GSA Data Repository 2017337

Tesfamichael et al., 2017, Settling the issue of "decoupling" between atmospheric carbon dioxide and global temperature: $[CO_2]_{atm}$ reconstructions across the warming Paleogene-Neogene divide: Geology, doi:10.1130/G39048.1.

Item DR1. U-Pb geochronology

Methods

Heavy minerals dominated by zircon were separated from hand samples of each volcanic tuff by conventional density and magnetic methods. The entire zircon separate was placed in a muffle furnace at 900°C for 60 hours in quartz beakers to anneal minor radiation damage. Following annealing, individual grains were hand-picked for further isotopic analysis. Selected zircon crystals were subjected to a modified version of the chemical abrasion method of Mattinson (2005), whereby single crystals were individually abraded in a single step with concentrated HF at 180°C for 12 hours. The detailed methods for U-Pb geochronology by chemical abrasion isotope dilution thermal ionization mass spectrometry (CA-IDTIMS) follow those previously published by Davydov et al. (2010) and Schmitz and Davydov (2012). U-Pb dates and uncertainties for each analysis were calculated using the algorithms of Schmitz and Schoene (2007) and the U decay constants of Jaffey et al. (1971). Uncertainties are based upon non-systematic analytical errors, including counting statistics, instrumental fractionation, tracer subtraction, and blank subtraction. These error estimates should be considered when comparing our $^{206}Pb/^{238}U$ dates with those from other laboratories that used tracer solutions calibrated against the EARTHTIME gravimetric standards. When comparing our dates with those derived from other decay schemes (e.g., $^{40}Ar/^{39}Ar$, ^{187}Re-^{187}Os), the uncertainties in tracer calibration (0.03%; Condon et al., 2015; McLean et al., 2015) and U decay constants (0.108%; Jaffey et al., 1971) should be added to the internal error in quadrature. Quoted errors for calculated weighted means are thus of the form ±X (Y) [Z], where X is solely analytical uncertainty, Y is the combined analytical and tracer uncertainty, and Z is the combined analytical, tracer and ^{238}U decay constant uncertainty.

Results

Ash 2: The sample "Ash 2" from Mush Valley if a thick fine-grained volcanic ignimbritic tuff immediately underlying the sampled fossil leaf-bearing lacustrine shales, and contained a sparse, homogeneous population of relatively small (100 to 200 microns in long dimension), equant to elongate prismatic zircon crystals. One crystal yielded discordant results indicative of Precambrian inheritance, while the other six analyzed grains yielded $^{206}Pb/^{238}U$ dates ranging from 22.42 to 21.71 Ma (Figure 1). Excluding two clearly older crystals interpreted as inherited from an earlier episode of volcanism, the four youngest grains produce a concordant and equivalent cluster of dates with a weighted mean $^{206}Pb/^{238}U$ age of 21.733 ± 0.060 (0.06) [0.07] Ma (2σ, MSWD = 1.47). This age is interpreted as the crystallization and depositional age of the tuff; the relatively large age uncertainty is due to the occurrence and correction for initial common Pb sourced from the abundant glass and feldspar inclusions in these grains.

MV8: The sample "MV8" from Mush Valley is a light greenish-gray, laminated, very coarse grained ash with visible biotite and pumice fragments, within a sequence of interbedded volcanic tuffs and tuffaceous mudstones and

approximately 5 meters below sample "Ash 2". An abundant population of relatively large, (approximately 100-300 micron in long dimension), elongate, prismatic zircon crystals was separated from the sample. Ten large (250 to 300 microns in long dimension) single zircon grains were analyzed from the homogeneous elongate prismatic zircon population of sample MV8. Four older grains ranging in age from 22.32 to 22.25 Ma are clearly resolvable antecrysts to the MV8 population derived from a prior eruptive event. The remaining six crystals with $^{206}Pb/^{238}U$ dates ranging from 21.76 to 21.71 Ma produce a concordant and equivalent cluster with a weighted mean $^{206}Pb/^{238}U$ age of 21.736 ± 0.015 (0.03) [0.03] Ma (2□, MSWD = 0.62), which is interpreted as the crystallization and depositional age of the tuff. This result is within uncertainty of and confirms the age interpretation for the overlying Ash-2 horizon.

CH08-06: The sample "CH08-06" is a light-green, massive, relatively indurated, fine-grained volcanic ash sampled within 50 cm of the sampled fossil leaves and 74.3 meters above the base of the Guang section at Chilga. An abundant population of relatively large (approximately 100-300 micron in long dimension), elongate, prismatic zircon crystals was separated from the sample. Ten relatively small (100 to 150 microns in long dimension) single zircon grains were analyzed from the homogeneous equant to short prismatic zircon population of sample CH08-06, yielding precise and concordant results with $^{206}Pb/^{238}U$ dates ranging from 27.19 to 28.87 Ma (Figure 1). Excluding two clearly older crystals interpreted as inherited from an earlier episode of volcanism, the eight youngest grains produce a concordant and equivalent cluster of dates with a weighted mean $^{206}Pb/^{238}U$ age of 27.225 ± 0.013 (0.02) [0.03] Ma (2□, MSWD = 1.72). Given the acceptable probability of fit, this age is interpreted as the crystallization and depositional age of the tuff.

CA-IDTIMS U-Pb age summary

Sample	Section	$^{206}Pb/^{238}U$ age (Ma)*	MSWD†	N
Ash-2	Mush Valley	21.733 ± 0.060 (0.06) [0.07]	1.47	4 of 7
MV8	Mush Valley	21.736 ± 0.015 (0.03) [0.03]	0.62	6 of 10
CH08-06	Chilga	27.225 ± 0.013 (0.02) [0.03]	1.72	8 of 11

Notes: *All weighted mean ages at the 95% confidence interval, as calculated from the internal 2σ errors. Uncertainties are quoted as analytical (analytical+tracer) [analytical+tracer+decay constant]. †mean squared weighted deviations.

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CA-IDTIMS U-Pb Isotopic Data

Grain (a)	Th/U (b)	^{206}Pb* x10^{-13} mol (c)	mol % ^{206}Pb* (c)	Pb*/Pbc (c)	Pbc (pg) (c)	^{206}Pb/^{204}Pb (d)	Radiogenic Isotopic Ratios: ^{208}Pb/^{206}Pb (e)	^{207}Pb/^{206}Pb (e)	% err (f)	^{207}Pb/^{235}U (e)	% err (f)	^{206}Pb/^{238}U (e)	% err (f)	corr. coef.	Radiogenic Isotopic Dates: ^{207}Pb/^{235}U (g)	± (f)	^{206}Pb/^{238}U (g)	± (f)
Mush Valley																		
Ash-2																		
z5	0.109	3.0045	0.993	37	1.85	2478	0.034	0.07447	0.1	0.924780	0.2	0.090069	0.072	0.905	664.9	0.7	555.9	0.3
z7	0.955	0.0227	0.769	1.1	0.57	78	0.308	0.04696	12.0	0.022562	12.4	0.003485	0.682	0.472	22.65	2.77	22.424	0.153
z8	0.803	0.0419	0.873	2.2	0.51	142	0.259	0.04577	4.3	0.021883	4.5	0.003468	0.345	0.651	21.98	0.97	22.315	0.077
z2	**0.884**	**0.0789**	**0.519**	**0.4**	**6.01**	**39**	**0.285**	**0.04664**	**8.3**	**0.021937**	**8.5**	**0.003411**	**1.032**	**0.246**	**22.03**	**1.85**	**21.953**	**0.226**
z6	**0.561**	**0.0449**	**0.439**	**0.2**	**4.72**	**33**	**0.181**	**0.04760**	**12.5**	**0.022236**	**12.8**	**0.003388**	**1.382**	**0.234**	**22.33**	**2.83**	**21.806**	**0.301**
z1	**0.633**	**0.1045**	**0.831**	**1.5**	**1.75**	**108**	**0.204**	**0.04729**	**3.3**	**0.022000**	**3.5**	**0.003374**	**0.327**	**0.688**	**22.10**	**0.76**	**21.714**	**0.071**
z4	**0.637**	**0.0421**	**0.720**	**0.8**	**1.35**	**65**	**0.205**	**0.04617**	**8.5**	**0.021477**	**8.9**	**0.003373**	**0.654**	**0.615**	**21.58**	**1.90**	**21.710**	**0.142**
MV8																		
z12	0.759	0.1249	0.871	2.2	1.52	143	0.245	0.04690	1.8	0.022431	1.9	0.003469	0.205	0.658	22.52	0.42	22.323	0.046
z9	0.655	0.0804	0.830	1.5	1.36	108	0.211	0.04690	2.8	0.022425	3.0	0.003468	0.283	0.680	22.52	0.66	22.315	0.063
z3	0.693	0.0821	0.892	2.6	0.82	168	0.223	0.04676	2.7	0.022346	2.8	0.003466	0.238	0.734	22.44	0.63	22.306	0.053
z8	0.607	0.0892	0.944	5.2	0.44	321	0.196	0.04514	2.5	0.021520	2.6	0.003457	0.326	0.422	21.62	0.55	22.249	0.072
z14	**0.742**	**0.1007**	**0.884**	**2.5**	**1.09**	**158**	**0.239**	**0.04730**	**2.2**	**0.022050**	**2.3**	**0.003381**	**0.220**	**0.722**	**22.15**	**0.51**	**21.758**	**0.048**
z13	**0.685**	**0.1216**	**0.939**	**4.8**	**0.66**	**294**	**0.221**	**0.04577**	**1.7**	**0.021321**	**1.8**	**0.003379**	**0.187**	**0.687**	**21.42**	**0.39**	**21.745**	**0.041**
z10	**0.804**	**0.0812**	**0.866**	**2.1**	**1.04**	**137**	**0.259**	**0.04745**	**2.6**	**0.022106**	**2.8**	**0.003379**	**0.253**	**0.714**	**22.20**	**0.61**	**21.743**	**0.055**
z7	**0.663**	**0.1317**	**0.971**	**10.3**	**0.33**	**613**	**0.214**	**0.04678**	**0.9**	**0.021792**	**1.0**	**0.003378**	**0.121**	**0.667**	**21.89**	**0.21**	**21.741**	**0.026**
z2	**0.836**	**0.2049**	**0.945**	**5.7**	**0.98**	**332**	**0.269**	**0.04639**	**1.1**	**0.021588**	**1.2**	**0.003375**	**0.137**	**0.704**	**21.69**	**0.26**	**21.720**	**0.030**
z11	**0.748**	**0.0860**	**0.830**	**1.6**	**1.45**	**108**	**0.241**	**0.04702**	**2.7**	**0.021869**	**2.9**	**0.003373**	**0.273**	**0.628**	**21.97**	**0.63**	**21.710**	**0.059**
Chilga																		
CH08-06																		
z7	1.259	0.1363	0.918	4.0	1.01	221	0.405	0.04713	1.5	0.029210	1.6	0.004495	0.165	0.734	29.23	0.46	28.912	0.048
z6	0.681	0.1138	0.939	4.9	0.61	296	0.219	0.04700	1.5	0.027865	1.6	0.004300	0.164	0.749	27.91	0.43	27.662	0.045
z5	0.558	0.1463	0.919	3.5	1.07	225	0.180	0.04753	1.4	0.028032	1.5	0.004277	0.158	0.734	28.07	0.41	27.514	0.043
z9	**0.378**	**0.1424**	**0.959**	**6.8**	**0.50**	**441**	**0.122**	**0.04685**	**1.1**	**0.027371**	**1.2**	**0.004238**	**0.124**	**0.767**	**27.42**	**0.32**	**27.259**	**0.034**
z14	**0.436**	**0.0810**	**0.882**	**2.2**	**0.89**	**155**	**0.140**	**0.04647**	**2.9**	**0.027148**	**3.1**	**0.004237**	**0.286**	**0.646**	**27.20**	**0.83**	**27.255**	**0.078**
z8	**0.441**	**0.1738**	**0.971**	**10.0**	**0.43**	**626**	**0.142**	**0.04653**	**0.7**	**0.027165**	**0.8**	**0.004234**	**0.094**	**0.829**	**27.21**	**0.22**	**27.235**	**0.026**
z10	**0.490**	**0.1685**	**0.962**	**7.6**	**0.55**	**474**	**0.158**	**0.04668**	**1.0**	**0.027241**	**1.1**	**0.004233**	**0.121**	**0.735**	**27.29**	**0.29**	**27.229**	**0.033**
z12	**0.444**	**0.0919**	**0.940**	**4.7**	**0.48**	**303**	**0.143**	**0.04656**	**1.8**	**0.027165**	**2.0**	**0.004231**	**0.162**	**0.833**	**27.22**	**0.53**	**27.220**	**0.044**
z2	**0.428**	**0.1430**	**0.963**	**7.6**	**0.46**	**483**	**0.138**	**0.04654**	**1.2**	**0.027143**	**1.3**	**0.004230**	**0.133**	**0.711**	**27.19**	**0.35**	**27.208**	**0.036**
z4	**0.458**	**0.1799**	**0.971**	**9.9**	**0.45**	**618**	**0.147**	**0.04609**	**0.8**	**0.026872**	**0.9**	**0.004229**	**0.114**	**0.657**	**26.93**	**0.24**	**27.203**	**0.031**
z13	**0.456**	**0.0893**	**0.937**	**4.4**	**0.50**	**288**	**0.147**	**0.04657**	**1.9**	**0.027126**	**2.0**	**0.004224**	**0.197**	**0.662**	**27.18**	**0.54**	**27.173**	**0.053**

Notes:

(a) z1, z2, etc. are labels for single zircon fragments chemically abraded at 190°C (Mattinson, 2005); bold font indicates analyses included in weighted mean.

(b) Model Th/U ratio calculated from radiogenic $^{208}Pb/^{206}Pb$ ratio and $^{207}Pb/^{235}U$ date.

(c) Pb* and Pbc are radiogenic and common Pb, respectively. mol % $^{206}Pb^*$ is with respect to total sample Pb.

(d) Measured ratio corrected for spike and fractionation only. Samples spiked with the ET535 tracer (Condon et al., 2015; McLean et al., 2015), with internal U fractionation correction and external Pb fractionation correction of 0.18 ± 0.03 (1-sigma) %/amu (atomic mass unit), based on analysis of ET2535-spiked samples analyzed in the same period.

(e) Corrected for fractionation, spike, common Pb, and initial disequilibrium in $^{230}Th/^{238}U$. Up to 0.7 pg common Pb is assigned to procedural blank with composition of $^{206}Pb/^{204}Pb$ = 18.042 ± 0.61%; $^{207}Pb/^{204}Pb$ = 15.537 ± 0.52%; $^{208}Pb/^{204}Pb$ = 37.686 ± 0.63% (1-sigma). Excess over blank was assigned to initial common Pb, using the Stacey and Kramers (1975) two-stage Pb isotope evolution model at the nominal sample age.

(f) Errors are 2-sigma, propagated using algorithms of Schmitz and Schoene (2007).

(g) Calculations based on the decay constants of Jaffey et al. (1971). $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ ratios and dates corrected for initial disequilibrium in $^{230}Th/^{238}U$ using a mineral-melt partition coefficient ratio for $D_{Th/U} = 0.2$.

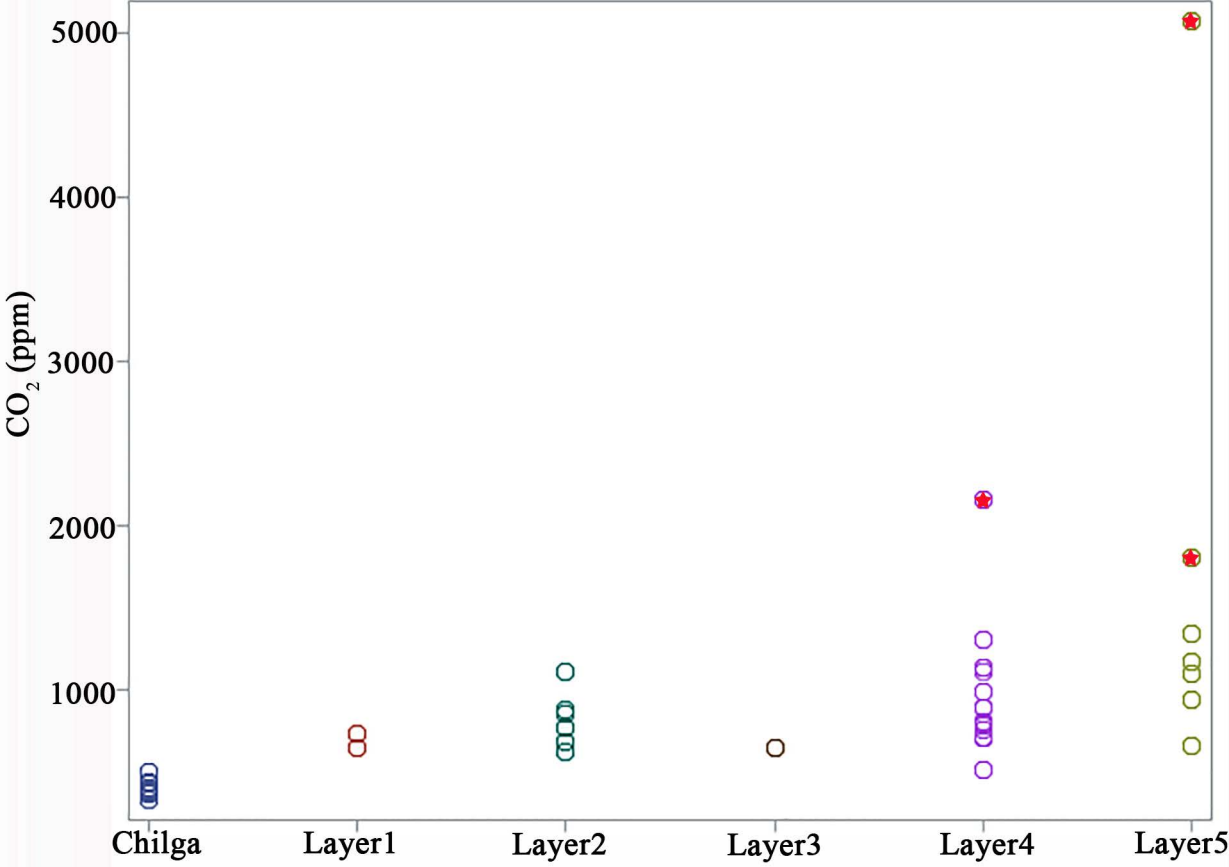

Figure DR1. All CO_2 (ppm) estimates. Outliers shown in red.

Fig. DR1. Distribution of resampled pCO2 values for early Miocene (MU13–24(3)#3) and late Oligocene (CH40–P70) specimens, graphs A and B respectively.

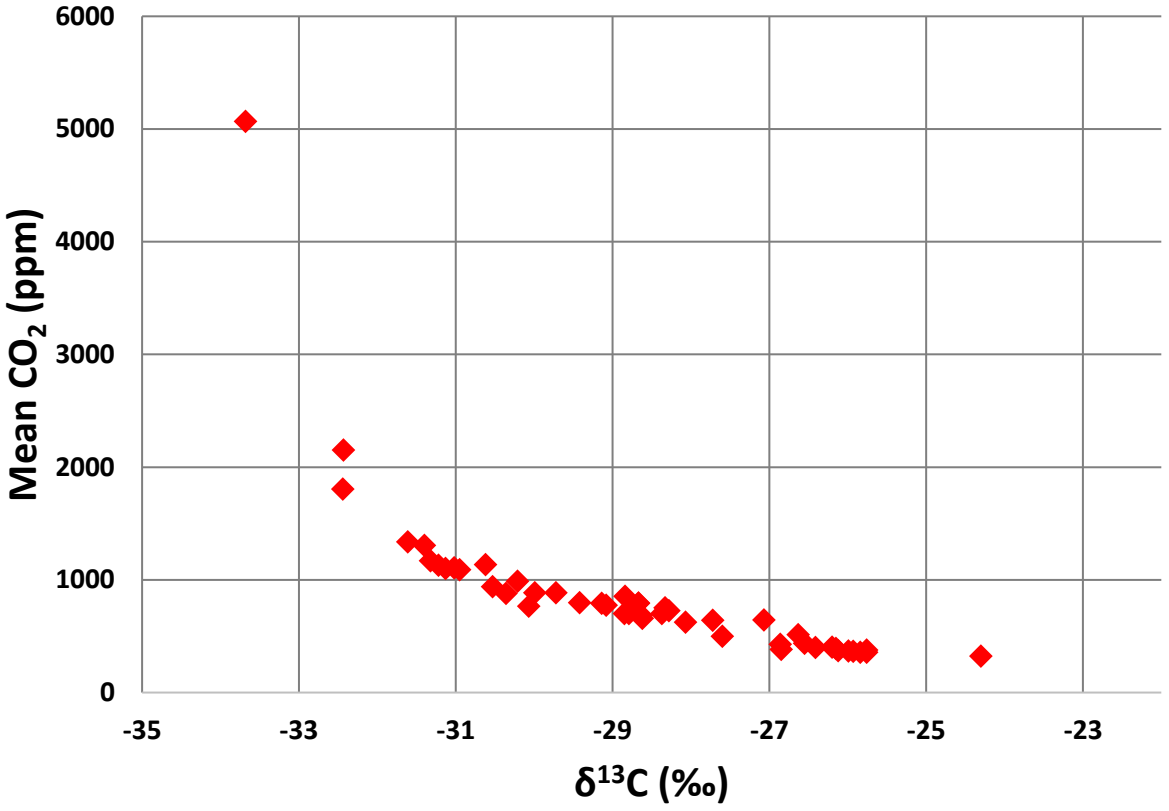

Figure DR2. Scatter plot of Mean CO_2 (ppm) against $\delta^{13}C$ (‰) values for all 48 samples.

TABLE DR1. SUMMARY OF pCO_2 VALUES FOR LATE OLIGOCENE AND EARLY MIOCENE FROM LITERATURE AND FROM THIS STUDY

Citation	**Method**	**Geochronology**	**pCO_2 estimates - late Oligocene**	**pCO_2 estimates -early Miocene**
Grein et al. (2013)	Stomatal parameters and gas exhchange model	Palynological Biochronology. L Oligocene: Kleinsaubernitz ~26.2 -27 Ma	213 - 771 ppm Mean of 431	
Grein et al. (2013)	Stomatal parameters and gas exhchange model	Litho- and Sequence Stratigraphy. L Oligocene: Borna Ost/Bockwitz ~ 25-23	287-1535 ppm Mean without Lauraceae: 453	
Grein et al. (2013)	Stomatal parameters and gas exhchange model	Palynological Biochronology. E Miocene: Wiesa 18.5 - 19.5 Ma		~257-1750 ppm Mean without Laruaceae: 438
Grein et al. (2013)	Stomatal parameters and gas exhchange model	Mammalian Biochronology. E Miocene: Oberdorf 17.2-17.6 Ma		~400 ppm Mean without Lauraceae: 402
Pagani et al., (2005)	Alkenones	Marine microfossil biochronology (27 Ma, 22 Ma)	650 ppm 560-820	300 ppm 280-410
Kürschner & Kvaček (2009)	Stomatal Index	K-Ar and small mammal biochronology. L Oligocene: ~26 – 24 Ma.	~480-600 ppm	
Kürschner & Kvaček (2009)	Stomatal Index	K-Ar and small mammal biochronology. E. Miocene ~23.5 – 20.5 Ma		280 - 400 ppm

This Study	Leaf stomatal conductance and $\delta^{13}C$ using Franks et al. (2014)	$^{235}U/^{205}Pb$ ages: 27.23 ± 0.03 Ma and 21.73 ± 0.03 Ma	Grand Mean 390 ppm; Range 325 – 500.	Grand Mean 870 ppm; Range 513 - 1337

TABLE DR2. MEAN VALUES OF VARIABLES AND THEIR CORRESPONDING STANDARD ERRORS FOR LATE OLIGOCENE AND EARLY MIOCENE FOSSIL LEAVES. CH SPECIMENS ARE LATE OLIGOCENE AND MU SPECIMENS ARE EARLY MIOCENE.

#	Specimens	Average Stomatal Densities (m^{-2})	St. Error	Average Stomatal Pore Lengths (m)	St. Error	Average Single Guard Cell Widths (m)	St. Error	Ratios of Stomatal Depth to Single Guard Cell Width	St. Error	$\delta^{13}C$ (‰VPDB)	St. Error
1	CH-40-125A	588356084	2915267	1.37×10^{-5}	4.23×10^{-7}	7.94×10^{-6}	2.70×10^{-7}	0.69	0.02	-25.84	0.01
2	CH40-169	512652220	4289831	1.60×10^{-5}	4.95×10^{-7}	8.50×10^{-6}	4.95×10^{-7}	0.77	0.04	-26.12	0.01
3	CH40-173A	454925393	2598442	1.46×10^{-5}	3.67×10^{-7}	8.33×10^{-6}	2.04×10^{-7}	0.71	0.03	-25.76	0.02
4	CH40-P31	483818605	3552416	1.66×10^{-5}	3.01×10^{-7}	8.32×10^{-6}	1.60×10^{-7}	0.80	0.02	-25.76	0.02
5	CH40-P49	454659185	1963346	1.26×10^{-5}	2.14×10^{-7}	6.39×10^{-6}	1.42×10^{-7}	0.79	0.02	-27.60	0.02
6	CH40-P70	404701257	2582716	1.61×10^{-5}	4.07×10^{-7}	8.32×10^{-6}	2.12×10^{-7}	0.78	0.02	-26.15	0.02
7	CH40-P95(2)	514100906	4510834	1.32×10^{-5}	3.45×10^{-7}	6.55×10^{-6}	1.50×10^{-7}	0.81	0.02	-26.86	0.02
8	CH40-P100(1)	506466114	4044668	1.54×10^{-5}	4.61×10^{-7}	7.29×10^{-6}	2.04×10^{-7}	0.85	0.03	-25.99	0.01
9	CH40-P100(2)	470301396	3469047	1.34×10^{-5}	4.18×10^{-7}	6.05×10^{-6}	1.86×10^{-7}	0.89	0.03	-24.30	0.01
10	CH41-13	454207331	2364877	1.39×10^{-5}	3.05×10^{-7}	7.63×10^{-6}	2.05×10^{-7}	0.74	0.02	-26.20	0.01
11	CH41-63	441420547	2606839	1.30×10^{-5}	3.70×10^{-7}	6.14×10^{-6}	1.67×10^{-7}	0.85	0.02	-26.55	0.02
12	CH41-67	618408565	4616897	1.23×10^{-5}	2.94×10^{-7}	6.39×10^{-6}	1.29×10^{-7}	0.78	0.02	-25.93	0.01
13	CH41-70	759334174	8311898	1.49×10^{-5}	3.45×10^{-7}	7.52×10^{-6}	1.92×10^{-7}	0.80	0.03	-26.85	0.02
14	CH52-98A	549948565	4538795	1.26×10^{-5}	2.92×10^{-7}	6.70×10^{-6}	1.87×10^{-7}	0.76	0.02	-26.41	0.01
15	MU7-7	243576496	698912	1.57×10^{-5}	2.37×10^{-7}	9.08×10^{-6}	1.85×10^{-7}	0.70	0.01	-28.63	0.12
16	MU7-10D	224864981	2264432	1.73×10^{-5}	2.97×10^{-7}	8.98×10^{-6}	1.29×10^{-7}	0.77	0.01	-28.07	0.03
17	MU7-16B	154893768	751087	1.69×10^{-5}	2.76×10^{-7}	8.91×10^{-6}	1.88×10^{-7}	0.77	0.02	-28.84	0.02
18	MU7-35A1#2	249070982	2171746	1.76×10^{-5}	2.08×10^{-7}	8.78×10^{-6}	1.66×10^{-7}	0.81	0.02	-31.13	0.01
19	MU7-38	217537852	1607794	1.60×10^{-5}	3.03×10^{-7}	8.22×10^{-6}	1.64×10^{-7}	0.79	0.02	-30.07	0.01
20	MU13-24(3)#3	317449537	2177659	1.56×10^{-5}	2.05×10^{-7}	8.50×10^{-6}	1.77×10^{-7}	0.74	0.02	-30.36	0.02

TABLE DR2. CONTINUED

#	Specimens	Average Stomatal Densities (m^{-2})	St. Error	Average Stomatal Pore Lengths (m)	St. Error	Average Single Guard Cell Widths (m)	St. Error	Ratios of Stomatal Depth to Single Guard Cell Width	St. Error	$\delta^{13}C$ (‰VPDB)	St. Error
21	MU17-11	248209305	2925652	1.78×10^{-5}	4.26×10^{-7}	9.44×10^{-6}	1.84×10^{-7}	0.76	0.02	-31.22	0.01
22	MU17-19B	245037311	1205938	1.59×10^{-5}	2.37×10^{-7}	8.20×10^{-6}	1.41×10^{-7}	0.78	0.02	-28.79	0.01
23	MU17-19C	187126580	1256635	1.56×10^{-5}	2.35×10^{-7}	9.18×10^{-6}	1.56×10^{-7}	0.68	0.01	-28.67	0.01
24	MU17-19D	209296776	1888573	1.79×10^{-5}	3.10×10^{-7}	1.09×10^{-5}	2.54×10^{-7}	0.66	0.01	-26.63	0.02
25	MU17-23A	185739121	1361922	1.81×10^{-5}	3.68×10^{-7}	9.63×10^{-6}	1.39×10^{-7}	0.75	0.01	-30.21	0.01
26	MU17-26A#2	198184410	792593	1.71×10^{-5}	2.83×10^{-7}	8.35×10^{-6}	1.63×10^{-7}	0.83	0.02	-28.37	0.02
27	MU17-26B	188516667	2116125	1.78×10^{-5}	2.99×10^{-7}	9.68×10^{-6}	1.41×10^{-7}	0.74	0.02	-29.14	0.01
28	MU17-29	217796206	2500168	1.72×10^{-5}	2.82×10^{-7}	9.28×10^{-6}	1.82×10^{-7}	0.75	0.02	-29.42	0.02
29	MU17-37	215359490	2663319	1.82×10^{-5}	2.52×10^{-7}	9.01×10^{-6}	1.78×10^{-7}	0.82	0.02	-28.85	0.03
30	MU18-3B#2	190000953	2685137	1.52×10^{-5}	2.59×10^{-7}	8.54×10^{-6}	1.67×10^{-7}	0.72	0.01	-28.67	0.02
31	MU18-3C#2	219227574	1514998	1.55×10^{-5}	2.34×10^{-7}	8.16×10^{-6}	1.40×10^{-7}	0.77	0.02	-29.72	0.01
32	MU18-5A2	224271996	1989695	1.81×10^{-5}	2.49×10^{-7}	9.59×10^{-6}	1.30×10^{-7}	0.76	0.01	-31.02	0.01
33	MU18-19#20	254039706	356180	1.53×10^{-5}	2.40×10^{-7}	8.80×10^{-6}	1.33×10^{-7}	0.70	0.01	-29.99	0.01
34	MU18-19(1A6A)#21	158956333	1209337	1.78×10^{-5}	2.89×10^{-7}	1.01×10^{-5}	1.89×10^{-7}	0.71	0.02	-28.33	0.02
35	MU27-2C#1	268558553	1815699	1.61×10^{-5}	1.74×10^{-7}	8.19×10^{-6}	1.05×10^{-7}	0.79	0.01	-31.32	0.01
36	MU27-25A	275184484	2177229	1.52×10^{-5}	2.15×10^{-7}	8.22×10^{-6}	1.53×10^{-7}	0.75	0.01	-28.62	0.09
37	MU27-25A#3	260066241	3250573	1.52×10^{-5}	1.75×10^{-7}	8.34×10^{-6}	1.50×10^{-7}	0.74	0.02	-31.61	0.02
38	MU29-29#1	273149176	1614563	1.62×10^{-5}	2.04×10^{-7}	1.01×10^{-5}	1.44×10^{-7}	0.64	0.01	-30.53	0.02
39	MU29-19(2)	241770438	2633722	1.74×10^{-5}	3.53×10^{-7}	9.66×10^{-6}	1.58×10^{-7}	0.72	0.01	-30.95	0.02

TABLE DR2. CONTINUED

#	Specimens	Average Stomatal Densities (m^{-2})	St. Error	Average Stomatal Pore Lengths (m)	St. Error	Average Single Guard Cell Widths (m)	St. Error	Ratios of Stomatal Depth to Single Guard Cell Width	St. Error	$\delta^{13}C$ (‰VPDB)	St. Error
40	MU31-14A#1	201069934	1456274	1.75×10^{-5}	1.99×10^{-7}	9.12×10^{-6}	1.74×10^{-7}	0.78	0.02	-29.08	0.03
41	MU31-14C#5	200667827	2715886	1.80×10^{-5}	2.78×10^{-7}	9.92×10^{-6}	1.44×10^{-7}	0.73	0.01	-31.40	0.01
42	MU17-5D	170746530	1387631	1.67×10^{-5}	2.65×10^{-7}	9.51×10^{-6}	1.83×10^{-7}	0.71	0.01	-32.43	0.02
43	MU32-5A	199981115	681182	1.61×10^{-5}	1.92×10^{-7}	8.73×10^{-6}	1.29×10^{-7}	0.74	0.01	-27.72	0.01
44	MU37-13-B2	143698139	1530520	1.88×10^{-5}	3.50×10^{-7}	9.53×10^{-6}	1.33×10^{-7}	0.79	0.02	-27.07	0.02
45	MU37-20	186256943	1170020	1.63×10^{-5}	3.69×10^{-7}	9.53×10^{-6}	1.10×10^{-7}	0.69	0.02	-28.28	0.01
46	MU41-56	182091399	1910119	1.69×10^{-5}	2.53×10^{-7}	9.41×10^{-6}	1.49×10^{-7}	0.72	0.01	-30.62	0.02
47	MU23-55(3)#1	184300157	1398288	1.67×10^{-5}	2.49×10^{-7}	9.18×10^{-6}	1.38×10^{-7}	0.73	0.01	-33.68	0.03
48	MU27-47AA#3	266269313	1540923	1.56×10^{-5}	2.03×10^{-7}	7.51×10^{-6}	1.16×10^{-7}	0.83	0.02	-32.44	0.02

TABLE DR3. $[CO_2]_{atm}$ RECONSTRUCTIONS FOR THE LATE OLIGOCENE AND EARLY MIOCENE. * INDICATES OUTLIER.

No.	Specimen	Locality	16th Percentile	Median $[CO_2]_{atm}$ (ppm)	84th Percentile	Mean $[CO_2]_{atm}$ (ppm)	Age
1	CH40-P100(2)	Chilga	295	323	354	325	late Oligocene
2	CH40-P31	Chilga	326	356	392	359	late Oligocene
3	CH-40-125A	Chilga	325	356	392	359	late Oligocene
4	CH41-67	Chilga	333	365	402	367	late Oligocene
5	CH40-P100(1)	Chilga	336	368	406	370	late Oligocene
6	CH40-169	Chilga	336	368	406	371	late Oligocene
7	CH40-173A	Chilga	342	375	413	378	late Oligocene
8	CH41-70	Chilga	346	380	420	383	late Oligocene
9	CH40-P70	Chilga	355	391	431	393	late Oligocene
10	CH52-98A	Chilga	362	399	440	401	late Oligocene
11	CH41-13	Chilga	363	400	441	402	late Oligocene
12	CH40-P95(2)	Chilga	387	428	474	430	late Oligocene
13	CH41-63	Chilga	392	433	479	436	late Oligocene
14	CH40-P49	Chilga	446	496	553	500	late Oligocene
15	MU37-13-B2	Layer 1	569	639	717	644	early Miocene
16	MU37-20	Layer 1	637	719	815	726	early Miocene
17	MU7-10D	Layer 2	553	620	698	625	early Miocene
18	MU7-7	Layer 2	600	677	767	684	early Miocene
19	MU7-38	Layer 2	660	754	873	767	early Miocene
20	MU7-16B	Layer 2	744	846	964	855	early Miocene
21	MU13-24(3)#3	Layer 2	750	864	1009	880	early Miocene
22	MU7-35A1#2	Layer 2	915	1075	1284	1101	early Miocene
23	MU32-5A	Layer 3	568	637	715	642	early Miocene
24	MU17-19D	Layer 4	459	510	567	513	early Miocene
25	MU17-19C	Layer 4	691	783	891	792	early Miocene
26	MU17-19B	Layer 4	616	695	789	702	early Miocene
27	MU17-37	Layer 4	615	694	788	701	early Miocene
28	MU17-26A#2	Layer 4	615	693	784	700	early Miocene
29	MU18-19(1A6A)#21	Layer 4	659	746	844	752	early Miocene
30	MU31-14A#1	Layer 4	677	767	875	776	early Miocene

TABLE DR3. CONTINUED

No.	Specimens	Locality	16th Percentile	Median $[CO_2]_{atm}$ (ppm)	84th Percentile	Mean $[CO_2]_{atm}$ (ppm)	Age
31	MU18-3B#2	Layer 4	695	788	896	796	early Miocene
32	MU17-26B	Layer 4	690	782	894	792	early Miocene
33	MU17-29	Layer 4	693	787	903	798	early Miocene
34	MU18-19#20	Layer 4	761	872	1011	886	early Miocene
35	MU18-3C#2	Layer 4	765	873	1007	886	early Miocene
36	MU17-23A	Layer 4	843	972	1133	988	early Miocene
37	MU18-5A2	Layer 4	923	1081	1288	1107	early Miocene
38	MU41-56	Layer 4	957	1113	1313	1135	early Miocene
39	MU17-11	Layer 4	934	1102	1321	1130	early Miocene
40	MU31-14C#5	Layer 4	1067	1268	1537	1305	early Miocene
41*	MU17-5D	Layer 4	1599	2022	2666	2151	early Miocene
42	MU27-25A	Layer 5	579	652	738	659	early Miocene
43	MU29-29#1	Layer 5	798	922	1080	939	early Miocene
44	MU29-19(2)	Layer 5	908	1065	1267	1089	early Miocene
45	MU27-2C#1	Layer 5	964	1139	1373	1170	early Miocene
46	MU27-25A#3	Layer 5	1083	1295	1584	1337	early Miocene
47*	MU27-47AA#3	Layer 5	1357	1696	2221	1806	early Miocene
48*	MU23-55(3)#1	Layer 5	2561	3743	6419	5069	early Miocene