

Table A.1. Paleosol geochemistry data

Sample	Soil type	Horizon	Height (m)	wt%											MAT (°C)*
				Fe ₂ O ₃	MnO	P ₂ O ₅	SiO ₂	TiO ₂	ZrO ₂	Al ₂ O ₃	CaO	Na ₂ O	MgO	K ₂ O	
HB-99	Alfisol	Bt	6	4.17	0.35	0.19	51.56	0.60	0.02	11.60	10.20	2.02	2.00	2.16	14.9
HB-113	Alfisol	Bt	18	5.67	0.15	0.26	50.00	0.63	0.05	13.45	6.78	1.53	2.58	2.69	15.0
HB-13	Alfisol	Bt	24.5	1.75	0.14	0.14	62.07	0.45	0.03	8.70	11.18	1.61	1.04	1.74	17.1
HB-133	Alfisol	Bt	41	2.55	0.03	0.08	60.38	0.57	0.04	14.69	5.61	2.15	2.34	2.96	14.3
HB-55	Alfisol	Bt	66.5	5.44	0.17	0.17	51.00	0.63	0.02	13.24	6.88	1.71	2.71	2.36	13.5
HB-59	Alfisol	Bt	72.5	6.27	0.12	0.29	49.22	0.65	0.02	14.59	7.28	1.22	2.65	2.46	13.7
HB-70	Alfisol	Bt	83	4.53	0.15	0.16	55.20	0.52	0.03	10.83	8.15	1.86	2.10	2.19	16.3
HB-78	Alfisol	Bt	93	3.13	0.29	0.38	49.18	0.37	0.02	9.43	13.78	1.64	1.90	2.01	17.6
HB-86	Alfisol	Bt	99	5.24	0.13	0.11	51.00	0.56	0.04	11.85	6.37	1.77	4.23	2.53	14.9
HB-182	Alfisol	Bt	107	6.62	0.11	0.15	50.57	0.62	0.03	14.00	5.08	2.04	2.38	2.53	14.2

* MAT presented is “high” estimates from PPM_{1.0} as described in Stinchcomb et al. (2016) and *Section 4.1*.

Table B.1. Clumped isotope data

Sample	Height (m)	$\delta^{13}\text{C}$ (‰)*	$\delta^{18}\text{O}$ (‰)*	Δ_{47} (‰)	S.E. (‰)	Δ_{48} (‰)	Ave. Δ_{47} (‰) [§]	T (°C)	$\delta^{18}\text{O}_{\text{ssw}}$ (‰) [†]
HB-109	5	-9.81	-10.95	0.627	0.010	0.45	0.628 ± 0.001	19 ± 3	-9.6
		-9.69	-10.84	0.629	0.009	-0.01			
		-9.54	-10.64	0.627	0.006	0.41			
HB-18	25	-6.36	-5.33	0.630	0.011	0.58	0.627 ± 0.001	19 ± 3	-3.9
		-6.59	-5.35	0.625	0.009	0.24			
		-6.57	-5.22	0.627	0.009	0.02			
HB-128	35	-5.54	-5.03	0.608	0.010	0.52	0.594 ± 0.010	29 ± 3	-1.4
		-5.53	-4.93	0.606	0.008	0.01			
		-5.51	-4.91	0.570	0.009	0.24			
HB-129	45	-6.20	-4.72	0.624	0.009	0.56	0.611 ± 0.009	24 ± 3	-2.2
		-6.22	-4.72	0.599	0.009	0.39			
HB-30	50	-5.90	-5.23	0.583	0.010	0.30	0.582 ± 0.001	34 ± 3	-0.9
		-5.90	-5.21	0.581	0.010	0.27			
D-20	60	-6.34	-4.72	0.603	0.009	0.28	0.591 ± 0.008	31 ± 3	-0.9
		-6.34	-4.76	0.570	0.007	0.22			
		-6.15	-4.60	0.600	0.008	0.32			
HB-47	65	-5.83	-5.02	0.594	0.010	0.33	0.607 ± 0.014	25 ± 4	-2.2
		-5.83	-5.03	0.633	0.009	0.85			
		-5.65	-4.91	0.634	0.010	0.26			
		-5.78	-4.83	0.566	0.007	0.04			
HB-162	80	-8.23	-7.43	0.603	0.008	0.44	0.605 ± 0.015	26 ± 4	-4.7
		-8.26	-7.48	0.638	0.009	-0.02			
		-8.29	-7.46	0.575	0.010	0.32			
HB-81	95	-7.46	-11.83	0.578	0.010	0.15	0.613 ± 0.011	23 ± 3	-9.6
		-7.48	-11.82	0.609	0.008	0.44			
		-7.37	-11.78	0.631	0.009	0.17			
		-7.44	-11.65	0.634	0.009	0.19			
HB-187	115	-6.91	-7.95	0.612	0.010	0.74	0.609 ± 0.011	25 ± 3	-5.4
		-6.81	-7.94	0.631	0.008	0.04			
		-6.89	-7.88	0.585	0.008	0.20			
129-A		-5.60	-5.14	0.629	0.009	0.13	0.621 ± 0.005	21 ± 3	-3.4
		-5.59	-5.25	0.626	0.009	0.01			
		-5.67	-5.24	0.609	0.009	0.03			
129-B		-5.59	-4.84	0.620	0.008	-0.11	0.618 ± 0.001	22 ± 3	-2.8
		-5.62	-4.88	0.617	0.009	-0.02			
187-A		-6.81	-8.91	0.647	0.008	0.00	0.631 ± 0.009	18 ± 3	-7.8
		-6.79	-8.93	0.609	0.007	-0.07			
		-6.83	-8.78	0.636	0.010	0.15			
187-B		-6.71	-8.83	0.619	0.007	-0.10	0.624 ± 0.003	20 ± 3	-7.1
		-6.72	-8.59	0.629	0.008	0.09			

Standards	# runs	$\delta^{13}\text{C}$ (‰)* [‡]	$\delta^{18}\text{O}$ (‰)* [‡]	Δ_{47} (‰) [‡]	S.D. (‰)	S.E. (‰)	ARF statistics reported in Table B.2 for 3 different analysis periods: <i>January - February 2015</i> <i>March - April 2015</i> <i>March 2017</i>
ETH-2	15	-10.16	-18.78	0.213	0.029	0.007	
NBS-19	9	2.04	-2.16	0.340	0.023	0.008	
C64	175	-2.05	-15.69	0.546	0.026	0.002	
COR	105	-2.22	-4.50	0.643	0.026	0.003	

* Measured versus Vienna Pee Dee Belemnite (VPDB).

† Calculated soil source water (ssw) composition versus Vienna standard mean ocean water (VSMOW), based on fractionation factor of Kim and O'Neil (1997).

§ Average of Δ_{47} measurements with no acid fractionation correction applied (e.g., Kelson et al., 2017).

‡ Values represent average for standard analyses during combined sample analysis periods (January 2015 - March 2017).

T₁ Temperatures calculated using inorganic calcite calibration of Kelson et al. (2017), including uncertainty (analytical S.E.) for each sample except where lower than long term S.E. of standards (0.01; ±2°C).

Table C.1. Floral lists and nearest living relative data

	Floral group	Updated affinity	Nearest living relative	Source
LATHAM	<i>Meliosma longifolia</i>	<i>Dyrana flexuosa</i>	Platanaceae	1,9
	<i>Cnemidaria magna</i>		<i>Cnemidaria grandifolia</i>	1
	<i>Platycarya americana</i>		<i>Platycarya strobilacea</i>	1
	<i>Salvinia preauriculata</i>		<i>Salvinia auriculata</i>	1,3
	<i>Lygodium kaulfussi</i>		<i>Lygodium palmatum</i>	1,4
	<i>Sabalites</i> sp.		Arecaceae	1
	<i>Zingiberopsis isonervosa</i>		Zingiberaceae	1,5
	<i>Apocynaceae</i> sp.		Apocynaceae	1,2
	<i>Alnus</i> sp.		<i>Alnus</i> sp.	1,2
	<i>Stillingia casca</i>		<i>Stillingia</i> sp.	1,5
	<i>Lauraceae</i> sp.		Lauraceae	1
	<i>Dombeya novi-mundi</i>	Malvaceae	Malvaceae	1,5
	<i>Averrhoites affinis</i>		Oxalidaceae	1,5
	<i>Populus wyomingiana</i>		<i>Populus</i> sp.	1,3,6
	SOURDOUGH	<i>Platycarya americana</i>		<i>Platycarya strobilacea</i>
<i>Alnus</i> sp.			<i>Alnus</i> sp.	1,2
<i>Apocynaceae</i> sp.			Apocynaceae	1,2
<i>Lauraceae</i> sp.			Lauraceae	1
<i>Hovenia oregonensis</i>			<i>Hovenia</i> sp.	1,7
<i>Dombeya novi-mundi</i>		Malvaceae	Malvaceae	1,5
<i>Populus wyomingiana</i>			<i>Populus</i> sp.	1,3,6
<i>Allophylus flexifolia</i>			<i>Allophylus racemosus</i>	1
<i>Cinnamomophyllum</i> sp.		Lauraceae	Lauraceae	1,9
<i>Equisetum</i> sp.			<i>Equisetum</i> sp.	1
<i>Woodwardia gravida</i>			<i>Woodwardia fimbriata</i>	1,5
<i>Cnemidaria magna</i>			<i>Cnemidaria grandifolia</i>	1,5
<i>Allantodiopsis erosa</i>			Polypodiaceae	1,2
<i>Salvinia preauriculata</i>			<i>Salvinia auriculata</i>	1,3
<i>Lygodium kaulfussi</i>			<i>Lygodium palmatum</i>	1,4
<i>Thelypteris iddingsi</i>			<i>Thelypteris kunthii</i>	1,6
<i>Glyptostrobus europaeus</i>			<i>Glyptostrobus pensilis</i>	1,4
<i>Philodendron</i> sp.			<i>Philodendron</i> sp.	1
<i>Sabalites</i> sp.			Arecaceae	1
<i>Zingiberopsis isonervosa</i>			Zingiberaceae	1,5
<i>Sparganium stygium</i>		<i>Platananthus</i> sp.	Platanaceae	1,4,9
<i>Dendropanax latens</i>			<i>Dendropanax</i> sp.	1,6
<i>Elaeocarpus sloanea</i>			<i>Elaeocarpus</i> sp.	1,2
<i>Stillingia casca</i>			<i>Stillingia</i> sp.	1,5
<i>Fagaceae</i> sp.			Fagaceae	1
<i>Magnoliaceae</i> sp.			Magnoliaceae	1
<i>Palaeosinomenium venablesii</i>			Menispermaceae	1,7
<i>Atriaecarpum clarnense</i>			Menispermaceae	1,7
<i>Syzygioides americana</i>			<i>Syzygium</i> sp.	1,2,7
<i>Nymphaeaceae</i> sp.			Nymphaeaceae	1
<i>Schoepfia republicensis</i>			<i>Schoepfia</i> sp.	1,8
<i>Macginitiea gracilis</i>			<i>Platanus</i> sp.	1,8
<i>Chaetoptelea microphylla</i>		<i>Ulmites microphylla</i>	<i>Ulmus</i> sp.	1,3,9
<i>Averrhoites affinis</i>			Oxalidaceae	1,5

Sources
¹ Wilf (1998, 2000)
² Wing (1998)
³ Berry (1916)
⁴ Heer (1859)
⁵ Hickey (1977, 1980)
⁶ MacGinitie (1969)
⁷ Manchester and Dilcher (1982)
⁸ Wolfe and Wehr (1987)
⁹ Manchester (2014)

Table C.1. (cont'd)

	Floral group	Updated affinity	Nearest living relative	Source
NILAND TONGUE	<i>Platycarya castaneopsis</i>	Malvaceae	<i>Platycarya</i> sp.	1,2
	<i>Dombeya novi-mundi</i>		Malvaceae	1,5
	<i>Averrhoites affinis</i>		Oxalidaceae	1,5
	<i>Equisetum</i> sp.		<i>Equisetum giganteum</i>	1
	<i>Acrostichum hesperium</i>		<i>Acrostichum aureum</i>	1,6
	<i>Salvinia preauriculata</i>		<i>Salvinia auriculata</i>	1,3
	<i>Lygodium kaulfussi</i>		<i>Lygodium palmatum</i>	1,4,6
	<i>Thelypteris iddingsi</i>		<i>Thelypteris kunthii</i>	1,6
	<i>Cycadaceae</i> sp.		Cycadaceae	1
	<i>Sabalites</i> sp.		Arecaceae	1
	<i>Zingiberopsis isonervosa</i>		Zingiberaceae	1,5
	<i>Dendropanax latens</i>		<i>Dendropanax</i> sp.	1,6
	<i>Alnus</i> sp.		<i>Alnus</i> sp.	1,2
	<i>Leguminosae gleditsia</i>		<i>Dalbergia hupeana</i>	1
	<i>Anamirta milleri</i>		<i>Anamirta cocculus</i>	1,8
	<i>Schoepfia republicensis</i>		<i>Schoepfia</i> sp.	1,8
	<i>Proteaciphyllum minutum</i>		Proteaceae	1,6
	<i>Populus wyomingiana</i>		<i>Populus</i> sp.	1,3,6
LITTLE MOUNTAIN	<i>Parvileguminophyllum coloradensis</i>	Cyclocarya sp.	Fabaceae	1
	<i>Lindera varifolia</i>		<i>Lindera obtusifolia</i>	1,6
	<i>Rhus nigricans</i>		<i>Rhus typhina</i>	1,6
	<i>Equisetum</i> sp.		<i>Equisetum giganteum</i>	1
	<i>Allantodiopsis erosa</i>		Polypodiaceae	1,2
	<i>Acrostichum hesperium</i>		<i>Acrostichum aureum</i>	1,6
	<i>Pinus</i> sp.		<i>Pinus</i> sp.	1
	<i>Pinus florissanti</i>		<i>Pinus ponderosa</i>	1
	<i>Taxodiaceae</i> sp.		Taxodiaceae	1
	<i>Sabalites</i> sp.		Arecaceae	1
	<i>Smilacaceae smilax</i>		<i>Smilax herbacea</i>	1
	<i>Acer</i> sp.		<i>Acer</i> sp.	1
	<i>Dipteronia</i> sp.		<i>Dipteronia</i> sp.	1
	<i>Alnus</i> sp.		<i>Alnus</i> sp.	1,2
	<i>Bignoniaceae</i> sp.		Bignoniaceae	1
	<i>Calycites ardtunensis</i>		Asteraceae	1
	<i>Ceratophyllum muricatum</i>		<i>Ceratophyllum muricatum</i>	1,3
	<i>Elaeocarpus sloanea</i>		<i>Elaeocarpus</i> sp.	1,2
	<i>Euphorbiaceae alchloanea</i>		<i>Alchloanea</i> sp.	1
	<i>Quercus</i> sp.		<i>Quercus polymorpha</i>	1,5
	<i>Acer lesquereuxi</i>		<i>Acer pictum</i>	1
	<i>Hydrangea</i> sp.		<i>Hydrangea</i> sp.	1
	<i>Palaeocarya clarnensis</i>		Juglandaceae	1,7
	<i>Pterocarya macginittii</i>		Juglandaceae	1,7,9
	<i>Juglandaceae</i> sp.		Juglandaceae	1
	<i>Caesalpinia flumen-iridensis</i>		<i>Caesalpinia</i> sp.	1
	<i>Cladrastris</i> sp.		<i>Cladrastris kentukea</i>	1
	<i>Gymnocladus hesperia</i>		<i>Gymnocladus dioicus</i>	1,6
	<i>Leguminosites lesquereuxiana</i>		<i>Dalbergia hupeana</i>	1
	<i>Triumfetta ovata</i>		<i>Triumfetta</i> sp.	1,6
	<i>Menispermaceae abuta</i>		Menispermaceae	1
	<i>Syzygioides americana</i>		<i>Syzygium</i> sp.	1,7
	<i>Macginitiea wyomingensis</i>		<i>Platanus</i> sp.	1,7
	<i>Platanus raynoldsii</i>		<i>Platanus</i> sp.	1,9
	<i>Proteaciphyllum minutum</i>		Proteaceae	1,6
	<i>Populus cinnamomoides</i>		<i>Populus angustifolia</i>	1,6
	<i>Allophylus flexifolia</i>		<i>Allophylus racemosus</i>	1,6
	<i>Cardiospermum coloradensis</i>		<i>Cardiospermum microcarpum</i>	1,6
	<i>Koelreuteria viridifluminis</i>		Rutaceae	1,9
	<i>Sapindales</i> sp.		<i>Sapindales</i> sp.	1
	<i>Ailanthus lesquereuxi</i>		<i>Ailanthus altissima</i>	1
	<i>Cedrelospermum nervosum</i>		<i>Ulmus</i> sp.	1,7
	<i>Astronium truncatum</i>		<i>Astronium graveolens</i>	1,6
	<i>Averrhoites affinis</i>		Oxalidaceae	1,3,5
	<i>Fraxinus</i> sp.		<i>Fraxinus</i> sp.	1

Table C.2. Climatic envelopes for modern plant taxa

Taxa*	MAT (°C) [†]	σ	WMT (°C) [†]	σ	CMT (°C) [†]	σ
<i>Acer</i>	9.0	2.5	22.2	3.2	-2.3	4.0
<i>Acrostichum</i>	24.8	2.6	31.8	2.5	17.0	4.1
<i>Ailanthus</i>	17.8	4.5	29.7	3.4	4.7	7.7
<i>Alchloanea</i>	21.7	3.7	29.8	3.4	13.0	5.7
<i>Allophyllus</i>	23.4	3.6	31.0	3.6	15.3	4.8
<i>Alnus</i>	8.4	2.6	21.0	2.7	-2.1	3.9
Apocynaceae	8.5	4.5	27.6	3.9	-9.0	7.1
Arecaceae	22.3	4.5	30.7	3.8	13.6	6.1
<i>Astronium</i>	24.3	2.4	31.8	2.3	16.2	3.7
Bignoniaceae	21.2	4.6	30.6	3.9	11.3	7.0
<i>Caesalpinia</i>	23.1	3.7	31.7	3.5	13.9	5.6
<i>Cardiospermum</i>	22.5	3.5	31.7	3.4	12.3	5.6
<i>Ceratophyllum</i>	9.8	3.1	22.6	3.1	-1.1	4.0
<i>Cladastris</i>	15.0	5.0	29.6	3.4	0.0	7.8
<i>Cnemidaria</i>	22.3	3.3	28.7	3.5	16.1	3.5
Cycadaceae	25.3	2.8	33.5	2.6	15.2	4.3
<i>Dalbergia</i>	23.2	3.5	31.4	3.1	14.4	5.6
<i>Dendropanax</i>	21.4	4.0	29.5	3.9	13.0	5.7
<i>Dipteronia</i>	13.3	3.1	28.3	2.9	-2.7	5.3
Malvaceae	20.7	3.4	29.6	3.6	10.2	5.1
<i>Elaeocarpus</i>	16.7	5.3	26.0	4.4	6.8	6.2
<i>Equisetum</i>	7.7	3.5	20.6	3.3	-3.4	5.3
<i>Fraxinus</i>	9.2	2.0	21.5	3.1	-0.9	3.0
<i>Glyptostrobus</i>	20.4	2.2	31.9	1.7	8.0	4.2
<i>Gymnocladus</i>	12.8	3.0	31.5	2.1	-6.1	4.5
<i>Hovenia</i>	15.7	3.0	30.4	2.4	0.7	4.1
<i>Hydrangea</i>	14.6	4.8	26.9	4.4	2.1	8.0
Juglandaceae	12.3	4.1	26.8	3.8	-0.7	6.0
Lauraceae	18.8	4.6	28.3	3.8	8.8	6.4
<i>Lindera</i>	15.0	4.6	28.8	3.4	0.8	7.3
<i>Lygodium</i>	22.8	4.4	31.5	3.1	13.5	7.2
Magnoliaceae	16.5	5.2	28.7	3.7	3.7	9.2
Menispermaceae	21.2	4.8	30.5	3.9	10.8	7.3
<i>Nymphaea</i>	10.4	5.9	22.5	4.8	-0.2	7.0
<i>Philodendron</i>	22.9	3.6	29.8	3.4	16.1	4.9
<i>Pinus</i>	9.4	4.0	23.4	4.4	-2.2	5.2
<i>Platanus</i>	13.5	3.7	28.9	3.5	-0.4	6.0
<i>Platycarya</i>	16.1	3.1	28.9	4.4	2.7	4.1
Polypodiaceae	11.7	5.8	22.9	4.5	1.7	7.3
<i>Populus</i>	8.1	3.0	21.8	3.3	-3.4	4.4
Proteaceae	18.0	4.8	29.8	4.9	6.5	4.8
<i>Quercus</i>	11.2	3.2	25.2	5.0	0.1	3.3
<i>Rhus</i>	14.1	4.4	29.8	3.5	-0.6	7.2
Rutaceae	17.9	4.5	29.3	4.1	6.9	5.9
<i>Salvinia</i>	21.6	5.7	31.7	2.7	11.4	9.6
<i>Schoepfia</i>	21.6	3.7	30.5	3.5	12.2	6.2
<i>Smilax</i>	17.2	4.6	28.5	3.7	6.1	6.4
<i>Stillingia</i>	19.1	3.0	33.8	5.2	5.6	5.1
<i>Syzygium</i>	21.2	4.6	29.7	4.1	11.5	6.0
Taxodiaceae	15.1	4.5	28.1	5.2	2.6	4.6
Thelypteridaceae	10.0	6.8	22.5	5.2	-1.3	8.7
<i>Triumfetta</i>	23.7	3.7	32.8	4.4	13.1	4.9
<i>Ulmus</i>	8.9	2.5	21.4	3.2	-1.4	3.3
<i>Woodwardia</i>	14.6	4.0	28.1	3.9	1.6	6.3
Zingiberaceae	21.5	4.5	29.5	3.6	12.9	7.1

* Analyzed modern taxa represent nearest living relative of fossil taxa from studied sites (summarized in Table C.1).

† Mean values and standard deviations derived from modern global distributions (GBIF, 2016) cross-plotted with high-resolution climatic maps (Hijmans et al., 2005).

Table C.3. Mean annual temperature comparison from floral sites

		Physiognometric Methods			NLR Method
Site	# of species	P	MAT1	MAT2	MAT3
Latham	19	0.500	16.4 (±3.9)	14.8 (±4.8)	16.0 (±1.5)
Sourdough	74	0.659	21.3 (±2.3)	18.0 (±4.8)	16.4 (±1.8)
Niland Tongue	24	0.714	23.0 (±3.1)	19.2 (±4.8)	18.2 (±2.1)
Little Mountain	87	0.602	19.6 (±2.3)	16.9 (±4.8)	15.2 (±1.5)

MAT1 = Mean annual temperature estimates from Wilf (2000), error estimates based on Miller et al. (2006)
MAT2 = Mean annual temperature estimates based on revised Peppe et al. (2011) equation
MAT3 = Mean annual temperature estimates from this work (Fig. 3), with error estimates calculated as 2σ

Table D.1. Modern climate data and future/Eocene model outputs

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	MART1	MART2	MART3
Modern*	-8.4	-6.9	-1.0	4.1	9.1	14.1	18.1	17.1	11.8	5.4	-2.2	-8.0	26.5	27.4	25.6
RCP4.5 ensemble†	-5.0	-3.3	1.6	6.4	12.2	16.5	20.4	19.9	14.4	7.3	-0.1	-4.6	25.4	26.6	24.2
RCP8.5 ensemble†	-2.9	-0.4	5.4	9.8	15.1	20.8	24.7	23.2	18.8	10.5	3.4	-1.8	27.6	28.2	27.0
Eocene LoCO§	4	6	8	13	15	20	24	23	18	11	8	5	20	22	18
Eocene HiCO§	6	8	11	15	18	26	30	27	20	13	10	7	24	28	20

* Average observed mean monthly temperature from NOAA 1981-2010 Climate Normals for stations in the GRB (n= 18; NCDC, 2010).

† Regional monthly mean temperature for downscaled area of GRB (40.5-43°N, 107-110.5°W) from 10-model ensemble (CMIP5) for future emissions scenarios (NCDMI, 2014).

§ Regional monthly mean temperature for area of GRB from RegCM3 configurations for low CO₂ (560 ppm) and high CO₂ (2240 ppm) scenarios (e.g., Thrasher and Sloan, 2009).

MART1 = WMMT-CMMT; MART2 = (WMMT-MAT)*2; MART3 = (MAT-CMMT)*2