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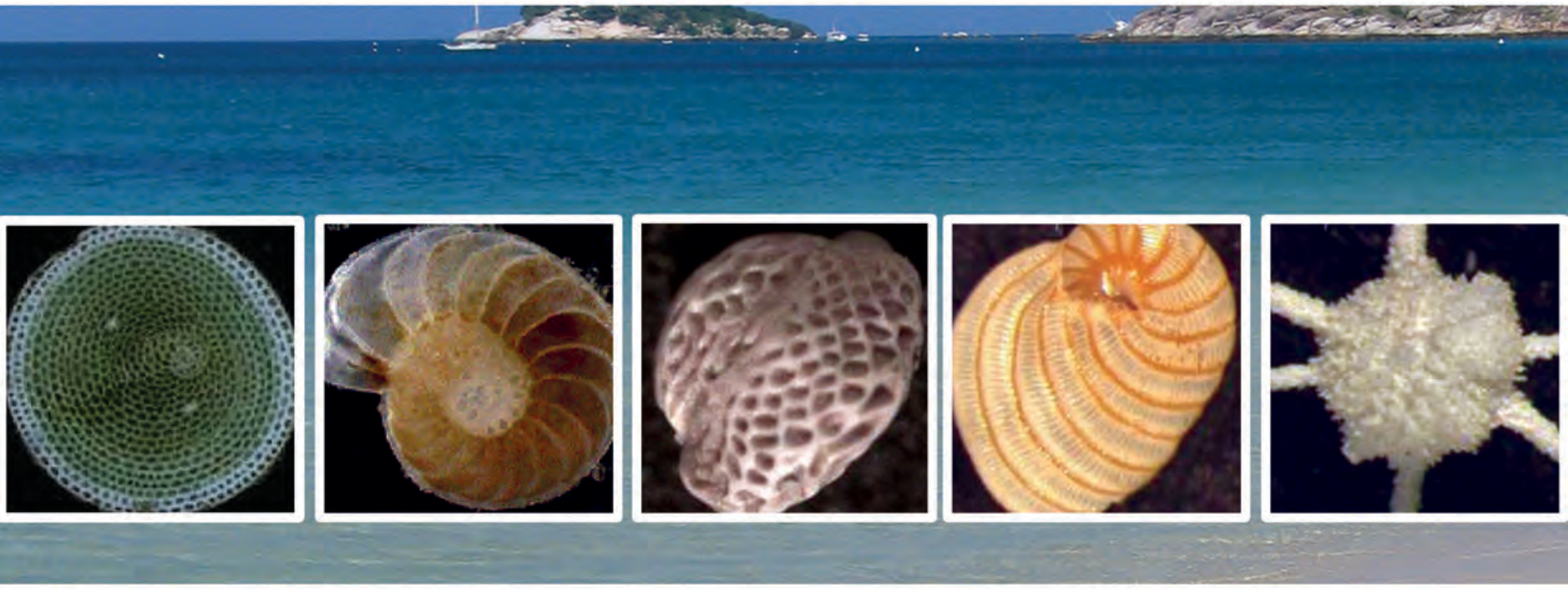
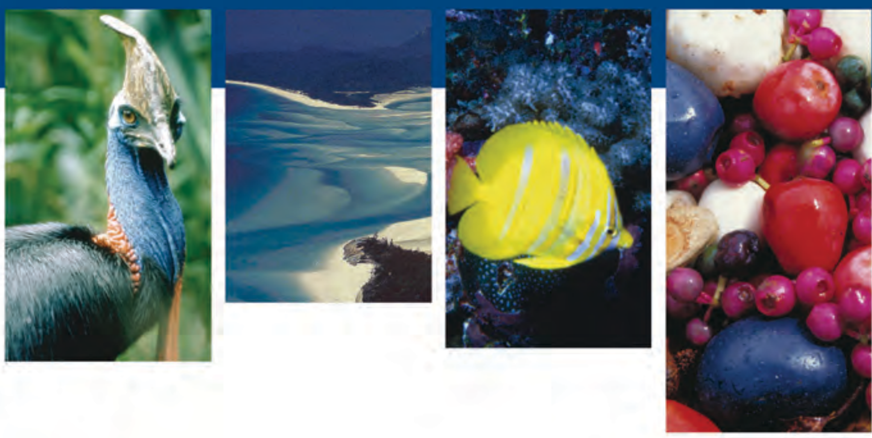


Benthic Foraminifera of the Great Barrier Reef

A guide to species potentially useful as Water Quality Indicators

Kristie Nobes and Sven Uthicke



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Benthic Foraminifera of the Great Barrier Reef

A guide to species potentially useful as Water Quality Indicators

Kristie Nobes and Sven Uthicke
Australian Institute of Marine Science, Townsville

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Project 3.7.1 Marine and estuarine indicators and thresholds of concern

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The Australian Government's Marine and Tropical Sciences Research Facility (MTSRF) supports world-class, public good research. The MTSRF is a major initiative of the Australian Government, designed to ensure that Australia's environmental challenges are addressed in an innovative, collaborative and sustainable way. The MTSRF investment is managed by the Department of the Environment, Water, Heritage and the Arts (DEWHA), and is supplemented by substantial cash and in-kind investments from research providers and interested third parties. The Reef and Rainforest Research Centre Limited (RRRC) is contracted by DEWHA to provide program management and communications services for the MTSRF.

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Reef & Rainforest
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Acknowledgements

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Introduction

Benthic foraminifera are important in sediment production in coral reef environments, and many beaches and sediments on the Great Barrier Reef are dominated by these organisms. A variety of different species of these single celled animals exist. Several of these have algal symbionts similar to corals, but these symbionts come from a variety of algal groups. These foraminifera receive a part of their energy demands from their symbionts, whereas species without symbionts rely entirely on feeding for energy intake. Differences in nutrient and light demand between the species suggest that foraminifera can be ideal indicators for water quality. Indeed, in temperate areas a variety of indicator species exist for different sources of pollution (Alve, 1995). Foraminifera have also been shown to be indicators for eutrophication in coral reefs of the Caribbean and Florida (Hallock *et al.* 2003) and our recent work supports that this is the case also for the Great Barrier Reef (Uthicke and Nobes 2008).

As part of the Marine and Tropical Sciences Research Facility (MTSRF) Project 3.7.1 *Marine and estuarine indicators and thresholds of concern* we investigate the use of foraminifera as indicators for changes in water quality. The purpose of this document is to provide a guide for the identification to genus or species level using pictures obtained by dissection microscopy.

We followed Loeblich and Tappan (1984) in the taxonomy of the higher taxa, and also cited rough descriptions of each Family from that publication.

Suborder: Lagenina

Lagenina have a monolamellar wall of radiate calcite, i.e. a perforated wall made up of only one layer, the outer lamella. The calcite crystals of the test are perpendicular to the surface making the test hyaline, and are encased by organic membranes (Loeblich and Tappan, 1984).

Polymorphinidae

The chambers have a spiral formation that occurs around a vertical axis, with the initial chambers overlapping. The aperture is located at the end furthest from the initial chamber (proloculus) of the test (Loeblich and Tappan, 1984).

Sigmoidella elegantissima (Parker and Jones)

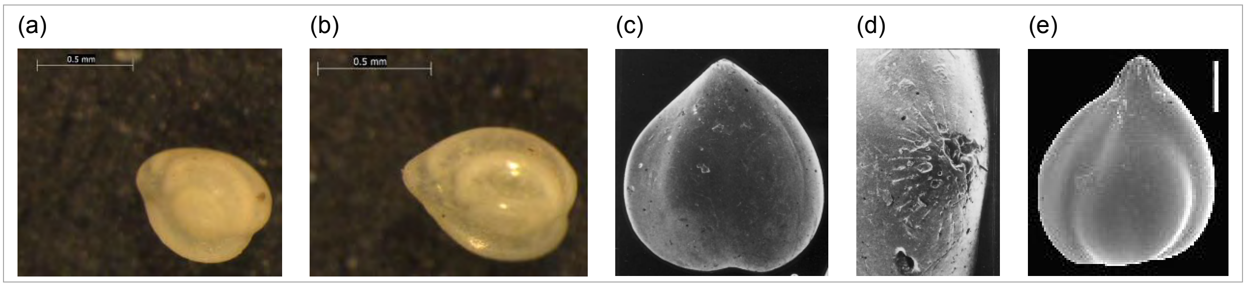


Figure 1: (a)-(b) Lateral view of *S. elegantissima*. (c) SEM picture of *S. elegantissima*, lateral view, magnification x43 (Coleman, 1979). (d) SEM picture of *S. elegantissima*, apertural view (Coleman, 1979). (e) SEM picture of *S. elegantissima*, lateral view, scale = 0.1mm (Haig, 2001).

Suborder: Miliolina

The porcelaneous test of Miliolina has an organic lining and in some cases foreign particles are collected and added to the test. Some species have a spiral passage (flexostyle) between the initial and later formed chambers (Loeblich and Tappan, 1984).

Alveolinidae

These foraminifera are generally large and are found free living. Their tests are long with tapered ends. The numerous chambers are arranged parallel to the elongated axis around which they coil. The chambers themselves are divided into chamberlets by septulae. Alveolinidae have numerous apertures which are arranged into rows, with some fusing the apertures to form a slit (Loeblich and Tappan, 1984).

Alveolinella quoyi (d'Obigny, 1826)

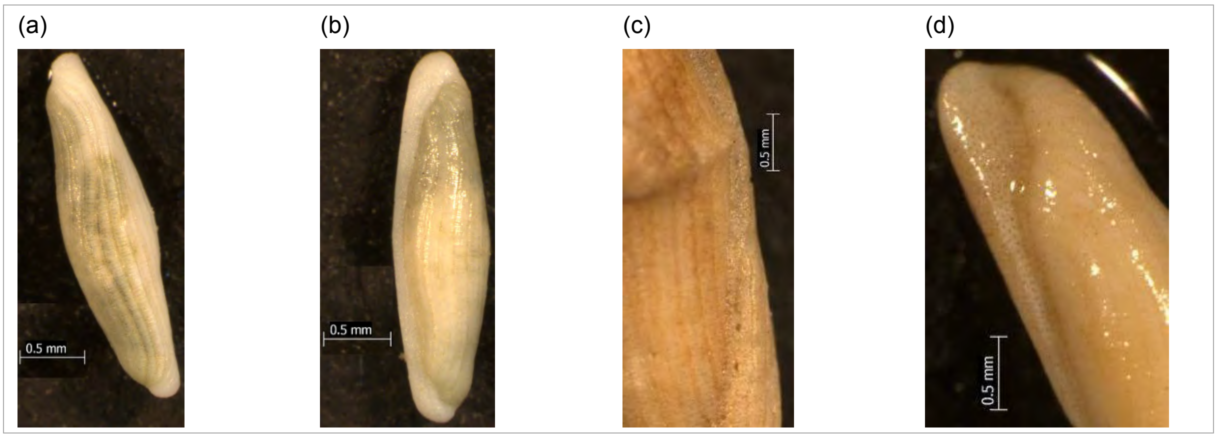


Figure 2: (a) Axial view of live *A. quoyi*. (b) Axial view onto apertural face of live *A. quoyi*. (c) Apertures on apertural face of *A. quoyi*. (d) Tapered end of *A. quoyi*.

Fischerinidae

The main chambers, of which there are only a few, have a tubular appearance and begin to spiral around the initial chamber and flexostyle. The aperture is a large opening at the end of the whorl (Loeblich and Tappan, 1984).

Planispirinella exigua (Brady, 1879)

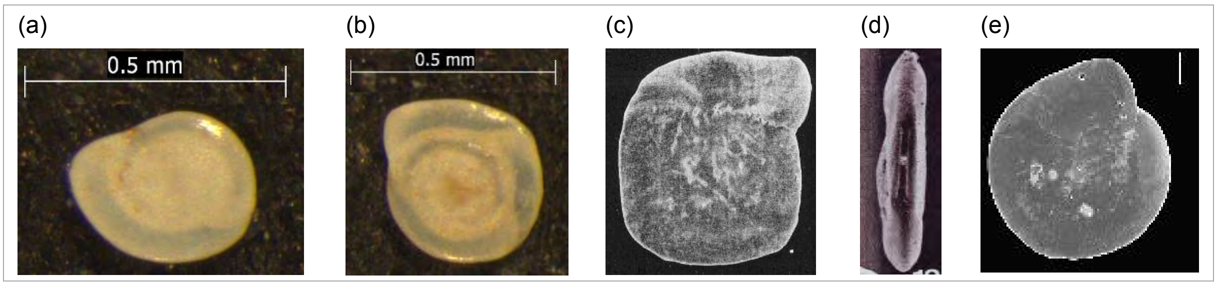


Figure 3: (a)-(b) Lateral view of *P. exigua*. (c) SEM picture of *P. exigua*, lateral view, magnification x70 (Haig, 1988). (d) SEM picture of *P. exigua*, apertural view, magnification x110 (Haig, 1988). (e) SEM picture of *P. exigua*, lateral view, scale = 0.1mm (Haig, 2001).

Vertebralina striata (d'Obigny, 1826)

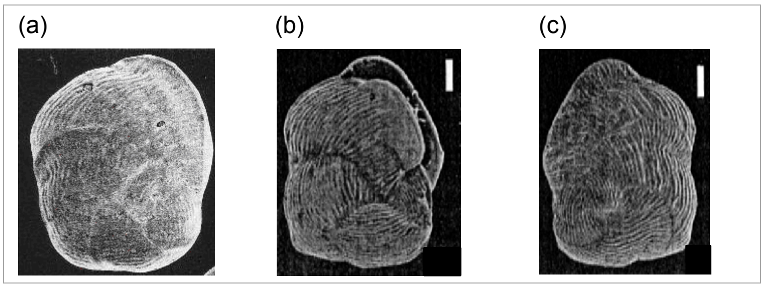
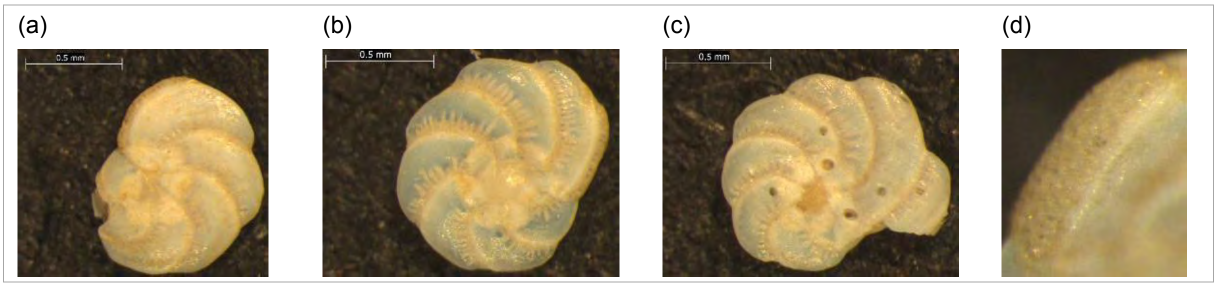


Figure 4: (a) SEM picture of *V. striata*, spiral side, magnification x80 (Haig, 1988). (b) SEM picture of *V. striata* umbilical side, scale = 0.1mm (Lobegeier, 2001). (c) SEM picture of *V. striata*, spiral sidfe, scale = 0.1mm (Lobegeier, 2001).

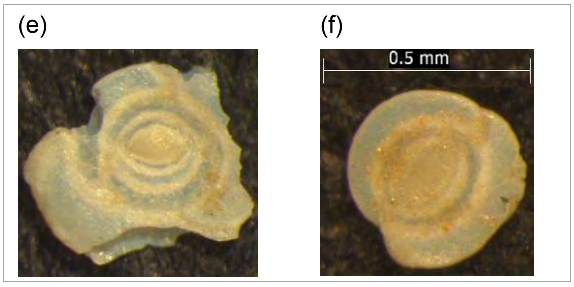
Hauerinidae

Hauerinidae have more than two chambers in each whorl with the later formed chambers being planispiral, which do not uncoil in most cases (Loeblich and Tappan, 1984).

Hauerina circinata (Brady, 1881)



Hauerina fragilissima (Brady, 1884)



Hauerina pacifica (Crushman, 1917)

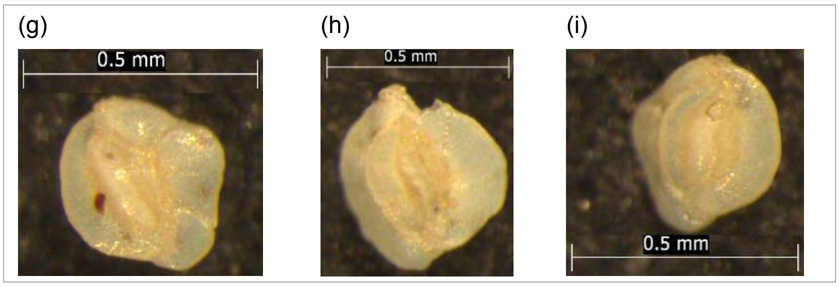


Figure 5: (a)-(c) Lateral view of *H. circinata*. (d) Apertural face of *H. circinata*, approximately 0.5mm in length. (e)-(f) Lateral view of *H. fragilissima*, approximately 0.5mm. (g)-(i) Lateral view of *H. pacifica*.

Miliola earlandi (Rasheed, 1971)

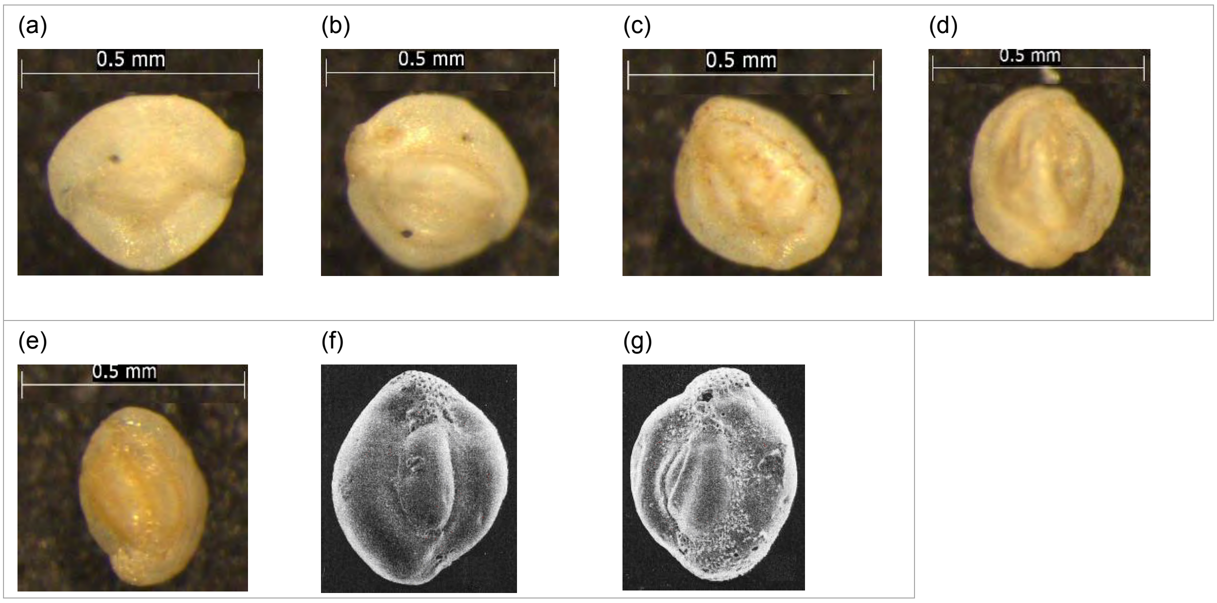
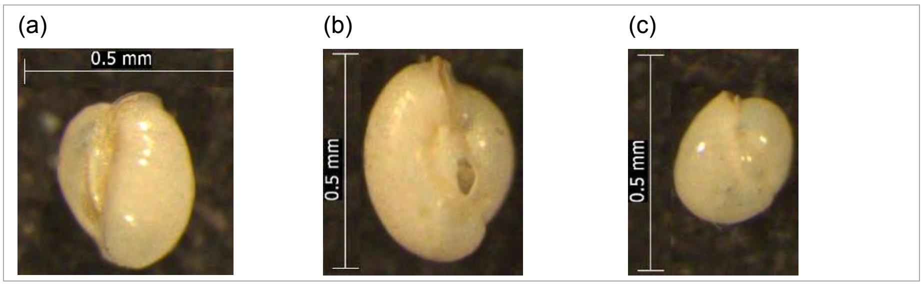


Figure 6: (a)-(e) Lateral view of *M. earlandi*. (f)-(g) SEM picture of *M. earlandi*, lateral view, magnification (f) x120, (g) x130 (Haig, 1988).

Miliolinella circularis



Miliolinella labiosa (d'Orbigny, 1839)

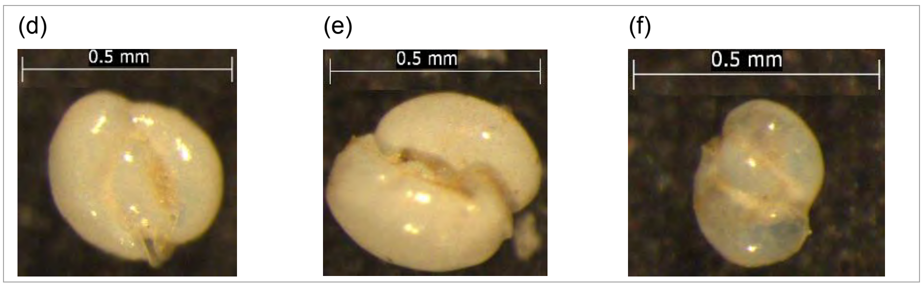


Figure 7: (a)-(c) Lateral view of *M. circularis*. (d)-(f) Lateral view of *M. labiosa*.

Pseudohauerina involute **(Crushman, 1946)**

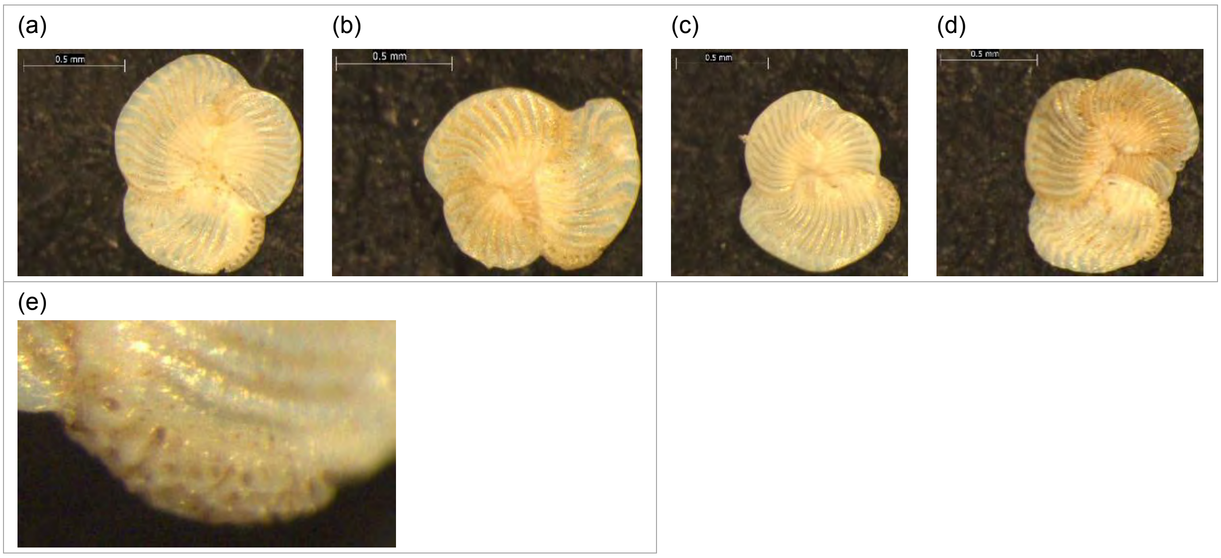


Figure 8: (a)-(d) Lateral view of *P. involute*. (e) Apertural face of *P. involute*, approximately 0.35mm in length.

Pseudomassilina macilenta **(Brady, 1884)**

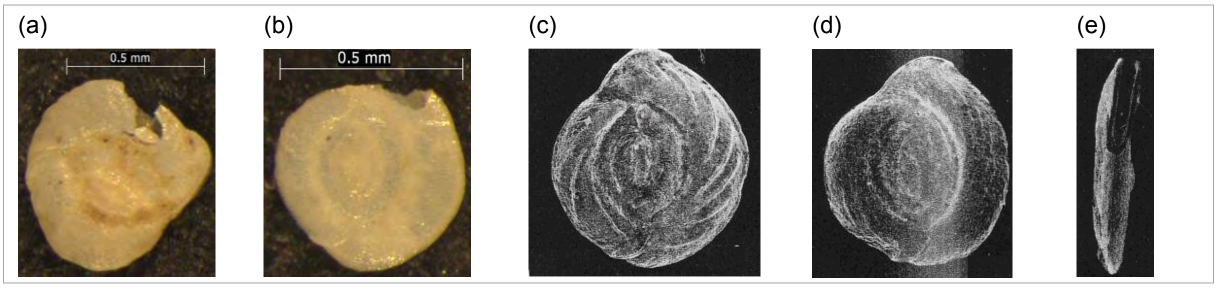
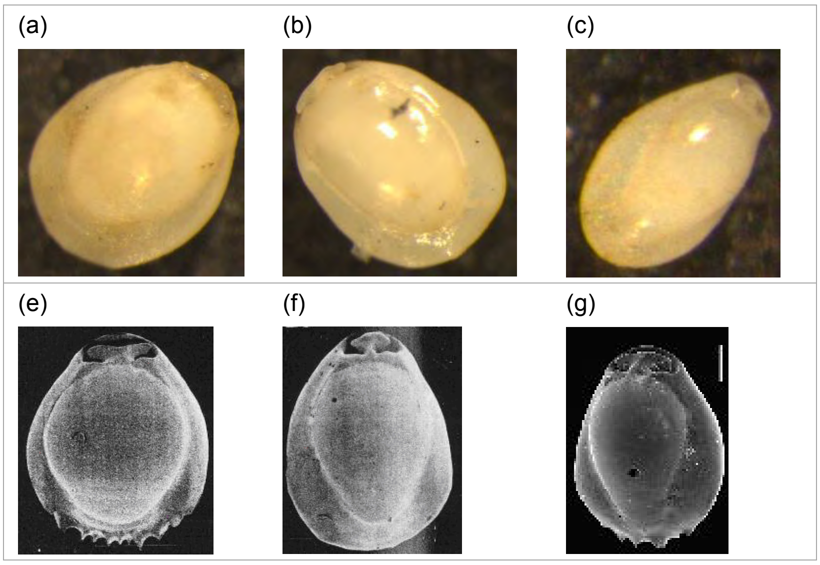


Figure 9: (a)-(b) Lateral view of *P. macilenta*. (c)-(d) SEM picture of *P. macilenta*, lateral view, magnification (c) x40, (d) x50 (Haig, 1988). (e) SEM picture of *P. macilenta*, aperture, magnification x70 (Haig, 1988).

Pyrgo denticulata (Brady, 1884)



Pyrgo striolata (Brady, 1884)

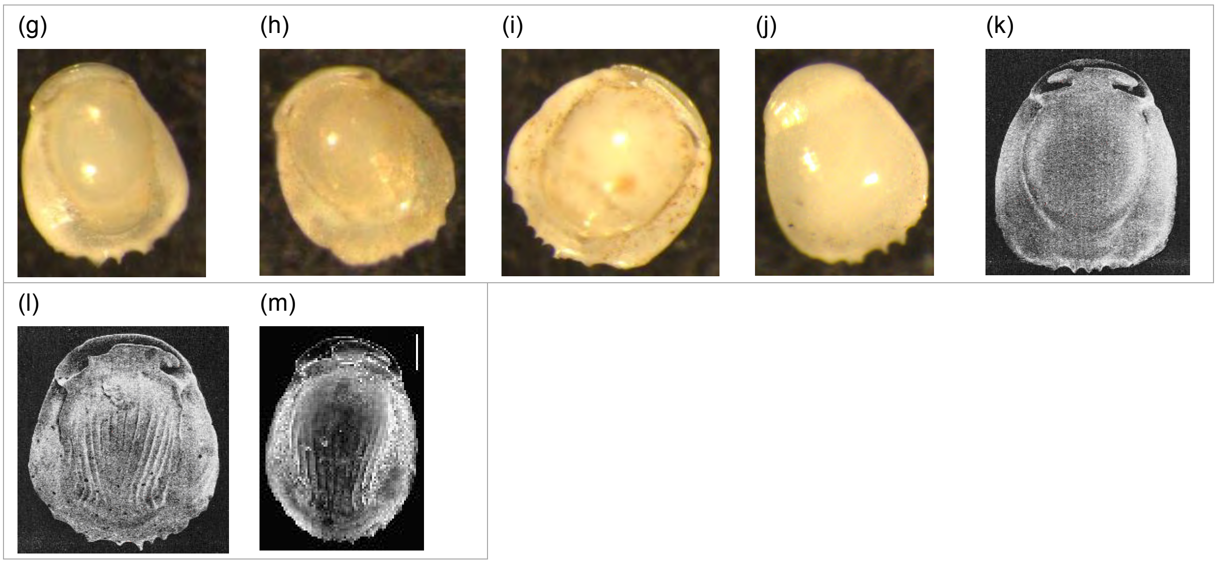


Figure 10: (a)-(c) Lateral view of *P. denticulata*, lateral view, approximately 0.5mm length. (d)-(e) SEM pictures of *P. denticulate*, lateral side, magnification (d) x50, (e) x70 (Haig, 1988). (f) SEM picture of *P. denticulate*, lateral view, scale = 0.1mm (Haig, 2001). (g)-(j) Lateral view of *P. striolata*, approximately 0.5mm length. (k)-(l) SEM pictures of *P. striolata*, lateral view, magnification (k) x60, (l) x50 (Haig, 1988). (m) SEM picture of *P. striolata*, lateral view, scale = 0.1mm (Haig, 2001).

Quinqueloculina spp.

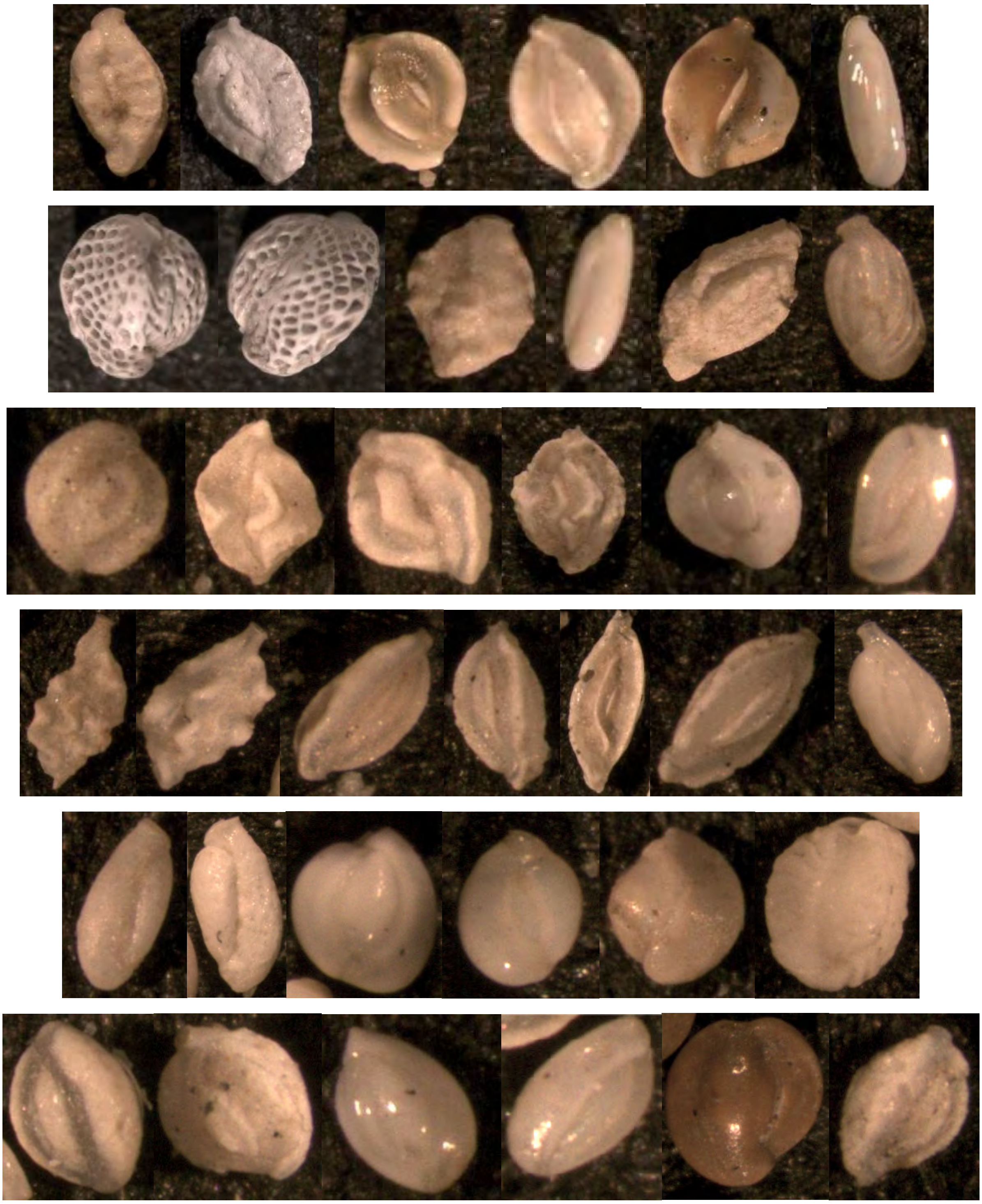


Figure 11: A range of *Quinqueloculina* species, ca. 0.07-0.5mm length.

Sigmohauerina involute

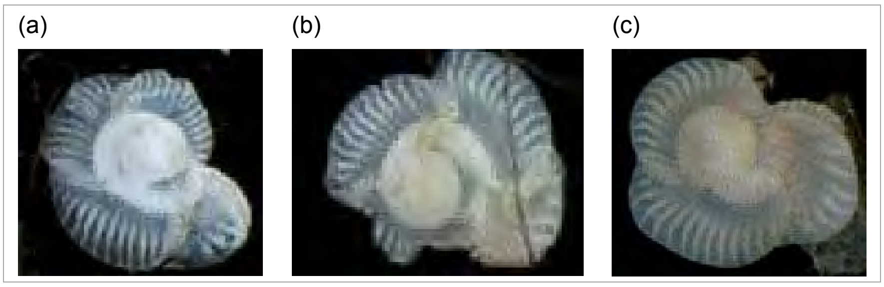
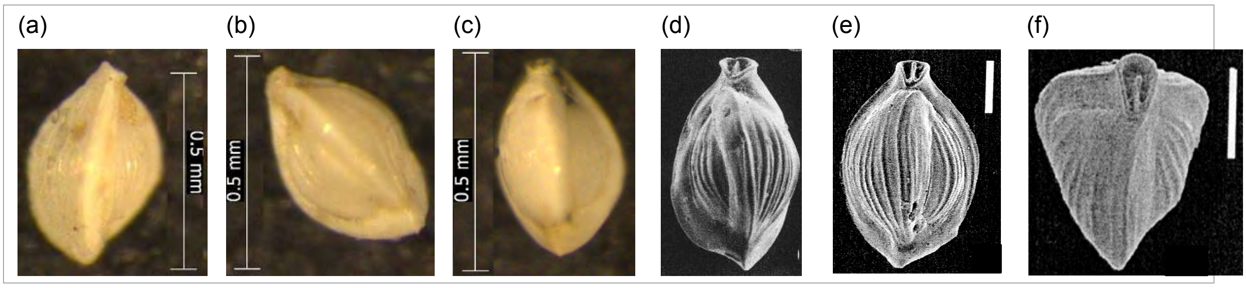
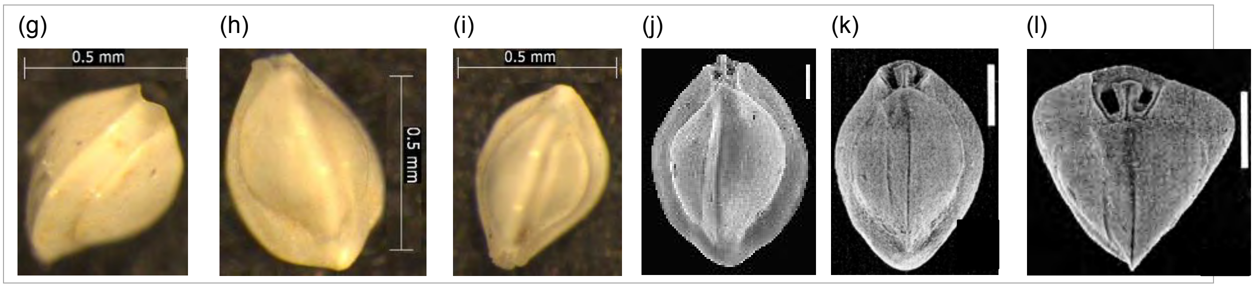


Figure 12: (a)-(c) Lateral view of *S. involute*, approximately 0.5mm width.

Triloculina barnardi (Rasheed, 1971)



Triloculina tricarinata (d'Orbigny, 1826)



Triloculina trigonula (Lamark, 1804)

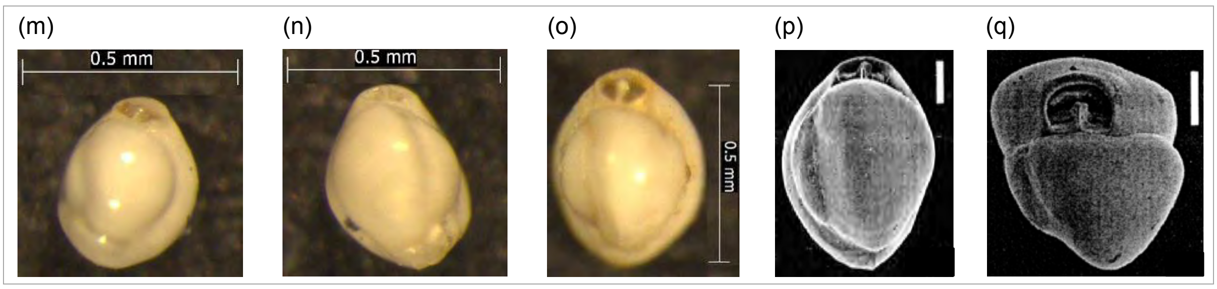


Figure 13: (a) Peripheral view of *T. barnardi*. (b)-(c) Lateral view of *T. barnardi.* (d) SEM picture of *T. barnardi*, lateral view, magnification x100 (Haig, 1988). (e) SEM picture of *T. barnardi*, lateral view scale = 0.1mm (Lobegeier, 2001) (f) SEM picture of *T. barnardi*, apertural view, scale = 0.1mm (Lobegeier, 2001). (g) Peripheral view of *T. tricarinata.* (h)-(i) Lateral view of *T. tricarinata.* (j) SEM picture of *T. tricarinata*, lateral view, scale = 0.1mm (Haig, 2001). (k) SEM picture of *T. tricarinata*, lateral view, scale = 0.1mm (Lobegeier, 2001). (l) SEM picture of *T. tricarinata*, apertural view, scale = 0.1mm (Lobegeier, 2001). (m)-(o) Lateral view of *T. trigonula*. (p) SEM picture of *T. trigonula*, lateral view, scale = 0.1mm (Lobegeier, 2001). (q) SEM picture of *T. trigonula*, apertual view, scale = 0.1mm (Lobegeier, 2001).

Ophthalmidiidae

The initial chamber and flexostyle are followed by half coiled chambers (Loeblich and Tappan, 1984).

Edentostomina cultrata (Brady, 1881)

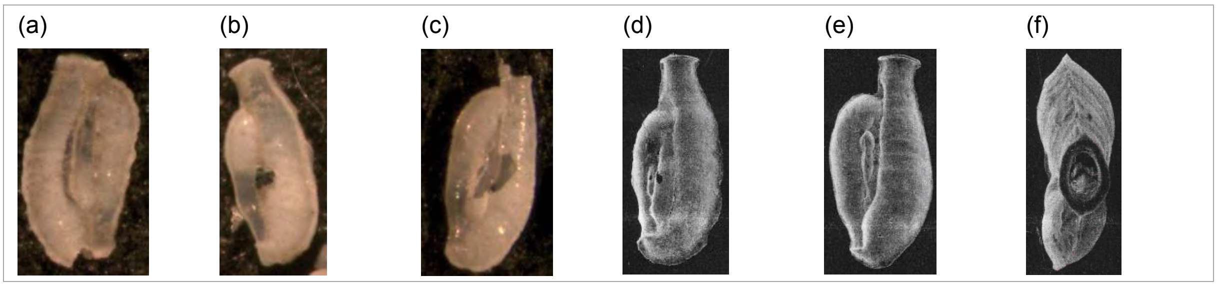


Figure 14: (a)-(c) Lateral view of *E. cultrata*, approximately 0.75mm length. (d)-(e) SEM picture of *E. cultrata*, lateral view, magnification x50 (Haig, 1988). (f) SEM picture of *E. cultrata*, apertural view, magnification x110 (Haig, 1988).

Peneroplidae

The first few chambers may be perforated and are tightly coiled, while the later adult chambers may begin to uncoil or develop annular chambers. The aperture can take many forms, being either rounded, slit-like, or in a series of pores (Loeblich and Tappan, 1984).

Peneroplis antillarum

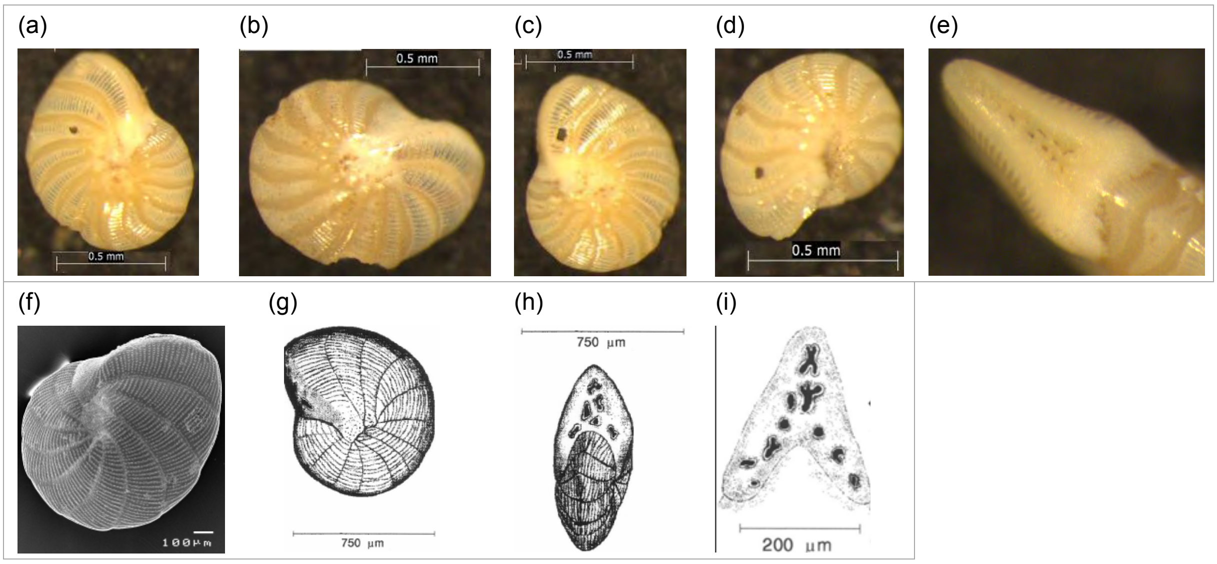
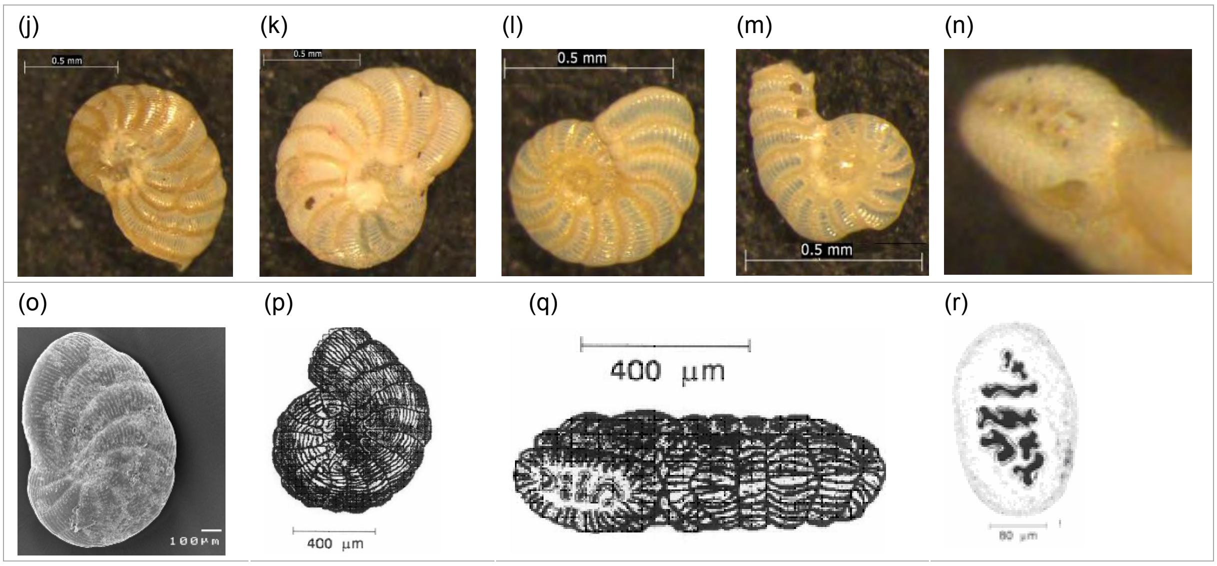


Figure 15: (a)-(d) Lateral view of *P. antillarum*. (e) Aperture of *P. antillarum*, approximately 0.4mm length. (f) SEM picture of *P. antillarum.* (g) Drawing of *P. antillarum*, lateral view (Gudmundsson, 1994). (h) Drawing of *P. antillarum*, apertural view (Gudmundsson, 1994). (i) Drawing of *P. antillarum*, aperture (Gudmundsson, 1994).

Peneroplis pertusus (Foraskal, 1775)



Peneroplis planatus (Fichtel and Moll, 1798)

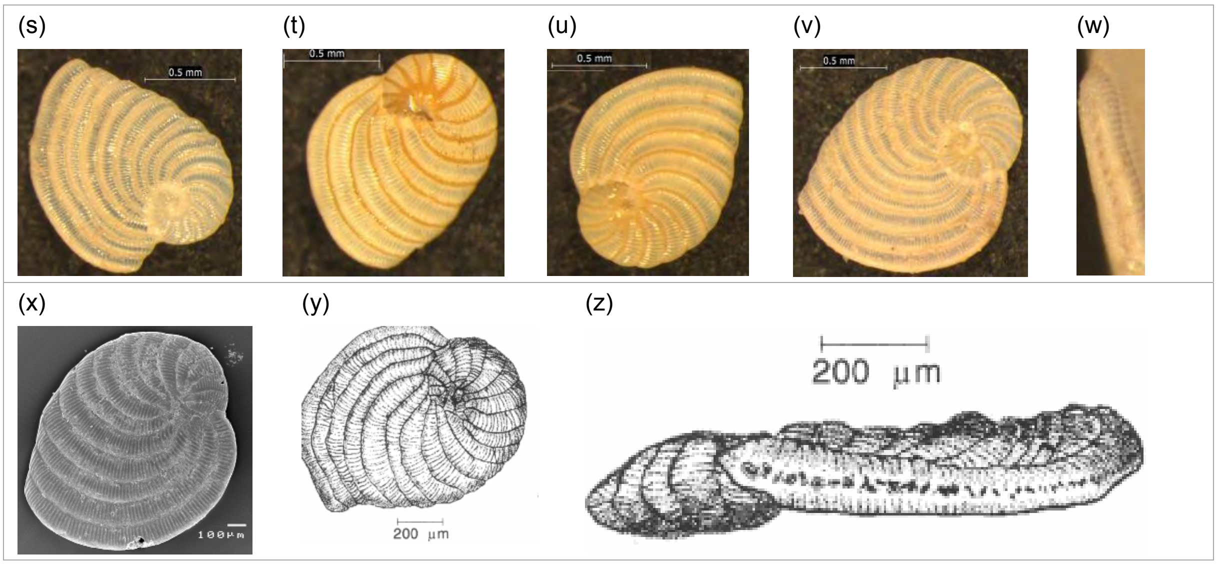
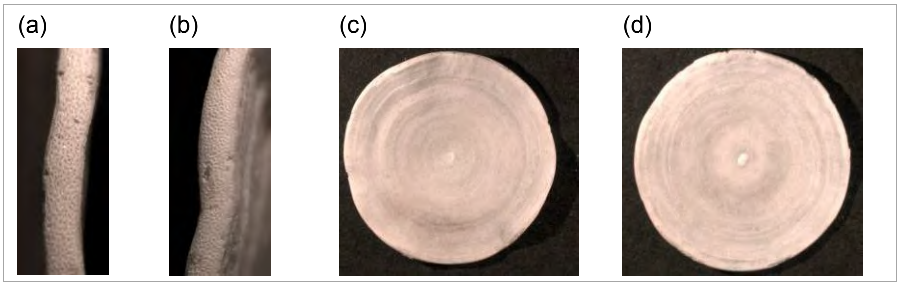


Figure 15 (continued): (j)-(m) Lateral view of *P. pertusus*. (n) Apertural face of *P. pertusus*, approximately 0.25mm length. (o) SEM picture of *P. pertusus*, lateral view. (p) Drawing of *P. pertusus*, lateral view (Gudmundsson, 1994). (q) Drawing of *P. pertusus*, apertural view (Gudmundsson, 1994). (r) Drawing of aperture face of *P. pertusus* (Gudmundsson, 1994). (s)-(v) Lateral view of *P. planatus*. (w) *P. planatus* apertural face. (x) SEM picture of *P. planatus*, lateral view. (y) Drawing of *P. planatus*, lateral view (Gudmundsson, 1994). (z) Drawing of *P. planatus*, aperture face (Gudmundsson, 1994).

Soritidae

Soritids have a planispiral test, with some uncoiling to take a flairing, fusiform or cylindrical structure in later life stages. They contain a large number of chambers divided into chamberlets but septula, as well as multiple apertures (Loeblich and Tappan, 1984).

Amphisorous sp.



Marginopera vertebralis (Quoy and Gaimard, 1830)

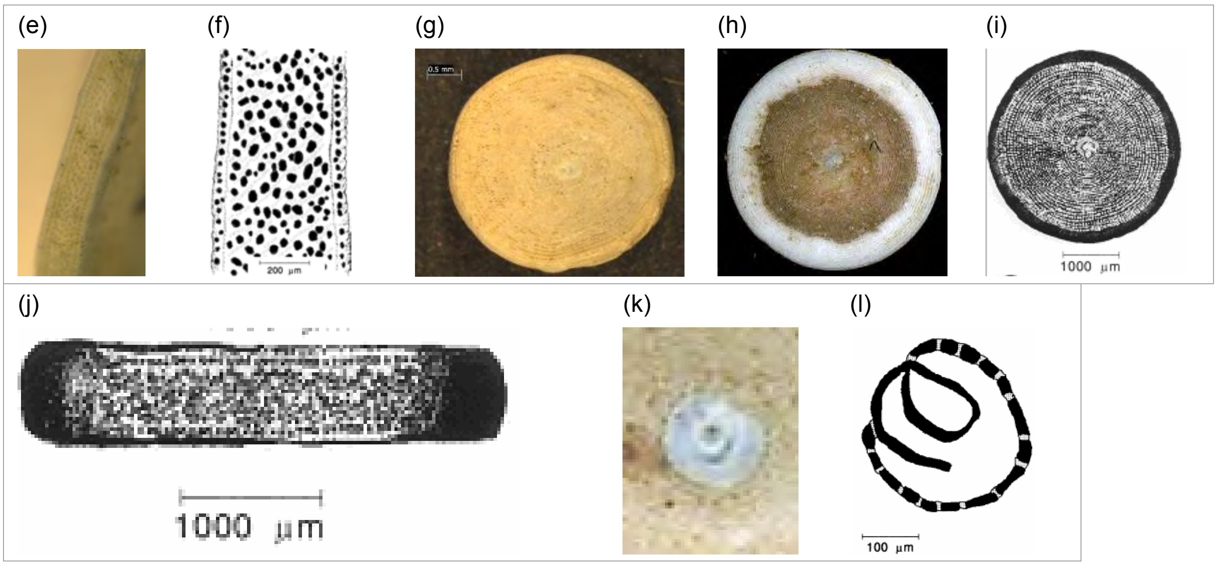
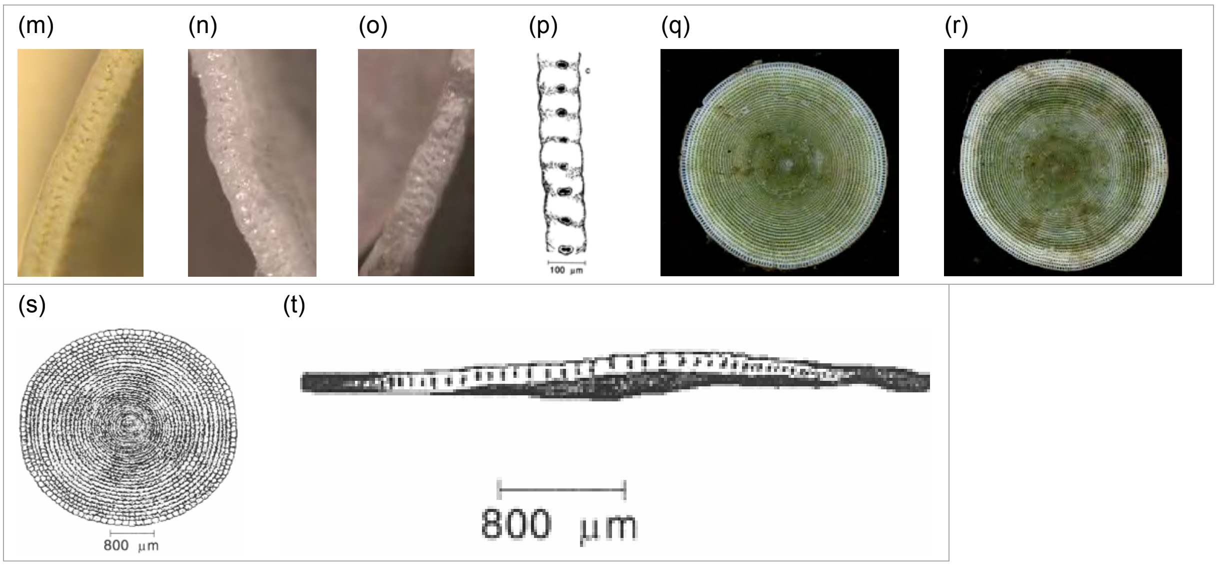


Figure 16: (a)-(b) Apertural face of *Amphisorous sp*., approximately 0.75mm width. (c)-(d) Lateral view of *Amphisorous sp*., approximately 15mm diameter. (e) Apertural face of *Marginopera vertebralis*, approximately 1mm width. (f) Drawing of *Marginopera vertebralis*, apertural face (Gudmundsson, 1994). (g)-(h) Lateral view of *M. vertebralis*. (i) Drawing of *M. vertebralis*, lateral view (Gudmundsson, 1994). (j) Drawing of *M. vertebralis*, peripheral view (Gudmundsson, 1994). (k) Close up of initial chamber of *M. vertebralis*, approximately 0.3mm width. (l) Drawing of *M. vertebralis*, initial chamber of the test (Gudmundsson, 1994).

Parasorites sp.



Sorites orbiculus

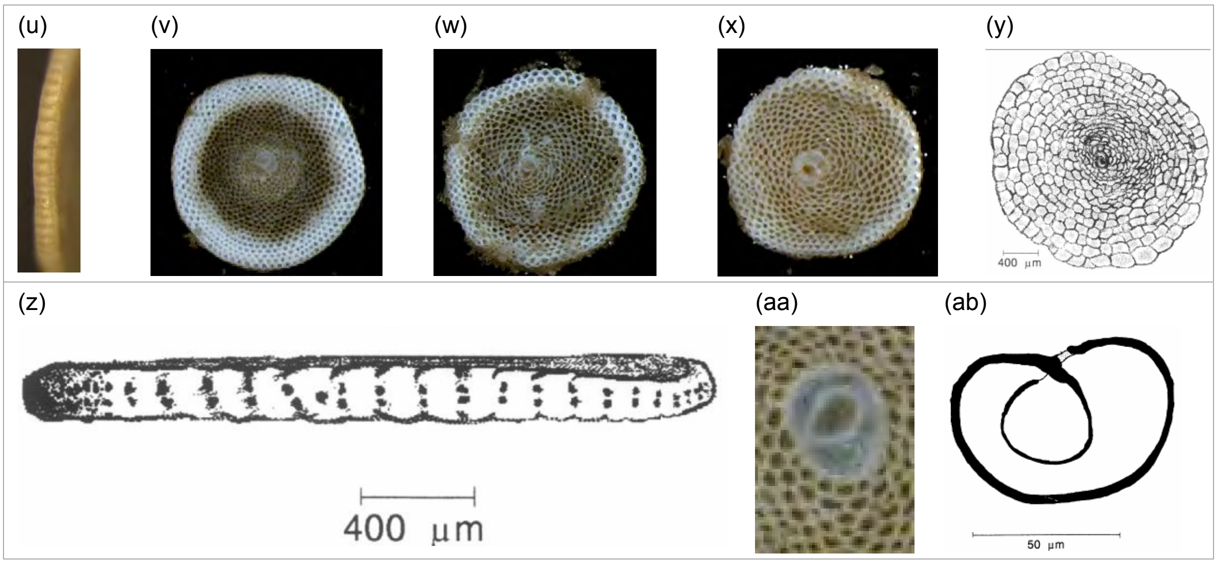
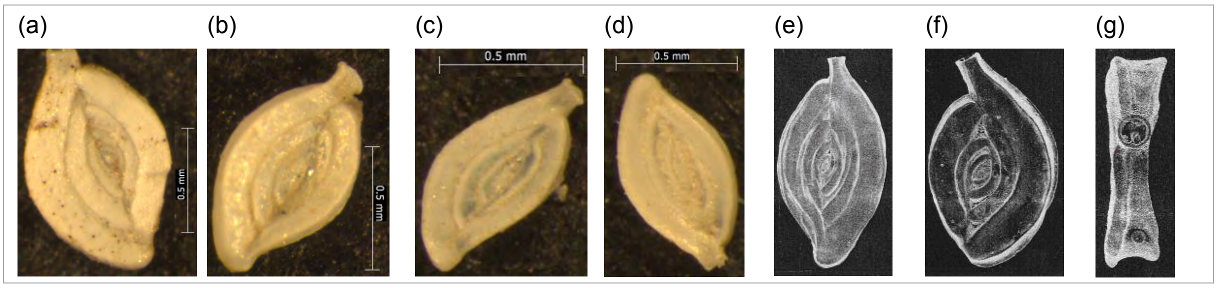


Figure 16 (continued): (m)-(o) Apertural face of *Parasorites*, approximately 0.2mm width. (p) Drawing of *Parasorites sp.*, apertural face (Gudmundsson, 1994, all subsequent drawings of Gudmundson as *Sorites orbiculus var. marginalis*). (q)-(r) Lateral view of *Parasorites sp.*, approximately 4mm width. (s) Drawing of lateral view of *Parasorites sp.* (Gudmundsson, 1994). (t) Drawing of *Parasorites sp.* peripheral view (Gudmundsson, 1994). (u) Apertural face of *Sorites obiculus*, approximately 0.2mm width. (v)-(x) Lateral view of *Sorites obiculus*, approximately 2.5mm width. (y) Drawing of *Sorites obiculus*, lateral view (Gudmundsson, 1994). (z) Drawing of *Sorites obiculus*, peripheral view (Gudmundsson, 1994). (aa) Close up of initial chamber of *Sorites obiculus*, approximately 0.5mm width. (ab) Drawing of initial chamber of *Sorites obiculus* test (Gudmundsson, 1994).

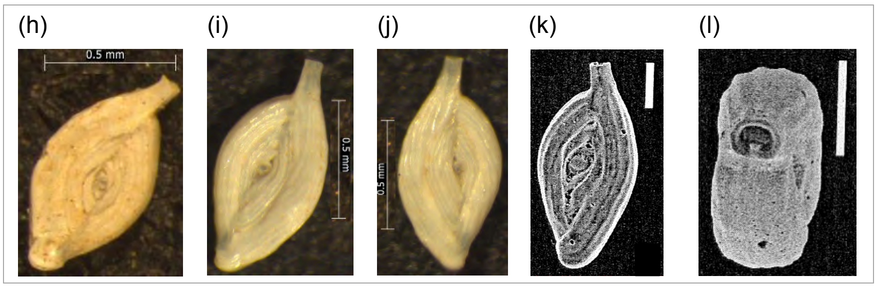
Spiroloculinidae

Each whorl contains two chambers which form a 180° angle between the median plane. The aperture is a simple opening that can be rounded and/or elongated. Some have a tooth structure which protrudes out into the opening (Loeblich and Tappan, 1984).

Spiroloculina angulata (Crushman, 1917)



Spiroloculina corrugata



Spiroloculina foveolata (Egger, 1983)

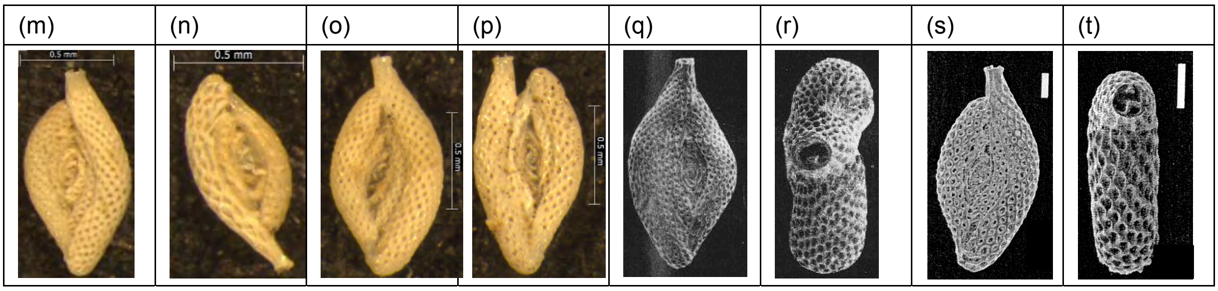


Figure 17: (a)-(d) Lateral view of *S.angulata*. (e)-(f) SEM picture of *S. angulata*, lateral view, magnification (e) x30, (f) x80 (Haig, 1988). (g) SEM picture of *S. angulata*, apertual view, magnification x40 (Haig, 1988). (h)-(j) Lateral view of *S. corrugata*. (k) SEM picture of *S. corrugate*, lateral view, scale = 0.1mm (Lobegeier, 2001). (l) SEM picture of *S. corrugate*, apertural view, scale = 0.1mm (Lobegeier, 2001). (m)-(p) Lateral view of *S. foveolata*. (q) SEM picture of *S. foveolata*, lateral view, magnification x40 (Haig 1988). (r) SEM picture of *S. foveolata*, apertural view, magnification x60 (Haig 1988). (s) SEM picture of *S. foveolata*, lateral view, scale = 0.1mm (Lobegeier, 2001). (t) SEM picture of *S. foveolata*, apertural view, scale = 0.1mm (Lobegeier, 2001).

Spiroloculina rugosa (Crushman and Todd, 1944)

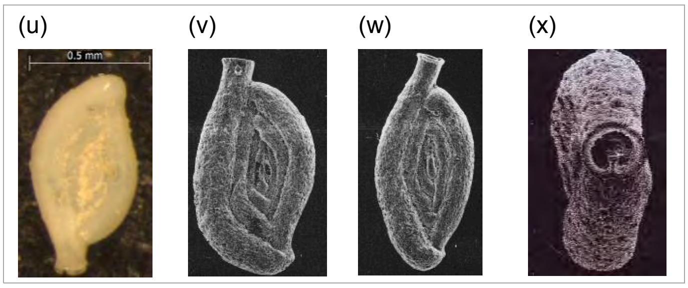


Figure 17 (continued): (u) Lateral view of *Spiroloculina rugosa*. (v)-(w) SEM pictures of *S. rugosa*, lateral view, magnification (v) x50, (w) x60 (Haig 1988). (x) SEM picture of *S. rugosa*, apertural view, magnification x70 (Haig, 1988).

Suborder: Rotaliina

Rotaliina have a perforated hyaline test made of lamellar calcite with some possessing a canal or stolon system. They have multiple chambers which are usually enrolled, but may also condense to form biserial or uniserial structures. The chambers can be either simple or divided into chamberlets. Rotaliina may also exhibit different forms of ornamentation, including: papillate, costate, striate and cancellate. The aperture may be simple or have an internal toothplate, entosolenian tube or hemicylindrical structure (Loeblich and Tappan, 1984).

Alfredinidae

Alfredinidae have supplementary chambers which form near the axis of the chambers spiral. Multiple apertures are located on the wall of the most recently formed chamber, as well as where it joins to the previous chamber (Loeblich and Tappan, 1984).

Epistomaroides polystomelloides

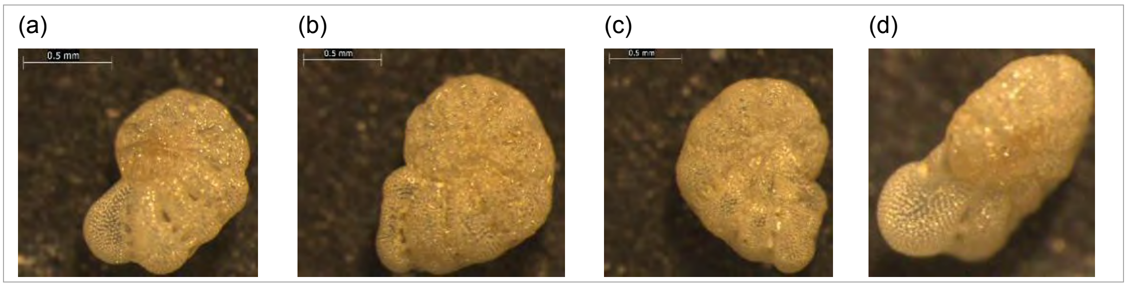
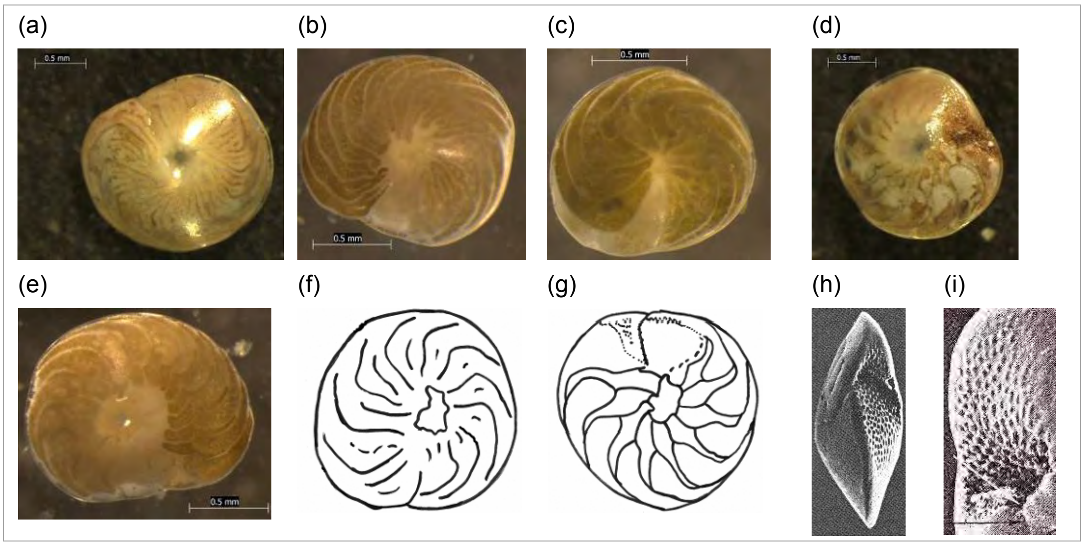


Figure 18: (a)-(b) *Epistomaroides polystomelloides*, spiral side. (c) *E. polystomelloides*, umbilical side. (d) *E. polystomelloides*, apertural view.

Amphisteginidae

Amphisteginidae have a large number of chambers with some divided into complex chamberlets. The aperture is in the form of a slit located where the final wall and proceeding spiral meet (Loeblich and Tappan, 1984).

Amphistegina lessonii (d'Orbigny, 1826)



Amphistegina lobifera

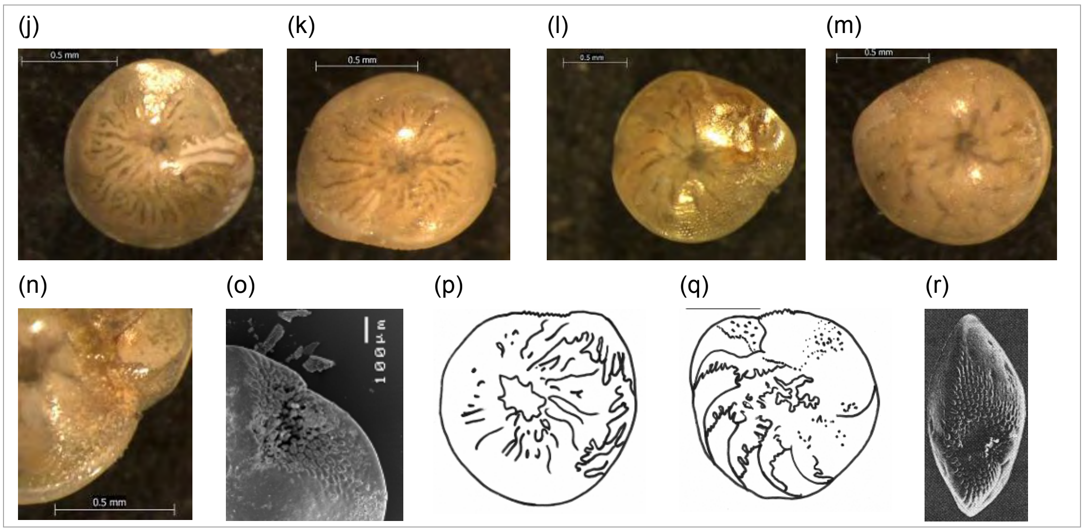


Figure 19: (a)-(c) *Amphistegina lessonii*, spiral side. (d)-(e) *A. lessonii*, umbilical side. (f) Drawing of *A. lessonii*, spiral side (amended from Larsen, 1976), scale = 0.5mm. (g) Drawing of *A. lessonii*, umbilical side (amended from Larsen, 1976), scale = 0.5mm. (h) Peripheral view of *A. lessonii*, 0.5mm width (Larsen, 1976). (i) Aperture of *A. lessonii* (Larsen, 1976). (j)-(k) *A. lobifera*, spiral side. (l)-(m) *A. lobifera*, umbilical side. (n) Aperture of *A. lobifera.* (o) SEM picture of *A. lobifera*, aperture. (p) Drawing of *A. lobifera*, spiral side (amended from Larsen, 1976), scale = 0.5mm. (q) Drawing of *A. lobifera*, umbilical side (amended from Larsen, 1976), scale = 0.5mm. (r) Peripheral view of *A. lobifera* (Larsen, 1976), approximately 0.5mm width.

Amphistegina radiata (Fichtel and Moll)

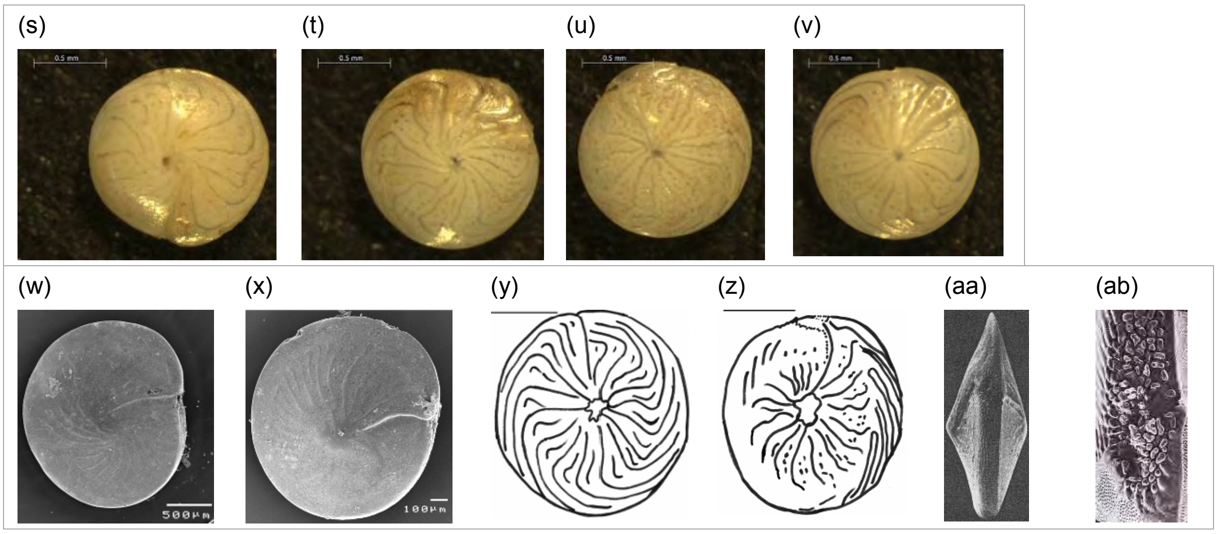


Figure 19 (continued): (s)-(v) Lateral view of *A. radiata*. (w)-(x) SEM picture of *A. radiate*, lateral view. (y) Drawing of *A. radiate*, spiral side (amended from Larsen, 1976), scale = 0.5mm. (z) Drawing of *A. radiate*, umbilical side (amended from Larsen, 1976), scale = 0.5mm. (aa) Peripheral view of *A. radiata* (Larsen, 1976), approximately 0.25mm. (ab) Aperture of *A. radiata* (Larsen, 1976).

Baginidae

The test is trochospiral and covered in fine pores except close to the aperture and umbilicus (Loeblich and Tappan 1984).

Cancris auriculus (Fichtel and Moll, 1798)

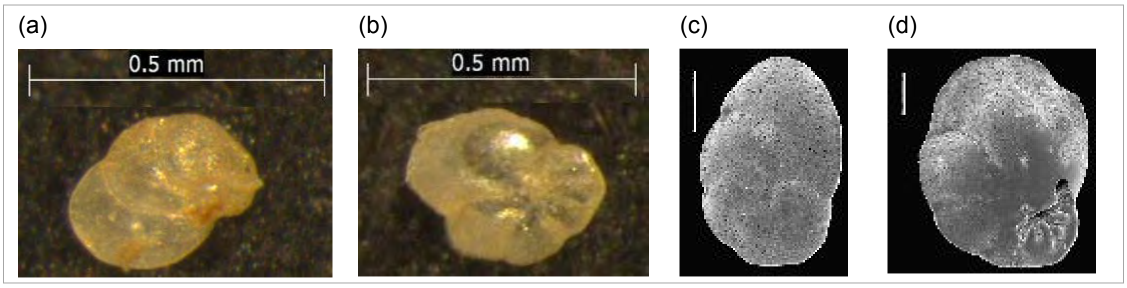


Figure 20: (a)-(b) *Cancris auriculus*, spiral side. (c) *C. auriculus*, spiral side, scale = 0.1mm (Haig, 2001). (d) *C. auriculus*, umbilical side, scale = 0.1mm (Haig, 2001).

Calcarinidae

Calcarinidae have an enrolled test which contains an internal canal system. Large spines may be also formed by lamellar thickening (Loeblich and Tappan 1984).

Baculogypsina sphaerulata (Parker and Jones, 1860)

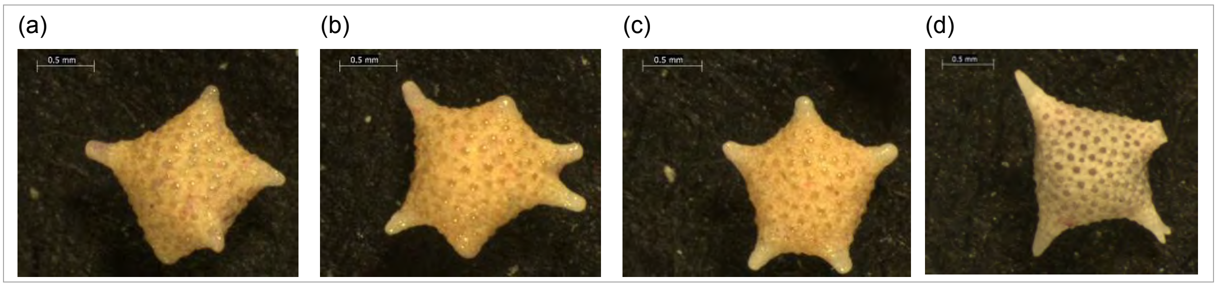


Figure 21: (a)-(d) *Baculogypsina sphaerulata*, lateral view.

Calcarina hispida

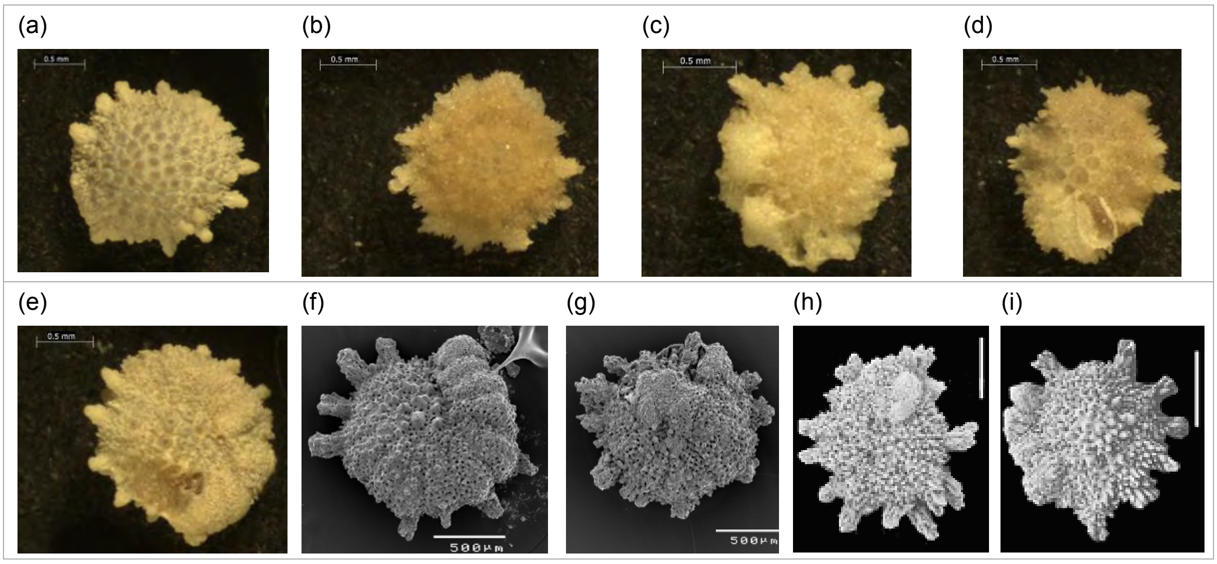
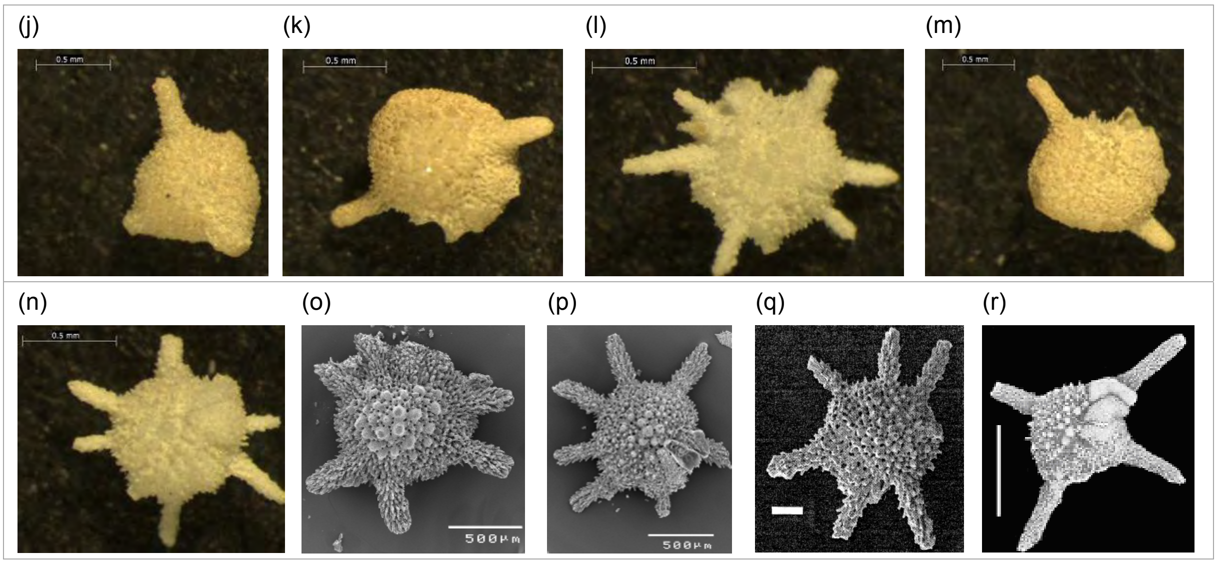


Figure 22: (a)-(e) Lateral view of *Calcarina hispida*. (f)-(g) SEM picture of *C. hispida*, lateral view. (h) SEM picture of *C. hispida*, spiral side, scale = 0.5mm (Renema and Hohenegger, 2005). (i) SEM picture of *C. hispida*, umbilical side, scale = 0.5mm (Renema and Hohenegger, 2005).

Calcarina mayorii (Crushman, 1924)



Calcarina spengleri (Gmelin, 1791)

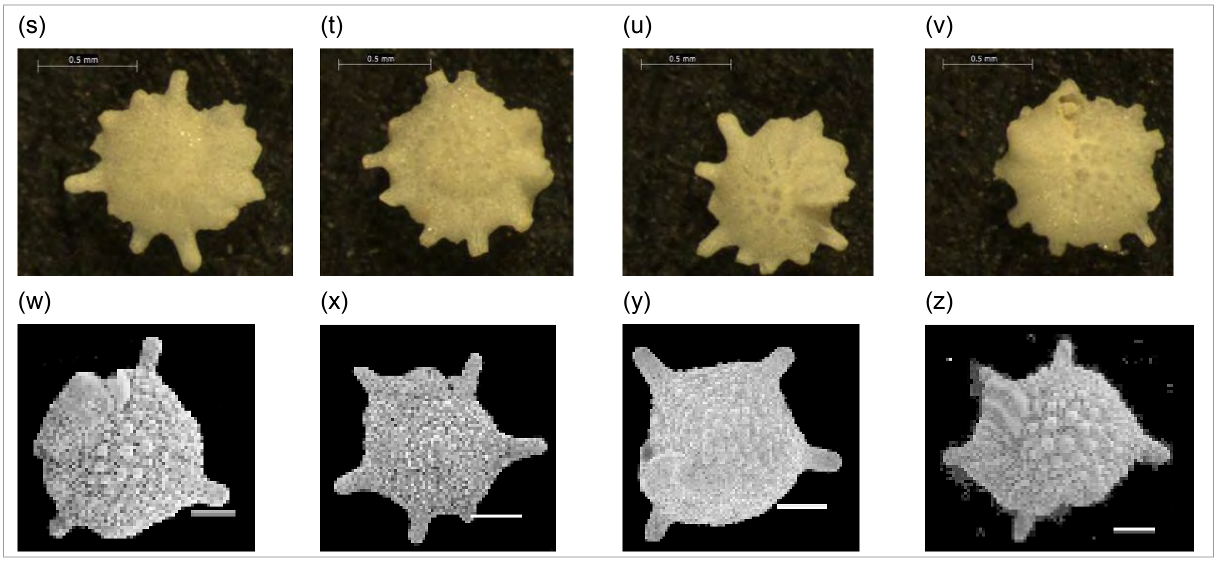


Figure 22 (continued): (j)-(l) *Calcarina mayorii*, spiral side. (m)-(n) *C. mayorii*, umbilical side. (o) SEM picture of *C. mayorii*, spiral side. (p) SEM picture of *C. mayorii*, umbilical side. (q) SEM picture of *C. mayorii*, spiral side, scale = 0.2mm (Lobegeier, 2001). (r) SEM picture of *C. mayorii*, umbilical side, scale = 0.2mm (Renema and Hohenegger, 2005). (s)-(t) *C. spengleri*, spiral side. (u)-(v) *C. spengleri*, umbilical side. (w)-(x) SEM picture of *C. spengleri*, spiral side, scale = 0.5mm (Renema and Hohenegger, 2005). (y)-(z) SEM picture of *C. spengleri*, umbilical side, scale = 0.5mm (Renema and Hohenegger, 2005).

Neorotalia calcar (d'Orbigny, 1839)

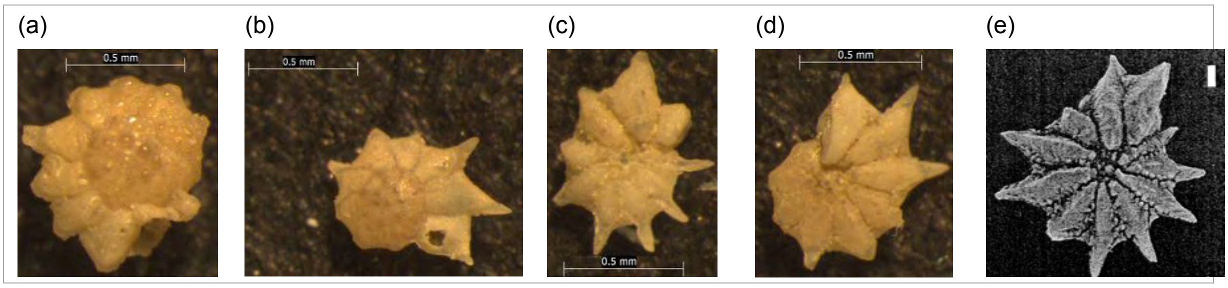


Figure 23: (a)-(b) *Neorotalia calcar*, spiral side. (c)-(d) *N. calcar*, umbilical side. (e) SEM picture of *N. calcar*, umbilical side, scale = 0.1mm (Lobegeier, 2001).

Cibicididae

Trochospiral, at least in early stages. There may be a single or multiple apertures in forms which become uncoiled. While enrolled Cibicididae have an opening that forms an arch, which may or may not extend to the spiral side (Loeblich and Tappan, 1984).

Cibicides cf. refulgens (Montfort, 1808)

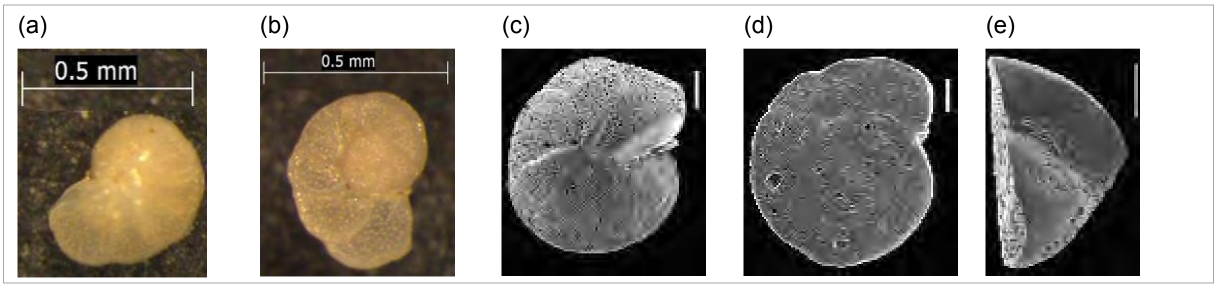
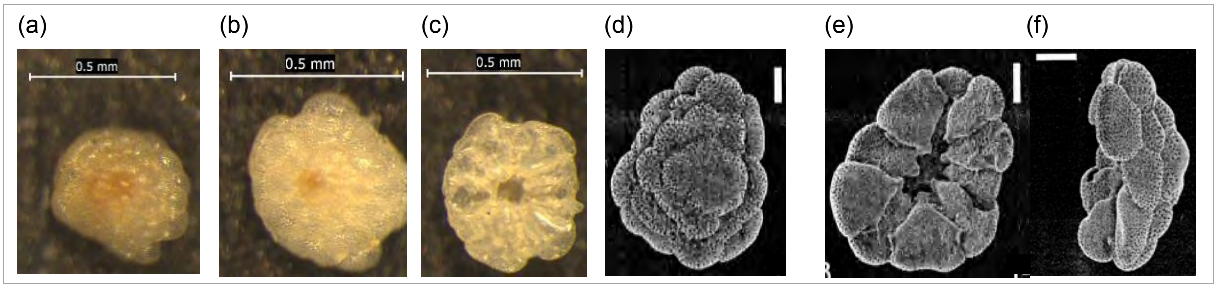


Figure 24: (a) *Cibicides cf. refulgens*, spiral side. (b) *Cibicides cf. refulgens*, umbilical side. (c) *Cibicides cf. refulgens*, spiral side, scale = 0.1mm (Haig, 2001). (d) *Cibicides cf. refulgens*, umbilical side, scale = 0.1mm (Haig, 2001). (e) *Cibicides cf. refulgens*, peripheral view, scale = 0.1mm (Haig, 2001).

Cymbalopoidae

The trochospiral test is covered in a large number of small apertures. The later chambers in the spiral form a flat to conical layer (Loeblich and Tappan, 1984).

Cymbaloporetta bradyii (Crushman, 1931)



Cymbaloporetta squamosa (d'Orbigny)

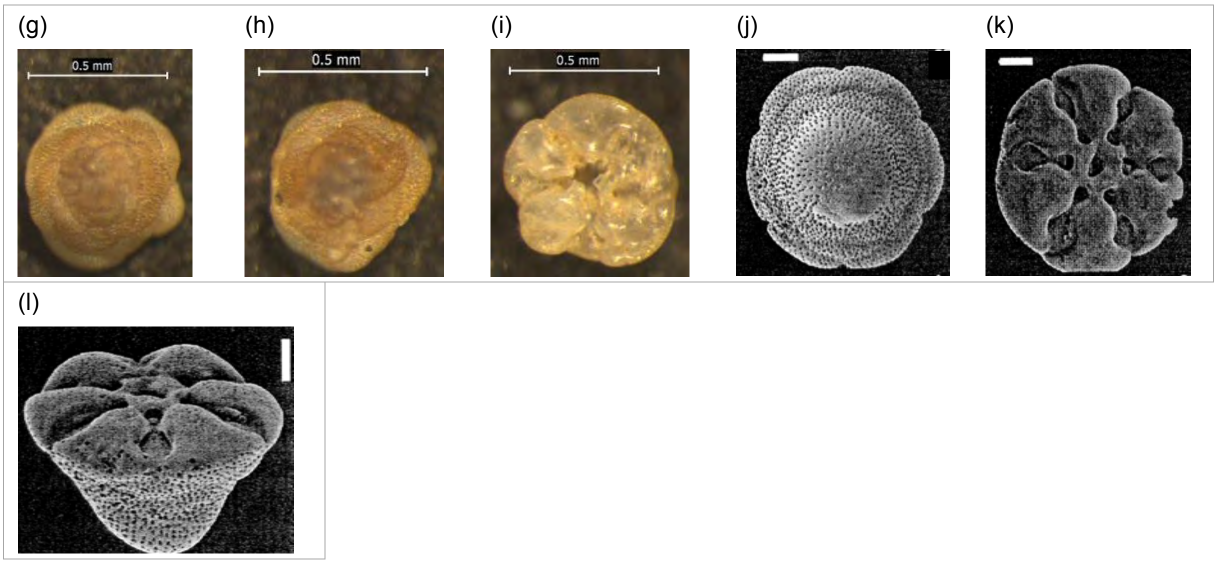


Figure 25: (a)-(b) *Cymbaloporetta. Bradyii*, spiral side. (c) *C. bradyii*, umbilical side. (d) SEM picture of *C. bradyii*, spiral side, scale = 0.1mm (Lobegeier, 2001). (e) SEM picture of *C. bradyii*, umbilical side, scale = 0.1mm (Lobegeier, 2001). (f) SEM picture of *C. bradyii*, peripheral view, scale = 0.1mm (Lobegeier, 2001). (g)-(h) *C. squammosa*, spiral side. (i) *C. squammosa*, umbilical side. (j) SEM picture of *C. squammosa*, spiral side, scale = 0.1mm (Lobegeier, 2001). (k) SEM picture of *C. squammosa*, umbilical side, scale = 0.1mm (Lobegeier, 2001). (l) SEM picture of *C. squammosa*, peripheral view, scale = 0.1mm (Lobegeier, 2001).

Discorbidae

Discorbidae have a trochospiral test with an open umbilical region forming the aperture (Loeblich and Tappan, 1984).

Rotorbis auberi

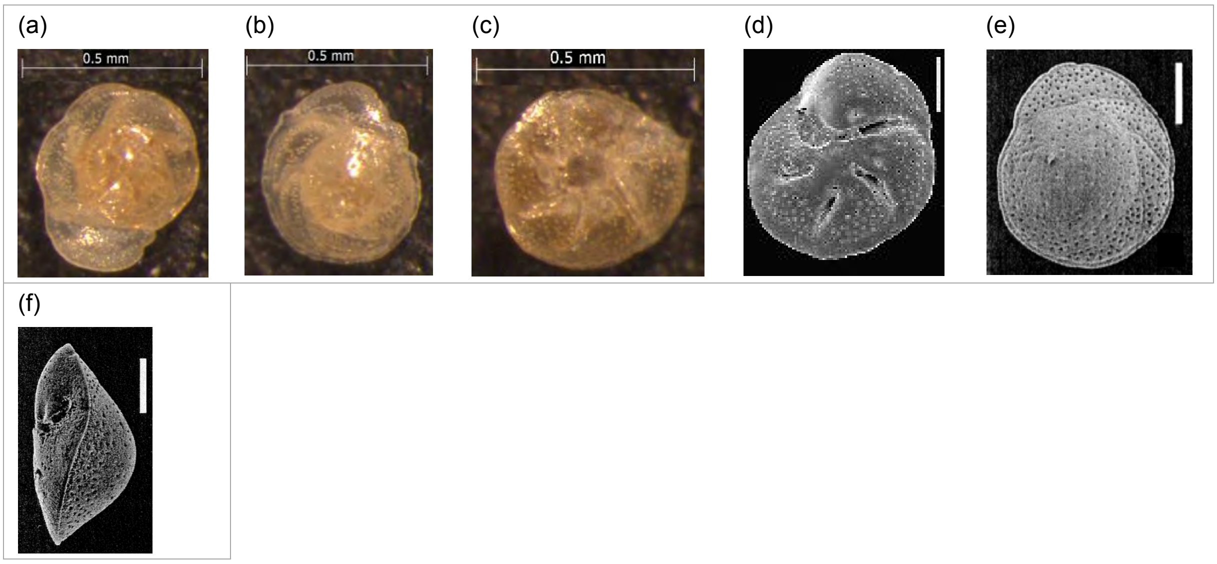


Figure 26: (a)-(b) *Rotorbis auberi*, spiral side. (c) *R. auberi*, umbilical side. (d) SEM picture of *R. auberi*, umbilical side, scale = 0.1mm (Haig, 2001). (e) SEM picture of *R. auberi*, spiral side, scale = 0.1mm (Lobegeier, 2001). (f) SEM picture of *R. auberi*, peripheral view, scale = 0.1mm (Lobegeier, 2001).

Discorbinellidae

The test forms a very flat trochospiral, with the aperture located between the last two chambers. Some have supplementary openings beneath the umbilical flaps (Loeblich and Tappan, 1984).

Discorbinella sp.

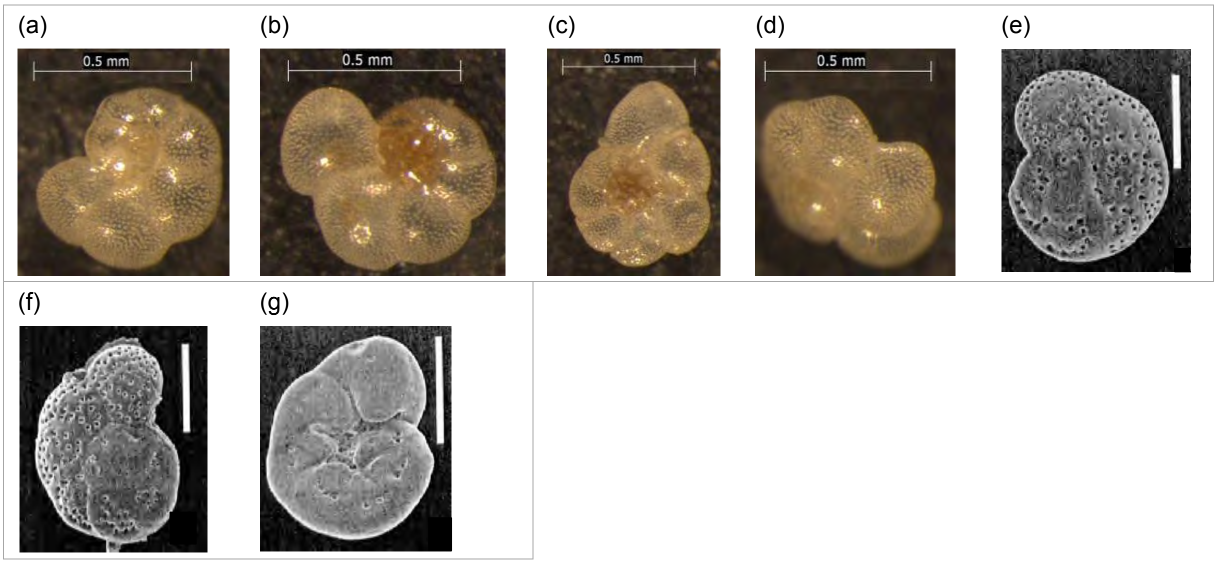
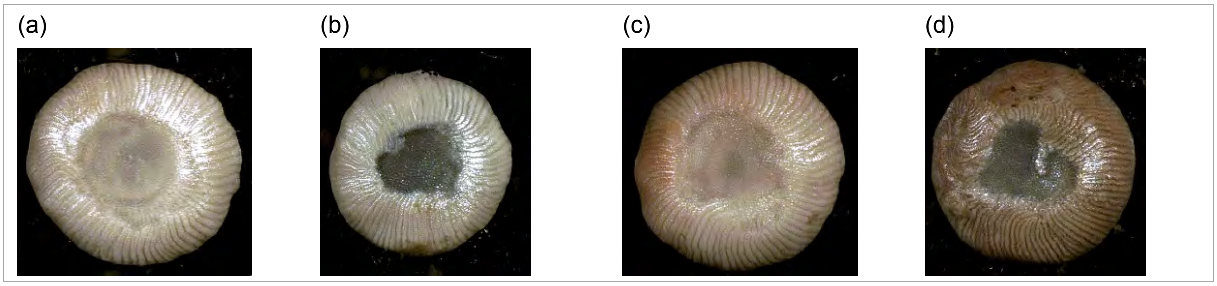


Figure 27: (a)-(b) Spiral side of *Discorbinella sp*. (c) Umbilical side of *Discorbinella sp*. (d) Peripheral view of *Discorbinella sp*. (e)-(f) SEM picture of *Discorbinella sp*., spiral side, scale = 0.1mm (Lobegeier, 2001). (g) SEM picture of *Discorbinella sp*., umbilical side, scale = 0.1mm (Lobegeier, 2001).

Elphididae

Elphididae can either have a planispiral to trochospiral test, with some uncoiling in later stages. There is also a sutural canal system which opens into sutural pores (Loeblich and Tappan, 1984).

Elphidium sp.



Elphidium cf. craticulatum (Crushman, 1933)

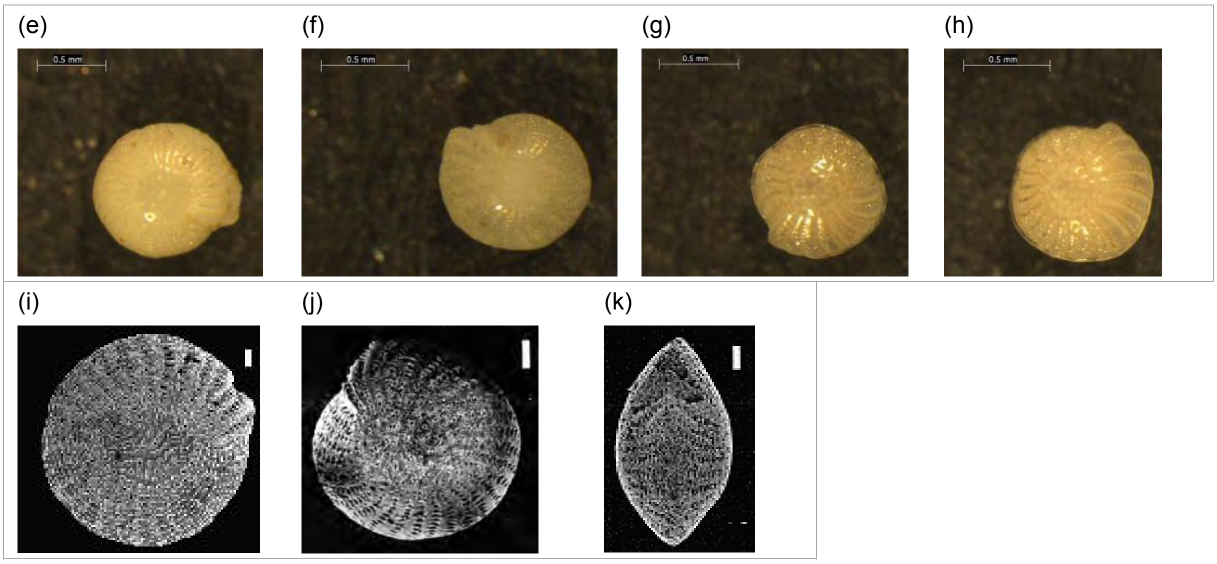
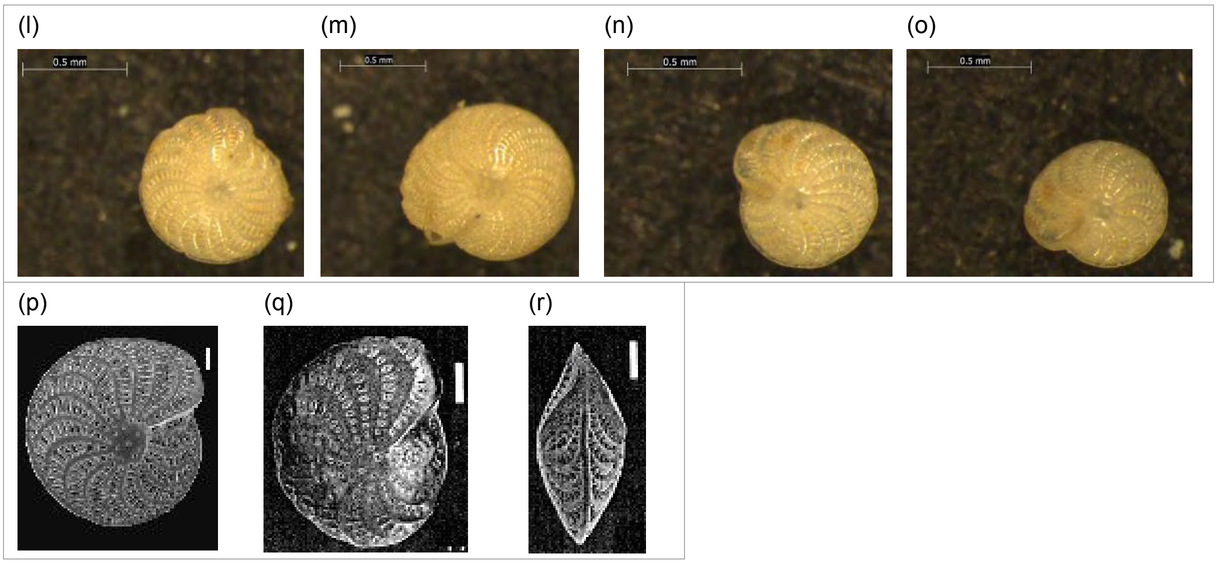


Figure 28: (a)-(d) Lateral view of *Elphidium sp.*, approximately 15mm diameter. (e)-(h) Lateral view of *Elphidium cf. craticulatum.* (i) SEM picture of *Elphidium cf. craticulatum*, lateral view, scale = 0.1mm (Haig, 2001). (j) SEM picture of *Elphidium cf. craticulatum*, lateral view, scale = 0.1mm (Lobegeier, 2001). (k) SEM picture of *Elphidium cf. craticulatum*, peripheral view, scale = 0.1mm (Lobegeier, 2001).

Elphidium crispum (Linnaeus, 1754)



Elphidium reticulosum

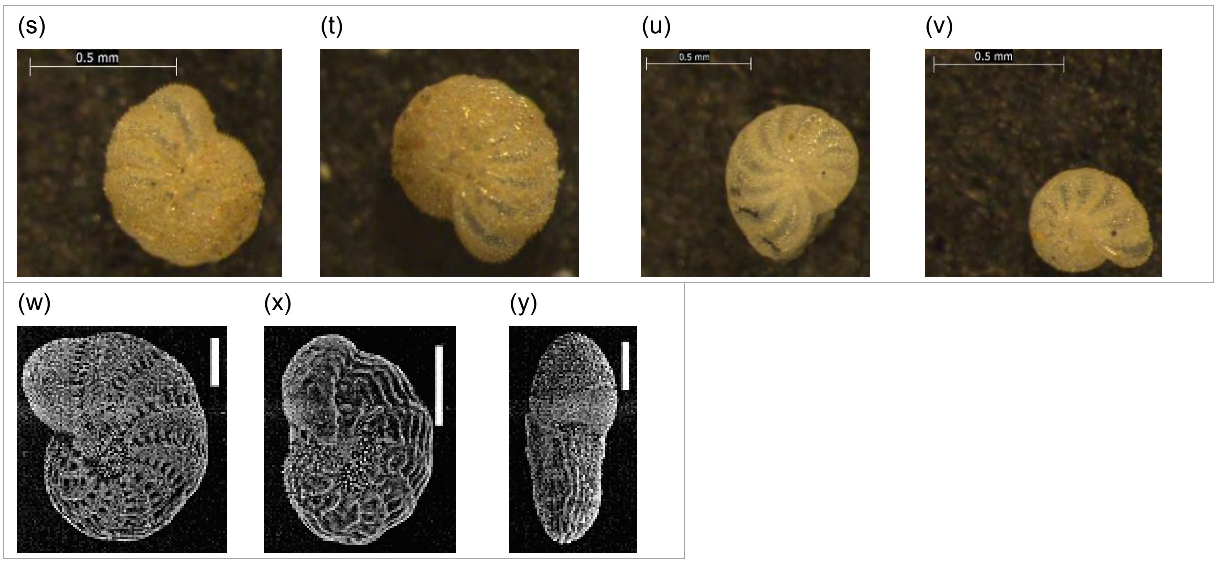


Figure 28 (continued): (l)-(o) Lateral view of *Elphidium crispum.* (p) SEM picture of *E. crispum*, lateral view, scale = 0.1mm (Haig, 2001). (q) SEM picture of *E. crispum*, lateral view, scale = 0.1mm (Lobegeier, 2001). (r) SEM picture of *E. crispum*, peripheral view, scale = 0.1mm (Lobegeier, 2001). (s)-(v) Lateral view of *E. reticulosum.* (w)-(x) SEM picture of *E. reticulosum*, lateral view, scale = 0.1mm (Lobegeier, 2001). (y) SEM picture of *E. reticulosum*, peripheral view, scale = 0.1mm (Lobegeier, 2001).

Eponididae

In initial stages Eponididae are trochospiral. The aperture extends from the umbilicus to the outer edge on the umbilical side and may be cribrate (Loeblich and Tappan, 1984).

Eponides cribrorepandus

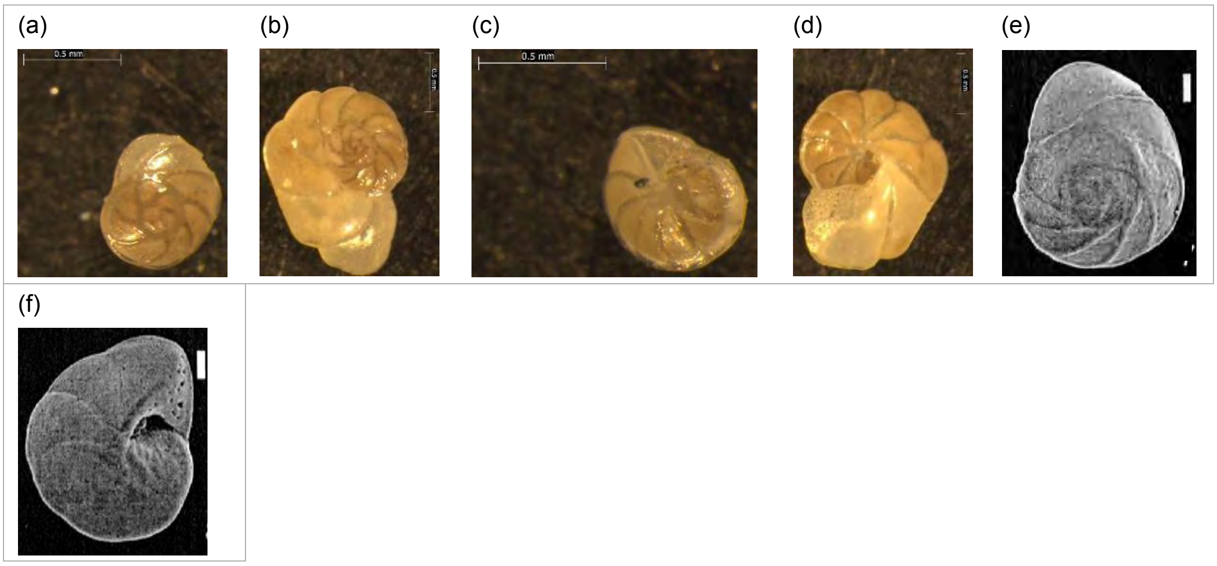


Figure 29: (a)-(b) *Eponides cribrorepandus*, spiral side. (c)-(d) *E. cribrorepandus*, umbilical side. (e) SEM picture of *E. cribrorepandus*, spiral side, scale = 0.1mm (Lobegeier, 2001). (f) SEM picture of *E. cribrorepandus*, umbilical side, scale = 0.1mm (Lobegeier, 2001).

Nummunlitidae

The planispiral test may be either involute or evolute, with the aperture forming an ached slit on the apertural face. They have a large number of chambers which can be subdivided into chamberlets. Internally, there is a complex canal system of septal, marginal and vertical canals (Loeblich and Tappan, 1984).

Heterostegina depressa (d'Orbigny, 1826)

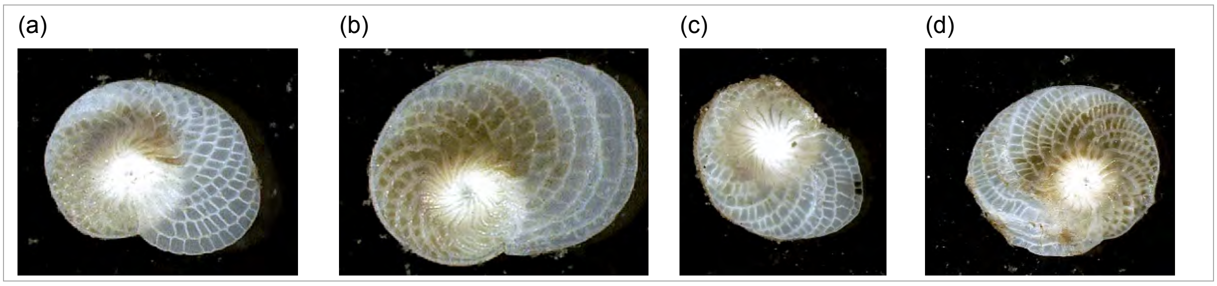


Figure 30: (a)-(d) Live *Heterostegina depressa*, lateral view, c. 1-3mm length.

Operculina ammonoides

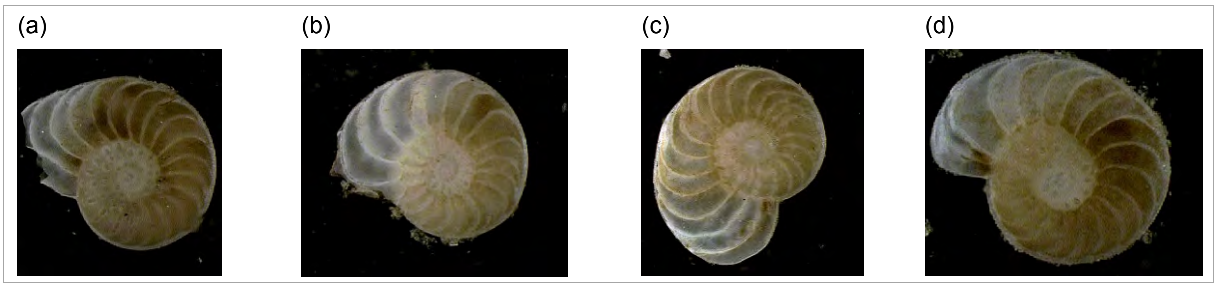


Figure 31: (a)-(d) Live *Operculina ammonoides*, lateral view, ca. 1-2mm length.

Planorbulinidae

Planorbulinidae begin trochospiral, to later form a discoid, cylindrical or conical test with single or multiple, peripheral apertures (Loeblich and Tappan, 1984).

Planorbulina acarvalis

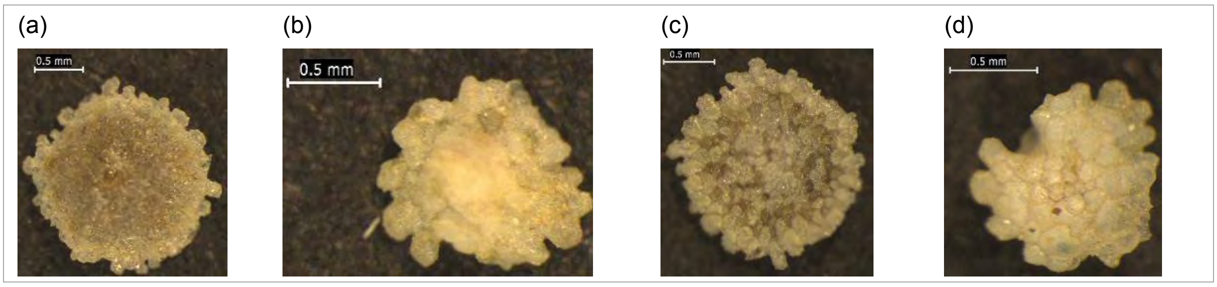


Figure 32: (a)-(b) *Planorbulina acarvalis*, dorsal side. (c)-(d) *P. acarvalis*, ventral side.

Reussellidae

The test begins triserial, to later become biserial or uniserial (Loeblich and Tappan, 1984).

Reussella sp.

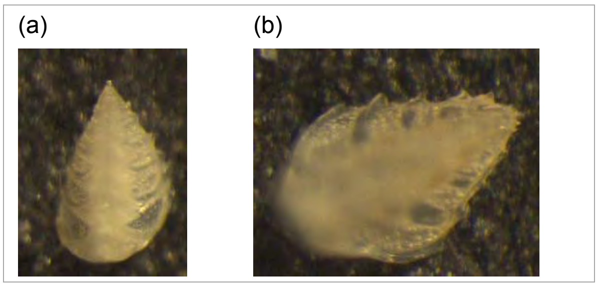


Figure 33: (a)-(b) Lateral view of *Reussella* sp., approximately 0.3mm length.

Rosalinidae

The test is trochospiral, with the aperture located at the base of the last chamber on the umbilical side (Loeblich and Tappan, 1984).

Rosalina bradyi (Crushman, 1915)

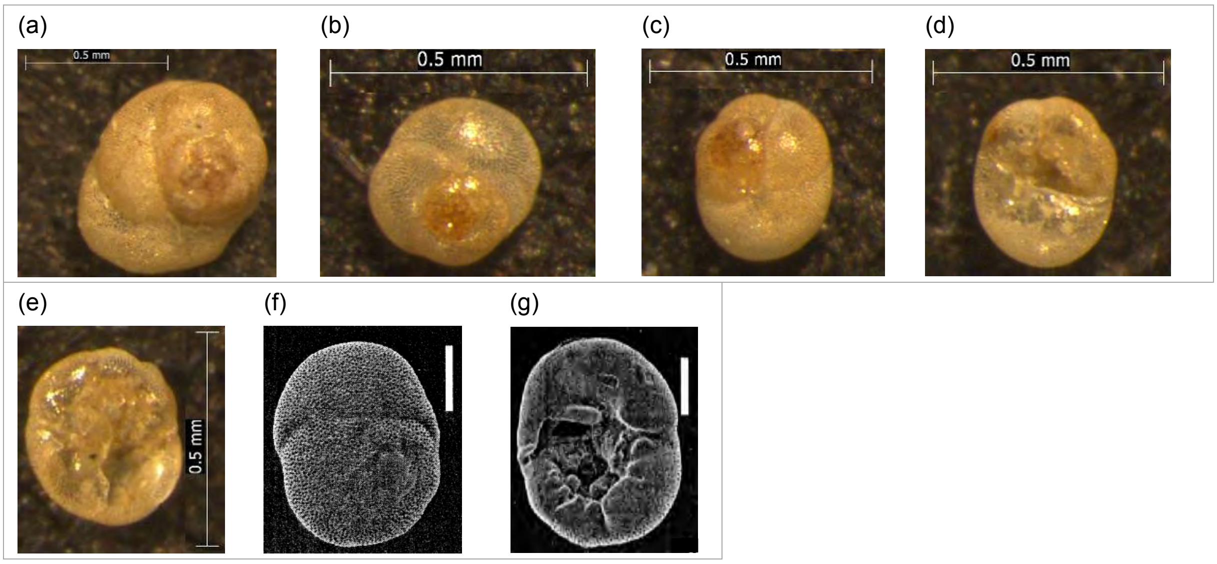
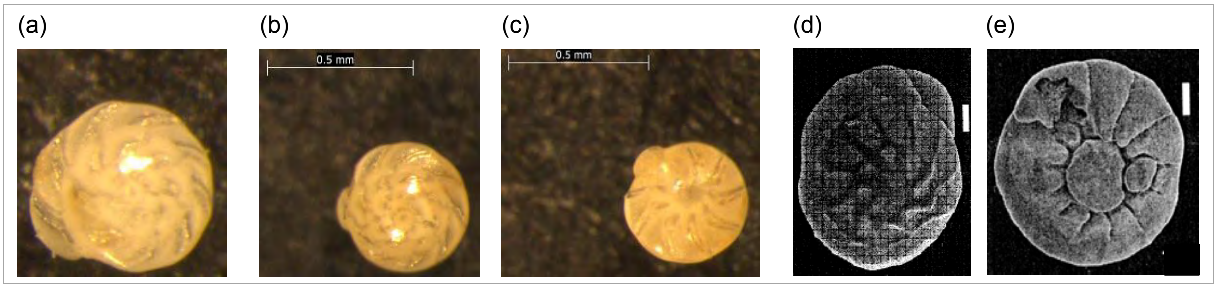


Figure 34: (a)-(c) Spiral side of *Rosalina bradyi*. (d)-(e) Umbilical side of *R. bradyi*. (f) SEM pictures of *R. bradyi*, spiral side, scale = 0.1mm (Lobegeier, 2001). (g) SEM pictures of *R. bradyi*, spiral side, scale = 0.1mm (Lobegeier, 2001). (i) SEM pictures of *R. bradyi*, umbilical side, scale = 0.1mm (Lobegeier, 2001).

Rotaliidae

The test is enrolled, with little difference between the spiral and umbilical sides. Can have large inflational spines (Loeblich and Tappan, 1984).

Ammonia convexa



Ammonia sp.

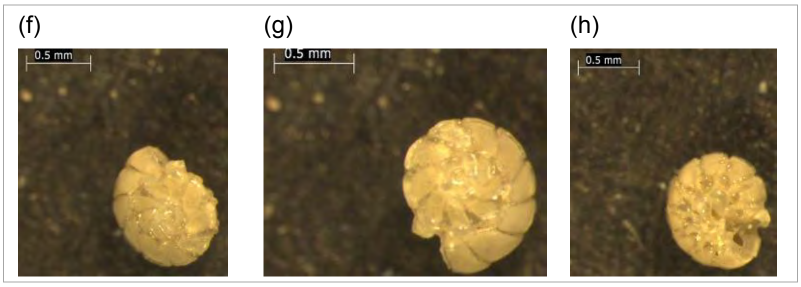
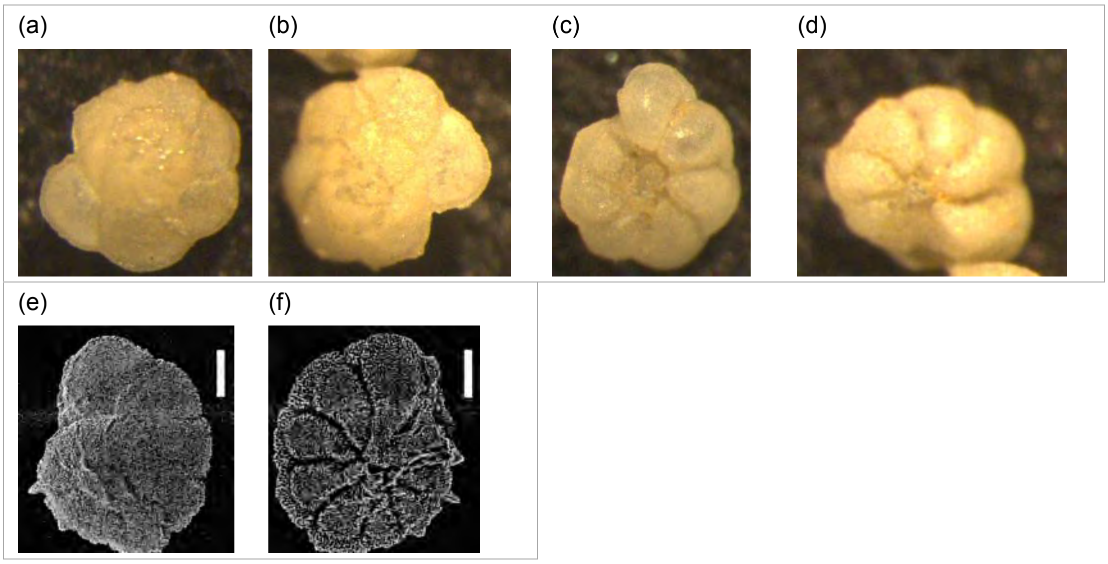


Figure 35: (a)-(b) Spiral side of *Ammonia convexa*. (c) Umbilical side of *A. convexa*. (d) SEM picture of *A. convexa*, spiral side, scale = 0.1mm (Lobegeier, 2001). (e) SEM picture of *A. convexa*, umbilical side, scale = 0.1mm (Lobegeier, 2001). (f)-(g) Spiral side of *Ammonia* sp. (h) Umbilical side of *Ammonia* sp.

Pararotalia sp.



Pararotalia venusta

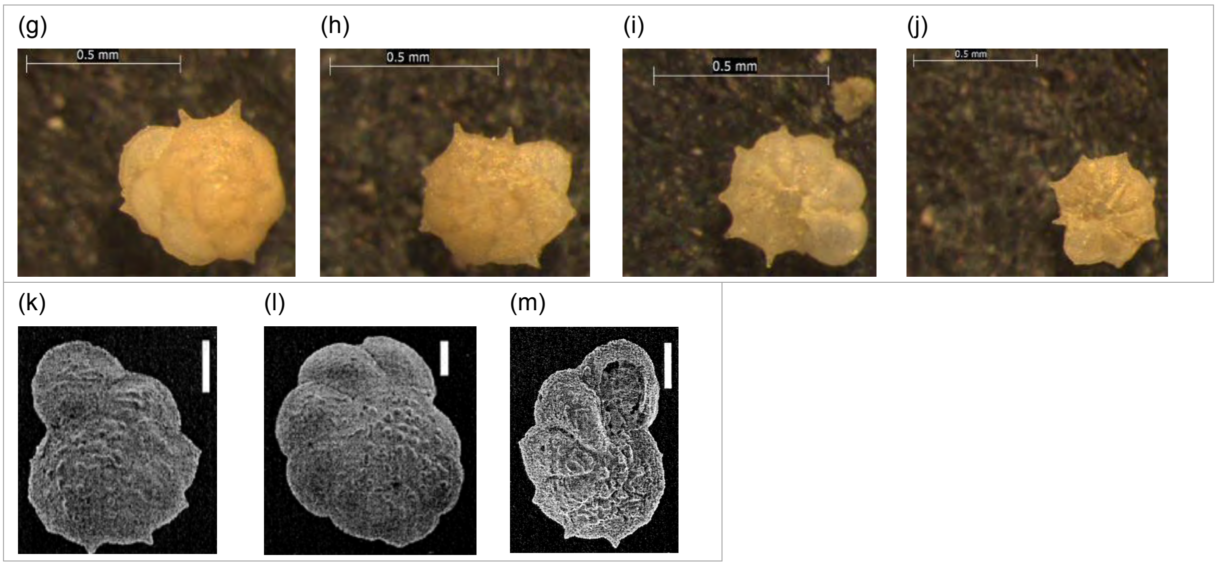


Figure 36: (a)-(b) *Pararotalia* sp., spiral side. (c)-(d) *Pararotalia* sp., umbilical side. (e) SEM picture of *Pararotalia* sp., spiral view, scale = 0.1mm (Lobegeier, 2001). (f) SEM picture of *Pararotalia* sp., umbilical view, scale = 0.1mm (Lobegeier, 2001). (g)-(h) *P. venusta*, spiral side. (i)-(j) *P. venusta*, umbilical side. (k)-(l) SEM picture of *P. venusta*, spiral view, scale = 0.1mm (Lobegeier, 2001). (m) SEM picture of *P. venusta*, umbilical view, scale = 0.1mm (Lobegeier, 2001).

Suborder: Textulariina

Textulariina have an agglutinated test.

Textulariidae

The wall is made of agglutinated material and maintains a canal system, with the test forming a biserial structure, which may become uniserial in later life stages. The aperture, which can consist of multiple openings, may be located in the suture between the most recently formed chambers or on the wall of the final chamber (Loeblich and Tappan, 1984).

Septotextularia sp.

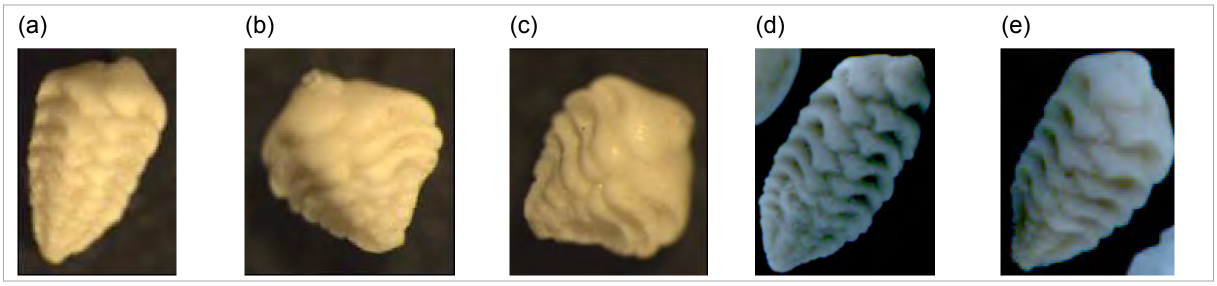


Figure 37: (a)-(e) Lateral view of *Septotextularia* sp., approximately 1.0mm length.

Siphoniferoides

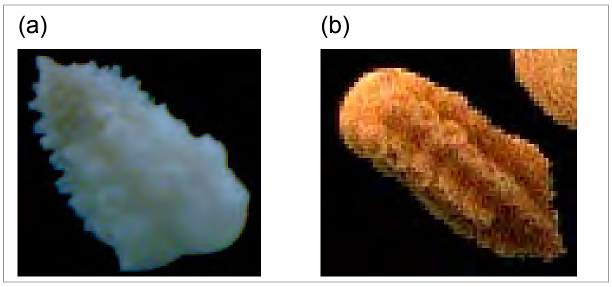


Figure 38: (a)-(b) Lateral view of S*iphoniferoides* sp., approximately 1.0mm length.

Textularia spp.

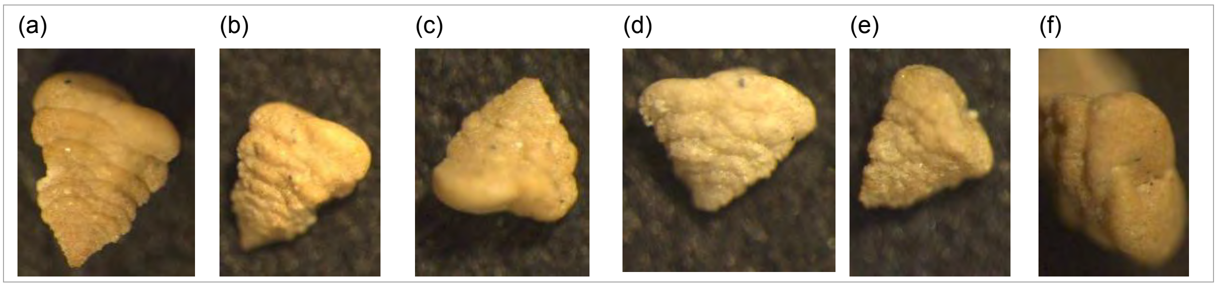


Figure 39: (a)-(e) Lateral view of *Textularia* spp., approximately 0.5mm length. (f) Top view of *Textularia* sp.

Valvulinidae

Valvulinidae have an agglutinated test which contains a canal system. Initially they are triserial, increasing the number of chambers in each whorl, or becoming uniserial in later stages. The aperture usually has a tooth or flap over the opening, but in some this may be present only in the early stages. Later on the aperture may multiply and is usually located on the wall of the last chamber, rather than where two chambers join (Loeblich and Tappan, 1984).

Clavulina pacifica

(a) (b)

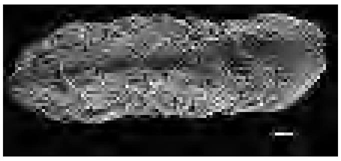


Figure 40: (a) Lateral view of *Clavulina pacifica*, approximately 1.0mm length. (b) SEM picture of *C. pacifica*, scale = 0.1mm (Haig, 2001).

Table 1: Benthic foraminiferal species listed in alphabetical order with information on the presence and absence of these species in four sectors of the Great Barrier Reef.

Based on samples analysed in 2006 and 2007, sectors are the Capricorn Bunker Group (**CB**, four locations investigated, a total of 2,380 foraminifera screened); the Whitsunday area (**WH**, seven locations, 4,315 foraminifera); Townsville sector (**TO**, seven locations, 5,194 foraminifera), Innisfail sector (**IN**, six locations, 4,582 foraminifera) and the Cairns sector. The foraminiferal taxa have also been placed into six taxonomic groups according to Hallock (see: http://www.marine.usf.edu/reefslab/foramcd/html_files/titlepage.htm)

Foraminifera species	Suborder	Family	Distribution	Taxonomic group
Alveolinella quoyi	Miliolina	Alveolinidae	CB	Symbiont bearing miliolid
Ammonia convexa	Rotaliina	Rotaliidae	CB, WH, TO, IN, CA	Opportunistic
Ammonia tepida	Rotaliina	Rotaliidae	CB, WH, TO, IN, CA	Opportunistic
Amphisorous sp.	Miliolina	Soritidae	*	Symbiont bearing miliolid
Amphistegina lessonii	Rotaliina	Amphisteginidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Amphistegina lobifera	Rotaliina	Amphisteginidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Amphistegina radiata	Rotaliina	Amphisteginidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Baculogypsina sphaerulata	Rotaliina	Calcarinidae	TO, IN, CA	Symbiont bearing rotaliid
Calcarina hispida	Rotaliina	Calcarinidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Calcarina mayorii	Rotaliina	Calcarinidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Calcarina spengleri	Rotaliina	Calcarinidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Cancris auriculus	Rotaliina	Baginidae	WH, TO	Smaller perforate taxa
Cibicides cf. refulgens	Rotaliina	Cibicididae	CB, WH, TO, IN, CA	Smaller perforate taxa
Clavulina pacifica	Textulariina	Valvulinidae	*	Agglutinated taxa
Cymbaloporetta bradyii	Rotaliina	Cymbaloporidae	CB, WH, TO, IN, CA	Smaller perforate taxa
Cymbaloporetta squammosa	Rotaliina	Cymbaloporidae	CB, WH, TO, IN, CA	Smaller perforate taxa
Discorbinella sp.	Rotaliina	Discorbinellidae	CB, WH, TO, IN	Smaller perforate taxa
Edentostomina cultrata	Miliolina	Ophthalmidiidae	*	Smaller miliolids
Elphidium cf craticulatum	Rotaliina	Elphidiidae	CB, WH, TO, IN, CA	Opportunistic
Elphidium crispum	Rotaliina	Elphidiidae	CB, WH, TO, IN, CA	Opportunistic

Foraminifera species	Suborder	Family	Distribution	Taxonomic group
Elphidium reticulosum	Rotaliina	Elphidiidae	WH, TO, IN	Opportunistic
Elphidium sp.	Rotaliina	Elphidiidae	*	Opportunistic
Epistomaroides polystomelloides	Rotaliina	Alfredinidae	CB, WH, TO, IN, CA	Smaller perforate taxa
Eponides cribrorepandus	Rotaliina	Eponididae	CB, WH, TO, IN, CA	Smaller perforate taxa
Hauerina circinata	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Hauerina fragilissima	Miliolina	Hauerinidae	CB, WH, TO, IN	Smaller miliolids
Hauerina pacifica	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Heterostegina depressa	Rotaliina	Nummunlitidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Marginopera vertebralis	Miliolina	Soritidae	WH, TO, IN	Symbiont bearing miliolid
Miliola earlandi	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Milliolinella circularis	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Miliolinella labiosa	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Neorotalia calcar	Rotaliina	Calcarinidae	WH, TO, IN	Symbiont bearing rotaliid
Operculina ammonoides	Rotaliina	Nummunlitidae	CB, WH, TO, IN, CA	Symbiont bearing rotaliid
Pararotalia sp.	Rotaliina	Rotaliidae	CB, WH, TO, IN	Opportunistic
Pararotalia venusta	Rotaliina	Rotaliidae	CB, WH, TO, IN, CA	Opportunistic
Parasorites (S.orb var marg)	Miliolina	Soritidae	WH, TO, IN	Symbiont bearing miliolid
Peneroplis antillarum	Miliolina	Peneroplidae	CB, WH, TO, IN, CA	Symbiont bearing miliolid
Peneroplis pertusus	Miliolina	Peneroplidae	CB, WH, TO, IN, CA	Symbiont bearing miliolid
Peneroplis planatus	Miliolina	Peneroplidae	CB, WH, TO, IN, CA	Symbiont bearing miliolid
Planispirinella exigua	Miliolina	Fischerinidae	WH, TO	Smaller miliolids
Planorbulina acervalis	Rotaliina	Planorbulinidae	WH, TO	Smaller perforate taxa
Pseudomassilina macilenta	Miliolina	Hauerinidae	CB, WH, TO, IN	Smaller miliolids
Pseudohauerina involuta	Miliolina	Hauerinidae	WH, TO, IN	Smaller miliolids
Pyrgo denticulata	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Pyrgo striolata	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids

Foraminifera species	Suborder	Family	Distribution	Taxonomic group
Quinqueloculina spp.	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Reussella sp.	Rotaliina	Reussellidae	CB, WH, TO, IN, CA	Smaller perforate taxa
Rosalina bradyi	Rotaliina	Rosalinidae	CB, WH, TO, IN, CA	Smaller perforate taxa
Rotorbis auberi	Rotaliina	Discorbidae	CB, WH, TO, IN, CA	Smaller perforate taxa
Septotextularia sp.	Textulariina	Textulariidae	*	Agglutinated taxa
Sigmohauerina involuta	Miliolina	Hauerinidae	*	Smaller miliolids
Sigmoidella elegantissima	Lagenina	Polymorphinidae	CB,TO	Smaller perforate taxa
Siphoniferoides sp.	Textulariina	Textulariidae	*	Agglutinated taxa
Sorites orbiculus	Miliolina	Soritidae	WH, TO, IN, CA	Symbiont bearing miliolid
Spiroloculina angulata	Miliolina	Spiroloculinidae	CB, WH, TO, IN, CA	Smaller miliolids
Spiroloculina corrugata	Miliolina	Spiroloculinidae	CB, WH, TO, IN, CA	Smaller miliolids
Spiroloculina foveolata	Miliolina	Spiroloculinidae	CB, WH, TO, IN, CA	Smaller miliolids
Spiroloculina rugosa	Miliolina	Spiroloculinidae	WH, TO, CA	Smaller miliolids
Textularia spp.	Textulariina	Textulariidae	WH, TO, IN	Agglutinated taxa
Triloculina barnardi	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Triloculina tricarinata	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Triloculina trigonula	Miliolina	Hauerinidae	CB, WH, TO, IN, CA	Smaller miliolids
Vertebralina striata	Miliolina	Fischerinidae	CB, WH, TO, IN, CA	Smaller miliolids

* Species were not found in the 2006 and 2007 samples, but have been identified in other samples collected on the Great Barrier Reef.

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Further information

Marine and Tropical Sciences Research Facility
PO Box 1762
CAIRNS QLD 4870

or

Marine and Tropical Sciences Research Facility
PO Box 772
TOWNSVILLE QLD 4810

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