Supplementary materials for:

Low-latitudes climate change linked to high-latitude glaciation during the Late Palaeozoic Ice Age: evidence from the terrigenous detrital kaolinite

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Figures

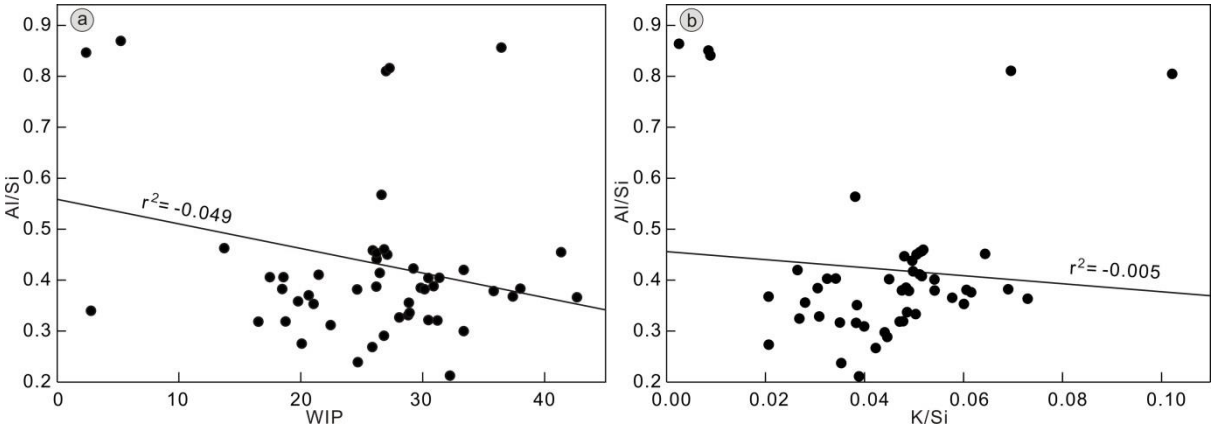

Figure S1. Plots of Al/Si ratio vs. weathering index of Parker (WIP) and K/Si showing no significant sedimentary sorting effect on sample compositions.

Tables

Table S1. Results of two tuffaceous claystone samples for zircon U–Pb dating in the study area.

Sample number	Zircon sample number	Content		Th/U	Isotope ratios				rho	Age		Concordance
		Th	U		$^{207}Pb/^{235}U$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$	$^{206}Pb/^{238}U$		$^{206}Pb/^{238}U$	$^{206}Pb/^{238}U$	
		ppm	ppm		Ratio	1sigma	Ratio	1sigma		Age (Ma)	1sigma	
HYD-1	HYD-1-1	400.3	324.4	1.23	0.6451	0.0332	0.0475	0.0009	0.3673	299.3	5.5	48%
	HYD-1-2	578.6	319.2	1.81	0.3373	0.0255	0.0472	0.0012	0.3262	297.3	5.2	99%
	HYD-1-3	315.7	277.2	1.14	0.3516	0.0308	0.0492	0.0015	0.3455	309.8	9.2	98%
	HYD-1-4	62.5	77.9	0.80	0.3835	0.0371	0.0502	0.0018	0.3713	315.9	11.1	95%
	HYD-1-5	67.6	93.2	0.73	0.3257	0.0375	0.0490	0.0013	0.2356	308.5	8.2	92%
	HYD-1-6	196.0	246.3	0.80	0.3270	0.0239	0.0478	0.0012	0.3411	300.9	7.3	95%
	HYD-1-7	348.8	238.7	1.46	0.3598	0.0268	0.0477	0.0011	0.3148	300.4	6.9	96%
	HYD-1-8	395.6	317.3	1.25	0.4926	0.0369	0.0689	0.0016	0.3017	429.4	9.4	94%
	HYD-1-9	412.3	396.0	1.04	0.3592	0.0405	0.0477	0.0013	0.2383	300.3	6.9	96%
	HYD-1-10	97.0	104.5	0.93	0.5572	0.0616	0.0699	0.0022	0.2818	435.5	13.1	96%
	HYD-1-11	562.0	955.3	0.59	0.6469	0.0622	0.0777	0.0023	0.3018	482.1	13.5	95%
	HYD-1-12	681.4	533.5	1.28	0.5899	0.0292	0.0731	0.0013	0.3462	454.6	7.5	96%
	HYD-1-13	618.0	418.4	1.48	0.3367	0.0150	0.0476	0.0009	0.4286	299.6	5.6	98%
	HYD-1-14	157.8	167.0	0.95	0.4328	0.0340	0.0548	0.0013	0.2987	343.9	7.8	93%
	HYD-1-15	144.7	134.2	1.08	0.6381	0.1639	0.0824	0.0019	0.0897	510.4	11.3	98%
	HYD-1-16	256.4	218.0	1.18	0.3602	0.0240	0.0483	0.0008	0.2547	304.3	5.1	97%
	HYD-1-17	87.4	100.7	0.87	0.3794	0.0376	0.0478	0.0014	0.2864	301.3	6.4	91%
	HYD-1-18	250.1	167.8	1.49	0.3765	0.0384	0.0519	0.0015	0.2868	326.0	9.3	99%
	HYD-1-19	305.8	417.7	0.73	0.6217	0.0532	0.0785	0.0023	0.3431	487.4	13.8	99%
	HYD-1-20	264.2	321.9	0.82	0.3564	0.0255	0.0474	0.0008	0.2284	298.3	4.8	96%
	HYD-1-21	46.8	64.1	0.73	0.3915	0.0780	0.0499	0.0027	0.2698	314.0	16.5	93%
	HYD-1-22	112.6	102.4	1.10	0.3963	0.0980	0.0473	0.0019	0.1627	297.6	11.7	87%
	HYD-1-23	214.2	301.9	0.82	0.3664	0.0245	0.0474	0.0008	0.2384	298.5	4.6	96%
	HYD-1-24	387.5	259.9	1.49	0.5427	0.0558	0.0699	0.0021	0.2958	435.3	12.8	98%
	HYD-1-25	155.1	174.6	0.89	0.3488	0.0258	0.0476	0.0008	0.2313	299.5	5.0	98%
	HYD-1-26	74.2	93.6	0.79	0.3287	0.0347	0.0477	0.0015	0.2919	300.3	7.1	95%
	HYD-1-27	176.4	276.4	0.64	0.3453	0.0186	0.0475	0.0007	0.2905	299.3	4.6	99%
HYD-2	HYD-2-1	329.4	338.4	0.97	0.3335	0.0214	0.0427	0.0007	0.2503	269.8	4.2	92%
	HYD-2-2	179.2	195.5	0.92	0.3426	0.0227	0.0494	0.0008	0.2338	311.1	4.7	96%
	HYD-2-3	385.1	216.6	0.95	0.3990	0.1030	0.0435	0.0012	0.1060	274.4	7.4	78%
	HYD-2-4	334.8	359.5	0.93	0.3314	0.0195	0.0430	0.0007	0.3412	271.6	4.2	93%
	HYD-2-5	176.6	151.7	1.16	0.3118	0.0196	0.0432	0.0008	0.3024	272.8	5.1	98%

Sample number	Zircon sample number	Content		Th/U	Isotope ratios				rho	Age		Concordance
		Th	U		$^{207}Pb/^{235}U$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$	$^{206}Pb/^{238}U$		$^{206}Pb/^{238}U$	$^{206}Pb/^{238}U$	
		ppm	ppm		Ratio	1sigma	Ratio	1sigma		Age (Ma)	1sigma	
HYD-2	HYD-2-6	286.4	314.6	0.91	0.3230	0.0193	0.0429	0.0007	0.2808	270.8	4.4	95%
	HYD-2-7	177.9	247.4	0.72	0.3530	0.0226	0.0463	0.0007	0.2513	291.8	4.6	94%
	HYD-2-8	493.1	364.2	1.35	0.2997	0.0214	0.0426	0.0008	0.2753	269.0	5.2	98%
	HYD-2-9	141.0	125.6	1.12	0.3737	0.0385	0.0500	0.0015	0.2947	314.7	9.3	97%
	HYD-2-10	250.6	264.5	0.95	14.5496	2.0090	0.5870	0.0543	0.6704	2977.1	220.7	93%
	HYD-2-11	493.1	539.1	0.95	1.2214	0.0635	0.1067	0.0024	0.4410	653.4	14.2	78%
	HYD-2-12	131.5	118.0	1.11	0.4729	0.0658	0.0606	0.0018	0.2146	379.2	11.0	96%
	HYD-2-13	88.0	99.7	0.88	0.4078	0.0316	0.0530	0.0013	0.3048	332.7	7.7	95%
	HYD-2-14	123.8	298.2	0.42	1.6625	0.0558	0.1725	0.0021	0.3619	1025.6	11.5	96%
	HYD-2-15	431.8	422.7	1.02	0.4368	0.0168	0.0533	0.0008	0.3904	335.0	4.9	93%
	HYD-2-16	524.7	361.1	1.45	0.4149	0.0217	0.0524	0.0008	0.2999	329.0	5.0	95%
	HYD-2-17	158.1	247.6	0.64	0.3666	0.0205	0.0552	0.0009	0.2978	346.1	5.6	95%
	HYD-2-18	143.7	134.4	1.07	0.3623	0.0260	0.0518	0.0011	0.2956	325.4	6.7	96%

Table S2. Results of clay mineral compositions (%), illite crystallinity (Δ°/2θ), Th and U concentrations (ppm), and Th/U ratios in the study area.

Formation	Sample	kaolinite	illite/smectite	illite	chlorite	KI	Th	U	Th/U
Shanxi	330	23	61	16	0	0.53	18.7	4.71	3.97
	331	24	62	11	3	0.37	21.1	5.79	3.64
	332	22	65	11	2	0.42	19.6	4.15	4.72
	333	21	61	14	4	0.73	22.7	4.43	5.12
	334	23	59	18	0	0.78	14.8	2.88	5.14
	335	19	42	35	4	0.76	14	3.16	4.43
	336	37	42	21	0	0.63	19.6	4.08	4.80
	337	40	42	18	0	0.72	23.2	6.03	3.85
	338	50	38	12	0	0.34	19.5	4.51	4.32
	339	47	37	16	0	0.74	22	6.31	3.49
	340	46	35	19	0	0.74	23.1	6.7	3.45
	341	42	34	21	3	0.45	18	4.21	4.28
	342	50	42	8	0	0.80	31.2	9.71	3.21
	343	45	36	19	0	0.30	23.8	6.34	3.75
	344	35	39	23	3	0.29	23.6	5.25	4.50
	345	32	57	6	5	0.50	20.8	4.59	4.53
	346	31	57	6	6	0.29	20	4.83	4.14
	347	32	42	22	4	0.29	24.6	5.56	4.42
	348	35	36	24	5	0.27	16.3	3.9	4.18
	349	43	39	12	6	0.22	20.5	5.05	4.06
Taiyuan	350	43	40	15	2	0.53	21.8	4.78	4.56
	351	40	40	14	6	0.40	17.9	3.78	4.74
	352	48	35	12	5	0.47	21.6	4.87	4.44
	353	41	49	2	8	0.31	18.4	3.67	5.01
	354	28	62	5	5	0.29	20.8	5.91	3.52
	355	27	62	5	6	0.45	15.6	4.15	3.76
	356	28	64	5	3	0.27	17.6	5.11	3.44
	357	46	35	12	7	0.35	17.4	6.25	2.78
	358	47	35	7	11	0.37	20.7	8.01	2.58
	359	52	33	5	10	0.55	18.3	7.23	2.53
	360	53	37	4	6	0.38	19.7	8.26	2.38
	361	56	36	3	5	0.39	21.7	7.9	2.75
	362	58	33	3	6	0.41	18.4	3.57	5.15
	363	61	31	1	7	1.88	7.63	8.03	0.95
	364	21	52	23	4	1.23	17.5	6.09	2.87
	365	20	53	24	3	0.68	15.2	3.33	4.56
	366	20	55	21	4	0.79	17.6	3.86	4.56
	367	24	60	9	7	0.47	16.2	3.15	5.14
	368	26	56	8	10	0.35	20.5	4.02	5.10
	369	25	56	8	11	0.46	12.7	4.2	3.02
Taiyuan	370	30	57	7	6	0.44	17.8	3.55	5.01
	371	29	58	6	7	0.39	15.1	2.89	5.22
	372	29	59	6	6	0.30	15.7	3.04	5.16
	373	28	59	3	10	0.37	16.2	3.38	4.79
Benxi	374	65	0	15	20	0.27	31.7	7.92	4.00
	375	67	0	15	18	0.28	70.8	12.2	5.80
	376	66	0	16	18	0.27	73.9	12.7	5.82
	377	63	0	20	17	0.40	50	9.59	5.21
	378	59	0	20	21	0.37	47.1	8.55	5.51
	379	54	0	28	18	0.33	50.2	8.82	5.69

Abbreviation: KI = illite crystallinity.

Table S3. Result of the quantitative conodont (number) from the studied borehole in the Yuzhou Coalfield.

Conodont	Taiyuan Formation								
	#L_1	#L_2	#L_3	#L_4	#L_5	#L_{7-1}	#L_{7-2}	#L_8	#L_9
Streptognathodus isolatus Chernykh, Ritter et Wardlaw, 1997	2	1							
Streptognathodus wabaunsensis Gunnell, 1933	1								
Streptognathodus elegantulus Stauffer et Plummer, 1932	5	4	3						
Streptognathodus gracilis Stauffer et Plummer, 1932	1		7	1	1				
Streptognathodus oppletus Ellison, 1941	3								
Streptognathodus parvus Dunu, 1966	3	6	>10	4	1				
Hindeodus minutus Ellison, 1941	2	1	11	2	2	2	7	3	2
Streptognathodus elongatus Gunnell, 1933		2	5						
Streptognathodus nodulinearis Reshetkova et Chernikh, 1986		2	4						
Streptognathodus ximplex Gunnell, 1933		1	3						
Streptognathodus cristellaris Reshetkova et Chernikh, 1987			6						
Streptognathodus cf. expansus Igo et Koike, 1964			1						
Streptognathodus constrictus Reshetkova et Chernikh, 1987				2					
Streptognathodus cf. constrictus Reshetkova et Chernikh, 1987				1					
Sweetognathus aff. *whitei*								2	1
Ozarkodina sp.	3		8	1	1	2	1	2	1
Cypridodella sp.				2	1		1		
Lonchodina sp.	1		3	1		1		1	2
Ligonodina sp.	2	2	3	1	1		1	4	1
Neohindeodella sp.	1	1	5	1	1	4	2	5	2
Hindeodella sp.	>10	5	>20	>10	>10	6	11	8	1
Enantiognathus sp.			3				2		
Streptognathodus sp.	>10	3	>100	7	6	1	3		
Trichonodella sp.						2	1		
Xaniognathus sp.				1	1	1			
Prioniodella sp.				1	2	1	2		
Diplognathodus sp.							2		
Hibbardelloides sp.								2	

Table S4. Results of major element contents including SiO_2 (%), Al_2O_3 (%), MgO (%), CaO (%), Na_2O_3 (%), K_2O (%), P_2O_5 (%), and weathering index of Parker (WIP) from the studied borehole in the Yuzhou Coalfield of the NCP.

Formation	Sample	SiO_2	Al_2O_3	MgO	CaO	Na_2O_3	K_2O	P_2O_5	WIP
Shanxi	330	53.49	20.90	0.517	0.157	0.336	3.23	0.054	32.24
	331	61.45	23.70	0.638	0.140	0.426	3.77	0.040	38.01
	332	58.25	21.80	1.030	0.148	0.459	3.35	0.047	35.82
	333	57.03	26.64	0.573	0.153	0.481	3.66	0.052	37.39
	334	57.30	21.33	0.702	0.191	0.388	4.17	0.046	41.35
	335	59.99	23.53	0.855	0.185	0.528	4.13	0.065	42.64
	336	61.53	23.98	0.517	0.145	0.368	2.91	0.038	29.84
	337	65.60	21.66	0.307	0.130	0.286	1.74	0.044	18.48
	338	62.09	22.26	0.734	0.132	0.621	2.37	0.056	28.08
	339	65.51	21.92	0.301	0.115	0.330	2.00	0.042	21.05
	340	58.16	26.87	0.406	0.139	0.410	2.78	0.036	28.80
	341	64.96	20.86	0.710	0.142	0.432	2.47	0.073	27.09
	342	56.23	24.33	0.357	0.195	0.306	1.47	0.088	16.52
	343	58.82	24.32	0.596	0.147	0.544	2.63	0.057	29.24
	344	58.51	25.16	0.618	0.132	0.521	2.90	0.051	31.37
	345	59.01	24.36	0.639	0.158	0.470	3.18	0.064	33.36
	346	54.63	21.62	1.050	0.231	0.538	2.63	0.116	30.46
	347	58.55	24.80	0.532	0.199	0.403	2.98	0.049	30.90
	348	55.59	17.88	1.630	0.357	0.547	1.93	0.126	26.48
	349	54.74	20.62	1.020	0.875	0.561	1.11	0.144	18.74
Taiyuan	350	57.52	23.86	0.634	0.243	0.208	1.95	0.071	20.66
	351	59.23	21.56	0.818	0.519	0.204	1.64	0.106	18.58
	352	57.22	23.73	0.637	0.291	0.204	1.84	0.081	19.78
	353	53.91	21.28	0.529	0.323	0.184	1.63	0.059	17.46
	354	52.32	20.35	0.598	0.422	0.246	2.55	0.037	26.20
	355	67.68	15.98	0.704	0.391	0.217	2.37	0.071	24.63
	356	60.27	18.91	0.794	0.368	0.185	2.39	0.093	24.68
	357	44.14	19.98	1.020	0.109	0.092	2.18	0.098	22.45
	358	50.46	23.76	1.100	0.105	0.112	2.57	0.110	26.22
	359	49.55	23.07	1.190	0.078	0.122	2.49	0.125	25.90
	360	49.03	23.20	1.210	0.083	0.122	2.52	0.119	26.21
	361	50.75	24.15	1.130	0.078	0.122	2.62	0.106	26.84
	362	68.91	18.96	0.338	0.094	0.080	1.40	0.032	13.72
	363	52.60	30.92	0.720	0.194	0.099	1.99	0.031	20.08
	364	60.46	17.62	0.865	0.252	0.123	2.68	0.049	26.63
	365	64.56	17.30	0.693	0.786	0.159	2.71	0.066	26.82
	366	60.25	18.14	0.782	0.337	0.106	2.64	0.079	25.86
Taiyuan	367	55.94	20.19	1.190	0.403	0.134	3.35	0.097	33.36
	368	55.29	23.22	1.190	0.285	0.120	2.84	0.094	28.86
	369	37.65	14.66	1.170	0.369	0.082	2.03	0.560	21.47
	370	58.51	19.88	1.220	0.372	0.159	2.93	0.105	30.16
	371	59.56	19.29	1.150	0.312	0.172	2.79	0.101	28.92
	372	57.01	18.50	2.460	2.720	0.114	2.71	0.105	31.21
	373	59.15	20.34	1.760	1.490	0.107	2.86	0.109	30.46
Benxi	374	21.25	18.84	0.273	0.086	0.049	0.18	0.049	2.80
	375	42.94	39.14	0.338	0.088	0.060	0.09	0.068	2.40
	376	43.24	38.80	0.487	0.100	0.097	0.35	0.073	5.24
	377	36.73	31.14	1.200	0.242	0.130	3.75	0.183	36.45
	378	38.61	32.98	1.050	0.206	0.110	2.68	0.197	26.99
	379	39.43	30.80	1.240	0.213	0.178	2.56	0.244	27.28

Note: WIP = $100\times[(2Na_2O/0.35)+(MgO/0.9)+(2K_2O/0.25)+(CaO^*/0.7)]$ (Yang et al., 2016).

References

Yang, J., Cawood, P.A., Du, Y., Li, W., Yan, J., 2016. Reconstructing Early Permian tropical climates from chemical weathering indices. Bull. Geol. Soc. Am. 128, 739–751. https://doi.org/10.1130/B31371.1