Records of the Australian Museum, Supplement 24 (1998): 1–189. ISBN 0-7313-8807-0

A Revision of the Scaphopoda from Australian Waters (Mollusca)

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ABSTRACT. The extant Australian fauna of the molluscan class Scaphopoda is reviewed. In total 108 species are recognized, of which 47 are new and 28 represent named species not previously recorded from the Australian region. Both scaphopod orders—Dentaliida and Gadilida—are well represented in the extant fauna, especially the Dentaliida with 79 species (59 in Dentaliidae alone). The following families and genera were noted, with the numbers of species in each genus indicated in brackets. Order Dentaliida—Dentaliidae, *Dentalium* s.st. (38 including 16 new) *Dentalium (Lentigodentalium)* (3 including 2 new), *Dentalium (Pictodentalium)* (1), *Tesseracme* (3 including 1 new), *Fissidentalium* (11 including 6 new), *Graptacme* (3 including 1 new); Fustiariidae, *Fustiaria* (2); Laevidentaliidae, *Laevidentalium* (13 including 5 new); Omniglyptidae, *Omniglypta* (2); Gadilinidae, *Episiphon* (4 including 2 new); Order Gadilida Entalinidae, *Entalina* (2 including 1 new), *Bathoxiphus* (4 including 2 new); Pulsellidae, *Pulsellum* (2 including 1 new), *Compressidens* (1); Gadilidae, *Gadila* (9 including 4 new), *Cadulus* (5 including 3 new), *Dischides* (2 including 1 new), *Polyschides* (3 including 2 new). The Omniglyptidae are recorded for the first time from Australia. Some previously named "species" are removed from the fauna (*Tesseracme beachportensis* Cotton & Ludbrook, probably a portion of a pennatulid rachis) or treated as unrecognizable (*Dentalium weldianum* Tenison-Woods, *D. tasmaniensis* Tenison-Woods). Full descriptions, comparisons and distribution maps are given for each valid species. In addition a series of keys are provided for the identification of Australian scaphopods from the level of order down to species. Reference is also made to the fossil scaphopods from Australia, although no attempt is made to review those species taxonomically. *Laevidentalium largicrescens* (Tate), formerly known only from Tertiary deposits is recorded as living in deep water from Bass Strait to southern Queensland.

LAMPRELL, KEVIN L., & JOHN M. HEALY, 1998. A revision of the Scaphopoda from Australian waters (Mollusca). Records of the Australian Museum, Supplement 24: 1–189.

Contents

Introduction

"The Scaphopoda have hitherto received comparatively little attention from either conchological or morphological naturalists. ... the list of species now known is doubtless a mere fraction of the grand total of living forms" (Henry A. Pilsbry, p. iii, from Preface to Pilsbry & Sharp's treatise on the Scaphopoda, volume XVII of the Manual of Conchology). These words, written a century ago by perhaps the most influential authority on scaphopod morphology and systematics, remain as valid today as they were then. In fact it is only 130 years ago that scaphopods or "tusk" or "tooth" shells as they were often known, were formally recognized as a separate class of the Mollusca by Keferstein (*in* Bronn, 1862–1866). It is remarkable that such a fascinating and unique group of molluscs should remain so poorly studied and understood, especially when it is kept in mind that these animals often constitute a significant component of the shallow water, marine benthos.

The present work represents an attempt to document, for the first time, the scaphopod fauna of Australia. Over the last twenty years or so, scaphopod material has steadily accumulated in the preserved ("wet") and dry shell collections of the Australian Museum (Sydney), Queensland Museum, Western Australian Museum and South Australian Museum. This material derives largely from state fisheries and CSIRO benthic surveys of the continental shelf in previously unsampled areas, especially in that wide arc from the North West Shelf, through the Arafura Sea and Torres Strait to northern Queensland. In addition we have had access to very recently collected material from the continental shelf survey of Bass Strait (from Museum of Victoria).

It is most unfortunate that the impressive diversity of scaphopods from the Australian region is not reflected in the available literature. Indeed, with the exception of the southern fauna, any attempt to identify other Australian scaphopods, particularly those from the northern half of the continent, must rely on existing overseas monographs and scattered papers which include Indo-Pacific species (e.g., Pilsbry & Sharp, 1897–98; Boissevain, 1906; Habe, 1955, 1963, 1964). Almost half the species documented in the present study are new to science, and a further 28 represent new records. These statistics are not surprising, given the extensive nature of the recent deep sea sampling, and the fact that the class has not previously been reviewed from the purely Australian perspective. It is to be expected that further species and possibly new genera will be added to the fauna as deep-sea benthic sampling continues. In this study we describe all the known, valid species of Scaphopoda from Australian territorial waters. In doing so we present a full diagnosis and comparison for each species as well as keys for the identification of orders, families, genera and species. Realizing that keys should be easy to use and not formidable barriers, we have endeavoured to keep terminology consistent and understandable. Hence we have focussed on readily observed shell features and have subdivided large genera into groups of species sharing similar features in much the same way as did Pilsbry & Sharp (1897–98) in their worldwide monograph on the class.

Limits of available funding and lack of well preserved animals for many species have meant that the present study could not include much anatomical work other than radular ultrastructure. Despite these constraints we hope that this monograph will provide a basis for future detailed studies on the Australian Scaphopoda and more generally that it stimulates interest in this long-neglected and important class of molluscs.

General biology and morphology

Occurrence and habit. Scaphopods, form a small but distinctive class of the Mollusca which are cosmopolitan in distribution and exclusively marine and infaunal. Most commonly they occur within the first few centimetres of sediments from the intertidal zone down to depths in excess of 6000 m (Knudsen, 1964), with several species exhibiting considerable bathymetric ranges. Two orders of scaphopods are recognized: (1) the Dentaliida [e.g., small to large species with a conical foot-tip and shells showing longitudinal ribs (Dentaliidae), transverse rings (Omniglyptidae) or a smooth surface (Laevidentaliidae, Fustiariidae)]; (2) the Gadilida [small to very small species with a vermiform foot and shells which either are polished and show some apertural constriction (Gadilidae) or show a few heavy ribs (Entalinidae)] (Figs 1A,B, 2A).

Characteristic of the class is the presence of an external tubular shell which is open at both ends and tapered posteriorly. In life the shell is orientated at a low angle (30–40°) to the substratum surface (Figs 1E, 2B), with the concave (dorsal) side uppermost and the apex projecting, at least intermittently, above the substratum to facilitate respiration, excretion and gamete release (Yonge, 1937; Morton, 1959; Palmer & Steiner, 1998). Scaphopods inhabit a wide variety of sediments ranging from coarse sand or coral rubble to clayey-mud, with the majority of species preferring fine sand or sandy mud. Most Dentaliida inhabit only the upper few centimetres of the substratum. Members of the Gadilida however have been observed in captivity to burrow to over 30 cm below the substratum surface (Shimek, 1989). Almost all the species described in the present account prefer subtidal, especially deep water habitats (60–300 m, often much deeper). Despite Cotton & Godfrey's (1940: 317) assertion that "there are no littoral species" some Dentaliidae and a few Gadilidae can be found intertidally, sometimes in abundance.

Scaphopods burrow by means of a well developed foot. In the Dentaliida the foot is conical and associated with a pair of scoop-shaped epipodial lobes. Burrowing in the Dentaliida occurs through muscular extension of the foot (epipodial lobes closely wrapped around the sides of the foot), followed by expansion of the epipodial lobes to grip the substratum, then muscular contraction to draw the animal further into the substratum (see Fig. 1C,D). Although it has been claimed that blood from the haemocoele plays a significant role in foot dilation during burrowing of Dentaliida, Trueman (1968) has concluded that such dilation is controlled by the action of the foot musculature. As Gainey (1972) has shown, dentaliids are capable of "reverse burrowing", a process which enables animals to alter direction and exploit new areas of the sediment in

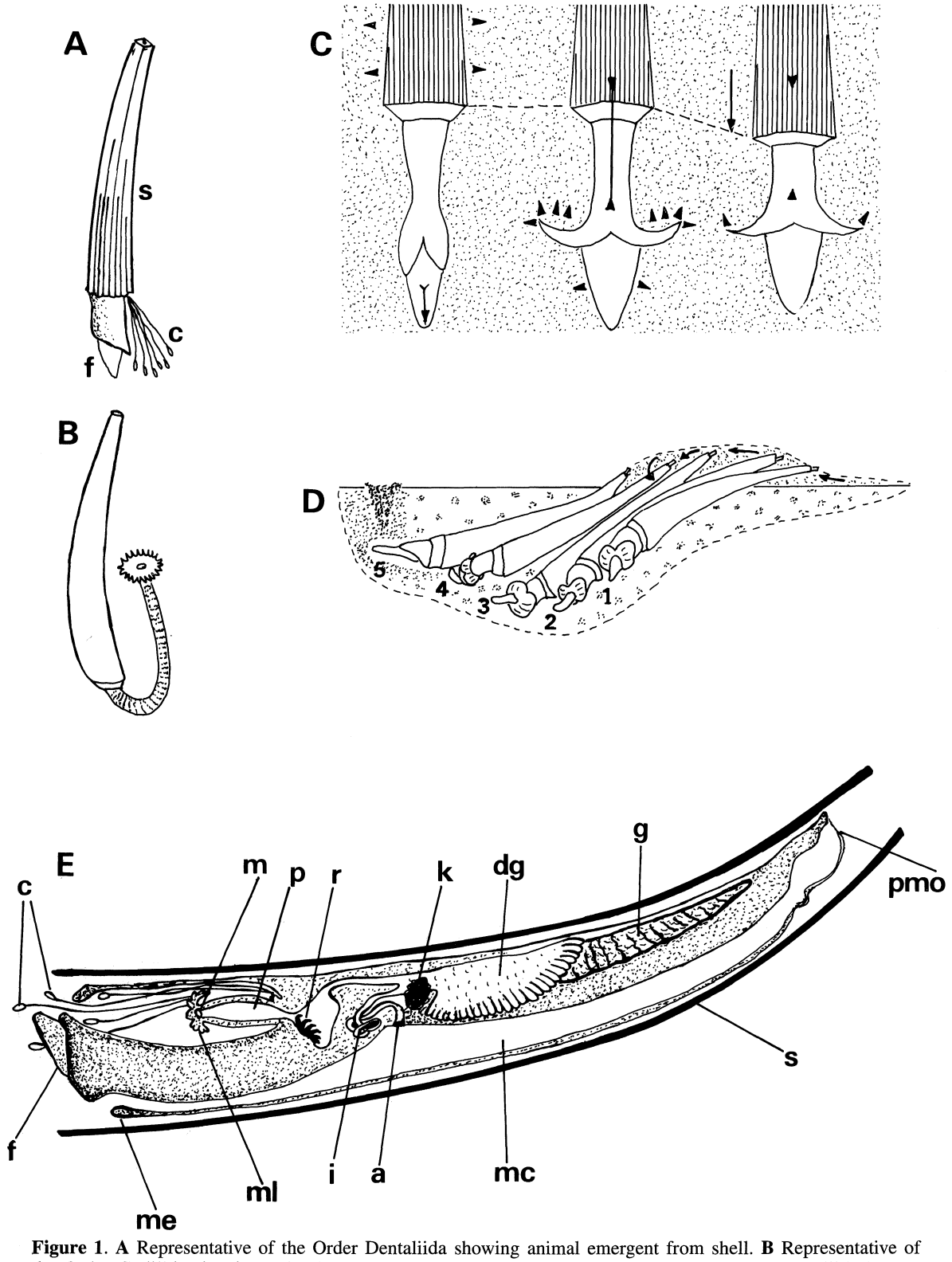


Figure 1. **A** Representative of the Order Dentaliida showing animal emergent from shell. **B** Representative of the Order Gadilida showing animal emergent from shell. **C** Mechanics of burrowing in a dentaliid. Arrows indicating direction of exerted force. **D** Sequential stages in re-burrowing of a dentaliid, shown in relation to the sediment. Arrows indicating twisting of shell. Note creation of a small feeding cavity near the head in stage 5. **E** Longitudinal section through a dentaliid in its shell (shown approximately in life orientation). Abbreviations: a, anus; c, captacula; dg, digestive gland; f, foot; g, gonad; i, intestine; k, kidney; m, mouth; mc, mantle cavity; me, mantle epithelium; ml, mouth lips; p, proboscis; pmo, posterior mantle opening; r, radula; s, shell. (A and B modified slightly from Palmer, 1974a; C—redrawn from Trueman, 1968; D—redrawn from Dinamani, 1964; E—composite drawing based primarily on a figure by Pelseneer, 1906).

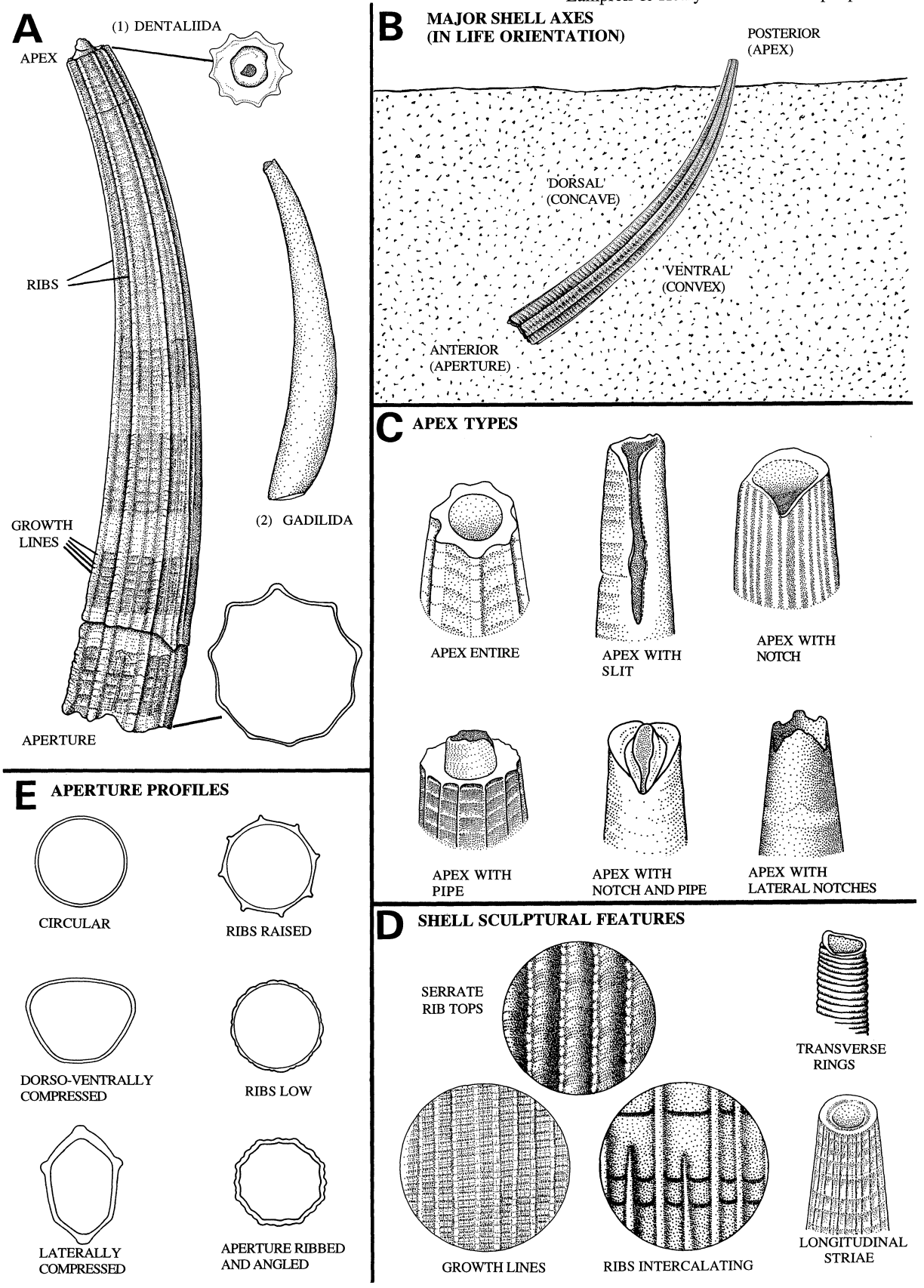


Figure 2. Diagrammatic summary of shell terminology used in the present study. **A** Representative shells of both orders of the Scaphopoda (*Dentalium, Gadila*). **B** Shell of *Dentalium* in life position showing principal axes, aperture and apex. **C** Commonest variations in apex shape and ornament. **D** Commonest types of shell sculpture and ornament. **E** Commonest variations in aperture profile. (Del.: A. Hill and C. Eadie).

their search for food. The ability of Dentaliida to "right" themselves if dislodged from the substratum has been described by Morton (1959) and Dinamani (1964). Maintaining correct positioning in the substratum (concave uppermost) is no doubt important in maintaining a channel from the apical orifice to the substratum surface for exhalent respiratory flow and waste/gamete release. The burrowing process in Gadilida is less well known, although the frequent development of an expanded, terminal disk on the vermiform foot suggests a similar anchoring function to the epipodial lobes of the Dentaliida. Unlike the Dentaliida, the Gadilida have a large pedal haemocoele, weakly developed pedal wall longitudinal muscles and three pairs of pedal retractor muscles (Steiner, 1992a,b). This arrangement obviously highlights the role of hydraulic forces in gadilid mobility and, as noted by Palmer & Steiner (1998: 443) "renders the gadilid foot an eversible burrowing organ analogous to the nemertean proboscis".

Shell form and sculpture. In all scaphopods, the shell is tubular and open to the external environment both anteriorly and posteriorly. Most species show some degree of shell curvature, the only notable exceptions being a few gadilid species with essentially barrel-shaped shells. Without exception scaphopod shells are tapered apically, and sometimes also at the anterior aperture in the case of many Gadilida (Fig. 1B, 2A).

As animals grow, new shell is added to the anterior aperture, while posteriorly the apex is enlarged through shell resorption and/or natural decollation. The posterior region of the mantle may also secrete a shell pipe (sometimes termed the secondary shell) which may or may not be associated with a shelly plug. The mode and reasons for alterations made to the apex during growth have been discussed by several authors (Pilsbry & Sharp, 1897–98; Shimek, 1989; Reynolds, 1992a; Steiner, 1995; Palmer & Steiner, 1998). There appears to be general agreement that as animals grow and especially as they approach sexual maturity, the posterior (apex) aperture must be widened to cope with, firstly an increasing passage of water for respiratory activity, secondly an increasing amount of waste products and thirdly the release of the gametes. Shimek (1989) concluded that the production of a secondary shell pipe in the eastern Pacific species *Dentalium rectius* Carpenter is only a response to shell damage inflicted by attempted fish predation. Shimek went further and questioned the taxonomic utility of all apical shell characters in scaphopods, including the slit and lobe features of cadulid shells. Although we would agree that apical shell features are often variable, even within a species, and should therefore be used with some caution (a fact long recognized by many workers), we also believe that apical characters can be extremely helpful, especially in differentiating closely related taxa. According to Reynolds (1992a), the shell-repair hypothesis for pipe secretion in *D. rectius* can no longer be supported. His detailed study of the phenomenon in this species led him to conclude (Reynolds, 1992a: 33) that "secondary shell" (i.e. pipe) production "appears to be a normal program of shell growth following mantle-mediated shell decollation".

Conchological features (Fig. 2) have been used extensively in the diagnosis of scaphopod taxa from the level of order down to species. Such features include: (1) the strength of shell curvature (sometimes calculated as a factor of shell length to give the "arc"), (2) the rate of expansion of the anterior shell aperture with growth, (3) longitudinal surface ornament (ribs, riblets, striae and their number, shape, strength, mode of generation and degree of interaction with transverse growth lines), (4) apical features (notch, slit, plug, pipe and their mode of generation), (5) transverse swellings or rings, (6) apertural shape, and lastly (7) colouration. All of these features vary to some extent within species (e.g., apical notch/slit, Fig. 3) but usually within narrow or at least definable limits. Marked differences in shell shape and ornament can occur between juvenile, adult and gerontic specimens, and for this reason it is advisable to have available a range of material when attempting identifications. For example, the anterior aperture rib-count in a species in which rib number increases by intercalation or rib-splitting will be markedly lower in young specimens than in fully mature ones (e.g., species of *Fissidentalium*). Figure 2 and the glossary presented in the Appendix, summarize scaphopod conchological features described and discussed in the present work, and should be consulted when reading diagnoses and keying out genera or species.

Whether or not surface sculpture can be associated with substratum texture is not resolved, although shell-substratum interaction must be considered a factor in the burrowing process (see Trueman, 1968). In the present study we could not find any definite association between shell ornament and sediment coarseness or composition—smooth and heavily ribbed species occurring in similar or identical substrata. Shimek (1989) has suggested that the constricted anterior aperture in adult gadilids, combined with a glossy shell surface, have been developed to enhance quicker (and relatively deeper) burrowing, possibly to minimize predator attack.

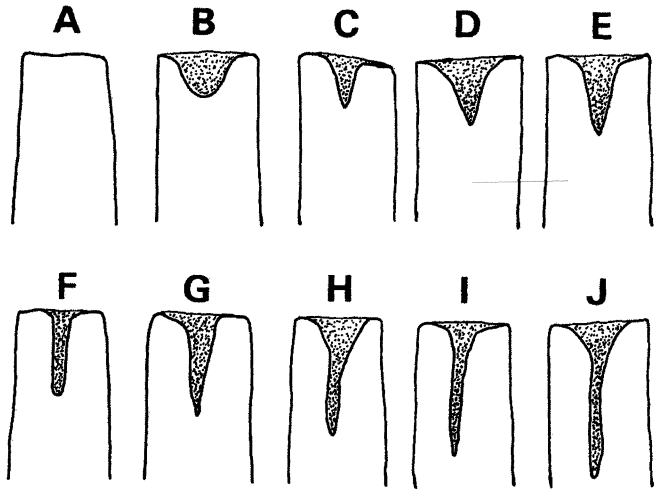


Figure 3. Variation in shell apex profile in a single population of *Dentalium exmouthensis* n.sp. Apex entire (**A**), apex with notch (**B–E**), apex with slit (**F–J**). An entire apex may often be the result of advanced decollation.

In terms of their microstructure, scaphopod shells consist of an outer chitinous layer (the periostracum), and three shelly (aragonitic) layers, beginning externally with a longitudinal, prismatic layer, a middle layer of cross-lamellar substructure and finally an inner layer of concentric substructure—the latter directly sheathing the animal (Emerson, 1962; Haas, 1972; Boss, 1982; Palmer & Steiner, 1998).

Feeding and waste elimination. During feeding, a cavity in the sediment is first created in the vicinity of the anterior shell aperture by the foot (Dinamani, 1964; Gainey, 1972). Food particles are then collected from the sediment by retractile, filamentous organs termed captacula and transferred to the proboscis lips and mouth either by ciliary movement along the captacula or, more rarely, directly by the captacular tips (Morton, 1959; Dinamani, 1963; Gainey, 1972; Poon, 1987; Shimek, 1988; Byrum & Ruppert, 1994; Palmer & Steiner, 1998). Detritus may also be ciliated from the foot groove to the mouth (Gainey, 1972). Movement of the foot itself also appears to play a significant role in maintaining the flow of fresh detrital material from the substratum (Dinamani, 1964; Gainey, 1972). The varied length of captacula is due to their ability to regenerate after autotomy (Cotton & Godfrey, 1940). Either the foot or the captacula may be extended, but not both simultaneously (Palmer & Steiner, 1998; in this regard Fig. 2A, redrawn from Palmer, 1974a, must be considered diagrammatic). Typically the diet consists of foraminiferans and/or detritus, with some species appearing to show preference for specific items (Morton, 1959; Gainey, 1972; Steiner, 1992a). Bivalve spat, ostracods, invertebrate eggs and diatoms are also sometimes ingested (Palmer & Steiner, 1998). Mostly foraminiferans are taken by members of the Gadilida (Palmer & Steiner, 1998). Palmer & Steiner (1998) have likened the ciliated movement of feeding captacula to the movement of interstitial worms between grains of the sediment. Certainly they appear to be efficient food collecting structures. Food is stored in the buccal pouch and then partially crushed by the jaw and radular apparatus before being passed to the stomach and ultimately the digestive gland (Morton, 1959; Palmer & Steiner, 1998). Eventually faecal and nitrogenous waste are passed into the mantle cavity, then expelled via the shell apex. Rhythmic movement of the foot combined with ciliary activity provide the energy for generating the water current needed for respiration and waste/gamete release (Yonge, 1937; Cotton & Godfrey, 1940; Gainey, 1972; Steiner, 1991; Palmer & Steiner, 1998). How waste products are eliminated in deep-burrowing Gadilida (e.g., see Shimek, 1989) is not clear. Presumably such animals return to the substrate surface periodically for waste and/or gamete release. Although pumping of nitrogenous products directly into the surrounding sediment is also possible, this activity would immediately place limitations on population size through eventual fouling of the sediment.

Radular morphology. The scaphopod radular complex is composed of serially arranged rows of chitinous teeth (collectively the radular ribbon) supported by a similarly chitinous radular membrane and attached via an odontophoral cartilage to the buccal muscles. Each tooth row consists of a central (rachidian) tooth flanked on either side by a lateral and an outlying marginal tooth giving a total of five teeth per row (i.e. transverse formula = 1.1.1.1.1) (Fig. 4). During the present study we found that the size and length of the radular ribbon varied between species and genera and to some degree also between the sexes. Within *Dentalium* s.st., the radular ribbon is small almost irrespective of the size of the species. By contrast, in the larger species of *Laevidentalium* and *Fissidentalium*, the ribbon is typically large and often heavily mineralized (the brown colouration being composed of the iron-based mineral, magnetite) suggesting heavy mechanical useage (crushing foramiferan tests). Recent research suggests that varying degrees of mineralization of radular teeth is typical of the Scaphopoda (Shimek & Steiner, 1997; Steiner, pers.

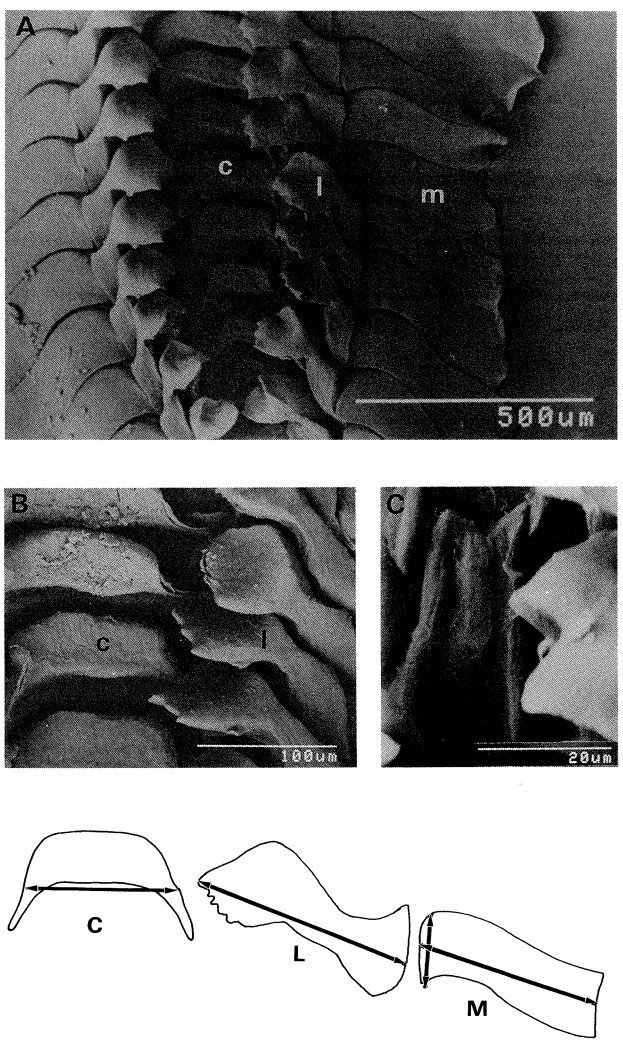


Figure 4. **A** Radular ribbon of a scaphopod (*Dentalium (Dentalium) jelli* n.sp.) as seen with scanning electron microscopy (SEM). Each row of teeth consists of a central tooth (c), two lateral teeth (l) and two marginal teeth (m). Note cusps present on the laterals. **B,C** Morphological differences between the two orders in central tooth morphology (**B** Dentaliida central tooth wider than high; **C** Gadilida central tooth square or higher than wide). **D** Axes used for measurement of scaphopod tooth dimensions. Abbreviations: c, central tooth; l, lateral tooth; m, marginal tooth.

comm.), as it is in the Polyplacophora (Lowenstam, 1967; Webb *et al.*, 1989; Evans *et al.*, 1994) and in certain prosobranch gastropods (Patellogastropoda, Hickman, 1984). Presumably the mineralization process (iron or phosphate-based) greatly enhances the strength and durability of radular teeth in scaphopods and in other molluscs showing this feature.

During the present study we found that females frequently had relatively larger radular ribbons than males of the same species. It should also be pointed out that females were usually larger than males, so the apparent correlation between sex and radular size may simply reflect the need for a larger radula in a larger animal (that is, increased food intake). Although no attempt has yet been made to associate scaphopod radular teeth with feeding patterns or specific food items, it seems wise to accept that tooth shape and ornament does reflect useage, as has been recently demonstrated in vetigastropod prosobranchs (Hickman, 1984; Warén, 1990). Nevertheless taxonomically useful features of the scaphopod radula are also recognizeable including the shape of the central tooth (wider than high in Dentaliida versus square or higher than wide in Gadilida; with or without cusps etc.) and shape and ornament of the lateral and marginal teeth (presence or absence of cusps; shape of tooth etc). The level of difference in radular tooth structure between species within a genus, and even between genera and between families was found to be variable but somewhat disappointingly (given the large number of genera examined) often low. Some profound differences however were shown by a few species indicating that comparative radular morphology may yet prove a most rewarding avenue for further taxonomic research when adequate material is available.

Respiration and sensory organs. In all scaphopods, true ctenidia or in fact gills of any type are absent. Respiration occurs directly across the surface of the mantle and is facilitated by currents generated by ciliary action and by movement induced by eversion and retraction of the foot (Palmer & Steiner, 1998; see also Reynolds, 1990a). The water pressure associated with sudden retraction of the foot into the shell is considerable (Cotton & Godfrey, 1940; Morton, 1959), and undoubtedly also assists in the voiding of wastes and/or gametes.

The configuration of the scaphopod nervous system is in general similar to that occurring in bivalves (Cotton & Godfrey, 1940). Eyes and osphradium are absent in all Scaphopoda (Boss, 1982; Palmer & Steiner, 1998). Statocysts—sometimes called "otocytes" (Cotton & Godfrey, 1940)—lie close to the pedal ganglia (Palmer & Steiner, 1998) and presumably these are important in helping maintain correct orientation of the animal within the substratum. Possibly the tips of the captacula may have some chemoreceptive capabilities (Byrum & Ruppert, 1994) because they are involved in the selection of food items, however this remains to be demonstrated (Palmer & Steiner, 1998). It has also been suggested that the subradular organ may have a tasting function, largely because of its position relative to the mouth and the fact that it is served by nerve endings (Byrum & Ruppert, 1994).

Reproduction and development. In all scaphopods, the sexes are separate and the gonad is a single, unpaired organ situated dorsally and composed of numerous acini. Under the dissecting microscope, mature females can be readily distinguished from mature males by the slightly granulate texture of the ovary (the granulations being ripe or advanced stage oocytes). Higher magnification using a light microscope adjusted for phase-contrast or Nomarski-interference phase viewing is required to ascertain the presence or absence of spermatogenic and sperm cells. In fresh material the colour of the gonad often differs between male and female, the testis being usually bright yellow to reddish while the ovary is usually cream coloured (occasionally red to orange in some Gadilida according to Steiner, 1993). During the course of the present study we found that, for a number of species, females showed a tendency to be larger than males (reflected also in size of the radular ribbon).

Fertilization in scaphopods takes place externally after sperm or eggs are released via the right kidney into the mantle cavity and thence into ambient sea water typically via the apical orifice (sometimes also via apertural orifice) (Cotton & Godfrey, 1940; Palmer & Steiner, 1998). Although early studies had suggested that the apical (posteriorly positioned) shell aperture was the only point of gamete release (*Antalis entalis*—Lacaze-Duthiers, 1856–57), recent study of the Gadilida (Steiner, 1993) indicates that at least in some species of *Pulsellum* and *Cadulus* (from 100–238 metres depth) the anterior aperture was preferred for egg release (eggs and sperm in the case of *Cadulus subfusiformis*). Steiner (1993) has suggested that gamete release via the posterior aperture would be most advantageous to animals living in very shallow water, where the risk of predation through visual detection would be relatively higher than below 60 metres where visual conditions noticeably deteriorate. This hypothesis could be tested by an analysis of gamete release in shallow water Gadilida. No study has yet examined scaphopod eggs and egg development on a comparative basis.

Spermatozoa of scaphopods are of the unmodified, aquasperm type, with a short, conical acrosomal vesicle and short, barrel-shaped nucleus (collectively, acrosome and nucleus constituting the "head") and a single, simple flagellum (Fig. 5A). The acrosome is distinctive in that it exhibits an apical dimple—giving the acrosomal vesicle a cup-shaped appearance (the plasma membrane, however is not likewise invaginated apically). This feature, recorded in a number of Dentaliida (Dufresne-Dube *et al.*, 1983; Hou & Maxwell, 1991; herein) can also be seen in the the order Gadilida (also confirmed by G. Steiner, pers. comm.), suggesting that this is a characteristic feature (in fact a probable autapomorphy) of the class Scaphopoda.

During the development of *Antalis entalis* (Dentaliidae) the zygote undergoes spiral cleavage and is transformed first into a blastula and then into a ciliated swimming larva termed the stenocalymma (Lacaze-Duthiers, 1856–57; Salvini-Plawen, 1981; Steiner, 1992a; Palmer & Steiner, 1998; see Fig. 5B, C). After 4–5 days the swimming larva sinks to the bottom and metamorphoses into the infaunal juvenile (Lacaze-Duthiers, 1856–57). The smooth, inflated

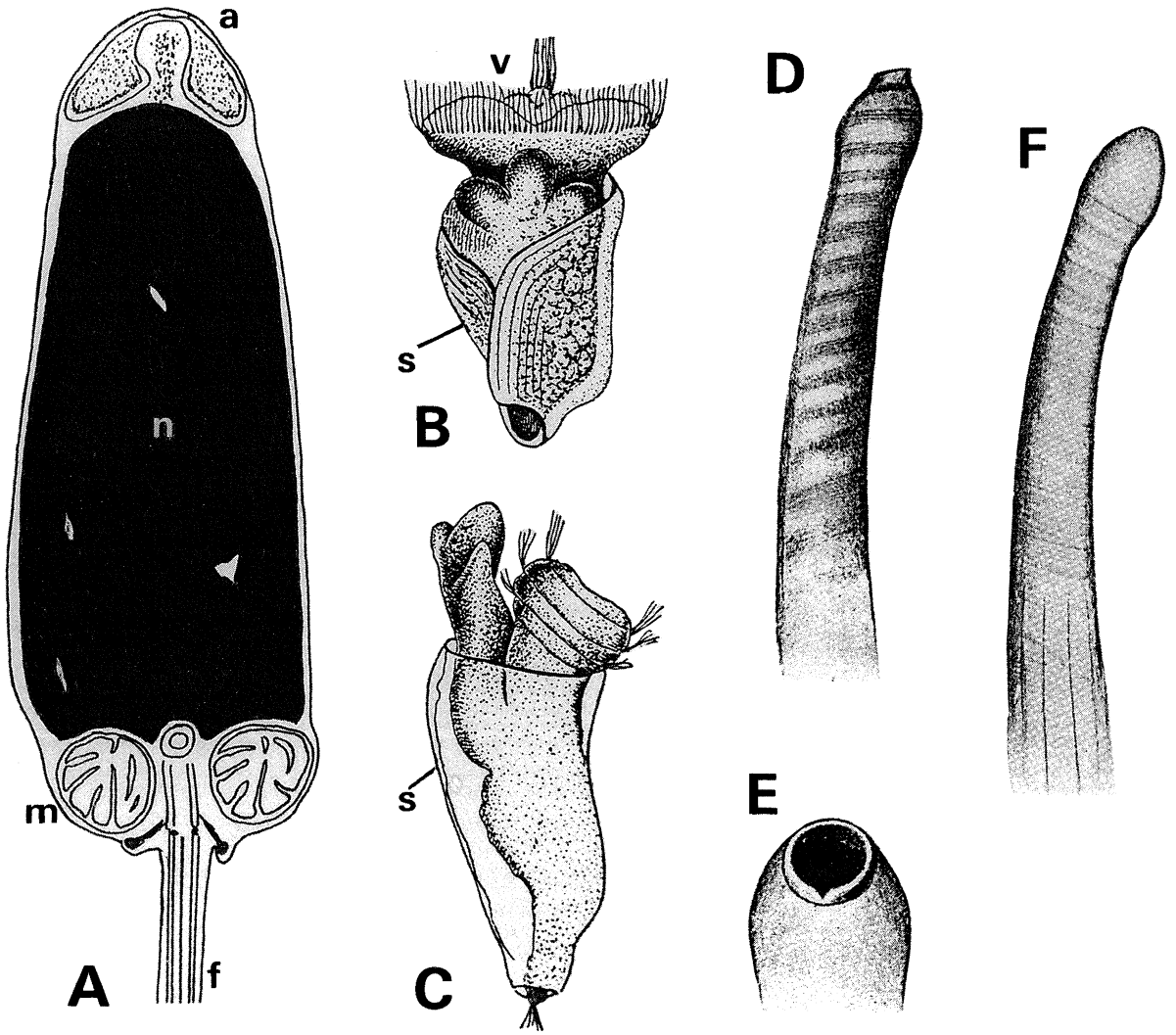


Figure 5. **A** Sperm morphology in the Scaphopoda (both orders have similar sperm). **B** Larva of *Dentalium* showing velum and bipartite shell. **C** Later stage larva of *Dentalium* showing single shell (protoconch—open both ends) and reduced velum. **D** Protoconch still attached to juvenile *Laevidentalium jaffaensis* (Cotton & Ludbrook, 1938). **E** Detail of posterior (apical) aperture of *L. jaffaensis*. **F** Protoconch still attached to juvenile *Dentalium (Dentalium) hyperhemileuron* Verco, 1911. Abbreviations: a, acrosomal complex; f, flagellum; m, mitochondria; n, nucleus; s, shell; v, velum. Sources: A (original), B (after Lacaze-Duthiers, 1856–57), C (after Wilson, 1904) and D–F (from Verco, 1911b, pl XXVI).

protoconch, frequently observed in juvenile specimens (Fig. 5D–F) is soon shed as growth continues, and the apex is lost by decollation (Reynolds, 1992a) or gradual dissolution (Steiner, 1991, 1995). A study of protoconch morphology in living and fossil scaphopods (Engeser *et al.*, 1993) indicates differences between the two orders:protoconchs of the Gadilida being relatively short (200–290 μm) and bulbous, while those of the Dentaliida are longer (360–800 μm), less inflated and exhibit annulations anteriorly. Protoconch morphology could therefore be very useful in determining the ordinal position of certain fossil species such as *Suevidontus jaegeri* Engeser, Riedel & Bandel, 1993 which has a teleoconch shaped and strongly ribbed as seen in many Dentaliida but possesses a bulbous, short protoconch typical of the Gadilida (this case, according to Engeser *et al.*, 1993, being probably the result of teleoconch convergence). Should further studies confirm protoconch differences between the two scaphopod orders, such a correlation will be of considerable taxonomic use in dealing with fossil and living material.

Classification and phylogeny

Taxobases. It has been shown for many groups of molluscs that shell features alone do not provide a totally reliable basis for a classification, primarily because convergence can act to produce striking similarities between distantly related forms (see above, also Engeser *et al.*, 1993). Nevertheless, shells still convey much taxonomically and biologically useful information, as can readily be appreciated by the rich literature on palaeontological

malacology (see Runnegar & Jell, 1976; Pojeta & Runnegar, 1985; Runnegar & Pojeta, 1985 and references therein for several detailed studies of Cambrian micromolluscs). In addition, for many rare or deep sea species, the shell may be the only portion of the mollusc available for study. In relation to the Scaphopoda, knowledge of comparative anatomy still trails far behind what is known of shell morphology. The work of Steiner (1991, 1992a,b) has demonstrated potentially useful cytological differences between taxa and it is hoped that DNA/RNA studies may eventually shed light on the relationships between families and orders. Fortunately within the Scaphopoda, enough shell characters can be found to provide workable definitions of families and genera, and as a result it is possible to use such characters in the construction of keys—an all important aspect of any monographic work (for visual summary of shell features see Fig. 2). We stress the word "workable" in the absence of comparative anatomical information. Undoubtedly as anatomical data become available for a wide variety of scaphopods, the scope and definitions of genera and families will require some degree of modification.

Pilsbry & Sharp (1897–98) used the shape of the central tooth of each radular row to differentiate "Dentaliidae" *sensu* Pilsbry & Sharp (now equivalent to the Order Dentaliida; central tooth wider than high) from the "Siphodentaliidae" *sensu* Pilsbry & Sharp (now equivalent to the Order Gadilida; central tooth square or higher than wide) (Fig. 4). Subsequent authors have pointed out further radular features useful for recognition of taxa, such as the number and arrangement of cusps on the central tooth and the presence/absence and shape of carinae on laterals and shape of marginals (see Boss, 1982; Steiner, 1992a). The two Orders also differ markedly in the external shape and internal musculature of the foot (Steiner, 1992b). Most recently Steiner (1991, 1992a) has demonstrated, through histological and ultrastructural studies, the taxonomic potential of the anterior and posterior mantle margins of scaphopods. He in fact used the results of such work in establishing the new family Fustiariidae (Order Dentaliida). Captacular number and ultrastructure may be another possible feature of taxonomic significance although the fragility of these structures would present problems when examining preserved material (captacula readily detach). Comparative sperm ultrastructure has proven an extremely valuable source of taxonomic and phylogenetic information within the Mollusca, especially from the level of family upwards (for recent reviews see Koike, 1985; Kohnert & Storch, 1984; Healy, 1996). Available information for sperm of scaphopods (Dufresne-Dube *et al.*, 1983; Hou & Maxwell, 1991; Steiner, pers. comm.; Healy unpublished; this study) suggests the presence of a class-level autapomorphy (dimple in acrosome apex). Unfortunately it appears that the group, at least so far, shows no obvious variation in sperm morphology which could be used for taxo-phylogenetic analyses.

Classification and identification. In comparison with the Gastropoda or Bivalvia, the Scaphopoda form a numerically small group with perhaps only 500–600 valid species[1]. The class is well represented in Australian waters by 108 species, 47 of which are described as new in the present account.

Classification of the Scaphopoda has recently undergone considerable re-assessment by various workers including Steiner (1991, 1992a), Chistikov (1975, 1979, 1982a,b) and Scarabino (1979, 1986a,b). Nevertheless Pilsbry & Sharp's (1897–98) long accepted division of the class into two broad taxa (their "families" Dentaliidae and Siphodentaliidae) still survives—these two taxa now constituting the Orders Dentaliida and Gadilida (see Steiner, 1992a for further discussion). In addition many of Pilsbry & Sharp's unofficial groupings of species have been accepted, as have many of their distinguishing features and keys to these species groups (repeated verbatim, and with much justification, by a number of workers including Boissevain, 1906; Cotton & Godfrey, 1940; Habe, 1964). Continuing anatomical studies at light microscopic and ultrastructural levels have supported the creation of new families and genera in a long-overdue expansion of the scaphopod classificatory framework. Many of these changes have only involved the raising of subgenera to full generic status, sometimes accompanied by the introduction of a separate family for an apparently isolated taxon (e.g., Fustiariidae for *Fustiaria*). In the present study we have followed the preliminary classification proposed by Steiner (1992a) which in turn draws extensively on earlier works such as Pilsbry & Sharp (1897–98), Ludbrook (1960), Habe (1963, 1964), Emerson (1962, 1978), Palmer (1974a,b), Chistikov (1975, 1979, 1982a,b), Boss (1982) and Scarabino (1986a,b). Anatomical work still needs to be carried out in order to test the validity and/or higher category placement of several genera. Some genera or subgenera seem, in our opinion, too poorly differentiated to recognize (e.g., *Antalis*) and have either not been used herein or used with some hesitation (for further discussion see pp 173–175 and Addendum, p 184).

The monograph of Pilsbry & Sharp was published over the two year period 1897–1898. The Zoological Record for these years gives the pagination and plate numbers as follows: 1897 (pp 1–144, pls i-xxvi, Scaphopoda); 1898 (parts 65A, 67, 68 pp 145–348, pls xvii-xlviii Scaphopoda and Aplacophora). Although Pilsbry & Sharp (in their text) only associate the year 1898 with pp 197–255 of the monograph (i.e. Appendix A. Fossil Scaphopoda), we have, like Scarabino (1979), followed the pagination given by The Zoological Record in determining the date associated with any Pilsbry & Sharp (or Sharp & Pilsbry) species or statements made by these authors. It does however seems puzzling that the 1897 portion of the monograph stops in the middle of Pilsbry & Sharp's discussion of *Cadulus (Dischides) politus* (Wood).

[1] This figure is an estimate, based on Boss's (1982) conservative figure of 350 species plus 47 new species described herein, plus 42 new species described by V. Scarabino (1995), plus, we estimate, a further 100 or so species resulting from further deep sea work. Palmer & Steiner (1998) give the same estimate.

Identification of juvenile scaphopod shells to the level of species or genus is often difficult or impossible owing to the fact that many important shell features only arise with adulthood (for example, the number, strength and growth pattern of shell ribs). Erosion of the shell surface before or after death can also be considerable, again creating the potential for confusion in identifying material. It is advised that caution be exercised when applying names to small, obviously juvenile shells, if these are all the material available from a collecting site. Always seek to collect a range of specimens from large to small. Similarly, identifying badly worn or broken specimens is usually difficult, unless of course the species concerned is so distinctive that it is recognizable even in poor condition (e.g., the large coloured species *Dentalium (Dentalium) elephantinum, Dentalium (Pictodentalium) formosum*).

Fossil history and phylogeny The source and first appearance of the Scaphopoda are still matters for debate, although it is generally accepted that the Bivalvia represent the closest extant class (Stasek, 1972; Steiner, 1992a). Connections have been suggested with the Monoplacophora (Starobogatov, 1974), the Gastropoda (Simroth, 1894), the Cephalopoda (Grobben, 1886), the Bivalvia (Stasek, 1972) or from the extinct Rostroconchia (Pojeta & Runnegar, 1976, 1979, 1985; Runnegar & Pojeta, 1974, 1985). Current opinion, based on fossil and anatomical evidence, favours a rostroconch origin for scaphopods (for detailed discussion see Pojeta & Runnegar, 1979; Steiner, 1992a). The subphylum Diasoma of Runnegar & Pojeta (1974) (termed the Loboconcha by Salvini-Plawen, 1990), formally associates the extinct Rostroconchia with the Scaphopoda and Bivalvia (see Fig. 6, from Steiner, 1992a), leaving the remaining single-shelled classes (Gastropoda, Cephalopoda and Monoplacophora) to form the paraphyletic Cyrtosoma.

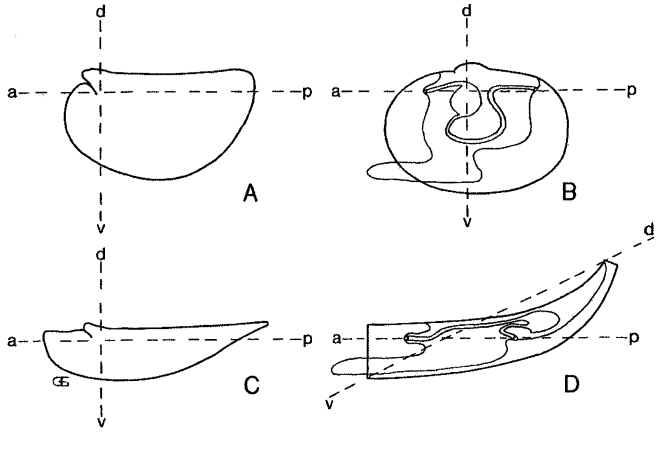


Figure 6. Comparative shell physiognomy and life habit of the three classes of the Diasoma. **A** *Riberia* (basal member of class Rostroconchia). **B** Class Bivalvia. **C** *Pinnocaris* (advanced member of class Rostroconchia). **D** Class Scaphopoda. Body axes indicated by dotted lines. Abbreviations: a, anterior; d, dorsal; p, posterior; v, ventral; (from Steiner, 1992a, fig. 2, p. 387).

The oldest fossil assignable to the Scaphopoda is *Rhytiodentalium kentuckyensis* Pojeta & Runnegar, 1979—a moderately large, evidently smooth-shelled species from the Middle Ordovician of the United States (Middle Lexington limestones). Although this species was placed by Pojeta & Runnegar (1979) into the Laevidentaliidae, this assignment should probably be considered as tentative, primarily because fine longitudinal ribbing (e.g., as seen in modern *Graptacme*) could have been present but not preserved. Yochelson (1978) queried the scaphopod affinities of *R. kentuckyensis* and another Ordovician species *Plagioglypta iowaensis* (see Bretsky & Bermingham, 1970), but Pojeta & Runnegar (1979), in our opinion, adequately defend such a placement for these fossils. The earliest undisputed fossil scaphopods are those belonging to the extinct genus *Protodentalium* Young. These finely ribbed species included the largest scaphopods ever to have existed, many of which reached lengths of 200–300+mm long and with a shell thickness of up to 8.0 mm (see Emerson, 1962).

In contrast to the many Palaeozoic and Mesozoic scaphopods recorded from the northern hemisphere, most fossil species from Australia date from the middle and late Tertiary (see Ludbrook, 1956, 1959, 1984). The strong southern state bias for scaphopod fossil occurrence (i.e. Victoria, Tasmania, South Australia, Western Australia) is probably due to the fact that suitable Tertiary marine deposits are largely absent in northern Australia. Presumably during the Tertiary, northern Australia had, as now, a significant scaphopod fauna. Yoo (1988) has described four new species from the Lower Carboniferous of New South Wales (Late Tournaisian, thin limestone bands of the upper part of the Dangarfield Formation, near Gundy, Upper Hunter, New South Wales), thereby establishing the presence of the class in Palaeozoic Australian seas. These species were assigned by Yoo to the Dentaliidae (one tentatively placed in *Fissidentalium*) and Laevidentaliidae (including two species placed in the new genera, *Scissuradentalium* and *Pipadentalium*). His placement of the genus *Plagioglypta* Pilsbry & Sharp in the Laevidentaliidae is based on Palmer's (1974a) original, broad concept of the family. *Plagioglypta* is now usually assigned to the Omniglyptidae, while living representatives of this family are accommodated in the genus *Omniglypta* Kuroda & Habe (see Steiner, 1992a). Although scaphopods have yet to be recovered from Mesozoic Australian marine deposits, their undisputed presence in the Lower Carboniferous suggests that specimens from this era will eventually be reported. Further study may even reveal species older than those described by Yoo.

Tate (1899), Cotton & Godfrey (1940) and Ludbrook (1956, 1959) list several species of fossil Dentaliidae from Australia (all Tertiary). Certain living species also occur as late Tertiary (Pleistocene) fossils, including *D. flindersi* Cotton & Ludbrook and *D. hyperhemileuron* Verco. In the present study *Laevidentalium largicrescens* (Tate) is demonstrated to be still living, several specimens obtained from deep water in Bass Strait being inseparable from the fossil type material.

Recently Steiner (1992a) has produced a phylogeny of the Scaphopoda based on a cladistic analysis of soft part and shell characters (28 characters, see Fig. 7). His results indicate that among the Dentaliida, a close relationship

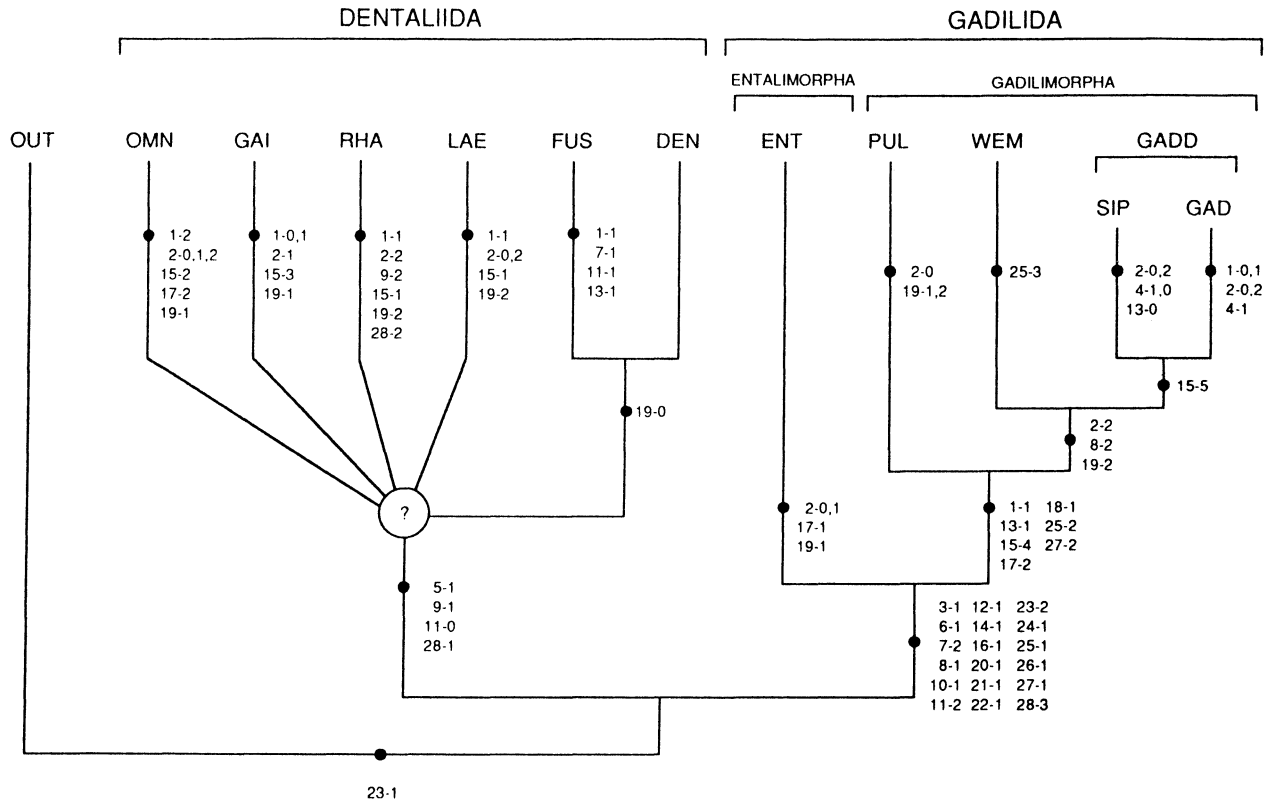


Figure 7. Cladogram showing possible relationships between scaphopod families within the two orders (Dentaliida and Gadilida) as reconstructed by cladistic analysis by Steiner (1992a, fig. 4, p. 394). Numbers refer to Steiner's character matrix (see Steiner, tables 1 and 2). Abbreviations of taxa (left to right): OUT, Outgroup; OMN, Omniglyptidae; GAI, Gadilinidae; RHA, Rhabdidae; LAE, Laevidentaliidae; FUS, Fustiariidae; DEN, Dentaliidae; ENT, Entalinidae; PUL, Pulsellidae; WEM, Wemersoniellidae; GADD, Gadilidae; SIP, Siphonodentaliinae; GAD, Gadilinae.

exists between the Dentaliidae and Fustiariidae, while the remaining families, Gadilinidae, Omniglyptidae, Rhabdidae and Laevidentaliidae form an unresolved polytomy. Steiner could not confirm the monophyly of the Dentaliida, but added that this was due to a lack of reliable synapomorphies for the order and incomplete anatomical information for the Omniglyptidae and Gadilinidae. He did, however, predict that the annular ciliary organ of the anterior mantle margin may prove to be a uniting synapomorphy for the Dentaliida. Among the Gadilida, Steiner concludes that the Entalinidae form the sister group to the Pulsellidae + Wemersoniellidae + Gadilidae. The sequence of appearance of dentallid taxa in the fossil record is difficult to establish with any certainty. Although apparently smooth-shelled taxa such as *Rhytiodentalium* seem to have appeared first, there is no guarantee that these really are true Laevidentaliidae (as currently defined). Given that annulate taxa are believed to have developed on separate occasions from smooth-shelled ancestors (accepted to be laevidentaliids by Palmer & Steiner, 1998), there seems every chance that the ancestral taxa themselves may not have constituted a homogeneous group. Leaving aside this probably intractable problem, all available evidence suggests that the bulk of the modern Dentaliidae are of very recent origin (see Palmer & Steiner, 1998, for discussion). Steiner (1992a) considers the ribbed Dentaliida to be less advanced than the Laevidentaliidae, and to be older geologically. The time and point of departure of the Gadilida from the ancestral scaphopod stem remain unknown. Nevertheless living Entalinimorpha resemble Dentaliida in details of the pedal musculature and in having a strongly ribbed, Dentaliidae-like shell, and as such offer a connecting link between other Gadilida and the Dentaliida (Steiner, 1992a). Perhaps a comparative analysis of scaphopod DNA may assist in reconstructing phylogenetic relationships between the two orders and their constituent families and genera.

Previous studies on Australian scaphopods. The study of Australian scaphopods essentially began with the description of three new species by G.B. Sowerby (1860) in his Thesaurus Conchyliorum. Subsequently Tenison-Woods (1877) added a further 2 species to the tally, but provided only brief descriptions and no supporting illustrations (both species herein treated as unrecognizable). The following year Brazier (1877) described six new species from the Australian-New Guinea region from material collected during the Chevert Expedition. Despite very brief descriptions and no illustrations a check of type material confirms the validity of all of Brazier's species. Occasional new species from Australian waters were described by Watson (1879), von Martens (1881), Melvill & Standen (1896), Pilsbry & Sharp (1897–98), Tate & May

(1900) and Hedley (1901, 1903). In addition, Tate (1887, 1899) described several fossil species from the Victorian Tertiary (Mornington and Muddy Creek beds, Miocene, Pliocene). The first author to study the endemic Australian fauna from a comparative standpoint was Verco (1911a,b, 1913), who not only described ten new species, but also attempted to document morphological variation and depth distribution within southern species. Cotton & Godfrey (1933, 1940) and Cotton & Ludbrook (1938) added further new species to the known southern Australian fauna (8 extant, 1 fossil from the South Australian Tertiary), and made efforts to fit the Australian Scaphopoda into the Pilsbry & Sharp classification. Cotton & Godfrey (1940) also introduced two new subgeneric taxa both of which have subsequently been synonomized with other taxa. Subsequently Ludbrook continued to advance our knowledge of the fossil Scaphopoda from Australia with her description of three new species (1956) and a revision of Tate's species (1959). By way of her contribution to the Treatise on Invertebrate Paleontology (1960, the "Scaphopoda" section) Ludbrook has also provided some idea of stratigraphic ranges for genera and subgenera. In 1958 Colman produced a brief but valuable paper on the scaphopods of New South Wales, in which he described 6 new species and provided important collection data for previously named species. Since the appearance of Colman's paper almost nothing has been published on the living scaphopods of Australia, aside from the listing of species in various local handguides or checklists (Tasmania—May, 1958; New South Wales—Iredale & McMichael, 1962) and occasional mentions in popular books (e.g., Allan, 1959; Rippingale & McMichael, 1961; McMichael, 1962; Coleman, 1982). It is also surprising that the Scaphopoda were one of the few classes of molluscs not to be researched by Iredale, perhaps reflecting a general lack of interest in the group. Most recently, Steiner (1998a,b) has presented a brief generic level synopsis of Australian scaphopods based on information and material supplied by the present authors.

Material and methods

Material examined. Material used for this study derives from several sources, the most extensive and important of which are the collections of the Australian Museum, the Western Australian Museum and the South Australian Museum. In addition, much recently collected (and preserved) scaphopod material has been made available to us from the "Cidaris" I-III cruises off the northern Queensland coast (1986–1988, Queensland Museum), the North-West Shelf Project Survey (1988), the Northern Territory Pearl Bed Survey (1988–1990), the Bass Strait Continental Shelf Survey (Museum of Victoria) and from the on-going CSIRO *Southern Surveyor* and *Franklin* cruises. Other sources of specimens (mainly dry shells, some wet-preserved specimens) were the Lamprell collection and from donations of small scaphopod lots of individual specimens made to us during the course of this work. Although individual distribution maps are provided for each species included in this study, most of the significant collection localities are indicated on Figure 8.

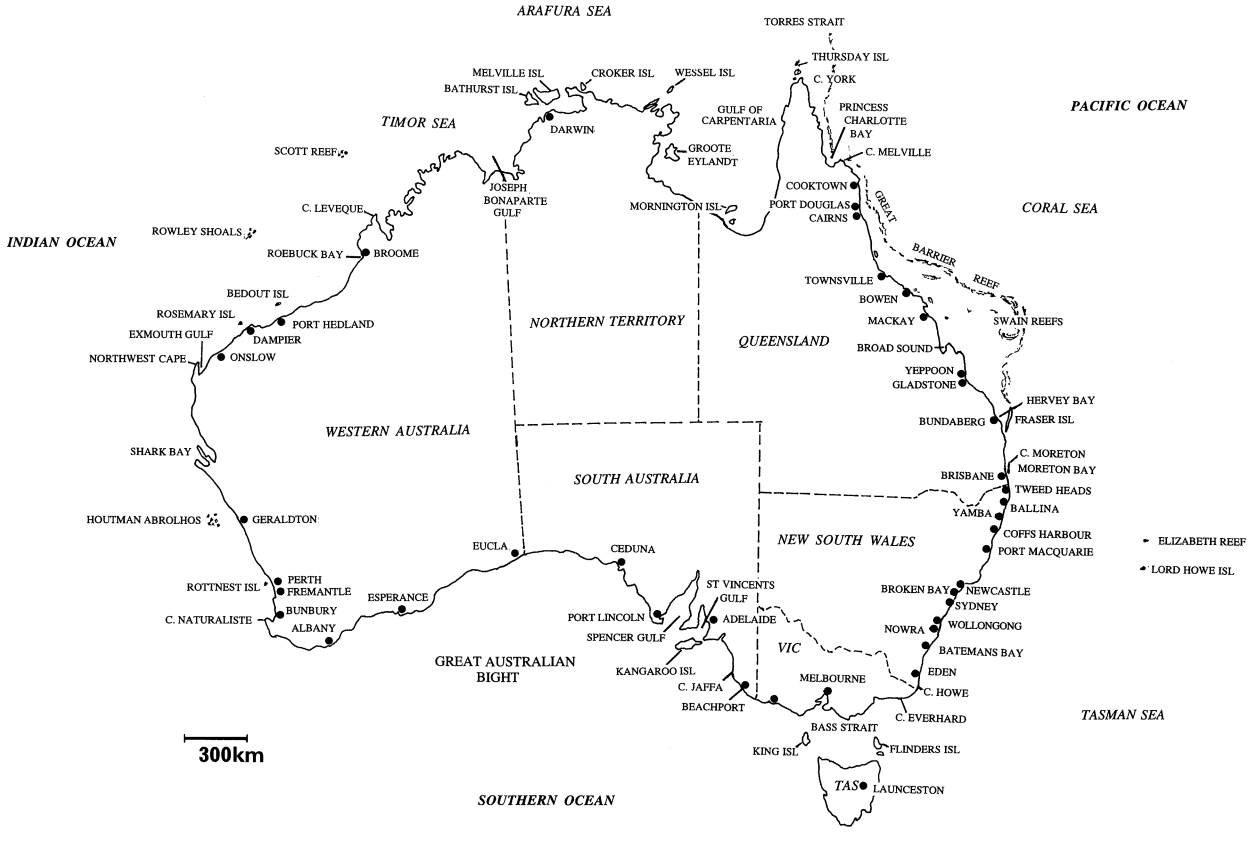


Figure 8. Map of Australia showing states, territories and major localities mentioned in the text.

Due to the often poor quality of illustrations accompanying many of the older (especially 18th and 19th Century) scaphopod species' descriptions (or occasionally total lack of illustrations), we found that an examination of type specimens was the only way to unequivocally determine the identity of some species. For this reason, we have made every effort to examine type material of all previously named species occurring in or near the Australian region. The Australian Museum (Sydney) and the various state museums freely made available their type lots, although in a few cases, types could not be located or isolated with certainty. Types of some species originally collected from Australian localities (e.g., *Fissidentalium clathratum* von Martens) or now known to occur in Australian waters (e.g., those with broad Indo-Pacific ranges or occurring in the Indonesian and Arafura Sea regions) were in most instances available for loan, but once again there were some species for which the type specimens appear to be lost. Specimens from the Linnean collection, now housed in the Natural History Museum (BMNH), were examined as photographs only, supplied to us by that institute.

With the exception of the holotype and paratype dimensions, the measurements given in the descriptions refer to the maximum observed size of adult specimens. For examination of details of shell sculptural and radular microstructure, a Hitachi 500 scanning electron microscope (SEM) was used. Radular ribbons for SEM were cleaned by boiling for 40 mins in 10% aqueous KOH or by emersion in a 5% aqueous KOH for 6–7 days. After three rinses in distilled water, radulae were then mounted using double-sided adhesive tape glued to SEM metal stubs and coated in gold using a sputter coater.

For each genus and species recognized herein as valid, we have presented the following information: the relevant publication and type specimen details (where available); a select synonomy (reference only to monographs and significant papers and not every recorded mention of a species in the literature); diagnosis; distribution (Australian and total distribution; map showing Australian distribution); remarks and comparisons and, for new species, etymology.

Terminology. The terminology used herein for descriptions follows that adopted by most workers including Pilsbry & Sharp (1897–98), Boissevain (1906), Cotton & Godfrey (1940), Habe (1964), Ludbrook (1960), Emerson (1962), Palmer (1974a), Steiner (1991, 1992a, 1998a,b) and Palmer & Steiner (1998). Although, as pointed out by Steiner (1992a), the concave and convex surfaces of the shell do not closely correspond with the anatomical dorsal/ventral axis of the animal (see Fig. 6D), the terms dorsal and ventral are well established and universally applied conchological terms, and are used throughout the present study. Similarly, the shell apex (narrowest extremity) actually represents the posterior end of the animal. Again, we use this term, and illustrate shells in the posterior-anterior axis, because this has become conventional among most recent workers on the class. Figure 2 and the glossary in the Appendix (p 182) summarize the principal terms applied in descriptions of shells in this study.

Keys. Keys to orders, families, genera and species are provided for the ready determination of material. Although it is well known that significant anatomical differences exist between taxa, especially between the two orders and between families, often only empty shells are available for study. Hence, in constructing the keys we have chosen to use almost exclusively shell features at and below the level of family. Many authors have drawn attention to the fact that certain seemingly important shell features, such as the presence or absence of an apical pipe, or apical fissure can vary markedly even within a species (e.g., see example shown in Fig. 3), genus or family. However, as pointed out by Pilsbry & Sharp (1897–98) this does not invalidate the use of such features in keys providing that they are cited in combination with other features. In fact, identification of many scaphopods can only be made after a consideration of all shell features and ideally a good range of material from the collection site. The following points should be kept in mind when trying to identify scaphopod species from shells: (1) do not expect precise identifications using very juvenile, badly broken, corroded or beach-worn material; (2) aim to have a good-sized sample of the species ideally a range from young to old, to appreciate variation with age, and variation between individuals; (3) always check specimen(s) against our figures of non-scaphopods (see p. 171) in order to ensure the sample is actually a scaphopod.

In devising keys for genera containing several species (e.g., *Dentalium, Laevidentalium*), we have adopted the Pilsbry & Sharp (1897–98) strategy of grouping species according to their shared conchological features (suites of features, with usually one or more critical traits). Hence we recognize clusters of species such as the "*D. elephantinum* group" or the "*D. decemcostatum* group" which have, in each case, been named after a typical member of the group. We prefer to use this flexible "group" system as it obviates the need to introduce new and probably unwarranted subgenera while at the same time providing the required framework for constructing a working key. A key to the groups is given at the beginning of the relevant section of the text, as are keys for each group. Attempts were made to construct a single key to all 38 Australian species of *Dentalium* (the largest genus considered herein) but always the resulting key proved unwieldy and therefore impractical for non-specialists to use.

Taxonomic decisions. Throughout this study we have followed the rulings and recommendations outlined in the third edition of the International Code of Zoological Nomenclature (1985). Determining the identity of any species depends on close scrutiny of the original description, published drawings and/or photographs and sometimes on an examination of the actual type specimen(s). In a few cases where the author has provided a poor description and a poor (or no) illustration, and for which no type specimen can be located, we have had no alternative but to designate the species concerned as being "unrecognizable" (see p. 172).

Abbreviations used in the text

Institutions: AMS—Australian Museum, Sydney, Australia; ANSP—Academy of Natural Sciences, Philadelphia, USA; BMNH—British Museum (Natural History Museum, London, England); MNHN—Muséum national d'Histoire naturelle, Paris, France; NMV—Museum of Victoria, Melbourne, Australia; NSMT—National Museum of Science, Tokyo, Japan; QM—Queensland Museum, Brisbane, Australia; SAM—South Australian Museum, Adelaide, Australia; TM—Tasmanian Museum and Art Gallery, Hobart, Australia; WAM —Western Australian Museum, Perth, Australia; USNM—United States National Museum (Smithsonian Institution), Washington, USA; ZMA—Zoological Museum, Amsterdam, The Netherlands; ZMB—Zoological Museum, Berlin, Germany; ZSI—Zoological Survey of India (collection).

Localities: NSW, New South Wales, Australia; NT, Northern Territory, Australia; PNG, Papua New Guinea; Qld, Queensland, Australia; SA, South Australia; Tas., Tasmania, Australia; Vic., Victoria, Australia; WA, Western Australia.

Other abbreviations: C:L—ratio of length of radular central tooth to length of lateral tooth (see Fig. 4D); Del.—[in figure captions] *delineavit* (Latin), drew this; L:M—ratio of length of radular lateral tooth to length of marginal tooth (see Fig. 4D); W:L—ratio of shell aperture width to shell length. KLColl—Kevin Lamprell collection.

Systematics

Class SCAPHOPODA

Keferstein (*in* Bronn, 1862–1866)

Diagnosis. Bilaterally symmetrical, infaunal, marine molluscs characterized by a tubular shell and ciliated, filamentous feeding structures termed captacula. Radula well developed, mineralized (to varying degrees) with transverse formula 1.1.1.1.1. Shell composed of chitinous periostracum, and three aragonitic layers [outer (longitudinal, prismatic) layer, middle (cross-lamellar layer) and inner (concentric) layer]. Foot modified for burrowing and associated either with epipodial lobes (Dentaliida) or terminal disk (Gadilida). Eyes, osphradium and gills absent. Larva of stenocalymma type.

Order DENTALIIDA Da Costa, 1778

Diagnosis. Scaphopoda with moderately large shells which are either ribbed or smooth and always widest anteriorly. The foot-tip is conical and associated with epipodial lobes. The central tooth is wider than high.

Key to Families of Dentaliida

1 Longitudinal ribs present, at least near the apex ..... Dentaliidae

—— Longitudinal ribs absent 2

2 Fine, raised regularly spaced transverse rings present, at least posteriorly ..... Omniglyptidae

—— Raised transverse rings absent or, if present, only coarsely developed and irregularly spaced 3

3 Apex always with pipe and plug, never with slit or notch; shell cross section at apex trigonal or circular ..... Gadilinidae

—— Apex sometimes with pipe (never a plug), commonly with slit or notch; shell cross section at apex oval to circular (never trigonal) 4

4 Apex usually with long, fine slit; shell always thin, translucent and glossy, increasing only slightly in diameter anteriorly; aperture narrow ..... Fustiariidae

—— Apex often with notch, slit if present, poorly developed; shell usually thick, opaque (rarely thin and transparent) and glossy, increasing markedly in diameter anteriorly; aperture narrow to wide ..... Laevidentaliidae

Family DENTALIIDAE Gray, 1847

Diagnosis. Shell thick-walled and sculptured with longitudinal ribs or striae, at least near the apex. Cross section of shell polygonal to circular. Rachis [central] tooth with an arched, smooth superior surface; marginal teeth curved. Ciliary organ of the anterior mantle margin consisting of 6–8 rows of cells (Steiner, 1992a: 396).

Key to Genera of Australian Dentaliidae

1 Apex quadrangular in cross section ..... *Tesseracme*

—— Apex polygonal to circular in cross section 2

2 Shell with strong ribbing throughout length (occasionally reduced anteriorly) 3

—— Shell with fine longitudinal striae posteriorly, smooth anteriorly ..... *Graptacme*

3 Shell slightly curved to almost straight; ribs usually greater than 14 apically, usually greater than 30 at anterior aperture ..... *Fissidentalium*

—— Shell moderately to strongly curved; ribs usually less than 14 apically, usually less than 30 at anterior aperture ..... *Dentalium*

Dentalium Linnaeus, 1758

Dentalium Linnaeus, 1758: 785; Montfort, 1810: 23; Pilsbry & Sharp, 1897: xxix; Boissevain, 1906: 7; Henderson, 1920: 22; Woodring, 1925: 197; Ludbrook, 1960: I37; Emerson, 1962: 467; Habe, 1964: 5; Palmer, 1974a: 119; Steiner, 1992a: 396.
Dentalia Perry, 1811: pl. 52 (for *D. viridis* Perry, 1811).
Dentalites Schlotheim, 1813: 91, 100, 110; *Heteroschisma* Simroth, 1894: 460.
Paradentalium Cotton & Godfrey, 1933: 139.
Heteroschismoides Ludbrook, 1960: 139.

Type species. *Dentalium elephantinum* Linnaeus, 1758; by subsequent designation, Montfort, 1810: 23.

Diagnosis. Shell curved, tapering, longitudinally sculptured; apex with or without small notch, slit or plug and pipe.

Dentalium sensu stricto Linnaeus, 1758

Diagnosis. Longitudinal ribs strong and less than 20 in number at the apex; interstices usually smooth, sometimes developing fine longitudinal striae or riblets.

Key to Group of *Dentalium elephantinum*

Nine to 12 ribs at apex; shell coloured green, paler at apex, robust, strongly curved.

1 Aperture relatively wide in proportion to length (width: length ratio from 1:7.6 to 10.4); with apical slit or notch 2

—— Aperture narrow in proportion to length (width:length ratio 1:14.4); without apical slit or notch ..... *D. aprinum*

2 Width: length ratio 1:7.6; rapidly tapering ..... *D. elephantinum*

—— Width: length ratio 1:10.4; moderately tapering ..... *D. exmouthensis*

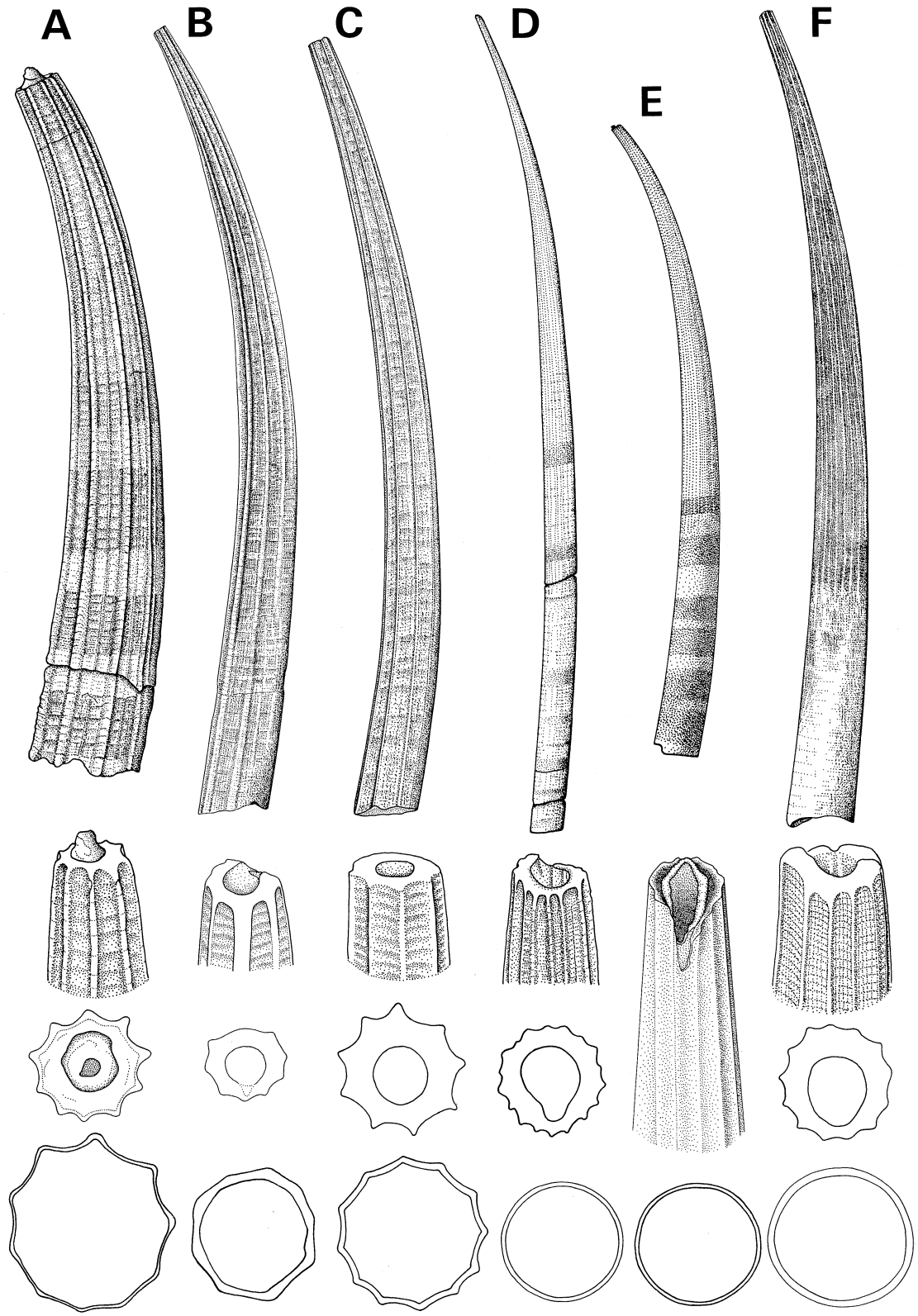


Figure 9. Dentaliida, Dentaliidae. *Dentalium (Dentalium)* Group of *D. elephantinum*. **A** *D. elephantinum* Linnaeus (AMS C138631, Euston Reef off Cairns, Qld, 23 m, length 60.5 mm). **B** *D. exmouthensis* n.sp. (holotype, QM MO38994, North West Cape Exmouth Gulf, WA, length 61.5 mm). **C** *D. aprinum* Linnaeus (KLColl, Cape Moreton, 120 m, length 53.0 mm). Group of *D. hedleyi*. **D** *D. hedleyi* n.sp. (holotype, AMS C174892, south-east of Swains Reefs, Qld, length 116.4 mm). **E** *D. grahami* n.sp. (holotype, AMS C174892, off Clarence River, NSW, 37–55 m, length 72.9 mm). **F** *D. jelli* n.sp. (holotype, QM MO45837, off Cairns, Qld, 703 m, length 52.8 mm). (Del.: all A. Hill, except E—C. Eadie).

Figure 10. Dentaliida, Dentaliidae. *Dentalium (Dentalium)* Group of *D. elephantinum*. **A** *D. elephantinum* Linnaeus (AMS C138631, Euston Reef off Cairns, Qld, 23 m, length 60.5 mm). **B** *D. exmouthensis* n.sp. (holotype, QM MO38994, North West Cape Exmouth Gulf, WA, length 61.5 mm). **C** *D. aprinum* Linnaeus (WAM 146/93, 94 km north Port Hedland WA, 56 m, length 98.0 mm). Group of *D. hedleyi*. **D** *D. hedleyi* n.sp. (holotype, AMS C171343, south-east of Swains Reefs, Qld, length 116.4 mm). **E** *D. grahami* n.sp. (holotype, AMS C174892, off Clarence River, NSW, 37–55 m, length 72.9 mm). **F** *D. jelli* n.sp. (holotype, QM MO45837, off Cairns, Qld, length 52.8 mm).

Dentalium (Dentalium) elephantinum Linnaeus, 1758

Figs 9A, 10A, 11, 13A–C

Dentalium elephantinum Linnaeus, 1758: (10), 686; 785; Linnaeus, 1767: (12), 783; Gmelin, 1788: (13), 3736; Lamarck, 1818: 326; Lamarck, 1818: 343; Wood, 1818: 183; Chenu, 1842–1843: 2, pl. 1, figs 11, 12; G.B. Sowerby, 1860: 102, pl. 223, fig. 4; Reeve, 1872: pl. 1, fig. 5; Pilsbry & Sharp, 1897: 1, pl. 1, figs 1–7; Boissevain, 1906: 7, pl. 1, fig. 1; Habe, 1961: 106, pl. 47, fig. 16; Habe, 1963: 253, pl. 37, fig. 3; Habe, 1964: 6, pl. 1, fig. 3; Allan, 1950: 241; McMichael, 1962: 124, fig. 283; Coleman, 1982: 271; non Born, 1780: 431; non Brocchi, 1814: 260.
Dentalium striatum Born, 1780 (in part): 431.
Dentalium arcuatum Gmelin, 1788: (13), 3738; Anton, 1839: 25.
Dentalium viridis Perry, 1811: pl. 52.
Dentalium recurvum Deshayes, 1825: 30.

Type material. None isolated or identified as such. Linnean Society (London) species reference number in 10th edition = 686. Type locality: Amboyna.

Material examined. QUEENSLAND: 1, AMS C138631, Euston Reef off Cairns, south-west side in 23 m, sand, 29 November 1972 (preserved); 4, AMS C173046, Fitzroy Island, January 1952; 1, AMS C174640, Kelso Reef, north-east of Townsville, subtidal, 29 January 1975; 1, AMS C173047, Broadhurst Reef, east of Townsville, subtidal 9–10 November 1974; 2, AMS C53557, Michaelmas Cay, May 1926; 1, AMS C10278, Lizard Island, November 1975; 1, AMS C134293, 13°45'S 144°16'E, south end No 5 Bank Reef, 3–6 m, sand, 8 December 1981; 1, AMS C134295, 12°47'S 143°48'E, south-west corner of reef, south of Hibernia Entrance, 16 m, rubble in gutters on slope, 11 December 1981; 1, AMS C172049, 14°42'S 145°27'E, south end of South Island, Lizard Island, 15 m, on outer side of reef, 16 January 1980; 1, AMS C171927, 13°49'S 144°17'E, 7–10 m, scattered coral heads on sand, north-west side of reef, 7 December 1981; 1, AMS C171926, Broadhurst Reef, east of Townsville, subtidal, 27 April 1975; 1, AMS C103197, Lizard Island, north-west side Macgillivray Cay, reef drop-off, 6–17 m, coral outcrops in sandy rubble, 10 December 1974; 1, AMS C172048, Lizard Island, off Crystal Beach Point, reef flat and face to 9 m, 1–12 December 1974; 2, AMS C42015, Dunk Island; 1, AMS C172052, off Rocky Point, Lizard Island, 9 m, coral and sand bottom, Lizard Island Expedition, 7 December 1974; 1, AMS C63123, Yirrkala, NT; 1, AMS C77161, Croker Island, Arnhem Land, NT; 1, WAM 255-93, east side of Hermite Island, Monte Bello Islands, WA, 13 December 1979.

Description. Shell length to 95.0 mm, aperture diameter to 11.0 mm, apex diameter to 3.0 mm; robust, strongly curved. Sculpture of 9–11 strong, projecting, raised, rounded, longitudinal ribs; interstices concave, with 1 or 2 low riblets. Aperture polygonal, the ribs stronger dorsally. Apex large, polygonal, usually with a slight notch excentrically on the ventral side, often with a short, central pipe. Colour dark green, darker in bands anteriorly, becoming white towards the apex.

Radula. Central tooth broad and narrow (371 μm wide) with smooth, convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped, 352 μm long with small cusps on the working surface; marginals strongly sigmoidal relatively short and broad (length 372 μm×breadth 136 μm) (see Fig. 13A–C). Ratios C:L = 1:1.09, L:M = 1:1.03, marginals breadth:length = 1:2.32.

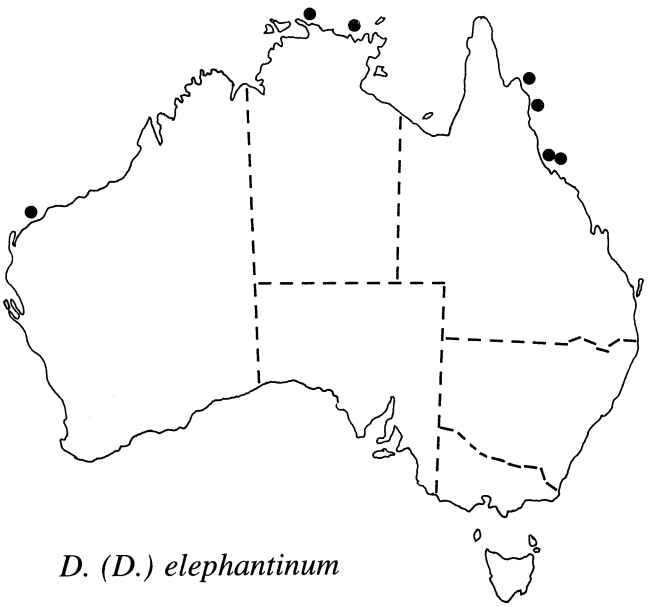


Figure 11. Australian distribution of *Dentalium (Dentalium) elephantinum* Linnaeus, 1758.

Range. Indonesia; Philippine Islands; Molluccas; Red Sea (Pilsbry & Sharp, 1897); northern Queensland, Northern Territory to northern Western Australia.

Habitat. Found in coral sand from 3 to 23 m.

Comparisons and remarks. *Dentalium elephantinum* Linnaeus, 1758 is a well known and conchologically consistent species, widely distributed throughout the Indo-West-Pacific (recorded from Australia, Philippine Islands, Indonesia and the Red Sea). Differentiating features from other green coloured Dentaliidae include: the wide aperture; green bands developed in anterior half of the shell; strong raised ribbing and sometimes the presence of an apical notch and pipe. When examining the Linnean collection in 1963, S.P. Dance (then with the BMNH) made the following comment on a card in relation to *D. elephantinum*: "I have isolated one undocumented shell apparently referable to this species". As with much material in the Linnean shell collection, there is no way of determining the true "Linnean" status of this specimen.

Dentalium (Dentalium) exmouthensis n.sp.

Figs 9B, 10B, 12, 13D–F

Etymology. Named after Exmouth Gulf, northern Western Australia, from where the first specimens of this species were obtained.

Type material examined. HOLOTYPE: QM MO38994. Type locality: near lighthouse, North West Cape, Exmouth Gulf, northern WA in littoral sand, September 1987. Length

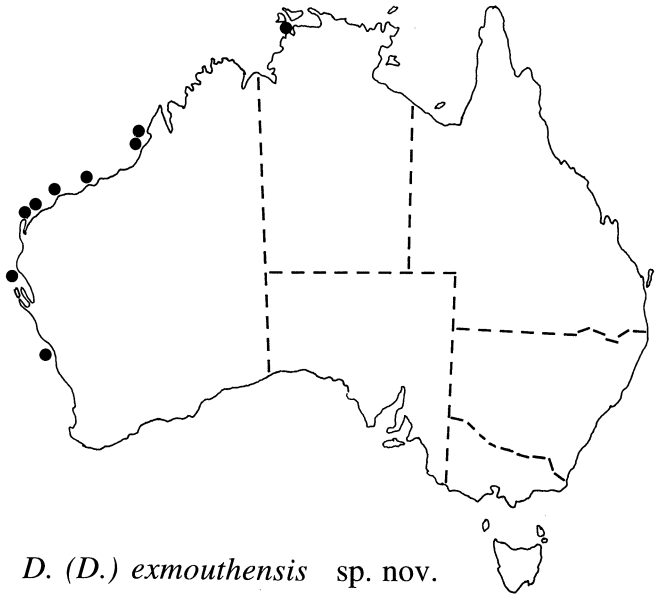


Figure 12. Known distribution of *Dentalium (Dentalium) exmouthensis* n.sp.

of holotype 61.5 mm, aperture diameter 5.1 mm, apex diameter 1.5 mm. PARATYPES: 1, QM MO38985, same locality data as holotype locality; 1, AMS C172174, same locality data as holotype; 2, WAM 282-93, same locality data as holotype.

Additional material examined. WESTERN AUSTRALIA: 3, WAM 252-93, 20 km south-west of Carnarvon, 16 May 1981; 1, AMS C172050, "Onslow Area"; 1, AMS C90836, 27 km south of Exmouth Town site, Exmouth Gulf, on sand flats with strewn coral, 19 January 1972; 1, AMS C172061, 19°04.4–04.2'S 119°04.4–0.7'E, 144 km north north-east of Port Hedland, 82 m, sand, 23 October 1983; 1, AMS C148719, 19°30.9–30.28'S 114°09.2–55.4'E, 96 km north north-east of Port Hedland, 36–37 m, sand, 24 October 1983 (preserved); 1, AMS C173453, 21°51'S 114°10'E, Bundegi Reef, Exmouth Gulf, 1–3 m, sand and coral, September 1972 (preserved); 2, AMS C90403, King George Sound; 4, AMS C149236, 19°30–31'S 118°52–49'E, 92 km off Port Hedland, 38–40 m, 25 October 1983; 29, AMS C148619, 19°30.9–28.2'S 118°49.2–55.0'E, 96 km north north-east of Port Hedland, 36–37 m, 24 October 1983; 1, AMS C149346, 19°56.7–56.0'S 117°53.6–53.4'E, 81 km north-west of Port Hedland, 40 m sand, 26 October 1983; 1, AMS C109203, beach flat east side of Exmouth Township, low tide, 17 June 1972; 2, WAM 95-93, north end of Good Friday Bay, Abrolhos Islands, 40 m, 6 February 1963; 1, WAM 250-93, 32 km west of Legrange Bay, 50 m; 6, WAM 249-93, 32 km north of Delambre, Dampier Archipelago, 46 m, 7 June 1960, sand; 2, WAM 2624-83, Shark Bay; 1, WAM 269-93, north of Dirk Hartog Island, Shark Bay, 52 m, 15 May 1960; 1, WAM 96-93, Bedout Island, 50 m, 12 October 1962 (preserved). NORTHERN TERRITORY: 6, USNM 747757, 12°12'S 130°26'E, Clarence Straits, north-west of Charles Point.

Description. Shell length to 61.5 mm, aperture diameter to 5.1 mm, apex diameter to 1.5 mm; robust, strongly curved, glossy. Sculpture of 9 strong, widely rounded longitudinal ribs, stronger and narrower at the apex, becoming obscure ventrally towards the aperture; interstices wider than the ribs, flat or slightly concave, with obscure transverse growth lines; shell constricted at sites of irregular growth pauses. Aperture polygonal, slightly ovate. Apex small, polygonal; with or without a ventral notch or slit, when a slit is present it is variable in depth, but usually well developed. Colour pale green, darker at sites of growth pauses, cream-white towards the apex.

Radula. Central tooth broad (239 μm wide) and shallow with smooth, convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped, 261 μm long with small cusps on the working surface; marginals sigmoidal, relatively short and broad (length 270 μm × breadth 116 μm) (see Fig. 13D–F). Ratios C:L = 1:1.09, L:M = 1:1.03, marginals breadth:length = 1:2.32 (based on possible female).

Range. Northern Western Australia to Northern Territory.

Habitat. In littoral sand and mud to 82 m.

Comparisons and remarks. *Dentalium exmouthensis* most closely resembles *D. elephantinum* Linnaeus, 1758. Differentiating features include: the ribs which are less raised than in *D. elephantinum*; the presence of slight constrictions of the shell marked by darker bands of green (constrictions absent in *D. elephantinum*); the relatively narrow aperture (wide in *D. elephantinum*); the glossy shell surface (not glossy in *D. elephantinum*); and absence of riblets within interstices (riblets frequently present in *D. elephantinum*). *Dentalium aprinum* Linnaeus, 1758 differs from *D. exmouthensis* in being more strongly curved with a narrower aperture, never showing an apical notch or pipe, being dark green throughout most of the shell length and in having very low ribs, frequently more than 9 in number. In addition *D. aprinum*, like *D. elephantinum* lacks the growth-pause constrictions seen in *D. exmouthensis*. Presence of an apical notch and/or pipe in *D. exmouthensis* appears to be variable (as it is in *D. elephantinum*). In one lot of 11 specimens studied, 4 had an apical slit, 2 had an apical notch and 5 had neither, while in another lot of 6 specimens 2 had slits while the remainder had none.

Dentalium (Dentalium) aprinum Linnaeus, 1767

Figs 9C, 10C, 14, 17A–C

Dentalium aprinum Linnaeus, 1767: 1263; Gmelin, 1788: 3736; Lamarck, 1818: 343; Deshayes, 1825: 351; Anton, 1839: 25; Chenu, 1842–3: 2; G.B. Sowerby, 1860: 102; Reeve, 1872: pl. 1, figs 2a-b; Pilsbry & Sharp, 1897: 3; Habe, 1963: 253; Habe, 1964: 6; Brocchi, 1814: 264.
Dentalium aprinum var. *incolor* Boissevain, 1906: 10.
Dentalium striatum Born, 1780 (in part): 431.
Dentalium striatulum Gmelin, 1788: (13), 3738; Wood, 1818: 84; non Turton, 1819: 352.
Dentalium caprinum Anton, 1839: 25.
Dentalium aprinum taiwanum Kuroda, 1941: 196; Habe, 1961: 106.

Type material. None isolated or identified as such. Linnean Society (London) species reference number in 12th edition = 784. Type locality: Philippines.

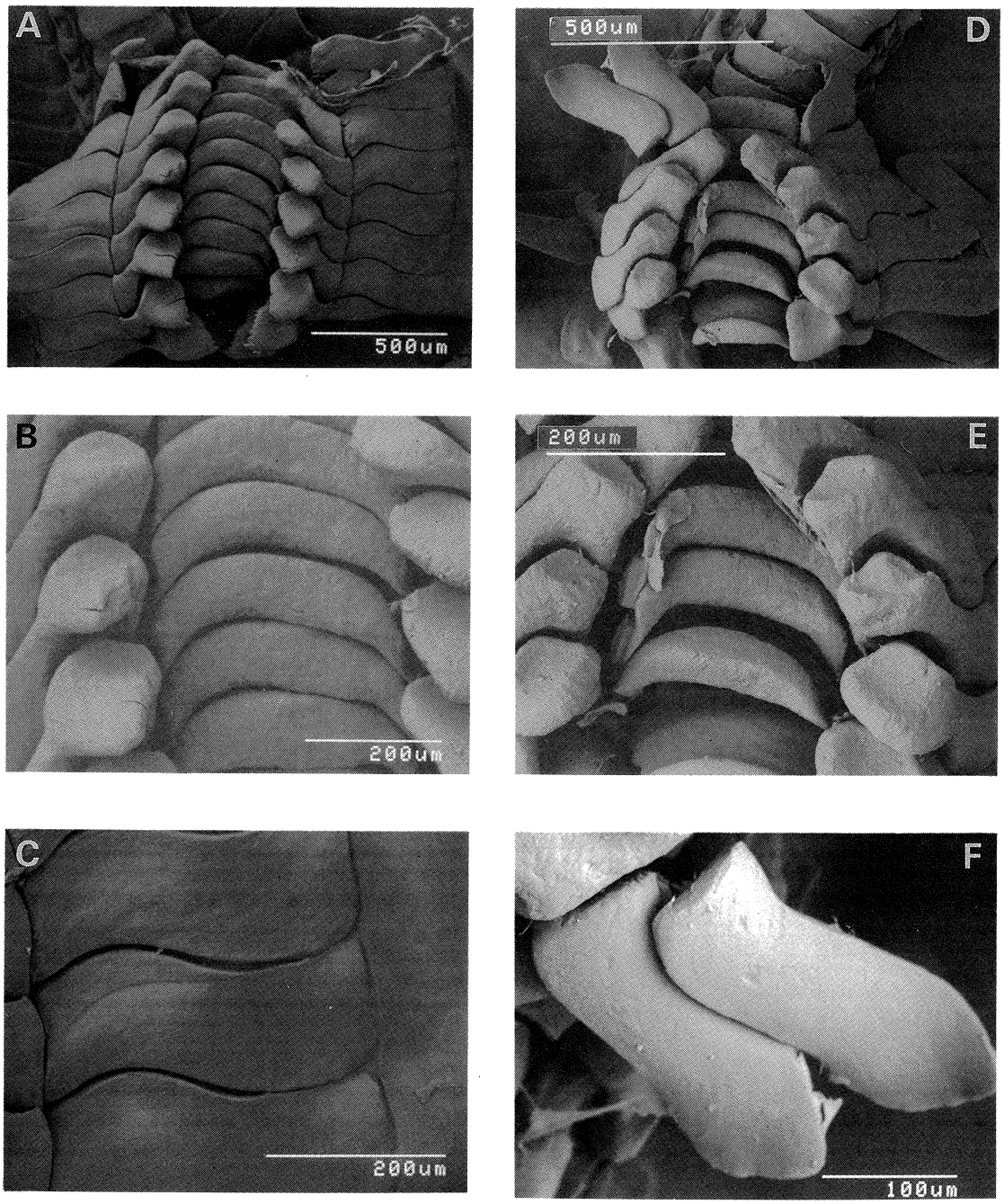


Figure 13. Radular ultrastructure of: **A–C** *Dentalium (Dentalium) elephantinum* Linnaeus, 1758 (Euston Reef off Cairns, Qld, 23 m, AMS C138631); **D–F** *Dentalium (Dentalium) exmouthensis* n.sp. (96 km north-north-east of Port Hedland, WA, 36–37 m, AMS C148719).

Material examined. QUEENSLAND: 2, trawled 120 m off Cape Moreton; 1, AMS C172583, 14°32'S 145°35'E, inner side of Carter Reef, 18 m, 15 January 1980. WESTERN AUSTRALIA: 3, WAM 154-93, 19°59'S 117°16'E, 70 km north of Port Walcott, 52 m, 15 April 1982; 1, WAM 148-93, 18°25'S 118°22'E, 210 km north of Port Hedland, 2 April 1982; 1, WAM 146-93, 19°29'S 118°22'E, 94 km north of Port Hedland, 56 m, muddy sand, 1 April 1982; AMS C172051, 19°03.6–3.4'S 119°03.4–3.5'E, 148 km north north-east of Port Hedland, sand, 23 October 1983; 1, WAM 46-93; 1, WAM 45-93, 11 km north of Long Island, Onslow, 56 m, 17 June 1960, fine sand and rubble.

Description. Shell length to 98.0 mm, aperture diameter to 5.5 mm, apex diameter to 1.8 mm; robust, narrow, long, strongly curved, glossy. Sculpture of 9–12, narrow, rounded, longitudinal ribs, stronger dorsally; interstices flat, wider than the ribs, often with an obscure central riblet and longitudinal striae, growth lines obscure. Aperture polygonal, the ribs stronger dorsally. Apex small, polygonal, without slit or notch. Colour pale to dark green, slightly lighter towards the apex, specimens from Queensland are usually white or with a pale green

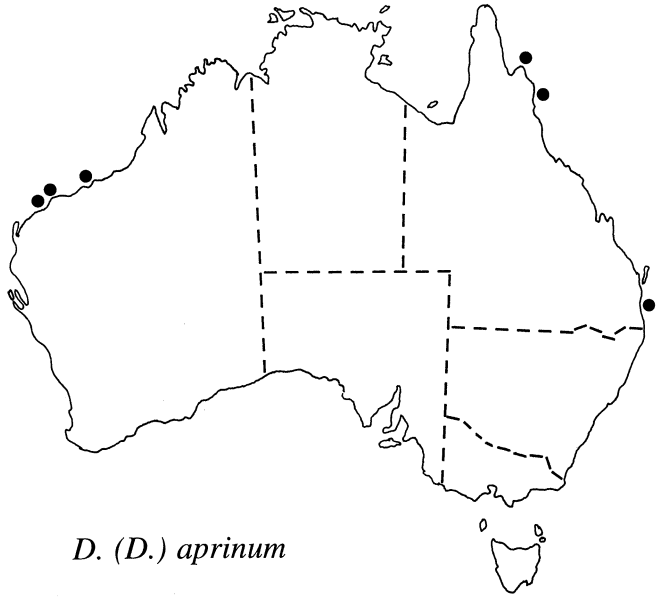


Figure 14. Australian distribution of *Dentalium (Dentalium) aprinum* Linnaeus, 1758.

hue and were given the varietal name "*incolor*" by Boissevain (1906).

Radula. Central tooth broad and shallow (210 μm wide) with smooth, weakly convex superior surface and correspondingly concave inferior surface (the latter showing evidence of a low, ridge-like cusp); laterals dumbbell shaped, 233 μm long with small cusps on the working surface; marginals strongly sigmoidal, relatively short and broad (length 247 μm × breadth 85 μm) (see Fig. 17A–C). Ratios C:L = 1:1.1, L:M = 1:1.06, marginals breadth:length 1:2.9 (sex indeterminate).

Range. Philippine Islands (Pilsbry & Sharp, 1897); Indonesia (Boissevain, 1906); Ryukyu Group, Japan (Habe, 1963); Queensland to northern Western Australia.

Habitat. Dredged in sand from 18 to 120 m.

Comparisons and remarks. *Dentalium aprinum* most closely resembles *D. elephantinum* Linnaeus, 1758 and *D. exmouthensis* n.sp. Shell features of *D. aprinum* which differentiate it from these two species include: markedly narrower throughout length (most noticeably at the aperture); low rounded ribs; uniformly coloured (prominent green bands anteriorly in *D. elephantinum*, creamy green with bands at growth pauses in *D. exmouthensis*); without apical notch or pipe. Specimens from Western Australia, are large (80–98.0 mm) and dark green, and compare well with specimens from the type locality (Philippines). In contrast, specimens from off Cape Moreton are usually smaller (50–60.0 mm) and light coloured, with occasional specimens being uniformly white (the latter being named "variety *incolor*" by Boissevain, 1906). From our observations and those of previous authors (especially Pilsbry & Sharp, 1897) it appears that this species can show substantial variation in aperture width and strength of shell curvature between populations. The precise status of specimens held in the Linnean collection is difficult to resolve. S.P. Dance in 1963 made the following statement on a card when he examined the Linnean collection in 1963: "In a Linnean metal box I found twenty-eight undocumented shells apparently referable to this species. A single large *Dentalium* wrapped in a scrap of old paper, and labelled simply "*Dentalium*" in an unknown handwriting, has the pale green hue alluded to by Hanley". There is no way of knowing if any of these specimens are of Linnean origin, or subsequent additions by other workers. We hasten to add that we have not personally examined the Linnean specimens, only a photograph of the larger shell mentioned by Dance. For the present we accept Dance's opinion that all 28 shells in the Linnean box were of the one species.

Although *D. aprinum* is a common species at certain Western Pacific localities (e.g., the Philippines) this is the first published record of this species from the Australian region.

Key to Group of *Dentalium hedleyi*

Shell coloured green, white towards the apex, robust, moderately curved, ribs usually becoming obsolete towards the aperture.

1 Ribs not intercalating 2

—— Ribs intercalating (13 narrow raised, rounded ribs at apex, intercalate to 26 low, ribs at the aperture) ..... *D. jelli*

2 20 narrow rounded ribs at the apex; colour pale green with darker green transverse rings ..... *D. hedleyi*

—— 17–18 narrow rounded ribs at the apex; colour light olive green; apex sometimes with a small ventral notch or slit ..... *D. grahami*

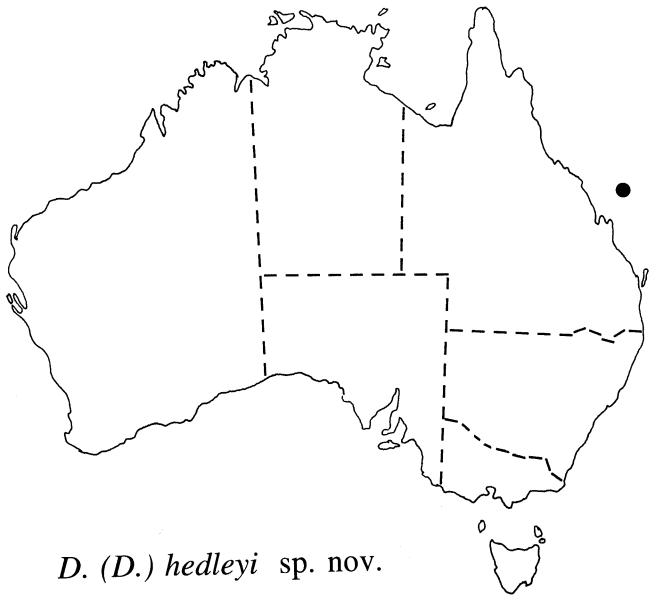


Figure 15. Known distribution of *Dentalium (Dentalium) hedleyi* n.sp.

Dentalium (Dentalium) hedleyi n.sp.

Figs 9D, 10D, 15

Etymology. Named after the late Mr Charles Hedley, an early Curator of Molluscs at the Australian Museum, in recognition for his many pioneering studies on the Australian Mollusca.

Type material examined. HOLOTYPE: AMS C171343. Type locality: Swains Reefs, Qld, dredged off sand bottom by fishing vessel, 1993. Length of holotype 116.4 mm, aperture diameter 5.7 mm, apex diameter 1.15 mm. PARATYPES: AMS C151517, 15 full specimens, 84 broken pieces, south-east of Swains Reefs, Qld, 22°31–4'S 152°32.6'E, 100 m, 6 July 1984.

Additional material examined. QUEENSLAND: 4, Lamprell Collection, purchased from dealer at Yeppoon, dredged off Swains Reefs.

Description. Shell length to 103.8 mm, aperture diameter 6.2 mm, apex diameter 3.7 mm; solid, almost straight becoming curved posteriorly. Sculpture of 20 rounded ribs, extending towards the aperture, weaker ventrally one third of the shell length from the apex, becoming obsolete about two thirds of the shell length from the apex; in specimens to 70.0 mm, the longitudinal sculpture continues to the aperture; interstices about equal width with the ribs with strong transverse growth lines. Aperture circular. Apex circular, crenulated by ribs, orifice large, ovate, without notch. Colour pale green with darker green transverse rings at irregular intervals.

Range. Swains Reefs, Queensland.

Habitat. Dredged in sand to 100 m.

Comparisons and remarks. *Dentalium hedleyi* most closely resembles *D. grahami* n.sp. and *D. jelli* n.sp., which are similar in colour and profile. Differentiating features of *D. hedleyi* include; lesser curvature; greater number of apical ribs (20 in *D. hedleyi*, 17–18 in *D. grahami*, 13 in *D. jelli*). *Dentalium hedleyi* also differs from the similarly green *D. elephantinum* group by being noticeably more tapering with much finer and more numerous ribs than any species in that group. Most of the specimens examined by us appear to have lost the apical section of the shell giving the impression that the species is almost straight. The holotype however, clearly indicates the slow tapering and even curvature of the species. *Dentalium hedleyi* is the largest Australian representative of the genus *Dentalium*, easily recognized by its size and its slowly tapering profile. This appears to be a rare species, although further collecting may show a much wider distribution than known at present.

Dentalium (Dentalium) grahami n.sp.

Figs 9E, 10E, 16, 17D–F

Etymology. Named after Ken Graham of the New South Wales State Fisheries who collected much of the material used for this study.

Type material examined. HOLOTYPE: AMS C174892. Type locality: trawled off Clarence River, NSW, 29°25'S 153°22'E, 37–55 m, October 1985. Length of holotype 72.9 mm, aperture diameter 5.1 mm, apex diameter 1.0 mm. Apical slit 1.5 mm in length. PARATYPES: 29, AMS C154599, same locality data

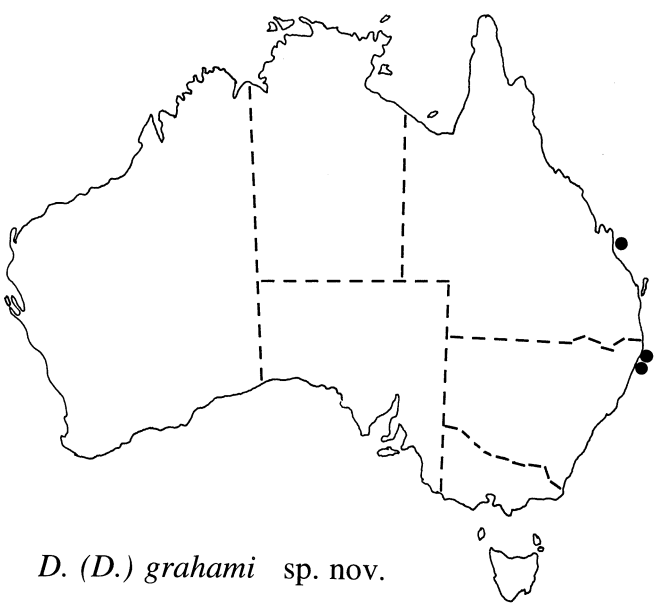


Figure 16. Known distribution of *Dentalium (Dentalium) grahami* n.sp.

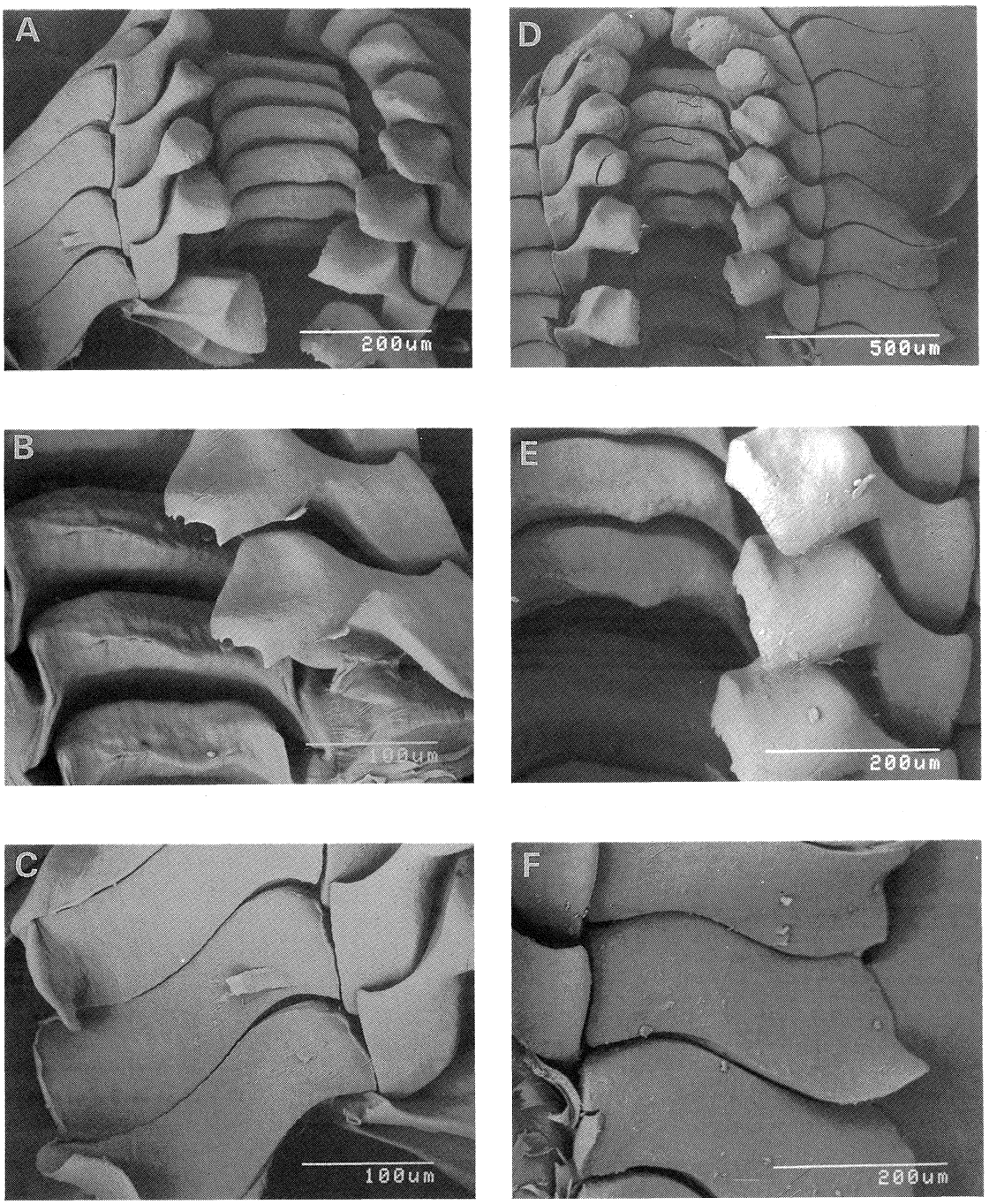


Figure 17. Radular ultrastructure of: **A–C** *Dentalium (Dentalium) aprinum* Linnaeus, 1758 (12.87 km south-west of Tg Ratoe, Timor Sea), WAM 102/93; **D–F** *Dentalium (Dentalium) grahami* n.sp. (from paratype, south of Yamba, NSW, 55 m, AMS C173469).

as holotype; 1, AMS C173469, 29°39.8'S 153°26.4'E, south of Yamba, NSW, 55 m, 22 February 1972; 55, AMS C154602, off Solitary Island, NSW, 29°50–53'S 153°24–23'E, 54–58 m, 10 October 1985; 1, AMS C169957, Keppel Bay, southern Qld, 54 m, 1977; 2, AMS C169958, Keppel Bay, southern Qld, 54 m, 1972.

Additional material examined. NEW SOUTH WALES: 8, AMS C154312, 29°24'S 153°21'E, off Illuka, 45–65 m, May 1986; 35, AMS C155933, 29°21'S 153°23.26'E, north-east of Yamba, 50 m, 21 February 1985; 3, AMS C156053, 29°39'S 153°23.26'E, south-east of Broomes Head, 57 m, 24 February 1985; 9, AMS C154291, 3, AMS C155935, 29°25.16'S 153°26.30'E, off Clarence River, 53–55 m, 11–15 October 1985; 9, AMS C173049, off Wooli, 80 m; 3, AMS C154132, 29°39'S 153°24'E, off Solitary Island, 55 m, 21 February 1985; 1, AMS C155954, 29°06'–28°57'S 153°34–38'E, south-east of Ballina, 53 m, 25 May 1986; AMS C173466, north of Coffs Harbour, 61 m, 22 February 1972 (preserved). QUEENSLAND: 1, AMS C169959, Keppel Bay, Qld, 30 m, 7 September 1970; 1, AMS C70799, between outer rock and Man and Wife to north-east of South Keppel Island, 28 m, 25 July 1969.

Description. Shell length to 73.0 mm, aperture diameter 4.8 mm, apex diameter 1.2 mm; solid, well curved, moreso towards the apex, evenly tapering. Sculpture at the apex of 17–18, narrow, rounded ribs, which become obsolete about half to two thirds of the shell length anteriorly; interstices flat, approximately twice the width of the ribs; ribs and interstices crossed by dense, transverse striae and growth lines. Aperture circular. Apex circular, crenulated by ribs, orifice large, some specimens with a small ventral notch or slit. Colour light olive-green, deeper centrally becoming pale and whitish towards the apex, with paler transverse zones over the length of the shell.

Radula. Central tooth broad and shallow (290 μm wide) with smooth, weakly convex superior surface and correspondingly concave inferior surface (the latter showing evidence of a low, ridge-like cusp); laterals dumbbell shaped, 333 μm long with small cusps on the working surface; marginals strongly sigmoidal, relatively short and broad (length 355 μm × breadth 138 μm) (see Fig. 17D–F). Ratios C:L = 1:1.14, L:M = 1:1.06, marginals breadth:length 1:2.6 (based on male).

Range. New South Wales to central Queensland.

Habitat. Trawled in sandy mud from 28 to 80 m.

Comparisons and remarks. *Dentalium grahami* most closely resembles *D. hedleyi* n.sp. being somewhat similar in shape. Differentiating features of *D. grahami* include: its smaller size; greater curvature; lesser number of apical ribs. Like *D. hedleyi, D. grahami* does not exhibit intercalation of ribs, which serves to separate both of these species from *D. jelli* n.sp. As with other members of the *D. hedleyi* group, *D. grahami* can be distinguished from the *D. elephantinum* group by the larger number of ribs. This species is relatively common but at present known only from off the central New South Wales coast to southern Queensland.

Dentalium (Dentalium) jelli n.sp.

Figs 9F, 10F, 18, 19

Etymology. Named after Dr Peter Jell of the Queensland Museum for his advice and generous assistance with aspects of photography during this project.

Type material examined. HOLOTYPE: QM MO45837. Type locality: off Cairns, northern Qld, 17°50.67'S 147°18.2'E, 703 m. Length of holotype 52.8 mm, aperture diameter 4.1 mm, aperture diameter 0.8 mm. PARATYPES: 9, QM MO17766, same locality data as holotype; 2, AMS

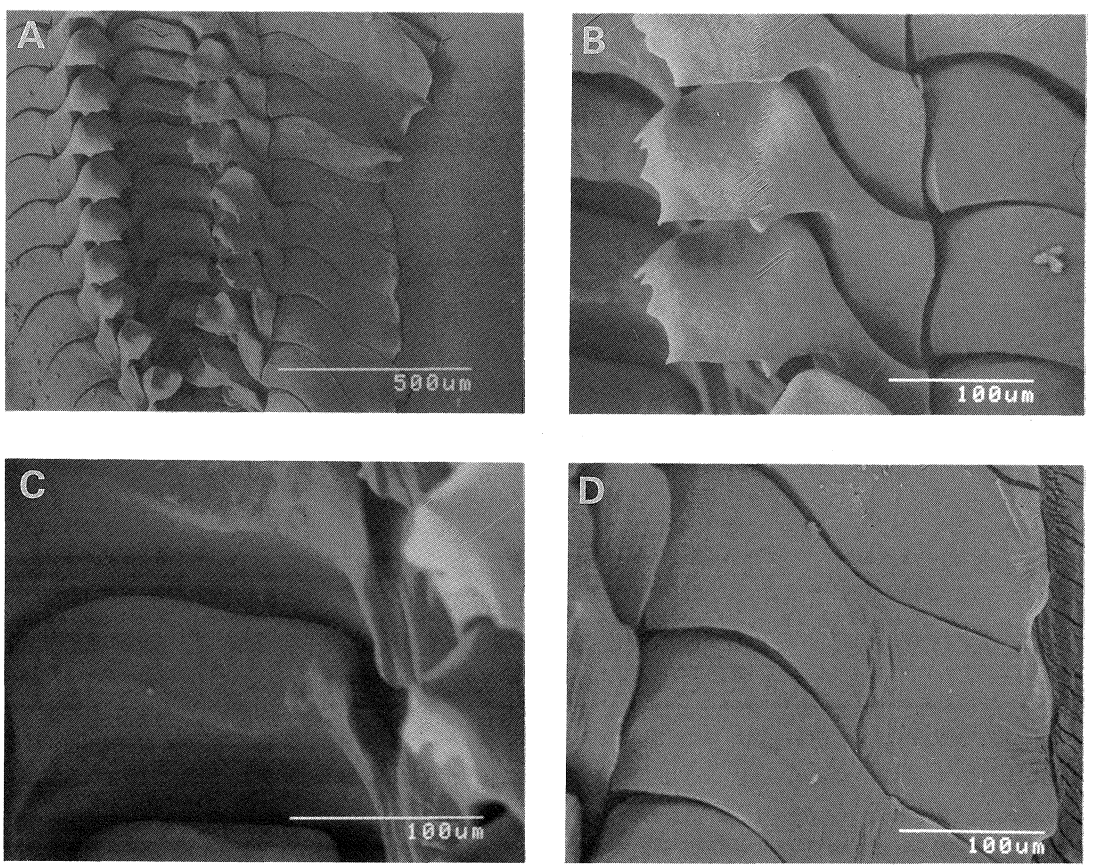


Figure 18. Radular ultrastructure of *Dentalium (Dentalium) jelli* n.sp. (from paratype, 26°10'S 153°13'E, south Qld, NMV F69579).

C171341 same locality data as holotype; 7, NMV F69579, 26°10'S 153°13'E, southern Qld (preserved).

Description. Shell length to 54.3 mm, aperture diameter 4.2 mm, apex diameter 0.8 mm; robust, moderately curved. Sculpture at the apex of 13 narrow, raised, rounded ribs and wide interstices which show fine longitudinal striae, the ribs intercalating to 26, becoming lower and wider anteriorly. In most specimens the ribs become almost obsolete anteriorly. Aperture circular. Apex circular, crenulated by ribs. Colour pale green with darker and lighter zones.

Radula. Central tooth broad, moderately shallow (180 μm wide) with smooth, weakly convex superior surface and correspondingly concave inferior surface (the latter showing evidence of a low, wide cusp); laterals dumbbell shaped, 243 μm long with small cusps on the working surface; marginals moderately to strongly sigmoidal, relatively short and broad (length 320 μm × breadth 109 μm) (see Fig. 18A–D). Ratios C:L = 1:1.35, L:M = 1:1.32, marginals breadth:length = 1:2.9 (based on probable male).

Range. Southern Queensland (Nambour) to Cairns, northern Queensland

Habitat. Dredged in sand to 703 m.

Comparisons and remarks. *Dentalium jelli* most closely resembles *D. grahami* n.sp. Differentiating features of *D. jelli* include: lighter colour; intercalation of ribs (the latter feature is also useful in separating *D. jelli* from *D. hedleyi*). In shell shape and sculpture *D. jelli* also shows some resemblance to certain species of *Fissidentalium*. However, no known species of *Fissidentalium* (Australian or otherwise) shows green colouration. To date *D. jelli* has not been recorded outside Queensland waters. Insufficient material was available to gauge the relative abundance of this species.

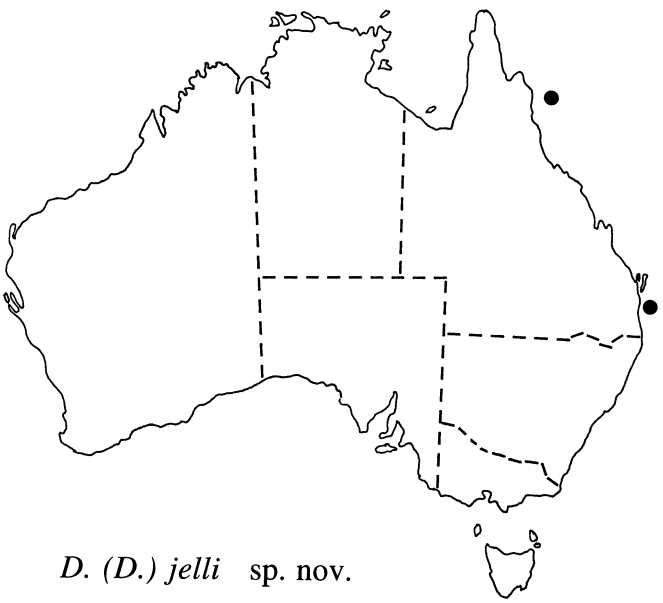


Figure 19. Known distribution of *Dentalium (Dentalium) jelli* n.sp.

Key to Group of *Dentalium hemileuron*

Ten (rarely 9) to 16 ribs, of variable strength at apex, becoming absent or at least obsolete anteriorly; shell white, moderately robust, moderately to weakly curved in most (strongly curved in a few species), slowly to rapidly tapering.

1 Shell slowly tapering apically; W:L ratio 1:13 to 1:14 2

—— Shell rapidly tapering apically; W:L ratio 1:9 to 1:10.5 3

2 Ribs weak but persisting to aperture ..... *D. collinsae*

—— Ribs absent from anterior half of shell 4

3 Ribs weak but persisting to aperture ..... *D. burtonae*

—— Ribs absent from anterior half of shell 5

4 Ribs relatively weak and present only at apex ..... *D. hyperhemileuron*

—— Ribs strong, extending from apex over one third to one half of shell length ..... *D. hemileuron*

5 Ribs low and limited to apical quarter of shell ..... *D. austini*

—— Ribs raised and extending from apex over one half to two thirds of shell length ..... *D. kessneri*

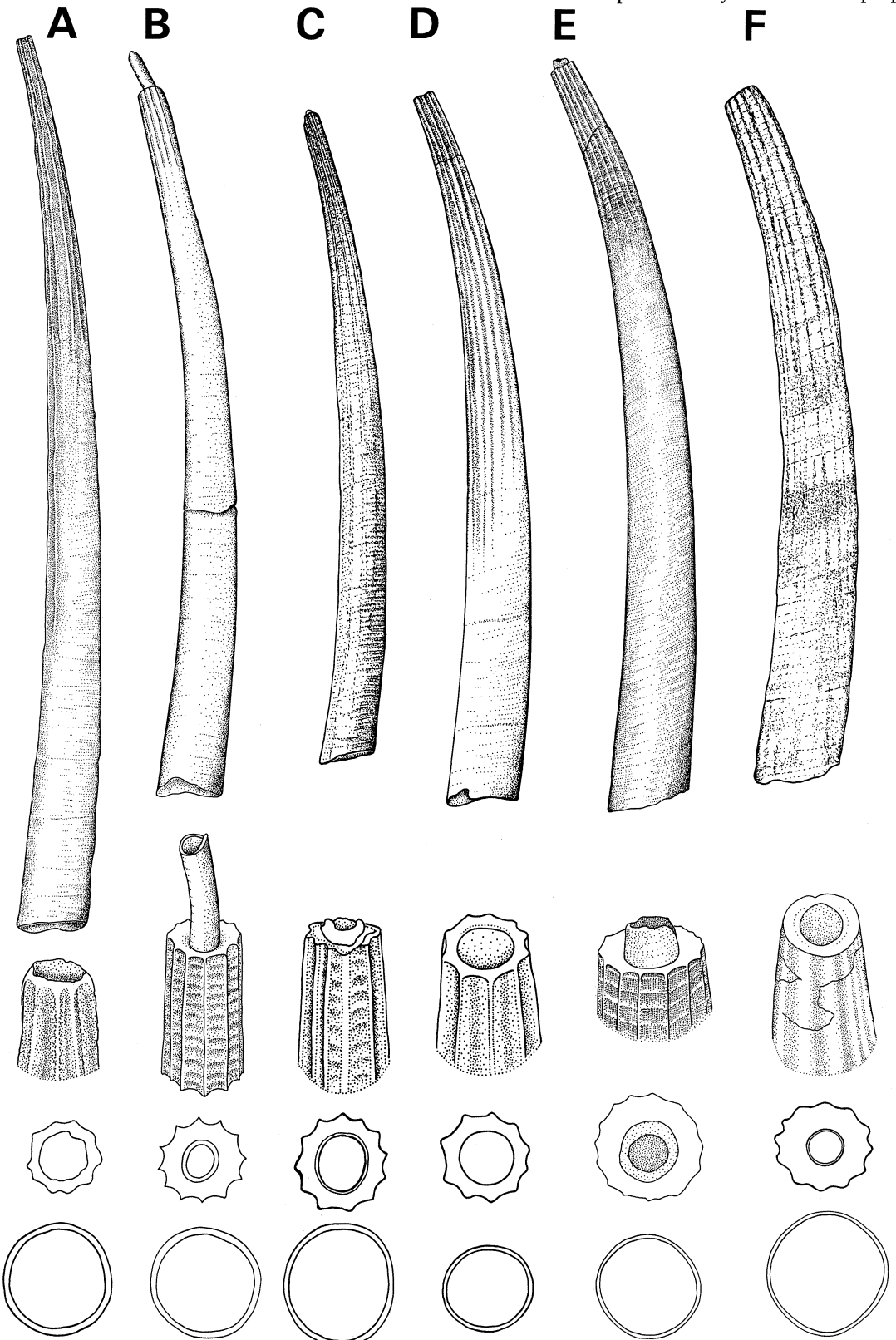


Figure 20. Dentaliida, Dentaliidae. Group of *D. hemileuron*. **A** *D. (D.) hemileuron* Verco, 1911 (holotype, SAM D13727, Cape Jaffa, 548 m, length 30.0 mm). **B** *D. (D.) hyperhemileuron* Verco, 1911 (holotype, SAM D13726, King George Sound, WA, 22–64 m, length 20.5 mm). **C** *D. (D.) collinsae* n.sp. (holotype, WAM 230/94, 0.8 km south of Green Island, Oyster Harbour, via Albany, WA, length 28.5 mm). **D** *D. (D.) kessneri* n.sp. (holotype, WAM 112/93, north-east of Rat Island, Abrolhos, WA, length 18.6 mm). **E** *D. (D.) austini* n.sp. (holotype, NMV F75838, Cullen Beach, Darwin N.T., length 28.0 mm). **F** *D. (D.) burtonae* n.sp. (holotype, AMS C173327. Roebuck Bay, Broome, length 15.6 mm; detail of apex and aperture profile, paratype AMS C174897 same locality as holotype). (Del.: all A. Hill, except C [apex profile] and F [longitudinal and apex profiles]—JMH).

Figure 21. Dentaliida, Dentaliidae. Group of *D. hemileuron*. **A** *D. (D.) hemileuron* Verco, 1911 (holotype, SAM D13727, Cape Jaffa, 548 m, length 30.0 mm). **B** *D. (D.) hyperhemileuron* Verco, 1911 (holotype, SAM D13726, King George Sound, WA, 22–64 m, length 20.5 mm). **C** *D. (D.) collinsae* n.sp. (holotype, WAM 230/94, 0.8 km south of Green Island, Oyster Harbour, via Albany, WA, length 28.5 mm). **D** *D. (D.) kessneri* n.sp. (holotype, WAM 112/93, north-east of Rat Island, Abrolhos, WA, length 18.6 mm). **E** *D. (D.) austini* n.sp. (paratype, NMV F67466, Cullen Beach Darwin, NT, length 20.0 mm). **F** *D. (D.) burtonae* n.sp. (holotype, AMS C173327, Roebuck Bay, Broome, length 15.6 mm).

Dentalium (Dentalium) hemileuron Verco, 1911

Figs 20A, 21A, 22

Dentalium hemileuron Verco, 1911a: 208, pl. 26, fig. 2; Cotton & Ludbrook, 1938: 220; Cotton & Godfrey, 1933: 144; Cotton & Godfrey, 1940: 328, fig. 350; Zeidler & Macphail, 1978: 383.

Dentalium tignum Colman, 1958: 141, pl. 1, fig. 1; Iredale & McMichael, 1962: 96.

Type material examined. HOLOTYPE: SAM D13727. Type locality: Cape Jaffa, SA, 300 fathoms [548 m]. Length of holotype 30.0 mm, aperture diameter 2.4 mm, apex diameter 0.4 mm. PARATYPES: USNM 251985, Cape Jaffa, SA, 238 m. *Dentalium (D.) tignum* holotype: AMS C24485; 27.5 miles east of Sydney, NSW, 550 m, 27 March 1905; *D. tignum* paratypes: AMS C170643, 27.5 miles east of Sydney, NSW, 550 m, 27 March 1905.

Additional material examined. WESTERN AUSTRALIA: 3, WAM 34-93, 31°45'S 115°02'E, north-west of Rottnest Island, 276 m, 18 February 1972; 1, WAM 261-93, 32°11.35'S 115°37.6'E, 24 November 1981; 1, WAM 3129, Oyster Harbour via Albany, dredged channel west of Green Island, 10 m, 20 July 1963; 1, SAM D18843, 34°13'S 124°37.9'E, 148 km east south-east Cape Arid, 540 m, 30 July 1988; 7, WAM N3125, 0.8 km south-east of Mistaken Island, King George Sound, 34 m, 21 July 1963; 6, WAM N3126; 1, WAM 1314, Oyster Harbour, 8 May 1960; 24, WAM N3129, east Green Island, Oyster Harbour via Albany, 20 July 1963; 1, SAM D18844, Great Australian Bight, approx 222 km south-west of Eucla 33°19'S 127°31'E, trawled 240 m, 12 January 1989. SOUTH AUSTRALIA: 4, AMS C33484, Cape Jaffa, 260 m; 17, SAM D18845, Cape Jaffa; 1, AMS C173199, 60 km west of Cape Wiles, 1 m, 29 August 1909; 13, SAM D296, Cape Jaffa. TASMANIA: 3, SAM 18846, 600 m, 25 December 1905, (preserved): 14, AMS C172277, 40°50.6'S 148°46.5'E, off Cape Naturaliste, 399 m, sand and bryozoa, 26 February 1973; NMV F67464, 42°43'S 148°25'E, 506 m, 25 June 1984; 7, SAM D18847, 39°00'S 148°25'E, 83 km north north-east of East Sister Island, 92 m, sandy bottom, 14 October 1984 (preserved). VICTORIA: 2, AMS C110848, 37°37–36'S 150°17–18'E, east of Gabo Island, 494 m, February 1977; 1, AMS C172990, 37°42–45'S 150°16–15'E, off Gabo Island, 456 m, 26 October 1979; 18, AMS C172978, 37°45–38'S 150°12–16'E, east of Gabo Island, 438 m, February 1977; 7, AMS C172977, 37°38–42'S 150°17–15'E, off Gabo Island, 384 m, 26 October 1979. NEW SOUTH WALES: 2, AMS C172881, 37°19.16'S 150°21'E, south of Eden, 274 m, 25 October 1979; 1, AMS C172888, 36°27.21'S 150°19–21'E, east of Bermagui, 383 m, 22 July 1975; 1, AMS C105420, 35°44–40'S 150°38–41'E, east of Brush Island, 549 m, 24 November 1978; 2, AMS C174316, 37°00.2'S 150°20.5'E, east of Eden, 300 m, 11 December 1986; 23, AMS C172979, 34°50'S 151°13'E, off Nowra, 550 m, 12 December 1978; 1, AMS C1728, 34°21.19'S 151°23.25'E, off Wollongong, 439 m, 13 December 1978; 1, AMS C102653, 34°21.19'S 151°23.25'E, off Wollongong, 402 m, 8 August 1975; 1, AMS C172989, 34°19'S 151°22'E, east of Wollongong, 281 m, 13 December 1978; 1, AMS C303573, 34°16–22'S 151°26.23'E, north-east of Wollongong, 366 m, 8 August 1975; 197, AMS C125562, 33°41'S 151°53'E, off Botany Bay, 366 m, 5 December 1977; 13, AMS C172880, 34°08'S 151°34'E, Sydney, 457 m, 13 December 1978; 5, AMS C173008, 33°46'S 151°43'E, off Port Kembla, 741 m, 5 December 1977; 84, AMS C125567; 1, AMS C172996, 33°48'S 151°52'E, east of Sydney, 550 m, 3 December 1979; 3, AMS C173451, 34°04'02"S 151°37'02"E, off Sydney, 384 m, 3 November 1976, sandy mud, fine shell (preserved); 2, AMS C172991, 33°46–43'S 151°47–50'E, off Port Kembla, 281 m, 5 December 1978; 51, AMS C173007, 20, AMS C172995, 46, AMS C172994, 1, AMS C172184, 33°42.39'S 151°52.54'E, off Sydney, 457–550 m, 11–20 December 1976; 1, AMS C173384, 33°42.39'S 151°52–54'E, off Sydney, 457 m, 29 December 1876; 6, AMS C172983, 33°41'S 151°53'E, off Botany Bay, 366 m, 5 December 1977; 11, AMS C172987, 33°41'S 151°01'E, off Sydney, 1125 m, 11 December 1977; 12, AMS C125569, 33°28.29'S 151°52'E, east of Cape Three Points, 476 m, 5 December 1979; 10, AMS C26651, 35 m east of Sydney, 1463 m; 1, AMS C1722, east of Sydney, 295 m, 18 June 1962; 17, AMS C67480, off Sydney, 400 m, 8 November 1960; 32, AMS C172276, 34°04.2'S 151°37.2'E, off Sydney, 384 m, 3 November 1976; 3, AMS C172280, 43 km east of Sydney, 549 m; 9, AMS C172281, east of Sydney, 75–150 m, 18 July 1962; 6, AMS C172278, 39, AMS C169788, 34°03'S 151°37'E, east of Sydney, 295 m, 18 July 1962; 1, AMS C172279, off Jervis Bay, 400–1000 m, in canyon, October-November 1980.

Description. Shell length to 50.0 mm, aperture diameter 3.0 mm, apex diameter 1.0 mm; shell narrow, moderately robust, moderately curved. Sculpture of 10–11 narrow, longitudinal ribs, well developed at the apex and the first half of the shell, becoming obsolete throughout the remaining portion of the shell and absent at the aperture of very mature specimens; interstices wide, with fine transverse striae. Aperture circular. Apex polygonal with a small notch on the ventral side of the shell. Colour white, opaque when dead, translucent and glossy when live.

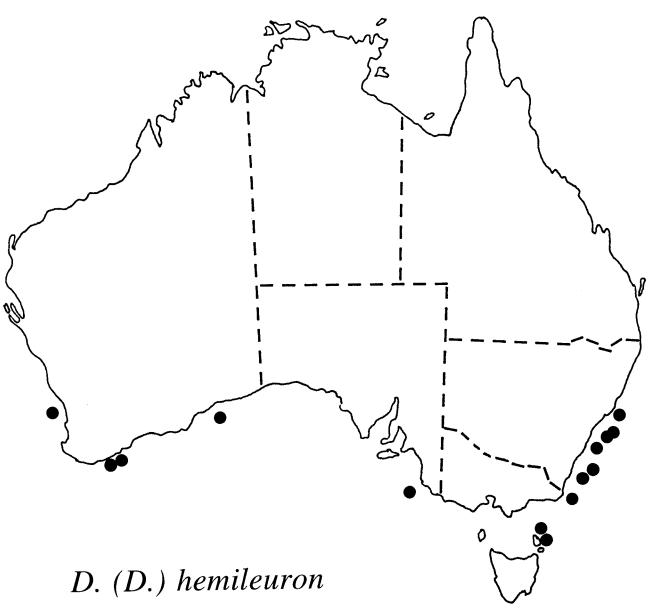


Figure 22. Known distribution of *Dentalium (Dentalium) hemileuron* Verco, 1911.

Range. Southern Western Australia, South Australia, Tasmania, Victoria and New South Wales.

Habitat. In littoral sand and trawled to 1463 m.

Comparisons and remarks. *Dentalium hemileuron* superficially resembles *D. decemcostatum* Brazier, 1877 which also has coarse ribs and no intercalating ribs or riblets. Differentiating features of *D. hemileuron* which separate it from *D. decemcostatum* include: ribs become obsolete anteriorly (a feature shared with all other species of the *D. hemileuron* group) and absence of apical plug and pipe. *Dentalium kessneri* n.sp. and *D. collinsae* n.sp., can be distinguished from *D. hemileuron* by the presence of intercalating riblets, while *D. hyperhemileuron* shows much weaker ribs than any other species of the *D. hemileuron* group. The remaining members of this group can be distinguished from *D. hemileuron* by the generally larger number of ribs (15–16 in *D. austini* n.sp., 12–14 in *D. burtonae* n.sp.); smaller size and more developed shell curvature. *Dentalium hemileuron* is a common southern species from moderately shallow to deep water.

Dentalium (Dentalium) hyperhemileuron Verco, 1911

Figs 20B, 21B, 23, 25A,B (see also Fig. 5F)

Dentalium hyperhemileuron Verco, 1911b: 217, pl. 26, fig. 3, 3a; Hedley, 1916: 74; Cotton & Godfrey, 1933: 146, pl. 1, figs 3, 3a; Cotton & Godfrey, 1940: 330, fig. 353; Zeidler & Macphail, 1978: 383.

Type material examined. HOLOTYPE: SAM D13726. Type locality: King George Sound, WA, 12–35 fathoms [22–64 m]. Length of holotype 20.5 mm, aperture diameter 1.8 mm, apex diameter 0.7 mm. PARATYPES: SAM D16000, 4 dry shells, same data as holotype; USNM 251993, King George Sound, WA, 22–26 m.

Additional material examined. SOUTH AUSTRALIA: 2, SAM D18891, 600 m, Cape Jaffa, 25 December 1905; 23, SAM D18892, 2 lots, Cape Jaffa, 1, 44–56 m, 2, 70 m; 9, SAM D18893, Cape Jaffa; 1, SAM D18890, Cape Jaffa, 44 m; 2, SAM D18900, Cape Jaffa, 30 m. WESTERN AUSTRALIA: 11, WAM N1638, Frenchmans Bay via Albany, 1–2 m west of Seal Island, dredged 34 m, 14 February 1962; 9, SAM D18894, 2, SAM D18895, 24 m off Fremantle; 3, SAM D18896, 30 m, Geographe Bay; 80, SAM D18897, King George Sound, 28 m; 1, SAM D18898, Bunbury, 230 m.

Description. Shell length to 25.0 mm, aperture diameter 2.0 mm, apex diameter 0.75 mm; shell narrow, moderately curved. Sculpture of 10–14, weak, narrow, longitudinal ribs which become obsolete at the anterior two thirds of the shell surface, then smooth with fine striae continuing to the aperture; interstices nearly flat, slightly concave. Aperture circular. Apex polygonal, typically with a long, narrow terminal pipe (directed dorsally) in younger specimens. Colour white when dead, translucent and glossy when live.

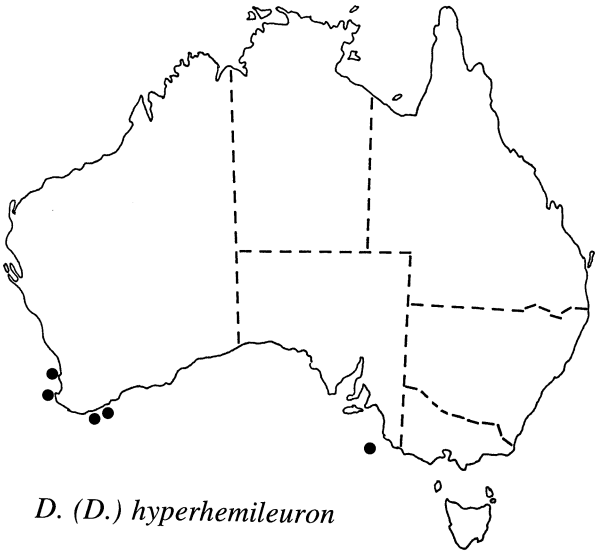


Figure 23. Known distribution of *Dentalium (Dentalium) hyperhemileuron* Verco, 1911.

Radula. Central tooth broad (111 μm wide), moderately shallow, with smooth, strongly convex superior surface and correspondingly concave inferior surface (the latter showing evidence of 1 or 2 low, ridge-like cusps); laterals dumbbell shaped, 122 μm long with small cusps on the working surface; marginals sigmoidal, moderately short (length 211 μm × breadth 55 μm) (see Fig. 25A,B). Ratios C:L = 1:1.09, L:M = 1:1.7, marginals breadth:length = 1:3.8 (sex indeterminate).

Range. Cape Jaffa, South Australia, to Bunbury, Western Australia.

Habitat. Dredged from 22 to 600 m.

Comparisons and remarks. *Dentalium hyperhemileuron* most closely resembles *D. hemileuron* Verco in shell shape. Differentiating features of *D. hyperhemileuron* include: (usually) a terminal pipe; greater rib number; ribs weak. Other species in the *D. hemileuron* group differ from *D. hyperhemileuron* in the degree of curvature, rib development and rate of shell attenuation (more pronounced in all other species). This species was placed in the genus *Episiphon* by Cotton & Ludbrook (1938) apparently because of its apical pipe. However, aside from this feature, *D. hyperhemileuron* does not conform to the original description of the genus *Episiphon* or resemble any known Australian species of that genus. The relatively few strong ribs apically, clearly indicate inclusion in the genus *Dentalium*. Numerous species throughout the Dentaliida also exhibit an apical pipe including species of *Omniglypta, Gadilina, Dentalium, Tesseracme* and *Laevidentalium*. *Dentalium hyperhemileuron* is evidently a scarce species restricted to the region from Bunbury, Western Australia to Cape Jaffa, South Australia. According to Ludbrook (1984) *D. hyperhemileuron* also occurs as a fossil in the Glanville Formation of South Australia (north of Port Sinclair, Late Pleistocene). Verco (1911b) illustrates the intact bulbous protoconch, (typical of the order Dentaliida), of this species (reproduced in Fig. 5F).

Dentalium (Dentalium) collinsae n.sp.

Figs 20C, 21C, 24, 25C,D

Etymology. Named after Mrs Barbara Collins (Cairns, Qld) for her assistance in this and other studies on Australian molluscs.

Type material examined. HOLOTYPE: WAM 230/94. Type locality: dredged in channel, 0.8 km south of Green Island, Oyster Harbour via Albany, WA, 22 July 1963. Length of holotype 28.5 mm, aperture diameter 2.4 mm, apex diameter 0.65 mm. PARATYPES: 10, WAM N3126, same locality data as holotype; 1, WAM N3129, dredged in channel west of Green Island, Oyster Harbour via Albany, WA, 10 m, 20 July 1963.

Description. Shell length to 35.6 mm, aperture diameter 2.5 mm, apex diameter 0.8 mm; moderately curved, slowly tapering; Sculpture of 10–13 narrow, raised, rounded longitudinal ribs at the apex, becoming wide, low, flattened and almost obsolete towards the aperture, with well defined, transverse growth lines; interstices wide at the apex becoming narrower towards the aperture with a single longitudinal riblet in some interstices. Aperture circular. Apex polygonal with a plug and small pipe, some specimens have a small ventral and dorsal notch. Colour white.

Radula. Central tooth broad (163 μm wide) moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface (showing slight evidence of a ridge-like cusp); laterals dumbbell shaped, 150 μm long with small cusps on the working surface; marginals sigmoidal, moderately short (length 237 μm × breadth 74 μm) (see Fig. 25C,D). Ratios C:L = 1:0.92, L:M = 1:1.6, marginals breadth:length 1:3.2 (sex indeterminate).

Range. Albany, south Western Australia.

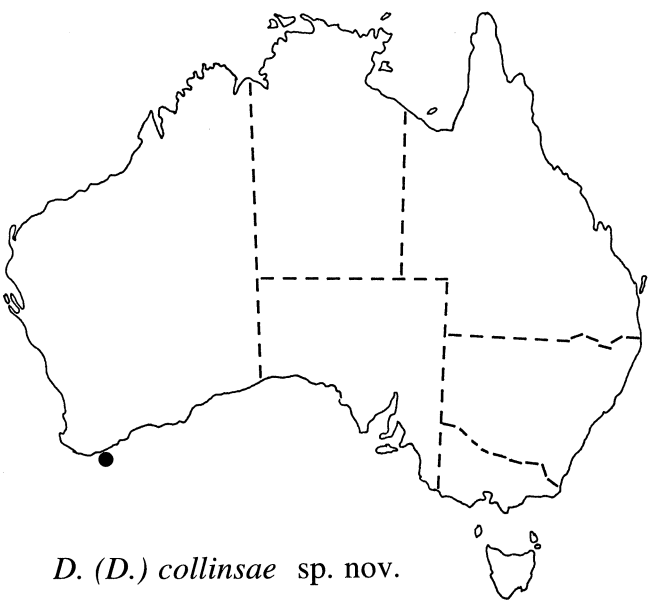


Figure 24. Known distribution of *Dentalium (Dentalium) collinsae* n.sp.

Habitat. Dredged to 10 m.

Comparisons and remarks. *Dentalium collinsae* most closely resembles *D. hemileuron* Verco in shell shape. Differentiating features from that and all other species of the *D. hemileuron* group include: flattened rib profile anteriorly; presence of well developed transverse striae; persistence of slight ribbing almost to the aperture. Further, *D. collinsae* differs from *D. austini* n.sp. in having fewer ribs and differs from *D. burtonae* n.sp. in being markedly less curved.

Dentalium (Dentalium) kessneri n.sp.

Figs 20D, 21D, 26

Etymology. Named after Mr Vince Kessner who collected scaphopod material used in this study.

Type material examined. HOLOTYPE: WAM 112-93. Type locality: north-east of Rat Island, Easter Group, Abrolhos, WA, 28°42'S 113°47.3'E, 201 m, rubble and grey mud, 23 August 1977. Length of holotype 18.6 mm, aperture diameter 1.8 mm, apex diameter 0.6 mm.

Description. Shell length to 18.6 mm, aperture diameter 1.8 mm; moderately curved. Sculpture of 10 strong, raised, narrow, longitudinal ribs, with one, two or three intercalating riblets occurring in each interstice becoming obsolete at the aperture; ribs and interstices crossed by transverse growth pauses. Aperture circular. Apex polygonal without a ventral notch or slit. Colour grey-white.

Range. North-east of Rat Island, Easter Group, Abrolhos, Western Australia.

Habitat. Dredged to 201 m in rubble and grey mud.

Comparisons and remarks. *Dentalium kessneri* most closely resembles the type of *D. pleuricostatum* (Boissevain). Differentiating features of *D. kessneri* include: much smaller size; absence of longitudinal striae. *Dentalium kessneri* can be separated from *D. hemileuron* and *D. hyperhemileuron* by its less tapering shape, smaller size and intercalating riblets. *Dentalium collinsae* may show one riblet within the interstices but has ribs which flatten anteriorly before becoming obsolete. Rib numbers conveniently separates *D. kessneri* (10) from the higher rib-count species *D. austini* (15–16) and *D. burtonae* (12–14). Presently this species is only known from the holotype.

Dentalium (Dentalium) austini n.sp.

Figs 20E, 21E, 27

Etymology. Named after Mr Jack Austin who first brought specimens of this species to our attention.

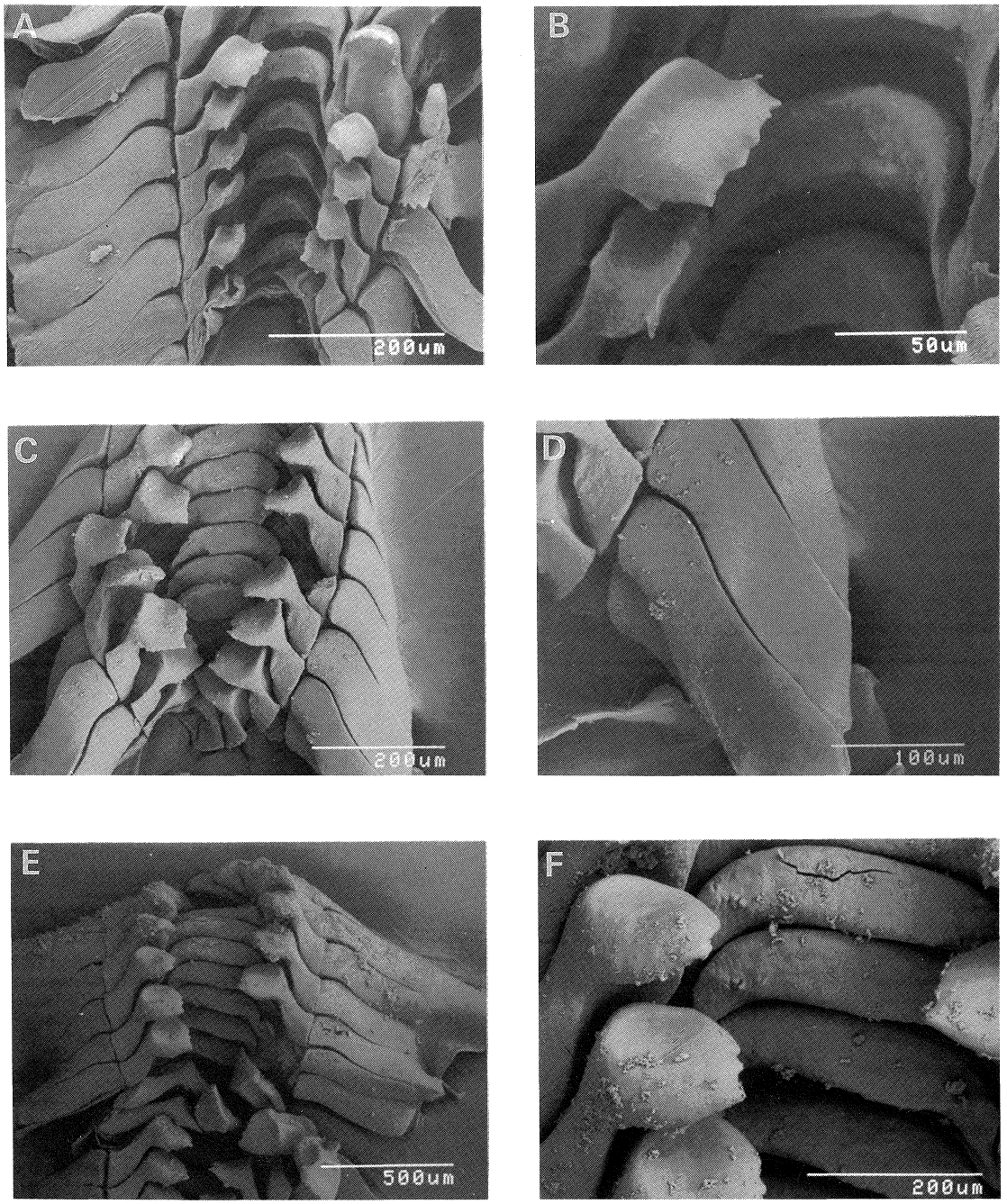


Figure 25. Radular ultrastructure of: **A,B** *Dentalium (Dentalium) hyperhemileuron* Verco, 1911 (off Cape Jaffa, South Australia, 600 m, SAMD 18891); **C,D** *Dentalium (Dentalium) collinsae* n.sp. (from paratype, 0.8 km south of Green Island, Oyster Harbour, via Albany, WA, 10 m, WAM N 3129); **E,F** *Dentalium (Dentalium) javanum* Sowerby, 1860 (off Spur Reef, east of Norman Reef, north of Cairns, 36.5 m, AMS C138634).

Type material examined. HOLOTYPE: NMV F75838. Type locality: Cullen Beach, Darwin, NT, 26 May 1983. Length of holotype 28.0 mm, aperture diameter 3.0 mm, apex diameter 1.2 mm. Length of pipe at apex 0.15 mm. PARATYPES: NORTHERN TERRITORY: 18, NMV F67466, same locality data as holotype; 13 juveniles, NMV F67474, Cameron Beach, Shoal Bay, Darwin, 4–5 September 1982; 13, AMS C172543, Dudley Point, on mud flats, 24 October 1964; 5, AMS C172539, east end Cullen Beach, Darwin, fine grey mud, 25 December 1973; 14, AMS C172540, Port Darwin; 16, NMV F67469, Cameron Beach, Shoal Bay, 10 June 1976; 2, AMS C308639, Mindel Beach, Darwin, low tide, 25 December 1973. WESTERN AUSTRALIA: 1, WAM 106-93, off Eagle Bay, 32 m, 22 February 1976 (preserved).

Additional material examined. QUEENSLAND: 1, AMS C173051, Fitzroy Island, January 1952; 3, AMS C14922, 17°29'S 140°50'E, Karumba Beach, 7–11 June 1903; 3, AMS C29924,

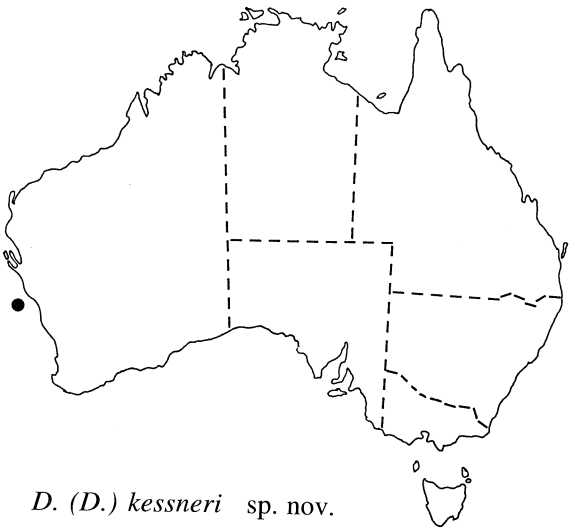


Figure 26. Known distribution of *Dentalium (Dentalium) kessneri* n.sp.

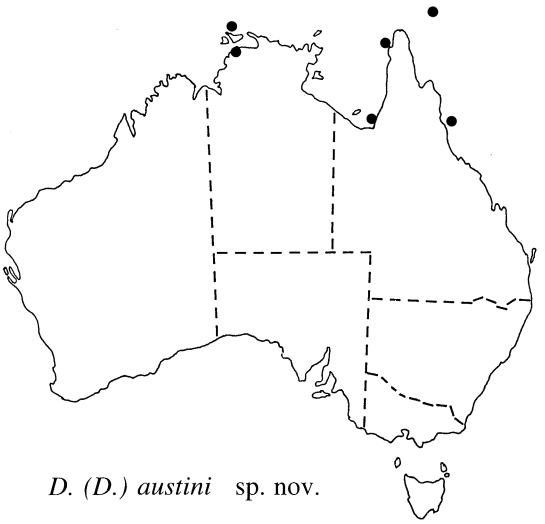


Figure 27. Known distribution of *Dentalium (Dentalium) austini* n.sp.

9°56'S 144°04'E, off Murray Island, Torres Strait, 15 m 30 August–3 October 1907; 1, AMS C169975, Mapoon, Gulf of Carpentaria. NORTHERN TERRITORY: 6, AMS C173273, 11°22'S 130°43'E, Melville Island, muddy sand, 14 December 1980; 22, AMS C63129, Buchanan Island, near Melville Island; 1, AMS C172544, East Point, Darwin, 2 January 1972; 1, AMS C173167, Lee Point, Darwin, 27 June 1921 (preserved); 21, AMS C169982, Mindel Beach, Darwin, low tide, 25 December 1973; 3, AMS C172542, Camp Point, Melville Island, north of Darwin; 12, AMS C55089, Port Darwin; 11, AMS C172541, Port Darwin; 8, NMV F69615, Fanny Bay, Darwin, intertidal, 22 October 1976 (preserved); 5, AMS C173368, 2, AMS C172538, 12°24'S 130°49'E, between East Point and mouth of Ludmilla Creek, Darwin, mudflats, 28 June 1983; 6, AMS C173279, 12°25'S 130°49'E, south of Dudley Point, Darwin, 29 June 1983; 1, AMS C173056, West Headland off Port Keats, 23 January 1952.

Description. Shell length to 28.0 mm, aperture diameter 3.0 mm, apex diameter 1.2 mm; solid, well curved. Sculpture of 15–16 narrow, strong, rounded ribs, becoming obsolete about one third of the shell length anteriorly; interstices twice the rib width at the apex, ribs become wider as their strength diminishes, rest of shell with well defined transverse growth striae, rarely the longitudinal ribs extend to the aperture. Aperture circular. Apex polygonal with a short, central pipe. Colour dull white, sometimes with rust coloured staining at the apex.

Range. Northern Queensland, Northern Territory to northern Western Australia.

Habitat. Collected in littoral areas after rough weather and dredged to depths of 32 m in mud and sand.

Comparisons and remarks. *Dentalium austini* most closely resembles *D. burtonae* n.sp. in shape and rib strength. Differentiating features of *D. austini* include: larger size; narrower shell; less curved; more ribs; with apical plug and pipe. In addition the ribs of *D. burtonae* persist much further anteriorly than do those of *D. austini*. Other species within the *D. hemileuron* group (*D. hemileuron* Verco, *D. hyperhemileuron* Verco, *D. collinsae* n.sp.) have straighter, more slowly tapering shells than *D. austini* although some of these species may produce an apical pipe as does *D. austini*. This species exhibits a considerable range from Fitzroy Island, northern Queensland to Eagle Bay, Western Australia.

Dentalium (Dentalium) burtonae n.sp.

Figs 20F, 21F, 28

Etymology. Named after Mrs Pat Burton in recognition of her effort in the initial sorting of recently collected scaphopods held in the Australian Museum.

Type material examined. HOLOTYPE: AMS C173327. Type locality: Roebuck Bay, Broome, WA, 18°03'S 122°17'E, 29 June 1983. Length of holotype 15.6 mm, aperture diameter 1.9 mm, apex diameter 0.8 mm. PARATYPES: 1, AMS C174897, same locality data as holotype; 1, AMS C307828, Lady Musgrave Island, Bunker Group, Qld, dredged in lagoon; 11, AMS C174526, 17°58'S 122°14'E, Broome Township, WA, seaward side of mangroves, 19 September 1985; 16, AMS C173297, 18°06'S 122°20'E, Roebuck Bay, Broome, WA, 1–3 cm in fine sand, 24 June 1983 (preserved).

Additional material examined. 2, WAM 105-93, west of Five Fathom Bank, WA, 32 m, 30 June 1977 (preserved).

Description. Shell length to 31.5 mm, aperture diameter 2.5 mm, apex diameter 1.0 mm; solid, moderately to strongly curved. Sculpture of 12–14 narrow, low, rounded ribs, extending anteriorly, becoming wider as their strength diminishes and obsolete near the aperture; interstices twice the rib width at the apex and often exhibiting 1, 2 or 3 riblets; shell surface with well defined transverse growth lines. Aperture circular. Apex polygonal, with a small ventral notch, sometimes with plug and pipe. Colour dull white, sometimes rust coloured staining at the apex.

Range. Central Queensland and northern Western Australia.

Habitat. Dredged in fine littoral sand to 32 m.

Comparisons and remarks. *Dentalium burtonae* most closely resembles *D. austini* n.sp. in shape and rib strength. Differentiating features of *D. burtonae* include: smaller size; markedly more curved; ribs restricted to the posterior quarter of the shell; presence of interstitial riblets. *Dentalium burtonae* differs from other members of the *D. hemileuron* group which have obsolete ribbing at the aperture by its small shell (strongly curved posteriorly) with a wide aperture and fine, widely spaced ribs with 1 to 3 riblets usually visible in the interstices (see Figs 20 and 21). *Dentalium kessneri* n.sp. is similar to *D. burtonae* in rib development including the presence of interstitial riblets, but only has 10 ribs apically. Specimens of *D. burtonae* often show a rust-coloured deposit at and near the shell apex, indicating the degree of exposure of the shell above the substratum.

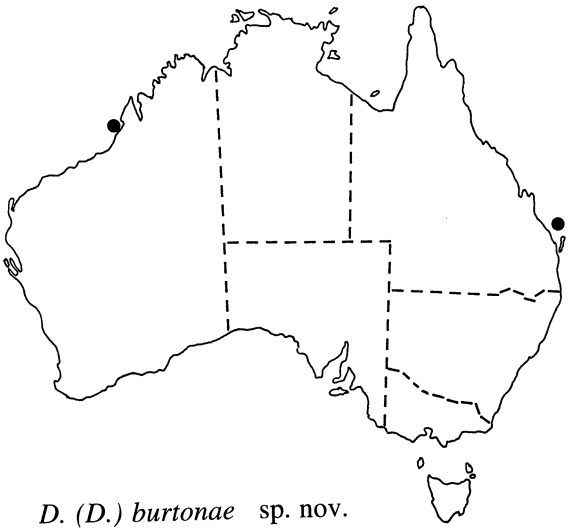


Figure 28. Known distribution of *Dentalium (Dentalium) burtonae* n.sp.

Key to Group of *Dentalium decemcostatum*

Ten ribs rounded, raised throughout shell length; white; robust, moderately curved, slowly tapering; apex without slit or notch.

1 Aperture wide; interstices smooth, usually with apical plug and pipe ..... *D. decemcostatum*

—— Aperture narrow; interstices with 1–3 riblets, never with apical pipe ..... *D. lochi*

Dentalium (Dentalium) decemcostatum Brazier, 1877

Figs 29A, 30A, 31

Dentalium decemcostatum Brazier, 1877: 55; Pilsbry & Sharp, 1897: 8; Boissevain, 1906: 27.

Type material examined. LECTOTYPE: AMS C170755 here selected from syntype lot AMS A90. Type locality: Katow, New Guinea, 8 fathoms [15 m]. Length of lectotype 21.3 mm, aperture diameter 2.8 mm, apex diameter 0.8 mm. PARALECTOTYPE: AMS C308152 same locality data as lectotype.

Additional material examined. QUEENSLAND: 1, AMS C172585, 22°31.4'S 152°32.6'E, south-east of Swains Reefs, 100 m, 6 July 1984; 1, AMS C108909, off Rocky Point, Lizard Island, 2–9 m, 1–12 December 1974. NORTHERN TERRITORY: 2, NMV F67576, Mud Bank Channel, East Arm, Darwin, 26 September 18; 5, AMS C172580, sandbar off Emery Point. Darwin, 25 October 1969; 84, AMS C303574, 9°30'S 132°34'E, Arafura Sea, approximately 160 km north of Croker Island, 124 m, 9 November 1969; 280, AMS C303571, 9°17.5'S 132°20'E, Arafura Sea, 168 m, 10 November 1969. WESTERN AUSTRALIA: 1, AMS C1725, 19°13'S 116°06'E, 270 km north-west of Port Hedland, 271 m, 30 November 1968; 1, AMS C172581, 19°25'S 115°51'E, 305 km north-west of Port Hedland, 256 m, 24 November 1968; 1, WAM 43-93, 22°41'S 113°39'E, bay north side of Point Cloates, 4 m, 23–24 August 1968.

Description. Shell length to 44.45 mm, aperture diameter 3.7 mm, apex diameter 1.3 mm; tapering, moderately curved. Sculpture of 10 strong, raised, rounded, longitudinal ribs; interstices concave, wide at aperture, narrow at apex, rarely with a minor rib in each interstice towards the aperture, ribs and interstices with dense, fine, transverse striae. Aperture circular with strongly raised ribs. Apex polygonal, orifice moderately large, some specimens have an apical pipe. Colour dull white.

Range. Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged in sandy mud from 2 to 271 m.

Comparisons and remarks. *Dentalium decemcostatum* most closely resembles *D. lochi* n.sp. in rib number and shape. Differentiating features of *D. decemcostatum* include: wider, straighter profile; interstices rarely with riblet (1–3 riblets in *D. lochi*). *Dentalium decemcostatum* is superficially similar to *D. octangulatum* Donovan in profile but is less curved, sculptured with 10 ribs (8 in *D. octangulatum*) and without any intercalating ribs (present in *D. octangulatum*). The

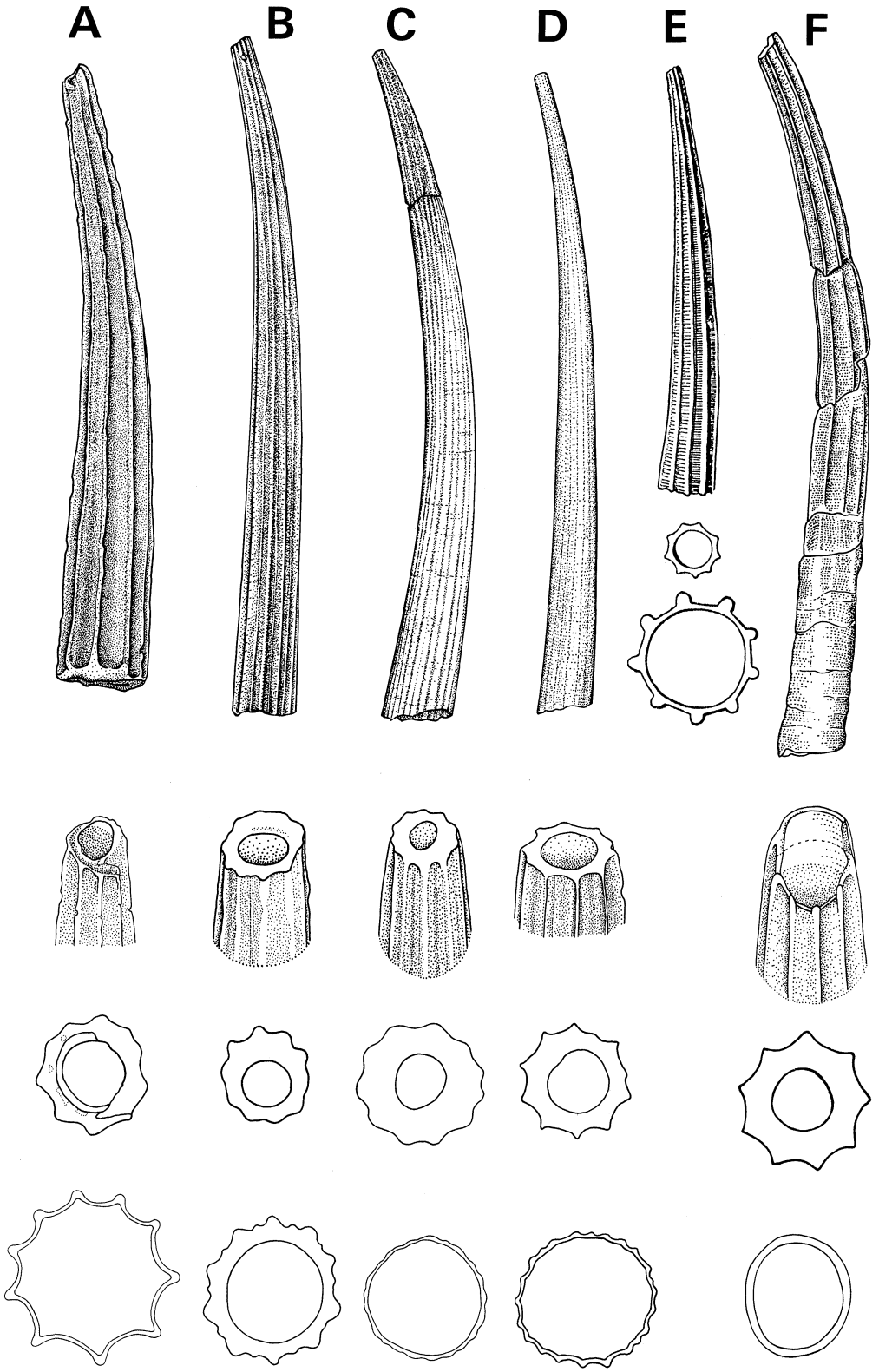


Figure 29. Dentaliida, Dentaliidae. *Dentalium (Dentalium)*. **A,B** Group of *D. decemcostatum*. **A** *D. (D.) decemcostatum* Brazier, 1877 (paralectotype, AMS C308152, Katow, PNG, length 15.6 mm; aperture profile of lectotype AMS C170755, same locality data as paralectotype). **B** *D. (D.) lochi* n.sp. (holotype, AMS C174628, Arafura Sea, 168 m, length 34.4 mm). **C,D** Group of *D. rowei*. **C** *D. (D.) rowei* n.sp. (holotype, WAM 231/94, 3.2 km north-east of Cape Bossut, WA, 7–10 m, length 35.0 mm). **D** *D. (D.) kathwayae* n.sp. (holotype, AMS C169943, 26 km north-east of North Reef, Qld, 115 m, length 39.0 mm). **E,F** Group of *D. robustum*. **E** *D. (D.) robustum* Brazier, 1877 (lectotype, AMS C170766, Katow, PNG, 14.5 m, length 21.0 mm). **F** *D. (D.) lessoni* Deshayes, 1825 (QM MO17676, off Cairns Qld, 904–916 m, length 36.8 mm). (Del.: all A. Hill, except E from Hedley, 1901; F [apex profile]—JMH).

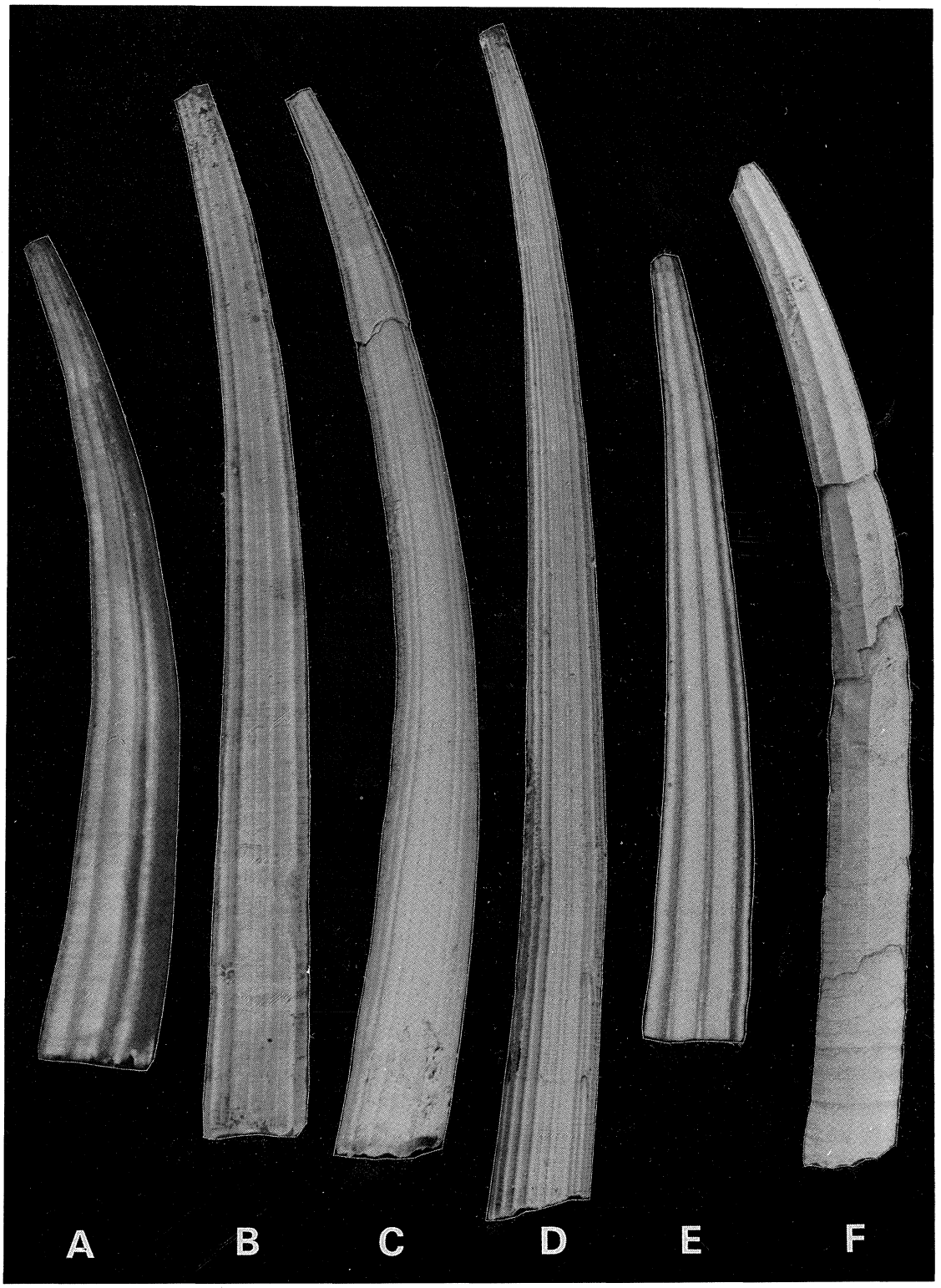


Figure 30. Dentaliida, Dentaliidae. *Dentalium (Dentalium)*. **A,B** Group of *D. decemcostatum*. **A** *D. (D.) decemcostatum* Brazier, 1877 (lectotype, AMS C170755, Katow, PNG, length 21.3 mm). **B** *D. (D.) lochi* n.sp. (holotype, AMS C174628, Arafura Sea, 168 m, length 34.4 mm). **C,D** Group of *D. rowei*. **C** *D. (D.) rowei* n.sp. (holotype, WAM 231/94, 3.2 km north-east of Cape Bossut, WA, 7–10 m, length 35.0 mm). **D** *D. (D.) kathwayae* n.sp. (holotype, AMS C169943, 27 km north-east of North Reef, Qld, 115 m, length 39.0 mm). **E,F** Group of *D. robustum*. **E** *D. (D.) robustum* Brazier, 1877 (lectotype, AMS C170766, Katow, PNG, 14.5 m, length 21.0 mm). **F** *D. (D.) lessoni* Deshayes, 1825 (QM MO17676, Cairns, Qld, 904–916 m, length 36.8 mm).

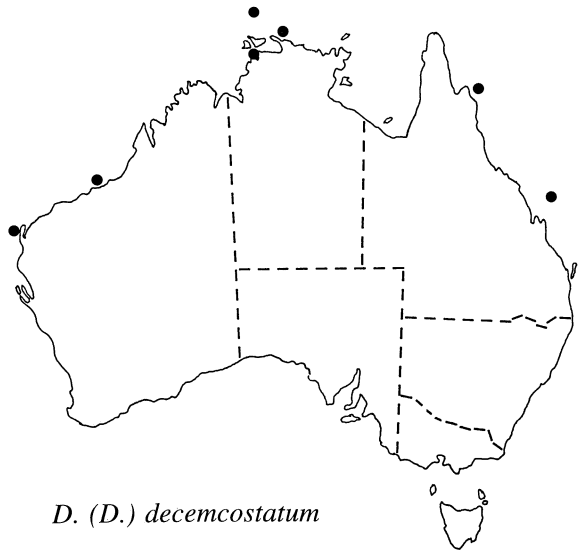


Figure 31. Australian distribution of *Dentalium (Dentalium) decemcostatum* Brazier, 1877.

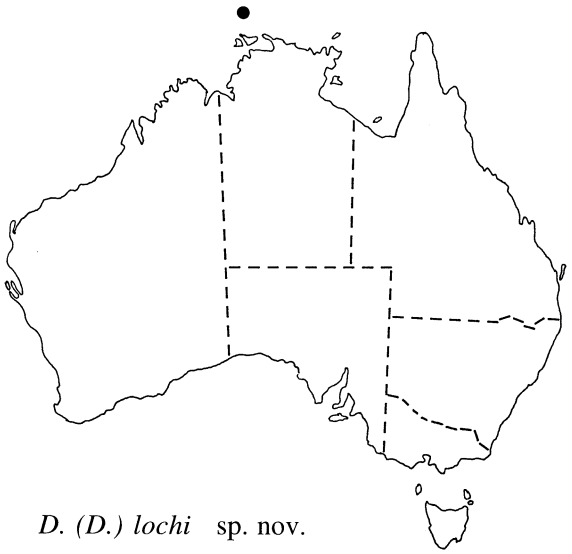


Figure 32. Known distribution of *Dentalium (Dentalium) lochi* n.sp.

registered lot AMS C170755 is marked as the Primary Type of this species (Primary Type number A90). This lot, however, contains two specimens. Although Brazier did not nominate a holotype, his given dimensions for the species match those of the larger specimen in AMS C170755. We therefore designate this larger specimen as the lectotype of *D. decemcostatum* (the smaller specimen therefore becoming a paralectotype). *Dentalium decemcostatum* appears to be a rare species, confined to northern Australian waters.

Dentalium (Dentalium) lochi n.sp.

Figs 29B, 30B, 32

Etymology. Named after Mr Ian Loch, Collection Manager of the malacological collections of the Australian Museum, for his generous assistance both in making material available to us and in providing useful information throughout the study.

Type material examined. HOLOTYPE: AMS C174628. Type locality: Arafura Sea, 9°17.5'S 132°20'E, 168 m, 10 November 1969. Length of holotype 34.4 mm, aperture diameter 3.3 mm, apex diameter 1.1 mm. PARATYPES: 2, WAM 153.93, 18°25'S 118°22'E, 210 km north of Port Hedland, WA, 201 m, 2 April 1982; 270, AMS C84257; same locality data as holotype.

Additional material examined. 83, AMS C172563, 9°30'S 132°34'E, Arafura Sea, 160 km north of Croker Island, NT, 124 m, 9 November 1969.

Description. Shell length to 44.0 mm, aperture diameter 3.5 mm, apex diameter 1.2 mm; moderately curved. Sculpture of 10 strong, raised, wide, rounded, longitudinal ribs, with 1–3 minor intercalating riblets occurring in each interstice behind the apex which become obsolete towards the aperture; interstices and ribs crossed by dense lateral striae, give a coarse, file-like appearance to the surface. Aperture polygonal. Apex polygonal, without slit or notch, orifice large, located dorsally. Colour white.

Range. Arafura Sea to northern Western Australia.

Habitat. Dredged between 124 and 201 m in sandy mud and shell.

Comparisons and remarks. *Dentalium lochi* most closely resembles *D. decemcostatum* Brazier in having strong, raised ribs and a slighty curved shell. Differentiating features of *D. lochi* include: developing 2 or 3 minor riblets in the rib interstices; nodulose rib tops (raised, rounded, smooth in *D. decemcostatum*); narrower aperture diameter. This species seems to be restricted to northern Australia.

Key to Group of *Dentalium rowei*

Ribs 8–14 fine, raised, narrow apically, intercalating to 20–24 at aperture, shell white.

1 Strongly curved; apex usually with a short, wide ventral slit or notch and small apical pipe ..... *D. rowei*

—— Slightly curved; without slit or notch ..... *D. kathwayae*

Dentalium (Dentalium) rowei n.sp.

Figs 29C, 30C, 33

Etymology. Named after Dr Frank Rowe (Suffolk, England, formerly Curator of Echinoderms, Australian Museum) who first collected this new species as well as a considerable amount of other material examined in this study.

Type material examined. HOLOTYPE: WAM 231/94. Type locality: 3.2 km north-east of Cape Bossut, northern WA, 7–10 m, 13 October 1962. Length of holotype 35.0 mm, aperture diameter 3.4 mm, apex diameter 0.8 mm. PARATYPES: 1, WAM 53-93, same locality data as holotype; 2, WAM 67-93, 24°54'S 113°17.75'E, 13 km north-east of Redcliff Point, Bernier Island, WA, 24.7 m, dead shells, rubble and sand, 2 May 1981; 2, WAM 66-93, 24°52'S 113°17.5'E, east north-east of Redcliff Point, Bernier Island, WA, 2 May 1981; 12, AMS C201738, Exmouth Gulf, northern WA, grab samples, November-December 1993.

Additional material examined. Many, WAM 56-94, 1, WAM 62-94, many, WAM 52-94, many, WAM 63-94, Exmouth Gulf, northern WA, grab samples, November-December 1993; 1, AMS C172252, 295 km north of Goulburn Island, NT, 8°41'S 133°12'E, 196 m, clayey sand, 6 November 1969; 20, WAM 54-93, Bowen, Qld, August 1966.

Description. Shell length to 35.0 mm, aperture diameter 3.4 mm, apex diameter 0.8 mm; moderately to strongly curved, tapering. Sculpture at the apex of 8–14 strong, sharp longitudinal ribs, ribs develop at irregular intervals in each interstice, progressively deepening so that at the aperture there are 20–24 very low ribs with some riblets; interstices flat to slightly concave, wider than the ribs; ribs and interstices crossed by transverse striae and growth pauses. Aperture circular, crenulated by ribs. Apex polygonal, with or without a short, wide ventral slit or notch and small pipe. Colour white or grey-white.

Range. Central Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged from 7 to 196 m among dead shells, rubble and sand.

Comparisons and remarks. *Dentalium rowei* most closely resembles *D. paucicontortum* Boissevain (syntype examined) in size and rib count, but has a narrower shell (shell diameter increasing gradually and steadily with age) and more pronounced ribs which persist until late in shell growth (that is, no rib obsolescence). *Dentalium rowei* also resembles *D. kathwayae* n.sp. in having fine, well developed ribs which increase through intercalation. However, *D. rowei* differs from *D. kathwayae* in having low, rounded ribs towards the aperture, stronger shell curvature, a relatively wide aperture, apically with a narrow orifice and ventral slit or notch. The only record of this new species from outside Western Australia is a lot of 20 specimens recorded from Bowen, central Queensland. If this locality information is correct then *D. rowei* would have a very disjunct distribution. Further collecting hopefully will not only help to confirm the species presence in Queensland, but also establish intermediate localities between Western Australia and Queensland. *Dentalium rowei* seems to be a rare species.

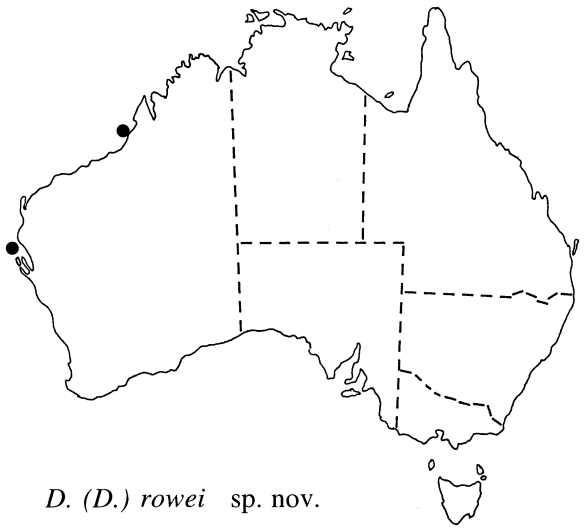


Figure 33. Known distribution of *Dentalium (Dentalium) rowei* n.sp.

Dentalium (Dentalium) kathwayae n.sp.

Figs 29D, 30D, 34

Etymology. Named after Kathie Way, Collections Manager (Mollusca), Natural History Museum, London (BMNH) for her generous assistance with information, loans of type material and photographs of scaphopods from the Linnean Collection.

Type material examined. HOLOTYPE: AMS C169943. Type locality: 26 km north-east of North Reef, Qld,

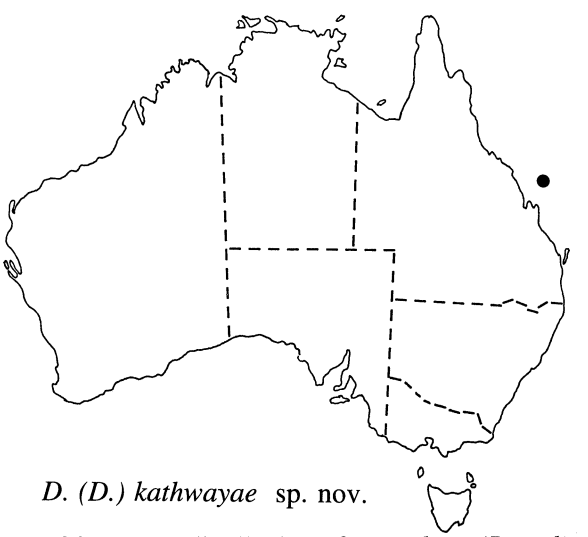


Figure 34. Known distribution of *Dentalium (Dentalium) kathwayae* n.sp.

23°08.4'S 152°12.3'E, 115 m, 14 December 1977. Length of holotype 39.0 mm, aperture diameter 3.1 mm, apex diameter 0.8 mm.

Description. Dimensions as for holotype: robust, slightly and evenly curved, slowly tapering. Sculpture of 10 raised longitudinal ribs, intercalating with 1 rib occurring in the interstices so that at the aperture there are 20 low rounded ribs; interstices slightly concave. Aperture circular, crenulated by ribs. Apex small, polygonal, without slit or notch. Colour grey white.

Range. North-east of North Reef, Queensland.

Habitat. Dredged in coarse coral sand at 115 m.

Comparisons and remarks. *Dentalium kathwayae* can be differentiated from *D. rowei* n.sp. by having a narrower aperture, weaker curvature, and no slit or notch. Although *D. kathwayae* is presently only known from the holotype, its sculpture separates it from any other known species of Dentalium. *Dentalium kathwayae* also superficially resembles some species of the genus *Fissidentalium*, but can be immediately separated by its fewer, spaced ribs apically and consistent absence of an apical slit or notch. In *Fissidentalium*, ribs are more numerous apically and typically remain prominent through to the aperture (ribs fewer and becoming low towards the aperture in *D. kathwayae*).

Key to Group of *Dentalium robustum*

Nine ribs at apex, evenly curved to almost straight, slowly tapering, apex without slit or notch, colour white.

1 9 angulated ribs at apex, raised and rounded at aperture ..... *D. robustum*

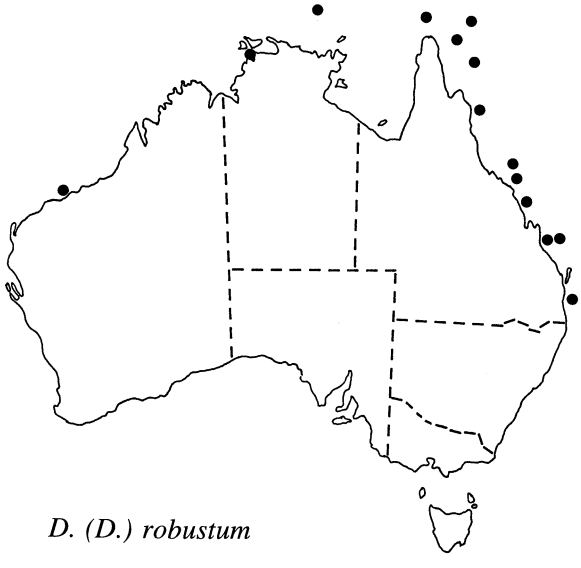
—— 9 raised ribs at apex, low and obsolete towards aperture ..... *D. lessoni*

Dentalium (Dentalium) robustum Brazier, 1877

Figs 29E, 30E, 35

Dentalium robustum Brazier, 1877: 56; Pilsbry & Sharp, 1897: 12; Boissevain, 1906: 29; Hedley, 1901: 128, pl. 17, fig. 32.

Type material examined. LECTOTYPE: AMS C170765, Katow New Guinea, 14.5 m, 1875. Selected by Ponder & Stanbury (1971) from syntype lot AMA 95. Length of lectotype 21.0 mm, aperture diameter 2.63 mm, apex diameter 0.79 mm. PARALECTOTYPES: 3, from AMS A95 (now = AMS C170766) same locality data as lectotype.



D. (D.) robustum

Figure 35. Australian distribution of *Dentalium (Dentalium) robustum* Brazier, 1877.

Additional material examined. QUEENSLAND: 5, AMS C172203, north-east of Cape Moreton Lighthouse, 115–119 m; 1, AMS C173073, 23°51.2'S 152°34.5'E, east of Lady Musgrave Island, 200 m, 4 July 1984; 2, AMS C173059, south-east of Gladstone, shell sand, 1967; 1, AMS C172242, 20°54'S 148°58'E, Seaforth, north of Mackay; 1, QM MO171317, Dunk Island; 1, AMS C165252, 18°11.01'S 147°25.50'E, Great Barrier Reef, 490 m, 26 August 1988; 6, QM MO40048, 10°01'S 145°00'E, 1777 m, 11 February 1992; 7, QM MO40049, 13°50'S 146°39'E, 6 September 1988; 2, QM MO40050, 12°26'S 144°36'E, 3150 m; 1, AMS C173414; 1, AMS C173419, 16°43.06'S 146°37.18'E, off Cairns, 1477 m, 13 October 1981; 1, AMS C12099, Torres Strait, 15 m, 1875. NORTHERN TERRITORY: 2, AMS C172153, Dingo Beach, Darwin, sievings from mud flats below mangrove, scattered rocks, mid low tide, 12 June 1976; 1, AMS C172204, 8°36'S 135°08'E, north of Wessel Island, Arafura Sea, 15 October 1969. WESTERN AUSTRALIA: 1, AMS C169789, 270 km north-west of Port Hedland, 19°13'S 116°06'E, 271 m, 30 November 1968.

Description. Shell length to 22.0 mm, aperture diameter 2.8 mm, apex diameter 1.0 mm; thin, almost straight. Sculpture of 9 strong, rounded, longitudinal ribs, narrow towards the apex. Aperture circular, with strongly raised ribs. Apex polygonal, with small orifice; interstices flat, smooth. Colour dull white.

Range. Northern Queensland, New Guinea, Northern Territory and northern Western Australia.

Habitat. Collected in littoral areas and dredged to 3150 m in sandy mud and coral rubble.

Comparisons and remarks. *Dentalium robustum* most closely resembles *D. decemcostatum* Brazier in rib structure and general size and shape of the shell. Differentiating features include: rib number (9 in *D. robustum*, 10 in *D. decemcostatum*); greater curvature;

aperture slightly more widely expanded. *Dentalium octangulatum* Donovan also bears some resemblance to *D. robustum*, but is appreciably larger, almost always strongly curved, with wider ribs and concave interstices.

Dentalium (Dentalium) lessoni Deshayes, 1825

Figs 29F, 30F, 36

Dentalium lessoni Deshayes, 1825: 357, pl. 16, fig. 13; Chenu, 1842–1843: 5, pl. 5, fig. 4 (not 4a); Pilsbry & Sharp, 1897: 8, pl. 6, figs 86, 90; Boissevain, 1906: 30, pl. 1, fig. 11.

Type material. Ms V. Heros, MNHN, Paris (pers. comm.) has advised us that the primary type of this species was lodged with the Ecole de Mines, Paris, but this specimen cannot be located. Type locality: New Guinea. Length of holotype 50.0 mm, aperture diameter 4.0 mm (*fide* Deshayes).

Material examined. 1, QM MO17676, 17°51.06'S 147°09.8'E, off Cairns, northern Qld, 904–916 m, 17 May 1986; 1, QM MO17706, 17°47.1'S 148°13.4'E, 1141 m, 9 May 1986, off Cairns, northern Qld.

Description. Shell length 37.0 mm, aperture diameter 3.5 mm, apex diameter 1.4 mm; slender, evenly curved. Sculpture of 9 moderately raised, rounded, longitudinal ribs, stronger at the apex, becoming low and obsolete towards the aperture; interstices concave at the apex becoming wide and flat towards the aperture with dense, transverse growth lines, becoming wider and stronger towards the aperture. Aperture obovate. Apex polygonal, without slit or notch. Colour white or yellow-white.

Range. New Guinea (Deshayes, 1825); northern Queensland.

Habitat. Dredged in gritty sand and mud from 904–1141 m.

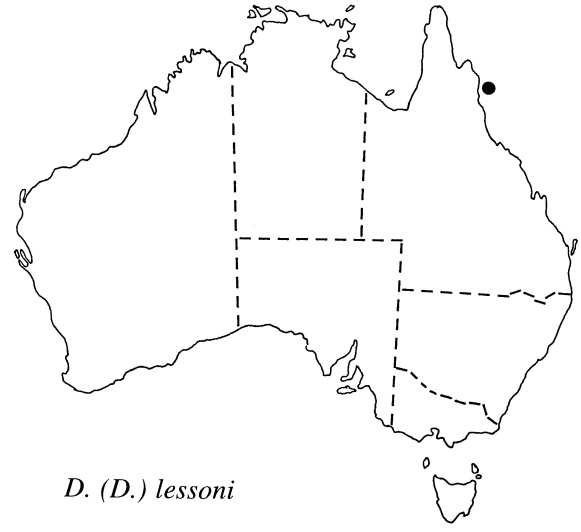


Figure 36. Australian distribution of *Dentalium (Dentalium) lessoni* Deshayes, 1825.

Comparisons and remarks. Our use of the name *D. lessoni* Deshayes for these two specimens from Australia is very tentative and based primarily on comparison with the figure given by Pilsbry & Sharp (1897–98), available descriptions of the species and geographic proximity to the type locality (New Guinea) to northern Queensland. Unfortunately, as noted above, the type of *D. lessoni* cannot presently be found, and as a consequence there is no way of directly checking species identity for the available Australian specimens. For the present we can only suggest continued use of the name *D. lessoni* until the type is located. *Dentalium lessoni*, as here understood, bears some resemblance to *D. hemileuron* Verco in shape and rib obsolescence anteriorly, but like *D. robustum* Brazier, consistently shows 9 ribs apically (12 in *D. hemileuron*).

Key to Group of *Dentalium javanum*

Eight (rarely 9) ribs at apex, shell colour white, robust, moderately to strongly curved, without slit or notch, aperture usually polygonal.

1 Shell long (to 68 mm) 2

—— Shell short (to 23 mm) 3

2 Ribs raised, equally prominent at apex and aperture, interstices smooth, strongly curved ..... *D. javanum*

—— Ribs raised, less prominent at the aperture, interstices usually with several unequal riblets, moderately curved ..... *D. octangulatum*

3 Shell slowly tapering, moderately curved 4

—— Shell rapidly tapering, strongly curved ..... *D. goftoni*

4 Interstices usually with 2–3 minor ribs ..... *D. jeanae*

—— Interstices without minor ribs but with 1 or more fine longitudinal striae ..... *D. octopleuron*

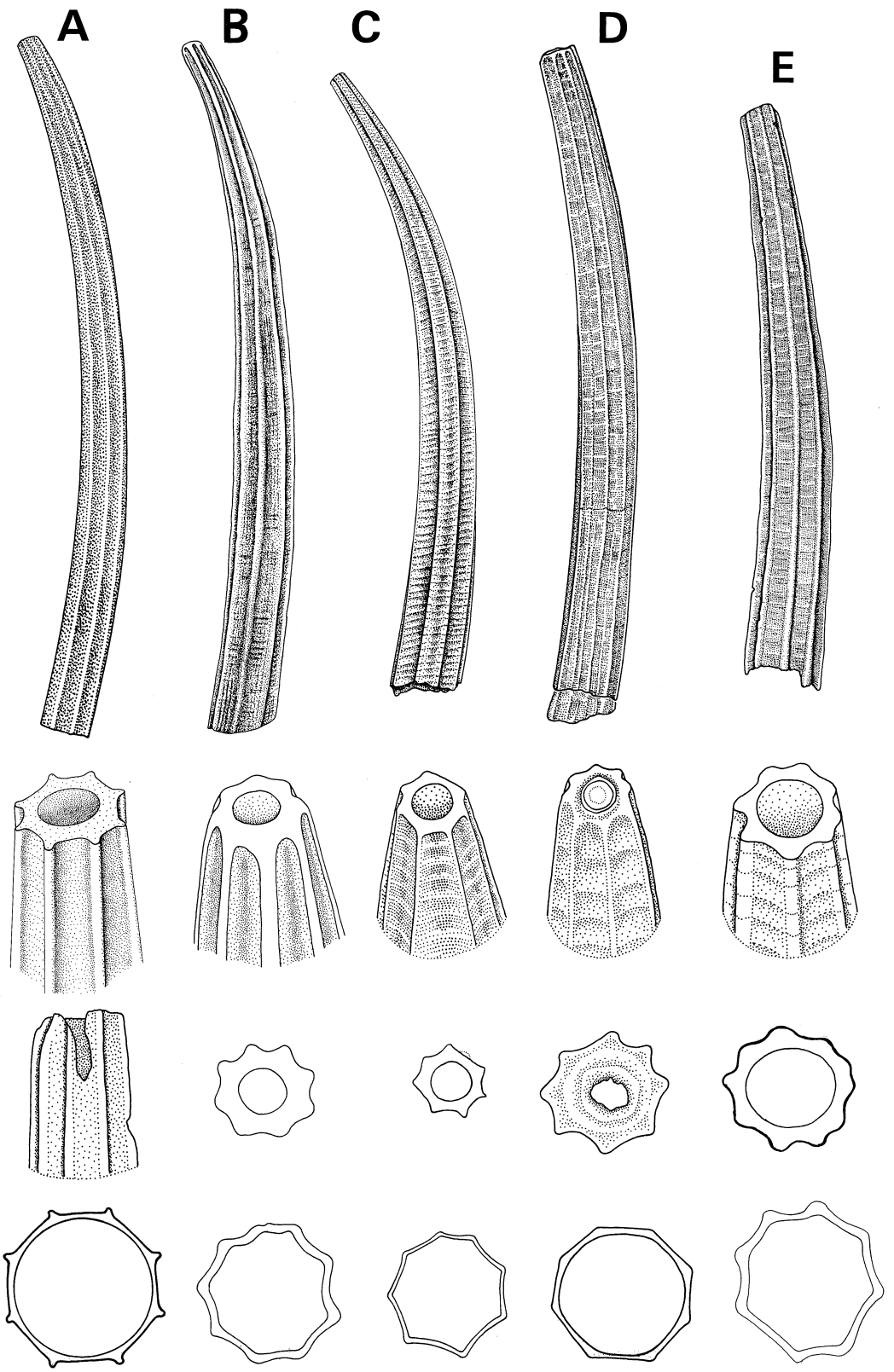


Figure 37. Dentaliida, Dentaliidae. *Dentalium (Dentalium)* Group of *D. javanum*. **A** *D. (D.) javanum* Sowerby, 1860 (QM MO38992, Gulf of Carpentaria, Qld, length 61.5 mm; apex with slit in lectotype BMNH 1993006 Malacca, 22 m, length 76.5 mm). **B** *D. (D.) octangulatum* Donovan, 1803 (neotype, BM BMNH 1952.2.23.1, length 51.5 mm). **C** *D. (D.) goftoni* n.sp. (holotype, QM MO38982, Middle Banks, Moreton Bay, Qld, 31 m, length 10.7 mm). **D** *D. (D.) jeanae* n.sp. (holotype, QM MO174889, 37 km east of Lady Musgrave Island, Qld, 348–357 m, length 17.6 mm). **E** *D. (D.) octopleuron* Verco, 1911 (holotype, SAM D13725, St Vincents Gulf, 27–40 m, length 19.0 mm). (Del.: all A. Hill, except A—C. Eadie; apex showing slit—A. Hill; E [apex profile]—JMH).

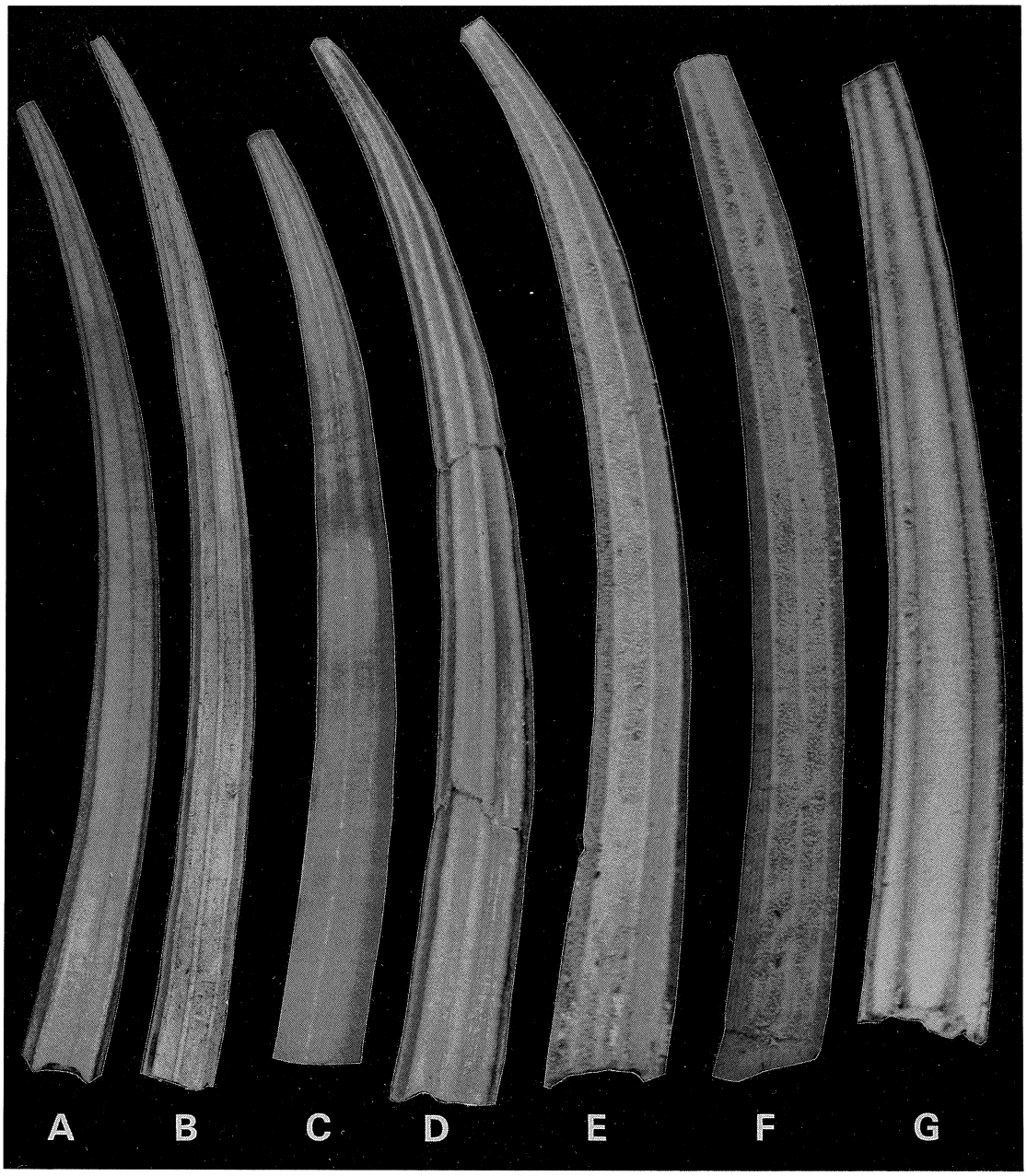


Figure 38. Dentaliida, Dentaliidae. *Dentalium (Dentalium)* Group of *D. javanum*. **A,B** *D. (D.) javanum* Sowerby, 1860 (A—lectotype, BMNH 1993006, Malacca, 22 m, length 76.5 mm; B—QM MO38992, Gulf of Carpentaria, Qld, length 61.5 mm). **C,D** *D. (D.) octangulatum* Donovan, 1803 (C—neotype, BMNH 1952.2.23.1, Japan, length 51.5 mm; D—KLColl, Dingo Beach, northern Qld, length 40.4 mm). **E** *D. (D.) goftoni* n.sp. (holotype, QM MO38982, Middle Banks, Moreton Bay, Qld, 31 m, length 10.7 mm). **F** *D. (D.) jeanae* n.sp. (holotype, QM MO174889, 37 km east of Lady Musgrave Island, Qld, 348–357 m, length 17.6 mm). **G** *D. (D.) octopleuron* Verco, 1911 (holotype, SAM D13725, St Vincents Gulf, 27–40 m, length 19.0 mm).

Dentalium (Dentalium) javanum G.B. Sowerby, 1860

Figs 25E,F, 37A, 38A,B, 39

Dentalium javanum G.B. Sowerby, 1860: 102, pls 1, fig. 12; Reeve, 1872: v.18, pl. 3, fig. 14; Watson, 1886: 12; Pilsbry & Sharp, 1897: 4, pl. 4, fig. 49; Hedley, 1910: 371; Habe, 1963: 254, pl. 37, figs 7, 8; Habe, 1963: 254, pl. 37, figs 7, 8; Habe, 1964: 9, figs 7, 8; Rippingale & McMichael, 1961: 160.

Type material examined. Lectoype here selected from syntype lot BMNH 1993006. Type locality: Malacca, coarse sand, 22 m. Length of lectotype 76.5 mm, aperture diameter 6.5 mm, apex diameter 1.67 mm. PARALECTOTYPES: 2, BMNH 1993006 (lengths: paralectotype no. 1, 79.8 mm; paralectotype no. 2, 63.5 mm; same locality data as lectotype).

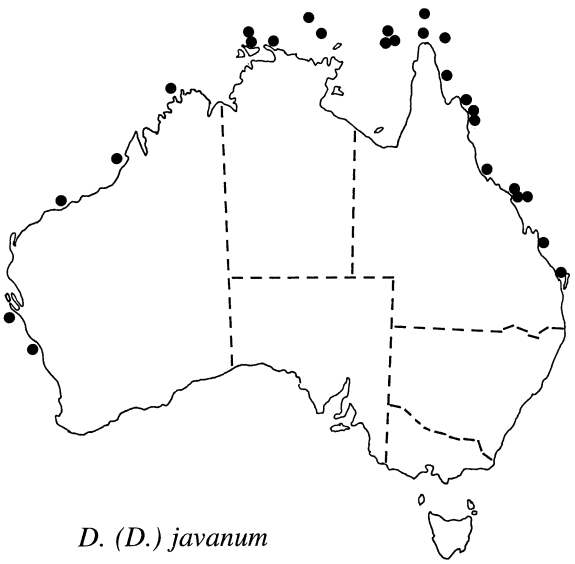


Figure 39. Australian distribution of *Dentalium (Dentalium) javanum* Sowerby, 1860.

Additional material examined. QUEENSLAND: 1, AMS C172091, Hervey Bay; 2, AMS C172083, Lammermoor Beach, Yeppoon, Qld, September 1972; 2, AMS C172090, 0.8 km off Yeppoon, Keppel Bay, 3.5 m; 3, AMS C172056, trawled Keppel Bay, November 1966; 3, AMS C77240, northern Keppel Bay, 55 m, September 1970; 19, AMS C90396, Lindeman Island; 2, AMS C119574, 19°44'S 148°14'E, off Bowen, 40 m, 12 December 1977; 1, AMS C172096, 15°42.9'S 145°25.6'E, 21 m, muddy coarse sand with forams, 2 September 1973; 3, AMS C172058, 15°45'S 145°33'E, 37 m, mud with coral and shell, 1 September 1973; 1, AMS C123884, 19°17'S 147°32'E, south of Townsville, 24 m coarse shell and forams, 20 November 1977; 1, AMS C172064, 15°39.3'S 145°22'E, 18 m, muddy sand with shells, 2 September 1973; 1, AMS C172075, 15°40.9'S 145°22.9'E, 20 m, muddy sand with oyster shell, 2 September 1973; 9, AMS C172084, 20°03'S 148°50'E, west of Hayman Island, 33 m, 19 November 1977, grey muddy sand; 10, AMS C172063, 20°52'S 149°29'E, east of Mackay, 35 m, 19 November 1977; 1, AMS C172078, 20°32.3'S 149°01.4'E, Whitsunday Passage, 27 m, 19 November 1977; 1, AMS C172099, Sarina Beach, tideline shell grit from south end of beach, 29 May 1977; 8, AMS C172073, 21°27.5'S 150°08'E, east of Sarina, 42 m, 13 December 1977, coarse shell/foram/bryozoan substratum; 3, AMS C172060, 21°58.5'S 150°45'E, east of Broad Sound, 57 m, 18 November 1977, coarse to fine sandy mud and shell; 6, AMS C172070, 21°47'S 150°34'E, south-east of Sarina, 59 m, 13 December 1977, coarse shell/bryozoan substratum; 3, AMS C172071, 21°28'S 150°08.5'E, east of Sarina, 40 m, 19 November 1977, grey sandy mud; 1, AMS C172205, Townsville (7 ribbed spec figured by Rippingale & McMichael, 1961); 3, AMS C42271, Dunk Island; 1, AMS C172094, 11, AMS C172061, 16°51'36"–51'00"S 146°01'12"–01'04"E, off Cairns, 33–35 m, 14 October 1981, sandy mud/shell; 1, AMS C172206, 16°39.2'S 146°01.2'E, 27 m, muddy sand with forams, 17 August 1973; 6, AMS C172072, 16°55'S 146°07'E, off Cairns, 37–40 m, 8 October 1981, sandy mud/shell; 1, AMS C172101, 16°40.3'S 146°00.2'E, 27 m, calcareous mud with forams, 16 August 1973; 1, AMS C172067, 17°11'42"–12'54"S 146°38'48"–37'42"E, off Cairns, 143–150 m, 12 October 1981, grey mud; 1, AMS C172074, 16°52–53'S 146°06'E, off Cairns, 37–38 m, 8 October 1981; 1, AMS C172086, 16°51'36"–51'00"S 146°01'12"–04'00"E, off Cairns, 33–35 m, sandy mud, dead shell, 14 August 1981; 1, AMS C172289, Cairns; 1, AMS C138634, off Spur Reef, east of Norman Reef, north of Cairns, 36.5 m, 28 November 1972, sandy bottom (preserved) 1, AMS C172088, 4 pieces, AMS C172087, 1, AMS C172076, 1, AMS C172054, 1, AMS C172068, Low Isle, near Port Douglas, 16–22 m, October-November 1928; 1, AMS C172147, 12°09.0'S 143°13.2'E, 24 m, black mud with shells, 7 November 1973; 2, QM MO38987, 11°34'S 143°11'E, 31 m, Shelburne Bay, 10 April 1992; 1, QM MO38986, 11°30.2'S 142°58.1'E, 20 m, 1 December 1990; 1, AMS C172095, Hope Island, south-east of Cooktown, 9–18 m, 2–6 August 1906; 2, QM MO389, 11°09'S 143°09'E, 28 m, Shelburne Bay; 1, QM MO38992, 11°00.4'S 140°42'E, 47 m, Gulf of Carpentaria, 4 December 1990; 4, AMS C172098, 13°28.2'S 143°42'E, 22 m, sticky black mud, 28 October 1973; 1, AMS C172059, 13°12.2'S 143°34.1'E, 11 m, sticky black mud, 29 October 1973; 1, AMS C29922, Murray Island, 16 m; 1, AMS C17788, Torres Strait; 12, AMS C123295, Saibai Island, Torres Strait, on sandy mud flats, 7 July 1976; 1, AMS C8029, Torres Strait; 1, AMS C172085, Saibai Island, Torres Strait, on muddy sand and rock beach, 7 July 1976. NORTHERN TERRITORY: 4 pieces, AMS C172066, 10°39'S 133°05'E, 68 km north-east of Croker Island, 62 m, sand-silt-clay, 4 November 1969; 6, AMS C76454, dredged off Melville Island, October 1962; 2, QM MO38991, 10°49.5'S 136°19.4'E, 40 m, Arafura Sea; 1, QM MO38987, 10°52.2'S 136°09.19'E, 42 m, 20 November 1991; 2, QM MO38981, 10°58.5'S 140°21'E, 54 m, 1989; 2, QM MO38989, 10°06.8'S 137°42.5'E, 46 m, 21 November 1991; 4, QM MO38990, 11°09'S 134°03'E, 45.7 m, 22 October 1989; 1, QM MO38980, 11°00'S 138°05'E; 1, QM MO38988, 12°23.7'S 140°41.1'E, 58 m, 26 November 1991; 1, AMS C172055, 32 km off Point Charles, Darwin, NT, 27–37 m, 14 July 1938; 1, AMS C172100, off Point Charles, north-west off Darwin, 27–37 m; 1, AMS C172080, 8°16'S 133°44'E, 364 km north of Goulburn Island, 112 m, sand, 3 November 1969; 1, AMS C172081, 10°08.5'S 133°05'E, 160 km north of Goulburn Island, 73 m, sand-silt-clay, 1 November 1969; 4, AMS C172097, 8°26'S 135°22'E, 321 km north-west of Wessel Island, Arnhem Land, 75 m, 13 October 1969; 1, AMS C172207, 8°36'S 135°08'E, approx 385 km north-east of Croker Island, 15 October 1968; 1, AMS C172152, Two Fella Creek, Darwin, September 1971; 1, AMS C172093, 10°16'S 135°09'E, approx, 305 km north-west of Gove, 60 m, 16 October 1969; 1, AMS C172092, 8°39'S 135°21'E, north of Wessel Island, Arafura Sea, 65 m, 15 December 1969. WESTERN AUSTRALIA: 5, AMS C90395, off Broome; 2, AMS C172079, 19°00.4–00.3'S 118°01.0–01.1'E, 157 km north north-west of Port Hedland, 116–120 m, sand-gravel, 29 October 1983; 1, AMS C172077, 18°40'S 117°55'E, north of Port Hedland, 150 m, 28 February 19; 2 broken, WAM 141-93, 18°47'S 117°58'E, 100 north-west of Port Hedland, 154 m, 28 February 1982; 3, AMS C69304, Geraldton, 17 August 1943; 1, WAM 247-93, 100 km north-east of Adele Island, 80 m, 20 October 1962, sand; 3, WAM 248-93, 341 km east north-east of Troughton Island, 64 m, 23 October 1962, mud.

Description. Shell length to 79.8 mm, aperture diameter 6.5 mm, apex diameter 1.3 mm; slender, moderately robust, strongly curved. Sculpture of 8 (rarely 7 or 9) prominent, projecting, longitudinal ribs, strongest at the apex but still very strong at the aperture; interstices broad, flat or slightly concave with dense transverse striae. Aperture octogonal. Apex octogonal, with or without small notch. Colour off-white.

Radula. Central tooth broad (333 µm wide) and shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped, 370 µm long with small cusps on the working surface; marginals sigmoidal, relatively elongate and narrow (length 463 µm × breadth 92 µm) (see Fig. 25E,F). Ratios C:L = 1:1.11, L:M = 1:1.25, marginals breadth:length 1:5 (based on possible male).

Range. Java (Pilsbry & Sharp, 1897), Malacca, Karachi (Melvill & Standen, 1901), Queensland, New Guinea, Northern Territory to northern Western Australia.

Habitat. Dredged from 3.5 to 150 m in gritty, sandy mud.

Comparisons and remarks. On the card associated with lot BMNH 1993006 Ms K.M. Way (BMNH) notes that the type material of *D. javanum* from Java cannot be located. Assuming for the present that these specimens are lost, the syntype series now consists only of the three Malacca specimens from the Cuming Collection (i.e. lot BMNH 1993006). This species most closely resembles *D. octangulatum* Donovan in rib numbers and general size and shape of the shell. Differentiating features which separate *D. javanum* from *D. octangulatum* include: strongly raised, narrow ribs at aperture (low and wider in *D. octangulatum*); interstices smooth (without longitudinal striae); more strongly curved. The same features separate *D. javanum* from *D. goftoni* n.sp., which in addition only grows to 13–14 mm (compared with 55–79.8 mm in *D. javanum*). *Dentalium octopleuron* Verco differs from *D. javanum* in being less curved, slowly tapering apically with rounded ribs. The significance of pronounced variation in aperture diameter in this species is not known. Possibly it may reflect some degree of sexual dimorphism within the species, but at present we have inadequate numbers of preserved animals to comment further on this issue. Among the numerous lots of *D. javanum* we have examined, the majority of specimens have 8 ribs while occasional specimens including the smallest syntype were observed to have 9 ribs. Presence or absence of an apical notch is variable, even in the type series (the larger without notch; the other two with notches).

Dentalium (Dentalium) octangulatum Donovan, 1803

Figs 37B, 38C,D, 40

Dentalium octangulatum Donovan, 1803: pl. 162; Pilsbry & Sharp, 1897: 16, pl. 2, figs 16, 17, 18, 22; Boissevain, 1906: 17, pl. 1, fig. 8, pl. 4, figs 8, 9; Hedley, 1910: 371; Habe, 1964: 7–9, pl. 1 fig. 1.

Dentalium octogonum Lamarck, 1818: 344.

Dentalium striatulum Turton, 1819 (in part): 352, pl. 16, figs 5–6. Not of Gmelin, 1788 (13): 3738.

Type material examined. NEOTYPE: BMNH 1952.2.23.1. Type locality: Japan (neotype selected by Ludbrook, 1954). Length of neotype 51.5 m, aperture diameter 5.1 mm, apex diameter 1.7 mm. Specimens associated with neotype: 11, BMNH 1952.2.23.2–12, same locality data as neotype.

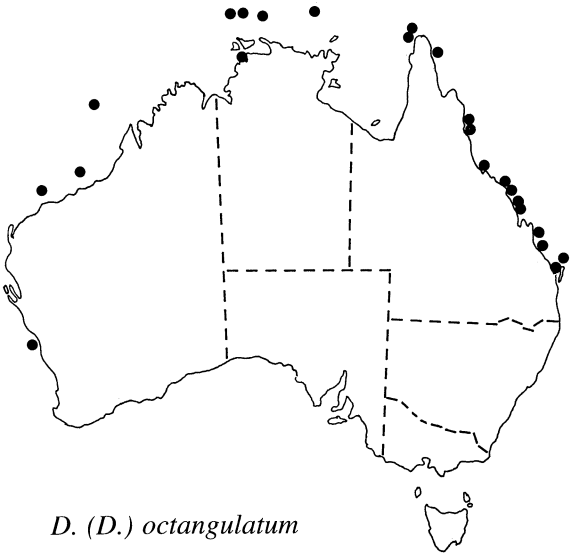


Figure 40. Australian distribution of *Dentalium (Dentalium) octangulatum* Donovan, 1803.

Additional material examined. QUEENSLAND: 1, AMS C172123, 24°28.2'S 153°31.2'E, north-east of Sandy Cape, 1330–1380 m, 8 July 1984; 2, AMS C172127, Urangan, 1958–9; 1, AMS C172141, Tannum Sands, Port Curtis, shell sand; 1, AMS C172144, 23°57'S 151°22'E, Tannum Beach; 1, AMS C172125, Gladstone Harbour; 1, AMS C172148, Facing Island, Port Curtis; 4 pieces, AMS C172114, 22°26.0–20.2'S 153°17.13–17.06'E, south-east of Swains Reefs, 187 m, 5 July 1984; 1, AMS C172110, 23°57'S 151°22'E, Tannum Beach; 1, AMS C172108, Tannum Sands, Port Curtis, shell sand; 8, AMS C172103, Quoin Island, Port Curtis, 2–5.5 m; 5, AMS C172115, Gladstone Harbour; 1, AMS C172150, off Yeppoon, Keppel Bay, 5 m; 1, AMS C76448, Yeppoon; 1, AMS C172146, north end Airley Beach, Prosperpine, August 1972; 4, AMS C172244, 3, AMS C172132, 20°05'S 148°30'E, Dingo Beach; 1, AMS C172112, 19°45.7'S 148°19'E, east of Bowen, 46 m, 19 November 1977, grey mud; 1, AMS C172111, Dingo Beach, Bowen; 2, AMS C172139, Seaforth, near Mackay; 1, AMS C172124, Brampton Island, near Mackay, July 1949; 2, AMS C172145, Sarina Beach, south of Mackay; 23, AMS C172134, 20°54'S 148°58'E, Seaforth, north of Mackay; 3, AMS C172135, Cape Palaranda, Beach, Townsville, August 1972; 1, 17°46'S 147°49'E, 1223–1224 m, 11 May 1986; 12, AMS C172109, Cairns Harbour; 1, QM MO40087, 17, AMS C172133, Cairns Harbour; 1, AMS C172137, Buchans Point, north of Cairns; 1, QM MO39010, 13°58.9'S 144°14.9'E, 38 m, mud and sand, 19 September 1979; 1, AMS C172143, Port Douglas; 2, QM MO39011, 11°09'S 143°09'E, Shelburne Bay, 28 m, 23 May 1992; 2, AMS C172117, Albany Passage, Cape York Peninsula, 7–26 m; 60, AMS C303575, 10°45'S 142°37'E, Albany Passage, Cape York, 26 m, October 1907; 2, AMS C172121, north of Terry Beach, Prince of Wales Island, Torres Strait, behind flats near mangroves, 30 June 1976; 1, AMS C169962, 16°28'S 145°28'E, Dicksons Inlet, Port Douglas, July 1969. NORTHERN TERRITORY: 3, AMS C172131, Port Darwin; 2, AMS C172106, 32 km north of Point Charles, 22 m, 7 July 1938; 1, AMS C172105, 9°34'S 131°22'E, Arafura Sea, approx. 176 km north of Melville Island, 135 m, 15 November 1969; 1, AMS C172564; 15, AMS C172136, 9°30'S 132°34'E, Arafura Sea, approx 160 km north of Croker Island, 124 m, 9 November 1969; 1, AMS C172130, 10°42'S 133°36'E, 91 km north of Goulburn Island, 58 m, clay-sand, 31 October 1969; 4, AMS C172119, 10°48.5'S 133°48'E, 84 km north-east

of Goulburn Island, 60 m, sand-silt-clay, 31 October 1969; 13 pieces, AMS C172122, 10°23'S 133°36'E, 125 km north of Goulburn Island, 62 m, clayey sand, 31 October 1969; 5 pieces, AMS C172126, 9°11'S 135°43'E, 60 m, 14 October 1969; 3 pieces, AMS C172129, 8°39'S 135°21'E, 321 km north-west of Wessel Island, Arnhem Land, 65 m; 1, AMS C172104, 8°39'S 135°39'E, 321 km north-west of Wessel Island, Arnhem Land, 63 m, 14 October 1969; 1, AMS C172107, 8°26'S 135°22'E, north of Wessel Island, Arafura Sea, 75 m, 13 October 1969; 2 pieces, AMS C172120, 8°00'S 132°47'E, Arafura Sea, approx. 336 km north of Croker Island, 243 m, 7 November 1969; 8 pieces, AMS C172140, 10°17'S 132°38'E, Arafura Sea, approx, 64 km north of Croker Island, 65 m; 3, AMS C172118, 8°18'S 133°58'E, Arafura Sea, approx, 336 km north-east of Croker Island, 132 m, 3 November 1969; 1, AMS C172151, 10°22.5'S 131°37'E, 100 km north-east of Melville Island, 71 m, sand-silt-clay, 14 November 1969. WESTERN AUSTRALIA: 1, AMS C172128, 19°28.9–29.0'S 116°29.4–29.0'E, 133 km north north-west of Dampier, 110 m, 26 October 1983; 1, AMS C172116, 14°07'S 122°52'E, north of Cape Levique, 256 m, 17 November 1967; 1, AMS C172102, 18°40'S 119°23'E, approx 192 km north of Port Hedland, 117 m, 6 October 1968; 2, AMS C90397, Geraldton; many, WAM 54-94, Exmouth Gulf, grab samples, November-December 1993.

Description. Shell length to 52.0 mm, aperture diameter 5.3 mm, apex diameter 1.7 mm; robust, moderately curved, becoming rapidly tapering. Sculpture of 8 thick, strong, rounded, longitudinal ribs, more prominent at the apex; interstices concave, usually smooth with well defined transverse striae and usually with several unequal, longitudinal striae. Aperture octogonal, sometimes slightly ovate. Apex octogonal, without slit or notch. Colour white or blue white, shining or lustreless.

Range. China Seas (Habe, 1964), Japan, Sri Lanka, Karachi (Melvill & Standen, 1901), Queensland, New Guinea, Northern Territory to northern Western Australia.

Habitat. Collected in littoral sievings and dredged to 1380 m in sandy mud.

Comparisons and remarks. *Dentalium octangulatum* most closely resembles *D. javanum* G.B. Sowerby in rib number and general size. Differentiating features include: less curvature; lower, wider ribs; interstitial striae. Compared with *D. goftoni* n.sp., *D. octangulatum* is much larger and does not have the sharp ribs and dense transverse striae of that species. Among the lots we have examined most of the specimens have 8 ribs. Qi Zhongyan & Ma Xiutong (1989: 113–4) examined 308 specimens from the South China Sea, of which 301 had 6 ribs, 6 had 7 ribs and 1 had 8 ribs. Habe (1964, p. 8) recorded a variation of 5–9 primary ribs in *D. octangulatum*. Habe (1964) and Qi Zhongyan & Ma Xiutong (1989) both considered *D. hexagonum* Gould to be a junior synonym of *D. octangulatum*. Comparing the type specimens of *D. octangulatum* with the holotype of *D. hexagonum, D. octangulatum* is wider in proportion at the aperture, more solid while the ribs are wider, rounder and less raised than in *D. hexagonum. Dentalium hexagonum* is more curved than *D. octangulatum* and, in addition *D. hexagonum* has only 6 ribs while in the numerous specimens of *D. octangulatum* we have examined we have not seen a 6 ribbed specimen. In our opinion both *D. octangulatum* and *D. hexagonum* exhibit sufficient character differences to be recognized as separate species.

Dentalium (Dentalium) goftoni n.sp.

Figs 37C, 38E, 41

Etymology. Named after Mr Peter Gofton (Department of Zoology, University of Queensland) who allowed us access to material of this new species (and other subtidal molluscs) from the wet collections of the late Professor W. Stephenson (formerly Head of the Department of Zoology, University of Queensland).

Type material examined. HOLOTYPE: QM MO38982. Type locality: Middle Banks, Moreton Bay, Qld, 31 m, 29 September 1973. Length of holotype 10.7 mm, aperture diameter 1.7 mm, apex diameter 0.45 mm. PARATYPES: 2, AMS C172168; 2, WAM 283-93; 2, MV68195, same locality data as holotype; 2, QM MO38996, Redland Bay, southern Qld, Zool. Dept. Univ. Queensland, 8 February 1962; 11, QM MO38983, Dunwich, Stradbroke Island, Moreton Bay, southern Qld, 1985; 21, AMS C169791, Shoal Point, Mackay, NQ.

Additional material examined. QUEENSLAND: 27, Middle Banks, Moreton Bay, sandy mud, 34 m, 29 September 1973; 2 preserved specimens, Banana Banks, between yellow beacon and Pats Point, Moreton Bay, in sandy mud amongst eel grass, 3–8 m, 1 November 1992; 1, AMS C172172, Amity Point, Stradbroke Island, Moreton Bay, shellgrit; 1, AMS C172169, 9 pieces, AMS C172157, Green Island, Moreton Bay; 2, AMS C172163; 1, AMS C172155, Peel Island, Moreton Bay; 3, AMS C172173, off Peel Island, Moreton Bay, 9–11 m; 2, AMS C172158, off Peel Island, Moreton Bay; 4, AMS C311180, 27°30'S 153°21'E, Peel Island, Moreton Bay, 1955; 3, AMS

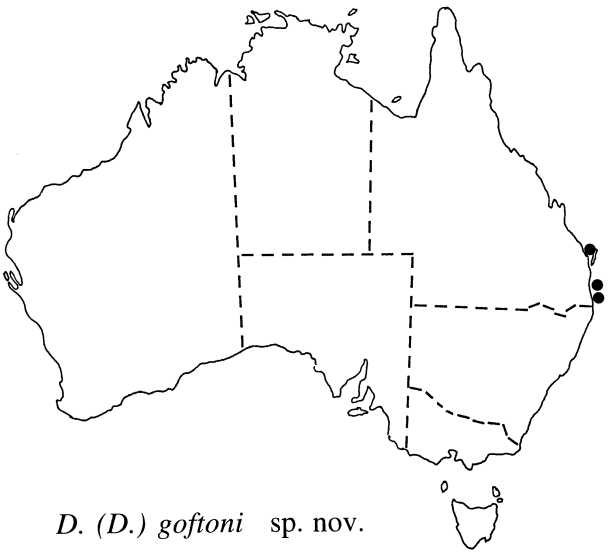


Figure 41. Known distribution of *Dentalium (Dentalium) goftoni* n.sp.

C172166, Sandgate, Moreton Bay, 1963; 1, AMS C172202, Clontarf Beach, Moreton Bay, 1963; 23, AMS C172162, Dring Bank, west of Moreton Island, Moreton Bay, 23 February 1962; 10, AMS C172170, 26°50–55'S 153°36'E, north north-east of Cape Moreton, 183 m; 1, AMS C172167, Woody Point, Moreton Bay, 1963; 1, AMS C172113, Southport, 12 November 1938; 2, AMS C172171, Hervey Bay; 1, AMS C172201, Dundowran Beach, Hervey Bay; 1, AMS C172159, Dundowran Beach, Hervey Bay, shell sand; 1, AMS C172161, Dundowran Beach, Hervey Bay; 11, AMS C172165, Hervey Bay; 1, AMS C172164, Hervey Bay; 1, AMS C172160, south of Urangan Boat Anchorage, Hervey Bay, sievings off mud flats, 24 October 1976; 1, Pialba, Hervey Bay, October 1972.

Description. Shell length to 13.6 mm, aperture diameter 1.9 mm, apex diameter 0.55 mm; moderately robust, well curved, rapidly tapering. Sculpture of 8 (rarely 9 or 10) strong, sharp, raised, longitudinal ribs with 1 or 2 faint riblets occasionally occurring in some of the interstices, interstices flat with dense transverse striae. Aperture typically octogonal, interstices slightly concave. Apex small, octogonal, orifice large without slit or notch. Colour chalky white.

Range. Southern to central Queensland coast.

Habitat. Dredged in sandy mud from 2 to 183 m.

Comparisons and remarks. *Dentalium goftoni* most closely resembles *D. jeanae* n.sp., both being small in size. Differentiating shell features of *D. goftoni* include: more strongly curved; more rapidly tapering towards apex; presence of crowded, transverse striae. *Dentalium goftoni*, compared with *D. octangulatum* Donovan and *D. javanum* G.B. Sowerby, is a much smaller species. In addition, the rib profile is lower than *D. octangulatum* or *D. javanum* and neither of those species have the dense transverse striae of *D. goftoni*. *Dentalium octopleuron* Verco appears similar superficially, but has rounded ribs (sharp in *D. goftoni*) with concave interstices (flat in *D. goftoni*). We have examined many specimens of *D. goftoni* and not found any exceeding 13.6 mm in length (animals sexually mature, as revealed by the presence of sperm in males or oocytes in females).

Dentalium (Dentalium) jeanae n.sp.

Figs 37D, 38F, 42

Etymology. Named after Mrs Jean Lamprell for her constant support throughout the project and assistance with much of the field work.

Type material examined. HOLOTYPE: AMS C174889. Type locality: 23°44'S 152°49'E, 37 km east of Lady Musgrave Island, Qld, 348–357 m, 17 November 1977, grey shelly ooze. Length of holotype 17.6 mm, aperture diameter 1.5 mm, apex diameter 0.9 mm. PARATYPES: 1, AMS C305472, same locality data as holotype.

Description. Shell length to 17.6 mm, aperture diameter 1.5 mm, apex diameter 0.9 mm; moderately robust, slightly curved, very slowly tapering towards apex (sides of shell almost parallel). Sculpture of 8 strong ribs decreasing in strength towards aperture; interstices with usually 2–4, low, intercalating riblets from middle of shell towards aperture. Aperture octogonal. Apex octogonal, without slit or notch. Colour white.

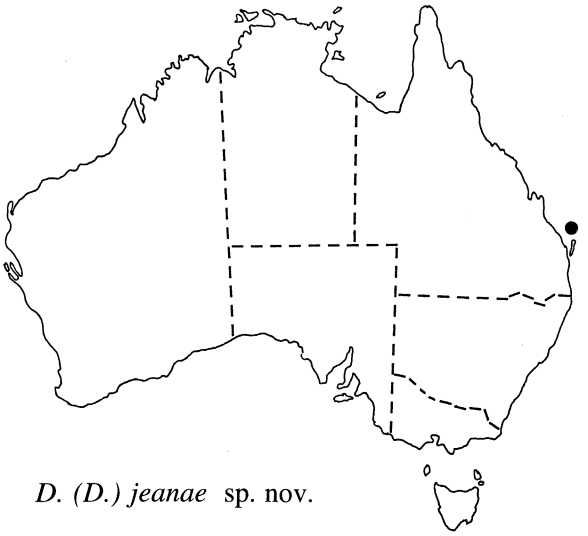


Figure 42. Known distribution of *Dentalium (Dentalium) jeanae* n.sp.

Range. 37 km east of Lady Musgrave Island, Queensland.

Habitat. Dredged in shelly ooze to 357 m.

Comparisons and remarks. *Dentalium jeanae* most closely resembles *D. concretum* Colman in being slowly tapering, almost parallel-sided with multiple intercalating riblets. Differentiating features of *D. jeanae* include: much smaller species; greater shell curvature; weaker riblets. This species can be distinguished from all other members of the *javanum* Group by its combination of a slowly tapering shell, moderate curvature, 8 ribs with multiple riblets intercalating and 8 angled aperture. Other 8 ribbed species are either much larger than *D. jeanae* (*D. javanum* G.B. Sowerby—no intercalating riblets), or have pronounced attenuation towards the apex (*D. goftoni* n.sp., *D. octangulatum* Donovan, *D. octopleuron* Verco).

Dentalium (Dentalium) octopleuron Verco, 1911

Figs 37E, 38G, 43

Dentalium octopleuron Verco, 1911a: 206; Cotton & Godfrey, 1933: 143; Cotton & Godfrey, 1940: 326, fig. 347; Zeidler & Macphail, 1978: 383.

Type material examined. HOLOTYPE: SAM D13725. Type locality: Gulf St. Vincent, SA, 15–22 fathoms [27–40 m]. Length of holotype 19.0 mm, aperture diameter 2.5 mm, apex diameter 1.2 mm.

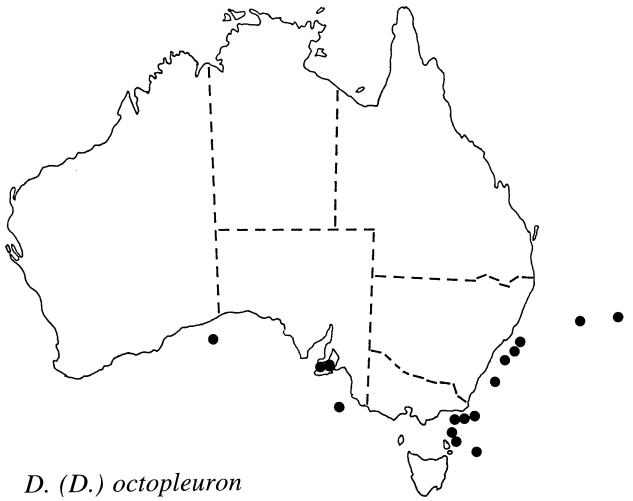


Figure 43. Australian distribution of *Dentalium (Dentalium) octopleuron* Verco, 1911.

Additional material examined. SOUTH AUSTRALIA: 9, AMS C172598, 60 km south of Cape Wiles, 183 m, August 1909; 4, SAM D18848, 44 m off the Gulf of St Vincent; 1, SAM D18849, 12 m off Black Point; 4, SAM D18850, 600 m off Cape Jaffa; 6, SAM D18851, 44 m, Backstairs Passage; 15, SAM D18852, 44 m, Gulf of St Vincent; 10, SAM D18853, 40 m, Gulf of St Vincent; 2, SAM D18854, 500 m, 80 m, west of Eucla; 2, SAM D18855, 600 m, Cape Jaffa, 25 December 1905 (preserved): 1, NMV F67465, 41°05.1'S 143°56.3'E, January 1985; 2, NMV F66538; 2, 2 pieces, AMS C172179, 38°59'S 148°34.1'E, midway between Cape Everard and Flinders Island, Bass Strait, 426 m, 7–9 May 1969; 5 pieces, AMS C172177, 40°50.6'S 148°46.5'E, off Cape Naturaliste, 399 m, silty sand and bryozoa, 26 February 1973. VICTORIA: 2, NMV F72173, south of Point Hicks, east Bass Strait, 400 m, 24 July 1986 (preserved); 3, NMV F67470, 38°05.6'S 149°24.5'E, south of Point Hicks, east Bass Strait, muddy sand, 328 m, 21 November 1973; 1, AMS C310243, 38°13'S 149°06'E, between Cape Howe and Lakes Entrance, 146–158 m, 20 June 1962; 5, AMS C310261, 37, AMS C310265, 38°20–40'S 149°25–35'E, 48 km south Cape Everard, 366 m, 22 July 1914; 37, AMS C172176, 43 km south-east of Cape Everard, 180–300 m, 9 May 1914; 16, AMS C172175, 48 km south of Cape Everard, 400 m, 22 October 1963; 13, AMS C172597, 38°15'S 149°12'E, 37 km south of Cape Everard, 315 m, 20 June 1962; NMV F72141, 38°19.10'S 149°14.30'E, south of Point Hicks, 600 m, 14 July 1986; 1pc, AMS C172178, 38°18.20'S 148°39.00'E, 58 km south of Cape Conran, Gippsland, May 1969. NEW SOUTH WALES: 7, AMS C172985, 33°42'S 151°55'E, off Sydney, 549 m, 11 December 1970; 1, AMS C172986, 33°31–33'S 152°08–07'E, off Sydney, 914 m, 10 December 1980; 5, AMS C173006, 33°41'S 151°53'E, off Botany Bay, 366 m, 5 December 1977; 1, AMS C172992, 33°26'S 152°11'E, east of Broken Bay, 877 m, 6 December 1979; 1, AMS C172993, 33°46'S 151°43'E, off Port Kembla, 741 m, 5 December 1977; 1, AMS C105417, 33°31–36'S 150°46–43'E, east of Brush Island, 439 m, 24 November 1976; 3, AMS C173003, 33°28–29'S 152°4–3'E, east of Cape Three Points, 476 m, 5 December 1979; 9, AMS C173004, 33°33'S 152°00'E, 750 m, 3 December 1979; 1, AMS C173022, 31°44'S 158°54'E, west side of Lord Howe Island, 37 m, 6 November 1976; 21, AMS C173079, 33°42–39'S 151°52–54'E, off Sydney, 457 m, 20 December 1976; 1, AMS C173080, 34°15–21'S 151°22–28'E, north-east of Wollongong, 457 m, 31 July 1975; 1, NMV F75839, 30°31'S 161°54.2'E, Tasman Sea, 1210 m, 29 December 1975.

Description. Shell length to 23.0 mm, aperture diameter 2.5 mm, apex diameter 1.2 mm; solid, slightly curved. Sculpture of 8 strong, rounded, longitudinal ribs; interstices wide, slightly concave, usually without longitudinal sculpture but specimens occur with 1 or more, fine longitudinal striae. Aperture octogonal. Apex octogonal, without slit or notch. Colour white.

Range. South Australia, Tasmania, Victoria to New South Wales.

Habitat. Dredged in muddy sand from 12 to 1210 m.

Comparisons and remarks. *Dentalium octopleuron* most closely resembles *D. goftoni* n.sp. Differentiating features of *D. octopleuron* include: less tapering; larger; only slightly curved. *Dentalium jeanae* n.sp. is similar in size, but differs substantially in ribbing structure. Other species of the *D. javanum* Group are larger, more strongly curved and tapering than *D. octopleuron*. The Tasmanian and Victorian specimens examined appear similar to the description of *D. tasmaniensis* Tenison Woods. The primary type of *D. tasmaniensis* cannot be traced, nor are there any other known type specimens. A communication received from Ms E. Turner (Tasmanian Museum of Arts and Sciences) advises that Tenison-Woods did not in fact designate type specimens of any of his species, and that May, Lodder and Hedley jointly determined which specimens lodged in the Tasmanian Museum of Arts and Sciences most closely matched the original description(s). A search by Ms Turner for any subsequently designated type material of *D. tasmaniensis* has proved fruitless. We have received a specimen from the NMV with the note "It was sent to us by Petterd, the same source as the type, but is not from the type locality". Other specimens in the NMV and AMS have an 8–10 rib count but otherwise conform to Tenison Woods' description. We are unable to separate these specimens from young specimens of *D. octopleuron*. However as *D. tasmanicus* was never figured and the description very brief, we have decided not to use that name as it would not be possible to say with certainty what shell Tenison Woods was referring to (see under Unrecognizable species, p. 172).

Key to Group of *Dentalium thetidis*

Seven (rarely 6 or 9) strong ribs at apex, usually with intercalating ribs or riblets, sometimes with small notch, moderately to slightly curved.

1 Rib interstices featuring crowded longitudinal striae 2

—— Rib interstices lacking longitudinal striae 3

2 7 ribs at apex and aperture ..... *D. thetidis*

—— 7 ribs at apex increasing to 32 at aperture ..... *D. wellsi*

3 Aperture width to shell length (W:L) ratio range 1:13–1:17 4

—— W:L ratio range 1:7.4–1:9.2 5

4 Ribs at aperture raised; interstices at aperture concave ..... *D. potteri*

—— Ribs at aperture low; interstices at aperture flattened ..... *D. concretum*

5 7 ribs throughout ..... *D. cheverti*

—— 7 ribs intercalating to 14 at aperture ..... *D. katowense*

Dentalium (Dentalium) thetidis Hedley, 1903

Figs 44A, 45A, 46

Dentalium thetidis Hedley, 1903: 327, fig. 61; Verco, 1911a: 205; Colman, 1958: 141, pl. 1, fig. 3.
Dentalium intercostatum Boissevain, 1906: 14, pl. 6, fig. 4.

Type material examined. HOLOTYPE: AMS C16212. Type locality: 5–8 miles off Port Kembla, NSW, 115–137 m. Length of holotype 7.7 mm, aperture diameter 1.4 mm. PARATYPES: 2, AMS C170641 (ex AMS C16212), 5–8 miles off Port Kembla, NSW 115–137 m, 18 March 1898.

Additional material examined. SOUTH AUSTRALIA: 10, AMS C32027, 35°39'S 136°40–50'E, 74 km south of Cape Wiles, 183 m, 28 August 1909; 2, SAM D188, 60 km south of Cape Wiles, 200 m. NEW SOUTH WALES: 1, AMS C16211, 9 km north-east of Cape Three Points, 79 m, sticky mud, 25 February 1898; 1, NMV F72155; off Nowra, 466 m, 22 October 1988; 1, NMV F72131, 37°00.6'S 150°20.7'E, off Eden, 363 m, 21 July 1986, coarse shell bottom; 2, NMV F72149, 34°57.90'S 151°08.00'E, off Nowra, 504 m, 14 July 1986; 4, NMV F72157, 29°46.6'S 167°58.9'E, Tasman Sea, 500 m, 1 January 1976. QUEENSLAND: 400, AMS C172208, north-east of Cape Moreton, 126–136 m, 1967; 1, AMS C172214, 27°01'S 153°36'E, off north end of Moreton Bay, 140 m, 29 February 1969; 24, AMS C172212, off Caloundra, 130–150 m; 1, AMS C172211, 23°08.6'S 152°16.6'E, Capricorn Channel, 155 m, 14 December 1977, dead shell, fine sand/mud; 5, AMS C310423, 23, AMS C173440, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 1, AMS C172216, 16°36.00–35.12'S 146°14.48–13.48'E, off Cairns, 172–197 m, 11 October 1981; 6, AMS C174646, 18°11.01'S 147°25.50'E, Great Barrier Reef, 490 m, 26 August 1988; 1, AMS C172191, 10°35'S 141°55'E, Gannet Passage, Torres Strait, 11 m. NORTHERN TERRITORY: 17, AMS C174627, 9°17.5'S 132°20'E, Arafura Sea, 168 m, 10 November 1969; 2, AMS C172192, sandbar no. 2, Darwin, 1 November 1970; 1, AMS C311589, 9°30'S 132°34'E, Arafura Sea, approx 160 km north of Croker Island, 124 m, 9 November 1969. WESTERN AUSTRALIA: 1, WAM 39-93, 31°04'S 113°50'E, west south-west of Lancelin, 256 m, 23 February 1972; 1, WAM 35-93, 32°00.5'S 115°12'E, west of Rottnest Island, 5 February 1976; 1, WAM 37-93, 31°47'S 115°58'E, west of Rottnest Island, 16 February 1976; 2, WAM 232/94, 18°47'S 117°58'E, 185 km north-west of Port Hedland, 154 m, 28 February 1982; 1, AMS C173531, 19°05.4–05.3'S 118°53.9–54.0'E, 136.90, north north-east of Port Hedland, 80 m, 30 October 1983.

Description. Shell length to 24.7 mm, aperture diameter 1.95, apex diameter 0.6; thin, moderately tapering, slightly curved. Sculpture of 6–9 raised, longitudinal ribs, those on the dorsal side, stronger and wider apart than those on the ventral side. Towards the aperture one or two interstitial riblets occur; interstices with densely packed, evenly spaced, longitudinal striae, faintly crossed by faint, transverse striae. Aperture polygonal. Apex polygonal, without slit or notch but sometimes with pipe. Colour white.

Range. South Australia, New South Wales, Queensland, Northern Territory and Western Australia.

Habitat. Dredged in sand and mud from 11 to 504 m.

Comparisons and remarks. *Dentalium thetidis* most closely resembles *D. duodecemcostatum* Brazier and *D. wellsi* n.sp., which also exhibit fine longitudinal striae within the interstices. Differentiating features of *D. duodecemcostatum* include: rapidly expanding aperture (less so in *D. thetidis*); generally heavier ribs (always 6 in number); more concave interstices. *Dentalium wellsi*

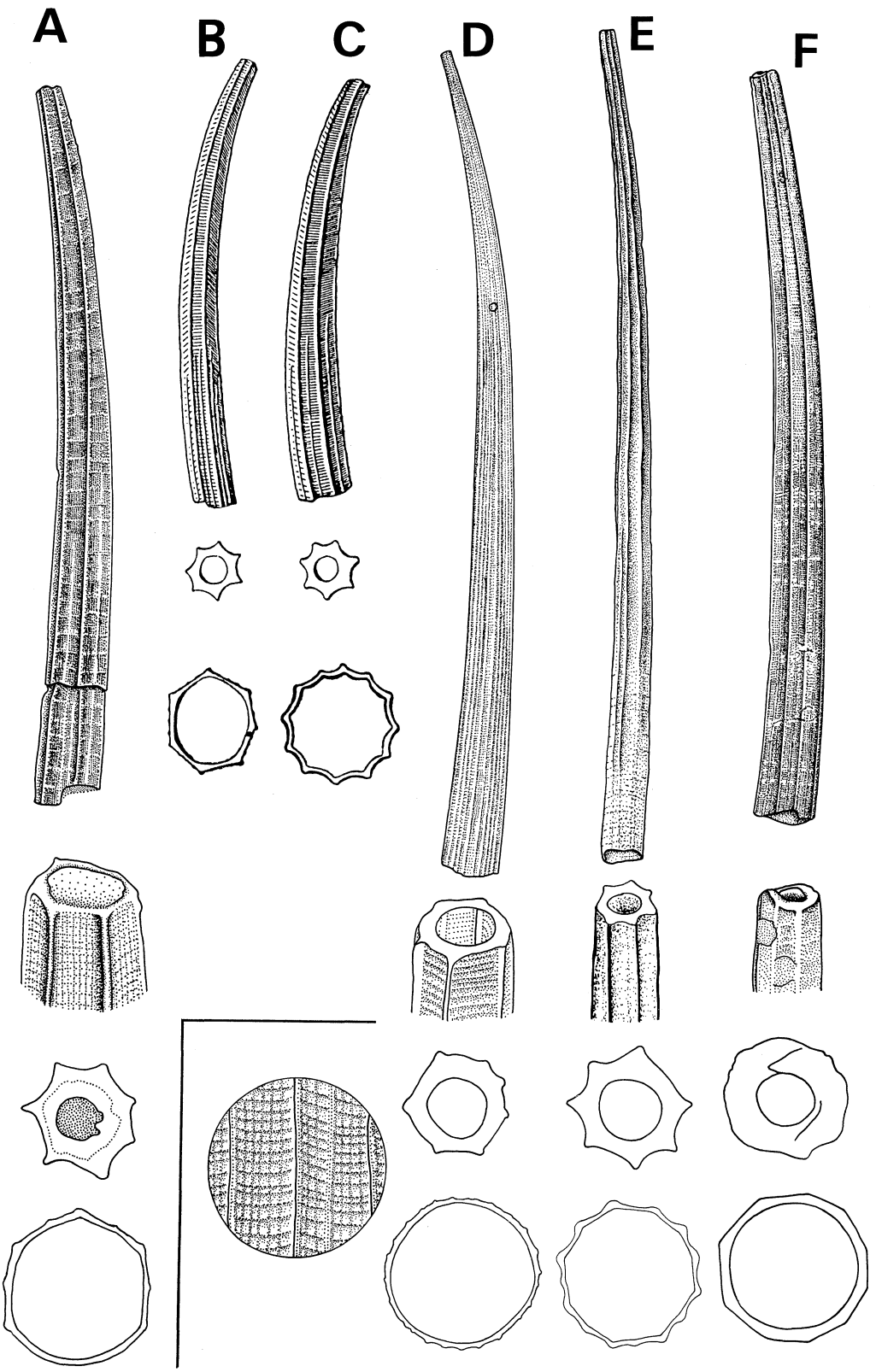


Figure 44. Dentaliida, Dentaliidae. **A–F** Group of *D. thetidis*. **A** *D. (D.) thetidis* Hedley, 1903 (AMS C172214, off north-east end of Moreton Bay, 140 m, length 17.0 mm; apex profile from holotype-AMS C16212, 12.8 km off Port Kembla, NSW, 116-137 m, length 7.7 mm). **B** *D. (D.) cheverti* Sharp & Pilsbry, 1897 (lectotype, AMS C170756, Evans Bay, Cape York, Qld, length 15.0 mm). **C** *D. (D.) katowense* Brazier, 1877 (holotype, AMS C170758, Katow, PNG, length 15.0 mm). **D** *D. (D.) wellsi* n.sp. (holotype, AMS C149930, 133 km north north-west of Dampier, WA, 110 m, length 46.2 mm). **E** *D. (D.) potteri* n.sp. (holotype, QM MO17888, 17°50.67'S 147°18.2'E, Qld, 703 m, length 38.2 mm). **F** *D. (D.) concretum* Colman, 1958 (holotype, AMS C62231, 43 km east of Sydney, 549 m, length 36.2 mm). (Del.: all A. Hill, except B and C from Hedley, 1901; A [aperture] and E [apex]—JMH).

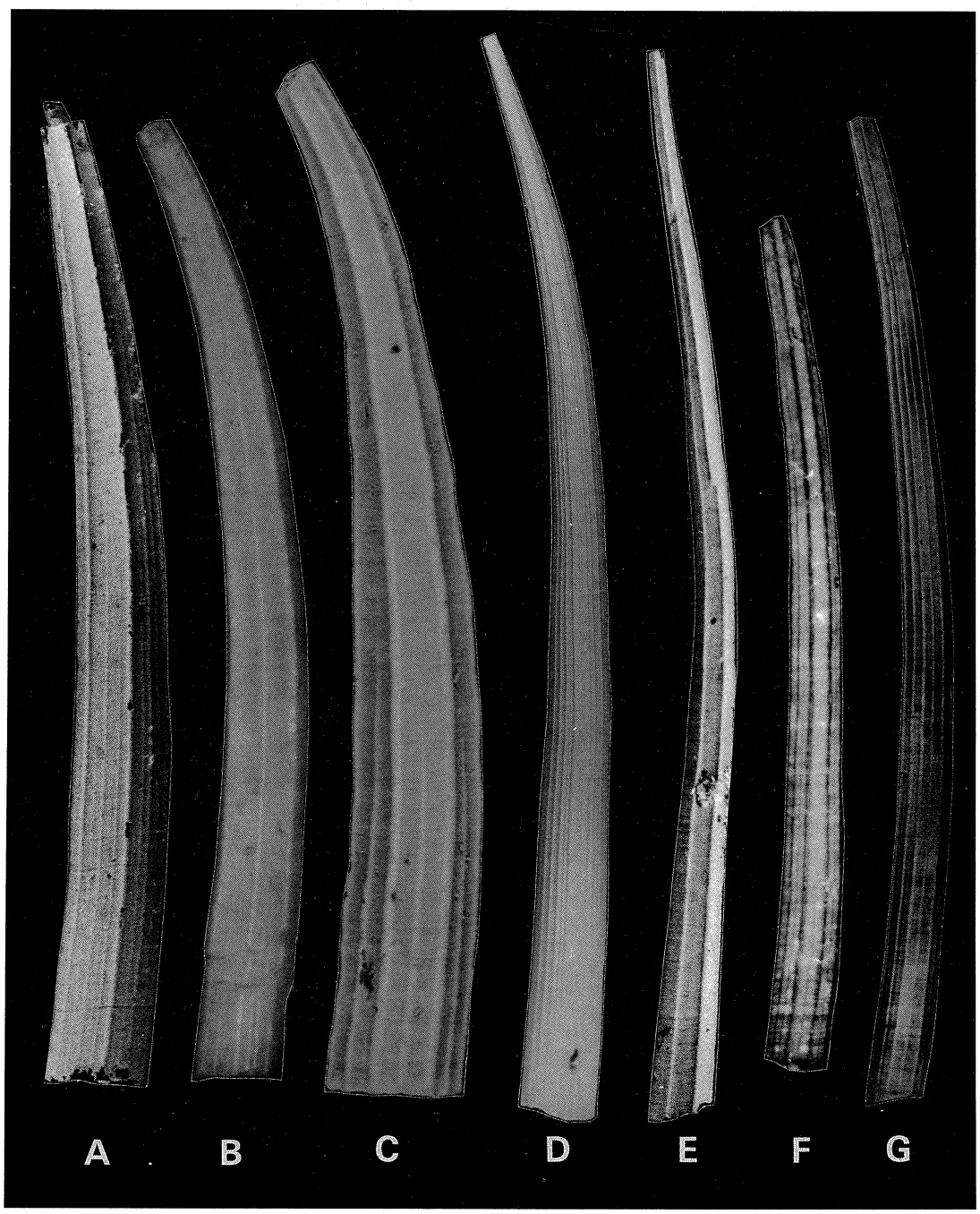


Figure 45. Dentaliida, Dentaliidae. Group of *D. thetidis*. **A** *D. (D.) thetidis* Hedley, 1903 (KLColl, Rottnest Island, WA, 150 m, length 22.3 mm). **B** *D. (D.) cheverti* Sharp & Pilsbry, 1897 (lectotype, AMS C170756, Evans Bay, Cape York, Qld, length 15.0 mm). **C** *D. (D.) katowense* Brazier, 1877 (holotype, AMS C170758, Katow, PNG, length 15.0 mm). **D** *D. (D.) wellsi* n.sp. (holotype, AMS C149930, 133 km north north-west of Dampier, WA, 110 m, length 46.2 mm). **E** *D. (D.) potteri* n.sp. (paratype, QM MO17766, Qld, 703 m, length 31.8 mm). **F,G** *D. (D.) concretum* Colman, 1958 (holotype, AMS C62231, 43 km east of Sydney, NSW, 549 m, length 36.2 mm. **G** *D. (D.) concretum* Colman, 1958 (KLColl, off Sydney NSW, 550 m, length 49.6 mm).

differs from *D. thetidis* in having numerous ribs at the aperture and usually stronger curvature. Habe (1964) regarded *D. thetidis* Hedley and *D. cheverti* Sharp & Pilsbry as synonyms of *D. intercostatum* (Boissevain) without offering any basis for this decision (Habe also without any apparent reason placed *D. intercostatum* into *Entalinopsis*—now a synonym of *Entalina*, Order Gadilida). *Dentalium cheverti* lacks any longitudinal striae within the interstices which are obvious in *D. thetidis* and *D. intercostatum*. During our examination of the types of *D. thetidis* and *D. intercostatum* we were unable to establish any feature which could separate these species. As Hedley's description of *D. thetidis* predates Boissevain's *D. intercostatum*, the name *D. thetidis* must take priority.

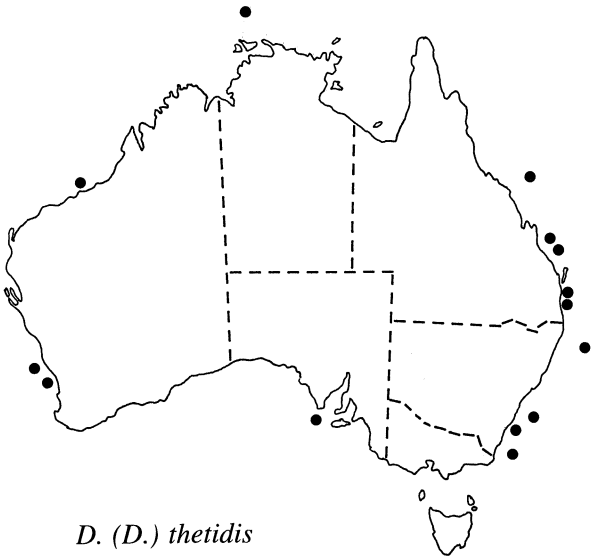


Figure 46. Known distribution of *Dentalium (Dentalium) thetidis* Hedley, 1903.

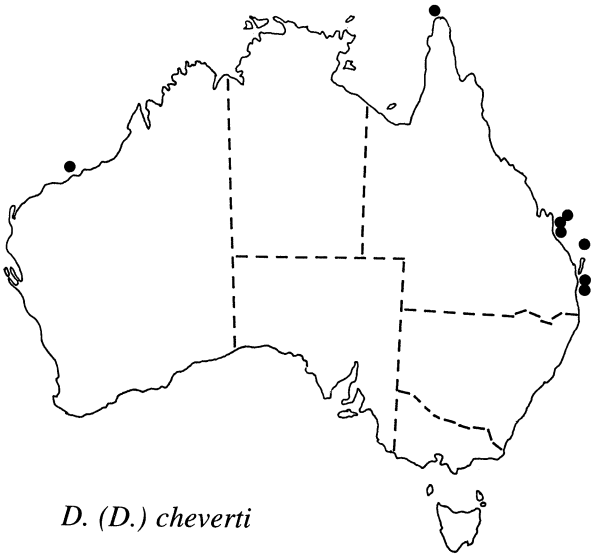


Figure 47. Australian distribution of *Dentalium (Dentalium) cheverti* Sharp & Pilsbry, 1897.

Dentalium (Dentalium) cheverti Sharp & Pilsbry, 1897

Figs 44B, 45B, 47

Dentalium cheverti Sharp & Pilsbry, *in* Pilsbry & Sharp, 1897: 9; Hedley, 1901: 129; Boissevain, 1906: 17; Hedley, 1910: 371.
Dentalium septemcostatum Brazier, 1877; 57, non Abich, 1859.

Type material examined. LECTOTYPE: selected by Ponder & Stanbury (1971) from AMS A96. Type locality: Evans Bay, Cape York, northern Qld. Length of lectotype 15.0 mm, aperture diameter 1.5 mm, apex diameter 0.75 mm. PARALECTOTYPES: 3, also AMS A96.

Additional material examined. QUEENSLAND: 11, AMS C172210, 21, AMS C172213, off Cape Moreton, 128–183 m; 4, AMS C172215, 26°34'S 153°40'E, east south-east of Noosa Heads, 128 m, 30 February 1969; 1, AMS C310411, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 1, AMS C173529, 23°52.5'S 152°42.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 31, AMS C173076, 23°08.4'S 152°12.3'E, north-east of North Reef, 115 m, 14 December 1977; 100, AMS C173077, off Yeppoon, 4 m; 2, AMS C173455, 23°08.6'S 152°16.6'E, Capricorn Channel, 155 m, fine sand and mud, 14 December 1977; 1, AMS C76450, Yeppoon; 1, AMS C15761, 10°42'S 141°31'E, beach about 24.1 km south-west of Cape York, 15 May, 1903; 1, AMS C63139, 10°45'S 142°37'E, Albany Passage, Cape York, 26 m, 1907. WESTERN AUSTRALIA: 1, WAM 142-93, 18°47'S 117°58'E, 185 km north-west of Port Hedland, 154 m, 28 February 1982.

Description. Shell length to 36.0 mm, aperture diameter 3.5 mm, apex diameter 1.8 mm; fragile, moderately curved. Sculpture of 7 sharp ribs, with secondary riblet in the interstices, extending from the midpoint of the shell to the aperture; interstices with fine transverse striae. Aperture polygonal. Apex polygonal, perforated with a minute notch on the dorsal side. Colour white.

Range. Queensland and northern Western Australia.

Habitat. Littoral to 4 m, dredged in sand to 296 m.

Comparisons and remarks. *Dentalium cheverti* resembles most closely *D. katowense* Brazier which is similar in shell curvature, size and sculpture. Features which help to differentiate *D. cheverti* from this species include: a narrower shell; presence of riblets within the interstices (versus a rib in *D. katowense*). Although we have examined many lots of scaphopods from Northern Territory during the course of this study, we found no specimens of *D. cheverti*. The apparent disjunct distribution of this species may simply reflect its scarcity (only one specimen recorded from Western Australia).

Dentalium (Dentalium) katowense Brazier, 1877

Figs 44C, 45C, 48

Dentalium katowense Brazier, 1877: 56; Pilsbry & Sharp, 1897: 9; Boissevain, 1906: 16; Hedley, 1901: 129, pl. 17, fig. 33.

Type material examined. HOLOTYPE: AMS C170758. Type locality: Katow, New Guinea, 8 fathoms [15 m]. Length of holotype 15.0 mm, aperture diameter 2.0 mm, apex diameter 1.0 mm.

Additional material examined. 1, Lamprell Collection, Pallarenda Beach, Townsville, Qld, alive on sand bar at low tide, 1992; 3, AMS C169793, Somerset, Cape York Peninsula, beach below old Residence site, 10 July 1976; 1, AMS C173370, 32 km off Port Charles, NT, 37 m, 14 July 1938; 1, AMS C173060, 8°48'S 134°58'E, 365 km north of Milingimbi, Arnhem Land, 100 m, 18 October 1969.

Description. Shell length to 16.9 mm, aperture diameter 2.4 mm, apex diameter 0.7 mm; thin, slightly curved.

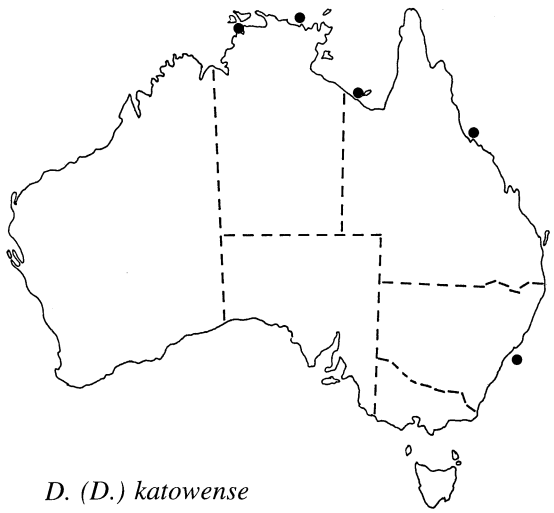


Figure 48. Australian distribution of *Dentalium (Dentalium) katowense* Brazier, 1877.

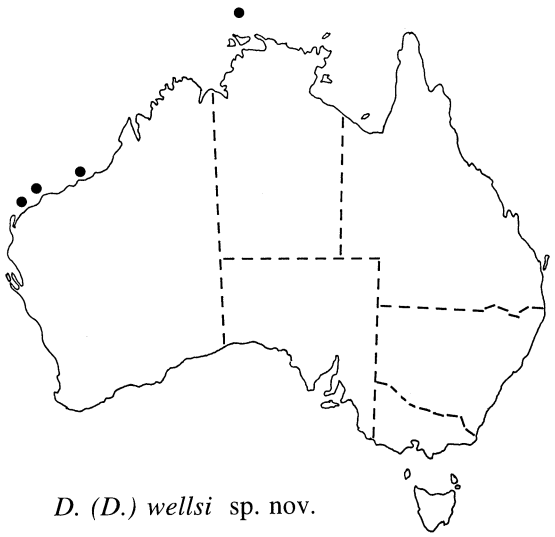


Figure 49. Known distribution of *Dentalium (Dentalium) wellsi* n.sp.

Sculpture of 7 strong longitudinal ribs at the apex with an additional rib developing by intercalation in the interstices from the midpoint of the shell to the aperture, making a total at the aperture of 14 ribs; interstices with dense, minute transverse striae. Aperture polygonal. Apex polygonal, orifice small. Colour white.

Range. Northern Queensland, New Guinea.

Habitat. Collected on sand bars at low tide and dredged in sandy mud and coral to 100 m.

Comparisons and remarks. *Dentalium katowense* resembles most closely *D. cheverti* Sharp & Pilsbry which is also moderately small and well curved. Features which differentiate *D. katowense* from this species include: more widely expanded aperture; presence of an intercalating rib in the interstices (versus riblets in *D. cheverti*). *Dentalium potteri* n.sp. and *D. concretum* Colman differ from *D. katowense* in being long, narrow and weakly curved to almost straight. *Dentalium thetidis* Hedley and *D. wellsi* n.sp. can be distinguished from *D. katowense* by their fine longitudinal interstitial striae. In addition *D. wellsi* has numerous intercalating ribs at the aperture. On examination of the holotype we have found that Hedley's original drawing of the aperture profile (see Fig. 44B) should be disregarded as it shows a circular aperture with scalloped interstices. In reality the aperture of the holotype is 7 sided with relatively flat interstices and ribs placed at each angle and one within each interstice.

Dentalium (Dentalium) wellsi n.sp.

Figs 44D, 45D, 49

Etymology. Named after Dr Fred Wells of the Western Australian Museum who collected many lots of material examined in this study and also for his assistance with previous projects.

Type material examined. HOLOTYPE: AMS C149930. Type locality: 133 km, north north-west of Dampier, WA, 19°28.9–29.0'S 116°29.4–29.0'E, 110 m, 26 October 1983. Length of holotype 46.2 mm, aperture diameter 3.4 mm, apex diameter 0.7 mm. PARATYPES: 2, AMS C172572, 19°00.8'S 118°01.3'E, 157 km north north-west of Port Hedland, WA, 112 m, sand/silt, 29 October 1983; 2, AMS C172573, same data as holotype; 4, WAM 142-93, 18°47'S 117°58'E, 185 km north-west of Port Hedland, WA, 154 m, 28 February 1982.

Additional material examined. WESTERN AUSTRALIA: 4, WAM 47-93, off Long Island, Onslow, 17 June 1960; NORTHERN TERRITORY: 3, AMS C311670, 9°17.5'S 132°20'E, Arafura Sea, 168 m, 10 November 1969.

Description. Shell length to 50.1 mm, aperture diameter 3.2 mm, apex diameter 0.7 mm; slightly curved, moreso toward the apex. Sculpture at the apex of 7 strong, slightly raised rounded ribs, which increase in number through intercalation in the interstices to 32 low, rounded ribs at the aperture; interstices with dense transverse striae and fine longitudinal striae. Aperture circular, finely crenulated by ribs. Apex polygonal, without slit or notch. Colour translucent white.

Range. Northern Territory to northern Western Australia.

Habitat. Dredged from 110 to 168 m in sand/silt.

Comparisons and remarks. *Dentalium wellsi* resembles most closely *D. thetidis* Hedley and *D. duodecemcostatum* Brazier in exhibiting fine longitudinal striae within the interstices. Differentiating features of *D. wellsi* include: much greater length; greater rib numbers (7 at apex increasing to 32 at aperture). Similarly, *Dentalium wellsi* can be readily distinguished from other members of the *D. thetidis* group by its high rib count at the aperture. Specimens of *D. wellsi*, even within the one lot, showed substantial variation in curvature especially near the

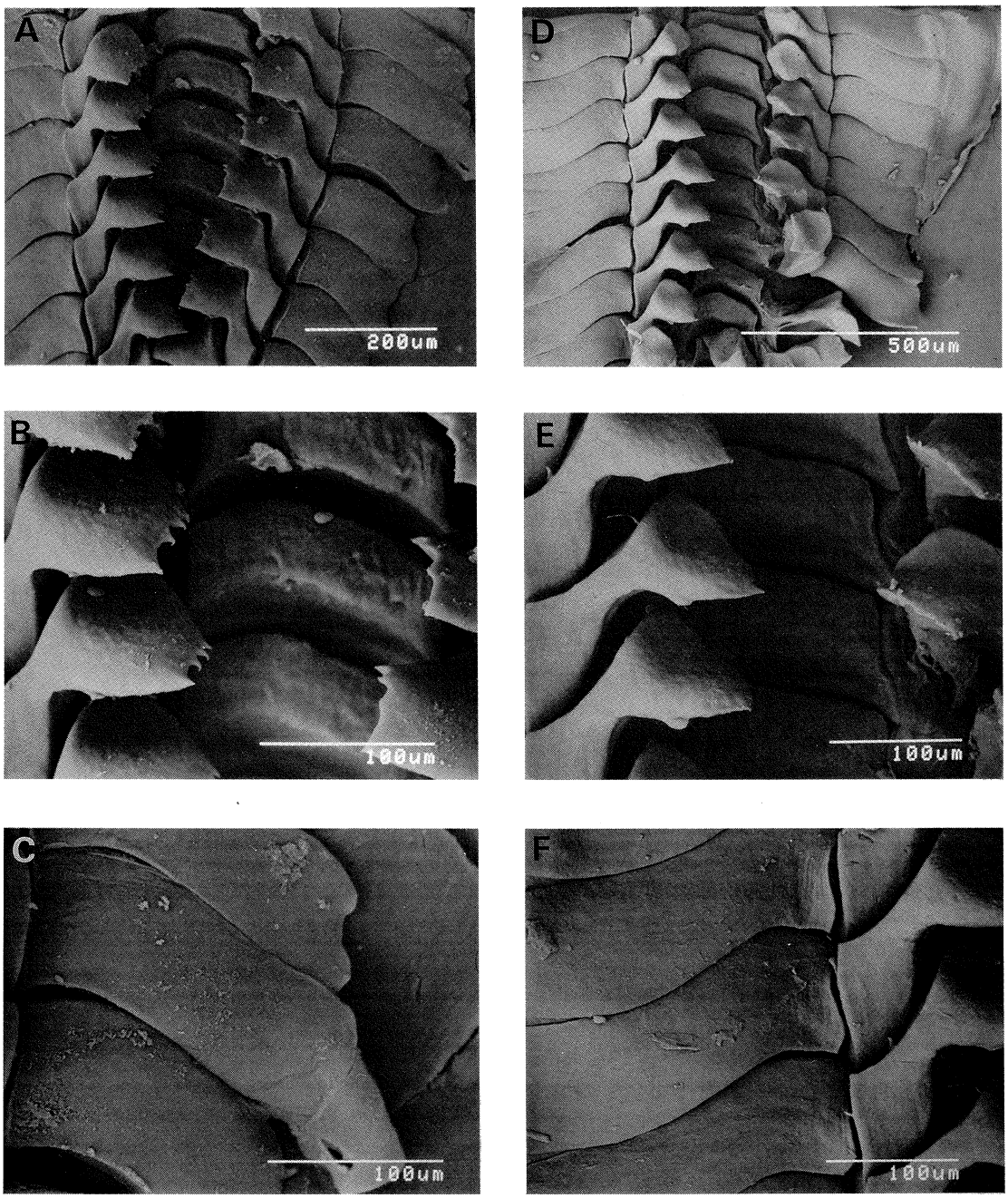


Figure 50. Radular ultrastructure of: **A–C** *Dentalium (Dentalium) potteri* n.sp. (from holotype, North Qld, 17°50.67'S 147°18.2'E, 703 m, QM MO17888). **D–F** *Dentalium (Dentalium) concretum* Colman, 1958 (E of Tathra-Bermagui, NSW, 390 m, AMS C173305).

apex. Also, depending on what proportion of the apex has been shed with age, rib number may also vary somewhat. Nevertheless the sculptural features of this species are consistent and readily observable.

Dentalium (Dentalium) potteri n.sp.

Figs 44E, 45E, 50A–C, 51

Etymology. Named after Mr Daryl Potter of the Malacology Section of the Queensland Museum for his assistance in this project.

Type material examined. HOLOTYPE: QM MO17888. Type locality: off Cairns, northern Queensland, 17°50.67'S

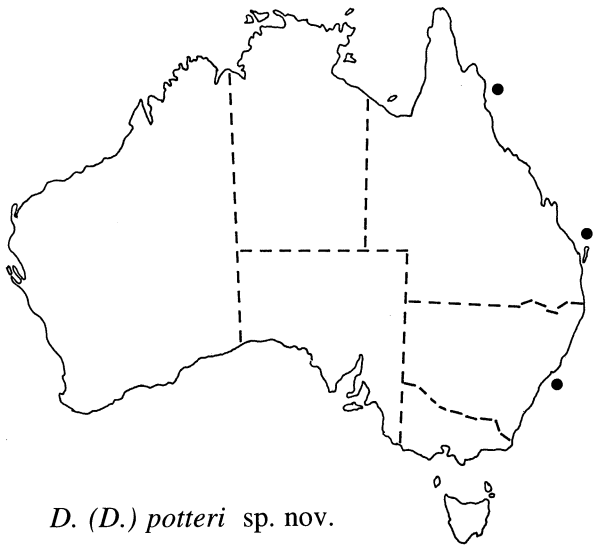


Figure 51. Known distribution of *Dentalium (Dentalium) potteri* n.sp.

147°18.2'E, 703 m, 17 May 1986 (preserved). Length of holotype 38.2 mm, aperture diameter 2.1 mm, apex diameter 0.6 mm. PARATYPES: 5, QM MO17732, same data as holotype; 1, QM MO17766, 2, AMS C201739, 17°51'S 147°18'E, northern Qld, 703 m, 17 May 1986.

Additional material examined. 28, AMS C173066, 24°00'S 153°06.5'E, east of Lady Elliot Island, Qld, 531 m, 17 November 1977; 1, QM MO17641, 704 m, 18 May 1986; 1, AMS C163402, east of Broken Bay, NSW, 33°46–44'S 151°49–50'E, 410–506 m, 9 September 1981.

Description. Shell length to 40.0 mm, aperture diameter 2.0 mm, apex diameter 0.7 mm; moderately fragile, slightly curved, often crooked in appearance, moderately tapering. Sculpture of 7 strong longitudinal ribs at the apex with an additional rib developing irregularly in the interstices, becoming 11–14 equal size, low, rounded ribs at the aperture, interstices wide, moderately concave with dense transverse striae. Aperture circular: externally, crenulated by 11–14 ribs; internally, profile polygonal. Apex polygonal, without slit or notch. Colour glossy white when live, chalky white when dead.

Radula. Central tooth broad (145 μm wide) and moderately shallow with smooth, convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped, 170 μm long with small cusps on the working surface; marginals curved to weakly sigmoidal, relatively short and broad (length 200 μm × breadth 85 μm) (see Fig. 50A–C). Ratios C:L = 1:1.17, L:M = 1:1.18, marginals breadth:length 1:2.35 (based on female).

Range. Central New South Wales to northern Queensland.

Habitat. Dredged from 410 to 704 m in sand.

Comparisons and remarks. *Dentalium potteri* resembles most closely *D. concretum* Colman in being long, slightly to weakly curved and slowly tapering. Differentiating features of *D. potteri* which separate it from *D. concretum* and other 7–ribbed Australian *Dentalium* species include: a delicate, extremely narrow shell commonly showing a crooked twist posteriorly; rib count (7 at apex intercalating to 11 to 14 at aperture); ribs showing tendency to become obsolete at the aperture (only in very mature specimens). This is an interesting and distinctive species, to date only recorded from deep water from off the central New South Wales coast to tropical Queensland.

Dentalium (Dentalium) concretum Colman, 1958

Figs 44F, 45F,G, 50D–F, 52

Dentalium concretum Colman, 1958: 141, pl. 1, fig. 2; Iredale & McMichael, 1962: 96.

Type material examined. HOLOTYPE: AMS C62231. Type locality: 43 km east of Sydney, NSW, 549 m. Length of holotype 36.2 mm, aperture diameter 2.8 mm, apex diameter 1.3 mm. PARATYPES: 11, AMS C170638, 43 km off Sydney, NSW.

Additional material examined. NEW SOUTH WALES: 5, AMS C173005, 36°43–36'S 150°19–20'E, east of Tathra-Bermagui, 390 m, 22 July 1975; 8, AMS C173009, 34°50'S 151°13'E, off Nowra, 550 m, 12 December 1978; 4, NMV F75840, 34°51.90'S 151°12.60'E, off Nowra, 770 m, 15 July 1986; 3, NMV F72165, 34°57.90'S 151°08.00'E, off Nowra, 503 m, 14 July 1986; 12, AMS C173395, 33°42–39'S 151°52–54'E, off Sydney, 457 m, 20 December 1976; 18, AMS C172995, 34°50'S 151°13'E, off Sydney, 550 m, 12 December 1978; 4, AMS C172996, 33°48'S 151°52'E, east of Sydney, 550 m, 3 December 1979; 14, AMS C172181, 34°05'S 15°43.6'E, off Sydney, 750 m, 3 November 1976, sandy mud and fine shell; 4 juveniles, AMS C172183,

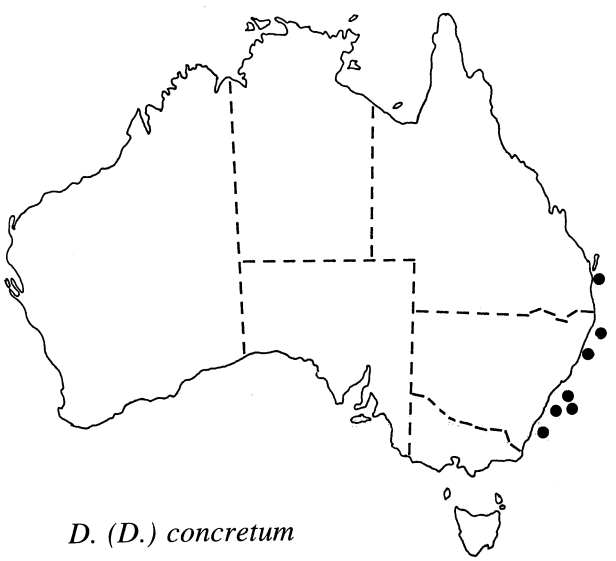


Figure 52. Known distribution of *Dentalium (Dentalium) concretum* Colman, 1958.

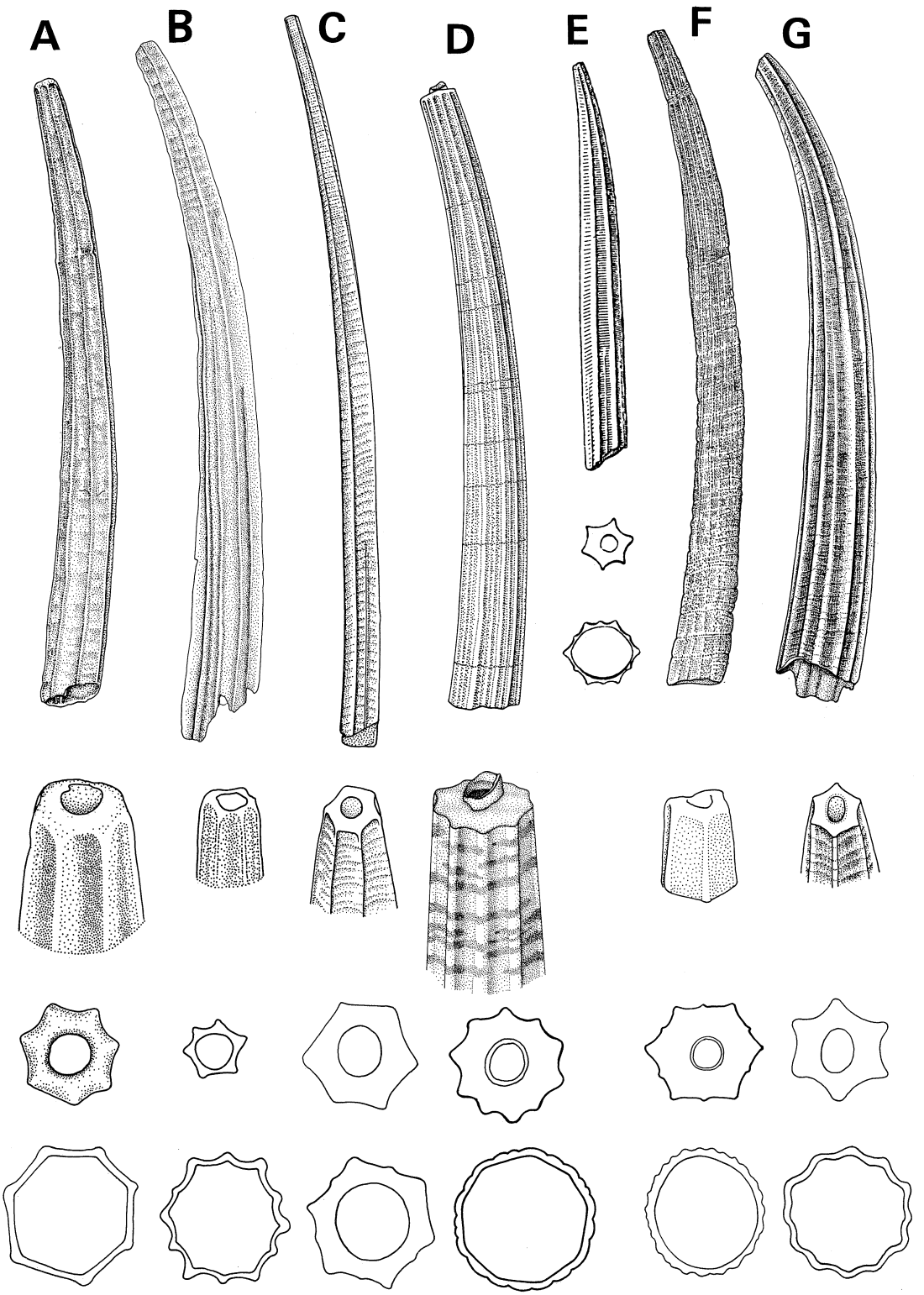


Figure 53. Dentaliida, Dentaliidae. *Dentalium (Dentalium)*. **A–C** Group of *D. hexagonum*. **A** *D. (D.) hexagonum* Gould, 1859 (AMS C14578, White Cliffs, east coast Mornington Island, Qld length 16.9 mm). **B** *D. (D.) sexcostatum* Sowerby, 1860 (QM MO40088, off Cairns, northern Qld, 303 m, juvenile, length 7.0 mm). **C** *D. (D.) hillae* n.sp. (holotype, AMS C169776, south-west of Scott Reef, 410 km north of Broome, WA, 500 m, length 47.7 mm). **D–G** Group of *D. intercalatum*. **D** *D. (D.) intercalatum* Gould, 1859 (KLColl, Port Lincoln, SA, length 30.4 mm). **E** *D. (D.) duodecemcostatum* Brazier, 1877 (holotype, AMS C170764, Darnley Island, Torres Strait, 50 m, length 21.5 mm). **F** *D. (D.) pseudosexagonum* Deshayes, 1825 (paralectotype, MNHN, locality unknown, length 27.0 mm). **G** *D. (D.) flindersi* Cotton & Ludbrook, 1938 (holotype, SAM D.13338, length 21.0 mm). (Del.: all A. Hill, except: D [apex profile], F [apex profile]—JMH; D [other figures]—C. Eadie; E from Hedley, 1901).

Figure 54. Dentaliida, Dentaliidae. *Dentalium (Dentalium)*. **A–C** Group of *D. hexagonum*. **A** *D. (D.) hexagonum* Gould (holotype, USNM Smithsonian Inst. No. C.2053, Hong Kong, length 42.9 mm). **B** *D. (D.) sexcostatum* Sowerby, 1860 (QM MO40088, northern Qld, 303m, length 10.0 mm). **C** *D. (D.) hillae* n.sp. (holotype, AMS C169776, south-west of Scott Reef, 410 km north of Broome, WA, 500 m, length 47.7 mm). **D,E** Group of *D. intercalatum*. **D** *D. (D.) intercalatum* Gould, 1859 (KLColl, Port Lincoln, SA, length 30.4 mm). **E** *D. (D.) intercalatum* Gould, 1859 (holotype, USNM24183, "China Seas", length 18.9 mm).

34°08'S 151°34'E, off Sydney, 457 m, 13 December 1978; 1, AMS C173402, 33°46–44'S 151°49–50'E, east of Broken Bay, 506 m, 9 September 1981; 8, AMS C173319, 29°41–32'S 153°45–47'E, south-east of Clarence River, 405 m, 10 October 1975 (preserved); 38, AMS C173307, 32°42'S 152°08'E, Duck Hole Bay, Port Stephens, 6 m, in mud, 26 October 1980 (preserved); 1, AMS C1721?, off Jervis Bay, 400–1000 m, in canyon, October-November 1980. QUEENSLAND: 1, AMS C173369, 26°47'S 153°35'E, off Caloundra, 140 m, 30 February 1969.

Description. Shell length to 56.9 mm, aperture diameter 2.95 mm, apex diameter 1.3 mm; solid, weakly curved to almost straight. Sculpture of 7–9 prominent, longitudinal ribs with 2–3 riblets in the interstices; interstices with faint irregular growth lines; external sculpture not visible internally. Aperture polygonal. Apex polygonal, without slit or notch; colour dull white.

Radula. Central tooth broad (177 μm wide) moderately shallow with smooth, weakly convex to almost straight superior surface and correspondingly weakly concave inferior surface; laterals dumbbell shaped, 200 μm long with small cusps on the working surface; marginals sigmoidal and moderately short (length 233 μm × breadth 96 μm) (see Fig. 50D–F). Ratios C:L = 1:1.12, L:M = 1:1.17, marginals breadth:length 1:2.42 (based on male).

Range. New South Wales to southern Queensland.

Habitat. Dredged from 6 to 1000 m in mud and sand.

Comparisons and remarks. *Dentalium concretum* resembles most closely *D. potteri* n.sp. in having a narrow, weakly curved shell profile. Differentiating features of *D. concretum* include: a thicker shell; ribs not visible internally at aperture; rib count 7–9 throughout, supplemented by riblets in interstices. Compared with the other species in the *D. thetidis* Group, *D. concretum* is long, slowly tapering and less curved. *Dentalium concretum* was originally described by Colman (1958) as having 9 principal ribs at the apex. Although the holotype has 9 ribs, the paratype lot AMS C170638 has two specimens with 9 ribs one with 8 and one with 7 ribs. Similarly, variation in rib number was encountered in other lots (AMS C172996, all four specimens with 7 ribs; AMS C172181 three specimens with 8 ribs; AMS C173369, one specimen with 8 ribs; lot AMS C172995 containing eighteen specimens has one with 9 ribs, seven with 8 ribs and ten with 7 ribs).

Key to Group of *Dentalium hexagonum*

Six strong ribs at apex, continuing undiminished to aperture; apex and aperture hexagonal; interstices with or without riblets; apex without slit or notch.

1 Shell moderately to strongly curved; aperture narrow to moderately wide 2

—— Shell almost straight; aperture exceptionally narrow ..... *D. hillae*

2 Shell moderately curved; interstices smooth ..... *D. hexagonum*

—— Shell strongly curved; interstices with one or two riblets ..... *D. sexcostatum*

Dentalium (Dentalium) hexagonum Gould, 1859

Figs 53A, 54A, 55

Dentalium hexagonum Gould, 1859: 166; G.B. Sowerby, 1860: pl. 223, f.10; G.B. Sowerby, 1872: pl. 2, f.6; Pilsbry & Sharp, 1897: 18, pl. 2, figs 20–24; Boissevain, 1906: pl. 1, fig. 14, pl. 6, fig. 1; Hedley, 1910: 371.

Type material examined. HOLOTYPE: USNM C2053. Type locality: Hong Kong. Length of holotype 42.9 mm, aperture diameter 4.0 mm, apex diameter 0.7 mm.

Additional material examined. QUEENSLAND: 2, AMS C172196, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 1, AMS C14578, 16°31'S 139°30'E, Mornington Island, 19–24 June 1903. NORTHERN TERRITORY: 1, AMS C172252, 8°41'S 133°12'E, 295 km north of Goulburn Island, 196 m, 6 November 1969; 1, AMS C172194, off Point Charles, Darwin; 1, AMS C172195, Darwin; 2, AMS C172197, Port Darwin; 1, WAM 260-93, 123 km off Nightcliff, Darwin, 5 June 1986. WESTERN AUSTRALIA: 7, AMS C301594, Joseph Bonaparte Gulf, 14°33.6'S 128°40.8'E, 16 m, 28 September 1980; 2, AMS C301614, Joseph Bonaparte Gulf, 14°45.6'S 128°17.9'E, 25 m, 9 June 1979; 3, AMS C301600, north-west of Rottnest Island, 31°45'S 115°02'E, 265–276 m, 18 February 1979.

Description. Shell length to 42.9 mm, aperture diameter 4.0 mm, apex diameter 0.7 mm; thin, smooth, moderately curved. Sculpture of 6 strong, rounded, longitudinal ribs from apex to aperture; interstices smooth with irregular growth lines only. Aperture hexagonal. Apex hexagonal, without slit or notch. Colour off-white.

Range. Hong Kong, Singapore, Japan (all Pilsbry & Sharp, 1897), Queensland, Northern Territory and Western Australia.

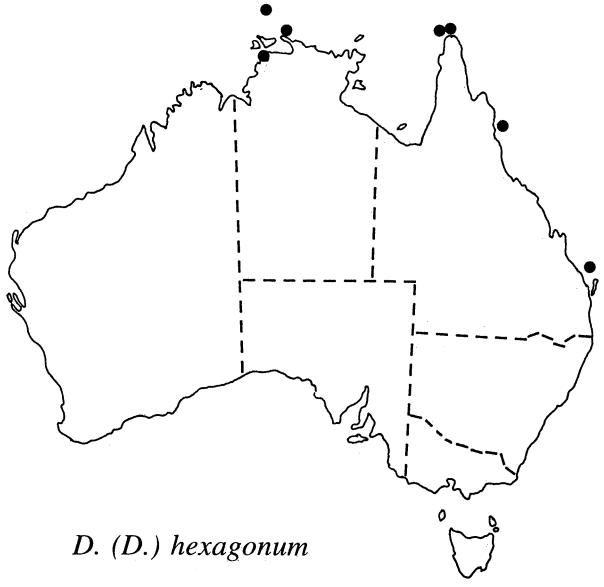


Figure 55. Australian distribution of *Dentalium (Dentalium) hexagonum* Gould, 1859.

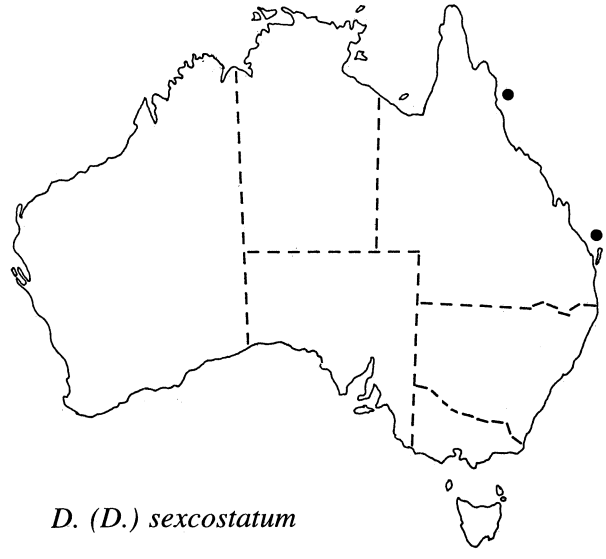


Figure 56. Australian distribution of *Dentalium (Dentalium) sexcostatum* Sowerby, 1860.

Habitat. Dredged from 16 to 296 m, in fine, yellow grey mud.

Comparisons and remarks. *Dentalium hexagonum* resembles most closely *D. sexcostatum* G.B. Sowerby in the 6 angled profile. Differentiating features of *D. hexagonum* include: absence of interstitial sculpture; less pronounced curvature; narrower aperture. *Dentalium hexagonum* has been placed in synonymy with *D. octangulatum* by some other authors (e.g., Habe, 1964). For comparison with that species and further discussion see p. 45 in the present work. *Dentalium hexagonum* differs from *D. hillae* n.sp. in having a much more strongly curved shell and lacking the interstitial riblet of that species.

Dentalium (Dentalium) sexcostatum G.B. Sowerby, 1860

Figs 53B, 54B, 56

Dentalium sexcostatum G.B. Sowerby, 1860: 103, pl. 223, fig. 11.

Dentalium hexagonum sexcostatum Pilsbry & Sharp, 1897: 19, pl. 2, figs 27–28; Boissevain, 1906: 13, pl. 6, fig. 2.

Type material. The holotype of this species—presumably deposited in the BMNH—cannot be located (Ms K. Wade, BMNH, pers. comm.). Type locality: China.

Additional material examined. 1, AMS C310410, 23°42.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, Qld, 296 m, 7 July 1984; 5, QM MO40088, 17°22'S 146°48'E, northern Qld, 303 m, 15 May 1986; 3, AMS C173418, 17°09.48–09.30'S 146°42.36'E, off Cairns, 329 m, 11 October 1981; 1, AMS C172193, mouth of Caiman Creek, Berkeley Bay, Port Essington, Cobourg Peninsula, NT, on sand bank, 2 June 1976.

Description. Shell length to 62.0 mm, aperture diameter 5.0 mm (Pilsbry & Sharp, 1897); slender, well curved, moreso towards the apex. Sculpture of 6 strong, projecting, longitudinal ribs from apex to aperture supplemented by a rib or more typically a riblet within the interstices at the aperture. Aperture hexagonal. Apex hexagonal, without slit or notch. Colour off-white.

Range. Japan (Pilsbry & Sharp, 1897), China (G.B. Sowerby, 1860), Queensland and Northern Territory.

Habitat. Littoral mud, Northern Territory and dredged from 296 to 303 m, in coarse sand.

Comparisons and remarks. *Dentalium sexcostatum* resembles most closely *D. hexagonum* Gould in the 6 angled profile. For differentiating features, see previous species. This species has been nominated as a variety of *D. hexagonum* by Pilsbry & Sharp (1897) who were of the opinion that *D. hexagonum* and *D. sexcostatum* intergrade. Unfortunately we have been unable to examine the type of *D. sexcostatum* (see reference under type material). The specimens which we have examined, although very juvenile, answer well to the original description of *D. sexcostatum* and cannot be regarded as juvenile *D. hexagonum*. Comparison of the two species show that *D. hexagonum* is markedly narrower anteriorly than *D. sexcostatum* and lacks any interstitial ribbing. *Dentalium sexcostatum* bears some similarity to *D. flindersi* Cotton & Ludbrook but that species is thicker-shelled and always exhibits intercalating ribs rather than riblets (typically only riblets in the interstices of *D. sexcostatum*). Within the Australian region this species is known from Queensland (Lady Musgrave Island to Cairns) and the Northern Territory (Caiman Creek).

Dentalium (Dentalium) hillae n.sp.

Figs 53C, 54C, 57

Etymology. Named after Alison Hill, our chief artist during this study for her many superb illustrations of Australian scaphopods.

Type material examined. HOLOTYPE: AMS C169776. Type locality: south-west of Scott Reef, 410 km north of Broome, northern WA, 14°39'S 121°29'E. 500 m, trawled, 11 February 1984. Length of holotype 47.7 mm, aperture diameter 2.8 mm, apex diameter 0.8 mm.

Description. Shell length to 47.7 mm, aperture diameter 2.8 mm, apex diameter 0.8 mm; very slightly curved, thin, slowly tapering; Sculpture of 6 narrow, raised, rounded longitudinal ribs with one obscure longitudinal rib in each interstice near the aperture; interstices with dense, microscopic, longitudinal and transverse striae. Aperture hexagonal. Apex hexagonal, entire. Colour white.

Range. South-west of Scott Reef, north of Broome, Western Australia.

Habitat. Dredged to 500 m in coarse sand.

Comparisons and remarks. *Dentalium hillae* resembles most closely *D. hexagonum* Gould in its 6 angled profile. Differentiating features include: more slowly tapering; almost straight with a single riblet in each interstice.

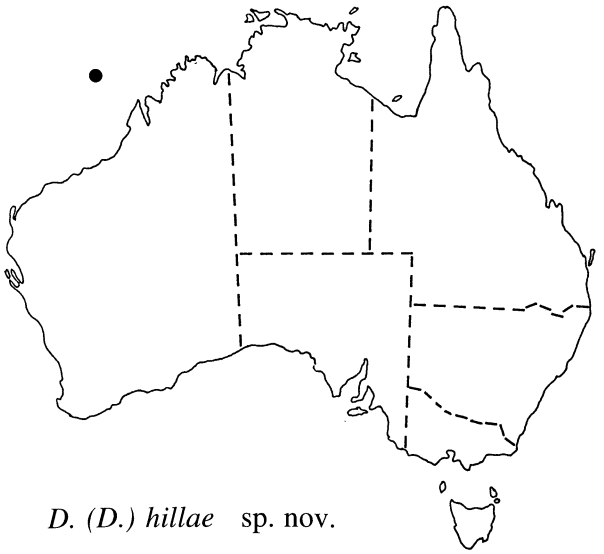


Figure 57. Known distribution of *Dentalium (Dentalium) hillae* n.sp.

Dentalium hexagonum is more curved and lacks any interstitial ribbing, while *D. sexcostatum* is more strongly curved and has longitudinal interstitial striae in addition to an interstitial riblet. Further collecting will be required to establish the range of this species and its abundance (currently known only from the holotype). For the present this appears to be a rare and restricted locality species.

Key to Group of *Dentalium intercalatum*

Six to nine ribs at apex increasing in number through intercalation towards the aperture.

1 Shell moderate to strongly curved; aperture profile rounded 2

—— Shell weakly curved; aperture profile hexagonal ..... *D. duodecemcostatum*

2 Shell rapidly tapering; ribs thick, strong 3

—— Shell slowly tapering; ribs narrow, fine ..... *D. pseudosexagonum*

3 Aperture ribs raised; aperture internally crenulated ..... *D. flindersi*

—— Aperture ribs low; aperture internally smooth but angled ..... *D. intercalatum*

Dentalium (Dentalium) intercalatum Gould, 1859

Figs 53D, 54D,E, 58, 59A–D

Dentalium intercalatum Gould, 1859: 166; G.B. Sowerby, 1872: pl. 7, fig. 45; Pilsbry & Sharp, 1897: 23, pl. 11, figs 88, 89; Verco, 1904: Boissevain, 1906: 22, pl. 1, fig. 9; Rippingale & McMichael, 1961: 160.

Dentalium octagonum Angas, 1878, non *octogonum* Lamarck, 1818: 868.

Dentalium bednalli Pilsbry & Sharp, 1897: 248, pl. 39, figs 88, 89; Cotton & Godfrey, 1940: 323.

Type material examined. HOLOTYPE: USNM 24183. Type locality: China Seas. Length of holotype 18.9 mm, aperture diameter 2.2 mm, apex diameter 0.9 mm. PARATYPE MCZ169197 ex NYSM 148, original no. G2408. TOPOTYPE 1, AMS C6970, *D. bednalli* South Australia.

Additional material examined. SOUTH AUSTRALIA: 11, NMV F67461, St Vincents Gulf, 29 October 1963; 8, USNM 251990, St Vincents Gulf, 30–44 m; 7, AMS C33483, St Vincents Gulf, 27–40 m, 1912; 1, AMS C33486, (as *D. katowense*) St Vincents Gulf, 30–40 m; 2, AMS C33490, (as *D. decemcostatum*) 30–44 m, off St Vincents Gulf; 6, SAM D18856, Cape Donnington,

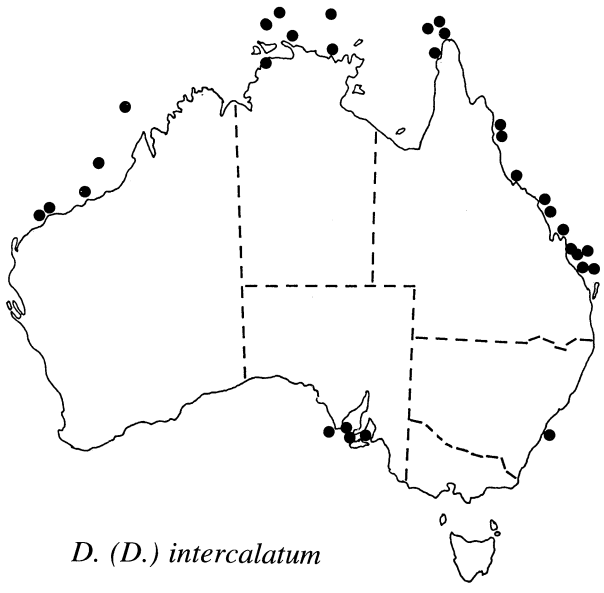


Figure 58. Australian distribution of *Dentalium (Dentalium) intercalatum* Gould, 1859.

Port Lincoln, 18 m; 12, SAM D18857, Rotten Bay to Haydon Reef, Boston Island; 5, SAM D18858, Yorke Peninsula, Port Moorowie, in sand pockets on reef, 6 m, 29 February 1986 (preserved); 1, SAM D18859, Yorke Peninsula, Port Moorowie, in sand pockets on reef, 7.5–9 m, 3 January 1988 (preserved); 3, SAM D18860, Yorke Peninsula, Port Moorowie, Point Gilbert in sand pockets on reef, 7.5–9 m, 18 April 1987 (preserved). NEW SOUTH WALES: 2, AMS C172257, dredged off North Head, Sydney. QUEENSLAND: 12, AMS C172565, 23°38.8'S 152°45.5'E, north-east of Lady Musgrave Island, 365 m, *Globigerina* mud, 14 December 1977; 1, AMS C311871, 21°58.5'S 150°45'E, east of Broad Sound, 57 m, coarse to fine sand, 18 November 1977; 6, AMS C172261, off Yeppoon, 4 m; 1, AMS C172267, Yeppoon, August 1952; 3, AMS C172560, One Tree Island, Capricorn Group, 55 m; 2, AMS C173607, 23°18'S 151°42'E, North West Island, Capricorn Group, May 1931; 1, AMS C172249, Heron Island, Capricorn Group, 15 m; 2, AMS C172263, Facing Island, Port Curtis; 1, AMS C172268, Tannum Sands, beach sand, 22 December 1976; 1, AMS C172251, Tannum Sands; 1, AMS C172239, 23°49'S 151°17'E, Quoin Island, Port Curtis, 2–5.5 m; 1, AMS C172255, Brampton Island, north of Mackay, in sand on beach; 2, AMS C172254, off Shaw Island, 37 m, 4 September 1935; 20, AMS C172245, Bowen; 1, AMS C172259, Dingo Beach, Bowen; 1, AMS C172260, Bowen, (figured by Rippingale & McMichael, 1961); 5, AMS C172258, Edgecombe Bay, Bowen; 1, AMS C172256, Edgecombe Bay, Bowen, 1935; 2, AMS C172270, Edgecombe Bay, Bowen, 1935; 4, AMS C172269, Port Denison Beach; 1, Pallarenda Beach, Townsville, live on sand bar at low tide, 28 August 1962; 1, AMS C172556, 22°42'S 151°37'E, north-east of Rockhampton, 68 m, 20 September 1970; 1, AMS C173410, 17°09.42–09.36'S 146°42.24–42.00'E, off Cairns, 668 m, 13 October 1981; 1, QM MO53673, 17°22'S 146°48'E, 296–303 m, 15 May 1986; 3, AMS C76445, 4 Mile Beach, Port Douglas, July 1964; 1, AMS C15762, 20 km south-west of Cape York, 10°42'S 141°31'E, Beach, 15 May 1903; 1, AMS C172266, Somerset Bay, Cape York Peninsula, under rocks, 10–13 July 1976; 20, AMS C14268, Mapoon; 1, AMS C172265, 10°38'S 142°35'E, east of Banks Island, Torres Strait, 18 m, 23 September 1968; 2, AMS C172272, Friday Island, Torres Strait. NORTHERN TERRITORY: 6, AMS C172271, beach below Crocodile Research Station, Maningrida, Arnhem Land, beach and rocks, 5 June 1976; 1, AMS C172250, 12°03'S 134°13'E, Maningrida, mudflats off beach, 27 February 1980; 1, AMS C172241, sandbar Darwin, 8 October 1971; 1, AMS C172237, 7, AMS C172262, sandbar No 1, Darwin, 14 November 1970; 1, NMV F67453, East Point, Darwin, September 1907; 1, AMS C172238, 12°22'S 130°37'E, off Point Charles Darwin; 6, AMS C172551, on sandbar off Emery Point, Darwin, 25 October 1969; 1, AMS C173081; 1, AMS C172246, 10°17'S 132°38'E, Arafura Sea, approx 64 km north of Croker Island, 65 m, 9 November 1969; 1, AMS C172253, 8°26'S 135°22'E, 321 km north-west of Wessel Island, Arnhem Land, 75 m, 13 October 1969. WESTERN AUSTRALIA: 2, AMS C172264, 18°00'S 118°56'E, 366 km west of Broome, 261 m, 6 November 1968; 1, AMS C172248, 14°07'S 122°52'E, north of Cape Levique, 256 m, 17 November 1967; 1, AMS C172247, 19°26'S 117°14'E, 164 km north-west of Port Hedland, 91 m, 21 November 1968; 1, AMS C172577, Gidley Island, Dampier Archipelago, 30 October 1945; 3, AMS C172562, 19°28.9–29.0'S 116°29.4–29.0'E, 133 km north north-west of Dampier, 110 m, 26 October 1983.

Description. Shell length to 30.4 mm, aperture diameter 3.3 mm, apex diameter 2.0 mm; moderately to strongly curved. Sculpture at the apex of 6–9 strong, sharp longitudinal ribs, near the apex a rib develops in each interstice, progressively deepening so that at the aperture there are 12 or more, very low ribs with some additional minor ribs; rarely the interstitial ribs continue right to the apex so that as many as 12 ribs can be seen at the apex with as many as 24 at the aperture; interstices are deeply concave and wide at the apex but shallow to obsolete at the aperture; interstices sculptured with fine longitudinal striae. Aperture usually polygonal but in aged specimens may be almost circular. Apex hexagonal, often with plug and pipe but without slit or notch. Colour white.

Radula. Central tooth broad (177 μm wide), moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface (showing evidence of a ridge-like cusp); laterals dumbbell shaped, 180 μm long with small cusps on the working surface; marginals sigmoidal and broad (length 333 μm × breadth 85 μm) (see Fig. 59A–C). Ratios C:L = 1:1.02, L:M = 1:1.85, marginals breadth:length 1:3.8 (sex indeterminable).

Range. China Seas (North Pacific Exploration Expedition), South Australia, New South Wales, Queensland, Northern Territory to northern Western Australia.

Habitat. Collected in littoral sand and dredged to 668 m in sand.

Comparisons and remarks. *Dentalium intercalatum* resembles most closely *D. flindersi* Cotton & Ludbrook in shape and rib count. Differentiating features of *D. intercalatum* include: aperture profile differences (ribs low and shell not internally crenulated in *D. intercalatum* versus ribs raised and shell internally crenulated in *D. flindersi*); frequent presence of an apical plug and pipe (absent in *D. flindersi*); presence of longitudinal striae in interstices (absent in *D. flindersi*). *Dentalium intercalatum* can also be compared with *D. duodecemcostatum* Brazier, *D.*

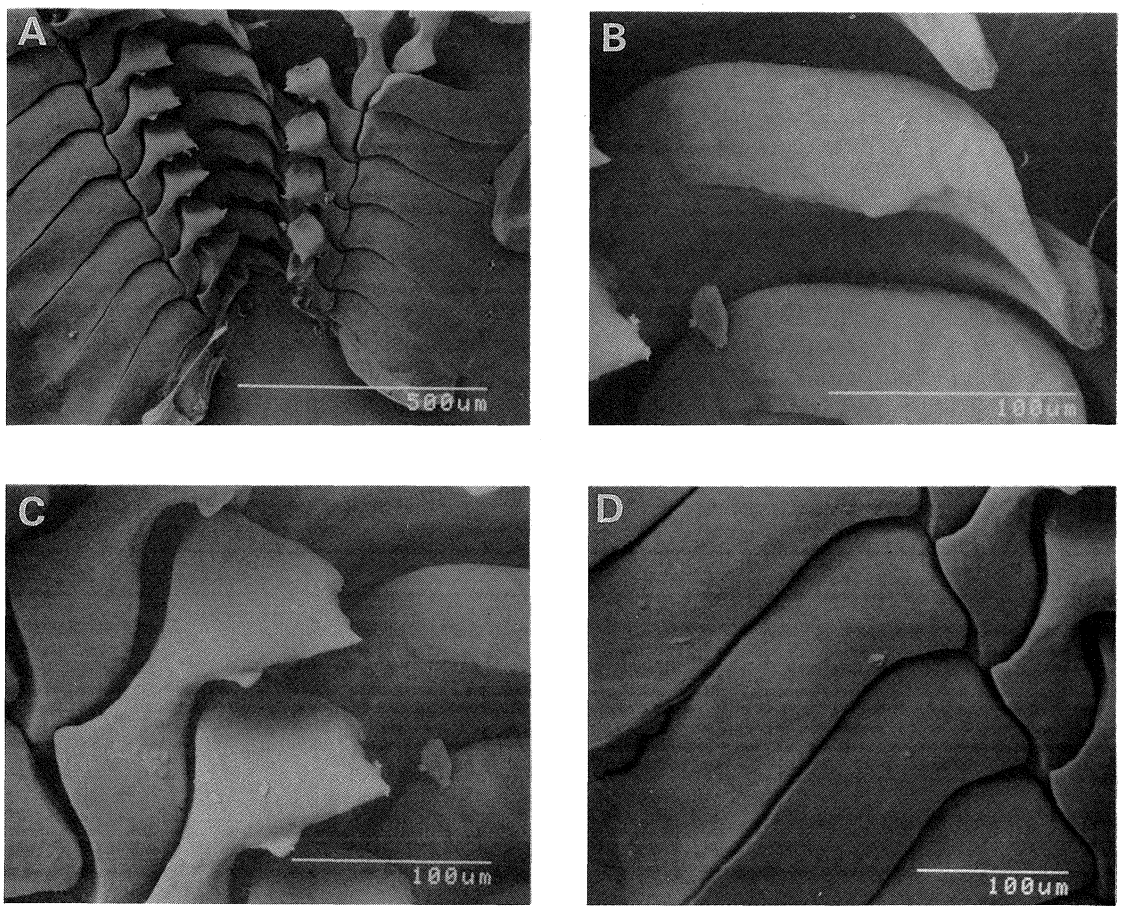


Figure 59. Radular ultrastructure of: **A–C** *Dentalium (Dentalium) intercalatum* Gould, 1859 (Yorke Peninsula, Port Moorowie, 6 m, SA, SAMD 18858).

thetidis Hedley and *D. wellsi* n.sp. in having fine longitudinal, interstitial striae but can be readily separated by shell shape and number of ribs. Pilsbry & Sharp (1897) created the species name *D. bednalli* for the southern members of this species but we agree with Verco's (1904: 135) decision to synonymise *D. bednalli* with *D. intercalatum*. In arriving at this decision Verco examined some 300 specimens, and our acceptance of Verco's view was based on examination of many other specimens from most Australian States, as well as the type of *D. intercalatum*. This reasonably common species occurs throughout Australian waters, ranging north to Japan.

Dentalium (Dentalium) duodecemcostatum Brazier, 1877

Figs 53E, 60A, 61

Dentalium duodecemcostatum Brazier, 1877: 56; Pilsbry & Sharp, 1897: 13; Hedley, 1901: 128, pl. 17, fig. 31; Boissevain, 1906: 15; Hedley, 1910: 371.

Type material examined. HOLOTYPE: AMS C170764. Type locality: Darnley Island, Torres Strait, 30 fathoms [50 m]. Length of holotype 21.5 mm, aperture diameter 2.5 mm, apex diameter 1.0 mm.

Additional material examined. QUEENSLAND: 11, AMS C172229, 23°38.8'S 152°45.5'E, north-east of Lady Musgrave Island, 365 m, 14 December 1977, *Globigerina* mud and siliceous sponge; 17, AMS C172273, 23°44'S 152°49'E, 37 km east of Lady Musgrave Island, 357 m, 17 November 1977, grey shelly ooze; 1, AMS C172228, 39, AMS C172275, 24°03.7'S 152°49.4'E, north-east of Lady Elliot Island, 150 m, 4 July 1984; 4, AMS C172274, 23°19.5'S 152°35.4'E, east of North West Island, 365 m, 14 December 1977, *Globigerina* mud; 24, AMS C172231, Horse Shoe Bay, Magnetic Island, off Townsville, 1959; 1, QM MO17890, 17°34.58'S 146°53.2'E, 458–500 m, 15 May 1986; 1, QM MO17970, 4, QM MO40088, 17°22'S 146°48'E, 296–303 m, 15 May 1986; 1, AMS C172233, Lizard Island, Granite Bluff, sandy mud, 23 m, 7 December 1974; 1, AMS C172234, Lizard Island, Research Station Beach, along tideline, 1–5 December 1974; 3, AMS C172230, 9°56'S 144°04'E, off Murray Island, Torres Strait, 9–15 m, 30 August–3 October 1907; 1, AMS C12098, Torres Strait, 15 m, 1875. NORTHERN TERRITORY: 3, AMS C311591, 9°30'S 132°34'E, Arafura Sea, approx 160 km north of Croker Island, 124 m, 9 November 1969; 1, AMS C14575, 16°31'S 139°30'E, White Cliffs and Melbidir Bay, east coast Mornington Island, 19–24 June 1903; 3, AMS C62683, 10°45'S 142°37'E, Albany Passage, Cape York, 26 m, October 1907, mud and sand.

Description. Shell length to 41.3 mm, aperture diameter 2.6 mm, apex diameter 1.4 mm; thin, smooth; moderately curved to almost straight. Sculpture of 6 narrow, raised,

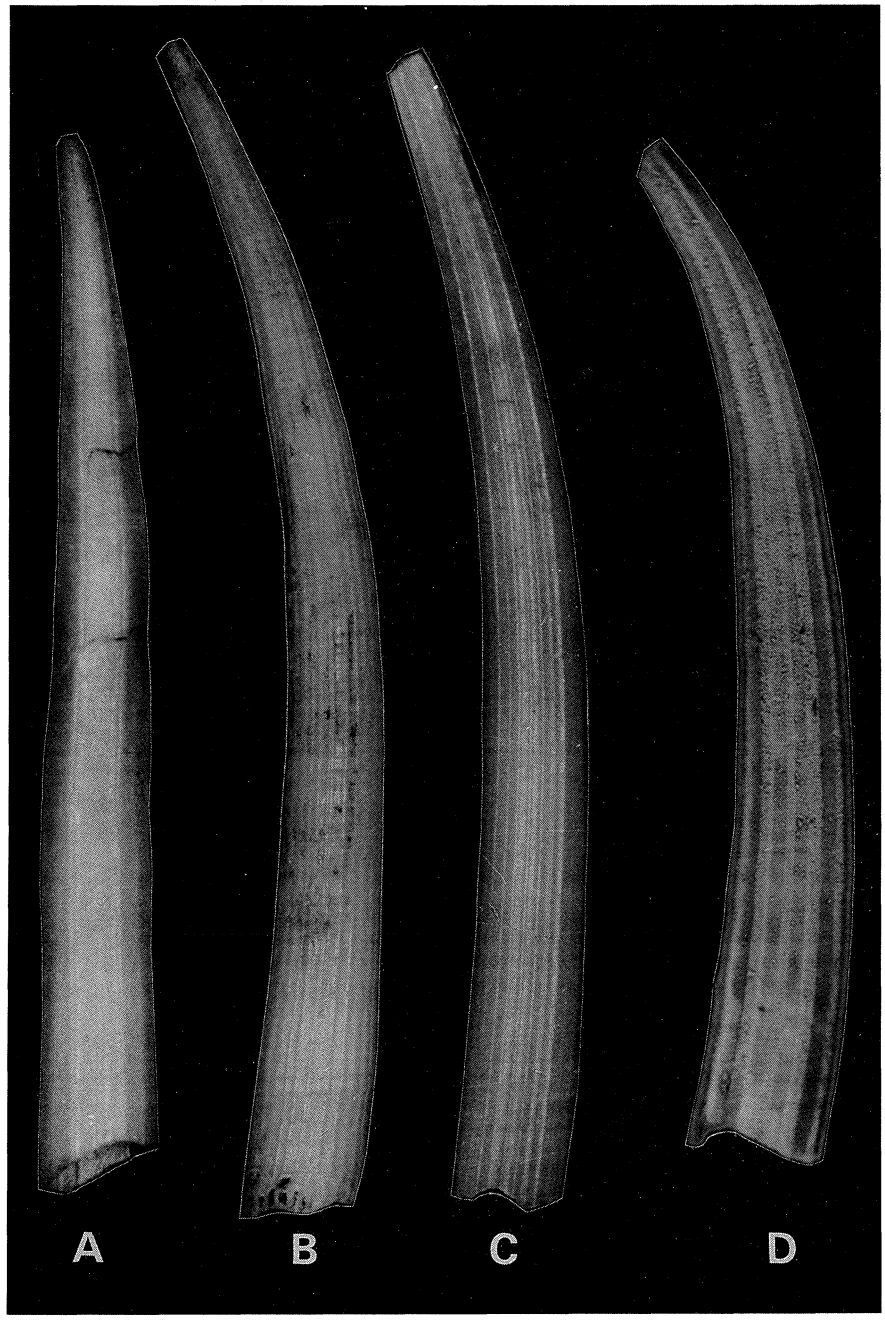


Figure 60. Dentaliida, Dentaliidae. *Dentalium (Dentalium)* Group of *D. intercalatum*. **A** *D. (D.) duodecemcostatum* Brazier, 1877 (holotype, AMS C170764, Darnley Island, Torres Strait, 50 m, length 21.5 mm). **B** *D. (D.) pseudosexagonum* Deshayes, 1825 (lectotype, MNHN [no number], locality unknown, length 29.8 mm). **C** *D. (D.) pseudosexagonum* Deshayes, 1825 (KLColl, Arafura Sea, NT, length 40.0 mm). **D**. *D. (D.) flindersi* Cotton & Ludbrook, 1938 (holotype, SAM D.13338, St Vincents Gulf, SA, 40 m, length 21.0 mm).

rounded longitudinal ribs, usually with one fine, longitudinal rib in each interstice from the midpoint of the shell to the aperture; interstices with dense, microscopic, longitudinal and transverse striae. Aperture retains a hexagonal shape, each interstice being divided by an additional rib. Apex hexagonal, without slit or notch. Colour white.

Range. Queensland to Northern Territory.

Habitat. Collected in littoral sand and dredged in sandy mud from 9 to 500 m.

Comparisons and remarks. *Dentalium duodecemcostatum* resembles most closely *D. robustum* Brazier in shape. Differentiating features include: interstitial ribs; rib numbers (9 in *D. robustum*). Although Brazier (1877) did not mention fine longitudinal striae within the interstices, these are visible on the holotype. Such striae also occur in

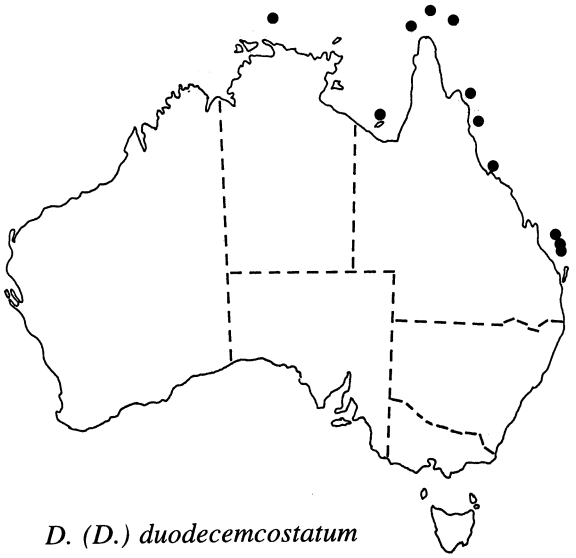


Figure 61. Australian distribution of *Dentalium (Dentalium) duodecemcostatum* Brazier, 1877.

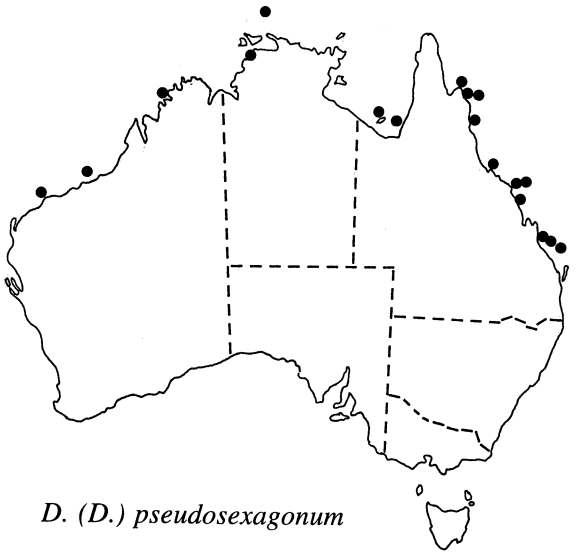


Figure 62. Australian distribution of *Dentalium (Dentalium) pseudosexagonum* Deshayes, 1825.

D. intercalatum Gould, *D. wellsi* n.sp. and *D. thetidis* Hedley. *Dentalium duodecemcostatum* differs from *D. intercalatum* in being almost straight and by its retention of a hexagonal appearance at the aperture. *Dentalium thetidis* and *D. wellsi* typically exhibit 7 ribs at the apex. In addition, *D. thetidis* is consistently narrower than *D. duodecemcostatum* with less pronounced ribbing.

Dentalium (Dentalium) pseudosexagonum Deshayes, 1825

Figs 53F, 60B,C, 62

Dentalium pseudosexagonum Deshayes, 1825: 358, pl. 16, figs 14, 15, 16; G.B. Sowerby, 1860: 103, pl. 224, fig. 34; G.B. Sowerby, 1872: pl. 4, f.23; Brazier, 1877: 56; Pilsbry & Sharp, 1897: 23, pl. 4, figs 47, 48; Boissevain, 1906: 14, pl. 1, fig. 10; Hedley, 1910: 371.

Type material examined. LECTOTYPE here selected from MNHN (no number), lot of 7 syntypes. Type locality: unknown. Length of lectotype 29.8 mm, aperture diameter 3.15 mm, apex diameter 1.15 mm. PARALECTOTYPES: 5, same locality data as lectotype; remaining specimen from syntype series not referable to this species.

Additional material examined. QUEENSLAND: 4, AMS C173064, 23°33.7'S 152°37'E, 36 km east of Lady Musgrave Island, 348 m, 17 November 1977, yellow-grey mud; 2, AMS C70951, Seaforth, dead on beach; 1, NMV F67454, Keppel Bay, October 1967; 1, AMS C172218, Heron Island, 36.5 m, December 1956; 1, AMS C172221, 20°05'S 148°30'E, Dingo Beach; 1, AMS C173062, Lindeman Island; 2, AMS C172224, 1, AMS C172219, 1, AMS C172220, 20°27'S 149°02'E, Lindeman Island, north of Mackay, Whitsunday Passage, 37 m, 1929; 1, AMS C100232, Bowen, 1957; 1, AMS C169961, Bowen, 1959; 6, AMS C169775, Horseshoe Bay, Magnetic Island, off Townsville, 1959; 1, AMS C172217, 19°06.8'S 146°51.8'E, Horseshoe Bay, Magnetic Island, off Townsville, 24 September 1980; 1, AMS C112607, north side of Kissing Point, Townsville, on silty rock, 31 May 1977; 16, QM MO53674, Dunk Island; 3, AMS C41463, off Annam River mouth, 15°32'S 145°17'E, 6 August 1916; 11, AMS C42271, Dunk Island, 17°57'S 146°10'E; 15, AMS C42290, Clump Point; 17, QM MO17/317, Dunk Island; 3, AMS C172223, 16°33.54–33.48'S 146°09.42–09.36'E, north-east of Cairns, 55 m, 11 October 1981; 1, AMS C172225, 14°36.8'S 145°28.7'E, east of Cape York, 22 m, Halimeda sand, 21 October 1973; 1, AMS C172226, 14°40'S 145°39'E, south-west end No Name Reef, east of Cape York, 15–20 m, rubble at bombie base, 18 December 1984; 1, AMS C107316, Kapok Cove, Lizard Island, 3 m, sand, 1–12 December 1974; 2, AMS C173377, 14°40'S 145°28'E, Lizard Island, 18–19 July 1916; 1, AMS C172222, 14°25'S 145°27'E, south end of South Island, Lizard Island, 15 m, on outer side of reef, 16 January 1980; 1, AMS C14576, Mornington Island; 11, AMS C15317, Van Diemens Inlet. NORTHERN TERRITORY: 1, AMS C173063, 1, AMS C173060, 9°30'S 132°54'E, 171 km north of Croker Island, 140 m, clay-sand 8 November 1969; 5, NMV F75841, dredged Darwin Harbour, 23 April 1983; 1, AMS C172227, 36 km off Point Charles, Darwin, 30–40 m, 14 July 1938. WESTERN AUSTRALIA: 1, WAM 180-93, 15°06'S 125°00'E, Careening Bay Kimberly, 13 July 1988; 1, AMS C172236, 19°00.4–00.3'S 118°01.0–01.1'E, 157 km north north-west of Port Hedland, 116–120 m, 29 October 1983; 1, AMS C173274, 18°54'S 117°27'E, 192 km north-west of Port Hedland, 183 m, 19 November 1968; 1, WAM 175-93, Norbill Bay, Rosemary Island, 21 April 1972.

Description. Shell length to 42.8 mm, aperture diameter 3.8 mm, apex diameter 1.9 mm; robust, moderately curved. Sculpture of 6 strong, longitudinal ribs at the apex. Behind the apex the interstices are divided by 1–3 longitudinal ribs covering the whole shell, the strong longitudinal ribs becoming slightly weaker at about the first quarter of the shell length from the apex, rib count at the aperture 23–25. Aperture hexagonal. Apex hexagonal, without slit or notch. Colour grey-white.

Range. Philippines (G.B. Sowerby, 1860; Pilsbry & Sharp, 1897), Queensland, Northern Territory to northern Western Australia.

Habitat. Collected in littoral sand and mud and dredged from 3 to 348 m in sand.

Comparisons and remarks. Differentiating features of *Dentalium pseudosexagonum* which separate it from the other members of the *D. intercalatum* group include: greater aperture rib count (12–24 in *D. intercalatum* Gould, 12 in *D. duodecemcostatum* Brazier and *D. flindersi* Cotton & Ludbrook, versus 23–25 in *D. pseudosexagonum*); more strongly curved than *D. duodecemcostatum*; lacks the plug and pipe typically present in *D. intercalatum*; and has much lower ribs at the aperture than those of *D. flindersi*. Australian specimens examined by us differ from the type series in having only one intercalating rib per interstice nearest the apex. As this also occurs between some ribs in the smallest paralectotype, it would seem that some variation in the number of intercalating ribs may be usual in this species. Great uncertainty exists as to the geographic range of *D. pseudosexagonum*. Deshayes did not give a locality for the type series, but Pilsbry & Sharp (1897) argued that these specimens more than likely emanated from an "East Indian" source. G.B. Sowerby (1872) gives the localities "Philippines" and "W. Columbia", the latter record in fact applicable to another species according to Pilsbry & Sharp (1897). We have examined a specimen from the Queensland Museum labelled "*Dentalium pseudosexagonum* Desh. China" which agrees well with the type series of this species. Brazier (1877) records *D. pseudosexagonum* from "Albany Is. N. Australia (11 fathoms)" and "Darnley Is. Torres Straits (30 fathoms)". Our check of these specimens, held in the Macleay Museum (University of Sydney) confirm Brazier's identification and firmly establishes the presence of Deshayes' species in northern Australian waters. The smallest of Deshayes' syntypes of *D. pseudosexagonum*, (a small, 12.5 mm, dead-taken specimen with 16 ribs at the aperture and a slit and pipe apically), is clearly not referable to this species.

Dentalium (Dentalium) flindersi
Cotton & Ludbrook, 1938

Figs 53G, 54E, 60D, 63

Dentalium flindersi Cotton & Ludbrook, 1938: 219, pl. 12, fig. 4; Cotton & Godfrey, 1940: 326, fig. 346; Zeidler & Macphail, 1978: 384.

Type material examined. HOLOTYPE: SAM D13338. Type locality: Gulf St. Vincent, 22 fathoms [40 m]. Length of holotype 21.0 mm, aperture diameter 2.9 mm, apex diameter 0.9 mm.

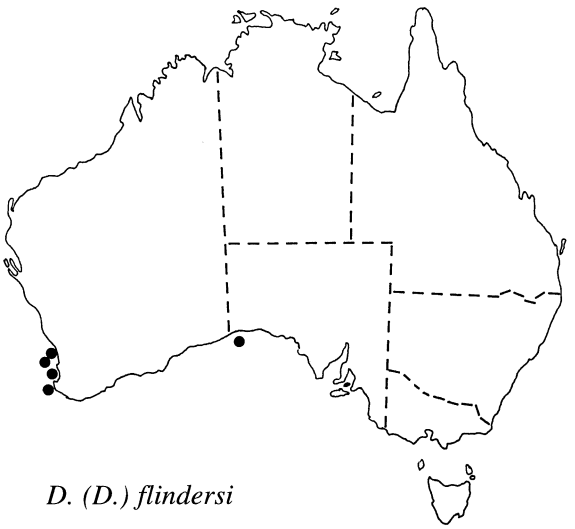


Figure 63. Known distribution of *Dentalium (Dentalium) flindersi* Cotton & Ludbrook, 1938.

Additional material examined. WESTERN AUSTRALIA: 1, AMS C301651, Gidley Island, Dampier Archipelago, 30 October 1945; 1, WAM N3571, 3 km north-west of Busselton Jetty, 26 m, 12 April 1963; 3, WAM N4135, 4 km west of Bunbury, 24 m, 13 May 1963; AMS C172586, 1.8 km east south-east of Mount Make, Garden Island, Cockburn Sound, 18–20 m, fine mud, 10 August 1958; 1, WAM 34-93, 31°45'S 145°02'E, north-west of Rottnest Island, 276 m, 18 February 1972. SOUTH AUSTRALIA: 2, AMS C172578, 33°05'S 128°40'E, Great Australian Bight, 75 m, 5 July 1962; 23, SAM D18883, Gulf St Vincent 44 m.

Description. Shell length to 21.0 mm, aperture diameter 2.9 mm, apex diameter 0.9 mm; solid, moderately curved towards the apex. Sculpture at the apex of 6 strong, narrow, raised ribs intercalating at one quarter of the shell length (from the apex) into 12 raised, narrow, rounded ribs; interstices wide, with fine longitudinal interstitial striae. Aperture polygonal. Apex hexagonal, without slit or notch. Colour white.

Range. South Western Australia to South Australia.

Habitat. Dredged from 18 to 276 m.

Comparisons and remarks. *Dentalium flindersi* resembles most closely *D. intercalatum* Gould (and some 7 ribbed *Dentalium* species) by having fine longitudinal striae within the interstices. Differentiating features of *D. flindersi* Cotton & Ludbrook from the other members of the *D. intercalatum* group include: stronger curvature towards the apex; much stronger ribs at the aperture; crenulated internal surface of aperture. Verco (1911a) incorrectly recorded this species as *D. duodecemcostatum* Brazier from St Vincents Gulf, South Australia. According to Ludbrook (1984) *D. flindersi* also occurs in the Glanville Formation of South Australia (north of Port Sinclair, Late Pleistocene).

Key to miscellaneous *Dentalium* sensu strictu

Twelve to 16 ribs at apex with or without an apical notch. Almost certainly an artificial group, but used here to accommodate species with no immediate connection with other *Dentalium* groups.

1 Strongly curved with typically 12 (11–13) strong, non-intercalating, moderately low ribs ..... *D. bisexangulatum*

—— Slightly curved with 15–16 raised, intercalating ribs with anadditional 2 or 3 ribs at the aperture ..... *D. francisense*

Dentalium (Dentalium) bisexangulatum G.B. Sowerby, 1860

Figs 64A, 65A,B, 66

Dentalium bisexangulatum G.B. Sowerby, 1860: 102, pl. 223, fig. 8; G.B. Sowerby, 1872: pl. 3, fig. 14; Brazier, 1877: 57; von Martens, 1881: 739; Cooke, 1886: 273; Pilsbry & Sharp, 1897: 15, pl. 2, fig. 25; Boissevain, 1906: 22, pl. 1, fig. 7; Hedley, 1910: 371.

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1993009. Type locality: Java. Length of lectotype 88.7 mm, aperture diameter 6.6 mm, apex diameter 0.6 mm. PARALECTOTYPES: 2, same locality data as lectotype.

Additional material examined. WESTERN AUSTRALIA: 1, WAM 42-93, north of East Wallabi Island, Wallabi Group, Houtman Abrolhos, 27 August 1977, 34 m; 1, WAM 97-93, Zeewyck Channel, Houtman Abrolhos, 42 m, 16 February 1963; 1, AMS C174535, 19°58.9–58.6'S 117°51.3–51.7'E, north of Port Hedland, 40 m, 22 April 1983.

Description. Shell length to 88.7 mm, aperture diameter 6.6 mm, apex diameter 0.6 mm; well curved, solid. Sculpture of 12 (11–13) strong, moderately low, rounded, longitudinal ribs; interstices concave, usually smooth. Aperture circular, crenulated by ribs, slightly compressed, strongly angulated by the projecting ribs on the concave margin. Apex circular, crenulated by ribs, with a shallow, wide, dorsal notch. Colour: white.

Range. Java, Singapore, Japan, Gulf of Suez, Mozambique (all Pilsbry & Sharp, 1897), northern Western Australia.

Habitat. Dredged in sand to 40 m.

Comparisons and remarks. The specimen here chosen as lectotype closely matches the dimensions and profile of the specimen illustrated by Sowerby and is marked "Type" on the label associated with lot BMNH no. 1993009. *Dentalium bisexangulatum* to some extent resembles *D. javanum* G.B. Sowerby in its general shape, but can be easily distinguished by having a larger rib count (12 in *D. bisexangulatum*) and markedly lower ribs. Rare in Australian waters.

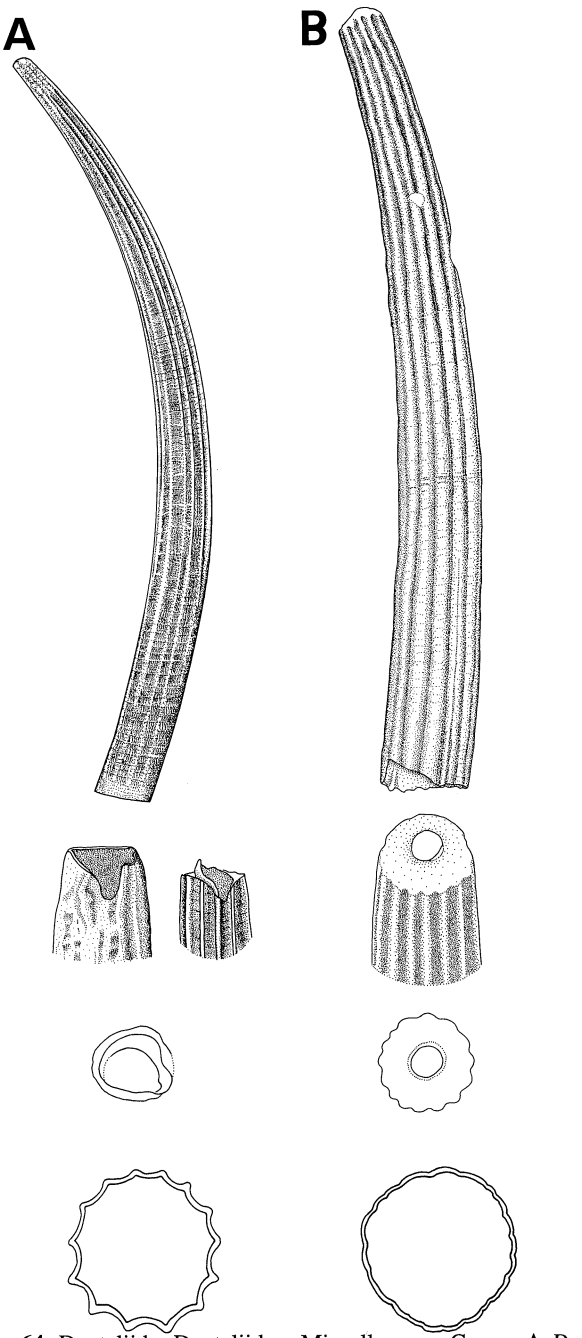


Figure 64. Dentaliida, Dentaliidae. Miscellaneous Group. **A** *D. (D.) bisexangulatum* Sowerby, 1860 (lectotype, BMNH 1993009, Java, length 88.7 mm; apex (on right) and aperture profile from WAM 97/93, Zeewyck Channel, Houtman Abrolhos WA, 42 m). **B** *D. (D.) francisense* Verco, 1911 (holotype, SAM D13724, Petrel Bay, St Francis Island, SA, 27–37 m, length 28.0 mm). (Del.: all A. Hill).

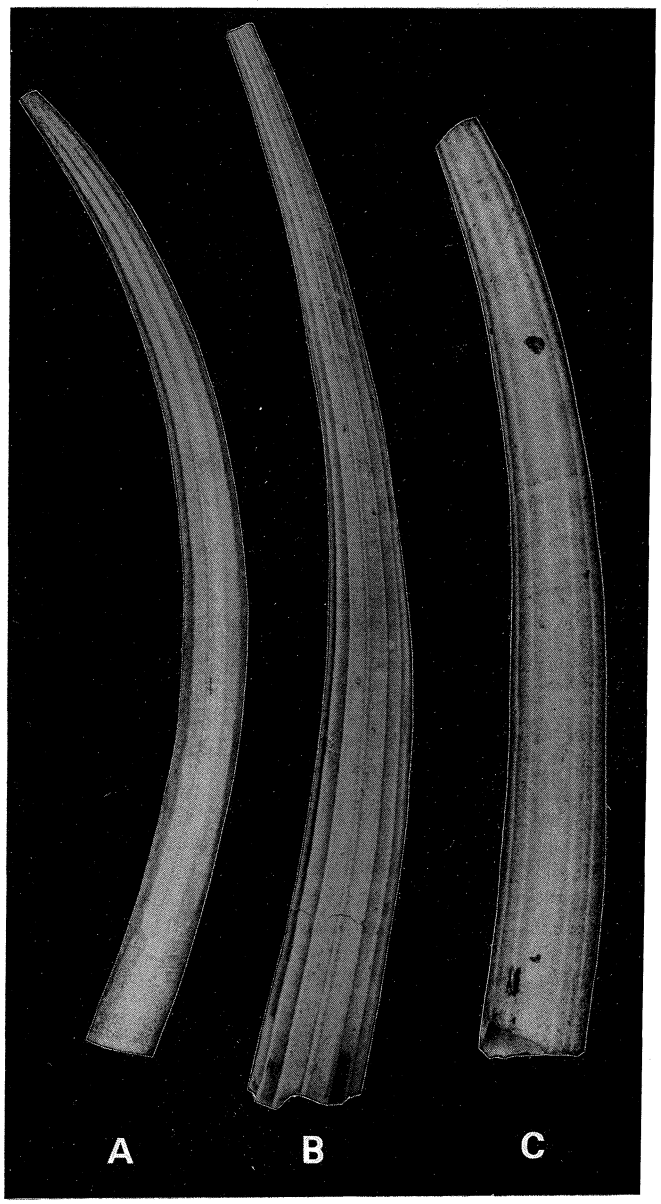


Figure 65. Dentaliida, Dentaliidae. Miscellaneous Group. **A,B** *D. (D.) bisexangulatum* Sowerby, 1860 (A—lectotype, BMNH 1993009, Java, length 88.7 mm; B—AMS C174535, north of Port Hedland, WA, 40 m, 72.0 mm). **C** *D. (D.) francisense* Verco, 1911 (holotype, SAM D13724, Petrel Bay, St Francis Island, SA, 27–37 m, length 28.0 mm).

Dentalium (Dentalium) francisense Verco, 1911

Figs 64B, 65C, 67

Dentalium francisense Verco, 1911a: 207; Hedley, 1916: 74; Cotton & Godfrey, 1933: 143; Cotton & Godfrey, 1940: 327, fig. 349; Zeidler & Macphail, 1978: 383.

Type material examined. HOLOTYPE: SAM D13724. Type locality: Petrel Bay, St Francis Island, SA, 15–20 fathoms [27–37 m]. Length of holotype 28.0 mm, aperture diameter 3.2 mm, apex diameter 1.6 mm. PARATYPES: SAM D16004 (ex D13724) juvenile dry shell, same data as holotype; 2, AMS C334, Gulf of St Vincent, SA, 27–40 m, 1912; USNM 251989, St Vincents Gulf, SA.

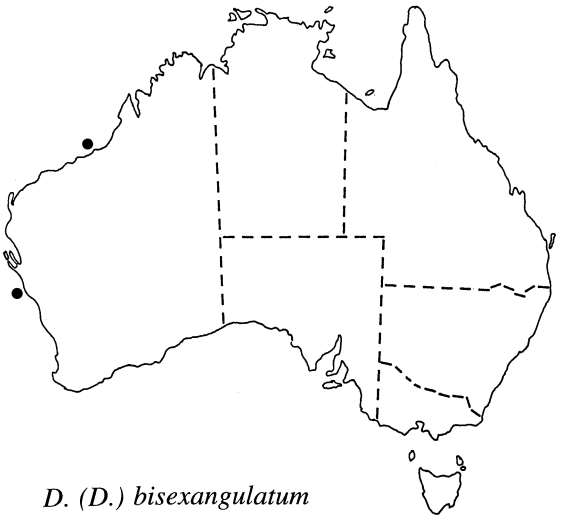


Figure 66. Australian distribution of *Dentalium (Dentalium) bisexangulatum* Sowerby, 1860.

Additional material examined. WESTERN AUSTRALIA: 1, AMS C169964, 19°30.9–28.2'S 118°49.2–55.4'E, 96 km north north-east Port Hedland, sand, 36–37 m, 24 October 1983; 1, AMS C172584, Oyster Harbour, via Albany, between Emu Point and Green Island, 8 April 1960; 7, AMS C172574, 1.8 km north of Green Island, Oyster Harbour via Albany, 9 m, 20 July 1963; 1, AMS C172575, 35°12'S 117°00'E, south of Wilson Inlet, 73–77 m, 8 August 1962; 8, SAM D18861, off Bunbury, 30–44 m; 1, SAM D18864, Bunbury, 30 m; 1, SAM D18862, off Fremantle, 24 m; many, WAM 65-94, Cockburn and Warnbro Sound, 1993; 1, WAM 609-84, Duck Rock Rottnest Island, 8 February 1984; 1, AMS C173317, 33°36'S 115°04'E, 3.5 km off Dunsborough, 165 m, 22 December 1971; 7, WAM 178-93, south Rumble Bay in Cygnet Bay, King George Sound, 6 September 1975; 1, SAM D18865, Geographe Bay, 44 m; 1, SAM D18866 Rottnest Island; 1, SAM D18867, Fremantle; 1, SAM D18878, Geographe Bay, 30 m; 1, SAM D18868, Hopetoun, 70 m. SOUTH AUSTRALIA: 4, SAM D18869, St Vincents Gulf, 30–44 m; 2, SAM D18870, Gulf of St Vincent, 32 m; 1, SAM D18871, 4.8 km off Tunk Head, 32 m; 5, SAM D18872, St Francis Island, 30–40 m; 8, SAM D18873, St Francis Island, 30–44 m; 1, SAM D295, west of St Francis Island, 70 m; 1, SAM D18874, 35°39'S 138°23'E, 4.8 km off Tunk Head, 32 m; 1, SAM D18875, off Cape Borda, 110 m; 1, SAM D18876, Gulf of St Vincent, 44 m; 1, SAM D18877, Newland Head, 40 m; 1, SAM D18879, St Vincent Gulf, 30–40 m; 4, SAM D18880, St Vincent Gulf, 30–44 m; 1, SAM D18881, off Tunk Head, 64 m; 1, AMS C173325, 32°07'S 132°58'E, Port Sinclair, 36.5 m; 1, AMS C33491, 30–44 m, off St Vincents Gulf; 1, AMS C172576, between Cape Jaffa and Kangaroo Island, 75–155 m, 24–26 July 1962. VICTORIA: 1, AMS C310256, 38°20–40'S 149°25–35'E, 30 mile, south of Cape Everard, 366 m, 22 November 1914. NEW SOUTH WALES: 2, AMS C169993, 34°50'S 151°13'E, off Nowra, 550 m, 12 December 1978; 1, AMS C166648, 29°53'S 159°01.65'E, Coral Sea, Elizabeth Reef, 420 m, 3 May 1989.

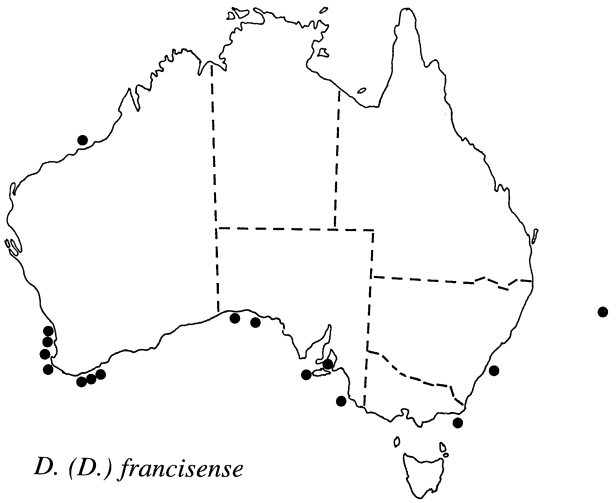


Figure 67. Known distribution of *Dentalium (Dentalium) francisense* Verco, 1911.

Description. Shell length to 28.0 mm, aperture diameter 3.2 mm, apex diameter 1.6 mm; moderately solid, curved more towards the apex. Sculpture of 14–16 raised longitudinal ribs which become flattened towards the aperture; interstices distinct with transverse, microscopic growth lines. Aperture circular, crenulated by ribs. Apex circular, crenulated by ribs, truncate, orifice small. Colour translucent white.

Range. Western Australia, South Australia, Victoria, New South Wales.

Habitat. Dredged in sandy mud from 27 to 550 m.

Comparisons and remarks. Morphologically *D. francisense* shows some similarity to *D. (Lentigodentalium) woolacottae* Colman, especially in rib structure. However all species of the subgenus *Lentigodentalium* are characterized by distinctive colouration (coloured bands and/or speckling of the rib tops), a feature not observed by us in any specimens of *D. francisense*, whether taken live or dead. A specimen of *D. francisense* in lot AMS C166648, from Elizabeth Reef, Tasman Sea cannot be separated from the type of that species. If the locality data associated with this shell are correct, this would create a highly disjunct distribution for the species. The type and other specimens examined all have constant ribs as per Verco's original description of the species. However, Cotton & Godfrey (1940) refer to intercalated ribs in some specimens. We have examined the scaphopods held in the South Australian Museum but have been unable to find the specimens referred to by Cotton & Godfrey.

Subgenus *Lentigodentalium* Habe, 1963

Lentigodentalium Habe, 1963: 258; Habe, 1964: 9; Palmer, 1974a: 118; Steiner, 1992b: 396.

Type species: *Dentalium variabile* Deshayes, 1825 by original designation.

Diagnosis. Sculpture as for *Dentalium (Dentalium)* but exhibiting, in fresh specimens, coloured spots on the rib tops and usually chevron-shaped bands of green-gray across the shell, 8 to 18 ribs at apex sometimes with intercalating ribs towards aperture, interstices and often ribs ornamented with fine longitudinal striae.

Key to Australian *Lentigodentalium*

1 Shell rapidly tapering posteriorly ..... *D. woolacottae*

—— Shell slowly tapering posteriorly 2

2 8–10 ribs at apex intercalating to 16–20 ribs at the aperture ..... *D. stumkatae*

—— 16–17 ribs at apex intercalating to 30–34 ribs at the aperture ..... *D. garrardi*

Dentalium (Lentigodentalium) woolacottae Colman, 1958

Figs 68A, 69A,B, 70, 73A–D

Dentalium woolacottae Colman, 1958: 142, pl. 1, fig. 4; Iredale & McMichael, 1962: 96.

Type material examined. HOLOTYPE: AMS C21230. Type locality: Cronulla, NSW. Length of holotype 10.6 mm, aperture diameter 2.3 mm, apex diameter 0.6 mm. PARATYPES: 1, AMS C170642 (ex AMS C21230), Cronulla, NSW; 2, AMS C32706, Middle Harbour, NSW.

Additional material examined. NEW SOUTH WALES: 1, AMS C173241, off North Head, Sydney; 1, AMS C173236, Narrabeen Beach; 2, AMS C172240, Sow and Pigs Reef, 16 m; 1, 12–18 m, off Sow and Pigs Reef, Sydney Harbour; 1, Narrabeen Beach; 1, AMS C24309, Manly Beach; 1, AMS C173023, 18, AMS C24509, Manly; 1, AMS C173024, Palm Beach; 1, AMS C173025, Windang; 1, AMS C301679, Green Point, Watsons Bay, Port Jackson, 9–14.5 m, June 1865; 1, AMS C301678, dredged, Sandy Bay, Port Stephens; 4, AMS C301665, Illuka, beach, February 1976. QUEENSLAND: 1, AMS C173244, Caloundra; 1, AMS C172591, Lady Elliot Island, 18 m; 14, AMS C19638, 27, AMS C18840, Masthead Reef, 31–40 m, 25–29 October 1904; 4, AMS C63130, 23°18'S 151°42'E, North West Island, 37 m, May 1931; 1, AMS

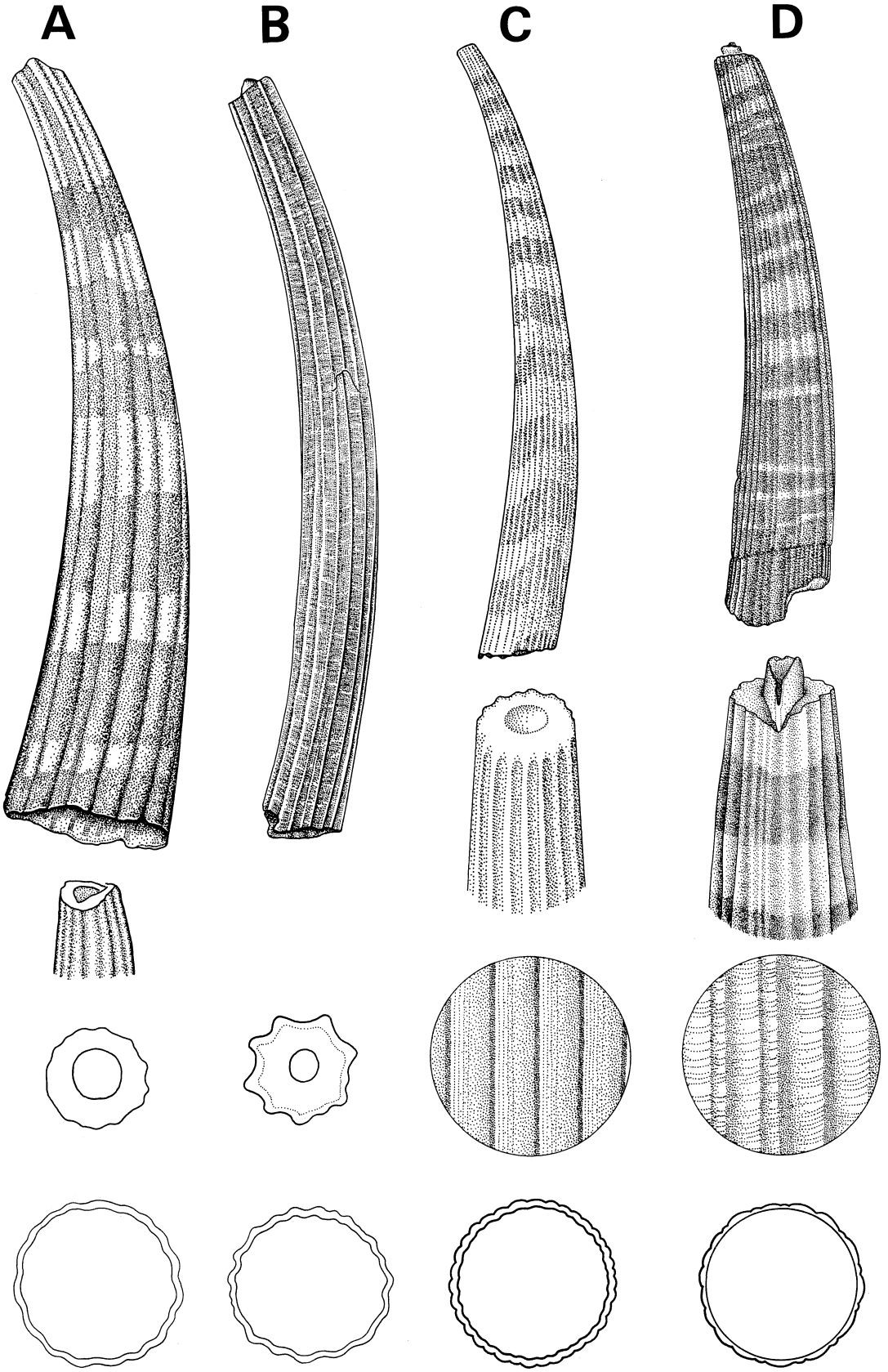


Figure 68. Dentaliida, Dentaliidae. **A–C** *Dentalium (Lentigodentalium)*. **A** *D. (L.) woolacottae* Colman, 1958 (holotype, AMS C21230, Cronulla, NSW, length 10.6 mm). **B** *D. (L.) stumkatae* n.sp. (holotype, AMS C174641, 32 km off Point Charles, north-west of Darwin, NT, 27–37 m, length 10.0 mm). **C** *D. (L.) garrardi* n.sp. (holotype, AMS C169770, Lady Musgrave Island, lagoon, Qld, length 16.7 mm). Detail of sculpture also shown. **D** *Dentalium (Pictodentalium) formosum* Adams & Reeve, 1848 (Exmouth Gulf, WA, length 50.0 mm KLColl) Detail of sculpture also shown. (Del.: A and B—A. Hill; C and D—C. Eadie).

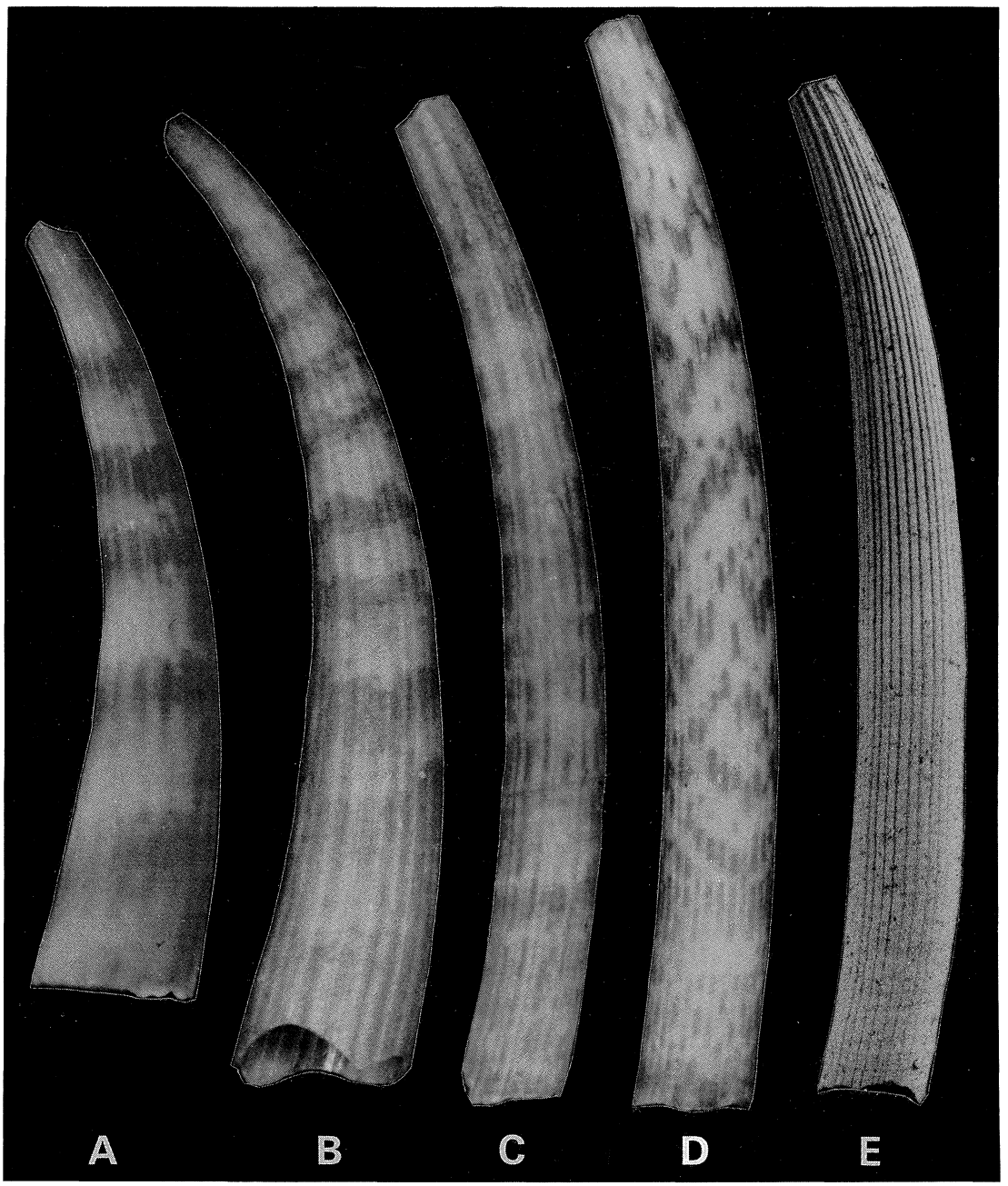


Figure 69. Dentaliida, Dentaliidae. *Dentalium (Lentigodentalium)*. **A,B** *D. (L.) woolacottae* Colman, 1958 (A—holotype, AMS C21230, Cronulla, NSW, length 10.6 mm; B—AMS C18840, Masthead Reef, Qld, 30–40 m, length 15.0 mm). **C** *D. (L.) stumkatae* n.sp.(holotype, AMS C174641, 32 km off Point Charles, north-west of Darwin, NT, 27–37 m, length 10.0 mm). **D,E** *D. (L.) garrardi* n.sp. (D—holotype, AMS C169770, Lady Musgrave Island, lagoon, Qld, length 16.7 mm; E—paratype, AMS C174887, same locality, length 19.4 mm, showing sculptural aspect).

C173243, 14°32.2'S 144°53.4'E, northern Qld, 11 m, muddy sand, 9 August 1973.

Description. Shell length to 20.0 mm, aperture diameter 2.3 mm, apex diameter 1.2 mm; thin, moderately curved. Sculpture of 15–18 longitudinal ribs, sometimes with smaller ribs in the interstices, more pronounced posteriorly; fine striae visible on the interstices and often on the ribs; interior of shell devoid of sculpture. Aperture circular, crenulated by ribs and very wide in comparison to shell length. Apex circular, crenulated by ribs, with a small apical notch dorsally. Colour opaque white, with irregular grey-black zigzag transverse bands.

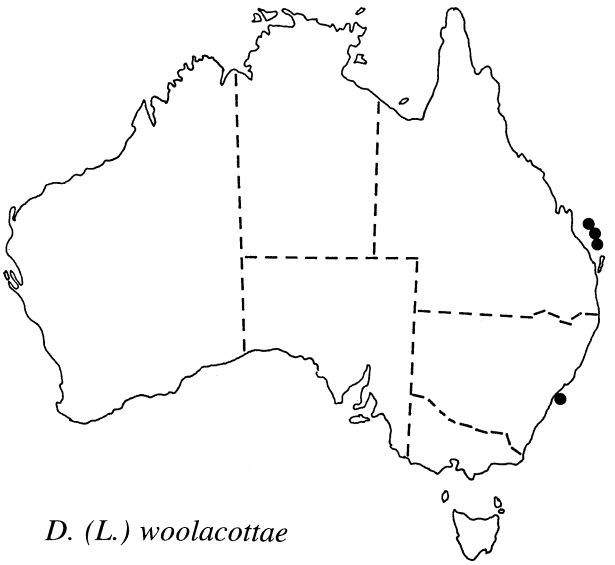


Figure 70. Known distribution of *Dentalium (Lentigodentalium) woolacottae* Colman, 1958.

Radula. Central tooth broad (144 μm wide), moderately shallow with smooth, convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped, 140 μm long with small cusps on the working surface; marginals sigmoidal, relatively short and broad (length 226 μm × breadth 78 μm) (see Fig. 74A–D). Ratios C:L = 1:0.97, L:M = 1:1.6, marginals breadth:length = 1:1.9 (sex indeterminable).

Range. Capricorn-Bunker Group (Queensland) south to Sydney, New South Wales.

Habitat. Dredged from 9 to 40 m in muddy sand.

Comparisons and remarks. Features which differentiate this species from the other members of the subgenus *Lentigodentalium* include: much wider aperture; broader shell; lower ribs; absence of an apical notch. Other features useful in distinguishing *D. (L.) woolacottae* are the rib count (*D. (L.) woolacottae*: apex 15–18, aperture 18; *D. (L.) garrardi* n.sp. apex 16–17, aperture 30–34; *D. (L.) stumkatae* n.sp.; apex 8–10, aperture 16–20), and distribution (*D. (L.) woolacottae*: central New South Wales coast to southern Queensland; *D. (L.) garrardi*: southern to central Queensland; *D. (L.) stumkatae* northern Western Australia to Northern Territory). *Dentalium (L.) woolacottae* and *D. (L.) garrardi* occur sympatrically in the Capricorn-Bunker Island Group. In Colman's original description of *D. (L.) woolacottae*, the number of ribs are given as 28–32. We have examined the holotype and the 3 paratypes and find the rib count to be a maximum at the apex of 18 and 18 at the aperture, although in each specimen examined the count is greater at the aperture than the apex. For example, the holotype has 15 ribs at the apex and 18 ribs at the aperture.

Dentalium (Lentigodentalium) stumkatae n.sp.

Figs 68B, 69C, 71

Etymology. Named after Mrs Kylie Stumkat (nee Williams) for her considerable skill in using SEM photography for all the radulae described in this study.

Type material examined. HOLOTYPE: AMS C174641. Type locality: 12°10'S 130°22'E, 32 km off Point Charles, north-west of Darwin, NT, 27–37 m, 14 July 1938. Length of holotype 10.0 mm, aperture diameter 1.05 mm, apex diameter 0.7 mm. PARATYPES: 2, AMS C174642, same locality data as holotype; 2, AMS C169964, 96 km north-east of Port Hedland, WA, 36–37 m, 19°30.9–28.2'S 118°49.2–55.4'E, sand, 24 October 1983.

Additional material examined. NORTHERN TERRITORY: 1, AMS C311191, 12°28'S 130°50'E, Port Darwin; 2, AMS C173370, 32 km off Port Charles, Darwin, 37 m, 14 July 1938. WESTERN AUSTRALIA: 1, WAM 139-93, 18°47'S 117°58'E, 185 km north-west of Port Hedland, 154 m, 28 February 1982; 1, AMS C173242, 27 km south of Exmouth townsite, Exmouth Gulf, on sand flats, 19 June 1972; 1, AMS C173379, 11°30'S 125°00'E, Sahul Banks, Timor Sea, August–September 1949.

Description. Shell length to 10.0 mm, aperture diameter 1.05 mm, apex diameter 0.7 mm; moderately solid, slightly to moderately curved. Sculpture of 8–10 longitudinal ribs at the apex, increasing by intercalation to 16–20 ribs at the aperture, with microscopic longitudinal striae on the ribs and interstices, crossed by even finer transverse striae giving a slightly cancellate appearance to the ribs under magnification. Aperture approximately circular, crenulated by ribs. Apex polygonal, with a plug and small pipe. Colour white, with irregular dark green/grey-black spots on the rib tops.

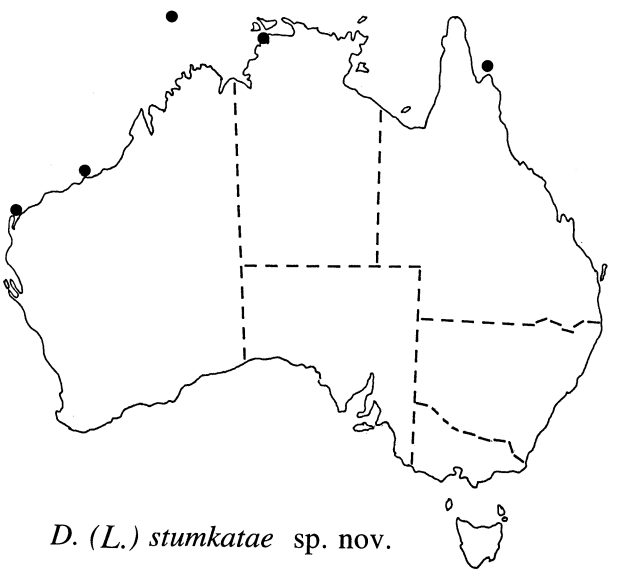


Figure 71. Known distribution of *Dentalium (Lentigodentalium) stumkatae* n.sp.

Range. Northern Territory (including Timor Sea) to northern Western Australia.

Habitat. Dredged from 37 to 154 m in sand.

Comparisons and remarks. *Dentalium (L.) stumkatae* resembles *D. (L.) garrardi* n.sp. in being narrow and usually in having an apical pipe. However these two species differ substantially in rib count—*D. (L.) stumkatae* having fewer ribs both apically and aperturally. *Dentalium (L.) stumkatae* differs from *D. (L.) woolacottae* and *D. (L.) garrardi* in distribution of shell colour (limited to flecks on the rib tops in *D. (L.) stumkatae*; primarily bands in the other two species). Figures of *D. (L.) variabile* Deshayes shown by Pilsbry & Sharp (1897) and Habe (1964) indicate restriction of the colour in that species to the rib tops, as observed in *D. (L.) stumkatae*. Although we were unable to trace the whereabouts of the type of *D. (L.) variabile*, the illustrations presented by Pilsbry & Sharp (1897) are good enough to state that *D. (L.) variabile* lacks the dense striae observed in *D. (L.) stumkatae*.

Dentalium (Lentigodentalium) garrardi n.sp.

Figs 68C, 69D,E, 72

Etymology. Named after Mr Tom Garrard who collected the specimens used in this study. This species also honours his contributions to Australian malacology.

Type material examined. HOLOTYPE: AMS C169770. Type locality: Lady Musgrave Island, Capricorn-Bunker Group, east of Gladstone, Qld, dredged in lagoon. Length of holotype 16.7 mm, aperture diameter 1.8 mm, apex diameter 1.0 mm. PARATYPES: 30, AMS C174887, same locality data as holotype; 2, NMV F67452, Lady Musgrave Island, Qld.

Additional material examined. QUEENSLAND: 1, AMS C173244, Caloundra; 10, AMS C303582, Lady Musgrave Island, 10 m; 2, NMV F67452, Lady Musgrave Island, 29 August 1963; 8, AMS C303579; 1, AMS C173238, North West Island, May 1929; 1, AMS C172239, 23°18'S 151°42'E, North West Island, 30 August 1967; 1, AMS C18840, 23°32'S 151°45'E, Masthead Island, 37 m, 29 October 1904.

Description. Shell length to 19.8 mm, aperture diameter 2.5 mm, apex diameter 1.1 mm; solid, slightly and evenly curved. Sculpture of 16–17 longitudinal ribs at the apex, increasing by intercalation to 30–34 ribs at the aperture, with microscopic longitudinal striae in the interstices. Aperture circular, crenulated by ribs. Apex polygonal, with a plug and small pipe. Colour white, with irregular green/grey zigzag transverse bands and dots on the ribs.

Range. Southern Queensland (Capricorn-Bunker Group south to Caloundra).

Habitat. Dredged in coarse coral sand from 10 to 37 m.

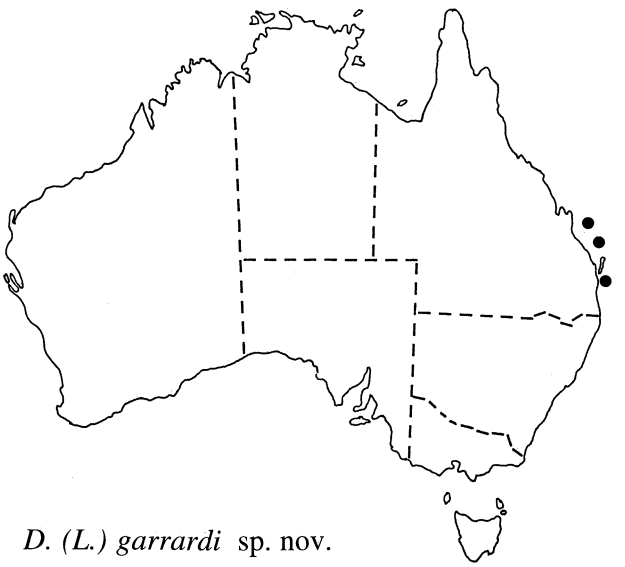


Figure 72. Known distribution of *Dentalium (Lentigodentalium) garrardi* n.sp.

Comparisons and remarks. For differentiating features of this species from the other members of the *D. (L.) woolacottae* group see also discussions of two previous species. This species, which occurs sympatrically with *D. (L.) woolacottae* Colman in at least one Queensland locality (Capricorn-Bunker Group) resembles *D. (L.) woolacottae* in colouration, but has a much narrower shell and narrow ribs which increase in number significantly towards the aperture. *Dentalium (L.) stumkatae* n.sp. resembles *D. (L.) garrardi* in being narrow and in frequently having an apical pipe, but is much less tapering anteriorly, with fewer ribs anteriorly and aperturally (see Key) and has its colour restricted to spots on the rib tops.

Subgenus *Pictodentalium* Kira, 1959

Pictodentalium Kira, 1959: 105; Habe, 1964: 14; Palmer, 1974a: 118.

Type species: *Dentalium (Pictodentalium) formosum hirasei* Kira, 1959, by monotypy.

Diagnosis. Shell large, solid, multi-coloured (red, white and often green bands); sculpture of numerous flat-topped longitudinal ribs with interstitial riblets and transverse growth lines; apical orifice circular and thick at the outer surface, rimmed on the inner.

Dentalium (Pictodentalium) formosum Adams & Reeve, 1848

Figs 68D, 73E,F, 74, 75

Dentalium formosum Adams & Reeve, 1848: 71, pl. 5, fig. 1a,b; G.B. Sowerby, 1860: 102, pl. 223, fig. 2; G.B. Sowerby, 1872: pl. 2, fig. 7; Clessin, 1896: 21, pl. 6, fig. 7; Pilsbry & Sharp,

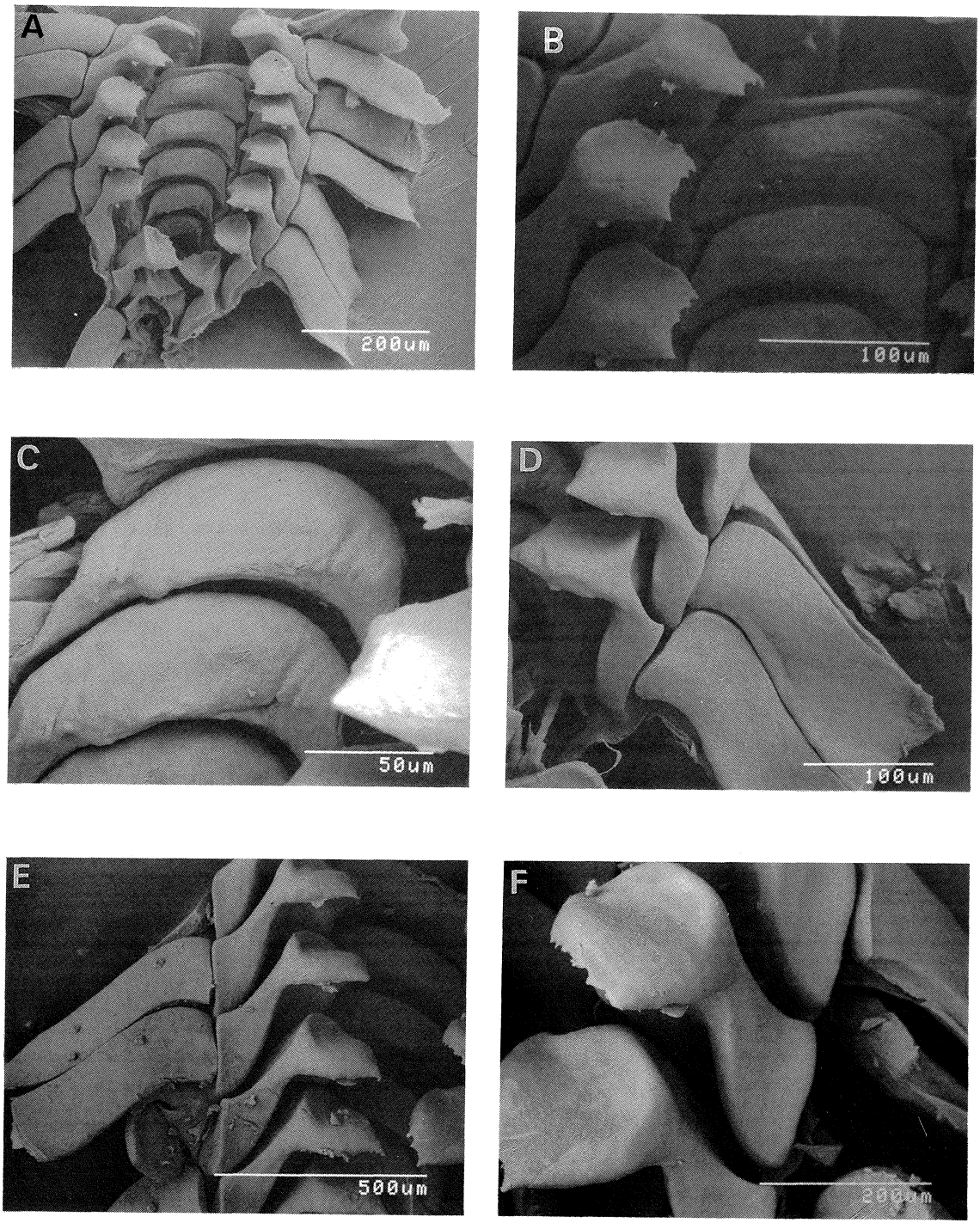


Figure 73. Radular ultrastructure of: **A–D** *Dentalium (Lentigodentalium) woolacottae* Colman, 1958 (Lady Musgrave Island, lagoon, AMS C172591). **E,F** *Dentalium (Pictodentalium) formosum* Adams & Reeve, 1848 (off Shoal Point, 50 m, WA, WAM 87/93).

1897: 2, pl. 1, figs 9–11; Boissevain, 1906: 8, pl. 1, fig. 2; Habe, 1964: 15, pl. 1, figs 4, 12, pl. 4, fig. 22.

Dentalium festivum G.B. Sowerby, 1913: 8.

Dentalium formosum hirasei Kira, 1959: 105, pl. 40, fig. 11.

Fissidentalium (Pictodentalium) formosum harrisoni Habe, 1970: 2, figs 1, 2.

Type material examined. LECTOTYPE: here selected from syntype lot BMNH 1951.2.14.1–3. Type locality: Sooloo Archipelago, outside coral reef near city of Sooloo, 16 fathoms [29 m]. Length of lectotype 58.3 mm, aperture diameter 11.5 mm, apex diameter 2.4 mm. PARALECTOTYPE 1, same locality data as lectotype (broken and glued

Figure 74. Dentaliida, Dentaliidae. *Dentalium (Pictodentalium)*. **A–C** *D. (P.) formosum* Adams & Reeve, 1848 (A—lectotype, BMNH 1951.2.12.1–3, Sooloo Archipelago, outside reef, 32 m, length 58.3 mm; B—KLColl, Exmouth Gulf, WA, length 50.5 mm; C—detail of sculpture of B).

specimen) length 28.9 mm, aperture diameter 6.3 mm. PARALECTOTYPE 2, same locality data as lectotype (broken specimen) length 59.8 mm, aperture diameter 11.9 mm. Holotype of *Dentalium festivum* G.B. Sowerby (type locality, New Caledonia) also examined.

Additional material examined. WESTERN AUSTRALIA: 3, WAM 160-93, west of Flat Island, near Long Island, off Onslow, 20 m, 1960; 2, WAM 281-93, 28°40.5'S 113°54'E, 6 km north-east of Leo Island, Easter Group, Abrolhos, 46 m, 22 August 1977, coral shale rubble; 3, WAM 87-93, 28°07'S 114°10'E, off Shoal Point, 50 m, 17 May 1982 (preserved); 2, Lamprell Collection, dived off Exmouth Gulf; 8, AMS C149177, 19°30.9–28'S 118°49.2–55.4'E, 96 km off Port Hedland, 37 m, 24 October 1983; 1, AMS C149224, 19°04.60–04.04'S 118°47.4–47.6'E, 144 km north north-east of Port Hedland, 30 October 1983; 1, AMS C149903, 19°30–31'S 118°52.49'E, 90 km north north-east of Port Hedland, 40 m, 25 October 1983; 1, AMS C174530, 19°29.0–58.2'S 118°53.5–53.2'E, north of Port Hedland, 40 m, 12 February 1983 (preserved); 3, AMS C173048, 19°03.6–03.4'S 119°03.4–03.5'E, 148 km north north-east of Port Hedland, 23 October 1983.

Description. Shell length to 67.2 mm, aperture diameter 10.2 mm, apex diameter 4.7 mm, apical pipe 2.5 mm in length; robust, moderately curved. Sculpture of 13–16, strong, rounded ribs, broader and flatter anteriorly; interstices of equal width; ribs and interstices with fine longitudinal lines. Aperture circular, slightly dorsoventrally compressed, crenulated by ribs. Apex circular, crenulated by ribs, with moderately wide dorsal notch and central pipe. Colour of transverse bands of rose, olive-green and white.

Radula. Central tooth broad (370 μm wide) shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped, 411 μm long with small cusps on the working surface; marginals sigmoidal and moderately short and broad (length 500 μm × breadth 155 μm) (see Fig. 73E,F). Ratios C:L = 1:1.11, L:M = 1:1.21, marginals breadth:length = 1:3.2 (based on female).

Range. Philippine Islands (Pilsbry & Sharp, 1897), New Guinea and islands of Shikoku and Honshu Japan (Habe, 1964), New Caledonia (type of *D. festivum* G.B. Sowerby), northern Western Australia.

Habitat. Dredged in coarse sand and coral rubble, 20 to 50 m.

Comparisons and remarks. This is the first published record of this species from Australia (presently known local distribution, Onslow to Port Hedland, WA). The large and distinctive, brightly coloured, strongly ribbed shell immediately separate *D. (P.) formosum* from all other Dentaliidae occurring in the Australian region. Australian specimens differ from the type series (lectotype and 2 paralectotypes) in accentuating the pink and white bands (that is, frequently showing reduced or no sign of green banding) and in having narrower interstices (this feature is however also somewhat variable). The same differences, in addition to differences in shell length and curvature, were cited by Habe (1970: 95) when differentiating his new subspecies *Fissidentalium (Pictodentalium) formosum harrisoni* from typical specimens of this species and the varietal form *hirasei* Kira [Note: Habe's "South China Sea" material (his presumed locality of origin), collected apparently by Taiwanese trawlers, could have originated from Australia as these boats also work off the WA coastline]. The holotype of *D. festivum* G.B. Sowerby likewise shows no sign of green banding and has narrow interstices, but is very strongly curved posteriorly. Until it can be demonstrated that there exists some anatomical basis for recognizing subspecies of *D. (P.) formosum*, we suggest treating all "forms" as merely variants within the one taxon. An apical pipe is usually present, and the apical notch may be of varied strength.

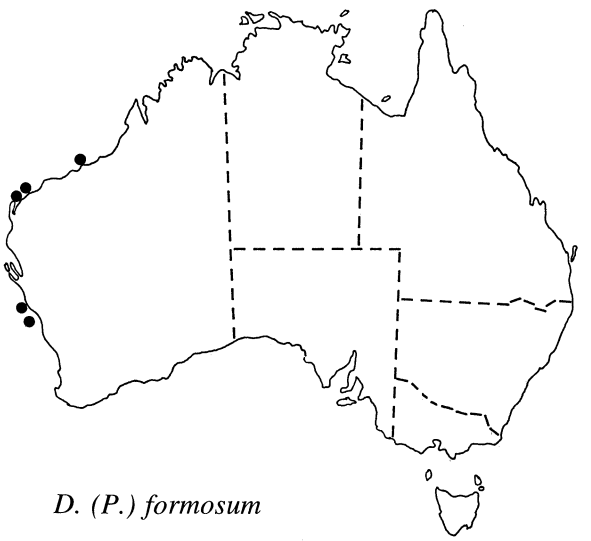


Figure 75. Australian distribution of *Dentalium (Pictodentalium) formosum* Adams & Reeve, 1848.

Genus *Tesseracme* Pilsbry & Sharp, 1897

Tesseracme Pilsbry & Sharp, 1897: 249; Boissevain, 1906: 39; Woodring, 1925: 199; Emerson, 1956: 2; Emerson, 1962: 469; Palmer, 1974a: 119.
Eudentalium Cotton & Godfrey, 1933: 140; Emerson, 1962: 467.

Type species: *Dentalium quadrapicale* G.B. Sowerby, 1860, Woodring, 1925, by subsequent designation.

Diagnosis. Shell quadrangular at the apex; interstices with or without intercalating longitudinal ribs or riblets.

Key to Australian *Tesseracme*

1 Quadrangular in profile from apex to aperture 2

—— Quadrangular at apex, with 32–36 intercalating ribs at aperture ..... *T. quadrapicale*

2 4 raised, finely serrated ribs at apex continuing to aperture; interstices smooth ..... *T. quadricostatum*

—— 4 raised, smooth ribs with a minor rib developing in each interstice towards the aperture ..... *T. philcolmani*

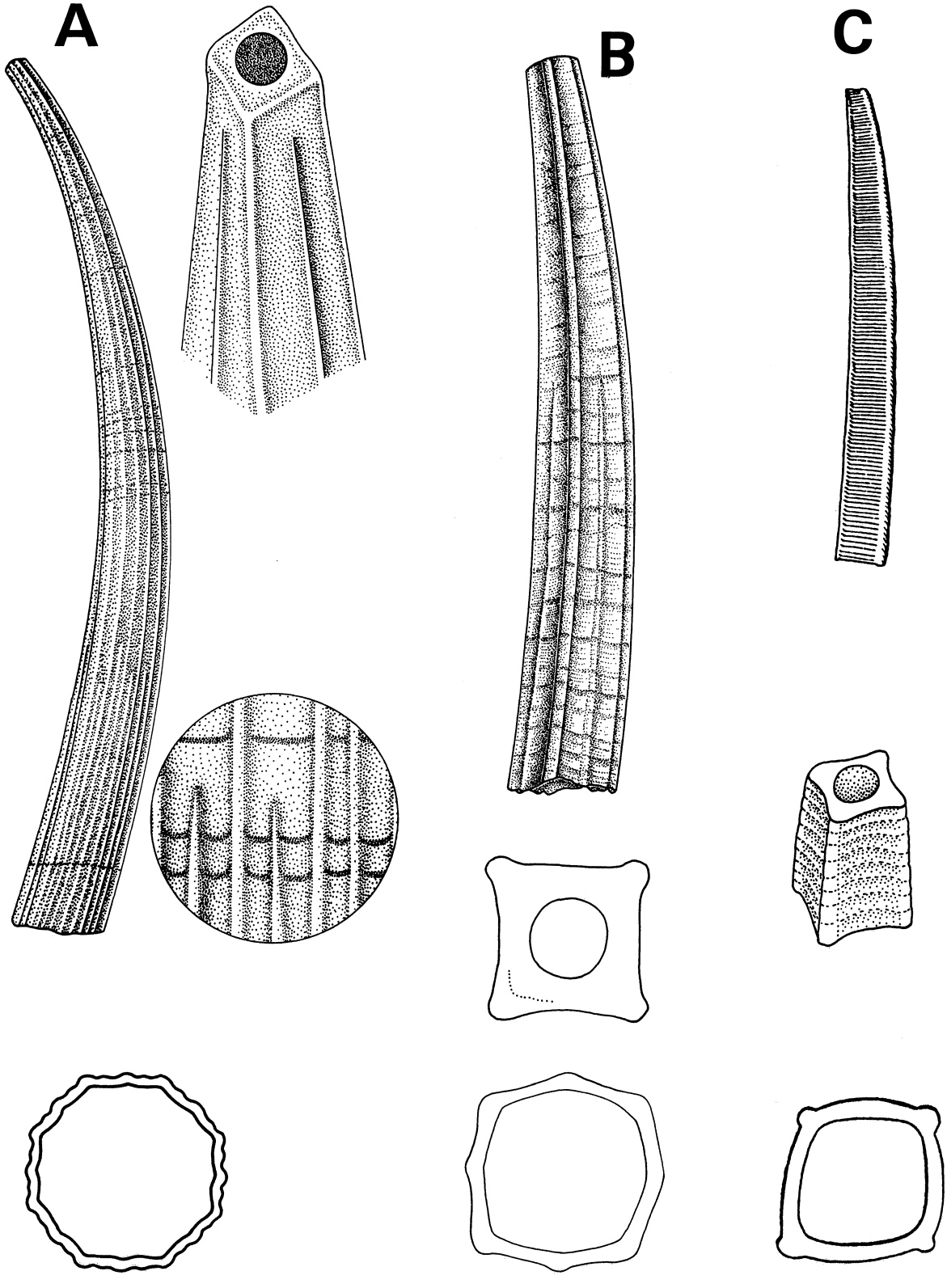


Figure 76. Dentaliida, Dentaliidae, *Tesseracme*. **A** *T. quadrapicale*. (Hanley in Sowerby, 1860) (KLColl, off Cairns, Qld, 1750 m, length 39.2 mm). **B** *T. philcolmani* n.sp. (holotype, WAM 233/94, 13 km north-east of Redcliff Point, Bernier Island, WA, 22.5 m, length 19.5 mm; aperture profile AMS C173310, 18.5 km N NW of Port Hedland, WA, 40 m). **C** *T. quadricostatum* (Brazier, 1877) (KLColl, Gulf of Carpentaria, Queensland; apex of lectotype AMS C170763, Princess Charlotte Bay, Qld, 24 m, length 15.5 mm). (Del.: A—C. Eadie; B and C [apex]—A. Hill; C [longitudinal profile and aperture] from Hedley, 1901).

Figure 77. Dentaliida, Dentaliidae, *Tesseracme*. **A** *T. quadrapicale*. (Hanley in Sowerby, 1860) (KL. coll., off Cairns, Qld, 1750 m, length 39.2 mm). **B** detail of previous figure showing sculpture. **C,D** *T. philcolmani* n.sp. (C—paratype, WAM 233/94, 13 km north-east of Redcliff Point, Bernier Island, WA, 22.5 m, length 19.5 mm; D—paratype, AMS C174543, north of Port Hedland, WA, 37 m, length 16.2 mm). **E,F** *T. quadricostatum* (Brazier, 1877) (E—lectotype, AMS C170763, Princess Charlotte Bay, Qld, 24 m, length 15.5 mm; F—N KL. coll., off Port Hedland, WA, 24 m, length 15.2 mm).

Tesseracme quadrapicale
(Hanley in G.B. Sowerby, 1860)

Figs 76A, 77A,B, 78, 81E,F

Dentalium quadrapicale Hanley in G.B. Sowerby, 1860: 103, pl. 225, fig. 61; Reeve, 1872: pl. 7, fig. 46; Clessin, 1896: 13; Pilsbry & Sharp, 1897: 34, pl. 4, fig. 50; Boissevain, 1906: 42, pl. 1, fig. 13.

Type material. HOLOTYPE: BMNH 1907.10.28.147. Type locality: Cochin, Malabar (India). Cannot presently be located (Ms K.M. Way, BMNH, pers. comm.). Length of holotype 31.5 mm (from original figure).

Material examined. QUEENSLAND: 135, AMS C173443, 14°45'S 141°25'E, 17 km from Edwards River mouth, Gulf of Carpentaria, October 1959; 1, QM MO38993, 11°10.2'S 136°34'E, Gulf of Carpentaria, 22 m, 19 November 1991; 1,

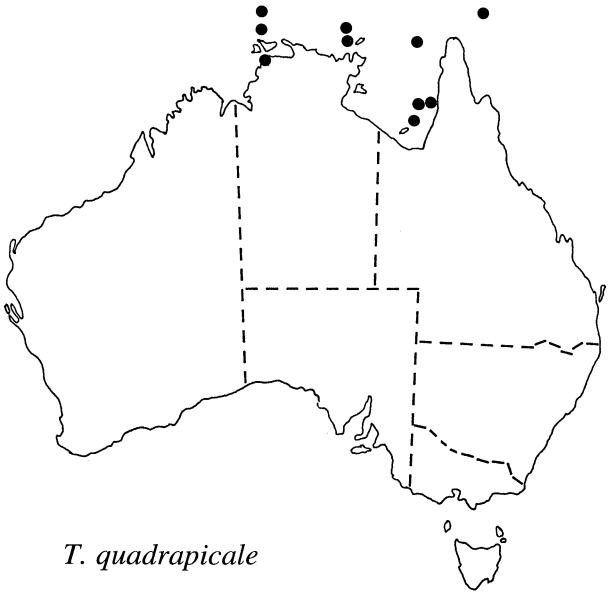


Figure 78. Australian distribution of *Tesseracme quadrapicale* (Hanley in Sowerby, 1860).

AMS C114549, 15°09.5'S 141°22'E, west of Mitchell River, Gulf of Carpentaria, 14.5 m, December 1976; 1, AMS C303580, 17°20'S 140°47'E, south-east corner Gulf of Carpentaria, 6.4 m, 20 May 1964; 1, QM MO38994, stn 30, 13°01.5'S 136°43'E, Gulf of Carpentaria, 22 m, 23 November 1991; 1, Lamprell collection, 12°36.23'S 141°39.62'E, Gulf of Carpentaria; 22, NMV F67467, 20, NMV F67468, 12°36.23'S 141°39.62'E, 10 m, 24 February 1983; 2, AMS C6652, Batavia River; 1, AMS C172190, 9°56'S 144°04'E, off Murray Island, Torres Strait, 9–15 m, 30 August–3 October 1907. NORTHERN TERRITORY: 2, AMS C172235, 9°30'S 132°34'E, Arafura Sea, approx. 160 km north of Croker Island, 124 m, 9 November 1969; 1, AMS C63134, off Croker Island, 11°07'S 132°33'E, 11 m, mud, 28 May 1938; 1, AMS C303581, 9°30'S 132°34'E, Arafura Sea, approx 160 km north of Croker Island, 124 m, 9 November 1969; 1, AMS C111859, Fannie Bay, Darwin, among rocks, 12 October 1965; 3, WAM 86-93, off Port Essington, 7–8 August 1986; 4, WAM 85-93, off Port Essington to west of Orantes Reef, 9–10 August 1986; 3, AMS C173380, 1, AMS C174888, 9°30'S 132°34'E, Arafura Sea, approx 160 km north of Croker Island, 124 m, 9 November 1969.

Description. Shell length to 58.9 mm, aperture diameter 5.1 mm, apex diameter 1.5 mm; solid, well curved. Sculpture at the apex of 4 ribs with an additional rib commencing at the apex intercalating to become 32–36 at the aperture. Aperture circular, slightly compressed anteroposteriorly. Apex 4 angled (see remarks), intercalating rib evident in each of the interstices. Colour white.

Radula. Central tooth broad (190 μm wide), moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface (showing slight evidence of a ridge-like cusp); laterals dumbbell-shaped, 200 μm long with small cusps on the working surface; marginals sigmoidal moderately short and broad (length 266 μm × breadth 100 μm) (see Fig. 81E,F). Ratios C:L = 1:1.14, L:M = 1:1.06, marginals breadth:length = 1:2.6 (sex not determined).

Range. India (Hanley in G.B. Sowerby, 1860), northern Queensland to Northern Territory.

Habitat. Dredged in coarse sand from 6.4 to 124 m.

Comparisons and remarks. Features differentiating *Tesseracme quadrapicale* from the other two Australian species of *Tesseracme*—*T. quadricostatum* (Brazier, 1877) and *T. philcolmani* n.sp.—include: larger size (20–60 mm); rounded aperture (quadrate in the other two species); larger number of ribs. After examining lot AMS C173443 with 129 specimens we found considerable variation in the number of ribs at the apex. In most specimens the typical 4 ribs are evident at the apex giving a quadrate shape. However in numerous specimens an interstitial rib extends to the apex. In some shells this additional rib is of equal strength to the four principal ribs thereby giving the apex an octangular shape. For this reason care should be exercised when identifying this species (possible confusion with 8–ribbed *Dentalium* species), and ideally a range of material should be examined. *Tesseracme dispar* (Sowerby) has been recorded from Australia by Brazier (as "*Dentalium dispar*"). Our examination of these specimens, now lodged in the McLeay Museum Sydney, showed that they are in fact *T. quadrapicale*.

Tesseracme philcolmani n.sp.

Figs 76B, 77C,D, 79, 81A–D

Etymology. Named after Mr Phillip Colman of the Malacology Section, Australian Museum, who has assisted in many ways in this study.

Type material examined. HOLOTYPE: WAM 233/94. Type locality: 13 km north-east of Redcliff Point, Bernier Island, 24°54'S 113°17.75'E, WA, 22.5 m, rubble and sand, 2 May 1981. Length of holotype 19.5 mm, aperture diameter 2.2 mm, apex diameter 0.8 mm. PARATYPES: 3, WAM 118-93, same locality data as holotype; 1, AMS C173310, 19°30.31'S 118°52.49'E, 18.5 km north north-east of Port Hedland, WA, 40 m, 25 October 1983; 1, AMS C174539, 19°29.2–29.5'S 118°52.5–52.3'E, 50 miles north-north-east of Port Hedland, WA, 40–41 m, 28 June 1983; 1, AMS C174543, 19°29.9–29.4'S 118°52.0–52.3'E, north of Port Hedland, WA, 37 m, 24 October 1983; 2, AMS C174548, 1, AMS C174547, 19°30.5–31.0'S 118°49.5'E, north of Port Hedland, WA, 39–41 m, 25 October 1983; 2, AMS C174645, 19°29.6–29.9'S 118°51.7–51.0'E, north of Port Hedland, 40–41 m, 25 October 1983.

Additional material examined. WESTERN AUSTRALIA: 1, AMS C173259, 1, AMS C172188, 14°29'S 123°03'E, approx 224 km north of Cape Leveque, 124 m, 12 November 1967; 1, AMS C172185, 17°37'S 121°15'E, approx 112 km north-west of

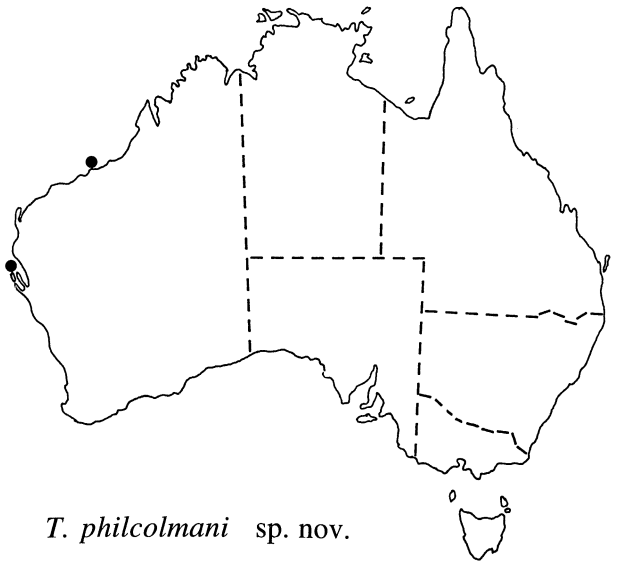


Figure 79. Known distribution of *Tesseracme philcolmani* n.sp.

Broome, 93 m, 22 November 1967; 1, AMS C172186, 19°07'S 118°15'E, 144 km north of Port Hedland, 88 m, 11 November 1968; 1, AMS C173267, 19°30.9–30.28'S 118°49.2–55.4'E, 83 km north north-east of Port Hedland, 37 m, 24 October 1983; 1, AMS C169966, 19°30.9–28.2'S 118°49.2–55.4'E, 96 km north north-east of Port Hedland, sand, 36–37 m, 24 October 1983.

Description. Shell length to 21.0 mm, aperture diameter 3.0 mm, apex diameter 1.7 mm; moderately robust, inclined to be moderately swollen centrally, slightly curved. Sculpture of 4 strong raised, smooth, rounded, longitudinal ribs; interstices flat with a central riblet (rarely 2–3 may occur) and strong transverse striae. Aperture quadrate (four-angled). Apex quadrate with a short plug and pipe. Colour chalk-white.

Radula. Central tooth broad (152 μm wide in male; 116 μm wide in female), shallow with smooth, weakly convex to almost straight superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped (145 μm long in male; 116 μm long in female) with small cusps on the working surface; marginals sigmoidal, moderately short and broad (length 200 μm × breadth 63 μm in male; length 167 μm, breadth 50 μm in female) (see Fig. 81A–D). Ratios: male C:L = 1:0.95, L:M = 1:1.38, marginals breadth:length = 1:3.17; female C:L = 1:1, L:M = 1:1.44, marginals breadth:length = 1:3.34.

Range. Northern Western Australia.

Habitat. Dredged in sandy mud and rubble from 40 to 124 m.

Comparisons and remarks. *Tesseracme philcolmani* resembles *T. quadricostatum* Brazier in size (shell less than 20 mm) and in the retention of a quadrate transverse profile from apex to aperture. *Tesseracme philcolmani* differs from *T. quadricostatum* in having: (1) smooth rib tops (rib tops serrated in *T. quadricostatum*); (2) intercalating ribs (intercalating ribs not present in *T. quadricostatum*) and (3) a short apical plug and pipe (absent in *T. quadricostatum*).

Tesseracme quadricostatum (Brazier, 1877)

Figs 76C, 77E,F, 80

Dentalium quadricostatum Brazier, 1877: 58; Pilsbry & Sharp, 1897: 33; Boissevain, 1906: 41; Hedley, 1901: 129, pl. 17, fig. 35; Hedley, 1910: 371.

Type material examined. LECTOTYPE: AMS C170763, selected from lot AMS.94ii. Type locality: Princess Charlotte Bay, northern Qld, 13 fathoms [24 m]. Length of lectotype 15.5 mm, aperture diameter 1.75 mm, apex diameter 1.0 mm. PARALECTOTYPES: 11, AMS C308638; same data as lectotype; 11, AMS C170762, Katow, New Guinea, 8 fathoms [15 m]; 1, AMS C170761, York Island, Torres Strait, 13 fathoms [24 m].

Additional material examined. QUEENSLAND: 2, AMS C173258, 19°45.7'S 148°19'E, east of Bowen, 46 m, 19 November 1977; 3, AMS C173251, 20°13.5'S 148°47.5'E, Whitsunday Passage; 4, AMS C169972, west of Hayman Island, 20°03'S 148°50'E, grey, muddy sand, 19 November. 1977; 1, AMS C169969, Whitsunday Passage, 27 m, 20°32.3'S 149°01.4'E, shelley, muddy sand, 19 November. 1977; 1, AMS C173265, 20°54'S 148°58'E, Seaforth; 1, AMS C173246, 19°06'S 146°48'E, off Townsville 9.5 m, 3 October 1982; 6, AMS C173260, 1, AMS C173253, off Horseshoe Bay, Magnetic Island, 5.9 m, 8 October 1965; 1, AMS C169968, Horseshoe Bay, Magnetic Island, 1959; 2, AMS C173256, 14°50'S 145°17'E, Decapolis Reef, Cape Flattery, 14 m, 25 February 1979; 1, AMS C173263, Buchans Point, 1964; 1, AMS C169973, 16°52–53'S 146°06'E, 8 October 1981, off

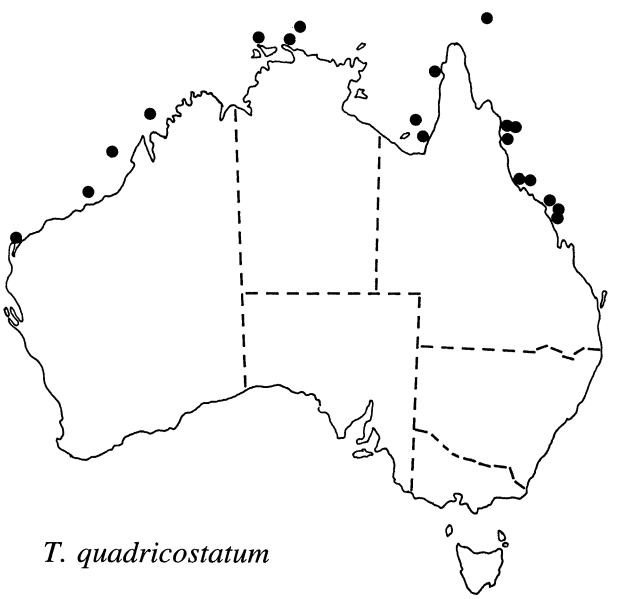


Figure 80. Australian distribution of *Tesseracme quadricostatum* (Brazier, 1877).

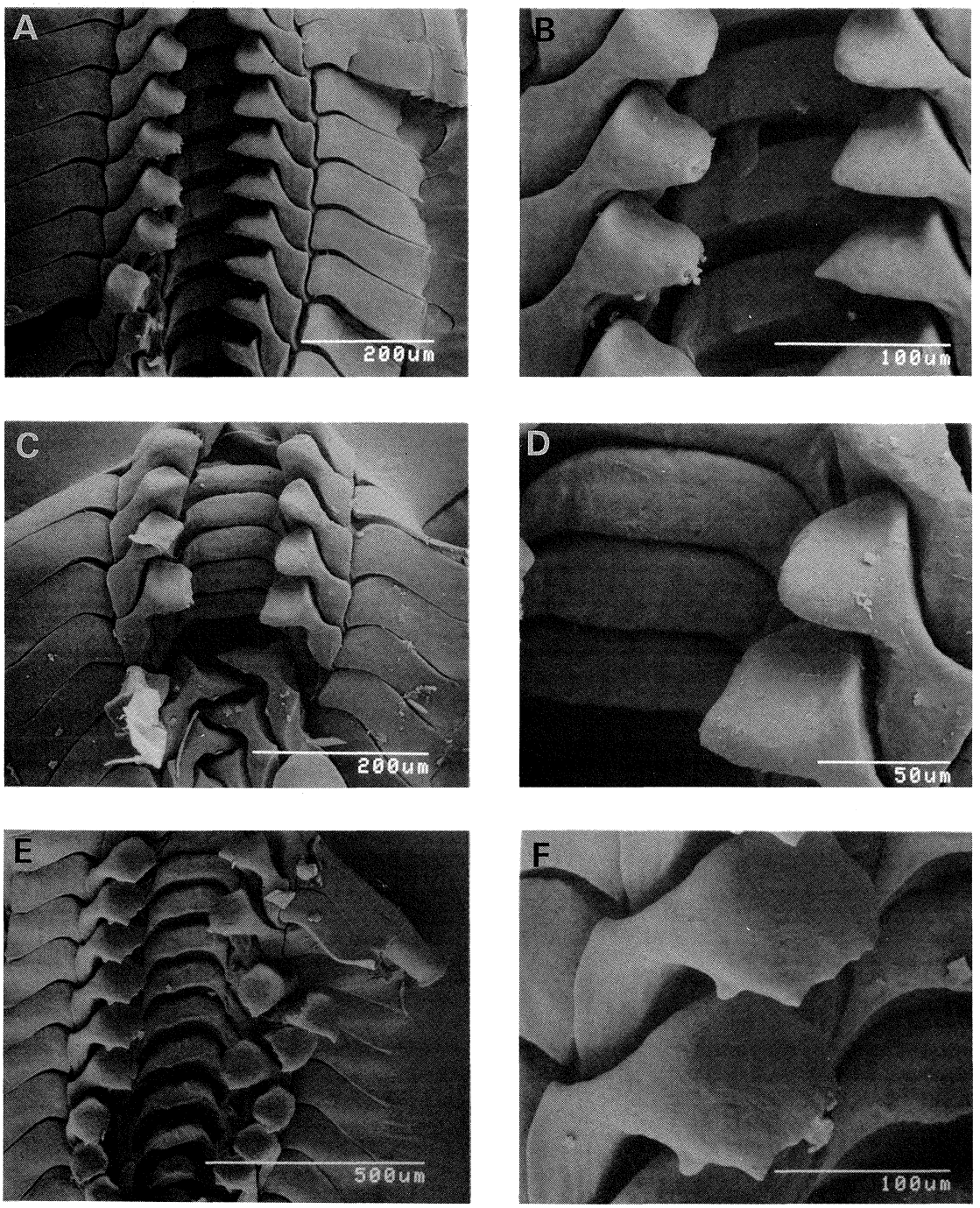


Figure 81. Radular ultrastructure. **A–D** *Tesseracme philcolmani* n.sp. (from paratypes, 13 km north-east of Redcliff Point, Betnier Island, WA, WAM 118/93 part), A and B—male, C and D—female. **E,F** *Tesseracme quadrapicale* (Hanley in Sowerby, 1860) (off Port Essington, WA, WAM 85/93).

Cairns; 5, AMS C173250, 16°51.36'S 146°01.12–01.04'E, off Cairns, 35 m, 14 October 1981; 2, AMS C76452, Buchans Point, north of Cairns; 1, AMS C172187, 4 mile beach, Port Douglas, 16 July 1974; 3, AMS C173252; 8, AMS C173247; 6, AMS C173248; 2, AMS C173249; 3, AMS C173266; 1, AMS C173264, Low Isles, 16–22 m, November 1928; 1, AMS C173245, Low Isles, 16–22 m, 24 April 1929; 1, AMS C173255, 9°56'S 144°04'E, off Murray Island, Torres Strait, Qld, 15 m, 30 August–3 October 1907; 52, AMS C44845, off Endeavour Reef, 40 m, 1918; 2, AMS C15316, 9.5 km west of Van Diemens Inlet, Gulf of Carpentaria, 16°54'S 140°54'E, 9 m, 5 July 1903; 4, AMS C15113, 3 km off Horsey River mouth, Gulf of Carpentaria, 9 m, 3 July 1903; 34, AMS C2585, 13°20'S 143°40'E, off Bow Reef, 19 m, 15 May 1895. NORTHERN TERRITORY: 1, AMS C172189, Sandbar no. 2, Darwin, 1 November 1970; 1, AMS C173257, 32 km off Point Charles, Darwin, 37 m, 14 July 1938; 1, AMS C173254, 10°36'S 132°56.5'E, 67 km north-east of Croker Island, 62

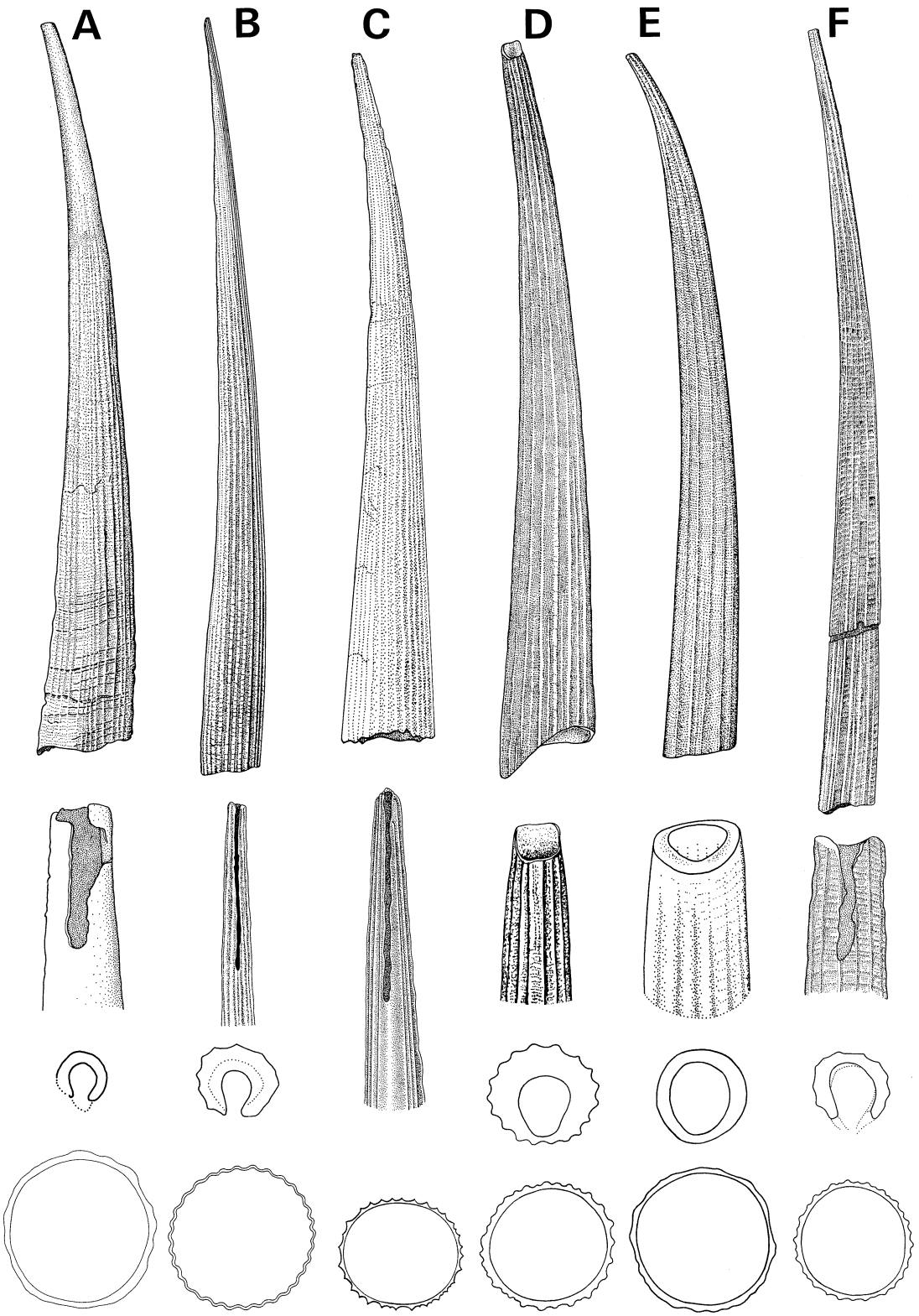


Figure 82. Dentaliida, Dentaliidae, *Fissidentalium*. **A–F** group of *F. ponderi*. **A** *F. ponderi* n.sp. (holotype, AMS C174624, off Newcastle, NSW, 444 m, length 79.6 mm). **B** *F. shirleyae* n.sp. (holotype, WAM 234/94, south-west of Imperieuse Reef, Rowley Shoals, WA, 356 m, length 132.0 mm). **C** *F. yokoyamai* (Makiyama, 1931) (KLColl, off Port Hedland, WA, 504 m, length 101.5 mm). **D** *F. verconis* (Cotton & Ludbrook, 1938) (holotype, SAM D13341, Beachport, SA, 366 m, length 47.1 mm). **E** *F. edenensis* n.sp. (holotype, AMS C303583, east of Eden, NSW., 616–1050 m, length 30.7 mm). **F** *F. clathratum* (von Martens, 1881) (holotype, ZM Berlin, No. 33122, near Moreton Bay, 1006 m, length 49.9 mm; aperture profile QM MO17729, off Cairns, 703 m). (Del. all A. Hill, except C—C. Eadie).

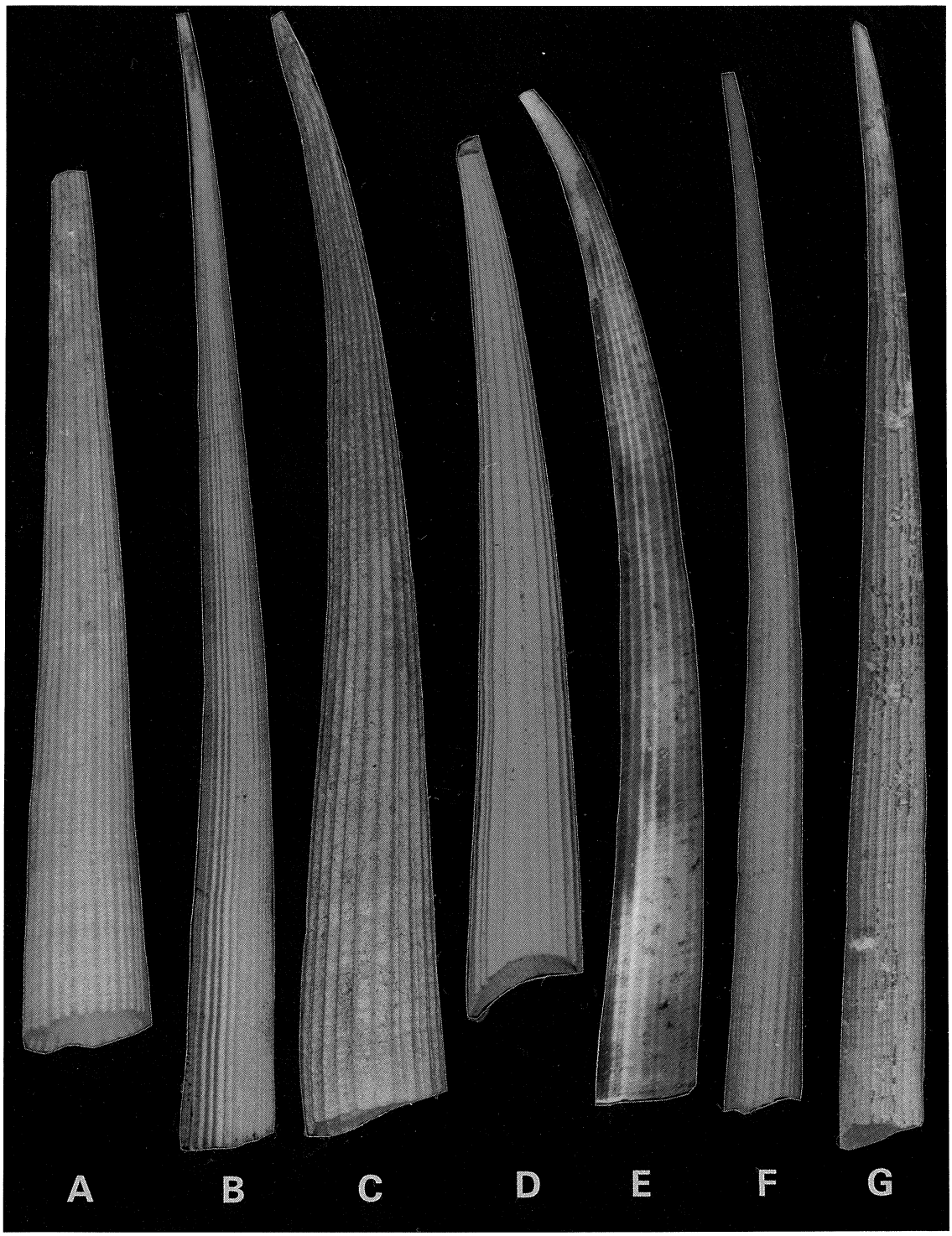


Figure 83. Dentaliida, Dentaliidae, *Fissidentalium*, group of *F. ponderi*. **A** *F. ponderi* n.sp. (holotype, AMS C174624, length 79.6 mm, shown from ventral aspect). **B** *F. shirleyae* n.sp. (holotype, WAM 234/94 part, south-west of Imperieuse Reef, Rowley Shoals, WA, 356 m, length 132.0 mm). **C** *F. yokoyamai* (Makiyama, 1931) (KLColl, off Port Hedland, WA, 504 m, length 101.5 mm). **D** *F. verconis* (Cotton & Ludbrook, 1938) (holotype, SAM D13341, Beachport, SA, 400 m, length 47.1 mm). **E** *F. edenensis* n.sp. (holotype, AMS C303583, east of Eden, 616–1050 m, length 30.7 mm). **F,G** *F. clathratum* (von Martens, 1881) (F—holotype, ZM Berlin, No. 33122, near Moreton Bay, 1006 m, length 49.9 mm; G—KLColl, off Moreton Island, Qld, 120 m, length 40.0 mm).

m, 8 November 1969; 1, AMS C169967, 11°01'S 132°34'E, off Croker Island, Coburg Peninsula, 11 m; 1, AMS C173362, 10°48.5'S 133°48'E, 84 km north-east of Goulburn Island, 60 m, 31 October 1969; 3, AMS C173261, Flinders Island, near Cape Melville, 26 m.

Description. Shell length to 58.9 mm, aperture diameter 5.0 mm, apex diameter 1.5 mm; moderately robust, slightly curved. Sculpture of 4 strong, raised, rounded, finely serrated, longitudinal ribs; interstices flat, with strong transverse striae. Aperture quadrate (four-angled). Apex quadrate without plug or pipe. Colour chalk-white.

Range. New Guinea, Queensland and Northern Territory.

Habitat. Dredged in sandy mud from 9 to 62 m.

Comparisons and remarks. This species resembles *T. philcolmani* n.sp. in size (shell less than 20 mm) and the retention of the quadrate transverse profile from apex to aperture. *Tesseracme quadricostatum* differs from *T. philcolmani* in having serrated ribs (ribs smooth in *T. philcolmani*); lacking intercalating ribs (intercalating ribs present in *T. philcolmani*); lacking a short apical plug and pipe (present in *T. philcolmani*). *Tesseracme quadricostatum* and *T. philcolmani* can both be distinguished from *T. quadrapicale* (Hanley in G.B. Sowerby) by their quadrate aperture profiles (circular in *T. quadrapicale*); fewer ribs and smaller shell size. Emerson (1962) suggested transferral of this species to the Entalinidae (Order Gadilida), but this is not supported by our studies of the radula which confirm a typical dentalioid central tooth (wider than high).

Genus *Fissidentalium* Fischer, 1885

Fissidentalium Fischer, 1885: 894; Pilsbry & Sharp, 1897: 63; Boissevain, 1906: 36; Ludbrook, 1960: I39; Emerson, 1962: 470; Habe, 1964: 11; Palmer, 1974a: 119; Steiner, 1992a: 396.
Schizodentalium G.B. Sowerby, 1894: 158; Emerson, 1962: 470.
Compressidentalium Habe, 1963: 260; Palmer, 1974a: 118.

Type species: *Dentalium ergasticum* Fischer, 1885: 894; by monotypy.

Diagnosis. Shell medium to large, solid, moderately curved to almost straight, with many longitudinal ribs; apex with or without a long slit; aperture ovate, often dorsoventrally compressed or slightly elliptical.

Key to Group of *Fissidentalium ponderi*

Twelve to 21 ribs at apex, intercalating to 20–44 at aperture, shell weakly to moderately curved, often somewhat dorsoventrally compressed.

1 Shell wide or relatively wide anteriorly, rapidly attenuate 2

—— Shell relatively narrow anteriorly, slowly attenuate 3

2 Apical rib count only half that at aperture 4

—— Apical and aperture rib count almost equal 5

3 17 ribs at apex; intercalating to approximately 32 strong ribs at aperture ..... *F. shirleyae*

—— 21 ribs at apex; intercalating to 26–30 at the aperture ..... *F. clathratum*

4 16 strong apical ribs intercalating to 32 low ribs at aperture ..... *F. ponderi*

—— 12 strong apical ribs intercalating to 22 narrow ribs and a weaker riblet in each interstice ..... *F. yokoyamai*

5 17 strong apical ribs intercalating to approximately 20 at aperture ..... *F. verconis*

—— 17 strong apical ribs continue to aperture, with a riblet in each interstice ..... *F. edenensis*

Fissidentalium ponderi n.sp.

Figs 82A, 83A, 84

Etymology. Named after Dr Winston Ponder, Malacology Section of the Australian Museum, who first suggested that this species was distinct from *F. zelandicum* and possibly not previously described.

Type material examined. HOLOTYPE: AMS C174624. Type locality: off Newcastle, 32°59'S 152°33.5'E, NSW, 444 m, 9 October 1982. Length of holotype 79.6 mm, aperture diameter 10.0 mm, apex diameter 1.7 mm, length of slit 4.5 mm. PARATYPES: 1, AMS C173468, same locality data as holotype; 2, SAM D18888, 37°37'S 150°17'E, 50 km east of Gabo Island, Vic., 436 m, 14 October 1984; 2, AMS C307826, 34°18–24'S 151°26–21'E, north-east of Wollongong, NSW, mud bottom, 457–484 m, 20 August 1975.

Additional material examined. SOUTH AUSTRALIA: 3, AMS C173016, 60 km west of Cape Wiles 182 m, 29 August 1909; 1, AMS C173017, 38°05–10'S 140°00'E, off Cape Martin, Beachport, 667 m. VICTORIA: 1, AMS C173015, 4, AMS C173014, 2, AMS C108614, 2, AMS C110726, 38°12.11'S 149°49.53'E, south-east of Gabo Island, 329–439 m, 10–19 July 1977; 1, NMV F72171, 38°17.70'S 149°11.30'E, south of Point Hicks, 400 m, 24 July 1986, coarse sand (preserved); 10, AMS C173018, off Gabo Island, 365 m, November-December 1913; 14, AMS C111843, 1, AMS C5737, south of Cape Everard, 320–366 m, 20–22 October 1914; 1, AMS C5744, Gabo Island, to Everard Banks, 400 m, October 1914; 9, AMS C110810, 1, AMS C117810, 37°45.42'S 150°17.18'E, off Gabo Island, 366 m, 29–30 November 1977. NEW SOUTH WALES: 2, AMS C110671, 37°10.14'S 150°22'E, south of Eden, 384 m, 12 July 1977; 2, NMV F72131, 37°00.60'S 150°20.70'E, off Eden, 363 m, 21 July 1986, coarse shell bottom; 1, AMS C82468, 1, AMS C82481, 37°42.39'S 150°16.17'E, south of Twofold Bay, 82–393 m, 30 July–1 August 1971; 5, AMS C110668, 37°22.33'S 150°20.16'E, off Cape Howe, 329 m, 18 March 1977; 2, AMS C110669, 37°21.24'S 150°21.20'E, east of Green Cape, 330 m, 14–17 July 1976; 1, AMS C110712, 37°15.13'S 150°17.18'E, 330 m, 12 October 1977; 15, AMS C100809, 2, AMS C102826, 36°43.36'S 150°19.20'E, east of Tathra-Bermagui, 380 m, 22 July 1975; 9, AMS C102829, 36°27.21'S 150°19.21'E, east of Bermagui, 383 m, 22 July 1975; 1, AMS C102365, 35°28.34'S 150°48.45'E, east of Brush Island, Batemans Bay, 467 m, 10 July 1975; 1, AMS C116474, 3, AMS C103416, 6, AMS C105417, 3, AMS C110720, 35°34.30'S 150°04.47'E, east of Brush Island, south of Ulladulla, 403–550 m, 22 November–15 December 1975; 1, AMS C173013, 34°38–32'S 150°40–45'E, east of Brush Island, south of Ulladulla, 439 m, 110 July 1975; 2, AMS C102897, 35°29.25'S 150°47.50'E, south-east of Ulladulla, 440 m, 16 December 1975; 1, AMS C117809, 34°57.54'S 151°09.07'E, off Nowra, 550 m, 12 December 1978; 2, NMV F75840, 34°51.90'S 151°12.60'E, off Nowra, 770 m, 15 July 1986; 2, Lamprell Collection, dredged off Sydney, 560–740 m. December 1986; 5, AMS C101620, 19°26'S 153°04'E, east north-east of Clarence River, NSW, 457 m, 12 October 1975; 1, AMS C100797, 12 km east of Port Stephens, 101 m, 18 August 1975; 2, AMS C120403, 32°50–52'S 152°42.4'E, off Port Stephens, 550 m, 6 December 1978; 1, AMS C173009, 32°52'S 152°32'E, off Broken Bay, 145 m, 6 December 1979; 6, AMS C100862, 34°28.34'S 151°19.17'E, east of Port Kembla, 412 m, 20 August 1975; 7, AMS C117905, 5, AMS C117890, 2, AMS C102373, 34°16.22'S 151°26.23'E, north-east of Wollongong, 366 m, 8 August 1975; 1, AMS C102584, 34°39.32'S 151°15.19'E, east of Kiama, 412 m, 16 December 1975; 3, AMS C155928, 34°38.33'S 151°16.17'E, east of Kiama, 500 m, 17 September 1986; 1, AMS C100449, 34°38.46'S 151°15.13'E, east of Kiama, 457 m, 30 July 1975; 1, AMS C173301, 34°13.8–15.8'S 151°29.1–26.6'E, south of Sydney, 381–395 m, 5 October 1982; 4, AMS C126547, 33°33'S 152°05'E, north-east of Sydney, 750 m, 3 December 1979; 5, AMS C125568, 5, AMS C173010, off Sydney, 457 m, 20 December 1976; 1, AMS C108841, 33°43.40'S 151°51.51'E, east of Sydney, 457 m, 6 May 1977; 1, AMS C125071, 33°45.48'S 151°52.50'E, east of Sydney, 513 m; 4, AMS C107981, 34°04.2'S 150°37.2'E, off Sydney, 3 November 1976; 5, AMS C154617, 33°44.50'S 151°50.46'E, 440 m, 13 September 1984; 1, AMS C110714, 33°46.43'S 151°50.52'E, 439 m, 8 July 1977; 8, AMS C125567, 33°48'S 151°52'E, 549 m, 3 December 1979; 4, AMS C102898, 34°48.43'S 151°48.51'E, 421 m, 17 December 1975; 1, AMS C173011, off Sydney, 400 m, 8 November 1960; 1, AMS C123018, off Sydney, 440 m, 26 July 1979; 2, AMS C102825, 34°21.16'S 151°24.28'E, south-east of Botany Bay, 421 m, 16 December 1975; 24, AMS C125562, 33°41'S 151°53'E, off Botany Bay, 366 m, 5 December 1978.

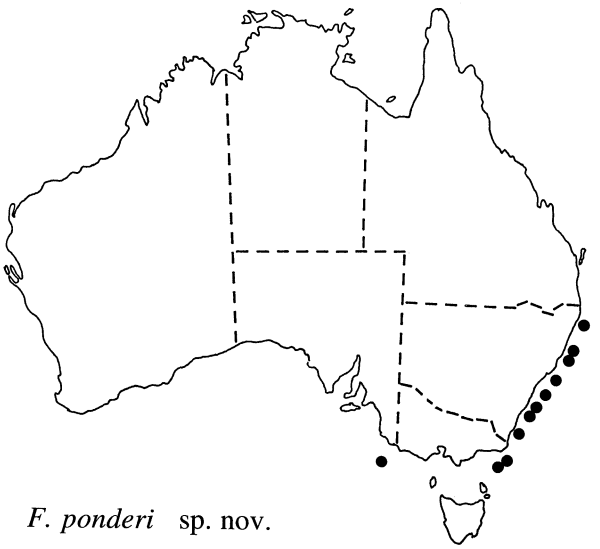


Figure 84. Known distribution of *Fissidentalium ponderi* n.sp.

Description. Shell length to 116.8 mm, aperture diameter 11.4 mm, apex diameter 2.9 mm; solid, slightly curved. Sculpture at apex of approximately 16, narrow, rounded, longitudinal ribs with minor ribs in the interstices which develop into low, unequal, rounded ribs (approx 32) of equal strength at the aperture; interstices wide at the apex and of equal size to the ribs at the aperture. Ribs and interstices crossed by dense, transverse growth lines over the whole surface of the shell. Aperture circular, slightly dorsoventrally compressed, crenulated by ribs. Apex circular, slightly dorsoventrally compressed, intact specimens crenulated by ribs, some specimens have a short slit on the ventral side. Colour white to grey-white.

Range. South Australia, Victoria to New South Wales.

Habitat. Trawled in coarse sand from 82 to 770 m.

Comparisons and remarks. *Fissidentalium ponderi* resembles most closely *F. verconis* Cotton & Ludbrook, *F. shirleyae* n.sp. and *F. yokoyamai* Makiyama, all of which show scaling of the ribs. Differentiating features of *F. ponderi* include: rib count, rib size and rib profile (refer to Key and Table 1, p.183). If a slit is present (ventral side of apex), it usually is very short (2.5–3 mm long). *Fissidentalium ponderi* has been mislabelled in museum collections as *F. zelandicum* (Sowerby). However, *F. ponderi* shows several differences from *F. zelandicum* including the rib number (21 at apex, 42 at aperture versus 16 at apex, 32 at aperture in *F. ponderi*), usually a dorsoventrally compressed aperture profile (round in *F. zelandicum*) and continuing strength of the ribs towards the aperture (ribs becoming almost obsolete towards aperture in *F. zelandicum*). Although we could not examine the holotype of *F. zelandicum* (not locatable in BMNH, K.M. Way, pers. comm.), we are confident that available material of this species is true to type. *Fissidentalium ponderi* also shows some resemblance to the Tertiary fossil species *F. mantelli* (Zittel) in shell profile, but differs from this species in being larger and heavier, more coarsely ribbed and exhibiting pronounced dorsoventral compression. In addition *F. ponderi*, unlike *F. mantelli*, shows no evidence of rib obsolescence near the aperture.

Fissidentalium shirleyae n.sp.

Figs 82B, 83B, 85, 86A,B

Etymology. Named after Mrs Shirley Slack-Smith (Western Australian Museum) who collected much of the Western Australian material used in this study and for her assistance in this and other projects.

Type material examined. HOLOTYPE: WAM 234/94. Type locality: 18°06'S 118°10'E, south-west of Imperieuse Reef, Rowley Shoals, 250 km north-north-west of WA, 356 m in mud, 17 August 1983. Length of holotype 132.0 mm, aperture diameter 11.3×10.95 mm, apex diameter 1.7 mm, length of slit 16.1 mm, width 4.0 mm. PARATYPES: 38, WAM 4304.83, same locality data as holotype; 2, AMS C201740, (ex WAM 4304.83) same locality data as holotype; 1, QM MO52532, (ex WAM 4304.83) same locality data as holotype; 1, WAM 119-93, 18°44'S 117°20'E, 220 km north-west of Port Hedland, WA, 326 m, 13 April 1982.

Description. Shell length to 132.0 mm, aperture diameter 11.3 × 10.95 mm, apex diameter 1.7 mm; solid; slightly and evenly curved; Sculpture of 20, moderately strong longitudinal ribs at the apex intercalating to 30 lower and rounded ribs towards the aperture; interstices narrow. Aperture circular, slightly dorsoventrally compressed, crenulated by ribs. Apex circular, crenulated by ribs, some specimens have a long ventral slit. Colour white, specimens often have a black encrustation over most of the surface.

Radula. Central tooth broad (800 μm wide) moderately shallow with smooth, convex superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped, 781 μm long, heavily mineralized, with small cusps on the working surface; marginals curved, slightly sigmoidal, moderately short and broad (length 909 μm × breadth 290 μm) (see Fig. 86A,B). Ratios C:L = 1:0.97, L:M = 1:1.16, marginals breadth:length = 1:3.13 (sex not determined).

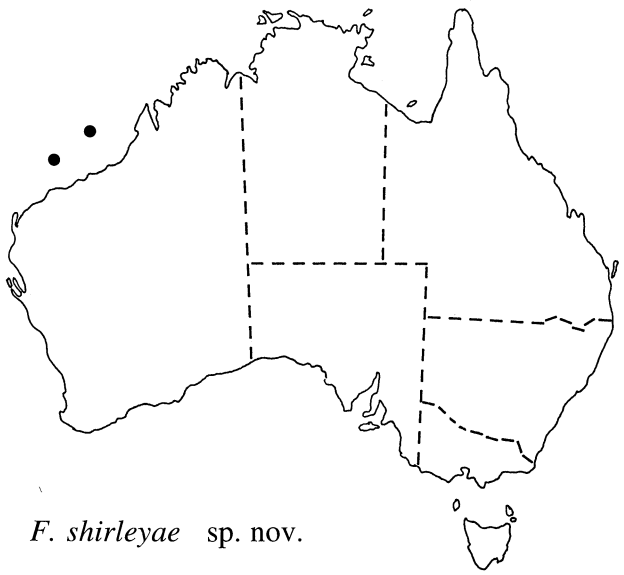


Figure 85. Known distribution of *Fissidentalium shirleyae* n.sp.

Range. Northern Western Australia.

Habitat. Dredged in mud to 356 m.

Comparisons and remarks. *Fissidentalium shirleyae* resembles most closely *F. ponderi* n.sp. and *F. yokoyamai* (Makiyama) in having a very large shell characterized by raised, scaled ribbing and usually a prominent apical slit. Differentiating features which help to separate *F. shirleyae* from these species include: rib number number (refer to Table 1, p. 183); slight curvature. In addition in proportion to its length, the shell aperture of *F. shirleyae* is much narrower than observed in *F. ponderi* or *F. yokoyamai*. The longitudinal profile of *F. shirleyae* is much more slender than either of these two, probably closely related species. This large and impressive species has only been recorded by recent dredging off northern Western Australia, where at certain localities, it seems to be relatively common.

Fissidentalium yokoyamai (Makiyama, 1931)

Figs 82C, 83C, 86C,D, 87

Dentalium yokoyamai Makiyama, 1931: 44, pl. 1, fig. 1.
Dentalium complexum Yokoyama, 1920: 101, pl. 6, fig. 27 (non Dall, 1895).
Dentalium (Fissidentalium) yokoyamai Makiyama. Kira, 1962: 117, pl. 41, fig. 12.
Fissidentalium (Fissidentalium) yokoyamai (Makiyama). Habe, 1963: 259, pl. 37, fig. 10; Habe, 1964: 12, pl. 1, fig. 10.

Type material. Collection: Science Department, Kyoto Imperial University. Type locality: Koshiba, Yokosuka City, Honshu (Koshiba zone, Pleistocene), Japan. Dimensions of holotype unknown (specimen not examined).

Additional material examined. WESTERN AUSTRALIA: 3, K.L trawled off Port Hedland, 504 m; 2, WAM 129-93, 14°43.1'S 121°44.9'E, 12 February 1984; 2, WAM 4303.83, 16°46'S 119°44'E, north-east of Mermaid Reef, Rowley Shoals, 19 August 1983; 1, WAM 123-93, 14°51.9'S 121°40.6'E, north-west of Cape Leveque, 16 February 1984; 2, WAM 122-93, 12°54.4'S 123°00.2'E, north-west of York Sound, 15 February 1982; 1, WAM 121-93, 12°48.1'S 122°56.7'E, north-west of York Sound, 15 February 1984; 1, WAM 4305-83, north of Karratha, 23 August 1983; 2, WAM 124-93, 16°54'S 119°52'E, west of Lacepede Archipelago, 23 February 1984.

Description. Shell length to 135.1 mm, aperture diameter 18.1 × 17.0 mm, apex diameter 2.3 mm; (length of slit 33.6 mm, width 1.1 mm on figured specimen); thick, moderately curved, more so towards the apex. Sculpture of 12 strong longitudinal ribs at the apex, intercalating to 22 narrow, moderately sharp, longitudinal ribs at the aperture usually with a slightly weaker rib in each interstice; interstices wide, concave, ribs and interstices crossed by fine transverse growth lines, giving a file like appearance to the ribs and interstices. Aperture circular to slightly obovate being slightly compressed dorsoventrally, crenulated by ribs. Apex circular, crenulated by ribs, sometimes with a ventral slit. Colour ash white to white.

Radula. Central tooth broad (555 μm wide), moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface (showing evidence of a long, low, ridge-like cusp); laterals dumbbell-shaped, 640 μm long, heavily mineralized, with small cusps on the working surface; marginals sigmoidal, moderately short and broad (length 777 μm × breadth 194 μm) (see Fig. 86C,D). Ratios C:L = 1:1.15, L:M = 1:1.21, marginals breadth:length = 1:4 (based on male).

Range. Japan (Habe, 1963); northern Western Australia.

Habitat. Trawled in sand and mud to 504 m.

Comparisons and remarks. *Fissidentalium yokoyamai* resembles most closely *F. verconis* Cotton & Ludbrook, *F. ponderi* n.sp. and *F. shirleyae* n.sp. Differentiating features of *F. yokoyamai* which help to distinguish it from these species include: sharp-edged ribs; different rib count (see Table 1, p.183). Although *F. shirleyae* attains almost the same maximum length as *F. yokoyamai*, its shell is consistently narrower and more weakly curved than that of *F. yokoyamai*. *Fissidentalium yokoyamai* is probably most closely related to *F. ponderi*, although the latter is a decidely smaller shell which has ribs which become low or almost obsolete towards the aperture. Prior to this study, *F. yokoyamai* was known only from Japan. This is the first record of the species from Australian waters. Presumably further collecting will show that *F. yokoyamai* occurs at other localities between Australia and Japan.

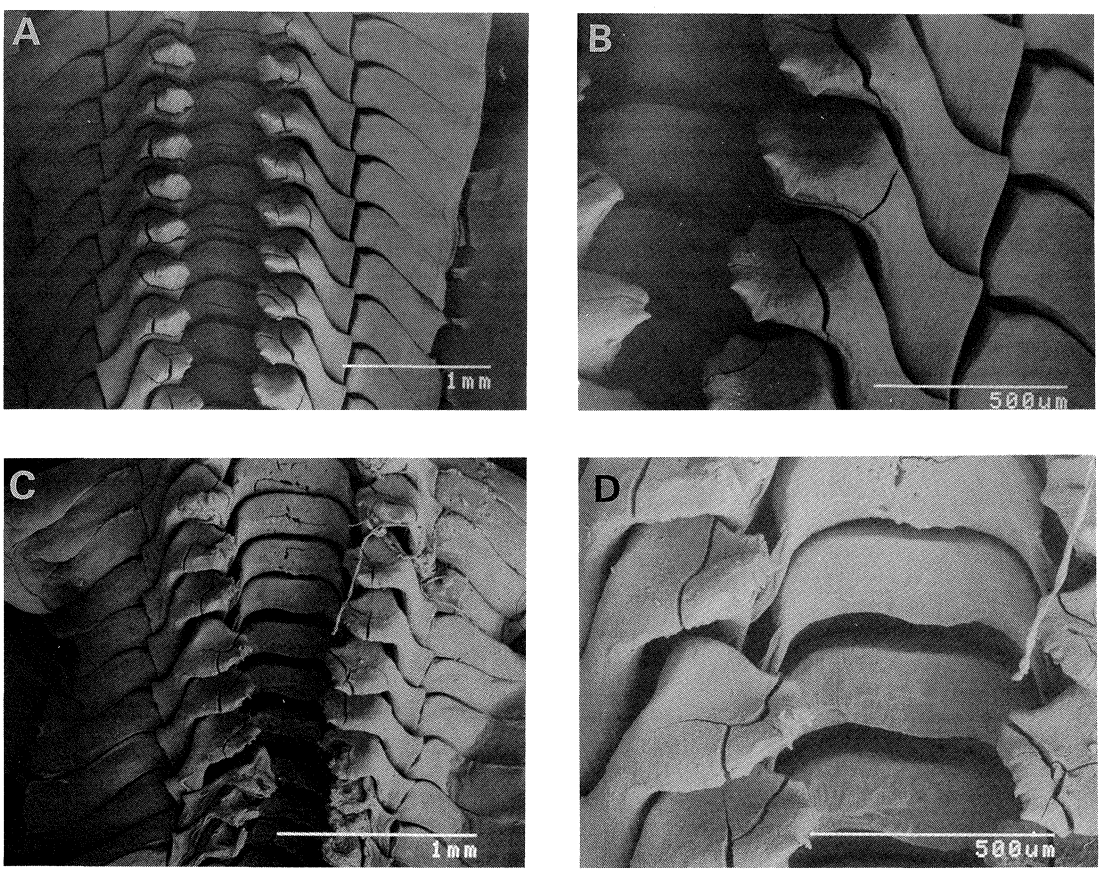


Figure 86. Radular ultrastructure. **A,B** *Fissidentalium shirleyae* n.sp. (from paratype, south-west of Imperieuse Reef, Rowley Shoals, Western Australia, 356 m, WAM 4304–83). **C,D** *Fissidentalium yokoyamai* (Makiyama, 1931) (W of Lacepede Archipelago, 440 m, WAM 124/93).

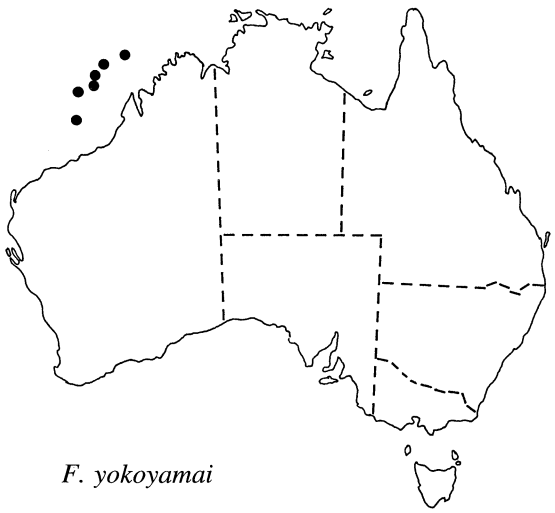


Figure 87. Australian distribution of *Fissidentalium yokoyamai* (Makiyama, 1931).

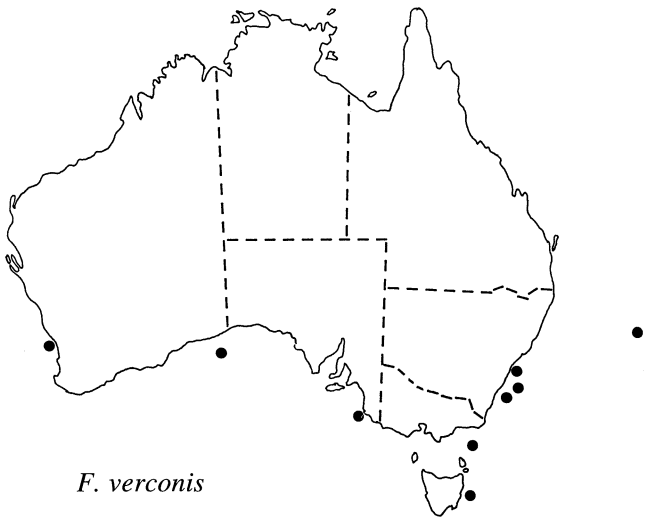


Figure 88. Known distribution of *Fissidentalium verconis* Cotton & Ludbrook, 1938.

Fissidentalium verconis (Cotton & Ludbrook, 1938)

Figs 82D, 83D, 88

Dentalium verconis Cotton & Ludbrook, 1938: 221, pl. 12, fig. 1; Cotton & Godfrey, 1940: 332, fig. 354, 355; Zeidler & Macphail, 1978: 384.

Type material examined. HOLOTYPE: SAM D13341. Type locality: Beachport, SA, 200 fathoms [366 m]. Length of holotype 47.1 mm, aperture diameter 6.2 mm, apex diameter 1.35 mm.

Additional material examined. WESTERN AUSTRALIA: 1, WAM 246-93, 31°43'S 114°53'E, 16 March 1976; 1, WAM 267-93, 1, WAM 266-93, west of Rottnest Island, 16 March 1976; 1, WAM 265-93, 31°01'S 114°49'E, west of Rottnest Island, 17 March 1979; 15, SAM D18884, 192 km west of Eucla. SOUTH AUSTRALIA: 1, AMS C172559, off Cape Martin, Beachport, 667 m; many, AMS C175225, 160 km south south-west of St Francis Island, 635 m, 9 March 1909; 1, SAM D18885, Beachport, 220 m; 8, SAM D18886 Cape Jaffa, 260 m; 1, SAM D18887, off Port Lincoln; 3, SAM D18888, Cape Jaffa, 260 m, 25, December 1905 (as *D. zelandicum*); 1, SAM D18889 off Beachport, 400 m, (as *D. zelandicum*). TASMANIA: 1, NMV F75842, 42°00.20'S 148°37.70'E, off Freycinet Peninsula, 720 m, 27 July 1986, coarse shelley sand; 1, NMV F75843, 42°02.20'S 148°38.70'E, off Freycinet Peninsula, 800 m, 27 July 1986, coarse shelley sand. VICTORIA: 1, NMV F72159, 38°21.90'S 149°20.00'E, south of Point Hicks, 1000 m, 23 July 1986. NEW SOUTH WALES: 1, AMS C169800, 34°50'S 151°15'E, off Nowra, 841 m, 12 December 1978; 1, AMS C173378, east of Sydney, 150 m, 18 July 1962; 1, NMV F72202, 30°31'S 161°40.6'E, Tasman Sea, 1210 m, 29 December 1975.

Description. Shell length to 47.1 mm, aperture diameter 6.2 mm, apex diameter 1.35 mm; solid, slightly curved posteriorly. Sculpture of 17 moderately strong, rounded, longitudinal ribs at the apex, increasing about midway along the shell to about 20 ribs at the aperture; interstices wider, flat, both ribs and interstices crossed by regular, fine, oblique growth lines. Aperture circular, slightly dorsoventrally compressed, crenulated by ribs. Apex circular, crenulated by ribs usually without slit. Colour white.

Radula. Cotton & Godfrey (1940, fig. 355) described the radular features of *F. verconis*, as seen with light microscopy. Their study shows that the central tooth of this species is broad and shallow, with an almost flat superior surface. Laterals are essentially as seen in the majority of Dentaliida examined herein: dumbbell-shaped with cusps on the working edge. Marginals of *F. verconis* are almost rectangular in shape, with little indication of curvature. No scale or measurements was provided by Cotton & Godfrey.

Range. South Australia, Tasmania, Victoria to New South Wales.

Habitat. Dredged in coarse sand from 150 to 1210 m.

Comparisons and remarks. *Fissidentalium verconis* resembles most closely *F. yokoyamai* (Makiyama) and *F. ponderi* n.sp., being similar in longitudinal shell profile and rib-growth line interaction. Differentiating features of *F. verconis* useful in separating it from these species include: smaller size; significantly different rib count (see Table 1). Although *F. verconis* and *F. ponderi* overlap considerably in their distributions and occur at similar depths, we have not examined lots containing both species. For this reason, we cannot state that these two species exist sympatrically. Specimens now referable to *F. verconis* were recorded as *F. zelandicum* by Verco (1911a) from off Cape Jaffa, South Australia, however, that New Zealand species does not appear to occur in Australian waters. Cotton & Ludbrook (1938) refer to a ventral fissure of 2.0 mm in length, but, as the apex of the holotype is broken, it is not possible to confirm this.

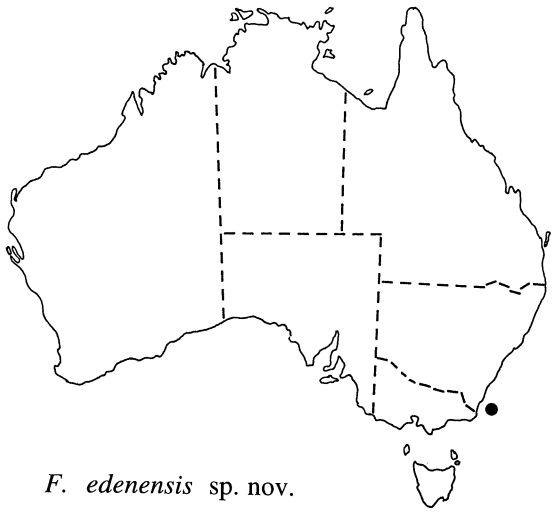


Figure 89. Known distribution of *Fissidentalium edenensis* n.sp.

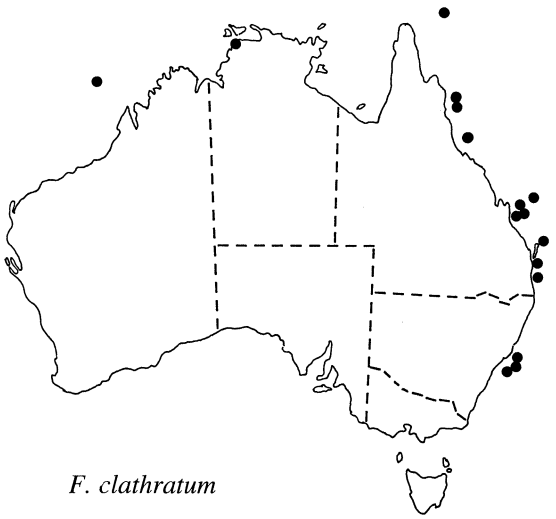


Figure 90. Known distribution of *Fissidentalium clathratum* (von Martens, 1881).

Fissidentalium edenensis n.sp.

Figs 82E, 83E, 89

Etymology. Named after the fishing port, Eden, New South Wales, off the coast of which most of the material studied was collected.

Type material examined. HOLOTYPE: AMS C303583. Type locality: Tasman Sea, east of Eden, 36°57.95'S 150°22'E, NSW, 616–1050 m, 11–12 December 1986. Length of holotype 30.7 mm, aperture diameter 3.5 mm, apex diameter 0.5 mm. PARATYPES: 2, AMS C174458; 3, AMS C174170; 3, AMS C174457, same locality data as holotype.

Additional material examined. 2, AMS C172571, 36°43–36'S 150°19–20'E, east of Tathra-Bermagui, NSW, 322–390 m, 22 July 1975.

Description. Shell length to 30.7 mm, aperture diameter 3.5 mm, apex diameter 0.5 mm; solid; slowly tapering, moderately curved moreso towards the apex. Sculpture of 17 narrow ribs at the apex, with minor ribs commencing near the apex and intercalating to become 17 strong flat ribs with a slightly smaller rib in each interstice at the aperture; interstices with transverse growth lines. Aperture circular, crenulated by ribs. Apex circular, crenulated by ribs, some specimens with a ventral slit or notch. Colour white.

Range. Southern New South Wales.

Habitat. Dredged in coarse sand from 322 to 1050 m.

Comparisons and remarks. *Fissidentalium edenensis* resembles most closely *F. verconis* Cotton & Ludbrook, *F. clathratum* (von Martens) and *F. elizabethae* n.sp. in being narrow and slowly tapering posteriorly. Differentiating features which help to separate *F. edenensis* from these species include: much smaller size; more strongly curved posteriorly. In addition the pattern of ribbing is particularly useful in differentiating *F. edenensis* from these three species: *F. edenensis*, 17 at apex, 17 intercalated with 17 riblets at aperture; *F. verconis*, 17 at apex, 20 at aperture; *F. clathratum*, 21 at the apex, 26–30 at the aperture; *F. elizabethae*, 14–16 at the apex, 40–44 at the aperture (see Table 1, p. 183).

Fissidentalium clathratum (von Martens, 1881)

Figs 82F, 83F,G, 90, 91A–E

Dentalium clathratum von Martens, 1881: 66; Pilsbry & Sharp, 1897: 84; Boissevain, 1906: 34, pl. 3, fig. 53; Hedley, 1910: 371.
Dentalium sedecimcostatum Boissevain, 1906: 33, pl. 6, figs 8–11.

Type material examined. HOLOTYPE: ZMB 33122. Type locality: near Moreton Bay, eastern Australia, 550 fathoms [1006 m]. Length of holotype 49.9 mm, aperture diameter (transverse) 4.0 mm (dorsoventral) 3.5 mm, apex diameter 0.7 mm.

Additional material examined. NEW SOUTH WALES: 6, AMS C155964, 32°58.8'S 152°41.6'E, off Newcastle, 951–1150 m, 9 October 1982; 1, AMS C303584, off Newcastle; 1, AMS C169802, north-east of Sydney, 33°41'S 151°56'E, 741 m, 5 December 1977; 2, AMS C173305, 1, AMS C169799, 33°35–37'S 152°05'E, off Sydney, 1143–1106 m, 4 December 1979–11 December 1980 (preserved); 3, AMS C169801, off Port Kembla, 33°46'S 151°43'E, 741 m, 5 December 1977; 7, AMS C155964, 32°58.8'S 152°41.6'E, off Newcastle, 951–1150 m, 9 October 1982. QUEENSLAND: 7, Lamprell Collection, trawled 120 m off Moreton Island; 3, AMS C172558, north-east of Cape Moreton, 126–136 m, 1967; 1, AMS C173374, off Caloundra, 150 m; 27, AMS C172587, 24°43.5–43.8'S 153°33.4–33.3'E, east of Sandy Cape, 604 m, 8 July 1984; 6, AMS C169960, south-east of Swains Reefs, 22°26.27–20.20'S 153°17.13–17.60'E, 187 m, 5 July. 1984; 3, AMS C173277, 3, AMS C173276, 23°19.5'S 152°35.4'E,

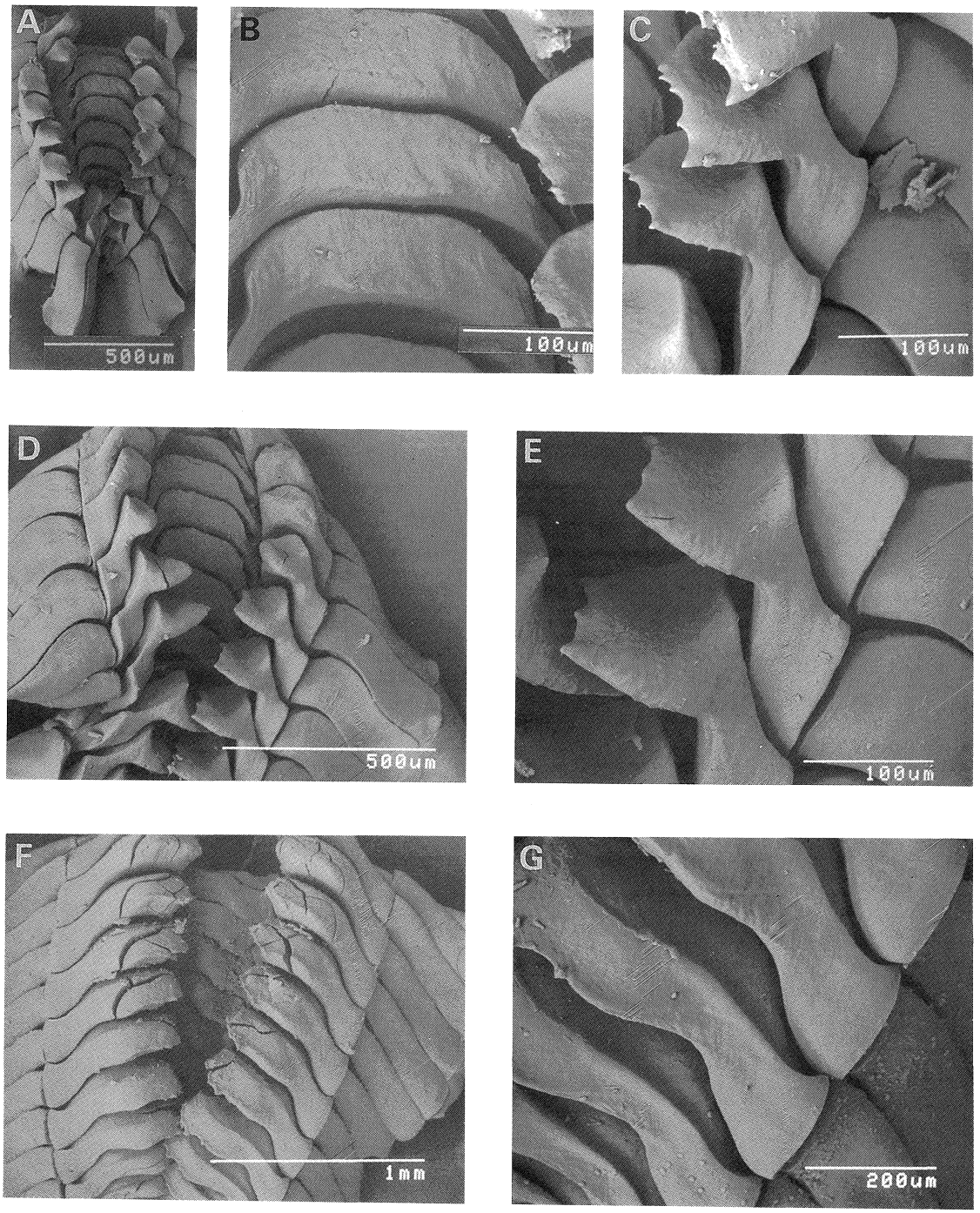


Figure 91. Radular ultrastructure. **A–E** *Fissidentalium clathratum* (von Martens, 1881), A–C—male, C,D—female, (off Cairns, 703 m, QM MO53675). **F,G** *Fissidentalium franklinae* n.sp. (from paratype, off Cairns, Qld, 990 m, QM MO18003).

east of North West Island, 14 December 1977; 1, AMS C169959, dredged 30 m, Keppel Bay, 7 September. 1970; 3, AMS C172560, One Tree Island, Capricorn Group, 55 m; 1, AMS C172284, off Great Keppel Island, 23 m, 1971; 10, AMS C173417, 17°09.48–9.30'S 146°42.36'E, off Cairns, 329 m, 11 October 1981; 18, QM MO17729, 17°50.67'S 147°18.2'E, 703 m, 17 May 1986; 1, QM MO40089, 17°46.53'S 147°48.8'E, off Cairns, 1224 m, 10 May 1986; 128, QM MO53675, 17°05.67'S 147°18.2'E, 703 m, 17 May 1986 (preserved); 1, QM MO18005, 18°09.15'S 147°56.7'E, 1116 m, 7 May 1986 (preserved); 3 juvenile, QM MO40031, 14°52'S 145°46'E, 685 m, 9 September. 1988; 10, QM MO17890, 17°34.58'S 146°53.2'E, 458–500 m, 15 May 1986; 2, QM MO17654, 17°22'S 146°48'E, 296–303 m, 15 May 1986; 9, QM MO18002, 17°50.67'S 147°18.2'E, 703 m, 17 May 1986; 4, QM MO17973, 17°37.00'S 146°57.4'E, 744 m, 15 May 1986; 7, QM MO17886, 18°10.56'S 148°21.6'E, 1110 m, 7 May 1986; 11, QM MO17972, 17°47.1'S 148°13.4'E, 1141 m, 9 May 1986; 8 juveniles, QM MO17989, 17°46.53'S 147°48.8'E, 1224

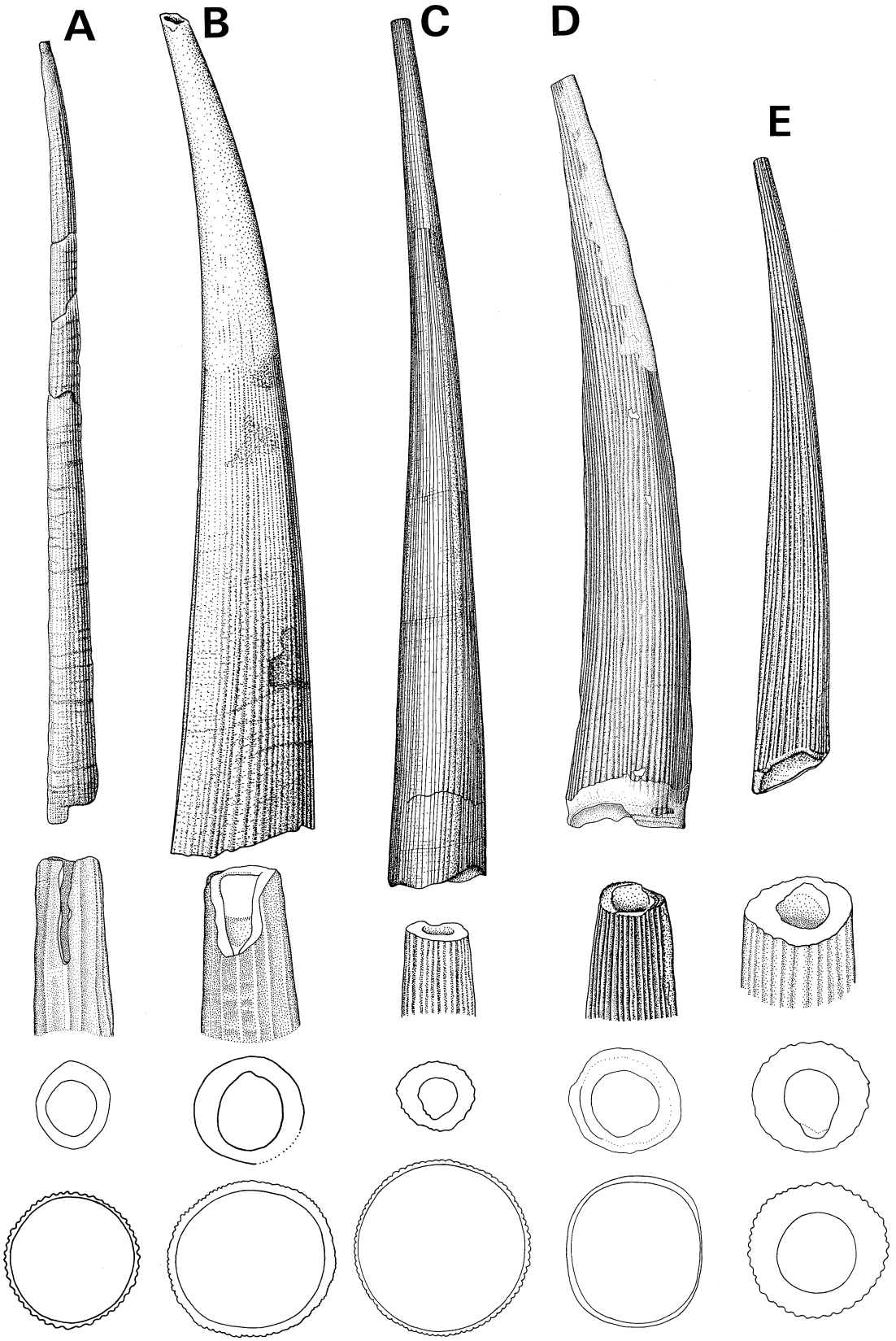


Figure 92. Dentaliida, Dentaliidae, *Fissidentalium*, group of *F. horikoshii*. **A** *F. elizabethae* n.sp. (holotype, AMS C174634, north of Newcastle, NSW, 1075 m, length 82.3 mm; apex slit shown for paratype AMS C152019, same locality data as for holotype). **B** *F. horikoshii* Okutani (QM MO40034, off Cairns, Qld, 2160 m, length 53.0 mm). **C** *F. franklinae* n.sp. (holotype, QM MO40030, off Cairns, Qld, 703 m, length 89.4 mm). **D** *F. profundorum* (E.A. Smith, 1894) (AMS C166615, Lord Howe Rise, Tasman Sea, 2000 m, length 58.2 mm; apex detail from paratype BMNH 1884.9.11.11, Ceylon). **E** *F. waterhousae* n.sp. (holotype, AMS C309881, Elizabeth Reef, Tasman Sea, 420 m, length 42.5 mm). (Del. all A. Hill).

Figure 93. Dentaliida, Dentaliidae, *Fissidentalium*, group of *F. horikoshii*. **A** *F. elizabethae* n.sp. (holotype, AMS C174634, north of Newcastle, NSW, 1075 m, length 82.3 mm). **B** *F. horikoshii* Okutani (NMV F72132, south of Point Hicks, Victoria, 1850 m, length 53.0 mm). **C** *F. franklinae* n.sp. (holotype, QM MO40030, off Cairns, Qld, 703 m, length 89.4 mm). **D,E** *F. profundorum* (E.A. Smith, 1894) (D—paratype, BMNH 1894.9.11.11 Ceylon, length 76.2 mm; E—AMS C166615, Lord Howe Rise, Tasman Sea, 2000 m, length 58.2 mm). **F** *F. waterhousae* n.sp. (holotype, AMS C309881, Elizabeth Reef, Tasman Sea, 420 m, length 42.5 mm).

m, 10 May 1986; 1, QM MO17985, 16°52.58'S 147°10.8'E, 1606 m, 13 May 1986; 1, QM MO17989, 17°46.53'S 147°48.8'E, 1224 m, 10 May 1986; 1, QM MO17978, 18°03.85'S 147°19.5'E, 704 m, 8 May 1986; 1, QM MO40045, 10°23'S 145°16'E, 1229 m; 62, AMS C173425, 4, AMS C173411, 17°09.42'S 146°42.24'E, off Cairns, 668 m, 13 October 1981; 2, AMS C165306, 10°35.8'S 144°44.81'E, Coral Sea, 1438 m, 21 August 1988. NORTHERN TERRITORY: 1, AMS C172592, Port Darwin. WESTERN AUSTRALIA: 1, AMS C169772, south-west of Scott Reef, 410 km north of Broome, 14°39'S 121°29'E, 500 m, bottom trawl, 11 February 1984.

Description. Shell length to 56.8 mm, aperture diameter 4.3 × 4.1 mm, apex diameter 0.8 mm; rather straight, slightly curved towards the apex. Sculpture of 12–21 angular, narrow, equal ribs at the apex, with ribs being intercalated in the interstices becoming 26–30 at the aperture, stronger ventrally with some smaller riblets occuring irregularly in the interstices; interstices wide, transversely striated. Aperture circular or slightly dorsoventrally compressed, crenulated by ribs. Apex circular, crenulated by ribs, some specimens have a long, moderately wide ventral slit. Colour opaque white.

Radula. Central tooth broad (240 μm wide in male; 222 μm wide in female), moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped (214 μm long in male; 260 μm long in female) with small cusps on the working surface; marginals sigmoidal, moderately short and broad (length 390 μm × breadth 107 μm in male; length 366 μm, breadth 111 μm in female) (see Fig. 91A–E). Ratios: male C:L = 1:0.89, L:M = 1:1.8, marginals breadth:length = 1:3.6; female C:L = 1:1.17, L:M = 1:1.4, marginals breadth:length = 1:3.3.

Range. New South Wales, Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged in sand from 23 to 1606 m.

Comparisons and remarks. *Fissidentalium clathratum* resembles most closely *F. elizabethae* n.sp. in shell profile. Differentiating features of *F. clathratum* which help to separate it from *F. elizabethae* include: a more rapidly tapering shell; significantly lower rib count (see Table 1). Examination of the syntype series of *F. sedecimcostatum* Boissevain reveals that that species is synonymous with *F. clathratum* (syntype series of *F. sedecimcostatum* compared with holotype of *F. clathratum*).

Key to Group of *Fissidentalium horikoshii*

Fourteen to 43 ribs at apex, intercalating to 40–90 narrow ribs at aperture, shell moderately curved to almost straight, aperture circular, sometimes slightly dorsoventrally.

1 Shell aperture wide or moderately so 2

—— Shell aperture narrow 3

2 17–24 strong ribs at apex ..... *F. horikoshii*

—— 35 or more ribs at apex 4

3 14–16 ribs at apex intercalating to 40–44 low ribs at the aperture ..... *F. elizabethae*

—— 30 ribs at apex intercalating to approximately 40 at aperture ..... *F. waterhousae*

4 35 ribs at apex intercalating to 90 ribs at aperture ..... *F. franklinae*

—— 43 ribs at apex intercalating to 76–80 at the aperture ..... *F. profundorum*

Fissidentalium elizabethae n.sp.

Figs 92A, 93A, 94

Etymology. Named after Ms Elizabeth Turner, Malacology Section, Museum and Art Gallery of Tasmania, in appreciation for her assistance in this and other projects.

Type material examined. HOLOTYPE: AMS C174634. Type locality: north of Newcastle, 32°49.3'S 152°49.1'E, NSW, 1075 m, 9 October 1982. Length of holotype 82.3 mm, aperture diameter 5.4 × 5.0 mm, apex diameter 1.1 mm. PARATYPES: 6, AMS C152019, same locality data as holotype.

Description. Shell length to 82.3 mm, aperture diameter 5.4 × 5.0 mm, apex diameter 1.1 mm; solid, almost straight, slightly curved towards the apex. Sculpture of 14–16 narrow ribs at the apex, intercalating to 40–44 low, rounded longitudinal ribs at the aperture, interstices at the apex are wide, twice the width of the ribs, becoming narrow at the aperture. Aperture circular or slightly dorsoventrally compressed, crenulated by ribs. Apex slightly dorsoventrally compressed, intact specimens crenulated by ribs, some specimens with a shallow, wide, ventral slit. Colour grey-white.

Range. North of Newcastle, New South Wales.

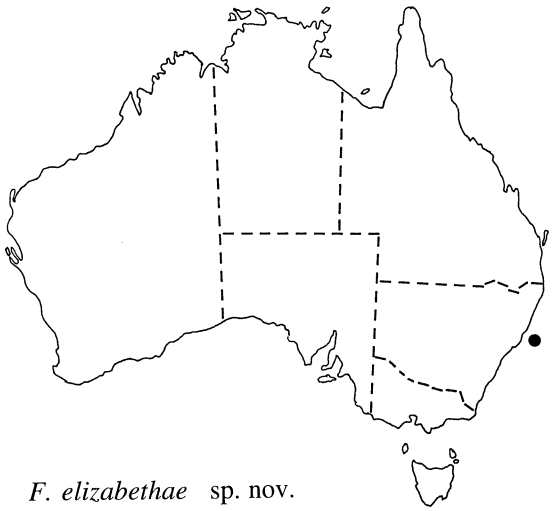


Figure 94. Known distribution of *Fissidentalium elizabethae* n.sp.

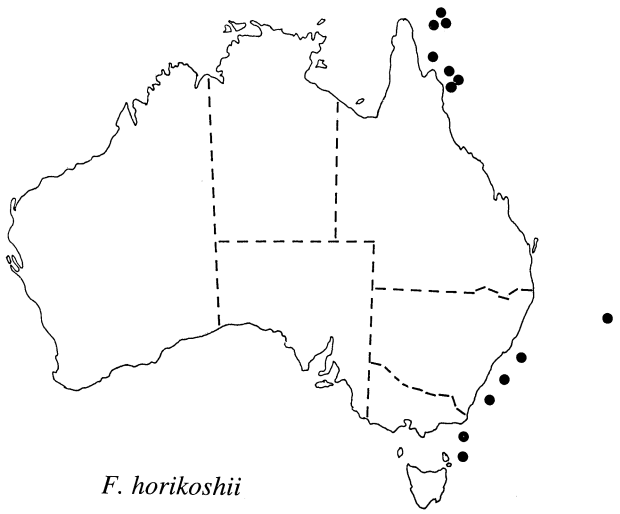


Figure 95. Australian distribution of *Fissidentalium horikoshii* n.sp.

Habitat. Dredged to 1075 m.

Comparisons and remarks. *Fissidentalium elizabethae* resembles most closely *F. clathratum* (von Martens) in being almost straight. Features of *F. elizabethae* which help to differentiate it from *F. clathratum* include: (1) much larger size; (2) significantly more ribs at the aperture. Compared with the other Australian species of *Fissidentalium, F. elizabethae* is narrower anteriorly and very slowly tapering posteriorly. This marked difference in shell profile is useful when distinguishing *F. elizabethae* from other *Fissidentalium* species with similar rib numbers (e.g., *F. ponderi* n.sp., see Table 1).

Fissidentalium horikoshii Okutani, 1982

Figs 92B, 93B, 95

Type material. HOLOTYPE: NSMT-MO 59950. Type locality: Soyo-Maru Stn R3—38°21.7'N 143°25.6'E, approximately east off Kinkazan [Honshu, Japan], 2930–3020 m. Length of holotype 80.9 mm, aperture diameter 14.1 × 13.5 mm, apex diameter 2.8 mm.

Material examined. TASMANIA: 8, AMS C165057, 40°45.94–46.54'S 149°01.62–00.27'E, 2500 m, 16 December 1986 (preserved). VICTORIA: 1, NMV F72132 (preserved) 38°25.90'S 148°58.60'E, south of Point Hicks, 1850 m; 1, NMV F72137, 38°25.90'S 148°58.60'E, south of Point Hicks, 1850 m, 22 July 1986. NEW SOUTH WALES: 1, NMV F72151, 34°50.21'S 151°23.47'E, off Nowra, 1720 m, 16 July 1986; 6, NMV F72133, 34°41.97'S 151°22.4'E, off Nowra, 1642 m, 22 October 1988; 1, AMS C174357, 36°59'S 150°30'E, Tasman Sea, east of Merimbula, 3500 m, 12 December 1986; 1, AMS C166615, Tasman Sea, Lord Howe Rise, 29°27.01'S 160°08.26'E, beam trawl, grey ooze, 2000 m, 4 May 1989. QUEENSLAND: 1, QM MO40034, 14°53'S 145°56'E, northern Qld, 2160 m, 30 August 1988; 3, QM MO40036, 13°17'S 144°50'E, northern Qld, 22 August 1988; 4, QM MO40035, 14°22'S 145°52'E, northern Qld, 2710 m, 8 September 1988; 1, QM MO40038, 12°26'S 144°36'E, northern Qld, 3150 m, 8 February 1992; 5, AMS C152022, 33°01.5'S 153°01.4–12.9'E, off Newcastle, 3058 m, 8 October 1982 (preserved). 3, QM MO53679, 14°30'S 145°53'E, east of Cape Melville, 2578 m, 10 September 1988; 2, QM MO40037, 14°53'S 145°56'E, east of Cape Melville, 2160 m, 30 August. 1988; 1, QM MO40044, 10°01'S 145°01'E, 1777 m, 11 February 1992; 2, QM MO40043, 13°17'S 144°50'E, north-east of Cape Melville, 2709 m; 4, QM MO40042, 10°51'S 145°49'E, north-east of Cape Grenville, 1379 m, 13 February 1992; 4, QM MO40041, 13°55.5'S 146°43'E, off Osprey Reef, 1615 m, 6 September 1988; 5, QM MO40040, 14°30'S 145°51'E, east of Cape Melville, 2569 m, 10 September 1988 (preserved).

Description. Shell length to 80.9 mm, aperture diameter 14.1×13.5 mm, apex diameter 2.8 mm (holotype measurements; Australian material generally of smaller dimensions—length 55.0–60.0 mm); solid; moderately curved; Sculpture of 17–24 strong ribs at the apex, intercalate to 50–80 low, rounded longitudinal ribs at the aperture; interstices narrow. Aperture circular, finely crenulated by ribs. Apex circular, intact specimens crenulated by ribs, some specimens with a wide, off-centre slit or notch. Colour white.

Radula. The radula of the Japanese holotype closely resembles the pattern seen throughout the genus *Dentalium* and in the *Fissidentalium clathratum* Group and not the heavy laterals style of *Fissidentalium franklinae* n.sp. Until the radula of the Australian material is examined, we refer these specimens to *F. horikoshii* with some reservation.

Range. Japan (Okutani), Tasmania, Victoria, New South Wales to northern Queensland.

Habitat. Dredged in coarse sand from 1615 to 3500 m.

Comparisons and remarks. The type series of *Fissidentalium horikoshii* Okutani, 1982 consists of the holotype and two

paratypes, in addition to an extracted radula of the holotype. Australian shells herein referred to *F. horikoshii*, although similar in shape to Japanese specimens, are significantly smaller and have finer, fewer ribs (rib count on Japanese specimens carried out at the same length as the largest Australian specimen).

Fissidentalium horikoshii resembles most closely *F. franklinae* n.sp. and especially *F. profundorum* (E.A. Smith, 1894) both of which are moderately large species characterized by a relatively wide aperture and high rib count (especially at the aperture). *Fissidentalium horikoshii* can be distinguished from *F. franklinae* and *F. profundorum* by longitudinal shell profile (compare Figs 92B–D; also Figs 93B–E) and on rib numbers (fewer at apex in *F. horikoshii* than either *F. franklinae* or *F. profundorum* see Table 1, p. 183). Other *Fissidentalium* from Australia which show a wide aperture (e.g., *F. ponderi* n.sp., *F. yokoyamai*) can be readily separated from *F. horikoshii* by their coarser ribs and lower rib count (at apex and aperture). *Fissidentalium horikoshii* appears to be restricted to very deep water, the shallowest Australian record being 1379 m.

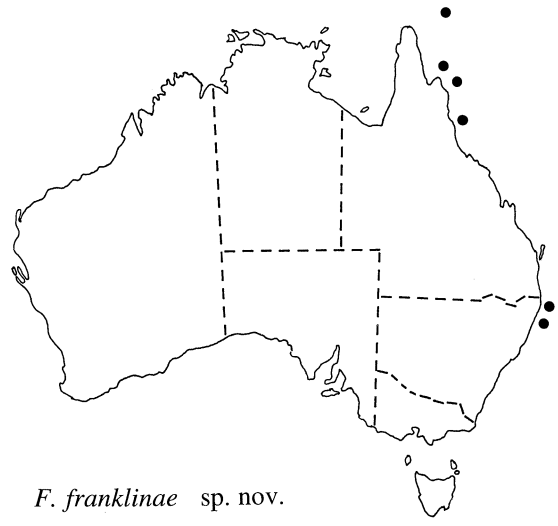


Figure 96. Known distribution of *Fissidentalium franklinae* n.sp.

Fissidentalium franklinae n.sp.

Figs 91F,G, 92C, 93C, 96

Etymology. Named after the O.R.V. "Franklin", the vessel used for the "Cidaris" Expeditions.

Type material examined. HOLOTYPE: QM MO40030. Type locality: off Cairns, 17°51'S 147°18'E, northern Qld, 703 m, 17 May 1986. Length of holotype 89.4 mm, aperture diameter 9.5 mm, apex diameter 2.1 mm. PARATYPES: 3, QM MO17771, same locality data as holotype; 2, AMS C201735, 17°36.98'S 146°57.43'E, off Cairns, Qld, 672–744 m, 15 May 1986; 1, QM MO18003, 17°49'S 148°40'E, off Cairns, northern Qld, 990 m, 8 May 1986 (preserved); 3, QM MO18004, 2, AMS C201735, 17°37'S 146°57'E, of Cairns northern Qld, 672 m (preserved).

Additional material examined. 1, AMS C169803, north-east of Tweed Heads, NSW, 28°02–05'S 153°57'E, 366 m; 1, AMS C102564, south-east of Clarence River, NSW, 29°41–32'S 153°45–47'E, 405 m, 16 December 1975; 4 juveniles, QM MO40032, 10°01'S 145°00'E, northern Qld; 4 juveniles, QM MO40033, 14°13'S 147°05'E, northern Qld, 1460 m.

Description. Shell length to 90.0 mm, aperture diameter 10.0 mm, apex diameter 2.0 mm; solid, weakly curved. Sculpture at apex of 35 narrow, longitudinal ribs, intercalating to approximately 90 round topped ribs at the aperture, near the centre of the shell the ribs become wide and flat topped with the interstices very narrow; numerous, fine, transverse, growth lines cross the ribs. Aperture circular, finely crenulated by ribs. Apex circular, crenulated by ribs, with or without slit. Colour white to dull buff.

Radula. Central tooth broad (466 μm wide), shallow with weakly convex or slightly corrugate superior surface and correspondingly concave inferior surface; laterals almost rectangular, 711 μm long, heavily mineralized, with small cusps on the working surface; marginals almost straight, moderately narrow (length 666 μm × breadth 155 μm) (see Fig. 91F,G). Ratios C:L = 1:1.53, L:M = 1:0.94, marginals breadth:length = 1:4.39 (sex not determined).

Range. Northern New South Wales to northern Queensland.

Habitat. Dredged in sandy mud from 366 to 1460 m.

Comparisons and remarks. *Fissidentalium franklinae* resembles most closely *F. horikoshii* Okutani and *F. profundorum* (E.A. Smith) by a very high rib count at the aperture (approximately 90 in *F. franklinae* as opposed to 80 in *F. horikoshii* and *F. profundorum*). Differentiating features of *F. franklinae* which help to separate it from these species include: relatively straight shell (only weakly curved); slender longitudinal profile. This deep water species has been found in the same dredge samples as *F. clathratum* (von Martens), suggesting that the two species occur sympatrically at some localities. Juveniles of *F. clathratum* could be initially mistaken for juveniles of *F. franklinae*, but the much finer ribbing of the latter should immediately clarify any identification problem.

Fissidentalium profundorum (E.A. Smith, 1894)

Figs 92D, 93D,E, 97

Dentalium profundorum E.A. Smith, 1894: 167, pl. 4, fig. 18; Pilsbry & Sharp, 1897: 79, pl. 6, fig. 82; Boissevain, 1906: 37, pl. 4, figs 14, 16.

Type material examined. HOLOTYPE: ZSI M60/1. Type locality: off Colombo, 6°32'N 79°37'E, 1235 m. Length of holotype 90.0 mm, aperture diameter 10.0 mm [measurements *fide* Habe, 1963: 14; holotype not examined]. PARATYPE: BMNH 1894.9.11.11, same locality data as holotype; length 76.2 mm, aperture diameter 9.5 mm.

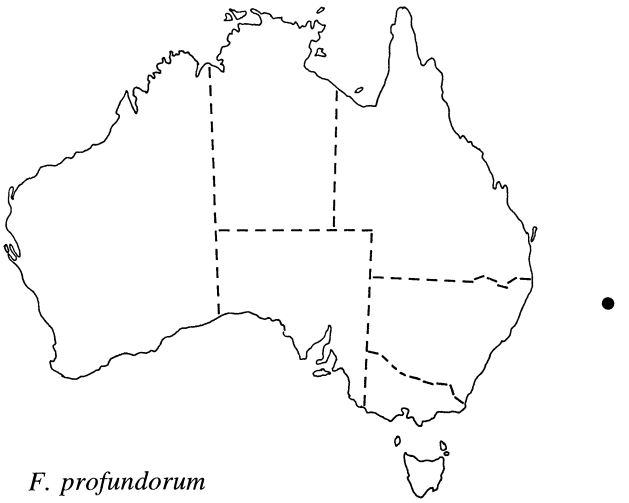


Figure 97. Australian distribution of *Fissidentalium profundorum* (E.A. Smith, 1894).

Additional material examined. 1, AMS C166615, 29°27.01'S 160°08.26'E, Tasman Sea, Lord Howe Rise, 2000 m, grey ooze, 4 May 1989.

Description. Shell length to 90.0 mm, aperture diameter 10.0 mm; moderately curved. Sculpture of 43 ribs at the apex intercalating to 76 to 80 at the aperture, with transverse growth lines finely crossing the ribs; interstices narrow. Aperture slightly obovate in intact specimens, crenulated by ribs. Apex circular, crenulated by ribs, with or without notch or slit. Colour white.

Range. Sri Lanka (type series), Indonesia (Boissevain, 1906), Malaysia, Japan (Habe, 1963), Tasman Sea, Lord Howe Rise.

Habitat. Dredged in pale grey ooze from 1350 to 2000 m.

Comparisons and remarks. *Fissidentalium profundorum* resembles most closely *F. horikoshii* Okutani and *F. franklinae* in exhibiting a very high rib count at the aperture but has more ribs apically and in comparison to *F. franklinae* n.sp. is more strongly curved. In longitudinal profile *F. profundorum* is more robust than *F. franklinae* but not as wide aperturally as *F. horikoshii*. Juveniles of *F. profundorum* and *F. horikoshii* could potentially be confused, although a check of rib numbers near the apex should settle any problem of identity. Comparison with the paratype of *F. profundorum* lodged in the BMNH (registration number 1894.9.11.11), clearly confirms the identity of our single Australian specimen, even to the point that both specimens show the same flaking erosion mentioned by Smith in his original description. Smith describes a ventrally positioned notch in the holotype, and we can confirm his statement that a laterally positioned slit occurs in the BMNH paratype. Smith was uncertain as to whether the lateral slit in this paratype may be a fracture or a misplaced true slit. The Australian specimen examined herein lacks any sign of a notch or slit. Given that slit/notch-bearing specimens may co-occur with specimens with an entire apex in some species of *Fissidentalium*, the presence or absence of a slit/notch in *F. profundorum* appears to be of secondary importance in identifying the species. A further paratype (not examined by us) presumably is held, together with the holotype, in the collections of the Zoological Survey, India, as Smith (1894) mentions a third specimen in his original description. Although *Fissidentalium profundorum* has a very wide distribution it appears to be a very rare species.

Fissidentalium waterhousae n.sp.

Figs 92E, 93F, 98

Etymology. Named after Ms Janet Waterhouse (now Mrs J. Macintosh) of the Malacology Section, Australian Museum, for her assistance with this project.

Type material examined. HOLOTYPE: AMS C309881. Type locality: Elizabeth Reef, Tasman Sea, 29°53.82'S 159°01.65'E, 420 m, 3 May 1969. Length of holotype 42.5 mm, aperture diameter 4.9 mm, apex diameter 1.0 mm. PARATYPES: 1, AMS C311734, same locality data as holotype; 1, AMS C174647, 29°58.82'S 159°01.65'E, Elizabeth Reef, Tasman Sea, 420 m, coarse shell/coral sand, 3 May 1969.

Description. Shell length to 42.5 mm, aperture diameter to 4.9 mm, apex diameter 1.0 mm; solid; slightly and evenly curved, rapidly tapering. Sculpture of numerous, low, rounded, longitudinal ribs, approx 30 at the apex, intercalating to approx 40 at the aperture; interstices narrow; ribs and interstices crossed by dense, microscopic, transverse growth lines. Aperture circular, crenulated by ribs. Apex circular, crenulated by ribs, in one paratype a small notch is evident which is not present in the holotype. Colour glossy white.

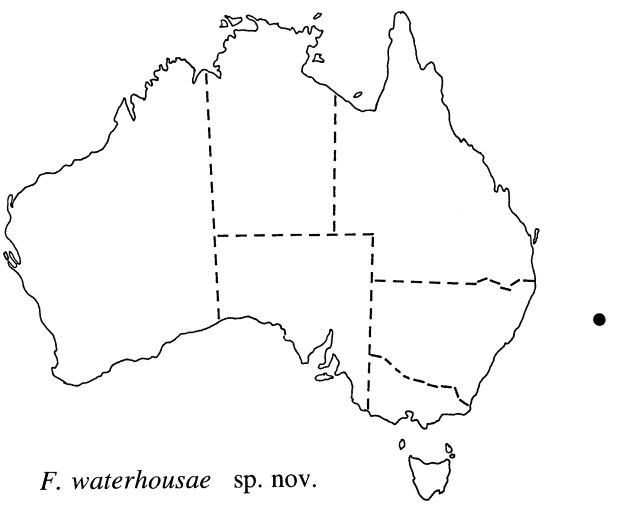


Figure 98. Known distribution of *Fissidentalium waterhousae* n.sp.

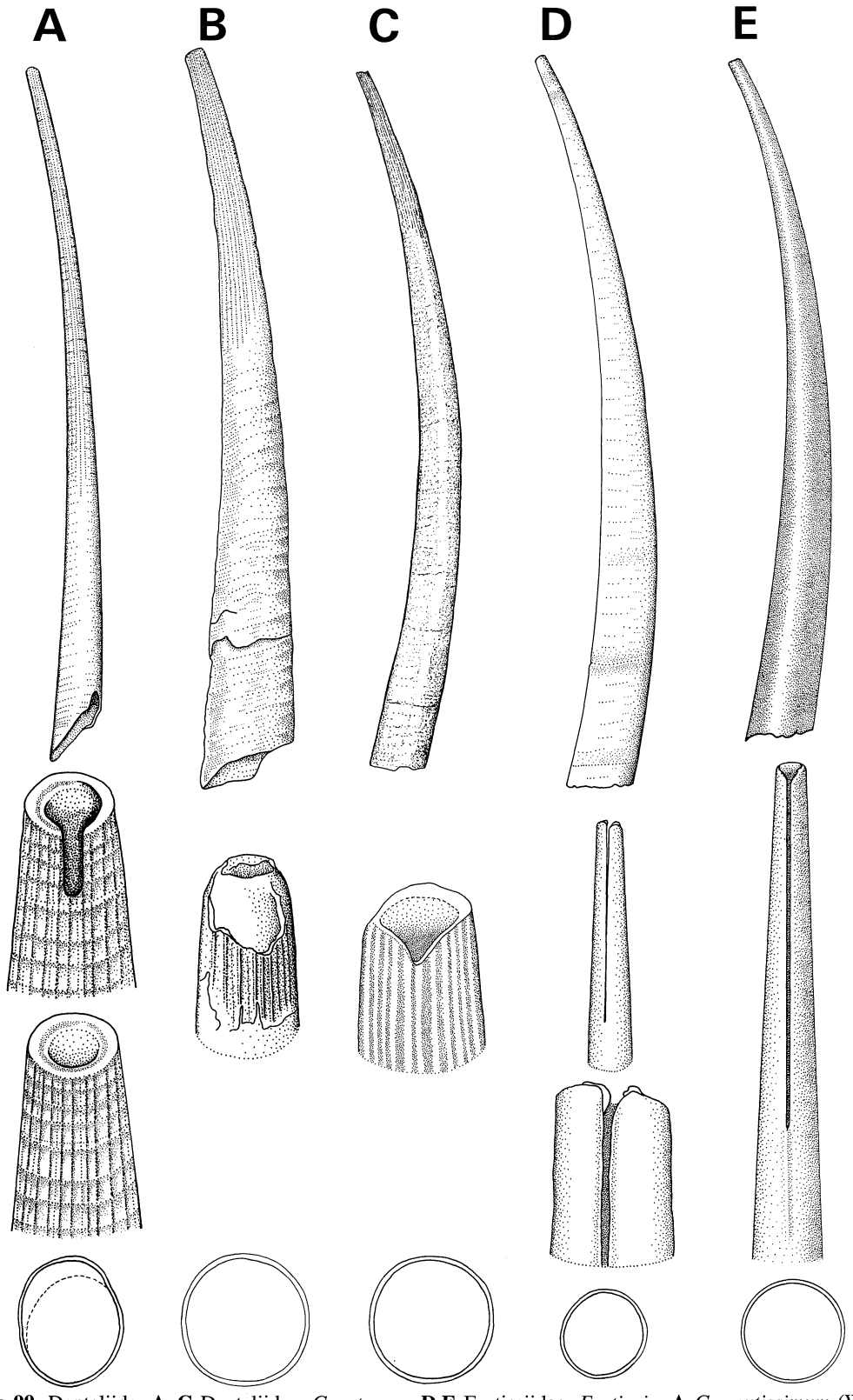


Figure 99. Dentaliida. **A–C** Dentaliidae, *Graptacme*; **D,E** Fustiariidae, *Fustiaria*. **A** *G. acutissimum* (Watson, 1879) (paralectotype, BMNH 1887.2.9.31-2, N. of Papua, 1070 m, length 37.5 mm). Note apex with slit (lectotype) or without slit (paralectotype). **B** *G. nielseni* n.sp. (holotype, QM MO40055, off Cairns N. Qld, 2016 m, length 68.0 mm). **C** *G. aciculum* (Gould, 1859) (KLColl, Freshwater Point, Sarina, Qld, beach, length 42.2 mm). **D,E** Fustiariidae, *Fustiaria*. **D** *Fustiaria stenoschizum* (Pilsbry & Sharp, 1897) (WAM 161/93, Rosemary Island, WA, 6 m, length 46.2 mm). **E** *F. caesura* (Colman, 1958) (AMS C172434, off Lady Musgrave Island, Qld, length 38.8 mm). (Del.: A, B and C [apex and aperture]—JMH; D—A. Hill; E—C. Eadie).

Figure 100. Dentaliida, Dentaliidae, *Graptacme*. **A–D** *G. acutissimum* (Watson, 1879) (A—lectotype, BMNH 1887.2.9.31-2, North of Papua, 1956 m, length 38.0 mm; B—paralectotype same locality data as lectotype; C,D—KLColl, off Cairns, Qld, 1764 m, 40.0 mm, 42.5 mm). **E** *G. nielseni* n.sp. (holotype, QM MO40055, Northern Qld, 2016 m, length 68.0 mm). Note striae in apex detail. **F** *G. aciculum* (Gould, 1859) (KLColl, Freshwater Point, Sarina, Qld, beach, length 42.2 mm).

Range. Elizabeth Reef, Tasman Sea.

Habitat. Dredged in sand to 420 m.

Comparisons and remarks. *Fissidentalium waterhousae* does not closely resemble any other Australian species of the genus. The white, moderately thick, glossy, finely ribbed shell easily distinguishes this species from similarly-sized *Fissidentalium* (e.g., *F. clathratum* (von Martens); *F. verconis* Cotton & Ludbrook). At present *F. waterhousae* is known from only three dead but fresh specimens from Elizabeth Reef.

Genus *Graptacme* Pilsbry & Sharp, 1897

Graptacme Pilsbry & Sharp, 1897: 85.

Type species: *Dentalium eboreum* Conrad, 1846; Woodring, 1925, by subsequent designation.

Diagnosis. Shell moderate to narrow in width, with close, fine (usually microscopic), longitudinal striae near apex, remainder smooth; aperture and growth lines oblique; apex diverse, either simple, with a small notch or narrow slit on the ventral side.

Key to Australian *Graptacme*

1 Shell narrow throughout, slowly attenuate; striae very fine, often microscopic 2

—— Shell moderately expanded at aperture, rapidly attenuate; striae fine but visible without magnification ..... *G. nielseni*

2 Shell slightly curved; striae on apical half of shell; apex usually with a deep, broad ventral slit ..... *G. acutissimum*

—— Shell moderately curved; striae on apical third of shell only; apex usually with small ventral notch ..... *G. aciculum*

Graptacme acutissimum (Watson, 1879)

Figs 99A, 100A–D, 101

Dentalium acutissimum Watson, 1879: 514; Watson, 1886: 8, pl. 1, fig. 8; Pilsbry & Sharp, 1897: 94, pl. 20, fig. 26; Boissevain, 1906: 45, pl. 2, fig. 39, pl. 5, figs 9, 10, 11, 12; Ludbrook, 1954: 109; Colman, 1958: 3.

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1887.2.9.31–2. Type locality: North of Papua, 1957 m. Length of lectotype 38.0 mm, aperture diameter 2.8 mm, apex diameter 0.5 mm. PARALECTOTYPE: same locality data as for lectotype.

Additional material examined. QUEENSLAND: 1, QM MO40054, 11°23'S 144°36'E, north-east of Cape York, 1999 m, 9 February 1992; 15, QM MO40053, 10°51'S 145°49'E, east of Cape York, 1379 m, 13 February 1992; 1, QM MO40047, 10°23'S 145°16'E, east of Cape Grenville, 1229 m, 12 May 1992; 2, QM MO40046, 9°47'S 145°16'E, north-east of Cape Grenville, 1764 m, 11 February. 1992; 24, QM MO40052, 10°01'S 145°01'E, 1777 m, 11 February. 1992; 15, QM MO40051, 9°47'S 145°16'E, north-east of Cape Grenville, 1764 m, 11 February 1992 (preserved); 1, QM MO40090, 14°22'S 145°52'E, 2710 m, 8 September 1988.

Description. Shell length to 44.0 mm, aperture diameter 2.8 mm, apex diameter 0.5 mm; glossy, slender, moderately curved. Sculpture of fine to microscopic, close, longitudinal striae over apical half of shell, the rest of the shell smooth with fine oblique growth lines. Aperture circular. Apex circular, weakly crenulated by ribs, usually with a deep, broad ventral slit. Colour translucent white in live shell, opaque white in dead specimens.

Range. Mid-Pacific, off Japan (2050 fathoms [3750 m]) (Watson, 1879), north of Papua (Watson, 1879), Indonesia (Boissevain, 1906), northern Queensland.

Habitat. Dredged from 1229 to 3750 m in sandy mud.

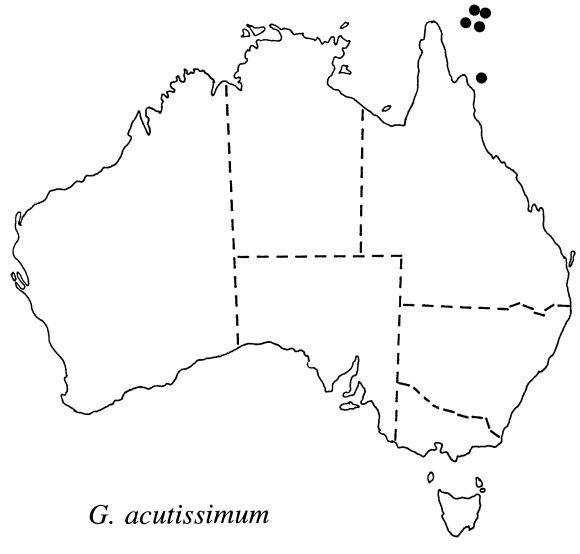


Figure 101. Australian distribution of *Graptacme acutissimum* (Watson, 1879).

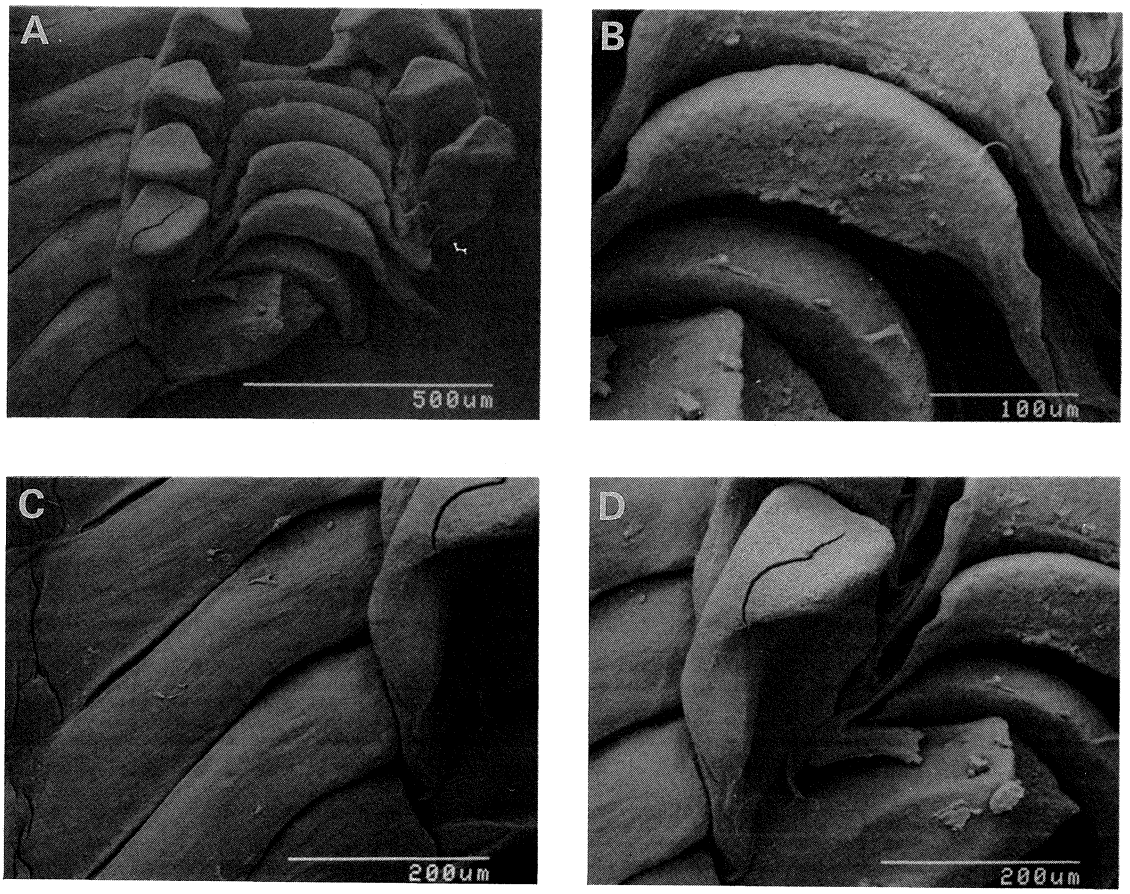


Figure 102. Radular ultrastructure of *Graptacme nielseni* n.sp. (from paratype, 11°23'S 144°36'E, Northern Qld, 1999 m, QM MO40058).

Comparisons and remarks. Differentiating features of *G. acutissimum* which separate it from the other two Australian species of *Graptacme* (*G. aciculum* (Gould) and *G. nielseni* n.sp.) include: long, slender profile; striae (extremely fine) extending half adult shell length; narrow apical slit. It should be noted that the paralectotype of *G. acutissimum* lacks any slit. Some variation in the persistence of the fine longitudinal ribbing is evident in material examined. Syntype BMNH 1887.2.9.33 is definitely not referable to this species although Watson regarded it simply as an "old and broken" specimen (apex completely missing). The exact status of this syntype is uncertain. No longitudinal sculpture is visible on its shell which, if also true of the apical region, would suggest that this could be a *Laevidentalium* species. If however longitudinal striae were present apically, then this syntype would be placed into *Graptacme*. What appears certain is that this syntype (1887.2.9.33) does not match Watson's own distinguishing criteria for *G. acutissimum*, nor does it correlate with any of the Australian material that we have examined. For stations from the "Challenger" Expedition see Watson, 1879: 514 and Watson, 1886. For stations from the "Siboga" Expedition see Boissevain, 1906: 45.

Graptacme nielseni n.sp.

Figs 99B, 100E, 102A–D, 103

Etymology. Named after the late Mr Tom Nielsen, a noted trawler fisherman and amateur malacologist from Yeppoon, Queensland, who collected by dredging, scaphopods and other molluscs for donation to the Australian and state museums.

Type material examined. HOLOTYPE: QM MO40055. Type locality: off Cairns, northern Qld, 11°22'S 144°35'E, 2016 m, 9 February 1992. Length of holotype 68.0 mm, aperture diameter 8.25 mm, apex diameter 2.0 mm. PARATYPES: 8, QM MO40057, same locality data as holotype; 1, QM MO40056, 14°27'S 146°51'E, northern Qld, 1855 m, 1 January 1988; 3, QM MO40058, AMS C201736, 11°23'S 144°36'E, northern Qld, 1999 m, 9 February 1992 (preserved).

Description. Shell length to 68.0 mm, aperture diameter to 8.25 mm, apex diameter to 2.0 mm; solid, moderately curved. Sculpture of 25–35 coarse striae (visible without magnification) at the apex extending over one half of the shell length, anterior half of shell smooth with microscopic oblique growth lines; interstices flat, shallow, with microscopic longitudinal striae. Aperture circular. Apex circular, weakly crenulated by ribs, entire or with a short, wide, ventral slit. Colour opaque white.

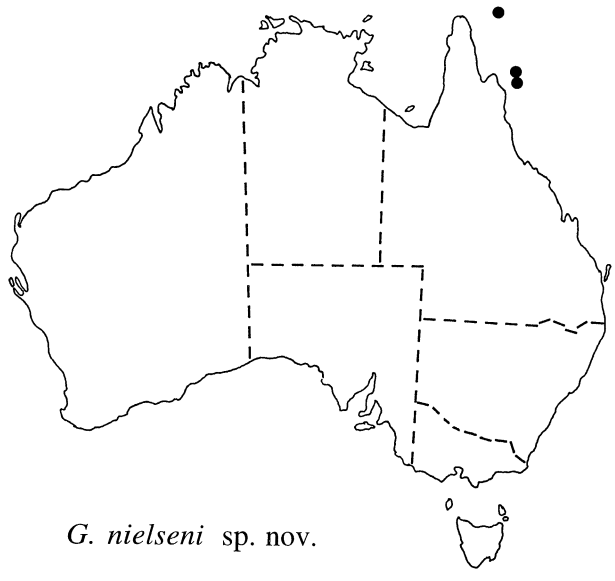


Figure 103. Known distribution of *Graptacme nielseni* n.sp.

Radula. Central tooth broad (322 µm wide), moderately shallow with smooth, convex superior surface and correspondingly concave inferior surface; laterals dumbbell shaped, 340 µm long with small cusps on the working surface; marginals slightly curved and broad (length 416 µm × breadth 127 µm) (see Fig. 102A–D). Ratios C:L = 1:1.05, L:M = 1:1.22, marginals breadth:length = 1:3.3 (sex not determined).

Range. Off Cairns, northern Queensland.

Habitat. Dredged in grey mud from 1855 to 2016 m.

Comparisons and remarks. *Graptacme nielseni* does not closely resemble the other Australian species of the genus. Compared with *G. aciculum* (Gould, 1859) and *G. acutissimum* (Watson, 1879), *G. nielseni* is much larger and a more solid species, with a wide aperture. Compared with *Fissidentalium horikoshii* Okutani which it superficially resembles, *G. nielseni* exhibits only striae over the anterior half of the shell. Like other species of *Fissidentalium, F. horikoshii* possesses longitudinal ribs which usually extend from the apex to the aperture (although some species of *Fissidentalium* may show rib obsolescence in aged specimens). *Graptacme nielseni* also shows some conchological similarity to *G. usitatum* (E.A. Smith). However, our comparison of the type series of *G. usitatum* with *G. nielseni* shows that the latter is less curved and lacks interstitial sculpture. The shape and texture of the shell of *G. nielseni* is very similar to that of the *Laevidentalium largicrescens* (Tate) (Laevidentaliidae), the only notable point of difference being the lack of striae in the latter. Striae have however been noted in this study in two species of *Laevidentalium* [*L. lubricatum* (G.B. Sowerby) and *L. longitrorsum* (Reeve)], thereby casting some doubt over the continued placement of *Graptacme* in the Dentaliidae (see also Discussion).

Graptacme aciculum (Gould, 1859)

Figs 99C, 100F, 104

Dentalium aciculum Gould, 1859: 165; G.B. Sowerby, 1872: pl. 7, fig. 52; Pilsbry & Sharp, 1897: 93, pl. 17, figs 65, 66, 67; Boissevain, 1906: 46, pl. 2, fig. 36, pl. 5, figs 13–14; Hirase, 1931: 139, pl. 3, fig. 10; Habe, 1963: 265, pl. 38, figs 4, 5; Habe, 1964: 24, pl. 2, figs 4–5, pl. 3, figs 3–4, pl. 4, figs 7, 8.
Dentalium luchuanum Dall, 1926: 63; Habe, 1955: no.9.

Type material. HOLOTYPE: USNM 24149. Type locality: Coast of China, 23°50'N in sand, 46 m, 1862. Length of holotype 30.0 mm, aperture diameter 3.0 mm. PARATYPES: MCZ 169033 ex NYSM 145, original No G2405; MCZ 216577 ex Smithsonian Institute (type series not examined herein).

Additional material examined. NEW SOUTH WALES: 1, AMS C172510, 29°39.8'S 153°26.4'E, 12 km east of Cakoro Point, south of Yamba, 55 m, 22 February 1972. QUEENSLAND: 1, NMV F75844, Lady Musgrave Island; 3, AMS C172505, Lady Musgrave Island, Bunker Group, east of Gladstone, dredged in lagoon; 1, AMS C172529, Lady Musgrave Island lagoon; 1, AMS C173095 Lady Musgrave Island, 54–100 m; 4, AMS C173057, Yeppoon, 4 m; 19, NMV F69578, dredged off Middle Island, Keppel Bay, 40 m, 6 September 1967 (preserved); 10, AMS C62682, north end of Considine Beach, North Keppel Island, April 1934; 12, AMS C67778, Keppel Bay; 1, AMS C172516, off One Tree Island, Capricorn Group, 55 m; 1, AMS C172522, 5, AMS C172526, Keppel Island, dredged, 6 September 1967; 3, AMS C173100, 23°12'S 150°58'E, Great Keppel Island, pre 1966; 9, AMS C172530, Humpy Island, Keppel Bay, 3.5 m; 6, AMS C172512, Dingo Beach, north of Prosperine, beach, 30 May 1977; 5, AMS C173182, Dingo Beach; 2, AMS C172501, 4, AMS C172532, many, AMS C301676, Bowen; 14, AMS C172520, Bowen; 1, AMS C172536, Grays Bay, Bowen, beach, July 1972; 25, AMS C173055, Bowen, 1989; 25, AMS C173406, Bowen; 21, AMS C172534, 20°27'S 149°02'E, Lindeman Island, north of Mackay, 37 m, 1929; 106, AMS C42291, 17°52'S 146°07'E, Clump Point; many, AMS C301675, Townsville, 1990; 1, AMS C172519, Edgecumbe Bay, 1935; 1, AMS C172515, Trinity Bay, September 1949; 37, Lamprell Collection, Freshwater Point, Sarina, beach after rough weather, July 1991; 2, AMS C172533, Buchan's Point, 1964; 1, AMS C172528, 17°52'S 146°06'E, Mission Beach, 27 September 1980; 1, AMS C76443, 21, AMS C172517, Kurramine Beach, July 1969 (preserved); 1, AMS C173449, 17°47'S 146°06'E, southern end of Kurramine Beach, 27 August 1973; 2, AMS C172537, Lizard Island, Casurina Beach, 1–2 m at boat anchorage, in sandy mud, 1 December 1975; 5, AMS C173058, Yorkies Knob, Half Moon Bay, July 1972; 24, AMS C172509, 31, AMS C76444, 5, AMS C172523, 4 Mile Beach, Port Douglas, July 1964; 4, AMS C172518, 4 Mile Beach, Port Douglas, August 1969; 4, AMS C172511, 4 Mile Beach, Port Douglas; 34, AMS C172527, 4 Mile Beach, Port Douglas, tide wash, July 1972; 1, AMS C63136, Albany Passage, 8–28 m; 1, AMS C172525, Lucinda, beach, 1 July 1977; 2, AMS C172507, Bird Islet, Lizard Island, 24 m, on live coral in rubble, 9 December 1974; 3, AMS C14922, Karumba, 17°29'S 140°50'E, beach, 7–11 June 1903; 1, AMS C121684, 11°32'S 144°10'E, 16 km north-east of Raine Island, 1000 m, 12 February 1979; 1, QM MO17654, 17°21.77'S 146°48.5'E, 296–303 m; 3, AMS C108321, Somerset, Cape York Peninsula, beach, 10 July 1976. NORTHERN TERRITORY: 2, AMS C172521, Port Darwin; 24, AMS C173020, Darwin. WESTERN

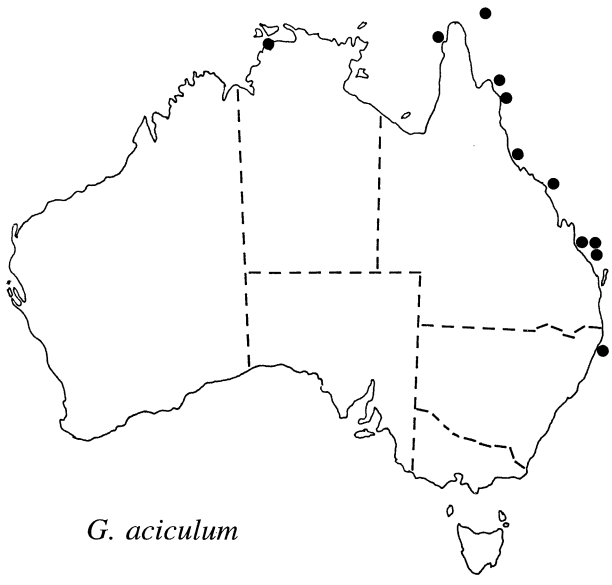


Figure 104. Australian distribution of *Graptacme aciculum* (Gould, 1859).

AUSTRALIA: 1, AMS C172531, Six Mile Creek, Port Hedland, October 1974; 2, AMS C100745, Denham, Shark Bay, beach, 10 January 1972; 1, AMS C172500, Lighthouse Beach, North West Cape, 1972; 1, AMS C173634, Rosemary Island, Dampier Archipelago, October 1973; 1 WAM 262-93, South Passage, Shark Bay, 6 March 1966, intertidal sand.

Description. Shell length to 42.0 mm, aperture diameter to 2.7 mm, apex diameter to 0.6 mm; glossy, slender, weakly to moderately curved. Sculpture of close, microscopic longitudinal striae towards the apex only, only seen under magnification, the rest of the shell smooth with microscopic growth lines. Aperture circular. Apex circular, usually with ventral notch. Colour opaque white.

Range. China, Japan, Philippines (all Habe, 1963, 1964), Indonesia (Boissevain, 1906), New South Wales, Queensland, Northern Territory to northern Western Australia.

Habitat. Sieved from littoral sand and dredged in sand 1000 m.

Comparisons and remarks. *Graptacme aciculum* resembles most closely *G. acutissimum* (Watson) but differs in being more curved and in having the striae limited to the apical third of the shell. *Graptacme nielseni* n.sp. has a larger, heavier shell, with much coarser striations and a wider aperture. *Graptacme aciculum* is a common species sometimes washed ashore after heavy storms.

Family FUSTIARIIDAE Steiner, 1991

Diagnosis. The shell is smooth, polished, without longitudinal sculpture, thin-walled and transparent. The shell cross section is circular. The rachis [central] tooth differs from that of the Dentaliidae by having a flat, not arched, superior edge. The annular ciliary organ of the anterior mantle margin has 5 to 6 rows of cells. Neither annular sinus, ventral bolster or gland cells are developed at the posterior mantle aperture. Instead the pavillon houses numerous large subepithelial gland cells. A conspicuous dorsal septum is located in the sinus of the pedal middle piece (Steiner, 1992a: 396).

Genus *Fustiaria* Stoliczka, 1868

Fustiaria Stoliczka, 1868: 439; Newton & Harris, 1894: 64; Pilsbry & Sharp, 1897: 127; Boissevain, 1906: 58; Ludbrook, 1960: I39; Emerson, 1962: 474; Habe, 1964: 26; Palmer, 1974a: 120; Steiner, 1992a: 396.
Pseudantalis Monterosato, 1884: 32.

Type species: *Dentalium circinatum* J. de C. Sowerby, 1823 (Eocene, Paris Basin) Pilsbry & Sharp, 1897, by subsequent designation.

Diagnosis. Shell regularly tapering, strongly curved, glossy, translucent when fresh; aperture circular; apex usually with a long, narrow, longitudinal slit on the ventral side.

Key to Australian *Fustiaria*

1 Apex not dorsally oblique, with a long, narrow, ventral slit; growth lines easily visible ..... *F. stenoschizum*

—— Apex dorsally oblique with a small dorsal notch and ventral slit; growth lines poorly visible ..... *F. caesura*

Fustiaria stenoschizum (Pilsbry & Sharp, 1897)

Figs 99D, 105B, 106, 108

Dentalium stenoschizum Pilsbry & Sharp, 1897: 128, pl. 19, fig. 10–15; Boissevain, 1906: 59, pl. 6, figs 16–17.

Type material. HOLOTYPE: not sighted. Type locality: West Indies. Length of holotype 35.0 mm, aperture diameter 3.4 mm (*fide* Pilsbry & Sharp).

Material examined. QUEENSLAND: 3, AMS C173606, 23°18'S 151°42'E, North West Island, Capricorn-Bunker Group, May

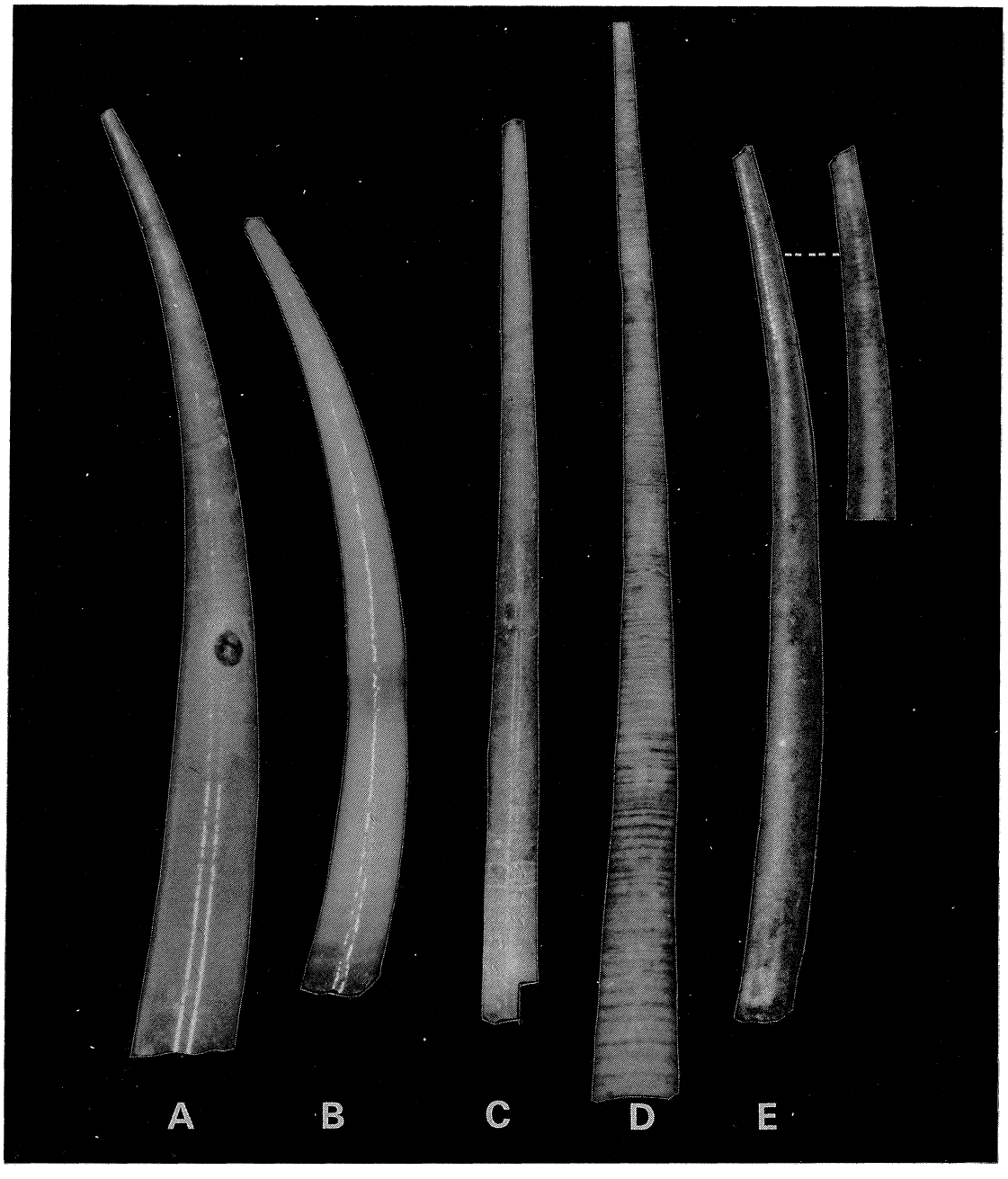


Figure 105. Dentaliida. **A,B** Fustiariidae, *Fustiaria*. **A** *F. caesura* (Colman, 1958) (holotype, AMS C62230, off Wollongong, NSW., 183 m, length 21.3 mm). **B** *F. stenoschizum* (Pilsbry & Sharp, 1897) (WAM 161/93, Rosemary Island, WA, 6 m, length 46.2 mm). **C–E** Omniglyptidae, *Omniglypta*. **C,D** *O. cerina* (Pilsbry, 1905) (C—holotype, ANSP 88305 Shimidzu, Japan, off spit, length 33.0 mm; D—AMS C172486, north-east of Croker Island, Arafura Sea, length 16.5 mm). **E** *O. anulosum* (Brazier, 1877) (lectotype, AMS C170759, Princess Charlotte Bay, Qld, 24 m, length 13.5 mm; note rings on detail of apex).

1931; 1, QM MO5472, Lady Musgrave Island, Bunker Group, dredged in sand, 4 m, August 1972; 1, NMV F67452, Lady Musgrave Island; 7, AMS C173269, Lady Musgrave Lagoon; 1, AMS C173270, Lady Elliot Island; 1, AMS C173002, North West Island, 30 August 1967; 13, AMS C172968, 21°49'S 151°54'E, Big Sandy Cay, Swains Reefs, 9 m; 4, AMS C173303, Swains Reefs, 4 m, October 1970; 1, AMS C172437, 14°55.5'S 145°42'E, south-west end of No 10 Ribbon Reef, 4.5–18 m, sandy rubble, 17 December 1982; 2, AMS C172971, Michaelmas Cay; 1, AMS C173302, 14°40'S 145°28'E, Macgillivray Cay, north-east of Lizard Island, coarse sand, 14 m, 10 December 1974 (preserved); 1, AMS C173091, Fitzroy Reef; 1, AMS C172435, 9°56'S 144°04'E, off Murray Island, Torres Strait, 9–15 m, 30 August–3 October 1907; 5, AMS C303586, Murray Island, Torres Strait, 116 m. WESTERN AUSTRALIA: 11, AMS C174533, 9, AMS C174528, 19°04.8–04.6'S 118°50.8–50.2'E, north of Port Hedland, 83 m, 14–15 February 1983 (preserved); 1, AMS C174549; 1, AMS C174620; 1, AMS C174542; 1, AMS

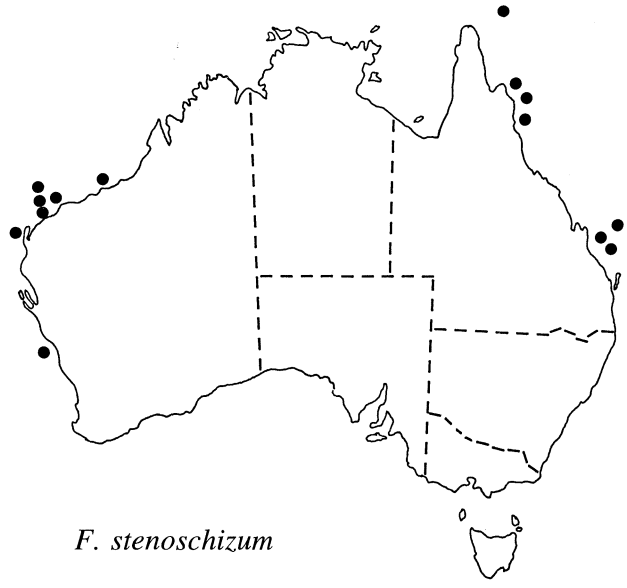


Figure 106. Australian distribution of *Fustiaria stenoschizum* (Pilsbry & Sharp, 1897).

C174532; 1, AMS C174538; 1, AMS C174540; 3, AMS C174529; 1, AMS C174541, north of Port Hedland, to 83 m, October 1983 (preserved); 1, 3, WAM 160-93, west of Flat Island, off Onslow, 19 July 1960; 1, WAM 110-93, north-east of Rosemary Island, Dampier Archipelago, 22 October 1971 (preserved); 9, WAM 176-93, Norbill Bay, Rosemary Island, 2 m, 21 April 1972; 6, WAM 111-93, outside Norbill Bay, Rosemary Island, Dampier Archipelago, dredged 4–5 m, in sand, 21 May 1972 (preserved); 1, AMS C173464, 20°29'S 116°36'E, Rosemary Island, 2 m, 25 September 1972 (preserved); 7, WAM 161-93, Anchorage Bay, Rosemary Island, Dampier Archipelago, 6 m, 27 August 1961; 1, WAM 173462, 20°29'S 116°36'E, Rosemary Island, Dampier Archipelago, 29 September 1972 (preserved); 7, WAM 50-93, Norbill Bay, Rosemary Island, Dampier Archipelago, 4 m, May 1974; 1, WAM 88-93, 25°54.3'S 113°08.4'E, north-west end of Denham Channel, Shark Bay, 8 October; 1, WAM 881-67, 20°58'S 115°20'E, east side of South Pasco Island, 2–6 m, sand, 5 August 1966 (preserved); 1, WAM 166-93, 22°41'S 113°39'E, bay on north side of Point Cloates, 6 m, 23–24 August 1968; 1, WAM 235/94, 18°25'S 118°22'E, north of Port Hedland; 5, AMS C174531; 2, AMS C174536, 19°05'S 118°57.8–57.2'E, north of Port Hedland, 83 m, 23 October 1983 (preserved); 1, AMS C175550, 19°04.1–04.4'S 119°00.8–00.5'E, north of Port Hedland, 82 m, 28 April 1983 (preserved); 2, WAM 170-93, Monte Bello Island; 1, WAM 1577-67, 20°48'S 115°27'E, Airport Beach, Barrow Island, on intertidal reef, 4 November 1966; 3, WAM 165-93, Useless Loop Groyne, 8 March 1966; 1, AMS C172438, 29°35.5–36.0'S 114°17.5–20.0'E, west of Beagle Island, 163 m, 17 February 1976.

Description. Shell length to 56.9 mm, aperture diameter 4.5 mm, apex diameter 0.8 mm; slender, polished, well curved, slowly attenuate; sculpture of dense, transverse growth lines. Aperture circular. Apex circular, usually with a long, narrow, ventral slit. Specimens which do not have a slit, usually have a longitudinal mark in its place. Colour white.

Radula. Central tooth broad (177 µm wide in male, 233 µm wide in female), shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped (216 µm long in male, 233 µm long in female) with small cusps on the working surface; marginals slightly sigmoidal and relatively narrow (length 322 µm × breadth 80 µm in male, length 300 µm × breadth 75 µm in female) (see Fig. 108A–D). Ratios: male C:L = 1:1.22, L:M = 1:1.5, marginals breadth:length = 1:4; female C:L = 1:1, L:M = 1:1.3, marginals breadth:length = 1:4.

Range. West Indies (Pilsbry & Sharp, 1897), Philippines (Boissevain, 1906), Queensland, northern Western Australia.

Habitat. Dredged in coarse sand from 2 to 163 m.

Comparisons and remarks. *Fustiaria stenoschizum* resembles closely *F. caesura* (Colman) in shape and glossy white surface. Differentiating features which help to separate *F. stenoschizum* from *F. caesura* include: larger size; dense transverse growth lines; absence of apical notch. *Fustiaria stenoschizum* bears some superficial similarity to *Laevidentalium lubricatum* (G.B. Sowerby), namely in the shape and glossy white surface of the shell. However *L. lubricatum* shows a notch apically and never a fine deep slit. In addition, the shell apex of *L. lubricatum* exhibits fine transverse growth lines and often fine longitudinal striae. Although *Fustiaria* species normally possess a slit, specimens without slits occur regularly within samples. Steiner (1991) drew attention to this, but emphasized that the animal of *Fustiaria* differs markedly from other Dentaliida, enough in fact to warrant establishing a separate family Fustiariidae. Nevertheless, special care should be taken in identifying laevidentaliid and fustiariid-like shells lacking a slit.

Fustiaria caesura (Colman, 1958)

Figs 99E, 105A, 107

Dentalium caesura Colman, 1958: 145; Iredale & McMichael, 1962: 97.

Type material examined. HOLOTYPE: AMS C62230. Type locality: off Wollongong, NSW, 100 fathoms [183 m]. Length of holotype 21.3 mm, aperture diameter 2.3 mm, apex diameter 0.5 mm. Length of apical slit 5.5 mm.

Additional material examined. WESTERN AUSTRALIA: 2, AMS C172440, 19°04.6–04.3'S 118°47.4–47.6'E, 144 km north north-east of Port Hedland, 82 m, sand, 30 October 1983; 3, AMS C301476, west of Guilderton, 31°30–34'S 114°56'–115°06'E, 146 m, 23 March 1972; 1, AMS C301418, off Albany, 34°51'S 118°40'E, 67 m, 20 March 1980; 1, AMS C301421, south-west of Mandurah, 32°45'S 114°47'E, 220 m, 17 March 1972. SOUTH AUSTRALIA: 2, AMS C3978, 60 km south of Cape Wiles, 183 m, August 1909. TASMANIA: 1, AMS C173180, 40°50.6'S 148°46.5'E, off Cape Naturaliste, 399 m, silty sand, 26 March 1973. VICTORIA: 1, AMS C172442, 43 km south-east of Cape Everard, 60–300 m, 9 May 1914; 3, AMS C172432, off Gabo Island, 160 m. NEW SOUTH WALES: 5, AMS C172441, 32°22'S

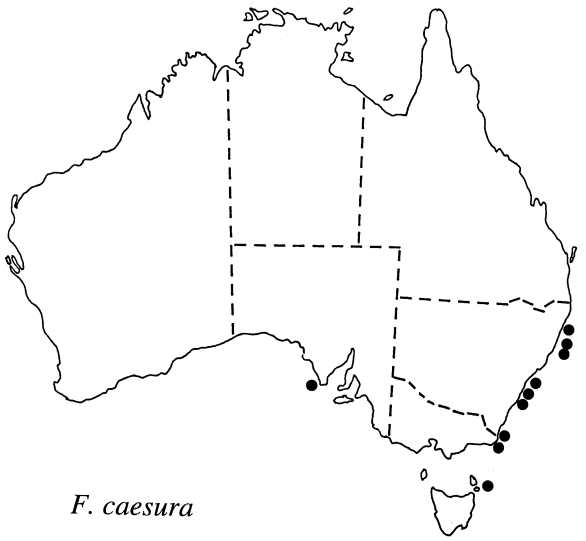


Figure 107. Known distribution of *Fustiaria caesura* (Colman, 1958).

152°57'E, 38 km east of Forster, 247 m, 27 February 1972; 1, AMS C172430, 32°52'S 152°32'E, off Broken Bay, 145 m, 6 December 1978; AMS C62229, 160 m, 32 km east of Narrabeen; 14, AMS C173385, 33°44'S 151°48'E, off Broken Bay, 263 m, 11 December 1978; 4, AMS C172436, 31°11'S 153°13.6'E, off Korogoro Point, 220 m, 25 February 1972; 3, AMS C173267, 34°25'S 151°15'E, 16 miles east of Wollongong, 183 m, August 1902; 4, AMS C173000, 33°46–43'S 151°47–50'E, off Port Kembla, 281 m, 5 December 1978; 29, AMS C172428, 33°58.54'S 151°33.38'E, off Sydney, 187 m, 9 August 1973; 1, AMS C173271, 33°46'S 151°43'E, off Sydney, 175 m, 5 December 1977; 7, AMS C172998, 33°46'S 151°43'E, off Botany Bay, 170 m, 5 December 1977; 2, AMS C172356, 33°58.54'S 151°33.38'E, 29 km east of Little Bay, Sydney, 183 m, 9 August 1973; 1, AMS C172997, 29°39.8'S 153°26.4'E, 12 km east of Cakora Point, south of Yamba, 55 m, 22 February 1972; 7, AMS C172999, Crookhaven, 64 m; 1, AMS C173001, off Cronulla, 100 m, December 1963. QUEENSLAND: 1, AMS C172434, Lady Musgrave Island.

Description. Shell length to 38.8 mm, aperture diameter 3.6 mm, apex diameter 0.7 mm; slender, strongly curved; devoid of sculpture but with obscure growth lines. Aperture circular, fragile. Apex obliquely cut on the dorsal side with a faint notch, on the ventral side the apex develops a small notch and a long, longitudinal slit, if present, up to one quarter of the shell length (see Comparisons and remarks). Colour off-white to cream-yellow, translucent when live.

Range. Western Australia, South Australia, Tasmania, Victoria, New South Wales to southern Queensland.

Habitat. Dredged in sand from 60 to 399 m.

Comparisons and remarks. *Fustiaria caesura* resembles most closely *F. stenoschizum* (Pilsbry & Sharp) in shape and glossy white surface. Differentiating features which separate *F. caesura* from *F. stenoschizum* include: generally smaller size; presence of apical notch; transverse growth lines poorly visible. In addition *F. caesura* appears to be limited to the south-eastern states in contrast to the central Queensland and northern Australian distribution of *F. stenoschizum*. In one lot examined by us (AMS C172428), of the 29 specimens in the sample only 5 exhibited the slit typical of the species.

Family OMNIGLYPTIDAE Chistikov, 1975

Omniglyptidae Chistikov, 1975; Steiner, 1992a: 397.

The shell nearly straight, sculpture of apical annulations.

Omniglypta Kuroda & Habe, 1953

Omniglypta Kuroda & Habe, 1953: 296; Palmer, 1974a: 120; Steiner, 1992a: 397.

Type species: *Dentalium cerinum* Pilsbry, 1905: by original designation.

Diagnosis. The shell is thin, transparent to translucent white, weakly curved to almost straight, glossy, slowly tapering posteriorly; apex without slit, notch, plug or pipe but showing fine, raised annulations which continue to varying distances along shell length; aperture circular. The radula bears a series of cusps on the superior edge of the central tooth.

Key to Australian *Omniglypta*

1 Annulations confined to apex, obscure or absent in remainder of shell ..... *O. anulosum*

—— Annulations extend over entire length of shell ..... *O. cerina*

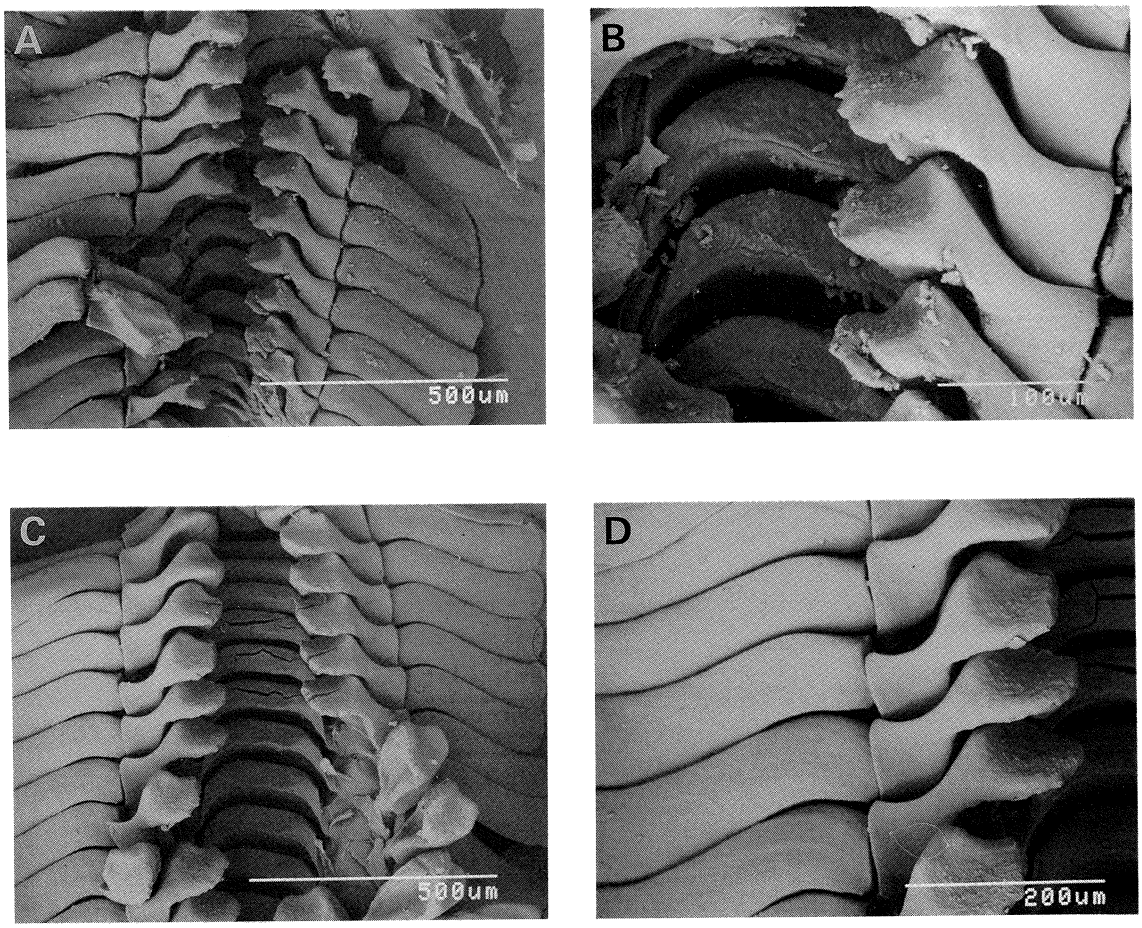


Figure 108. Radular ultrastructure of *Fustiaria stenoschizum* (Pilsbry & Sharp, 1897), A and B—male, C and D—female (Swain Reefs, Qld, 4 m, AMS C173303).

Omniglypta anulosum (Brazier, 1877)

Figs 105E, 109A, 110

Dentalium anulosum Brazier, 1877: 58; Pilsbry & Sharp, 1897: 101; Boissevain, 1906: 57, pl. 6, figs 38, 39; Hedley, 1901: 129, pl. 17, fig. 36; Hedley, 1910: 371, (*D. annulosum* in error).

Type material examined. LECTOTYPE: AMS C170759, selected by Ponder & Stanbury, 1971 from lot A89. Type locality: Princess Charlotte Bay, north-east Australia, 13 fathoms [24 m]. Length of lectotype 13.5 mm, aperture diameter 1.0 mm, apex diameter 0.35 mm. PARALECTOTYPE: 1, same locality data as lectotype.

Additional material examined. QUEENSLAND: 1, AMS C310217, 20°32.3'S 149°01'E, Whitsunday Passage, 27 m, shelley muddy sand, 19 November 1977; 3, AMS C169939, 19°44'S 148°14'E, off Bowen, 40 m, 12 December 1977, thick fine mud; 1, AMS C172508, 20°54'S 148°58'E, Seaforth, north of Mackay; 3, AMS C173052, 21°03'S 149°39.2'E, off Mackay, 37 m, 13 December 1977; 29, AMS C169951, Cairns Harbour; 2, AMS C169941, north-east of Cape Moreton Lighthouse, trawled, 115–119 m; 1, AMS C2587, Cape Sidmouth; 6 AMS C174618, Palm Island, 27 m July-August 1901; 3 AMS C301218, 16°28'S 145°28'E, Dicksons Inlet, Port Douglas, July 1969.

Description. Shell length to 15.3 mm, aperture diameter 1.0 mm, apex diameter 0.35 mm; thin, translucent, slowly tapering, slightly curved. Sculpture of transverse annulations from the centre of the shell to the apex, sometimes obscure centrally, rest of shell smooth, devoid of sculpture. Aperture circular or slightly obovate. Apex entire, without slit or notch. Colour translucent white.

Range. Indonesia (Boissevain, 1906), central to northern Queensland.

Habitat. Dredged in sand and mud from 26 to 119 m.

Comparisons and remarks. *Omniglypta anulosum* most closely resembles *O. cerina* (Pilsbry) which also possesses a white, weakly curved shell. Differentiating features which help to separate *O. anulosum* from *O. cerina* include: annulations confined to the apex (annulations present throughout shell of *O. cerina*). *Dentalium semitracheatum* Boissevain may prove to be a synonym of *O. anulosum*.

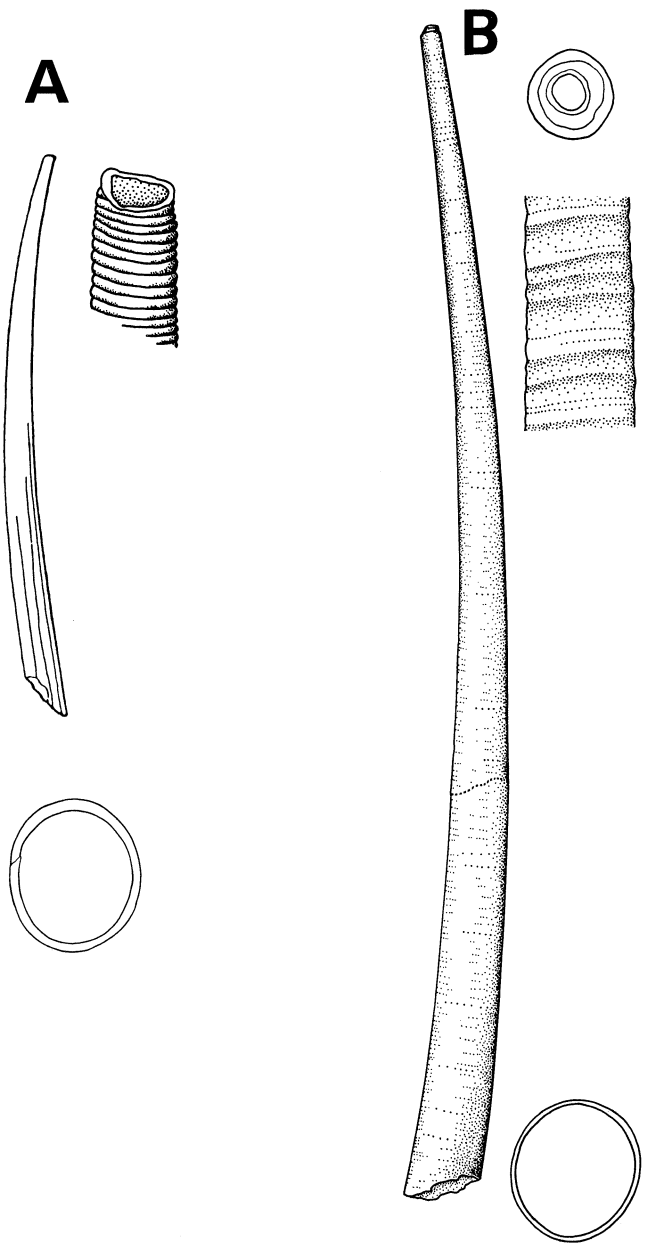


Figure 109. Dentaliida, Omniglyptidae, *Omniglypta*. **A** *O. anulosum* (Brazier, 1877) (lectotype, AMS C170759, Princess Charlotte Bay, Qld, 24 m, length 13.5 mm). **B** *O. cerina* (Pilsbry, 1905) (AMS C173422, off Cairns northern Qld; aperture profile of specimen AMS C172486, north-east of Croker Island, Arafura Sea, length 16.5 mm). (Del.: all A. Hill, except longitudinal profile in A—from Hedley, 1901).

Omniglypta anulosum appears to be restricted to tropical Australian waters. Ponder & Stanbury (1971) cite Hedley's (1901: 129) spelling of this species name as "*annulosum*" as a correction of Brazier's name. However, as Hedley gave no reason for his alteration, and as the original spelling has been accepted in major works on scaphopods (e.g., Pilsbry & Sharp, 1897–98, Boissevain, 1906), we can see no compelling reason to reject Brazier's name as originally published.

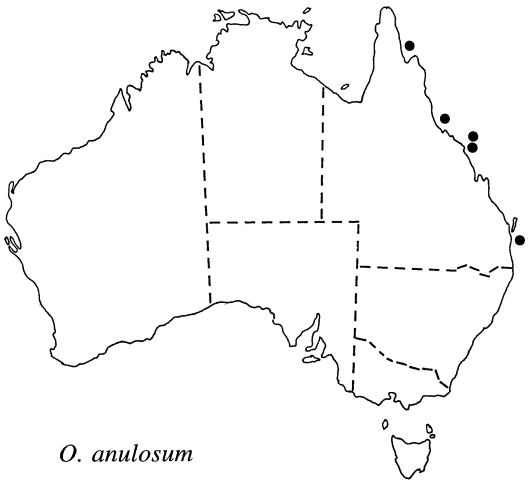


Figure 110. Known distribution of *Omniglypta anulosum* (Brazier, 1877).

Omniglypta cerina (Pilsbry, 1905)

Figs 105C,D, 109B, 111

Dentalium cerinum Pilsbry, 1905: 117, pl. 5, fgs 40, 41; *Omniglypta cerina* Habe, 1955: 24; Habe, 1957: 132, txt figs 3, 4, 10; Habe, 1961: 106, pl. 47, fig. 13; Habe, 1963: 270, txt figs 23, 24.

Dentalium tracheatum Boissevain, 1906: 56, pl. 4, fig. 22.

Type material examined. HOLOTYPE: ANSP 88305. Type locality: Shimidzu, Suruga-Wan, Honshu Island, Shizuoka Prefecture, Japan off spit. Length of holotype 33.0 mm, aperture diameter 1.9 mm, apex diameter 0.9 mm.

Additional material examined. QUEENSLAND: 5, AMS C172494, 24°28.2'S 153°31.2'E, north-east of Sandy Cape, 1330–1380 m, 8 July 1984; 10, AMS C310270, 23°44'S 152°49'E, 34 km east of Lady Musgrave Island, 348–351 m, 17 November 1977; 18, AMS C310431, 4, AMS C173435, 45, AMS C310408, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 12, AMS C172482, 24°03.7'S 152°49.4'E, north-east of Lady Elliot Island, 150 m, 4 July 1984; 40, AMS C172547, 23°19.5'S 152°35.4'E, east of North West Island, 320 m, *Globigerina* mud, 14 December 1977; 4 AMS C310228, 23°15.2'S 152°24.1'E, east of North West Island, 284 m, 14 December 1977; 1, AMS C173452, 23°08.4'S 152°12.3'E, north-east of North Reef, 115 m, 14 December 1977; 3, AMS C172550, 23°08.4'S 152°12.3'E, 26 km north-east of North Reef, 115 m, 14 December 1977; 1, AMS C169938, 20°32.3'S 149°01.4'E, Whitsunday Passage, shelly muddy sand, 27 m; 4, AMS C169937, 19°45.7'S 148°19'E, east of Bowen, 46 m, thin grey sand; 1, AMS C172488, Zilzie, Keppel Bay, August 1969; 2, AMS C173197, off Bowen, 50 m in mud; 1, AMS C172477, 2 km north-west of Low Isles, 20 m, 1929; 4, AMS C172497, Low Isles, near Port Douglas, 16–22 m, October-November 1928; 13, AMS C27513, 15°42'S 145°30'E, between Cairns Reef and Hope Island, 9–18 m, 2–6 August 1906; 19, AMS C44843, 15°45'S 145°35'E, between Cairns and Endeavour Reefs, 37 m,

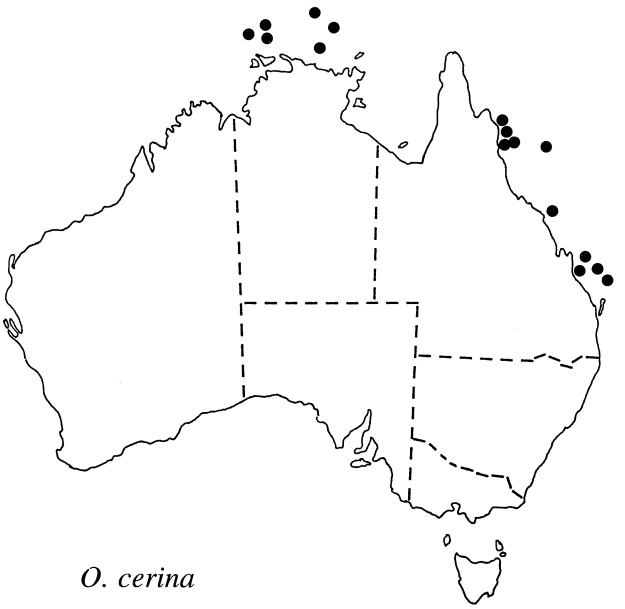


Figure 111. Australian distribution of *Omniglypta cerina* (Pilsbry, 1905).

16 June 1918; 3, AMS C173195, 4 Mile Beach Port Douglas. NORTHERN TERRITORY: 20, AMS C172478, 9°30'S 132°34'E, approx 160 km north of Croker Island, Arafura Sea, 124 m, 9 November 1969; 3, AMS C201281, 8°18'S 133°58'E, 336 km north-east of Croker Island, 3 November 1969; 7, AMS C172486, 8°09'S 134°50'E, approx 401 km north-east of Croker Island, Arafura Sea, 115 m, 3 November 1969; 2, AMS C174631, 9°17.5'S 132°20'E, Arafura Sea, 150 miles north of Coburg Peninsula, 168 m, 10 November 1969; 16, AMS C172549, 3, AMS C172545, 10°17'S 132°38'E, approx 64.5 km north of Croker Island, Arafura Sea, 65 m, 9 November 1969; 3, AMS C172480, 8°18'S 134°11'E, 420 km north of Melville Island, 141 m, sand, 3 November 1969; 2, AMS C172485, 9°53'S 130°02'E, 150 km north-west of Melville Island, 205 m, sand, 5 November 1969; 3, AMS C172493, 9°17.5'S 132°20'E, 240 km north of Cobourg Peninsula, 168 m, 10 November 1969; 2, AMS C172484, 9°30'S 132°34'E, approx 320 km north of Croker Island, 124 m; 6, AMS C172476, 10°22.5'S 131°37'E, 100 km north-east. of Melville Island, 71 m, sand-silt-clay, 14 November 1969; 2, AMS C201280, 8°48'S 134°58'E, 365 km north of Milingimbi Island, Arnhem Land, 100 m, clay/sand, 18 October 1969; 3, AMS C173196, 11°08'S 134°18.5'E, 96 km north-east of Goulburn Island, Arnhem Land, 50 m, 5 October 1969. WESTERN AUSTRALIA: 1, WAM 62-94; 1, Lamprell Collection, Exmouth Gulf, grab samples, November-December 1993.

Description. Shell length to 38.9 mm, aperture diameter 2.6 mm, apex diameter 1.0 mm; almost straight, glossy. Sculpture of strong, transverse, irregular, close-set annulations, closer towards the apex, more distant towards the aperture. Aperture circular, slightly oblique in some specimens. Apex circular. Colour translucent white.

Range. Indonesia (Boissevain, 1906), Japan (Pilsbry, 1905; Habe, 1963), Queensland, Northern Territory and Western Australia.

Habitat. Dredged in sandy mud from 16 to 1380 m.

Comparisons and remarks. *Omniglypta cerina* most closely resembles *O. anulosum* (Brazier) which also possesses a white, weakly curved shell. *Omniglypta cerina* differs from *O. anulosum* in having dense transverse annulations at the apex continuing more distantly to the aperture. Presumably further collecting will establish whether the geographical range of this species is disjunct or continuous from Japan to Australia.

Family LAEVIDENTALIIDAE Palmer, 1974

Laevidentaliidae Palmer, 1974a: 117; Steiner, 1992a: 396.

Diagnosis. Shell smooth to glossy, weakly to strongly curved, almost always devoid of longitudinal sculpture.

Genus *Laevidentalium* Cossmann, 1888

Laevidentalium Cossmann, 1888: 7; Pilsbry & Sharp, 1897: 97; Boissevain, 1906: 51; Henderson, 1920: 73; Woodring, 1925: 202.

Type species: *Dentalium incertum* Deshayes, 1825 by original designation.

Diagnosis. Shell of moderate to large size, with smooth (usually glossy) surface and circular to ovate transverse profiles at apex and aperture. Apex often with notch and/or pipe. Sculpture usually only consisting of transverse growth lines, but longitudinal striae present apically in some species at least in young specimens.

Key to Group of *Laevidentalium erectum*

Very narrow throughout, weakly curved beyond apical region, polished, apex often with dorsal notch.

1 Shell narrow, thin but strong; slowly but perceptively increasing in diameter towards aperture 2

—— Shell needle-like, very thin and somewhat fragile; only slight increase in diameter towards aperture ..... *L. arnoldi*

2 Usually with dorsal notch; growth lines not oblique ..... *L. erectum*

—— Without dorsal notch; growth lines oblique ..... *L. leptosceles*

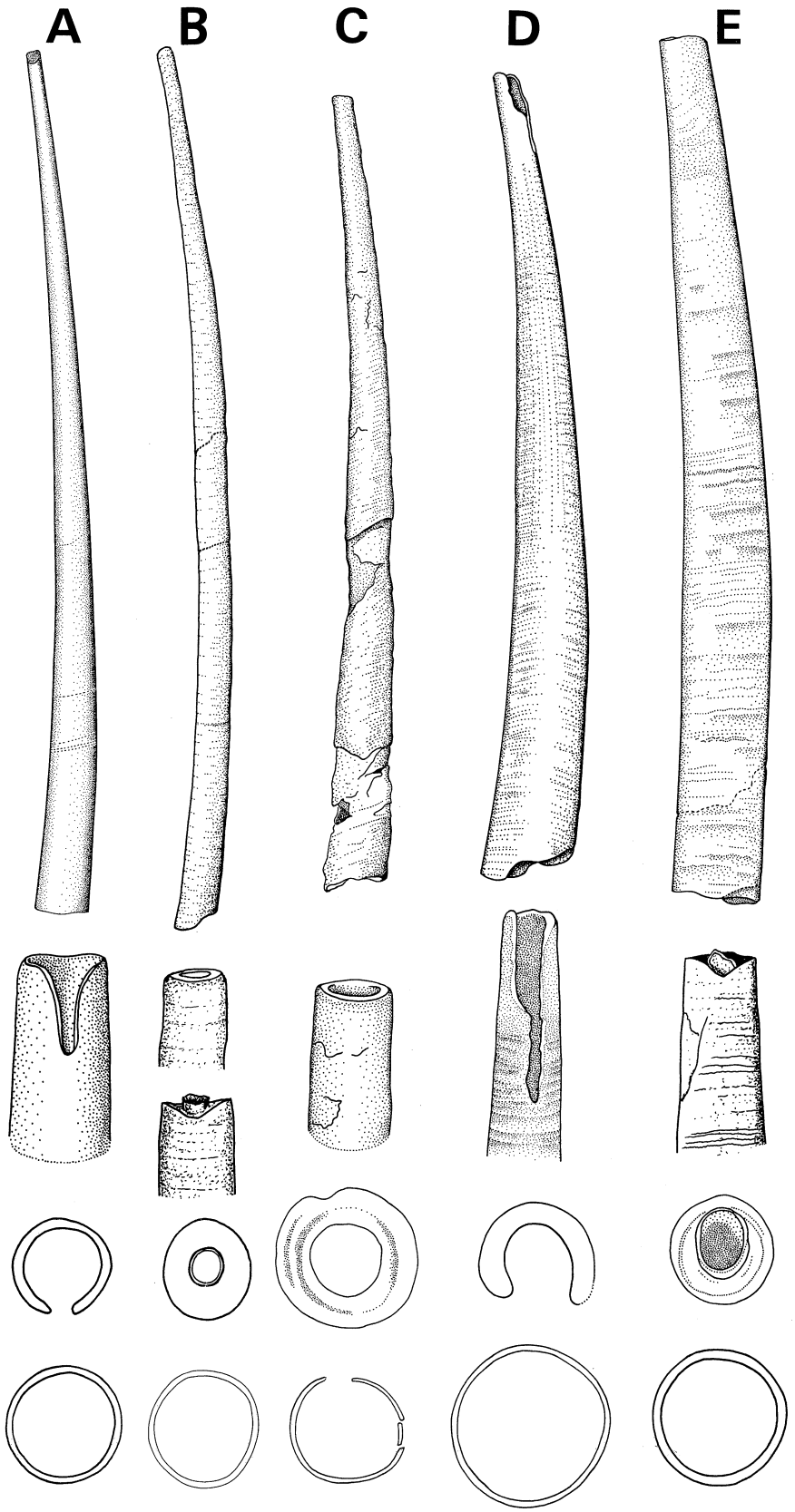


Figure 112. Dentaliida, Laevidentaliidae, *Laevidentalium*, group of *L. erectum*. **A** *L. erectum* (Sowerby, 1860) (lectotype BMNH 1993130, Sydney, length 55.5 mm). **B** *L. arnoldi* n.sp. (holotype, QM MO53676, off Cairns, Qld, 303 m, length 41.4 mm). **C** *L. leptosceles* (Watson, 1879) (lectotype BMNH 1887.2.9.21–2, S. of Australia, 4756 m, length 38.0 mm). Group of *L. lubricatum*. **D** *L. jaffaensis* (Cotton & Ludbrook, 1938) (holotype, SAM D13337, off Cape Jaffa, SA, 165 m, length 24.0 mm). **E** *L. zeidleri* n.sp. (holotype, SAM D18903, 29 km south-east of Scamander, Tasmania, 122 m, length 25.0 mm). (Del.: all A. Hill, except B [apex] and E [apex]—JMH).

Figure 113. Dentaliida, Laevidentaliidae, *Laevidentalium*, group of *L. erectum*. **A,B** *L. erectum* (Sowerby, 1860) (A—lectotype BMNH 1993130, Sydney, length 55.5 mm; B—variant showing increased curvature of profile). **C** *L. leptosceles* (Watson, 1879) (lectotype BMNH 1887.2.9.21-2, S. of Australia, 4756 m, length 38.0 mm). **D** *L. arnoldi* n.sp. (holotype, QM MO53676, off Cairns, Qld, 303 m, length 41.4 mm). Group of *L. lubricatum*. **E** *L. jaffaensis* (Cotton & Ludbrook, 1938) (holotype, SAM D13337, off Cape Jaffa, SA, 165 m, length 24.0 mm). **F** *L. zeidleri* n.sp. (holotype, SAM D18903, 29 km south-east of Scamander, Tasmania, 122 m, length 25.0 mm).

Laevidentalium erectum (G.B. Sowerby, 1860)

Figs 112A, 113A,B, 114, 115

Dentalium erectum G.B. Sowerby, 1860: 99, pl. 225, fig. 55; Clessin, 1896: 29, pl. 9, fig. 1; Colman, 1958: 143, pl. 1, fig, 6; Iredale & McMichael, 1962: 96.
Antalis erecta Angas, 1867: 220.
Dentalium pluteum Colman, 1958: 143, pl. 1, fig. 8; Iredale & McMichael, 1962: 96.

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1993130. Type locality: Sydney. Length of lectotype 55.5 mm, aperture diameter 3.4 mm, apex diameter 1.0 mm. PARALECTOTYPES: 2, same locality data as for lectotype.

Additional material examined. WESTERN AUSTRALIA: 23, AMS C171808, 19°03.6–03.4'S 119°03.4–03.5'E, 148 km north north-east of Port Hedland, 82 m, 23 October 1983; 1, AMS C148647, 19°04.9–04.7'S 118°50.6–50.8'E, 140 km north north-east of Port Hedland, 81 m, sand, 30 October 1983; 8, AMS C171816, 19°05.0–04.9'S 118°58.2'E, 142 km north north-east of Port Hedland, 82 m, 23 October 1983, sand/gravel; 1, AMS C171815, 19°05.4–05.3'S 118°53.9–54.0'E, 137 km north north-east of Port Hedland, 80 m, 30 October 1983, sand; 11, AMS C149973, 19°04.4–04.2'S 119°04.4–04.0'E, 144 km north north-east of Port Hedland, 82 m, sand, 23 October 1983; 4, AMS C171806, 18°48'S 119°00.8'E, 174 km north north-east of Port Hedland, 92-94 m, 23 October 1983; 1, WAM 132-93, 24°03'S 113°02'E, north-west of Carnarvon, 96 m, 7 October 1963; 6, AMS C171842, south of Cape Leeuwin, 73–144 m, 9 August 1962; 6, AMS C171817, 35°12'S 117°00'E, south of Wilsons Inlet, 73–77 m, 8 August 1962; 1, AMS C171828, 34°55'S 119°00'E, east off Cheyne Bay, 75 m, 7 August 1962; 21, AMS C172976, 34°21'S 121°16'E, east of Hood Point, 82 m, 9 July 1962; 9, AMS C171847, 8, AMS C311156, 33°03'S 114°44'E, west of Bunbury, 156 m, 10 August 1962; 14, AMS C171800, 17, AMS C171885, between Eucla and Esperance, 75–293 m, 5–9 July 1962; 1, WAM 131-93, north north-west of Rottnest Island, dredged 130 m, 15 August 1962; 1, WAM 135-93, 30°30'S 114°31'E, west of Cape Naturaliste, 250 m, 15 March 1972; 10 (juveniles) AMS C169787, 30°45'S 114°51'E, west of Jurien Bay, 143 m, 21 August 1962; 10, SAM D18901, 80 m west of Eucla, 162 m, January 1958; 4, SAM D18902, Hopetoun, 70 m; 1, AMS C173094, 34°12'S 121°31'E, western side of Great Australian Bight, 9 July 1962; 1, AMS C173309, 33°20'S 128°45'E, Great Australian Bight, 5 July 1962 (preserved); 2, AMS C173037, 32°42'S 131°27'E, south-west of Cape Adieu, Great Australian Bight, 29 m, 4 July 1962. SOUTH AUSTRALIA: 1, SAM D299, west of Cape Borda, 124 m; 3, AMS C33487, off Cape Borda, 110 m; 1, AMS C173031, 38°5–10'S 140°00'E, off Cape Martin, Beachport; 13, AMS C171821, 33°20'S 128°45'E, Great Australian Bight, 150 m, 5 July 1962. TASMANIA: 2, AMS C171843, 40°22.5'S 143°39'E, south of King Island, 128 m, 25 April 1973; 5, AMS C171820, 40°36.5'S 143°37'E, south of King Island, 108 m, 29 April 1973; 5 AMS C311151, 40°36.5'S 143°37'E, south of King Island, 108 m, 29 April 1973. VICTORIA: 1 (juvenile) AMS C310258, 38°20–40'S 149°25–35'E, 48 km south of Cape Everard, 366 m, 22 October 1916; 3, NMV F67455, off 90 Mile Beach, 8 October 1935; 1, AMS C171812, 38°12'S 148°35'E, 440 km south of Marlo, in Bass Strait, 146 m, 7–9 May 1969. NEW SOUTH WALES: Holotype; 1, AMS C18217, *L. pluteum* type location, 34°25'S 151°15'E, 183 m, off Wollongong; 3, AMS C173268, off Wollongong; paratypes: 2, AMS C170644 (ex C18217), 200 m off Wollongong; 1, AMS C173373, 58 km south-east of Green Cape, 940 m, 2 October 1912; 8, AMS C303590, 33°59.36'S 151°22.07'E, 14.5 km east of Cape Banks, Sydney, 110–115 m, 25 October 1973; 7, AMS C174455, 36°57.95–58.41'S 150°22.00–22.14'E, Tasman Sea, 12 December 1986; 2, AMS C171832, 33°46–43'S 151°47–50'E, off Port Kembla, 281 m, 5 December 1978; 5, AMS C171825, 33°46'S 151°43'E, off Sydney, 175 m, 5 December 1977; 58, AMS C171824, 33°58'S 151°29'E, off Sydney, 150 m, 18 July 1962; 27, AMS C171854, 5, AMS C171855, 1, AMS C171856, 33°59.26'S 151°16.46'E, 2.6 km east north-east of Cape Banks, Sydney, 66 m, 19 July 1974; 5, AMS C171841, Twofold Bay; 10, AMS C18217, off Wollongong, 183 m; 6, AMS C173314, 33°59.26'S 151°16.46'E, 2–6 km east north-east of Cape Banks, Sydney, 66 m (preserved); 4, AMS C171820, 33°52.3'S 151°40'E, off Sydney, 200 m, 12 March 1972; 6, AMS C174455, 36°57.95–58.41'S 150°22.00–22.14'E, Tasman Sea, 12 December 1986; 2, AMS C171832, 33°46–43'S 151°47–50'E, off Port Kembla, 281 m, 5 December 1978; 5, AMS C171825, 33°46'S 151°43'E, off Sydney, 175 m, 5 December 1977; 58, AMS C171824, 33°58'S 151°29'E, off Sydney, 150 m, 18 July 1962; 5, AMS C171841, Twofold Bay; 10, AMS C18217, off Wollongong, 183 m; 6, AMS C173314, 33°59.26'S 151°16.46'E, 2–6 km east north-east of Cape Banks, Sydney, 66 m; 5, AMS C171820, 33°52.3'S 151°40'E, off Sydney, 200 m, 12 March 1972; 1, AMS C171813, 33°28–29'S 151°52'E, east of Cape Three Points, 457–476 m, 5 December 1979; 1, AMS C171829, 1, AMS C171803, 3, AMS C171836, 33°59.27'S 150°16.48'E, 2.3 km east of Malabar, Sydney, 66 m, 24–26 October 1973; 8, AMS C173036, 2, AMS C171889, 33°59.27'S 150°16.49'E, 2.3 km east of Malabar, Sydney, 66 m, October 1973; 16, AMS C171818, 9, AMS C171852, 1, AMS C171814, 33°59.27'S 150°16.48'E, 2.3 km east of Malabar, Sydney, 66 m, 3 December 1973– 29 January 1974; 3, AMS C171805, east of Malabar, Sydney, 137 m, 1973; 3, AMS C171839, 33°58.42'S 150°16.0'E, 0.5 km east of Long Bay, Sydney, 36.6–40 m, 26 March 1973; 22, AMS C171878, 33°58.12'S 151°16.47'E, 3 km east of Long Bay, Sydney, 47 m, 1973; 5, AMS C171804, Sow and Pigs Reef, Port Jackson, 11–16 m; 2, AMS C171884, Sow and Pigs Reef, Port Jackson; 1, AMS C171857, off Sow and Pigs Reef, Port Jackson; 2, AMS C173169, 1, AMS C173044, off Port Jackson, 183 m, 4 May 1960; 2, AMS C171826, Sow and Pigs Reef, Port Jackson, 11–14.5 m, 1950–60; 1, AMS C171810, Western Channel, off Sow and Pigs Reef, Sydney Harbour, dredged, 1875; 4, AMS C171827, 33°49.30'S 150°21.48'E, 5.6 km east of North Head, Sydney, 66 m, 26 April 1973; 1, AMS C171880, 33°58.48'S 151°34.30'E, 30 km east of Little Bay, Sydney, 192–203 m, 9 August 1973; 6, AMS C173072, 33°58–54'S 151°33.38'E, 28.1 km east of Little Bay Sydney, 192 m, 9 August 1973; 8, AMS C171799, 33°58.26'S 151°16.19'E, 2 km south-east of Long Bay, Sydney, 40 m, 20 July 1972; 19, AMS C171831, 33°43'S 151°40'E, off Botany Bay, 143 m, 5 December 1978; 3, AMS C173168, 34°01'S 151°21'E, east of Botany Bay, 128 m, 4 May 1960; 1, AMS C173043, east of Botany Bay, 165 m, 4 May 1960; 23, AMS C171809, 33°96'S 151°43'E, off Botany Bay, 170 m, 5 December 1977; 99, AMS C171838, 33°58–48'S 151°34.30'E, 32 km east of Little Bay, South Head (Malabar) Sydney, 192–203 m, 9 August 1973; AMS C25878, 160 m, 35 km east of Narrabeen; 1, AMS C19827, 203 m, off Cape Byron; AMS C22417, 40 m, at Wreck Bay; AMS C62228, Broken Bay; 18, AMS C168102, off Cronulla, 200 m, 16 July 1965; 1, AMS C171860, 4.5 km off Cronulla, 130 m, fine mud, 31 January 1966; 35, AMS C173041, off Cronulla, 180 m, 16 July 1965; 1, AMS C171811, Brush Island, south of Ulladulla, 1938; 1, AMS C171882, trawled off Ulladulla, 40–60 m, 1963; 2, AMS C11863, Brisbane Water; 2, AMS C11863, Brisbane Water; 4, AMS

C173038, 28°17'S 153°44'E, off Tweed Heads, 73 m, 9 November 1976; 4, AMS C171801, 29°10'S 153°36.8'E, off Evans Head, 59 m, 21 February 1972; 3, AMS C166531, 28°42.8'S 161°55.64'E, Tasman Sea, Lord Howe Rise, 1325 m, 5 May 1989 (preserved); 1, AMS C166526, 29°24.57'S 160°08.73'E, Tasman Sea, Lord Howe Rise, 2000 m, 4 May 1989 (preserved). QUEENSLAND: many, AMS C303591, north of Cape Moreton, 124 m, 1967; 2, AMS C173086, Lady Musgrave Island, 54–100 m; 2, AMS C171848, 27°31'S 153°40'E, off Moreton Bay, 82–88 m, 29 March 1969; 17, AMS C172491, north north-east of Cape Moreton, 183 m; 15, AMS C173040, off Cape Moreton, 183 m; 3, Lamprell Collection, off Cape Moreton, 120 m; 1, AMS C171881, 26°47'S 153°35'E, off Caloundra, 128 m, 30 March 1969; 12, AMS C173042, 8, AMS C171844, 25°48'S 153°46'E, off southern end of Fraser Island, 73–201 m, 10 November 1976; 1, AMS C173454, 24°22.5'S 153°17'E, 32 km north of Fraser Island, 15 December 1977 (preserved); 9, AMS C171823, 25°58.8'S 153°51'E, off southern end of Fraser Island, 210–219 m, 10 November 1976, sand, brachiopods, bryozoa; 7, AMS C171833, 25°57.85'S 153°51'E, off southern end of Fraser Island, 201 m, 10 November 1976, sand, brachiopods, bryozoa; 2, AMS C171891, 27°57.8'S 153°51.3'E, S. end Fraser Island, 201 m, 10 November 1976, sand, brachiopods, bryozoa; 32, AMS C171807, 25°58.85'S 153°51'E, off southern end of Fraser Island, 210–219 m, 10 November 1976; 5, AMS C171830, 1, AMS C171851, 24°57.9'S 153°37.3'E, off Fraser Island, 210 m, 15 December 1977 coarse calcareous nodules; 1, AMS C173039, 1, AMS C173304, 26°41.2'S 153°38.5'E, off Maroochydore, 200 m, 18 November 1976 (preserved); 23, AMS C171835, 1, AMS C171837, 1, AMS C171894, dredged in Lady Musgrave Lagoon; 14, AMS C310429, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave, 296 m, 7 July 1984; 3, AMS C171850, 23°09'S 151°58'E, 6 km east of North Reef, 64 m, 14 December 1977, coarse shell/bryozoan substratum; 1, AMS C171883, 22°26.27–20.2'S 153°17.13–17.6'E, south-east of Swains Reefs, 187 m, 5 July 1984; 11, AMS C311587, 22°26.27–20.2'S 153°17.13–17.6'E, south-east. of Swains Reefs, 187 m, 5 July 1984; 3, AMS C171888, Seaforth, dead on beach; 2, AMS C172447, Bowen; 1, AMS C172489, Keppel Sands, Keppel Bay, 14 January 1959; 4, QM MO17887, 18°11'S 148°22'E, 7 May 1986, 1110 m; 2, QM MO40062, 13°52'S 146°43'E, 1615 m, 6 September 1988; 1, QM MO40059, 14°22'S 145°52'E, 2714 m, 9 August 1988; 3, QM MO17889, 17°45'S 148°11'E, 1162 m; 1, QM MO40060, 14°30'S 145°51'E, 2569 m, 19 September 1988; 1, QM MO17771, 17°51'S 147°18'E, 703 m, 17 May 1986; 6, QM MO17891, 17°46'S 147°49'E, 1224 m, 10 May 1986; 5, QM MO40061, 13°50'S 146°39'E, 1553 m, 6 September 1988; 4, QM MO17733, 17°45.49'S 148°37.5'E, 945 m, 9 May 1986; 1, QM MO40063, 14°53'S 145°56'E, 2245 m, 30 August 1988; 7, QM MO17706, 17°47.1'S 148°13.4'E, 1141 m; 1, QM MO53689, 17°46'S 147°49'E, 1224 m, 11 May 1986; 35, QM MO17891, 17°46.53'S 147°48.8'E, 1224 m; QM MO17885, 18°08'S 147°59'E, 1107 m (preserved); 2, AMS C171802, Michaelmas Cay, off Cairns, May-July 1926; 1, AMS C171819, 16°34'S 145°31'E, Yule Point, north of Cairns, shell sand, 1 October 1980; 1, AMS C172471, Kurramine Beach, south of Innisfail, July 1969; 1 juvenile, AMS C172502, off tip of Casuarina Beach, Lizard Island, 15 m, fine muddy sand with *Caulerpa*, 3 December 1976; 3, AMS C171873, Cape York. NORTHERN TERRITORY: 5, AMS C172420, 10°15'S 132°54'E, 91 km north-east of Croker Island, 70 m, silty clay, 8 November 1969; 5, AMS C173035, 8°18'S 133°58'E, Arafura Sea, 337 km north-east of Croker Island, 132 m, 3 November 1969.

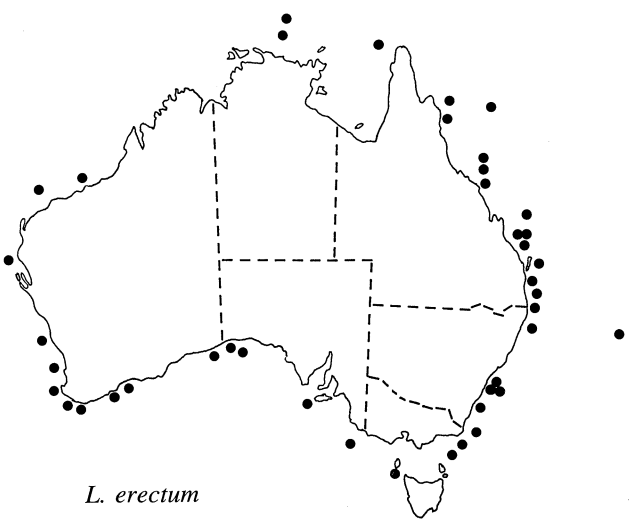


Figure 114. Australian distribution of *Laevidentalium erectum* (Sowerby, 1860).

Description. Shell length to 55.5 mm, aperture diameter 3.4 mm; aperture diameter variable; shell slender, slightly to well curved, glossy. Sculpture of fine, irregularly spaced transverse growth lines not obliquely oriented. Aperture circular. Apex circular with a ventral notch, short slit and shallow dorsal notch. Colour translucent white in live-taken specimens, opaque white to faintly green in dead specimens.

Radula. Central tooth broad (240 μm wide), moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped, 233 μm long with small cusps on the working surface; marginals sigmoidal, moderately short and broad (length 360 μm × breadth 100 μm) (see Fig. 115A–D). Ratios C:L = 1:0.97, L:M = 1:1.5, marginals breadth:length = 1:3.6 (sex not determined).

Range. Western Australia, South Australia, Tasmania, Victoria, New South Wales, Queensland to Northern Territory.

Habitat. Dredged in sand and gravel from 11 to 2569 m.

Comparisons and remarks. The specimen here chosen as lectotype closely matches the original dimensions and profile of the specimen illustrated by Sowerby. *Laevidentalium erectum* resembles most closely *L. leptosceles* (Watson) in profile. Differentiating features include: circular aperture profile (slightly dorsoventrally compressed in *L. leptosceles*); transverse growth lines not obliquely oriented (oblique in *L. leptosceles*); a ventral notch and slit (absent in *L. leptosceles*); no longitudinal striate texture in the posterior end of the shell (texture visible in *L. leptosceles*). Features differentiating *L. erectum* from the other species in the group include: long slender shape; ventral notch and short slit and shallow dorsal notch (these features damaged in lectotype, but visible in one of the paralectotypes). The only other slender-shelled *Laevidentalium* which could be confused with *L. erectum* is *L. arnoldi* n.sp. However, *L. arnoldi* is appreciably thinner and narrower and less tapering than *L.*

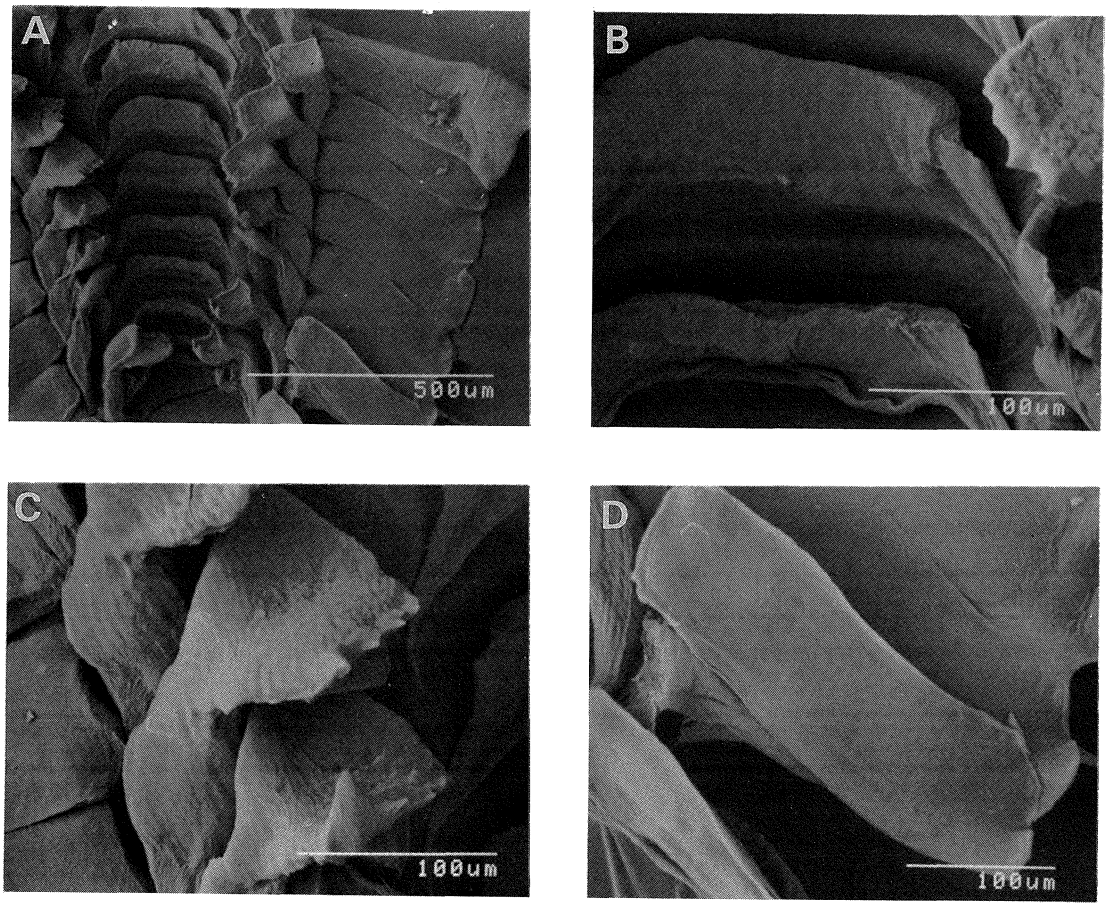


Figure 115. Radular ultrastructure of *Laevidentalium erectum* (Sowerby, 1860) (off Cairns, Qld, 17°46.53'S 147°48.8'E, 1224 m, QM MO17891).

erectum, in addition it lacks any trace of an apical notch. The specimen illustrated by Coleman (1982) as "*Dentalium erectum* Sowerby" is in fact *Laevidentalium crocinum* (Dall, 1907). Curvature and aperture diameter of *L. erectum* vary markedly even in samples from the one locality, although well curved or straight shells may predominate. The colour may also vary from white to faintly green, the latter common in dead specimens from localities off New South Wales and southern Queensland (possibly due to mud staining). The holotype and both paratypes of *L. pluteum* (Colman) exhibit the faint green colouration, but otherwise cannot be separated from *L. erectum* on structural grounds, hence our decision to synonomize *L. pluteum* with *L. erectum*. *Laevidentalium erectum* is a deep water species with an impressive geographical range within the Australian region. Wherever it occurs, it appears to be moderately to very common, and presumably constitutes an important component of deep water benthic communities.

Laevidentalium arnoldi n.sp.

Figs 112B, 113D, 116

Etymology. Named after Dr Peter Arnold (Museum of Tropical Queensland, Townsville) who assisted with the loan of material for this study.

Type material examined. HOLOTYPE: QM MO53676. Type locality: 17°22'S 146°48'E, off Cairns, northern Qld, 303 m, 15 May 1986. Length of holotype 41.4 mm, aperture diameter 2.0 mm, apex diameter 0.8 mm. PARATYPES: 229, AMS C201737, 17°21.77'S 146°48.52'E, east of Innisfail, Qld, 296–303 m, 15 May 1986; 189, QM MO17768; 15, QM MO17996, 17°21.77'S 146°48.5'E, northern Qld. 303 m, 15 May 1986; 202, QM MO53677, 45, QM MO17892, 56, QM MO17996, many, AMS C201737, 17°22'S 146°48'E, 303 m, 15 May 1986 (preserved); 27, QM MO17971, 17°21.06'S 147°02.50'E, northern Qld, 303 m, 15 May 1986 (preserved); 2, AMS C310225, 23°15.2'S 152°24.1'E, east of North West Island, Qld, 284 m, 14 December 1977.

Additional material examined. QUEENSLAND: 26, AMS C173198, 23°33.7'S 152°37'E, 37 km east of Lady Musgrave Island, 348 m, 17 November 1977, yellow grey sand; 23, QM MO17654, 17°22'S 146°48'E, 303 m, 15 May 1986; 3, QM MO17891, 17°46.53'S 147°48.8'E, 1224 m, 10 May 1986; 1, AMS C172546, 23°08.6'S 152°16.6'E, Capricorn Channel, 155 m, fine sand/mud, 14 December 1977; 7, AMS C311586, 22°26.27–20.2'S 153°17.13–17.6'E, south-east of Swains Reefs, 187 m, 5 July 1984.

Description. Shell length to 41.4 mm, aperture diameter 2.0 mm, apex diameter 0.8 mm; needle-shaped, slightly curved; glossy, translucent. Sculpture of fine, transverse growth lines.

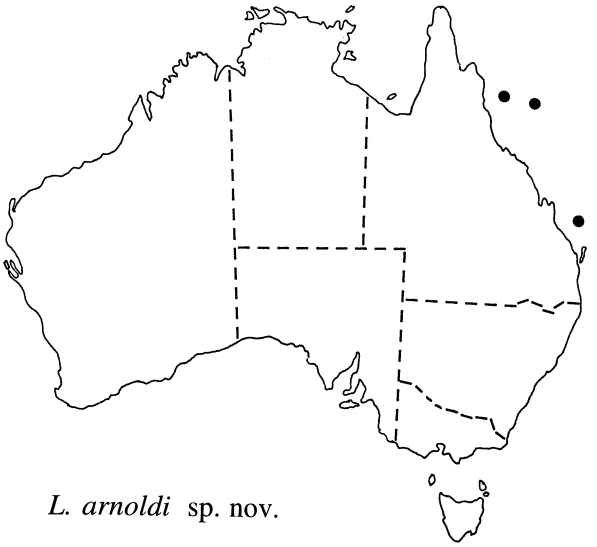


Figure 116. Known distribution of *Laevidentalium arnoldi* n.sp.

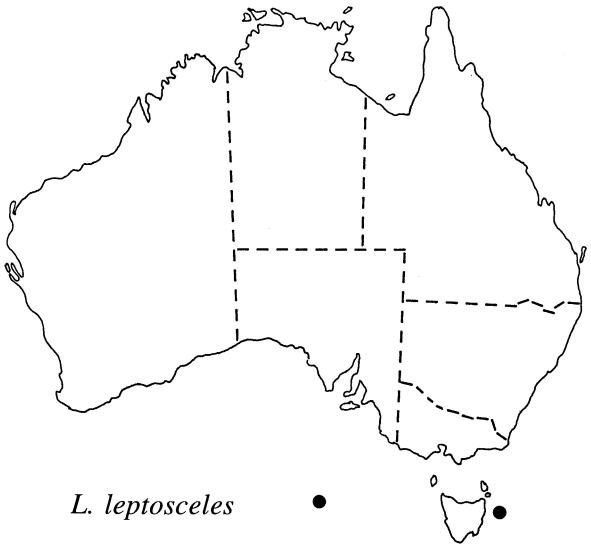


Figure 117. Known distribution of *Laevidentalium leptosceles* (Watson, 1879).

Aperture circular. Apex circular with or without a small, off-centre, ventral notch; some specimens with a central apical pipe. Colour translucent when live, white when dead.

Range. Queensland.

Habitat. Dredged in sandy mud from 155 to 1224 m.

Comparisons and remarks. *Laevidentalium arnoldi* can be easily differentiated from other members of the *L. erectum* group by its translucent, almost transparent shell, needle-like shape and frequent presence of a pipe. Occasional specimens of *L. arnoldi* may bear a superficial resemblance to juvenile *L. longitrorsum* (Reeve), but the massive difference in size between adults of these species combined with the common presence of fine, longitudinal striae near the apex in *L. longitrorsum* should quickly resolve any identification problems. Only known from deep water dredgings, but evidently very common at some localities.

Laevidentalium leptosceles (Watson, 1879)

Figs 112C, 113C, 117

Dentalium leptosceles Watson, 1879: 513; Pilsbry & Sharp, 1897: 110, pl. 3, figs 44–46.
Dentalium leptoskeles Watson, 1886: 7, pl. 1, fig. 6 (spelling variant).

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1887.2.9.21–2. Type locality: South of Australia, 42°42'S 134°10'E, 2600 fathoms [4756 m], red clay, March 13, 1874. Length of lectotype 38.0 mm, aperture diameter 3.0 mm, apex diameter 1.1 mm. PARALECTOTYPES: paralectotype no. 1, same locality data as for lectotype; paralectotype no. 2, (preserved) from syntype lot BMNH 1889.11.11.162 same locality data as for lectotype.

Description. Shell length to 38.0 mm, aperture diameter 3.0 mm, apex diameter 1.1 mm; nearly straight, slightly curved towards apex; glossy. Smooth without sculpture but with flexuous longitudinal textural lines (microscopic) in the shell surface, growth lines slightly oblique, irregular, crowded. Aperture subcircular and oblique. Apex slightly dorsoventrally compressed. Colour translucent to opaque, irregularly flecked with white.

Range. South of Australia.

Habitat. Dredged from 4756 m.

Comparisons and remarks. The lectotype (here chosen) of *Laevidentalium leptosceles*, although distorted through growth and shell breaks, appears to be mature, as in fact does the paralectotype which is only a broken posterior half of a shell. Paralectotype no. 2 (a preserved specimen) appears to be mature, and although the shell is broken midway, the animal is in good condition. As pointed out by Pilsbry & Sharp (1897), this species does bear a close resemblance to *L. erectum* G.B. Sowerby but can be distinguished by its markedly oblique growth lines (lines not oblique in *L. erectum*). In addition, *L. leptosceles* shows longitudinal textural lines within the posterior portion of the shell which are absent or poorly visible in shells of *L. erectum*. Watson also drew attention to the slight, but noticeable dorsoventral compression of the shell in *L. leptosceles*. Lots examined from the AMS with a similar locality data have been identified by us as *L. erectum*, having the typical slit and notch of that species. As has been pointed out elsewhere in this monograph, these apical features are not consistent. *Laevidentalium banale* (Boissevain) differs from *L. leptosceles* in having more pronounced curvature and in lacking the longitudinal texture characteristic of *L. leptosceles*. In addition *L. banale* occurs in the region from the east Timor Sea to northern Western Australia, whereas *L. leptosceles* is known only from the type locality south of the Great Australian Bight.

Key to Group of *Laevidentalium lubricatum*

Solid, smooth to polished, usually with apical notch or notches, usually moderately to strongly curved, moderately expanded anteriorly.

1 Shell yellow or orange ..... *L. crocinum*

—— Shell white or bone/grey 2

2 Shell surface showing low, annulate, swellings at irregular intervals along length 3

—— Shell surface always smooth, never showing annulate swellings 4

3 Shell large (50 mm+); apex rarely truncate ..... *L. lubricatum*

—— Shell moderately small (30 mm); apex truncate ..... *L. marshae*

4 Shell bone white to grey; strongly curved and tapering; very wide aperture ..... *L. largicrescens*

—— Shell white, slightly to moderately curved, moderate to weakly tapering posteriorly; aperture narrow 5

5 Shell weakly curved; growth lines accentuated ..... *L. zeidleri*

—— Shell moderately curved; growth lines not accentuated 6

6 Shell moderately tapered posteriorly; apex with ventral slit ..... *L. jaffaensis*

—— Shell weakly tapered posteriorly, sometimes with shallow notch but never a slit ..... *L. banale*

Laevidentalium jaffaensis
(Cotton & Ludbrook, 1938)

Figs 112D, 113E, 118

Dentalium jaffaensis Cotton & Ludbrook, 1938: 221, pl. 12, fig. 5; Cotton & Godfrey, 1940: 333, fig. 356, 357.

Type material examined. HOLOTYPE: SAM D13337. Type locality: off Cape Jaffa, SA, 90 fathoms [165 m]. Length of holotype 24.0 mm, aperture diameter 2.7 mm, apex diameter 0.85 mm.

Additional material examined. SOUTH AUSTRALIA: 4, AMS C169981, 36, AMS C172639, 35°15'S 134°32'E, south of Cape Carnot, 150–178 m, 12 July 1962; 2, AMS C32030, 64.37 km south of Cape Wiles, 200 m; 5, AMS C173993, 33°05'S 128°40'E, Great Australian Bight, 75 m, 5 July 1962 (preserved); 2, SAM D18904, off Beachport, 80 m; 1, SAM D18905, off Beachport, 300 m; 4, SAM D18906, north-west of Cape Borda, 110 m; 4, SAM D18907, off Cape Jaffa, 180 m. WESTERN AUSTRALIA: 1, WAM 133-93, 31°02'S 115°00'E, west of Cape Leschenault, 150 m, 11 October 1963.

Description. Shell length to 34.4 mm, aperture diameter 3.1 mm, apex diameter 1.0 mm; smooth, polished, moderately curved; without sculpture. Aperture circular. Apex narrow usually with a long slit on the ventral side, the protoconch in the young shell is an elliptical bulb with a very short, slightly contracted, tubular extension, set obliquely and directed towards the ventral side of the shell. Colour white with opaque transverse rings on the early part of the shell.

Range. Southern Western Australia to South Australia.

Habitat. Dredged in sand and mud from 75 to 300 m.

Comparisons and remarks. Cotton & Ludbrook (1938: 221) originally placed *Laevidentalium jaffaensis* in *Fissidentalium* (regarded by them as a subgenus of *Dentalium*) by presumably because of the presence of an apical slit. However, this species totally lacks any of the characteristic shell features of *Fissidentalium* such as the crowded longitudinal ribs (see p. 82 for diagnosis). In addition, presence or absence of a slit in many species of *Fissidentalium* is known to be a variable feature. The highly polished, white shell which shows an apical (ventral) slit and no sculpture other than growth lines all suggest placement within *Laevidentalium*. An alternative position, in the genus *Fustiaria* is possible, although the coarseness of the slit strongly argues against this (slit, when present in *Fustiaria*, very long and fine). The exact position of *L. jaffaensis* will probably only be settled by examination

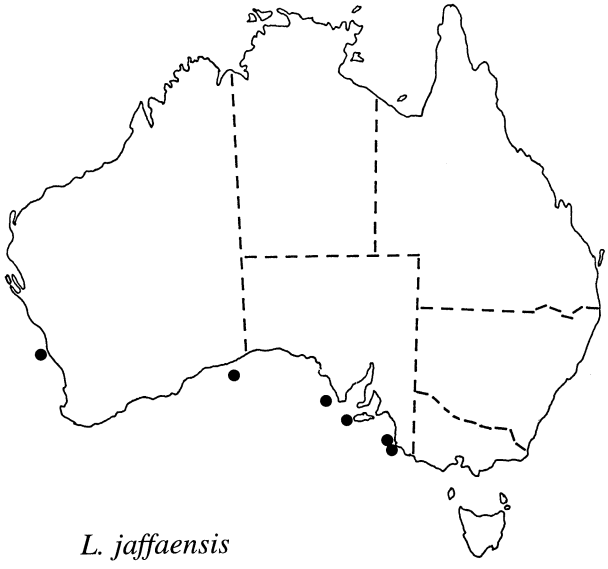


Figure 118. Known distribution of *Laevidentalium jaffaensis* (Cotton & Ludbrook, 1938).

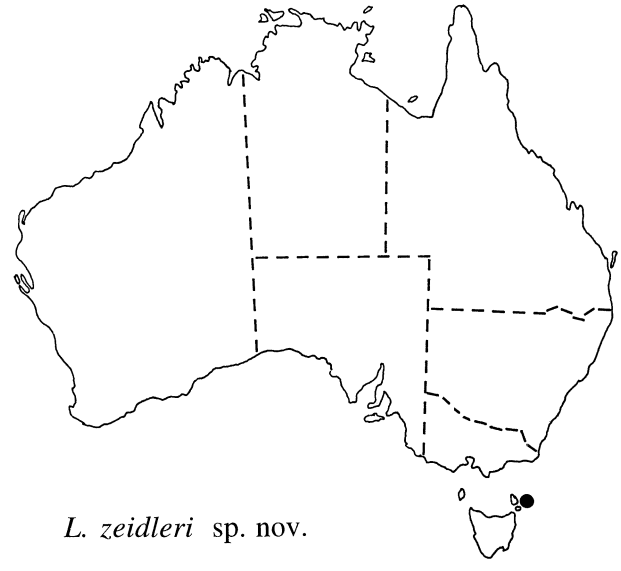


Figure 119. Known distribution of *Laevidentalium zeidleri* n.sp.

of animals when they become available. Verco (1911b) illustrates a shell of this species with an intact (bulbous) protoconch (this shell identified incorrectly by Verco as "*Dentalium lubricatum*" G.B. Sowerby) (illustrations reproduced in Fig. 5D,E).

Laevidentalium zeidleri n.sp.

Figs 112E, 113F, 119, 120

Etymology. Named after Dr W. Zeidler (South Australian Museum) who collected the specimen used in this study.

Type material examined. HOLOTYPE: SAM D18903. Type locality: 29 km south-east of Scamander, 41°33'S 148°36'E, Tas., 122 m, 10 October 1984 (preserved). Length of holotype 25.0 mm, aperture diameter 2.5 mm, apex diameter 1.4 mm.

Description. Shell length 25.0 mm, aperture diameter 2.5 mm, apex diameter 1.4 mm; slightly curved, smooth. Sculpture of transverse growth lines only. Aperture circular, peristome moderately thick. Apex with a broad ventral notch and central, ovate apical pipe which is obliquely angled to fit into the wide notch. Colour grey-white (periostacum), bone white where marked or chipped.

Radula. Central tooth broad (171 μm wide), shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped, 190 μm long with small cusps on the working surface; marginals curved near laterals, moderately short and broad (length 203 μm × breadth 75 μm) (see Fig. 120A–D). Ratios C:L = 1:1.11, L:M = 1:1.06, marginals breadth:length = 1:2.7 (sex not determined).

Range. Northern coast of Tasmania.

Habitat. Dredged to 122 m.

Comparisons and remarks. *Laevidentalium zeidleri* does not closely resemble any other Australian species of the genus, and a study of the radula failed to provide any clues as to its relationships within the Laevidentaliidae, other than to say that it is not closely related to *L. crocinum* (Dall) which has heavily developed laterals. The weak curvature suggests a possible link with the *L. erectum* group, although shells of that group all have very slender, glossy shells. This appears to be a very rare yet distinctive southern species.

Laevidentalium banale (Boissevain, 1906)

Figs 121A, 122A–D, 123

Dentalium banale Boissevain, 1906: 1–76, pls 1–6.

Type material examined. LECTOTYPE: here selected from syntype lot ZMA (no number), Stn 300 Siboga Expedition. Type locality: East Timor Sea, 10°48.6'S 123°23.1'E, 918 m, fine grey mud. Length of lectotype 42.3 mm, aperture diameter 3.4 mm, apex diameter 1.5 mm. PARALECTOTYPE: 1, same locality data as lectotype.

Additional material examined. WESTERN AUSTRALIA: 8, WAM 151-93, 2, WAM 150-93, 18°25'S 118°22'E, 211 km north of Port Hedland, 2 April 1982; many, Lamprell collection, in sandy mud pools, low tide, Broome, 14 August 1994 (preserved).

Description. Shell length to 43.0 mm, aperture diameter 3.4 mm, apex diameter 1.5 mm; moderately and evenly curved; glossy with fine, transverse growth lines. Aperture ovate. Apex circular, without slit; some specimens with shallow notch, usually with small apical pipe. Colour white.

Range. North of Port Hedland, Western Australia.

Habitat. Dredged in fine grey mud to 918 m.

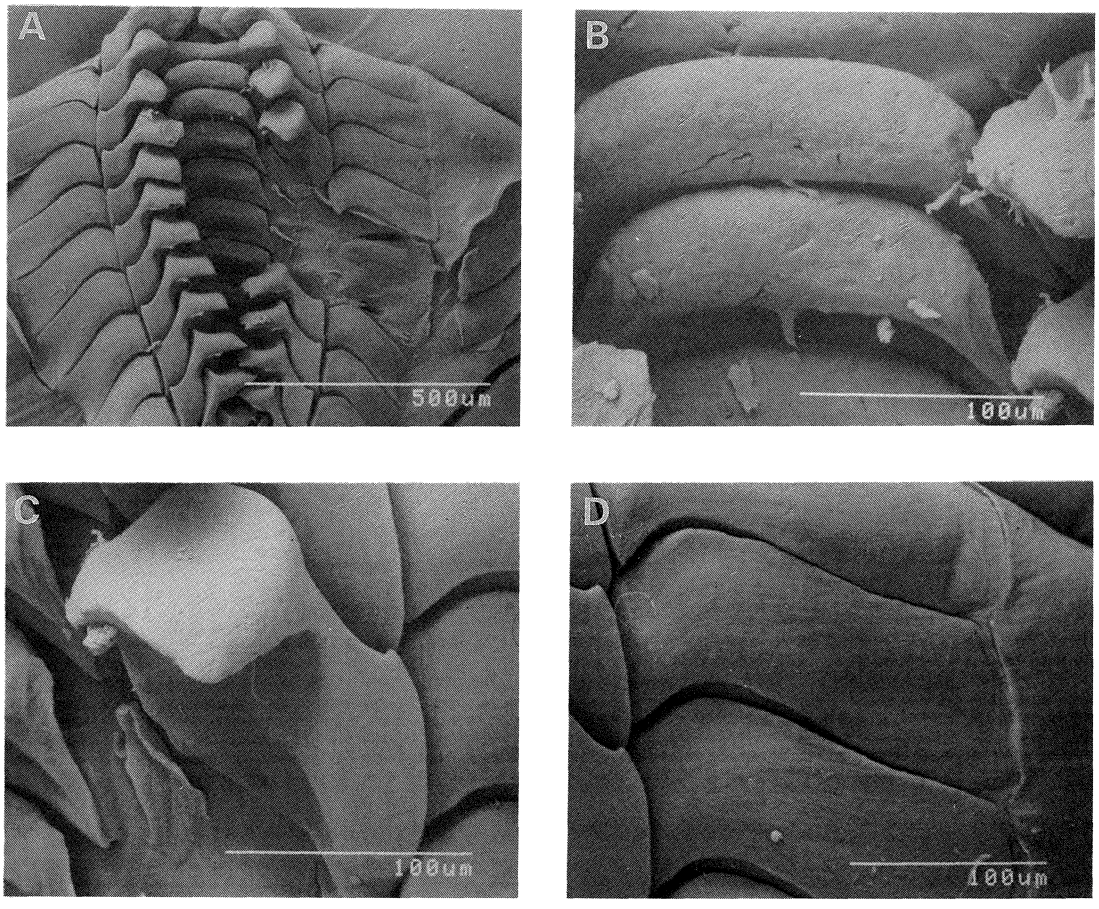


Figure 120. Radular ultrastructure of *Laevidentalium zeidleri* n.sp. (from holotype, 29 km south-east of Scamander, Tasmania, 122 m, SAMD18903).

Comparisons and remarks. *Laevidentalium banale* resembles most closely *L. lubricatum* (G.B. Sowerby) in shape. Shell features of *L. banale* which differentiate it from *L. lubricatum* include: lacking apical notch; weak (almost obsolete) growth lines; slightly laterally compressed aperture. *Laevidentalium banale* shows much stronger curvature than *L. leptosceles* (Watson), and is often compressed slightly laterally (dorsoventrally compressed in *L. leptosceles*). The apex is similar to species of *Episiphon*, being solid, often with an apical pipe, however the longitudinal and apertural profiles of the shell clearly place this species within the Laevidentaliidae.

Laevidentalium largicrescens (Tate, 1899)

Figs 121B, 122E,F, 124, 129A,B

Dentalium largicrescens Tate, 1887: 264, pl. 8, figs 10–10a; Cotton & Ludbrook, 1938: 225; Ludbrook, 1959: 145, pl. 1.

Type material examined. LECTOTYPE: selected by Ludbrook (1959, see discussion) from lot SAM D18934 (T1611, Tate Museum Coll) from 6 specimens mounted on tablet: the lectotype still loose, and contained within a glass vial. Type locality: Beaumaris, Victoria, Sandringham Sands, Black Rock Member, Cheltenhamian (Upper Miocene). Length of holotype 44.0 mm, aperture diameter 6.5 mm, apex diameter 1.0 mm. PARALECTOTYPES: 5, SAM D18935, (ex Tate Museum Coll), sama locality data as holotype; 1, SAM D18936, Pliocene, Muddy Creek.

Additional material examined. VICTORIA: (fossil) 1, SAM 18937, Tate Museum Coll, Muddy Creek. TASMANIA: (Recent) 16, AMS C174618, 40°45.94–46.54'S 149°01.62–00.27'E, 2500 m, 10 December 1986. NEW SOUTH WALES: 2, AMS C174619, 32°59.7'–33°01.5'S 153°01.4–12.9'E, off Newcastle, NSW, 3058 m, 8 October 1982; 12, AMS C174147, 36°56.2'S 150°23.00'E, Tasman Sea, Merimbula, 1600 m, 12 December 1986; 7, AMS C169807, 33°35–37'S 152°05'E, off Sydney, 1143 m, 10 December 1980. QUEENSLAND: 13, AMS C171896, 5, AMS C172618, 23°19.5'S 152°35.4'E, east of North West Island, 320 m, 14 December 1977; 4, AMS C172619, 23°15.2'S 152°24.1'E, east of North West Island, 284 m, 14 December 1977; 35, AMS C310271, 37 km east of Lady Musgrave Island, 23°44'S 152°49'E, 348–357 m, 17 November 1977, grey shelly ooze.

Description. Shell length to 55.4 mm, aperture diameter 8.2 mm, apex diameter 3.2 mm; solid, moderately curved, smooth to glossy rapidly tapering. Sculpture of oblique growth lines. Aperture circular. Apex circular, some specimens with ventral notch. Colour bone white to grey.

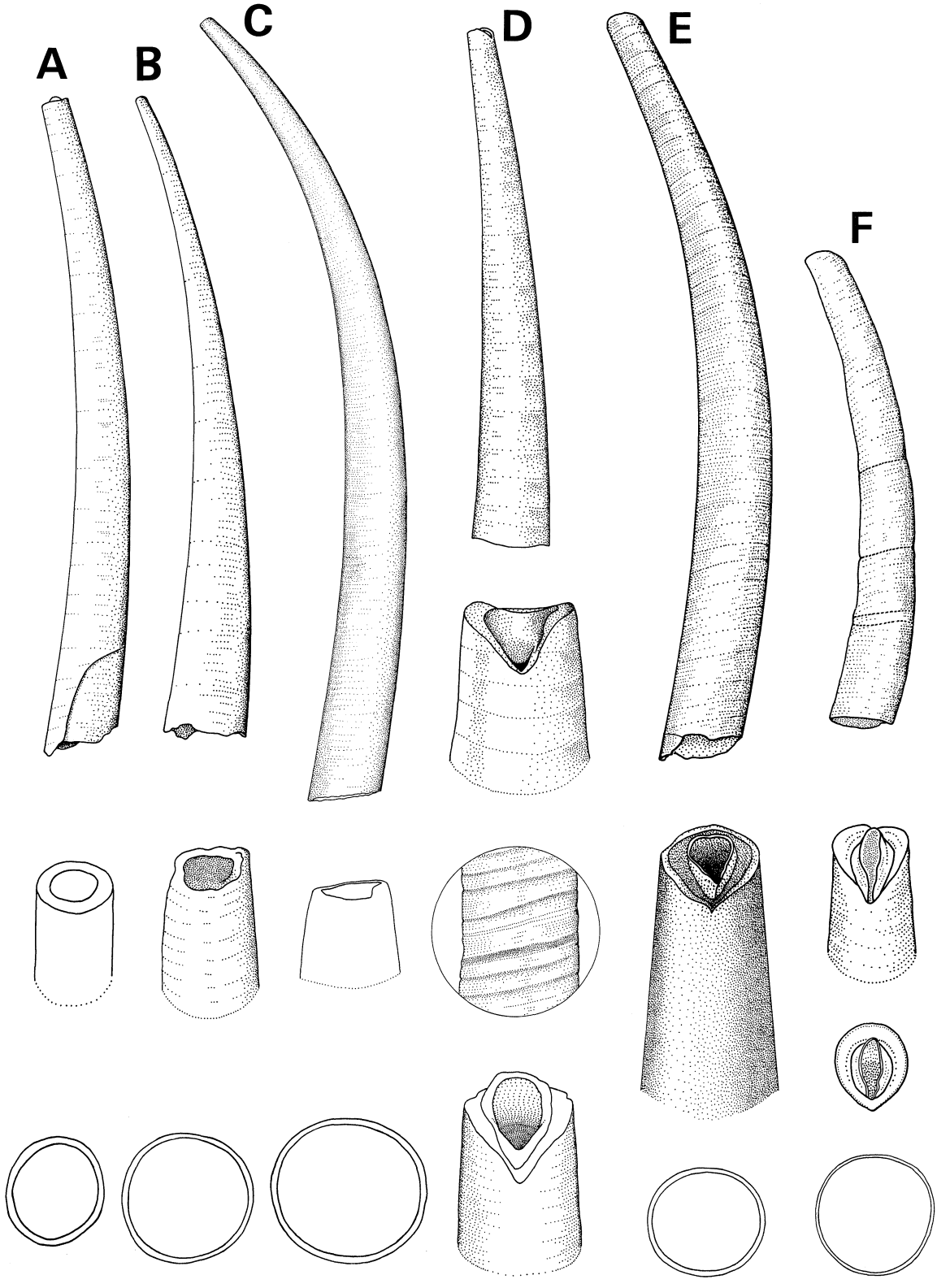


Figure 121. Dentaliida, Laevidentaliidae, *Laevidentalium*. Group of *L. lubricatum* (continued). **A** *L. banale* (Boissevain, 1906) (WAM 151/93, 211 km north of Port Hedland, WA, 200 m, length 19.9 mm). **B** *L. largicrescens* (Tate, 1899) (AMS C174618, Tasmania, 40°45'S 149°01'E, 2500 m, length 43.0 mm). **C** *L. lubricatum* (Sowerby, 1860) (KLColl, Monkey Mia, WA, length 58.5 mm). **D** *L. lubricatum* (Sowerby, 1860) (holotype of *Dentalium laseroni* Colman, 1958, AMS C62221, Broken Bay, NSW, length 36.4 mm). **E** *L. crocinum* (Dall) (KLColl, off Cape Moreton, Qld, 128 m, length 63.5 mm). **F** *L. marshae* n.sp. (holotype, AMS C174622, 29 km north of Port Hedland, WA, 82 m, length 25.8 mm). (Del.: all A. Hill, except E [apex and aperture]—C. Eadie).

Figure 122. Dentaliida, Laevidentaliidae, *Laevidentalium*. Group of *L. lubricatum* (continued). **A–D** *L. banale* (Boissevain, 1906) (A—WAM 151/93, north of Port Hedland, WA, 200 m, 19.9 mm; B—same shell dusted to show surface detail; C—lectotype, ZMA, east of Timor, 918 m, length 39.0 mm; D—paralectotype, same locality data as lectotype). **E,F** *L. largicrescens* (Tate, 1899) (E—lectotype [fossil] TMC T1611, Upper Miocene, Beaumaris, Victoria, length 44.0 mm; F—[live-collected] AMS C174618, Tasmania, 40°45'S 149°01'E, 2500 m, length 43.0 mm).

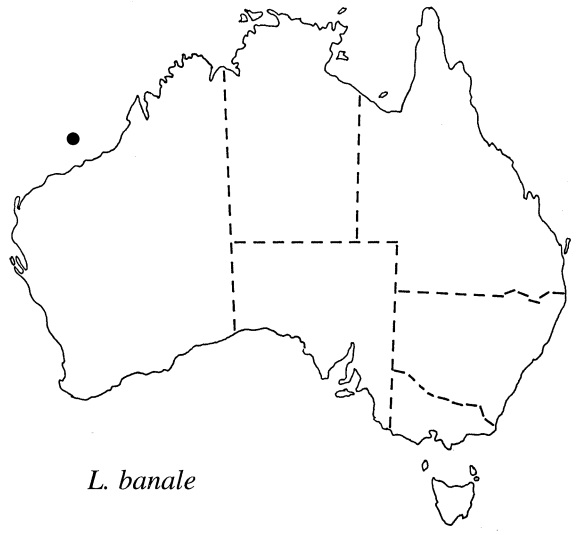


Figure 123. Australian distribution of *Laevidentalium banale* (Boissevain, 1906).

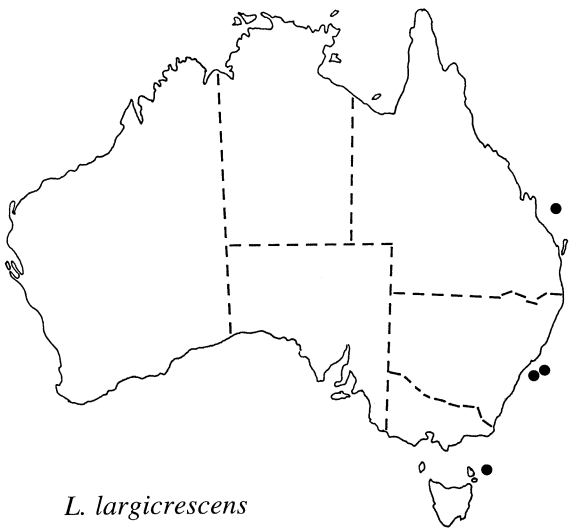


Figure 124. Known distribution of *Laevidentalium largicrescens* (Tate, 1899).

Radula. Central tooth broad (544 μm wide), shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped, 477 μm long with small cusps on the working surface; marginals sigmoidal and moderately narrow (length 722 μm × breadth 188 μm) (see Fig. 129A,B). Ratios C:L = 1:0.88, L:M = 1:1.5, marginals breadth:length = 1:3.8 (sex not determined).

Range. Victoria (Fossil, Upper Miocene-Pliocene), Tasmania, New South Wales, Queensland (Recent).

Habitat. Dredged in grey mud from 284 to 3058 m.

Comparisons and remarks. In his description of *Dentalium largicrescens*, Tate (1899) failed to specify a "type" specimen. His material consisted of six shells of varying size, five of which are glued to a wooden tablet with a further shell contained within a glass phial also glued to the tablet. Tate's given dimensions of the species (length 44.0 mm, aperture diameter 6.5 mm, apex diameter 1.0 mm) and drawing detail (showing a small but distinct apical fissure) match the specimen within the phial. Ludbrook (1959) cited these points of similarity in formally recognizing the glass phial specimen as the "holotype". Although the ICZN Code (1985 edition) states that "The holotype of a new nominal species-group taxon can only be designated in the original publication and by the original author" (Article 73 [a][iii]), it also has provision for the recognition of a lectotype through Article 74(b) ("Designation of a lectotype by inference of holotype: When it cannot be determined that a nominal species-group taxon was established on a single specimen, and when a holotype was not designated, the first subsequent author to have published the inference (see Article 73a[ii]) that one original specimen is the "holotype", or "the type", is deemed, should another syntype or syntypes be discovered, to have designated a lectotype"). We therefore cite Article 74(b) as being appropriate in the case of *L. largicrescens*, the net result being that Ludbrook (1959) should now be considered to have designated a lectotype instead of a holotype.

As there are no demonstrable differences between fossil material of *Laevidentalium largicrescens* and specimens dredged from depths ranging from 320 m of 3058 m off the east coast of Australia, this species can, with confidence, be added to the extant Australian fauna. Previously *L. largicrescens* was known only from the Tertiary beds of Victoria (upper Miocene to lower Pliocene).

This species resembles most closely *L. crocinum* Dall, 1907 and *L. lubricatum* (G.B. Sowerby, 1860) which are similar in shape and apical features. Differentiating features of *L. largicrescens* which separate it from these species include: more expanded aperture; colour differences [bone or grey white in *L. largicrescens*, yellow or orange in *L. crocinum* (Dall), pure white in *L. lubricatum* (G.B. Sowerby)]; and curvature differences (*L. largicrescens* less curved than either *L. lubricatum* or *L. crocinum*).

Laevidentalium lubricatum (G.B. Sowerby, 1860)

Figs 121C,D, 125A–C, 126, 129C,D

Dentalium lubricatum G.B. Sowerby, 1860: 97, pl. 225, fig. 56; G.B. Sowerby, 1872: pl. 7, fig. 55; Brazier, 1878: 370; Pilsbry, & Sharp, 1897: 110, pl. 19, fig. 22; Hedley, 1903: 328, Verco, 1911a: 210, 218; Hedley, 1917: 112; Iredale & McMichael, 1962: 96.

Dentalium laseroni Colman, 1958: 143, pl. 1, fig. 7; Iredale & McMichael, 1962: 96.

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1957.10.10.2–4 (pt). Type locality: Dogs Bay, Australia on the sands. Length of lectotype 65.2 mm, aperture diameter 6.0 mm, apex

Figure 125. Dentaliida, Laevidentaliidae, *Laevidentalium*. Group of *L. lubricatum* (continued). **A–C** *L. lubricatum* (Sowerby, 1860) (A—lectotype, BMNH 1957.10.10.2–4 part, Dogs Bay, Australia, length 65.2 mm; B—WAM 150/93, Port Hedland, WA, length 43.0 mm; C—*L. lubricatum* (Sowerby, 1860) (KLColl, Kurramine Beach northern Qld, length 43.7 mm). **D,E** *L. crocinum* (Dall, 1907) (D—holotype, USNM 110508, Gulf of Tokyo, Japan, 162 m, length of assembled shell 38.9 mm; E—KLColl, off Cape Moreton, 130 m, length 63.8 mm). **F** *L. marshae* n.sp. (holotype, AMS C174622, 125.5 km north of Port Hedland, WA, 82 m, length 25.8 mm).

diameter 1.1 mm. PARALECTOTYPES: 2, same locality data as for lectotype. Holotype of *Dentalium laseroni* Colman, 1958, AMS C62221, Broken Bay.

Additional material examined. TASMANIA: 2, AMS C173461, 41°00.2'S 148°31.5'E, off Eddystone Point, 97 m, 25 March 1973, muddy silty sand. VICTORIA: 2, NMV F72142, 38°21.90'S 149°20.00'E, south of Point Hicks, 1000 m, 23 July 1986; 4, AMS C173192, 38°43'S 142°29'E, south of Warnambool, 75 m, 24 July 1962. NEW SOUTH WALES: 1 AMS C310281, 37°33–36'S 150°26–30'E, 33 miles south-east of Green Cape, 860 m, 2 October 1912; 6, AMS C173312, 5, AMS C173190, 34°50'S 151°13'E, off Sydney, 550 m, 12 December 1978 (preserved); 2, AMS C173191, 33°41'S 152°01'E, off Sydney, 1125 m, 11 December 1978; 1, AMS C174633 off Jibbon, Port Hacking, 80 m, February 1964; 1, AMS C174632, 28°17'S 153°44'E, off

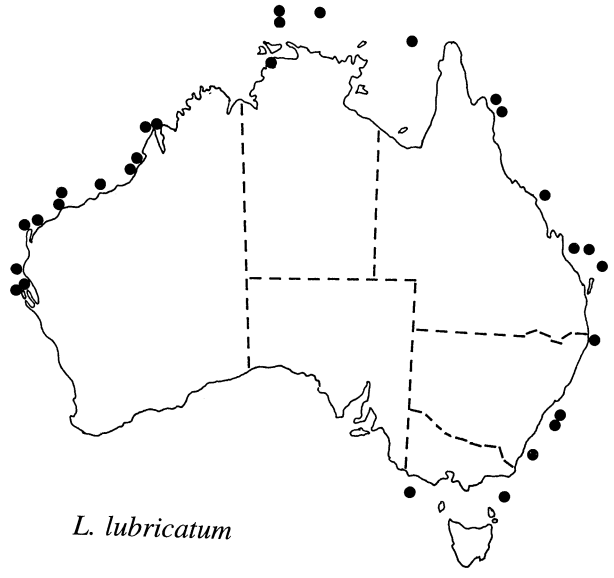


Figure 126. Known distribution of *Laevidentalium lubricatum* (Sowerby, 1860).

Tweed Heads, coarse sand, 73 m; 4, AMS C62220, Broken Bay. QUEENSLAND: 1, AMS C31029, 23°44'S 152°49'E, ca 25 miles east of Lady Musgrave Island, 348–357 m, 17 November 1977; 43, AMS C173437, 23°52.5'S 152°42.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 3, AMS C69064, north-east of Herald Cay, Swains Reefs, November 1964; 1, QM MO53806, 11°17.8'S 140°18.5'E, Gulf of Carpentaria, 58 m, 28 November 1991; 11, QM MO17768, 17°48.5'S 146°48.5'E, 303 m, 15 May 1986; 8, QM MO17970, 17°21.77'S 146°48.5'E, 303 m; 3, QM MO17893, 300 m, 16 May 1986; 12, QM MO45836, 17°22'S 146°48'E, 303 m, 15 May 1986; 2, AMS C169974, Murray Island, Torres Strait, August 1947; 1, AMS C173308, 17°14.18'S 146°40.00'E, off Cairns, 176 m, 12 October 1981 (preserved); 1, AMS C171902, Palfrey Island, Lizard Island, from tideline, shell-sand on north beach, 3 December 1974. NORTHERN TERRITORY: 1, AMS C73117, Ludmilla Creek, in mud around mangroves at low tide, 27 October 1969; 1, AMS C171870, 10°15'S 132°54'E, 91 km north-east of Croker Island, 70 m, silty clay, 8 November 1969; 1, AMS C171874, 8°18'S 134°11'E, 420 km north of Melville Island, 141 m, sand, 3 November 1969; 2, AMS C171876, 9°45'S 132°04.5'E, 150 km north of Cobourg Pensinsula, 108 m, clayey sand, 11 November 1969. WESTERN AUSTRALIA: 2, QM MO38998, One Arm Point, 1987; 4, AMS C160826, 16°24'S 122°56'E, Cape Leveque, October 1989; 8, QM MO38999, Broome, in littoral sand; 2, AMS C173450, 18°03'S 122°18'E, Roebuck Bay, Broome, on mud flats, 23 October 1972 (preserved); 29, AMS C57007, Broome; 3, AMS C303572, 18°06'S 122°20'E, Roebuck Bay, Broome, 3 m, fine sand, 24 July 1983; 12, AMS C171378, Roebuck Bay Broome, coarse sand and mud, August 1960; 1, AMS C173470, 17°35'S 122°09'E, Quondong Point, north of Broome, July 1986 (preserved); 1, AMS C171871, 19°03.6–03.4'S 119°03.4–03.5'E, 148 km north north-east of Port Hedland, 82 m, sand, 23 October 1983; 1, NMV F69581, 19°05'S 117°46.23'E, North West Shelf between Port Hedland and Dampier, 122 m, 12 July 1983, muddy sand (preserved); 39, Port Hedland; 1, AMS C171864, 19°00.8'S 118°01.3'E, 157 km north north-west of Port Hedland, 112 m, sand/silt, 29 October 1983; 6, AMS C172969, off Port Hedland; 1, AMS C171863, Port Hedland; 11, AMS C172975, Port Hedland, 1958; 7, AMS C172970, 1, AMS C69359, Dirk Hartog Island, 26°00'S 113°12'E, 3 July 1939; 5, AMS C171872, Roeburn; 2, Lamprell Collection, Legrange Mission; 8, WAM 275-93, east side of Hermite Island, Monte Bello Island, 13 December 1979; 1, WAM 274-93, Onslow, reef flat out from Town site, 24–26 March 1990; 2, AMS C171861, Bush Bay, Carnarvon, September 1959; 26, AMS C173299, 72, AMS C156048, 25°10'S 114°39'E, Bush Bay, Carnarvon, shallow sand flats, 6 January 1984; 4, AMS C78007, Carnarvon, August 1960; 3, AMS C173092, Carnarvon, mangrove salt flats and estuary beach, 23 January 1972; 1, AMS C173093, Beagle Bay; 2, AMS C171862, Rosemary Island, Dampier, 3 m, sandy rubble, 1 October 1972; 6, WAM 49-93, Rosemary Island, Dampier Archipelago, sand flats, 23 August 1961; 5, WAM 172-93, Rosemary Island, coll on beach, 28 August 1961; 4, WAM 177-93, Norbill Bay, Rosemary Island, 1–2 m, May 1974; 1, AMS C148681, 19°28.9–29.0'S 116°29.4–29.0'E, 133 km north north-west of Dampier, 110 m, 26 October 1983; 1, AMS C171868, 19°28.9–29.0'S 116°29.4–29.0'E, 133 km north north-west of Dampier, 110 m, 26 October 1983; 15, WAM 44-93, Barrow Island, August 1976; 3, WAM 271-93, Forty Mile Beach, Pilbara; 1, WAM 272-93, beach at mouth of Watering Valley, Depuch Island, 29 May 1962; 1, AMS C171866, Lharidon Bight, Shark Bay, shell beach, 28 July 1981; 4, WAM 79-93, 25°55.4'S 113°31'E, Shark Bay, nth side of lagoon, Point Peron Peninsula, dredged 1 m, 9 May 1981 (preserved); 1, WAM 284-93, Monkey Mia, Sharks Bay, littoral sand, 1987; 5, WAM 91-93, Useless Loop, Shark Bay, in front of main bar access, 3 March 1966 (preserved); 2, WAM 116-93, Bay of Rest, North West Cape, September 1981 (preserved); 17, WAM 81-93, Bay of Rest, North West Cape, September 1981 (preserved); 2, WAM 137-93, near Islets off Eagle Bluff, Peron Peninsula, Shark Bay, 10 May 1981; 3, WAM 169-93, west of Entrance to Big Lagoon, south of Cape Lesueur, Peron Peninsula, 16 March 1980; 1, WAM 164-93, Monkey Mia, Sharks Bay, sand, 5 September 1964; 2; WAM 114-93, Monkey Mia, Shark Bay, in sand low tide, 30 August 1981 (preserved); 8, Lamprell Collection Exmouth Gulf, near lighthouse in littoral sand, 1987; 1, WAM 77-93, 22°18'S 114°07'E, Bay of Rest, Exmouth Gulf, 27 August 1968 (preserved); 6, WAM 273-93, Beach along south-east Coast of North West Cape, 15 July 1977; 9, AMS C171869, 1, AMS C171865, south-east of Exmouth Homestead, south of Learmonth, on mud-sandflats, 20 January 1972; 1, AMS C90836, 27 km south of Exmouth Town site, Exmouth Gulf, on sand flats with strewn coral, 19 January 1972; 14, WAM 78-93, Bay of Rest, Exmouth Gulf, 30 July 1977, in silt and mud in 1st 25 mm of mud (preserved); 8, AMS C303593, Learmonth, Exmouth Gulf; 14, AMS C45123, 14°02'S 126°18'E, Vansittart Bay; 7, Lamprell Collection, Monkey Mia, in littoral sand, 1987; 8, AMS C876289, Monkey Mia, Shark Bay, 11 January 1972, on sand flats; 19, AMS C78017, Shark Bay; 1, AMS C303594, Denham Shark Bay, 3 August 1943; 68, AMS C121372, beach between Hamelin Pool and Shark Bay, April 1956; 2, AMS C303595, Hamelin Pool, 14 July 1939; 11, AMS C303596, Peron Peninsula, Shark Bay.

Description. Shell length to 65.2 mm, aperture diameter 6.0 mm, apex diameter 1.1 mm; evenly curved, tapering posteriorly; glossy. Sculpture of irregular raised transverse annulations, low and rounded, with numerous transverse growth lines; frequently fine longitudinal striae are present apically (juveniles and adults with uneroded apex). Aperture circular or ovate. Apex small, circular; some specimens have a notch on the ventral side; Colour white.

Radula. Central tooth broad (796 μm wide), shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals

dumbbell-shaped, 962 µm long with small cusps on the working surface; marginals almost straight, moderately narrow (length 1074 µm × breadth 259 µm) (see Fig. 129C,D). Ratios C:L = 1:1.21, L:M = 1:1.12, marginals breadth:length = 1:4.15 (sex not determined).

Range. Northern Tasmania, Victoria, New South Wales, Queensland, Northern Territory to northern Western Australia.

Habitat. In littoral coarse or fine sand and dredged in muddy silt, or sand to 1125 m.

Comparisons and remarks. *Laevidentalium lubricatum* is similar in profile to *L. crocinum* (Dall), but has annulate swellings and is always white in colour (smooth shell, yellow/orange in colour in *L. crocinum*). The presence of the irregular annular swellings suggests a close relationship with the much smaller species, *L. marshae* n.sp., which can distinguished by its much less attenuate profile and wide, oblique ventral notch. Compared with *L. longitrorsum* (Reeve), *L. lubricatum* (G.B. Sowerby) does not attain the length of that species and is more rapidly tapering. *Laevidentalium lubricatum* has occasionally been confused by some authors (e.g., Colman, 1958; Iredale & McMichael, 1962) with the large, yellow-orange species *L. crocinum*. Aside from being of similar dimensions, these two species can be readily separated on the basis of radular features, shell colour and aperture profile as well as the frequent presence of longitudinal striae at the apex in well preserved and juvenile *L. lubricatum*. Close examination of Sowerby's original figure, description and type material of *L. lubricatum* leave no doubt that *Dentalium laseroni* Colman can be synonomized with *L. lubricatum*.

Laevidentalium crocinum (Dall, 1907)

Figs 121E, 125D,E, 127, 129E,F

Dentalium crocinum Dall, 1907: 169; Dall, 1925: 16, pl. 27, fig. 8.
Dentalium (Laevidentalium) crocinum (Dall) Habe, 1953: 291, figs 751, 752; Habe, 1957: 130, text figs 5, 6.
Laevidentalium crocinum (Dall) Habe, 1963: 268, pl. 38, figs 29, 35, text figs 28, 29.
Calliodentalium crocinum (Dall) Habe, 1964: 31, pl. 2 fig. 35, Pl. 4, figs 28, 29.

Type material examined. HOLOTYPE: USNM 110508 (in 2 pieces). Type locality: Gulf of Tokyo, Japan. 162 m. Length of holotype (pieces joined) 38.9 mm, aperture diameter 5.0 mm, apex diameter 1.5 mm.

Additional material examined. WESTERN AUSTRALIA: 1, WAM 252-93, south-west of Rottnest Island, 166 m, 17 September 1965. TASMANIA: 1, SAM D18903, 41°33'S 148°36'E, 29 km south-east of Scamander, 122 m, 10 October 1984 (preserved); 1, AMS C173178, 41°00.2'S 148°31.5'E, off Eddystone Point, 97 m, mud-silt-sand, 25 March 1973. VICTORIA: 1 (juvenile) NMV F67473, 39°43.5'S 146°18.8'E, Bass Strait, 80 m, 13 November 1981, bryozoan mud; 1, AMS C173176, 37 km off Cape Everard, 146 m; 1, AMS C173462, 39°00'S 148°24.50'E, 112 km south of Lakes Entrance, sand, 95 m, May 1969. NEW SOUTH WALES: 1, AMS C171898, off Batemans Bay, 110 m, 1926; 4, AMS C172974, 29°39.8'S 153°26.4'E, 12 km east of Cakora Point south of Yamba, 55 m, 22 February 1972; 2, AMS C171789, 32°53'S 152°35'E, off Newcastle, 146–175 m, 15 August 1985; 4, AMS C171845, 32°54'S 152°35'E, off Newcastle, 165 m, 15 August 1985; 5, AMS C303597, Port Stephens, 60–80 m; 2, WAM 89-93, off Cronulla, 75 m, 30–31 October 1963; 1, AMS C25879, 35 km east of Narrabeen; 20, AMS C173465, off Wollongong, 1200 m, 13 December 1976 (preserved); 41, AMS C171780, 33°42.5'S 151°55'E, off Sydney, 549 m, 11 December 1978; 47, AMS C173026, east of Sydney, 150 m, 18 July 1962; 1, AMS C173171, Balmoral, 3 July 1905; 3, AMS C171858, 33°20'S 151°39.4'E, off Tuggerah Lake, 60 m, 11 March 1972; 3, AMS C171777, 2, AMS C303598, 2, AMS C171840, 33°59.36'S 151°22.07'E, 14.5 km east of Cape Banks, Sydney, 110–115 m, 25 October 1973; 5, AMS C171855, 1, AMS C171856, 33°59.26'S 151°16.46'E, 2.6 km east north-east of Cape Banks, Sydney, 66 m, 19 July 1974; 1, AMS C171781, 33°58.48'S 151°15.48'E, 1.5 km south-east of Long Bay, Sydney, 27 m, 20 July 1973; 7, AMS C171770, 33°01.0'S 151°19.51'E, 9.1 km east of Cape Solander, Sydney, 110 m, 26 January 1973; 6, AMS C172367, off Sydney; 4, AMS C171859, 34°00.22'S 151°20.48'E, 13.7 km east of Cape Solander, Sydney, 180 m, 23 January 1973; 1, AMS C171778, 33°96'S 151°43'E, off Botany Bay, 170 m, 5 December 1977; many, AMS C155668, off Cronulla, Sydney, 80 m, 3 February 1965 (preserved); 3, AMS C88848, Sydney Harbour; 1, AMS C173179, Port Jackson, off Shark Island; 1, AMS C22417, Wreck Bay, 37 m; 1, AMS C100233, off Eden; 5, AMS C101217, 11, AMS C101218, off Port Hacking, 90 m; 16, AMS C100695, 64, AMS C90385, 3, AMS C172459, off Jibbon, Port Hacking, 80 m, February-September 1964; 5 pieces, AMS C171890, 34°09.6'S 151°26.3'E, south of Port Hacking, 205 m, 13 March 1972; 5, AMS C171775, 7, AMS C171768, off Jibbon, Port Hacking, 60–100 m, December 1963; 3, AMS C171796, Broken Bay; 1, AMS C171977, off Ulladulla, 40–60 m, 1964; 1, AMS C172974, 29°39.8'S 153°26.4'E, off Cakora Point, south of Yamba, 55 m, 22 February 1972; 4, AMS C154131, 29°39'S 153°24'E, off Solitary Island, 54–58 m, 21 March–10 October 1985; 6, AMS

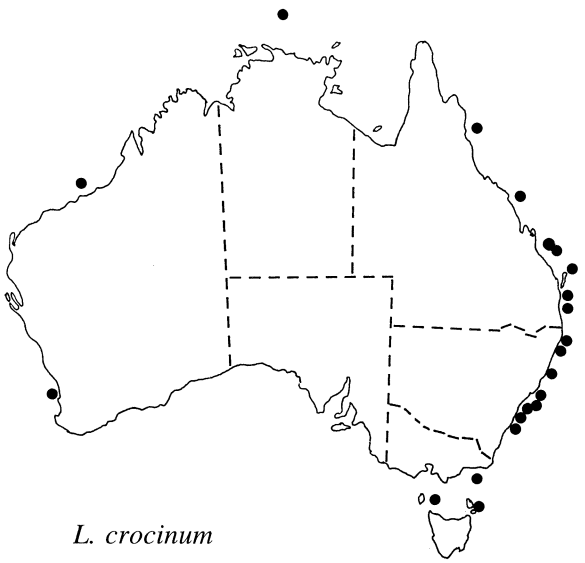


Figure 127. Australian distribution of *Laevidentalium crocinum* (Dall, 1907).

C154613, 29°50–53'S 153°24–23'E, off Solitary Island, 58 m, 10 October 1985; 1, AMS C171774, 29°25–16'S 153°26–30'E, off Clarence River, 40–53 m, 15 October 1985; 1, AMS C171772, 29°21–26'S 153°29–28'E, off Clarence River, 45–55 m, 11 October 1985; 3, AMS C171794, 34°13'S 151°07'E, off Game beach, 882 m, December 1963; 3, AMS C171790, 30°00'S 153°23'E, north of Coffs Harbour, 61 m, 22 February 1972. QUEENSLAND: 2, QM MO43314, trawled off Cape Moreton, 128 m; 2, QM MO43315, 11, KLColl, off Cape Moreton, 128 m; many, AMS C90388, north of Cape Moreton, 124 m, 1967; 9, AMS C112286, 26°34'S 153°40'E, east south-east of Noosa Heads, 128 m, 30 March 1969; 4, AMS C171785, 24°57.9'S 153°37.3'E, off Fraser Island, 210 m, 15 December 1977; 2, AMS C171895, 23°51.2'S 152°34.5'E, east of Lady Musgrave Island, 175–200 m, 4 July 1984; 21, AMS C173085, 23°33.7'S 152°37'E, east of Lady Musgrave Island, 348 m, 17 November 1977; 1, AMS C171903, dredged Lagoon, Lady Musgrave Island; 32, AMS C173090, 23°38.8'S 152°45.5'E, north-east of Lady Musgrave Island, 14 December 1977; 1, AMS C171791, 24°00'S 153°06.5'E, east of Lady Elliot Island, 476–531 m, fine ooze/sand; 1, AMS C171782, 24°04.2'S 152°48.6'E, east of Lady Elliot Island, 130–200 m, 7 July 1984; 1, AMS C171792, 23°15.2'S 152°24.1'E, east of North West Island, 284 m, 14 December 1977; 1, AMS C173175, 23°08.6'S 152°16.6'E, Capricorn Channel, 155 m; 5, AMS C171793, 17°09.53'S 146°42.36–42.38'E, off Cairns, 11 October 1981, 243–2533 m; 8, AMS C120129, 21°58.5'S 150°45'E, east of Broad Sound, sand, 18 November 1977. NORTHERN TERRITORY: 6 pieces, AMS C171771, 8°39'S 133°34'E, 320 km north of Goulburn Island, 192 m, 1 November 1969 sand-silt-clay. WESTERN AUSTRALIA: 1, WAM 236/94, 18°25'S 118°22'E, 211 km north of Port Hedland, 2 April 1982.

Description. Shell length to 65.9 mm, aperture diameter 6.55 mm, apex diameter 3.5 mm; shell curved, stronger posteriorly. Sculpture smooth, glossy, with irregular transverse growth rings. Aperture circular. Apex circular with an apical notch and pipe ventrally. Colour yellow to orange.

Radula. Central tooth broad (611 μm wide), shallow with slightly corrugated and concave superior surface and deeply concave inferior surface; laterals almost straight, thick, 777 μm long and heavily mineralized, with small cusps on the working surface; marginals almost straight, moderately narrow (length 482 μm × breadth 180 μm) (see Fig. 129E,F). Ratios C:L = 1:1.27, L:M = 1:0.62, marginals breadth:length = 1:2.7 (sex not determined).

Range. Japan (Dall, 1907; Habe, 1964) Tasmania, Victoria, New South Wales, Queensland, Northern Territory and northern Western Australia.

Habitat. Dredged in sand, silt, clay or ooze/sand from 27 to 1200 m.

Comparisons and remarks. This moderately large species is easily distinguished from all other Australian Laevidentaliidae by its yellow-orange colouration, rapid expansion of the shell from juvenile to adult stages and, slight flattening dorsally (a character emphasized by Habe, 1964 in his creation of the genus *Calliodentalium* for this species) and typically, the presence of an apical notch and pipe in mature specimens. Some authors have confused this species with *L. lubricatum* (G.B. Sowerby) (see Colman, 1958) or more recently *L. erectum* (G.B. Sowerby) (see Coleman, 1982). Although *Laevidentalium lubricatum* does occur in New South Wales it usually lacks a pipe, is narrower, entirely white and exhibits annulate swellings at irregular intervals along the length of the shell. Similarly marked differences in shell shape and colour separate *L. crocinum* from *L. erectum*, removing any possibility of confusion in separating these species.

The precise placement of *L. crocinum* is uncertain. Habe (1964) erected the genus *Calliodentalium* expressly for this species, citing the "dorsoventrally compressed shell with the roundly ovate aperture" as adequate basis for his decision. Subsequently Palmer (1974a) regarded *Calliodentalium* as a subgenus of *Laevidentalium* (family Laevidentaliidae) while Steiner (1992a) only recognizes *Laevidentalium* within the Laevidentaliidae. *Laevidentalium crocinum* differs substantially from all the other *Laevidentalium* spp. investigated herein in radular ultrastructure [*L. erectum* (G.B. Sowerby), *L. zeidleri* n.sp., *L. largicrescens* (Tate), *L. lubricatum* (G.B. Sowerby), *L. longitrorsum* (Reeve), *L. martyi* n.sp.] by having heavily developed laterals, structurally reminiscent of those seen in *Fissidentalium franklinae* n.sp. (see p. 174 for further discussion). Until more is known of the range of radular variation between species of *Laevidentalium* on the one hand and species of *Fissidentalium* on the other we have chosen to include *L. crocinum* within *Laevidentalium*.

Laevidentalium crocinum is unrecorded from the littoral region but is reasonably common in dredgings below 50 m.

Laevidentalium marshae n.sp.

Figs 121F, 125F, 128

Etymology. Named after Mrs L. Marsh who collected much of the Western Australian material used in this study.

Type material examined. HOLOTYPE: AMS C174622. Type locality: 78 mile north north-east of Port Hedland, 19°04.1–04.7'S 118°47.8–47.2'E, WA, 82 m, 30 October 1983. Length of holotype 25.8 mm, aperture diameter 3.5 mm, apex diameter 1.8 mm. PARATYPES: 3, AMS C174546, same locality data as holotype; 4, AMS C174542, 19°03.4–03.6'S 119°03.3–03.6'E, north of Port Hedland, WA, 81 m, 1 September 1983; 1, AMS C308353, 18°03'S 122°17'E, 29 July 1983; 1, AMS

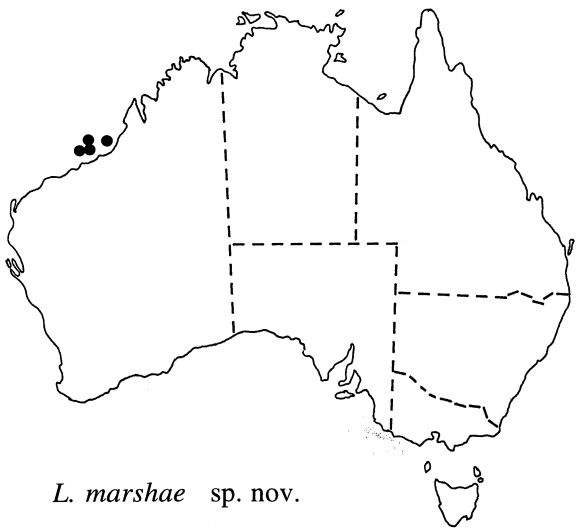


Figure 128. Known distribution of *Laevidentalium marshae* n.sp.

C173298, 18°48'S 119°00.8'E, 94 mile north north-east of Port Hedland, WA, 92-94 m, 23 October 1983.

Description. Shell length to 25.8 mm, aperture diameter 3.5 mm, apex diameter 1.8 mm; well curved, slowly tapering. Sculpture of transverse striae and growth lines. Aperture circular. Apex circular with a large central apical pipe and wide oblique, ventral notch which extends from the dorsal side to 1.9 mm down the ventral side bissecting the apical pipe so that also is oblique; dorsal side of the apex also with a wide shallow notch and an apical pipe split ventrally by a slit, widest centrally. Colour porcellaneous white, some specimens with a rust stain at the apex.

Range. Northern Western Australia.

Habitat. Dredged in depths to 94 m.

Comparisons and remarks. This species resembles most closely *L. crocinum* (Dall) and *L. lubricatum* (G.B. Sowerby) in shape and apical features. Features which differentiate *L. marshae* from both of these species include: less attenuate towards apex; markedly smaller size. In addition, the shell of *L. crocinum* is coloured yellow to orange, tapers more rapidly towards the apex and is more strongly curved. Mature specimens of *L. marshae* are readily distinguished from other Australian Laevidentaliidae by their truncated apex (with very well developed notch and wide, ventrally cut apical pipe) and wide, slowly attenuating shell profile. *Laevidentalium longitrorsum* (Reeve) and *L. martyi* n.sp., although often showing evidence of annulate swellings, can be distinguished from *L. marshae* by their much larger and slenderer shells.

Key to Group of *Laevidentalium martyi*

Large, strongly curved, narrow and slowly tapering posteriorly; shells typically showing annular swellings (weak or strongly developed).

1 Shell smooth; with strong annular swellings becoming ring-like towards the apex; no longitudinal sculpture; apex without ventral notch ..... *L. martyi*

—— Shell smooth; lacking annular swellings; fine longitudinal striae visible apically (in fresh specimens); apex with an off-centre ventral notch ..... *L. longitrorsum*

Laevidentalium martyi n.sp.

Figs 130A, 131C,D, 132, 134E,F

Etymology. Named after Mr Marty Healy who has rendered much assistance during this and previous studies.

Type material examined. HOLOTYPE: QM MO39004. Type locality: Gulf of Carpentaria, 10°58.5'S 140°21'E, Qld, 54 m, 29 November 1991. Length of holotype 52.7 mm, aperture diameter 3.5 mm, apex diameter 0.8 mm. PARATYPES: 1, QM MO39006, 13°01.5'S 136°43'E, Gulf of Carpentaria, Qld, 22 m, 23 November 1991; 1, QM MO39009, 11°04.1'S 142°52.4'E, Gulf of Carpentaria, Qld, 21 m, 30 November 1991; 6, AMS C171342, 10°48.4'S 135°52.0'E, 98 km west of Cape Wessel, Arafura Sea, NT, 44 m, 14 December 1990.

Additional material examined. QUEENSLAND: 1, AMS C172496, 21°58.5'S 150°45'E, east of Broad Sound, 57 m, coarse to fine sandy mud and shell, 18 November 1977; 1, AMS C173528, 23°52.5'S 152°42.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 3, AMS C172489, Bowen; 1, AMS C172498, 19°50'S 146°33'E, Havanah Island, off Townsville, 28.7 m, 31 January 1976; 5, AMS C76451, 4, AMS C172475, Buchans Point, north of Cairns; 3, AMS C201279, 16°51.36–51.00'S 146°01.12–01.04'E, off Cairns, 33–35 m, 14 October 1981, sandy mud and shell; 4, AMS C169944, 17°09'53"–7'24"S 146°42'36"–42'48"E, north of Cairns, 253–243 m, 12 October 1981, grey mud; 6, QM MO39003, 11°04.1'S 142°52.4'E, Gulf of Carpentaria, 21 m, 30 November 1991 (preserved); 1, Lamprell Collection, Torres Strait, 1989; 1, Lamprell Collection, 15°03'S 139°12'E, Gulf of Carpentaria; 1, AMS C169942, 16°41'S 139°50'E, off Bountiful Island, Gulf of Carpentaria, 15 m, December 1963; 2, QM MO39002, 1, QM MO39007, 10°41.8'S 138°31.1'E, Gulf of Carpentaria, 52 m, 21 November 1991; 1, QM MO39007, 10°41.8'S 138°31.1'E, Gulf of Carpentaria, 46 m, 21 November 1991; 4, AMS C169940, 13°28.2'S 143°42'E, 22 m, sticky black mud, 28 October 1973. NORTHERN TERRITORY: 1, QM MO39008, 10°06.8'S 137°42.5'E, Gulf of Carpentaria, 46 m, 21 November 1991; 1, AMS C172472, 10°23'S 133°36'E, 125 km north of Goulburn Island, 62 m, clayey sand, 31 October 1969; 1, AMS C76454, dredged off Melville Island, October 1962; 1, AMS C172481, 10°17'S 132°38'E, Arafura Sea, approx 64.5 km north of Croker Island, 65 m, 9 November 1969. WESTERN AUSTRALIA: 1, WAM 240-93, 32 km north of Adele Island, 80 m, 20 October 1962; 1, WAM 239-93, 57 km south-west of Adele Island, 80 m, 17 October 1962.

Description. Shell length to 52.7 mm, aperture diameter 3.5 mm, apex diameter 0.8 mm; well curved, glossy. Sculpture of dense, strong, transverse, irregular annulations at the apex, becoming more distant and wider towards the aperture. Aperture circular, slightly oblique in some specimens. Apex circular. Colour translucent orange.

Radula. Central tooth broad (244 μm wide), moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped, 266 μm long with small cusps on the

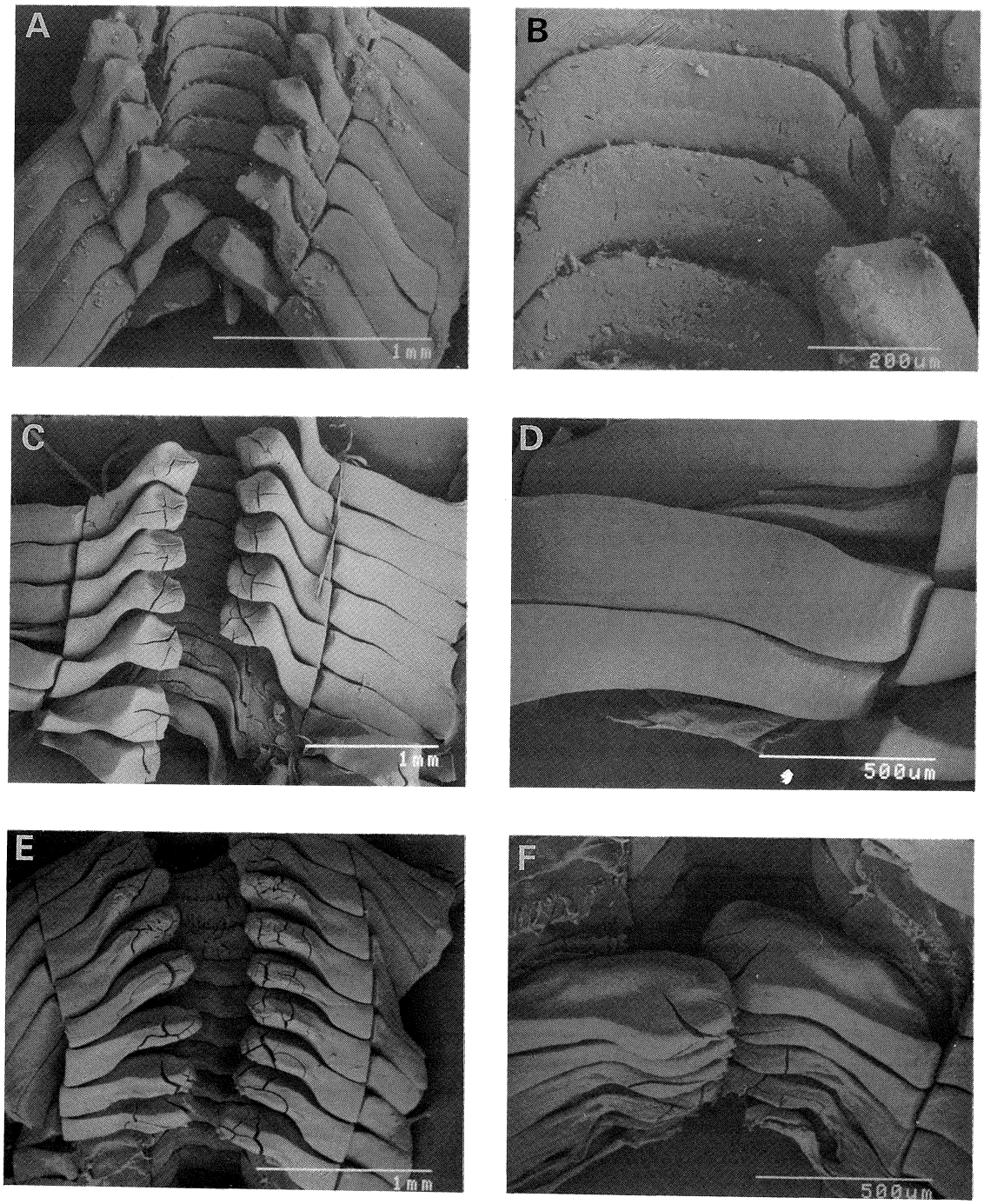


Figure 129. Radular ultrastructure. **A,B** *Laevidentalium largicrescens* (Tate, 1899) (37 km east of Lady Musgrave Island, Qld, 348–357 m, AMS C169786). **C,D** *Laevidentalium lubricatum* (Sowerby, 1860) (Bay of Rest, Exmouth Gulf, WA, WAM 78/93). **E,F** *Laevidentalium crocinum* (Dall, 1907) (Port Hacking, NSW, 90 m, AMS C101217).

working surface; marginals slightly sigmoidal, moderately short and broad (length 350 μm × breadth 127 μm) (see Fig. 134E,F). Ratios C:L = 1:1.09, L:M = 1:1.32, marginals breadth:length = 1:2.8 (sex not determined).

Range. Central Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged in grey mud from 15 to 296 m.

Comparisons and remarks. The systematic position of *Laevidentalium martyi* is difficult to resolve. A close relationship with *L. eburneum* (Linnaeus) and *L. philippinarum* (Sowerby) seems evident judging from available figures and descriptions of these two rather poorly known species. *Laevidentalium martyi*, like *L.*

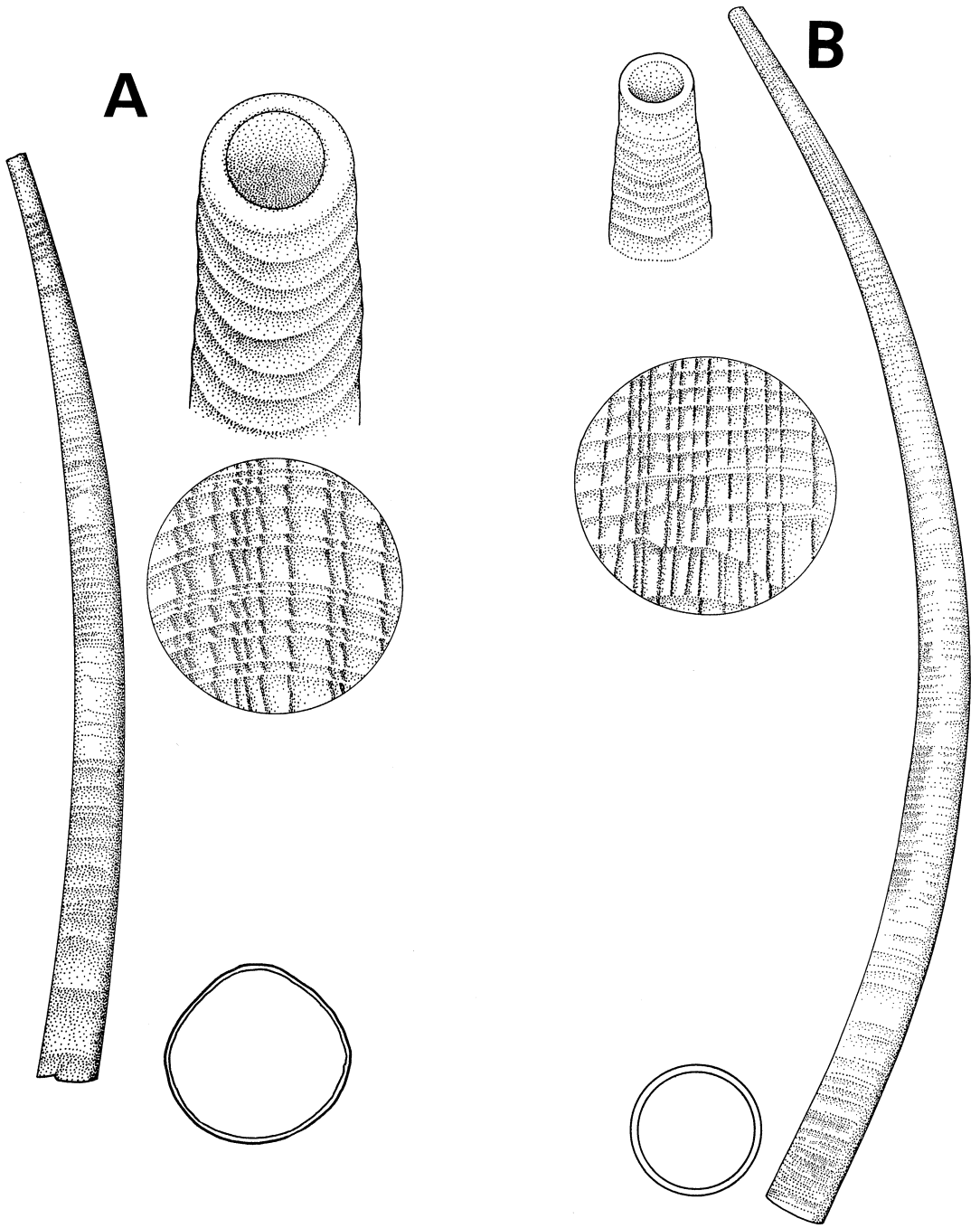


Figure 130. Dentaliida, Laevidentaliidae, *Laevidentalium*. Group of *L. martyi*. **A** *L. martyi* n.sp. (holotype, QM MO39004, Gulf of Carpentaria, Qld, 54 m, length 52.7 mm). **B** *L. longitrorsum* (Reeve, 1842) (holotype, BMNH 1952.3.4.21, Zanzibar, length 109.6 mm). (Del.: A and B [aperture and sculptural detail]—C. Eadie; A [aperture]—JMH; B—A. Hill).

eburneum and *L. philippinarum*, has a moderate to strongly curved, slender shell which exhibits irregularly spaced annular swellings. The chief differentiating feature of *L. martyi* is the closely spaced rings ornamenting the posterior half of the shell, especially towards the apex. These rings initially suggested to us that *L. martyi* could be referable to the Omniglyptidae (genus *Omniglypta*) which are characterized by such shell ornament. However, SEM study of the radula of *L. martyi* clearly demonstrated that the central tooth lacked cusps on the superior edge—one of the characteristic features of the Omniglyptidae (Scarabino, 1979; Boss, 1982; Steiner, 1992a). The species seems to be restricted to tropical Australian waters.

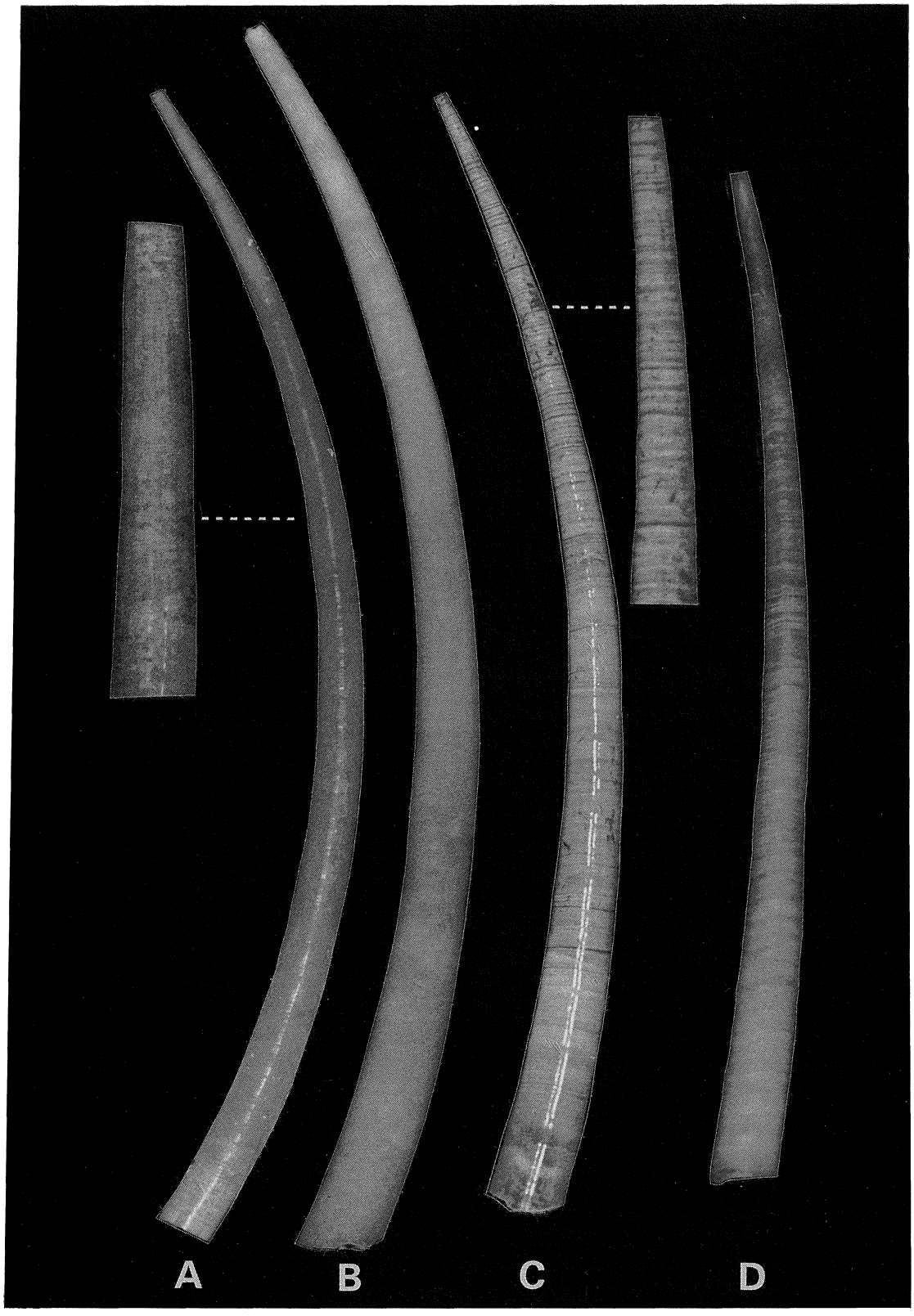


Figure 131. Dentaliida, Laevidentaliidae, *Laevidentalium* Group of *L. martyi*. **A** *L. longitrorsum* (Reeve, 1842) (holotype, BMNH 1952.3.4.21, Zanzibar, length 109.6 mm). Note detail of apex showing striae. **B** *L. longitrorsum* (Reeve, 1842) (QM MO39002, Torres Strait, Qld, length 81.8 mm). **C** *L. martyi* n.sp. (holotype, QM MO39004, Gulf of Carpentaria, Qld, 54 m, length 52.7 mm). Note detail of apex showing irregular rings. **D** *L. martyi* n.sp. (KLColl, Port Hedland, WA, beach, length 55.5 mm).

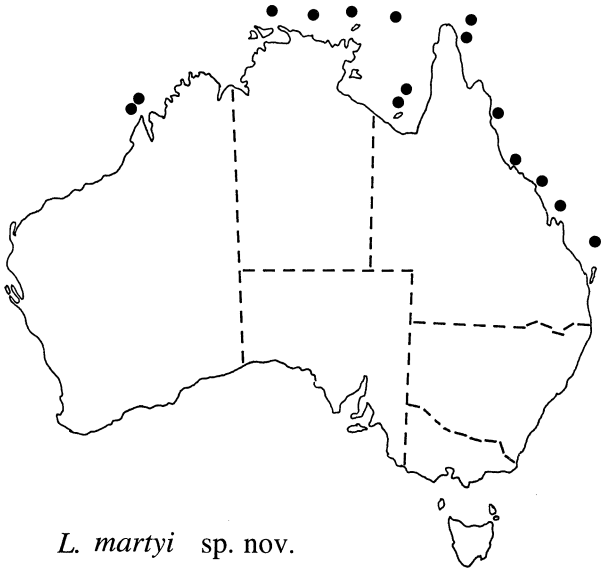


Figure 132. Known distribution of *Laevidentalium martyi* n.sp.

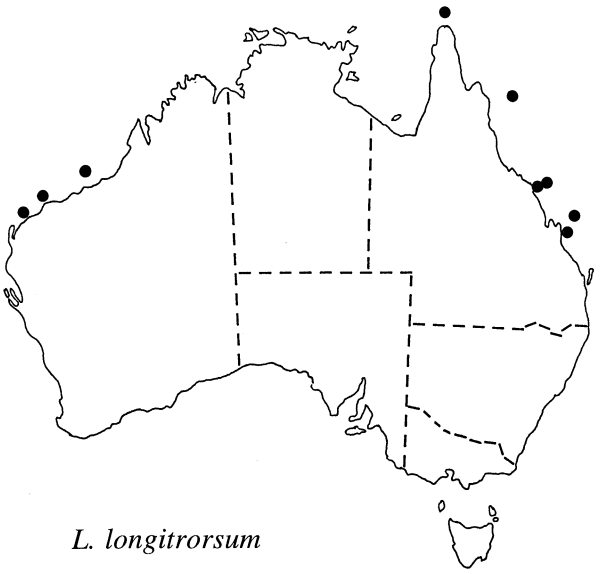


Figure 133. Australian distribution of *Laevidentalium longitrorsum* (Reeve, 1842).

Laevidentalium longitrorsum (Reeve, 1842)

Figs 130B, 131A,B, 133, 134A–D

Dentalium longitrorsum Reeve, 1842a: 197; Reeve, 1842b: 6, pl. 130, fig. 6; G.B. Sowerby, 1860: 98, pl. 225, figs 59–60; G.B. Sowerby, 1872: pl. 2, figs 9a,b; Brazier, 1877: 59; Watson, 1879: 515; Watson, 1886; Pilsbry & Sharp, 1897: 111, pl. 20, figs 35, 36; Boissevain, 1906: 52, pl. 2, figs 33, 33a; Hedley, 1910: 316; Ludbrook, 1954: 104.
Dentalium lamarckii Chenu, 1842–1843: 5, pl. 6, figs 15, 15a.

Type material examined. HOLOTYPE: BMNH 1952.3.4.21. Type locality: Zanzibar. Length of holotype 109.6 mm, aperture diameter 5.4 mm, apex diameter 1.3 mm.

Additional material examined. QUEENSLAND: 4, AMS C121373, Yeppoon, 1957; 4, AMS C100485, south side of Pinnacle Point, 2.5 km south of Yeppoon, 28 December 1972; 2, NMV F69578, off Middle Island, Keppel Bay, Qld, 10–40 m; 6, AMS C172474, Hill Inlet, Whitsunday Island; 13, AMS C172969, 21°49'S 151°54'E, Big Sandy Cay, Swains Reefs, 9 m; 1, 18°31.1'S 147°07.7'E, Slasher Reef, no. 1, dredged in sand, 10 m; 2, AMS C171906, Kurramine Beach, July 1964; 1, AMS C173021, 20°27'S 149°02'E, Lindeman Island; 2, QM MO39002, Torres Strait. WESTERN AUSTRALIA: 1, WAM 254-93, 22 km west of Eagle Hawk Island, Dampier, 14 July 1960; 1, WAM 253-93, 2.5 km north north-east of Anchor Island, Onslow; mud, 44 m, 16 July 1960.

Description. Shell length to 114.0 mm, aperture diameter 5.5 mm, apex diameter 1.7 mm; solid, evenly and strongly curved, slender; glossy. Sculpture of obscure longitudinal striae extending 20.0 mm from the apex and obscure growth lines. Aperture circular. Apex circular or ovate with an off-centre ventral notch from the centre of the ventral side. Colour white, amber or carnelian.

Radula. Central tooth broad (130 μm wide in male, 148 μm wide in female) moderately shallow with smooth, weakly convex superior surface and correspondingly concave inferior surface; laterals dumbbell-shaped (170 μm long in male; 185 μm in female) with small cusps on the working surface; marginals sigmoidal. short and broad (length 230 μm × breadth 96 μm in male; measurements not determined for female) (see Fig. 134A–D). Ratios: male C:L = 1:1.31, L:M = 1:1.35, marginals breadth:length = 1:2.4; female C:L = 1:1.25, L:M = not determined, marginals breadth:length = not determined.

Range. East Africa (Zanzibar [Reeve, 1842a]); Indonesia (Boissevain, 1906); Queensland to northern Western Australia.

Habitat. Dredged in sand or mud to 155 m.

Comparisons and remarks. This species resembles most closely *L. martyi* n.sp. and *L. eburneum* (Linnaeus) in shape. Differentiating features of *L. longitrorsum* which help to separate it from these two species include: lack of annular swellings; presence of apical notch; presence (in fresh specimens) of fine longitudinal striae apically. In fact the combination of an elongate, white, narrow shell of strong curvature distinguishes *L. longitrorsum* from all other Australian members of the genus. One of the key features cited by all previous authors in the definition of the genus *Laevidentalium* is the absence of any longitudinal sculpture (e.g., see Pilsbry & Sharp, 1897–98; Palmer, 1974a; Steiner, 1992a). During this study we have found longitudinal striae on numerous specimens of *L. longitrorsum*, including the type series. Longitudinal striae also occur on juvenile *L. lubricatum*. Given that we can find no other features to separate *Laevidentalium* specimens with striae from those without, it seems wise to simply alter the definition of the genus rather than create a new genus on this basis only.

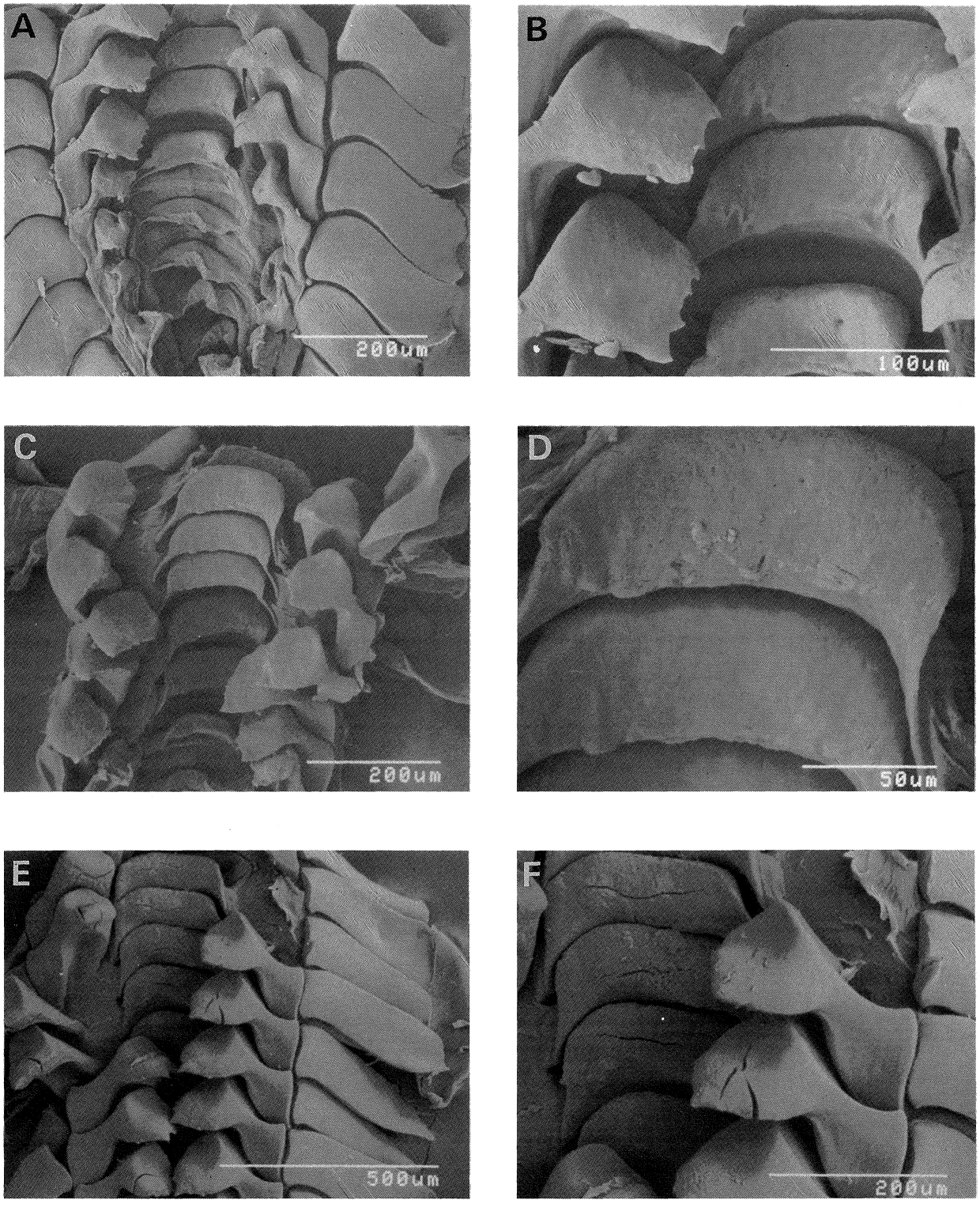


Figure 134. Radular ultrastructure. **A–D** *Laevidentalium longitrorsum* (Reeve, 1842) (off Middle Island, Keppel Bay, Qld, 10–40 m, NMV F69578). A,B—male, C,D—female. **E,F** *Laevidentalium martyi* n.sp. (11°04.1'S 142°52.4'E, Gulf of Carpentaria, 21 m, QM MO39003).

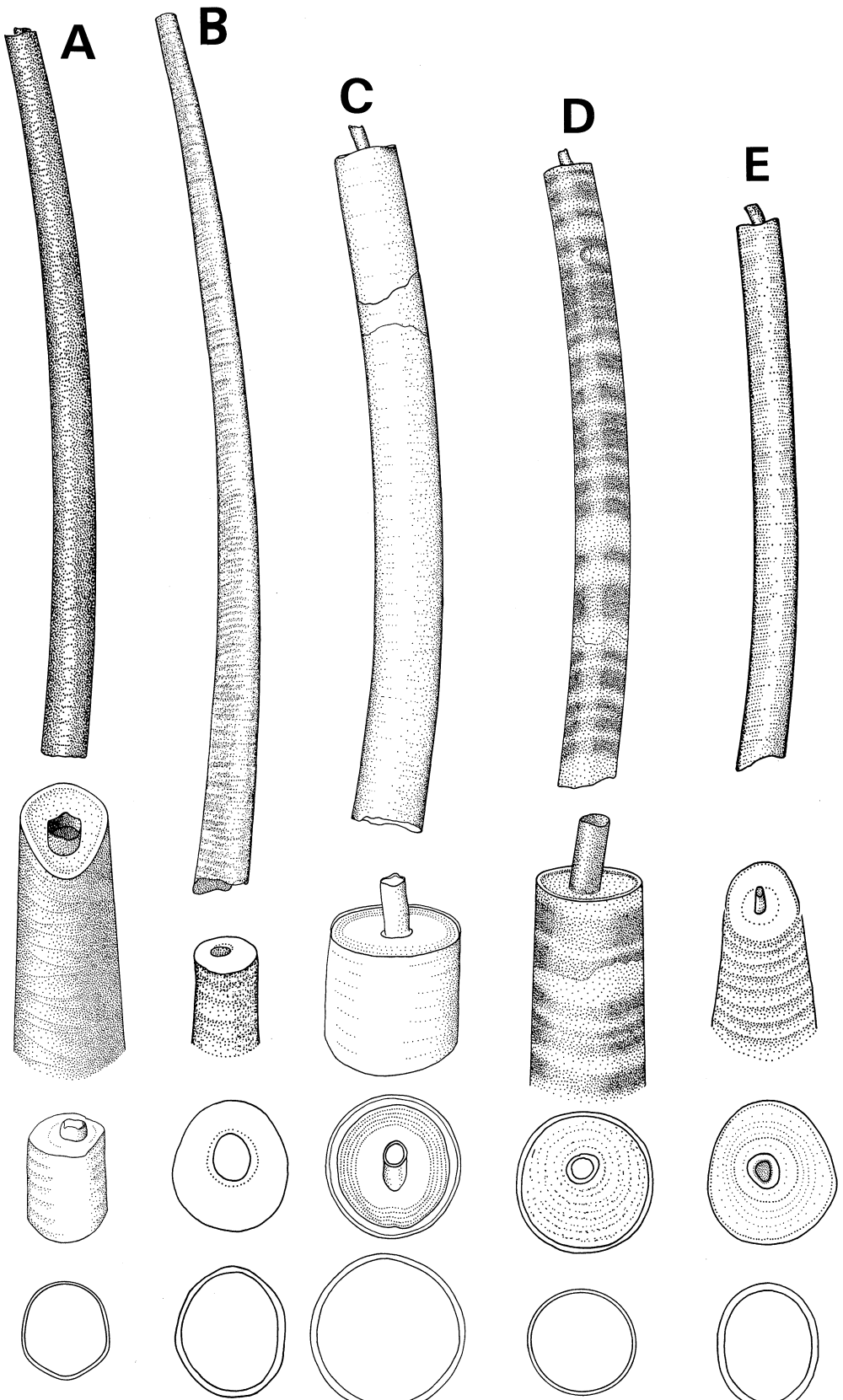


Figure 135. Gadilinidae, *Episiphon*. **A,B** *E. jamiesoni* n.sp. (A—paratype, QM MO17730, off Cairns, Qld, 703 m, length 29.0 mm; B—holotype, QM MO45835, off Cairns, Qld, 703 m, length 32.6 mm). **C** *E. bordaensis* (Cotton & Ludbrook, 1938) (holotype, SAM D13340, Cape Borda, SA, 110 m, length 19.0 mm). **D** *E. virgula* (Hedley, 1903) (AMS C10420, east off Lady Musgrave Island, Qld, 296 m, length 17.9 mm). **E** *E. pichoni* n.sp. (holotype, QM MO40064, off Cairns, Qld, 303 m, length 13.7 mm). (Del.: all A. Hill, except A and D [longitudinal profiles]—C. Eadie).

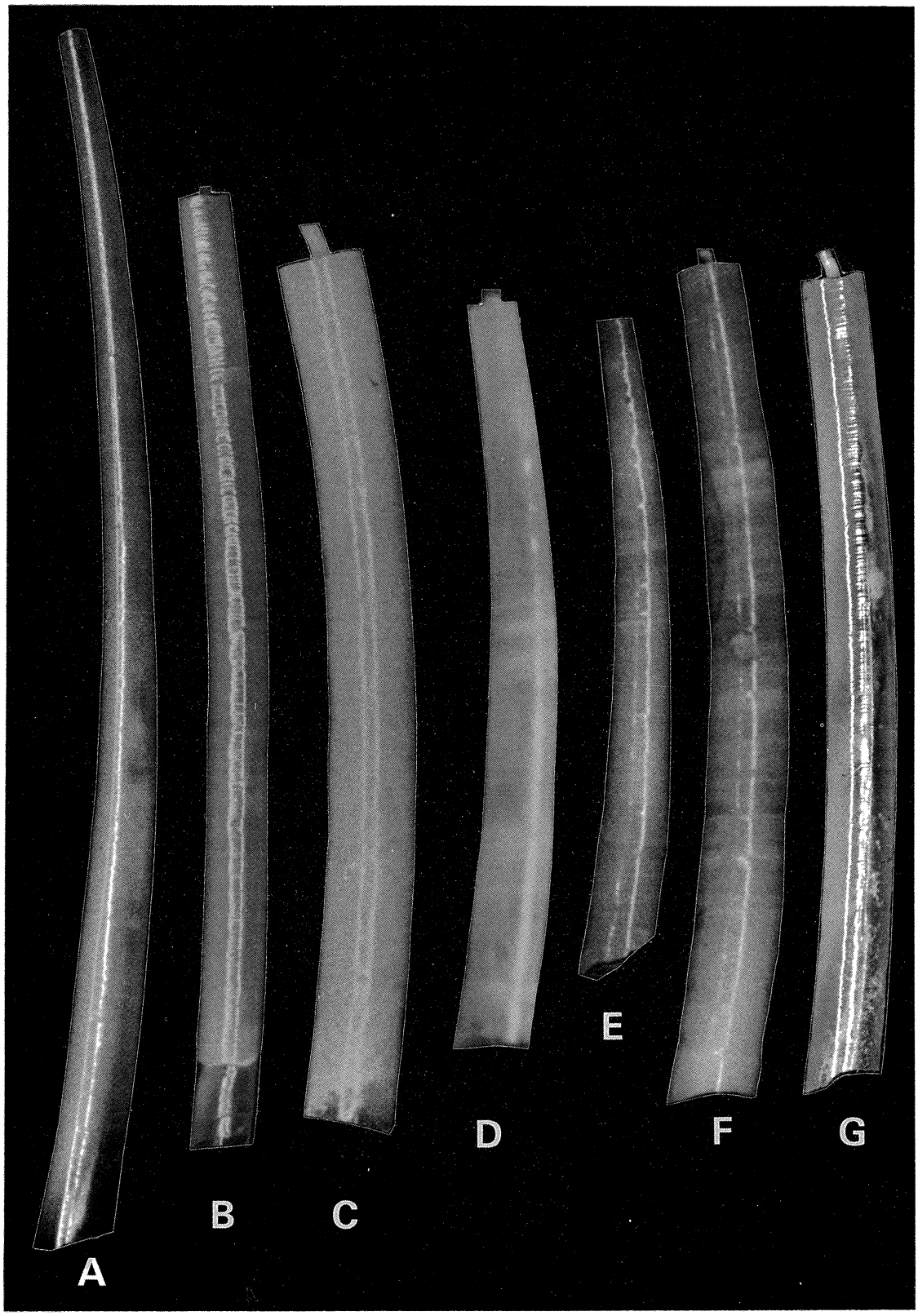


Figure 136. Gadilinidae, *Episiphon*. **A,B** *E. jamiesoni* n.sp. (A—holotype, QM MO45835, off Cairns, Qld, 703 m, length 32.6 mm; B—paratype, QM MO17730, off Cairns, Qld, 703 m, length 29.0 mm). **C** *E. bordaensis* (Cotton & Ludbrook, 1938) (holotype, SAM D13340, Cape Borda, SA, 110 m, length 19.0 mm). **D** *E. virgula* (Hedley, 1903) (holotype, AMS C16217, 9.3 km off Port Kembla, NSW, 115–137 m, length 10.5 mm). **E,F** *E. virgula* (Hedley, 1903) (AMS C173432, east off Lady Musgrave Island, Qld, 296 m, length E—12.0 mm, F—17.9 mm). **G** *E. pichoni* n.sp. (holotype, QM MO40064, off Cairns, Qld, 303 m, length 13.7 mm).

Family GADILINIDAE Chistikov, 1975

Diagnosis. The shell characters in this family are extremely variable; thick or thin walled, strongly curved to nearly straight, 3 longitudinal ribs or smooth, with or without apical annulation, triangular to circular in cross section. The rachis [central] tooth has 3 denticles, the marginals are curved (Steiner, 1992a, p. 397).

Genus *Episiphon* Pilsbry & Sharp, 1897

Episiphon Pilsbry & Sharp, 1897: 117; Boissevain, 1906: 46; Suter, 1913: 821; Henderson, 1920: 77; Woodring, 1925: 203; Ludbrook, 1960: I38; Emerson, 1962: 474; Habe, 1964: 28; Palmer, 1974a: 120; Steiner, 1992a: 397.

Type species: *Dentalium sowerbyi* Guilding, 1834, by subsequent designation, Suter, 1913: 821.

Diagnosis. Shells small to medium sized, slightly curved, slender, slightly tapering; glossy, generally smooth or with fine transverse growth lines. Apex usually truncate in mature specimens, with a projecting pipe and plug.

Key to Australian *Episiphon*

1 Aperture somewhat laterally compressed, wider dorsally 2

—— Aperture ovate 3

2 Shell white, up to 36 mm ..... *E. jamiesoni*

—— Shell cream to yellow, up to 18 mm ..... *E. pichoni*

3 Shell profile very narrow, white opaque with well defined transverse bands ..... *E. virgula*

—— Shell profile moderately narrow, evenly white, with microscopic transverse bands ..... *E. bordaensis*.

Episiphon jamiesoni n.sp.

Figs 135A,B, 136A,B, 137

Etymology. Named after Professor Barrie Jamieson (Department of Zoology, Univerity of Queensland) in recognition of his outstanding contribution to taxonomic and phylogenetic zoology, particularly in relation to the Australian invertebrate fauna.

Type material examined. HOLOTYPE: QM MO45835. Type locality: off Cairns, 17°50.67'S 147°18.2'E, northern Qld, 703 m, 17 May 1986. Length of holotype 32.6 mm, aperture diameter 2.0 × 1.1 mm, apex diameter 1.25 × 1.1 mm. PARATYPES: 6, QM MO17730, same locality data as holotype; 2, QM MO17950, same locality data as holotype; 26, AMS C173422, 17°09.42–09.36'S 146°42.24–42.00'E, off Cairns, Qld, 668 m, 13 October 1981; 2, AMS C169798, 33°33'S 152°05'E, north-east of Sydney, NSW, 3 December 1979, 750 m; 8, AMS C173306, 24°43.5–43.8'S 153°33.4–33.3'E, east of Sandy Cape, Qld, 604 m, 8 July 1984.

Additional material examined. NEW SOUTH WALES: 1, NMV F75845, 34°51.90'S 151°12.60'E, off Nowra, 770 m, 15 July 1986; 3, AMS C169797, 33°41'S 151°56'E, north-east of Sydney, 741 m, 5 December 1977. QUEENSLAND: 1, AMS C310227, 23°15.2'S 152°24.1'E, east of North West Island, 284 m, 14 December 1977; 5, AMS C172600, 11, AMS C172599, 24°43.5–43.8'S 153°33.4–33.3'E, east of Sandy Cape, 604 m, 8 July 1984; 4, AMS C174893, 23°52.5'S 152°42.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 1, AMS C173221, 23°19.5'S 152°35.4'E, east of North West Island, 320 m, 14 December 1977; 1, QM MO17996, 17°22'S 146°48'E, 303 m, 15 May 1986. NORTHERN TERRITORY: 4, AMS C169947, 8°39'S 133°34'E, 320 km north of Goulburn Island, 192 m, sand-silt-clay, 1 November 1969; 6, AMS C172590, 9°30'S 132°34'E, approx 160 km north of Croker Island, Arafura Sea, 124 m, 9 November 1969. WESTERN AUSTRALIA: 2, WAM 259-93, 29°43'S 114°20'E, north-west of Beagle Bay, 256 m, 20 March 1972.

Description. Shell length to 36.5 mm, aperture diameter 2.2 × 2.0 mm apex diameter 1.25 × 1.1 mm; slowly tapering, very slender, moderately curved; smooth, without longitudinal sculpture, but with microscopic transverse growth lines. Aperture cylindrical, the convex side slightly laterally compressed. Apex with an apical plug and a short pipe. Colour glossy white.

Range. New South Wales, Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged in sandy mud from 192 to 770 m.

Comparisons and remarks. *Episiphon jamiesoni* most closely resembles *E. pichoni* n.sp. which also shows clear signs of lateral compression of the shell. Shells of these two species can be easily distinguished from each

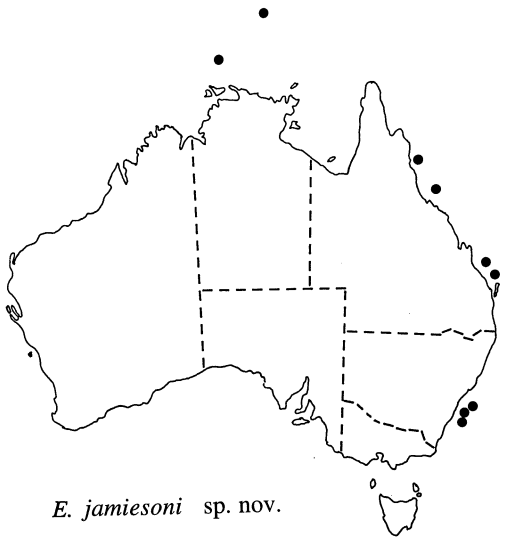


Figure 137. Known distribution of *Episiphon jamiesoni* n.sp.

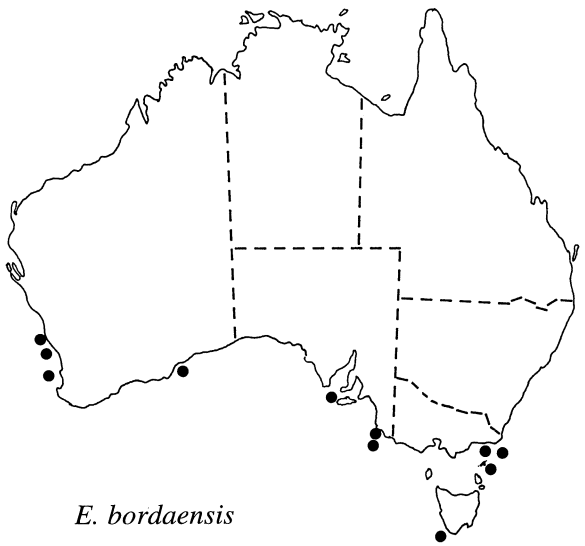


Figure 138. Known distribution of *Episiphon bordaensis* (Cotton & Ludbrook, 1938).

other on the basis of size (*E. jamiesoni* much larger than *E. pichoni*) and colouration (translucent white in *E. jamiesoni*, cream-yellow in *E. pichoni*). *Dentalium pachypleurum* Boissevain approaches *E. jamiesoni* in size, colour and longitudinal profile, but differs in having a markedly thicker dorsal edge (see Boissevain, 1906: 51). Other than the lateral compression, *E. jamiesoni* and *E. pichoni* show shell facies consistent with placement in the genus *Episiphon*. Nevertheless a comparative investigation of the anatomy and radular ultrastructure could prove very useful in reaching a better understanding of the relationships between *Episiphon* spp. and at the generic level, between *Episiphon* and *Gadilina*.

Episiphon bordaensis (Cotton & Ludbrook, 1938)

Figs 135C, 136C, 138

Dentalium bordaensis Cotton & Ludbrook, 1938: 220, pl. 12, fig. 3; Cotton & Godfrey, 1940: 330, fig. 352.

Type material examined. HOLOTYPE: SAM D13340. Type locality: Cape Borda, SA, 60 fathoms [110 m]. Length of holotype 19.0 mm. Aperture diameter 2.0 mm, apex diameter 1.9 mm.

Additional material examined. WESTERN AUSTRALIA: 3, AMS C301607, north-west of Rottnest Island, 183–192 m, 18 March 1972; 8, AMS C301517, west of Rottnest Island, 347–384 m, 17 March 1976; 1, WAM 104-93, 32°05.7'S 115°36.1'E, 22 m, 28 June 1977; 2, AMS C171925, between Eucla and Esperance, 75–293 m, 5–9 July 1962; 1, AMS C301560, west of Green Head, 30°45'S 114°46'E, 237–247 m, 19 March 1972; 2, AMS C301623, north-west of Cervantes, 30°30'S 114°38'E, 256–192 m, 22 March 1972; 1, AMS C301535, south-west of Mandurah, 32°45'S 114°45'E, 283 m, 17 March 1972; 3, WAM 71-93, 33°15'S 114°32'E, north-west of Bunbury, 17 March 1972; 7, WAM 258-93, 3, WAM 257-93, north-west of Lancelin, 256–274 m, 23 March 1972. SOUTH AUSTRALIA: 2, AMS C6847, north of Cape Borda, Kangaroo Island, 80 m, 26 August 1909; 4, AMS C33488, off Neptune Island, Spencer Gulf, 190 m; 2, AMS C32030, 60 km south of Cape Wiles, 200 m; 43, Cape Borda, 120–124 m; 23, off Cape Jaffa, 180 m; 51, south-west of the Neptune Islands, 208 m; 25, off Beachport, 220 m; 3, off Cape Jaffa, 260 m; 93, off Beachport, 300 m; 4, off Beachport, 400 m; 11, AMS C310260, 38°20–40'S 149°25–35'E, 38 km south of Cape Everard, 366 m, 22 October 1914. TASMANIA: 2, AMS C169984, 38°59'S 148°34.1'E, midway between Cape Everard and Flinders Island, Bass Strait, 7–9 May 1969; 2, NMV F67456, 39°43'S 14°36'E, east of northern Point, Flinders Island, Bass Strait, 110 m, dredged in mud, 24 November 1973; 5, AMS C171921, 43°38.5'S 146°07.8'E, south-east of South West Cape, 119 m, 9 April 1973. VICTORIA: 57, AMS C169987, 38°13'S 149°06'E, between Cape Howe and Lakes Entrance, 146–158 m, 20 June 1962.

Description. Shell length to 20.3 mm, aperture diameter 2.0 mm, apex diameter 1.9 mm; glossy, slightly curved; devoid of sculpture but with microscopic transverse growth lines. Aperture circular. Apex large, circular with a central, narrow pipe. Colour opaque white.

Range. Southern Western Australia, South Australia, Tasmania to Victoria.

Habitat. Dredged in sand and mud from 75 to 400 m.

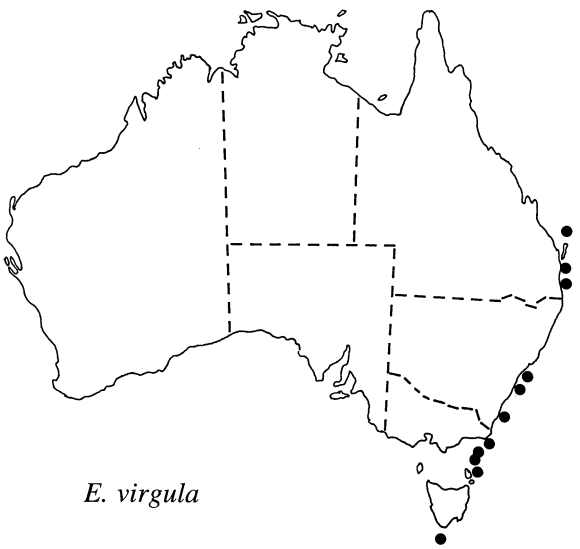


Figure 139. Known distribution of *Episiphon virgula* (Hedley, 1903).

Comparisons and remarks. *Episiphon bordaensis* most closely resembles *E. virgula* (Hedley). Shell features which differentiate *E. bordaensis* from *E. virgula* include: much larger and wider; less curved; an even white colour (strong opaque bands in *E. virgula*). Compared with *E. pichoni* n.sp., *E. bordaensis* is much larger, has a circular aperture and lacks the cream colour of that species.

Episiphon virgula (Hedley, 1903)

Figs 135D, 136D–F, 139

Dentalium virgula Hedley, 1903: 328, fig. 62; Verco, 1911a: 209; Colman, 1958: 144, pl. 1, fig. 10; Iredale & McMichael, 1962: 97; Macpherson & Gabriel, 1962: 268.

Type material examined. HOLOTYPE: AMS C16217. Type locality: 5.8 miles [9.3 km] off Port Kembla, NSW, 115–137 m, 18 March 1898. Length of holotype 10.5 mm, aperture diameter 1.1 mm, apex diameter 0.6 mm. PARATYPES: AMS C170639, same locality data as holotype.

Additional material examined. TASMANIA: 1, AMS C173218, 32 km east of Babel Island, Furneaux Group, Bass Strait, 120 m; 1, AMS C171909, 43°55'S 146°51'E, south of South East Cape, 168 m, 2 April 1973. VICTORIA: 3, AMS C171912, 38°12'S 148°35'E, south of Marlo, in Bass Strait, 146 m, 7–9 May 1969; 3, AMS C173219, 38°12'S 148°35'E, south of Marlo, Bass Strait, 146 m, 7–9 May 1969; 5, AMS C173206, 38°03.50'S 149°08.50'E, 30 km south-west of Cape Everard, 119 m, 7–9 May 1969; 8, AMS C173213, off Cape Everard and Point Hicks, 146 m; 1, AMS C173084, 37°22'S 150°02'E, 20.5 km off Twofold Bay, 75 m, 19 June 1962. NEW SOUTH WALES: 57, AMS C171918, 10, AMS C173207, 8, AMS C171923, off Cronulla, 40–100 m, December 1963; 4, AMS C173209, 4.5 km off Cronulla, 130 m, fine mud; 110, AMS C16215, 82–100 m, off Cape Three Points; AMS C16218, 108–118 m, off Wata Mooli; 2, AMS C173214, Crookhaven, 64 m; 9, AMS C63445, east of Botany Bay, 150 m; 11, AMS C173205, off Botany Bay, 150 m; 1, AMS C16216, 95–104 m, off Botany Heads; 1, AMS C171924, 37 m, Sydney; 1, AMS C173212, 33°59.26'S 151°16.46'E, 2.6 km east north-east of Cape Banks, Sydney, 66 m, 25 October 1973; 17, AMS C173215, off Port Jackson, 110 m, 26 July 1960; 1, AMS C171917, 33°58.50'S 150°17'E, 2 km east of Long Bay, Sydney, 66 m, 27 February 1974; 5, AMS C173200, off Broken Bay; 16, AMS C62225, Port Stephens; 1, AMS C55086, Salamander Bay, Port Stephens, 22 m, 1874; 1, AMS C173082, Broughton Island, Port Stephens, 70 m; 1, AMS C171913, trawled off Port Stephens; 5, AMS C11677, off Sydney Harbour, 137 m; 5, AMS C173202, off Sydney, 91 m; 5, AMS C173201, off Cronulla, 90 m, August 1964; 1, AMS C169986, 33°59.26'S 151°16.46'E, 2.6 km east north-east of Cape Banks, 66 m, 19 June 1974; 1, AMS C171914, 33°59.36'S 151°22.07'E, 14.5 km east of Cape Banks, Sydney, 110–115 m, 25 October 1973; 9, AMS C55088, north of Cabbage Tree Island, Port Stephens, 1929; 30, AMS C173204, 28, AMS C169985, 9, AMS C173210, 7, AMS C171919, off Jibbon, Port Hacking, 60–100 m, December-February 1963–4; 15, AMS C171915, off Jibbon, Port Hacking, 80 m, September 1964; 14, AMS C16218, Wata Mooli, 108 m; 1, AMS C173217, 28°49.6'S 153°51.3'E, 24 km east of Ballina, 185 m, 19 February 1972. QUEENSLAND: 12, AMS C169977, off Cape Moreton, 128–183 m, trawled; 33, AMS C169976, north-east of Cape Moreton, 126–136 m, 1967; 8, AMS C173211, 26°34'S 153°40'E, east south-east of Noosa Heads, 128 m, 30 March 1969; 10, AMS C171922, 130–150 m, off Caloundra; 22, AMS C310420, 65, AMS C173432, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984.

Description. Shell length to 20.5 mm, aperture diameter 1.1 mm, apex diameter 0.7 mm; slightly curved; without sculpture but with well defined, irregular, transverse growth rings. Aperture circular. Apex of mature specimens truncate with a narrow, smooth, centrally situated pipe (0.2 mm diameter), not parallel to the longitudinal axis of the shell. Colour of white opaque rings which sometimes alternate with pale orange translucent ones, apical pipe white or brown.

Range. Tasmania, Victoria, New South Wales to southern Queensland.

Habitat. Dredged in fine mud or sand from 22 to 296 m.

Comparisons and remarks. *Episiphon virgula* most closely resembles *E. bordaensis* (Cotton & Ludbrook). Shell features differentiating *E. virgula* from *E. bordaensis* include: smaller and narrower; more curved; stronger transverse growth lines. This species is also distinguished by the presence of opaque white bands which contrasts with the even white colouration of *E. bordaensis* and the yellow shells of *E. pichoni* n.sp.

Episiphon pichoni n.sp.

Figs 135E, 136G, 140

Etymology. Named after Dr Michel Pichon, leader of the Cidaris Expeditions which collected much of the northern Queensland scaphopod material examined herein.

Type material examined. HOLOTYPE: QM MO40064. Type locality: off Cairns, northern Qld, 17°22'S 146°48'E, 303 m, 15 May 1986. Length of holotype 13.7 mm, aperture diameter 1.25 mm, apex diameter 1.0 mm, length of apical pipe 0.9 mm, diameter 0.15 mm. PARATYPES: 44, QM MO40068, 32, QM MO40065, 180, QM MO40066, same locality data as holotype; 1, AMS C172490, 22°26.27–20.2'S 153°17.13–17.6'E, south-east of Swains Reefs, Qld, 187 m, 5 July 1984; 1, AMS C172479, 9°30'S 132°34'E, approx 160 km north of Croker Island, NT, 9 November 1969.

Additional material examined. QUEENSLAND: 2, AMS C172492, north north-east of Cape Moreton, 183 m; 7, AMS C171908, 24°03.7'S 152°49.4'E, north-east of Lady Elliot Island, 150 m, 4 July 1984; 20, AMS C171911, 23°19.5'S 152°35.4'E, east of North West Island, 320 m, *Globigerina* mud, 14 December 1977; 3, AMS C169786, 23°44'S 152°49'E, 37 km east of Lady Musgrave Island, 348–351 m, grey shelly ooze, 17 November 1977; 29, QM MO40067, 17°21.77'S 146°48.5'E, 296–303 m, 15 May 1986; 1, AMS C169979, 20°32.3'S 149°01.4'E, Whitsunday Passage, 27 m, shelly sand mud, 19 November 1977; 15, AMS C310226, 23°15.2'S 152°24.1'E, east of North West Island, 284 m, 14 December 1977; 22, AMS C10642, 9°42'S 143°25'E, 3 km off Yorke Island, Torres Strait, 18 m, muddy bottom. NORTHERN TERRITORY: 1, WAM 75-93, Darwin, 27 October 1982; 1, AMS C84257, 9°17.5'S 132°20'E, Arafura Sea, 168 m, 10 November 1969.

Description. Shell length to 18.1 mm, aperture diameter 1.1 × 1.25 mm, apex diameter 1.1 mm; scarcely tapering; slightly curved, highly glossed; without sculpture but with microscopic transverse growth lines. Shell laterally compressed, wider dorsally. Aperture cylindrical. Apex laterally compressed, with apical pipe. Colour translucent cream to yellow when live, glossy white when dead.

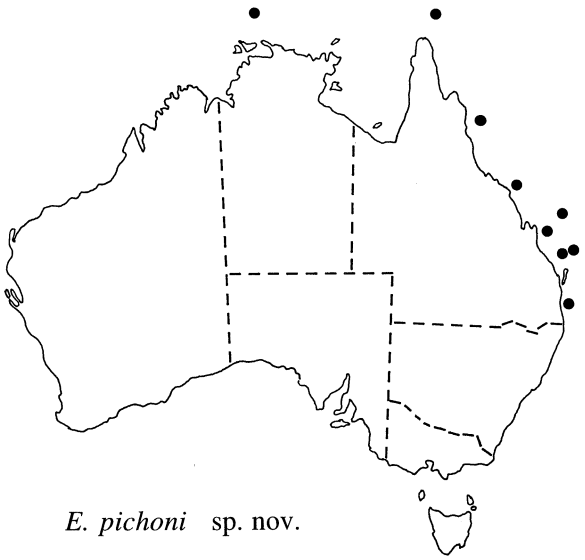


Figure 140. Known distribution of *Episiphon pichoni* n.sp.

Range. Southern Queensland to Northern Territory.

Habitat. Dredged in shelly sand or mud and sand from 18 to 351 m.

Comparisons and remarks. *Episiphon pichoni* resembles most closely *E. jamiesoni* n.sp. which is also laterally compressed. *Episiphon pichoni* however can be readily distinguished by its much smaller size (maximum of 18.1 mm in *E. pichoni* versus up to 36.5 mm in *E. jamiesoni*) and yellow colouration (white in *E. jamiesoni*). *Episiphon pichoni* differs from other Australian *Episiphon* spp. [*E. virgula* (Hedley) and *E. bordaensis* (Cotton & Ludbrook)] by its yellow colour; lesser degree of curvature and laterally compressed aperture (ovate in *E. virgula* and *E. bordaensis*).

Order GADILIDA Starobogatov, 1974

Diagnosis. Scaphopoda with very small to medium sized shells which are polished or to varying degrees ribbed. Typically gadilids with highly polished shells have a contracted aperture (in ribbed species, as in the Dentaliida, the aperture is not contracted). The foot is vermiform often terminating in a terminal disk. The rachidian (central) tooth is square or higher than wide (for a detailed anatomical diagnosis, see Steiner, 1992a: 397).

Key to Families of Australian Gadilida

1 Anterior aperture contracted; apex often with notches ..... Gadilidae

—— Anterior aperture not contracted; apex without notches 2

2 Shell smooth or ribbed; anterior aperture and growth lines not oblique ..... Entalinidae

—— Shell usually smooth sometimes with fine striae apically; anterior aperture and growth lines oblique ..... Pulsellidae

Suborder ENTALIMORPHA Steiner, 1992a

Diagnosis. The shell has 4 to 13 longitudinal ribs and a polygonal or laterally compressed cross section. The superior edge of the rachis tooth is smooth and without denticulation. The lateral teeth are characterized by 5 to 9 denticles of equal size. The marginals are not keeled. The central pedal retractor muscles are 4 to 6 in number, detaching from the pedal wall in the proximal middle piece. The captacula are retracted by 6 or 7 longitudinal muscles (Steiner, 1992a).

Family ENTALINIDAE Chistikov, 1979

Diagnosis. Shell small to medium in size, weakly to well curved, sculptured with strong longitudinal ribs; transverse profile of aperture usually angled and/or compressed laterally or dorsoventrally, occasionally rounded; aperture widest part of shell. Anatomical details as for suborder.

Genus *Entalina* Monterosato, 1872

Entalina Monterosato, 1872: 27; Sacco, 1897: 114; Pilsbry & Sharp, 1897: 131; Boissevain, 1906: 61; Henderson, 1920: 87; Ludbrook, 1960: I40; Emerson, 1962: 474; Habe, 1964: 38; Palmer, 1974a: 120; Steiner, 1992a: 397.
Entalinopsis Habe, 1957: 132, fig. 9.

Type species: *Dentalium tetragonum* Brocchi, 1814; by subsequent designation, Sacco, 1897: 144.

Diagnosis. Shell tapering as in *Dentalium*, widest at aperture, strongly curved and with stong ribbing; shell pentagonal at apex, anteriorly quadrate or tubular.

Key to Australian *Entalina*

1 Aperture shaped like the letter D ..... *E. mirifica*

—— Aperture subquadrate ..... *E. dorsicostata*

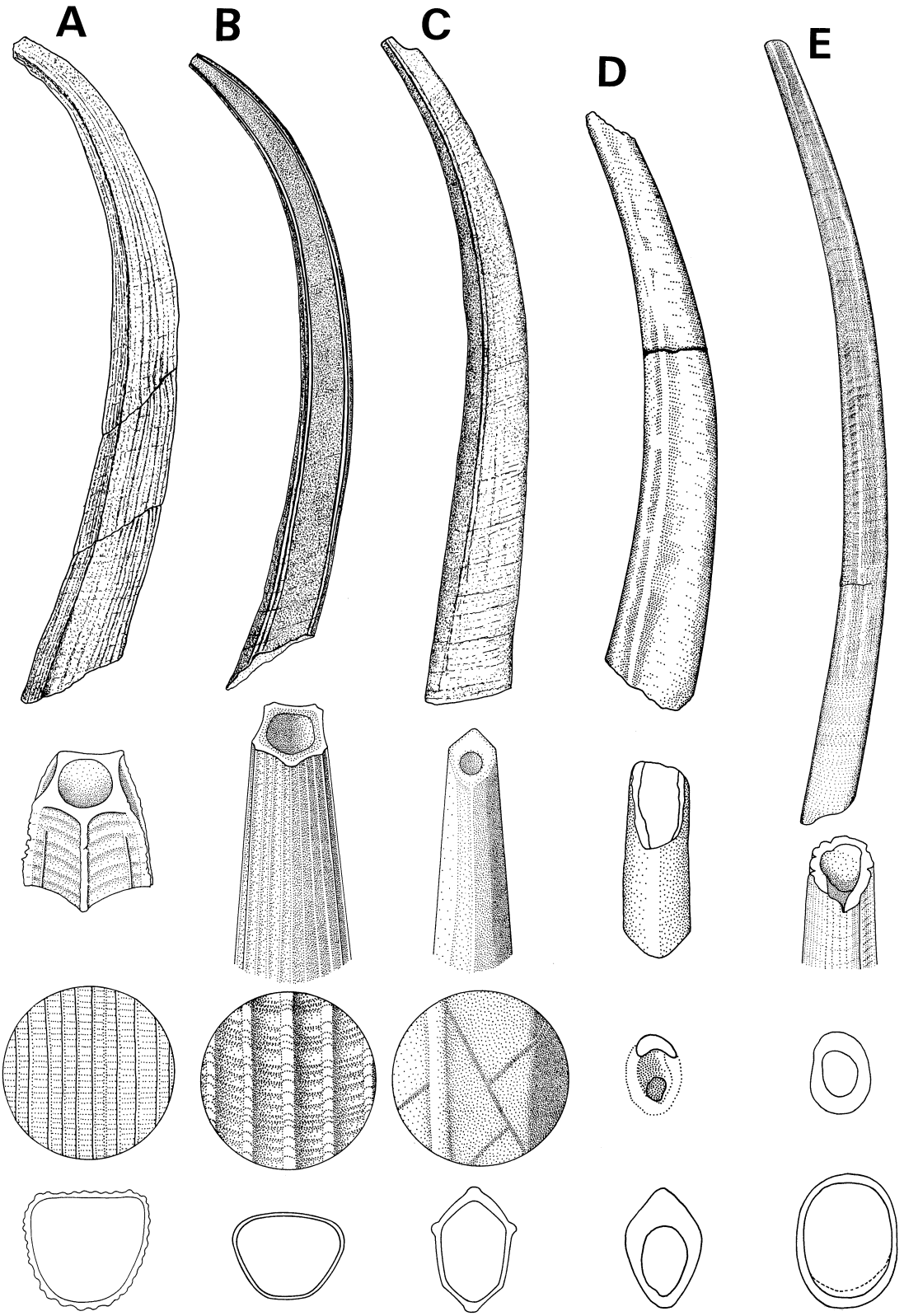


Figure 141. Gadilida. Entalinidae. **A,B** *Entalina*. **A** *E. mirifica* (Smith, 1895) (holotype, BMNH 1895.7.2.26, Trincomalee, Ceylon, 366–640 m, length 17.0 mm; apex detail from paratype same Reg. No. as holotype). **B** *E. dorsicostata* n.sp. (holotype, QM MO17729, off Cairns, Qld, 703 m, length 15.35 mm). **C–E** *Bathoxiphus*. **C** *B. tricarinatum* (Boissevain, 1906) (paralectotype, ZMA no number, East Timor Sea, 918 m, length 19.4 mm). **D** *B. colmani* (Palmer, 1974) (holotype, AMS C22652, 52.5 km east of Sydney,NSW, 1463 m, length 23.5 mm). **E** *B. steineri* n.sp. (holotype, QM MO40078, off Cairns, Qld, 1379 m, length 21.0 mm). (Del.: A, B and C [longitudinal whole shell profiles]—JMH; other portions of A, B and C—C. Eadie; D and E—A. Hill).

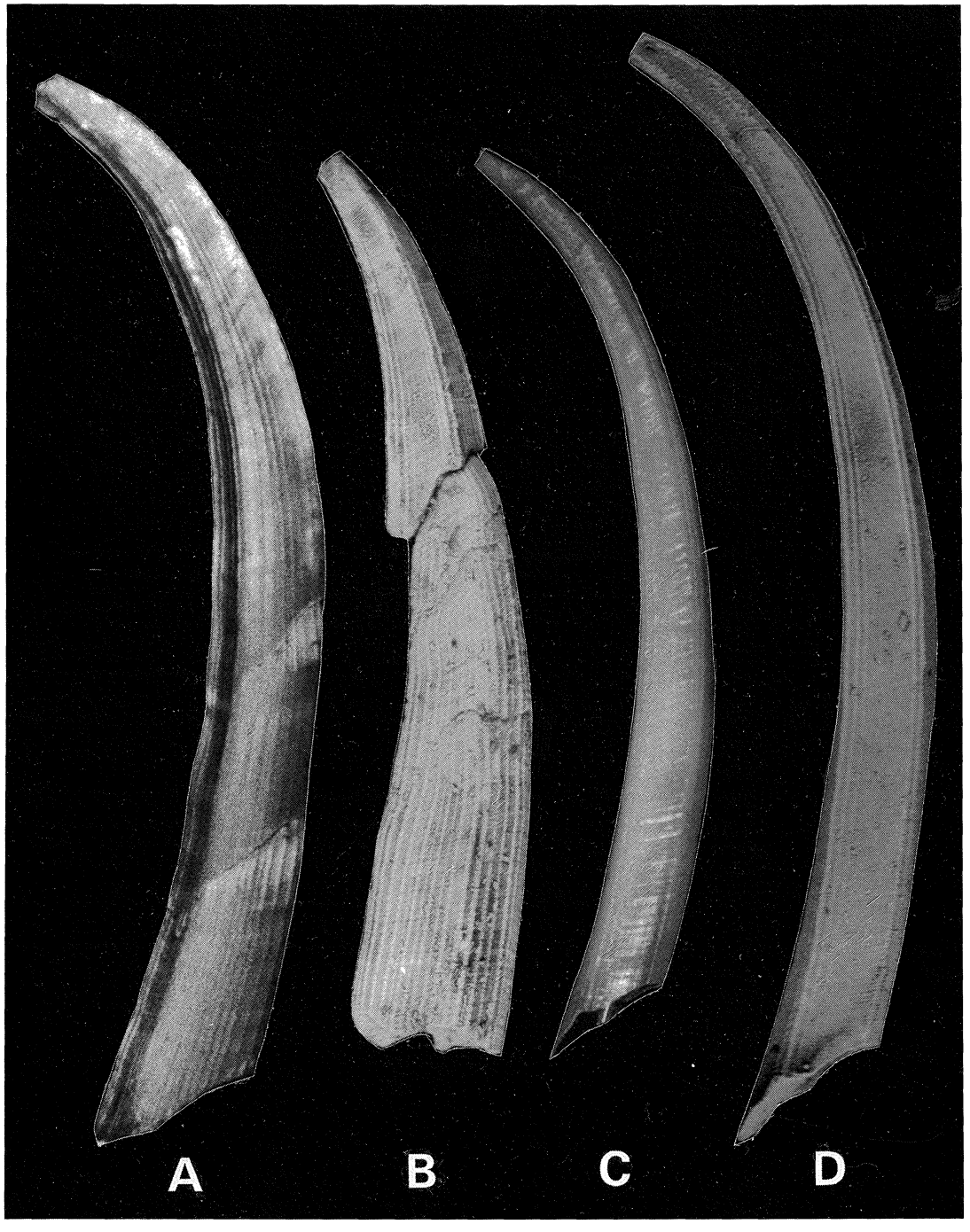


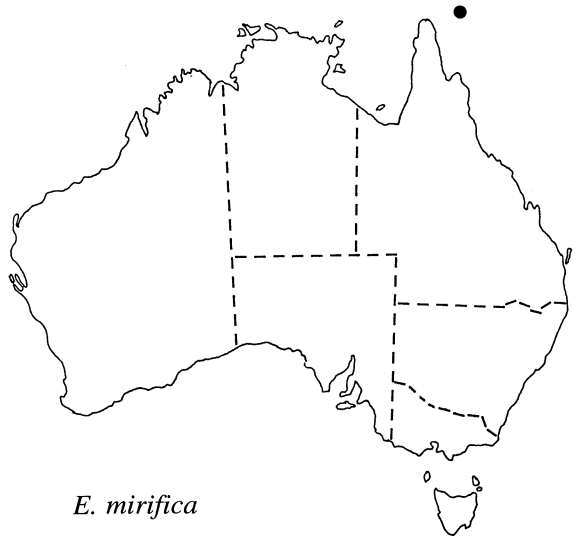
Figure 142. Gadilida, Entalinidae, *Entalina*. **A,B** *E. mirifica* (Smith, 1895) (A—holotype, BMNH 1895.7.2.26, Trincomalee, Ceylon, 366–640 m, length 17.0 mm; B—AMS C165282, east-north-east of Cape York Peninsula, Qld, 495–534 m, length mm). **C,D** *E. dorsicostata* n.sp. (C—holotype, QM MO17729, off Cairns, Qld, 703 m, length 15.35 mm; D—detail of holotype showing sculptural aspect).

Entalina mirifica (E.A. Smith, 1895)

Figs 141A, 142A,B, 143

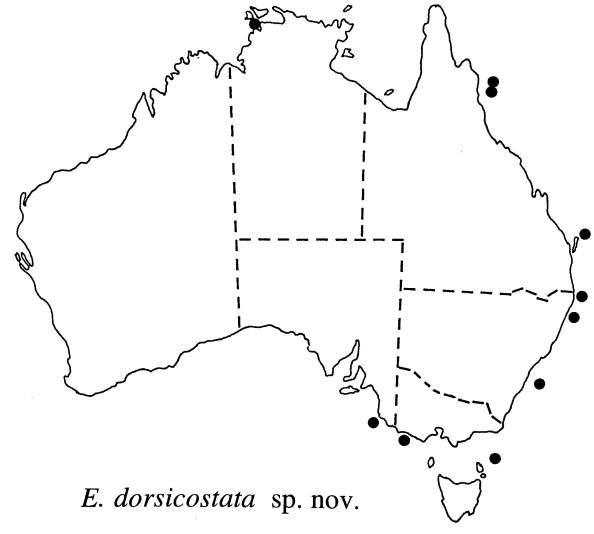
Dentalium mirificum E.A. Smith, 1895: 9, pl. 2, fig. 1; Pilsbry & Sharp, 1897: 134, pl. 20, fig. 29; Boissevain, 1906: 62, pl. 2, fig. 37; Habe, 1964: 33, pl. 5, figs 69, 70.

Type material examined. HOLOTYPE: BMNH 1895.7.2.26. Type locality: Trincomalee, Ceylon (Sri Lanka), 200–350 fathoms [366–640 m]. PARATYPE examined, same number and data as holotype. Length of holotype 17.0 mm, aperture diameter 2.0 mm, apex diameter 0.5 mm. Length of paratype 15.7 mm. Aperture diameter 2.45 × 2.0 mm, apex diameter 0.7 mm.



E. mirifica

Figure 143. Australian distribution of *Entalina mirifica* (Smith, 1895).



E. dorsicostata sp. nov.

Figure 144. Known distribution of *Entalina dorsicostata* n.sp.

Additional material examined. 1, AMS C165282, 10°29.81'S 144°00.39'E, east north-east of Cape York Peninsula, 495–534 m, 20 August 1988.

Description. Shell length to 17.0 mm (holotype), aperture diameter 2.0 mm, apex diameter 0.5 mm; strongly curved, quadrate tubular, wider along the dorsal side than the ventral, centrally along the dorsal side the shell gradually forms a fifth angle towards the apex. Sculpture of fine transverse growth lines and numerous, minor, longitudinal ribs. Aperture is shaped like the letter D. Apex five sided, the ventral side narrower than the dorsal, the four lateral angles each have two parallel sided ribs while the central dorsal side angle has a single rib. Colour white.

Range. Sri Lanka (type series), Indonesia (Boissevain, 1906), Japan (Habe, 1964), Cape York Peninsula (Queensland).

Habitat. Dredged in sand and rubble from 183 to 640 m.

Comparisons and remarks. *Entalina mirifica* is readily distinguished from other members of the genus by its possession of a D-shaped aperture. This is the first record of this rare species from Australian waters.

Entalina dorsicostata n.sp.

Figs 141B, 142C,D, 144

Etymology. Name indicating the presence of minor ribs on the dorsal (concave) surface of the shell.

Type material examined. HOLOTYPE: QM MO17729. Type locality: off Cairns, northern Qld, 17°50.67'S 147°18.2'E, 703 m, 17 May 1986. Length of holotype 15.35 mm, aperture diameter 1.6 mm laterally, dorsoventrally 1.5 mm, apex diameter 0.4 mm. PARATYPES: 6, AMS C169774, 37°50–55'S 139°15–25'E, 80 km south-west of Cape Martin, SA, 1555 m, 14 August 1909; 30, AMS C169795, 48 km south of Cape Nelson, Vic., 2000 m; 3, AMS C169989, 34°27–26'S 151°27'E, off Wollongong, NSW, 1200 m, 13 December 1976; 1, AMS C169796, 24°43.5–43.8'S 153°33.4–33.3'E, east of Sandy Cape, Qld, 604 m; 1, QM MO40069, same locality data as holotype; 1, QM MO17756, 17°33'S 146°55'E, northern Qld, 15 May 1986.

Additional material examined. VICTORIA: 9, NMV F72147, 38°25.90'S 148°58.60'E, south of Point Hicks, 1850 m, 22 July 1986 (preserved); 5, NMV F72140, 38°25.00'S 149°00.00'E, south of Point Hicks, 1500 m, 22 July 1986. NEW SOUTH WALES: 1, AMS C172589, 30°01'S 153°37'E, off Coffs Harbour, 713–768 m, 31 March 1969. QUEENSLAND: 3 pieces, AMS C169794, 28°13.8'S 154°06.9'E, off Southport, 1554–1646 m, ooze, 8 November 1976; 1, AMS C173294, 13, AMS C173423, 17°09.42'S 146°42.24'E, off Cairns, 613 m, 13 October 1981; 4, AMS C173428, 17°13.42'S 146°48.54'E, off Cairns, 116 m, 12 October 1981. NORTHERN TERRITORY: 1, AMS C172588, 32 km north of Point Charles, Darwin, 22 m, 7 July 1938.

Description. Shell length to 17.4 mm, aperture diameter laterally to 1.8 mm dorsoventrally to 1.6 mm, apex diameter 0.6 mm; rapidly tapering, strongly curved. Mature specimens with four sides, the dorsal being convex and ornamented with well-defined, evenly spaced minor ribs, the ventral and lateral sides being slightly concave and smooth. Two strong ribs define the angle of adjacent sides. Aperture subquadrate. Apex five-sided, wider dorsally. Juvenile specimens have five weakly concave sides, two of which are dorsal and ornamented with riblets. The dorsal angle of lateral sides in juveniles defined by three ribs. Colour white.

Range. South Australia, Victoria, New South Wales, Queensland to Northern Territory.

Habitat. Dredged in fine mud or ooze from 153 to 2000 m.

Comparisons and remarks. Boissevain (1906) described three species from the Indonesian area—*E. quadrangularis, E. mediocarinata, E. cornucopiae*—none of which have so far been collected from Australia. *Entalina dorsicostata* resembles *E. quadrangularis* Boissevain and *E. platamodes* Watson in having a four sided aperture (in mature specimens), but is distinguishable from these species by the constant presence of riblets on the dorsal surface. *Entalina dorsicostata* differs from *E. mirifica* (E.A. Smith) in having a smoother shell and in lacking the D-shaped aperture profile so characteristic of *E. mirifica*.

Genus *Bathoxiphus* Pilsbry & Sharp, 1897

Dentalium (Bathoxiphus) Pilsbry, & Sharp, 1897: 121; Boissevain, 1906: 48; Ludbrook, 1960: I38; Emerson, 1962: 473, pl. 78, fig. 3; Habe, 1964: 33; Palmer, 1974a: 120; Steiner, 1992a: 397.

Type species: *Dentalium ensiculus* Jeffreys, 1877; by subsequent designation, Boissevain (1906).

Diagnosis. Shell thin to thick, conspicuously compressed laterally, nearly or quite smooth, with a broad notch on the convex side of the apex (Pilsbry & Sharp, 1897: 121).

Key to Australian *Bathoxiphus*

1 Lateral compression strong, forming keels 2

—— Lateral compression only moderate, forming no angles or archs in adults but in juveniles two faint ridges appear on each lateral side 3

2 Lateral compression more pronounced ventrally, each side meeting at a sharp keel ..... *B. colmani*

—— Lateral compression forms a narrow arch on the ventral and a sharp keel on the dorsal curve ..... *B. tricarinatum*

3 Shell showing few longitudinal striae ..... *B. steineri*

—— Shell surface entirely covered with longitudinal striae ..... *B. stanisici*

Bathoxiphus tricarinatum (Boissevain, 1906)

Figs 141C, 145A–C, 146

Dentalium tricarinatum Boissevain, 1906: 48, pl. 6, figs 40, 41; Habe, 1964: 33, pl. 5, figs 69, 70.

Type material examined. LECTOTYPE: here accepted as being designated by Habe (1964) from lot ZMA (no number), largest specimen of three in lot, Stn. 178, 2°40.0'S 128°37.5'E, Ceram Sea, 835 m, blue mud. Type locality as for lectotype (designated by Habe). Length of lectotype, 21.5 mm; aperture diameter 2.5 × 1.6 mm. Lectotype not examined. PARALECTOTYPES (2): paralectotype no. 1, ZMA (no number), stn 300 Siboga Expedition, 10°48.6'S 123°31.1'E, east Timor Sea, 918 m, fine grey mud. Length paralectotype no. 1 21.7 mm, aperture diameter 2.7 × 1.7 mm, apex diameter 0.7 × 0.11 mm. Paralectotype no. 2 from stn 300: same locality data as lectotype. Length of paralectotype 19.3 mm, aperture 2.4 × 1.6 mm, apex 0.8 × 0.5 mm.

Additional material examined. NEW SOUTH WALES: 2, NMV F72203, 30°31'S 161°54.2'E, Tasman Sea, 1210 m, 29 December 1975; 12, NMV F72152, 34°51.90'S 151°12.60'E, off Nowra, 770 m, 15 July 1986; 50, AMS C173220, 33°33'S 152°05'E, north-east of Sydney, 750 m; 3, AMS C173223, 52.5 km east of Sydney, 1600 m. QUEENSLAND: 1, AMS C169970, 24°43.5–43.8'S 153°33.4–33.3'E, east of Sandy Cape, 604 m; 9, AMS C169971, 24°28.2'S 153°31.2'E, north-east of Sandy Cape, 1330–1380 m; 1, KLColl, 24°28.2'S 153°31.2'E, northeast of Sandy Cape, 1330–1380 m; 1, AMS C173424, 16°37.42'S 146°20.24'E, off Cairns, 686 m, 13 October 1981; 11, QM MO40076, 1, QM MO40070, 10°01'S 145°00'E, 1777 m, 11 February 1992; 3, QM MO40075, 13°50'S 146°39'E, 1553 m, 6 September 1988; 1, QM MO40073, 17°46'S 147°49'E, off Cairns, northern Qld, 1224 m; 13, QM MO40072, 17°22'S 146°55'E, off Cairns, northern Qld, 916 m, 15 May 1986; 1, QM MO17756, 17°32.70'S 146°54.8'E, off Cairns, northern Qld, 16 May 1986; 1, QM MO40071, 9°47'S 145°16'E, north-east of Thursday Island, 1764 m, 11 February 1992; 6, AMS C165305, 10°35.8'S 144°44.81'E, Coral Sea, 1382–1438 m, 21 August 1988; 1, AMS C165354, 10°35.83'S 144°30.65'E, Coral Sea, 1108–1161 m, 21 August 1988; 1, AMS C174648, 10°35.8'S 144°44.61'E, Coral Sea, 1438 m, 21 August 1988 (preserved).

Description. Shell length to 21.7 mm, aperture diameter 2.7 mm dorsoventrally 1.7 mm laterally, apex diameter 0.7 × 0.11 mm; well curved, strongly compressed laterally, forming a narrow arch ventrally and a sharp keel dorsally. Sculpture of one longitudinal rib or keel on each lateral side, closer dorsally, and numerous close-set lateral striae covering the ribs and the interstices. Aperture keeled on the ventral margin and narrowly arched on the dorsal margin, not oblique. Apex with a wide deep notch cutting away the convex side of the apex; margin on the ventral side thin-edged, on the dorsal side thick-edged. Colour white.

Figure 145. *Bathoxiphus*. **A–C** *B. tricarinatum* (Boissevain, 1906) (A—paralectotype ZMA no number, East Timor Sea, 918 m, length 19.3 mm; B,C—AMS C169971 northeast of Sandy Cape, Qld, 1330–1380 m, length B, C 17.5 mm). **D,E** *B. colmani* (Palmer, 1974) [D,E—*B. colmani* (Palmer, 1974) holotype, AMS C22652, 52.5 km east of Sydney, NSW., 1463 m, length 23.5 mm]. **F** *B. steineri* n.sp. (holotype, QM MO40078, off Cairns, Qld, 1379 m, length 21.0 mm). **G** *B. stanisici* n.sp. (holotype, AMS C173420, off Cairns, Qld, 1477 m, length 15.9 mm).

Range. Indonesia (Boissevain, 1906), Japan (Habe, 1964), New South Wales to northern Queensland.

Habitat. Dredged in coarse gritty sand or grey mud from 750 to 1788 m.

Comparisons and remarks. Habe (1964), by designating a "type locality" and "type" specimen from Boissevain's syntype series of *B. tricarinatum* (4 lots, all in the Zoological Museum, Amsterdam) has fulfilled all the requirements of Article 74(b) of the International Code on Zoological Nomenclature ("Designation of a lectotype by inference of holotype") (see discussion under *Laevidentalium largicrescens* (Tate) for details of this Article).

Bathoxiphus tricarinatum differs from *B. colmani* (Palmer, 1974) and *B. steineri* n.sp., in having a

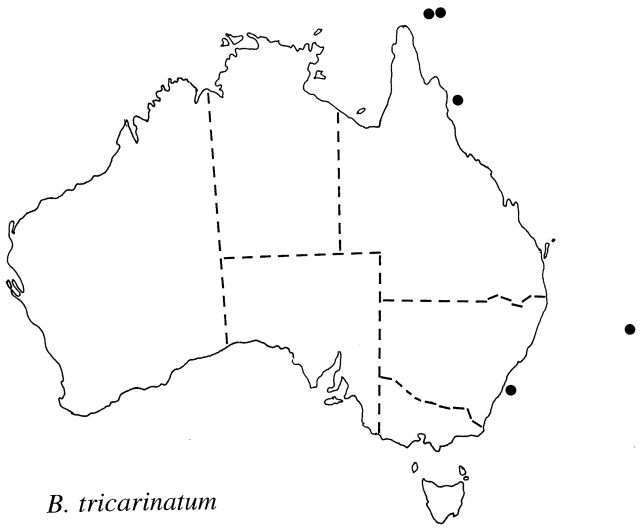


Figure 146. Australian distribution of *Bathoxiphus tricarinatum* (Boissevain, 1906).

dorsal and ventral keel with an angle on each lateral side dorsally. The shell does not show the marked dorsal thickening observed in *B. colmani*.

Bathoxiphus colmani (Palmer, 1974)

Figs 141D, 145D,E, 147

Dentalium colmani Palmer, 1974b: 124. Colman, 1958: 145, pl. 1, fig. 12; Iredale & McMichael, 1962: 97; Palmer, 1974b: 124, non Torley, 1908.

Type material examined. HOLOTYPE: AMS C26652. Type locality: 52.5 km east of Sydney, NSW, 1463 m. Length of holotype 8.4 mm, aperture diameter 1.0 mm dorsoventrally × 0.6 mm laterally, apex 2.1 mm. PARATYPES: 24, AMS C170645, 52.5 km east of Sydney, 1463 m, 26–27 October 1906. This type material is that used by Colman (1958) in describing *Dentalium applanatum*.

Additional material examined. WESTERN AUSTRALIA: 2, WAM 263-93, 32°03.5'S 115°06'E, south-west of Rottnest Island, 15 March 1976; 3, SAM D18927, 192 km west of Eucla, 600 m, January 1958. TASMANIA: 1, AMS C173226, 42°02.5'S 148°21.15'E, 15 km Cape Mistaken, Maria Island, 714 m, 25 March 1970. VICTORIA: 4, SAM D18928, Port Albert. NEW SOUTH WALES: 6, AMS C173230, 34°50'S 151°15'E, off Nowra, 841 m, 12 December 1978; 15, AMS C173233, 34°05'S 151°43.6'E, off Sydney, 750 m, 3 November 1976, sandy mud and fine shell; 20, AMS C173228, 33°41'S 151°56'E, north-east of Sydney, 741 m, 5 December 1977; 3, AMS C173227, 33°35–37'S 154°05'E, off Sydney, 1143 m, 10 December 1980; 31, AMS C311594, 33°44'S 151°57'E, east of Sydney, 322 m, 7 December 1978; 11, AMS C173234, 33°31–33'S 152°08–07'E, off Sydney, 914 m, 10 December 1980; 1, AMS C172640, 33°37–39'S 152°04–02'E, off Sydney, 896–924 m, 10 December 1980; 6, AMS C173232, 33°27'S 152°05'E, off Sydney, 366 m, 31 October 1972; 1, AMS C173224, 33°35'S 152°09'E, off Sydney, 1097 m, 4 December 1979; 3, AMS C173222, 33°32'S 152°08'E, east of Broken Bay, 914 m, 4 December 1979; 1, AMS C173291, 33°02.6'S 153°04.4'E, south of Newcastle, 3658 m, 8 October 1982 (preserved); 1, AMS C173225, off Broken Bay, 1800 m, 6 December 1979 m; 1, AMS C173229, 33°26'S 152°43'E, east of Broken Bay, 877 m, 6 December 1979.

Description. Shell length to 23.5 mm, aperture diameter (dorsoventral) 2.9 mm, 2.1 mm laterally, apex diameter 1.0 mm; fragile, strongly curved, flattened laterally, more so ventrally, where each side forms a sharp keel; reinforced dorsally with a thick ridge extending longitudinally along the shell. Two faint ridges extend on the external surface along the dorsal side indicating the beginning of the reinforcing ridge. Aperture very oblique. Apex with a broad notch ventrally, this notch cuts away about half of the posterior end. Sculpture of growth lines only. Colour dull white.

Range. Southern Western Australia, Tasmania, Victoria to South New South Wales.

Habitat. Dredged in sandy mud from 241 to 3658 m.

Comparisons and remarks. This species most closely resembles *B. tricarinatum* (Boissevain). Features which differentiate *B. colmani* from *B. tricarinatum* include: a dorsal and ventral keel only (only a hint of lateral keels); pyriform aperture profile. The aperture profile of *B. steineri* n.sp. is ovate, with some lateral compression. The shell of *B. colmani* is very thick dorsally in comparison to both *B. tricarinatum* and *B. steineri*. Although Habe, 1964: 34, listed *B. applanatum* = *B. colmani* as a synonym of *Bathoxiphus soyomaruae* Okutani, 1964, our comparison of the holotypes of *B. soyomaruae* (a specimen very distorted apically) and *B. colmani* leads us to conclude that both are valid species, *B. colmani* in fact being much more laterally compressed than *B. soyomaruae*.

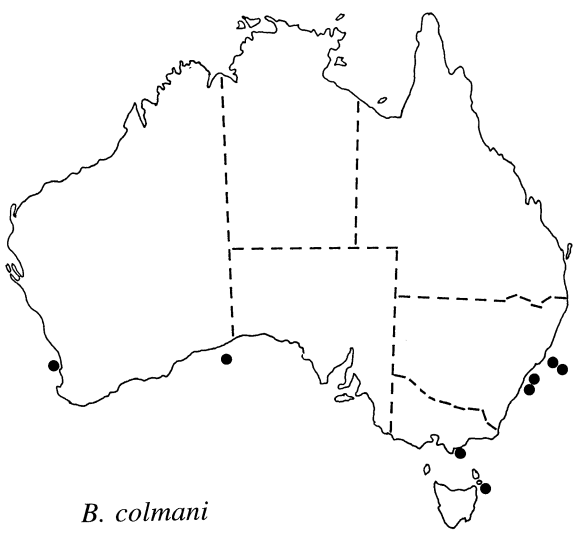


Figure 147. Known distribution of *Bathoxiphus colmani* (Palmer, 1974).

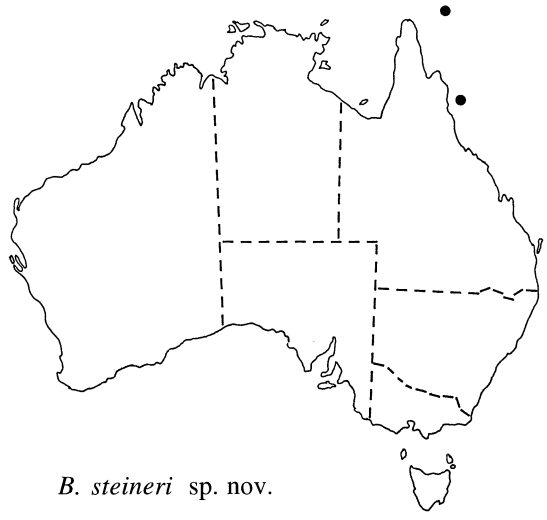


Figure 148. Known distribution of *Bathoxiphus steineri* n.sp.

Bathoxiphus steineri n.sp.

Figs 141E, 145F, 148, 166E,F

Etymology. Named after Dr Gerhard Steiner (Institute of Zoology, University of Vienna) in recognition of his recent work on the anatomy, phylogeny and classification of the Scaphopoda.

Type material examined. HOLOTYPE: QM MO40078. Type locality: 10°51'S 145°49'E, north-east Thursday Island, 1379 m. Length of holotype 21.0 mm, aperture diameter (dorsoventrally) 1.4 mm, 1.1 mm (laterally); apex diameter 0.6 × 0.5 mm. PARATYPES: 1, AMS C175551, 16°43.1–42.1'S 146°37.3–36.4'E, 1468–1477 m, 13 October 1981; 3, QM MO40079, same locality data as holotype; 2, QM MO40080, 10°01'S 145°00'E, northern Qld, 1777 m, 11 February 1992; 12, QM MO40081, 17°46'S 147°49'E, northern Qld, 1224 m, 10 May 1986; 1, AMS C175551, 16°43'06"–42'06"S 146°37'18"–36'24"E, off Cairns, northern Qld, grey clay 1468–1477 m.

Additional material examined. 8 pieces, QM MO40077, 10°01'S 145°00'E, northern Qld, 1777 m, 11 February 1992; 2, AMS C165355, 18°06.63'S 147°27.08'E, Great Barrier Reef, Qld, 950–978 m, 25 August 1988.

Description. Shell length to 21.0 mm, aperture diameter 1.4 mm (dorsoventrally) × 1.1 mm (laterally), apex diameter 0.6 × 0.5 mm; moderately curved, glossy, compressed laterally, moreso ventrally, in juvenile specimens this compression gives the young shell four ribs, two on each of the lateral sides, in adult specimens these ribs are not evident but the compression of the two sides is quite obvious. Sculpture of numerous, microscopic, longitudinal striae and stronger transverse growth ridges. Aperture obovate. Apex obovate, thickened with a small orifice. Colour white.

Radula. Central tooth unobservable in preparation; laterals 70 μm long, curved, scythe-like with a few large pointed cusps and several small pointed cusps on the working surface; marginals almost straight, narrow 80 μm long (sex not determined) (Fig. 166E,F).

Range. Northern Queensland.

Habitat. Dredged in coarse gritty sand from 950 to 1777 m.

Comparisons and remarks. *Bathoxiphus steineri* differs from both *B. colmani* (Palmer) and *B. tricarinatum* (Boissevain) in not having any sharp longitudinal angles or ribs, the aperture being obovate (laterally compressed).

Bathoxiphus stanisici n.sp.

Figs 145G, 149, 150A

Etymology. Named after Dr John Stanisic, Malacology Section, Queensland Museum, in appreciation of his assistance during the course of this study and previous projects.

Type material examined. HOLOTYPE: AMS C173420. Type locality: off Cairns, 16°43.06'S 146°37.18'E, northern Qld, 1477 m, 13 October 1981. Length of holotype 15.9 mm, aperture diameter 1.15 mm (dorsoventrally) × 0.7 mm (laterally). PARATYPE: 1, AMS C173421, same locality data as holotype.

Description. Shell length to 15.9 mm, aperture diameter 1.15 × 0.7 mm; apex diameter 0.4 mm; moderately tapering, very slender, moderately curved. Sculpture of microscopic longitudinal striae and fine transverse growth lines. Aperture cylindrical, the convex side slightly laterally compressed. Apex with an apical plug but without a supplementary pipe. Colour glossy white.

Range. Northern Queensland.

Habitat. Dredged in coarse sand at 1477 m.

Comparisons and remarks. This species can be readily differentiated from other Australian *Bathoxiphus* spp. by the presence of fine longitudinal striae over the entire shell surface. Live taken specimens have yet to be collected.

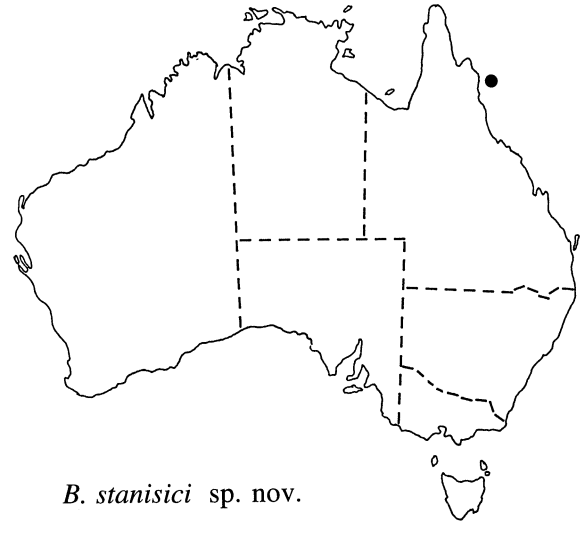


Figure 149. Known distribution of *Bathoxiphus stanisici* n.sp.

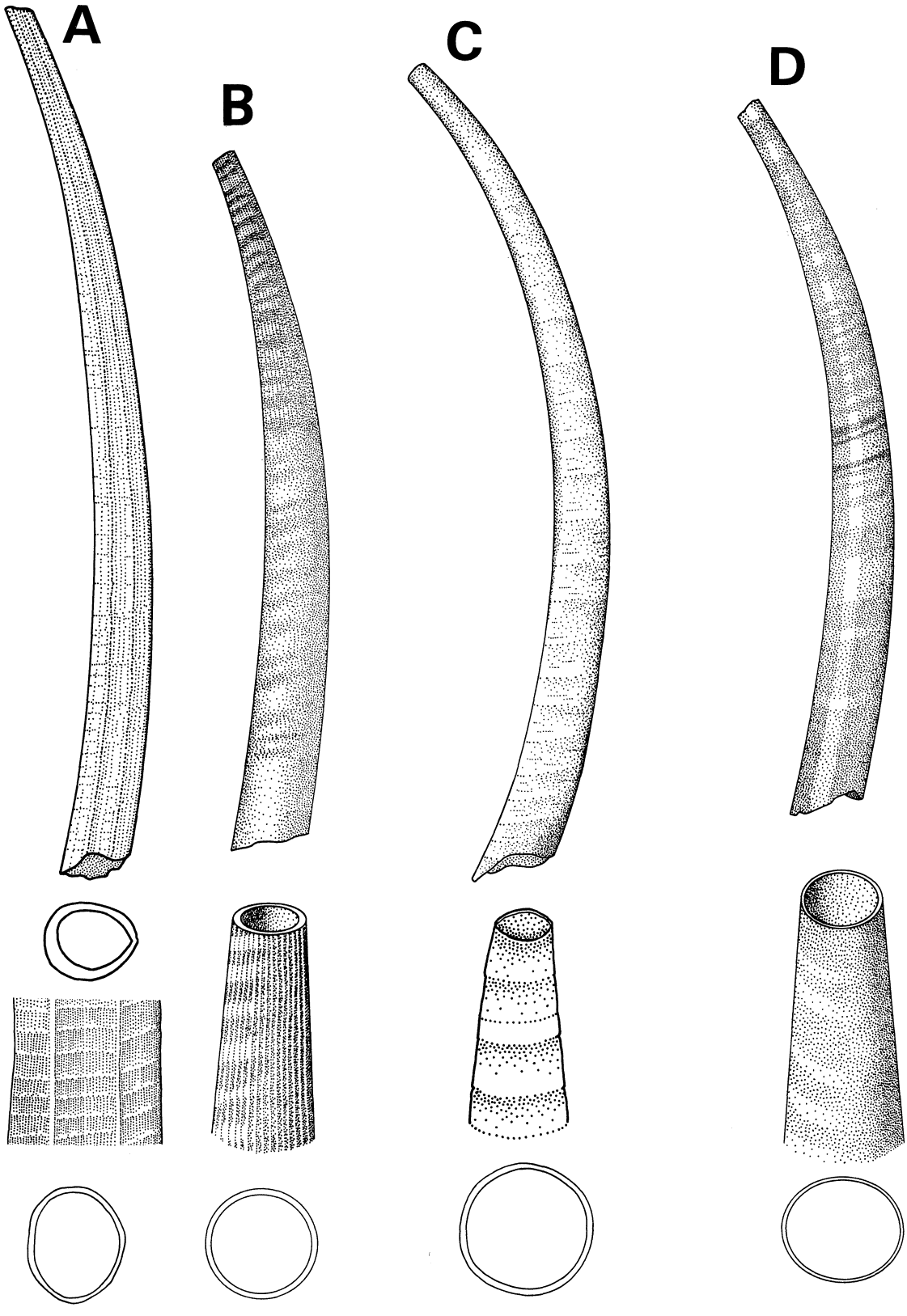


Figure 150. Gadilida. **A** Entalinidae, *Bathoxiphus stanisici* n.sp. (holotype, AMS C173420, off Cairns, Qld, 1477 m, length 15.9 mm). **B–D** Pulsellidae. **B** *Pulsellum eboracense* (Watson, 1879) (KL col., vicinity of Gladstone Power Station, Qld, length 9.8 mm). **C** *P. beecheyi* n.sp. (holotype, AMS C174890, 200 km north of Croker Is, NT, 145 m, length 10.0 mm). **D** *Compressidens platyceras* (Sharp & Pilsbry, 1897) (AMS C172625, Broken Bay, NSW, 7 m, length 10.5 mm). (Del.: A and C—A. Hill; B and D—C. Eadie).

Suborder GADILIMORPHA Steiner, 1992a

Diagnosis. Shell not ribbed, seldom bearing striae, but is mostly smooth and polished. The cross section is circular or depressed in cross-section. The rachis [central] tooth carries at least one cusp, the lateral teeth always 3. The marginal teeth are keeled. Two large central pedal retractor muscles originate directly from the dorsoventral muscles and traverse the intestinal sinus, the pedal base and the middle piece to insert at the terminal disk. The centre of the disk is covered by a mucoid epithelium, (Steiner, 1992a: 398).

Family PULSELLIDAE Boss, 1982

Diagnosis. Shell typically small, smooth to glossy, weakly to strongly curved, sculpture consisting of oblique growth lines and sometimes fine striae posteriorly; aperture is widest part of the shell and is not contracted; apex simple without notch, slit, pipe or plug. According to Steiner (1992a: 398) the rachis or central tooth of each radular row has a single median denticle. Other anatomical details as for suborder.

Genus *Pulsellum* Stoliczka, 1868

Pulsellum Stoliczka, 1868: 138; Cossmann, 1888: 15; Pilsbry & Sharp, 1897: 138; Henderson, 1920: 92; Ludbrook, 1960: I40; Emerson, 1952: 475; Habe, 1964: 43; Palmer, 1974a: 120; Steiner, 1992a: 398.
Siphonentalis G.O. Sars, 1878: 104.
Siphonodentalis Clessin, 1896: 30.

Type species: *Pulsellum lofotense* M. Sars, 1865; by subsequent designation, Cossmann, 1888.

Diagnosis. Smooth, circular or subcircular in section, moderately to strongly curved; apex simple without lobes or notches, growth lines oblique.

Key to Australian *Pulsellum*

1 Translucent and transparent in alternate bands; shell with fine longitudinal striae in fresh specimens; shell moderately curved ..... *P. eboracense*

—— Shell surface glossy without longitudinal sculpture; shell strongly curved ..... *P. beecheyi*

Pulsellum eboracense (Watson, 1879)

Figs 150B, 151A,B, 152

Siphodentalium eboracense Watson, 1879: 523; Watson, 1886: 17, pl. 2, fig. 10; Pilsbry & Sharp, 1897: 140, pl. 26, fig. 75; Boissevain, 1906: 64, pl. 3, fig. 44; Hedley, 1910: 371.

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1887.2.9.69. Type locality: Torres Strait, Cape York, north-east Australia, 3–11 fathoms [5.5–20 m], 7 September 1874. Length of lectotype 5.0 mm, aperture diameter 0.6 mm, apex diameter 0.2 mm. PARALECTOTYPES 1–3, same locality data as lectotype.

Additional material examined. NEW SOUTH WALES: 24, AMS C172466, Killcare Bay, Brisbane Waters; 3, AMS C172460, off Jibbon, Port Hacking, 80 m, September 1964; 1, AMS C172332, Ocean Beach, Manly; 1, AMS C172339, 32°22'S 152°57'E, 38 km east of Forster, 247 m, 27 February 1972. QUEENSLAND: 1, AMS C172290, Peel Island, Moreton Bay, 1955; 1, AMS C172297, Green Island, Moreton Bay, dredged; 32 juveniles, AMS C172338, Hervey Bay; 6, AMS C172451, Hervey Bay; 12, AMS C172445, 21°58.5'S 150°45'E, east of Broad Sound, 57 m, coarse to fine mud and shell, 18 November 1977; 1, AMS C172456, Dundowran, beach shell sand, 1963; 2, AMS C172318, south of Urungan Boat Anchorage, Hervey Bay, 24 October 1976; 1, AMS C172427, Pialba, Hervey Bay, in debris among rocks, October 1972; 3, AMS C20840, Bundaberg; 1, AMS C172421, 24°37.2'S 152°33'E, off Bundaberg, 22 m, 12 October 1970; 10, AMS C172295, 5 km west of North Keppel Island, Keppel Bay; 1, AMS C172291, 22°21'S 150°39'E, Island Head Creek, 80 km north of Yeppoon, August 1978; 4, AMS C172306, off Yeppoon, Keppel Bay, 5 m; 1, AMS C172342, Lammermoor Bch, Yeppoon, September 1972; 1, AMS C172286, 23°57'S 151°22'E, Tannum Beach; 1, AMS C172298, Tannum Beach, beach sand, 22 December 1976; 1, AMS C172313, 23°49'S 151°17'E, Quoin Island, Port Curtis, 1.5 m; 5, AMS C172469, Facing Island, Port Curtis; 41, AMS C172316, Facing Island, Port Curtis; 5, AMS C172343, Gladstone Harbour; 14, AMS C172423, Tannum Sands, Gladstone, shell sand, 1969; many, AMS C173300, Gladstone Power Station, Calliope River, 1974–83; 11, AMS C172320, 20°03'S 148°50'E, west of Hayman Island, 33 m, 19 November 1977; 3, AMS C172308, 20°52'S 149°29'E, east of Mackay, 35 m, 19 November 1977; 110, AMS C169791, Shoal Point, Mackay, June 1972, beach; 1, AMS C172418, Shoal Point, Mackay, shell sand from reef between Green Island and shore, June 1972; 8, AMS C2587, Cape Sidmouth; 16, AMS C172322, 17, AMS C172417, Cape Sidmouth, 24 m; 20, AMS C169980, Gladstone Power Station, Calliope River, 1974 and 1983; 1, AMS C172611, 23°19.5'S 152°35.4'E, east of North West Island, 320 m, *Globigerina* mud, 14 December 1977; 7, AMS C311190, 20°32.3'S 149°01.4'E, Whitsunday Passage, 27 m, shelly muddy sand, 19 November 1977; 1, AMS C172312, Sinclair Bay; 10, AMS C172303, 19°45.7'S 148°19'E, 46 m, 19 November 1977, thin grey mud; 1, AMS C172304, Henning Island, off Bowen, June 1950; 15, AMS C172446, Bowen; 1, AMS C172444, Sarina Beach, 5 July 1969; 6, AMS C172299, 21°27.5'S 150°08'E, east of Sarina, 42 m, 13 December 1977; 1, AMS C172319, 3, AMS C172464, off Horseshoe Bay, Magnetic Island, Townsville, 8 October 1965; 4, AMS C172452, Horseshoe Bay, Magnetic Island, off Townsville, 1959; 17, AMS C172449, Cape Pallarenda, Townsville, August 1972; approx 300, AMS C10242,

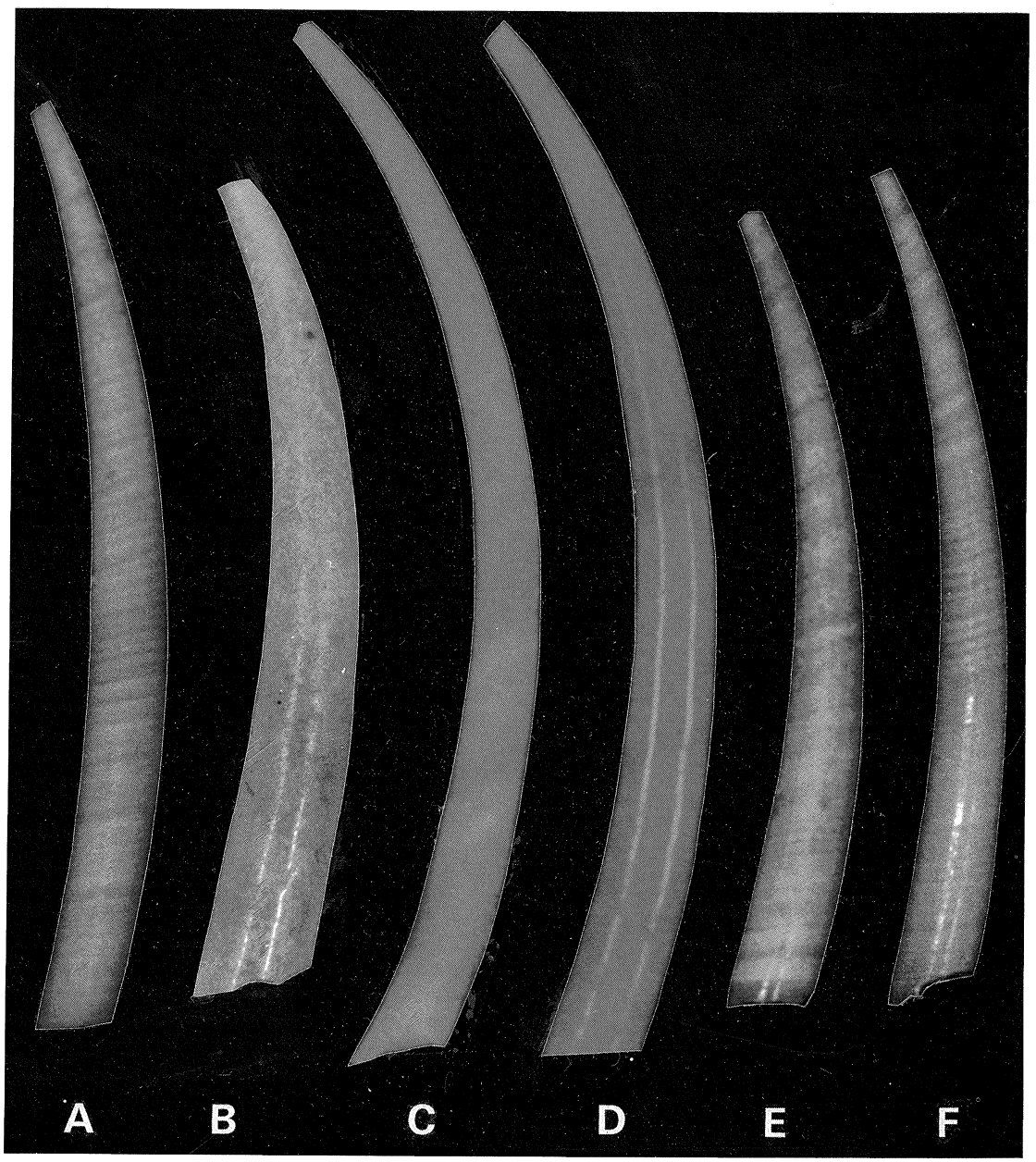


Figure 151. Pulsellidae. **A–C** *Pulsellum*. **A** *P. eboracense* (Watson, 1879) (A—KLColl, vicinity of Gladstone Power Station, length 9.8 mm. **B** *P. beecheyi* n.sp. (holotype, AMS C174890, 200 km north of Croker Island, NT, 145 m, length 10.0 mm), **C** detail of holotype. **D,E** *Compressidens platyceras* (Sharp & Pilsbry, 1897) (AMS C172625, Broken Bay, NSW, 7 m, lengths 9.0 mm, 10.5 mm).

Palm Island, 30 m; 1, AMS C172424, Pipon Island, off Cape Melville, 15 m; 4, AMS C172465, 17°52'S 146°06'E, Mission Beach, 27 September 1980; 14, AMS C172454, 14°50'S 145°17'E, Decapolis Reef, Cape Flattery, 12–14 m, mud, 25 February 1979; 1, AMS C172461, Lucinda, tide washings on extensive mud-sand flats, 1 June 1977; 24, AMS C172334, 54, AMS C172443, Cairns Harbour; 5, AMS C172337, approx 3 km north of Ellis Beach, north of Cairns, July 1964; 8, AMS C172336, Cairns; 1, AMS C172329, 16°52–53'S 146°06'E, off Cairns, 37–38 m, 8 October 1981; 1, AMS C172331, 16°45'S 145°40'E, Palm Beach; 1, AMS C172311, Buchans Point, north of Cairns, July 1964; 1, AMS C172448, west of Rocky Point, Lizard Island, 15 m, fine, muddy sand and *Caulerpa*, 1–12 December 1974; 1, AMS C172292, Four Mile Reef, Port Douglas, July 1972; 3, AMS C172301, Low Isles, near Port Douglas, 1929; 8, AMS C172310, Low Isles, near Port Douglas, 16–22 m, 24 April 1929; 3, AMS C173910, 16°23'S 143°34'E, Low Isles, near Port Douglas, October-November 1928; 1, AMS C172309, Flinders Island, near Cape Melville, 26 m, in anchorage; 2, AMS C172457, Somerset, Cape York Peninsula, 10 July 1976; 3, AMS C172317, north of Terry Beach, Prince of Wales Island, Torres Strait, 30 June 1976; 1, AMS C172327, 3 km off Yorke Island, Torres Strait, 18 m, hard yellow mud bottom; 1, AMS C172349, 3 km off Yorke Island, Torres Strait, Qld. 18 m, hard yellow mud; 6, AMS C172464, Saibai Village, Saibai Island, Torres Strait, muddy sand and rock, 7 July 1976; 1, AMS C172287, 22, AMS C172300, 4.9 miles off Albert River mouth, Gulf of Carpentaria, December 1963; 17, AMS C100498,

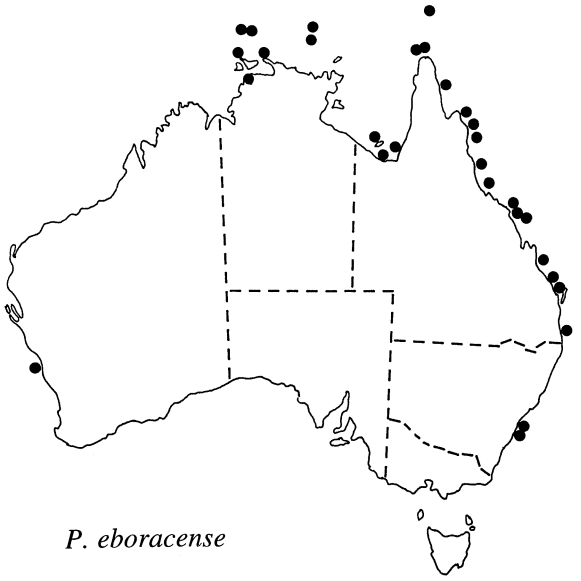


Figure 152. Australian distribution of *Pulsellum eboracense* (Watson, 1879).

1, AMS C303601, Karumba, Gulf of Carpentaria, December 1963; 1, AMS C14577, Mornington Island. NORTHERN TERRITORY: 1, AMS C172416, 8°26'S 135°22'E, 321 km north-west of Wessel Island, Arnhem Land, 75 m, 13 October 1969; 1, AMS C172294, Mouth of Caiman Ck, Berkeley Bay, Port Essington, Cobourg Peninsula, on sand bank, 2 June 1976; 1, AMS C172340, 9°23'S 131°22'E, 200 km north of Melville Island, 215 m, clayey sand, 15 November 1969; 1, AMS C172328, 10°26–26'S 136°03–07'E, Arafura Sea, 52 m, mud, 21 November 1980; 1, AMS C172345, 8°26'S 135°22'E, north-west of Wessel Island, Arafura Sea, 75 m, 13 October 1969; 4, AMS C172415, 9°30'S 132°34'E, approximately 642 km north of Croker Island, Arafura Sea, 124 m 9 November 1960; 1, AMS C172624, 8°36'S 135°08'E, north of Wessel Island, Arafura Sea, 82 m, 15 November 1969; 1, AMS C172426, 9°07'S 132°33'E, 205 km north of Croker Island, 218 m, clayey sand, 9 November 1969; 8, AMS C172307, Darwin, on sandbar, 8 October 1971; 3, AMS C172363, off Point Charles, north-west of Darwin, 27–37 m, 1960; 1, AMS C172422, Port Darwin; 62, AMS C7306, Port Darwin; 10, AMS C172302, off Emery Point, Darwin, on sand bar, 25 October 1969; 19, AMS C172315, sandbar no. 1, Darwin, 14 November 1970; 1, AMS C172325, 12°24'S 150°49'E, Ludmilla Creek, Darwin, sand in front of mangroves, 28 June 1983; 24, AMS C172335, sandbar no. 2, Darwin, 1 November 1970; 1, AMS C172305, 8°48'S 134°58'E, 365 km north of Milingimbi Island, Arnhem Land, 100 m, 18 October 1969. WESTERN AUSTRALIA: 1, AMS C172341, 29°28.0–28.5'S 114°11.0–11.2'E, off Pelsart Bank, 183 m, 18 February 1976.

Description. Shell length to 9.8 mm, aperture diameter 0.85 mm, apex diameter 0.25 mm; moderately to well curved; glossy, translucent and transparent in alternate bands. Sculpture of irregular transverse-oblique growth lines; fresh specimens with fine, sharp longitudinal striae near apex. Aperture circular, oblique. Apex circular, simple. Colour white.

Range. New South Wales, Queensland, Northern Territory to northern Western Australia.

Habitat. Sieved in littoral sand and dredged in mud and sand to 321 m.

Comparisons and remarks. The lectotype here chosen from the syntype series matches the description and dimensions given by Watson (1879) and the figure given by Watson (1886). *Pulsellum eboracense* differs from *P. beecheyi* n.sp. in being less curved and in having fine longitudinal striae over the shell surface. Watson (1886) mentions that the fine striae can easily be rubbed off the surface. However, specimens lacking striae cannot be confused with *P. beecheyi* which has a glossy shell surface and greater shell curvature.

Pulsellum beecheyi n.sp.

Figs 150C, 151C,D, 153

Etymology. Named after Mr Desmond Beechey (formerly of the Australian Museum) for his assistance in this study.

Type material examined. HOLOTYPE: AMS C174890. Type locality: 29°14'S 132°54'E, 200 km north of Croker Island, NT, 145 m, in sandy clay, 7 November 1969. Length of holotype 10.0 mm, aperture diameter 0.8 mm, apex diameter 0.3 mm. PARATYPES: 6, AMS C172289, 9°14'S 132°54'E, 200 km north of Croker Island, NT, 145 m, in sandy clay, 7 November 1969; 2, AMS C172288, 17°34'S 120°22'E, approx 212 km north-west of Roebuck Bay, WA, 188 m, 30 November 1967; 7, AMS C172293, 9°18'S 133°38'E, 230 km north of Goulburn Island, NT, 135 m, clayey sand, 1 November 1969; 4, AMS C172296, 9°24'S 133°02'E, 180 km north of Croker Island, NT, 125 m, clayey sand, 7 November 1969.

Additional material examined. QUEENSLAND: 1, AMS C27513, 15°42'S 145°30'E, between Cairns Reef and Hope Island, 18 m, 2–6 August 1906. WESTERN AUSTRALIA (northern): 13, AMS

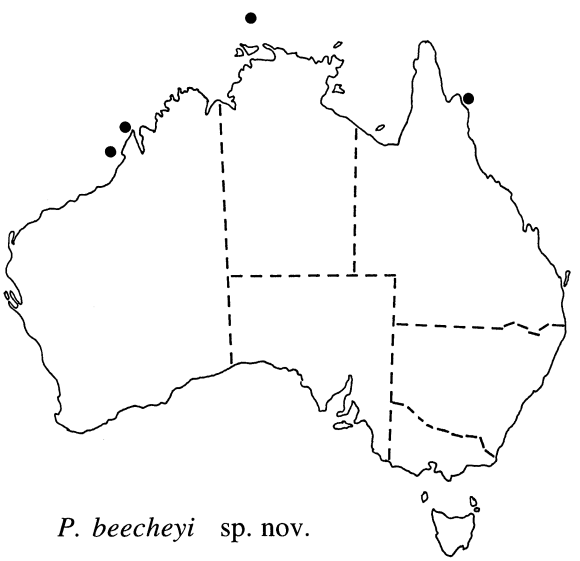


Figure 153. Known distribution of *Pulsellum beecheyi* n.sp.

C172333, 14°07'S 122°52'E, north of Cape Leveque, 256 m, 17 November 1967; 7, WAM 53-94, Exmouth Gulf, grab sample, November-December 1993.

Description. Shell length to 11.3 mm, aperture diameter 0.8 mm, apex diameter 0.3 mm; evenly and strongly curved, fragile, glossy. Sculpture of microscopic transverse growth lines, without longitudinal sculpture. Aperture circular. Apex circular, apical orifice large. Colour bone white when dead, translucent when live.

Range. Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged in sandy mud from 18 to 256 m.

Comparisons and remarks. *Pulsellum beecheyi*, compared with *P. eboracense* (Watson), *P. beecheyi* is more slowly tapering, more curved and lacks the longitudinal striae of that species (shell surface entirely glossy in *P. beecheyi*). This species could possibly be confused with some species of Laevidentaliidae (Order Dentaliida) which also have glossy shells. However, the strongly oblique growth lines of *P. beecheyi* are not observed in any Australian species of Laevidentaliidae, but instead suggest placement of this species in the family Pulsellidae. Examination of the radula and soft parts, whenever animals become available, would be useful in checking our taxonomic assignment of this species.

Genus *Compressidens* Pilsbry & Sharp, 1897

Compressidens Pilsbry & Sharp, 1897: 123; Ludbrook, 1960: I38; Emerson, 1962: 474; Habe, 1964: 29; Palmer, 1974a: 121; Steiner, 1992a, 398.

Type species: *Dentalium pressum* Sharp & Pilsbry, 1897, *in* Pilsbry & Sharp, 1897: 124; by original designation.

Diagnosis. Shell small, decidedly tapering, compressed between the convex and concave sides, weakly sculptured, nearly smooth, anal orifice simple without notch or notch (Pilsbry & Sharp, 1897: 123).

Compressidens platyceras (Sharp & Pilsbry *in* Pilsbry & Sharp, 1897)

Figs 150D, 151D,E, 154

Dentalium platyceras Sharp & Pilsbry, 1897, *in* Pilsbry & Sharp, 1897: 126, pl. 22, figs 58, 59, 60; Hedley, 1917: 112; Colman, 1958: 144, pl. 1, fig. 9; Iredale & McMichael, 1962: 96; Macpherson & Gabriel, 1962: 268.

Type material examined. LECTOTYPE here selected from syntype lot ANSP 35565. Type locality: Port Stephens, NSW. Length 10.8 mm, aperture diameter 1.1 mm dorsoventrally × 1.25 mm laterally. PARALECTOTYPES: 17, ANSP 35565, same locality data as lectotype; 7, AMS C11721, 15–20 m, Salamander Bay, Port Stephens, NSW; 7, AMS C55085, 24 m, Salamander Bay, Port Stephens, NSW.

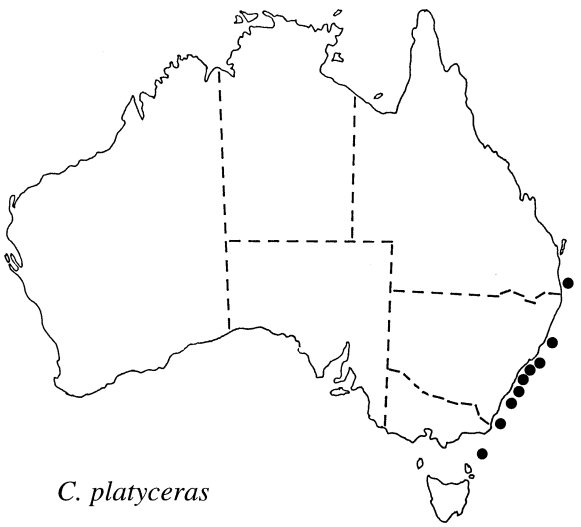


Figure 154. Australian distribution of *Compressidens platyceras* (Sharp & Pilsbry, 1897).

Additional material examined. VICTORIA: 2, NMV F72168, 38°40.29'S 149°18.06'E, 96 km south of Point Hicks, 2900 m, 25 October 1988; 4, AMS C172348, 38°24.00'S 149°08.50'E, 60 km south of Tamboon Inlet, off Gippsland, 7 m, May 1969. NEW SOUTH WALES: 1, AMS C172346, Ulladulla, beach sand, 1950–60; 1, AMS C172347, Narrabeen Beach, Sydney, 1950–60; 2, AMS C172366, Patonga, Broken Bay; 1, AMS C172625, Challenger Head, Broken Bay, 4–7 m, December 1947; 1, AMS C169806, 33°32'S 152°08'E, east. of Broken Bay, 914 m, 4 December 1979; 13, AMS C172630, 14, AMS C172414, 11–16 m, Pittwater, Broken Bay, dredged, 1950–60; 12, AMS C172361, northern end of Towers Bay, Pittwater, 2 m, sand and mud, 4 December 1971; 6, AMS C172344, off Cronulla, 70 m; 38, AMS C172409, dredged Cronulla Bay; many, AMS C173307; 9, AMS C172354, Duck Hole Bay, Port Stephens, 4–6 m, in mud, 26 October 1980 (preserved); 21, AMS C62226, Port Stephens; 3 juveniles, AMS C172463, Fingal Bay, Port Stephens, on beach in shell sand, 1950–60; 94, AMS C173742, 6, AMS C172473, Port Stephens; 3, AMS C172359, Port Stephens; 1, AMS C172358, Port Stephens, 9 m, between beacons; 4, AMS C172305, Port Stephens; 1, AMS C172353, 33°58.48'S 151°15.43'E, 1.5 km south-east of Long Bay, Sydney, 27 m, 20 July 1972; 90, AMS C11971, off Goat Island, Sydney; 2, AMS C172410, Green Point, Watsons Bay, Port Jackson, 9–14.5 m, June 1865; 3, AMS C172455, 33°46'S 151°43'E, east of Port Jackson, 176 m, 5 December 1977; 1, AMS C172350, west Channel, Port Jackson, 27 m, 1955–68; 76, AMS C172622, off Morts Dock, Balmain, Port Jackson, 7 m, 22 October 1963; 1, AMS C172360, south of Sydney, 36–55 m; 21, AMS C172364, Fairlight, North Harbour, 7–11 m, in weed; 2, AMS C88848, Sydney Harbour, 1929–30; 12 AMS C172628, near bridge, Sydney Harbour, mud, 1929–30; 2, AMS C172413, off Balmoral, Middle Harbour, 3.5–9 m, 1950–60; 126, AMS C71616, off Morts Dock, Balmain, Port Jackson Dredge, 8 m; 2, AMS C172355, Green Point, Watsons Bay, Port Jackson, 9–14.5 m, June 1865; 1, AMS C172362, inside Port Stephens, 5.5–13 m, mud, 1950–60; 13, AMS C172412, Soldiers Point, Port Stephens, 22 m; 1, AMS C172408, southern end of Colloroy Beach, Sydney, 14 January 1950; 3, AMS C172351, off Sow and Pigs Reef, Port Jackson, 14 May 1881; 1, AMS C172357, off Sow and Pigs Reef, Port Jackson, 11–14.5 m, 1950–1960; 2 juveniles, AMS C172411,

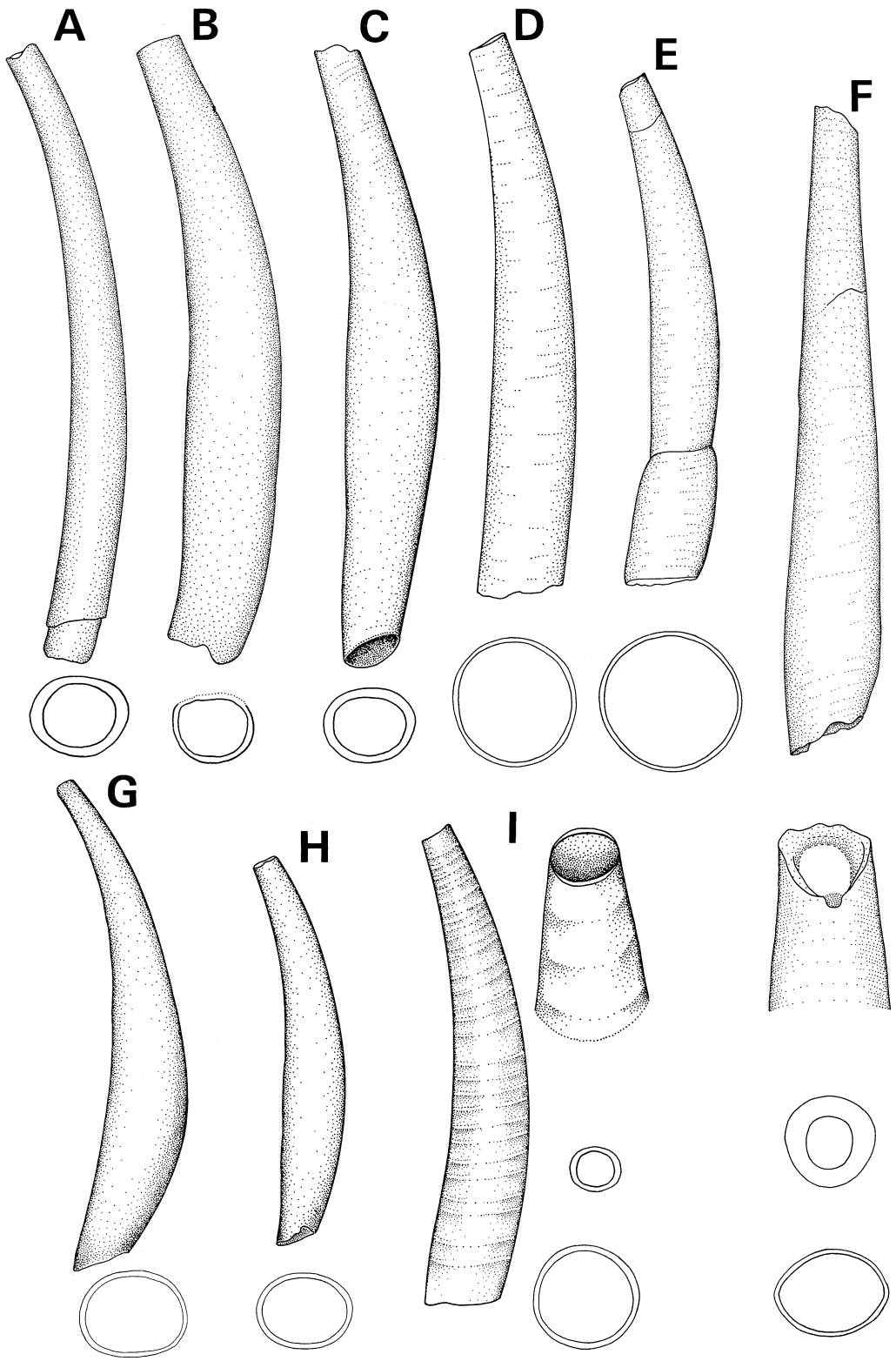


Figure 155. Gadilida, Gadilidae, *Gadila*. **A** *G. angustior* (Verco, 1911) (holotype, SAM D13728, 29 km south-east of Newland Head, SA, 48 m, length 4.6 mm). **B** *G. occiduus* (Verco, 1911) (holotype, SAM D13759, Geographic Bay, off Bunbury, WA, 27 m, length 9.6 mm). **C** *G. whitneyae* n.sp. (holotype, AMS C174636, Buchanan Island, south of Melville Island, NT, length 4.2 mm). **D** *G. bordaensis* (Cotton & Godfrey, 1940) (holotype, SAM D13761, off Cape Borda, Kangaroo Island, SA, 110 m, length 6.0 mm). **E** *G. ludbrookae* (Cotton & Godfrey, 1940) (holotype, SAM D13760, north-west of Cape Borda, Kangaroo Island, SA, 113 m, length 7.0 mm). **F** *G. carlessi* n.sp. (holotype, QM MO40084, east of Cape Melville, Qld, 2710 m, length 19.2 mm). **G** *G. cobbi* n.sp. (holotype, AMS C174638, off Cairns, Qld, 685 m, length 14.8 mm). **H** *G. brycei* n.sp. (holotype, WAM 237/94, NNW of Dampier, WA, 110 m, length 5.7 mm). **I** *G. spretus* (Tate & May, 1900) (lectotype [TM1095] E1202/8543, Port Esperance, Tasmania, 44 m, length 5.5 mm). (Del.: all A. Hill).

Figure 156. Gadilida, Gadilidae, *Gadila*. **A** *G. angustior* (Verco, 1911) (holotype, SAM D13728, 29 km south-east of Newland Head, SA, 48 m, length 4.6 mm). **B** *G. occiduus* (Verco, 1911) (holotype, SAM D13759, Geographic Bay, off Bunbury, WA, 27 m, length 9.6 mm). **C** *G. bordaensis* (Cotton & Godfrey, 1940) (holotype, SAM D13761, off Cape Borda, Kangaroo Island, SA, 110 m, length 6.0 mm). **D** *G. cobbi* n.sp. (holotype, AMS C174638, off Cairns, Qld, 685 m, length 14.8 mm). **E** *G. ludbrookae* (Cotton & Godfrey, 1940) (holotype, SAM D13760, north-west of Cape Borda, Kangaroo Island, SA, 113 m, length 7.0 mm). **F** *G. whitneyae* n.sp. (holotype, AMS C174636, Buchanan Island, south of Melville Island, NT, length 4.2 mm). **G** *G. brycei* n.sp. (holotype, WAM 237/94, NNW of Dampier, WA, 110 m, length 5.7 mm). **H-J** *G. spretus* (Tate & May, 1900) (H—SAM D18919, 48km west of Eucla, Great Australian Bight, 144m, length 4.5 mm. **I** Paralectotype, SAM D15848, Port Esperance, southern Tasmania, 44 m, length 4.0 mm. **J** Lectotype (TM 1095) E1202/8543, Port Esperance, southern Tasmania, 44 m, length 5.5 mm).

Eden Harbour, 1955–68; 1, AMS C172352, Simpsons Beach, Bundeena, Port Hacking, September 1944; 2, AMS C173929, 14.5 km north-east of Coffs Harbour, 82 m. QUEENSLAND: 1, AMS C172419, Green Island, Moreton Bay, dredged.

Description. Shell length to 12.0 mm, aperture diameter 1.1 mm dorsoventrally × 1.3 mm laterally, apex diameter 0.75 mm; slender, smooth to polished when worn, otherwise dull and rough. Sculpture of irregular oblique growth rings, with fine longitudinal striae towards the apex. Aperture oblique, dorsoventrally compressed. Apex circular, simple. Colour white or dirty brown, opaque.

Range. Victoria, New South Wales to southern Queensland.

Habitat. Sieved from littoral sand and dredged in mud and sand to 2900 m.

Comparisons and remarks. The status of the genus *Compressidens* Pilsbry & Sharp, 1897 is questionable. The only shell feature separating the group from *Pulsellum* is the slight dorsoventral compression of the aperture profile. An examination of 276 specimens of *C. platyceras* revealed that only half exhibited this feature, the remaining specimens showing apertures with lateral compression or circular profiles. As discussed by Pilsbry & Sharp, 1897, Cossmann (1888) erected *Laevidentalium* for smooth species showing growth lines only, circular or slightly oval in section, apex simple or with a short notch on the convex side. Pilsbry & Sharp found it practically impossible to draw the line between circular and slightly oval, an opinion with which we concur.

Family GADILIDAE Stoliczka, 1868

Diagnosis. The greatest shell diameter is at the anterior aperture or in the anterior part of the shell. The anterior aperture is circular, slightly compressed or depressed. A few have striae, but the shell surface is usually smooth and polished. The rachis [central] tooth is highly variable. The marginals show a conspicuous keel. Few sensory papillae are developed in the frontal epithelium of the anterior mantle margin. The central filament of the terminal disk may be missing. The number of the captacular muscles is 5 or 6 (Steiner, 1992a: 398).

Subfamily Gadilinae Stoliczka, 1868 (*partim.*)

The anterior shell aperture is constricted, the maximum diameter is posterior to it in the anterior half of the shell. The captacula have 5 or 6 longitudinal muscles (Steiner, 1992a: 398).

Genus *Gadila* Gray, 1847

Gadila Gray, 1847: sp.280; Pilsbry & Sharp, 1898: 162; Henderson, 1920: 130; Woodring, 1925: 205; Ludbrook, 1960: I40 Emerson, 1962: 478; Habe, 1964, 46; Palmer, 1974a: 121; Steiner, 1992a: 398.
Helonyx Stimpson, 1865: 63.
Loxoporus Jeffries, 1883: 664.
Gadilopsis Woodring, 1925: 206.

Type species: *Dentalium gadus* Montagu, 1803, by original designation.

Diagnosis. Shell weakly to strongly curved, more or less swollen near the middle or towards the aperture, then tapering to the apex, apical orifice not contracted by a callous ring or with obsolete callous ring far within; apex without notches or lobes.

Key to Australian *Gadila*

1 Shell curved 2

—— Shell almost straight ..... *G. carlessi*

2 Shell with well defined annulate constriction in anterior third of shell ..... *G. ludbrookae*

—— Shell without constriction, or constriction poorly defined and limited to aperture region 3

3 Shell narrow through length ..... *G. angustior*

—— Shell not narrow throughout length 4

4 Shell widest at aperture, aperture circular 5

—— Shell widest away from aperture, aperture dorsoventrally compressed 6

5 Shell strongly curved; growth lines prominent ..... *G. spretus*

—— Shell curvature not strong; growth lines not prominent ..... *G. bordaensis*

6 Shell tapered towards apex and towards aperture 7

—— Shell tapered only towards apex ..... *G. occiduus*

7 Shell strongly curved ..... *G. cobbi*

—— Shell weakly curved 8

8 Shell widest at midpoint ..... *G. whitneyae*

—— Shell widest posteriorly ..... *G. brycei*

Gadila angustior (Verco, 1911)

Figs 155A, 156A, 157

Cadulus angustior Verco, 1911a: 211, pl. 26, figs 5, 5a, 5b; Verco, 1911b: 218; Cotton & Godfrey, 1933: 149; Cotton & Godfrey, 1940: 337, fig. 359; Zeidler & Macphail, 1978: 384.

Type material examined. HOLOTYPE: SAM D13728. Type locality: 18 miles [29 km] south-east of Newland Head outside Backstairs Passage, SA, 26 fathoms [48 m]. Length of holotype 4.6 mm, aperture diameter 0.5 mm dorsoventrally × 0.6 mm laterally.

Additional material examined. SOUTH AUSTRALIA: 3, AMS C172629, 160 km south south-west of St Francis Island, 635 m, 9 March 1909; 1, AMS C173585, Petrel Bay, north of Island of St Francis, 30 m, 28–29th December 1973; 5, AMS C33498, Backstairs Passage, 54 m; 10, AMS C32031, 60 km south of Cape Wiles, 200 m; 23, AMS C169965, 38°5–10'S 140°00'E, off Cape Martin, Beachport, 667 m; 60, SAM D297, south-west of Neptunes Island, 208 m. TASMANIA: 3, TM E13037a, stn 74, Little Swanport Bay, 1978; 2, AMS C173890, 42°14.5'S 148°08.1'E, in Great Oyster Bay, 24 m, 18 March 1973. NEW SOUTH WALES: 6, AMS C172631, Fingal Bay, Port Stephens, 1950–60.

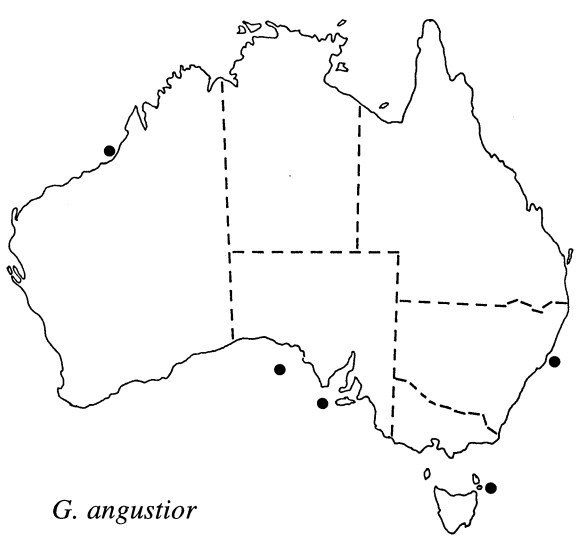


Figure 157. Australian distribution of *Gadila angustior* (Verco, 1911).

Description. Shell length to 4.6 mm, aperture diameter 0.5 mm dorsoventrally × 0.6 mm laterally, apex diameter 0.2 mm; translucent, thin, moderately and evenly curved, slowly tapering; without sculpture. Aperture moderately posteroventrally compressed. Apex orifice large. Colour translucent white.

Range. South Australia, Tasmania, Victoria (Macpherson & Gabriel) to New South Wales.

Habitat. Dredged from 24 to 667 m.

Comparisons and remarks. The holotype of *Gadila angustior* is only very slightly swollen towards the anterior end. Only one of the three shells illustrated by Verco (1911a) as *Cadulus angustior* appears to conform to the general features of the species as defined by him. In fact none of Verco's illustrated shells closely matches the holotype of this species, and it is impossible to determine whether Verco actually depicted the holotype. It should, however, be pointed out that the holotype has, lodged within it, a further specimen, which we could not remove without damage to the holotype. Possibly this shell may match one of Verco's illustrations. Our examination of the holotype failed to confirm the statement by Verco that this specimen has a "transverse milky line near the front" (i.e. an internal annulate callous), and for this reason we have transferred *Cadulus angustior* to the genus *Gadila*.

Gadila occiduus (Verco, 1911)

Figs 155B, 156B, 158

Cadulus occiduus Verco, 1911b: 218, pl. 26, fig. 7; Cotton & Godfrey, 1940: 339, fig. 361; Zeidler & Macphail, 1978: 384.

Type material examined. HOLOTYPE: SAM D13759. Type locality: Geographe Bay, off Bunbury, WA, 27 m, December 1910–January 1911. Length of holotype 9.6 mm, aperture diameter 1.0 mm, apex diameter 0.5 mm.

Additional material examined. WESTERN AUSTRALIA: 2, AMS C173925, Port Hedland; 1, AMS C69358, near Denham Shark Bay; many, WAM 64-94, Cockburn and Warnbro Sound, grab samples, 1993; 2, WAM 241-93, Cockburn Sound, July 1958;

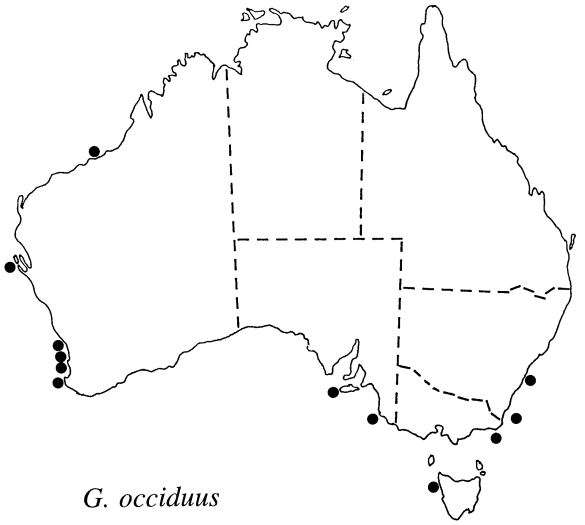


Figure 158. Known distribution of *Gadila occiduus* (Verco, 1911).

4, WAM N4972, Careening Bay, Garden Island, sieved mud, 6.5 m, 16 January 1965; 52, AMS C173646, Cockburn Sound, south-west of Woodmans Point, 20 m, 1963; many, WAM N5205, Perkins Point, Garden Island, intertidal, on sand spit, in top 50 mm sand, 16 January 1965; 32, AMS C173957, Cockburn Sound, south-west of Woodmans Point, 20 m, 10 August 1958; 8, AMS C173956, Woodmans Point, Cockburn Sound, 1973–1974; 75, SAM D18921, 24 m off Fremantle; 6, SAM D18922, Bunbury Beach; 6, WAM 243-93, Swan Estuary, Rocky Bay, slope at west end of sand slope, 8 m, 16 January 1973; 2, AMS C173630, Mandurah, 1 September 1964; 2, AMS C33494, off Fremantle, 20 m; 8, WAM 242-93, 30°58'S 114°49'E, west north-west of Lancelin, 215 m, 18 March 1972. SOUTH AUSTRALIA: 2, NMV F67460, 8 October 1935; 18, SAM D18923, 180 m off Cape Jaffa; 2, SAM D18924, 300 m off Beachport; 3, SAM D18925, 126 m off Cape Borda. TASMANIA: 1, AMS C173891, 42°30'S 145°01'E, south-east of Macquarie Harbour, 104 m, 11 April 1973. VICTORIA: many, NMV F72138, 7, NMV F72163, 1, NMV F72142, 18, NMV F72170, south of Point Hicks, 400–1750 m, 22–24 July 1986–26 October 1988; 1, NMV F72169, 38°40.29'S 149°18.06'E, south of Point Hicks, 2900 m, 25 October 1988, compacted clay; 9, AMS C173667, 39°00'S 148°24.50'E, 112 km of Lakes Entrance, 114 m, May 1969. NEW SOUTH WALES: 1, NMV F72136, 1, NMV F72153, off Nowra, 1650–2250 m, 16–17 July 1986.

Description. Shell length to 9.7 mm, aperture 1.7 mm, apex diameter 0.7 mm, greatest diameter of shell 1.9 mm; ventral curve slightly convex, moreso posteriorly, dorsal side swollen about one third of the shell length from the aperture. Sculpture absent, smooth with microscopic, transverse striae. Aperture oblique, slightly dorsoventrally compressed. Apex circular, simple. Colour white.

Range. Northern Western Australia, South Australia, Tasmania, Victoria to New South Wales.

Habitat. Found intertidally and dredged down to 2900 m in compacted clay.

Comparisons and remarks. *Gadila occiduus* most closely resembles *G. whitneyae* n.sp., in having a dorsoventrally compressed aperture profile. Differentiating features include: anteriorly placed swelling near aperture (centrally positioned swelling in *G. whitneyae*); much larger size (almost twice the size of *G. whitneyae*). The other species which show a dorsoventrally compressed aperture profile (*G. cobbi* n.sp., *G. carlessi* n.sp.) differ substantially in shell shape from *G. occiduus*. *Gadila occiduus* not only has an impressive geographical distribution (from northern Western Australia to Nowra, New South Wales) but also has an equally impressive bathymetric range (intertidal down to 2250 m).

Gadila whitneyae n.sp.

Figs 155C, 156F, 159

Etymology. Named after Mrs Annette Whitney (Sarina, Qld) for her assistance in obtaining scaphopods used in this study.

Type material examined. HOLOTYPE: AMS C174636. Type locality: 11°49'S 130°39'E, Buchanan Island, southern side of Melville Island, near Darwin, NT, 2 December 1938. Length of holotype 4.2 mm, aperture diameter 0.25 mm dorsoventrally × 0.34 laterally, apex diameter 0.2 mm. PARATYPES: 19, AMS C173913, Bowen, Qld; 5, AMS C173924, Facing Island, Port Curtis, Qld; 21, AMS C173790, same locality data as holotype; 1, AMS C173795, Beach below Crocodile research Station, Maningrida, Arnhem land, NT, 5 June 1976; 1, AMS C174637, 12°10'S 130°22'E, 32 km off Point Charles, Darwin, NT, 27–37 m, 14 July 1938; 1, AMS C173791, Port Darwin, NT.

Additional material examined. QUEENSLAND: 3, AMS C173692, dredged off Ellis Reef near Kurramine, 19 October 1965; 1, AMS C173915, Thursday Island, Torres Strait; 2,

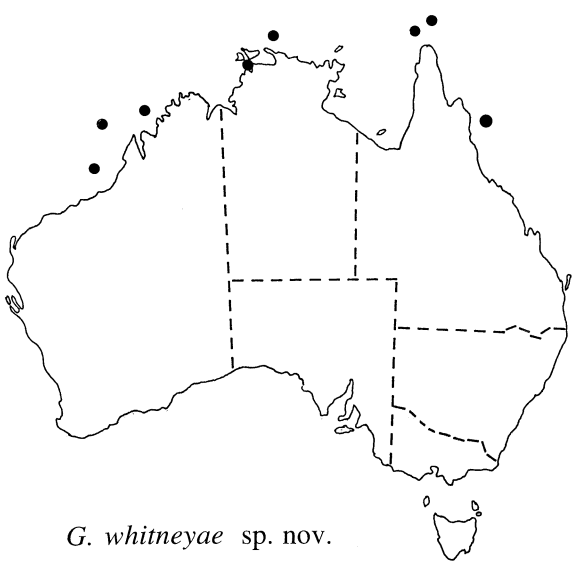


Figure 159. Known distribution of *Gadila whitneyae* n.sp.

AMS C173731, 10°35'S 141°55'E, Gannet Passage, Torres Strait, 11 m; 5, AMS C173907, 9°56'S 144°04'E, off Murray Island, Torres Strait, 15 m, 30 August–3 October 1907; 1, AMS C173730, Thursday Island, Torres Strait. NORTHERN TERRITORY: 1, AMS C173535, off Point Charles north-west of Darwin, 37 m, 1960; 1, AMS C173793, Port Darwin; 1, AMS C173605, 12°23'S 130°50'E, Nightcliff, Darwin, 15 July 1988; 4, AMS C173604, on sandbar off Emery Point, Darwin, 25 October 1969; 4, AMS C173603, 12°24'S 150°49'E, Ludmilla Creek, Darwin, in front of mangroves; 1, NMV F67463, dredged Darwin Harbour, 23 April 1983; 29, AMS C173675, Lee Point, Darwin, May 1973; 51, AMS C173676, Port Darwin; 5, AMS C173802, Buchanan Island, southern side of Melville Island, Darwin, 2 December 1938; 1, AMS C173801, 11°01'S 132°34'E, off Croker Island, Cobourg Peninsula, 11 m; 4, AMS C173678, 11°22'S 130°43'E, Melville Island, 14 December 1980; 84, AMS C173677, Darwin. WESTERN AUSTRALIA: 4, AMS C173635, 14°29'S 123°03'E, 224 km north of Cape Leveque, 124 m, 12 November 1967; 8, AMS C173636, 18°30'S 118°03'E, 369 km west of Roebuck Bay, 238 m, 11 October 1968; 2, AMS C173640, 15°27'S 121°31'E, 270 km north of Broome, 210 m, 20 November 1967.

Description. Shell length to 4.2 mm, greatest diameter 0.7 mm, aperture diameter 0.25 mm dorsoventrally × 0.34 laterally, apex diameter 0.2 mm; greatest width approximately centrally located giving shell a fusiform appearance, shell smooth almost transparent, slightly curved. Aperture oblique, moderately dorsoventrally compressed. Apex circular, tapering, much narrower than the aperture. Colour translucent white.

Range. Queensland, Northern Territory to northern Western Australia.

Habitat. Sieved from littoral sand and dredged in mud and sand to 238 m.

Comparisons and remarks. *Gadila whitneyae* shares with *G. cobbi* n.sp., *G. carlessi* n.sp. and *G. occiduus* (Verco) a dorsoventrally compressed aperture profile. Differentiating features include: spindle-like shape (featuring a centrally positioned swelling); generally smaller size. This appears to be an entirely tropical species. *Gadila whitneyae* also shows some resemblance in profile to the fossil species *C. mucronatus* Tate, but is consistently much narrower.

Gadila bordaensis (Cotton & Godfrey, 1940)

Figs 155D, 156C, 160

Cadulus bordaensis Cotton & Godfrey, 1940: 340, fig. 362; Zeidler & Macphail, 1978: 384.

Type material examined. HOLOTYPE: SAM D13761. Type locality: off Cape Borda, Kangaroo Island, SA, 110 m. Length of holotype 6.0 mm, aperture diameter 1.0 mm, apex diameter 0.5 mm.

Additional material examined. SOUTH AUSTRALIA: 1, Lamprell Collection, 35°15'S 134°03'E, south of Cape Carnot, 110–600 m. TASMANIA: 16, NMV67578, east of Maria Island, 50 m, 23 April 1985; 1, NMV67577, east of Maria Island, 75 m, 23 April 1985; 5, AMS C173458, 42°50'S 147°59.8'E, Marion Bay, south of Maria Island, 58 m, 13 March 1973 (preserved); 5, AMS C173601, Ringarooma Bay; 2, AMS C173750, 41°39.5'S 144°37.1'E, south-west of Sandy Cape, 130 m, 15 April 1973; 2, AMS C173893, 43°55'S 146°51'E, south of South East Cape, 168 m, 2 April 1973; 5, AMS C173661, 39°00'S 148°30'E, midway between Cape Everard and Flinders Island, Bass Strait, 126 m, 7–9 May 1969. VICTORIA: 1, AMS C169987, 38°13'S 149°06'E, between Cape Howe and Lakes Entrance, 146–158 m, 20 June 1962.

Description. Shell length to 6.0 mm, aperture diameter 1.0 mm, apex diameter 0.5 mm; almost straight; devoid of sculpture. Aperture circular, transverse, contracted near the aperture but slightly dilated terminally. Apex circular, slightly dilated. Colour white, with transverse, opaque white rings and bands.

Range. South Australia, Tasmania to Victoria.

Habitat. Dredged from 50 to 600 m.

Comparisons and remarks. *Gadila bordaensis* most closely resembles *G. ludbrookae* (Cotton & Godfrey) in having an annular constriction near the aperture. Shell features differentiating *G. bordaensis* from *G. ludbrookae* include: annular constriction near the aperture (constriction prominent and occurring two thirds of the shell length from the apex in *G. ludbrookae*; constriction faint and close to aperture in *G. bordaensis*); widest centrally (widest at the aperture *G. ludbrookae*). *Gadila bordaensis* is superficially similar to *G. spretus* (Tate & May) but is larger, straighter, widest centrally, with a much narrower apex and in intact specimens, possess a faint annular constriction near the aperture.

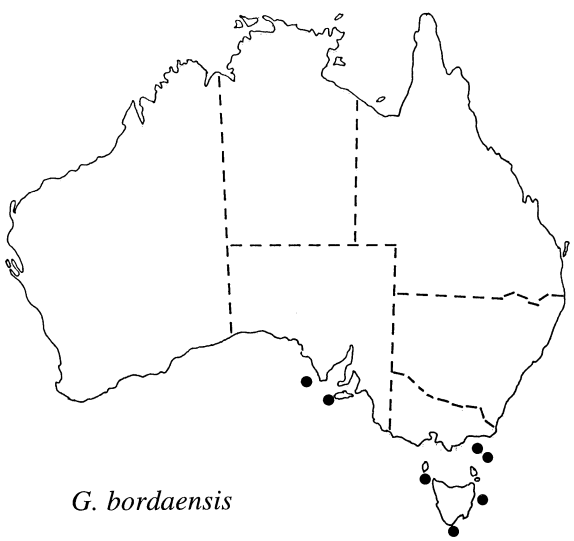


Figure 160. Known distribution of *Gadila bordaensis* (Cotton & Godfrey, 1940).

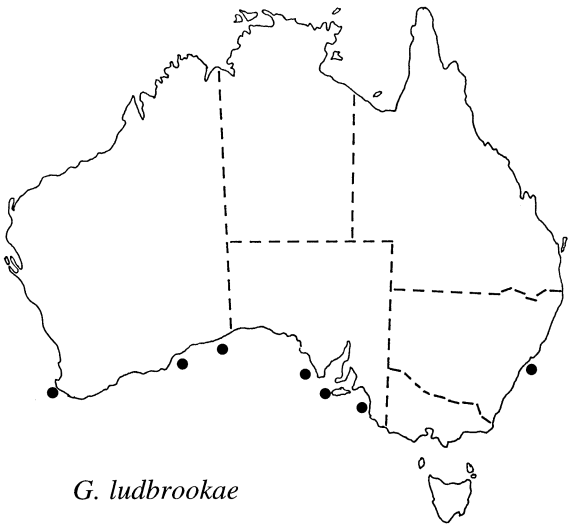


Figure 161. Known distribution of *Gadila ludbrookae* (Cotton & Godfrey, 1940).

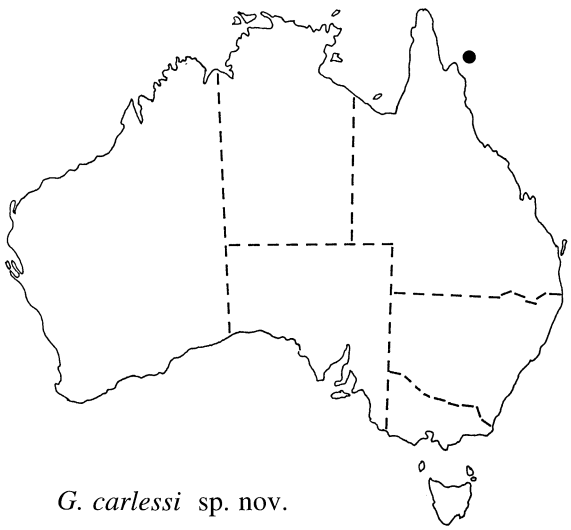


Figure 162. Known distribution of *Gadila carlessi* n.sp.

Gadila ludbrookae (Cotton & Godfrey, 1940)

Figs 155E, 156E, 161

Cadulus ludbrookae Cotton & Godfrey, 1940: 340, fig. 363; Zeidler & Macphail, 1978: 384.

Type material examined. HOLOTYPE: SAM D13760. Type locality: north-west of Cape Borda, Kangaroo Island, SA, 113 m. Length of holotype 7.0 mm. Aperture diameter 1.0 mm, apex diameter 0.5 mm.

Additional material examined. WESTERN AUSTRALIA: 36, AMS C173595, between Eucla and Esperance, 5–9 July 1962; 5, AMS C173536, 33°20'S 128°45'E, Great Australian Bight, 150 m, 5 July 1962; 1, AMS C172604, 0.8 km off Peppermint Grove Beach, between Bunbury and Busselton, 4.6–7.6 m, in sand. SOUTH AUSTRALIA: 1, AMS C172603, 37°10'S 138°30'E, south-east of Kangaroo Island, 155 m, 26 June 1962; 6, AMS C173665, 1, AMS C310239, 35°15'S 134°32'E, south of Cape Carnot, 150–178 m, 12 July 1962. NEW SOUTH WALES: 1, AMS C172613, off Jibbon, Port Hacking, 80 m, September 1964.

Description. Shell length to 7.0 mm, aperture diameter 1.0 mm, apex diameter 0.5 mm; glossy; thin, slightly curved. Devoid of sculpture but with a distinct constriction towards the aperture at which point the curve of the shell often alters. Aperture circular, contracted. Apex circular. Colour white.

Range. Southern Western Australia, South Australia to New South Wales.

Habitat. Dredged from 80 to 155 m.

Comparisons and remarks. *Gadila ludbrookae* most closely resembles *G. bordaensis* (Cotton & Godfrey) in having an annular constriction. *Gadila ludbrookae* can be distinguished by the prominence of the constriction and its placement two thirds of the shell length from the apex. Juveniles which have yet to develop the constriction may possibly be confused with certain other *Gadila* species. However, attention to the form of the apex and shell shape should in most cases resolve identification.

Gadila carlessi n.sp.

Figs 155F, 162, 166D, 168A

Etymology. Named after Mr Terry Carless for his contribution to the Brisbane Branch of the Malacological Society of Australia.

Type material examined. HOLOTYPE: QM MO40084. Type locality: east of Cape Melville, northern Qld, 14°22'S 145°52'E, 2710 m, 8 September 1988. Length of holotype 19.2 mm, aperture diameter (laterally) 3.1 mm, (dorsoventrally) 2.5 mm, widest diameter laterally 3.4 mm, widest diameter (dorsoventrally) 2.8 mm, apex diameter 1.4 mm.

Description. Shell dimensions as for holotype; shell almost straight, solid; the widest part being 2.6 mm from the aperture. Sculpture of fine transverse growth lines. Aperture dorsoventrally compressed. Apex obliquely broken but does not appear to be compressed. Colour, porcelainous white.

Radula. Central tooth not observed in preparation (obscured by laterals); laterals strongly curved 220 μm long and keeled; marginals almost straight, moderately broad (length 200 μm) (Fig. 166D).

Range. Northern Queensland.

Habitat. Dredged in coarse sand at 2710 m.

Comparisons and remarks. *Gadila carlessi*, although presently known only from the holotype, can be readily distinguished from other Australian *Gadila* species by its large, almost straight shell and oblique apical profile. The dorsoventral compression of the aperture profile suggests closest relationship with *G. whitneyae* n.sp. and *G. occiduus* (Verco).

Gadila cobbi n.sp.

Figs 155G, 156D, 163

Etymology. Named after the late Mr Dick Cobb, long time member of the Malacological Society of Australia, for his contribution to the study of molluscs within Australia.

Type material examined. HOLOTYPE: AMS C174638. Type locality: 16°37.7'S 146°20.4'E, off Cairns, northern Qld, 685–658 m, 13 October 1981, pale yellow, clay-mud. Length of holotype 14.8 mm, aperture diameter 1.9 mm dorsoventrally × 2.3 mm laterally, greatest width of shell 2.8 mm, apex diameter 0.6 mm. PARATYPES: QUEENSLAND: 1, AMS C173427, same locality data as holotype; 2, AMS C8017, Darnley Island, Torres Strait; 14, QM MO40083, 17°22'S 146°48'E, off Cairns, northern Qld, 303 m, 15 May 1986; 6, AMS C173685, 23°52.5–51.9'S 152°42.7–41.7'E, north-east of Lady Musgrave Island, 296 m, 7 July 1984; 1, AMS C173655, 17°09.53'S 146°42.36'E, off Cairns, 253 m, 12 October 1981; 1, AMS C173438, 12, AMS C174639, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984.

Additional material examined. QUEENSLAND: 1, AMS C173555, 22°26.27–20.2'S 153°17.13–17.6'E, south-east of Swains Reefs, 187 m, 5 July 1984; 46, AMS C173553, 24°03.7'S 152°49.4'E, north-east of Lady Elliot Island, 150 m, 4 July 1984; 2, AMS C310224, 23°15.2'S 152°24.1'E, east of North West Island, 284 m, 14 December 1977; 18, AMS C173902, 23°19.5'S 152°35.4'E, east of North West Island, 320 m, 14 December 1977; 3, AMS C173684, 96, AMS C173441, 1, AMS C173442, 12, AMS C174639, 1, AMS C173653, 23°38.8'S 152°45.5'E, north-east of Lady Musgrave Island, 365 m, 14 December 1977; 2, AMS C173551, 23°51.2'S 152°34.5'E, east of Lady Musgrave Island, 200 m, 4 July 1984; 1, AMS C173917, 14°40'S 145°28'E, Lizard Island, 23 September 1977; 1, AMS C165351, 10°35.83'S 144°30.65'E, Coral Sea, 1108–1161 m, 21 August 1988. NORTHERN TERRITORY: 3, AMS C63129, Buchanan Island, near Melville Island. WESTERN AUSTRALIA: 2, AMS C173627, 14°07'S 122°52'E, north of Cape Leveque, 256 m, 17 November 1967; 1, WAM 149-93, 18°25'S 118°22'E, 211 km north of Port Hedland, 2 April 1982.

Description. Shell length to 14.8 mm, aperture diameter 2.3 mm laterally × 1.9 mm dorsoventrally, greatest width of shell 2.8 mm, apex diameter 0.6 mm; shell strongly curved, with its widest part approximately one quarter of the shell length from the aperture; widest part of shell slightly angulated, situated on the ventral curve but is also observable on the dorsal curve. Sculpture of fine transverse scratches. Aperture oblique, dorsoventrally compressed. Apex slightly dorsoventrally compressed. Colour semi-opaque white.

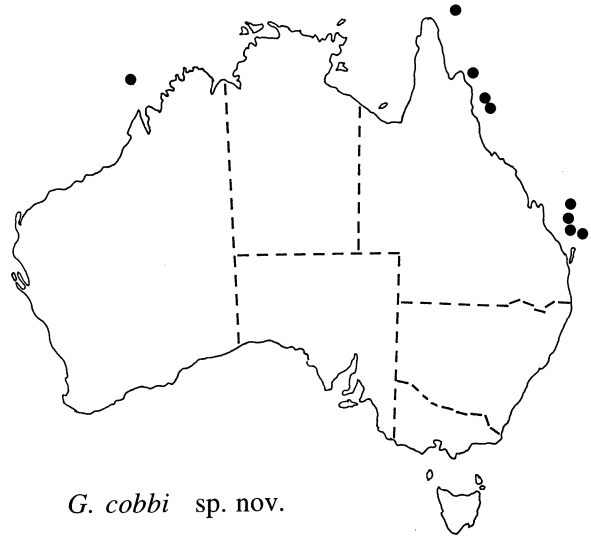


Figure 163. Known distribution of *Gadila cobbi* n.sp.

Range. Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged in grey ooze from 150 to 1161 m.

Comparisons and remarks. *Gadila cobbi* most closely resembles *G. whitneyae* n.sp., *G. carlessi* n.sp. and *G. occiduus* (Verco) in having a dorsoventrally compressed aperture profile. Differentiating features of *G. cobbi* include: shell shape (degree of curvature); swelling and apex size. *Gadila cobbi* is probably closest to *G. occiduus*, but is larger and has a more pronounced swelling positioned close to the aperture. *Gadila cobbi* has a reasonably wide Australian distribution and is moderately common wherever collected.

Gadila brycei n.sp.

Figs 155H, 156G, 164, 166A–C

Etymology. Named after Mr Clay Bryce (Malacology Section, Western Australian Museum) who collected material used in this study and generously made available photographic slides of living scaphopods for examination.

Type material examined. HOLOTYPE: WAM 237/94. Type locality: north north-west of Dampier, 19°34'S 116°08'E, WA, 110 m, 19 October 1979. Length of holotype 5.7 mm, aperture diameter 0.6 mm, apex diameter 0.37 mm; greatest width of shell 0.9 mm. PARATYPES: WESTERN AUSTRALIA: 7, WAM 64-93, 19°34'S 116°08'E, north north-west of Dampier, 110 m, 19 October 1979; 2, NMV69582, 19°05'S 117°26'E, North West Shelf, between Port Hedland and Dampier, 122 m, 12 June 1983, muddy sand; 10, WAM 238/94, Exmouth Gulf, grab samples, November-December 1993; 1, AMS C311959, 25°48'S 113°43'E, Monkey Mia, Shark Bay, in sand, 27 August 1989; 1, AMS C173593, 19°00.8'S 118°01.3'E, 133 km north north-west

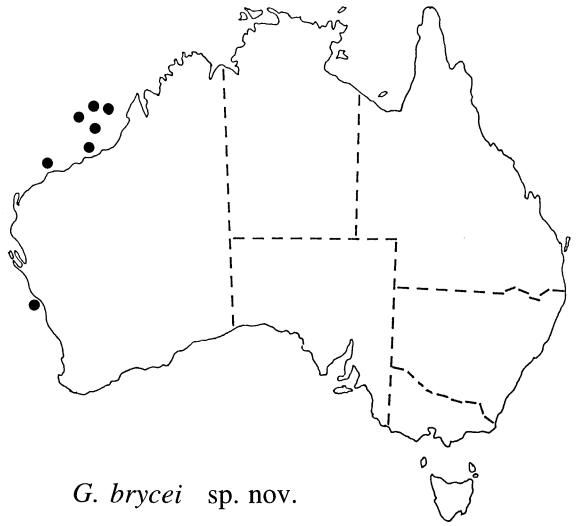


Figure 164. Known distribution of *Gadila brycei* n.sp.

of Port Hedland, 112 m, 29 October 1983; 5, AMS C173754, 17°34'S 120°22'E, 220 km north-west of Roebuck Bay, 188 m, 30 November 1967.

Additional material examined. WESTERN AUSTRALIA: 2, AMS C173959, Bluff Point north Geraldton, 1973–74; 1, AMS C173960, 12, AMS C173594, 19°28.9–29.0'S 116°29.4–29.0'E, 115 km north north-west of Dampier, 110 m, 26 October 1983; 2, AMS C173633, 19°32'S 115°49'E, 304 km north-west of Port Hedland, 183 m, 27 November 1968; 2, AMS C173637, 19°29'S 116°01'E, 270 km west of Port Hedland, 137 m, 1 December 1968; 4, AMS C173597, 19°55.2–55.6'S 117°56.00–56.55'E, 83 km north-west of Port Hedland, 40 m sand, 26 October 1983; 1, AMS C174544, 19°59.0–58.6'S 117°51.1–51.0'E, north of Port Hedland, 41 m, 26 October 1983 (preserved); 5, AMS C173895, 1, AMS C173628, 192 km north of Port Hedland, 161 m, 25 November 1968; 1, AMS C173894, 19°12'S 115°57'E, 382 km west north-west of Port Hedland, 274 m, 24 November 1968; 30, Lamprell Collection, 80 Mile Beach, 31 August 1982; 24, AMS C310676, 16°58'S 120°47'E, approx 160 km north-west of Broome, 194 m, 29 November 1967; 2, AMS C173896, 18°00'S 118°56'E, 366 km west of Broome, 261 m, 6 November 1968; 1, AMS C173647, 1, AMS C173756, 16°16'S 120°45'E, 240 km west of Cape Leveque, 330 m, 21 November 1967; 1, WAM 62-93, 1, WAM 60-93, south of Rowley Shoals, 266 m, 20 December 1969.

Description. Shell length to 5.7 mm, aperture diameter 0.6 mm dorsoventrally × 0.73 mm laterally, apex diameter 0.37 mm; greatest width of shell 0.9 mm, one third of the shell length from the aperture; well curved. Sculpture of fine transverse growth lines. Aperture oblique, moderately dorsoventrally compressed. Apex moderately dorsoventrally compressed, tapering, much narrower than the aperture. Colour translucent white.

Radula. Central tooth deep, 35 μm high, with central ridge, superior surface narrow and slightly concave, inferior surface also concave; laterals 70 μm long, curved, scythe-like with large and small, sharp cusps on the working edge; marginals 70 μm long, almost straight, moderately broad (Fig.166A–C).

Range. Northern Western Australia.

Habitat. Sieved in littoral sand and dredged from 40 to 330 m in sand.

Comparisons and remarks. *Gadila brycei* most closely resembles *G. cobbi* n.sp. and *G. occiduus* (Verco) in shape, but differs from both of those species, and in fact all other Australian *Gadila* species, in having a laterally compressed aperture (aperture dorsoventrally compressed in *G. cobbi* and *D. occiduus*). This appears to be a reasonably common, though relatively localized species.

Gadila spretus (Tate & May, 1900)

Figs 155I, 156H–J, 165

Cadulus spretus Tate & May, 1900: 102; Tate & May, 1901: 420, pl. 25, fig. 52; Hedley, 1903: 328.

Type material examined. LECTOTYPE here selected from syntype lot (TM 1095) E1202/8543 (specimen on left hand side of board). Type locality: Port Esperance, southern Tasmania, 44 m. Length of lectotype 5.5 mm, aperture diameter 0.7 mm, apex diameter 0.3 mm. PARALECTOTYPES: 1, attached to board, right hand side of lectotype; 21, SAM D15848 (May no. 1048) same locality data as lectotype; 5, SAM D16002, no data.

Additional material examined. WESTERN AUSTRALIA: 2, AMS C173632, between Eucla and Esperance, 293 m, 5–9 July 1962. SOUTH AUSTRALIA: 7, SAM D18919, 144 m, 48 km west of Eucla, Great Australian Bight; 33, SAM D18915, to 300 m off Beachport; 16, SAM D18916, to 260 m off Cape Jaffa; 5, WAM 7346, Cape Jaffa, 180 m; 30, SAM D18917, 132 m, north-west of Cape Borda; 6, SAM D18918, 110 m off Cape Borda; 5, SAM D18920, Guichen Bay. TASMANIA: 2, AMS C172627, 40°09.2'S 145°11.6'E, north of Three Hummock Island, 51 m, 24 April

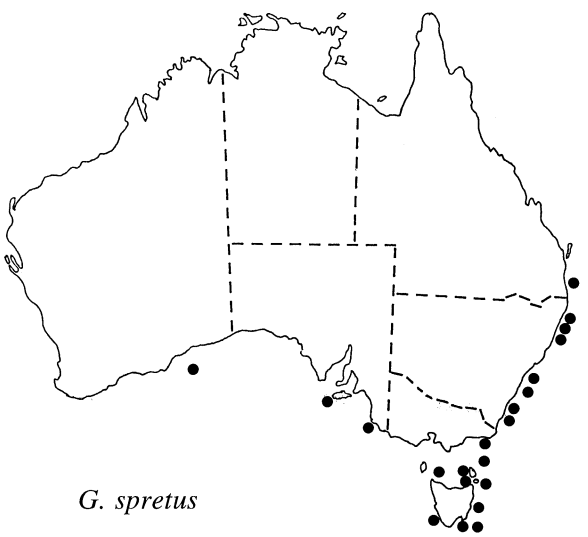


Figure 165. Known distribution of *Gadila spretus* (Tate & May, 1900).

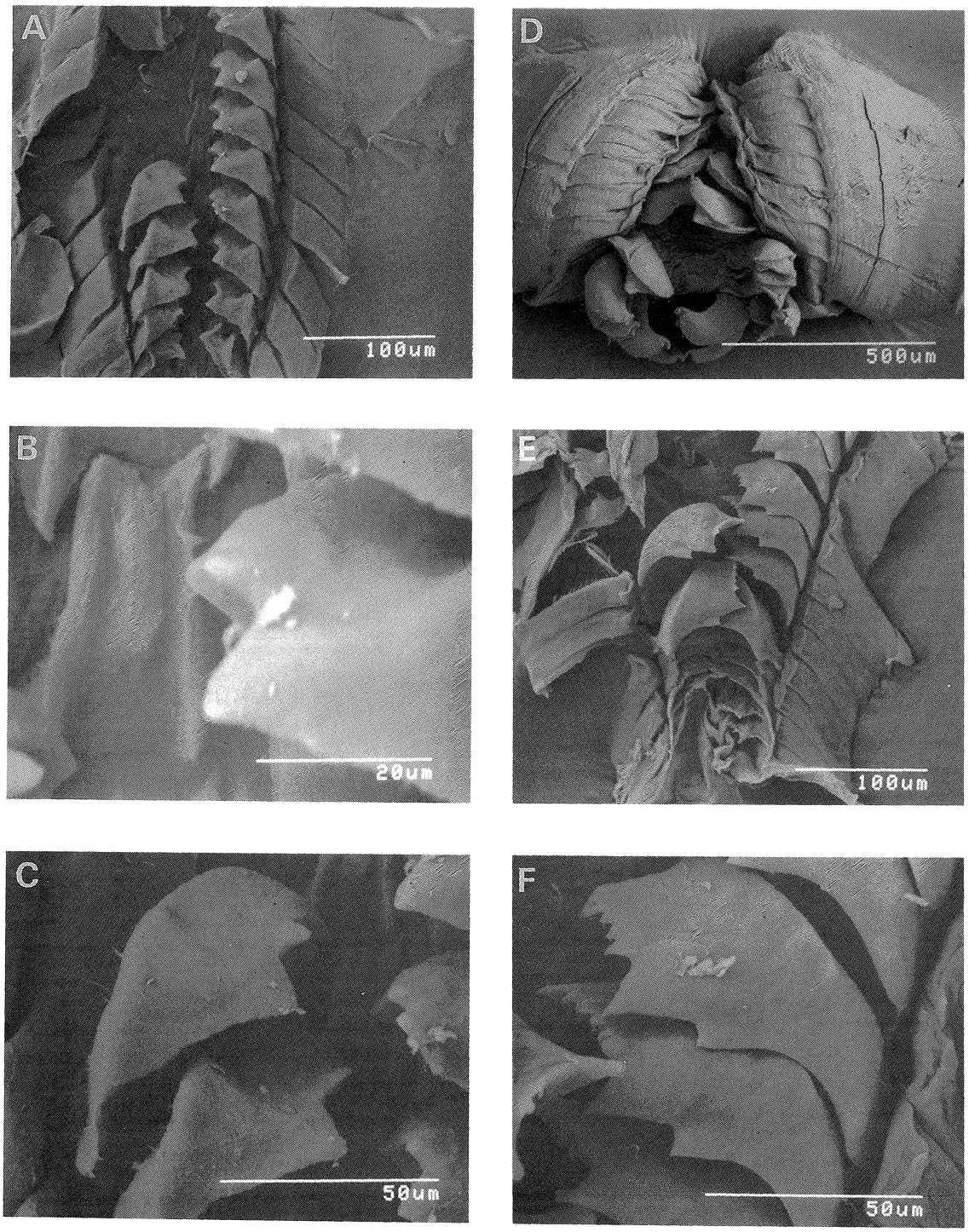


Figure 166. Radular ultrastructure. **A–C** *Gadila brycei* n.sp. (from paratype, Monkey Mia, WA, WAM 103/93). **D** *Gadila carlessi* n.sp. (from holotype, east of North Qld, 14°22'S 145°52'E, 2710 m, QM MO40084). **E,F** *Bathoxiphus steineri* n.sp. (from paratype, 17°46'S 147°49'E, Cairns, Qld, 1224 m QM MO40081).

1973; 10 AMS C173760, 41°20.6'S 148°30'E, off St Helens Point, 110 m, 25 March 1973; 1, AMS C173799, 42°56.32'S 147°37.10'E, 46.5 km south of Cape Bernier, south-west of Cape Peron, Maria Island, fine sand, 26 March 1970; 8, AMS C173892, 42°50'S 148°07.3'E, south of Maria Island, 84 m, 13 March 1973; 4, AMS C172605, 43°23.54'S 147°06.36'E, Partridge Island, on south-east side D'Entrecasteaux channel, 16.5–20 m, 23 March 1970; 3, AMS C173599, 43°53.2'S 147°08.3'E, D'Entrecasteaux channel, 148 m, 1 April 1973; 12, AMS C172626, 43°13.8'S 145°36.9'E, north of Port Davey, 132 m, 10 April 1973; 9, AMS C172608, 43°22.5'S 145°44.5'E, west of Port Davey, 144 m, 9 April 1973; 3, AMS C172606, 43°20.3'S 147°37.7'E, south of Storm Bay, 97 m, 8 April 1973; 1, AMS C172607, 43°38.5'S 146°07.8'E, south-east of South West Cape, 119 m, 9 April 1973; 2, AMS C173194, 42°20'S 148°13'E, Great Oyster Bay, 45 m, yellow mud and sand; 4, AMS C173567, 40°22.5'S 143°39'E,

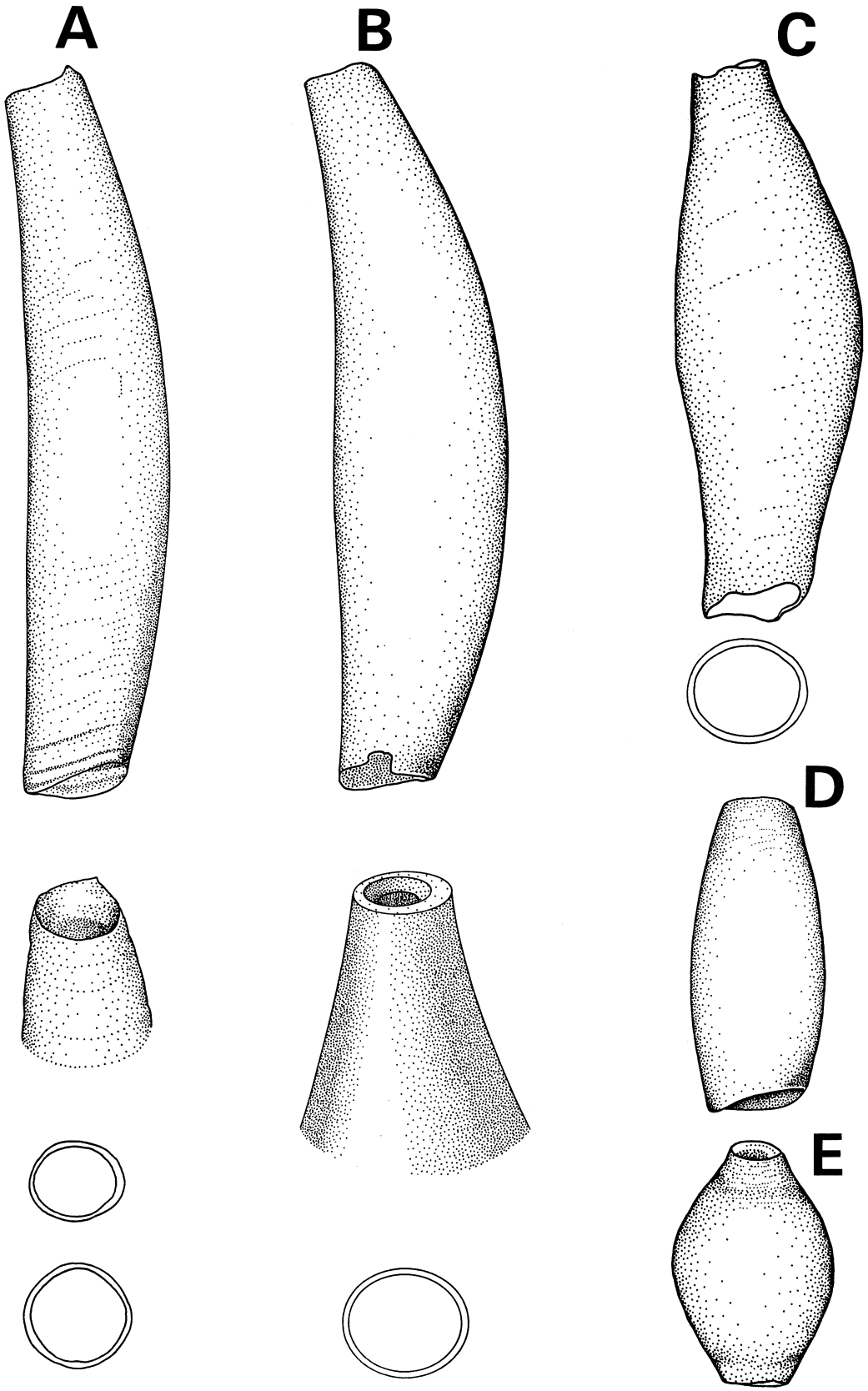


Figure 167. Gadilida, Gadilidae, *Cadulus*. **A** *C. vincentianus* Cotton & Godfrey, 1940 (holotype, SAM D13730, Holdfast Bay, Gulf St Vincent, SA, length 4.0 mm). **B** *C. simillimus* Watson, 1879 (AMS C173914, Bowen Qld, 4.0 mm). **C** *C. colliverae* n.sp. (holotype, QM MO17654, off Cairns, Qld, 296–303 m, length 5.4 mm). **D** *C. woodhousae* n.sp. (holotype, AMS C174625, 64.5 km north of Croker Island, Arafura Sea, NT, 65 m, length 1.97 mm). **E** *C. rudmani* n.sp. (holotype, AMS C174626, off Cairns, Qld, 668 m, length 2.38 mm). (Del.: all A. Hill).

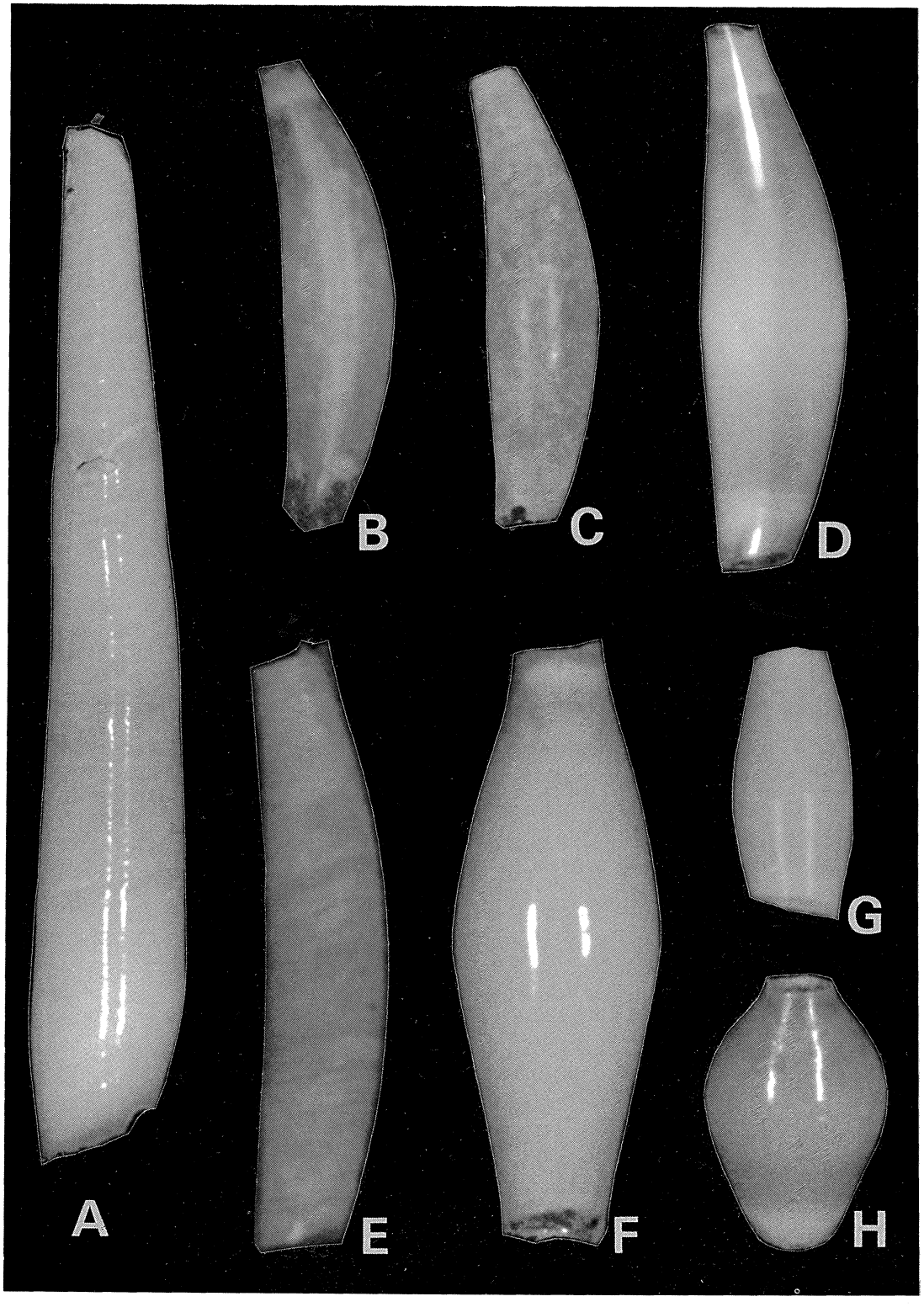


Figure 168. Gadilida, Gadilidae. **A** *Gadila carlessi* n.sp. (holotype, QM MO40084, east of Cape Melville, Qld, 2710 m, length 19.2 mm). **B–H** *Cadulus*. **B** *C. simillimus* Watson, 1879 (lectotype BMNH 1887.2.9.80, Raine Island, Cape York, 284 m, length 4.0 mm). **C** *C. simillimus* Watson, 1879 (AMS C173914, Bowen Qld, 4.0 mm). **D** *C. simillimus* Watson, 1879 (KLColl, Exmouth Gulf, WA 4.77 mm). **E** *C. vincentianus* Cotton & Godfrey, 1940 (holotype, SAM D13730, Holdfast Bay, Gulf St Vincent, SA, length 4.0 mm) **F** *C. colliverae* n.sp. (holotype, QM MO17654, off Cairns, Qld, 296–303 m, length 5.4 mm). **G** *C. woodhousae* n.sp. (holotype, AMS C174625, 64.5 km north of Croker Island, Arafura Sea, NT, 65 m, length 1.97 mm). **H** *C. rudmani* n.sp. (holotype, AMS C174626, off Cairns, Qld, 668 m, length 2.38 mm).

south of King Island, 25 April 1973; 1, NMV F72134, off Freycinet Peninsula, 720 m, 27 July 1986, coarse shelly sand; 1, NMV F72160, 41°57.30'S 148°58.54'E, off Freycinet Peninsula, 1770 m, 30 October 1988, coarse biogenic rubble; 1, SAM D18841, off Cape Pillar. VICTORIA: 21 pieces, AMS C310268, 38°20–40'S 149°25–35'E, 48 km south of Cape Everard, 366 m, 22 October 1914; 3, AMS C173784, 37°50.6'S 149°37.5'E, 12 km south of Ram Head, 119 m, 4 April 1972; 3, AMS C173789, 38°18.20'S 148°38.40'E, 53 km south of Cape Conran, off Gippsland, 290 m, May 1969; 1, AMS C173563, 39°19'S 146°12'E, 37 km south of Wilson Promontory, 76 m, 22 July 1962; 1, AMS C173672, 1.6 km north of Gabo Island, 27 m; 23, AMS C173564, 38°18.20'S 148°30.00'E, 58 km south of Cape Conran, Gippsland, 820 m, May 1969; 3, AMS C173758, 37°55'S 149°00'E, between Cape Howe and Lakes Entrance, 78 m, 20 June 1962. NEW SOUTH WALES: 1, AMS C173942, Eden Harbour; 1, AMS C169992, 33°46–43'S 151°47–50'E, off Port Kembla, 281 m, 5 December 1978; 9, AMS C168100, Port Stephens; 32, AMS C16220, Port Kembla, 126–150 m; 1, AMS C169991, 36°43–36'S 150°19–20'E, east of Bermagui, 387 m; 14, AMS C172614, off Green Point, Port Jackson; 1, AMS C172612, Quarantine Bay, Sydney Harbour, 9–11 m, 9 March 1969; 2, AMS C173779, 37°27'S 150°17'E, 37 km east of Twofold Bay, 304 m, 19 June 1962; 2, AMS C173398, 34°27–26'S 151°27'E, off Wollongong, 1200 m, 13 December 1976; 1, AMS C173770, 36°16'S 150°12'E, off Montague Island; 1, AMS C172615, Chinamans Beach, near Balmoral, Sydney; 1, AMS C172609, off Jervis Bay, 400–1000 m, October-November 1980; 1, AMS C172467, Killcare Bay, Brisbane Waters; 3, AMS C172616, off Jibbon, Port Hacking, 80 m, September 1964; 1, AMS C173735, off Cronulla, 100 m, December 1963; 1, AMS C173773, 29°10'S 153°36.8'E, off Ballina, 59 m, 21 February 1972; 2, AMS C173574, 29°39.8'S 153°26.4'E, 12 km east of Cakora Point, south of Yamba, 55 m, 22 February 1972; 8, AMS C173776, 29°40.3'S 153°30.4'E, north of Coffs Harbour, 71 m, 22 February 1972; 1, AMS C173193, 30°18.4'S 153°17.7'E, 14 km of Coffs Harbour, 76 m, 22 February 1972. QUEENSLAND: 3 juveniles, AMS C172610, Amity Point, Stradbroke Island, beach, June 1973.

Description. Shell length to 5.7 mm, aperture diameter 1.0 mm, apex diameter 0.3 mm; moderately curved, constricted towards the aperture; glossy. Sculpture of dense, strong, transverse growth lines. Aperture circular, slightly contracted. Apex circular. Colour translucent white.

Range. Western Australia, South Australia, Tasmania, Victoria, New South Wales to southern Queensland.

Habitat. Sieved from littoral sand and dredged in yellow clay to fine sand from 9 to 1770 m.

Comparisons and remarks. Material obtained from the TM (TM 1095) E1202/8543, with the locality data, Port Esperance, south Tasmania, 48 m, has two specimens attached to a board and marked "Type". The specimen on the left hand side of the board appears exactly as that figured by Tate & May but is slightly smaller in length possibly because of damage. We therefore select this specimen as the lectotype. *Gadila spretus* superficially resembles *Compressidens platyceras* (Sharp & Pilsbry) but is shorter and wider, lacks oblique growth lines and exhibits a slightly contracted aperture. *Gadila spretus* can be readily distinguished from all other *Gadila* species by its strong transverse growth lines (microscopic in *G. brycei* n.sp., *G. cobbi* n.sp., *G. occiduus* (Verco) and *G. carlessi* n.sp.). Juvenile *G. occiduus* could perhaps be confused with *G. spretus*, but differences in aperture profile should clarify this.

Genus *Cadulus* Philippi, 1844

Cadulus Philippi, 1844: 209; Pilsbry & Sharp, 1897: 142; Boissevain, 1906: 65; Henderson, 1920: 95, 141; Woodring, 1925: 205; Ludbrook, 1960: I40; Emerson, 1962: 476; Habe, 1964: 46; Palmer, 1974a: 121; Steiner, 1992a: 398.

Type species: *Dentalium ovulum* Philippi, 1844; by subsequent designation, Pilsbry & Sharp, 1897.

Diagnosis. Shell more or less swollen near the middle or anteriorly, contracting towards the aperture as well as tapering posteriorly. Apex simple with a wide circular callus or ledge within.

Key to Australian *Cadulus*

1 Shell barrel-shaped 2

—— Shell moderately elongate 3

2 Shell very swollen centrally, more inflated on the convex side; apex and aperture narrowly tapering, apex moreso ..... *C. rudmani*

—— Shell slightly swollen centrally and equally all round the shell, aperture and apex widely tapering ..... *C. woodhousae*

3 Shell almost straight, swollen centrally and equally around the shell ..... *C. colliverae*

—— Shell slightly to moderately curved, central swelling evident mainly ventrally 4

4 Shell narrow throughout length, only weakly swollen centrally, dorsal surface almost straight, ventral surface moderately curved ..... *C. vincentianus*

—— Shell narrow only at ends, swollen centrally, dorsal surface slightly sinuate owing to central swelling, ventral surface strongly curved ..... *C. simillimus*.

Cadulus simillimus Watson, 1879

Figs 167B, 168B–D, 169

Cadulus simillimus Watson, 1879: 526; Watson, 1886: 20, pl. 3, fig. 6; Pilsbry & Sharp, 1898: 182, pl. 26, fig. 77; Boissevain, 1906: 69, pl. 3, fig. 46; Hedley, 1910: 371.

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1887.2.9.80 (the larger specimen). Type locality: Raines (sic) Island, 11°35'S 144°03'E, Cape York, north-east Australia, 155 fathoms [284 m], sand. Length of lectotype 4.0 mm, aperture diameter 0.47 mm, greatest width of shell 0.9 mm, apex diameter 0.4 mm. PARALECTOTYPE: same data as lectotype.

Additional material examined. VICTORIA: 2, AMS C173673, 38°02'S 148°08.50'E, 52.5 km south of Tamboon Inlet, off Gippsland, 800 m, May 1969. NEW SOUTH WALES: 10, AMS C169990, 34°50'S 151°15'E, off Nowra, 841 m, 12 December 1978; 1, AMS C173899, 28°13.8'S 154°06.9'E, 1646 m, 8 November 1976. QUEENSLAND: 1, AMS C173897, 26°41.2'S 153°38.4'E, off Maroochydore, 200 m, 18 November 1976; 1, AMS C173900, 27°57.8'S 153°51.3'E, southern end of Fraser Island, 201 m, 10 November 1976; 50, AMS C173554, 24°03.7'S 152°49.4'E, north-east of Lady Elliot Island, 150 m, 4 July 1984; 6, AMS C303602, 5, AMS C173732, 21°43'S 152°25'E, Gillett Cay, Swains Reefs, 27–37 m, 16–19 October 1962; 22, AMS C173556, 22°31.4'S 152°32.6'E, south-east of Swains Reefs, 100 m, 5–6 July 1984; 21, AMS C173552, 5, AMS C173557, 23°51.2'S 152°34.5'E, east of Lady Musgrave Island, 200 m, 4 July 1984; 40, AMS C310407, 23°52.5–51.9'S 152°42.7–41.7'E, east of Lady Musgrave Island, 296 m, 7 July 1984; 1, AMS C173914, Bowen; 11, AMS C173543, off Yeppoon, Keppel Bay, 5 m; 1, AMS C4513, Thursday Island; 14, AMS C10235, Palm Island, 27 m, July-August 1901; 2, NMV F72199, 18°17'S 146°38'E, Britomart Reef, 27 November 1982; 1, AMS C173947, Cape Grenville, 36 m; 3, AMS C173948, 10°35'S 141°55'E, Gannet Passage, Torres Strait, 11 m. NORTHERN TERRITORY: many, WAM 73-93, Darwin, July 1973. WESTERN AUSTRALIA: 4, AMS C173641, 16°58'S 120°47'E, 160 km north-west of Broome, 194 m, 29 November 1967; 1, AMS C173591, 18°40'S 117°55'E, north of Port Hedland, 150 m, 28 March 1982; many, WAM 59-94, Exmouth Gulf, grab sample, November-December 1993.

Description. Shell length to 5.2 mm, aperture diameter 1.25 mm, apex diameter 1.2 mm; greatest width of shell 1.4 mm, thin, polished, very slightly curved, bulging centrally, slightly on the concave side, more so on the convex side, narrowed at both ends. Sculpture of faint transverse growth lines. Aperture rather large, oblique, thin, slightly compressed dorsoventrally. Apex small, circular. Colour translucent white with an opaque ring near the apex.

Range. Victoria, New South Wales, Queensland, Northern Territory to northern Western Australia.

Habitat. Dredged in sand from 5 to 1646 m.

Comparisons and remarks. *Cadulus simillimus* most closely resembles *C. vincentianus* Cotton & Godfrey with an almost central swelling and which, in the northern part of its range, can occur sympatrically with *C. simillimus*. Shell features differentiating *C. simillimus* (from *C. vincentianus*) include: profile wider; dorsal edge with slight bulge present. The type material of this species consists of two lots of syntypes (BMNH 1887.2.9.80; 1887.2.9.81), each lot containing two shells. Unfortunately it appears that more than one species is contained within this type series, with the result that the true identity of *C. simillimus* requires clarification. As Watson did not nominate a holotype we herein choose a lectotype from the syntype series. In doing so we have sought to match Watson's description and illustration (his Plate III, number 6) of the species with one of the four syntypes. Although lot BMNH 1887.2.9.81 contains a note stating "specimen figured" neither of the shells from this lot matches Watson's description or illustration (his Plate III, figure 6). In contrast, the specimen we have selected as lectotype (the larger specimen from BMNH 1887.2.9.80) appears to match reasonably closely the description and illustration given by Watson. The other specimen from BMNH 1887.2.9.80 shows an unusual lobulate apex reminiscent of *Polyschides* but this could be due to

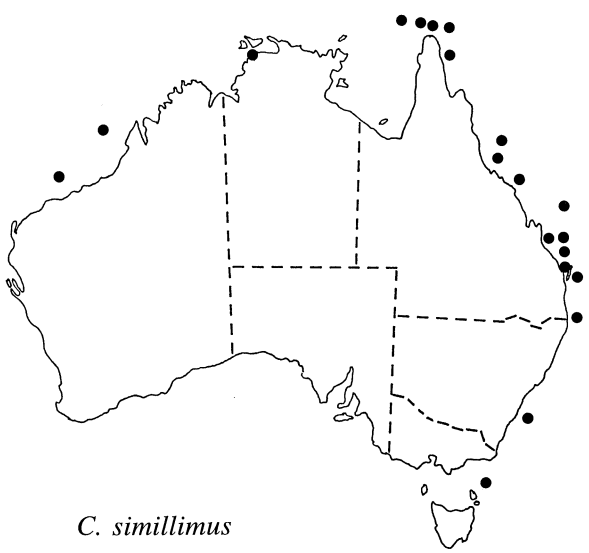


Figure 169. Known distribution of *Cadulus simillimus* Watson, 1879.

breakage—any similarities to *Polyschides* merely being coincidental. Of the remaining two original syntypes (BMNH 1887.2.9.81) one is broken and has been subsequently glued back together (badly). Its status is uncertain. The other specimen is intact but does not closely resemble those shells from BMNH 1887.2.9.80 nor Watson's description or illustration. This specimen in fact seems to be inseparable from *C. vincentianus* Cotton & Godfrey, the holotype of *C. vincentianus* agreeing in all respects with this shell.

Cadulus vincentianus Cotton & Godfrey, 1940

Figs 167A, 168E, 170

Cadulus vincentianus Cotton & Godfrey, 1940: 338, fig. 360; Zeidler & Macphail, 1978: 384.

Type material examined. HOLOTYPE: SAM D13730. Type locality: Holdfast Bay, Gulf of St Vincent, SA. Length of holotype 4.0 mm, aperture diameter 0.6 mm, apex diameter 0.5 mm, greatest width of shell 0.75 mm.

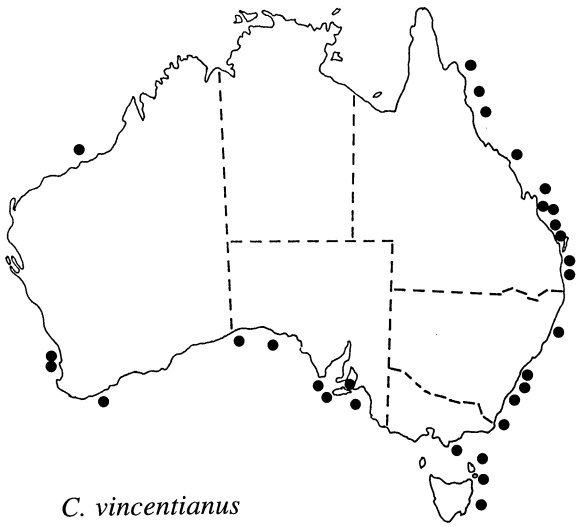


Figure 170. Known distribution of *Cadulus vincentianus* Cotton & Godfrey, 1940.

Additional material examined. WESTERN AUSTRALIA: many, WAM 58-94, Exmouth Gulf, grab samples, November-December 1993; 5, AMS C173642, 18°40'S 119°23'E, 192 km north of Port Hedland, 117 m, 6 October 1968; 5, AMS C173644, 18°33'S 119°08'E, 321 km west of Roebuck Bay, 128 m, 7 October 1968; 1, AMS C173539, 31°59'S 115°45'E, Cottesloe Beach, Perth, 30 January 1972; 2, AMS C173639, Thompson Bay, Rottnest Island, 1973; 4, SAM D18933, 32, SAM D18914, King George Sound, 28 m; 1, WAM 256-93, 30°04'S 113°50'E, north of Lancelin, 274 m, 23 March 1972, sand; 6, WAM 264-93, Albany, 1967. SOUTH AUSTRALIA: 1, AMS C173608, Arno Bay, Eyre Peninsula, Spencer Gulf; 3, AMS C173796, north of St Francis Island, 20–30 m, September 1974; 1, SAM D18929, Port Willunga; 1, AMS C173798, Hardwick Bay, south-west Yorke Peninsula; 3, SAM D301, Cape Borda, 124 m; 28, SAM D18908, Guichen Bay; 12, SAM D18909, Investigator Strait, 40 m; 1, SAM D18910, off Ardrossan, 28 m; 2, SAM D18911, off St Francis Island, 70 m; 7, SAM D18912, Gulf of St Vincent; 8, SAM D18913, Robe; 44, AMS C13407, Hardwick Bay; 9, AMS C173664, Arno Bay; 1, AMS C173584, 32°42'S 131°27'E, 80 km south-west of Cape Adieu, Great Australian Bight, 79 m, 4 July 1962. TASMANIA: 5, AMS C4936; 6, AMS C173660, 3, AMS C173658, 42°14.8'S 148°02.8'E, in Great Oyster Bay, 18 m, 18 March 1973; 2, AMS C174208, 43°34.05'S 149°53.47'E, Tasman Sea, Cascade Plateau, 2780 m, 17 December 1986; 1, NMV F72158, 41°57.30'S 148°58.54'E, off Freycinet Peninsula, 1735 m, 30 October 1988; 29, AMS C173920, West Head, Greens Beach, Tamar River mouth; 4, NMV F75846, 42°00.20'S 148°37.70'E, off Freycinet Peninsula, 720 m, 27 July 1986, coarse shelly sand; 3, NMV F72139, 42°02.20'S 148°38.70'E, off Freycinet Peninsula, 800 m, 27 July 1986, coarse shelly sand. VICTORIA: 2, AMS C173786, Port Fairy; 1, AMS C173785, 48 km south of Cape Nelson, 2000 m; 7, AMS C173759, 5, AMS C173668, Port Albert; 1, AMS C173666, 38°18.20'S 148°39.00'E, 58 km south of Cape Conran, Gippsland, 820 m, May 1969. NEW SOUTH WALES: many, AMS C173781, Eden Harbour, 1955–68; 1, AMS C173940, Ulladulla, 1950–60; 5, AMS C168101, Chinamans Beach, Sydney, 1940; 5, AMS C173613, 54, AMS C173614, Botany Bay, 6 m; 9, AMS C173963, Sydney Harbour, 1929–30; 1, AMS C173739, Disaster Bay, 33 m; 1, AMS C173734, Warriewood Beach; 1, AMS C173771, Gunnamatta Bay, Port Hacking; 3, AMS C173067, off Jibbon, Port Hacking, 85 m, January 1964; 12 AMS C173068, dredged Port Hacking off Weemalah, 23 September 1972; 5, AMS C173069, Gunnamatta Bay, Port Hacking, low tide, 1950–60; 7, AMS C173807, 36°19.9'S 150°16.9'E, south-east of Montague Island, 124 m, 31 March 1972; 8 AMS C173772, 31°40'S 152°50.4'E, off Laurieton, 20 m, 25 February 1972; 1, AMS C173952, Clontarf, Middle Harbour, Sydney, 6 April 1972; 10, AMS C173689, Ocean Beach, Manly, 1950–60; 2, AMS C173912, 8 km east of Woody Head, 36.5 m, 3 April 1939; 2, AMS C173622, dredged off Green Point, Port Jackson; 4, AMS C173765, many, AMS C173782, Jervis Bay, 27.5 m; 4, AMS C173931; many, AMS C173575, Fingal Bay, southern Port Stephens, in beach wash, 1950–1960; 1, AMS C173071, dredged off Nelson Heads, Port Stephens, 1880; 6, AMS C173573, 35°59.8'S 150°10'E, east of Moruya, 16 m; 4, AMS C173951, off Sow and Pigs Reef, Port Jackson; 1, AMS C173053, Hunter Bay, Middle Harbour, Port Jackson, 5 m; 1, AMS C173953, southern end of Calloroy Beach, 14 January 1950; 6, AMS C173623, Pittwater Broken Bay, 1950–60; 6, AMS C173614, Fingal Bay, Port Stephens; 17, AMS C173777, Batemans Bay, 1950–60; 4, AMS C173889, Huskisson, Jervis Bay; 26, AMS C173569, Twofold Bay, South Coast, 46 m, 1950–60; 1, AMS C173778, Twofold Bay; 1, AMS C173768, Balmoral Beach, Sydney, January 1951; 18, AMS C173571, off Cronulla, 140 m; 1, AMS C173780, Clarence River. QUEENSLAND: 1, AMS C173616, 1, AMS C173954, Caloundra Beaches, 1963; 6, AMS C173944, 2, AMS C173649, 4, AMS C173943, Amity Point, Stradbroke Island, June 1973; 6, AMS C173950, Point Lookout, Stradbroke Island, 12 December 1969; 1, AMS C173648, Peel Island, Moreton Bay, 1955; 56, AMS C173656, 113, AMS C173683, Hervey Bay; 1, AMS C173680, 24°37.2'S 152°33'E, off Bundaberg, 22 m, 12 October 1970; 2, AMS C173909, 23°18'S 151°42'E, North West Island, May 1931; 4, AMS C173687, 22°50'S 151°39'E, north-east of Rockhampton, 64 m, 25 September 1970; 4, AMS C173587, Humpy Island, Keppel Bay, 3.5 m; 3, AMS C173652, Yeppoon, 4 m; 1, AMS C173945, One Tree Island, Capricorn-Bunker Group, 55 m; 52, AMS C173657, Bowen, June 1972; 35, AMS C173686, Port Denison, Bowen; 2, AMS C173927, Sarina Beach, 5 July 1969; 1, NMV F72156, 18°17'S 146°38'E, Britomart Reef; 1, AMS C174643, 17°09'07"–09'06"S 146°42'04"–42'00"E, off Cairns, 13 October 1981, 668–613 m, firm clay-mud; 7, AMS C173681, Lizard Island, 15 m, 3 December 1974. NORTHERN TERRITORY: 1, AMS C173602, off Point Charles, north-west of Darwin, 37 m, 1960.

Description. Shell length to 6.0 mm, aperture diameter 0.7 mm, apex diameter 0.5 mm; greatest width of shell 1.0 mm; narrow throughout length, only slightly swollen centrally; glossy. Sculpture absent but with microscopic transverse lines and a white, opaque, internal callous ring near the apex. Aperture circular. Apex orifice large, slightly dorsoventrally compressed. Colour translucent white, glassy in juveniles.

Radula. The radula of *C. vincentianus* was illustrated and described by Cotton & Godfrey (1940, fig. 360) in their original description of the species. Their figure reveals a typically gadiloid radula, characterized by a central tooth which is higher than wide.

Range. Western Australia, South Australia, Tasmania, Victoria, New South Wales, Queensland to Northern Territory, Heard Island, southern Ocean.

Habitat. Intertidal and dredged in sand from 3.5 to 2780 m.

Comparisons and remarks. *Cadulus vincentianus* most closely resembles *C. simillimus* Watson. Shell features of *C. vincentianus* which separate the species from *C. simillimus* include: less swollen centrally; lacks any swelling on the dorsal side; less tapering each end. In the early stages of growth this species is shaped similarly to juvenile *Laevidentalium*, becoming slightly swollen centrally in its adult stage, often with a constriction towards the aperture. Ms L. Turner (TM) advises that this species has also been recorded as subfossil (100,000 ybp) from Smithton, on the northern coast of Tasmania. We have also examined a specimen of *Cadulus vincentianus* collected from 400 m depth off Heard Island (Antarctica) (NMV F72164, 65°56.4'S 50°52.1'E).

Cadulus colliverae n.sp.

Figs 167C, 168F, 171

Etymology. Named after Mrs Mary Colliver for her volunteer work with the Department of Malacology at the Queensland Museum.

Type material examined. HOLOTYPE: QM MO17654. Type locality: 17°22'S 146°48'E, off Cairns, northern Qld, 296–303 m, 15 May 1986. Length of holotype 5.4 mm, aperture diameter 0.95 mm, apex diameter 0.76 mm; greatest width of shell 1.78 mm.

Description. Shell dimensions as for holotype; small, glossy; devoid of sculpture; very inflated centrally, more inflated on the ventral edge. Aperture slightly dorsoventrally compressed, longer and wider than the apex. Apex circular, narrow and tapering. Colour porcellaneous white.

Range. Northern Queensland.

Habitat. Dredged in coarse sand from 296 to 303 m.

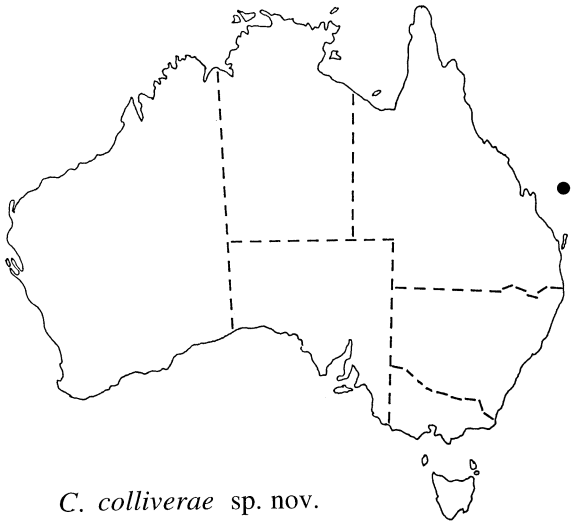


Figure 171. Known distribution of *Cadulus colliverae* n.sp.

Comparisons and remarks. *Cadulus colliverae* does not closely resemble any other species of the genus known from Australian waters. The almost straight shell and its pronounced central swelling immediately separates it from the other elongate species—*C. simillimus* Watson and *C. vincentianus* Cotton & Godfrey (compare longitudinal profiles in Fig. 167). This species is at present known only from the holotype.

Cadulus woodhousae n.sp.

Figs 167D, 168G, 172

Etymology. Named after the late Mrs Joyce Woodhouse for her contribution to Australian malacology.

Type material examined. HOLOTYPE: AMS C174625. Type locality: 10°17'S 132°38'E, Arafura Sea, 64.5 km north of Croker Island, 65 m, 9 November 1969. Length of holotype 1.97 mm, aperture diameter 0.44 mm, apex diameter 0.47 mm; greatest width of shell 0.88 mm. PARATYPES: 7, AMS C173679, sama data as holotype, 3 whole specimens, 4 damaged.

Additional material examined. 1, AMS C173906, 24°28.2'S 153°31.2'E, north-east of Sandy Cape, Qld, 1330–1380 m, 8 July 1984.

Description. Shell dimensions as for holotype; small, glossy; devoid of sculpture; barrel-shaped, inflated centrally and equally all round the shell. Aperture circular, short and obliquely terminating. Apex short, narrower than the aperture, circular and obliquely terminating. Colour porcellaneous white.

Range. Queensland, Arafura Sea.

Habitat. Dredged in sand from 65 to 1380 m.

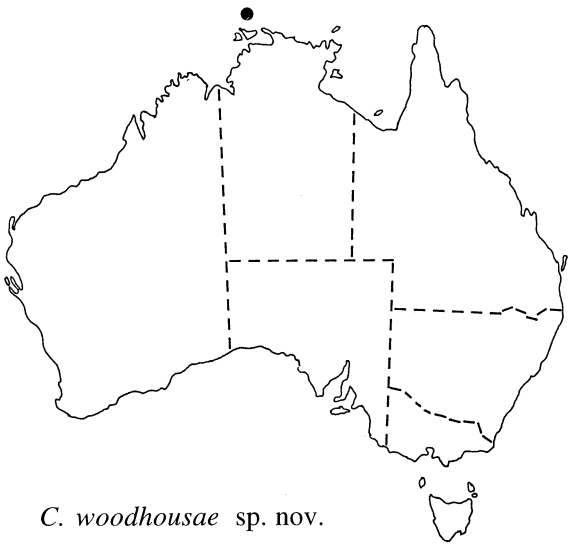


Figure 172. Known distribution of *Cadulus woodhousae* n.sp.

Comparisons and remarks. *Cadulus woodhousae* does not closely resemble any other Australian species of the genus. Compared with the Indo-West Pacific *C. cyathoides* Jaeckel and European *C. cyathus* (Cristofori & Jan), *C. woodhousae* is more equally inflated and each end much more obliquely truncate. *Cadulus woodhousae* can also be compared with *C. gibbus* Jeffreys from the north Atlantic which, while equally inflated, has a longer and more tapering aperture and apex, in addition the apex and aperture are not obliquely truncate as in *C. woodhousae*. *Cadulus rudmani* n.sp. is also similar in shape but is more inflated and even shorter in the aperture and apical ends than in *C. woodhousae*.

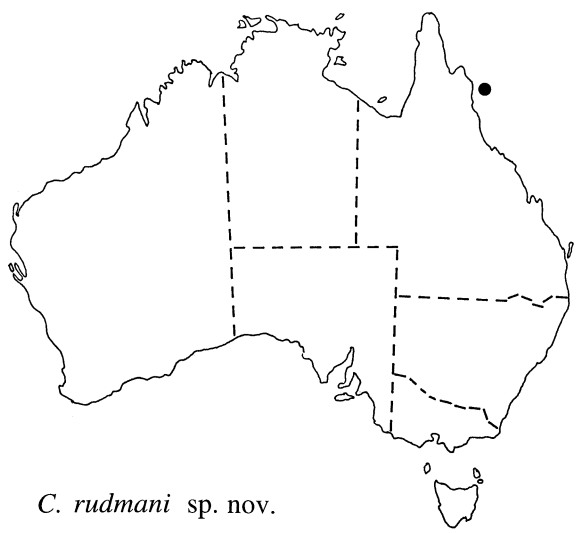


Figure 173. Known distribution of *Cadulus rudmani* n.sp.

Cadulus rudmani n.sp.

Figs 167E, 168H, 173

Etymology. Named after Dr Bill Rudman (Malacology Section, Australian Museum) for his extensive contribution to Australian malacology and his assistance in this and other projects.

Type material examined. HOLOTYPE: AMS C174626. Type locality: 17°09.42'S 146°42.24'E, off Cairns, Qld, 668 m, 13 October 1981. Length of holotype 2.38 mm, aperture diameter 0.63 mm, apex diameter 0.66 mm; greatest width of shell 1.59 mm. PARATYPES: 1, AMS C173407, same locality data as holotype.

Description. Shell dimensions as for holotype; small, glossy; devoid of sculpture; barrel-shaped, very inflated centrally, more inflated on the ventral edge. Aperture circular, wider than the apex. Apex circular, shorter and more narrowly tapering than the aperture. Colour porcelaineous white.

Range. Northern Queensland.

Habitat. Dredged at 668 m in firm clay and mud.

Comparisons and remarks. *Cadulus rudmani* n.sp., like the previous species, shows no close similarity to any other Australian species of the genus. Compared with the European-Atlantic *C. ovulus* (Philippi, 1844) and *C. ampullaceus* Watson, 1879 and the Indo-Pacific *C. cyathoides* Jaeckel, 1932, *C. rudmani* is more inflated, the inflation situated centrally. *Cadulus rudmani* can also be compared with *C. gibbus* from the north Atlantic which has longer and more tapering aperture and apex. *Cadulus rudmani* resembles *C. woodhousae* in being a short, stocky species, but is more inflated and has pronounced contraction of the apex and aperture.

Genus *Dischides* Jeffreys, 1867

Gadus "Rang" Deshayes, 1864–1866: 217, [not Rang, 1829, not Linnaeus, 1758].
Dischides Jeffreys, 1867: 251; Pilsbry & Sharp, 1897: 143; Boissevain, 1906: 65; Ludbrook, 1960: I40; Emerson, 1962: 479; Habe, 1964: 49; Palmer, 1974a: 121; Steiner, 1992a: 398.
Dicides Sacco, 1897: 115.

Type species: *Dentalium bifissum* Wood, 1842: by monotypy.

Diagnosis. Shell slender, only slightly inflated; constricted at aperture; apex cut into ventral and dorsal lobes by two deep lateral notches one on each side.

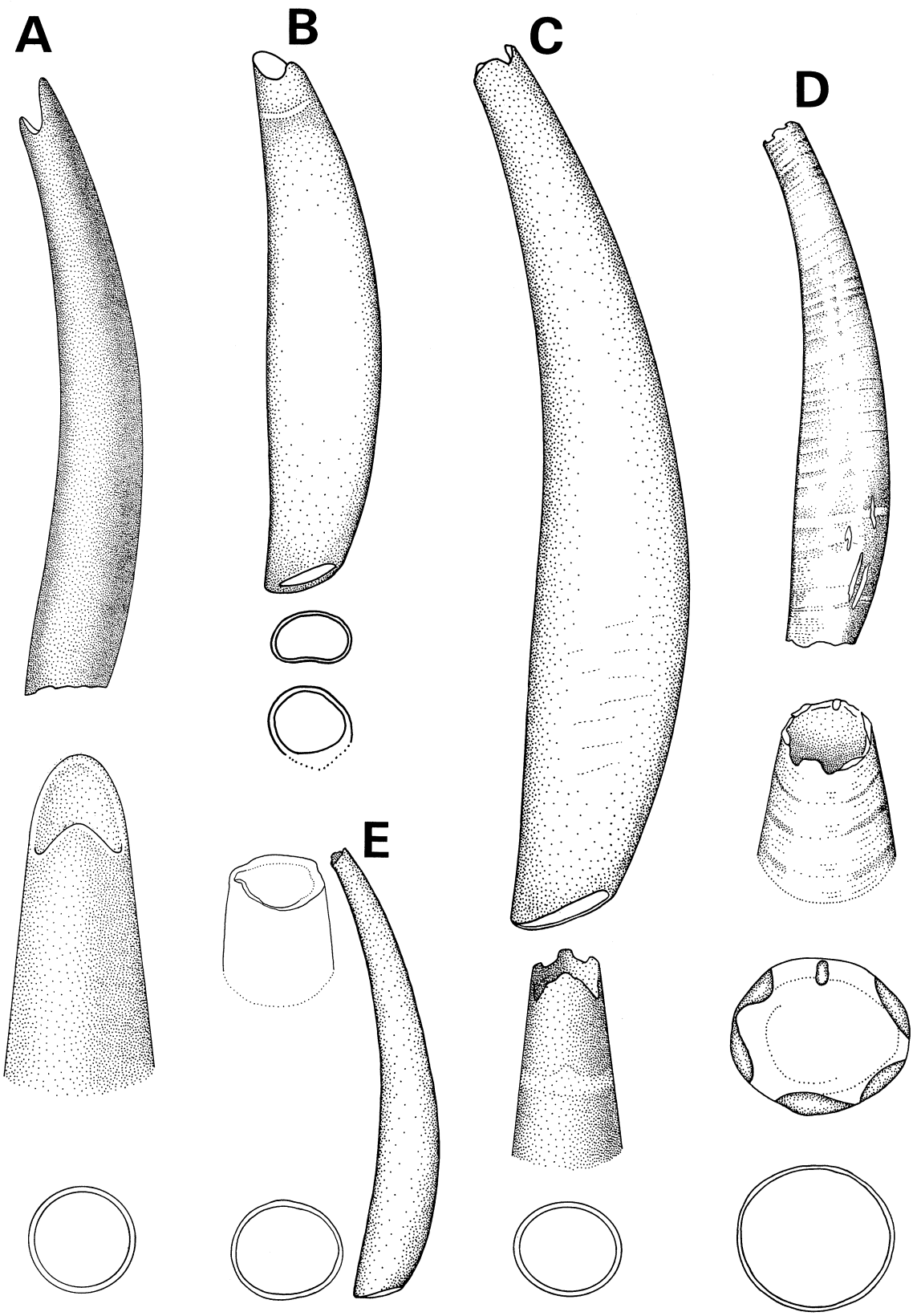


Figure 174. Gadilida, Gadilidae. **A,B** *Dischides*. **A** *D. prionotus* (Watson, 1879) (AMS C19257, Masthead Reef, Qld, 40 m, length 5.5 mm). **B** *D. hintoni* n.sp. (holotype, AMS C174894, 3 km north-east of west side of Gillett Cay, Swain Reefs, Qld, 80 m, length 4.0 mm). **C–E** *Polyschides*. **C** *P. gibbosus* (Verco, 1911) (holotype, SAM D13729, Cape Jaffa, SA, 549 m, length 9.7 mm). **D** *P. sutherlandi* n.sp. (holotype, QM MO53677, off Cairns, Qld, 296–303 m, length 12.4 mm). **E** *P. andersoni* n.sp. (holotype, ACM174896, off Wollongong, NSW, 1200 m, length 11.2 mm). (Del.: all A. Hill, except A and C [apex and aperture]—C. Eadie).

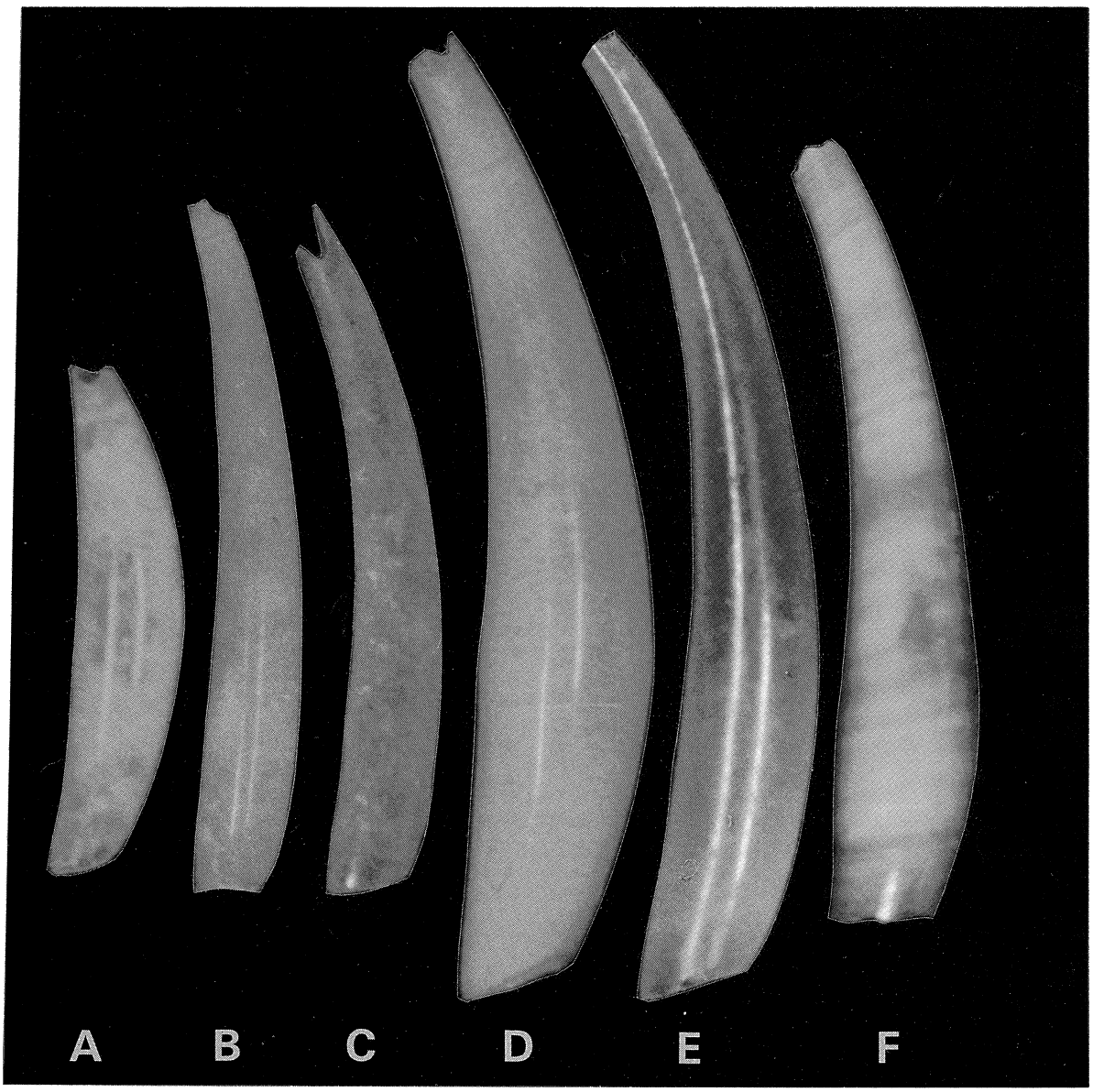


Figure 175. Gadilida, Gadilidae. **A–C** *Dischides*. **A** *D. hintoni* n.sp. (holotype, AMS C174894, 3 km north-east of west side of Gillett Cay, Swain Reefs, Qld, 80 m, length 4.0 mm). **B** *D. prionotus* (Watson, 1879) (lectotype, BMNH 1887.2.9.67–8, Raine Island, Cape York, Qld, 284 m, length 8.2 mm). **C** *D. prionotus* (Watson, 1879) (AMS C19257, Masthead Reef, 40 m, Qld, length 5.5 mm). **D–F** *Polyschides*. **D** *P. gibbosus* (Verco, 1911) (holotype, SAM D13729, Cape Jaffa, SA, 549 m, length 9.7 mm). **E** *P. andersoni* n.sp. (holotype, AMS C174896 off Wollongong, NSW, 1200 m, length 11.2 mm). **F** *P. sutherlandi* n.sp. (holotype, QM MO53677, off Cairns, Qld, 296–303 m, length 12.4 mm).

Key to Australian *Dischides*

1 Ventral lobe longer than the dorsal; shell widest near aperture ..... *D. prionotus*

—— Dorsal lobe more extended than the ventral; shell widest centrally ..... *D. hintoni*

Dischides prionotus (Watson, 1879)

Figs 174A, 175B,C, 176

Siphodentalium prionotum Watson, 1879: 522; Watson, 1886: 16, pl. 2, fig. 9; Pilsbry & Sharp, 1898: 146, pl. 26, fig. 74; Boissevain, 1906: 66, pl. 3, fig. 47; Hedley, 1910: 371.

Type material examined. LECTOTYPE here selected from syntype lot BMNH 1887.2.9.67–8. Type locality: Raine Island, Cape York, north-east Australia, 155 fathoms [284 m]. Length of lectotype 8.2 mm, aperture diameter 0.7 mm, apex diameter 0.5 mm. PARALECTOTYPES: 3, same locality data as lectotype.

Additional material examined. NEW SOUTH WALES: 75, AMS C59714, 31°33'S 159°05'E, Lord Howe Island. QUEENSLAND: 14, AMS C173549, dredged 150 m, off west side of Lady Elliot Island, Capricorn-Bunker Group, 18 m, August 1964; 1, AMS C173544, 2, AMS C172602, Lady Musgrave Island, Capricorn-Bunker Group, dredged in lagoon; 4, AMS C173534, North West Island, Capricorn-Bunker Group, May 1931; 10, AMS C173542, 23°18'S 152°42'E, North West Island, Capricorn-Bunker Group, May 1931; 1, AMS C18840; 80, AMS C19257, Masthead Reef, 34–40 m, 25–29 October 1904; 2, AMS C172601, Heron Island, Capricorn-Bunker Group, 15 m; 1, AMS C173548, 22°23.5'S 151°56.5'E, Heron Island, 40 m, 3 October 1970; 100, AMS C173650, 1, AMS C173545, 4, AMS C311127, 21°43'S 152°25'E, Gillett Cay, Swains Reefs, 27–37 m, inside reef, 16–19 October 1962; 3, AMS C173946, dredged Ellis Reef, near Kurramine, 19 October 1965; 15, NMV F72200, 18°17'S 146°38'E, Britomart Reef, 27 November 1982; 1, AMS C173586, off Spur Reef, east of Norman Reef, north of Cairns, 36.5 m, 28 November 1972; 2, AMS C173547, Rocky Point, Lizard Island, 7.5 m, 2 December 1975; 23 AMS C173908, 9°56'S 144°04'E, off Murray Island, Torres Strait, 15 m, 30 August–3 October 1907. NORTHERN TERRITORY: 1, AMS C173792, 32 km off Point Charles, Darwin, 37 m, 14 July 1938. WESTERN AUSTRALIA: 2, AMS C173752, 14°29'S 123°03'E, 224 km north of Cape Leveque, 124 m, 12 November 1967; 3, AMS C169787, 30°45'S 114°51'E, west of Jurien Bay; 143 m, 21 August 1962; 7, WAM 64-93, 19°34'S 116°08'E, north north-west of Dampier, 110 m 19 August 1979; 1, AMS C173537, 18°48'S 119°00'E, 174 km north north-east of Port Hedland, 94 m, 23 October 1983; 1, AMS C172590, 18°48'S 114°00'E, 174 km north north-east of Port Hedland, 94 m, 23 October 1983; 1, AMS C173592, 19°29'S 116°01'E, 272 km west of Port Hedland, 137 m, 1 December 1968; 6, AMS C310677, 16°58'S 120°47'E, 160 km north-west of Broome, 194 m, 29 November 1967.

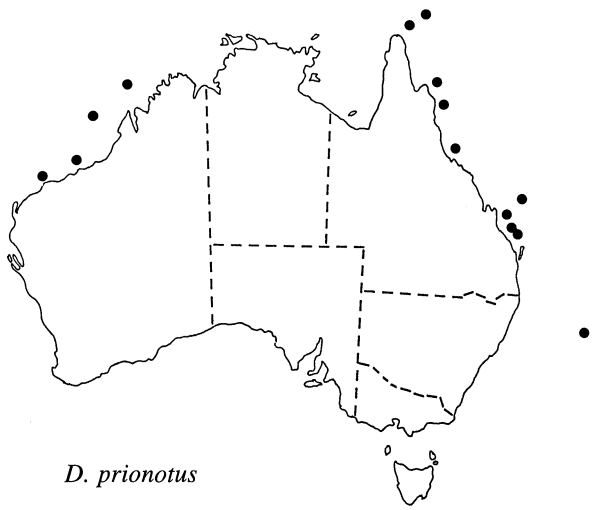


Figure 176. Australian distribution of *Dischides prionotus* (Watson, 1879).

Description. Shell length to 8.2 mm, aperture diameter 0.7 mm, apex diameter 0.5 mm; narrow, slightly curved. Sculpture of faint, transverse growth lines. Aperture circular, contracted. Apex circular, roundly notched on both sides, the ventral end longer than the dorsal, giving a sharp, projecting point on the dorsal and ventral ends. Within the opening a minute riblet extends out along the centre of the posterior rim, obvious within the opening. Colour translucent white.

Range. Lord Howe Island, central Queensland, Northern Territory to Western Australia.

Habitat. Dredged in sand and mud from 7.5 to 284 m.

Comparisons and remarks. *Dischides prionotus* can be readily separated from its only other Australian congener, *D. hintoni* n.sp. by its pronounced ventral lobe at the apex and weakly developed dorsal lobe. *Dischides hintoni* in contrast shows the reverse arrangement of apical lobes (well developed dorsal lobe, poorly developed ventral lobe). The lectotype, herein selected from the syntype series, is the specimen for which Watson gives measurements. This species has a considerable Australian distribution (Lord Howe Island, Queensland, Northern Territory, to southern Western Australia) and appears to be common at certain localities.

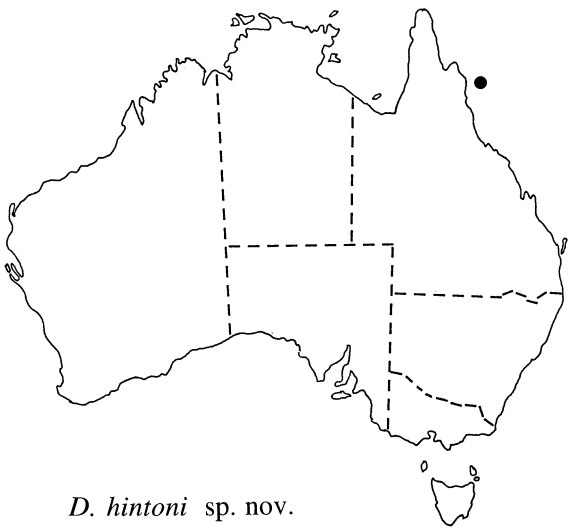
Dischides hintoni n.sp.

Figs 174B, 175A, 177

Etymology. Named after Mr Alan Hinton for his contributions to Australian malacology.

Type material examined. HOLOTYPE: AMS C174894. Type locality: 3 km north-east of west side of Gillett Cay, Swains Reefs, Qld, 80 m, 17–19 October 1962. Length of holotype 4.0 mm, aperture diameter 0.5 mm, apex diameter 0.3 mm, greatest width 0.85 mm. PARATYPES: 28, AMS C173611 (pt), same locality data as holotype.

Description. Shell dimensions as for holotype; moderately curved, contracted towards each end, swollen centrally. Sculpture of microscopic transverse growth lines. Aperture oblique, contracted, slightly flattened on the ventral side. Apex contracted, smaller



D. hintoni sp. nov.

Figure 177. Known distribution of *Dischides hintoni* n.sp.

than the aperture, contracted and flattened on both the ventral and dorsal sides, cut into two lobes the dorsal lobe more extended than the ventral. Colour translucent, almost transparent white with a transverse white opaque ring near the apex, glossy.

Range. Gillett Cay, Swains Reefs, Queensland.

Habitat. Dredged in coral sand to 80 m.

Comparisons and remarks. As noted above, *Dischides hintoni* shows the reverse degree of development of the dorsal and ventral shell lobes shown in *D. prionotus* (Watson). *Dischides hintoni* resembles *Cadulus vincentianus* Cotton & Godfrey and *Cadulus simillimus* Watson in being swollen centrally but differs from both of these species in having the two apical lobes characteristic of the genus *Dischides*. Among the numerous specimens of *D. hintoni* examined, several have the white internal callous ring near the apex, usually a feature confined to the genus *Cadulus*. The delicacy of the apical lobes is well demonstrated by the fact that of the 28 paratypes 15 specimens have the apical lobes broken off.

Genus *Polyschides* Pilsbry & Sharp, 1898

Polyschides Pilsbry & Sharp, 1898: 146; Boissevain, 1906: 67; Henderson, 1920: 96; Woodring, 1925: 207; Ludbrook, 1960: I40; Emerson, 1962: 479; Habe, 1964: 50; Palmer, 1974a: 121; Steiner, 1991: 398.

Type species: *Cadulus tetraschistus* Watson, 1879, by original designation.

Diagnosis. Shell small to moderately large, inflated especially in anterior half; apex divided into a number of lobes (typically 4) by a symmetrical arrangement of notches.

Key to Australian *Polyschides*

1 Shell aperture circular; apex small, 3 lobed (2 ventral notches and 1 shallow dorsal notch) ..... *P. sutherlandi*

—— Shell aperture dorsoventrally compressed; apex 4 or 5 lobed 2

2 Apex 4 lobed, with a lobe on the dorsal and ventral side, the dorsal side wider; shell widest at the anterior third ..... *P. gibbosus*

—— Apex 5 lobed, with a wide dorsal notch, other notches wide at their extremity, narrow at their base; shell widest near aperture ..... *P. andersoni*

Polyschides gibbosus (Verco, 1911)

Figs 174C, 175D, 178

Cadulus gibbosus Verco, 1911a: 213, pl. 26, fig. 6; Cotton & Godfrey, 1940: 341, fig. 364.

Type material examined. HOLOTYPE: SAM D13729. Type locality: Cape Jaffa, SA, 300 fathoms [549 m]. Length of holotype 9.7 mm, aperture diameter 1.1 mm, apex diameter 0.45 mm; widest diameter of shell 1.8 mm.

Additional material examined. WESTERN AUSTRALIA: 2, AMS C310276, 30°45'S 114°51'E, west of Jurien Bay, 143 m, 11 August 1962; 1, AMS C173753, 18°48'S 117°57'E, off Port Hedland, 152 m; 10, AMS C173757, 18°30'S 118°03'E, 369 km west of Roebuck Bay, 238 m, 11 October 1968; 11, AMS C173631, off Dunsborough, 16.5 m, 27 December 1971; 12, AMS C173629, 3, AMS C173538, 33°03'S 114°44'E, west of Bunbury, 10 August 1962; 3, WAM 245-93, west of Rottnest Island, 120 m, 2 December 1970; 1, WAM 244-93, 32°00'S 115°21'E, west of Rottnest Island, 100 m, 11 October 1963. SOUTH AUSTRALIA: 1, SAM D18926, Cape Jaffa, 600 m, 25 December 1905; 2, AMS C33497, Cape Jaffa, 260 m; 1, AMS C3943, 60 km south of Cape Wiles, 183 m, August 1909. TASMANIA: 2, AMS C174113, 43°31.86–32.04'S 149°56.25–54.90'E, Tasman Sea, Cascade Plateau, 2770–2780 m, 16 December 1986. VICTORIA: 1, NMV F72135, 38°25.00'S 149°00.00'E, south of Point Hicks, 1500 m, 22 July 1986; 1, AMS C17369, 38°24'S 149°08.50'E, 54 km south of Tamboon Inlet, Gippsland, 1080 m, May 1969. NEW SOUTH WALES: 1,

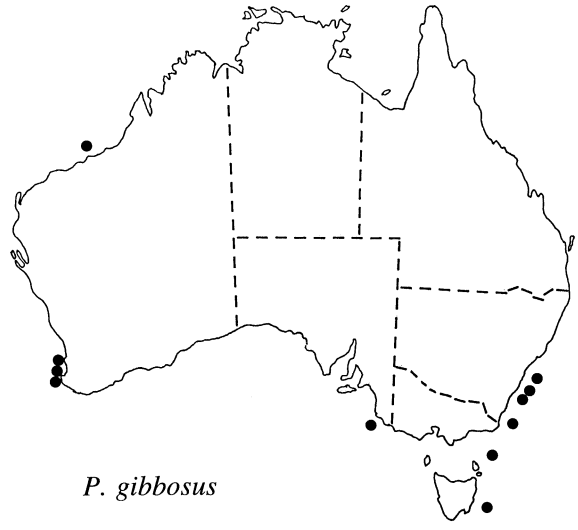


Figure 178. Known distribution of *Polyschides gibbosus* (Verco, 1911).

NMV F72146, 34°52.29'S 151°15.02'E, off Nowra, 1096 m, 15 July 1986; 1, AMS C173289, 33°32'S 152°08'E, east of Broken Bay, 914 m, 4 December 1979; 3, AMS C173292, 33°38'S 152°06'E, off Broken Bay, 1000 m, 6 December 1979; 1, AMS C173403, 34°53–56'S 152°13–13'E, off Shoalhaven Bight, 1097 m, 26 October 1983; 2, AMS C173387, 35°31–28'S 150°50–53'E, north-east of Batemans Bay, 969 m, 8 September 1983; 1, AMS C173610, 51 km east from Green Cape, 860 m, 2 October 1912; 1, AMS C173382, 1, AMS C173400, 35°27.30'S 150°55–52'E, south-east of Ulladulla, 1006 m, 25 October 1983; 2, AMS C173581, 3, AMS C173397, 34°54–50'S 151°14–15'E, east of Nowra, 1015 m 26 October 1983; 4, AMS C173404, 3, AMS C173384, 34°54–50'S 151°14–15'E, off Shoalhaven Bight, 1006 m, 26 October 1983.

Description. Shell length to 17.2 mm, aperture diameter 2.7 mm, greatest diameter 2.8 mm, apex diameter 1.5 mm; smooth, polished; narrow, slightly compressed dorsoventrally, smaller behind, inflated at the anterior third, dorsal surface obtusely angled at this point, ventral surface evenly convex. Sculpture of some microscopic, oblique growth lines, at 0.1 mm from posterior end is a transverse colourless line. Aperture moderately dorsoventrally compressed, oblique, sloping forward from the ventral to dorsal surface. Apex circular with a notch each side, wider on the dorsal side. Colour milky white.

Range. Southern Western Australia, South Australia, Victoria to New South Wales.

Habitat. Dredged in sand and mud from 16.5 to 2780 m.

Comparisons and remarks. *Polyschides gibbosus* can be easily separated from *P. sutherlandi* n.sp. by its typical four lobed apex (versus three lobes in *P. sutherlandi* created by a shallow dorsal notch and two ventral notches) and greater expansion of the shell profile towards the aperture. In shape *P. gibbosus* approaches *G. cobbi* n.sp., but these species can be separated on the aperture profile (markedly dorsoventrally compressed in *G. cobbi*, only slightly compressed in *P. gibbosus*), apical features and the less inflated profile of *G. cobbi*. *Polyschides gibbosus* is a reasonably common species with a large, predominantly southern distribution.

Polyschides sutherlandi n.sp.

Figs 174D, 175F, 179

Etymology. Named after the late Dr Keith Sutherland and the Keith Sutherland Award of the Australian Museum which provided some of the funding support for this project.

Type material examined. HOLOTYPE: QM MO53677. Type locality: 17°22'S 146°48'E, off Cairns, northern Qld, 296–303 m, 15 May 1986. Length of holotype 12.4 mm, aperture diameter 1.4 mm, apex diameter 0.6 mm, greatest width of shell 1.7 mm. PARATYPES: 1, QM MO45834, 17°22'S 146°48'E, off Cairns, northern Qld, 296–303 m, 15 May 1986; 11, QM MO40085, same locality data as holotype; 1, AMS C172620, 23°15.2'S 152°24.1'E, east of North West Island, Qld, 284 m, 14 December 1977; 4, AMS C173955, mouth of Caiman Creek, Berkeley Bay, Port Essington, Cobourg Peninsula, NT, 2 June 1976.

Additional material examined. NEW SOUTH WALES: 6, AMS C169931, 33°31–33'S 152°08–07'E, off Sydney, 914–907 m, 10 December 1980; 42, AMS C174436, 36°57.95–58.41'S 150°22.00–22.14'E, Tasman Sea, east of Eden, 960–1050 m, 12 December 1986. QUEENSLAND: 9, AMS C173901, 23°19.5'S 152°35.4'E, east of North West Island, 320 m, 14 December 1977; 1, QM MO40086, 9°47'S 145°16'E, 1764 m, 11 February 1992; 1, AMS C173296, 17°09.53'S 146°42.36'E, off Cairns, 243 m, 12 October 1981, grey mud (preserved).

Description. Shell length to 20.0 mm, aperture diameter 2.8 mm, apex diameter 1.4 mm; moderately curved, smooth, tapering to the aperture and apex, inflated towards

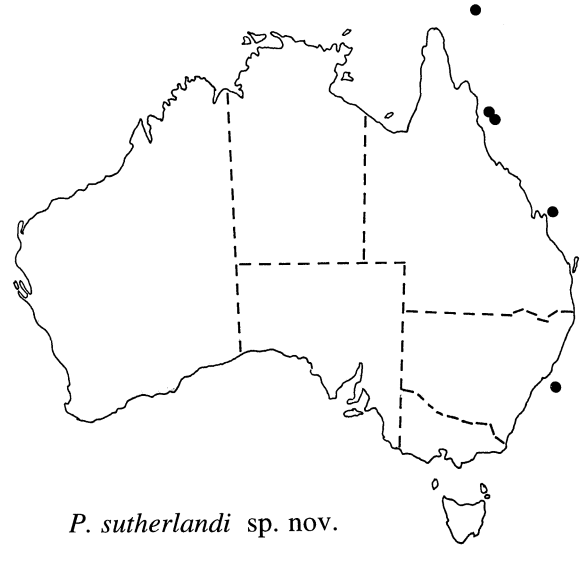


Figure 179. Known distribution of *Polyschides sutherlandi* n.sp.

the aperture on the ventral side. Sculpture of oblique, transverse, darker coloured rings. Aperture slightly dorsoventrally compressed. Apex very small, with two notches ventrally and one shallow notch dorsally (resulting in three shell lobes). Colour translucent milk-white.

Range. New South Wales to northern Queensland.

Habitat. Dredged in sand and mud from 243 to 1764 m.

Comparisons and remarks. *Polyschides sutherlandi* most closely resembles *P. gibbosus* (Verco). Differentiating features include: markedly narrower; three notches and three lobes apically (four notches and four lobes in *P. gibbosus*). *Polyschides sutherlandi* resembles *Dischides viperidens* (Melvill & Standen) in longitudinal profile but differs in having three lobes and three notches (versus two lobes and two notches in *D. viperidens*). *Dischides viperidens* has also only doubtfully been recorded from Australia (see remarks for *P. andersoni* n.sp.). *Gadila cobbi* n.sp. shows a similar degree of curvature to *P. gibbosus*, but aside from apical differences (all *Gadila* lack apical notches) can be distinguished by its much more inflated shell.

Polyschides andersoni n.sp.

Figs 174E, 175E, 180

Etymology. Named after Emeritus Professor Don Anderson FRS AO (formerly School of Biological Sciences, University of Sydney), in recognition of his outstanding contribution to Australian zoology, particularly the study of marine invertebrates.

Type material examined. HOLOTYPE: AMS C174896. Type locality: off Wollongong, 34°27–26'S 151°27'E, 1200 m, NSW, 13 December 1976. Length of holotype 11.2 mm, aperture diameter 1.1 × 1.7 mm, apex diameter 1.0 mm; greatest width of shell 2.0 mm. PARATYPES: 2 AMS C173797, 37°50–55'S 139°15–25'E, 80 km south-west of Cape Martin, SA, 1555 m, 14 August 1909; 22, AMS C169929, same locality data as holotype; 1, AMS C169930, 33°37–39'S 152°04.02'E, off Sydney, NSW, 924–896 m, 10 December 1980; 5, AMS C169934, 33°35'S 152°09'E, off Sydney, NSW, 1097 m, 4 December 1979; 3, AMS C169933, 34°50'S 151°15'E, off Nowra, NSW, 841 m, 12 December 1978; 3, AMS C174895, 33°31.33'S 152°08–07'E, off Sydney, NSW, 914–907 m, 10 December 1980; 7, AMS C169988, 33°44'S 151°57'E, east of Sydney, NSW, 322 m, 7 December 1978; 9, AMS C169932, 33°35–37'S 152°05'E, off Sydney, NSW, 1143–1106 m, 10 December 1980.

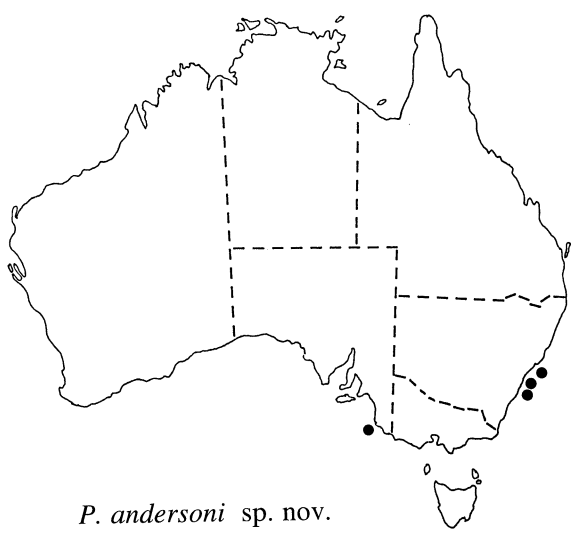


Figure 180. Known distribution of *Polyschides andersoni* n.sp.

Additional material examined. NEW SOUTH WALES: 1 specimen, 14 pieces, AMS C169930, 33°37–39'S 152°04–02'E, off Newcastle, 924–896 m, 10 December 1980.

Description. Shell length to 21.7 mm, aperture diameter 3.7 mm, apex diameter 1.6 mm; strongly curved, smooth, tapering to the aperture and apex, strongly inflated near the aperture on the ventral side (inflation appears almost angulate), dorsal side evenly curved. Without sculpture but with oblique, translucent markings in fresh specimens. Aperture moderately dorsoventrally compressed. Apex moderately dorsoventrally compressed, with a wide notch on the dorsal side, other notches are wide at their extremity becoming narrow at their base giving 5 shell lobes. Colour in fresh specimens, translucent milk-white becoming opaque white in dead specimens.

Range. South Australia and New South Wales.

Habitat. Dredged in sand and mud from 153 to 1555 m.

Comparisons and remarks. *Polyschides andersoni* differs from *P. gibbosus* (Verco, 1911) and *P. sutherlandi* n.sp., in having a marked swelling towards the aperture and in having five apical lobes (three notches and three lobes apically in *P. sutherlandi*; four notches and four lobes in *P. gibbosus*). *Dischides viperidens* (Melvill & Standen, 1896) somewhat resembles *P. andersoni* in longitudinal profile but shows the characteristic two notches of the genus *Dischides*. Moreover, the only record of *D. viperidens* from Australia ("North Australia" Melvill & Standen, 1896) is dubious and cannot be confirmed herein. *Gadila carlessi* n.sp. shows a similar swelling to that of *P. andersoni*, but has an almost straight profile, and lacks any apical notches. This species appears to retain the apical notching only in smaller specimens. Some lots examined contained very large shells which were usually eroded and exhibited a circular apex without notches. Nevertheless the apical orifice of these specimens was usually found to be rough, suggesting loss of the apical section, probably as a consequence of senescence. For this reason we have selected one of the smaller (though mature) specimens for the holotype, but do note that the species may attain a considerable size for the genus. Unfortunately all of our material of *P. andersoni* was dead-taken (and mud-filled).

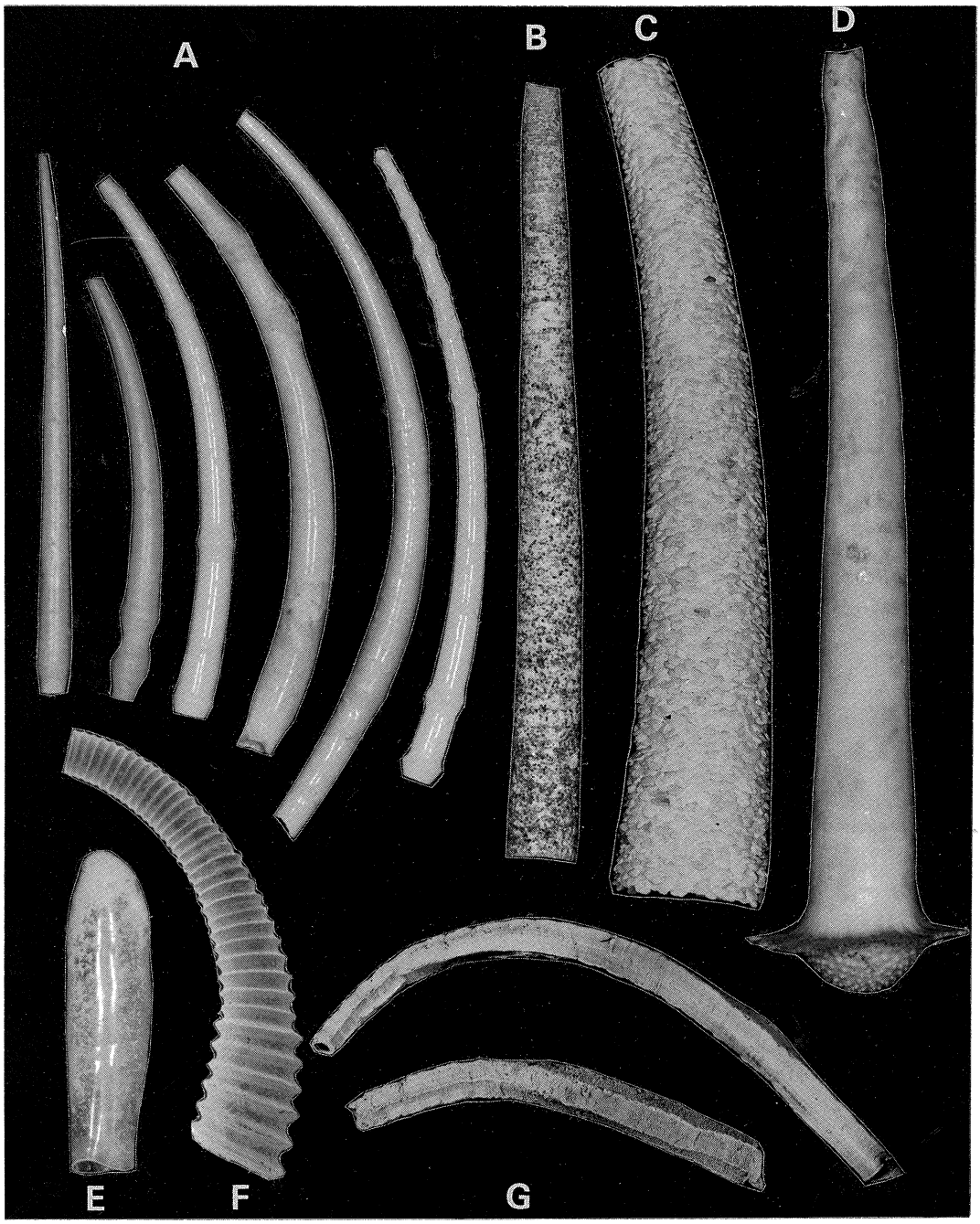


Figure 181. Shells and/or tubes of invertebrates sometimes confused with those of scaphopods. **A** *Ditrupa gracillima* Grube, 1878 (polychaete worm, Serpulidae, Annelida; range of specimens shown including the beaded ["moniliform"] variant) (off Cape Moreton, 109 m. **B** A polychaete worm tube (possible Onuphidae, Annelida); **C** A sand and coral fragment cemented tube of a polychaete worm, *Pectinaria* sp. (Pectinariidae, Annelida). **D** *Brechites penis* (Linnaeus, 1758) (a secondary shelly tube: Clavagellidae, Bivalvia, Mollusca). **E** *Cuvierina columnella* (Rang, 1827) (a pteropod opisthobranch: Gastropoda, Mollusca). **F** *Caecum* sp. (a prosobranch, Caecidae, Gastropoda, Mollusca; length 2.3 mm). **G** A polychaete worm tube showing longitudinal ribs (Serpulidae, Annelida).

Doubtful species and non-scaphopods

Shells of several other groups of invertebrates are sometimes mistaken for those of scaphopods (a selection shown on Fig. 181). These include certain pteropod opisthobranch gastropods (shells straight and glassy, open only one end—Fig. 181E), caecid prosobranch gastropods (shell plugged apically after shedding of coiled juvenile shell—Fig. 181F), some protistans (straight-shelled foraminiferans, shell chambered), clavagellid bivalves (secondary shell—Fig. 181D) and finally certain polychaete marine worms (curved, sometimes ribbed or sand encrusted, calcareous tubes of certain serpulids—Fig. 181A–C,G). Only the latter

could be easily confused with scaphopod shells, and indeed have been on a number of occasions in the literature (for references see Pilsbry & Sharp, 1897–1898; ten Hove & R.S. Smith, 1990). Shells of the polychaete genus *Ditrupa* for example, are strongly curved and open at both ends, usually glossy externally but dull and grooved internally, with a nodular swelling at the aperture. Sometimes swellings also occur along the entire shell length, resulting in the deeper water "moniliform" morph of *Ditrupa* (Fig. 181A). Shells of another serpulid genus (of uncertain identity) exhibit strong longitudinal ribs not unlike those of several *Dentalium* spp (Fig. 181G). In fact one of these shells was described as a dentaliid by Dell (1957). In this case the ribbing is often slightly twisted and usually accompanied by sudden transverse growth breaks in the shell. Inspection of the animal, if still present inside the shell, should clarify the status of any scaphopod-like invertebrate. It should however be borne in mind that empty scaphopod shells often become inhabited by hermit crabs (Forest, 1987), polychaetes, sipunculids and sponges.

During the present study, *Ditrupa* were commonly found in dry shell lots from museum collections, as well as freshly collected samples from the recent CSIRO Southern Surveyor cruises throughout the Gulf of Carpentaria. In fact at certain collection sites in the Gulf of Carpentaria, these polychaetes are abundant. It would be interesting to determine firstly whether *Ditrupa* exerts any competitive impact on scaphopods cohabiting at such sites (in terms of living space) and secondly whether predators such fish and crabs discriminate between *Ditrupa* and scaphopods when feeding.

Non-scaphopod species described as scaphopods from Australia

Dentalium beachportensis
Cotton & Ludbrook, 1938: 220

Type material examined. HOLOTYPE: SAM D13339. Type locality: Beachport, SA, 201 m.

Remarks. Almost certainly this represents a worn fragment of the rhachis of a pennatulid (sea pen, Phylum Cnidaria). The fine longitudinal striations described by Cotton & Ludbrook are in fact only scratch or abrasion marks on the sides of the "shell". It is remarkable that this specimen should have been accepted by a number of workers as being a scaphopod given the unusual substructure of the "shell" wall.

Dentalium laeve Brazier, 1877: 55–60

Type material examined. LECTOTYPE: AMS A93, 1–111, AMS C7523, a, AMS C7528. Type locality: north-east Australia.

Remarks. First recognized by Pilsbry & Sharp (1898) as a serpulid polychaete (see above discussion for further details).

Unrecognizable species

Dentalium weldianum Tenison-Woods, 1877: 140

Type material examined. HOLOTYPE: TM E1200/8541. Type locality: north coast of Tasmania (Tenison-Woods Collection). Measurement of holotype: length 11.0 mm, aperture diameter 1.5 mm, apex diameter 1.0 mm.

Remarks. The holotype is a very worn 8 ribbed shell glued to a small board. The condition of this specimen is such that it could represent a juvenile of any one of several species. This being the case we have chosen not to recognize *D. weldianum* as a species.

Dentalium tasmaniensis Tenison-Woods, 1877: 140

Type material examined. HOLOTYPE: no type material could be located for this species (material probably lost—E. Turner, TM, pers. comm.). Type locality: north west coast of Tasmania.

Remarks. Tenison-Woods' inadequate description combined with the absence of figures or type material leaves little alternative but to declare this an unrecognizable species.

DISCUSSION

Distribution

Although the Australian scaphopod fauna includes a number of Indian Ocean and West Pacific species (i.e. species known to have wide geographic ranges) it also contains a high proportion of apparently endemic species. Possibly these species also occur outside the Australian region. If so, it is surprising that they were not previously uncovered by Boissevain (1906) in her detailed analysis of Indonesian and Philippines material from the Siboga expedition, nor by Dell (1957) in his review of the New Zealand fauna. A detailed treatment of the biogeography of the Australian Scaphopoda is beyond the scope of the present account, principally because adequate collection material is not available from many localities. Presumably the direction of ocean currents is an important factor in the dispersal of larvae of endemic species to surrounding areas. Available records for some species suggest the possibility of disjunct distributions, but, as discussed below this could simply reflect the somewhat patchy nature of benthic sampling carried out to date off the Australian coast (superficial in some areas, thorough in others). In addition, it is possible that substratum preference may constrain the geographic distribution of some species (e.g., settling larvae not surviving in unsuitable substrata).

It is well known that many species of scaphopods can exhibit considerable bathymetric ranges (Pilsbry & Sharp, 1897–98; Boissevain, 1906; present study), indicating that water depth alone is not a limiting factor to dispersal. More likely, sediment type plays a more significant role in determining where a species can live, although there are some species capable of existing in a relatively wide variety of substrata.

Systematic implications of the present study (with special reference to radular and shell morphology)

It is unfortunate that so little comparative anatomical information is currently available for the Scaphopoda. Although workers such as Shimek (1988), Steiner (1991, 1992a,b, 1993, 1998a,b) and Reynolds (1990a,b, 1992a,b) are presently engaged in researching this aspect of the class (including ultrastructural studies of cells) insufficient data exist to critically assess the naturalness of many of the genera. With the exception of the two orders (Dentaliida, Gadilida) which can be reasonably well defined, the classification of the Scaphopoda as presently understood, can at best be regarded as being serviceable but clearly in need of a thorough revision. In this study we examined radular ultrastructure in a range of Dentaliida partly with the intention of assessing the robustness of accepted genera and families as taxonomic units. Our results indicate that some genera either exhibit marked variation in their radular tooth morphology (perhaps reflecting dietary shifts or specialization) or are assemblages of one or more unrelated species groups united only by conchological features. The following discussion deals principally with families, genera and subgenera of the Dentaliida, with some commentary on families within the Gadilida.

Dentaliidae

Dentalium

We have adopted a conservative approach in recognizing the boundaries of this genus, preferring to regard certain evidently distinct species groups such as *Lentigodentalium* Habe, 1963 (coloured bands and flecking of rib tops) and *Pictodentalium* Habe, 1963 (bands of red, white and, frequently, also green) as subgenera of *Dentalium* rather than full genera. Colour is a taxonomically useful feature within the Dentaliida although limited to specimens which are reasonably fresh or at least have not undergone marked fading or surface erosion after death. In the present account we have chosen not to use the genus *Antalis* for any Australian Dentaliidae, although there are several species (Group of *D. hemileuron*) which could be so assigned if taxonomic importance is given to the occurrence of rib obsolescence during shell growth. Aside from this feature, this group of species closely resemble typical *Dentalium* spp. especially in younger specimens which show ribs just as strongly developed as those of typical *Dentalium* spp. (such juvenile specimens would on this basis, key out as *Dentalium* and not *Antalis*). Varying degrees of rib obsolence occur in various species of *Dentalium* as well as in species of other ribbed genera (e.g., some species of *Fissidentalium*) and we therefore consider it a very weak character on which to define a genus. Pilsbry & Sharp (1897, pp 37–39) were the first workers to list rib obsolescence as one of the features of the genus *Antalis*. Interestingly, H. & A. Adams (1854) who are credited with the authorship of *Antalis* (although they attribute the name to Aldrovandus, 1642) do not mention rib development in their original diagnosis of the genus, but do make reference to weakly sculptured or smooth shells in their brief discussion following the generic diagnosis. Until detailed anatomical information supporting the generic status of *Antalis* is published, we see no reason to continue recognizing it as a valid taxonomic unit.

Results we have obtained for radular ultrastructure in *Dentalium* (*sensu lato*) suggests that tooth size and the ratios developed by contrasting lengths of the three tooth types may both be useful additional criteria for recognition of species, and possibly the recognition of species groups within the genus (see Table 2, p. 183).

Tesseracme

Although all three species of *Tesseracme* examined by us (*T. quadrapicale, T. quadricostatum* Brazier, *T. philcolmani* n.sp.) exhibit a quadrangular transverse profile at the apex, differences in shell size, longitudinal profile and rib development suggests that the genus may consist of two distinct groups. The differences can be defined as follows: (1) shell moderately large, strongly curved, with additional ribs intercalating from the apex (aperture profile hexagonal), masking the quadrate apex profile in mature specimens; (2) shells usually small, never large, weakly curved to almost straight, quadrate apex profile always

retained (also quadrate at aperture, even with rib intercalation). Both groups show a typical dentaliid radular morphology with no special defining features apparent (although radular ratios seem consistent within the representatives of the genus examined herein—see Table 2, p. 183). Currently Dr Gerhard Steiner (Zoologische Institut, Wien, Austria) is examining the anatomy of representatives of both groups, but at the time of writing, his results are not available to us for reference. Such work should prove highly informative and confirm one way or the other if the genus *Tesseracme* consists of two distinct, (? possibly even unrelated) groups.

Graptacme

The relationships of this genus to other Dentaliidae and to the Laevidentaliidae remain uncertain. The principal reason for inclusion of this group within the Dentaliidae seems to be the presence of longitudinal sculpture of the shell (in *Graptacme*, striae limited to the posterior half of the shell, especially in vicinity of the apex). As we have demonstrated in this study, the presence of longitudinal striae in shells of typical *Laevidentalium* spp. (*L. longitrorsum, L. lubricatum*) indicates that the inclusion of *Graptacme* among the Dentaliidae rather than the Laevidentaliidae is difficult to support. However until more is known of the anatomy of *Graptacme* spp. we have tentatively retained this genus in its traditional position.

Fissidentalium

The status and species composition of the genus *Fissidentalium* is in need of review, ideally based on anatomical and molecular data. Purely on the basis of shell features at least two broad groups seem apparent: (1) those with strong ribs (16–36 at aperture), aperture often dorsoventrally compressed; (2) shells with weak but numerous ribs (50–90 at aperture), aperture circular. In the first group, the radula is similar to those of *Dentalium* species, whereas in the second group, at least one species (*F. horikoshii*) is known to have a *Dentalium*-like radula (see Okutani, 1982) while in *F. franklinae* (herein) the radula shows heavily mineralized, almost straight laterals similar to those of *Laevidentalium crocinum* Dall. It would be interesting to document the extent of morphological diversity in the radula throughout the genus *Fissidentalium*, and to determine whether any observed differences were connected with diet shifts or perhaps indicative of more profound, taxonomic problems within the group.

Laevidentaliidae

With the exception of *Laevidentalium*, all other genera included by Palmer (1974a) in his original concept of the Laevidentaliidae have subsequently been removed to separate families (*Rhabdus* to Rhabdidae; *Fustiaria* to Fustiariidae; *Omniglypta* and *Plagioglypta* to Omniglyptidae; *Gadilina* and *Episiphon* to Gadilinidae; *Bathoxiphus* to order Gadilida, family Entalinidae—see Chistikov, 1982a,b; Steiner, 1991, 1992a, 1998a,b).

Our studies on the radulae of Australian *Laevidentalium* spp. have shown that most have a dentalioid-type tooth morphology. In fact we could not confirm the radular differences mentioned by Boss (1982) in his synopses of the Dentaliidae and Laevidentaliidae. The one notable exception is *L. crocinum* which exhibits strongly developed, almost straight laterals—a pattern elsewhere seen by us only in *Fissidentalium franklinae*. Conceivably this may be the result of convergence through demands imposed by a similar diet. Habe (1964) erected the genus *Calliodentalium* expressly for *L. crocinum*—a view which seems supportable from radular morphology. For the present we have opted for the more conservative alternative, and retained *L. crocinum* within *Laevidentalium* but recognize that Habe's genus *Calliodentalium* may have a good anatomical basis for recognition. As further species of Laevidentaliidae are studied for radular ultrastructure (and ideally, general anatomy), a more precise picture will hopefully emerge as regards the genus level subdivisions of the family (see Addendum).

According to Boss (1982) and Steiner (1992a) the laevidentaliid radula is characterized by a rectangular to polygonal central (rachidian) tooth, long laterals and slender, almost straight marginals (Boss, 1982; Steiner, 1992a). Our study has revealed that the shape of the marginals varies substantially between species, from almost straight (e.g., *L. largicrescens*) to sigmoidal (e.g., *L. erectum*)—the latter condition also commonly encountered in the Dentaliidae. Similarly, the central tooth of laevidentaliids may be long with a weakly convex superior edge, or relatively wide with a markedly convex superior edge. Aside from *L. crocinum* (discussed above) all other investigated laevidentaliids have marginal teeth resembling those of the Dentaliidae. One of the new species described herein, *L. martyi* exhibits raised rings on the shell, especially in the vicinity of the apex. As raised rings are typical of the Omniglyptidae we initially believed that this species should be placed in that family. Subsequent examination of radular ultrastructure revealed that *L. martyi* clearly lacked cusps on the superior edge of the central tooth—a feature occurring in *Omniglypta cerina* Pilsbry (see Habe, 1957) and "*O. gabriellae*" (unpublished species of Scarabino, 1979) and believed to be characteristic of the Omniglyptidae (Scarabino, 1979; Boss, 1982 and Steiner, 1992a, 1998a).

Yoo (1988) assigned three Carboniferous fossil species from New South Wales (2 from newly erected genera) to the Laevidentaliidae. His placement of the genus *Plagioglypta* in the Laevidentaliidae is based on Palmer's (1974a) original concept of the family. Although *Plagioglypta* is now usually assigned to the Omniglyptidae (see Steiner, 1992a), at least one laevidentaliid examined in the present study (*L. martyi* n.sp.) does develop raised shell rings reminiscent of but more coarse and irregularly spaced than those of the Omniglyptidae. In this connection it is interesting to note Palmer & Steiner's (1998) comment that annulate Dentaliida have arisen on a number of occasions from completely smooth ("laevidentaliid") ancestors. Four fossil species of *Laevidentalium* have been recorded from the upper Oligocene to the lower Pliocene

of South Australia, Tasmania and Victoria (Ludbrook, 1956, 1959, 1984). Another species, *Laevidentalium largicrescens* Tate, from the Upper Miocene to Lower Pliocene (Ludbrook, 1959) is here reported living in deep water off the east coast of Australia from Tasmania to southern Queensland.

Fustiariidae

This recently created family (Steiner, 1992a) contains Dentaliida with thin, slender, translucent to almost transparent shells. A long, straight, extremely fine slit is usually developed apically, but may be absent in some individuals within a single population. Steiner differentiates fustiariids from all other Dentaliida by the flattened superior edge of the rhachidian (central) tooth and features of the posterior mantle margin (lacking a ventral bolster of connective tissue). Given the wide variation in central tooth morphology in the Dentaliidae and Laevidentaliidae demonstrated herein, it would appear that the primary defining features of the family are the distinctive type of slit (precision cut in comparison with all other slit-bearing scaphopods) and mantle features described by Steiner (1992a). In his preliminary cladistic analysis of scaphopod phylogeny, Steiner (1992a) found that the Fustiariidae associated with the Dentaliidae based on perceived similarities in the shape of the marginal teeth ("marginals recurved"). In the present study we found the marginal teeth of *Fustiaria stenoschizum* Pilsbry to be similar to species of *Dentalium* and *Laevidentalium*. Steiner acknowledges the fact that a lack of anatomical data for many families and genera of the Scaphopoda has greatly hampered phylogenetic analysis of relationships within the class. The presence of a glossy, strongly curved, often moderately large shell lacking prominent longitudinal sculpture suggests to us a possible connection with the Laevidentaliidae. We must however await further anatomical studies on the Laevidentaliidae to test such a view.

Omniglyptidae

This relatively small family is represented by only a single extant genus, *Omniglypta* and, in the Australian fauna, by only two species (*O. anulosum* Brazier, *O. cerina* Pilsbry). Aside from the raised, closely spaced rings on the shell and absence of longitudinal ribs or striae, the family is also defined by the presence of cusping on the superior edge of the central tooth (Habe, 1957; Scarabino, 1979; Boss, 1982; Steiner, 1992a). The latter feature was found very useful for determining the placement of one of our new species which also shows raised rings on the shell, but lacks any trace of central tooth cusping (*Laevidentalium martyi* n.sp. see discussion above). In the Australian fossil record the Omniglyptidae is represented by *Plagioglypta numerosa* Yoo from the lower Carboniferous of New South Wales [this species originally placed in the Laevidentaliidae by Yoo, (1988)]. The presence of strong, raised, regularly spaced rings and apparent absence of any apical slit or longitudinal sculpture in the Tertiary (Victorian Pliocene) species *Dentalium (Episiphon) tornatissimum* Tate suggest that it too may be referable to the Omniglyptidae.

Order Gadilida

We have had the opportunity to examine only three species of this order for radular ultrastructure, including one species of the suborder Entalimorpha (*Bathoxiphus steineri* n.sp., Entalinidae) and two species of the suborder Gadilimorpha (*Gadila brycei* n.sp.; *Gadila vincentianus*—Gadilidae). Little can be said of these results other than to confirm the general radular features of the Gadilida (central tooth higher than wide; claw-shaped laterals, well cusped).

Concluding remarks

The present study has demonstrated that Australia possesses a remarkable and diverse scaphopod fauna, certainly ranking among the world's richest. The two orders and a large proportion of the known families and genera are represented by two or more species. The Dentaliidae in particular appear to dominate the fauna (59 species, 26 new), followed by the Gadilidae (19 species, 10 new) and Laevidentaliidae (13 species, 5 new). Although many of the new species described in the present account are most prolific in relatively deep water (100 m and deeper), a number of new shallow water species are also described. In addition to new species several new records for the Australian region have emerged from the present study. Unquestionably as further deep sea benthic sampling is carried out, more new species and new records will result.

List of valid extant species in Australian scaphopod fauna

Order DENTALIIDA
DENTALIIDAE
Dentalium (Dentalium) Linnaeus, 1758
D. (D.) elephantinum Linnaeus, 1758
D. (D.) exmouthensis n.sp.
D. (D.) aprinum Linnaeus, 1758
D. (D.) hedleyi n.sp.
D. (D.) grahami n.sp.
D. (D.) jelli n.sp.
D. (D.) hemileuron Verco, 1911
D. (D.) hyperhemileuron Verco, 1911
D. (D.) collinsae n.sp.
D. (D.) kessneri n.sp.
D. (D.) austini n.sp.
D. (D.) burtonae n.sp.
D. (D.) decemcostatum Brazier, 1877
D. (D.) lochi n.sp.
D. (D.) rowei n.sp.
D. (D.) kathwayae n.sp.
D. (D.) robustum Brazier, 1877
D. (D.) lessoni Deshayes, 1825
D. (D.) javanum G.B. Sowerby, 1860
D. (D.) octangulatum Donovan, 1803
D. (D.) goftoni n.sp.
D. (D.) jeanae n.sp.
D. (D.) octopleuron Verco, 1911
D. (D.) thetidis Hedley, 1903
D. (D.) cheverti Sharp & Pilsbry, 1897
D. (D.) katowense Brazier, 1877
D. (D.) wellsi n.sp.
D. (D.) potteri n.sp.
D. (D.) concretum Colman, 1958
D. (D.) hexagonum Gould, 1859
D. (D.) sexcostatum G.B. Sowerby, 1860
D. (D.) hillae n.sp.
D. (D.) intercalatum Gould, 1859
D. (D.) duodecemcostatum Brazier, 1877
D. (D.) pseudosexagonum Deshayes, 1825
D. (D.) flindersi Cotton & Ludbrook, 1938
D. (D.) bisexangulatum Hanley in G.B. Sowerby, 1860
D. (D.) francisense Verco, 1911
Dentalium (Lentigodentalium) Habe, 1963
D. (L.) woolacottae Colman, 1958
D. (L.) garrardi n.sp.
D. (L.) stumkatae n.sp.
Dentalium (Pictodentalium) Kira, 1959
D. (P.) formosum Adams & Reeve, 1848
Tesseracme Pilsbry & Sharp, 1897
T. quadrapicale (Hanley in G.B. Sowerby, 1860)
T. philcolmani n.sp.
T. quadricostatum (Brazier, 1877)
Fissidentalium Fischer, 1885
F. ponderi n.sp.
F. shirleyae n.sp.
F. yokoyamai (Makiyama, 1931)
F. verconis (Cotton & Ludbrook, 1938)
F. edenensis n.sp.
F. clathratum (von Martens, 1881)
F. elizabethae n.sp.
F. horikoshii Okutani, 1982
F. franklinae n.sp.
F. profundorum (E.A. Smith, 1894)
F. waterhousae n.sp.
Graptacme Pilsbry & Sharp, 1897
G. acutissimum (Watson, 1879)
G. nielseni n.sp.
G. aciculum (Gould, 1859)
FUSTIARIIDAE
Fustiaria Stoliczka, 1868
F. stenoschizum (Pilsbry & Sharp, 1897)
F. caesura (Colman, 1958)
OMNIGLYPTIDAE
Omniglypta Kuroda & Habe, 1953
O. anulosum (Brazier, 1877)
O. cerina (Pilsbry, 1905)
LAEVIDENTALIIDAE
Laevidentalium Cossmann, 1888
L. erectum (G.B. Sowerby, 1860)
L. arnoldi n.sp.
L. leptosceles (Watson, 1879)
L. jaffaensis (Cotton & Ludbrook, 1938)
L. zeidleri n.sp.
L. lubricatum (G.B. Sowerby, 1860)
L. banale (Boissevain, 1906)
L. largicrescens (Tate, 1899)
L. marshae n.sp.
L. nielseni n.sp.
L. crocinum (Dall, 1907).
L. martyi n.sp.
L. longitrorsum (Reeve, 1842)
GADILINIDAE
Episiphon Pilsbry & Sharp, 1897
E. jamiesoni n.sp.
E. pichoni n.sp.
E. virgula (Hedley, 1903)
E. bordaensis (Cotton & Ludbrook, 1938)
Order GADILIDA
ENTALINIDAE
Entalina Monterosato, 1872
E. mirifica (E.A. Smith, 1895)
E. dorsicostata n.sp.
Bathoxiphus Pilsbry & Sharp, 1897
B. tricarinatum (Boissevain, 1906)
B. colmani (Palmer, 1974)
B. steineri n.sp.
B. stanisici n.sp.
PULSELLIDAE
Pulsellum Stoliczka, 1868
P. eboracense (Watson, 1879)
P. beecheyi n.sp.
Compressidens Pilsbry & Sharp, 1897
C. platyceras (Sharp & Pilsbry, 1897)
GADILIDAE
Gadila Gray, 1847
G. angustior (Verco, 1911)
G. occiduus (Verco, 1911)
G. whitneyae n.sp.
G. bordaensis (Cotton & Godfrey, 1940)
G. ludbrookae (Cotton & Godfrey, 1940)
G. spretus (Tate & May, 1900)
G. cobbi n.sp.
G. carlessi n.sp.
G. brycei n.sp.
Cadulus Philippi, 1844
C. vincentianus Cotton & Godfrey, 1940
C. simillimus Watson, 1879
C. colliverae n.sp.
C. woodhousae n.sp.
C. rudmani n.sp.
Dischides Jeffreys, 1867
D. prionotus (Watson, 1879)
D. hintoni n.sp.
Polyschides Pilsbry & Sharp, 1898
P. gibbosus (Verco, 1911)
P. sutherlandi n.sp.
P. andersoni n.sp.

ACKNOWLEDGMENTS. Many people have assisted us during the course of this project and to all of them we extend our sincere thanks. Dr J. Stanisic and Dr P. A. Jell (Queensland Museum) provided technical help with aspects of SEM and photography and access to the museum's scaphopod collection and SEM facilities. The Malacology Section, Australian Museum, strongly supported this project from its inception and provided access to the extensive wet and dry scaphopod collection (including loan of type specimens); in particular we would like to thank Mr I. Loch, Dr W.F. Ponder, Messrs P.H. Colman and C. Allen for advice and for their considerable efforts in making available type material and other collection lots for examination. The following staff from other Australian museums are thanked for much helpful information on, and access to, scaphopod type specimens and collection material (wet and dry material) in their charge: Mrs S.M. Slack-Smith (Western Australian Museum); Ms S. Boyd (Museum of Victoria); Ms K. Gowlett-Holmes and Dr W. Zeidler (South Australian Museum); Ms E. Turner (Museum and Art Gallery of Tasmania). Thanks are also due to the following staff from overseas institutions for the generous loan of type specimens for comparison with our Australian material: Drs P. Bouchet and V. Heros of the Muséum national d'Histoire naturelle (Paris, France), Ms K.M. Way of the British Museum (Natural History) (London, U.K.), Dr R. Moolenbeek of the Zoological Museum (Amsterdam, Netherlands); Mrs R. Germon of the Smithsonian Institution (Washington, U.S.A.); Dr G. Rosenberg and other staff of the Malacology Department, Academy of Natural Sciences (Philadelphia, U.S.A.), Dr H. Saito, National Science Museum (Tokyo, Japan). Mr Des Beechy (NSW) assisted with obtaining literature not readily available to us. We reserve special thanks firstly for our artists, Mrs A. Hill and Ms C. Eadie, for their meticulous attention to detail in the line drawings, which we feel have greatly added to the value of the finished work and secondly to Mrs K. Stumkat (Queensland Museum) for her considerable patience and skill in scanning all the scaphopod radulae included in this monograph. In addition we are grateful to the Dr G. Ross, Director of the Australian Bureau of Research Services for permission to re-use Ms C. Eadie's drawings in the present work. We are also much indebted to the referees for their many helpful suggestions for improving the text. Financial assistance with artwork and technical costs were obtained from the CSIRO Science and Industry Endowment Fund and the Keith Sutherland Award (Australian Museum). Some of the costs of photography were covered by personal funds (KL). An Australian Research Fellowship and a Senior Research Fellowship from the Australian Research Council made possible the participation of one of us (JH) in this project. Finally we extend sincere thanks to Dr S.F. McEvey for his skill and patience with copyediting of this monograph.

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Manuscript received 25 August, 1994; accepted 5 April, 1995.

Appendix

Glossary of conchological terms used

The following glossary lists all the terms used throughout this text. Figures 1E, 2 and 3 should be consulted for explanatory illustrations of the various features.

aperture anterior shell orifice; qualified by the following descriptors (applied to aperture transverse profile): *wide, narrow, contracted, circular, ovate, polygonal, octagonal, dorsoventrally compressed, laterally compressed.* Sudden narrowing of aperture in certain Gadilida = *a contracted aperture.*

apex posterior (narrow or *apical*) end of shell; site of posterior shell orifice; apex may be simple or possess a notch and/or slit, and/or pipe.

curvature curved shape of shell, usually qualified by the descriptors: *weakly, moderately, strongly (curved).*

dorsal typically the uppermost or concave surface of shell (based on life position of animal).

growth line transverse line of discontinuity in shell marking former site of aperture.

intercalation mode of development of new ribs or riblets in interstices.

interstice longitudinal space between ribs; qualified by descriptors: *flat* or *concave, narrow, wide* or *obsolete.*

lateral at sides of shell; at 90° to dorsoventral axis of shell.

notch shallow incision into shell apex; may co-occur with slit.

pipe secondary growth of shell emergent from apex (an apical pipe); presence of pipe often accompanied by plug of shell material; an alternative but less common term used in the literature is *apical tube.*

plug infilling of shell at apex associated with development of pipe.

rib prominent longitudinal ridge, forming principal feature of shell ornament in many Dentaliida and a few Gadilida; qualified by descriptors: *low* or *raised*; *rounded* or *sharp*; *strong* or *weak* etc.; rib number increasing by *intercalation* in interstices or by *rib-splitting*; rib count = number of ribs present (often increasing towards aperture).

riblet minor longitudinal ridge, often occurring between rib interstices.

rib-splitting development of new ribs through longitudinal splitting of existing ribs (rare in comparison to intercalation).

rings raised annulations in shell surface; sculptural feature characteristic of the dentaliid family Omniglyptidae.

sculpture shell ornament; typically consisting of ribs (various shapes and degrees of development), sometimes of raised rings; sometimes of interaction of ribs and growth lines.

slit parallel-sided fissure in shell; of variable development and shape depending on species and genus; may be present and absent in a single species (eg some species of *Dentalium* and *Fissidentalium*); may co-occur with notch.

striae fine longitudinal incisions into shell surface.

thread microscopic longitudinal ridge.

ventral lower or convex surface of shell; based on life position of animal.

Table 1. Average rib count on the Australian *Fissidentalium*.

	Maximum At Apex	Maximum At Aperture
F. ponderi	16	32
F. shirleyae	20	30
F. yokoyamai	12	22
F. verconis	17	20
F. edenensis	17	34
F. clathratum	21	30
F. elizabethae	16	44
F. horikoshii	24	80
F. franklinae	35	90
F. profundorum	43	80
F. waterhousae	30	40

Table 2. Radular dimensions and ratios (lengths in μm ±5.0 μm) in the Dentaliida; n/a—data not available.

	Central tooth (C)	Lateral tooth (L)	Marginal tooth (M)	C:L	L:M	L Width:Length
DENTALIIDAE						
Dentalium (Dentalium) elephantinum	371	352	372	1:0.95	1:1.06	1:2.73
D. (Dentalium) exmouthensis n.sp.	239	261	270	1:1.09	1:1.03	1:2.32
D. (Dentalium) aprinum	210	233	247	1:1.10	1:1.06	1:2.9
D. (Dentalium) grahami n.sp.	290	333	355	1:1.14	1:1.06	1:2.6
D. (Dentalium) jelli n.sp.	180	243	320	1:1.35	1:1.32	1:2.9
D. (Dentalium) hyperhemileuron	111	122	211	1:1.09	1:1.70	1:3.8
D. (Dentalium) collinsae n.sp.	163	150	237	1:0.92	1:1.60	1:3.2
D. (Dentalium) javanum	333	370	463	1:1.11	1:1.25	1:5
D. (Dentalium) potteri n.sp.	145	170	200	1:1.17	1:1.18	1:2.35
D. (Dentalium) concretum	177	200	233	1:1.12	1:1.17	1:2.42
D. (Dentalium) intercalatum	144	180	333	1:1.02	1:1.85	1:3.8
D. (Lentigodentalium) woolacottae	144	140	226	1:0.97	1:1.6	1:1.9
D. (Pictodentalium) formosum	370	411	500	1:1.11	1:1.21	1:3.2
Tesseracme quadrapicale	190	200	266	1:1.05	1:1.33	1:2.66
T. philcolmani n.sp. (male)	152	145	200	1:0.95	1:1.38	1:3.17
T. philcolmani n.sp. (female)	116	116	167	1:1	1:1.44	1:3.34
Fissidentalium shirleyae n.sp.	800	781	909	1:0.97	1:1.16	1:3.13
F. yokoyamai	555	640	777	1:1.15	1:1.21	1:4
F. clathratum (male)	240	214	390	1:0.89	1:1.8	1:3.6
F. clathratum (female)	222	260	366	1:1.17	1:1.4	1:3.3
F. franklinae n.sp.	466	711	666	1:1.53	1:0.94	1:4.39
Graptacme nielseni n.sp.	322	340	416	1:1.05	1:1.22	1:3.3
FUSTIARIIDAE						
Fustiaria stenoschizum (male)	177	216	322	1:1.22	1:1.5	1:4
Fustiaria stenoschizum (female)	233	233	300	1:1	1:1.3	1:4
LAEVIDENTALIIDAE						
Laevidentalium erectum	240	233	360	1:0.97	1:1.5	1:3.6
L. zeidleri n.sp.	171	190	203	1:1.11	1:1.06	1:2.7
L. lubricatum	796	962	1074	1:1.21	1:1.12	1:4.15
L. largicrescens	544	477	722	1:0.88	1:1.5	1:3.8
L. crocinum	611	777	482	1:1.27	1:0.62	1:2.7
L. martyi n.sp.	244	266	350	1:1.09	1:1.32	1:2.8
L. longitrorsum (male)	130	170	230	1:1.31	1:1.35	1:2.4
L. longitrorsum (female)	148	185	n/a	1:1.25	n/a	n/a

Addendum

While this study was in press a monograph on the tropical Pacific and Indian Ocean Scaphopoda by Victor Scarabino was published (Scarabino, 1995). This work incorporates many of the familial and subfamilial taxa proposed by Chistikov over a series of papers (1975, 1979, 1982, 1983) and Steiner (1991, 1992a,b), as well as adding three new genera and 42 new species (see revised classification of the Scaphopoda by Scarabino, table 1, pp 194–196). Having had the opportunity to examine voucher specimens of Scarabino's intended new species near the completion of the present project we are confident that with a few possible exceptions, our new species proposed herein are distinct. A future study based on comparison of types will of course be necessary to confirm species validity in all cases. We here take the opportunity to comment on specific items from that monograph and certain other publications relevant to the content of the present work.

1. *Paradentalium* Cotton & Godfrey, 1933; *Eudentalium* Cotton & Godfrey, 1933; *Striodentalium* Habe, 1964; *Compressidentalium* Habe, 1963; *Coccodentalium* Sacco, 1896. Although Scarabino may well be proven correct in recognizing all of these genera, at present there exists no anatomical or convincing conchological or radular evidence to do so. The status and limits of the genus *Fissidentalium* (herein recognized) is also in need of clarification given the marked difference between the radula of certain species (see under *F. franklinae* and general discussion).
2. Like many authors Scarbino recognizes *Antalis* H. & A. Adams, 1854 as a valid genus. As discussed in our text we see no reason to do this, as to our knowledge there is no anatomical or radular basis for such recognition.
3. *Pictodentalium*. Bieler & Petit (1990) considered the name *Pictodentalium* Kira (1959) to be a nomen nudum because Kira failed to fulfill the criteria for availability under ICZN Articles 13 (a) and (e). They concluded that authorship for *Pictodentalium* should probably be given to Palmer (1974a) who indicated *Dentalium formosum hirasei* Kira, 1959 as the type species "for the multicoloured dentaliids including *D. formosum, D. hirasei* and *D. festivum*". Scarabino has followed this decision. However, as Habe (1963) listed *Dentalium (Pictodentalium) formosum hirasei* as the type species of the subgenus *Pictodentalium* Kira, 1959, and provided a subgeneric diagnosis, we would conclude that it is he who should be credited with the authorship of *Pictodentalium*.
4. *Calliodentalium*. Originally introduced by Habe (1964) as a genus of Dentaliidae [expressly for *C. crocinum* (Dall)], but later placed into a subfamily of Dentaliidae (Calliodentaliinae—comprising the genera *Calliodentalium* and *Laevidentalium*) by Chistikov (1975) and included by Palmer (1974a) as a subgenus of *Laevidentalium* in a separate family Laevidentaliidae (in his original sense a very broad group now split into a number of families). Scarabino includes four species within the genus and raises Chistikov's subfamily to full family status based on the important observation that the central radular tooth (rachidian) of all *Calliodentalium* species is flanked on each side by an extra abutting tooth which he termed the subrachidian, thus producing a radular tooth row formula at present unique among scaphopods (1+1+1+1+1+1+1; that is: marginal + lateral + subrachidian + central/rachidian + subrachidian + lateral + marginal). Due to infolding of the laterals over the edges of the central tooth in our SEM preparation of the radula of *Calliodentalium crocinum* the edges of the central tooth and hence the subrachidian tooth were not observed by us. The unique radular formula combined with some anatomical features (size differences in the pedal retractor muscles, shape of epipodial collar and mantle lobes (cited by Chistikov, 1975, 1979) would support Scarabino's recognition of a separate family to accommodate the genus *Calliodentalium*. Our original decision to retain *Calliodentalium crocinum* within the genus *Laevidentalium* (in the Laevidentaliidae) was based on what we considered to be insufficient shell differences cited by Habe (1964) in erecting *Calliodentalium* ("dorsoventrally compressed shell with the roundly ovate aperture").
5. *Laevidentalium leptosceles* (Watson, 1879). Although Scarabino considers *Dentalium banale* Boissevain, 1906 [herein = *Laevidentalium banale* (Boissevain)] to be a synonym of *Laevidentalium leptosceles*, we consider that these are two distinct species, based on our examination of the type material of both (see photographs herein of type specimens and descriptions).
6. The status of the Laevidentaliidae as a cohesive family needs to be addressed at some future stage as does the relationship between species assigned to *Antalis, Laevidentalium* and *Graptacme*. The placement of *L. longitrorsum* (Reeve) and *L. lubricatum* (G.B. Sowerby) is perhaps debatable since fine longitudinal striae are often present in juveniles (herein). We emended the diagnosis of Laevidentaliidae (and *Laevidentalium*) to accommodate this variation, but here note that Kilburn & Rippey (1982) and Scarabino (1995) place *L. longitrorsum* within the Dentaliidae under *Antalis*.
7. Two species herein included in the genus *Bathoxiphus* Pilsbry & Sharp, 1897 are included in *Rhomboxiphus* Chistikov, 1983 by Scarabino, based on the rhomboidal transverse profile of the shell and strong primary ribs. This seems a reasonable suggestion, although the radulae of the two genera are similar according to Scarabino, and no other anatomical details are yet available.
8. Scarabino records the following range extensions of Australian species: *Dentalium thetidis* Hedley (as *Striodentalium thetidis*) (Philippines); *Fustiaria caesura* (Colman) (New Caledonia, Philippines); *Bathoxiphus colmani* (Palmer) (as *Rhomboxiphus colmani*) (New Caledonia); *Cadulus simillimus* Watson (New Caledonia); *Dischides prionotus* (Watson) (New Caledonia, Réunion Island, north-west Madagascar). As we have not had the opportunity to examine Scarabino's material for these species, we cannot comment on the validity of these range extensions.

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