IDENTIFICATION KEY FOR HOLOCENE LACUSTRINE ARCELLACEAN (THECAMOEBIAN) TAXA

Arun Kumar and Andrew P. Dalby

ABSTRACT

Arcellaceans (thecamoebians), predominantly freshwater protozoans, have been studied for over a century. However, in the last ten years their usefulness as paleoenvironmental indicators has become better understood because researchers have recognized that certain morphotypes (strains) prefer distinct microenvironments. Unfortunately, the monoclonal nature and simle morphorphology of the group has led to considerable taxonomic confusion, threatening their utility in paleolimnological research. This key was created to help new researchers studying the group, and to standardize the taxonomy.

Arun Kumar and Andrew P. Dalby, Ottawa-Carleton Geoscience Centre, Department of Earth Sciences, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, CANADA K1S 5B6

KEY WORDS: thecamoebian(s), arcellacean(s) Holocene, indentification key

Submission: 10 November, 1997
Acceptance: 7 January, 1998

INTRODUCTION

Arcellaceans (thecamoebians) are clonal, predominantly freshwater protozoans, although they can also occur in brackish water environments and moist soils (Medioli and Scott 1983). They can be found in a wide range of geographic settings, ranging from tropical to arctic latitudes (Nair and Mukherjee 1968; Green 1975; Dallimore et al. 1997). These organisms have an amoebid sarcodine cell with pseudopods and a simple sac-like test, either flattened or rounded with an aperture located on or near the tapered end, or a beret-shaped test with an invaginated aperture on the ventral side which is more or less flattened. A substantial amount of morphological variability has been observed among these two broad groups.

A few forms like *Lagenodifflugia* and *Pontigulasia* appear to have a second chamber consisting of an enlarged collar separated from the rest of the test by a distinct constriction (Medioli and Scott 1988; Medioli et al. 1990). Tests are either secreted (autogenous), or agglutinated (xenogenous) with sand particles or diatom frustules (xenosomes) in autogenous cement. Autogenous tests are usually smooth, proteinaceous, sometimes made of siliceous platelets (idiosomes), or rarely calcareous. (See Medioli et al. 1990, for a review of fossil arcellaceans).

Arcellacean tests do not demonstrate a high degree of morphological diversity, but important taxonomic characteristics include (Asioli et al. 1996): presence or absence of spines; nature and shape of xenosomes and idiosomes; shape and composition of tests; and morphological

features associated with the apertures, such as diaphragms, collars, lobes, and teeth.

Test size can vary between 50 to 300 um or even greater, thus it is of no taxonomic importance as it is determined at the time of fission by the volume of cytoplasm available in the parent test (Medioli and Scott 1983). Cytoplasmic volume is in turn probably controlled by the availability of food in the period preceeding reproduction (Medioli et al. 1990).

It has long been known that various arcellacean species preferentially inhabit specific environments. Rcent research has determined that some infrasubspecific variants (strains) are particularly sensitive to environmental variations (Asioli et al. 1996; Patterson et al. 1996; Reinhardt et al. 1997). In particular, arcellaceans have proven to be useful tools in assessing remediation rates within industrially polluted settings (Asioli et al. 1996; Patterson et al. 1996; Reinhardt et al. 1997).

Unfortunately, the subtle criteria used to differentiate the rather simple arcellacean morphologies, and confusion over the proliferation of taxonomic names during the last hundred years has limited their utility (Medioli and Scott 1983). In this paper, we present a taxonomic key designed to:

1. illustrate the various morphologies that we find useful in paleolimnological research and;
2. provide an arcellacean identification guide for future researchers engaged in paleolimnological research.

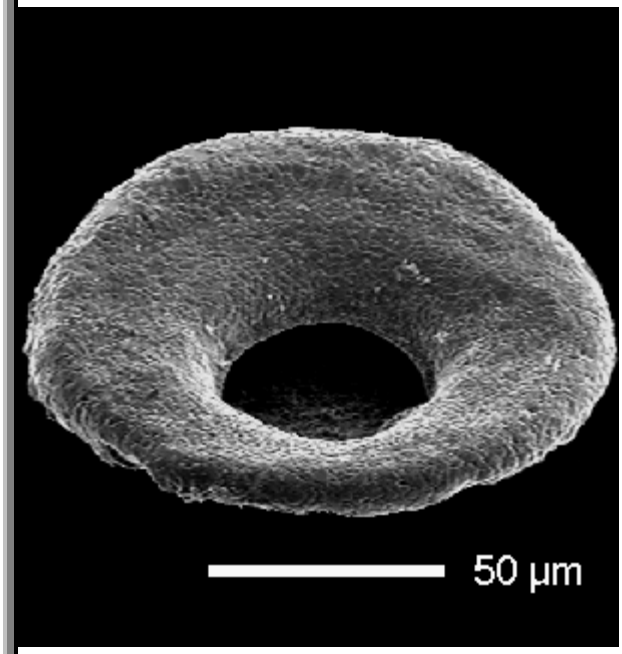
Taxa illustrated in this key are from Crosswise and Peterson lakes, near Cobalt, Ontario; Swan Lake, north of Toronto, Ontario; Lake Erie, Ontario; and Lake Orta, northern Italy. Exact sample locations are provided with individual illustrations.

Key Position: 1	
1a. Test circular, hemispherical to ovoid; made of proteinaceous matter and agglutinated grains. **Proceed to 2**	**1b.** Test ovoid, pyriform, elongate to acuminate; made of agglutinated mineral grains or diatom frustules. **Proceed to 7**

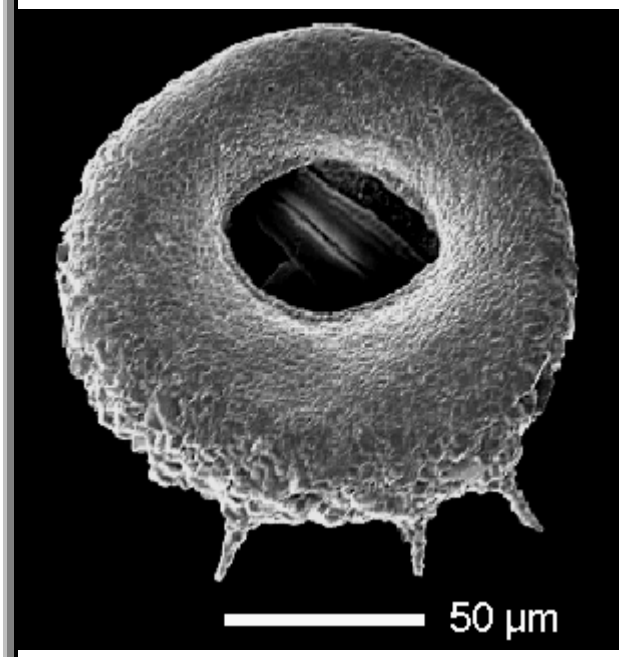
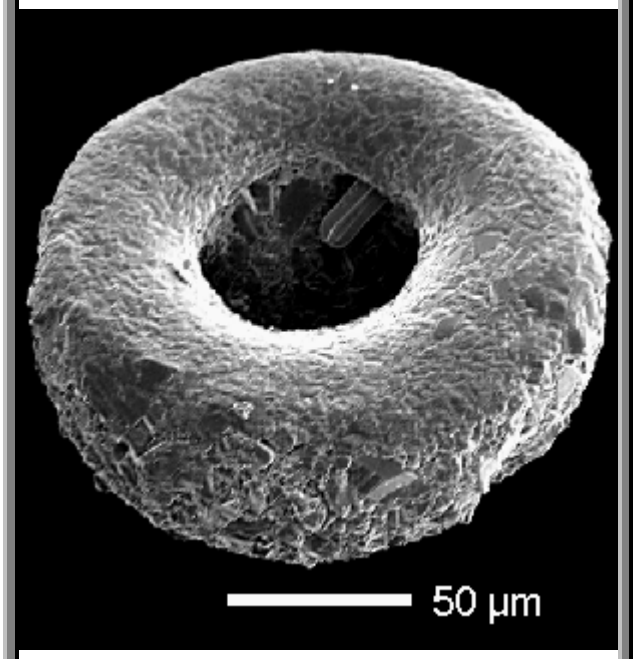
Key Position: 2	Back to (1a)
2 a. Test circular in dorso-ventral view, plano-convex to hemispherical in lateral view, made of proteinaceous matter, surface smooth or punctate; aperture central, large and circular. **SEE Figure 2-1**	**2 b.** Test with or without spines, agglutinated with mineral grains, aperture sub-terminal or occasionally central, circular or oval, invaginated. **Proceed to 3**

FIGURE 2-1

***Arcella vulgaris* Ehrenberg 1830**
Arcella vulgaris EHRENBERG 1830, p. 40, pl. 1, fig. 6
Arcella vulgaris Ehrenberg REINHARDT et al. 1997, pl. 1, fig. 3
Remarks: Distinguished from *Centropyxis aculeata* "discoides" by having no agglutinated particles whatsoever, thus the test is hyaline and transparent. Specimen from Crosswise Lake, near Cobalt, Ontario.



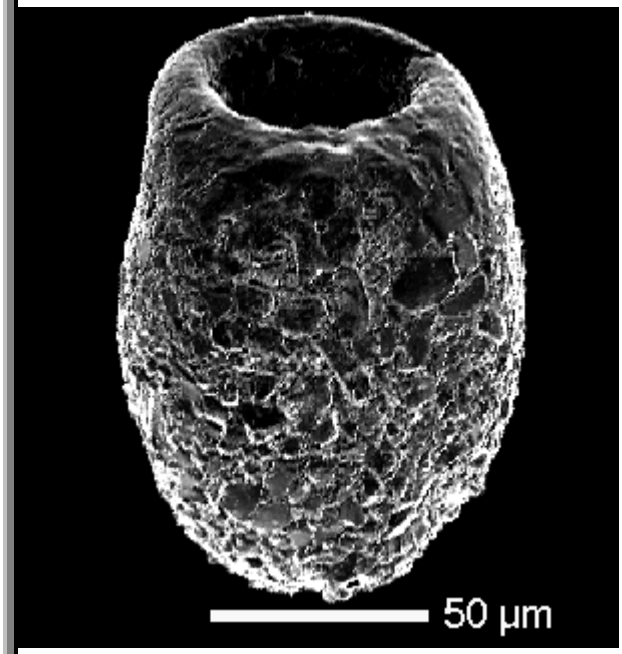
Key Position: 3	**Back to (2b)**
3a. Test ventrally depressed, almost circular dorso-ventrally, anterior angle varies between 15-40 degrees, posterior slope ill-defined or practically absent. Height/length ratio is low (0.4 - 0.5). **Proceed to 4**	**3b.** Test less depressed on ventral side than in 3a, elliptical in dorsal view. Anterior angle varies between 45-60 degrees and posterior angle well defined. Height/length ratio high (0.5 - 1.1). **Proceed to 5**

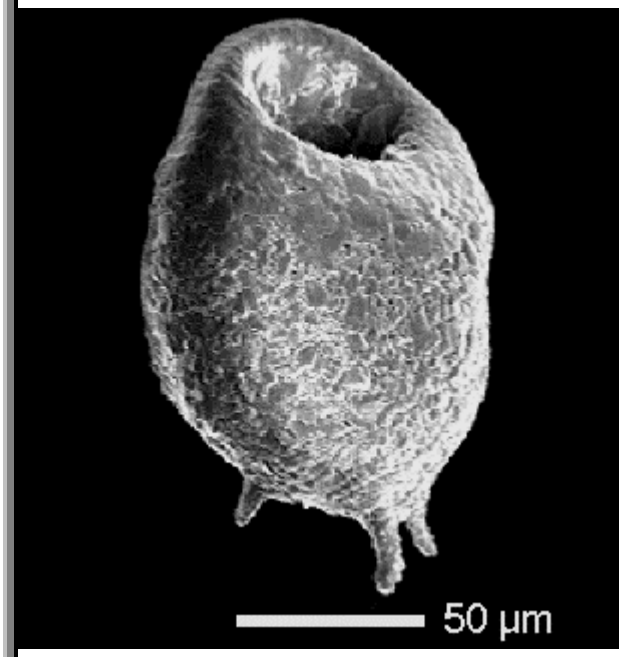
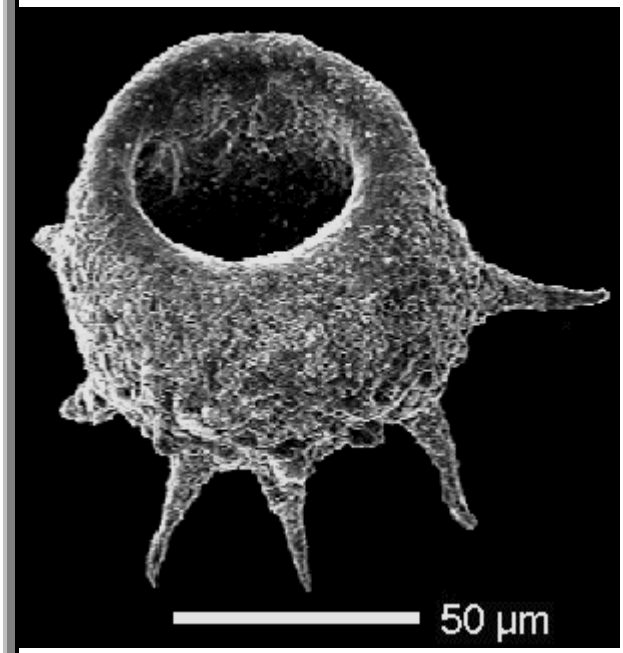
Key Position: 4	**Back to (3a)**
4 a. Test with 1 to 8 spines on postero-lateral margin. **SEE Figure 4 -1**	**4 b.** Test "doughnut" shaped, without spines. **SEE Figure 4 -2**
FIGURE 4 -1 ***Centropyxis aculeata* Ehrenberg 1832 "aculeata"** *Arcella aculeata* EHRENBERG 1832, p. 91 *Arcella aculeata* "aculeata" REINHARDT et al. 1997, pl. 1, fig. 1 Remarks: Distinguished from *Centropyxis aculeata* "discoides" by having spines. It should be noted that on some specimens these spines have broken off, but the stubs at the bases of the spines remain. Specimen from Crosswise Lake, near Cobalt, Ontario.  	**FIGURE 4 -2** ***Centropyxis aculeata* Ehrenberg 1832 "discoides"** *Arcella discoides* EHRENBERG 1843, p. 139 *Arcella discoides* Ehrenberg, EHRENBERG 1872, p. 259, pl. 3, fig. 1 *Arcella discoides* Ehrenberg, LEIDY 1879, p. 173, pl. 28, figs. 14-38 *Centropyxis aculeata* var.*discoides* PENARD 1890, p. 150, pl. 5, figs. 38-41 *Centropyxis discoides* Penard [sic], OGDEN and HEDLEY 1980, p. 54, pl. 16, figs. a-e *Centropyxis aculeata* "discoides" REINHARDT et al. 1997, pl. 1, fig. 2 Specimen from Crosswise Lake, near Cobalt, Ontario. 

Key Position: 5	Back to (3b)
5 a. Apertural lip thickened and at an angle of 45-60 degrees with respect to the test; spines absent. **SEE Figure 5-1**	**5 b.** Apertural lip thickened and at an angle of 45-60 degrees with respect to the test; spines present. **Proceed to 6**

FIGURE 5-1

***Centropyxis constricta* (Ehrenberg 1843) "aerophila"**
Centropyxis aerophila DEFLANDRE 1929
Centropyxis aerophila Deflandre OGDEN and HEDLEY 1980, p. 48-49
Cucurbitella [sic.] *constricta* REINHARDT et al. 1997, pl. 1, fig. 6
Specimen from Peterson Lake, near Cobalt, Ontario.



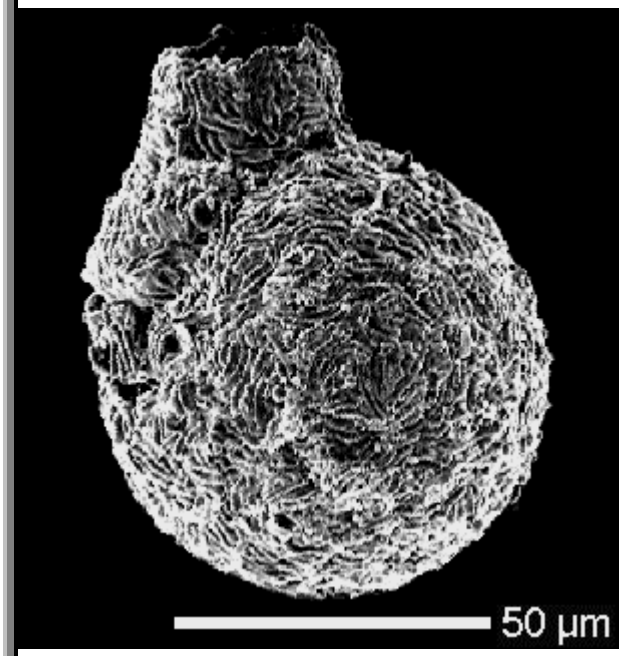
Key Position: 6	Back to (5b)
6 a. Test less flattened than 6b with generally 3 or less spines on fundus, but may have more. **SEE Figure 6 -1**	**6 b.** Test more flattened than 6a with 4 or more spines on fundus. **SEE Figure 6 -2**
FIGURE 6 -1 ***Centropyxis constricta* (Ehrenberg 1843) "constricta"** *Arcella constricta* EHRENBERG 1843, p. 410, pl. 4, fig. 35, pl. 5, fig. 1 *Centropyxis constricta* "constricta" REINHARDT et al. 1997, pl. 1, fig. 4 Specimen from Crosswise Lake, near Cobalt, Ontario.  	**FIGURE 6 -2** ***Centropyxis constricta* (Ehrenberg 1843) "spinosa"** *Centropyxis spinosa* CASH in CASH and HOPKINSON 1905, p. 135, text figs. 26 a-c, pl. 16, fig. 15 *Centropyxis spinosa* Cash, OGDEN and HEDLEY 1980, p. 62, pl. 20, figs. a-d *Centropyxis constricta* "spinosa" REINHARDT et al. 1997, pl. 1, fig. 5 Specimen from Peterson Lake, near Cobalt, Ontario. 

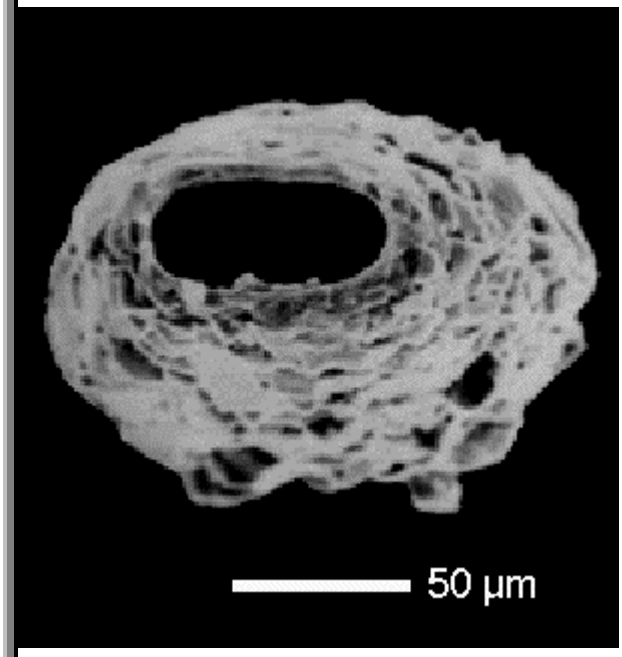
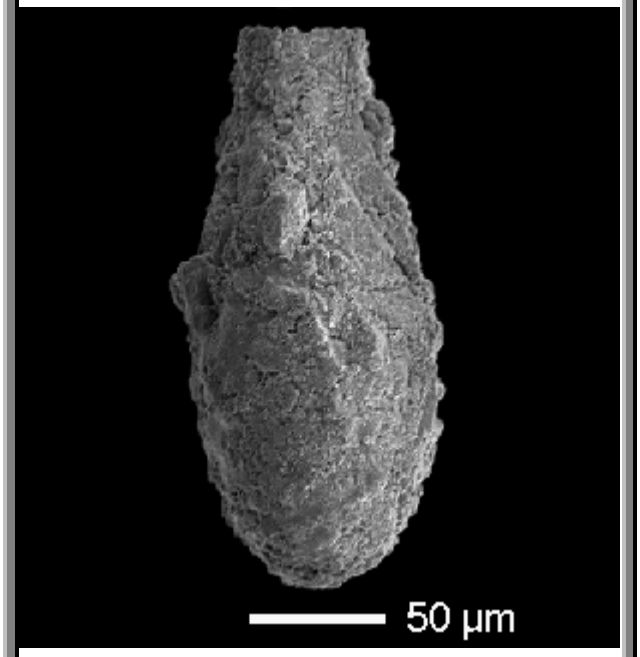
Key Position: 7	**Back to (1b)**
7 a. Test globular and somewhat laterally compressed; aperture terminal, oval, linear or circular. **Proceed to 8**	**7 b.** Test pyriform, acuminate or ovoid, aperture terminal, circular or lobed. **Proceed to 10**

Key Position: 8	Back to (7a)
8 a. Test comprised of curved siliceous rods, with neck. **SEE Figure 8-1**	**8 b.** Test made of siliceous plates, without neck. **Proceed to 9**

FIGURE 8-1

***Lesquereusia spiralis* (Ehrenberg 1840)**
Difflugia spiralis EHRENBERG 1840, p. 199
Difflugia spiralis Ehrenberg EHRENBERG 1872, p. 274, pl. 3, figs. 25-27 *Lesquereusia spiralis* (Ehrenberg) PATTERSON, MacKINNON, SCOTT, and MEDIOLI 1985, p. 135, pl. 2, figs. 9, 12
Lesquereusia spiralis (Ehrenberg) REINHARDT et al. 1997, pl. 1, fig. 9
Specimen from Peterson Lake, near Cobalt, Ontario.

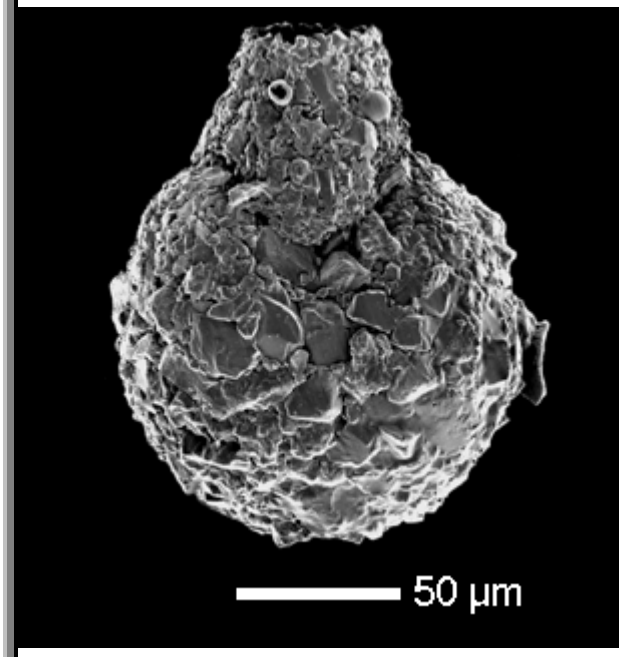


Key Position: 9	Back to (8b)
9 a. Aperture elliptical without collar. **SEE Figure 9 -1**	**9 b.** Aperture oval with thin collar. **SEE Figure 9 -2.**
FIGURE 9 -1 ***Heliopera sphagni* (Leidy 1874)** *Difflugia sphagni* LEIDY 1874, p. 157 *Heliopera sphagni* (Leidy) MEDIOLI and SCOTT 1983, p. 37-38, pl. 6, figs. 15-18 Specimen from Lake Erie, Ontario.  	**FIGURE 9 -2** ***Nebella collaris* Ehrenberg 1848** *Nebella collaris* Ehrenberg OGDEN and HEDLEY 1980, p. 94-95 Specimen from Crosswise Lake, near Cobalt, Ontario. 

Key Position: 10	Back to (7b)
10 a. Test with a distinct constriction at the base of the neck. **SEE Figure 10-1 .**	**10 b.** Test without constriction at the base of the neck. **Proceed to 11**

FIGURE 10-1

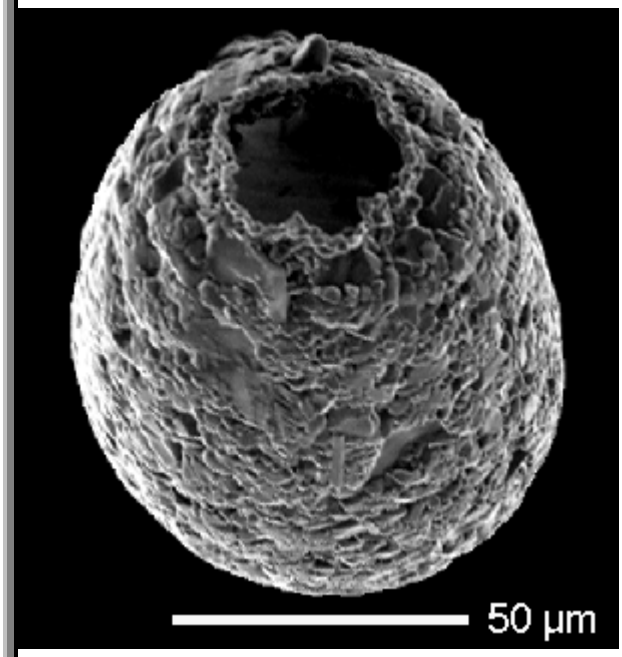
***Pontigulasia compressa* (Carter 1864)**
Difflugia compressa CARTER, p. 22, pl. 1, figs. 5-6
Pontigulasia compressa (Carter) MEDIOLI and SCOTT 1983, p. 35-36, pl. 6, figs. 5-14
Specimen from Swan Lake, north of Toronto, Ontario.



Key Position: 11	Back to (10b)
11 a. Aperture lip thin, crenulated, terminal, circular, surrounded by a 3- or 4-lobed collar. **SEE Figure 11-1**	**11 b.** Aperture terminal, circular or lobed. **Proceed to 12**

FIGURE 11-1

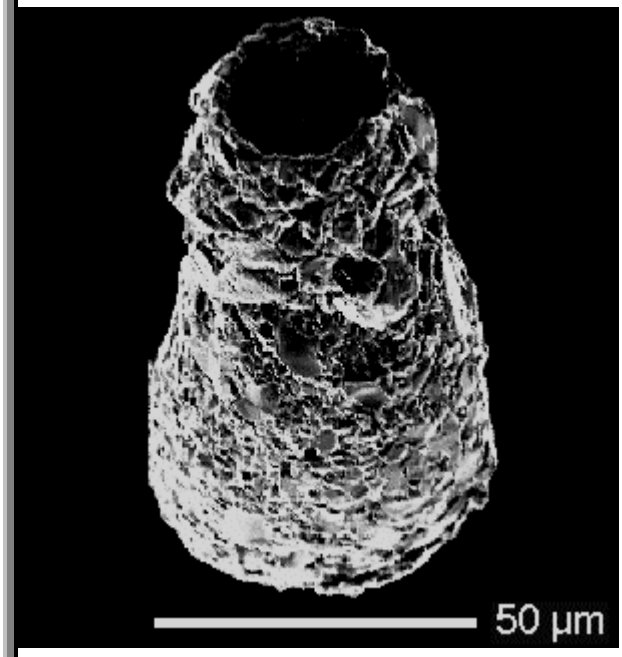
***Cucurbitella tricuspis* (Carter 1856)**
Difflugia tricuspis CARTER 1856, p. 221, fig. 80
Cucurbitella tricuspis (Carter) MEDIOLI, SCOTT, and ABBOTT, 1987, p. 42, pls. 1-4, text figs. 1, 4
Cucurbitella tricuspis (Carter) REINHARDT et al. 1997, pl. 1, fig. 7
Remarks: This species has a seasonally controlled irregularly shaped test, being larger and spherical during the benthic phase, and smaller and vase-shaped during the planktic phase. The crenulated aperture has a variable number of teeth ranging from three to twenty, depending on the number of teeth on the parent test (Medioli, personal commun., 1996).
Specimen from Peterson Lake, near Cobalt, Ontario.



Key Position: 12	Back to (11b)
12 a. Test elongated, pyriform, fundus bulbous and wide, with distinct tapering neck with a prominent constriction at its base. **SEE Figure 12-1**	**12 b.** Test ovoid, pyriform or acuminate, constriction at the base of the neck may or may not be present. **Proceed to 13**

FIGURE 12-1

***Lagenodifflugia vas* (Leidy 1874)**
Difflugia vas LEIDY 1874, p. 155
Lagenodifflugia vas (Leidy) MEDIOLI and SCOTT 1983, p. 33, pl. 2, figs. 18-23, 27, 28
Lagenodifflugia vas (Leidy) REINHARDT et al. 1997, pl. 1, fig. 8
Specimen from Peterson Lake, near Cobalt, Ontario.

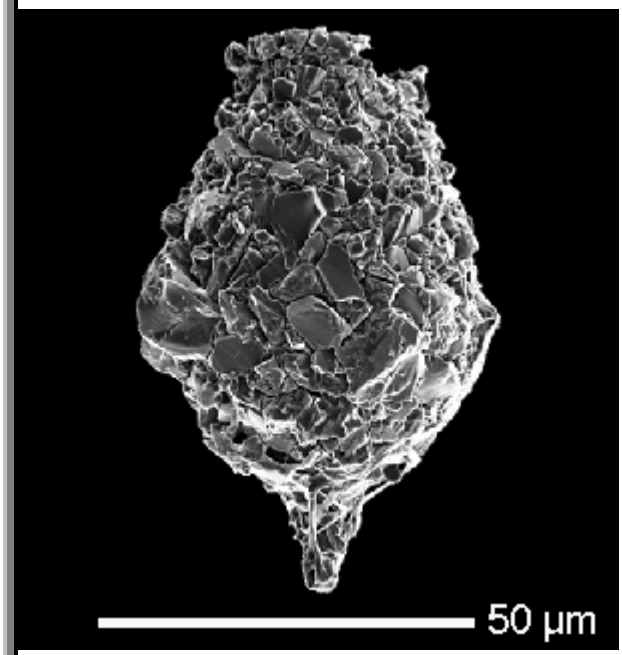


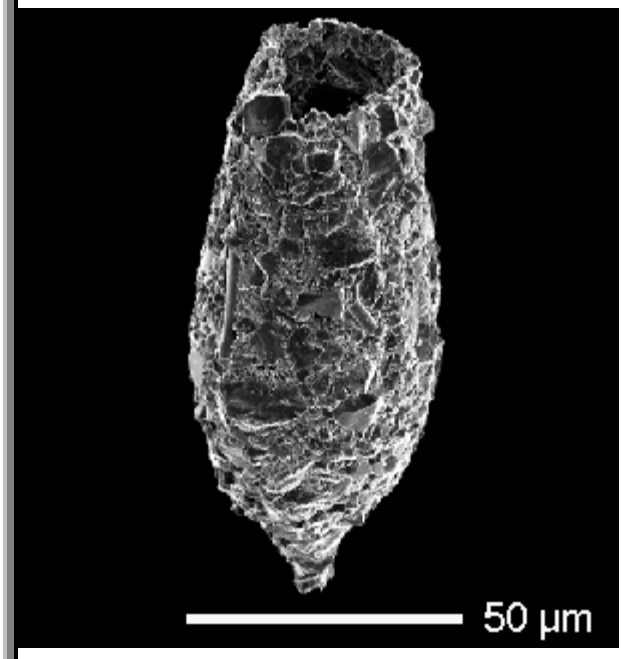
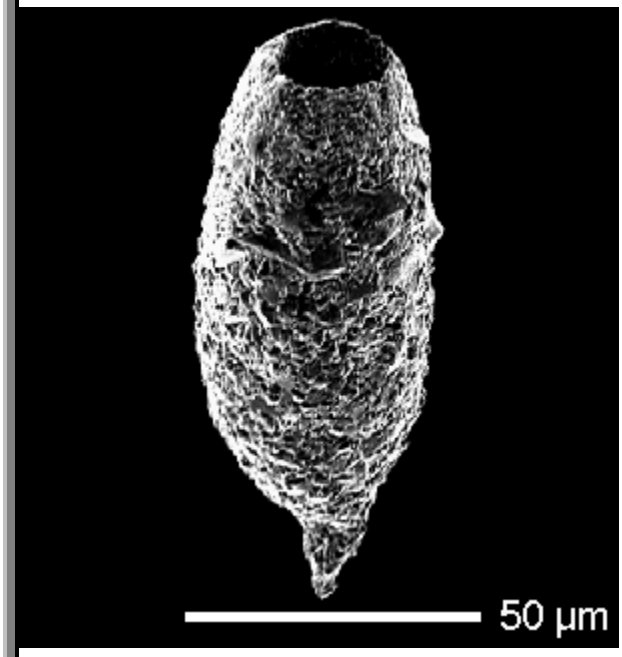
Key Position: 13	**Back to (12b)**
13 a. Test elongated, fundus tapering, acuminate with one or more spines. **Proceed to 14**	**13 b.** Test subspherical, ovoidal with or without spines. **Proceed to 16**

Key Position: 14	Back to (13a)
14 a. Test almost biconical, narrowing towards aperture, widest at fundus with one or more spines. **SEE Figure 14-1**	**14 b.** Test subcylindrical, fundus with single spine. **Proceed to 15**

FIGURE 14-1

***Difflugia protaeiformis* Lamarck 1816 "amphoralis"**
Difflugia protaeiformis LAMARCK 1816, p. 95
Difflugia amphoralis HOPKINSON in CASH and HOPKINSON 1909, p. 43, pl. 21, fig. 13
Difflugia protaeiformis "amphoralis" REINHARDT et al. 1997, pl. 2, fig. 4
Remarks: Distinguished from *Difflugia protaeiformis* "claviformis" and *Difflugia protaeiformis* "acuminata" by having a prominent widening of the fundus at the aboral end.
Specimen from Peterson Lake, near Cobalt, Ontario.

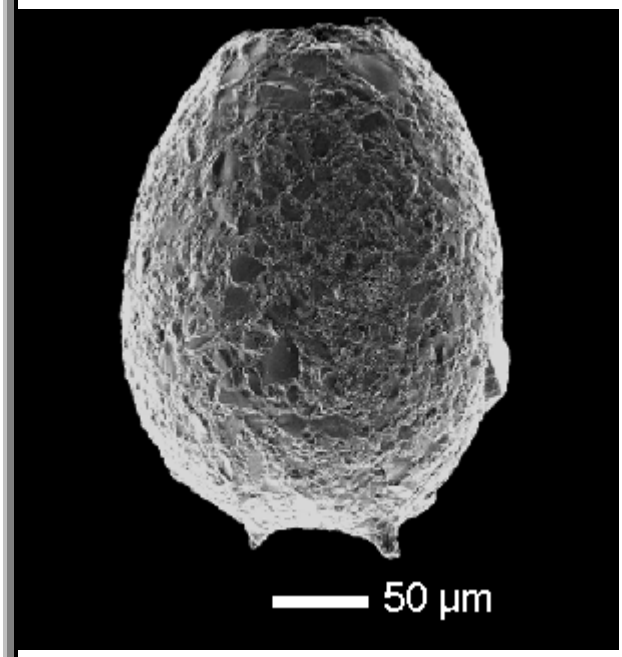


Key Position: 15	Back to (14b)
15 a. Test made from coarse grains, opaque. **SEE Figure 15 -1**	**15 b.** Test agglutinated with silt or fine sand-sized xenosomes, hyaline; may have a slight constriction in the anterior part. **SEE Figure 15 -2**
FIGURE 15 -1 ***Difflugia protaeiformis* Lamarck 1816 "claviformis"** *Difflugia protaeiformis* LAMARCK 1816, p. 95 *Difflugia pyriformis* var. *claviformis* PENARD 1899, p. 25, pl. 2, figs. 12-14 *Difflugia claviformis* OGDEN and HEDLEY 1980, p. 126, pl. 52, figs. a-d *Difflugia proteiformis* "proteiformis" [sic.] ASIOLI et al. 1996, p. 250, pl. 2, fig. 1 a-b *Difflugia protaeiformis* "claviformis" REINHARDT et al. 1997, pl. 2, fig. 3 Remarks: Distinguished from *Difflugia protaeiformis* "acuminata" by having a thicker wall, which appears opaque under a light microscope. Specimen from Peterson Lake, near Cobalt, Ontario.  	**FIGURE 15 -2** ***Difflugia protaeiformis* Lamarck 1816 "acuminata"** *Difflugia protaeiformis* LAMARCK 1816, p. 95 *Difflugia acuminata* EHRENBERG 1830, p. 95 *Difflugia acuminata* Ehrenberg 1830, OGDEN and HEDLEY 1980, p. 118, pl. 4, figs. a-c *Difflugia acuminata* Ehrenberg 1830, SCOTT and MEDIOLI 1983, p. 818, fig. 9d *Difflugia protaeiformis* "acuminata" REINHARDT et al. 1997, pl. 2, fig. 5 Remarks: Distinguished from *Difflugia protaeiformis* "claviformis" by having a thinner wall which appears transparent under a light microscope. Specimen from Crosswise Lake, near Cobalt, Ontario. 

Key Position: 16	Back to (13b)
16 a. Test laterally compressed with 2 to 3 short spines. **SEE Figure 16-1**	19 b. Test not compressed laterally. **Proceed to 17**

FIGURE 16-1

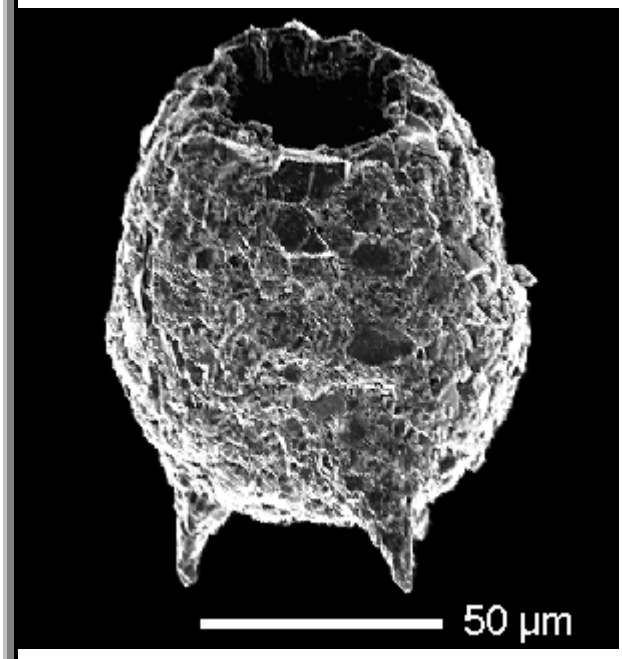
***Difflugia bidens* Penard 1902**
Difflugia bidens PENARD 1902, p. 264, figs. 1-8
Difflugia bidens Penard MEDIOLI and SCOTT 1983, p. 21-22, pl. 1, figs. 1-5
Specimen from Swan Lake, north of Toronto, Ontario.



Key Position: 17	Back to (16b)
17 a. Fundus with 1 to 10 short spines; aperture circular, crenulated by 6 to 20 indentations forming thin collar. **SEE Figure 17-1**	**17 b.** Fundus without spines; aperture without crenulations. **Proceed to 18**

FIGURE 17-1

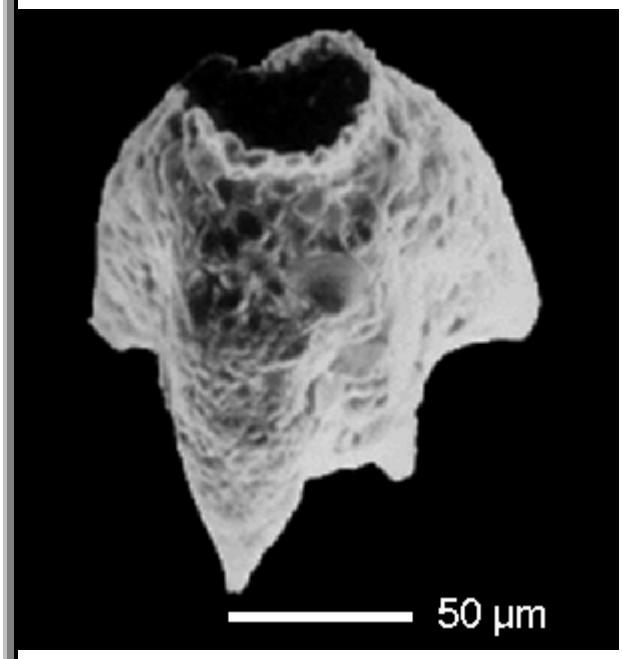
***Difflugia corona* Wallich 1864**
Difflugia protaeiformis (sic) Ehrenberg subsp. *D. globularis* (Dujardin) var. *D. corona* WALLICH 1864, p. 244, pl. 15, fig. 4a-c, pl. 16, figs. 19, 20
Difflugia corona Wallich 1864 ARCHER 1866, p. 186
Difflugia corona Wallich REINHARDT et al. 1997, pl. 2, fig. 1
Specimen from Peterson Lake, near Cobalt, Ontario.



Key Position: 18	Back to (17b)
18 a. Test with 1 to 8 large ribs running from middle of the test to the fundus and may extend to form blunt spines or tubercles. **SEE Figure 18-1**	**18 b.** Test without large ribs. **Proceed to 19**

FIGURE 18-1

***Difflugia fragosa* Hempel 1898**
Difflugia fragosa HEMPEL 1898, p. 320, figs. 1-2
Difflugia fragosa Hempel MEDIOLI and SCOTT 1983, p. 22-24, pl. 1, figs. 21-27
Specimen from Lake Erie, Ontario.

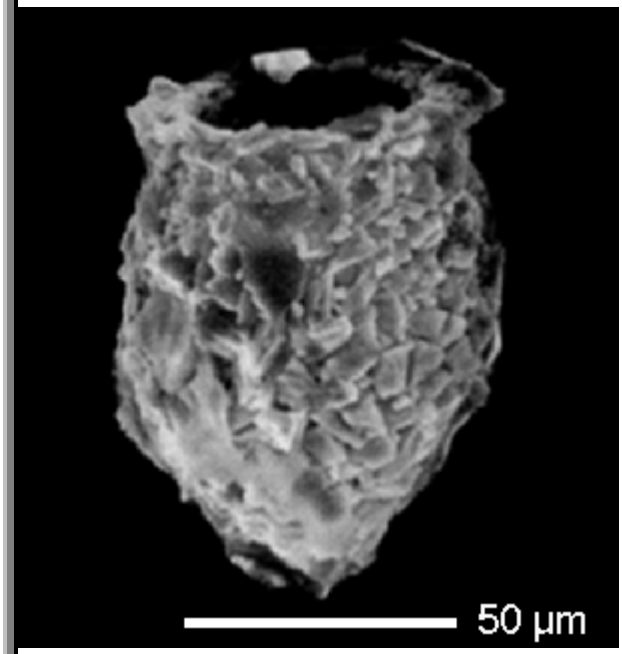


Key Position: 19	Back to (18b)
19 a. Test amphora- or cauldron-shaped, aperture circular with distinct collar. **Proceed to 20**	**19 b.** Test flask-shaped, sphaeroidal to ellipsoidal, aperture circular to subcircular without collar. **Proceed to 23**

Key Position: 20	Back to (19a)
20 a. Test broader than long, fundus conical, a constriction forms a broad collar under the wide aperture. **SEE Figure 20-1**	**20 b.** Test spheroidal, fundus rounded to acuminate, short neck attached to recurved or straight collar. **Proceed to 21**

FIGURE 20-1

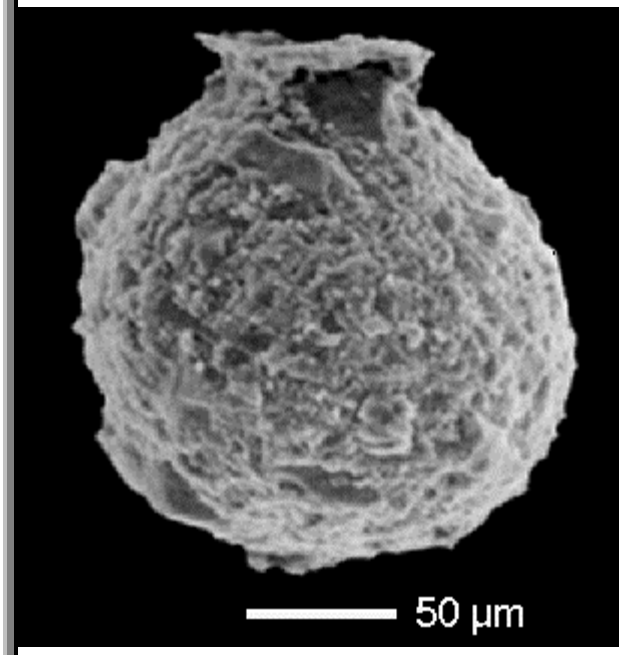
***Difflugia bacillaliarum* Perty 1849**
Difflugia bacillaliarum PERTY 1849, p. 27
Difflugia bacillaliarum Perty MEDIOLI and SCOTT 1983, p. 20-21, pl. 5, figs. 16-19, pl. 6, figs. 1-4
Specimen from Lake Erie, Ontario.

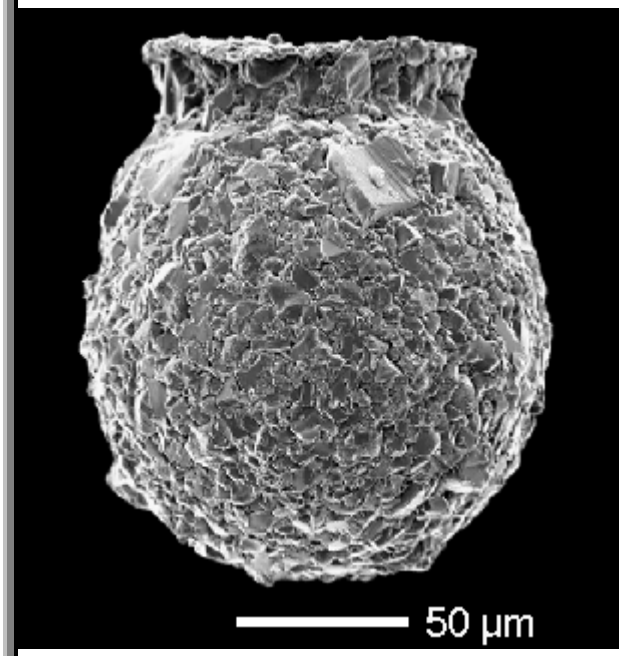
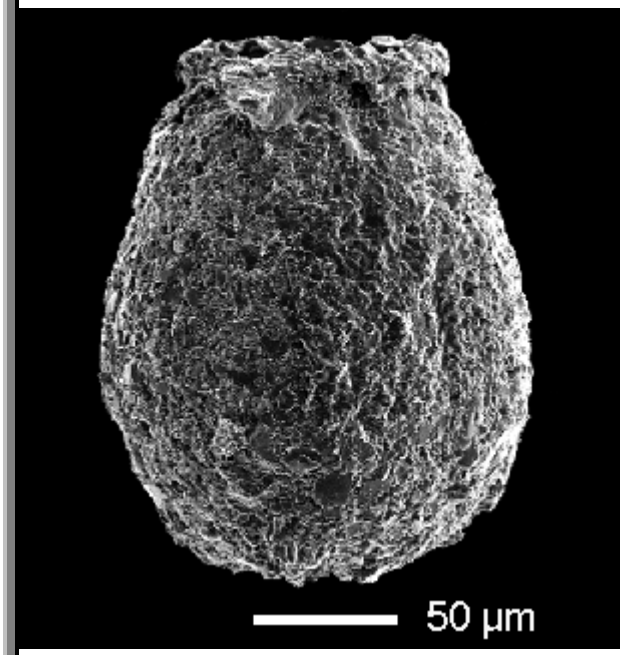


Key Position: 21	Back to (20b)
21 a. Aperture very small with expanded flanged collar of variable width. **SEE Figure 21-1**	**21 b.** Aperture wide, collar of variable shapes and sizes. **Proceed to 22**

FIGURE 21-1

***Difflugia urens* Patterson et al. 1985**
Difflugia urens PATTERSON et al. 1985, p. 130, pl. 3, figs. 5-14
Specimen from Midway Lake, Nova Scotia.

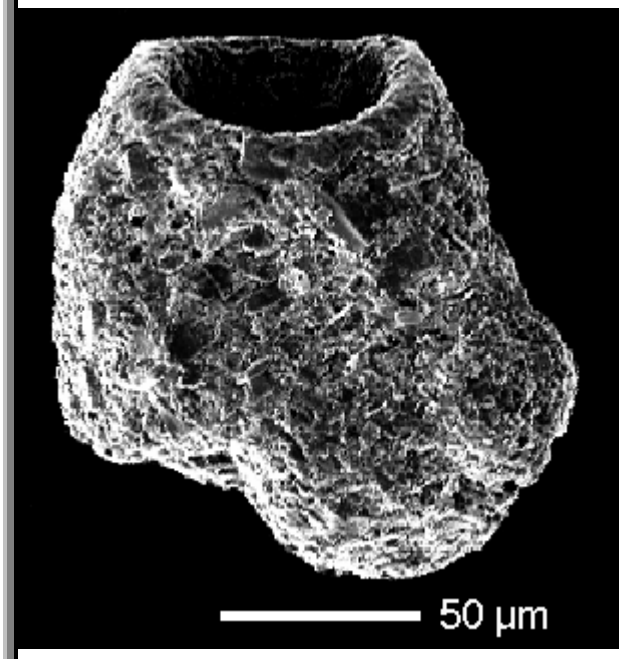


Key Position: 22	Back to (21b)
22 a. Test sphaeroidal to ovoidal. **SEE Figure 22 -1**	**22 b.** Test elongate. **SEE Figure 22 -2**
FIGURE 22 -1 ***Difflugia urceolata* Carter 1864 "urceolata"** *Difflugia urceolata* CARTER 1864, p. 27, pl. 1, fig. 7 *Difflugia urceolata* Carter REINHARDT et al. 1997, pl. 2, fig. 2b Specimen from Peterson Lake, near Cobalt, Ontario.  	**FIGURE 22 -2** ***Difflugia urceolata* Carter 1864 "elongata"** *Difflugia elongata* PENARD 1905, p. 33, fig. on p. 34 *Difflugia urceolata* Carter MEDIOLI and SCOTT 1983, p. 31-33, pl. 3, figs. 1-23 *Difflugia urceolata* Carter REINHARDT et al. 1997, pl. 2, fig. 2a Specimen from Peterson Lake, near Cobalt, Ontario. 

Key Position: 23	Back to (19b)
23 a. Test spheroidal to ellipsoidal; oral pole truncated by a large circular aperture. **SEE Figure 23-1**	**23 b.** Test of variable shape, pyriform to flask shaped, with or without neck, aperture circular, small or large. **Proceed to 24**

FIGURE 23-1

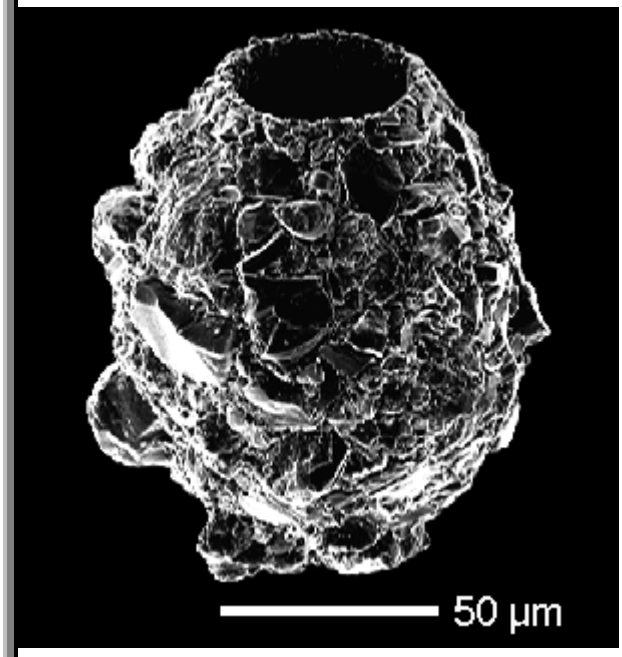
***Difflugia globula* (Ehrenberg 1848)**
Arcella globulus EHRENBERG 1848, p. 379
Difflugia globulus (Ehrenberg) MEDIOLI and SCOTT 1983, p. 24-25, pl. 5, figs. 1-15
Remarks: We have modified the specific term *globula* (formerly *globulus*) to agree in gender with the generic term.
Specimen from Crosswise Lake, near Cobalt, Ontario.



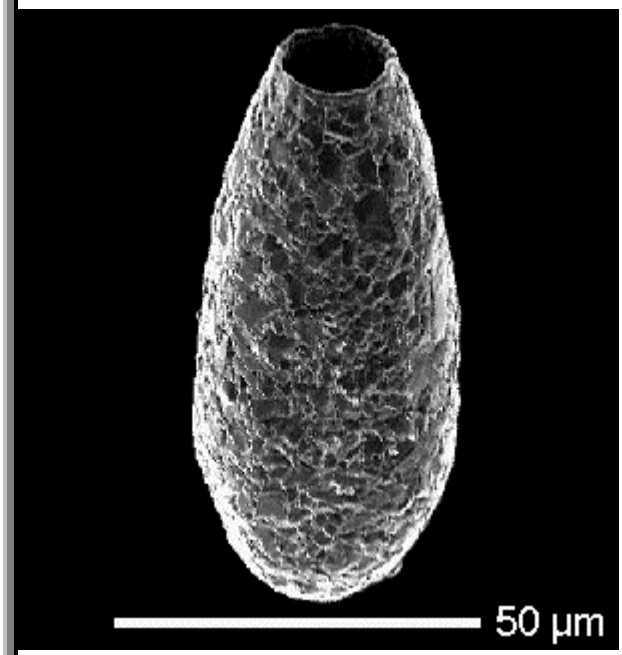
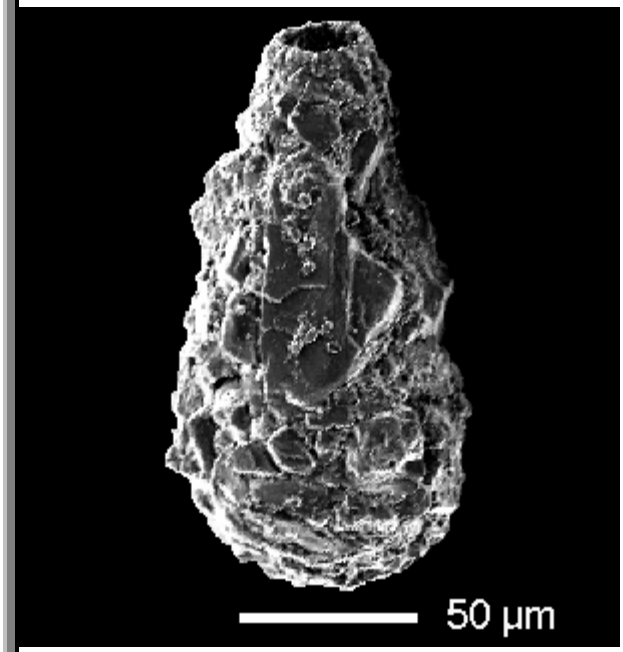
Key Position: 24	Back to (23b)
24 a. Test ovoid with rounded fundus, aperture large and circular. **SEE Figure 24-1**	**24 b.** Test elongate, flask-shaped, aperture circular, large or small. **Proceed to 25**

FIGURE 24-1

***Difflugia oblonga* Ehrenberg 1832 "glans"**
Difflugia glans PENARD 1902
Difflugia oblonga "glans" REINHARDT et al. 1997, pl. 2, fig. 7
Specimen from Crosswise Lake, near Cobalt, Ontario.



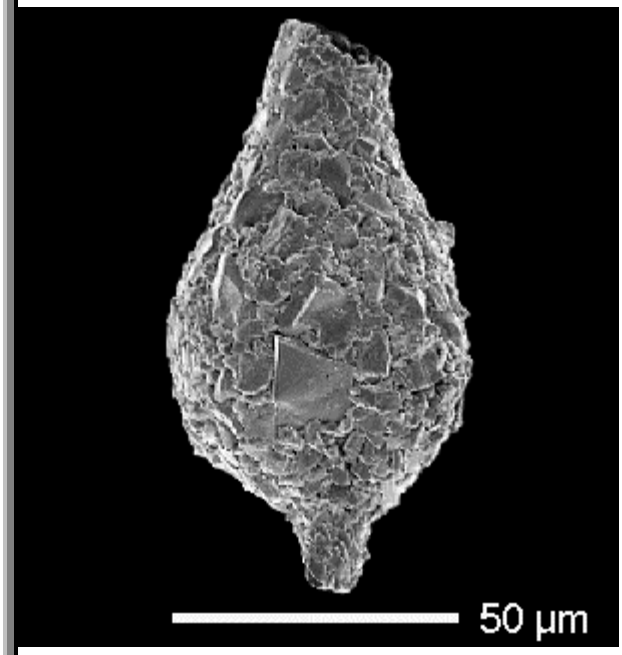
Key Position: 25	**Back to (24b)**
25 a. Aperture with crenulations. **Proceed to 26**	**25 b.** Aperture without crenulations. **Proceed to 27**

Key Position: 26	**Back to (25a)**
26 a. Test elongate; aperture circular without lip. **SEE Figure 26 -1**	**26 b.** Test flask-shaped, aperture small with 5 to 6 crenulations. **SEE Figure 26 -2**
FIGURE 26 -1 ***Difflugia oblonga* Ehrenberg 1832 "lanceolata"** *Difflugia lanceolata* PENARD 1890, p. 145, pl. 4, figs. 59-60 *Difflugia lanceolata* Penard, OGDEN and HEDLEY 1980, p. 140, pl. 59, figs. a-d *Difflugia oblonga* "lanceolata" REINHARDT et al. 1997, pl. 2, fig. 6 Specimen from Crosswise Lake, near Cobalt, Ontario.  	**FIGURE 26 -2** ***Difflugia oblonga* Ehrenberg 1832 "linearis"** *Difflugia pyriformis* var. *linearis* PENARD 1890, p. 137, pl. 3, figs. 42-44 *Difflugia oblonga* "linearis" REINHARDT et al. 1997, pl. 2, fig. 8 Specimen from Peterson Lake, near Cobalt, Ontario. 

Key Position: 27	Back to (25b)
27 a. Test flask-shaped with a spine on fundus. **SEE Figure 27-1**	**27 b.** Test flask-shaped without spine on fundus. **Proceed to 28**

FIGURE 27-1

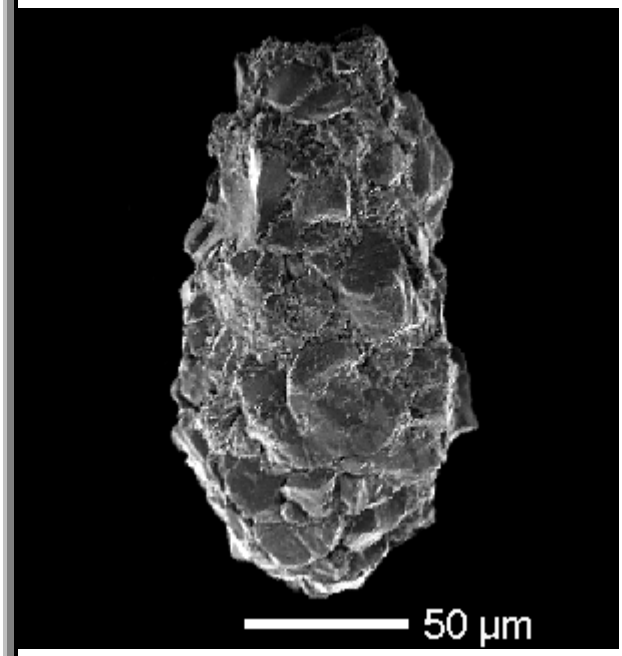
***Difflugia oblonga* Ehrenberg 1832 "spinosa"**
Difflugia oblonga "spinosa" REINHARDT et al. 1997, pl. 2, fig. 11
Specimen from Crosswise Lake, near Cobalt, Ontario.

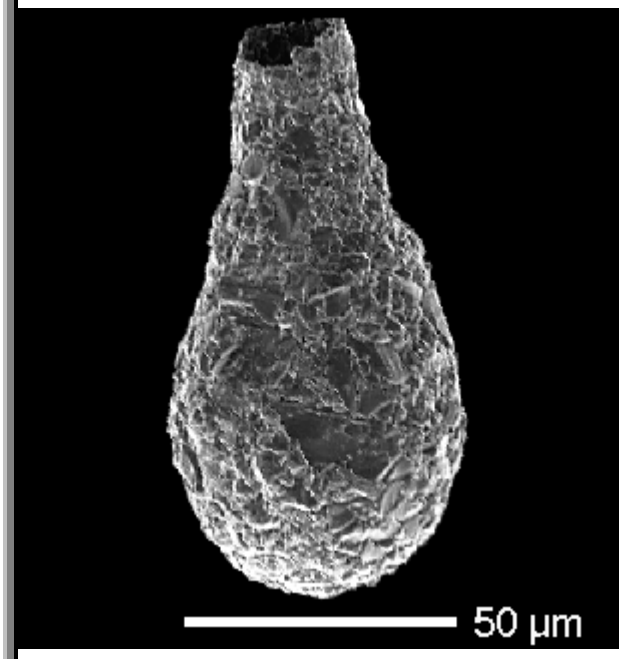
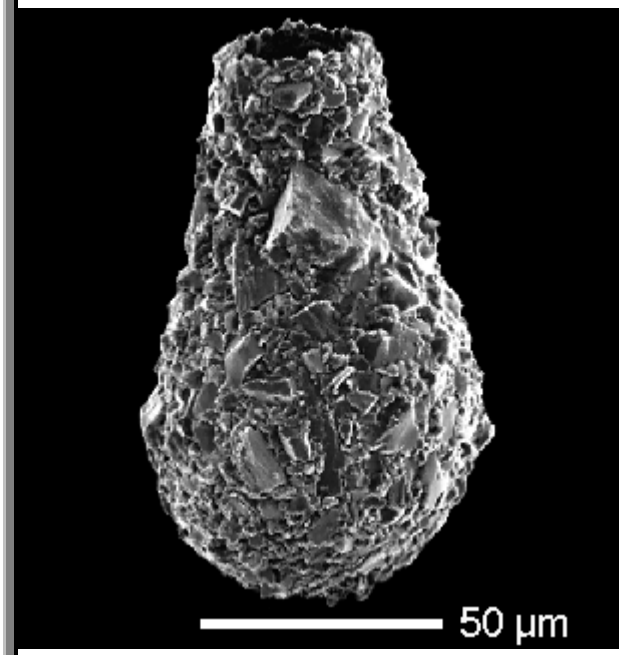


Key Position: 28	Back to (27b)
28 a. Test made of course sand grains. **SEE Figure 28-1**	**28 b.** Test made of predominantly fine mineral grains. **Proceed to 29**

FIGURE 28a

***Difflugia oblonga* Ehrenberg 1832 "bryophila"**
Difflugia pyriformis var. *bryophila* PENARD 1902, p. 221, text fig. 7
Difflugia bryophila Penard [sic], OGDEN and ELLISON 1988, p. 234, pl. 1, figs. 1-3
Difflugia oblonga "bryophila" REINHARDT et al. 1997, pl. 2, fig. 9
Specimen from Crosswise Lake, near Cobalt, Ontario.



Key Position: 29	Back to (28b)
29 a. Test oblong to elongate with a neck, fundus rounded. **SEE Figure 29 -1**	**29 b.** Test elongated without neck, fundus almost subconical. **SEE Figure 29 -2**
FIGURE 29 -1 ***Difflugia oblonga* Ehrenberg 1832 "oblonga"** *Difflugia oblonga* EHRENBERG 1832, p. 90 *Difflugia oblonga* Ehrenberg OGDEN and HEDLEY 1980, p. 148, pl. 63, figs. a-c *Difflugia oblonga* Ehrenberg HAMAN 1982, p. 367, Pl. 3, Figs. 19-25 *Difflugia oblonga* Ehrenberg SCOTT and MEDIOLI 1983, p. 818, figs. 9a-b *Difflugia oblonga* "oblonga" REINHARDT et al. 1997, pl. 2, fig. 10 Specimen from Crosswise Lake, near Cobalt, Ontario.  	**FIGURE 29 -2** ***Difflugia oblonga* Ehrenberg 1832 "tenuis"** *Difflugia pyriformis* var. *tenuis* PENARD 1890, p. 138, pl. 3, figs. 47-49 *Difflugia oblonga* "tenuis" REINHARDT et al. 1997, pl. 2, fig. 12 Specimen from Crosswise Lake, near Cobalt, Ontario. 

REFERENCES

Archer, W. 1866. **Quarterly Journal of Microscopical Science**, new series, 6:185-188.

Asioli, A., Medioli, F.S., and Patterson, R.T. 1996. Thecamoebians as a tool for reconstruction of paleoenvironments in some Italian lakes in the foothills of the southern Alps (Orta, Varese and Candia). **Journal of Foraminiferal Research**, 26:248-263.

Carter, H.J. 1856. Notes on the freshwater Infusoria of the island of Bombay. No. 1. Organization. **Annals and Magazine of Natural History**, series. 2, 18(105):221-249.

Carter, H.J. 1864. On freshwater Rhizopoda of England and India. **Annals and Magazine of Natural History**, series 3, 13:18-39.

Cash, J., and Hopkinson, J. 1905. The British freshwater Rhizopoda and Heliozoa. Vol. I: Rhizopoda, part 1. **Ray Society**, London.

Cash, J., and Hopkinson, J. 1909. The British freshwater Rhizopoda and Heliozoa. Vol. II: Rhizopoda, part 2. **Ray Society**, London.

Dallimore, A., Schršder-Adams, C.J., and Burn, C.R. 1997. Environmental control on thecamoebian assemblages in lakes on Richards Island, MacKenzie Delta, N.W.T. **Geological Association of Canada-Mineralogical Association of Canada Annual Meeting May 19-21, 1997, Abstract Volume**, A34

Deflandre, G. 1929. Le genre centropyxis Stein. **Archiv fur Protistenkunde**, 67:323-375.

Ehrenberg, C.G. 1830. Organisation, systematik und geographisches VerhŠltnis der Infusionsthierchen. **Druckerei der Kšnigliche Akademie der Wissenschaften**, Berlin.

Ehrenberg, C.G. 1832. †ber die Entwicklung und Lebensdauer der Infusionsthiere, nebst ferneren BeitrŠgen zu einer Vergleichung ihrer organischen Systeme. **Kšnigliche Akademie der Wissenschaften zu Berlin Physikalische Abhandlungen**, 1831, 1-154.

Ehrenberg, C.G. 1840. Das grššsere Infusorienwerke. **Kšnigliche Preussischen Akademie der Wissenschaften zu Berlin Bericht**, 198-219.

Ehrenberg, C.G. 1843. Verbreitung und Einfluss des mikroskopischen Lebens in SŸd-und Nord Amerika. **Kšnigliche Akademie der Wissenschaften zu Berlin Physikalische Abhandlungen**, 1841, 291-446.

Ehrenberg, C.G. 1848. Fortgesetzte Beobachtungen uber jetzt herrschende atmospharische mikroskopische Verhaltnisse. **Bericht uber die zur Bekanntmachung geeigneten Verhandlungen der Koniglichen Preussischen Akademie der Wissenschaften zu Berlin**, 13:370-381.

Ehrenberg, C.G. 1872. Nachthrag zur †bersicht der organischen AtmosphŠrilien. **Kšnigliche Akademie der Wissenschaften zu Berlin Physikalische Abhandlungen**, 1871, 233-275.

Green, J. 1975. Freshwater ecology in the Mato Grosso, Central Brazil, IV: Associations of testate Rhizopoda. **Journal of Natural History**, 9:545-560.

Haman, D. 1982. Modern Thecamoebinids (Arcellinida) from the Balize Delta, Louisiana. **Transactions of the Gulf Coast Association of Geological Societies**, 32:353-376.

Hempel, A. 1898. A list of the Protozoa and Rotifera found in the Illinois River and adjacent lakes at Havana, Ill. **Illinois State Laboratory of Natural History Bulletin**, 5:301-388.

Lamarck, J.B. 1816. Histoire naturelle des animaux sans vertebres. **Verdiere**, Paris, 2:1-568.

Leidy, J. 1874. Notice of some new fresh-water rhizopods. **Proceedings of the Academy of Natural Sciences**

of Philadelphia, series 3:77-79.

Leidy, J. 1879. Fresh water rhizopods of North America. **United States Geological Survey of the Territories Report**, 12:1-324.

Medioli, F.S., Scott, D.B., and Abbott, B.H. 1987. A case study of protozoan interclonal variability: taxonomic implications. **Journal of Foraminiferal Research**, 17:28-47.

Medioli, F.S., and Scott, D.B. 1983. Holocene Arcellacea (Thecamoebians) from eastern Canada. **Cushman Foundation For Foraminiferal Research Special Publication 21**.

Medioli, F.S., and Scott, D.B. 1988. Lacustrine thecamoebians (mainly arcellaceans) as potential tools for paleolimnological interpretations. **Paleogeography, Paleoclimatology, Paleoecology**, 62:361-386.

Medioli, F.S., Scott, D.B., Collins, E.S., and McCarthy, F.M.G. 1990. Fossil thecamoebians: present status and prospects for the future. In Hemleben, C., Kaminski, M.A., Kuhnt, W. and Scott, D.B., (eds.), **Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera, North Atlantic Treaty Organization Advanced Study Institute Series, Series C. Mathematical and Physical Sciences**, 327:813-840.

Nair, K.N., and Mukherjee, R.N. 1968. On some testacean rhizopods (Protozoa: Sarcodina) of the ground and tree mosses from Calcutta and its environs. **Proceedings of the National Academy of Sciences of India**, 38B:185-193.

Ogden, C.G., and Ellison, R.L. 1988. The value of the organic cement matrix in the identification of the shells of fossil testate amoeba. **Journal of Micropalaeontology**, 7: 233-240.

Ogden, C.G., and Hedley, R.H., 1980. **An Atlas of Freshwater Testate Amoeba. British Museum (Natural History)**, Oxford University Press.

Patterson, R.T., MacKinnon, K.D., Scott, D.B., and Medioli, F.S. 1985. Arcellaceans (Thecamoebians) in small lakes of New Brunswick and Nova Scotia: modern distribution and Holocene stratigraphic changes. **Journal of Foraminiferal Research**, 15:114-137.

Patterson, R.T., Barker, T. and Burbidge, S.M. 1996. Arcellaceans (thecamoebians) as proxies of arsenic and mercury contamination in northeastern Ontario lakes. **Journal of Foraminiferal Research** 26:172-183.

Penard, E. 1890. *f*tudes sur les Rhizopodes d'eau douce. **M moires de la Soci t de Physique et d'Histoire Naturelle de Gen ve**, 31(2), 1-230.

Penard, E. 1899. Les Rhizopodes de faune profonde dans le lac L man. **Revue Suisse de Zoologie**, 7, 1-142.

Penard, E. 1902. Faune Rhizopodique du Bassin du L man. **Henry Kundig**, Gen ve.

Penard, E. 1905. Les Sarcodines des grands lacs. **Henry Kundig**, Gen ve.

Perty, M. 1849. Uber vertikale Verbreitung mikroskopischer Lebensformen. **Naturforschende Gesellschaft in Bern Mittheilungen**, 153-176.

Reinhardt, E.G., Dalby, A.P., Kumar, Arun, and Patterson, R.T. 1997. In press. Utility of arcellacean phenotypic variants as pollution indicators in mine tailing contaminated lakes near Cobalt, Ontario, Canada. **Micropaleontology** 43(3).

Scott, D.B., and Medioli, F.S., 1983. Testate rhizopods in Lake Erie: modern distribution and stratigraphic implications. **Journal of Paleontology**, 57:809-820.

Wallich, G.C. 1864. On the extent, and some of the principal causes, of structural variation among the difflugian rhizopods: **Annals and Magazine of Natural History**, series 3, 13:215-245.

GLOSSARY

Acuminate - tapering to form a spine.
Agglutination - foreign particles bound together by cement into a test.
Aperture - opening of the test. It is standard procedure to figure the specimens aperture up.
Autogenous - a test secreted by the organism.
Frustule - diatom shell.
Fundus - the end of the test opposite the aperture (also called the aboral end).
Idiosomes - agglutinated foreign particles of the test made from other organic material.
Strain - infraspecific morphological variant.
Test - shell, or external hard part, of a protozoan.
Xenogenous test - test composed of agglutinated foreign particles.
Xenosome -agglutinated foreign particles of the test made from mineral grains.