10. TROPICAL PACIFIC SILICOFLAGELLATE ZONATION AND PALEOTEMPERATURE TRENDS OF THE LATE CENOZOIC[1]

David Bukry, United States Geological Survey, Scripps Institution of Oceanography[2]

ABSTRACT

Quantitative study of late Cenozoic silicoflagellates at tropical Pacific DSDP Sites 572 and 575 shows that the greatest amplitude of fluctuation in relative paleotemperature values occurred in the late Miocene. The coolest minimum paleotemperature values (near $Ts = 30$) also occurred in the late Miocene. The warmest intervals ($Ts = 80$ to 100) occurred in the middle Miocene and late Pliocene to Quaternary. In detail, the silicoflagellate relative paleotemperature curve correlates fairly well with the eustatic sea-level curve and deep-sea hiatus sequence.

The only upper Cenozoic low-latitude biostratigraphic units not identified are the *Distephanus speculum haliomma* Subzone and *Naviculopsis quadrata* Zone, owing to the absence of the nominative species, which probably had nontropical ecologic preference. Several *Naviculopsis* occurrence events within the *Naviculopsis ponticula* Zone correlate between DSDP Hole 575A and DSDP Hole 495 off Guatemala. Many local and regional biostratigraphic events are recognized.

New taxa identified from DSDP Leg 85 include *Dictyocha nola* Bukry, n. sp., *Distephanus stradneri* var. *grandis* Bukry, n. var., *Mesocena elliptica* var. *rhomboidea* Bukry, n. var., and *Naviculopsis obtusarca* var. *acicula* Bukry, n. var.

INTRODUCTION

A composite section of upper Cenozoic sediment, rich in siliceous skeletons, from the equatorial Pacific at DSDP Sites 572 and 575 was studied quantitatively for silicoflagellate relative-paleotemperature trends and biostratigraphic zonation. This composite section (Hole 572A, Cores 1 to 17; Hole 572D, Cores 1 to 33; and Hole 575A, Cores 1 to 33) provides a tropical and open-ocean comparison with the previous quantitative studies of silicoflagellates recovered nearer the Pacific coast, from California to Ecuador (DSDP Legs 63 to 69). Relations examined in this study include the correlation of early Miocene *Naviculopsis* between DSDP Site 495, off Guatemala, and DSDP Site 575; the paleotemperature significance of *Naviculopsis;* and the distribution of silicoflagellates through the lower Miocene, which has been poorly known in the Pacific area. Also examined are the pattern of the *Ts* paleotemperature curve relative to Pacific currents and eustatic sea-level changes. The possible changing significance of certain silicoflagellate morphologies, such as quadrate and hexagonal *Distephanus*, for paleotemperature is discussed with reference to previous DSDP investigations for higher latitudes.

Early occurrence data on tropical eastern Pacific silicoflagellates for DSDP Leg 9 sites were provided by D. Milow and published in Volume 9 of the *Initial Reports*[3]; those data, however, were nonquantitative. Similarly, a subsequent study of DSDP eastern Pacific silicoflagellates by Ling (1977) examined some tropical sites to provide a biostratigraphic framework, but yielded no quantitative data needed for paleoecological comparison or correlation. Quantitative data for upper Cenozoic silicoflagellate assemblages are available in Volumes 16, 54, and 67 to 69 of the *Initial Reports*.

METHODS AND MATERIALS

Acid-residue strewn slides were prepared for 136 samples from DSDP Holes 572A, 572D, and 575A. Light-microscope counts of silicoflagellates were made at the generic level for Holes 572A and 572D; some stratigraphic and ecologic key species also were counted. The light-microscope counts of silicoflagellates were made at more detailed subgeneric levels for Hole 575A, but diversity was low in these less abundant assemblages.

Identifications were made at magnifications of $250\times$ to $500\times$. Broken specimens possessing the apical structure were counted as whole specimens, but other broken segments were not counted; breakage was minor, though (typically less than 5%). Counts of 300 specimens or one complete slide area (22×40 mm) were made to compute percentages. For the sparse assemblages of Hole 575A, counts were terminated at the round figures of 50 or 100 if only a little slide area remained uncounted. Percentages were not calculated for populations of less than 50 specimens because of the unlikelihood of consistent rankings.

Many of the Leg 85 samples examined are the same sample preparations used, aboard ship and ashore, for diatom studies (Barron, this volume). These samples, kindly made available by John A. Barron, permit better age control and correlation of the silicoflagellates with diatoms for Leg 85 and other eastern Pacific cruises, such as Legs 54 and 67 to 69. Diatom ages for Leg 85 were provided by John A. Barron (personal communication, 1983).

The basis for relative paleotemperature values (*Ts*) and biostratigraphic zonation for silicoflagellates has been given by Bukry (1981a, 1981b, and 1983). Species distributions are compared against those at other DSDP sites in the eastern Pacific region (Fig. 1) and more distant Pacific and Atlantic sites.

COMMENTS ON SILICOFLAGELLATE ZONES

Low-latitude zones (Table 1) can be applied through the lower Miocene to the Quaternary composite section formed by DSDP Holes 572A, 572D, and 575A (Tables 2 to 5). The only missing biostratigraphic units, defined
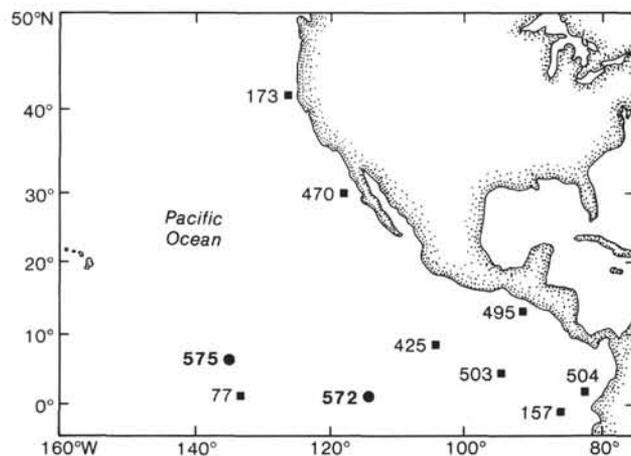
Figure 1. Locations of silicoflagellate-rich DSDP sites in the eastern Pacific, referred to in text. DSDP Leg 85 sites are shown by circles.

Table 1. Late Cenozoic low-latitude silicoflagellate zonation (Bukry, 1981b and 1983).

Age	Zone	Subzone
Quaternary	Dictyocha aculeata	
	Mesocena quadrangula	
late Pliocene	Dictyocha stapedia	Dictyocha delicata
		Dictyocha ornata ornata
early Pliocene	Dictyocha fibula	Dictyocha angulata
		Dictyocha pulchella
late Miocene		Dictyocha neonautica
	Dictyocha brevispina	
middle Miocene	Corbisema triacantha	Distephanus stauracanthus
		—
early Miocene	Naviculopsis ponticula	
	Naviculopsis quadrata[a]	
	Naviculopsis lata	
Oligocene	Naviculopsis biapiculata	Distephanus speculum haliomma[a]
		—

[a] Not identified at DSDP Leg 85 sites.

for low to middle latitudes (Bukry, 1981b), are the *Naviculopsis quadrata* Zone and the *Distephanus speculum haliomma* Subzone. The guide species for these zones are missing from the tropical assemblages of Leg 85, but are present at middle and high latitudes (e.g., DSDP Legs 38, 41, and 49). Comments on the Leg 85 zonal assemblages follow.

Naviculopsis biapiculata Zone

The zonal assemblages of the *Naviculopsis biapiculata* Zone are sparse, with no *Corbisema* or *Mesocena* (Table 2). *Distephanus speculum patulus, Naviculopsis*

biapiculata s. ampl., and *N. constricta* are the most distinctive taxa present at Hole 575A. No specimens of subzonal guide taxa *Distephanus speculum haliomma* or *D. speculum hemisphaericus* are present at Hole 575A, suggesting that they are more useful for biostratigraphy at middle or high latitudes, where their occurrence is more consistent. One new variety, *Distephanus stradneri* var. *grandis*, n. var., is limited here to the *N. biapiculata* Zone.

Naviculopsis lata Zone

A transition from *Distephanus schauinslandii* to *D. crux scutulatus* appears to occur in the *N. lata* Zone of Hole 575A (Plate 3, Figs. 2–5, 7, 8). *D. speculum patulus* is prominent, along with *N. biapiculata* s. ampl. and *N. lata* (Table 3). The absences of *Corbisema triacantha* and the *Mesocena apiculata* group contrast with high-latitude assemblages preserved at DSDP Site 407 west of Iceland. *N. lata* is more abundant at tropical DSDP Site 575 (Hole 575A) than at higher-latitude sites, suggesting that *N. lata* had a warm-water preference, which makes it a good biostratigraphic guide for low latitudes.

Naviculopsis quadrata Zone

The interval between the first *Naviculopsis quadrata* and the first *N. ponticula* or the last *N. quadrata* defines the *Naviculopsis quadrata* Zone (Bukry and Foster, 1974; Bukry, 1981a). Owing to the very poor silicoflagellate assemblage in Core 13 of Hole 575A and the absence of *N. quadrata*, no *N. quadrata* Zone can be identified at Hole 575A (Table 3). The tropical location of Leg 85 sites probably precludes good representation of the *N. quadrata* Zone, because *N. quadrata* favors cooler regions. For example, high-latitude DSDP Site 338, off Norway, has up to 16% *N. quadrata*, whereas coeval assemblages at mid-latitude DSDP Site 369, off northwest Africa, contain a maximum of only 1% *N. quadrata*.

The higher abundance of *N. quadrata* and the lower abundance of *N. lata* (1 or 2%) at high latitude, seen for DSDP Sites 338 and 369, show a trend that is supported by the high (48%) abundance of *N. lata* and by the absence of *N. quadrata* at tropical Hole 575A. If this indicated difference in paleogeographic preference is confirmed at other lower Miocene localities, then the biostratigraphic application of *Naviculopsis* would be linked closely with paleoceanographic interpretations of the assemblages. Whole-assemblage taxonomy and *Ts* calculation may be needed to help define the lower Miocene *Naviculopsis* stratigraphy (see the section on Silicoflagellate *Ts* Comparison).

Naviculopsis ponticula Zone

At Hole 575A, the *Naviculopsis ponticula* Zone is identified by the range of *N. ponticula*. *N. ponticula spinosa* is the dominant *Naviculopsis* at the top of the zone, but maximum numbers of *N. ponticula* occur in the lower part of the zone. *N. ponticula* is missing in the middle part of the zone, where the *Naviculopsis* population is dominated sequentially by *N. obtusarca* and *N. contraria* (Table 3). A similar distribution was recorded off Guatemala in the *N. ponticula* Zone of DSDP Site

Table 2. Early Miocene silicoflagellate biostratigraphy, relative paleotemperature values (*Ts*), and percent distribution of various genera and morphologic subgroups, with remarks on significant occurrences for Hole 575A.

Zone	Core-Section, interval (cm)	Sub-bottom depth (m)	Total specimens	Ts value	Corbisema	Dictyocha	Distephanus (quadrate)	Distephanus (nonquadrate)	Mesocena (quadrate)	Mesocena (nonquadrate)	Naviculopsis	Octactis	Noteworthy occurrences
							Generic percents						
C. triacantha	1,CC	99	50	98	96	4							Only asperoid *Dictyocha*
	2,CC	102	18	—									
	3,CC	105	7	—									
	4,CC	110	100	51		1	99						
	5,CC	114	50	46	2	2	84	8					
N. ponticula	6,CC	119	100	61	8		38	20			34		*Naviculopsis ponticula spinosa* (30%) acme
	7-2, 42–43	121	50	44			74	16	6		4		
	7-3, 24–25	122	100	53	3		57	17	4		19		
	7,CC	123	50	50			48	16	20		16		
	8-1, 42–43	124	24	—									Solution-thinned specimens
	8-2, 42–43	125	50	51			4	28	38		30		
	8,CC	126	200	90		1	4	9			87		*Naviculopsis contraria* (87%) acme
	9-2, 42–43	127	100	72			6	25			69		
	9,CC	128	300	81			10	2	22		65		
	10-2, 42–43	129	100	96			7	1			92		
	10-3, 42–43	130	50	96			4	2			94		*Naviculopsis obtusarca* (66%) acme
	10,CC	132	30	—									
	11-3, 24–25	134	100	82	2		32	2			64		
	11,CC	136	100	86			25				73		
	12,CC	139	100	49			94	4			2		
—	13,CC	143	10	—									
N. lata	14,CC	146	100	73			1	27			72		
	15,CC	149	50	72	20	10		22			47		Second acme of *Naviculopsis lata*
	16,CC	152	50	91	16	10		4			70		*Distephanus crux scutulatus* evolved from *D. schauinslandii*
	17,CC	154	300	74	6		38	8			49		
	18,CC	157	100	65			44	12			43		
	19,CC	161	100	72			1	28			71		First acme of *Naviculopsis lata*
	20,CC	165	12	—									
N. biapiculata	21,CC	169	80	91			1	9			90		
	23,CC	175	100	93	2	1		7			90		
	27,CC	188	9	—									
	29,CC	194	17	—									
	33,CC	208	27	—									Only *Distephanus* occurs

Note: Species distribution for Hole 575A is shown in Table 3. The top of Hole 575A in Core 1 is older by about 1 m.y. than the base of Hole 572D, according to diatom and paleomagnetic correlation (John Barron, personal communication, 22 Aug. 1983).

495 (Bukry, 1982a). The two stratigraphic sequences differ in the presence of an *N. lacrima* acme horizon at Site 495 and the greater abundance of *N. ponticula* near the top of the zone at Hole 575A. There is an unusual positive correlation between the two sites in the exceptionally high abundance of cruxoid *Distephanus* just above the lower zone boundary (85% at Site 495 and 94% at Hole 575A) and just above the upper zone boundary (83% at Site 495 and 84% at Hole 575A). *Mesocena elliptica* var. *rhomboidea*, n. var. is also essentially limited to the zone at both sites. These distinctive silicoflagellate stratigraphic similarities and the fast plate-tectonic spreading in the region of Site 495 and Hole 575A (van Andel and Bukry, 1973) suggest that Sites 495 and 575 were in much closer proximity during the early Miocene.

Corbisema triacantha Zone

Corbisema triacantha is sparse and sporadic at Hole 575A, but the extinction of *Naviculopsis*, defining the base of the *Corbisema triacantha* Zone, is distinct. Preservation and diversity deteriorate upward through the zone. Sample 575A-1,CC (Table 3), the highest sample studied from Hole 575A, is dominated by *Dictyocha brevispina ausonia*, and contains sparse specimens of *Dictyocha pons*, which marks a short interval just above the *Naviculopsis ponticula* Zone at DSDP Hole 416A off northwest Africa (Bukry, 1980a). No deflandroid *Dictyocha pulchella* were recorded at Hole 575A, so the strata assigned to the *C. triacantha* Zone must represent a short interval at the base of the zone. The absence of any *Distephanus stauracanthus* or well-developed *Dictyocha pulchella*, which characterize the upper *C. triacantha* Zone at the base of Hole 572D, also support an assignment of the Hole 575A assemblages to the lower part of the zone.

A somewhat higher stratigraphic level within the zone, with more diversity, is preserved in a thick (116 m) section at Hole 572D. A distinctive acme of short-ranging,

Table 3. Occurrences (%) of early Miocene silicoflagellates in samples from Hole 575A.

Zone	Core-Section, interval (cm)	Sub-bottom depth (m)	Total specimens	*Corbisema triacantha*	*Dictyocha brevispina ausonia*	*D. brevispina brevispina*	*D. fibula*	*D. pons*	*D. sp. cf. D. pulchella*	*Distephanus crux crux s. ampl.*	*D. crux parvus*	*D. crux scutulatus*	*D. hannai*	*D. schauinslandii*	*D. speculum patulus*	*D. sp. cf. D. speculum patulus*	*D. stradneri*	*D. stradneri var. grandis*	*Mesocena elliptica*	*M. elliptica var. rhomboidea*	*Naviculopsis biapiculata s. ampl.*	*N. constricta*	*N. constricta (semibarred)*	*N. contraria*	*N. sp. aff. N. contraria*	*N. sp. aff. N. lacrina*	*N. lata*	*N. lata (narrow)*	*N. navicula*	*N. obtusarca*	*N. obtusarca var. acicula*	*N. ponticula*	*N. ponticula spinosa*	*N. spp.*
Corbisema triacantha	1,CC	99	50		54	20		4	18	4																								
	2,CC	102	18	X	⊗					X	X	X	X																					
	3,CC	105	7				X				X	⊗			X																			
	4,CC	110	100			1				43		56																						
	5,CC	114	50	2		2				70		14			8																			
Naviculopsis ponticula	6,CC	119	100	8						8		30			20						1											3	30	
	7-2, 42-43	121	50							4		70			16				6													4		
	7-3, 24-25	122	100	3							1	56			17																	19		
	7,CC	123	50							6		42			16					20												8	8	
	8-1, 42-43	124	24									X			X				X	X												⊗		
	8-2, 42-43	125	50							4	1				28				2	36				24								6		
	8,CC	126	200			1				3					9									87										
	9-2, 42-43	127	100							2	2	1			25	1								68										
	9,CC	128	300								1	9			2									65	<1									
	10-2, 42-43	129	100							3		4			1									75	8									
	10-3, 42-43	130	50							4					2														70	24				
	10,CC	132	30								X	X			X									X		X			⊗	X	X			8
	11-3, 24-25	134	100			2					1	28			2	1			2				1							7	3	36		8
	11,CC	136	100							1	1	23			4				10										1			72		
	12,CC	139	100							1		83			4				10				1									1		
—	13,CC	143	10							X		⊗																						
Naviculopsis lata	14,CC	146	100									1			27						33	1				7	23							8
	15,CC	149	50		2	18						10			22						30						8							8
	16,CC	152	50			16						10			4						4			14		48				2			2
	17,CC	154	300			6						36		2	8						34		1			11	3							
	18,CC	157	100									4		40	12						4					33	6							
	19,CC	161	100						1						25	3					17					40	14							
	20,CC	165	12			X									X	X										⊗							
Naviculopsis biapiculata	21,CC	169	80							1					9						65	20	3											2
	23,CC	175	100							1					7						6	53	20											11
	27,CC	188	9		⊗											X																		
	29,CC	194	17	X	⊗											⊗																		
	33,CC	208	27		X										X	X		⊗																

Note: For samples where silicoflagellates are too sparse for meaningful percents, presence (X) and predominance (⊗) are shown by symbols. See Table 2 for comparisons of relative paleotemperature values (Ts).

Table 4. Late and middle Miocene silicoflagellate biostratigraphy, relative paleotemperature values (*Ts*), and percent distribution of various genera and morphologic subgroups, with remarks on significant occurrences for Hole 572D.

Age	Zone or Subzone	Core-Section, interval (cm)	Sub-bottom depth (m)	Total specimens	Ts value	Corbisema	Dictyocha	Distephanus (quadrate)	Distephanus (nonquadrate)	Mesocena (quadrate)	Mesocena (nonquadrate)	Naviculopsis	Octactis	Noteworthy occurrences
late Miocene	D. fibula	1,CC	156	300	86		85	1	15					
		2,CC	170	300	93		93		7					No *Dictyocha pulchella*
		3,CC	180	300	91		91		9					
		4,CC	189	300	84		84		16					
		5-3, 70–72	193	300	53		52	2	46					*Distephanus speculum tenuis* 38% acme
		5-4, 70–72	194	300	32		32		67					
		5,CC	199	300	56		56		45					Fibuloid ≫ asperoid *Dictyocha*
		6-5, 50–52	202	300	37		37		63					
		6,CC	205	300	30		30		70					First *Dictyocha longa*
	D. brevispina	7-1, 50–52	209	300	61		61		39					Asperoid *Dictyocha* predominant
		7,CC	218	300	82		82		18					First *Distephanus speculum tenuis*
		8,CC	227	300	65		65		34					Fibuloid ≫ asperoid *Dictyocha*
		9-3, 50–52	231	300	74		74		26					Asperoid *Dictyocha* predominant
		9,CC	232	300	74		74		26		<1			
		10-2, 50–51	239	300	60		60		40					
		10-4, 50–52	242	300	32		32		68					
		10-6, 50–52	245	300	43		42	1	57					
		10,CC	246	300	64		64	<1	35		<1			
		11-1, 50–51	247	300	52		52		48		<1			
		11-4, 50–52	250	300	42		40	3	56		1			*Mesocena circulus* 1%
		11,CC	256	300	44		44	<1	54		1			
		12-2, 50–52	258	300	36		36		63		1			
		12,CC	262	300	51		51		48		<1			<1% pentagonal *Distephanus*
		13-4, 50–52	270	300	88		86	3	11		<1			5% pentagonal *Distephanus*
		13,CC	272	300	78		78		22		1			7% pentagonal *Distephanus*
		14-2, 50–52	277	50	96		96		4					Dilution by diatom *Thalassiothrix*
		14,CC	282	300	68		68		32					*Dictyocha pulchella* predominant
		15-1, 50–52	285	300	58		18	80	1					Low diversity
		15,CC	288	300	85		81	7	12					*Dictyocha pulchella* predominant
		16,CC	303	300	79		79	<1	21					
		17-1, 50–52	304	300	72		71	1	28					Consistently shaped *Dictyocha pulchella* predominant
		17,CC	306	300	89		89		11					No fibuloid *Dictyocha*
		18-1, 50–52	313	300	81		81		19					
		18,CC	321	300	63		62	2	36					
		19,CC	326	300	83		74	17	8	<1	<1			
		20,CC	335	300	92		91	2	7					
middle Miocene	D. stauracanthus	21,CC	349	300	88	4	76	15	5	1				*Dictyocha pulchella* predominant
		22,CC	355	300	80	14	54	23	9		1			*Distephanus stauracanthus* 5%, top. Two *D. polyactis*.
		23,CC	369	200	75	12	41	44	3		1			
		24,CC	379	300	77	3	52	38	1	5	2			
		25,CC	389	300	95	8	82	9	1					*Dictyocha pulchella* predominant
		26,CC	397	300	71	18	28	49	5					First *Distephanus stauracanthus* 14%
	C. triacantha —	27,CC	408	300	94	18	69	12	1	1				
		28,CC	415	300	82	38	34	19	6					No fibuloid *Dictyocha*
		29,CC	424	100	98	5	92	1	2					Deflandroid *Dictyocha pulchella* 38%
		30,CC	434	200	99	22	75	4	1					Deflandroid *Dictyocha pulchella* 1%
		31,CC	444	100	87	39	44	7	10					
		32,CC	454	200	98	2	96		3					Equal numbers of asperoid and fibuloid *Dictyocha*
		33,CC	465	100	100	3	97							

Note: Silicoflagellate data support the correlation between the top of Hole 572D (Core 1) and the base of Hole 572A (Core 17); see Table 5.

deflandroid *Dictyocha pulchella* in Sample 572D-29,CC accounts for 38% of the assemblage (Table 4). This value approaches 41%, the maximum recorded, in the *Corbisema triacantha* Zone of DSDP Site 543 northeast of Barbados in the tropical North Atlantic (Bukry, in press b).

The section at Hole 572D is distinguished by a thick *Distephanus stauracanthus* Subzone occupying the top 48 m of the zone. *Distephanus stauracanthus* is a persistent meager (5%) to common (14%) member of the assemblages in Cores 572D-22 to 572D-26. An indication that the phenotypic shift from apical ring dominance in early populations of *D. stauracanthus* to apical bar dominance in later populations could be of strati-

graphic use for eastern Pacific Site 470 (Bukry, 1981a) is only partly evident at Hole 572D. Ring specimens predominate in Cores 572D-22 and 572D-26 (Plate 3, Fig. 6), whereas bar specimens predominate in the intervening Cores 572D-23 to 572D-25, gainsaying a consistent, one-way shift at this oceanic site.

Dictyocha brevispina Zone

The assemblages between the extinction of *Corbisema* and the appearance of *Dictyocha longa* are characterized at Hole 572D by low diversity, asperoid-bar dominance within *Dictyocha*, and the predominance of *Dictyocha pulchella* among asperoid *Dictyocha* (often exceeding 90%) (Table 4). Aside from a mid-zone cool-

ing marked by the entry of sparse *Mesocena circulus* into the assemblages, there are few stratigraphically significant changes.

Dictyocha fibula Zone

The first *Dictyocha longa* of Hole 572D defines the base of the *Dictyocha fibula* Zone and coincides with a locally permanent change from asperoid- to fibuloid-bar dominance in *Dictyocha* (compare Martini, 1971). The lower zonal assemblages of Hole 572D are characterized by low diversity, persistent *Distephanus speculum tenuis*, the appearance of *Dictyocha longa* var. *paxilla* in Sample 572D-2,CC, and the scarcity or absence of *D. pulchella* in Cores 572D-1 to 572D-3 (Tables 4 and 5). Similar basal assemblages from Cores 16 and 17 of Hole 572A suggest correlation between the two holes at this interval. The best evidence of correlation is the predominance of *D. longa*, presence of *D. speculum tenuis*, and decline of *D. pulchella*. The paleotemperature correlation is also supportive of stratigraphic occurrences.

The lower interval of the zone in Cores 15 to 17 of Hole 572A, below the *Dictyocha neonautica* Subzone, contains persistent *D. longa*, *D. longa* var. *paxilla*, and *Distephanus speculum tenuis* (Table 5). A distinct increase in *Distephanus* in Core 572A-15 suggests that the stratigraphic appearance of *Dictyocha neonautica* at the top of the core is related to a cool-water event.

Only two closely spaced samples contain *Dictyocha neonautica* Subzone assemblages. A possibly compressed section is indicated by the dominance of *D. neonautica*, which characterizes the lower part of the subzone, in Sample 572A-15-1, 68–69 cm, and by the contrasting dominance of younger *D. neonautica* var. *cocosensis*, just above in Sample 572A-14,CC. Both samples contain fibuloid *Dictyocha*, but the asperoid *D. brevispina/D. pulchella* group is very sparse (< 1 to 3%). This relationship suggests that *D. neonautica* filled the asperoid niche at Hole 572A.

The *Dictyocha pulchella* Subzone is not well defined at Hole 572A, because of the sporadic and sparse occurrence of *Dictyocha pulchella*. *D. brevispina* predominates among asperoid *Dictyocha*.

Dictyocha angulata, a guide fossil for the *Dictyocha angulata* Subzone, occurs in Cores 7, 9, and 10 of Hole 572A, but is most abundant at the top of the subzone in Core 7. A minor, rarely encountered species, *Dictyocha orbiculata*, occurs only in Sample 572A-7,CC (Table 5). This provides a local horizon correlation with Sample 77B-6-5, 100–101 cm, where *D. orbiculata* was first described (Ling, 1977).

Fibuloid *Dictyocha* species, including *D. longa* var. *paxilla*, *D. perfecta*, and *D. perlaevis*, dominate the assemblages at the top of the *D. fibula* Zone in Cores 572A-6 and 572A-7. No particular morphologic type is diagnostic for this interval between the last *D. angulata* and the first *D. flexatella* and *D. ornata africana* or *D. ornata ornata*.

Dictyocha stapedia stapedia Zone

The late Pliocene silicoflagellate guide species *Dictyocha flexatella* and the *D. ornata* group (Bukry, 1982a)

occur in close order in Samples 572A-6-1, 66–67 cm and 572A-5,CC, and indicate the base of the *Dictyocha ornata ornata* Subzone. Early *Dictyocha stapedia stapedia*, which first occurs in Sample 572A-6-3, 66–67 cm, is a consistent member of assemblages in Sample 572A-6-1, 66–67 cm and above. The *D. ornata* group is sparse and sporadic, but the companion species *D. flexatella* is more ubiquitous, although it is abundant (37%) only in Core 572A-5 (Table 5). *Dictyocha calida calida* and *Distephanus mesophthalmus* occur in the top sample of the *D. ornata ornata* Subzone. A similar occurrence in Sample 157-11,CC, recovered to the east, has the conjunction of these two species plus *D. ornata africana*, signifying the stratigraphic potential of short-term conjunctions for correlation in the eastern equatorial Pacific. Both samples are assigned to the highest coccolith subzone of the upper Pliocene (CN12d).

The *Dictyocha delicata* Subzone of the *D. stapedia stapedia* Zone is identified in the lower part of Core 572A-3. Because *Octactis pulchra* is present in this interval with *Dictyocha delicata*, a Quaternary assignment is made. Minor occurrences of *Mesocena quadrangula* in the subzone presage the consistent presence of this species above, in the *Mesocena quadrangula* Zone.

Mesocena quadrangula Zone

The common occurrence of *Mesocena quadrangula* above the range of *Dictyocha delicata* defines the *M. quadrangula* Zone in Cores 2 and 3 of Hole 572A. *Dictyocha stapedia stapedia* is abundant, but *D. aculeata* is absent or sparse up to Sample 572A-2-3, 68–69 cm, where *D. aculeata* constitutes a third of the assemblage though *D. stapedia stapedia* (47%) still predominates.

Dictyocha aculeata Zone

At Hole 572A, *Dictyocha aculeata* is present throughout the *Dictyocha aculeata* Zone, but diversity is very low, and, aside from Sample 572A-1-5, 68–69 cm, *D. stapedia stapedia* predominates. Solution-thinning and small-sized specimens are most prominent in this zone, suggesting reduced silica and increased solution relative to DSDP Site 425, which is farther to the east (Bukry, 1980b), where higher sedimentation rates and fossil diversity are indicated in this zonal interval.

SILICOFLAGELLATE *Ts* COMPARISON

The lower Miocene silicoflagellate assemblages of DSDP Hole 575A are significant in relative-paleotemperature (*Ts*) studies, especially because of the near absence of *Corbisema*, the scarcity of *Dictyocha*, and the high abundance of *Naviculopsis*. Previous work on Pacific lower Miocene silicoflagellates at DSDP Site 495 had questioned the paleotemperature significance of *Naviculopsis* (Bukry, 1982a), because no living relatives or similarly formed taxa survived into the Quaternary and the known fossil record suggested a cosmopolitan range with greater productivity in cool regions. But the generally high abundances of *Naviculopsis* through the lower Miocene and the displacement of regular *Dictyocha* species by naviculopsoid *D. neonautica* in the upper Miocene (Hole 572A) show that *Naviculopsis* and *Navicu-*

Table 5. Late Miocene to Quaternary silicoflagellate biostratigraphy, relative paleotemperature values (*Ts*), and percent distribution of various genera and morphologic subgroups, with remarks on significant occurrences for Hole 572A.

Age	Zone or Subzone	Core-Section, interval (cm)	Sub-bottom depth (m)	Total specimens	*Ts* value	Corbisema	Dictyocha	Distephanus (quadrate)	Distephanus (nonquadrate)	Mesocena (quadrate)	Mesocena (nonquadrate)	Naviculopsis	Octactis	Noteworthy occurrences
Quaternary	*D. aculeata*	1-1, 105–106	1	300	100		100							*D. stapedia stapedia* 98%
		1-3, 67–68	4	300	99		99						1	
		1-5, 68–69	7	300	99		99						1	*D. aculeata* > *D. stapedia stapedia*
		1,CC	9	200	96		96						4	*D. stapedia stapedia*
		2-1, 68–69	10	300	99		99						1	*D. stapedia stapedia* 84%
	M. quadrangula	2-2, 68–69	12	300	96		94			4			2	*D. stapedia stapedia* and last *M. quadrangula*
		2-3, 68–69	13	300	95		90			10			<1	*D. stapedia stapedia* > *D. aculeata*
		2-4, 68–69	15	300	87		74			26			<1	
		2-5, 68–69	16	300	75		54	<1	2	42			2	
		2-6, 68–69	18	300	73		46		<1	53			<1	*D. stapedia stapedia*
		2,CC	19	300	71		44		2	53			1	
		3-1, 68–69	20	300	66		35		3	61			<1	*D. stapedia stapedia* 98% of *Dictyocha*
		3-2, 68–69	21	300	89		83		2	12			4	
	D. stapedia / *D. delicata*	3-3, 16–17	22	300	93		88	<1	1	9			3	*Dictyocha delicata* 9%
		3-4, 68–69	24	300	98		97	<1	2				<1	*D. delicata* 23%
		3-5, 68–69	26	300	92		92		8				1	*D. delicata* 8%
		3-6, 68–69	27	300	93		93	<1	7					*D. delicata* 39%
		3,CC	28	300	94		93		6		1		<1	
late Pliocene	*D. stapedia* / *D. ornata ornata*	4-3, 23–24	32	300	93		88	10	2					*Dictyocha calida calida* and *Distephanus mesophthalmus*
		4,CC	36	300	97		97		3		<1			*Dictyocha flexatella* 4%, top
		5-3, 16–17	39	300	91		91		9					*D. flexatella* 37%; no *D. ornata* group.
		5,CC	45	300	92		92		8		<1			*D. brevispina* 1%, top. Two *D. ornata africana.*
		6-1, 66–67	46	300	88		88		12					*D. flexatella* 1%
early Pliocene	*D. fibula* / —	6-3, 17–18	49	300	76		76		24					*Dictyocha* more equant than elongate, solution thinning.
		6-3, 66–67	50	300	93		93		7		<1			Solution thinning
		6-5, 66–67	53	300	79		79		21					*Dictyocha longa* var. *paxilla* predominant
		6,CC	55	300	80		80		20					Low diversity (4 species), no asperoid *Dictyocha*
		7-2, 66–67	57	100	89		89	1	10					
		7-3, 19–20	58	300	93		81	2	17					No asperoid *Dictyocha*
	D. fibula / *D. angulata*	7-4, 66–67	60	300	90		90		10					*Dictyocha angulata* ~50%, no *D. pulchella*
		7,CC	64	300	81		80	1	19			<1		*Dictyocha orbiculata* 1%
		8-3, 16–17	67	300	58		57	1	41			1		Small *Distephanus speculum speculum*
		8-3, 66–67	68	300	60		59	1	39			1		
		8,CC	72	300	45		45		43			12		No *Dictyocha pulchella*, only two asperoid specimens
		9-3, 66–67	76	300	61		61	<1	39			<1		
		9,CC	82	300	90		87	6	6			<1		*D.* sp. cf. *D. angulata*
		10-3, 66–67	85	300	72		72	<1	18			10		*D.* sp. cf. *D. angulata*; small *Mesocena circulus.*
	D. fibula / —	10,CC	91	300	56		51	6	40			3		Only one asperoid *Dictyocha*
		11-3, 67–68	95	300	44		40	5	53			3		Low diversity
		11-5, 67–68	98	300	83		82	<1	18			<1		
	D. fibula / *D. pulchella*	11,CC	101	300	82		82	<1	17					
		12-2, 68–69	103	300	67		66	2	32					
		12,CC	110	300	52		51	2	46					
		13-3, 66–67	114	300	49		45	1	47			6		One *Distephanus polyactis*
		13,CC	119	300	52		48	2	43			7		
		14-3, 18–19	122	300	60		59	1	39			1		*Distephanus xenus* 6%
	D. neonautica	14,CC	128	300	74		73	1	26					*Dictyocha neonautica* var. *cocosensis* 63%
		15-1, 68–69	129	300	66		66		33					*D. neonautica* 38%
late Miocene	—	15-3, 19–20	132	300	44		43	1	56					*Distephanus speculum tenuis* 3%, top
		15,CC	137	300	29		28	2	69			<1		*D. speculum tenuis* 17%
		16-2, 66–67	139	300	71		71	<1	29					*D. speculum tenuis* 7%
		16-3, 19–20	140	300	81		80	2	18					*D. speculum tenuis* 5%
		16,CC	145	300	88		83	9	8					*D. speculum tenuis* 1%
		17,CC	154	300	84		83	2	15					*D. speculum tenuis* 3%

Note: Silicoflagellate data support the correlation between the base of Hole 572A (Core 17) and the top of Hole 572D (Core 1); see Table 4.

lopsis-like forms occupied a paleotemperature niche similar to that of *Dictyocha* at tropical Sites 572 and 575.

New *Naviculopsis* paleotemperature information is indicated by the absence of the stratigraphic guide species *Naviculopsis quadrata* at Hole 575A. The first *N. quadrata* can be used to distinguish a zonal interval above the *N. lata* Zone (Bukry, 1981b). To account for its absence, sites at high latitude (Site 338) and low latitude (Site 369) in the Atlantic were compared. *Naviculopsis quadrata* was quantitatively more abundant than *N. lata* at high latitude, whereas at low latitude *N. lata* far outnumbered *N. quadrata*. Therefore, the very high abundances of *N. lata* (up to 48%) at Hole 575A, and the complete absence of *N. quadrata*, show that the distribution of certain species within *Naviculopsis* can probably be used effectively for relative-paleotemperature comparisons.

Calculation of *Ts* values for Hole 575A yields fluctuations of considerable amplitude in the lower Miocene, with values from *Ts* 44 to *Ts* 96 (Fig. 2). *Naviculopsis*
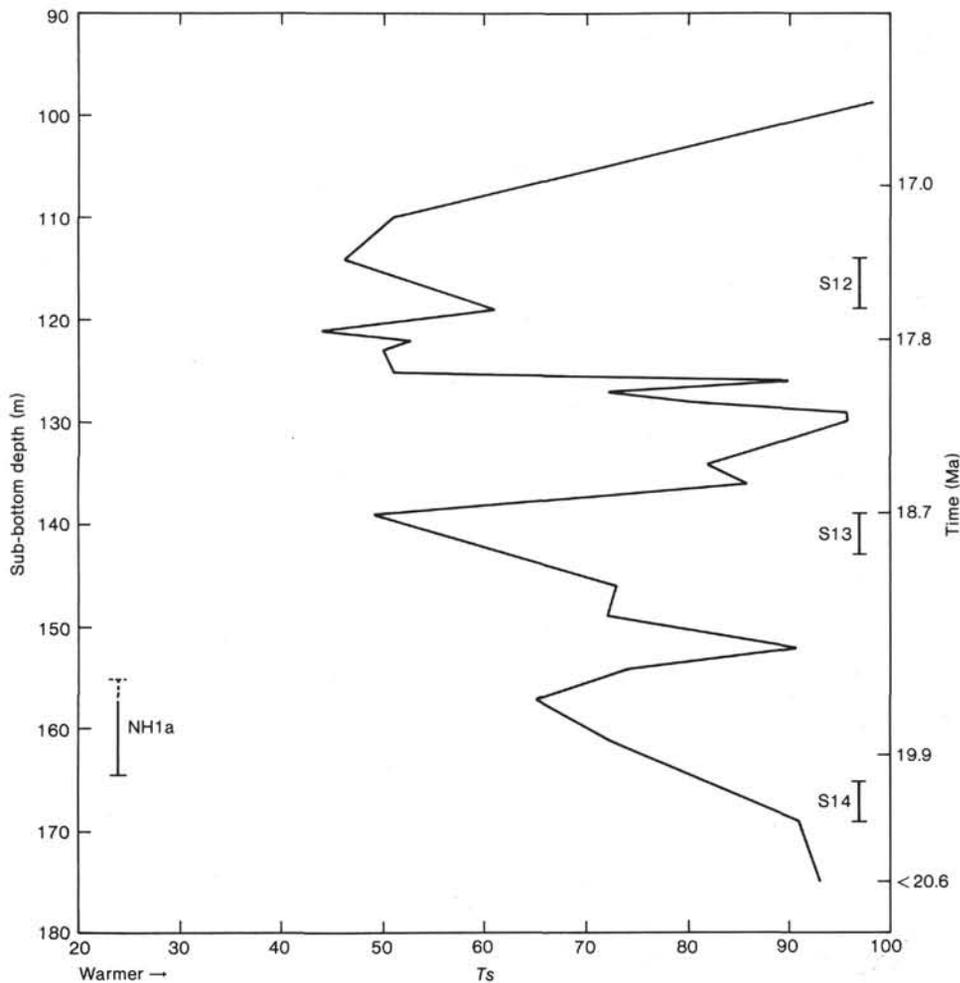
Figure 2. Silicoflagellate relative paleotemperature curve for Hole 575A samples. The chronology shown is based on diatom ages (Ma); see Barron (this volume). Silicoflagellate data for the curve are available in Table 3. Useful silicoflagellate events: S12 = last *Naviculopsis ponticula ponticula;* S13 = first *Naviculopsis ponticula ponticula;* S14 = first *Naviculopsis lata.* A deep-sea hiatus (NH1a) interval, representing a cool-water event beginning at 20.0 Ma (Keller and Barron, 1983), is shown.

was counted as warm, filling the niche occupied by *Dictyocha* in younger Neogene strata. Surprisingly, the cool troughs within Cores 7, 12, and 18 of Hole 575A are not the levels of maximum abundance for cool-water indicator *Distephanus* (hexagonal). Instead, these *Ts* minima are dominated by the temperate-water indicator *Distephanus* (quadrate). Because the *Ts* paleotemperature model was designed for middle Miocene and younger assemblages (Bukry, 1981a), it is possible that the paleotemperature significance of older species in the genera cited was not the same. In other words, Oligocene and early Miocene *Distephanus* (quadrate) could have been an indicator of cool water, instead of temperate, whereas *Distephanus* (hexagonal) could have been a temperate- and not a strictly cool-water indicator. There is some evidence supporting such a paleotemperature transition, beyond the record at Hole 575A, in the abundances of *Distephanus* (quadrate versus hexagonal) at different latitudes during the Oligocene and early Miocene. Quadrate specimens equal or outnumber the hexagonal at high-latitude DSDP Holes 173, 267, 274, 278, 280A, 328B,

338, and 407. Hexagonal specimens of *Distephanus* achieved continuing dominance over quadrate first at higher-latitude sites, such as Site 278 (Bukry, 1975) in the early Miocene, and somewhat later at lower-latitude sites, such as nearshore Site 470 in the late Miocene and offshore Hole 572D in the late middle Miocene (see Table 4). Therefore, hexagonal *Distephanus* can be the cool-water indicator for the late Miocene to Holocene, but for the Oligocene and part of the early Miocene, quadrate *Distephanus* and probably *Mesocena* may be the better cool-water indicators.

Corbisema has been used as a warm-water indicator because of its great abundance during the Paleocene and Eocene thermal highs and subsequent extinction at the beginning of a sharp thermal drop in the middle Miocene (see Shackleton, 1982). However, the last few species of the genus in the Miocene are nearly absent at tropical Hole 575A. The record and abundance at Hole 572D are better, with some values almost as high as the 58% recorded at Site 407 between Iceland and Greenland. Other high abundances of *C. triacantha* appear to

occur at temperate coastal sites, such as DSDP Sites 415 and 470 (Bukry, in press b), where the maximum values are 48 and 23%, respectively. By contrast, the values for *Corbisema* at cool-water sites such as DSDP Sites 173 and 278 are very low, from 0 to 12% and from 0 to 3%, respectively. Also, at DSDP Site 407, up to 17% of the *Corbisema* specimens belong to *C. flexuosa*, which is also present at high-latitude Site 278 but missing at most low- or mid-latitude sites.

Although temperature seems to affect the abundance of *Corbisema*, other fertility-enhancing conditions, such as nitrogen or phosphorus enrichment, must have contributed to the high abundances at Sites 407 and 415 in the Atlantic.

A major cooling of *Ts* relative-paleotemperature values in the lower Miocene of Hole 575A occurs from the middle of the *Naviculopsis ponticula* Zone up into the lower *Corbisema triacantha* Zone in Cores 4 to 9. This cool portion of the *Ts* curve corresponds to an interval of increased foraminifer dissolution (see Fig. 2 and site chapter for Site 575) and deep-sea hiatus NH1b (Barron and Keller, 1982; Keller and Barron, 1983). The association of effects suggests a global cooling event corresponding to a level near the extinction of *Naviculopsis* at the base of the *Corbisema triacantha* Zone.

Quadrate *Distephanus* have two levels of maximum abundance in the lower Miocene at Holes 575A and 495. The samples just above the base of the *Naviculopsis ponticula* Zone and just above the top have the highest percentages (84 to 99%) recorded for quadrate *Distephanus* at Hole 575A. At Site 495, the sampling interval was less detailed, but a similar occurrence pattern for quadrate *Distephanus* is recorded, showing the highest percentages (81 and 82%) at the boundaries of the *N. ponticula* Zone.

The *Ts* relative-paleotemperature curves for the *Naviculopsis ponticula* Zone at Holes 575A and 495 show the same major trends (Figs. 2 and 3). There are cool

values of *Ts* = 49 to 53 for the upper and lower parts of the zone, bracketing a pronounced warm peak (*Ts* = 88 to 96) in the middle. This close correspondence between biostratigraphic and paleotemperature records at Holes 575A and 495 indicates a much closer proximity of these sites or much more uniform conditions in the eastern Pacific during the early Miocene.

Oxygen-isotope thermometry from benthic foraminifers shows a steep decline in paleotemperatures of world oceans from about 15 Ma to 8 Ma (Shackleton, 1982). The long-term record of silicoflagellate relative-paleotemperature values, *Ts*, for Holes 572A and 572D encompasses the last 15 m.y. of the Cenozoic and shows a fluctuating decline (major cool events progressively cooler) from about 15 Ma to 7 Ma, followed by a fluctuating increase (major cool events progressively warmer) after 7 Ma (Figs. 4 and 5). Within the interval of declining paleotemperature, from the *Corbisema triacantha* Zone to the lower *Dictyocha fibula* Zone, there was a lower part below 321 m sub-bottom where lower-amplitude fluctuations prevailed, principally in the *C. triacantha* Zone. The upper part of the decline, mainly within the *D. brevispina* Zone, has higher-amplitude fluctuations, as the coolest points diverge further from the intervening warm points.

Comparison of the upper part of the *Ts* curve for Hole 572D to that for Hole 503A (farther east) shows corresponding cool points at about 7.3 Ma and warm points at 6.0 to 6.1 Ma. The *Ts* values of these warm points are in close agreement at *Ts* = 93 and *Ts* = 97, respectively. But the cool point at Hole 572D (*Ts* = 30) is considerably cooler than the coeval point at Hole 503A (*Ts* = 67), suggesting a greater westward—versus northward—vector of Peru Current waters or related systems. The paleotemperature contrast is evidenced by the 70% abundance of hexagonal *Distephanus* for Hole 572D, versus only 29% for Hole 503A. This paleotemperature contrast between the oceanographic regimes at the two
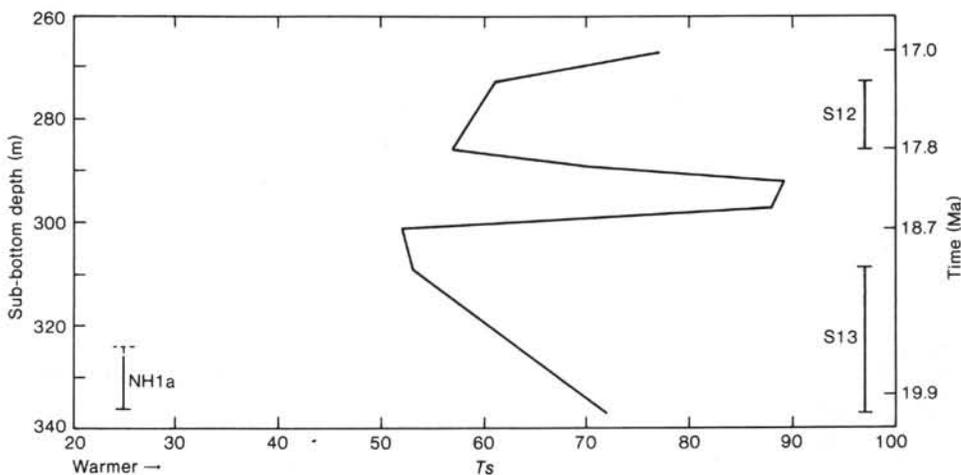
Figure 3. Silicoflagellate relative paleotemperature curve for Hole 495 samples. The chronology shown is based on diatom ages (Ma); see Barron (1983 and this volume). Silicoflagellate data for the curve are available in Bukry (1982a). Useful silicoflagellate events: S12 = last *Naviculopsis ponticula ponticula;* S13 = first *Naviculopsis ponticula ponticula.* A deep-sea hiatus (NH1a) interval, representing a cool-water event beginning at 20.0 Ma (Keller and Barron, 1983), is shown.
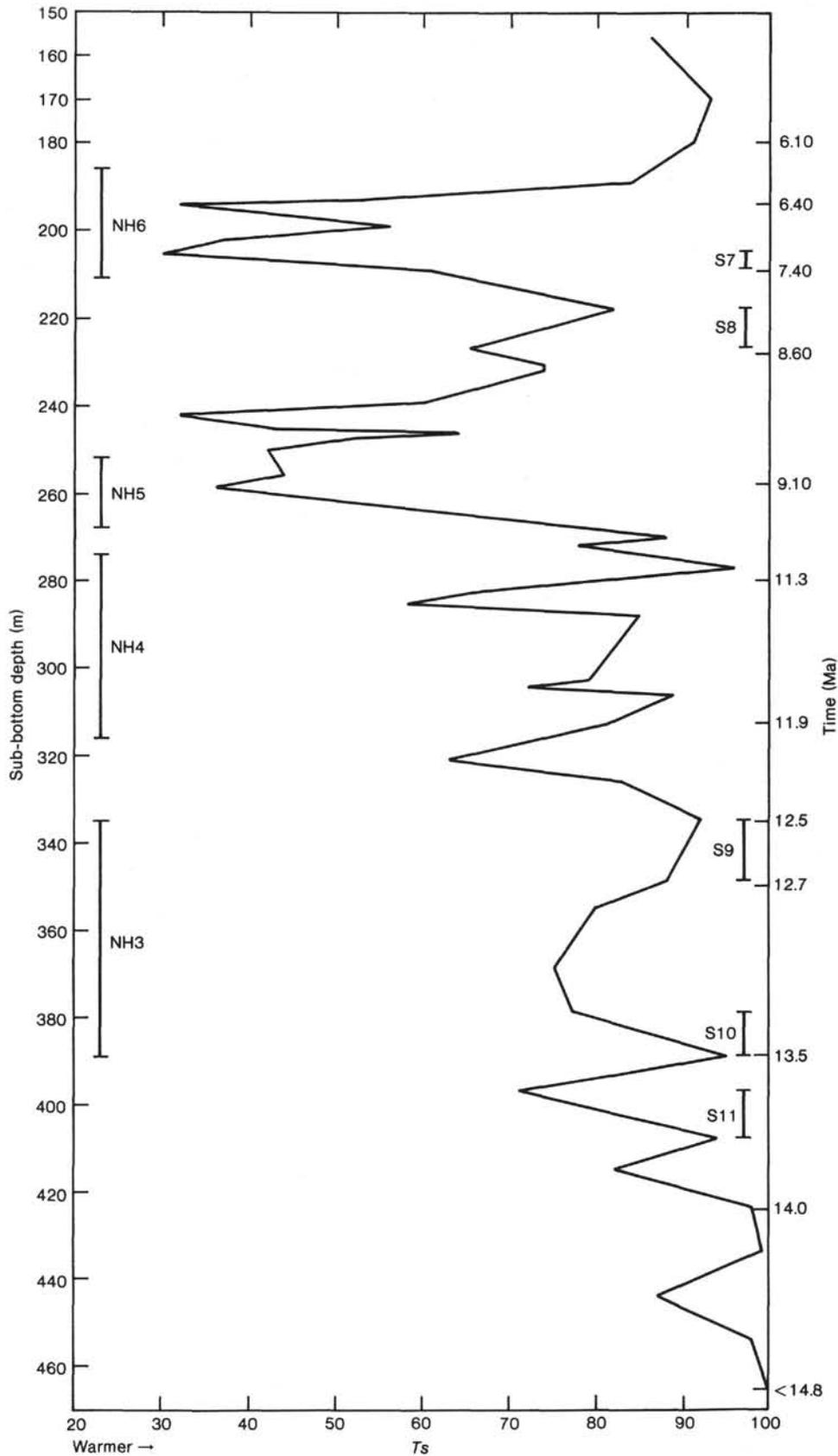
Figure 4. Silicoflagellate relative paleotemperature curve for Hole 572D samples. The chronology shown is based on diatom ages (Ma); see Barron (this volume). Silicoflagellate data for the curve are available in Table 4. Useful silicoflagellate events: S7 = first *Dictyocha longa;* S8 = first *Distephanus speculum tenuis;* S9 = last *Corbisema triacantha;* S10 = first *Mesocena circulus;* S11 = first *Distephanus stauracanthus.* Deep-sea hiatus (NH3 to NH6) intervals, representing cool-water events (Keller and Barron, 1983), are shown.
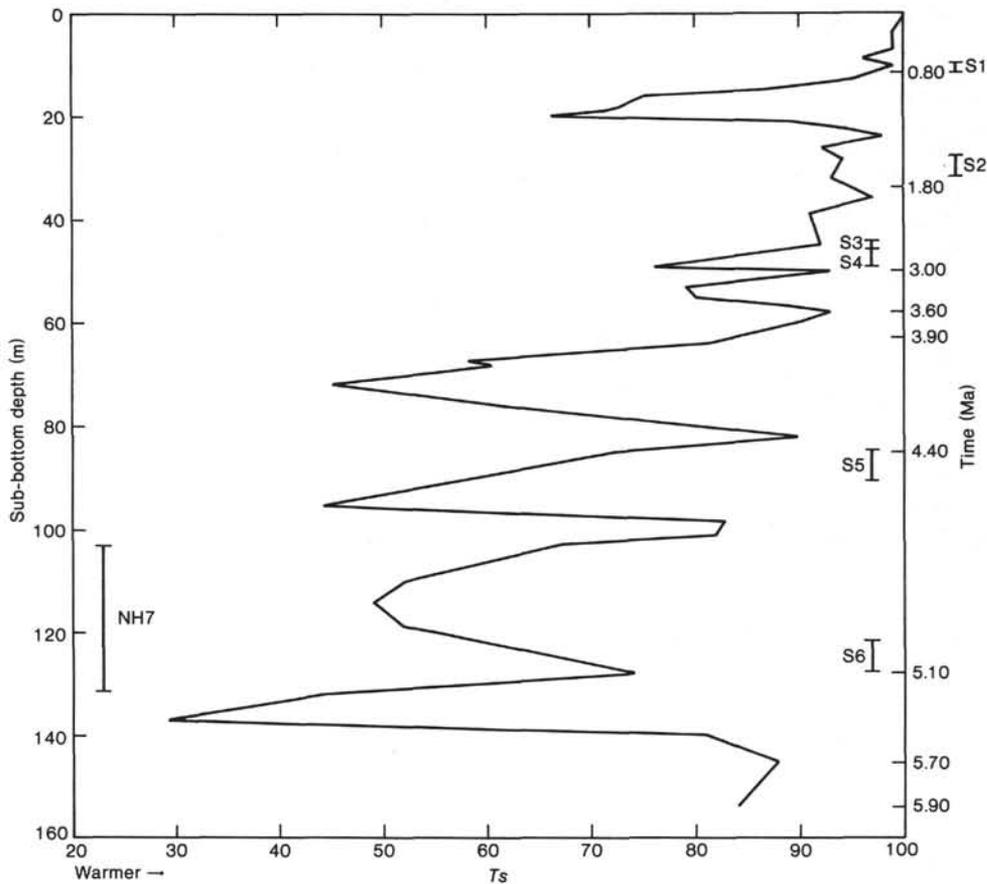
Figure 5. Silicoflagellate relative paleotemperature curve for Hole 572A samples. The chronology shown is based on diatom ages (Ma); see Baldauf (this volume) and Barron (this volume). Silicoflagellate data for the curve are available in Table 5. Useful silicoflagellate biostratigraphic events: S1 = last *Mesocena quadrangula;* S2 = first *Octactis pulchra;* S3 = first *Dictyocha ornata africana;* S4 = first *Dictyocha stapedia stapedia;* S5 = first *Dictyocha angulata;* S6 = last *Dictyocha neonautica* var. *cocosensis.* A deep-sea hiatus (NH7) interval, representing a cool-water event or events between 4.7 and 5.2 Ma (Keller and Barron, 1983), is shown.

locations persisted for a considerable period because cool-water indicator *Mesocena circulus* is recorded at Hole 572D but missing from Hole 503A.

The Miocene/Pliocene boundary warm peak (about 5.0 Ma) is present at Holes 572A and 503A, but like the 6.0-Ma warm peak the Hole 572A assemblage yields a cooler ($Ts = 74$) value than that of Hole 503A ($Ts = 92$). A nearly 20-point difference is also seen for the *Dictyocha pulchella/Dictyocha angulata* cool peak at about 4.5 Ma in Core 11 of Hole 572A ($Ts = 44$) and Cores 24 to 27 of Hole 503A ($Ts = 68$). The following *Dictyocha angulata* warm peak (3.4 to 3.8 Ma) occurs in the middle of Core 7 of Hole 572A, and the Ts value of 93 is nearly identical to the correlative Ts value of 97 for Hole 503A. Above this level the values are very similar. Therefore, between 7.3 and 3.8 Ma the Ts values at Hole 572A gradually changed from much cooler ($\Delta37$) to cooler ($\Delta24$) to nearly identical ($\Delta4$), at fairly high values in the 80s and 90s. A weakening of the westward component of the Peru Current, combined with the oceanic effects resulting from the closing of the Panamani-

an Land Bridge, could have contributed to this convergence of relative-paleotemperature records.

A possibly analogous modern feature is the eastern equatorial tongue of cool surface waters, below 21°C, that in July and August extends as far west as Site 572 (Bernstein and Morris, 1983). The tongue is maintained by westward advection of cool water from coastal South America and by locally wind-driven equatorial upwelling (Bernstein and Morris, 1983). Site 503 lies slightly north of this cool tongue, in the latitudinal band of warmest temperatures, where isotherms are compressed and rise as high as 27°C. Shifting of these temperature zones in response to oceanographic changes could be responsible for the exceptional contrast in cool and warm values portrayed by the Ts relative-paleotemperature curve.

Above the *Dictyocha angulata* warm peak, the high amplitudes ($Ts = \Delta30$ to $\Delta50$) of the upper Miocene and lower Pliocene relative-paleotemperature fluctuations at Hole 572A are remarkably diminished to amplitudes of less than $Ts = \Delta24$, typically less than $Ts = \Delta5$. The

major event in the upper Pliocene and Quaternary is the acme and extinction of *Mesocena quadrangula* at about 1 Ma. Although the acme of *M. quadrangula* occurs at low latitude and is missing at high latitude, the paleotemperature character of *M. quadrangula* is considered to be temperate at low latitude because an upper Miocene bloom of this species coincides with locally elevated numbers of cool-water *Distephanus speculum speculum* at DSDP Sites 157 and 504. This supports the presumption that later occurrences of the same morphology reflect similar temperature trends.

Owing to a general decline of cool-water indicator *D. speculum speculum* in the Quaternary of tropical areas, *M. quadrangula* is thought to indicate relatively cool or temperate paleotemperatures. The few *D. speculum speculum* at Hole 572A in the *M. quadrangula* acme have a distribution of 2 specimens and 5 specimens just below the acme, 9 specimens at the acme, and 5 specimens, followed by 0 specimens, above, in the interval of the decline of *M. quadrangula* to extinction.

The coolest value ($Ts = 66$) for the Quaternary is assigned to the *Mesocena quadrangula* acme at Hole 572A. Correlative *M. quadrangula* acme Ts values are $Ts = 65$ at Site 157 and $Ts = 63$ at Site 504. Silicoflagellates indicate close similarity in paleotemperature response for the eastern tropical Pacific region at that time.

In the Atlantic, an especially cool event, producing 63% *D. speculum speculum*, coincides with a reduced acme of *M. quadrangula* at Site 397 ($Ts = 28$). Just above the acme at Site 397, the value is more similar to that for the Pacific, at $Ts = 69$ (Bukry, 1979b).

The general trend of the upper Cenozoic eustatic sea-level curve, constrained by Midway Island stratigraphy (Major and Matthews, 1983), shows a long-term decline for the Pacific between 13 and 6.7 Ma. Although the Midway evidence reduces the amplitudes of eustatic sea-level fluctuation (Major and Matthews, 1983), the principal times of rapid change of sea level (Vail et al., 1977) are corroborated. The end of a highstand of sea level at about 13 Ma corresponds to a warming trend ($Ts = 76$ to 92) on the silicoflagellate relative-paleotemperature curve for Cores 572D-23 to 572D-20, at the base of the *Dictyocha brevispina* Zone. A sharp decline in Ts values from $Ts = 96$ to $Ts = 36$ occurs between about 11.3 and 10.7 Ma, and is the first major cooling event within the late Miocene. This was also the time of one of the maximum declines of eustatic sea level at about 11 Ma, and indicates that marine temperature response (measured by silicoflagellate Ts) to rapid sea-level changes is similarly rapid.

After the maximum lowering at about 6.7 Ma, the eustatic sea level has an average upward trend that is overlain by higher-frequency oscillations. The general average trend for Ts values is also inflected upward between 6 and 7 Ma toward warmer Ts values at Site 572. A broad warming across the Miocene/Pliocene boundary has been shown by Ts values for Holes 503A and 504 in the eastern Pacific and for Hole 552A in the North Atlantic. At Hole 572A this warming is abbreviated near a stratigraphically compressed section that re-

duced the upper and lower *Dictyocha neonautica* Zone to a short 1-m section.

Correlations between the Pliocene and Pleistocene eustatic sea-level fluctuations and Ts fluctuations are less positive than for the Miocene. The sea-level decline at about 3.0 Ma is distinguished as a major event comparable to the maximum lowering at 6.7 Ma. Many biostratigraphic events, such as the first *Dictyocha flexatella* and *D. ornata africana*, occur at about 3.0 Ma. It is one of the last times of depressed Ts values ($Ts = 76$) at Hole 572A, following the *Dictyocha angulata* warm peak ($Ts = 93$).

Comparison of the Ts relative-paleotemperature curve of silicoflagellates to the sequence of Neogene deep-sea hiatuses (Barron and Keller, 1982; Keller and Barron, 1983) shows good correlation between cool Ts minima and hiatus intervals such as NH1a, NH3, NH6, and NH7 (Figs. 2 to 5). Also, some of the major declines in Pacific eustatic level (Major and Matthews, 1983) occur at the same times as Ts minima and deep-sea hiatuses, such as NH3 and Eustatic Event (EE) 1 after 13 Ma, and NH6 and EE3 at about 6.7 Ma (Fig. 4). The rising sea level at EE5 correlates with the warming Ts values from about 5.2 Ma to 5.1 Ma at Hole 572A (Fig. 5). Such correlations suggest that paleoceanographic changes linking cool paleotemperatures, lowered sea levels, and deep-sea hiatuses may be detected in the Ts relative-paleotemperature record of shallow-dwelling siliceous phytoplankton such as silicoflagellates.

The paleoecologic signal to be derived from absolute and relative comparisons of silicoflagellate Ts values is significant enough to consider such information a useful addition to other chemical and physical measures for paleoceanography. The silicoflagellate photosynthetic habitat in surface waters and the temperature-sensitive variation in generic proportions make silicoflagellates valuable indicators for changes in marine paleotemperature in areas where their productivity has been sufficient.

SYSTEMATIC PALEONTOLOGY OF NEW TAXA

Genus *DICTYOCHA* Ehrenberg, 1837

Dictyocha nola Bukry, n. sp.
(Plate 2, Figs. 1–5)

Description. *Dictyocha nola* has a moderate-sized, generally wide, oblong basal ring with slightly protruding minor-axis portals and short spines. The outer margins of portals are squared off, and the basal pikes are close to the strut junctions. The short to moderate apical bar is oriented along the minor axis of the basal ring. A few specimens have apiculate basal rings or lack minor-axis spines.

Remarks. *Dictyocha nola* is distinguished from other taxa with the same structural elements, such as *Dictyocha brevispina ausonia*, *D. brevispina brevispina*, and *D. pulchella*, by a combination of different proportions. The flattened ends of the major-axis portals (resembling the top of a large bell) and the subparallel sides of the portal yield an oblong outline missing in the other taxa. The larger, protruding, minor-axis portals and basal pike location distinguish *D. nola* from *D. brevispina ausonia*. The other asperoid taxa have a more rhomboid than oblong outline. The squared-off portals of *D. nola* are an effect similar to that seen in the smaller, fibuloid species *D. angulata*, which occurs just above *D. nola* in Cores 7 to 10 of Hole 572A.

Occurrence. *Dictyocha nola* accounts for 20% of the *Dictyocha* specimens in Sample 572A-11-3, 67–68 cm (95 m), which is assigned to the lower Pliocene *Dictyocha fibula* Zone, between 4.40 and 5.10 Ma,

according to diatom ages. It was not identified in other samples, and may represent a useful, short-lived, horizon species.

Size. Maximum inner diameter 25 to 33 μm (holotype 31 μm).

Holotype. USNM 371373 (Plate 2, Fig. 3).

Isotypes. USNM 371374 to 371377.

Type locality. Eastern equatorial Pacific, Sample 572A-11-3, 67–68 cm (95 m sub-bottom).

Genus *DISTEPHANUS* Stöhr, 1880

Distephanus stradneri (Jerković) Bukry var. *grandis* Bukry, n. var.
(Plate 4, Figs. 1–7)

Description. *Distephanus stradneri* var. *grandis* has a large, elongate-rhomboid basal ring and a small, slightly oblong apical ring, connected together by symmetric struts. The major-axis spines are two to four times the length of the minor-axis spines, but all spines are short. Minor-axis portals are less angular than major-axis portals because of rhomboid elongation. Elongation, measured by the ratio of major- and minor-axis inner diameters, ranges from 1.13 to 1.29, and the outer-diameter ratio (including spines) ranges from 1.30 to 1.44. Some specimens show small basal pikes next to the strut junctions.

Remarks. *Distephanus stradneri* var. *grandis* is distinguished from *D. stradneri*, including *D. pusillus* (see Bukry, 1982a), by the rhomboid elongation of the basal ring, shown by the inner-diameter ratio, which is higher (1.13 to 1.29, average 1.16) for *D. stradneri* var. *grandis* and lower (1.00, 1.04, and 1.08) for *D. stradneri* (including *D. pusillus*). The small pikes present on some *D. stradneri* var. *grandis* are absent on *D. stradneri*. The short spines may also help to distinguish *D. stradneri* var. *grandis*.

Occurrence. *Distephanus stradneri* var. *grandis* occurs in the lower Miocene *Naviculopsis biapiculata* Zone, Core 33 of Hole 575A. Ling (1977) illustrated a square-ringed *D. stradneri* from the lower Miocene of the eastern Pacific, which also has short spines but is slightly older than *D. stradneri* var. *grandis*, according to diatom correlations (Barron, 1983 and this volume), and which is probably a lineal source of the elongate evolution evidenced by *D. stradneri* var. *grandis*.

Size. Maximum inner diameter 35 to 45 μm (holotype 41 μm).

Holotype. USNM 371378 (Plate 4, Fig. 2).

Isotypes. USNM 371379 to 371384.

Type locality. Eastern equatorial Pacific, DSDP Sample 575A-33,CC (208 m sub-bottom).

Genus *MESOCENA* Ehrenberg, 1843

Mesocena elliptica (Ehrenberg) Ehrenberg var. *rhomboidea* Bukry, n. var.
(Plate 5, Figs. 1–6)

Mesocena elliptica (Ehrenberg), Bukry, 1978a, p. 698, pl. 2, fig. 16.

Description. *Mesocena elliptica* var. *rhomboidea* has a straight-sided, elongate, rhomboid-shaped basal ring with angular corners and four short, nearly equal spines at the corners. The elongation of the basal ring, measured by the ratio of major and minor axes, ranges from 1.2 to 1.5, with an average of 1.4.

Remarks. *Mesocena elliptica* var. *rhomboidea* is distinguished from *Mesocena elliptica* (see Ehrenberg, 1840, 1854) by its rhomboid basal ring with straight sides, instead of curved, elliptic, or oval basal ring. It is distinguished from *Mesocena quadrangula* by having an elongate rhomboid ring, instead of a square ring. *M. elliptica* var. *rhomboidea* is classified with *M. elliptica* because of short, nearly equant spines and stratigraphic similarities.

Locker's (1974) designation of a rhomboidal lectotype for *M. elliptica* is considered superfluous because Ehrenberg described *M. elliptica* as an elliptic form from Zante, Greece (Ehrenberg, 1840) and illustrated a group of elliptic specimens from Zante, Greece (Ehrenberg, 1854). Therefore, Ehrenberg's species concept was adequately fixed in the last century. Designation of Ehrenberg's (1854) pl. 20, fig. 44b as the lectotype for *M. elliptica* is preferred to the subsequent rhomboid specimen illustrated in 1974 by Locker.

Occurrence. *Mesocena elliptica* var. *rhomboidea* occurs in the lower Miocene *Naviculopsis ponticula* Zone in Cores 7 to 10 of DSDP Hole 575A in the Pacific and in Core 3 of DSDP Hole 370 in the Atlantic. It occurs below and with *M. elliptica* sensu Ehrenberg at DSDP Hole 575A. Therefore, the presently known range is upper lower Miocene.

Size. Maximum inner diameter 40 to 50 μm (holotype 49 μm).

Holotype. USNM 371385 (Plate 5, Fig. 1).

Isotypes. USNM 371386 to 371390.

Type locality. Equatorial Pacific Ocean, DSDP Sample 575A-8-2, 42–43 cm (125 m sub-bottom).

Genus *NAVICULOPSIS* Frenguelli, 1940

Naviculopsis obtusarca Bukry var. *acicula* Bukry, n. var.
(Plate 6, Figs. 5–9)

Naviculopsis sp. cf. *N. obtusarca* Bukry, Bukry, 1982a, p. 444, pl. 8, figs. 6, 8–10.

Description. *Naviculopsis obtusarca* var. *acicula* has a boat-shaped basal ring with narrow, protruding ends that are rounded. The apical bar is aligned with the minor axis of the ring. The lengths of the solid end-points of the ring are about equal to the maximum width of the ring opening along the minor axis. There are no spines developed, and the end points may have an oblong hyaline area oriented along the major axis.

Remarks. *Naviculopsis obtusarca* var. *acicula* is distinguished from *N. obtusarca* by the single, narrow ends of the ring, instead of the blunt or doubly pointed concave ends for *N. obtusarca*. Also, the hyaline area at the end of *N. obtusarca* var. *acicula* shows elongation along the major axis, not across it. *N. obtuscarca* var. *acicula* is distinguished from *N. ponticula* by the bowed sides of the basal ring and the protruding, long, narrow ends, and from *N. navicula* by the protruding ends with hyaline areas.

Occurrence. *Naviculopsis obtusarca* var. *acicula* occurs in lower Miocene *Naviculopsis ponticula* Zone Cores 10 and 11 of DSDP Hole 575A and in Core 32 of DSDP Hole 495. Both sources are in the eastern Pacific, on opposite sides of the East Pacific Rise, and probably represent the same or contiguous populations. Populations of *N. obtusarca* from Austria, illustrated by Stradner (1961) and Bachmann (1970), did not reveal specimens of this new variety.

Size. Maximum inner diameter 50 to 60 μm (holotype 51 μm).

Holotype. USNM 371391 (Plate 6, Fig. 5).

Isotypes. USNM 371392 to 371395.

Type locality. Eastern equatorial Pacific, DSDP Sample 575A-10-2, 42–43 cm (129 m sub-bottom).

SYSTEMATIC PALEONTOLOGY OF NEW COMBINATIONS

Genus *DICTYOCHA* Ehrenberg, 1837

Dictyocha flexatella (Bukry) Bukry, n. comb.

Dictyocha perlaevis flexatella Bukry, 1979b, p. 984, pl. 3, figs. 1–3.

AUTHORSHIP AND ILLUSTRATION REFERENCES TO PUBLISHED LITERATURE FOR CITED TAXA

Corbisema triacantha (Ehrenberg) Hanna—Bukry, 1979a
Dictyocha aculeata (Lemmermann) Dumitrică—Bukry, 1980b
D. angulata Bukry—Bukry, 1982a
D. brevispina ausonia (Deflandre) Bukry—Bukry, 1978a
D. brevispina brevispina (Lemmermann) Bukry—Bukry, 1981a
D. calida calida Poelchau—Poelchau, 1976
D. delicata (Bukry) Bukry—Bukry, 1980b
D. fibula Ehrenberg—Bukry, 1980a
D. longa Bukry—Bukry, 1982a
D. longa var. *paxilla* Bukry—Bukry, 1982a
D. neonautica Bukry—Bukry, 1981a
D. neonautica var. *cocosensis* Bukry—Bukry, 1981a
D. orbiculata Ling—Ling, 1977
D. ornata africana Bukry—Bukry, 1982a
D. ornata ornata (Bukry) Bukry—Bukry, 1982a
D. pons Ehrenberg—Bukry, 1980a
D. pulchella Bukry—Bukry, 1980a
D. stapedia stapedia Haeckel—Bukry, 1980b
Distephanus crux crux (Ehrenberg) Haeckel—Ehrenberg, 1854
D. crux parvus (Bachmann) Bukry emend.—Bukry, 1982a
D. crux scutulatus Bukry—Bukry, 1982a
D. hannai (Bukry) Bukry—Bukry, 1975
D. mesophthalmus (Ehrenberg) Haeckel—Bukry, 1982a
D. polyactis (Ehrenberg) Deflandre—Bukry, 1981a

D. schauinslandii Lemmermann—Lemmermann, 1901
D. speculum haliomma (Ehrenberg) Bukry—Bukry, 1978a
D. speculum hemisphaericus (Ehrenberg) Bukry—Bukry, 1978a
D. speculum patulus Bukry—Bukry, 1982a
D. speculum speculum (Ehrenberg) Haeckel—Bukry, 1980b
D. speculum tenuis Bukry—Bukry, 1982b
D. stauracanthus (Ehrenberg) Haeckel—Dumitrică, 1973
D. stradneri (Jerkovíc) Bukry—Stradner, 1961
D. xenus Bukry—Bukry, in press a
Mesocena apiculata apiculata (Schulz) Hanna—Schulz, 1928
M. circulus (Ehrenberg) Ehrenberg—Bukry, 1979b
M. elliptica (Ehrenberg) Ehrenberg—Bukry, 1978b
M. quadrangula Ehrenberg ex Haeckel—Bukry, 1978b
Naviculopsis biapiculata (Lemmermann) Frenguelli—Bukry, 1975
N. constricta (Schulz) Bukry emend.—Barron et al., in press
N. contraria Bukry—Bukry, 1982a
N. lacrima Bukry—Bukry, 1982a
N. lata (Deflandre) Frenguelli—Bukry, 1978b
N. navicula (Ehrenberg) Deflandre—Bukry, 1982a
N. obtusarca Bukry—Bukry, 1982a
N. ponticula ponticula (Ehrenberg) Bukry—Bukry, 1982a
N. ponticula spinosa Bukry—Bukry, 1982a
N. quadrata (Ehrenberg) Ling—Bukry, 1979a
Octactis pulchra Schiller—Bukry, 1980b

CONCLUSIONS

Silicoflagellates provide a useful relative paleotemperature record that reflects major paleoceanographic events for the lower Miocene to Holocene of Leg 85 sites. For purposes of comparison, the tropical, oceanic setting for the lower Miocene of Hole 575A provides corroboration of major latitudinal trends in silicoflagellate morphology. For example, the virtual absence of fibuloid *Dictyocha* at high- and middle-latitude Holes 407, 391A, 370, 369A, and 278 is a cosmopolitan relation because they are, likewise, absent at tropical Hole 575A. Thus, Neogene populations of fibuloid *Dictyocha* did not become established anywhere until the middle Miocene *Corbisema triacantha* Zone. This happens to coincide with the time of major transition in silicoflagellate morphologies, which was much more extreme than at the earlier worldwide boundary between Neogene and Paleogene.

The lack of fibuloid *Dictyocha* in the lower Miocene suggests, further, that no direct lineages exist between the small populations of fibuloid *Dictyocha* in the Paleogene and those extensive populations of the Neogene, above the lower Miocene.

The early Miocene record of Holes 575A and 495 is distinguished by the absence of the *Mesocena apiculata* group, which is present at nontropical sites and is most abundant at the coldest site, 278 (Bukry, 1975), south of New Zealand. Because of the absence of *Corbisema triacantha* in the lower Miocene of Holes 575A and 495, its presence in the lower middle Miocene of Hole 572D, and its lower Miocene occurrences at middle and high latitudes, *C. triacantha* shows a mixed pattern that is less clear than that of *Mesocena apiculata*.

A pattern of changing paleotemperature values (*Ts*) and species arrays in the *Naviculopsis ponticula* Zone of Hole 575A is practically the same as at Site 495 off Guatemala. Quantitative silicoflagellate data show that tectonic backtracking across the East Pacific Rise should place these two sites in the same vicinity during the period 17 to 19 Ma.

High-amplitude fluctuation in silicoflagellate relative-paleotemperature values characterizes the upper Miocene of Hole 572D, which is situated to the east of Hole 575A and at the westernmost position of a modern tongue of cool equatorial waters advected from coastal South America. The substantial populations of cool-water indicator taxon *Distephanus speculum speculum* suggest the presence of an analogous cool-water tongue as long ago as the late middle Miocene. Following the maximum coolings in the late late Miocene, a general warming trend and reduction in the amplitude of *Ts* fluctuation occurred. The latest major cooling (below *Ts* = 50) occurred in the early Pliocene. Aside from the mid-Quaternary cooling (*Ts* = 71) associated with the acme of *Mesocena quadrangula*, warm *Ts* values of 80 to 100 are typical for the late Pliocene and Quaternary of Hole 572A.

The low-latitude, open-ocean application of the *Ts* relative-paleotemperature technique appears to be successful for Leg 85, as shown by cool peaks matching deep-sea hiatuses in conjunction with fluctuations of cool and warm currents in the area during the late Cenozoic. Both absolute and relative comparisons of *Ts* values for Leg 85 correlate well within the eastern equatorial Pacific and also reflect global paleoceanographic changes.

REFERENCES

Bachmann, A., 1970. Silicoflagellaten aus dem oberösterreichischen Egerien (Oberoligozän). *Österreichische Geol. Bundesanst. Verh.*, 2:275–305.
Barron, J. A., 1983. Latest Oligocene through early middle Miocene diatom biostratigraphy of the eastern tropical Pacific. *Mar. Micropaleontol.*, 7:487–515.
Barron, J. A., Bukry, D., and Poore, R. Z., in press. Correlation of the middle Eocene Kellog Shale of northern California. *Micropaleontology.*
Barron, J. A., and Keller, G., 1982. Widespread Miocene deep-sea hiatuses: Coincidence with periods of global cooling. *Geology*, 10: 577–581.
Bernstein, R. L., and Morris, J. H., 1983. Tropical and mid-latitude North Pacific sea surface temperature variability from the SEASAT SMMR. *J. Geophys. Res.*, 88:1877–1891.
Bukry, D., 1975. Silicoflagellate and coccolith stratigraphy, Deep Sea Drilling Project Leg 29. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 845–872.
_____, 1978a. Cenozoic coccolith and silicoflagellate stratigraphy, offshore northwest Africa, Deep Sea Drilling Project Leg 41. *In* Lancelot, Y., Seibold, E., et al., *Init. Repts. DSDP*, 41: Washington (U.S. Govt. Printing Office), 689–707.
_____, 1978b. Cenozoic coccolith, silicoflagellate, and diatom stratigraphy, Deep Sea Drilling Project Leg 44. *In* Benson, W. E., Sheridan, R. E., et al., *Init. Repts. DSDP*, 44: Washington (U.S. Govt. Printing Office), 807–863.
_____, 1979a. Coccolith and silicoflagellate stratigraphy, northern Mid-Atlantic Ridge and Reykjanes Ridge, Deep Sea Drilling Project Leg 49. *In* Luyendyk, B. P., Cann, J. R., et al., *Init. Repts. DSDP*, 49: Washington (U.S. Govt. Printing Office), 551–581.

_____, 1979b. Comments on opal phytoliths and stratigraphy of Neogene silicoflagellates and coccoliths at Deep Sea Drilling Project Site 397 off northwest Africa. *In* Luyendyk, B. P., Cann, J. R., et al., *Init. Repts. DSDP*, 49: Washington (U.S. Govt. Printing Office), 977–1009.

_____, 1980a. Miocene *Corbisema triacantha* Zone phytoplankton from Deep Sea Drilling Project Sites 415 and 416, off northwest Africa. *In* Lancelot, Y., Winterer, E. L., et al., *Init. Repts. DSDP*, 50: Washington (U.S. Govt. Printing Office), 507–523.

_____, 1980b. Silicoflagellate biostratigraphy and paleoecology in the eastern equatorial Pacific, Deep Sea Drilling Project Leg 54. *In* Rosendahl, B. R., Hekinian, R., et al., *Init. Repts. DSDP*, 54: Washington (U.S. Govt. Printing Office), 545–573.

_____, 1981a. Silicoflagellate stratigraphy of offshore California and Baja California, Deep Sea Drilling Project Leg 63. *In* Yeats, R. S., Haq, B. U., et al., *Init. Repts. DSDP*, 63: Washington (U.S. Govt. Printing Office), 539–557.

_____, 1981b. Synthesis of silicoflagellate stratigraphy for Maestrichtian to Quaternary marine sediment. *Soc. Econ. Paleontol. Mineral. Spec. Publ.*, 32:433–444.

_____, 1982a. Cenozoic silicoflagellates from offshore Guatemala, Deep Sea Drilling Project Site 495. *In* Aubouin, J., von Huene, R., et al., *Init. Repts. DSDP*, 67: Washington (U.S. Govt. Printing Office), 425–445.

_____, 1982b. Neogene silicoflagellates of the eastern equatorial Pacific, Deep Sea Drilling Project Hole 503A. *In* Prell, W. L., Gardner, J. V., et al., *Init. Repts. DSDP*, 68: Washington (U.S. Govt. Printing Office), 311–323.

_____, 1983. Upper Cenozoic silicoflagellates from offshore Ecuador, Deep Sea Drilling Project Site 504. *In* Cann, J. R., Langseth, M. G., Honnorez, J., Von Herzen, R. P., White, S. M., et al., *Init. Repts. DSDP*, 69: Washington (U.S. Govt. Printing Office), 321–342.

_____, in press a. Cenozoic silicoflagellates from Rockall Plateau, Deep Sea Drilling Project Leg 81. *In* Roberts, D. G., Schnitker, D., et al., *Init. Repts. DSDP*, 81: Washington (U.S. Govt. Printing Office).

_____, in press b. Neogene silicoflagellates from DSDP Site 543, western tropical Atlantic Ocean. *In* Hyndman, R. D., Salisbury, M. H., et al., *Init. Repts. DSDP*, 78B: Washington (U.S. Govt. Printing Office).

Bukry, D., and Foster, J. H., 1974. Silicoflagellate zonation of Upper Cretaceous to lower Miocene deep-sea sediment. *U.S. Geol. Surv. J. Res.*, 2:303–310.

Dumitrică, P., 1973. Paleocene, late Oligocene and post-Oligocene silicoflagellates in southwestern Pacific sediments cored on DSDP Leg 21. *In* Burns, R. E., Andrews, J. E., et al., *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office), 837–883.

Ehrenberg, C. G., 1840. 274 Blätter von ihm selbst ausgeführter Zeichnungen von ebenso vielen Arten. *K. Preuss. Akad. Wiss. Berlin Ber. Jahrg.*, 1840(Nov.):197–219.

_____, 1854. *Mikrogeologie:* Leipzig (Leopold Voss), pp. 1–374.

Hays, J. D., et al., 1972. *Init. Repts. DSDP*, 9: Washington (U.S. Govt. Printing Office).

Keller, G., and Barron, J. A., 1983. Paleoceanographic implications of Miocene deep-sea hiatuses. *Geol. Soc. Am. Bull.*, 94:590–613.

Lemmermann, E., 1901. Silicoflagellatae. *Deutsche. Bot. Gesell. Ber.*, 19:247–271.

Ling, H. Y., 1977. Late Cenozoic silicoflagellates and ebridians from the eastern North Pacific region. *First Internat. Congr. Pacific Neogene Stratigraphy Proc.* (Tokyo), pp. 205–233.

Locker, S., 1974. Revision der Silicoflagellaten aus der Mikrogeologischen Sammlung von C. G. Ehrenberg. *Eclogae Geol. Helvetiae*, 67:631–646.

Major, R. P., and Matthews, R. K., 1983. Isotopic composition of bank margin carbonates on Midway Atoll: Amplitude constraint on post-early Miocene eustasy. *Geology*, 11:335–338.

Martini, E., 1971. Neogene silicoflagellates from the equatorial Pacific. *In* Winterer, E. L., Riedel, W. R., et al., *Init. Repts. DSDP*, 7, Pt. 2: Washington (U.S. Govt. Printing Office), 1695–1708.

Poelchau, H. S., 1976. Distribution of Holocene silicoflagellates in North Pacific sediments. *Micropaleontology*, 22:164–193.

Schulz, P., 1928. Beiträge zur Kenntnis fossiler und rezenter Silicoflagellaten. *Bot. Archiv*, 21:225–292.

Shackleton, N. J., 1982. The deep-sea sediment record of climate variability. *Prog. Oceanogr.*, 11:199–218.

Stradner, H., 1961. Über fossile Silicoflagelliden und die Möglichkeit ihrer Verwendung in der Erdölstratigraphie. *Erdol Kohle*, 14:87–92.

Vail, P. R., Mitchum, R. M., Jr., and Thompson, S., 1977. Global cycles of relative changes of sea level. *In* Payton, C. E. (Ed.), *Seismic stratigraphy—applications to hydrocarbon exploration:* Tulsa (Am. Assoc. Pet. Geol.), pp. 83–98.

van Andel, T. H., and Bukry, D., 1973. Basement ages and basement depths in the eastern equatorial Pacific from Deep Sea Drilling Project Legs 5, 8, 9, and 16. *Geol. Soc. Am. Bull.*, 84:2361–2370.
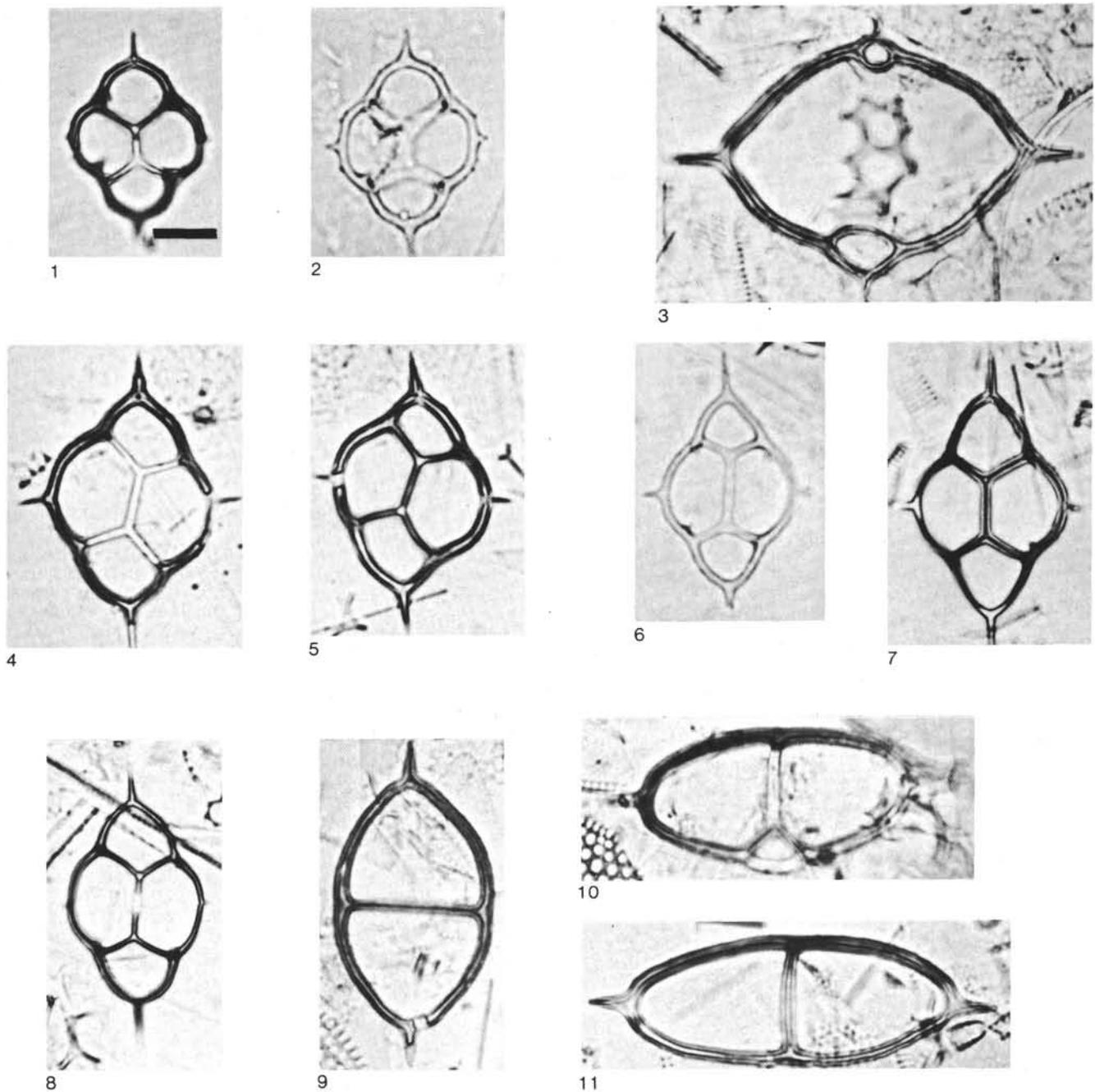
Plate 1.   Silicoflagellates from DSDP Leg 85. (Scale bar = 10 μm.)   **1–2.** *Dictyocha angulata* Bukry, Sample 572A-7-4, 66–67 cm.   **3.** *Dictyocha brevispina* (Lemmermann) (no bar), Sample 572A-10,CC. A form identical to the coeval (approx. 4.5 Ma) population in Section 504-45-1 (Bukry, 1983), which also lacks barred asperoid specimens.   **4–5.** *Dictyocha flexatella* (Bukry), Sample 572A-5-3, 16–17 cm.   **6–8.** *Dictyocha longa* Bukry, (6) Sample 572A-8-3, 66–67 cm, (7) Sample 572A-8-3, 16–17 cm, (8) rounded ends, Sample 572A-8-3, 16–17 cm.   **9.** *Dictyocha neonautica* var. *cocosensis* Bukry, Sample 572A-14,CC.   **10–11.** *Dictyocha neonautica* Bukry, Sample 572A-15-1, 68–69 cm, (10) transitional specimen, (11) normal specimen.
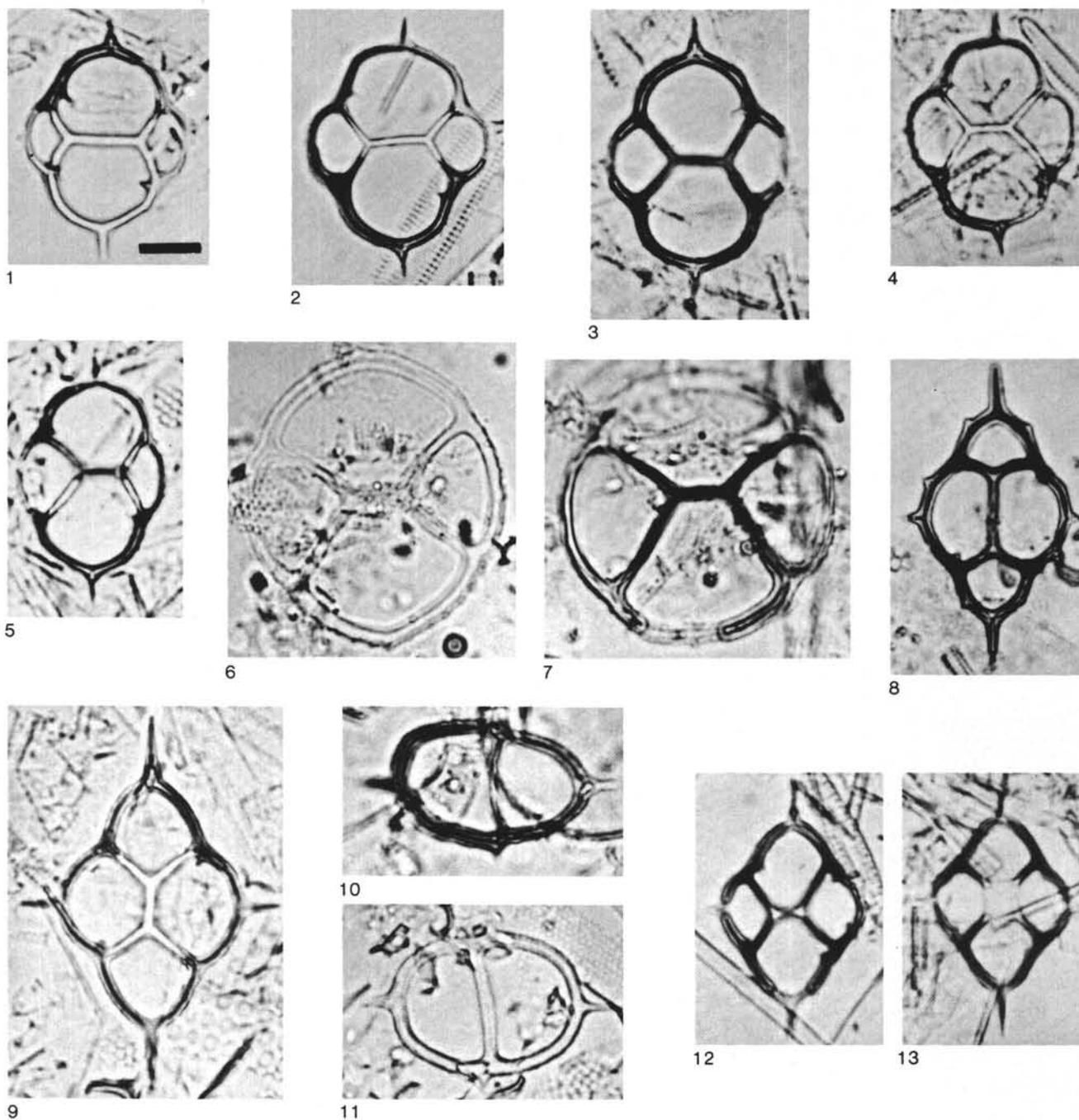
Plate 2. Silicoflagellates from DSDP Leg 85. (Scale bar = 10 μm.) **1–5.** *Dictyocha nola* Bukry, n. sp., Sample 572A-11-3, 67–68 cm, (1) USNM 371374, (2) USNM 371375, (3) holotype, USNM 371373, (4) USNM 371376, (5) USNM 371377. **6–7.** *Dictyocha orbiculata* Ling, Sample 572A-7,CC. **8.** *Dictyocha ornata africana* (Bukry), Sample 572A-5,CC. **9.** *Dictyocha perfecta* Bukry, Sample 572A-8-3, 66–67 cm. **10–11.** *Dictyocha pons* Ehrenberg, Sample 575A-1,CC. **12–13.** *Dictyocha pulchella* Bukry, Sample 572D-18,CC, (12) normal specimen, (13) deflandroid specimen.
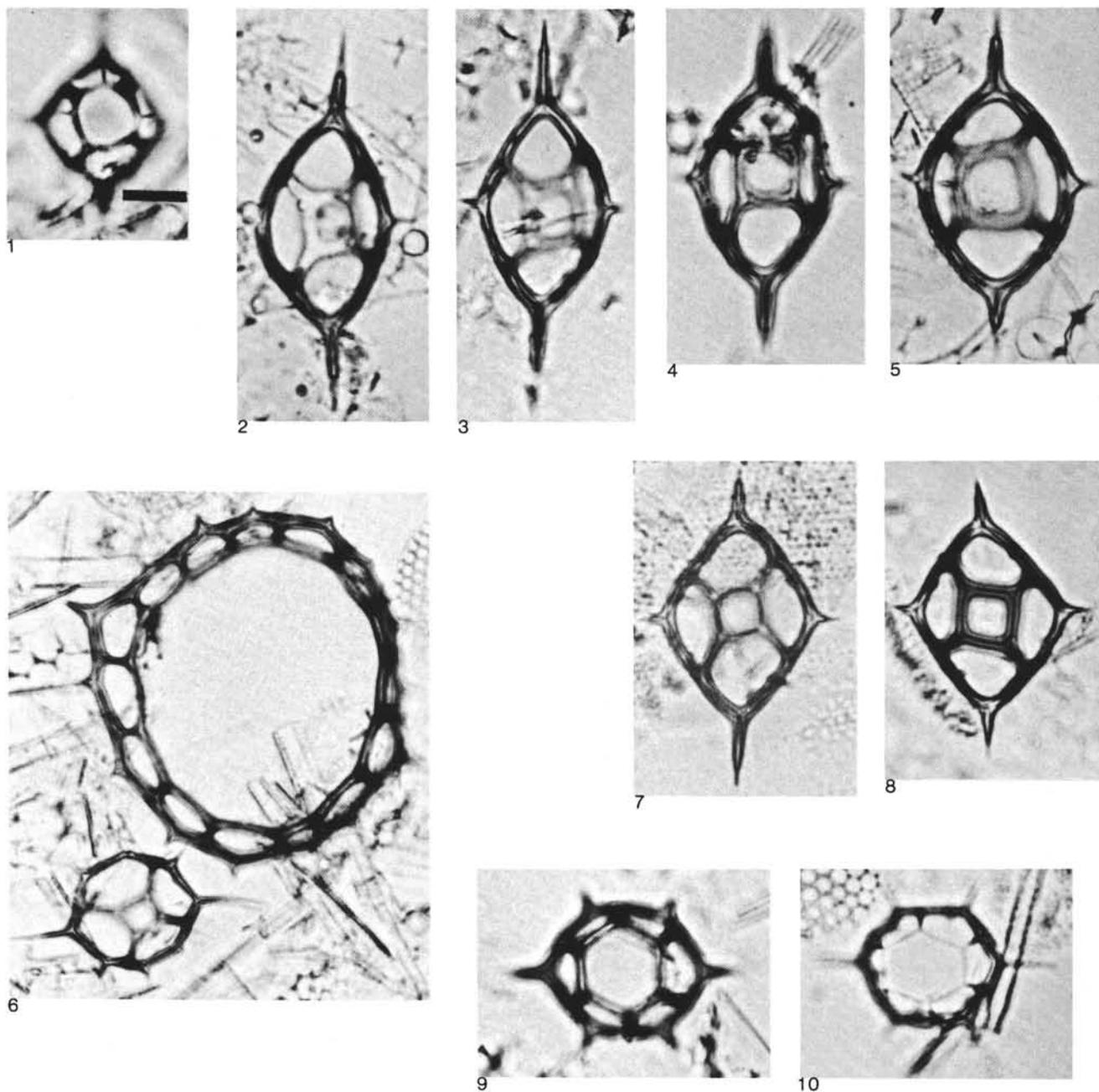
Plate 3. Silicoflagellates from DSDP Leg 85. (Scale bar = 10 μm.) **1.** *Distephanus mesophthalmus* (Ehrenberg), Sample 572A-15-3, 19–20 cm. **2–5.** *Distephanus schauinslandii* Lemmermann, (2) Sample 575A-18,CC, (3) Sample 575A-11-3, 24–25 cm, (4) Sample 575A-18,CC, (5) Sample 575A-17,CC. **6.** *Distephanus polyactis* (Ehrenberg) above *Distephanus stauracanthus* (Ehrenberg), Sample 572D-22,CC. **7–8.** *Distephanus crux scutulatus* Bukry, (7) Sample 575A-12,CC, (8) Sample 575A-7-2, 42–43 cm. **9.** *Distephanus speculum patulus* Bukry, Sample 575A-19,CC. **10.** *Distephanus speculum tenuis* Bukry, Sample 572A-16-3, 19–20 cm.
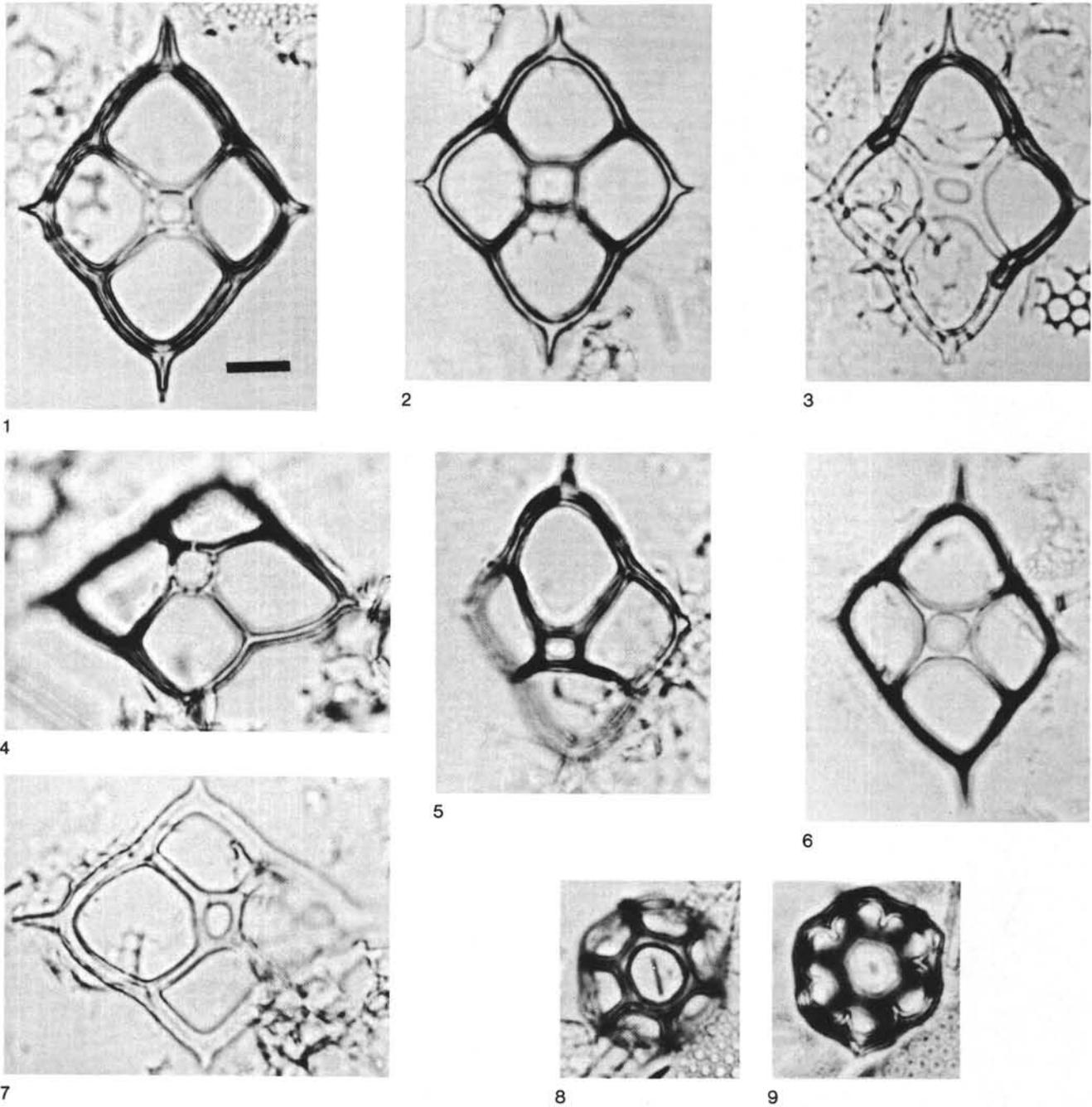
Plate 4. Silicoflagellates from DSDP Leg 85. (Scale bar = 10 μm.) **1–7.** *Distephanus stradneri* var. *grandis* Bukry, n. var., Sample 575A-33,CC, (1) USNM 371379, (2) holotype, USNM 371378, (3) USNM 371380, (4) USNM 371381, (5) USNM 371382, (6) USNM 371383, (7) USNM 371384. **8–9.** *Distephanus xenus* Bukry, Sample 572A-14-3, 18–19 cm, (8) apical focus, (9) basal focus.
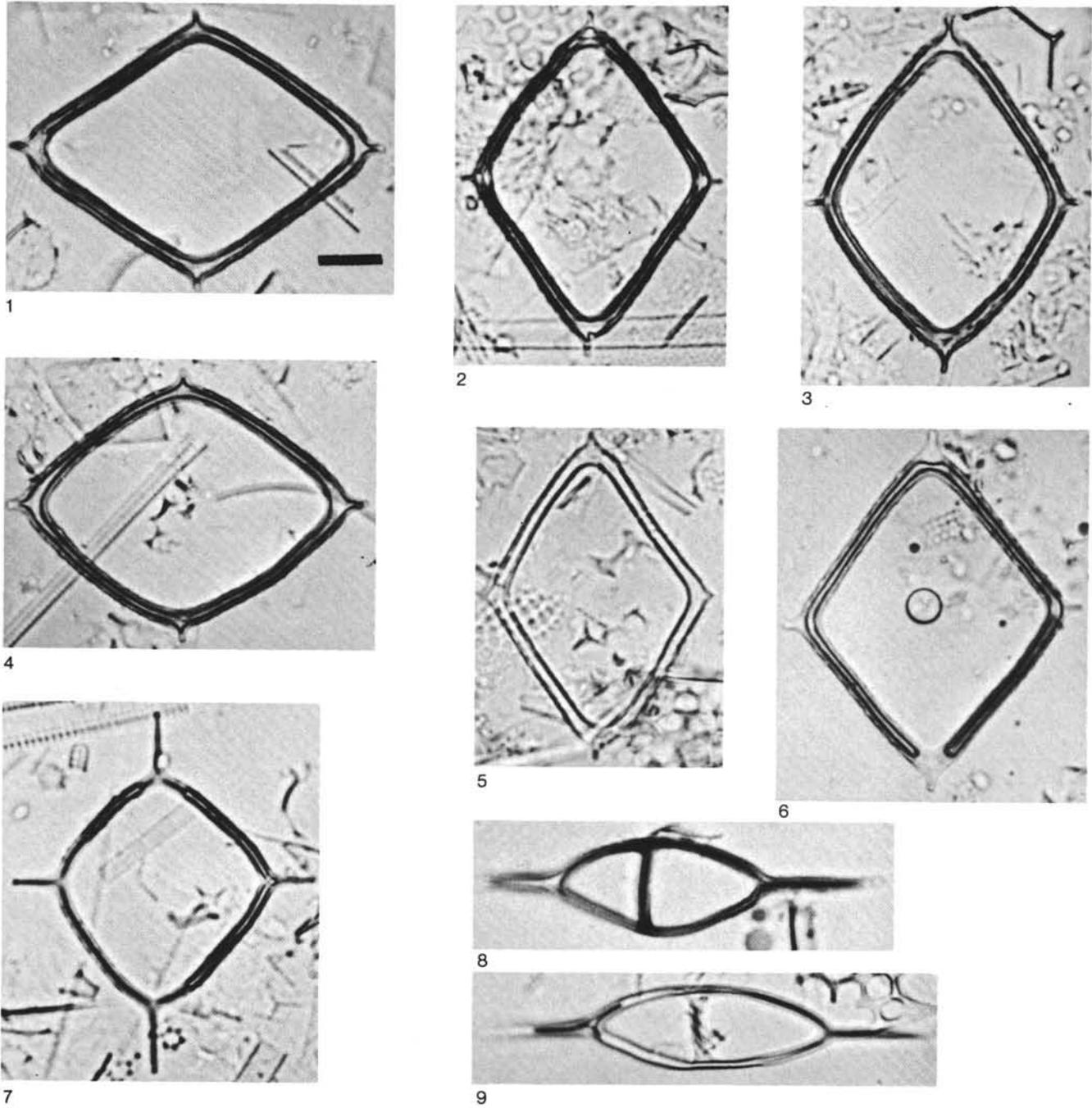
Plate 5.   Silicoflagellates from DSDP Leg 85. (Scale bar = 10 μm.)   **1–6.** *Mesocena elliptica* var. *rhomboidea* Bukry, n. var., (1) holotype, USNM 371385, Sample 575A-8-2, 42–43 cm, (2) USNM 371386, Sample 575A-9,CC, (3) USNM 371387, Sample 575A-7-3, 24–25 cm, (4) USNM 371388, Sample 575A-8-2, 42–43 cm, (5) USNM 371389, Sample 575A-7,CC, (6) USNM 371390, Sample 575A-10,CC.   **7.** *Mesocena quadrangula* Ehrenberg ex Haeckel, Sample 572A-3-1, 68–69 cm.   **8–9.** *Naviculopsis biapiculata* (Lemmermann) s. ampl., (8) Sample 575A-19,CC, (9) Sample 575A-17,CC.
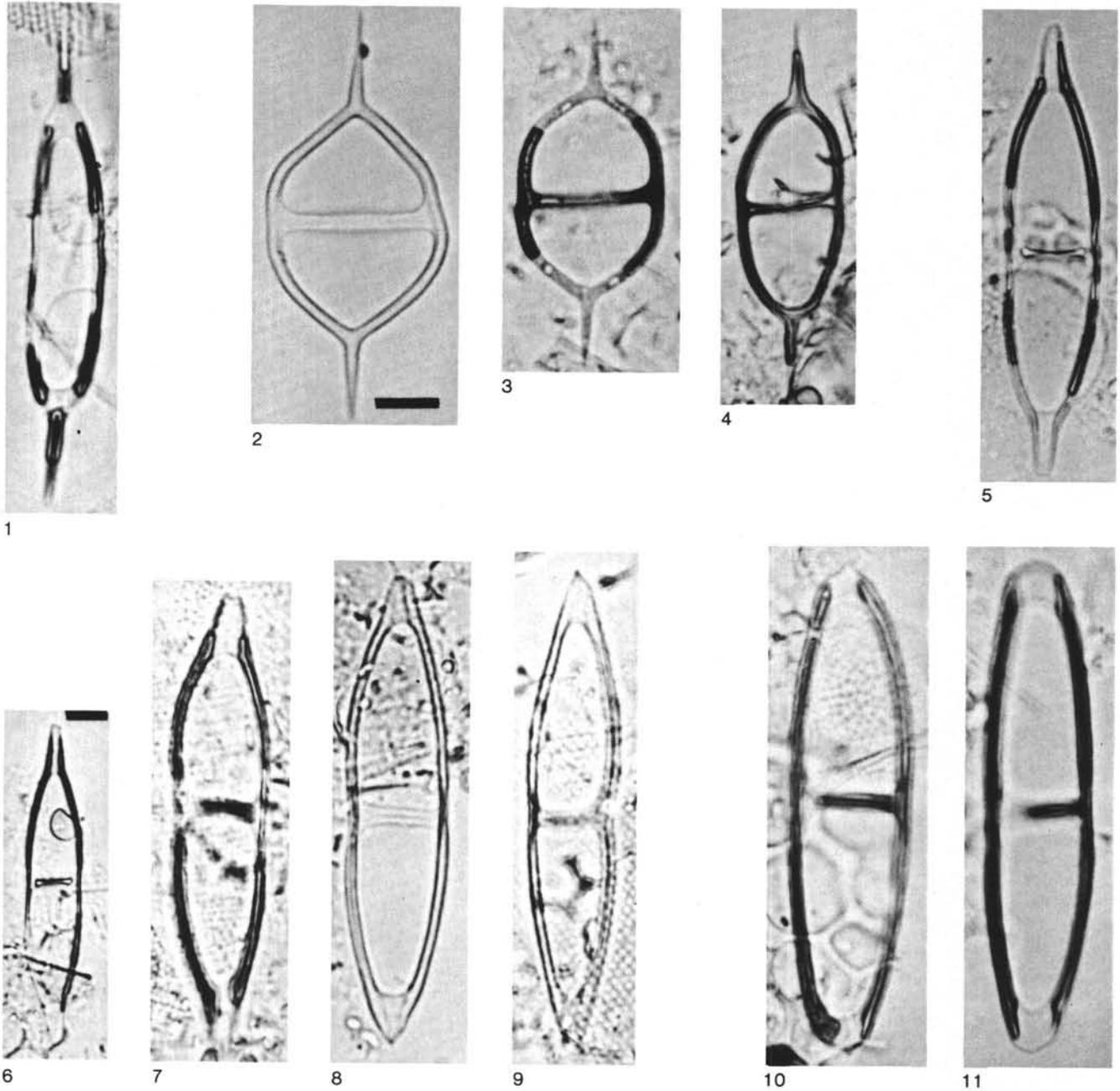
Plate 6. Silicoflagellates from DSDP Leg 85. (Scale bar for Figs. 1–5 and 7–11 = 10 μm. Scale bar for Fig. 6 = 20 μm.) **1.** *Naviculopsis contraria* Bukry, Sample 575A-9,CC. **2–4.** *Naviculopsis lata* (Deflandre), (2) hexagonal, Sample 575A-20,CC, (3) normal, Sample 575A-19,CC, (4) narrow, Sample 575A-19,CC. **5–9.** *Naviculopsis obtusarca* var. *acicula* Bukry, n. var., (5) holotype, USNM 371391, Sample 575A-10-2, 42–43 cm, (6) USNM 371392, Sample 575A-10-2, 42–43 cm, (7) USNM 371393, Sample 575A-10-2, 42–43 cm, (8) USNM 371394, Sample 575A-10-3, 42–43 cm, (9) USNM 371395, Sample 575A-10-3, 42–43 cm. **10–11.** *Naviculopsis ponticula* (Ehrenberg), (10) vestigial spine, Sample 575A-7-2, 42–43 cm, (11) smooth end, Sample 575A-7-3, 24–25 cm.