

**Coeval Decline of Biological Productivity and Bottom-water Oxygenation in EEP Ocean
Recorded by Magnetofossils during the Antarctic Glaciation**

Dunfan Wang¹, Yang Lu¹, Congcong Gai¹, Peiling Xie¹, Yutong Jiang¹, Zeheng Ruan¹, Qingsong
Liu^{1,2*}

¹ Centre for Marine Magnetism (CM2), Department of Ocean Science and Engineering, Southern University of Science
and Technology, Shenzhen 518055, China.

² Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), 511458, China.

*Corresponding author: Qingsong Liu, qslu@sustech.edu.cn

Contents of this file

Text S1
Figures S1
Tables S1

Introduction

This supporting information includes the details of magnetic and geochemical analysis methods (Text S1), revised age model for the studied sites (Figure. S1), and parameters associated with components identified from isothermal remanent magnetizations (IRM) unmixing analysis (Table. S1) which discussed in the main text.

Text S1. Magnetic and geochemical analysis methods

Hysteresis loops (maximum field at 0.5 T), IRM acquisition curves (measured at 80 logarithmically spaced field steps), and backfield demagnetization curves were measured using a vibrating sample magnetometer (VSM, Princeton MicroMag 3900). For FORC measurements, up to 201 FORCs were measured with 300-400 ms averaging times; the data were processed using the FORCinel package with VARIFORC smoothing (Harrison & Feinberg, 2008; Egli, 2013). An anhysteretic remanent magnetization (ARM) was imparted by superimposing a 0.05 mT direct current (DC) bias field on a smoothly decreasing 100 mT peak alternating field (AF), which was then demagnetized with a 20 mT peak AF to obtain $ARM_{@20\text{ mT}}$. The concentration of high-coercivity magnetic minerals such as hematite and goethite has been widely used as an eolian dust indicator in previous studies. In our study, the dust record was obtained by determining the $RelHm+Gt$, which represents the combined relative concentration of hematite and goethite sourced from continental land desert with dust (Zhang et al., 2018).

TEM samples were prepared following Lu et al. (2021). About 0.5 g untreated sediment was mixed with 50 ml distilled water and ultrasonic vibrated for 20 min. Then, a magnet-containing Teflon stick with a smooth surface was inserted into the solution which was, afterward, ultrasonic vibrated for another 10 min. In the process of ultrasonic vibration, some ice made from distilled water was put into the solution to keep the temperature low. After that, the Teflon stick was left in the solution for over 2 h and, subsequently, transferred into a new bottle with distilled water. After removing the magnet, the Teflon stick was ultrasonic vibrated for 5 min to separate magnetic particles from its surface. Magnetic extracts were loaded and clipped between carbon laced double-layer copper grids to be viewed and analysed using Thermo Scientific Talos F200S TEM.

Biogenic silica (opal) was measured using the timed-dissolution technique (Mortlock and Froelich, 1989). About 50 mg of powder sample was placed into a 50 mL tube, 40 mL of 0.2 mol/L sodium carbonate solution was added, and the mixture was heated at 85°C for 6 hours with shaking

every 2 hours. The remaining mixture was centrifuged at 4,000 revolutions/minute for 5 minutes and 100-400 μL of supernatant was taken immediately for analysis, with addition of 4 mL of deionized water and 2 mL of ammonium molybdate acid solution, followed by shaking and reacting for 10 minutes. Then, 2 mL of oxalic acid solution (100 g/L) was added, followed by addition of 4 mL of ascorbic acid solution (1.5%) to a constant volume of 25 mL. After 1 hour, samples were analysed in the spectrophotometer at an 812 nm wavelength. The standard deviation for analyses is $< 4\%$.

Geochemical elements were measured with IRIS Intrepid II XSP ICP-OES and Varian 820 ICP-MS systems, respectively. Samples (0.04 g) were weighed precisely in a Teflon cup before adding 1.5 mL of HF and 0.5 mL of HNO_3 . After digestion in an oven at 180°C for 12 hours, samples were removed and placed on a hot plate (150°C) to dry. Subsequently, 1 mL of HNO_3 and 1 mL of deionized water were added. After 12 hours of airtight digestion at 150°C , samples were cooled, and were then weighed and diluted to 40 g (dilution ratio of 1,000) for analysis. The relative error of major and trace element results is $< 2\%$ and $< 5\%$, respectively. To calculate the biogenic “excess” Ba (xsBa) concentration in sediment samples, we excluded the detrital Ba component which is estimated by multiplying the detrital Th concentration by the average upper crustal Ba/Th ratio of 51.4 ([Taylor & McLennan, 1985](#)).

Sediment ages were obtained by linear interpolation using the revised age model of Westerhold et al. ([2012](#)). Aeolian dust, opal, xsBa, and $\text{ARM}_{@20 \text{ mT}}$ fluxes were calculated by multiplication with the mass accumulation rate (MAR), where $\text{MAR} = \text{density} * \text{LSR}$ (linear sedimentation rate).

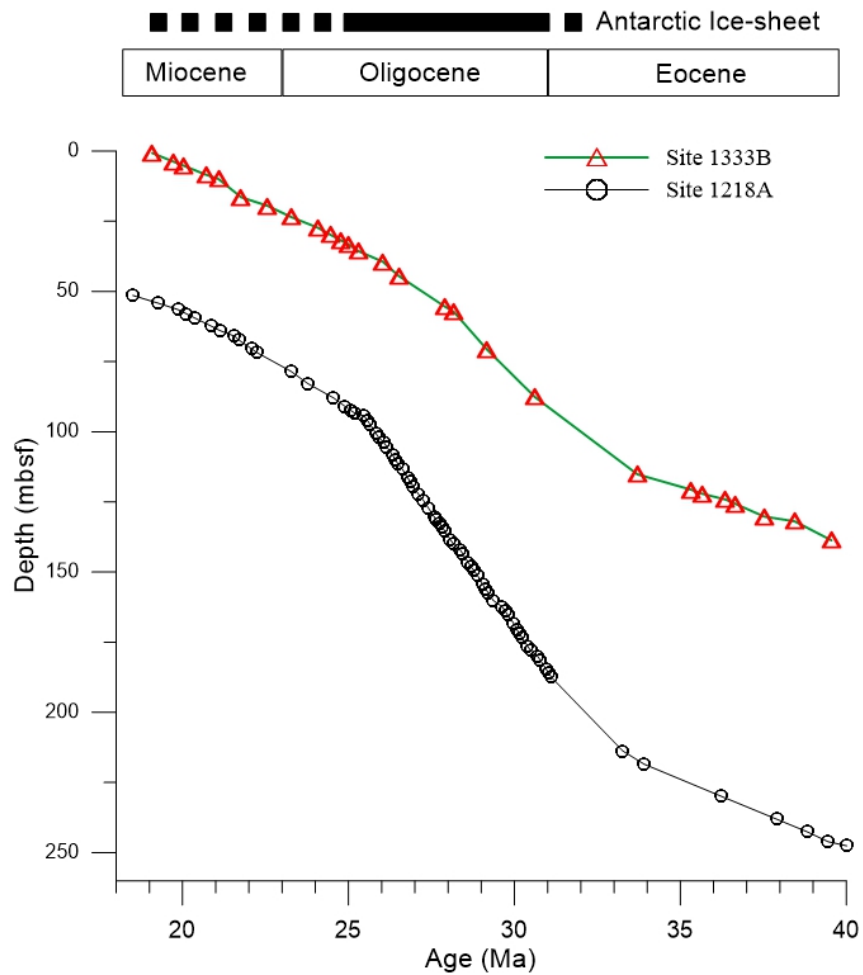


Figure S1. Revised age model for IODP Sites U1333 and 1218 based on magnetic polarity stratigraphy ([Westerhold et al., 2012](#)). Dashed and solid bars (top) represent periods of small (<50%) and large (>50%) southern hemisphere ice coverage ([Zachos et al., 2001](#)).

Table S1. IRM unmixing results for representative samples. Components 1 and 4 represent aeolian magnetic materials with low and high coercivity. Components 2 and 3 represent the biogenic soft and biogenic hard components, respectively. DP is the dispersion of the distribution.

Sample	Component 1	Component 2	Component 3	Component 4
U1333B (Ma)	Percentage (%)			
1H-4 (20.04)	17.1	58.5	15.6	8.8
3H-2 (22.56)	17.9	56.4	17.4	8.2
7H-2 (28.16)	17.0	57.8	17.0	8.1
11H-5 (32.00)	17.0	54.9	19.3	8.9
12H-1 (32.39)	16.3	62.7	13.1	7.8
12H-5 (33.06)	17.2	62.7	11.8	8.3
13H-2 (33.71)	17.5	59.8	14.4	8.2
13H-3 (33.93)	18.5	63.6	8.5	9.4
13H-6 (35.33)	17.8	65.3	7.1	9.8
14H-2 (36.36)	17.2	66.1	7.9	8.8
14H-5 (37.18)	17.2	67.1	7.9	7.9
15H-4 (39.19)	17.3	71.3	5.4	5.9
U1333 (Ma)	$B_{1/2}$ (mT)			
1H-4 (20.04)	12.3	30.9	60.7	173.8
3H-2 (22.56)	12.3	30.1	60.0	173.8
7H-2 (28.16)	12.3	30.2	60.1	173.8
11H-5 (32.00)	12.0	30.2	60.3	172.2
12H-1 (32.39)	12.0	31.6	60.3	172.2
12H-5 (33.06)	12.0	30.2	60.3	173.8
13H-2 (33.71)	12.0	33.1	61.7	172.2
13H-3 (33.93)	12.0	30.9	53.7	171.8
13H-6 (35.33)	12.0	30.9	57.5	173.8
14H-2 (36.36)	12.3	30.2	53.7	171.8
14H-5 (37.18)	12.0	30.9	54.3	169.8
15H-4 (39.19)	12.0	30.1	52.5	173.8
U1333 (Ma)	Dispersion parameter (DP)			
1H-4 (20.04)	0.33	0.20	0.20	0.33
3H-2 (22.56)	0.33	0.19	0.20	0.33
7H-2 (28.16)	0.33	0.19	0.19	0.34
11H-5 (32.00)	0.33	0.20	0.19	0.32
12H-1 (32.39)	0.33	0.20	0.19	0.33

12H-5 (33.06)	0.33	0.19	0.19	0.33
13H-2 (33.71)	0.33	0.20	0.20	0.33
13H-3 (33.93)	0.33	0.19	0.20	0.33
13H-6 (35.33)	0.33	0.20	0.20	0.33
14H-2 (36.36)	0.33	0.19	0.20	0.34
14H-5 (37.18)	0.33	0.20	0.20	0.33
15H-4 (39.19)	0.33	0.20	0.19	0.33
Sample	Component 1	Component 2	Component 3	Component 4
1218A (Ma)	Percentage (%)			
9H-1 (22.80)	17.4	58.9	15.5	8.2
11H-5 (25.82)	17.0	59.9	15.1	8.0
15H-5 (28.07)	17.5	57.5	16.9	8.1
19H-6 (30.48)	16.7	58.7	17.1	7.6
24X-7 (35.06)	17.8	74.3	5.0	3.0
26X-4 (38.20)	17.3	73.5	4.1	5.1
1218A (Ma)	$B_{1/2}$ (mT)			
9H-1 (22.80)	12.6	30.9	60.3	179.9
11H-3 (25.82)	12.9	31.6	60.8	175.8
15H-5 (28.07)	13.2	31.6	60.3	179.9
19H-6 (30.48)	13.2	33.1	60.3	173.8
24X-7 (35.06)	13.2	33.1	50.1	173.8
26X-4 (38.20)	12.3	33.1	52.5	171.8
1218A (Ma)	Dispersion parameter (DP)			
9H-1 (22.80)	0.33	0.19	0.19	0.33
11H-3 (25.82)	0.33	0.19	0.19	0.33
15H-5 (28.07)	0.33	0.18	0.19	0.33
19H-6 (30.48)	0.33	0.20	0.19	0.33
24X-7 (35.06)	0.33	0.20	0.19	0.33
26X-4 (38.20)	0.33	0.20	0.19	0.33