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27. *DATA REPORT:* CALCAREOUS NANNOFOSSIL ASSEMBLAGES OF THE LAST 27 K.Y. IN HOLE 1017E, SANTA LUCIA SLOPE, OFF POINT CONCEPTION[1]

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INTRODUCTION

Ocean Drilling Program (ODP) Site 1017E (34°32.10′N, 121°6.43′W; 955.5 m water depth) is located on Santa Lucia Slope, ~50 km west of Point Arguello. The location of Hole 1017E, influenced by the California Current and associated coastal upwelling systems, is the best field to monitor paleoclimate change in the North Pacific.

Living coccolithophorid is generally restricted in the photic zone and is one of the major primary producers in modern oceans. Thus, fossil coccolith assemblages can be used for paleoceanographic reconstruction in the surface waters. Winter (1985) reported that the living coccolithophore flora in the California Current system of Southern California has significant variability in community structure, diversity, and standing crop. Wei and Peleo-Alampay (1995) reported that nannofossil diversity is low during oxygen isotope Stages 1–6 in the Santa Barbara Basin. These studies indicate that the low temperature and upwelling in the California Current system are responsible for the dominance of nannofossil flora in the California Borderland. However, very little is known about the paleoceanographic interpretation of nannofossil flora off Point Conception. The purpose of this report is to document the change in calcareous nannofossil assemblages for the last 27 k.y. in relation to the past surface water conditions at Hole 1017E.

METHODS

Preparation for light microscopy and measurement of absolute abundance followed the procedure described by Beaufort (1991). Approximately 0.02 g of dried sediments was placed in a flask, and 100 mL of water was added. This flask was placed in an ultrasonic cleaner at a moderate vibration setting to homogenize the suspension. After 5 s, the flask was removed from the ultrasonic cleaner and shaken. The suspensioned particles were poured into the 100-mL beaker. The cover glass was heightened above the bottom of this beaker. The beaker was placed in the oven and left at room temperature for a day. The temperature of the oven was raised to ~30°–40°C so that water could evaporate after the grainy particles descended quietly to the cover glass. The cover glass was then mounted to the slide glass with the mounting medium “Photocuring Adhesive.”

The coccolith absolute abundance was estimated under a polarized microscope at 1500× magnification. The absolute abundance was calculated from the number of coccoliths observed per a field of view, the volume of suspension poured in the beaker, and the volume of dry sediment.

Three hundred coccoliths were identified to species level in each slide prepared for the light microscopy under a magnification of 1500×. The relative abundance of each nannofossil taxon is defined as follows:

D = dominant (>50% of the total assemblages);
A = abundant (32%–50% of the total assemblages);
C = common (8%–32% of the total assemblages);
F = few (2%–8% of the total assemblages);
R = rare (1%–2% of the total assemblages); and
VR = very rare (<1% of the total assemblages).

The preservation of the nannofossils was recorded using the criteria of Steinmetz (1979) where

G = good (fossils lack evidence of dissolution or overgrowth); and
M = moderately good (the majority of the specimens slightly etched [fine structures are missing, but no diagnostic changes of form are evident in light microscopy; all taxa may be easily identified]).

RESULTS

The absolute abundance of calcareous nannofossils ranged from 3.0×10^7 to 46.4×10^7 individuals per gram of sediment, with an average value of 12.3×10^7 individuals per gram of sediment (Fig. 1). Higher abundances of calcareous nannofossils were observed at 20–17 ka, 15–12 ka, and 11–6.5 ka, whereas the lower values occurred at 23–21 ka and 6–0 ka. Sharp peaks of nannofossil abundance were observed at 10 ka during Termination IB after the Younger Dryas cooling event (Fig. 1).

The coccolith assemblage during the last 27 k.y. was dominated by *Gephyrocapsa muellerae, Florisphaera profunda, Emiliania huxleyi, Gephyrocapsa* spp. (small size), and *Gephyrocapsa oceanica* (Table 1).

G. muellerae, regarded to prefer cool surface-water conditions (Samtleben et al., 1995), was highest in abundance between 22 and 16 ka, reaching 70% of the total coccolith assemblages (Fig. 2). The second abundance peak of this species was observed between 12 and 9 ka, followed by a gradual decrease towards the Holocene. Weaver and Pujol (1998) have reported that the abundance of *G. muellerae* increased in cold episodes before Termination IA and IB in the Alboran Sea. In Hole 1017E, *G. muellerae* has maxima values in the last glacial maximum and in the Younger Dryas.

F. profunda, generally abundant in the lower photic zone of tropical to temperate regions with a temperature range of 10°–28°C (Okada and McIntyre, 1979), increased in abundance during relatively warm intervals (Fig. 2). The peak values of this species were observed from 16 to 10.5 ka and 6 to 1 ka, and became rare between 18 and 17 ka and at 9 ka.

Highest abundance of *Gephyrocapsa* spp. (small size) occurred between 9 and 6 ka after Termination IB. The dominance of small

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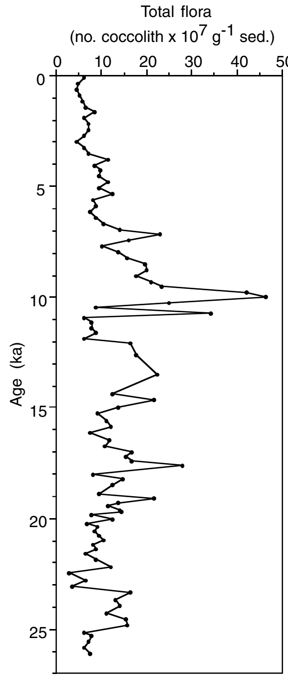

Figure 1. Stratigraphic change in absolute abundance (in number per gram of sediment) of total nannofossils for the last 27 k.y. in Hole 1017E. Ages after Kennett et al. (Chap. 21, this volume).

Gephyrocapsa together with *E. huxleyi* are associated with periods of higher primary productivity or upwelling (Okada and Wells, 1997; Lototskaya et al., 1998). In Hole 1017E, therefore, it is presumed that upwelling took place during 9–6 ka.

A sharp increase in *G. oceanica,* which is generally abundant along ocean margins and in warm regions, was observed at 15.5 ka. *E. huxleyi* was abundant to common throughout the studied period but did not show a clear trend. *Coccolithus pelagicus*, which inhabits the cold water region, had a high peak between 24 and 23 ka and was diminished after 23 ka. *Calcidiscus leptoporus* and *Helicosphaera carteri* gradually increased their abundances toward the Holocene from 15 ka. *Umbellosphaera irregularis,* resident of warm surface waters, was present sporadically after ~18 ka (Samples 167-1017E-1H-1, 0–3 cm, through 1H-3, 54–57 cm) and scarcely between 27 and 18 ka (Samples 167-1017E-1H-3, 60–63 cm, through 1H-CC, 18–21 cm).

Species diversity expressed in Shannon-Weaver's information function varied between 1.1 and 2.2 (Fig. 3). The lowest value was recorded at 18 ka, and the higher values were observed between 15 and 0 ka. Generally, the species diversity increases when the abundance of *G. muellerae* decreased (correlation coefficient $R^2 = 0.78$).

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Table 1. Distribution of calcareous nannofossils in Hole 1017E during the last 27 k.y.

Core, section, interval (cm)	Depth (mbsf)	Preservation	Abundance (no. coccolith × 10^7 g^{-1} sed.)	*Braarudosphaera bigelowi*	*Calcidiscus leptoporus*	*Calciosolenia murrayi*	*Ceratolithus cristatus*	*Coccolithus pelagicus*	*Emiliania huxleyi*	*Florisphaera profunda*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa muellerae*	*Gephyrocapsa oceanica*	*Gephyrocapsa* spp. (small) < 2.5 µm	*Helicosphaera carteri*	*Helicosphaera wallichii*	*Oolithotus fragilis*	*Reticulofenestra producta*	*Reticulofenestra* spp. (small) < 2.5 µm	*Rhabdosphaera clavigera*	*Syracosphaera pulchra*	*Umbellosphaera irregularis*	*Umbilicosphaera sibogae*
167-1017E-																							
1H-1, 0-3	0.01	M	6.1		C			C	A	C	R	F	C	R	F			C		VR			VR
1H-1, 6-9	0.07	M	4.9		C			F	A	C	VR	F	C	F	F			F	VR		VR	VR	
1H-1, 12-15	0.13	M	4.7		C		VR	C	C	C		C	C	F	F			R			VR		
1H-1, 18-21	0.19	M			C		VR	F	C	C		R	C	C	F			F				VR	VR
1H-1, 24-27	0.24	G	5.9		C			F	C	C		F	C	C	F			F			R		
1H-1, 30-33	0.30	G	6.6		C		VR	F	C	C		F	C	F	F			F	VR		V		VR
1H-1, 36-39	0.36	M	8.5		C			F	C	C		R	C	F	F		VR	F	R	VR	VR		
1H-1, 42-45	0.42	M	6.3		C		VR	F	C	C		C	C	F	F			F	R		VR	VR	
1H-1, 48-51	0.47	M	7.3		C		VR	F	C	C		F	C	F	F			R	VR	VR			VR
1H-1, 54-57	0.53	M	7.1		C		VR	F	C	C		F	C	C	F			F	F		VR		VR
1H-1, 60-63	0.59	M	6.2		C		VR	F	C	C		F	C	C	F			R	F	F		VR	VR
1H-1, 66-69	0.65	M	4.6		C		VR	F	C	C		F	C	F	F				R	VR			
1H-1, 72-75	0.70	M	6.4		C		VR	F	C	C		F	C	C	F		VR	R	R	VR	VR		
1H-1, 78-81	0.76	M	7.1		C		VR	F	C	C	VR	F	F	C	F			F		R	VR		VR
1H-1, 84-87	0.82	M	11.4		C		VR	R	C	C	VR	C	C	F	F			R	R	R		VR	VR
1H-1, 90-93	0.88	G	8.7		F		VR	F	C	C		C	C	C	F			F	F	VR			VR
1H-1, 96-99	0.93	G	9.9		C			VR	C	A		C	C	C	F		VR	R	F	VR			
1H-1, 102-105	0.99	G	9.4		C		VR	F	C	C		C	F	C	F		VR	R	F	R	VR	VR	
1H-1, 108-111	1.05	M	11.5		C			F	C	C		C	C	F	F		VR	F	R	VR			VR
1H-1, 114-117	1.11	M	9.4		C		R	F	C	C		C	F	C	C			R	F	F	VR		
1H-1, 120-123	1.16	G	12.4		F		VR	VR	C	C		C	F	C	F			F	R	F	VR		VR
1H-1, 126-129	1.22	G	8.1		F			R	C	C	VR	C	F	C	F				F	F	R		
1H-1, 132-135	1.28	G	8.8		F			F	C	C		C	C	C	F			F		R			VR
1H-1, 138-141	1.34	G	7.5		F		R	R	C	C		C	F	C	C				VR	R	R		VR
1H-1, 144-147	1.39	G	9.0		F	VR	R	R	C	C		C	F	C	F	VR		R		R	VR	VR	VR
1H-2, 0-3	1.45	G	10.6		F		R	F	C	C		C	F	C	F			VR		F	VR		
1H-2, 6-9	1.51	G	14.2		F		VR	VR	C	C		C	C	C	F			R	F	R	VR		VR
1H-2, 12-15	1.57	G	22.9		F		R	VR	A	C		C	C	C	F		R		R	F		VR	
1H-2, 18-21	1.62	M	16.0		F			R	C	C		C	C	C	F			VR	F	F	R		
1H-2, 24-27	1.68	G	10.1		F		VR	R	C	C		C	C	C	F				F	F			VR
1H-2, 30-33	1.74	G	13.7		F			VR	C	C		F	C	C	F			VR	R	F	VR		VR
1H-2, 36-39	1.80	G	15.7		C			R	C	C		C	C	C	F			VR	R	R	VR		
1H-2, 42-45	1.85	G	19.8		F		VR	R	C	F	VR	C	C	C	F				F	VR	VR		
1H-2, 48-51	1.91	G	20.1		F		VR	R	C	F		C	C	C	F			VR	R	F	VR	VR	
1H-2, 54-57	1.97	G	17.8		F			R	C	F		C	C	C	F				R	F	VR	VR	
1H-2, 60-63	2.03	G	21.1		F		VR	R	C	C		C	C	C	F		VR		VR	F	VR	VR	
1H-2, 66-69	2.08	G	23.2		F			F	C	F		A	C	C	F				R	F	VR		VR
1H-2, 72-75	2.14	G	42.1		R		VR	F	C	F		A	C	F	VR			VR	VR	R	R		
1H-2, 78-81	2.20	G	46.4		R			R	C	F		C	C	C	F	VR	VR	VR	VR	F	F	R	VR
1H-2, 84-87	2.26	G	24.9		F	VR		R	C	C		A	C	C	VR			VR	VR	F	R		
1H-2, 90-93	2.31	G	8.9		VR	VR			C	C		C	C	F	R			R	F	F		R	
1H-2, 96-99	2.37	G	34.3		VR	VR	VR	F	C	C		C	C	C	F		VR	VR	VR	F	R	R	
1H-2, 102-105	2.43	M	6.3		R			F	C	C		A	C	C	VR			VR	VR	R	VR		
1H-2, 108-111	2.49	M	7.8		F			F	C	C		A	C	C	VR			R	R	VR	VR		
1H-2, 114-117	2.54	M	7.8		F			F	C	C		A	C	C	R			VR	VR	F	VR		
1H-2, 120-123	2.60	G	8.8		F			F	C	C		A	C	C	R			R	F	F	VR		
1H-2, 126-129	2.66	G	6.2		F			VR	C	C		A	C	C	R			VR	R	F			VR
1H-2, 132-135	2.72	G	16.6		R		VR	F	C	C		C	C	C	F		VR			R	R	VR	VR
1H-2, 138-141	2.77	G	17.9		F			R	C	C		C	C	F	F			VR		VR		R	
1H-2, 144-147	2.83	G	22.4		F			F	C	C		C	C	C	F			R	VR	VR	VR	VR	
1H-3, 0-3	2.89	G	12.5		R		VR	R	C	C		C	C	F	F		VR	VR	R	F	R		
1H-3, 6-9	2.95	G	21.6		F			VR	C	C		C	C	F	R	VR		VR	R	R		R	
1H-3, 12-15	3.00	G	13.7	VR	R		R	F	C	C		C	C	F	F			VR	VR	R	R	VR	VR
1H-3, 18-21	3.06	M	9.3		R		VR	F	C	C		C	C	F	R			VR		VR			
1H-3, 24-27	3.12	G	11.1		VR			F	C	C		D	C	C	R				R	VR	VR	VR	
1H-3, 30-33	3.18	G	12.0		VR			F	C	F	VR	D	F	C	R				VR	VR	VR		
1H-3, 36-39	3.23	G	7.6		VR			F	C	C		D	F	F					VR	F	VR	VR	
1H-3, 42-45	3.29	G	11.7					F	C	F		D	F	F	VR			VR		VR			
1H-3, 48-51	3.35	G	10.7		VR			F	C	F		D	F	F	R			VR	VR	VR	VR		
1H-3, 54-57	3.41	G	16.7		VR			F	C	F		D	F	F	VR			VR	F	VR		VR	
1H-3, 60-63	3.46	G	15.3		VR			F	C	F		D	F	F				VR	VR	VR			
1H-3, 66-69	3.52	G	16.8		R			F	C	F		D	R	F	VR			R	R	VR			
1H-3, 72-75	3.58	G	27.9			VR		F	C	F		D	F	F	F			VR	R				
1H-3, 84-87	3.69	G	8.4		VR			R	C	F		D	F	C	VR				VR		VR		
1H-3, 90-93	3.75	G	14.7		VR			R	C	C		D	F	F				VR	R	VR			
1H-3, 96-99	3.81	G	12.6		VR			F	C	C		D	F	C	R				VR	R			
1H-3, 102-105	3.87	G	14.6		VR			R	C	F	VR	D	F	F	R			VR		VR	VR		
1H-3, 108-111	3.92	G	9.6					F	C	F	VR	D	F	C	R					VR			
1H-3, 114-117	3.98	G	21.7		VR			F	C	F	VR	A	F	C	R				VR	VR	VR		
1H-3, 120-123	4.04	G	13.9		VR			F	C	F		D	F	F	R		VR		VR	VR		VR	
1H-3, 126-129	4.10	G	11.7					F	C	F	VR	D	F	C	F					VR			
1H-3, 132-135	4.15	G	14.1		VR			F	F	F		D	F	C	F						R	VR	
1H-3, 138-141	4.21	G	7.9		F			C	C	F		A	C	F	R			VR	VR				

Table 1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Preservation	Abundance (no. coccolith × 10^7 g^{-1} sed.)	*Braarudosphaera bigelowi*	*Calcidiscus leptoporus*	*Calciosolenia murrayi*	*Ceratolithus cristatus*	*Coccolithus pelagicus*	*Emiliania huxleyi*	*Florisphaera profunda*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa muellerae*	*Gephyrocapsa oceanica*	*Gephyrocapsa* spp. (small) < 2.5 µm	*Helicosphaera carteri*	*Helicosphaera wallichii*	*Oolithotus fragilis*	*Reticulofenestra producta*	*Reticulofenestra* spp. (small) < 2.5 µm	*Rhabdosphaera clavigera*	*Syracosphaera pulchra*	*Umbellosphaera irregularis*	*Umbilicosphaera sibogae*
1H-3, 144-147	4.27	G	12.4					F	C	F		D	F	C	R				F	VR			
1H-4, 0-3	4.33	G	6.9		R			F	C	F	VR	A	C	C	VR				R	F			
1H-4, 6-9	4.38	G	9.1		R			R	C	F		D	F	F	VR			R		VR			
1H-4, 12-15	4.44	G	8.6			VR		F	C	F		D	F	C	VR				F	VR			
1H-4, 18-21	4.50	G	9.7		R			F	C	C		A	F	C	VR			VR	F	VR	VR		
1H-4, 24-27	4.56	G	10.7					F	C	F		D	F	F	VR			VR	F				
1H-4, 30-33	4.61	G	8.2		R			F	C	F		A	R	C				R	R				
1H-4, 36-39	4.67	G	8.9		R			F	A	C		A	F	F	VR				F	R	VR		
1H-4, 42-45	4.73	G	6.5		VR			C	C	C		A	F	C	R			VR	F	VR	VR		
1H-4, 48-51	4.78	G	8.9					F	C	C		A	F	F	VR			VR	F	F	VR		
1H-4, 54-57	4.84	G	12.3		VR			F	C	C		A	R	F	VR				F	VR	VR		
1H-4, 60-63	4.90	G	3.0		VR			A	C	C		C	F	F	R			VR		VR			
1H-4, 66-69	4.96	M	6.6		VR			C	C	C		A	F	C	F				F				
1H-4, 72-75	5.01	M	3.6		VR			C	C	C		C	F	F	F			VR	F	VR		VR	
1H-4, 78-81	5.07	G	16.6					F	C	F		A	F	F	R				F	VR			
1H-4, 84-87	5.13	G	13.2		VR			F	A	F	VR	A	F	F	F			VR	F	R	VR	VR	
1H-4, 90-93	5.19	G	14.0					F	C	F	VR	A	R	F	F			VR	F	VR	VR		
1H-4, 96-99	5.24	G	11.0					F	C	C	VR	A	F	F	VR				VR				
1H-4, 102-105	5.30	G	15.6					F	C	F	VR	A	F	F	VR			VR	F		VR		
1H-4, 108-111	5.36	G	15.8					F	C	C		A	F	F				R	F	VR			
1H-4, 114-117	5.42	G	6.2					C	C	F		A	F	C	R				F	R			
1H-CC, 0-3	5.47	M	7.9		VR			C	C	F	VR	A	R	C	VR			VR	C				
1H-CC, 6-9	5.52	G	7.4					C	C	F		A	F	F	VR			VR	C	VR			
1H-CC, 12-15	5.58	G	6.2		VR			C	C	F		A	F	F				VR	C	R			
1H-CC, 18-21	5.64	M	7.7					C	A	F		C	F	F				R		F			

Note: G = good preservation, M = moderately good preservation, D = dominant, A = abundant, C = common, F = few, R = rare, VR = very rare.

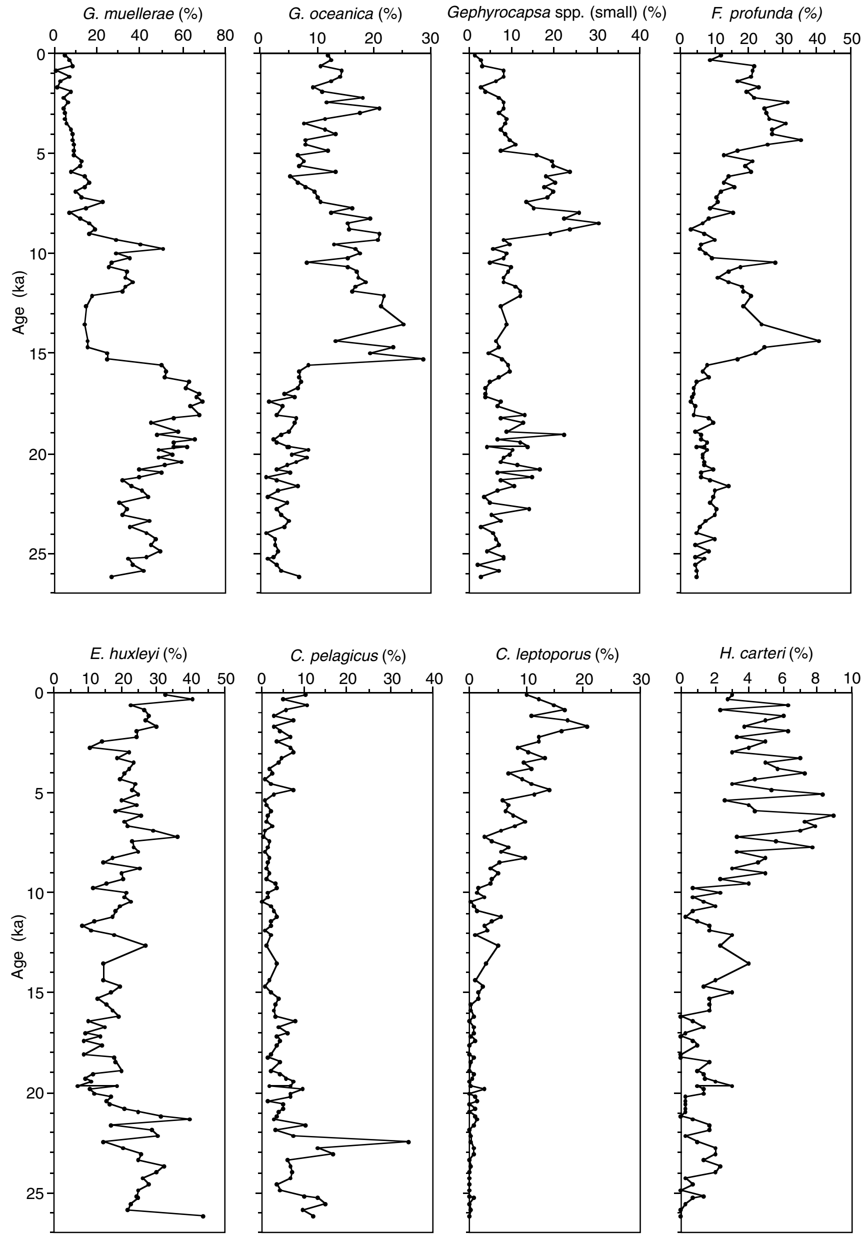

Figure 2. Relative abundances of the major calcareous nannofossil taxa for the last 27 k.y. in Hole 1017E.

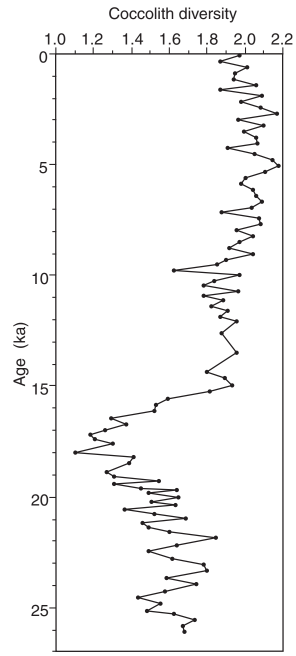

Figure 3. Temporal change in the species diversity measured by Shannon-Weaver's information function for the last 27 k.y. in Hole 1017E.