata* complex.

Bolma midwayensis (Habe & Kosuge, 1970)

Fig. 6i-k

Galeoastrea midwayensis Habe & Kosuge, 1970: 88, pl. 6, figs 4-6.

DIAGNOSIS. Shell: Whorls slightly convex, sculptured with gemmate spiral cords, lacking spines and sutural channel. Periphery rounded. Sculpture of 7 primary and 7 interstitial rows of gemmate spiral cords on upper surface of last whorl, 11-13 on base. Base bearing prominent gemmate spiral cords, gemmae fused into radial ridges in paratype, similar to those of *B. recens*. Basal callus narrow. Outer lip thickened and slightly flared. Surface light brownish-red to yellowish-brown with irregular white maculations, the base pale yellow.

Operculum: Thick, convex, smooth.

DIMENSIONS. Holotype: height 28.6 mm, diameter 29.5 mm; paratype: height 25.0 mm, diameter 27.6 mm.

TYPE LOCALITY. Off Midway Is., central Pacific Ocean. Taken by coral fishing boats.

TYPES. Holotype, NSMT, 37292; one paratype, NSMT, 37293.

Bolma midwayensis is similar to *B. tamikoana* (Shikama) but differs in its inflated whorls, simple sculpture, and complete lack of peripheral spines.

Bolma persica (Dall, 1907)

Fig. 12a-g

Astraea persica Dall, 1907: 167; Dall, 1925: 5, pl. 35, fig. 4, 6.

Bolma persica. — Oyama & Takemura, 1960: *Bolma*, fig. 7, 8.

Galeoastrea persica. — Habe, 1958: 46; Habe, 1961: 14, pl. 7, fig. 16; Habe, 1964: 20, pl. 7, fig. 16; Okutani, 1972: 77, fig. 12.

DIAGNOSIS. Shell: Rather small, spire low, whorls flat-sided, with persistent long spines on all whorls. Body whorl with strong peripheral angle bearing 10-15 triangular, hollow spines, the posterior edges of which are at right angles to shell and form main part of spine. Basal angle rather weakly gemmate, area between it and peripheral angle slightly concave with single very weak spiral thread. Six weakly beaded spirals on upper surface of whorls, 3 on base below basal angle. Growth lines prosocline, fine and sharp. Basal callus very narrow, merely a thickened rim against columella, white. Surface yellowish-white with radial wine-red streaks dorsally and ventrally, and small spots on the gemmae of the spiral threads.

Operculum: Very thick and convex, sides weakly concentrically striated, lightly concave, centre a deep, narrow depression; the raised marginal portion appears to be a tight spiral and is weakly pustulose; white.

DIMENSIONS. Holotype: height 20 mm, diameter 22 mm (excluding spines); figured specimen: height 15.1 mm, diameter 28.35 mm (including spines), 18.5 mm (excluding spines).

TYPE LOCALITY. Off Kagoshima Bay, Japan, 188 m, "Albatross" Stn 4936.

HOLOTYPE. USNM, 110507.

OTHER MATERIAL EXAMINED. Japan: Off Tosa Bay, Shikoku, 200 m (NSMT) (1); 34°28.3'N, 139°11.4'E, 110 m (Tokai Regional Fisheries Lab.) (1); Zenisu Stn 32, near Izu-Shichito Ids, 113 m (Tokai Regional Fisheries Lab.) (1).

OTHER LOCALITIES. Off Kii Peninsula, Japan (Oyama & Takemura, 1960); "rather rarely collected from Tosa Bay, Shikoku to Kyushu at depths of 50-200 m" (Habe, 1964, p. 21). Okutani (1972, p. 77) gave the distribution as from Kagoshima Bay eastwards to Zenisu Bank, probably in 100-200 m.

This relatively small, very long-spined species is related to the *B. guttata* complex. The spines are markedly longer and fewer (10 to 15 on the last whorl), the granular sculpture is finer, the subsutural channel weaker, and the axial growth lamellae more indistinct than in related species.

***Bolma* ? aff. *persica* (Dall, 1907)**

Fig. 3g-i

DIAGNOSIS. Shell: Close to *B. persica* but with coarser granules and spines and more numerous spirals on the base and shoulder. A narrow sutural channel present. Seven primary rows and 3 secondary rows of granules on shoulder at commencement of body whorl and 6 rows on base. Basal angle very indistinct, represented by a row of sharp gemmules with a single weak, spiral cord between this and peripheral row of spines. Spines downwardly pointing, anterior margin upturned to give a double spined effect. Basal callus white, thick, not separated from columella, extending over about 1/3 of base. Outer lip of aperture thickened within but with sharp edges. Colour purplish pink, some granules white.

Operculum: Almost circular, with flattened central area showing a shallow depression and wrinkled surface. Edges with faint spiral grooves.

DIMENSIONS. Height 27.3 mm, diameter (without spines) 27.1 mm, (with spines) 29.3 mm.

LOCALITY. Off Pratas Island, China Sea, U.S. Bureau of Fisheries Stn 5311, 161 m, coarse shell sand (USNM, 237697) (1).

The single shell shows 3 mended "breaks" following which are changes in details of sculpture and shape (such as the peculiar spines) that may be due to a damaged mantle. Although this specimen may possibly represent an undescribed species it is more likely to be a freak form of *B. persica*.

***Bolma recens* (Dell, 1967)**

Fig. 11h, i

Incilaster recens Dell, 1967: 305, fig. 6, 7, text-fig. 8 (radula).

DIAGNOSIS. Shell: very similar to *B. bartschi*, differing in its slightly taller shape; slightly more prominent spiral threads between the peripheral and basal angulations; in having three equally coarse gemmate cords above the periphery, rather than a markedly coarser subsutural row with other rows extremely fine, as in *B. bartschi*; in having a more

coarsely sculptured base on which the cords are gemmate around the margin of the base and the gemmae are fused into short radial ridges over the inner two-thirds of the base; in having a thicker outer shell layer, and thus lacking the nacreous gleam of *B. bartschi*; and in lacking the striking magenta and cream colour pattern of *B. bartschi*. Colour uniform greyish fawn.

Operculum: Convex, almost circular, with weak pustules in slight central depression, and with weak concentric marginal striations; white.

DIMENSIONS. Holotype: height 31.0 mm, diameter 30.1 mm; paratype: height 29.3 mm, diameter 29.0 mm.

TYPE LOCALITY. Kiwi Seamount, 30°45'S, 173°15'E, between northern New Zealand and the Kermadec Islands, 358-677 m, M.V. "Tui" Stn. AUZ 11.

TYPES. Holotype, N.Z. National Museum, M21297, with one paratype.

OTHER MATERIAL EXAMINED. NZOI Stn 197, 32°22.9' to 23.3'S, 167°28.2'E, Wanganella Bank, Norfolk Ridge, 540-544 m, NZOI (1); NZOI Stn P40, 29°10.2'S, 167°50.0'E, west of Norfolk Is., 394-472 m, NZOI (1); NZOI Stn J659, 35°00.6'S, 179°15.1'E., Silent 1 Seamount, S. Kermadec Ridge, off East Cape, New Zealand, 689 m, NZOI (1).

The differences in basal sculpture, shell structure and colour pattern suggest that the similarity of *B. recens* to *B. bartschi* is probably superficial.

Bolma recens differs from *B. marshalli* in its larger size, taller spire, wider area between the peripheral and basal angulations, markedly finer sculpture, and fusing of basal granules into radial ridges. Possibly *B. recens* is descended from *B. marshalli* but the differences are too large and the age difference too great to be sure of the relationship.

***Bolma somaliensis* n. sp.**

Fig. 4a-c

DIAGNOSIS. Shell: Small, very solid, with moderately tall spire, sutures not channelled, very slightly stepped, with coarsely granular sculpture and a single row of very short spines on body whorl. Peripheral angulation weak on body whorl and at suture on spire whorls, so that spines rest on upper shoulder of whorl below. Basal angle very weak, represented by a row of gemmules, sub-spinose. A single, weak, sharply gemmate to scaly cord between peripheral and basal angles. Uppermost cord on shoulder slightly stronger than others, of which there are 5-6 on body whorl; 4-6 gemmate cords on base. Whole surface crowded with fine, strongly prosocline growth lines. Basal callus small, occupying about ¼ of base, rather thick when fully developed, pale yellow, white near columella; not separated by a groove from columella when fully mature but a very indistinct groove present in subadults. Colour pale fawn, with a white zone below sutures, gemmules and spines on periphery and base white, aperture white.

Operculum: Unknown.

DIMENSIONS. Holotype: height 26.04 mm, diameter 23.76 mm; largest paratype: height 28.10 mm, diameter 24.30 mm.

TYPE LOCALITY. Off Somali coast, E. Africa, 11°24'N to 11°29'N, 51°35'E, to 51°36'E, 75-175 m (mostly about 150 m) collected H. E. Vokes.

TYPES. Holotype, USNM, 758386, with 3 paratypes, USNM 758387; 1 paratype in Geol. Dept., Tulane University, New Orleans; 1 paratype in AM, C.106307.

The new species is very similar to the Tasmanian fossil species *B. flindersi*, but differs in its larger size, relatively stronger minor sculpture and in having a more convex base. The base of *B. flindersi* is flat, whereas in *B. somaliensis* it is slightly convex (in immature specimens) to moderately convex (in mature specimens).

B. guttata bathyraphis and *B. guttata guttata* are similar to *B. somaliensis* but differ in being larger, in having a thin, white basal callus, and in having a distinct sutural channel.

Bolma tamikoana (Shikama, 1973)

This species is characterised by its rather weak sculpture, reduced spines, simple sutures, almost complete absence of a peripheral angulation, and the small basal callus which is coloured orange or yellow. Two geographic subspecies are recognised.

Bolma tamikoana flava n. sub sp.

Fig. 13i-k

DIAGNOSIS. Shell: Spire moderately tall; body whorl weakly convex, expanded beyond line of flat spire whorls, with short spines and simple suture. Teleoconch of about 5 whorls, all with numerous, short, hollow spines on periphery, 15 on last two whorls. Body whorl almost evenly convex (peripheral and basal angulations very weak), basal angle marked by a row of gemmules slightly stronger than other basal sculpture on first $\frac{1}{3}$ of body whorl, indistinguishable on remainder of whorl. Sculpture of closely spaced rows of rather coarse gemmules, 12 on shoulder of body whorl, 3 between peripheral and basal angles, about 13 on base, becoming coarser towards columellar region. Basal callus small, occupying approximately $\frac{1}{5}$ of base, thin, transparent. Colour pale lemon-yellow, with regular, rather large, radial, brown blotches on shoulder (6 on body whorl) and a few very small pale brown specks on base; columellar callus bright lemon-yellow behind columella, whitish where spread on base. Outer lip bright lemon-yellow.

Operculum: Oval, white, simple, with weakly wrinkled surface.

DIMENSIONS. Holotype: height 27 mm, diameter (excluding spines) 29 mm, (including spines) 32 mm.

TYPE LOCALITY. 15°24.5'S, 46°02.0'E, off Majunga, N.W. Malagasy Republic, 250-265 m; A. Crosnier Colln.

HOLOTYPE. AMS, C. 112907.

B. tamikoana flava differs from *B. tamikoana tamikoana* in its shorter spire which gives the subspecies a more ovate outline, finer spiral sculpture and a weaker basal angle. The colour patterns of the two subspecies are similar but the basic colour of *B. tamikoana flava* is lemon-yellow whereas in *B. tamikoana tamikoana* it is fawn. The two forms are here recognized as geographic subspecies because of their general morphological similarity, their wide geographic separation and because the observed differences in shell characters are much greater than between widely separated populations of *B. tamikoana tamikoana*.

The new subspecies is known from only one specimen, an adult which was collected alive.

Bolma tamikoana tamikoana (Shikama, 1973)

Fig. 13a-h

Astralium (Bolma) modestum var. *girgyllus*. — Schepman, 1908: 28 (not of Reeve, 1843).

Astraea tayloriana. — Kuroda & Habe, 1952: 39 (not of E.A. Smith, 1880).

Bolma tayloriana. — Oyama & Takemura, 1960: *Bolma*, fig. 1, 2 (not of Smith).

Galeoastraea tayloriana. — Habe, 1961: 14, pl. 7, fig. 18; Habe, 1964: 21, pl. 7, fig. 18 (not of Smith).

Galeoastraea tayloriana tamikoana Shikama, 1973: 3, pl. 1, fig. 3, 4; Okutani, 1975: 189, pl. 8, fig. 10.

DIAGNOSIS. Shell: Of medium size, spire of medium height to relatively tall, whorls lightly convex, with indistinct sutures and bearing granular spiral cords. Body whorl bi-angled, upper (peripheral) angulation weak, with or without short, hollow spines, 20 small spines on the last whorl of one Japanese specimen, none on another Japanese specimen, and 12 in the only Australian specimen. Spines persistent at suture on early whorls. Spines are narrowly triangular, slightly downwardly directed. Basal angle sharp, with a prominent row of gemmae that are pointed (but not spinose) in the Australian specimen but rounded in Japanese material. Two rows of gemmae between peripheral and basal angles, a weak third in Australian shell; 9-10 closely-packed gemmate spirals on flat base and 7 on side of penultimate whorl, with interstitial spiral threads developing on body whorl of most specimens. Subsutural cord stronger than others on upper whorl surface, situated at base of very narrow, steep subsutural area. Surface of shell between gemmae sculptured with faint, prosocline axial growth lamellae. Basal callus rather thin, spread over about $\frac{1}{5}$ of the base, separated from columella by a groove when immature, a continuous glaze when mature (not fully developed on large Japanese shells examined), bright orange (pale yellowish-white in the dead Australian shell), columella nacreous white. Outer lip very slightly reflected in mature Australian shell, simple in Japanese shells. Surface pinkish-fawn, with pale yellow-brown base; very faint purplish, radial blotches on upper surface.

Operculum: White; almost circular, with a high but slightly concave edge, and convex upper surface; edge concentrically sculptured, upper surface irregularly pustulose.

DIMENSIONS. Holotype: height 33.0 mm, diameter 32.0mm; paratype: height 33.6 mm, diameter 37.5 mm; figured Japanese specimen: height 34.7 mm, diameter (excluding spines) 33.1 mm; Australian specimen: height 36.3 mm, diameter (excluding spines) 35.5 mm.

TYPE LOCALITY. Off Uotsuri Isle, Senkaku Ids, S.W. Japan, trawled.

TYPE. Holotype, Shikama Colln, Geological Institute, Yokohama National University, with one paratype.

OTHER MATERIAL EXAMINED. Off Torishima Is., Izu Ids, central Japan, 250 m (NSMT) (1); Japan (NSMT) (2); Tosa Bay, Shikoku, Japan (ANSP) (4); Arafura Sea, off Arnhem Land, Northern Territory, Australia, 8°14'S, 133°12'E, 125 m (AM, C.72710) (1); "Siboga" Stn 100, 6°11'N, 120°37.5'E, Indonesia, on dead coral, 450 m (Zoölogisch Museum, Amsterdam), the specimen recorded as *Astralium (Bolma) modesta* var. *girgyllus* by Schepman (1908).

OTHER LOCALITIES. Stn D86 (L1), 33°22.0'N, 133°39.1' E, 150-190 m, Kurose Bank, off Hachijo Island, Japan (Okutani, 1975).

The Japanese shells loaned to us from the NSMT (fig. 13a-c) and shells figured by Oyama & Takemura (1960, *Bolma*, figs. 1, 2), Habe (1961, pl. 7, fig. 18; 1964, pl. 7, fig. 18) and Shikama (1973, pl. 1, fig. 3, 4) differ from the single specimen from the Arafura Sea (fig. 13g, h) only in having shorter and more numerous peripheral spines. As the peripheral spines of *Bolma* vary greatly between individuals we consider the Japanese and Australian specimens to be conspecific.

Bolma tamikoana tamikoana differs from all other species of *Bolma* in its relatively weak sculpture, reduced spines, almost straight spire outlines, simple sutures, and almost absent peripheral angulation and prominent basal angle. From the South African *B. tayloriana*, with which it has been confused by several Japanese authors, it differs in its taller spire, coarser sculpture, different dorsal coloration, thicker shell, much smaller basal callus, in bearing a row of small peripheral spines, in having a basal angulation, in the different operculum, and in lacking an obvious periostracum.

Bolma tayloriana (E.A. Smith, 1880)

Fig. 14a-h

Turbo (Pomaulax?) taylorianus E.A. Smith, 1880: 483, pl. 48, fig. 9.

Turbo (Pomaulax) taylorianus. — G. B. Sowerby 3rd, 1886: 225, pl. 505, fig. 169.

Pachypoma tayloriana. — G.B. Sowerby 3rd, 1897: 18.

Astraea tayloriana. — Bartsch, 1915: 146; Barnard, 1963: 217, figs. 5d, e, 7a, b.

Astralium tayloriana. — Odhner, 1923: 6; Turton, 1932: 176.

DIAGNOSIS. Shell: Broadly conical, of light build, whorls lightly convex, without spines on body whorl, and with simple sutures (except on early spire whorls where there is a sutural channel as described by Barnard (1963, p. 218) and short peripheral spines). Sculpture of fine, closely gemmate spirals. Periphery sharply angled, with 11-16 rows of finely gemmate spiral threads on penultimate and body whorls and 16-18 on base. No basal angulation. Columellar callus yellow, narrow, a thin basal callus spreading over about 1/3 of base, pale yellowish-white, apertural edge of columella white. Outer lip thin, not expanded. Surface pinkish-mauve above, sometimes with brownish axial bands (fig. 14e, f), yellowish-white on base. Periostracum rather thick, brown.

Operculum: Oval, rather pointed at outer end, sharply rounded on columellar end and slightly concave on the edge against the parietal wall; columellar end thick, remainder thin, the central area slightly excavated, smooth; white.

DIMENSIONS. Holotype: height 40 mm, diameter 49 mm; figured specimen: height 39.75 mm, diameter 48.76 mm.

TYPE LOCALITY. Not known.

HOLOTYPE. BMNH, 1879.2.26.229.

OTHER MATERIAL EXAMINED. South Africa: Trawled off Cape Town (AMNH) (2); off Mossel Bay (AMNH) (1); False Bay, Cape of Good Hope, 37 m (SAM) (1); off Cape Columbine, 146 m, 26 April 1962 (NM, F6630); 34°54'S, 19°48'E, 48 m (NM, A3585).

OTHER LOCALITIES. *South Africa*: Port Elizabeth (Sowerby, 1897); Port Alfred (Bartsch, 1915; Turton, 1932); Walker Bay, 44 m (Odhner, 1923); False Bay, Cape of Good Hope, 26-73 m; False Bay, 68 and 95 m; off Cape St. Blaize, 68 m; 33°52'S, 25°43'E, 95 m (Barnard, 1963, p. 219).

The only similar species are *B. midwayensis*, which has markedly coarser granular sculpture and more inflated whorls than *B. tayloriana*, and *B. tamikoana*. Both of these species are of different shape from *B. tayloriana*. The low spire, elongate operculum, and thick periostracum set *B. tayloriana* apart from the other described species of *Bolma*, but the juvenile shell and the radula described by Barnard (1963, p. 217) are typical of *Bolma*.

When E.A. Smith (1880) described *B. tayloriana*, no locality was known for the holotype. Subsequently Sowerby (1897, p. 18) recognised it as a South African shell, and several workers (see above in synonymy) have since recorded South African specimens. Examination of the holotype has shown that it is undoubtedly the species described by Barnard (1963, p. 217) from South Africa.

Bolma* cf. *tayloriana (E.A. Smith, 1880).

Fig. 14i-k

Two large specimens and a fragment are referred to *B. tayloriana* but are atypical in some respects. They resemble typical *B. tayloriana* in their purplish pink, convex upper whorl surfaces, their almost flat bases, their widely spread, smooth, thick, white basal calluses with bright orange edge, their sutural channels on early spire whorls, and their weakly differentiated, granular cord at about a quarter of the height of later whorls, but differ from typical specimens in their markedly taller spires, slightly coarser dorsal and ventral granular sculpture and in bearing relatively large, widely spaced, pointed, hollow, scale-like spines around all lower sutures, remaining prominent to the end of the last whorl of one shell and becoming obsolete over the last quarter whorl of the other. There seems to be little doubt that these are specimens of *B. tayloriana* in which the peripheral spines of early spire whorls remain prominent to the last whorl, rather than dying out after a few whorls.

DIMENSIONS. Figured specimens: height (actual) 78 mm, diameter (excluding spines) 80 mm, diameter (including spines) 85 mm; height 76 mm, diameter (excluding spines) 82 mm, diameter (including spines) 84 mm.

LOCALITIES. Trawled eastern Cape Province (NM, A. 3585) (2); trawled off Durban, 494 m (NM, 9304) (1).

The spinose form of *B. tayloriana* is perhaps geographically isolated and so distinguishable as a subspecies, as the one well localised (juvenile) specimen occurs well north of the range of typical *tayloriana*. The two large specimens are, however, poorly localised and more information is required about the distribution of the two forms before they can be properly assessed.

Subgenus *Senobolma* Okutani, 1964

Senobolma Okutani, 1964: 135. Type species (original designation): *Senobolma venusta* Okutani, 1964, deep water off Japan.

This subgenus contains two Japanese species that differ from *Bolma* (*sensu stricto*) in their very small size (up to only 13 mm), tall spires, and sculpture of smooth spiral cords. Okutani (1964, pl. 8, fig. 1) figured the typical *Astraea* protoconch of *B. (Senobolma) venusta*.

Bolma (Senobolma) exotica (Okutani, 1969)

Fig. 5k,l

Senobolma exotica Okutani, 1969: 138, text-fig. 2, 3.

DIAGNOSIS. Differs from *B. (Senobolma) venusta* in having low, rounded gemmae on the upper three spiral cords of early spire whorls, the gemmae becoming progressively more fused into axial ridges down the shell, so that on the last whorl they form short, rounded, very strongly prosocline ridges.

DIMENSIONS. Holotype: height 12.2 mm, diameter 9.8 mm; paratype: height 12.9 mm, diameter 10.7 mm.

TYPE LOCALITY. 26°46.0'N, 135°22.5'E, 644 km off Cape Shiono-Misaki, Japan, 435 m.

TYPES. Holotype, NSMT, with one paratype.

Bolma (Senobolma) venusta (Okutani, 1964)

Figs 5i, j; 17i, j

Senobolma venusta Okutani, 1964: 135, pl. 8, fig. 1-3; Okutani, 1969: 138, text-fig. 4; Kuroda *et al.*, 1971: 49, pl. 15, fig. 7; Okutani, 1972: 80, fig. 13, 14.

DIAGNOSIS. A small, tall-spined *Bolma* with sculpture of smooth spiral cords on surfaces of whorls, short peripheral spines on early spire whorls only, and with a smooth base. The natural-size coloured illustration by Kuroda *et al.* (1971, pl. 15, fig. 7) shows the colour to be brownish red, with the aperture and base white.

DIMENSIONS. Holotype: height 13.0 mm, diameter 11.0 mm.

TYPE LOCALITY. 34°02.8'N, 138°54.5'E, Zenisu Bank, S.W. of Kozu Is., Izu Ids, Japan, 140-200 m.

TYPES. Holotype, NSMT, with one paratype.

OTHER LOCALITIES. 98 m, S. of Jagoshima, Sagami Bay, Honshu, Japan (Kuroda *et al.* 1971, p. 49); seven localities on Zenisu, Hyotanse and Takase Banks, south of the Izu-Shichito Ids, Japan, in 106 to 260 m (Okutani, 1972, p. 80).

RECENT SPECIES OF *BOLMA*

In summary, we list our classification of the world Recent species and subspecies of *Bolma*:

Subgenus *Bolma* Risso, 1826*Bolma rugosa* group:

Bolma andersoni (Smith, 1902), South Africa.

aureola (Hedley, 1907), Queensland and northern New South Wales, Australia.

girgylla (Reeve, 1843), Japan to Indonesia.

jacquelineae (Marche-Marchad, 1957), W. Africa.

johnstoni (Odhner, 1923), Angola.

modesta (Reeve, 1842), Japan and China.

rugosa (Linné, 1767), Mediterranean Sea and eastern Atlantic Ocean.

Bolma guttata group:

Bolma bartschi (Dall, 1913), Moluccas to Japan.

guttata bathyraphis (E. A. Smith, 1899), Maldive Islands to South Africa.

guttata guttata (A. Adams, 1863), Sagami Bay, Japan.

guttata millegranosa (Kuroda & Habe in Habe, 1958), southern Japan and southern Queensland.

guttata subsp.?, Western Australia.

henica (Watson, 1885), West Pacific from Australia to Japan, Fiji, Indonesia and southern Africa.

kermadecensis n. sp., Kermadec Islands, South Pacific.

midwayensis (Habe & Kosuge, 1970), Midway Island, Pacific Ocean.

persica (Dall, 1907), Japan.

sp. ?aff. *persica* (Dall), China Sea.

recens (Dell, 1967), north of New Zealand.

somaliensis n. sp., East Africa.

tamikoana tamikoana (Shikama, 1973), Arafura Sea and southern Japan.

tamikoana flava n. subsp., Malagasy Republic.

tayloriana (E. A. Smith, 1880), South Africa.

Subgenus *Senobolma* Okutani, 1964

Bolma (*Senobolma*) *exotica* (Okutani, 1969), Japan.

venusta (Okutani, 1964), Japan.

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ADDENDUM

Since page proofs have been received descriptions of two new taxa, *Galeoastraea formosana* Shikama, 1977 (*Sci. Rep. Yokohama Natl. Univ.*, 2 (24): 12, pl. 2, figs 6a, b) and *Galeoastraea tamikoae* (sic!) *shikamai* Habe, 1978 (*Venus*, 53 (5): 46) have been received. Both of these names appear to fall into synonymy. *G. formosana* appears to be, as Habe (1978) points out, a colour form of *B. guttata millegranosa*. *G. tamikoana shikamai* is proposed for the spineless form of *tamikoana* figured as *G. tayloriana* by Habe (1961: 14, pl. 7, fig. 18) which we do not consider to be sufficiently distinct to be recognised as a separate taxon.

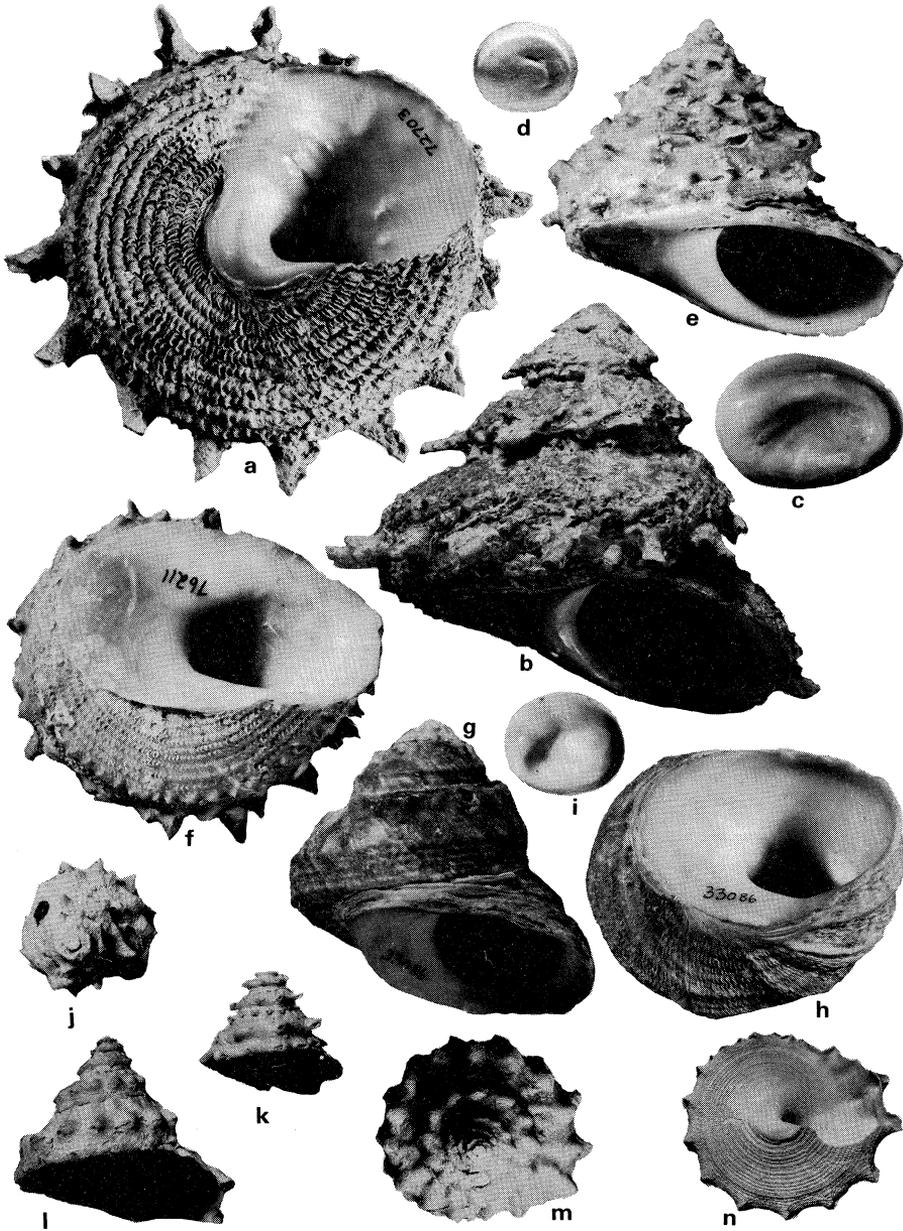


Fig. 1 a-c *Bolma aureola* (Hedley), Off Wide Bay, Queensland, 55 m, AM, C. 72703. Height 62 mm. **d-f** *Bolma modesta* (Reeve), Japan; AM, C. 76211. Height 50 mm. **d**, operculum coated with ammonium chloride. **g-i**. *Bolma rugosa* (Linné), Marseilles, France, Mediterranean Sea; AM, C.33086. Height 46 mm. **j-n**. *Bolma andersoni* (Smith); **j**, **k**, juvenile, off Durban, South Africa, ex gut loggerhead turtle; NM, A235. Height 12.1 mm; **l-n**, off Natal; NM, 3729. Height 31.6 mm

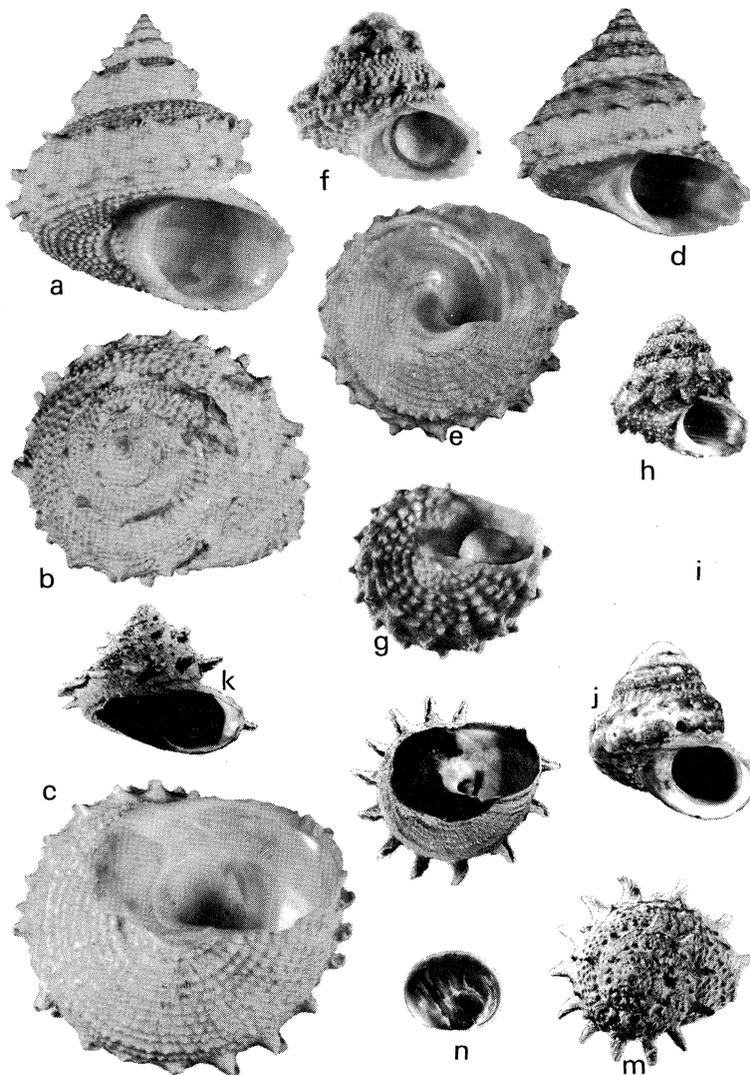


Fig. 2. **a-c.** *Bolma girgylla* (Reeve), lectotype, "China," H. Cuming Colln.; BMNH, 1968673. Height 57.4 mm. **d-e.** *Bolma modesta* (Reeve), Japan: BMNH, 19782. Height 45.7 mm. **f-j.** *Bolma jacquelineae* (Marche-Marchad); **f-i**, off Tema, Ghana, W. Africa, coll. R. Isaacs, from fisherman, depth probably 37-42 m; **f, g**, AM, C.92185. Height 23.5 mm; **h, i**, NMW, 71.39.Z1. Height 28.5 mm.; **j**, — São Thomé Is., Gulf of Guinea, W. Africa (ex Melville-Tomlin colln.), NMW, 72.2.Z1. Height 36.2 mm. **k-n** *Bolma johnstoni* (Odhner), holotype, Porto Alexander, Angola, 110 m; Natural History Museum, Stockholm. Dimensions not known. Photos **h-n** courtesy of S. P. Dance.

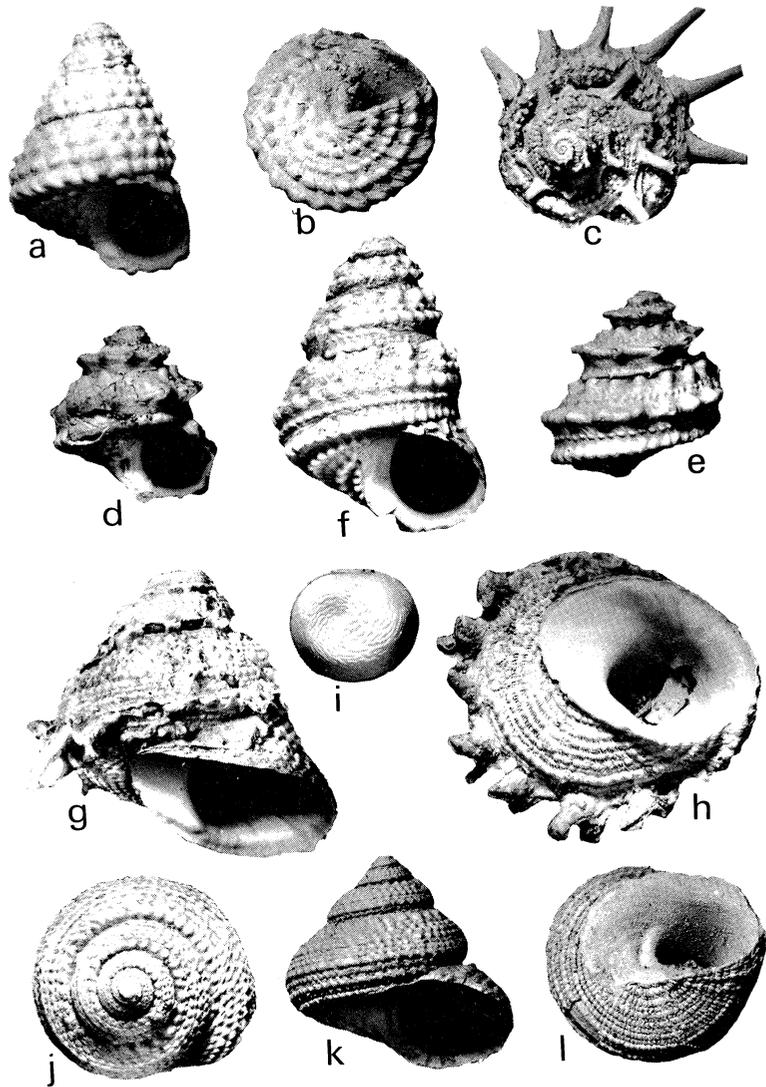


Fig. 3 a-b. *Bolma austroconica* n. sp., holotype, Jan Juc Formation, Bird Rock Cliffs, Torquay, Victoria (Janjukian, Oligocene); NMV, P.31183. Height 15.45 mm. **c.** *Bolma* aff. *flindersi darraghi* n. subsp., long-spined specimen, Jan Juc Formation, Bird Rock Cliffs, Torquay, Victoria (Janjukian, Oligocene); NZGS WM11, 742. Height 10.5 mm. **d-f** *Bolma crassigranosa* (T. Woods), Freestone Cove Sandstone, Fossil Bluff, near Wynyard, Tasmania (Longfordian, Lower Miocene). **d, e**, juvenile resembling holotype of *Astraliium ornatissimum* T. Woods; NMV, P.31188. Height 11.8 mm. **f**, adult; NMV, P.31189. Height 19.5 mm. **g-i.** *Bolma* ? aff. *persica* (Dall), U.S. Bureau of Fisheries Stn 5311, 161 m, Pratas Is., China Sea; USNM, 237697. Height 27.3 mm. **i**, operculum coated with ammonium chloride. **j-l.** *Bolma anacanthos* n. sp. holotype, Jan Juc Formation, ledge, Bird Rock Cliffs, Torquay, Victoria (Janjukian, Oligocene); NMV, P.31183. Height 21.45 mm.

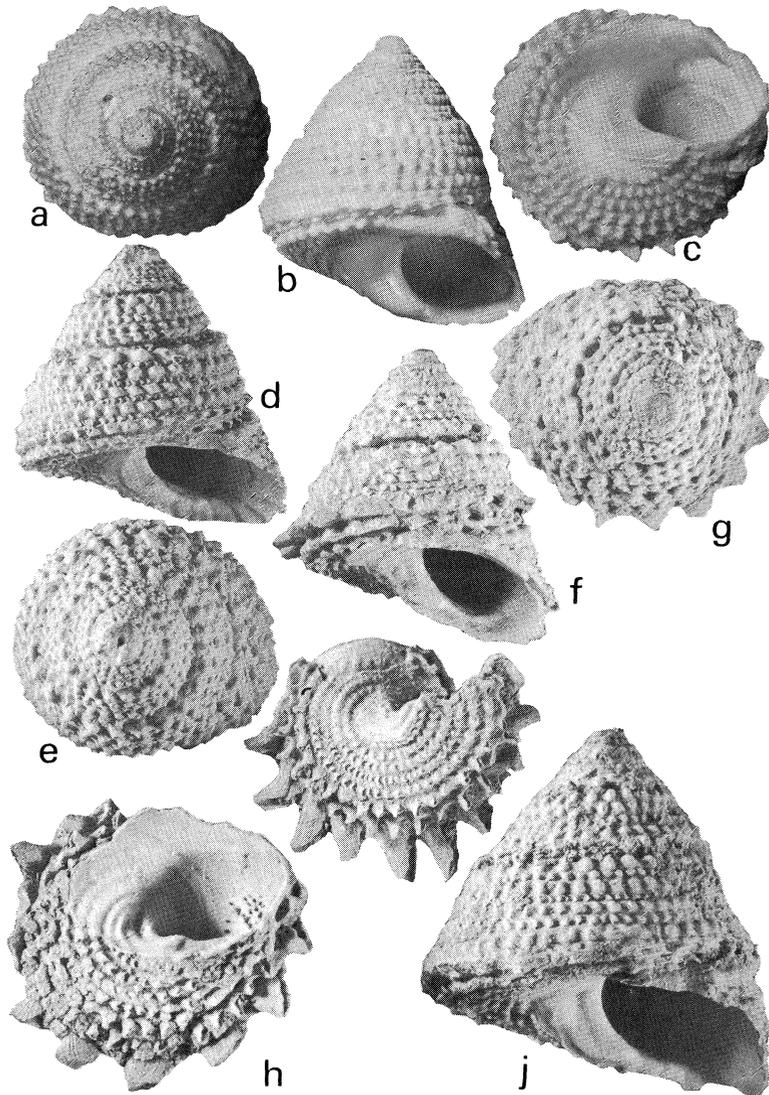


Fig. 4. **a-c.** *Bolma somaliensis* n. sp., holotype, off Somali Coast, E. Africa, 11°24'N to 11°29'N, 51°35'E, 74-175 m; USNM, 758386. Height 26.04 mm. **d-j.** *Bolma flindersi flindersi* (T. Woods), Freestone Cove Sandstone, Fossil Bluff, near Wynyard, Tasmania (Longfordian, Lower Miocene); all in NMV. **d, e**, common form. Height 18.0 mm; **f-h**, long-spined specimen. Height 17.8 mm; **i**, extremely long-spined individual. Height 13.8 mm; **j**, largest specimen seen. Height 21.5 mm.

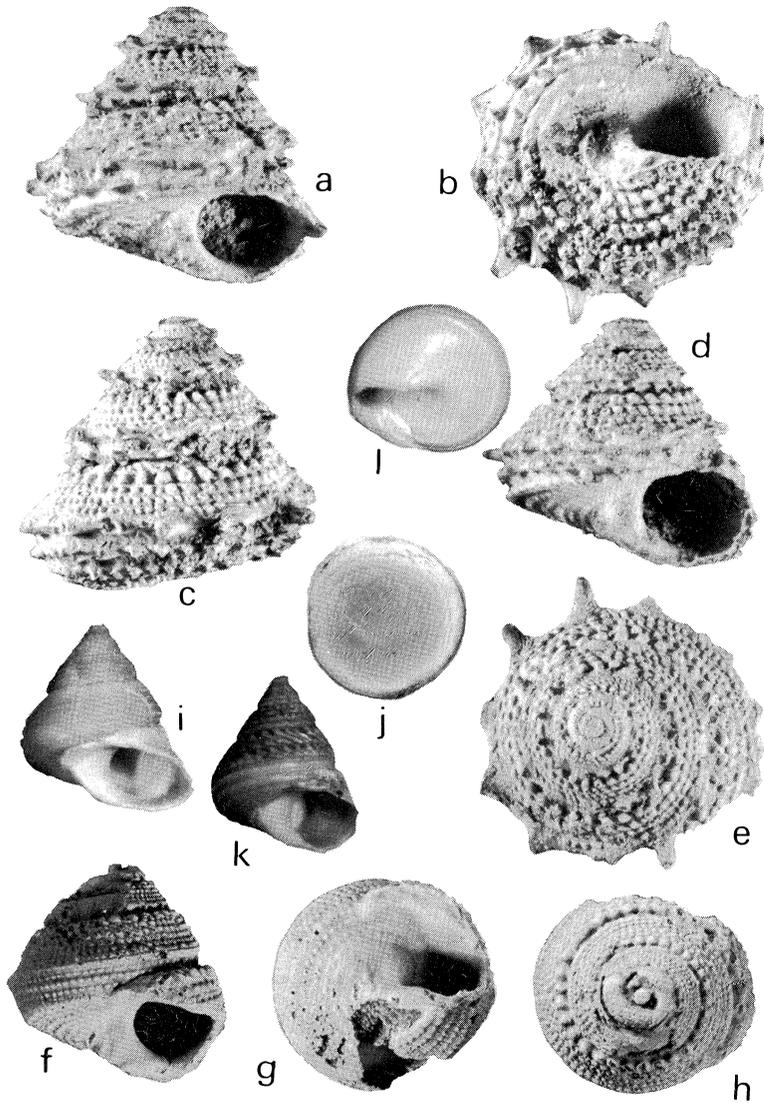


Fig. 5. **a-h.** *Bolma flindersi darraghi* n. subsp., Brown's Creek, Johanna, west of Cape Otway, Victoria, Brown's Creek Clay (Aldingan, Upper Eocene). **a-c,** holotype, NMV, P.30767. Height 13 mm; **d, e,** paratype, NMV, P.30768. Height 11.96 mm; **f-h,** 25 km N. of Walpole along Thomson Highway, W.A. (Aldingan, Upper Eocene); WAM (78-922). Height 11 mm. **i-j,** *Bolma (Senobolma) venusta* (Okutani), holotype, Zenisu Bank, off Izu Ids, Japan, 140-220 m; NSMT, Tokyo. Height 13 mm; **j,** operculum (SEM photo). 34°27.2'N, 139°11.1'E, Takase Bank, off Izu Ids, central Japan, 130 m; Tokai Regional Fisheries Laboratory. **k-l.** *Bolma (Senobolma) exotica* (Okutani), holotype, 26°46.0'N, 135°22.5'E, 644 km off Cape Shiono-misaki, Japan, 435 m; NSMT. Height 12.2 mm.

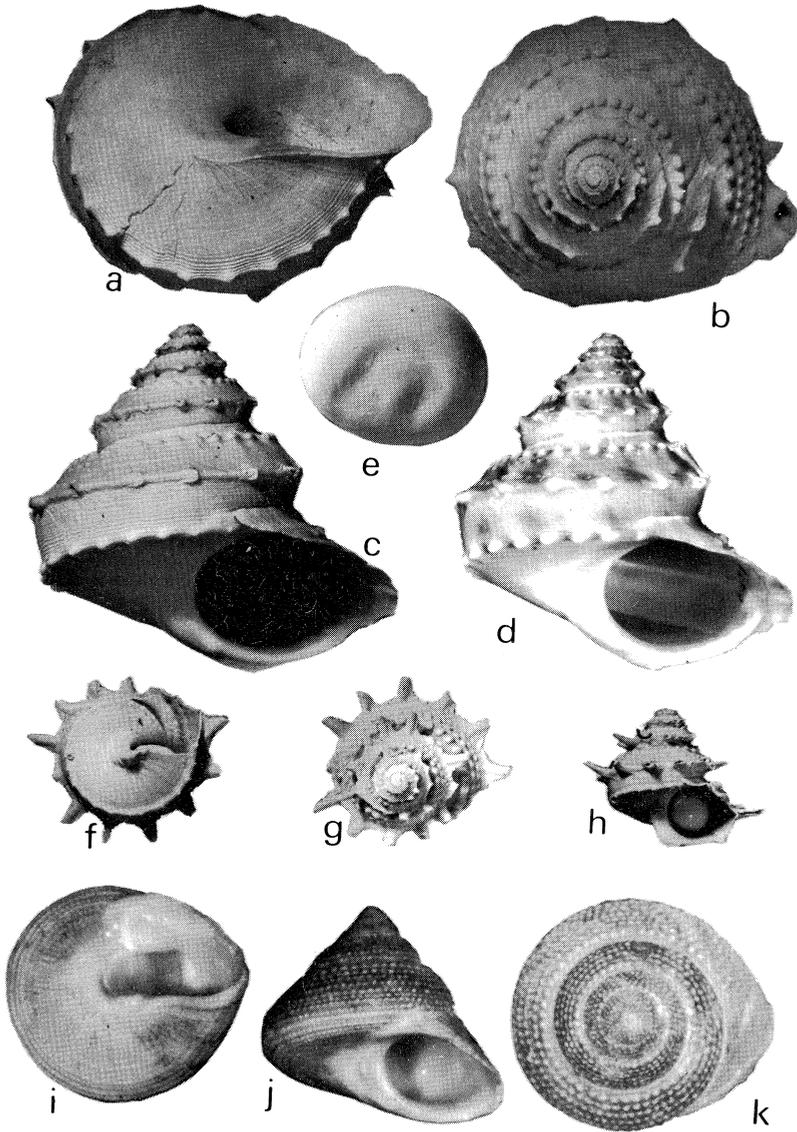


Fig. 6. **a-h.** *Bolma bartschi* Dall, **a-e**, holotype, off Dowarra Is., Molucca Passage, 0°50'S, 128°12'E, 375 m; USNM 214444. Height 30 mm. **a-c**, coated with ammonium chloride; **d**, uncoated, showing colour-pattern; **e**, operculum coated with ammonium chloride; **f-h**, holotype of *Turbo asteriola* Dall, Colnett Strait, Inland Sea of Japan, 251 m; USNM, 205733. Height 14 mm. **i-k.** *Bolma midwayensis* (Habe & Kosuge), holotype, off Midway Is., Pacific Ocean; NSMT. Height 28.6 mm.

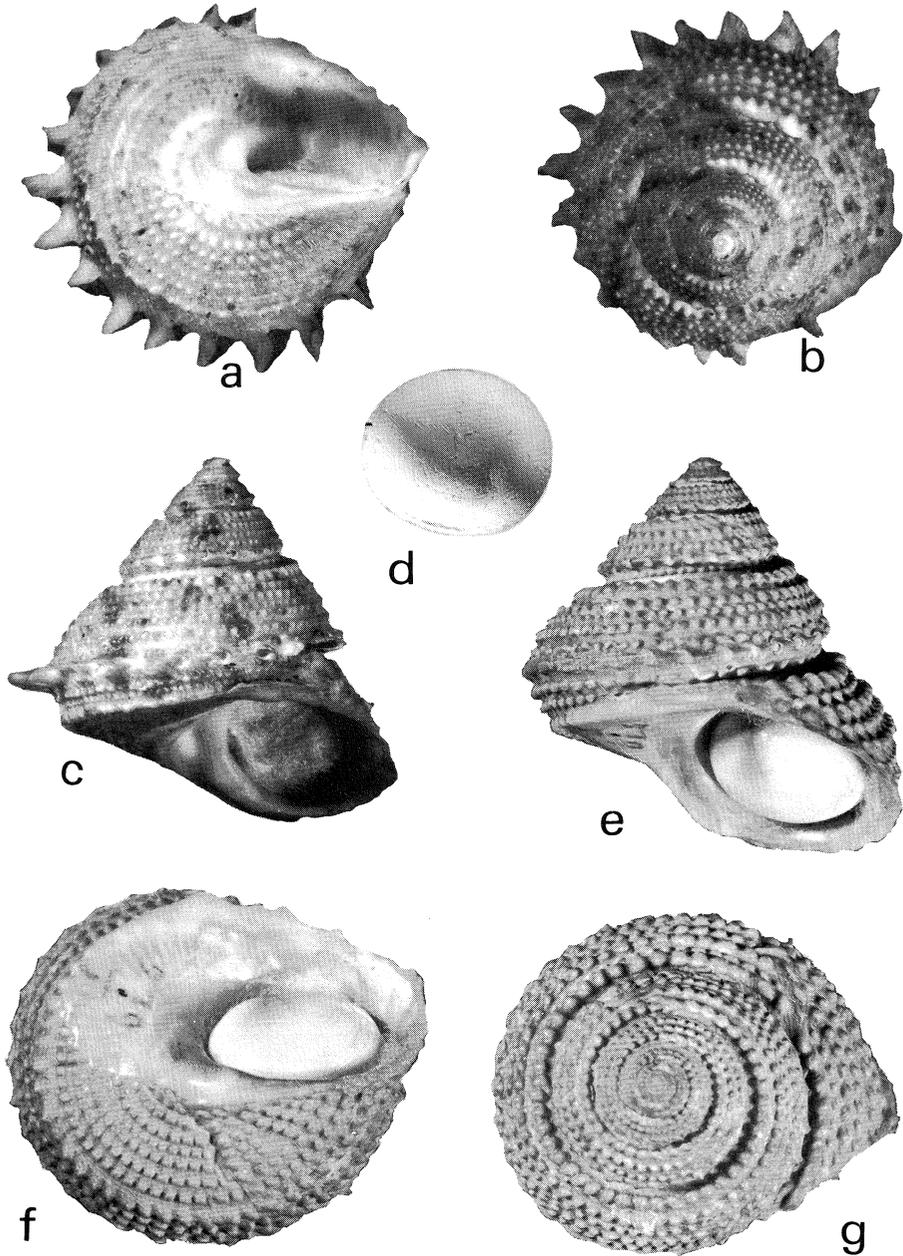


Fig. 7. **a-g.** *Bolma guttata bathyraphis* (Smith), **a-d,** holotype of *Astralium gilchristi* Sowerby, 15 km WNW of O'Neil Peak, Natal, 165 m; SAM, A5219. Height 26.9 mm. **d,** operculum coated with ammonium chloride; **e-g,** holotype of *Astralium bathyraphe* Smith, Maldive Atoll, 384 m, Zoological Survey of India, Calcutta. Height 34 mm.

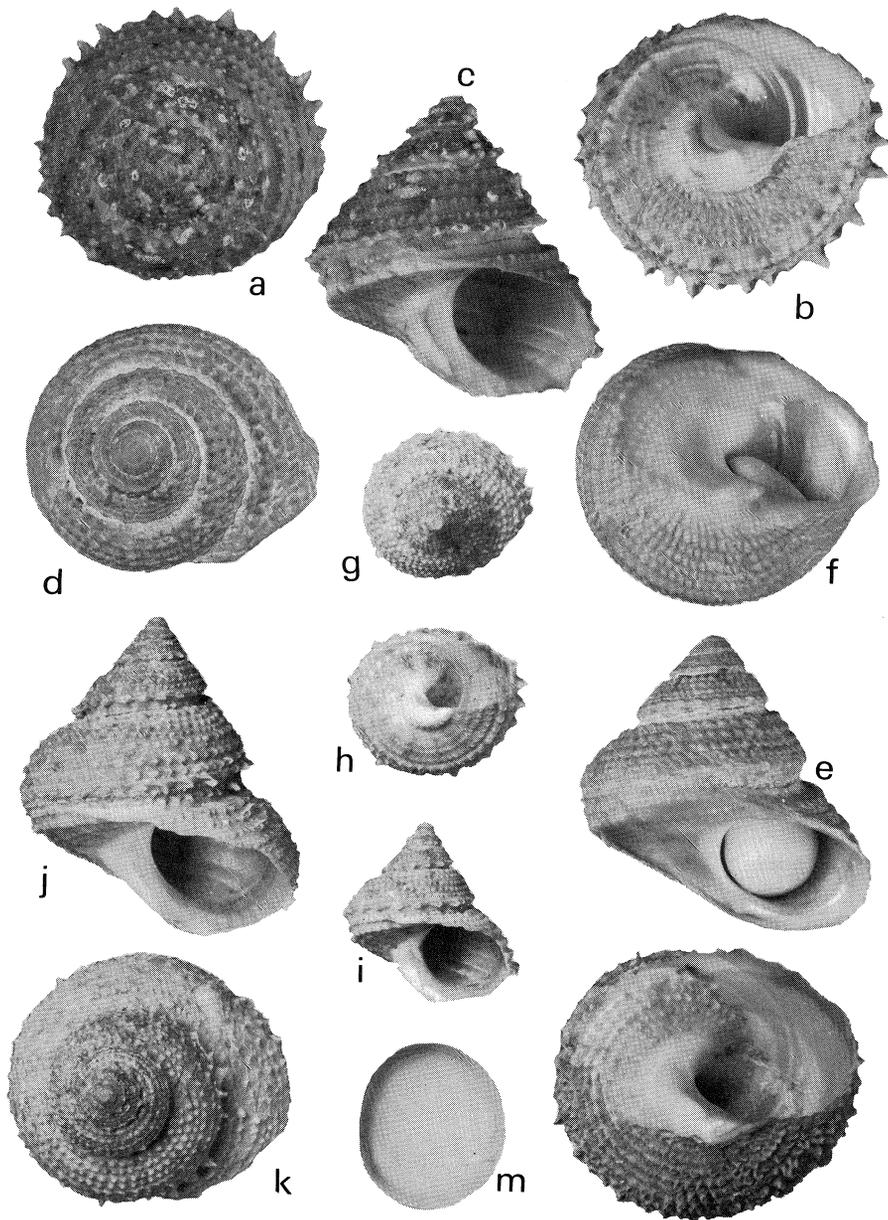


Fig. 8. **a-m.** *Bolma guttata bathyraphis* (Smith), **a-c**, 23°36.3'S, 43°32.5'E, off Tuléar, S.W. Malagasy Republic, 250 m; AMS. Height 29.6 mm; **d-f**, 12°51'S, 48°06.3'E, off Nossi Bé, N.W. Malagasy Republic, 675-705 m; AMS. Height 29.2 mm; **g-m**, 4°43'48"N to 4°44'00"N, 72°55'24"E to 72°54'18"E, Maldive Ids, Indian Ocean, 229 m; BMNH; **g-i**, juvenile. Height 21.1 mm; **j-l**, subadult. Height 38.6 mm; **m**, operculum coated with ammonium chloride.

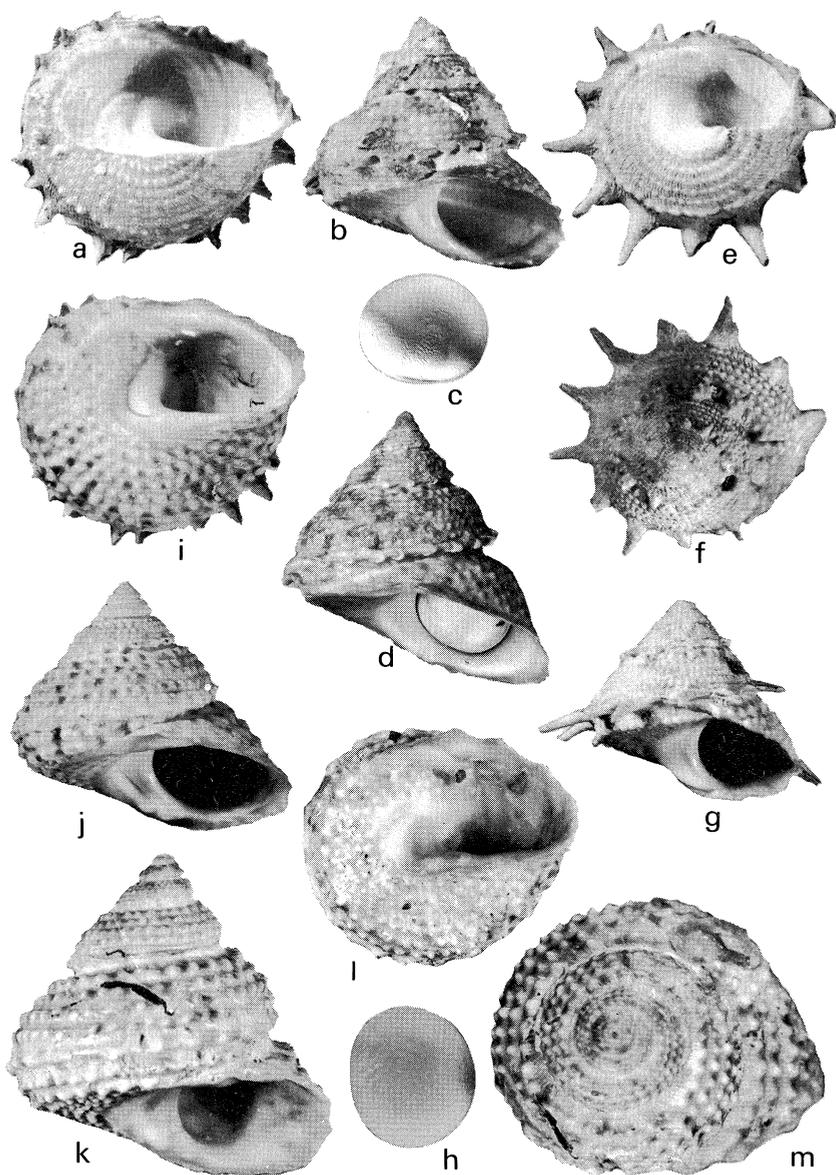


Fig. 9. **a-d.** *Bolma guttata millegranosa* (Kuroda and Habe), **a-c**, off Tosa Bay, Shikoku, Japan, 98 m; NSMT. Height 29.5 mm; **c**, operculum coated with ammonium chloride; **d**, off Tanabe, Kii, Japan; Thaanum-Langford Colln, Bernice P. Bishop Museum, 10629. Height 41 mm. **e-h.** *Bolma guttata* subsp.?, between Shark Bay and Onslow, Western Australia; WAM, 1603-70. Height 15.73 mm; operculum uncoated. **i-m.** *Bolma guttata guttata* (A. Adams), **i-j**, Okinose Bank, off Sagami Bay, central Honshu, Japan, 48 m; NSMT. Height 31 mm; **k-m**, presumed holotype, Tateyama, Japan; H. Cuming Colln., BMNH, 1968210. Height 40 mm.

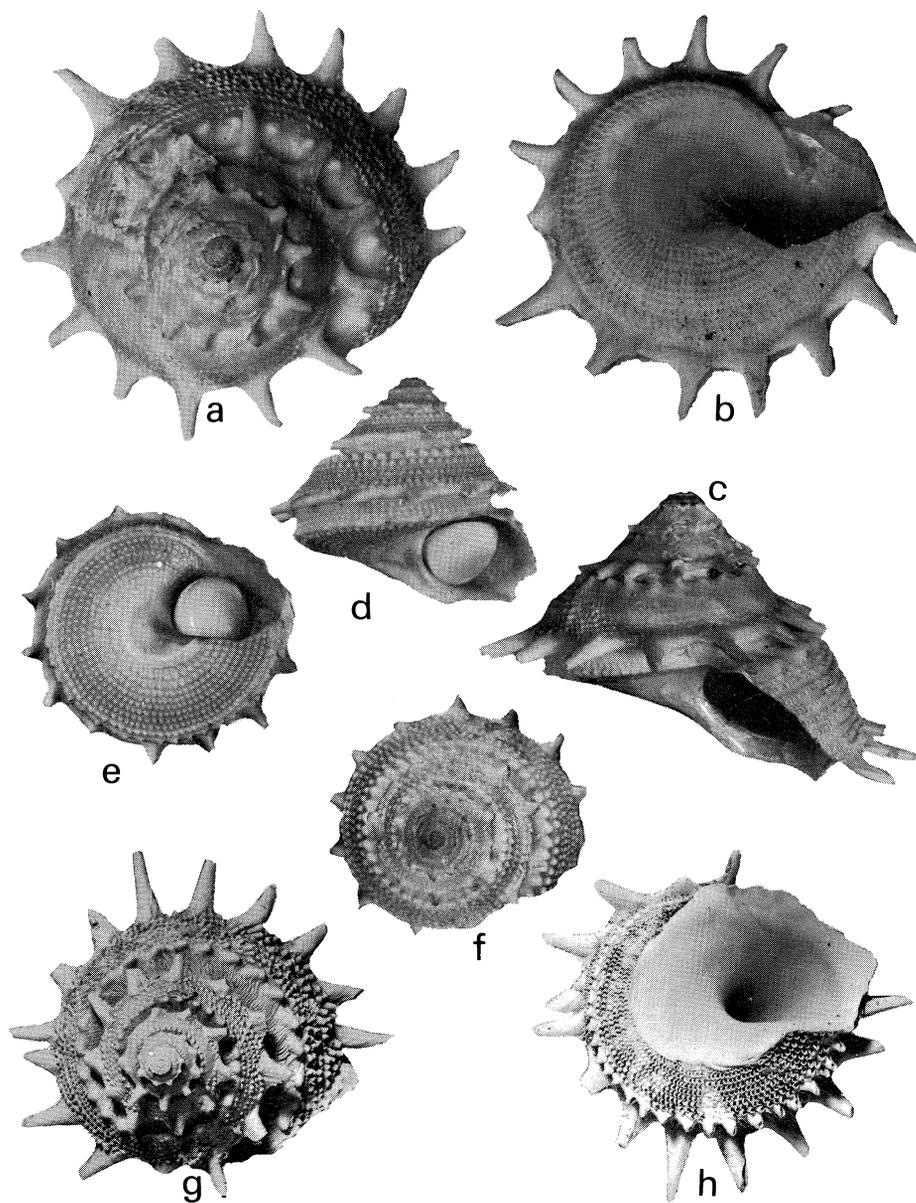


Fig. 10. **a-h.** *Bolma henica* (Watson), **a-c**, lectotype (here designated) of *Astraliium* (*Pseudastraliium*) *abyssorum* Schepman, "Siboga" Stn 59, west entrance to Samau Strait, Indonesia, 390 m; Zoölogisch Museum, Amsterdam, 2532. Height 17 mm; **d-f**, lectotype (here designated) of *Turbo henicus* Watson, "Challenger" Stn 173, off Fiji, 576 m; BMNH, 87.2.9.453. Height 21.6 mm; **g-h**, the form *gloriosa* Kira, trawled off Tosa Bay, Shikoku, Japan; USNM, 596190. Height 22.9 mm, diameter (including spines) 35.5 mm.

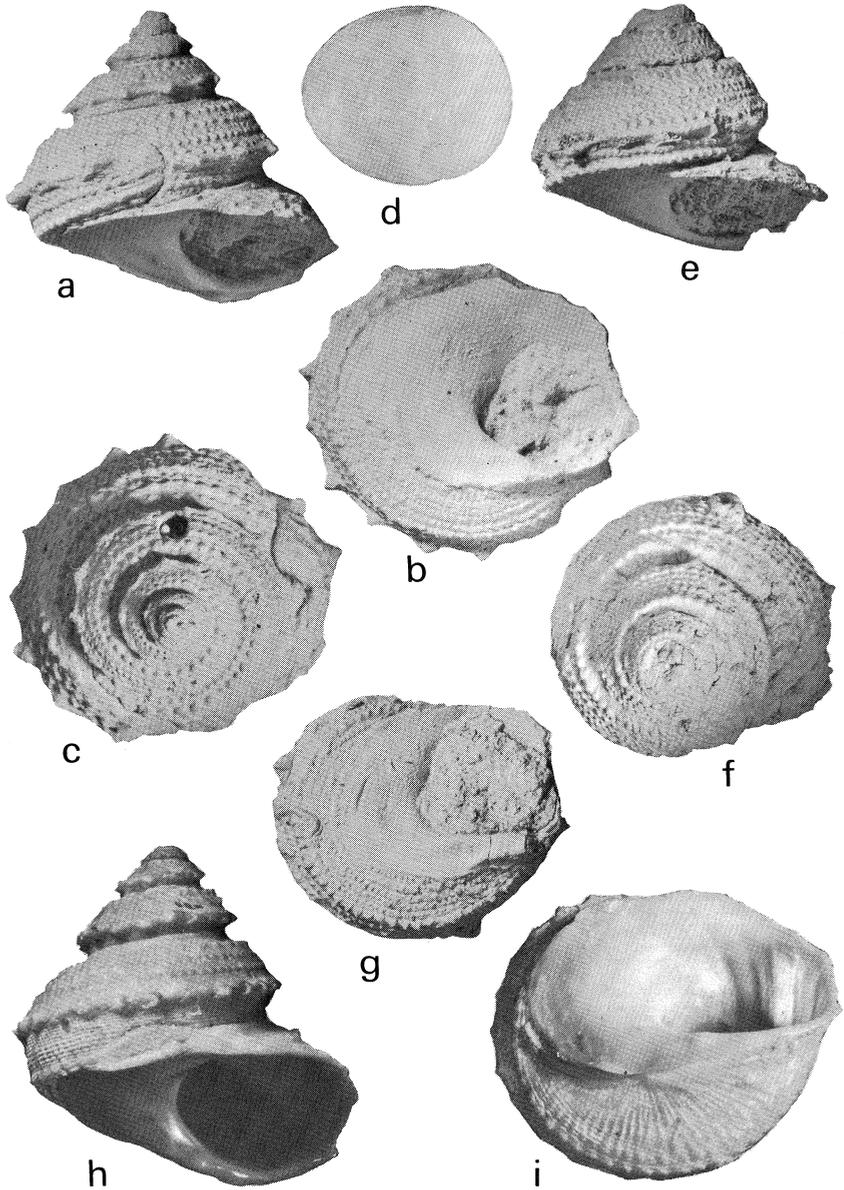


Fig. 11. **a-d** *Bolma marshalli* (Thomson), NZGS locality GS9535, cliffs below Everett's Quarry, south of Oamaru, New Zealand (Whaingaroan, Oligocene); NZGS, TM5421. Height 28.3 mm; **d**, operculum uncoated. **e-g**. *Bolma* aff. *marshalli* (Thomson), GS9481, fallen block of Waiareka Volcanic Formation at base of Williams Bluff, Lorne, inland from Oamaru, New Zealand (Kaiatan, Upper Eocene); NZGS, TM5422. Height 22.8 mm. **h-i**. *Bolma recens* (Dell), holotype, Kiwi Seamount, between New Zealand and Kermadec Ids, 358-677 m; N.Z. National Museum, M21297. Height 31 mm.

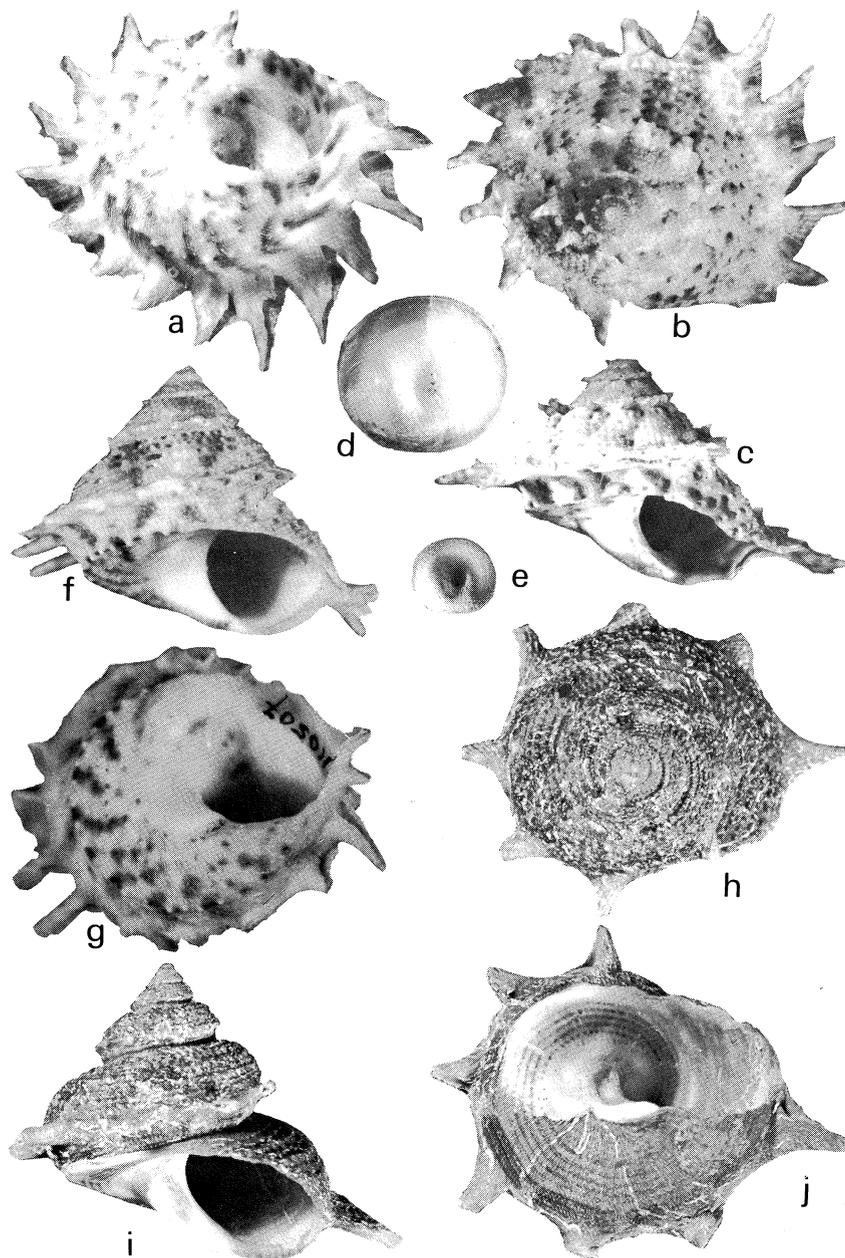


Fig. 12. **a-g.** *Bolma persica* (Dall), off Tosa Bay, Shikoku, Japan, 200 m; NSMT. Height 15.1 mm; **d-e,** operculum; coated with ammonium chloride (**e**); uncoated (**d**); **f-g,** holotype, "Albatross" Stn 4936, 188 m, Kagoshima Gulf, Japan; USNM, 110507. Height 20 mm. **h-j.** *Bolma kermadecensis* n. sp., holotype, east of Curtis Is, Kermadec Ids, 165-135 m; NZOI, H235. Height 36 mm.

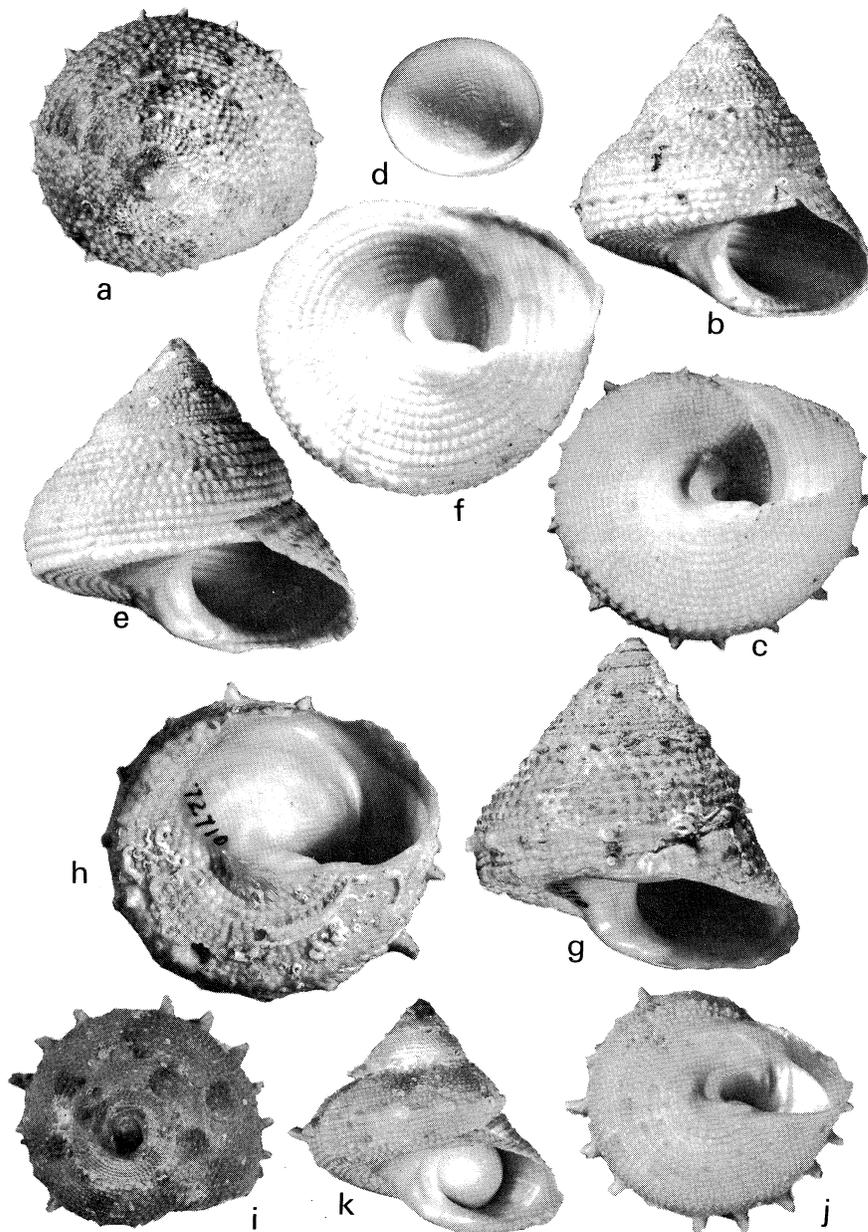


Fig. 13. **a-h.** *Bolma tamikoana tamikoana* (Shikama), **a-c**, off Torishima Is., Izu Ids, central Japan, 250 m; NSMT, 15079. Height 34.7 mm; **d-f**, Japan; NSMT. Height 35 mm; **d**, operculum coated with ammonium chloride; **g-h**, Arafura Sea, off Arnhem Land, Northern Territory, Australia, 125 m; AM, C.72710. Height 36.3 mm. **i-k.** *Bolma tamikoana flava* n. subsp., holotype, 15°24.5'S, 46°02.0'E, off Majunga, N.W. Malagasy Republic, 250-265 m; AMS. Height 27 mm.

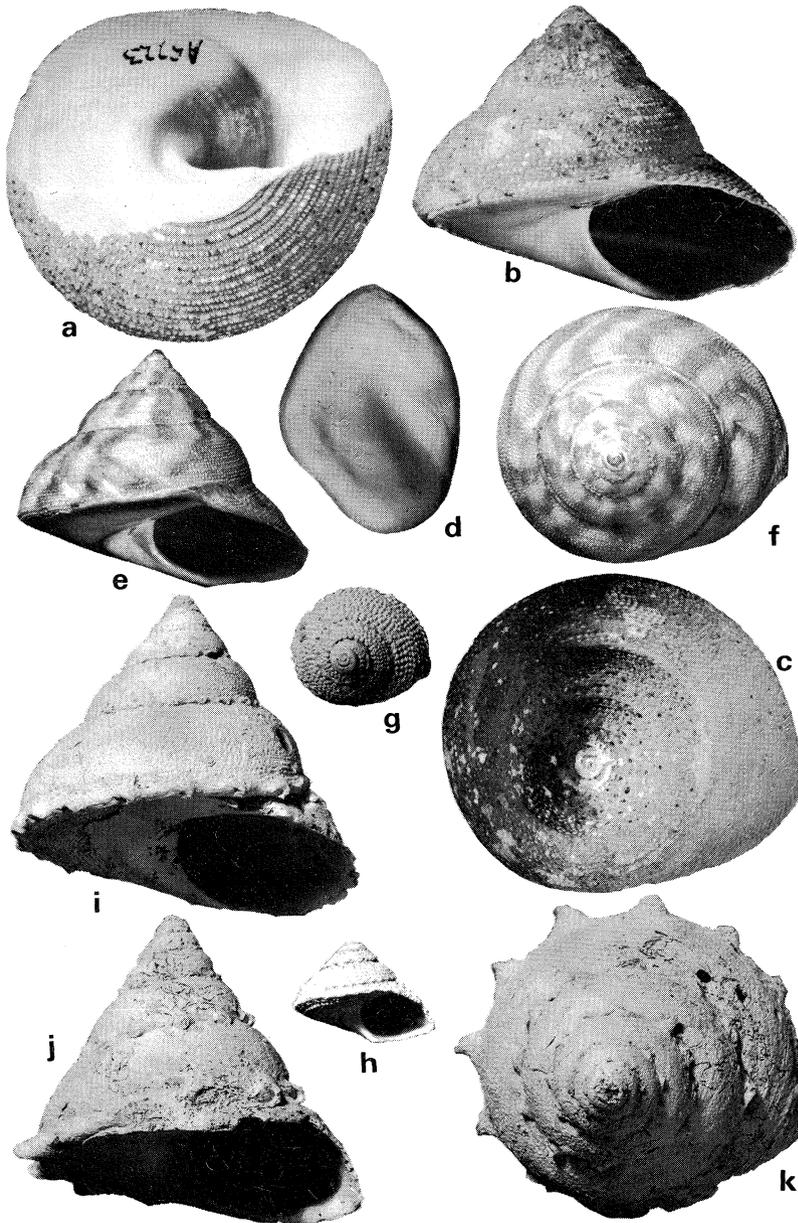


Fig. 14. **a-h.** *Bolma tayloriana* (Smith), **a-c.** False Bay, Cape of Good Hope, 37 m; SAM, A.5223. Height 39.75 mm; **d-f.** axially banded specimen, off Cape Columbine, South Africa, 146 m; NM, F 6330. Height 56.4 mm; **d.** operculum, coated with ammonium chloride; **g-h.** juvenile, 34°54'S, 19°49'E, 48 m, NM, F7284. Height 12.9 mm. **i-k.** *Bolma cf. tayloriana* (Smith), trawled, eastern Cape Province, South Africa; NM, A3585 (2 specimens, **i.** height 76 mm, **j-k.** height 78 mm).

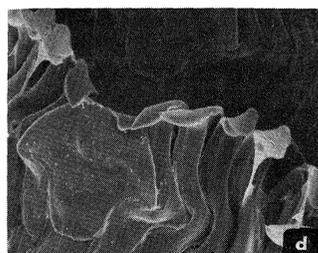
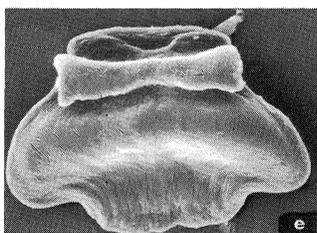
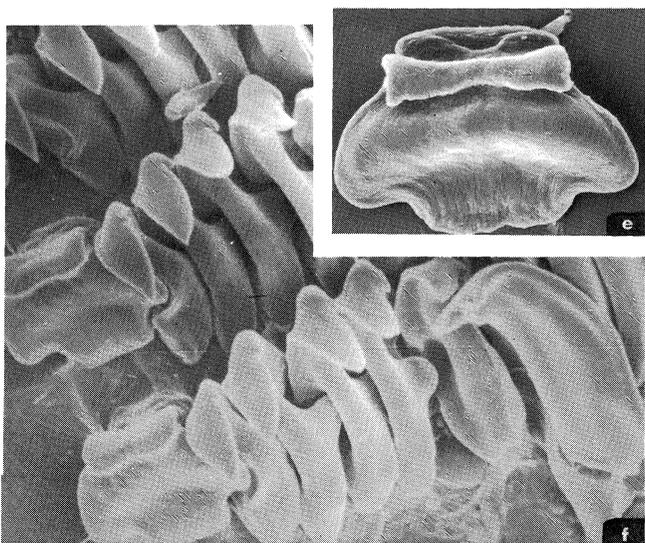
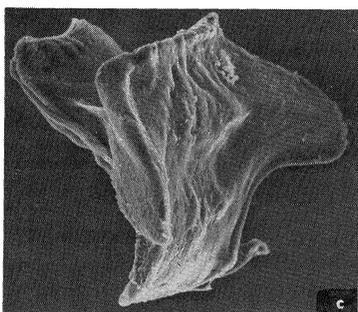
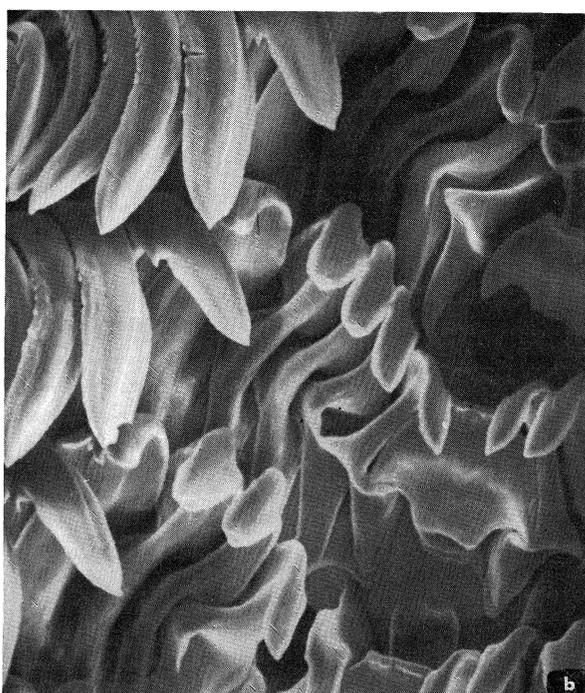
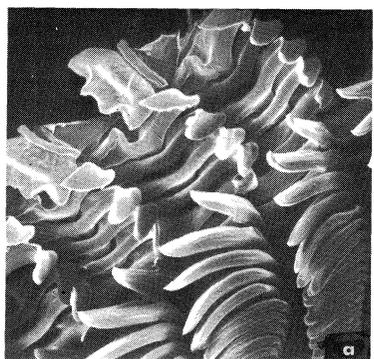


Fig. 15. Radulae of Turbinidae. **a-g.** *Astralium tentoriiforme* (Jonas), Minnie Waters, N.S.W., Australia; AM, C.99730, (SEM stub 84). **a**— central, lateral, and marginal teeth, x 67. **g**— front view of central tooth, x 225. **b.** *Astralium aureus* (Jonas), type species of *Micrastraea* Cotton; Salmon Pt., Elliston Bay, Spencer Gulf, S. Australia, 1 m; AM, C.99773 (SEM stub 81), central, lateral and marginal teeth, X 290. **c-d.** *Astralium kesteveni* (Iredale), type species of *Bellastraea* Iredale; Bare Is., Botany Bay, N.S.W., 3-10 m; AM, C.99774 (SEM stub 159). **c**— partial side view of central tooth, X 340. **d**— central and lateral teeth, X 135. **e-f.** *Astralium calcar* (Linné), type species of *Astralium* Link; Tayabus Bay, W. Quezon Prov., Luzon, Philippines; WAM 684-70 (SEM stub 79). **e**— front view of central tooth, X 340. **f**— lateral and central teeth, X 150 (note: cusp is broken off inner marginal at lower right).

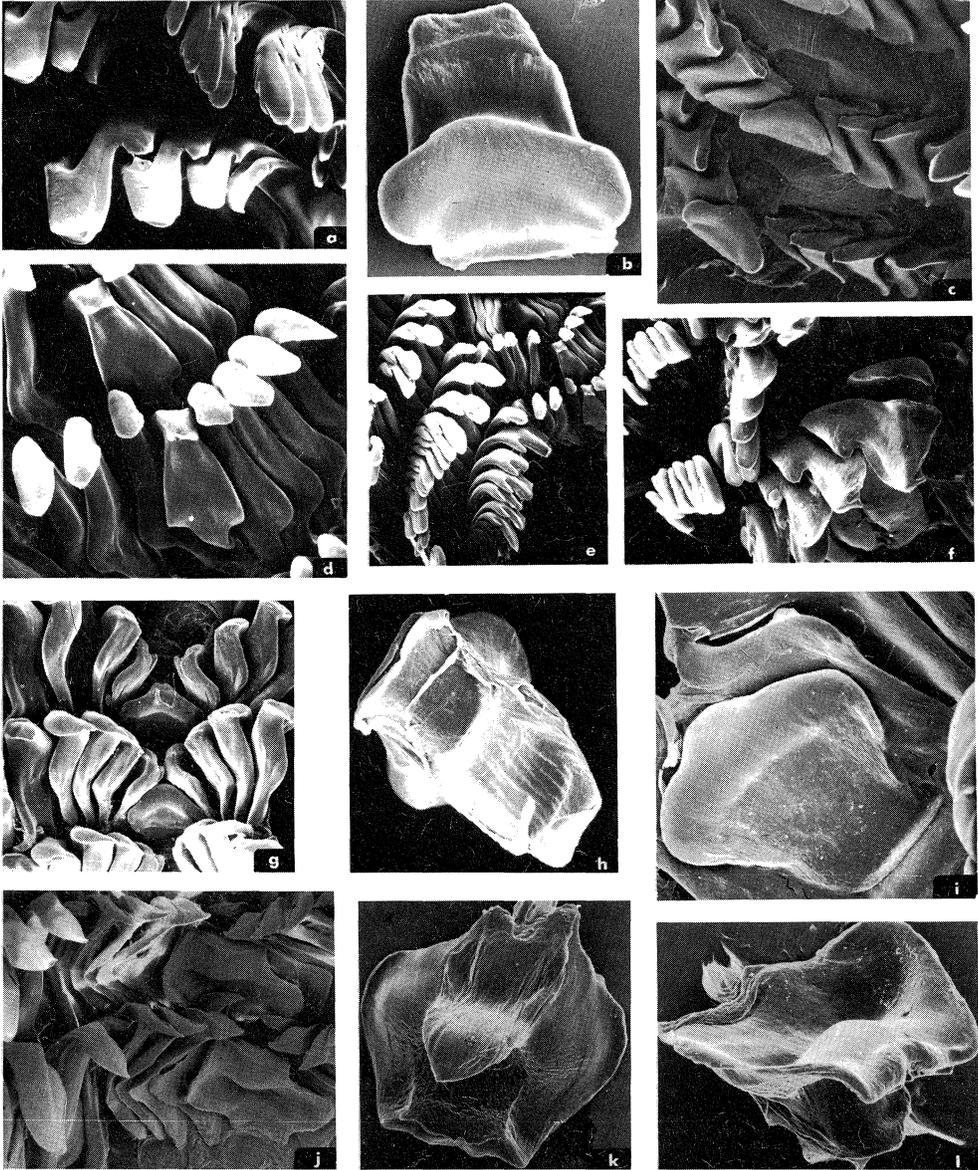


Fig. 16. Radulae of Turbinidae. **a-c.** *Turbo (Marmarostoma) chrysostomus* Linné, type species of *Marmarostoma* Swainson, Louisiade Archipelago, New Guinea; AM, C.96363 (SEM stub 88). **a** — median marginal tooth, X 150. **b** — front view of central tooth, X 300. **c** — central and lateral teeth, X 65. **d-e.** *Lithopoma tuber* (Linné), type species of *Lithopoma* Gray; Silver Sands, Christchurch, Barbados; AM, C.99728 (SEM stub 92). **d** — central and lateral teeth, X 120. **e** — central, lateral and marginal teeth, X 40. **f-i.** *Lithopoma (Cookia) sulcata* (Martyn), type species of *Cookia* Lesson; Pauatahanui Harbour, near Wellington, New Zealand; N.Z. National Museum (SEM stub 86). **f** — marginal teeth, X 50. **g** — central and lateral teeth, X 50. **h** — back view of central tooth, X 150. **i** — front view of central tooth, X 150. **j-l.** *Astraea heliotropium* (Martyn), type species of *Astraea* Röding; South Arm, Port Pegasus, Stewart Is., New Zealand; N.Z. National Museum (SEM stub 156). **j** — central, lateral and inner marginal teeth, X 45. **k** — back view of central tooth, X 85. **l** — partial side view of central tooth, X 100.

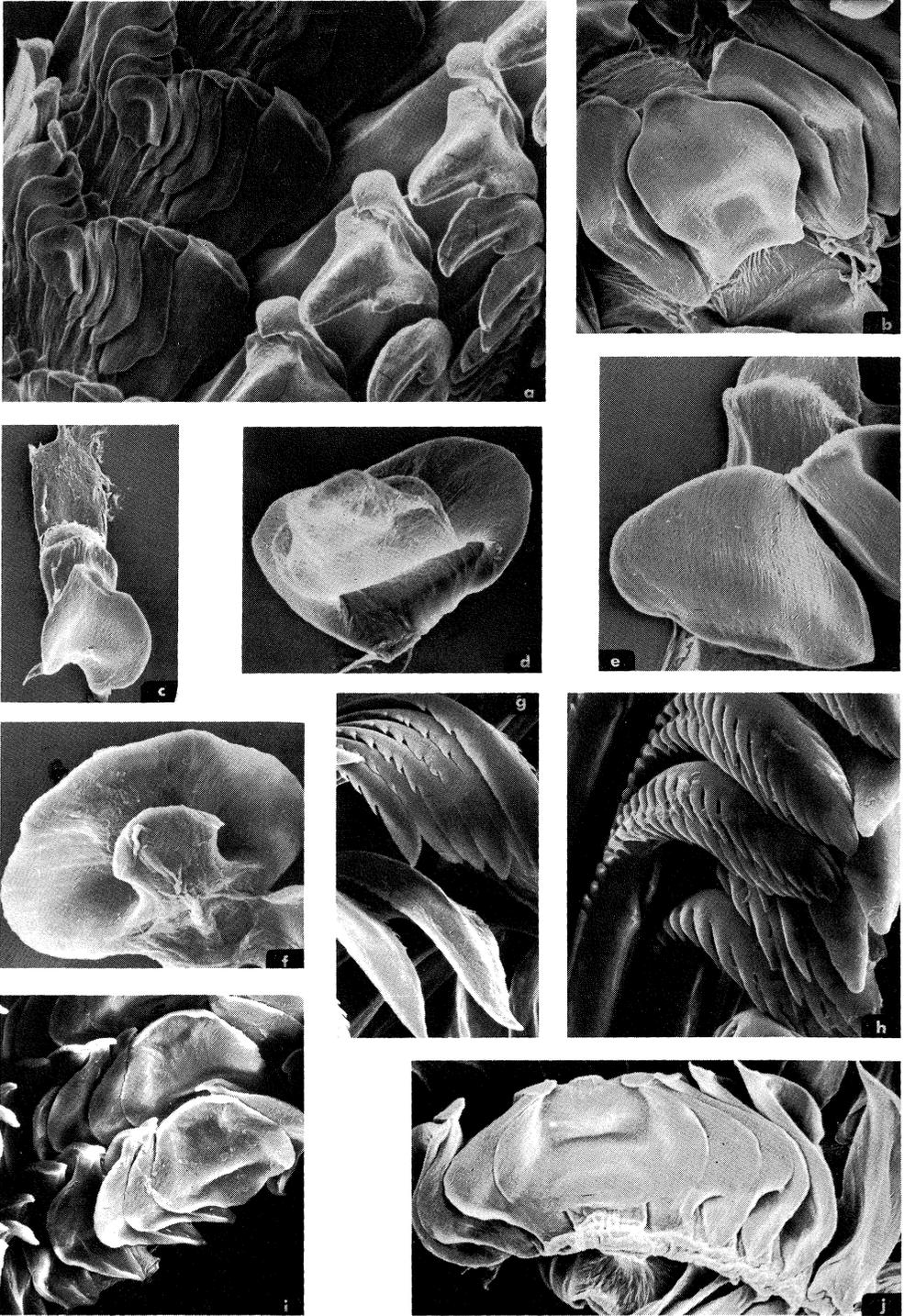


Fig. 17. Radulae of Turbinidae. **a.** *Turbo (Modelia) granosus* Martyn, type species of *Modelia* Gray; Easy Harbour, Stewart Is., New Zealand, 7-18 m; N.Z. National Museum (SEM stub 155); central, lateral and inner marginal teeth, X 80. **b-c.** *Turbo (Ninella) torquatus* Gmelin, type species of *Ninella* Gray; Ulladulla, N.S.W., Australia; AM, C.99732 (SEM stub 93). **b** — central and inner lateral teeth, X 160. **c** — partial side view of central teeth, X 130. **d-e.** *Turbo (Subninella) undulatus* Solander in Lightfoot, type species of *Subninella* Thiele; Ulladulla, N.S.W., Australia; AM, C.99731 (SEM stub 91). **d** — back view of central tooth, X 350. **e** — front view of central tooth, X 380. **f,g,j.** *Guildfordia yoka* (Jousseume), 7°25'N, 123°14'E, off Philippine Ids, 460 m; Zoological Museum Copenhagen (SEM stub 87). **f** — back view of central tooth, X 600. **g** — median marginal teeth, X 480. **j** — central and lateral teeth, X 320. **h-i.** *Bolma (Senobolma) venusta* (Okutani), type species of *Senobolma* Okutani; 34°27.2'N, 139°11.1'E, Takase Bank, Japan, 130 m; Tokai Regional Fisheries Laboratory (SEM stub 83). **i** — median marginal teeth, X 370. **h** — central and lateral teeth, X 1200.

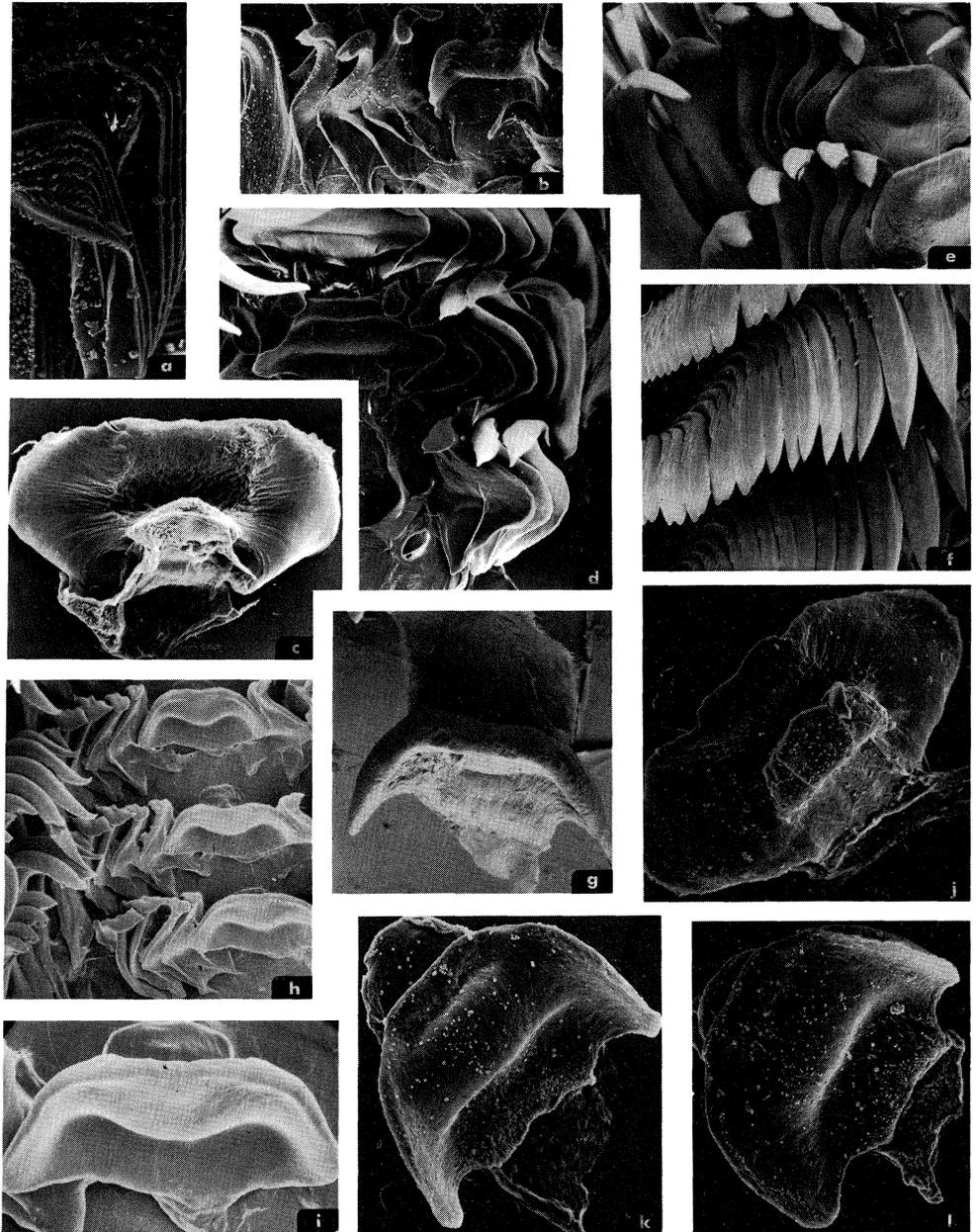


Fig. 18. Radulae of *Bolma*. **a-b, j-l.** *Bolma rugosa* (Linné), type species of *Bolma* Risso; Mediterranean Sea (Zoological Museum, Copenhagen) (SEM stub 72). **a** — median marginal teeth, X 170. **b** — central and lateral teeth, X 110. **j** — back view of central tooth, X 190. **k, l** — front views of central teeth in slightly different orientations, X 190. **c-d.** *Bolma modesta* (Reeve), type species of *Hirasazaea* Habe; W. of Amami-Oshima Is., East China Sea, 25°52.6'N, 125°34.8'E, 109 m Tokai Regional Fisheries Lab. (SEM stub 89). **c** — back view of central tooth, X 160. **d** — central and lateral teeth, X 90. **e-g.** *Bolma jacquelineae* (Marche-Marchad), off Tema, Ghana; AM, C.99729 (SEM stub 5). **e** — central and lateral teeth, X 200. **f** — marginal teeth, X 200. **g** — top view of central tooth, X 380. **h-i.** *Bolma aureola* (Hedley), off Double Island Pt., Tin Can Bay Queensland, 46-55 m; AM, C.99742 (SEM stub 74). **h** — central, lateral and inner marginal teeth (some inner marginal teeth have broken cusps) X 55. **i** — central tooth, tilted forward (X 155).

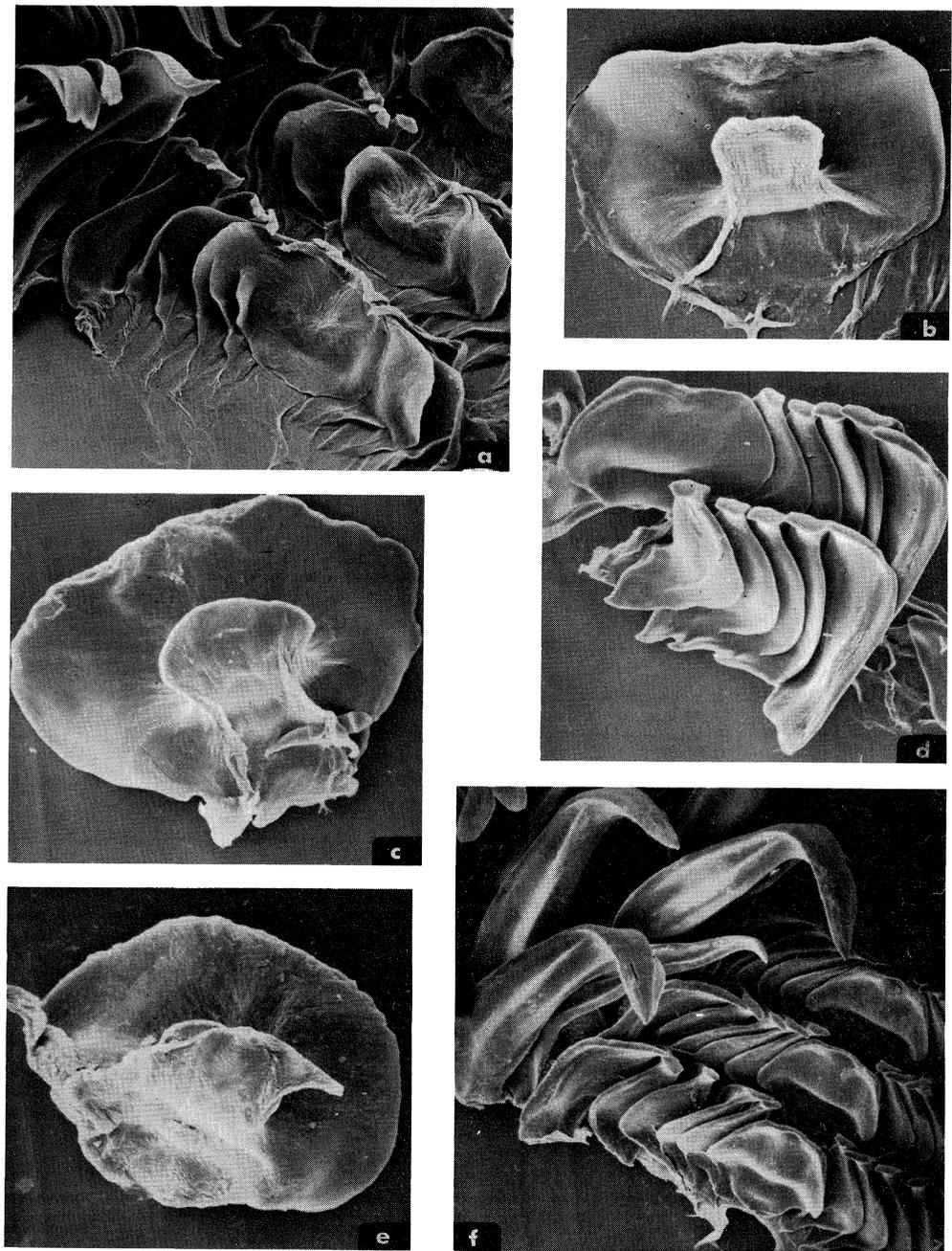


Fig. 19. Radulae of *Bolma*. **a-b.** *Bolma henica* (Watson), type species of *Pseudastraliium* Schepman; 5°46'30''S, 132°51'E, S.W. of West Irian, 348 m; Zoological Museum, Copenhagen (SEM stub 85). **a** — central, lateral and inner marginal teeth, X 210. **b** — ventral view of central tooth, X 430. **c-d.** *Bolma guttata bathyraphis* (Smith), Maldive Iids, Indian Ocean, 229 m; BMNH (SEM stub 70). **c** — back view of central tooth, X 320. **d** — central and lateral teeth, X 160. **e-f.** *Bolma guttata guttata* (A. Adams), 34°26'N, 139°11'E, Takase Bank, Japan, 95 m; Tokai Regional fisheries Lab. (SEM stub 73). **e** — back view of central tooth, X 290. **f** — central, lateral and inner marginal teeth, X 100.