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# AN ILLUSTRATED KEY TO THE IDENTIFICATION OF UNILOCULAR GENERA OF CALCAREOUS FORAMINIFERA

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ABSTRACT—Taxonomic keys are rarely used as an aid to the identification of foraminifera. Such keys become increasingly attractive, however, as the number of taxa which must be distinguished becomes large. The proliferation of known genera over the last 25 years is nowhere more apparent than in the unilocular calcareous foraminifera, where the number of genera has risen from 5 to 46. We present herein a dichotomous key in which any species may be assigned to its proper genus by progressing through a series of steps, consisting of paired statements, in which only one choice is made at a time.

## INTRODUCTION

KEYS FOR the identification of foraminiferal genera have rarely been developed, the only prominent ones known to us being published by Cushman (1933, 1948) for all genera recognized. This is surprising in view of the fact that taxonomic keys have been integral and indispensable tools in both the botanical and zoological (Borror et al., 1981; Britton, 1986) disciplines since at least the middle of the nineteenth century (e.g., Lacordaire, 1856).

The use of a key as an aid to rapid identification of a genus becomes desirable as the number of genera becomes large. This condition is satisfied by the foraminifera. Loeblich and Tappan (1964) recognized 1,192 genera of foraminifera, whereas their most recent compilation (Loeblich and Tappan, 1987) recognized 2,455 genera. The rapid growth in the number of valid published genera has made it increasingly difficult for micropaleontologists to keep abreast of recent developments. This is due partly to the fact that adequate diagnoses, including distinction of similar genera, have been lacking, largely due to space considerations in the case of Loeblich and Tappan (1987).

The unilocular foraminifera were selected for the development of a key for three reasons. The first is that in recent years there have been several papers containing significant revisions at the generic and suprageneric level, as well as accounts of many new genera (Jones, 1984; Patterson and Richardson, 1987, 1988). While the Treatise volume on the foraminifera by Loeblich and Tappan (1964) recognized five genera of unilocular calcareous foraminifera, their subsequent volume (Loeblich and Tappan, 1987) recognized 41 genera and several others have been described subsequently. At the time of writing, 46 genera of calcareous unilocular genera are known to have been described.

The second reason for selecting the unilocular foraminifera is that they are amenable to the use of a taxonomic key. The number of morphologic characters and possible character states associated with most foraminiferal genera is quite large, particularly related to chamber arrangement, chamber shape, and suture style. The suite of characters associated with unilocular foraminifera is more manageable, consisting in essence of test shape, aperture, presence or absence of an entosolen, wall structure, and surface sculpture.

The third reason for constructing a key based on unilocular foraminifera is to stimulate interest in unraveling the evolutionary history and paleoecology of the group. Unilocular foraminiferal taxa are typically diverse and not very abundant in any given sample and thus often ignored for pragmatic reasons by paleoceanographers and biostratigraphers. Nonetheless, representatives of the group often comprise more than one-third of the foraminiferal taxa in modern deep-sea sediments. A recent study of Oligocene to Pleistocene benthic foraminiferal samples from DSDP Site 357 (Leg 39) on the Rio Grande Rise has shown that there has been a doubling of the mean number of unilocular foraminiferal taxa relative to the total number of benthic foraminiferal taxa since the Oligocene (Patterson, 1986a). Unfortunately, because of the lack of paleoecologic studies on this group it remains uncertain whether this increase in total numbers of taxa in combination with the general increase in compressed morphologies is to some extent controlled by changes in oceanographic parameters of substrate composition and grain size.

Abundances of individual species of unilocular foraminifera are generally too low for successful utilization as biostratigraphic markers (see Boltovskoy and Giussani de Kahn, 1983). However, based on a literature search and primary research data, Patterson (1986a) has shown that it is possible biostratigraphically to resolve at least the Neogene to the epoch level using unilocular foraminiferal genera (Figure 1). It is hoped that if classification of unilocular foraminiferal genera at least to the genus level was made relatively simple more researchers would start including them in quantitative and qualitative tallies resulting in a better understanding of the group.

This key is intended strictly as an aid to assigning species to the correct genus. It bears no explicit relationship to suprageneric classification, although in broad terms it may reflect higher taxonomic affiliations. Such relationships were avoided because there are several classification schemes in print. There is no intended inference in the key for phylogeny; for example, the genus *Rimulina* d'Orbigny, 1826, is in the key even though it is not in any of the families traditionally associated with unilocular foraminifera.

The key is also rigorously dichotomous, which means that all steps in the key contain only two statements, one of which will apply to the species at hand, assuming that the key has been correctly followed to that point. This key was successively tested in the process of identifying over 160 species of unilocular foraminifera recovered from a suite of samples from the southwest Pacific Ocean (Clark, 1990).

## USE OF THE KEY

The species at hand is compared with the numbered steps in the dichotomous key, beginning always with the first step. One of the two statements describes the species being identified. Following that statement is a number, corresponding to the step that contains the next applicable pair of statements. This procedure is followed until a statement is found that names a genus rather than giving the number of another step. The type description of the genus should then be consulted to ensure that

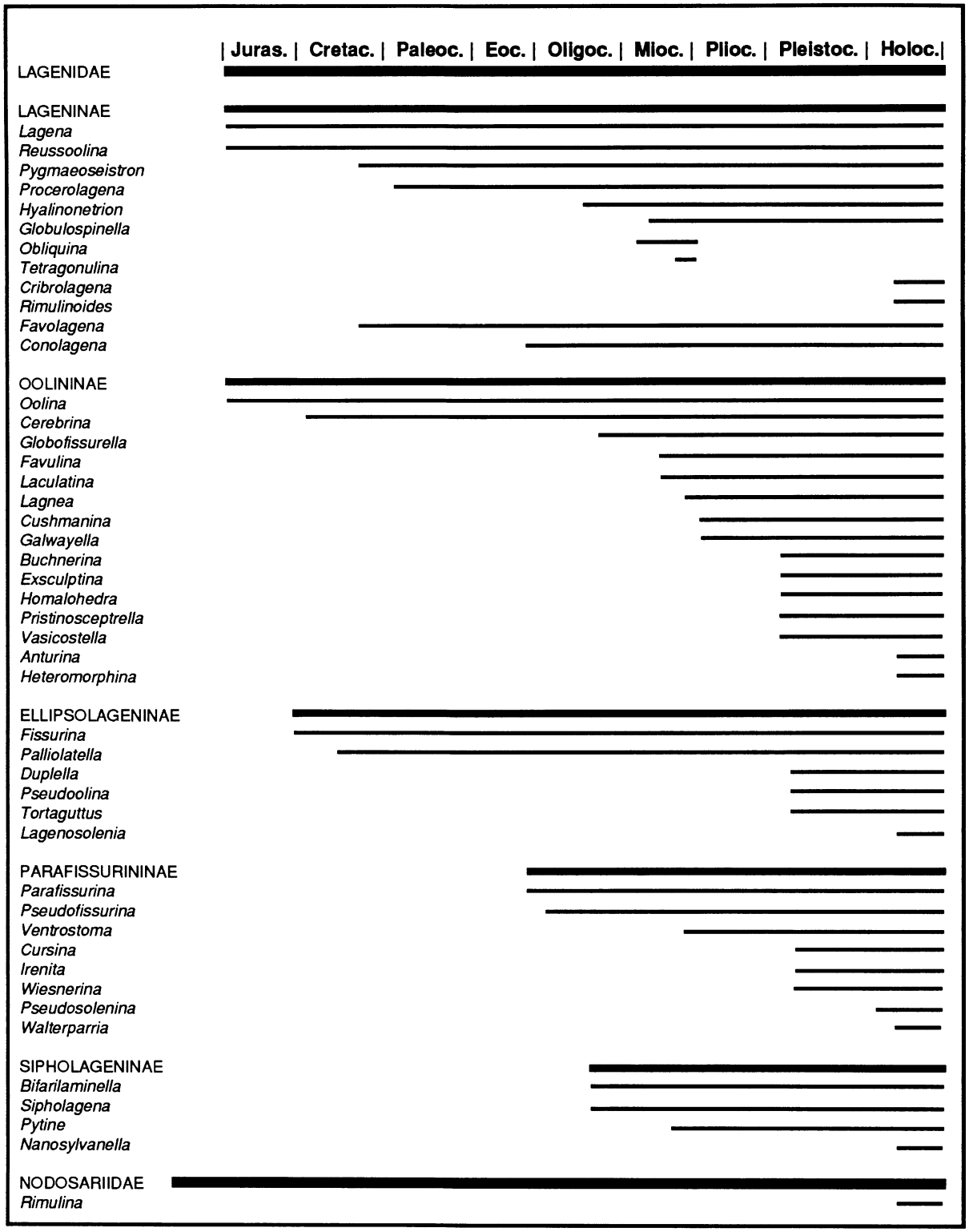


FIGURE 1—Geologic ranges of the family Lagenidae, six subfamilies, and genera. *Rimulina,* a unilocular genus of the family Nodosariidae, is also included. Taxonomic framework is based on Patterson and Richardson (1987).

the identification is indeed correct. In cases where the result appears to be in error, the worker may simply trace back through the key until the error is detected. To facilitate this, the number of each step is followed in brackets by the number of the statement that led immediately to it. Researchers will note that the genus *Pygmaeoseistron* appears twice in the key. This is due to the highly variable wall structure of species classified in this genus and suggests that a future systematic reanalysis of the genus may be warranted.

The statements in the key are not exhaustively worded, but instead are constructed to enable the genera to be identified with a minimum of characters, and without regard to highly variable

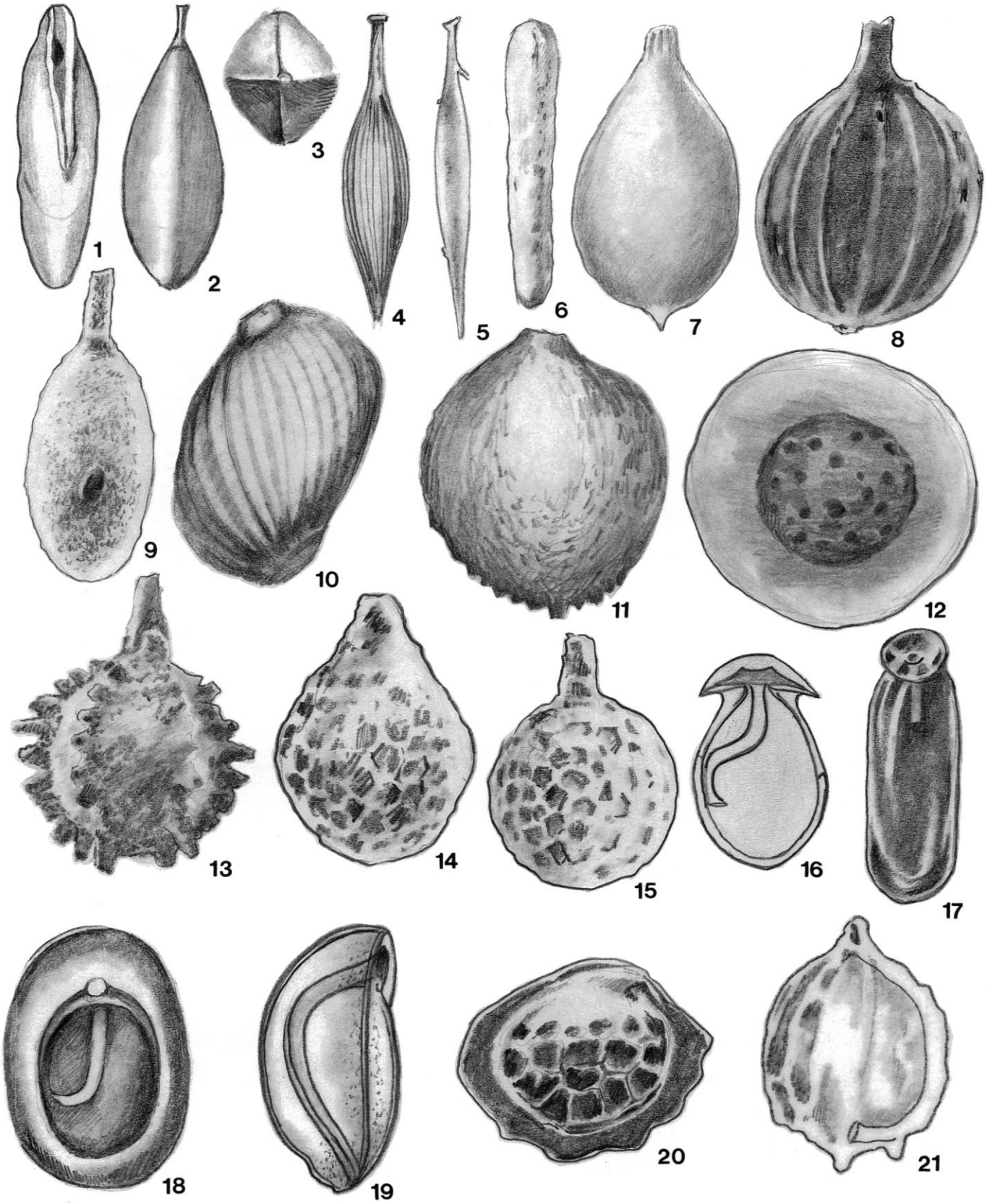


FIGURE 2—*1, Rimulina glabra* d'Orbigny, 1826 (after Loeblich and Tappan, 1987), ×56. *2, 3, Tetragonulina prima* Seguenza, 1862 (after Seguenza, 1862), both ×50. *4, Procerolagena gracilis* (Williamson), 1848 (after Williamson, 1848). *5, Hyalinonetrion sahulense* Patterson and Richardson, 1987 (after Patterson and Richardson, 1987), ×59. *6, Rimulinoides elongatus* Saidova, 1975 (after Saidova, 1975), ×6. *7, Reussoolina apiculata* (Reuss, 1851) (after Loeblich and Tappan, 1964), ×97. *8, Lagena sulcata* (Walker and Jacob *in* Kanmacher, 1798) (after Patterson and

characters that have little or no diagnostic value. This key may not accommodate a few exceptional or new species of unilocular foraminifera and will require revision in the future. The illustrations are technical sketches drawn after original scanning electron micrographs, light photographs, or drawings. Sketches were used to standardize the presentation and because it was possible to emphasize important diagnostic features sometimes less obvious in a photograph.

### A KEY TO THE GENERA OF UNILOCULAR FORAMINIFERA

1. a. Test unilocular, calcareous, always lacking entosolenian tube ..... 2
   b. Test unilocular, calcareous, with entosolen (may be absent during gametogenesis) ..... 15
2. (1a) a. Cross section strongly compressed, margin subacute, aperture an elongate slit from apex well down one margin ..... *Rimulina* d'Orbigny, 1826: Fig. 2.1.
   b. Cross section circular to subquadrangular, not compressed, aperture variable as to style and location .. 3
3. (2b) a. Cross section subquadrangular, angles rounded, aperture terminal, on neck ..... *Tetragonulina* Seguenza, 1862: Fig. 2.2, 2.3.
   b. Cross section circular ..... 4
4. (3b) a. Surface smooth ..... 5
   b. Surface variously ornamented or sculptured ..... 9
5. (4a) a. Aperture terminal, radiate ..... 6
   b. Aperture rounded or cribrate ..... 7
6. (5a) a. Test cylindrical, tapering at both ends, aperture consists of three elongate radiating slits ..... *Rimulinoides* Saidova, 1975: Fig. 2.6.
   b. Test ovate in outline, aperture consists of radial grooves surrounding central round opening ..... *Reussoolina* Colom, 1956: Fig. 2.7.
7. (5b) a. Test ovate in outline, aperture cribrate, consisting of numerous large pores on apertural end ..... *Cribrolagena* R. W. Jones, 1984: Fig. 2.11, 2.12.
   b. Aperture terminal and round ..... 8
8. (7b) a. Test elongate, fusiform, aperture on tapering neck, with lip; some species slightly longitudinally bowed ..... *Hyalinonetrion* Patterson and Richardson, 1988: Fig. 2.5.
   b. Test globular to ovate, aperture on elongate neck ... *Pygmaeoseistron* Patterson and Richardson, 1988: Fig. 2.9.
9. (4b) a. Surface of test striate or costate ..... 10
   b. Surface of test with ornament other than striae or costae. ..... 12
10. (9a) a. Striae oblique to long axis of chamber; aperture asymmetrically located to one side of chamber, rounded, on short neck ... *Obliquina* Seguenza, 1862: Fig. 2.10.
    b. Striae either parallel to, or spiralling along, test axis; aperture symmetrical with respect to test axis ..... 11
11. (10b) a. Test elongate and slender, striate to costate, aperture on long slender neck ..... *Procerolagena* Puri, 1954: Fig. 2.4.
    b. Test globular to ovate, striate to costate although parts of either neck or test body may be smooth; may have a basal process; neck and lip variably developed ... *Lagena* Walker and Jacob (*in* Kanmacher), 1798: Fig. 2.8.
12. (9b) a. Test with raised reticulate sculpture ..... 13
    b. Test with hispid or tubular sculpture ..... 14
13. (12a) a. Chamber globular to ovate, with distinct elongate neck ..... *Favolagena* Malumián, Náñez, and Caramés (1991): Fig. 2.15.
    b. Chamber globular to ovate, with thickened collar but no neck .. *Conolagena* Malumián, Náñez, and Caramés (1991): Fig. 2.15.
14. (12b) a. Test globular to ovate, finely hispid, aperture on elongate neck .....

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Richardson, 1987), ×386. *9, Pygmaeoseistron hispidulum* (Cushman, 1913) (after Patterson and Richardson, 1987), ×276. *10, Obliquina acuticosta* Seguenza, 1862 (after Seguenza, 1862), ×73. *11, 12, Cribrolagena cribrostomoides* (Cushman, 1913) (after Cushman, 1913); *11,* side view, ×108; 12, apertural view, ×638. *13, Globulospinella porcuspina* Patterson, 1988 (after Patterson, 1988), ×92. *14, Conolagena argentina* Malumián, Náñez, and Caramés (1991) (after Malumián et al., 1991), ×140. *15, Favolagena atilai* (Bertels, 1964) (after Malumián and others, 1991), ×147. *16, Irenita cornigera* (Buchner, 1940) (after Buchner, 1940), ×175. 17, *Walterparria millettiformis* (McCulloch, 1977) (after McCulloch, 1977) ×190. *18, Wiesnerina unguis* (Heron-Allen and Earland, 1913) (after Heron-Allen and Earland, 1913), ×185. *19, Ventrostoma fovigerum* (Buchner, 1940) (after Buchner, 1940), ×285. *20, 21, Cursina adornata* Patterson and Richardson, 1988 (after Patterson and Richardson, 1988); *20,* side view, ×141; *21,* edge view, ×290.

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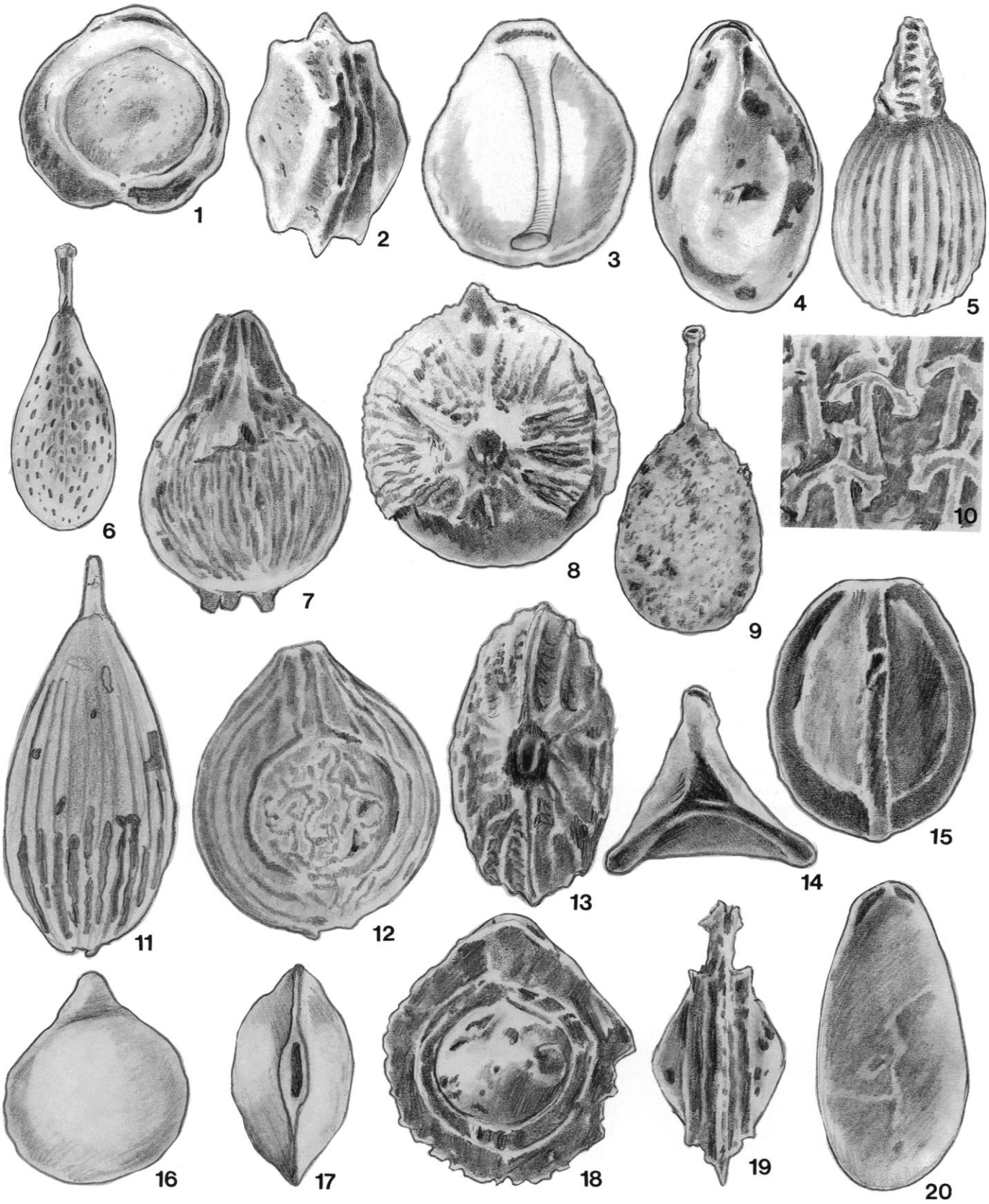
FIGURE *3—1, 2, Pseudofissurina mccullochae* R. W. Jones, 1984 (after R. W. Jones, 1984); *1,* side view, ×125; *2,* apertural view, ×165. *3, Parafissurina ventricosa* (A. Silvestri, 1904) (after Loeblich and Tappan, 1964), ×130. *4, Pseudosolenina borealis* R. W. Jones, 1984 (after R. W. Jones, 1984), ×142. *5, Pytine parthenopeia* Moncharmont Zei and Sgarrella, 1978 (after Moncharmont Zei and Sgarrella, 1978), ×220. *6, Sipholagena benevestita* (Buchner, 1940) (after Moncharmont Zei and Sgarella, 1978), ×250. *7, 8, Bifarilaminella advena* (Cushman, 1913) (after Patterson and Richardson, 1988); *7,* side view, ×135; *8,* apertural view, × 180. *9, 10, Nanosylvanella palmulina* Patterson, 1990 (after Patterson, 1990); *9,* side view, ×90; *10,* enlargement of surface sculpture, ×1,200. *11, Sipholagena* sp. (after Clark, 1990), ×250. *12, 13, Cerebrina perplexa* Patterson, 1986 (after Patterson, 1986b); *12,* side view, ×80; *13,* apertural view, ×100. *14, 15, Galwayella trigonoelliptica* (Balkwill and Millett, 1884) (after Patterson and Pettis, 1986); *14,* apertural view, ×365; *15,* side view, ×345. *16, 17, Fissurina laevigata* Reuss, 1850 (after Reuss, 1850); *16,* side view, ×130; *17,* apertural view, ×165. *18, 19, Palliolatella avita* Patterson and Richardson, 1987 (after Patterson and Richardson, 1987); *18,* side view, ×230; *19,* edge view, ×240. *20, Duplella apexadina* Patterson and Richardson, 1987 (after Patterson and Richardson, 1987), ×230.

FIGURE *4—1, 2, Tortaguttus timmsensis* (Cushman and Gray, 1946) (after Barrick et al., 1989); *1,* edge view, ×175; *2,* apertural view, ×366. *3, 4, Buchnerina iberica* R. W. Jones, 1984 (from R. W. Jones, 1984); *3,* side view, ×145; *4,* apertural view, ×165. *5, Anturina haynesi* R. W. Jones, 1984 (after R. W. Jones, 1984), ×210. *6, 7, Vasicostella helophoromarginata* (F. W. O. R. Jones, 1874) (after Patterson and Richardson, 1987); *6,* side view, ×260; *7,* apertural view, ×450. *8, 9, Lagnea tenuistriatiformis* (McCulloch, 1977) (after McCulloch, 1977); *8,* side view, ×186; *9,* apertural view, ×300. *10, Pristinosceptrella hispida* Patterson and Richardson, 1987 (after Patterson and Richardson, 1987), ×190. *11, Homalohedra guntheri* (Earland, 1934) (after Patterson and Richardson, 1988), ×256. *12, 13, Oolina laevigata* d'Orbigny, 1839 (after Loeblich and Tappan, 1964); *12,* side view, ×76; *13,* apertural view, ×83. *14, Favulina hexagona* (Williamson, 1848) (after Patterson and Richardson, 1988), ×438. *15, 16, Laculatina striatula* (Earland, 1934) (after Patterson and Richardson, 1988); *15,* apertural view, ×580; *16,* side view, ×106. *17, Exsculptina sidebottomi* (Earland, 1934) (after Patterson and Richardson, 1988), ×308. *18, Heteromorphina heteromorpha* (Parr, 1950) (after Parr, 1950), ×128. *19, Cushmanina striatopunctata* (Parker and Jones, 1865) (after Patterson and Richardson, 1987), ×218. *20, Lagenosolenia soulei* McCulloch, 1977 (after McCulloch, 1977), ×153.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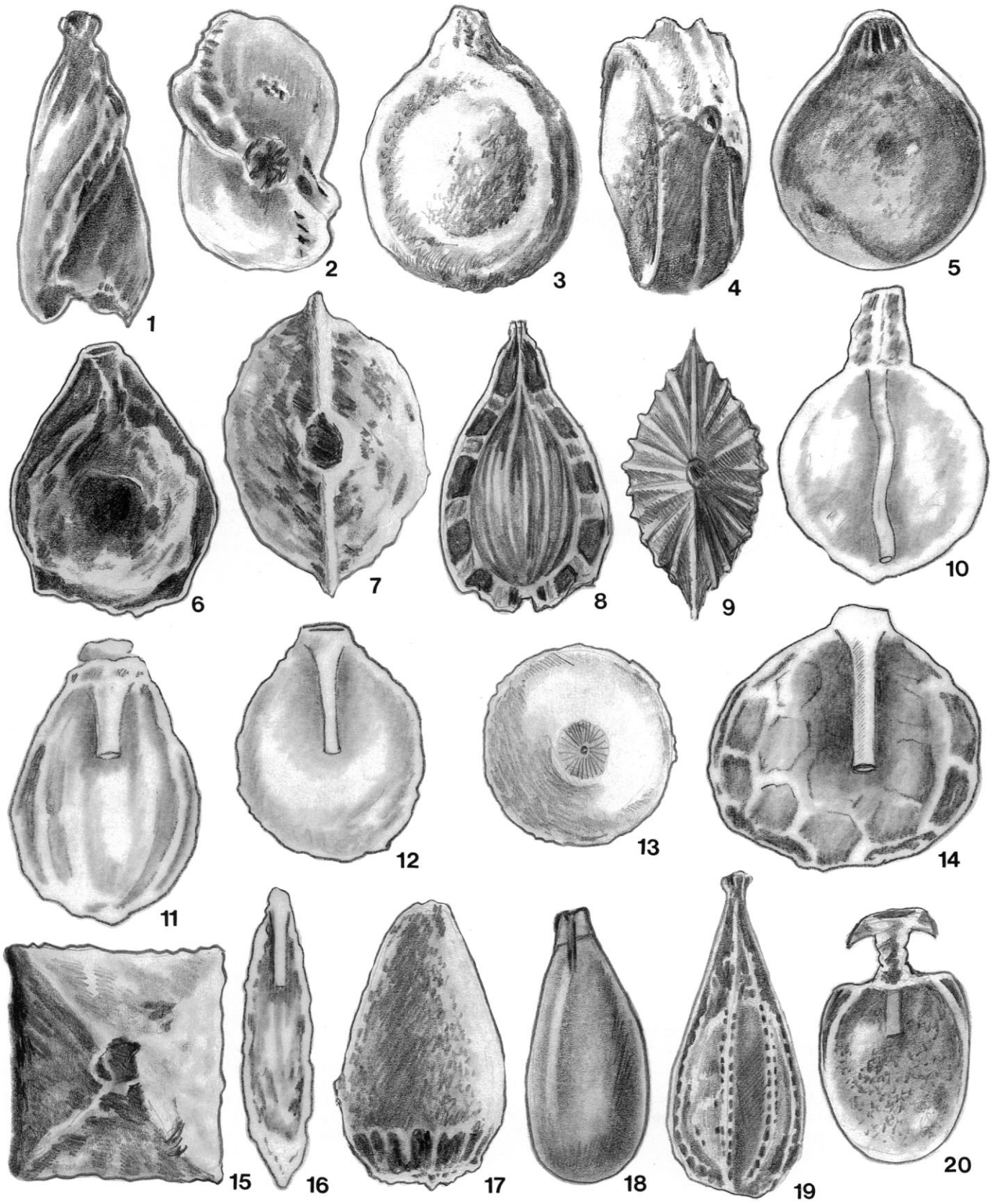
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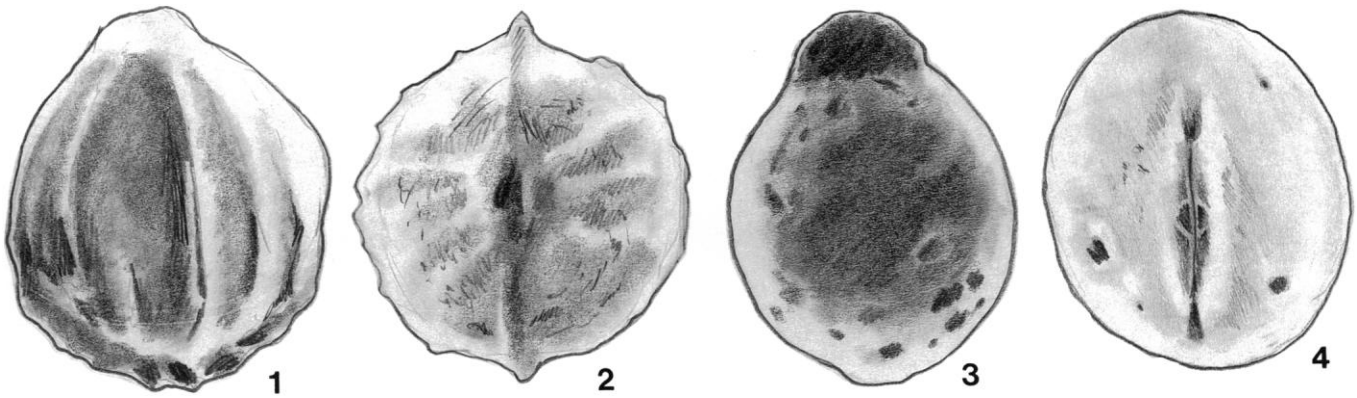


FIGURE 5—*1, 2, Globofissurella scotti* Patterson, 1986 (after Patterson, 1986b); *1,* side view, ×274; *2,* apertural view, ×270. *3, 4, Pseudoolina fissurinea* R. W. Jones, 1984 (after R. W. Jones, 1984); *3,* side view, ×197; *4,* apertural view, ×192.

.... *Pygmaeoseistron* Patterson and Richardson, 1988: Fig. 2.9.

b. Test globular, sculpture consists of elongate tubular processes aligned in longitudinal rows ..... ..... *Globulospinella* Patterson, 1988: Fig. 2.13.

15. (1b) a. Aperture subterminal or eccentric ..... 16

b. Aperture terminal, on axis of test ..... 23

16. (15a) a. Aperture in large subcircular surface found on one face of test ..... 17

b. Aperture spatially related to periphery or carina ... 18

17. (16a) a. Test symmetrically compressed, aperture surrounded by everted sucker-like lip ..... ..... *Walterparria* R. W. Jones, 1984: Fig. 2.17.

b. Cross section asymmetrical, aperture on gentle circular depression on less strongly convex face of test ..... ..... *Ventrostoma* Schnitker, 1970: Fig. 2.19.

18. (16b) a. Cross section subcircular, chamber with raised reticulate sculpture, periphery with complete keel, aperture on elongate slit in ventral face of keel ..... ..... *Cursina* Patterson and Richardson, 1988: Fig. 2.20, 2.21.

b. Surface of chamber smooth, test may have marginal carina(e) ..... 19

19. (18b) a. Aperture located at junction of broad, complete keel with chamber, on ventral face ..... ..... *Wiesnerina* R. W. Jones, 1984: Fig. 2.18.

b. Aperture subterminal ..... 20

20. (19b) a. Aperture with broad, crescentic lips, lip more strongly developed on dorsal side of peripheral plane ..... ..... *Irenita* R. W. Jones, 1984: Fig. 2.16.

b. Aperture without lips. ..... 21

21. (20b) a. Aperture crescentiform, with dorsal margin projecting as a hood; test may or may not have carina or basal spines ..... *Parafissurina* Parr, 1947: Fig. 3.3.

b. Aperture without hood ..... 22

22. (21b) a. Test rounded to ovate in outline, periphery with one prominent and often two lesser, flanking keels; aperture crescentic, to one side of central keel, without neck ..... *Pseudofissurina* R. W. Jones, 1984: Fig. 3.1, 3.2.

b. Test ovate in outline, with broad carina embracing well-developed neck, one margin of aperture more strongly produced ..... ..... *Pseudosolenina* R. W. Jones, 1984: Fig. 3.4.

23. (15b) a. Chamber with fully to incompletely developed second or outer wall, which may be supported by pillars .. 24

b. Chamber with single wall ..... 29

24. (23a) a. Outer wall without evident supporting pillars, having closely spaced bifurcating and anastomosing costae . ..... *Bifarilaminella* Patterson and Richardson, 1988: Fig. 3.7, 3.8.

b. Outer wall supported by struts or pillars ..... 25

25. (24b) a. Outer wall completely developed and continuous ... ... *Sipholagena* Moncharmont Zei and Sgarrella, 1980: Fig. 3.6, 3.11.

b. Outer wall incompletely developed, discontinuous .. 26

26. (25b) a. Outer wall consists of broad, flattened longitudinal slats separated over much of test length ..... .. *Pytine* Moncharmont Zei and Sgarella, 1978: Fig. 3.5.

b. Outer wall weakly developed, formed by flanges developed on terminations of pillars; flanges may or may not coalesce ..... ..... *Nanosylvanella* Patterson, 1990: Fig. 3.9, 3.10.

27. (23b) a. Test with compressed cross section ..... 28

b. Cross section circular or radially symmetrical ..... 36

28. (27a) a. Aperture double, consisting of two elongate slits in peripheral plane, separated by transverse bridge at apex of test; entosolen bifurcates to connect with both openings; some species slightly longitudinally bowed .... .. *Duplella* Patterson and Richardson, 1987: Fig. 3.20.

b. Aperture single, terminal ..... 29

29. (28b) a. Test with complex keel, either single with transverse tubules or multiple, connected by transverse fillets or struts ..... 30

b. Test with simple keel(s) or carinal band, with variable extent, from restricted to base to bordering entire test, or noncarinate ..... 31

30. (29a) a. Carina(e) sigmoidal or twisted, not in one plane ..... ..... *Tortaguttus* Barrick, Beverage, Patterson, and Schubert, 1989: Fig. 4.1, 4.2.

b. Carina(e) nonsigmoidal, defining peripheral plane .. ..... *Lagnea* Popescu, 1983: Fig. 4.8, 4.9.

31. (29b) a. Chamber with distinct surface sculpture, may have multiple carinae. ..... 32

b. Chamber surface smooth, may have multiple carinae. ..... 33

32. (31a) a. Chamber with reticulations or other regular to irregular raised ridges or gentle depressions; multiple carinae common .. *Cerebrina* Patterson, 1986b: Fig. 3.12, 3.13.

b. Chamber surface with longitudinally arranged costate, nodose, or punctate sculpture; periphery carinate. .. ..... *Vasicostella* Patterson and Richardson, 1987: Fig. 4.6, 4.7.

33. (31b) a. Broad principal carina embraces neck and is symmetrically expanded at apertural end to form convex hood; accessory carinae frequently developed ..... ..... *Palliolatella* Patterson and Richardson, 1987: Fig. 3.18, 3.19.

b. Peripheral carina not expanded at apertural end ... 34

34. (33b) a. Aperture terminal, ovate to slit-like, without neck; may have basal flanges or spines ..... ..... *Fissurina* Reuss, 1850: Fig. 3.16, 3.17.

b. Aperture with neck ..... 35

35. (34b) a. Neck short and thick, may be indistinct; test ovate in outline, frequently with multiple carinae. ..... ..... *Buchnerina* R. W. Jones, 1984: Fig. 4.3, 4.4.

b. Neck distinct, may have lip; test ovate to elongate in outline, often with single carina ..... ..... *Lagenosolenia* McCulloch, 1977: Fig. 4.20.

36. (27b) a. Cross section not circular ..... 37
b. Cross section circular or nearly so ..... 38
37. (36a) a. Cross section trigonal, with carinate angles ..... *Galwayella* Patterson and Pettis, 1986: Fig. 3.14, 3.15.
b. Cross section quadrate to rectangular, angles sharp to carinate ..... *Laculatina* Patterson and Richardson, 1988: Fig. 4.15, 4.16.
38. (36b) a. Aperture slit-like, between broad, heavy lips ..... 39
b. Aperture rounded, radiate, or otherwise equant ... 40
39. (38a) a. Surface smooth to rarely costate, costae not related to peripheral plane ..... *Pseudoolina* R. W. Jones, 1984: Fig. 5.3, 5.4.
b. Surface costate, usually more strongly so near base; peripheral plane defined by prominent costae as well as elongation of aperture; weak carina may be developed .... *Globofissurella* Patterson, 1986: Fig. 5.1, 5.2.
40. (38b) a. Chamber surmounted by apertural chamberlet of lesser size .. *Heteromorphina* R. W. Jones, 1984: Fig. 4.18.
b. Chamber without chamberlet ..... 41
41. (40b) a. Aperture radiate ..... 42
b. Aperture other than radiate ..... 43
42. (41a) a. Aperture consists of central round opening surrounded by radiating slits; surface of test smooth to striate, with or without basal spine(s) ..... *Oolina* d'Orbigny, 1839: Fig. 4.12, 4.13.
b. Aperture consists of fine radiating slits only ..... *Anturina* R. W. Jones, 1984: Fig. 4.5.
43. (41b) a. Surface sculpture consists solely of raised reticulate to polygonal network ..... *Favulina* Patterson and Richardson, 1988: Fig. 4.14.
b. Surface sculpture nonreticulate or mixed ..... 44
44. (43b) a. Surface costate ..... 45
b. Surface without costae ..... 46
45. (44a) a. Longitudinal and/or anastomosing costae arise from basal ring, may or may not reach base of neck or collar ..... *Homalohedra* Patterson and Richardson, 1988: Fig. 4.11.
b. Some or all costae with punctae or perforations in wall on both sides of costae, centered in costae, or between paired costae; may have a basal spine; some species slightly longitudinally bowed ..... *Cushmania* R. W. Jones, 1984: Fig. 4.19.
46. (44b) a. Surface pustulose to hispid, aperture on distinct, rather narrow elongate neck ..... *Pristinosceptrella* Patterson and Richardson, 1987: Fig. 4.10.
b. Test on lower portion with contiguous longitudinal excavations having rounded upper terminations, separated by narrow ridges which are not raised costae; base with reticular network ..... *Exsculptina* Patterson and Richardson, 1988: Fig. 4.17.

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# ORDOVICIAN SPONGE SPICULES FROM NEW SOUTH WALES, AUSTRALIA

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ABSTRACT—An abundant, varied, and well-preserved assemblage of discrete sponge spicules of late Ordovician age is described from the Malongulli Formation of central New South Wales. It is associated with one of the most diverse Ordovician siliceous sponge faunas known. The assemblage occurs in allochthonous limestone blocks within breccia deposits of a predominantly graptolitic and spiculitic siltstone succession, and is composed mainly of hexactinellid spicule types. Included are a number of distinctive forms, recognized as new taxa—*Silicunculus bengtsoni, Kometia cruciformis, Chelispongia prima,* and *Pseudolancicula exigua.* All are new genera except *Silicunculus* Bengtson, 1986, which was previously described from the upper Cambrian of Queensland. The problematical *Anomaloides reticulatus* Ulrich, 1878, is reported for the first time from Australia. A wide variety of other diagnostic, but more generalized, spicule types also occurs, including stauractines, pinnular and nonpinnular pentactines and hexactines, ornamented oxyhexasters and echinhexasters, clavules, anchorate root-tufts, and uncinates. The pinnular pentactines may be assigned to the form genus *Palaeorubus* Ishiga (*in* Ishiga et al., 1987), interpreted incorrectly by Ishiga as a radiolarian. The sponges, discrete spicules, and radiolarians of these limestone clasts were transported in debris flows to a basinal setting from peri-platform oozes that formed on the flanks of the shallow offshore island-arc platform of the Molong High.

## INTRODUCTION

DISARTICULATED SPICULES have been found in great abundance and variety in acid-etched residues of allochthonous limestone clasts in breccia deposits of the late Ordovician Malongulli Formation of central New South Wales (Figures 1, 2). These are the beds containing the diverse siliceous sponge fauna and radiolarians documented previously by Rigby and Webby (1988) and Webby and Blom (1986). The spicules include vast numbers of generalized spicule types, but also a most varied and abundant assemblage of distinctive, well-preserved morphologies. These form the basis of the present paper. Some of the more diagnostic spicule types may prove to have biostratigraphic significance. However, until a great deal more documentation of such spicule assemblages is undertaken globally, and through the Phanerozoic column, it will be difficult to establish their real biostratigraphic potential and their value in better understanding the evolutionary development of the siliceous sponges.

There are very few contributions in the literature devoted entirely to descriptions of sponge spicule assemblages. Exceptions include papers by Weller (1930), Butler (1961), Rigby (1975), and Mostler (1985, 1986, 1990). Mostly, spicules are given less than adequate attention in taxonomic descriptions of individual sponges, and only rarely are the discrete spicules