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APPENDIX

Southward shift of the Intertropical Convergence Zone due to Northern Hemisphere cooling at the Oligocene–Miocene boundary

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Age model

The age model has been constructed based on the shipboard magnetostratigraphy and biostratigraphic zonations (Pälike et al., 2010). For the chronology of studied samples, we used magnetostratigraphy and nannofossil biostratigraphy. We excluded radiolarian and planktonic foraminifera biostratigraphy in the age model because it shows wide variability and large uncertainties in determined age (Fig. DR1).

Samples and methods

$^{143}Nd/^{144}Nd$ (reported as ε_{Nd}) and $^{87}Sr/^{86}Sr$ isotopic ratios were measured on a Thermo Finnigan TRITON thermal ionization mass spectrometer at the Korea Polar Research Institute using standard techniques (Lee et al., 2011). The data were corrected mass fractionation by normalizing to $^{86}Sr/^{88}Sr$ = 0.1194 and $^{146}Nd/^{144}Nd$ = 0.7219 using exponential law. Replicate analyses of NBS 987 and JNdi-1 standard gave $^{87}Sr/^{86}Sr$ = 0.710260±4 (n=2) and $^{143}Nd/^{144}Nd$ = 0.510215±5 (n=20). We did not measure $^{147}Sm/^{144}Nd$ ratios to estimate $\varepsilon_{Nd(t)}$ values, ε_{Nd} at the time of deposition, as $^{147}Sm/^{144}Nd$ ratios of Asian and Central/South American dust are uniform at ~ 0.100 (Pettke et al., 2002). Thus, ε_{Nd} change with time due to variations in the concentrations of parent element in the dust is expected to be insignificant. The same batch was also analyzed for Sr, Ba, and Al concentrations on an Inductively Coupled Plasma Mass Spectrometer (ICP-MS) at the Korea Basic Science Institute using a HF-HNO_3 digestion method. The elemental concentrations were quantified based on external calibration method with matrix-matched rock standard solutions (BHVO2, AGV-1, GSP-2, MESS-2, MAG-1, HISS-1). Triplicate analyses of a sample revealed relative error of less than 5%. XRD analyses using X'Pert PRO were carried out for semi-quantitative estimates of clay mineral composition (Biscaye, 1965). The oriented samples were prepared for < 4 μm fraction and scanned from 3˚ to 30˚ 2θ using a Kα radiation generated at 40 kV and 30 mA after salvation with ethylene glycol.

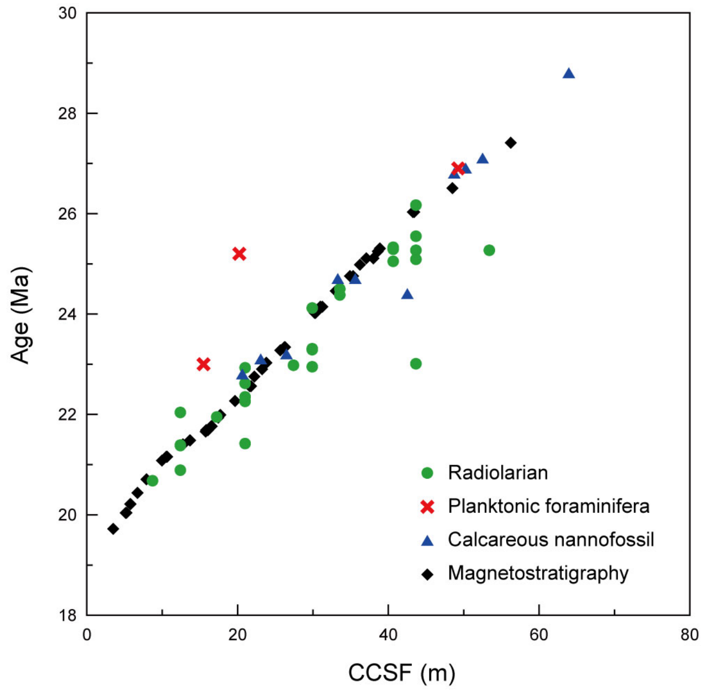

Figure DR1. Tuned age versus composite depth in sediment of U1333 samples (Pälike et al., 2010). CCSF = Core composite depth below seafloor.

Table DR1. ε_{Nd} and mineral composition of eolian dust fractions extracted from IODP U1333B sediments.

Sample ID	Depth (CCSF, m)	Age* (Ma)	$^{143}Nd/^{144}Nd$	ε_{Nd}†	Mineral Composition (%)§			
					Sm	Il	K	Chl
1H-2-W 33/35	1.84	19.5	0.512327 ± 9	-6.08	-	-	-	-
2H-1-W 33/35	8.05	20.6	0.512322 ± 14	-6.16	-	-	-	-
2H-2-W 33/35	9.55	20.9	-	-	44	34	14	8
2H-5-W 33/35	14.05	21.6	0.512306 ± 10	-6.47	-	-	-	-
2H-7-W 33/35	17.05	22.0	-	-	45	39	11	5
3H-3-W 103/105	23.31	23.0	0.512196 ± 13	-8.61	32	44	14	10
3H-4-W 33/35	24.11	23.1	-	-	26	52	11	11
3H-7-W 33/35	28.61	24.0	0.512243 ± 5	-7.71	45	39	10	7
4H-2-W 33/35	31.72	24.3	-	-	53	30	9	8
4H-3-W 103/105	33.92	24.6	0.512252 ± 9	-7.54	-	-	-	-

*Age model based on shipboard magnetostratigraphy and nannofossil biostratigraphy (Pälike et al., 2010). † $\varepsilon_{Nd} = ((^{143}Nd/^{144}Nd)_{sample}/0.512638 - 1) \times 10^4$) (Jacobsen and Wasserburg, 1980). §Sm: smectite, Il: illite, K: kaolinite, and Chl: chlorite. CCSF = Core composite depth below seafloor.

Correction of the measured $^{87}Sr/^{86}Sr$ for co-eval seawater signal

The measured $^{87}Sr/^{86}Sr$ ($^{87}Sr/^{86}Sr_{measured}$) decreases linearly with increasing Ba contents (r^2 = 0.79) toward the early Miocene seawater $^{87}Sr/^{86}Sr$ (0.7082 – 0.7085, McArthur et al., 2001). It suggests the effect of co-eval seawater $^{87}Sr/^{86}Sr$ ($^{87}Sr/^{86}Sr_{seawater}$) signal in the measured values. To remove the effect of $^{87}Sr/^{86}Sr_{seawater}$ from the measured values, we calculated the amount of excess Sr (Sr_{excess}) that is thought to exist in Ba mineral phase by the following equation: $Sr_{excess} = Sr_{measured} - ((Sr/Al)_{reference} \times Al_{measured})$. $Sr_{measured}$ and $Al_{measured}$ stand for the Sr and Al concentrations of samples determined in this study (Table DR2). $(Sr/Al)_{reference}$ value was taken from Hyeong et al. (2011) that provides Sr and Al concentrations of a core sediments dominated by Asian dust (170 ppm of Sr and 8.5 wt.% of Al on average, n=8) and Central/South American dust (250 ppm of Sr and 8.3 wt.% of Al on average, n=3). The pristine $^{87}Sr/^{86}Sr$ of dust ($^{87}Sr/^{86}Sr_{dust}$) was then estimated by the following relationship: $^{87}Sr/^{86}Sr_{measured} = {}^{87}Sr/^{86}Sr_{seawater} \times Sr_{excess}/Sr_{measured} + {}^{87}Sr/^{86}Sr_{dust} \times (Sr_{measured} - Sr_{excess})/Sr_{measured}$. Two different $(Sr/Al)_{reference}$ values were applied for the estimation, which yielded two corrected $^{87}Sr/^{86}Sr_{dust}$ values (corrected-1 and corrected-2 in Table A2). For "corrected-1", Sr (210 ppm) and Al (8.4 wt.%) concentrations, averaged for both Asian and Central/South American dust-dominated intervals in Hyeong et al. (2011) were applied for $(Sr/Al)_{reference}$ to estimate excess Sr ($Sr_{excess\text{-}1}$, Table DR2). For "corrected-2", the average Sr and Al concentrations of the Asian dust-dominated interval were applied for the Mi-1 interval and, for the other samples, those of the Central/South American dust-dominated interval were applied for $(Sr/Al)_{reference}$ to estimate excess Sr ($Sr_{excess\text{-}2}$, Table DR2). Therefore, the latter estimation reflects the dust source regimes projected from ε_{Nd} and mineral compositions. Both results are not much different in estimated ratios, but the latter estimation provided more consistent results with ε_{Nd} and mineral compositions (Fig. DR2).

Table DR2. Estimation of dust $^{87}Sr/^{86}Sr$ signals from the measured ratios (see the text for details)

Depth (CCSF, m)	Age (Ma)	$^{87}Sr/^{86}Sr$				Ba (%)	Sr (ppm)			Al (%)
		seawater	measured	corrected-1	corrected-2		measured	excess-1	excess-2	
1.84	19.48	0.70848	0.708375 ± 13	0.7081	0.7082	1.99	620	431	392	7.46
8.05	20.6	0.70841	0.708431 ± 11	0.7085	0.7085	1.69	683	489	449	7.52
14.05	21.55	0.70837	0.709143 ± 11	0.7096	0.7094	0.67	316	118	77	7.82
23.31	22.95	0.70830	0.709060 ± 13	0.7116	0.7124	1.32	777	595	632	7.18
24.11	24.02	0.70826	0.708970 ± 10	0.7108	0.7103	1.08	519	372	341	5.81
33.92	24.6	0.70821	0.708623 ± 14	0.7103	0.7099	1.33	845	677	642	6.64

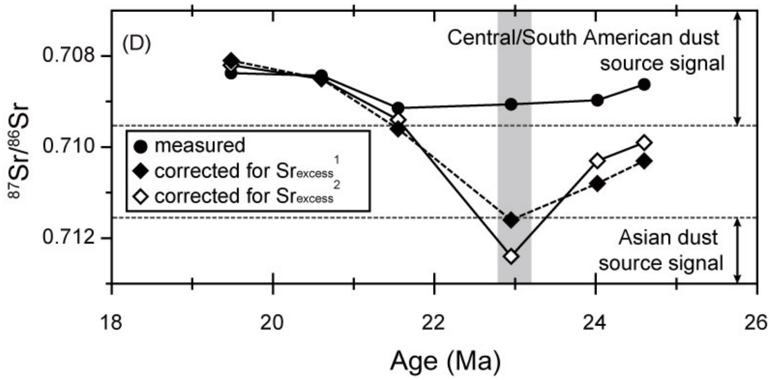

Figure DR2. $^{87}Sr/^{86}Sr$ of eolian dust fractions determined in this study. The estimated $^{87}Sr/^{86}Sr$ of dust corrected for co-eval Sr signal was shown together (see the text for details).

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