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16. RADIOLARIANS FROM SITES 794, 795, 796, AND 797 (JAPAN SEA)[1]

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ABSTRACT

Japan Sea ODP Leg 127 shipboard radiolarian biostratigraphic data are compiled and improved. The sequence of biostratigraphic events determined in sediments above the opal-A/opal-CT transition is illustrated graphically with depth-depth plots. The absence of biostratigraphic indicators from the North and subtropical Pacific and differences between the compositions of the Japan Sea and Pacific radiolarian assemblages suggest that the planktonic populations of the Japan Sea have been partially isolated from the Pacific since the late Miocene. Subtropical fauna in sediments younger than ~1.8 Ma at Site 797 record the occurrence of a paleo-Tsushima current. These same fauna record larger volumes of the paleo-Tsushima current, or warmer intervals during the colder glacial climate regime at Site 794. The variability of Pleistocene assemblage composition and preservation shows that radiolarian dissolution has played a large part in determining what is preserved. Preliminary taxonomic evaluations are made, and the stratigraphic and paleoceanographic implications of radiolarian species are discussed.

INTRODUCTION

Previous studies of Japan Sea radiolarian paleontology were limited to samples obtained with piston cores which span the last several hundreds to thousands of years (e.g., Morley et al., 1986; Oba et al., 1991), Miocene through Pleistocene sediments cored at four sites during Leg 31 of the Deep Sea Drilling Project (DSDP) (Ling, 1975), and Miocene and Pliocene deposits found on Japan (e.g., Nakaseko et al., 1965; Nakaseko, 1969). Piston cores from the Japan Sea contain stratigraphic sections that can be sampled at a rather high stratigraphic resolution, and Japan Sea Leg 31 cores contain relatively long records, but display sediment disturbances due to drilling problems (Karig, Ingle, et al., 1975). One of the principal objectives of Ocean Drilling Program (ODP) Japan Sea Leg 127 was to use the coring techniques of the advanced hydraulic piston corer (APC) and extended core barrel (XCB) to recover more complete stratigraphic sections that improve upon the recovery rates of DSDP Leg 31 sediments for paleontological and paleoceanographic study (Tamaki, Pisciotto, Allan, et al., 1990). Indeed, the sedimentary sections obtained during Leg 127, contain the longest, most continuous, records of radiolarian paleontology from the Japan Sea.

Radiolarians are found in sediment samples from Leg 127 sites that are as old as middle Miocene in age (Tamaki, Pisciotto, Allan, et al., 1990). The radiolarian assemblages in these samples display wide variability in both abundance and preservation. Younger (Pleistocene) assemblages show the highest variability in both preservation and abundance. Many Pleistocene samples are barren, and the dominant taxa in the assemblages from these samples change dramatically. The oldest radiolarians are found in sediments where opal-CT comprises the dominant siliceous phase and where diatoms are no longer preserved except in dolomitic nodules. Radiolarians are not found in sediments below the level of the diagenetic change from opal-CT to quartz. Radiolarians found in opal-CT sediments are not very abundant and rather poorly preserved, but were not completely obliterated from the opal-CT sediments because certain taxa dissolved relatively slowly and became coated and preserved by opal-CT precipitates. The details of radiolarian preservation within the opal-CT sediments from Japan Sea Leg 127 sites await further investigation.

The intent of this study is to document radiolarian biostratigraphy and differences in assemblages among samples from the sediments of the Leg 127 Japan Sea sites in order to determine the sequence of radiolarian biostratigraphic events recorded in the cores and the paleoceanographic significance of assemblages with respect to the geologic history of the basin. Questions that concern how radiolarian assemblages reflect changes in sill depths, sources of nutrients, surface- and deep-water circulation, and the degree of isolation of the Japan Sea from the Pacific are addressed. Because distinctive preservational differences are observed among samples, these aspects of the radiolarian assemblages are examined in detail. Although there have been several thorough taxonomic studies of Japan Sea radiolarians, the taxonomy of Japan Sea radiolarians is still rather limited with respect to the diversity displayed by the Leg 127 assemblages. Therefore while summarizing the radiolarian paleontology and stratigraphy outlined in the Leg 127 shipboard reports (Tamaki, Pisciotto, Allan, et al., 1990), preliminary taxonomic evaluations are made on some dominant taxa and known stratigraphic indicators of Japan.

SAMPLE PREPARATION AND DATA COLLECTION

Samples were taken from Holes 794, 795, and 797 during Leg 127 for radiolarian paleontological analysis. The 10-cm^3 sample plugs taken from sediments above the opal-A/opal-CT transition were dried and weighed. They were subjected to treatment with 10% hydrogen peroxide, and if calcium carbonate material was present in the samples, with HCl. Sodium pyrophosphate was added to the samples, which were then washed several times over a 63-µm sieve. Residues of the sample-washing procedure were then settled onto glass slides using the standard technique of Moore (1973), and after drying under heat lamps, cover slips (24 × 50 mm) were mounted to the slides using several drops of Canada Balsam. Slides were cured by heating on a hot plate. Although contamination of Leg 127 radiolarian samples by the frustules of large diatoms was obvious and troublesome during the slide-making procedure, samples were not treated with sodium carbonate or sodium hydroxide to break down and wash out the diatoms because this sample preparation step would probably alter the preservation of radiolarians in these samples as well.

Because of several complicating factors including limited time and the aggravating occurrence of *Coscinodiscus marginatus* in radiolarian slides made from samples stratigraphically below the opal dissolution transition zone (White and Alexandrovich, this volume), complete stratigraphic analyses that include total slide scans and tabulations of all important and identifiable radiolarian species were not performed for this study. Therefore, the stratigraphy presented here (Table 1) represents a

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summation of the stratigraphy presented in the Leg 127 *Initial Reports* (Tamaki, Pisciotto, Allan, et al., 1990), with some additional refinement of events. The refinement consists of a reduced sample-spacing uncertainty for several datum levels. This was accomplished by using Leg 127 shipboard radiolarian stratigraphy to identify the interval (core) where the stratigraphic event was found. Samples from that core were then scanned for the presence or absence of the indicator species, and the refined datum level is recorded in Table 1. Entire radiolarian slides from samples located stratigraphically above the opal dissolution transition zone (White and Alexandrovich, this volume) were scanned in order to observe preservational differences. Abundance and preservation in these samples are recorded (Tables 2, 3, and 4) following preservation and abundance guidelines outlined in the radiolarian section of the "Explanatory Notes" of Tamaki, Pisciotto, Allan, et al. (1990, p. 49). During slide scanning, the occurrence of distinctive features of the assemblages or specimens were observed. Samples from Hole 794A that contain warm-water assemblages are tabulated in Table 5. Radiolarian species are identified using previously established names and descriptions, and all radiolarian species discussed in this report are listed in the Appendix, with several important stratigraphic, preservation, and paleoceanographic indicators illustrated in the plates.

Because many opaline sponge spicules are larger than 63 μm, they are commonly observed in samples prepared for radiolarian paleontological analysis. Sponge spicules are quite abundant in samples prepared from Leg 127 sediments, and are also indicative of the degree of dissolution certain radiolarian assemblages have been subjected to (Alexandrovich and White, this volume). There is one type of opaline sponge spicule from Japan Sea Leg 127 sediments which is noteworthy in this report on radiolarians. Sterraster sponge spicules (Pl. 1, Figs. 1, 2, and 3) are quite common in Leg 127 Japan Sea sediments and in radiolarian samples. This type of sponge spicule was observed in radiolarian samples analyzed during Leg 127, but was largely ignored because it is not a radiolarian and represented a seemingly unimportant unknown. In several instances, however, this microfossil was found concentrated in sediments that were termed "bioclastic oozes" by the Leg 127 sedimentologists, but the bioclasts could not be positively identified during Leg 127. The "bioclast" microfossil is positively identified here as a long-ranging (back to at least the Jurassic) sterraster sponge spicule belonging to the family Geodiidae, which has a broad latitudinal distribution and can be found in a variety of water depths (R. M. Finks, pers. comm., 1991). Because sterraster sponge spicules that are greater than 63 μm are somewhat common in radiolarian samples, this sponge spicule has been erroneously identified and classified as a radiolarian by several workers (*Spumellina* incertae sedis Form A and B by Benson, 1966; *Hataina ovata* by Huang, 1967).

RADIOLARIAN PRESERVATION

Records of the preservation of Leg 127 Japan Sea radiolarian assemblages are very variable, reflecting several conditions of sediment deposition and sediment diagenesis. For this reason, the material

Table 1. Radiolarian biostratigraphy of Leg 127 sites by ODP sample designation and depth (m below seafloor). LO and FO refer to the last-occurrence and first-occurrence datum levels of the species, respectively. Depth interval is caused by sample spacing.

	Hole 794A	Hole 794B	Hole 795A	Hole 795B	Hole 796A	Hole 796B	Hole 797B
FO *L.* sp. cf. *L. grande*	1H-4, 60–62–1H-5, 44–57 5.1–6.55		2H-CC–3H-CC 18.8–28.3		1H-CC–2H-CC 3.2–12.7		3H-CC–4H-1,118–120 24.9–26.08
LO *C. cabrilloensis*	3H-6, 60–62–3H-CC 24.4–25.8		4H-CC–5H-CC 37.8–47.3		5H-CC–6H-CC 41.2–50.7	5R-CC–6R-CC 59.5–69.1	4H-CC–5H-CC 34.4–43.9
LO *S. robusta*	4H-6, 59–62–4H-CC 33.89–35.3		12H-4, 70–72–12H-5, 70–72 109.5–111		10X-CC–11X-CC 78.3–88.1	9R-CC–10R-CC 97.9–252.7	5H-CC–6H-CC 43.9–53.4
LO *D. acquilonius*	5H-4, 59–61–5H-5, 58–60 40.39–41.88		10H-CC–11H-CC 94.8–104.3		8H-CC–9H-CC 58.7–68.4		8H-CC–9H-3, 118–120 72.4–76.58
FO *D. acquilonius*					18X-CC–19X-CC 155.8–165.3		17H-CC–18H-CC 157.9–166.4
LO *L.* sp. aff. *T. redondoensis*	7H-CC–8H-CC 63.8–73.3		17H-CC–18H-CC 151.9–162.4				13H-CC–14H-CC 119.9–129.4
FO *T. davisiana*	8H-CC–9H-CC 73.3–82.8		16H-4, 74–76–16H-CC 147.54–151.8		10X-CC–11X-CC 78.3–88.1	6R-CC–7R-CC 69.1–78.8	12-6, 117–119–12H-CC 109.57–110.4
LO *T. japonica*	9H-3, 59–61–9H-4, 59–61 76.89–78.39		11H-CC–12H-CC 104.3–113.8		9X-CC–10X-CC 68.4–78.3		11H-CC–12H-CC 100.9–110.4
FO *S. langii*	10H-CC–11H-CC 92.3–101.8		19H-CC–20X-CC 171.9–181.6		12X-CC–13X-CC 97.7–117.2	9R-CC–10R-CC 97.9–252.7	16H-CC–17H-CC 148.4–157.9
LO *S.* sp. cf. *S. acquilonarium*	10H-CC–11H-CC 92.3–101.8		15H-CC–16H-CC 142.3–151.8		10X-CC–11X-CC 78.3–88.1		16H-CC–17H-CC 148.4–157.9
LO *T. akitaensis*			16H-CC–17H-CC 151.8–151.9				11H-CC–12H-CC 100.9–110.4
FO *T. akitaensis*			30X-CC–31X-CC 279.1–288.8				23X-CC–24X-CC 214.3–224
FO *L.* sp. aff. *T. redondoensis*	15H-CC–16X-CC 139.8–149.5		34X-CC–35X-CC 317.6–327.2				22X-CC–23X-CC 204.8–214.3
LO *B. bramlettei*	10H-CC–11H-CC 92.3–101.8						
LO *S. peregrina*	12H-CC–13H-CC 111.3–120.8						18H-CC–19H-CC 166.4–175.9
LO *T. redondoensis*	18X-CC–19X-1, 60–62 168.5–169.1						
LO *S. japonica*	18X-CC–19X-1, 60–62 168.5–169.1		38X-CC–39X-CC 356.2–365.9				20X-CC–21X-CC 185.5–195.2
FO *T. japonica*	20X-CC–21X-CC 187.9–197.5		35X-CC–36X-CC 327.2–336.9				25X-CC–26X-CC 233.7–243.4
LO *L. nipponicum*	20X-CC–21X-CC 187.9–197.538			2R-CC–3R-CC 384.7–394.4			24X-CC–25X-CC 224–233.7
LO *S. delmontensis*	21X-CC–22X-CC 197.5–207.2						
LO *T. anthopora*	25X-CC–26X-CC 236.2–246			7R-CC–8R-CC 432.8–442.4			
LO *T. mammillaris*	26X-CC–27X-CC 246–255.7			7R-CC–8R-CC 432.8–442.4			
LO *S. wolfii*	27X-CC–28X-CC 255.7–265.4						
LO *L. tochigiensis*	28X-1, 60–62–28X-2, 60–62 256.3–257.8			7R-CC–8R-CC 432.8–442.4			
LO *C. tetrapera*		5R-CC–6R-CC 338.3–347.8					

Table 2. Late Pliocene and Pleistocene age Hole 794A radiolarian samples with estimates of radiolarian abundance and preservation.

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	Slide weight (g)	Radiolarians Abundance	Radiolarians Preservation	Comments[a]
127-794A-						
1H-1, 53–55	0.53	0.015	6.00			
1H-2, 60–62	2.10	0.060	5.49			
1H-3, 60–62	3.60	0.103	4.19	Barren		
1H-4, 60–62	5.10	0.146	8.18	Rare	Poor	High IR
1H-5, 55–57	6.55	0.188	10.44	Rare	Moderate	*
1H-CC	6.80	0.195		Few	Good	
2H-1, 60–62	7.40	0.212	10.16	Barren		*
2H-2, 60–62	8.90	0.255	5.59	Few	Moderate	*
2H-3, 60–62	10.40	0.298	9.93	Rare	Poor	High IR
2H-4, 60–62	11.90	0.341	8.41	Barren		*
2H-5, 60–62	13.40	0.384	10.17	Few	Moderate	
2H-6, 60–62	14.90	0.427	9.06	Barren		*
2H-7, 60–62	16.40	0.469	5.79	Few	Moderate	D, *
2H-CC	16.30	0.467		Rare	Moderate	
3H-1, 60–62	16.90	0.484	8.48	Few	Poor	2 IR, trissocyclids
3H-2, 60–62	18.40	0.527	7.97	Common	Moderate	D
3H-3, 60–62	19.90	0.570	11.12	Rare	Moderate	D, *
3H-4, 60–62	21.40	0.613	8.64	Rare	Moderate	D, * 2 IR
3H-5, 59–61	22.89	0.655	4.87	Barren		*
3H-6, 60–62	24.40	0.699	8.71	Barren		
3H-7, 60–62	25.90	0.742	10.97	Rare	Poor	
3H-CC	25.80	0.739		Rare	Moderate	
4H-1, 59–61	26.39	0.756	12.23	Barren		
4H-2, 59–61	27.89	0.800	7.92	Few	Good	D
4H-3, 59–62	29.39	0.844	8.36	Few	Moderate	2 IR
4H-4, 59–61	30.89	0.889	7.35	Few	Moderate	High IR
4H-5, 59–61	32.39	0.933	8.50	Common	Moderate	2 IR
4H-6, 59–62	33.89	0.977	10.42	Common	Moderate to poor	D
4H-7, 58–60	35.38	1.024	14.66	Rare	Moderate to poor	
4H-CC	35.30	1.021		Abundant	Good	
5H-1, 60–63	35.90	1.040	10.72	Few	Moderate	D
5H-2, 62–65	37.42	1.088	16.83	Barren		*
5H-3, 60–63	38.90	1.135	15.50	Barren		*
5H-4, 59–61	40.39	1.182	15.75	Rare	Poor	*
5H-5, 58–60	41.88	1.229	12.96	Rare	Poor	*
5H-6, 63–65	43.43	1.278	15.91	Barren		D, *
5H-CC	44.80	1.322		Rare	Moderate	
6H-1, 59–61	45.39	1.340	8.94	Few	Moderate	
6H-2, 59–61	46.89	1.388	14.13	Few	Good	
6H-3, 71–74	48.51	1.439	15.97	Barren		*
6H-4, 62–64	49.92	1.484	12.82	Barren		*
6H-5, 59–61	51.39	1.530	11.81	Few	Moderate	*
6H-6, 59–61	52.89	1.577	19.59	Barren		*
6H-CC	54.30	1.622		Barren		
7H-1, 60–62	54.90	1.641	10.98	Rare	Moderate	*
7H-2, 60–62	56.40	1.697	13.84	Barren		
7H-3, 60–62	57.90	1.758	10.92	Rare	Moderate	
7H-4, 60–62	59.40	1.819	10.87	Rare	Poor	
7H-5, 60–62	60.90	1.880	9.38	Few	Moderate to poor	
7H-6, 60–62	62.40	1.941	8.38	Few	Moderate	
7H-CC	63.80	1.998		Common	Good	
8H-1, 60–62	64.40	2.022	7.78	Few	Poor	
8H-2, 60–62	65.90	2.083	12.95	Common	Moderate	
8H-3, 60–62	67.40	2.144	10.02	Common	Moderate	
8H-4, 60–62	68.90	2.205	6.52	Abundant	Moderate	f
8H-5, 59–61	70.40	2.266	5.46	Abundant	Moderate	f
8H-6, 60–62	71.90	2.328	8.48	Few	Moderate	f, 2 IR
8H-CC	73.30	2.385		Abundant	Good	
9H-1, 59–61	73.89	2.409	6.59	Abundant	Good	f
9H-2, 59–61	75.39	2.470	11.24	Abundant	Moderate	f
9H-3, 59–61	76.89	2.516	7.79	Common	Moderate	
9H-4, 59–61	78.39	2.561	9.22	Abundant	Good	
9H-5, 59–61	79.89	2.607	12.66	Common	Moderate	
9H-6, 59–61	81.39	2.653	9.40	Abundant	Moderate	
9H-7, 59–61	82.89	2.699	8.91	Abundant	Moderate	
9H-CC	82.80	2.696		Abundant	Good	
10H-1, 60–62	83.40	2.715	10.84	Abundant	Good	*
10H-2, 60–62	84.90	2.761	9.51	Abundant	Moderate	
10H-3, 60–62	86.40	2.806	6.71	Common	Moderate	
10H-4, 60–62	87.90	2.852	15.16	Abundant	Good	

[a] f indicates presence of floaters, D indicates sample comes from a dark layer, * indicates presence of sand-sized grains, and 2IR indicates that radiolarians are present with two states of refractive index (IR).

Table 3. Late Pliocene and Pleistocene age Hole 795A radiolarian samples with estimates of radiolarian abundance and preservation.

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	Slide weight (g)	Radiolarians Abundance	Radiolarians Preservation	Comments[a]
127-795A-						
1H-CC	9.30	0.194		Rare	Good	
2H-CC	18.80	0.392		Rare to few	Moderate	
3H-CC	28.30	0.590		Abundant	Good	
4H-CC	37.80	0.780		Rare	Moderate	
5H-CC	47.30	0.950		Abundant	Good	
6H-CC	56.80	1.120		Few	Moderate	
7H-CC	66.30	1.290		Rare	Poor	
8H-CC	75.80	1.460		Few	Moderate	
9H-CC	85.30	1.630		Rare	Poor	
10H-CC	94.80	1.761		Rare	Moderate	
11H-CC	104.30	1.884		Few	Moderate	
12H-1, 70–72	105.00	1.893	13.01	Common	Moderate	* 2 IR
12H-2, 70–72	106.50	1.912	9.90	Few	Moderate	
12H-3, 70–72	108.00	1.932	11.05	Few	Good	
12H-4, 70–72	109.50	1.951	8.19	Few	Good	f
12H-5, 70–72	111.00	1.971	9.82	Few	Moderate	f, 2 IR
12H-6, 70–72	112.50	1.990	11.66	Common	Moderate	f, 2 IR
12H-CC	113.80	2.007		Common	Moderate	
13H-1, 74–76	114.54	2.016	15.85	Few	Moderate	
13H-2, 74–76	116.04	2.036	12.58	Common	Good	f
13H-3, 74–76	117.54	2.055	15.35	Few	Moderate	f, 2 IR
13H-4, 74–76	119.04	2.075	11.22	Few	Moderate	f, 2 IR
13H-5, 74–76	120.54	2.094	13.93	Common	Moderate	f
13H-6, 74–76	122.04	2.114	10.52	Common	Good	f
13H-7, 51–53	123.21	2.129	15.51	Common	Good	f
13H-CC	123.30	2.130		Common	Moderate	
14H-2, 73–75	125.53	2.159	12.27	Common	Moderate	2 IR
14H-3, 73–75	127.03	2.178	13.88	Common	Moderate	f
14H-4, 73–75	128.53	2.198	11.88	Abundant	Moderate	f
14H-5, 73–75	130.03	2.217	13.45	Abundant	Good	f
14H-6, 73–75	131.53	2.236	13.16	Abundant	Moderate	f
14H-7, 51–53	132.81	2.253	16.25	Abundant	Moderate	f
14H-CC	132.80	2.253		Abundant	Good	
15H-1, 73–75	133.53	2.262	8.85	Common	Good	f
15H-2, 73–75	135.03	2.282	9.72	Abundant	Good	f
15H-3, 73–75	136.53	2.301	6.84	Few	Good	f
15H-4, 73–75	138.03	2.320	6.88	Rare	Poor	f, 2 IR
15H-5, 73–75	139.53	2.340	9.97	Few	Good	f
15H-6, 73–75	141.03	2.359	9.17	Common	Moderate to good	f
15H-7, 51–53	142.31	2.376	11.14	Few	Good	f
15H-CC	142.30	2.376		Abundant	Moderate	
16H-1, 73–75	143.03	2.385	9.42	Abundant	Good	f
16H-2, 73–75	144.53	2.405	12.12	Few	Moderate	f
16H-3, 73–75	146.03	2.424	11.72	Common	Moderate	
16H-4, 74–76	147.54	2.444	11.73	Common	Moderate	f
16H-CC	151.80	2.499		Common	Good	
17H-CC	151.90	2.500		Common	Good	

[a] f indicates presence of floaters, * indicates presence of sand-sized grains, and 2IR indicates that radiolarians are present with two states of refractive index (IR).

obtained from these sediments provides an excellent opportunity to study the preservation of radiolarians. The preservation of radiolarian assemblages from Japan Sea Leg 127 sediments represents several rather extreme examples of preservation state. The radiolarians from the deeper, opal-CT sediments are rather poorly preserved, however, the state of poor preservation of radiolarians found in the opal-CT sediments is quite different from other states of poor preservation found in sediments of the Japan Sea from above the opal-A/opal-CT transition, because they were preserved by coatings of opal-CT. Radiolarians from the Miocene and Pliocene diatomaceous sediments are relatively well preserved, and display few visible signs of dissolution; however, their preservation and abundance records are somewhat obscured because they are outnumbered in the radiolarian slides by high abundances of the diatom *Coscinodiscus marginatus*. The Pleistocene radiolarian assemblages in Japan Sea ODP Leg 127 sediments are in general the most poorly preserved; however, there is a small minority of samples from sediments younger than the opal dissolution transition zone which contain well-preserved, abundant radiolarian assemblages (Tables 2, 3, and 4).

Observations on and comparisons between the preservation of radiolarians in the late Pliocene and Pleistocene samples from Sites 794, 795, and 797 reveal that certain types of radiolarians from Japan Sea sediments are solution resistant. The two types of most dissolution-resistant radiolarians include morphotypes (Pl. 1, Figs. 4 and 5, and Pl. 2, Fig. 2) of trissocyclids (Goll, 1968), and a radiolarian identified as *Peripyramis* species (Pl. 2, Fig. 3, and Pl. 4, Fig. 5). In samples where only these species were found, tests displayed visible signs of dissolution (Pl. 1, Fig. 4), which made identifications of species impossible, but confirmed the notion that concentrations of these species in samples are indicators of high levels of dissolution. The dissolution-resistant trissocyclids of the Japan Sea are very similar in form to the spyrid radiolarians identified as dissolution-resistant forms by Holdsworth and Harker (1975), which supports the hypothesis that trissocyclid radiolarians are solution-resistant forms. It is interesting to note that collosphaerids, which were also

Table 4. Late Pliocene and Pleistocene age Hole 797B radiolarian samples with estimates of radiolarian abundance and preservation.

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	Slide weight (g)	Radiolarians Abundance	Radiolarians Preservation	Comments[a]
127-797B-						
1H-CC	5.90	0.130		Common	Moderate	
2H-1, 118–120	7.08	0.156	6.91	Rare	Poor	2 IR
2H-2, 118–120	8.58	0.189	8.16	Rare	Moderate	*
2H-3, 131–133	10.11	0.222	11.41	Rare	Moderate	* 2 IR
2H-4, 118–120	11.58	0.255	10.31	Rare	Moderate	2 IR
2H-5, 118–120	13.08	0.287	6.65	Common	Moderate	2 IR
2H-6, 118–120	14.58	0.320	11.25	Barren		*
2H-CC	15.40	0.338		Rare	Moderate	
3H-1, 117–119	16.57	0.364	7.02	Rare	Moderate	D, 2 IR
3H-2, 117–119	18.07	0.397	4.85	Common	Poor	f, 2 IR
3H-3, 117–119	19.57	0.430	8.85	Barren		f, *
3H-4, 117–119	21.07	0.463	6.74	Common	Moderate	f, D
3H-5, 111–113	22.51	0.495	7.02	Rare	Moderate	2 IR
3H-6, 117–119	24.07	0.529	9.62	Rare	Poor	f, *
3H-CC	24.90	0.547		Rare	Good	
4H-1, 118–120	26.08	0.573	5.02	Common	Poor	High IR
4H-2, 118–120	27.58	0.606	6.49	Abundant	Poor	f, High IR, trissocyclids
4H-3, 118–120	29.08	0.639	7.05	Common	Poor	f, High IR
4H-4, 118–120	30.58	0.672	6.84	Abundant	Good	f
4H-5, 118–120	32.08	0.705	5.89	Common	Poor to moderate	f, *High IR
4H-6, 118–120	33.58	0.738	8.25	Common	Moderate	f, D trissocyclids
4H-CC	34.40	0.756		Rare	Moderate	
5H-1, 118–120	35.58	0.782	7.24	Barren		f, *
5H-2, 118–120	37.08	0.815	8.48	Rare	Poor	f, D High IR
5H-3, 118–120	38.58	0.848	8.88	Common	Moderate	2 IR
5H-4, 118–120	40.08	0.881	7.22	Few	Poor	f, High IR
5H-5, 118–120	41.58	0.914	11.63	Rare	Poor	*High IR
5H-6, 118–120	43.08	0.947	11.79	Rare	Moderate	*
5H-CC	43.90	0.965		Common	Good	
6H-1, 115–117	45.05	0.990	10.10	Rare	Poor	f, *
6H-2, 118–120	46.58	1.024	9.12	Common	Moderate	f, *
6H-3, 118–120	48.08	1.057	5.10	Common	Moderate	f, D
6H-4, 110–112	49.58	1.090	7.86	Abundant	Moderate	f
6H-5, 118–120	51.08	1.123	6.06	Rare	Moderate	
6H-6, 118–120	52.58	1.156	13.02	Rare	Moderate	f, *
6H-CC	53.40	1.174		Abundant	Good	
7H-1, 118–120	54.58	1.200	11.88	Few	Moderate	f, *
7H-2, 118–120	56.08	1.233	9.33	Rare	Good	*
7H-3, 117–119	57.57	1.265	7.47	Common	Moderate	
7H-4, 117–119	59.07	1.298	7.01	Common	Moderate	
7H-5, 117–119	60.27	1.325	8.63	Rare	Moderate	
7H-6, 117–119	62.07	1.364	9.22	Rare	Poor	
7H-CC	62.90	1.382		Abundant	Good	
8H-1, 118–120	64.08	1.408	8.49	Abundant	Good	f
8H-2, 118–120	65.58	1.441	11.72	Rare	Poor	
8H-3, 118–120	67.08	1.474	12.11	Rare	Moderate	*
8H-4, 118–120	68.58	1.507	8.60	Abundant	Good	
8H-5, 118–120	70.08	1.540	10.13	Rare	Moderate	*
8H-6, 118–120	71.58	1.573	8.75	Common	Moderate	
8H-CC	72.40	1.591		Common	Good	
9H-1, 118–120	73.58	1.617	8.75	Rare	Moderate	*
9H-2, 118–120	75.08	1.650	13.70	Rare	Moderate	*
9H-3, 118–120	76.58	1.683	9.29	Rare	Poor	
9H-5, 118–120	79.58	1.749	10.68	Rare	Poor	
9H-6, 118–120	81.08	1.782	8.29	Few	Moderate	
9H-CC	81.90	1.800		Common	Moderate	
10H-1, 118–120	83.08	1.824	11.73	Common	Moderate	
10H-2, 118–120	84.58	1.854	11.72	Abundant	Moderate	2 IR
10H-3, 118–120	86.08	1.884	16.53	Few	Moderate	
10H-4, 118–120	87.58	1.914	7.92	Common	Moderate	
10H-5, 118–120	89.08	1.944	7.93	Common	Moderate	
10H-6, 118–120	90.58	1.975	11.66	Few	Moderate	
10H-CC	91.40	1.991		Few	Moderate	
11H-1, 118–120	92.58	2.015	8.07	Common	Moderate	
11H-2, 118–120	94.08	2.045	9.10	Common	Moderate	
11H-3, 118–120	95.58	2.075	10.24	Few	Moderate	f
11H-4, 118–120	97.08	2.105	10.68	Abundant	Moderate	High IR
11H-5, 118–120	98.58	2.136	9.46	Few	Poor	2 IR
11H-6, 118–120	100.58	2.176	8.57	Common	Moderate	f, trissocyclids
11H-CC	100.90	2.182		Common	Moderate	

Table 4 (continued).

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	Slide weight (g)	Radiolarians Abundance	Preservation	Comments[a]
12H-1, 117–119	102.70	2.218	6.80	Abundant	Good	
12H-2, 117–119	103.57	2.236	6.66	Abundant	Moderate to poor	f
12H-3, 117–119	105.07	2.266	7.45	Abundant	Good	f
12H-4, 113–115	106.53	2.296	9.77	Abundant	Moderate to poor	f, trissocyclids
12H-5, 117–119	108.07	2.327	5.29	Abundant	Good	
12H-6, 117–119	109.57	2.357	7.40	Abundant	Good	f
12H-CC	110.40	2.373		Common	Good	
13H-1, 118–120	111.58	2.397	7.40	Abundant	Good	
13H-2, 118–120	113.08	2.427	8.88	Common	Moderate	trissocyclids

[a] f indicates presence of floaters, D indicates sample comes from a dark layer, * indicates presence of sand-sized grains, and 2 IR indicates that radiolarians are present with two states of refractive index (IR).

found concentrated with trissocyclid radiolarians in the dissolved assemblages described by Holdsworth and Harker (1975), were not found in any samples from the Leg 127 sites. Because collosphaerid radiolarians may be indicative of more oligotrophic conditions, the absence of them from Japan Sea sediments suggests that the Japan Sea has always been highly productive. Also, because collosphaerids live in colonies that can grow quite large, it is possible that the absence of collosphaerid radiolarians from Japan Sea sediments is due to oceanographic conditions unsuitable for the survival of these species, such as high levels of grazing and/or a well-mixed water column.

Another important preservational indicator of radiolarians of Leg 127 sediments is the radiolarian refractive index. Although it is not clear what changes in the refractive index of radiolarians record, samples from Leg 127 that contain radiolarians with high indices of refraction, typically also contain radiolarians that show visible signs of dissolution. Differences in refractive index are easily observed in radiolarians. Radiolarians with a high index of refraction appear ghostly because their index of refraction is closer to that of Canada Balsam (Pl. 1, Fig. 8), whereas radiolarians with a normal or lower index of refraction appear darker. Typically, when radiolarians in a sample display two states of index of refraction (e.g., Pl. 1, Fig. 6), reworking may be inferred because older radiolarians commonly have a lower index of refraction. However, the occurrence of two states of index of refraction within a sample does not necessarily imply that reworking has occurred. In fact, some single test radiolarian specimens within Japan Sea samples with assemblages that displayed two refractive index states also display two states of index of refraction.

Close inspections of specimen that display two states of refractive index (IR) revealed that although the fossils are still relatively complete, the high-IR portions of some of the tests are slightly thinner, indicating that the change to a higher index of refraction accompanies and probably precedes dissolution. Because many radiolarians from samples that display two states of IR display obvious signs of dissolution such as pitting, thinning of connecting bars, reduction of lattice "lace," etc., but do not necessarily display high IR values, it is likely that dissolution occurs after deposition of the radiolarians either at the sediment/water interface or within the sediment column. Because skeletal thinning will make the skeletons of radiolarians more fragile, radiolarians that start dissolving within the water column are more likely to become fragmented due to the rigors of transport and deposition than are those that began dissolving within the sediments.

Reworking

The distribution of reworked radiolarians in sediments cored during Leg 127 is a good indicator of sediment transport and tectonically induced deposits. Reworking of radiolarians was lowest in the sediments of Site 794, and was more common at Sites 795 and 797 (Tamaki, Pisciotto, Allan, et al., 1990). Relatively low amounts of reworked radiolarians were identified in Site 796 sediments; however, the presence of sands and sediment slumping obscures the radiolarian record at this site. For this reason no additional samples were processed from Site 796 cores for this study. Radiolarian reworking is confirmed in Pliocene and Pleistocene sediments where Miocene forms are identified and also in sediments where there are abundant fragmented radiolarians (Pl. 2, Figs. 1 and 2). Commonly, older reworked radiolarians appear thickened and have a lower index of refraction than the rest of the radiolarians in the assemblage. The most common reworked radiolarians were usually species from the genera *Stichocorys* or *Cyrtocapsella* (Pl. 2, Fig. 4). Some cycladophorid radiolarians most like *Anthocorys akitaensis* looked suspiciously reworked in several samples due to slightly lower apparent index of refraction.

RADIOLARIAN STRATIGRAPHIC INDICATORS OF JAPAN SEA SEDIMENTS

Because of their continuous nature, the sites cored during Leg 127 can be used to construct a reference section for radiolarians from Japan. Therefore, an objective of this radiolarian paleontology and stratigraphy study is to precisely identify the sequence of radiolarian biostratigraphic events of the Japan Sea. Once the radiolarian stratigraphy is clearly established and age models for Leg 127 sediments are refined, the radiolarian stratigraphy can be used to help decipher the depositional history of basins of the Japan Sea where radiolarians are found. However, the identification of stratigraphic datum levels in Leg 127 Japan Sea sediments is complicated by poor preservation in the youngest and oldest sediments recovered, by radiolarian sample contamination by the diatom *Coscinodiscus marginatus* in Miocene and Pliocene sediments, by incomplete inventories and taxonomies of Japan Sea radiolarian species, and by evolutionary changes throughout the sections examined.

The radiolarian stratigraphy of the Japan Sea is also hard to tie directly to standard zonations from other parts of the Pacific because Pacific indicator species do not occur or occur sporadically in the sediments recovered on Leg 127. The radiolarian stratigraphy from the Leg 127 sites can be tied to the radiolarian zonations set up for middle Miocene to Pliocene sedimentary deposits of Japan by Nakaseko and Sugano (1973). This zonation is very useful because the boundaries of the zones are defined by only a few species and the ranges of 36 taxa that range between the middle Miocene and Pliocene are traced through these zones. Although indicator species from several genera such as *Didymocyrtis, Calocycletta,* or *Lithopera* were not found in the Leg 127 sediments, the fact that they are present in deposits on Japan allows for some correlation with radiolarian assemblages assigned to North Pacific zonations.

Radiolarian zonations set up for Japan Sea sediments (Nakaseko and Sugano, 1973, Tamaki, Pisciotto, Allan, et al., 1990) will not be used to describe the Leg 127 sites examined in this study, because the stratigraphic resolution of the zonations is rather low, and the poor preservation of the late Pliocene and Pleistocene sediments prohibits the exact determination of zonal boundaries. Instead, radiolarian stratigraphy determined in this study is used to examine the correla-

Table 5. Samples from Hole 794A containing subtropical radiolarians.

Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	Slide weight (g)	Radiolarians Abundance	Preservation	Comments[a]
127-794A-						
1H-4, 60–62	5.10	0.146	8.18	Rare	Poor	
1H-5, 55–57	6.55	0.188	10.44	Rare	Moderate	*
2H-2, 60–62	8.90	0.255	5.59	Few	Moderate	*
4H-4, 59–61	30.89	0.889	7.35	Few	Moderate	
4H-5, 59–61	32.39	0.933	8.50	Common	Moderate	
4H-6, 59–62	33.89	0.977	10.42	Common	Moderate to poor	
5H-1, 60–63	35.90	1.040	10.72	Few	Moderate	
6H-1, 59–61	45.39	1.340	8.94	Few	Moderate	
6H-2, 59–61	46.89	1.388	14.13	Few	Good	
7H-1, 60–62	54.90	1.641	10.98	Rare	Moderate	*

[a] * indicates samples containing sand-sized grains.

tions and relative timing of the events among Japan Sea Sites 794, 795, and 797. Although Ling (1975) examined radiolarians in DSDP Leg 31 sediments and documented the levels of several biostratigraphic events, no previous studies exist in which radiolarian first-occurrence (FO) and last-occurrence (LO) event stratigraphy from Japan Sea or marine sediments from Japan are tied to a paleomagnetic time scale. In addition, most of the radiolarian datum levels identified in Japan Sea sediments have not been assigned ages in studies of Pacific sediments. Therefore, radiolarian stratigraphy cannot be used to define and refine age models for the Japan Sea Leg 127 sites. The Leg 127 Japan Sea sites can, however, be used as reference sections, and radiolarian datum levels can be assigned ages by interpolating between age control points of other chronological indicators identified in the cores.

Before radiolarian biostratigraphic events can be dated, the sequence and relative reliability of the events must be documented. This is achieved by plotting the 25 first- or last-occurrence events identified in the Japan Sea Leg 127 sediments (Table 1) on depth-depth plots (Fig. 1). In these plots, the sample-spacing uncertainty of the datum levels is represented by boxes, and unreliable or diachronous radiolarian datum levels are identified when they violate apparent lines of correlation between the stratigraphic sections. Lines of correlation are not indicated in Figure 1 because many of the radiolarian datum levels have not been researched in detail and appear to be out of sequence at some of the sites. The best correlation of the radiolarian datum levels from Leg 127 sites occurs between Sites 794 and 797; however an offset of the correlation is found below the FO of *Theocalyptra davisiana* and the opal dissolution transition zone (Fig. 1). This offset could be indicative of problems in the identification of the LO of *Lipmanella* sp. aff. *L. redondoensis,* a relative decrease in the sedimentation rate at Site 797, or, an increase in the sedimentation rate at Site 794 in the younger sediments. The gaps in the depth-depth plots between Site 795 and Sites 794 and 797 suggest that the sedimentation rate in the interval corresponding to the range of *Lipmanella* sp. aff. *L. redondoensis* (175 and 300 m below seafloor) at Site 795 is significantly higher.

The depth-depth plots that compare the radiolarian stratigraphy of Leg 127 Sites 794, 795, and 797 illustrate that further biostratigraphic analysis is warranted. Until taxonomic uncertainties are resolved and a clear homotaxial pattern is discerned between the three sites, any conclusions about the correlation of the stratigraphic records of these sites is tentative. This preliminary stratigraphic analysis includes illustrations of 14 Japan Sea radiolarian stratigraphic indicators in the plates, and observations on several of these indicator species which are discussed in the following.

The identification of the LO of *Clathrocyclas cabrilloensis* (Pl. 5, Figs. 7, 8, 9, and 10) is complicated by both close affinities with other Cycladophorid morphotypes (Pl. 5, Figs. 4, 5, and 6) and the poor preservation of the Pleistocene assemblages. Despite this, the morphological definition followed for this species is rather robust, and the stratigraphic level of this LO event correlates well among the three sites (Fig. 1).

Because the LO of *Stylacontarium acquilonius* (Pl. 3, Fig. 2) occurs within the cyclical Pleistocene sediments that exhibit a large variability in preservation, the reliability of this datum level may be suspect. Because it is a rather abundant species, however, its last occurrence is somewhat reliable and appears to correlate among Sites 794, 795, and 797. The LO of the hypothesized ancestor of *Stylacontarium acquilonius, Stylacontarium* sp. cf. *S. acquilonarium,* is distinguished from its descendant mainly by the shape of the cortical shell. Because the differences between these two species are very subtle, it is likely that this lineage is equivalent to the species *Stylatractus yatsuoensis* as described by Nakaseko (1969). The similarities between *Stylacontarium acquilonium* and *Stylatractus yatsuoensis* were noted previously by Ling (1975).

The LO of *Sphaeropyle robusta* (Pl. 3, Fig. 7) and the FO of its descendant, *Sphaeropyle langii* (Pl. 3, Fig. 3), were used as zonal boundary markers for the shipboard reports. Although there are evolutionary intergrades between these two radiolarians in Japan Sea sediments, the first morphotypic appearance of *S. langii* can be easily identified and appears to correlate nicely among sites. The LO of *S. robusta* may not be a reliable stratigraphic indicator because it displays very low abundances in the Pleistocene sediments.

The FO of *Theocalyptra davisiana* (Pl. 1, Fig. 6, and Pl. 4, Fig. 8) is closely associated with the late Pliocene opal dissolution transition zone (ODTZ). Near the base of the range of *Theocalyptra davisiana,* ancestral forms and morphotypical intergrades are abundant; therefore, in the Japan Sea, the FO of *Theocalyptra davisiana* is a morphotypic first appearance. The datum level is probably reliable and synchronous within the Japan Sea sediments, although the occurrence of morphological intergrades deserves more attention.

The LO of *Stichocorys peregrina* as determined during Leg 127 correlates well between Sites 794 and 797. However, the estimated age for the event is approximately 1 Ma younger in these Japan Sea sites than at Pacific sites, and the range of this event is not consistent with the ranges of the species in the North Pacific. Reworking of this species in the sediments complicates the selection of the level of this last occurrence event.

Sethocyrtis japonica (Pl. 3, Fig. 9), *Theocorys redondoensis* (Pl. 3, Fig. 5), and *Lipmanella* sp. aff. *Theocorys redondoensis* (Pl. 3, Fig. 4) appear to be closely related and may possibly share a common evolutionary lineage. Reynolds (1980) suggested that *Sethocyrtis japonica* is the ancestor of *Theocorys redondoensis.* In their overlapping ranges, an intergradation of morphotypes was observed. The complicated evolutionary relationships of these species may explain the apparent

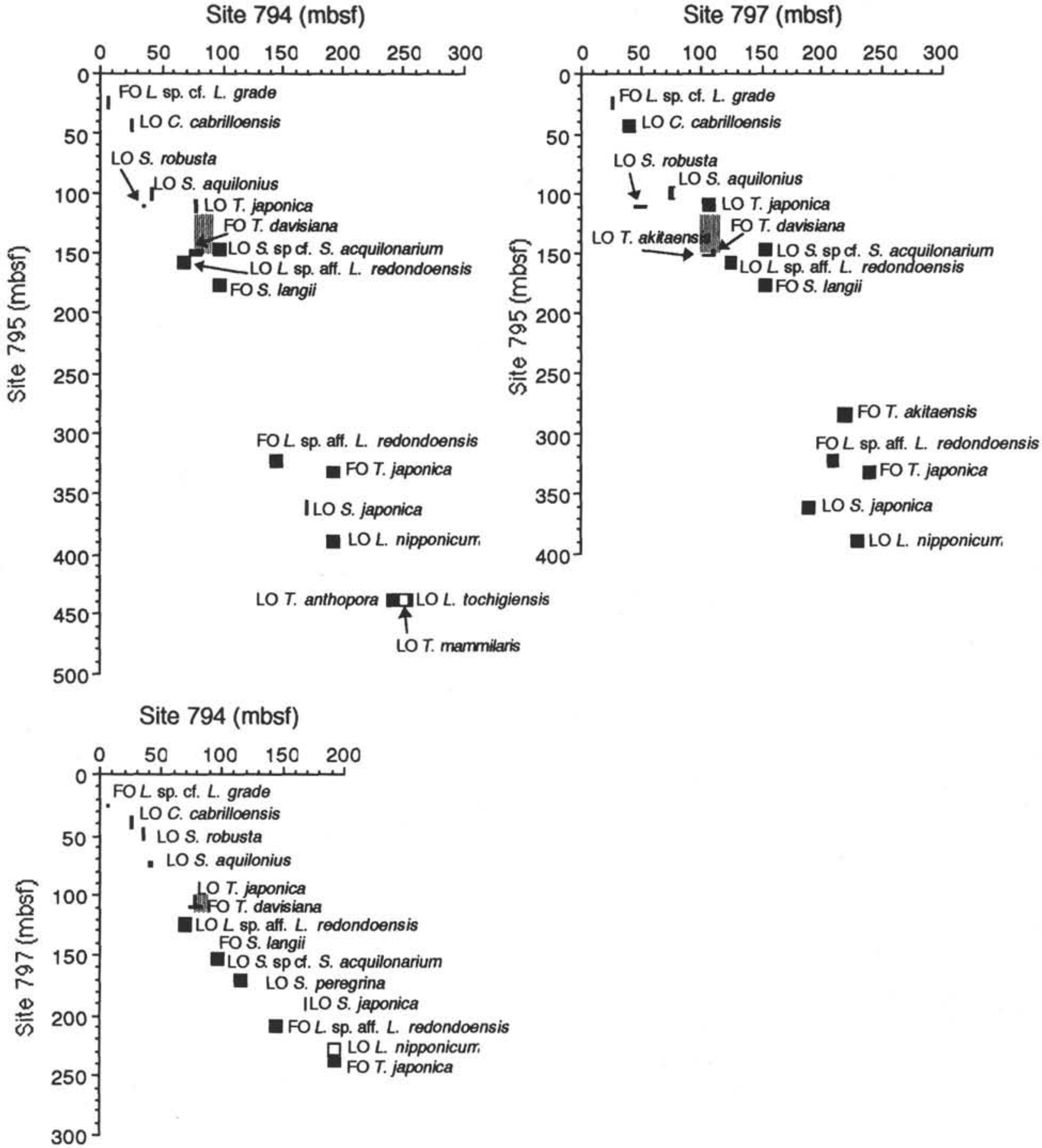

Figure 1. Depth-depth plots comparing the location of radiolarian biostratigraphic events at Leg 127 Sites 794, 795, and 797. The shaded areas denote the opal dissolution transition zone of White and Alexandrovich (this volume), and box sizes represent sample-spacing uncertainties of the datum levels. LO and FO refer to the last-occurrence and first-occurrence datum levels of the species, respectively.

diachroneity of the LO of *S. japonica* (Fig. 1) because it may not be an extinction event but rather a pseudo-extinction event, which is more difficult to define.

PALEOCEANOGRAPHIC IMPLICATIONS OF JAPAN SEA RADIOLARIANS

There are many interesting forms of radiolarians found in the Leg 127 Japan Sea sediments. Many of these have specific ecological tolerances and affinities which can be used to make paleoclimatic and paleoceanographic interpretations. Some Japan Sea radiolarians have undergone morphological changes through time, and can be used to delineate evolutionary histories. A number of noteworthy radiolarian species and lineages with interesting paleoceanographic and evolutionary implications are illustrated and described as follows.

Radiolarian Evidence of a Paleo-Tsushima Current

Shipboard analyses indicated that radiolarians species with subtropical affinities are not present or are not common in three of the sites cored on Leg 127 (Sites 794, 795, and 796), but are common in core-catcher samples from Core 127-797A-8H and above. During Leg 127, Sample 127-796A-6H-CC was the only sample from a site other than Site 797 observed to contain a warmer water assemblage. The subtropical faunal indicators include *Tetrapyle octacantha* (Pl. 4, Figs. 1 and 2), *Didymocyrtis tetrathalamus* (Pl. 4, Fig. 3), a species belonging to the genus *Euchitonia* (Pl. 4, Fig. 7), and *Spongaster tetras.* Shore-based observations indicate that subtropical species are absent from all samples from Hole 795A (Table 3) and are common in samples containing preserved radiolarians from Hole 797B. The first occurrence of these warmer water radiolarian taxa was recorded between Samples 127-797B-9H-6, 118–120 cm, and 127-797B-9H-CC, and the sporadic occurrences of these taxa found in samples from Hole 794A are recorded in Table 5.

Presently Site 797 is situated beneath the Tsushima current (an arm of the warm Kuroshio). The occurrence of warm-water (subtropical) fauna in all samples with preserved radiolarians younger than approximately 1.8 Ma from Hole 797B (Table 4) indicates that the Tsushima current probably flowed into the Japan Sea through much of the Pleistocene. However, because the abundance of Tsushima current indicators goes to zero in the Hole 797B barren samples, there may have been intermittent flow of the Tsushima current since this time. In addition, because *Tetrapyle octacantha* is present in low abundance in the cooler glacial period (Morley et al., 1986), its presence in the Hole 794A samples may record the increased influence of the Tsushima current. These conclusions largely contradict the supposition of Oba et al. (1991) that warmer water from the Tsushima current did not enter the Japan Sea until approximately 10,000 yr ago, but is in agreement with Matoba (1984), who indicated that there was intermittent influx of the Tsushima current since late Pliocene time. If there was a land barrier at the Tsushima Strait throughout most of the Pleistocene (Oba et al., 1991; and Iijima and Tada, 1990), then the occurrence of subtropical radiolarian fauna throughout the Pleistocene would imply that temperatures over Site 797 were much warmer than at the northern sites. It is not likely that warm temperatures could be solely responsible for the persistence of subtropical radiolarians at Site 797, because the influx of the Tsushima current into the Japan Sea is presently responsible for the temperate climate of the region.

Cycladophorid Radiolarians

Several described taxa compose the Cycladophorid radiolarians in the Leg 127 Japan Sea sediments. These species include *Theocalyptra davisiana* (Pl. 1, Fig. 6, and Pl. 4, Fig. 8), *Cycladophora robusta, Clathrocyclas cabrilloensis,* and *Anthocorys akitaensis* (Pl. 5). Many morphological intergrades were observed in addition to these species, and identification at the species level was hindered by the abundance and diversity of Cycladophorid forms. *Cycladophora robusta* (Pl. 5, Figs. 11 and 12), a probable ancestor of *Theocalyptra davisiana,* is present in Miocene samples, but its stratigraphic range was not determined. If *Cycladophora robusta* had an ecological niche similar to its probable descendant *Theocalyptra davisiana,* the high abundances of *Cycladophora robusta* observed in samples suggests that cold conditions with a stable upper layer (Morley and Hays, 1983) persisted throughout the entire interval of its range. The fluctuations in the abundance of this radiolarian could imply that these conditions also fluctuated.

Radiolarian Productivity and Paleoclimatic Indicators

In general, except for the Tsushima current indicators found in Pleistocene samples from Sites 797 and 794, samples examined from the Japan Sea Leg 127 sites contain cool-water radiolarian assemblages. The consistent occurrence of Spongodiscid radiolarians such as *Spongotrochus glacialis* is indicative that upwelling has persisted in the Japan Sea since the late Miocene. In addition, the negative evidence of the lack of collosphaerid radiolarians in the assemblages, as discussed previously, also indicates that productivity in the Japan Sea was high. There are many other radiolarians found in the Leg 127 Japan Sea sediments that can be used to record fluctuations in water mass properties, such as the species *Larnacantha polyacantha, Theocalyptra davisiana, Stylochlamydium venustum,* and *Tetrapyle octacantha,* which define the paleoceanographic factors determined by Morley et al. (1986) from an 80,000-yr-long record from core RC12-379 in the Japan Sea. These same radiolarian factors can be used to describe the radiolarian assemblages at Site 797, but will probably not be very useful at the other sites (Sites 794, 795, and 796) due to the lack of the important species *Tetrapyle octacantha.*

Radiolarians from Japan Sea Pleistocene Light and Dark Cycles

An interesting feature of the Leg 127 Japan Sea sediments is the occurrence of distinct light- and dark-color banding. The controls of these Pleistocene light and dark cycles are not well understood and are probably dependent on many factors such as tectonics, sea level, Northern Hemisphere glaciations, deep-water oxygen content, climate, and productivity. Shipboard analyses indicated that the most distinctive feature of the radiolarian assemblages observed in the cyclical Pleistocene sediments of the Japan Sea is high variability in preservation and assemblage composition. Therefore, observations of the details of radiolarian preservation and species composition from the light and dark cycles were made. The occurrence of nonradiolarian material such as sand-sized grains and sponge spicules was also noted.

Radiolarian paleontological samples were not taken for the specific study of light and dark layers and were not obtained at the resolution required to quantify changes in radiolarian assemblages that occur on the time scales of the cycles. By noting if samples from Holes 794A and 797B processed for radiolarians came from dark layers by an examination of the core photos (Tables 2 and 4), a preliminary analysis of the relationship between radiolarian assemblages and sediment banding could be made. No obvious correlation is found between radiolarian assemblage composition or preservation and light and dark color banding. However, because most distinctive dark layers were not sampled, the conclusion that radiolarian assemblage changes can not be related to the light and dark color banding of Leg 127 Japan Sea sediments can not be made. Although no properties observed in radiolarian samples correlate directly with light and dark color banding, it is possible that the variability in the abundance of *Theocalyptra davisiana* could be correlated to the light and dark cycles. If the correlation of light and dark layers of Japan Sea sediments to the global benthonic oxygen isotope record is correct (Tada, this volume), *Theocalyptra davisiana* stratigraphy could also be correlated to the cyclicity of light and dark layers because *Theocalyptra davisiana* records from other deep sea cores have been correlated to records of $\delta^{18}O$ (Hays et al., 1976, and Morley and Hays, 1979).

Changes in Japan Sea Sill Depths and Isolation of Evolutionary Lineages

Much more work needs to be performed to determine the evolutionary history of radiolarian assemblages found in Japan Sea sediments. Even with an incomplete understanding of these histories, the paleontological records of radiolarian assemblages from Japan Sea ODP Sites 794, 795, and 797 suggest that radiolarians have been influenced by the changing oceanography of the Japan Sea. The isolation of this marginal basin is illustrated by the lack of stratigraphic indicator species found in the sediments of the North Pacific (such as species found by Sakai, 1980). The sporadic occurrence (with common abundances) of radiolarians such as *Lamprocyrtis heteroporos,* and *Eucyrtidium matuyamai* and the occurrence of several stratigraphic indicators found outside the Japan Sea suggest that although there was communication between the Japan Sea and the Pacific throughout the Miocene and Pliocene, the water mass present in the Japan Sea must have had properties unique to this marginal basin and mixing with the Pacific was limited.

Tectonic changes as well as climatic changes of the Japan Sea have played a very important role in shaping the late Pliocene and Pleistocene Leg 127 radiolarian assemblages. Subtropical radiolarians in Japan Sea sediments record the influence of the sill at the Tsushima Strait, and the opal dissolution transition zone reflects communication with the Pacific at the Tsugaru Strait (White and Alexandrovich, this volume). The fact that many of the Miocene and Pliocene deposits studied on Japan contain radiolarian species common in the North Pacific (e.g., Nakaseko and Sugano, 1973), whereas most sediments of this age recovered during Leg 127 are lacking these same species, implies that the intra-arc deep-sea basins (Iijima and Tada, 1990) where these sediments were deposited had a more extensive connection with the waters of the North Pacific than did the major basins within the Japan Sea and that the presence of the islands of Japan formed a significant barrier between the Pacific and the Japan Sea.

SUMMARY

Radiolarians from the Japan Sea Leg 127 sediments are diverse and many interesting morphotypes are found. There are 25 relatively reliable biostratigraphic events found in these sediments, and because there are many forms of radiolarians present in these samples that have not been identified, more events are likely to be found. Depth-depth plots of the radiolarian datum levels from Sites 794, 795, and 797 show that additional stratigraphic evaluation is needed to refine the stratigraphic resolution of the radiolarian datum levels and correlations between sites.

Sediments of the Leg 127 sites provide excellent material for study of the controls of radiolarian preservation because several states of preservation are observable in the assemblages. The differing states of radiolarian preservation in the Japan Sea sediments record several different processes. Radiolarian assemblages from sediments in the Japan Sea with high indices of refraction suggest that dissolution probably occurred after deposition, either on the seafloor or within the sediment column, whereas concentrations of dissolution-resistant forms and/or radiolarian fragments suggest that dissolution probably occurred during deposition.

Compositional and preservational changes of radiolarians found in the Leg 127 sediments resulted from the unique oceanographic conditions in the Japan Sea and can be used to trace fluctuations of the paleo-Tsushima current, and the dissolution of radiolarian tests that may be related to changes in productivity, dissolved silicon concentration, and tectonics. Faunal changes observed in the Site 797 and 794 sediments indicate that the Japan Sea has been influenced by the Tsushima current as early as the late Pliocene or early Pleistocene (~1.8 Ma). The absence of biostratigraphic events recorded in the Pacific suggests that sill depths played an important role in determining the species composition of the radiolarian assemblages.

Because the evolutionary taxonomy of radiolarians found in the Japan Sea sediments is rather poorly developed, the cores from the Leg 127 sites provide a wealth of material for further study. Qualitative observations of the Leg 127 radiolarian assemblages revealed that there are many interesting morphological changes observable in radiolarian lineages, but evolutionary relationships between morphotypes are complex. There are a number of very unusual, as well as less distinctive, forms of radiolarians that have unknown species affiliations present in the samples, and large fluctuations in the ratio between spumellarian and nassellarian radiolarians may be an important paleontological record. Future studies that quantify the radiolarian paleontology of sediments obtained during Leg 127 are sure to reveal many interesting facts.

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APPENDIX

Systematic Species List

Radiolarians species discussed and figured in the plates of this report are listed below in alphabetical order. References to original and nominal descriptions and some taxonomic notes are provided.

Anthocorys akitaensis Nakaseko, 1969
(Pl. 5, Figs. 1, 2, and 3)

Botryostrobus bramlettei (Campbell and Clark, 1944) Nigrini, 1977

Clathrocyclas cabrilloensis Campbell and Clark, 1944
(Pl. 5, Figs. 7, 8, 9, and 10)

Cycladophora robusta Lombari and Lazarus, 1988
(Pl. 5, Figs. 11 and 12)

Cyrtocapsella tetrapera Haeckel, 1887
(Pl. 2, Figs. 4 and 5)

Didymocyrtis tetrathalamus (Haeckel, 1887) Sanfilippo and Riedel, 1980
(Pl. 4, Fig. 3)

Euchitonia species
(Pl. 4, Fig. 7)

Remarks. Specimens identified as belonging to the genus *Euchitonia* probably belong to the species *Euchitonia elegans, Euchitonia furcata,* or *Euchitonia triangulum.*

Eucyrtidium matuyami Hays, 1970

Lamprocyrtis heteroporos (Hays, 1965) Kling, 1973

Larnacantha polyacantha Campbell and Clark, 1944
(Pl. 4, Fig. 5)

Remarks. This species is equivalent to *Phorticium pylonium* Haeckel, used in faunal analyses of Robertson (1975), and Morley et al. (1986).

Lipmanella sp. aff. *Theocorys redondoensis* Reynolds, 1980
(Pl. 3, Fig. 4)

Lithatractus tochigiensis Nakaseko, 1969
(Pl. 3, Fig. 10)

Lychnocanium nipponicum Nakaseko, 1963
(Pl. 3, Fig. 8)

Lychnocanium sp. cf *L. grande* Campbell and Clark, 1944
(Pl. 3, Fig. 1)

Peripyramis species
(Pl. 2, Fig. 3, and Pl. 4, Fig. 5)

Remarks. It is hard to identify radiolarians belonging to this genus to the species level, due to the effects of dissolution. Species that may be represented in this category include *Peripyramis circumtexta* Haeckel, 1887 and *Plectopyramis pacifica* Nakaseko, 1963.

Sethocyrtis japonica Nakaseko, 1963
(Pl. 3, Fig. 9)

Remarks. This species actually belongs to the genus *Theocorys* (Reynolds, 1980), however the genus name *Sethocyrtis* has been retained in order to avoid confusion in discussions between this species and the spumellarian *T. (Thecosphaera) japonica.*

Sphaeropyle langii Dreyer, 1889
(Pl. 1, Fig. 7, and Pl. 3, Fig. 3)

Sphaeropyle robusta Kling, 1973
(Pl. 3, Fig. 7)

Spongaster tetras Ehrenberg 1862

Spongotrochus glacialis Popofsky, 1908
(Pl. 4, Fig. 4)

Stichocorys delmontensis (Campbell and Clark, 1944) Sanfilippo and Riedel, 1970

Stichocorys peregrina (Riedel, 1953) Sanfilippo and Riedel, 1970

Stichocorys wolfii Haeckel, 1887

Stylacontarium acquilonius (Hays, 1970) Kling, 1973
(Pl. 3, Fig. 2)

Stylacontarium sp. cf. *S. acquilonarium* (Kling, 1973) Reynolds, 1980

Stylatractus universus Hays, 1970

Stylochlamydium venustum (Bailey, 1856) Haeckel, 1887
(Pl. 4, Fig. 6)

Tetrapyle octacantha Müller, 1858
(Pl. 4, Figs. 1 and 2)

Theocorys redondoensis (Campbell and Clark, 1944) Kling, 1973
(Pl. 3, Fig. 5)

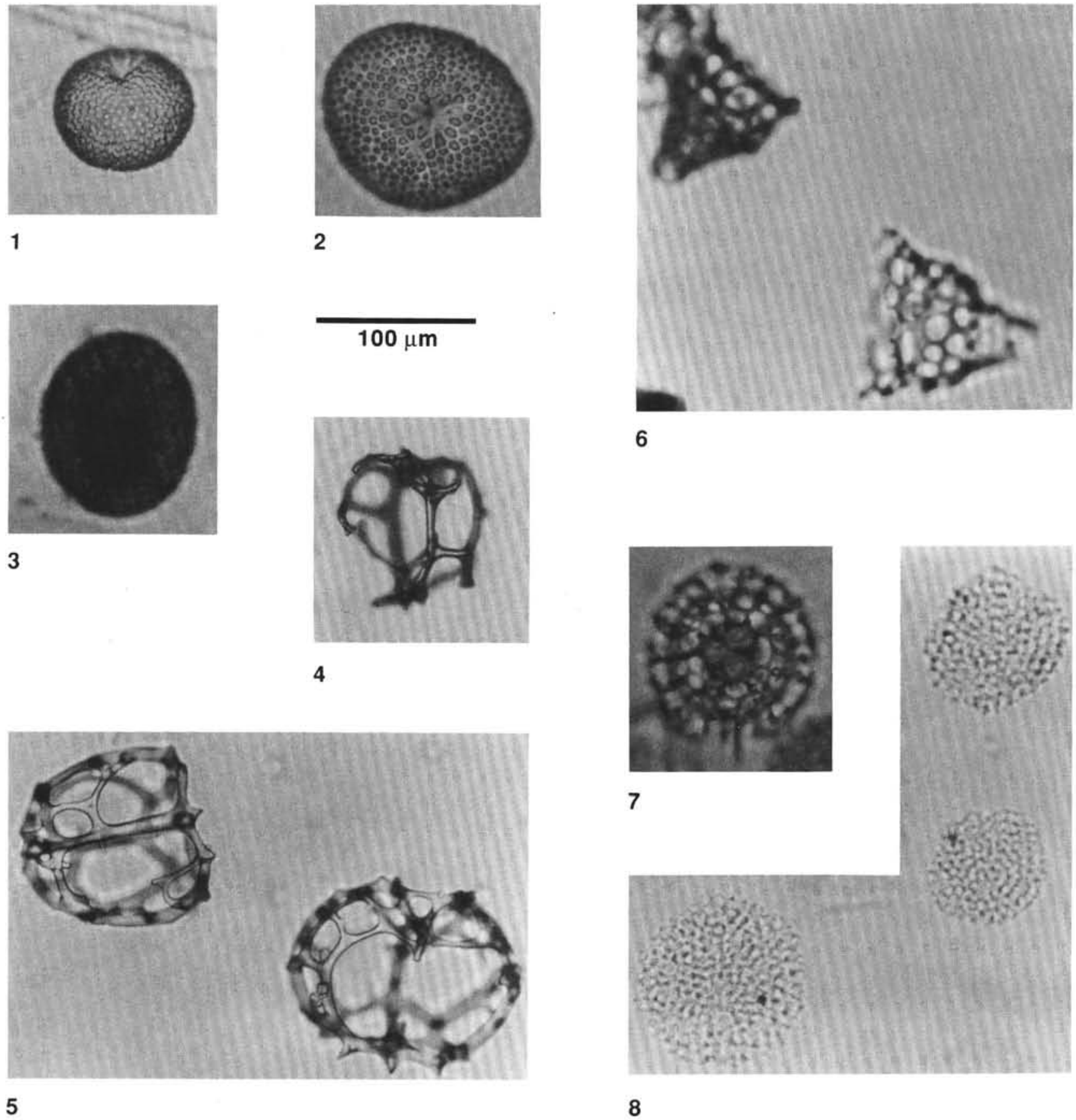
Thecosphaera akitaensis Nakaseko, 1972

Thecosphaera japonica Nakaseko, 1972
(Pl. 3, Fig. 11)

Theocalptra davisiana (Ehrenberg, 1862) Riedel, 1958
(Pl. 1, Fig. 6, and Pl. 4, Fig. 8)

Tholospyris anthopora (Haeckel, 1887) Goll, 1968

Tholospyris mammillaris (Haeckel, 1887) Goll, 1968
(Pl. 3, Fig. 6)



Photographs presented in the following plates were taken using a 35-mm camera mounted on a beam splitter on a Wild M20 microscope. All figures are at the same scale (2.5 cm = 100 μm). EF refers to the England Finder location (Riedel and Foreman, 1961) of the specimen on the sample slide. Samples are kept at the Department of Geology, Florida Atlantic University.

Plate 1. Sterraster sponge spicules and radiolarian indicators of dissolution. **1–3.** Sterraster sponge spicules: (1) Sample 127-794A-1H-3, 60–62 cm, EF T51/1; (2) Sample 127-797B-26X-5, 108–110 cm, EF L47/4; (3) Sample 127-794A-1H-5, 55–57 cm, EF F40. **4, 5.** Trissocyclid radiolarians: (4) Highly dissolved trissocyclid radiolarian representing the only radiolarian recovered from Sample 127-794A-1H-3, 60–62 cm, EF M43; (5) 127-797B-10H-4, 118–120 cm, EF O39. **6.** *Theocalyptra davisiana*. These two specimen show two states of index of refraction of the same species in Sample 127-795A-12H-1, 70–72 cm, EF Q40/3. Top left has low index of refraction and bottom right has high index of refraction. **7.** *Sphaeropyle langii*. Partially dissolved or juvenile specimen missing cortical shell from Sample 127-795A-12H-5, 70–72 cm, EF L35/3. **8.** Spongodiscid radiolarians displaying high index of refraction from Sample 127-797B-4H-1, 118–120 cm, EF W44/3.

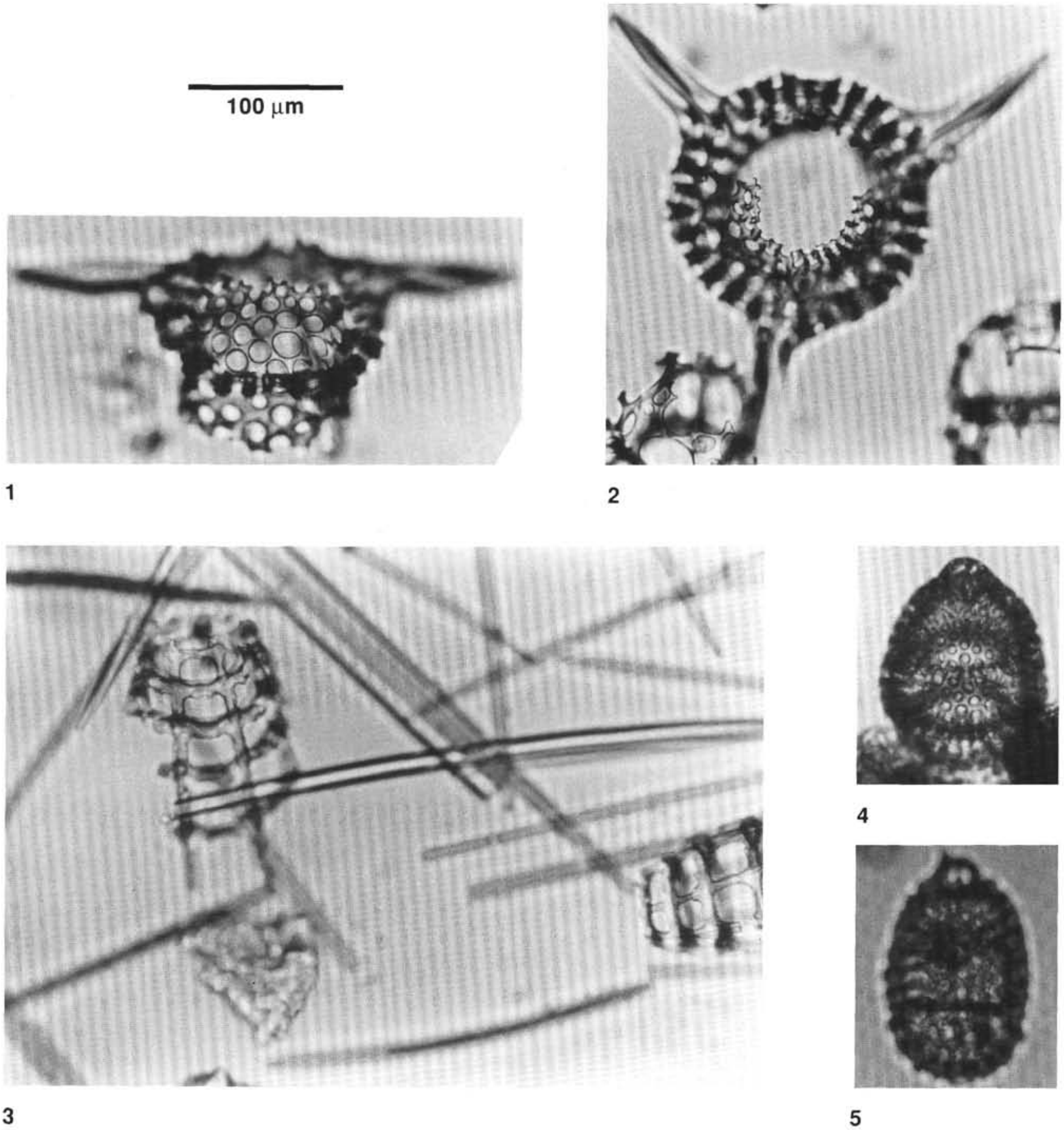


Plate 2. Radiolarian indicators of dissolution and reworking. **1, 2.** Two views of an unidentified nassellarian radiolarian, present in high abundance, but found only as broken specimens indicating disturbance and reworking. Both figures are from Sample 127-794A-4H-6, 60–62 cm: (1) EF U46/2; (2) EF M37/3. The presence of high numbers of trissocyclid radiolarians (Fig. 2) in this sample is another indicator that this sample has been subjected to high levels of dissolution. **3.** Highly dissolved specimen of the species *Peripyramis circumtexta* or *Circumtexta pacifica*, and sponge spicules in Sample 127-795A-12H-2, 70–72 cm, EF V25/4. **4, 5.** *Cyrtocapsella tetrapera*: (4) found as an indicator of reworking in Pleistocene Sample 127-797B-7H-2, 118–129 cm, EF P48/1; and (5) within its actual stratigraphic range in Sample 127-794B-5R-CC, EF V13.

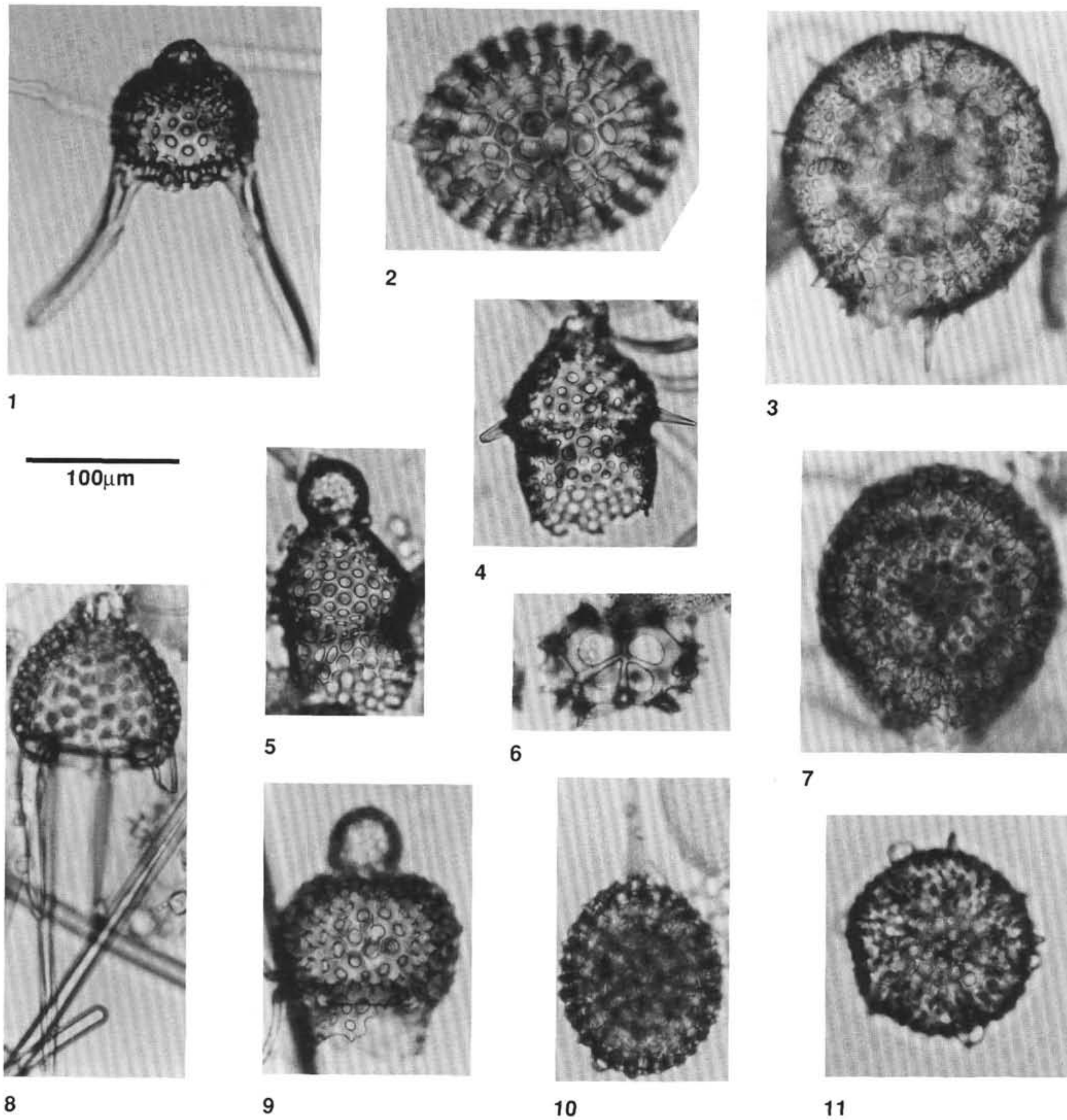


Plate 3. Japan Sea radiolarian stratigraphic indicators. **1.** *Lychnocanium* sp. cf *L. grande*. Sample 127-797B-2H-5, 118–120 cm, EF M52. **2.** *Stylacontarium acquilonius*. Sample 127-794A-7H-6, 60–62 cm, EF Q31. **3.** *Sphaeropyle langii*. Sample 127-794A-11H-3, 60–62 cm, EF H2/3. **4.** *Lipmanella* sp. aff. *Theocorys redondoensis*. Sample 127-794A-19X-2, 60–62 cm, EF R40/4. **5.** *Theocorys redondoensis*. Sample 127-794A-19X-1, 60–62 cm, EF Y43. **6.** *Tholospyris mammilaris*. Sample 127-794A-29X-1, 60–62 cm, EF X29/3. **7.** *Sphaeropyle robusta*. Sample 127-797B-23X-5, 108–110 cm, EF S4. **8.** *Lychnocanium nipponicum*. Sample 127-797A-26X-5, 108-110 cm, EF G33/3. **9.** *Sethocyrtis japonica*. Sample 127-794A-28X-2, 60–62 cm, EF Z47/4. **10.** *Lithatractus tochigiensis*. Sample 127-794A-29X-1, 60–62 cm, EF V35/3. **11.** *Thecosphaera japonica*. Sample 127-795A-12H-1, 70–72 cm, EF R49.

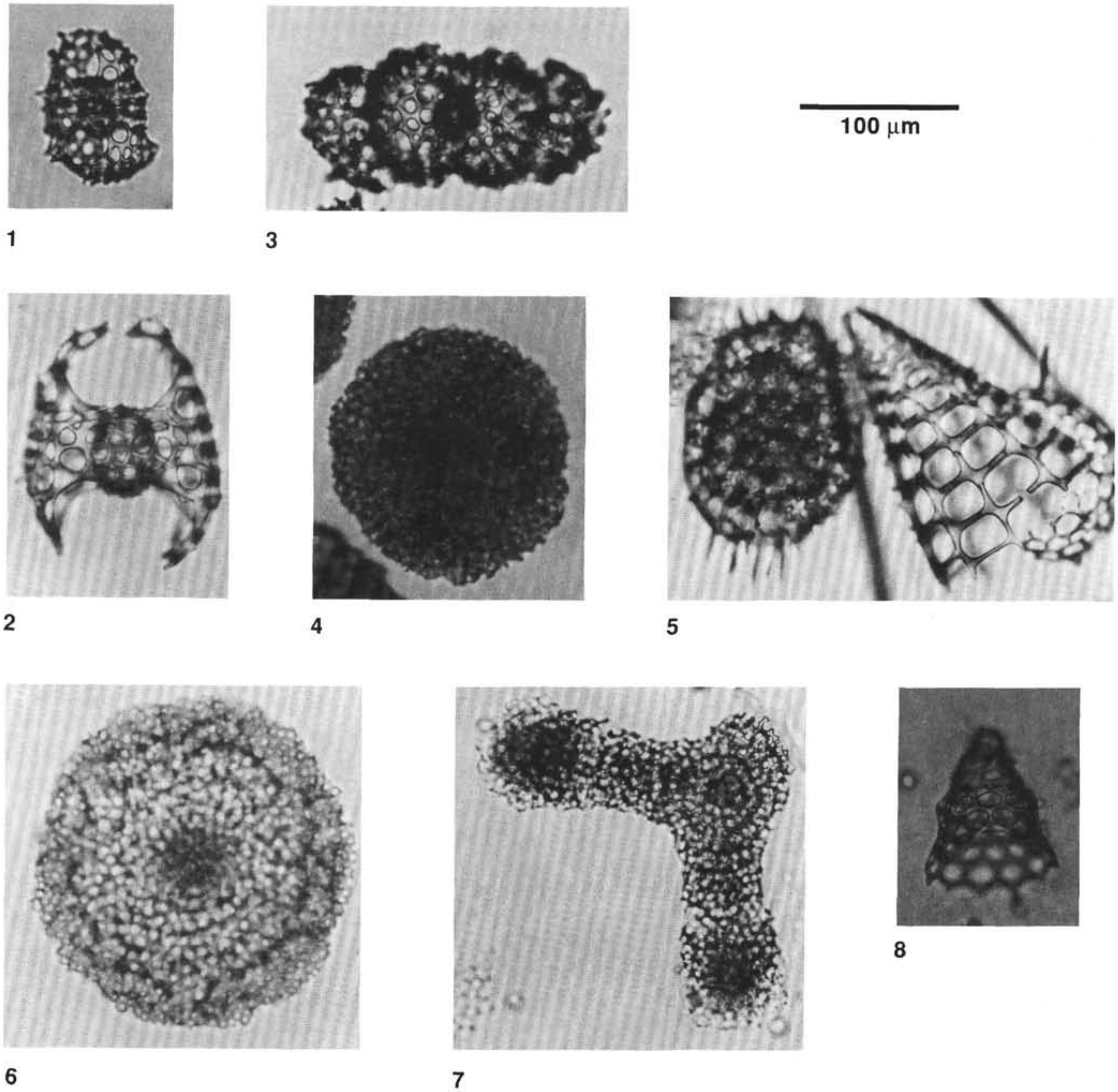


Plate 4. Japan Sea radiolarian paleoceanographic indicators. **1, 2.** *Tetrapyle octacantha*: (1) Sample 127-794A-6H-2, 59–61 cm, EF X47/2; (2) Sample 127-797B-7H-3, 117–119 cm, EF Y43/4. **3.** *Didymocyrtis tetrathalamus*. Sample 127-797B-8H-4, 118–120 cm, EF T45. **4.** *Spongotrochus glacialis*. Sample 127-795A-19H-4, 73–75 cm, EF H41/3. **5.** *Larnacantha polyacantha* on left and *Peripyramis* species on right. Sample 127-795A-15H-1, 73–75 cm, EF C33/2. **6.** *Stylochlamydium venustum*. Sample 127-797B-8H-1, 118–120 cm, EF R20/1. **7.** *Euchitonia* species. Sample 127-794A-3H-2, 60–62 cm, EF X16. **8.** *Theocalyptra davisiana*. Sample 127-794A-6H-1, 59–61 cm, EF W11.

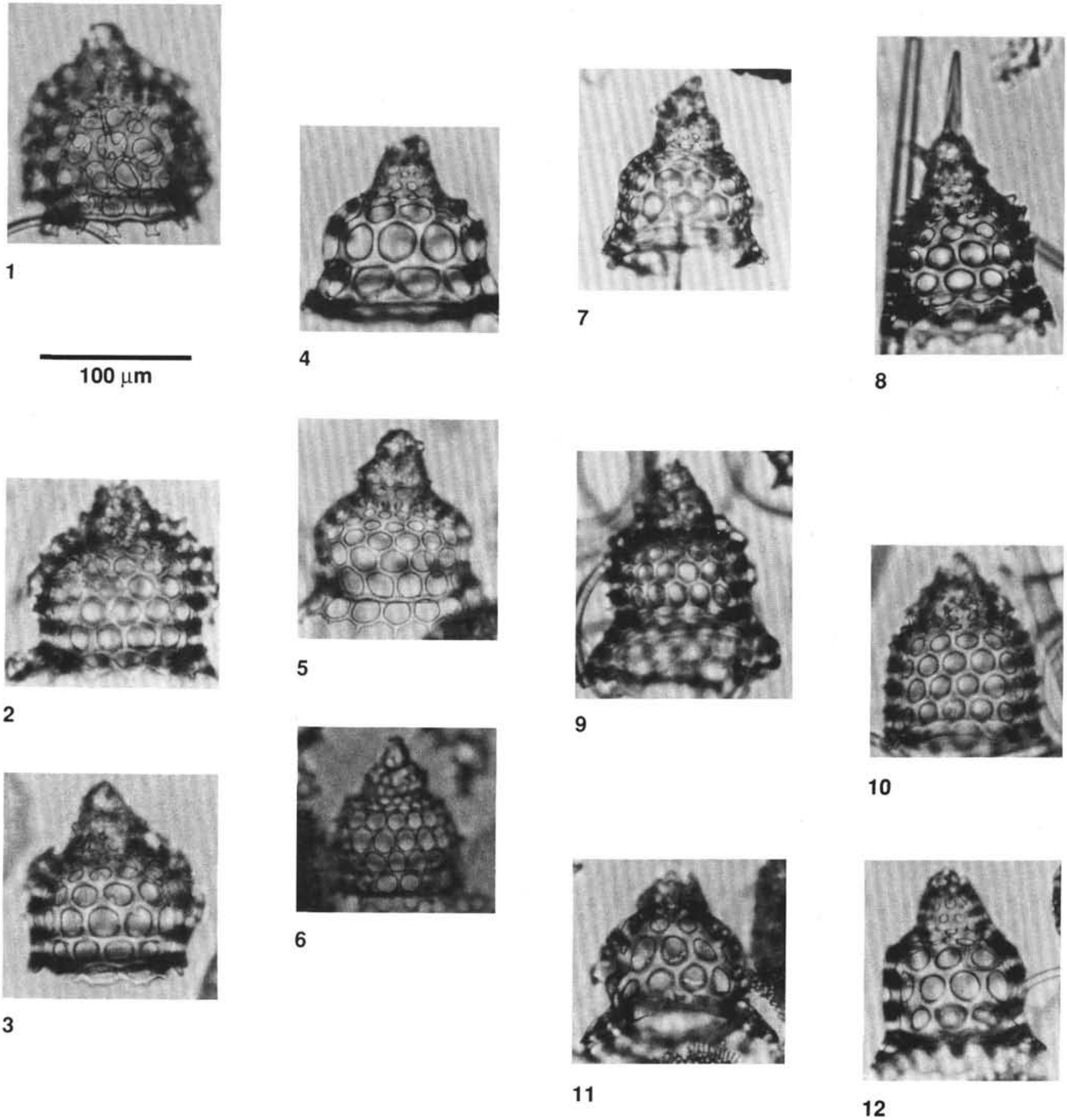


Plate 5. Synchronopticon of Cycladophorid radiolarians showing some of the variability of these forms in Japan Sea sediments. Horizontal level of the top of each photo represents relative age of radiolarian (youngest at top, oldest at bottom. Ages listed with samples are calculated using the age model listed in Tamaki et al. (1990) and summarized in White and Alexandrovich (this volume). **1–3.** *Anthocorys akitaensis*: (1) age = 0.29 Ma, Sample 127-797B-2H-5, 118–120 cm, EF N21; (2) age = 3.3 Ma, Sample 127-797B-17H-7, 118–120 cm, EF J25/4; (3) age = 5.3 Ma, Sample 127-797B-26X-5, 108–110 cm, EF L47/4. **4–6.** Unidentified Cycladophorid radiolarians: (4) age = 1.4 Ma, Sample 127-794A-6H-2, 59–61 cm, EF H26; (5) age = 2.7 Ma, Sample 127-794A-9H-6, 59–61 cm, EF S13/4; (6) age = 5 Ma, Sample 127-794A-17H-6, 60–62 cm, EF T25/1. **7–10.** *Clathrocyclas cabrilloensis*: (7) age = 1.2 Ma, Sample 127-794A-5H-5, 58–60 cm, EF Q26; (8) age = 1.1 Ma, Sample 127-797B-6H-4, 110–112 cm, EF T15/4; (9) age = 2.9 Ma, Sample 127-794A-10H-6, 60–62 cm, EF K13; (10) age = 3.8 Ma, Sample 127-797A-20X-4, 108–110 cm, EF Q26/4. **11, 12.** Two specimens of *Cycladophora robusta* from Sample 127-794A-28X-2, 60–62 cm, age = 7.2 Ma: (11) with lace, EF W47; (12) without lace, EF X34/2.