Chesapeake Bay Dinoflagellates

By Stacey Verardo

The present report is part of a study to document modern dinoflagellate cysts in Chesapeake Bay sediments and temporal trends in cysts over the last few millennium from sediment cores of the middle Bay. Dinoflagellates, which are part of the division Dinoflagellata, are primarily organic-walled, single-celled organisms that often occur as motile cells, called theca, in marine, brackish, and freshwater environments. Living dinoflagellates may be autotrophs, heterotrophs or symbionts. Photosynthetic forms (autotrophs) account for approximately 50% of the dinoflagellate genera. Free living genera are a major component of marine phytoplankton and are important primary producers in the oceans. When dinoflagellates leave fossil remains, they usually consist of their nonmotile or cyst stage. Dinoflagellate cysts are produced within the motile dinoflagellate theca and are also made of organic material (Fensome *et al,* 1996).

The dominant dinoflagellate cyst genus in modern Chesapeake Bay sediments is *Spiniferites* (see Lewis & Rochon, 1998 for discussion on *Spiniferites*). In the Bay, this taxonomic complex includes several morphotypes, but primarily representatives of the species *Spiniferites ramosus* (Harland, 1977). Today, *Spiniferites ramosus* cysts occur mainly in oceanic environments along the southeastern United States as well as within the Caribbean. It is generally considered a warm surface water species (Wall *et al*, 1977; Harland, 1983). In Recent Bay sediments, *Spiniferites* spp. comprises ~80% of the total dinoflagellate population. In samples from the 16th-17th century, *Spiniferites* spp. comprises approximately 50% of the total population. Another species, *Spiniferites mirabilis,* also increases in abundance over the past few centuries (from 1% in the 16th century to ~20% in modern sediments). The increase in *Spiniferites mirabilis* may be

related to increased nutrient concentrations of phosphate, and nitrate, lower salinities, and warm surface waters (Harland, 1983; Turon, 1984).

Operculodinium centrocarpum is the second most abundant dinoflagellate cyst type occurring in Chesapeake Bay sediments. Its modern distribution shows that it is often associated with the North Atlantic current and estuarine and coastal waters in mild to cool-temperate regions (Harland, 1977, 1983; Brenner, 1998). During the past 1000 years, the abundance of this species has decreased in the Chesapeake Bay.

Other species found in lower abundances in Chesapeake Bay sediments, are *Polysphaeridium zoharyi* (an indicator of polyhaline waters), *Lingulodinium machaerophorum*, *Nematosphaeropsis labyrintha, Tuberculodinium vancampoae* and *Multispinula quanta* (Wall *et al,* 1977; Harland, 1983; Edwards & Anderle, 1992). These cyst species decreased in abundance during the past 1000 years and signify an overall long term decrease in cyst species diversity. Natural and anthropogenic factors in the Bay region, including natural climate and land use practices may be a cause of decreasing dinocyst diversity.

The two sections given below are three plates of scanning electron micrographs illustrating nine dinoflagellate species found in the mesohaline parts of the Bay, and species census data in Appendix 3. Dinoflagellate taxa are listed in Table 4.

Table 4. Some Dinoflagellate cysts from Chesapeake Bay sediments

Achomosphaera sp.

Impagidinium sp.

Lingulodinium machaerophorum Wall 1967

Multispinula quanta Bradford1975

Nematosphaeropsis labyrintha (Ostenfeld) Reid 1974

Operculodinium centrocarpum (Deflandre and Cookson) Wall 1967

Polysphaeridium zoharyi Bujak *et al.* 1980

Spiniferites mirabilis Sarjeant 1970

Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966

Spiniferites sp.

Tectatodinium sp.

Tuberculodinium vancampoae (Rossignol) Wall 1967

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Fensome, R., J. Riding, F. Taylor, 1996. Dinoflagellates. In: Palynology: Principles and Applications (*eds*.) Jansonius, J and D. McGregor, American Association of Stratigraphic Palynologists, 107.

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Lewis, J. and Rochon, A., 1998. Cyst-Theca relationships in the *Spiniferites* complex. Norges Teknisk Naturvitenskapelige Universitet Vitenstapmuseet Rapport botanisk Serie 1.

Turon, J., 1984. Le palynoplancton dans l'environnement de l'Atlantique nord-oriental. Évolution climatique et hydrologique depuis le dernier maximum glaciaire. *Mémoires de l'Institut de Géologie du Bassin d'Aquitaine*, 17: 1-313, pl. 1-5.

Wall, D., B. Dale, G. Lohmann and W. Smith, 1977. The environmental and climatic distribution of dinoflagellate cysts in modern marine sediments from regions in the North and South Atlantic Oceans and adjacent seas. *Marine Micropaleontology*, 2: 121-200.

Plate 1

1) *Spiniferites ramosus,* (Ehrenberg) Loeblich and Loeblich 1966, PRCK 1-P-2 90-92 cm., x 2000.

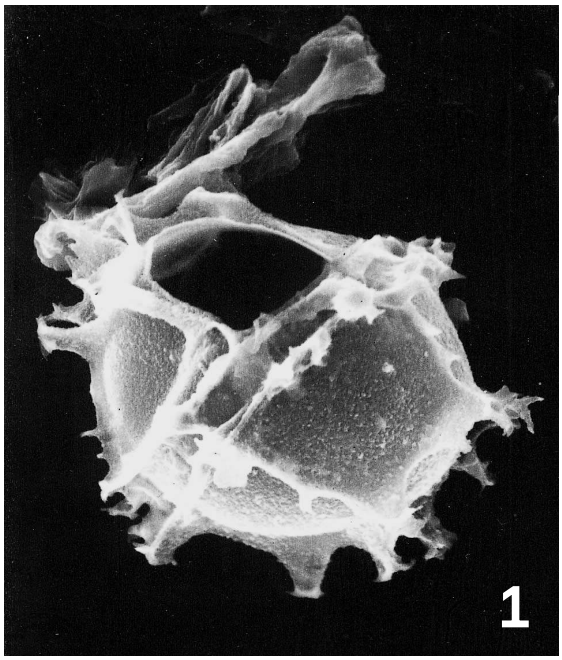
2) *Spiniferites* sp., PTMC 3-P-2 106-108 cm., x 1800.

3) *Spiniferites* sp., PTMC 3-P-2 446-448 cm., x 1800.

4) *Spiniferites mirabilis* Sarjeant 1970, PTMC 3-P-2 106-108 cm., x 1300.

5) *Spiniferites mirabilis* Sarjeant 1970, PTMC 3-P-2 106-108 cm., x 1500.

6) *Lingulodinium machaerophorum* Wall 1967, PTMC 3-P-2 200-202 cm., x 1300.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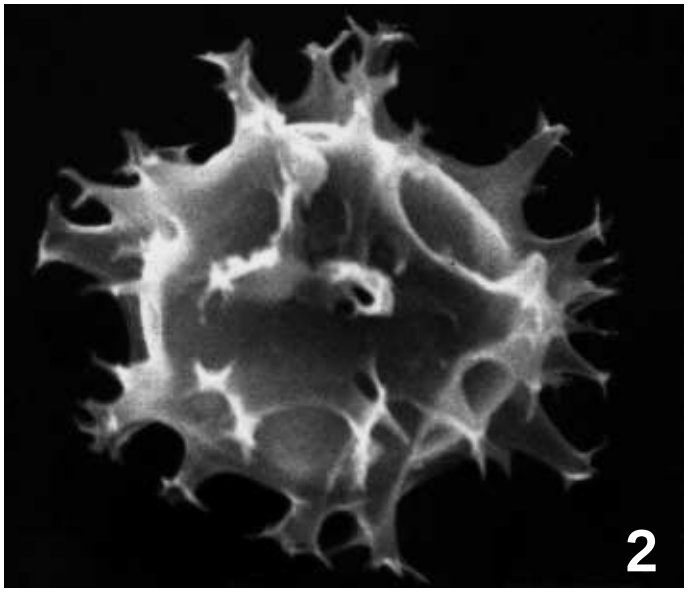
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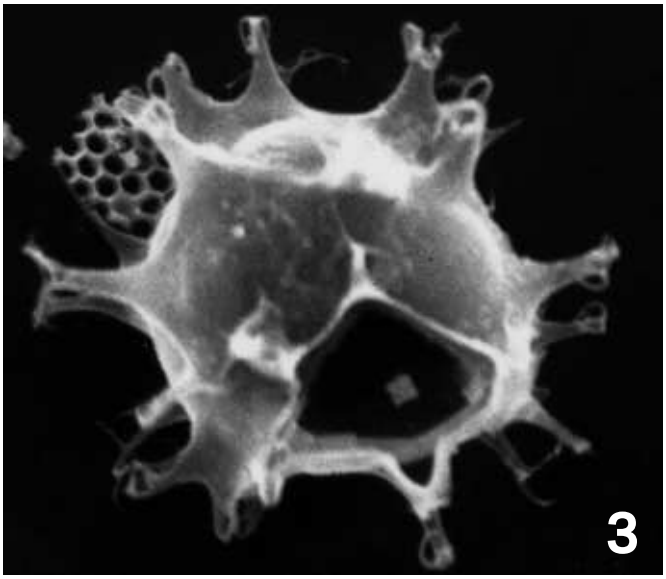
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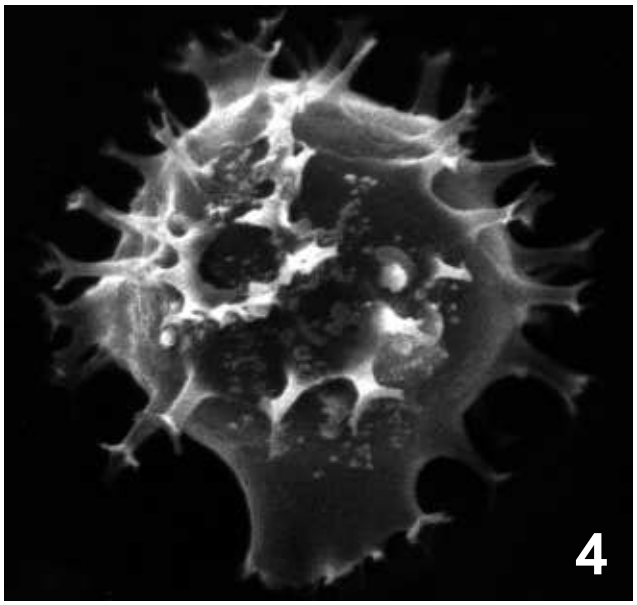
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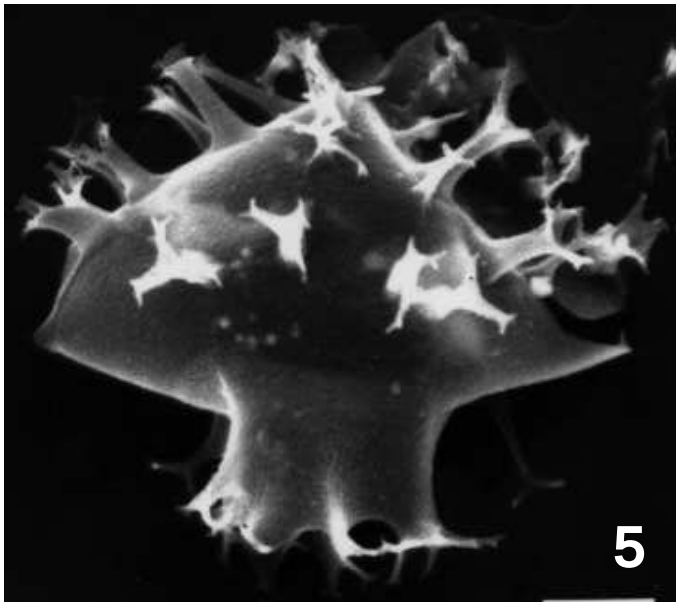
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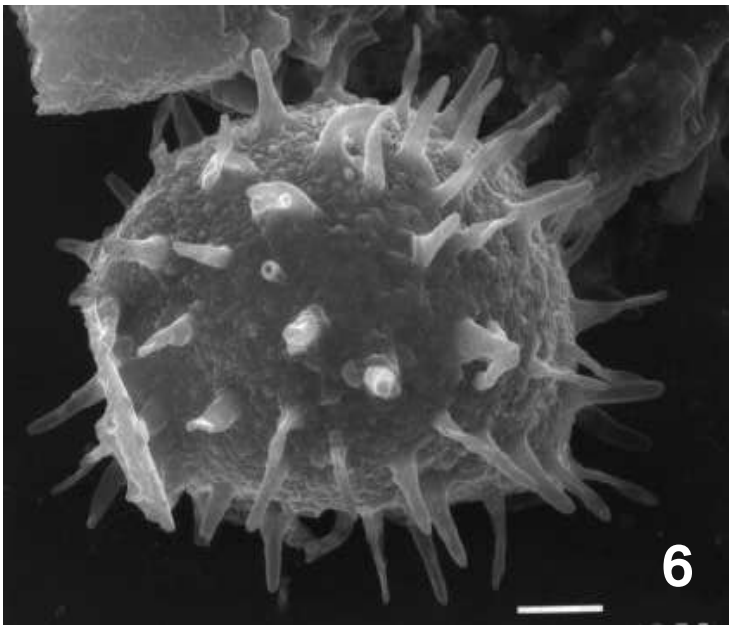
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Plate 2

1) *Spiniferites mirabilis* Sarjeant 1970, PTMC 3-P-2 446-448 cm., x 1300.

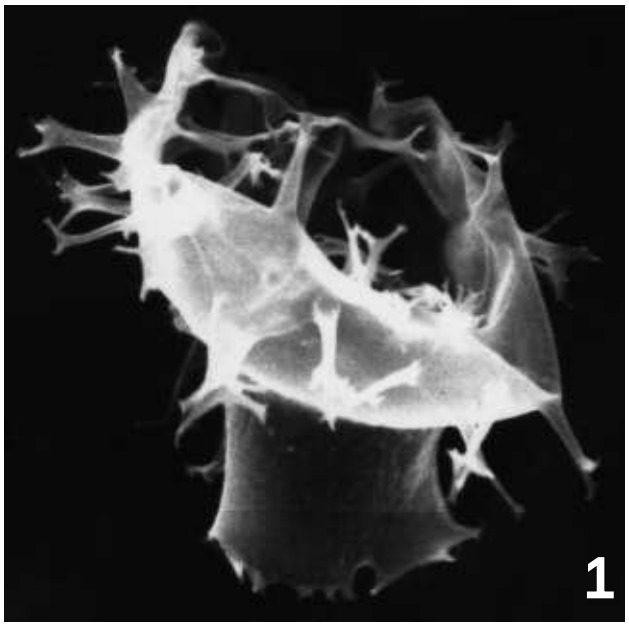
2) *Spiniferites mirabilis* and *Spiniferites* sp. PTMC 3-P-2 190-192 cm., x 1300.

3) *Operculodinium centrocarpum* (Deflandre and Cookson) Wall 1967, PRCK 1-P-2 90-92 cm., x 1200.

4) *Operculodinium* sp., PTMC 3-P-2 106-108 cm., x 1600.

5) *Nematosphaeropsis labyrinthea* (Ostenfeld) Reid 1974, PTMC 3-P-2 446-448 cm., x 1300.

6) *Nematosphaeropsis labyrinthea* (Ostenfeld) Reid 1974, PTMC 3-P-2 446-448 cm., x 1200.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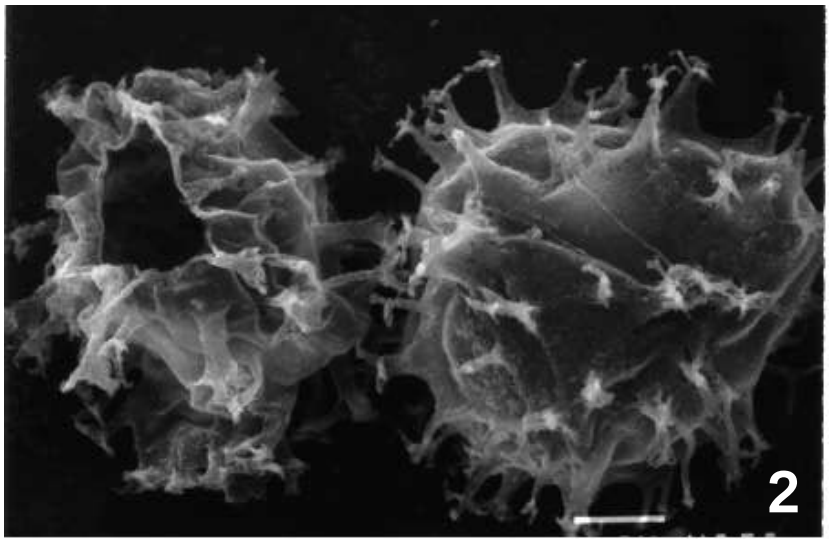
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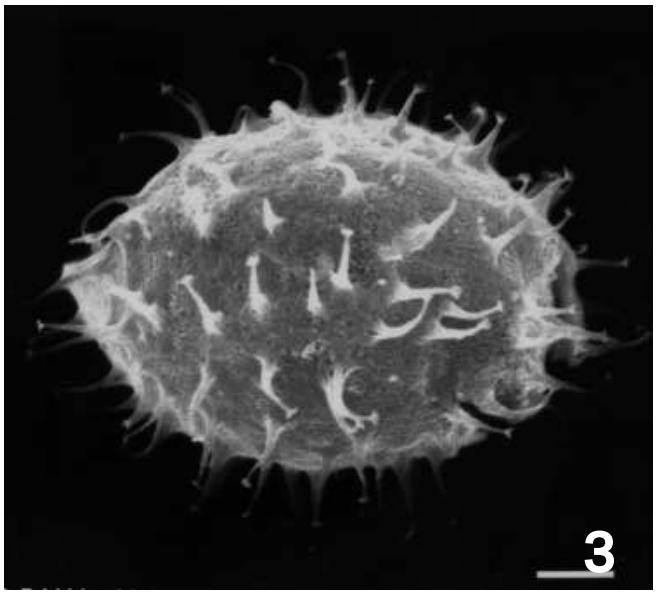
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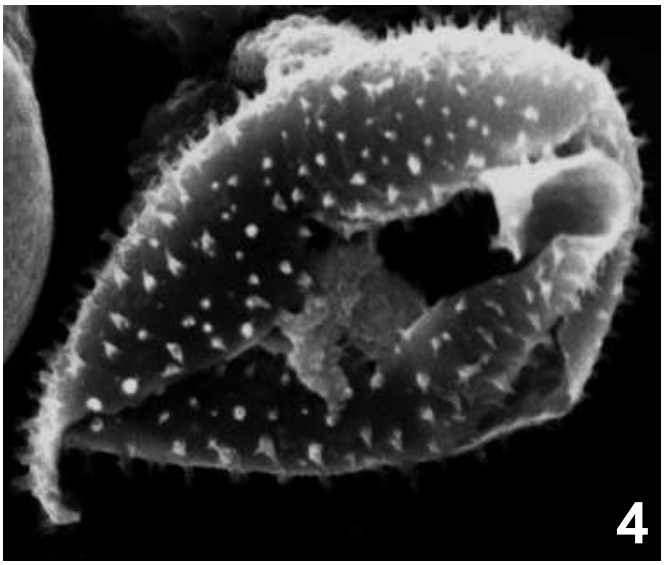
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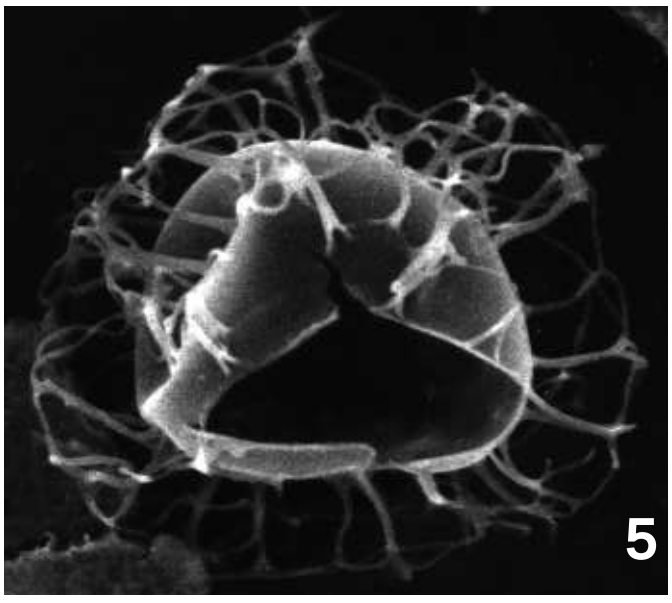
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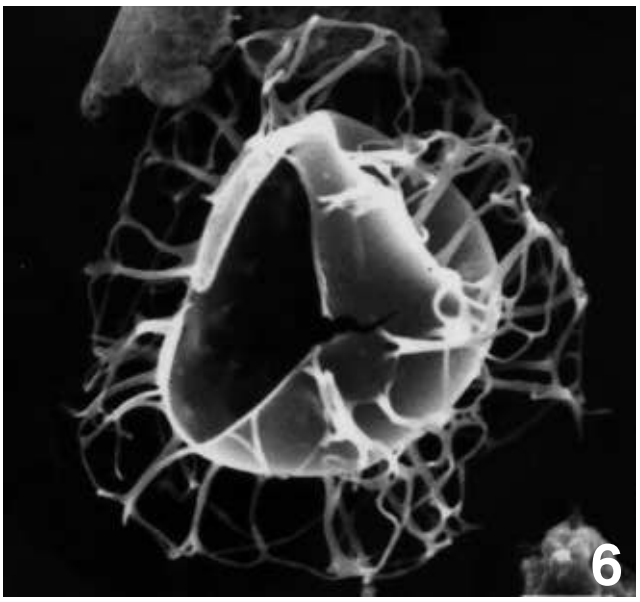
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Plate 3

1) *Polysphaeridium zoharyi* Bujak *et al.* 1980, PTXT 2-P-3 110-112 cm., x 1300.

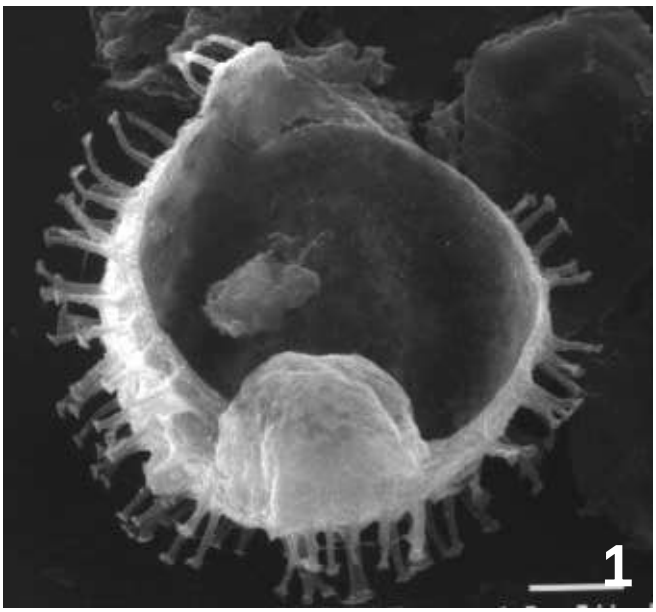
2) *Polysphaeridium zoharyi* Bujak *et al.* 1980, PRCK 1-P-2 90-92 cm., x 1400.

3) *Polysphaeridium zoharyi* Bujak *et al.* 1980, PTMC 3-P-2 106-108 cm., x 1500.

4) *Polysphaeridium zoharyi* Bujak *et al.* 1980 and *Multispinula quanta* Bradford 1975, PTXT 2-P-3 110-112 cm., x 1500.

5) *Multispinula quanta* Bradford 1975, PTMC 3-P-2 106-108 cm., x 1100.

6) *Tuberculodinium vancampoae* (Rossignol) Wall 1967, PTMC 3-P-2 106-108 cm., light microscope.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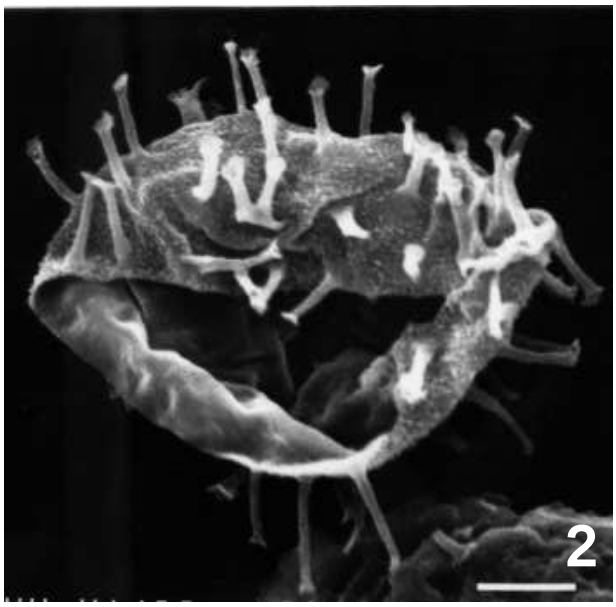
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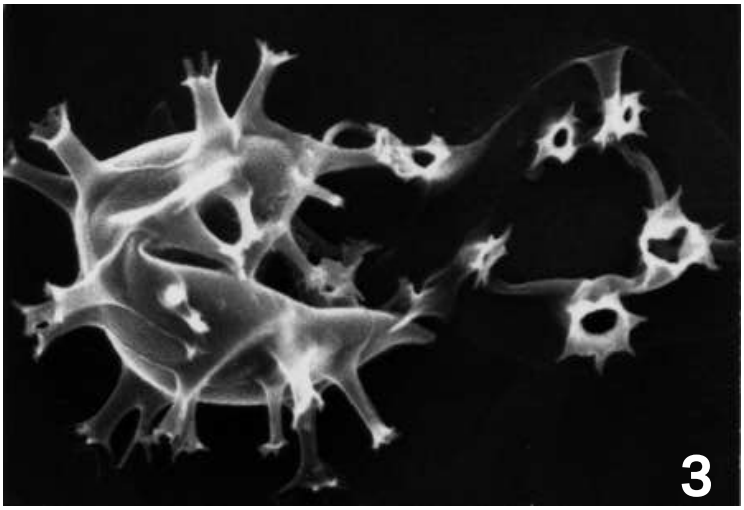
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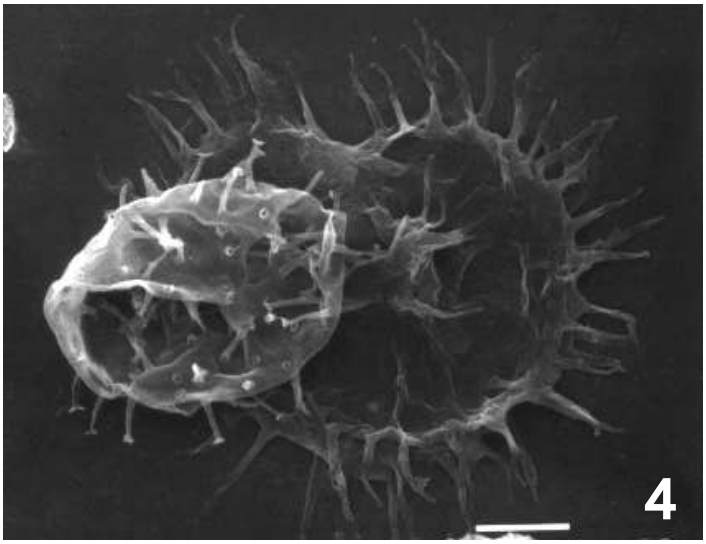
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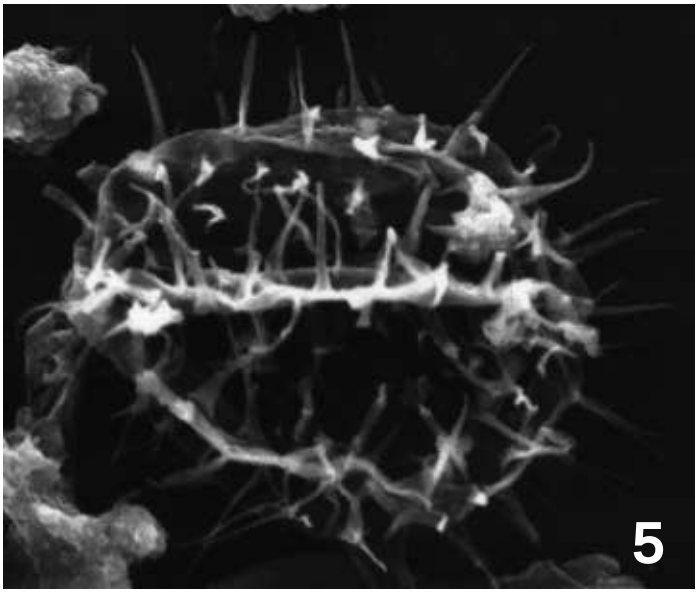
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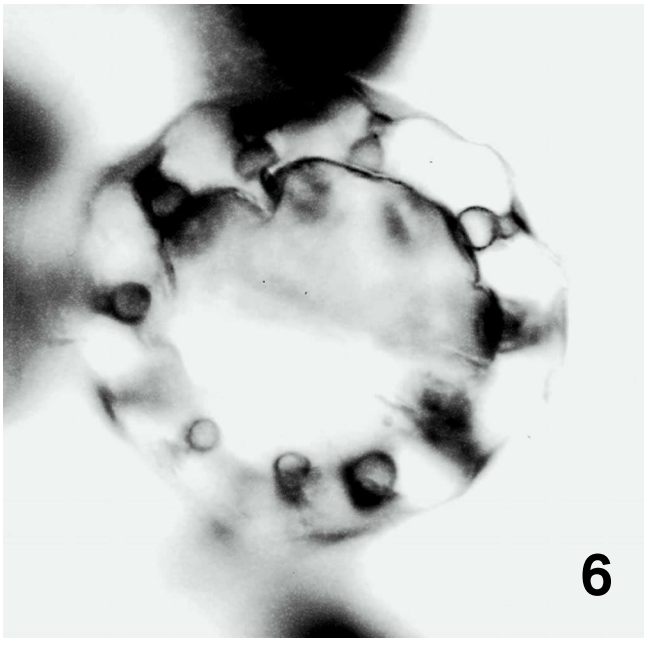
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Depth (cm)	*Tectatodinium* sp.	*Spiniferites* spp.	*Spiniferites mirabilis*	*Operculodinium centrocarpum*	*Multispinula quanta*	*Polysphaeridium zoharyi*	*Lingulodinium machaerophorum*	*Nematosphaeropsis labyrintha*	*Tuberculodinium vancampoae*	*Achomosphaera* sp.	*Impagidinium* sp.	forma b	theca	unidentified	Total*	reworked dinoflagellate → *Wetzeliella* sp.
1	10	123	13	17	2	2	1	6	1			3		1	179	
5	11	77	12	13	1	3		2	1						120	
9	7	201	54	31		18	2	12	4						329	
15	8	235	64	21		4	2	4							338	
21	12	183	74	13		2		2	6			3		1	296	
27	9	225	40	41		8	6	10	4					3	346	
31	7	229	38	55		8	6	2	6						351	
35	4	207	10	123	2	4	12	12	6						380	
39	5	207	12	183		10	4	6	4						431	
43	16	189	14	55	2	6	6	2	2			2	1	1	296	
53	3	96	44	34		16	2	4	10					1	210	
57	3	50	12	26				2	2						95	
69	1	134	48	38		12	6	2	20					1	262	
77	4	19	10	19	2	8	4		4			6	1	10	87	
83	2	19	2	17			2								42	
97	5	127	14	69	2	4	4		6			3	1		235	
107	16	209	29	37	6	12	14		22			5	2	1	353	1
117	10	42	12	24		2			22						112	
129	15	155	42	34	2	14	8	4	16	8		9			307	
139	7	188	62	54		6	6	8	6					1	338	
151	7	133	4	147	10			2	6			5			314	
157	5	189	44	37		20	10	16	10						331	
161	12	117		89	6	21	12	8	8			7	2	2	284	
165	5	93	6	81		6	4	6	2				3		206	
171	10	165	2	107	12	36	12	14	8			9	2		377	
175	5	177	26	77	2	18	6	8	16				4		339	
181	5	131	16	83	2	14	14	12	16				7		300	
185	5	91	6	57		8	4	2	2		2		1		178	
191	2	131	4	83	14	34	16	18	6			8	1	1	318	
195	5	135	6	75		18	12	12	18				4		285	
201	8	89		53	8	46	11		10	6		9	10	7	257	
205	5	65		65	4	14	10	4	16				8	3	194	
211	9	59	4	60	10	12	10	8	8		6	4	12		202	
215	5	95	4	73		12	10	2	8				2	3	214	
219		25		25			2							1	53	
221	5	21		23		10			4						63	
225		25		14	3	4	1	2				1	1		51	

*Total does not include reworked dinoflagellates

Depth (cm)	*Tectatodinium* sp.	*Spiniferites* sp.	*Spiniferites mirabilis*	*Operculodinium centrocarpum*	*Multispinula quanta*	*Polysphaeridium zohayi*	*Lingulodinium machaerophorum*	*Nematosphaeropsis labyrintha*	*Tuberculodinium vancampoae*	*Achomosphaera* sp.	*Impagidinium* sp.	forma b	theca	unidentified	Total*	reworked dinoflagellate ↓ *Wetzeliella* sp.
227	2	21	2	23	6	8			2			2			66	
229	10	53		45	8	14	4						2		136	
233	5	25		17		6	2		4	4			2		65	
237	2	100	2	59	6	32	12	4	6	15		10	6	6	260	
259	5	111		87		16	10	4	10						243	
261	7	157	8	57	4	54	10	2	8	8		12	16	4	347	
263	5	81		71	2	20	2	4	6	10					201	
271		36	2	26		4	4	4	1						77	1
283	13	39	2	39	1	18	8	2	12	1		8	8		151	
287	3	162	2	98		28	10	12	2				3		320	1
291	3	170	20	84		18	6	12	14						327	
293		12		6			2		4						24	
297	2	32	6	8		2			42						92	
299	1	10		2		2									15	
307	8	35	2	25		20	10	4		10	2	10	2	4	132	
319	2	56	2	26			2	2	8						98	
321		196	14	90		12	2	8	14				2		338	
323		196	14	90		12	2	8	14				2		338	
343	3	172	16	90		14	12	22	2		1				332	
335	6	11		7		6	6	4	4		2	4		4	54	
351															0	1
353		8		4		4									16	
357	10	77	14	57		26	6	6	8	10		8	3		225	
365		8		4											12	
369		16	4												20	
381		122	10	54		12	16	14	8						236	
395	10	43	4	13	2	26	6		12		4	14	4	1	139	2
399		2		2											4	
409	3	142	14	86		18	16	8	6				1		294	
419	4	48	2	13	2	12	2	10	2			12	2	5	114	
423	3	88	6	30		18	6	14					4		169	
427	3	142	8	50		34	12	14	12						275	
431		6		4											10	
435		160	4	80	6	28	10	18	8						314	
437		78	8	60	2	4	2	20	2				1		177	
443		128	10	108	2	8	12	22	4				1		295	
447	10	109	20	131		32	16	28	12	14		12	1	1	386	

*Total does not include reworked dinoflagellates

Depth (cm)	Tectatodinium sp.	Spiniferites spp.	Spiniferites mirabilis	Operculodinium centrocarpum	Multispinula quanta	Polysphaeridium zoharyi	Lingulodinium machaerophorum	Nematosphaeropsis labyrintha	Tuberculodinium vancampoae	Achomosphaera sp.	Impagidinium sp.	formB	theca	unidentified	Total*	reworked dinoflagellates: Melitosphaeridium choanophorum	Hystrichokolpoma sp.	Wetzeliella sp.	Wilsonidium tabulatum	Labyrinthodinium sp.	Spiniferites pseudo	Homotryblium sp.
51		176	24	52		20	18	4	14	8	2	1		1	318	2				3	1	
61		214	44	56		18	10	4	4	6	2		2	1	358							2
71	5	180	26	42		24	20	6	6		4	2			313							
81	2	208	68	38		6	10	4	4	2	2	1	1	1	344	1	2					
91	1	202	60	74		16	16		20	8		1	2	1	397	2						
101	2	40		8	2	5	4		2		2	1		1	65			1		1		
111	4	208	16	72	2	26	12	12	8	8	4	1		5	372	6			2		2	
121	3	72	2	12		2	8	4	6	4	1	2	1	1	114	2	2					
131	1	106	2	40		8	6	4	4	4		3	1		175	1			1			
141	3	86	8	38		8	10	2	8	1			1	2	164							
151		128	8	56		14	10	4	6	8	2		1	1	236							
161	4	112	4	68	2	18	20	12	2	8	2	4			252							
171	2	82	14	34		16	22		10	4	2				186							
181		60	4	30	2	6	16		4	2	2	3		1	126							
191	4	192	14	44		24	26	6	8	6	2	6		1	326							
201		110	10	42	4	14	24	4	14	16	10	2	1		248							

*Total does not include reworked dinoflagellates

Depth (cm)	Tectatodinium sp.	Spiniferites spp.	Spiniferites mirabilis	Operculodinium centrocarpum	Multispinula quanta	Polysphaeridium zoharyi	Lingulodinium machaerophorum	Nematosphaeropsis labyrintha	Tuberculodinium vancampoae	Achomosphaera sp.	Impagidinium sp.	forma B	theca	unidentified	Total*	reworked dinoflagellates: Melitasphaeridium choanophorum	reworked dinoflagellates: Wetzeliella sp.	reworked dinoflagellates: Homotryblium sp.
1		86	8	58			8	2						1	163			
11	1	84	4	54	2										145			
21	2	44	6	30	2										84			
31		28	4	28	2	2									64			
41	2	68	2	24	2	2									100			
51	2	50	4	20	2				2			1			81	1		
61	2	62	6	34	2			2			4	4			116			
71	2	50	2	14	2	2			2				2		76		2	
81		48	14	16	2			4				1	4		89			
91	5	140	24	78	2	2	2	4	4			4		1	266			
101	4	110	14	40	4		6	10	8			3	8		207			
111	1	22		22				4				3	7		59			
121	3	70		32	6	6		2	4			1	4		128			
131	2	120	4	16		6	6	8				2	2		166			
141	4	22	4	20			2	4	10			2			68		1	
151		46	4	24		2	8		24			2	3		113			
161		24		6		2			2						34			
171		12	2	4									1		19			
181		4											1		5			
191		8		8			4								20			
201		4	4												8			1

*Total does not include reworked dinoflagellates

Depth (cm)	Tectatodinium sp.	Spiniferites spp.	Spiniferites mirabilis	Operculodinium centrocarpum	Multispinula quanta	Polysphaeridium zoharyi	Lingulodinium machaerophorum	Nematosphaeropsis labyrintha	Tuberculodinium vancampoae	Achomosphaera sp.	Impagidinium sp.	forma B	theca	unidentified	Total*	reworked dinoflagellates: Melitasphaeridium choanophorum	reworked dinoflagellates: Wetzeliella sp.	reworked dinoflagellates: Homotryblium sp.
21	3	198	36	36		16	2	16	4						311			
31	2	186	20	28		8	4	14	10						272			
61	2	88	6	14	2	2		6							120			
71		154	20	46	2	10	12	10	10						264			1
81		208	20	46		4	6	10	22						316			
91	1	176	50	34		12	8	14	30						325			
111	5	164	46	40		4	12	4	8				1		284			
131		164	42	74		8	4	8	12				1		313			
141	2	170	44	50		6	8	12	26						318			
161		8		2					2				1		13			

*Total does not include reworked dinoflagellates

reworked dinoflagellates

Depth (cm)	Tectatodinium sp.	Spiniferites sp.	Spiniferites merabilis	Operculodinium centrocarpum	Multispinula quanta	Polysphaeridium zoharyi	Lingulodinium machaerophorum	Nematosphaeropsis labyrintha	Tuberculodinium vancampoae	Achomosphaera sp.	unidentified	Total*	Wetzeliella sp.
0	3	48		4								55	2
5		217	10	26	4				1		2	260	
12	12	122	8	3	1	2			1		2	151	
16	21	155	1	8	3	3		1			3	195	
20	18	70	4	4	6	4					3	109	
24	12	138	7	20	7	9	1	1	1		2	198	

*Total does not include reworked dinoflagellates

Site & Date	*Tectatodinium* sp.	*Spiniferites* spp.	*Spiniferites mirabilis*	*Operculodinium centrocarpum*	*Multispinula quanta*	*Polysphaeridium zoharyi*	*Lingulodinium machaerophorum*	*Nematosphaeropsis labyrintha*	*Tuberculodinium vancampoae*	*Impagidinium* sp.	theca	unidentified	Total*	reworked dinoflagellates: *Wetzeliella* sp.	reworked dinoflagellates: *Hystrichokolpoma* sp.
BRIS 6/1/1996		2											2		
BRIS 7/1/1996		190	2	24		8		1	1				226		
BRIS 8/1/1996		264	18	18	6	6	8	2	2				324		
BRIS 9/1/1996		46	2	12	2			2	2				66		
BRIS 6/1/1997		256	16	14		2	4		2				294		
BRIS 6/1/1998		140	6	20		4	2						172		
BUVA 6/1/1996	1	4											5		
BUVA 7/1/1996		2											2		
BUVA 8/1/1996		6	2	4									12		
BUVA 9/1/1996		2	2	2									6		
BUVA 6/1/1997		1											1		
BUVA 6/1/1998		8		2									10	1	
HNPT 7/1/1996		2											2		
HNPT 8/1/1996		110	4										114		
HNPT 9/1/1996		36		2		2							40		
HNPT 6/1/1997													0		
MRPT 6/1/1996		28	2	12									42		
MRPT 7/1/1996	1	48		10	2								61		
MRPT 8/1/1996		60		10			4						74		
MRPT 9/1/1996		52		2	8			2				2	66		
MRPT 6/1/1997		22											22		
MRPT 6/1/1998	2	140	10	10	0	4	4	2					172		
PNPT 6/1/1996	2	84	12	16		6	2	2	2		1		127		

*Total does not include reworked dinoflagellates

Site & Date	*Tectatodinium* sp.	*Spiniferites* spp.	*Spiniferites mirabilis*	*Operculodinium centrocarpum*	*Multispinula quanta*	*Polysphaeridium zoharyi*	*Lingulodinium machaerophorum*	*Nematosphaeropsis labyrintha*	*Tuberculodinium vancampoae*	*Impagidinium* sp.	theca	unidentified	Total*	reworked dinoflagellates: *Wetzeliella* sp.	reworked dinoflagellates: *Hystrichokolpoma* sp.
PNPT 7/1/1996	1	84	4	54	2								145		
PNPT 8/1/1996	3	206	36	42		10	2	8	4		3		314		
PNPT 6/1/1997		250	46	20		2	2	2	12				334		
R-64 6/1/1996	10	60	2	48	2	4	4	2	6				138		
R-64 7/1/1996	9	168	2	14	2	2		4	1		3		205		
R-64 8/1/1996	4	212		68	6						1		291		
R-64 6/1/1996	2	110	6	16		6	4	2	2				148		
RGPT 6/1/1996		58	6	4	1								69		
RGPT 7/1/1996	2	138	16	36	2		4	4	4		5		211	1	
RGPT 8/1/1996	1	232	52	24		18	2	2	2				333		
RGPT 9/1/1996		170	26	18		6	4	2	2				228	1	
STLC 6/1/1996		72	2	12	2		2	2	4				96		
STLC 7/1/1996		126	12	6		2			4				150		
STLC 8/1/1996	1	112	16	12		16	4	4	6			2	173		1
STLC 6/1/1998		184	6	16		4	2	4	6				222		2
STPD 7/1/1996		6											6		
STPD 8/1/1996		4											4		
PRCK 1- 6/1/1998		142	2	16			2						162		
PRCK 3-6/1/1998	4	124	16	4		2	4		2		2		158		
PTMC 1-2--6/1/1997		240	44	12				4	4				304		
PTMC 2-2--6/1/1997		250	54	26		6	4	10	6				356		

*Total does not include reworked dinoflagellates

Site & Date	*Tectatodinium* sp.	*Spiniferites* spp.	*Spiniferites mirabilis*	*Operculodinium centrocarpum*	*Multispinula quanta*	*Polysphaeridium zoharyi*	*Lingulodinium machaerophorum*	*Nematosphaeropsis labyrintha*	*Tuberculodinium vancampoae*	*Impagidinium* sp.	theca	unidentified	Total*	reworked dinoflagellates: *Wetzeliella* sp.	reworked dinoflagellates: *Hystrichokolpoma* sp.
PTMC 3-2--6/1/1996		232	30	21		6	6	10	8				313		
PTXT 2-6/1/1998	9	104	8	12		2	4	2	8			1	150		
PTXT 2-3--6/1/1997		260	38	18			6	6	2				330		
PTXT 3-6/1/1998	3	240	34	22	2	4	6	2	16		1		330		

*Total does not include reworked dinoflagellates