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Supplementary Materials for:

Global continental weathering trends across the Early Permian glacial to postglacial transition: Correlating high and low paleo-latitude sedimentary records

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ANALYTICAL PROCEDURES

Whole-rock major and trace element concentrations were determined with X-ray florescence and ICP-MS by ALS Chemex, and mineralogical X-Ray Diffraction analysis and zircon LA-ICPMS dating were conducted in the State Key Laboratory of Geological Process and Mineral Resources, China University of Geosciences (Wuhan).

1. U-Pb isotope LA-ICPMS analysis of zircons

Zircons were separated from sample PSG3 by conventional procedures before hand-picking under a binocular microscope, mounting in epoxy and polished. Back scatter electron (BSE) and cathodoluminescence (CL) images were conducted on a JEOL JXA-8100 electron microprobe. Representative CL images for the analyzed zircons are shown in Figure DR1. Prior to LA-ICPMS analysis, zircons were subject to washing with dilute HNO_3 in an ultrasonic bath to eliminate surface contamination. For the LA-ICPMS analyses, laser sampling was performed using a Geolas 2005, and ion-signal intensities were acquired by an Agilent 7500a ICP-MS instrument. The diameter of the laser spot was 32 µm. Each analysis incorporated a background acquisition of approximately 20-30 s (gas blank) followed by 50 s data acquisition from the sample. The Agilent Chemstation was utilized for the acquisition of each individual analysis. Detailed operating conditions for the laser ablation system and the ICP-MS instrument and data reduction are described by Liu et al. (2010). Zircon 91500 ($^{206}Pb/^{238}U$ age = 1062.4 ± 0.4 Ma, Wiedenbeck et al., 1995) was used as external standard for U-Pb dating, and was analyzed twice every 6 analyses. Off-line selection and integration of background and signals, and time-drift correction and quantitative calibration for trace element analyses and U-Pb dating were performed by ICPMSDataCal (Liu et al., 2010; Liu et al., 2008). Concordia diagrams and weighted mean calculations were made using Isoplt/Ex_ver3 (Ludwig, 2003). Zircon standards Gj-1 was analyzed as unknown and the obtained mean $^{206}Pb/^{238}U$ age is 599.1 ± 8.4

Ma (2σ) in line with the recommended age of 599.8 ± 1.7 Ma (2σ, Jackson et al., 2004).

2. Mineralogical X-Ray Diffraction analysis

X-ray diffraction (XRD) studies of samples were performed with a PANalytical X'Pert Pro using a Cu-Ni tube at 40 kV and 40 mA, under continuous scanning with a speed of 8°/min. The mass percentage (mass %) of the main mineral phases identified were semi-quantified with an analytical error of ± 10 %.

3. Whole-rock geochemical analysis

After removing surface layer, solid samples were grounded to less than 200 mesh. For elemental oxide concentration analysis, sample powders were mixed with dry lithium tetraborate and borate and fused to glass beads, and analytical performance was conducted on a PANalytical Axios X-ray florescence spectrometer with accuracy better than 5% and uncertainty less than 5 %. Trace element (Rb, Sr, Ba, and Zr) contents were obtained on Perkin Elmer Elan 9000 ICP-MS with accuracy better than 10 % and uncertainty less than 10 % for the analyzed elements after complete fusion of samples with lithium borate and dissolution in ultrapure HNO_3.

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Table DR1. Zircon U-Pb isotope data for tuffaceous sandstone Sample PSG3

Spot	Pb	Th	U	Th/U	$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		rho	$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		Concordance
	ppm	ppm	ppm		Ratio	±1σ	Ratio	±1σ	Ratio	±1σ		Age (Ma)	±1σ	Age (Ma)	±1σ	Age (Ma)	±1σ	
PSG3-1	45.0	119	132	0.90	0.0550	0.0045	0.3649	0.0262	0.0499	0.0010	0.2875	409	183	316	20	314	6	99%
PSG3-2	18.0	84.0	118	0.71	0.0572	0.0041	0.3602	0.0254	0.0459	0.0008	0.2529	498	159	312	19	289	5	92%
PSG3-3	27.9	134	152	0.88	0.0542	0.0047	0.3377	0.0283	0.0458	0.0010	0.2565	389	196	295	21	289	6	97%
PSG3-4	18.6	91.8	108	0.85	0.0540	0.0050	0.3337	0.0299	0.0459	0.0010	0.2347	372	209	292	23	289	6	98%
PSG3-5	21.1	108	118	0.92	0.0554	0.0037	0.3524	0.0242	0.0465	0.0011	0.3460	428	150	307	18	293	7	95%
PSG3-6	31.8	149	183	0.81	0.0476	0.0031	0.3177	0.0207	0.0487	0.0010	0.3071	80	148	280	16	306	6	91%
PSG3-7	23.4	107	132	0.81	0.0526	0.0040	0.3240	0.0239	0.0460	0.0010	0.3002	322	174	285	18	290	6	98%
PSG3-8	22.6	102	126	0.82	0.0520	0.0033	0.3276	0.0208	0.0465	0.0010	0.3440	283	153	288	16	293	6	98%
PSG3-9	18.7	77.3	121	0.64	0.0663	0.0051	0.4525	0.0374	0.0504	0.0015	0.3526	817	156	379	26	317	9	82%
PSG3-10	112	74.2	97.8	0.76	0.1122	0.0036	5.3605	0.1810	0.3461	0.0048	0.4117	1836	59	1879	29	1916	23	98%
PSG3-11	31.4	150	208	0.72	0.0535	0.0038	0.3402	0.0223	0.0476	0.0010	0.3246	346	163	297	17	300	6	99%
PSG3-12	15.6	69.9	111	0.63	0.0558	0.0044	0.3649	0.0277	0.0479	0.0011	0.3110	443	174	316	21	302	7	95%
PSG3-13	19.9	95.6	127	0.75	0.0539	0.0049	0.3422	0.0298	0.0475	0.0012	0.2870	369	206	299	23	299	7	99%
PSG3-14	19.4	80.0	134	0.60	0.0623	0.0046	0.3941	0.0284	0.0465	0.0010	0.2967	687	158	337	21	293	6	85%
PSG3-15	12.8	60.0	84.9	0.71	0.0637	0.0059	0.4135	0.0366	0.0475	0.0012	0.2839	731	196	351	26	299	7	83%
PSG3-16	18.4	83.4	90.6	0.92	0.0815	0.0068	0.5083	0.0423	0.0455	0.0012	0.3134	1235	165	417	28	287	7	63%
PSG3-17	20.1	85.1	154	0.55	0.0568	0.0044	0.3708	0.0269	0.0482	0.0010	0.3007	483	175	320	20	304	6	94%
PSG3-18	12.9	58.3	87.8	0.66	0.0522	0.0049	0.3385	0.0312	0.0482	0.0012	0.2647	300	217	296	24	303	7	97%
PSG3-19	12.8	51.8	80.6	0.64	0.0629	0.0053	0.4089	0.0344	0.0473	0.0011	0.2792	706	175	348	25	298	7	84%
PSG3-20	16.3	80.5	108	0.74	0.0563	0.0046	0.3724	0.0330	0.0478	0.0011	0.2689	465	183	321	24	301	7	93%
PSG3-21	18.6	88.0	125	0.71	0.0541	0.0042	0.3450	0.0263	0.0465	0.0011	0.3014	376	174	301	20	293	7	97%
PSG3-22	17.7	83.8	93.7	0.89	0.0704	0.0060	0.4387	0.0346	0.0478	0.0012	0.3220	939	176	369	24	301	7	79%
PSG3-23	21.6	92.4	143	0.65	0.0578	0.0048	0.3761	0.0306	0.0470	0.0009	0.2271	524	183	324	23	296	5	90%
PSG3-24	142	717	571	1.26	0.0568	0.0025	0.3671	0.0169	0.0463	0.0007	0.3408	483	103	318	13	292	4	91%
PSG3-25	15.0	66.0	90.8	0.73	0.0569	0.0055	0.3545	0.0305	0.0474	0.0012	0.2930	487	215	308	23	298	7	96%
PSG3-26	11.3	54.0	91.8	0.59	0.0679	0.0063	0.4446	0.0374	0.0486	0.0012	0.2985	878	194	373	26	306	8	80%
PSG3-27	15.2	75.6	110	0.69	0.0636	0.0053	0.3785	0.0288	0.0445	0.0010	0.2839	728	177	326	21	281	6	85%
PSG3-28	29.6	143	203	0.71	0.0543	0.0037	0.3351	0.0213	0.0456	0.0009	0.3201	383	149	293	16	288	6	98%
PSG3-29	16.6	77.4	114	0.68	0.0570	0.0050	0.3636	0.0295	0.0481	0.0011	0.2785	500	193	315	22	303	7	96%
PSG3-30	13.5	53.9	74.5	0.72	0.0638	0.0056	0.3996	0.0344	0.0464	0.0012	0.3001	744	185	341	25	293	7	84%
PSG3-31	15.3	75.2	117	0.64	0.0531	0.0036	0.3286	0.0213	0.0456	0.0010	0.3375	345	154	288	16	288	6	99%
PSG3-32	37.7	167	228	0.73	0.0557	0.0033	0.3577	0.0212	0.0471	0.0008	0.2980	439	135	310	16	296	5	95%
PSG3-33	12.5	52.9	75.6	0.70	0.0693	0.0058	0.4443	0.0378	0.0469	0.0014	0.3402	906	173	373	27	295	8	76%

PSG3-34	20.2	88.0	124	0.71	0.0593	0.0046	0.3635	0.0251	0.0462	0.0010	0.3091	589	136	315	19	291	6	92%
PSG3-35	11.5	54.7	74.3	0.74	0.0663	0.0068	0.3956	0.0388	0.0446	0.0011	0.2584	817	214	338	28	281	7	81%
PSG3-36	58.1	34.8	77.9	0.45	0.1063	0.0043	4.7052	0.1983	0.3210	0.0054	0.4027	1737	74	1768	35	1794	27	98%
PSG3-37	28.9	136	136	1.00	0.0553	0.0044	0.3620	0.0273	0.0484	0.0011	0.3142	433	181	314	20	305	7	97%
PSG3-38	19.6	31.5	43.0	0.73	0.2131	0.0192	1.6076	0.1256	0.0582	0.0022	0.4861	2929	146	973	49	365	13	9%
PSG3-39	33.9	161	165	0.97	0.0600	0.0042	0.3724	0.0255	0.0458	0.0010	0.3051	611	154	321	19	288	6	89%
PSG3-40	18.6	88.8	115	0.78	0.0537	0.0045	0.3446	0.0268	0.0469	0.0008	0.2294	361	189	301	20	295	5	98%
PSG3-41	41.7	205	223	0.92	0.0579	0.0034	0.3616	0.0206	0.0453	0.0008	0.3154	528	130	313	15	286	5	90%
PSG3-42	14.7	72.1	96.8	0.74	0.0592	0.0053	0.3676	0.0324	0.0460	0.0012	0.2842	576	199	318	24	290	7	90%
PSG3-43	25.3	130	107	1.21	0.0631	0.0049	0.3949	0.0285	0.0455	0.0010	0.2987	722	169	338	21	287	6	83%
PSG3-44	14.4	69.4	99.3	0.70	0.0568	0.0053	0.3570	0.0348	0.0458	0.0012	0.2782	483	209	310	26	289	8	92%
PSG3-45	60.0	300	381	0.79	0.0538	0.0025	0.3455	0.0163	0.0462	0.0007	0.3171	365	112	301	12	291	4	96%
PSG3-46	11.1	50.0	84.0	0.60	0.0591	0.0048	0.3700	0.0299	0.0461	0.0011	0.3075	572	178	320	22	290	7	90%
PSG3-47	60.4	45.4	33.3	1.36	0.1050	0.0045	4.8545	0.2011	0.3347	0.0055	0.3984	1714	78	1794	35	1861	27	96%
PSG3-48	23.1	108	157	0.69	0.0514	0.0042	0.3426	0.0272	0.0486	0.0010	0.2521	261	185	299	21	306	6	97%
PSG3-49	18.5	91.0	116	0.79	0.0541	0.0049	0.3450	0.0290	0.0476	0.0010	0.2604	376	201	301	22	299	6	99%
PSG3-50	15.0	72.6	85.7	0.85	0.0686	0.0051	0.4166	0.0274	0.0458	0.0011	0.3583	887	154	354	20	289	7	79%
PSG3-51	25.9	132	116	1.15	0.0548	0.0045	0.3363	0.0279	0.0456	0.0010	0.2691	406	190	294	21	287	6	97%
PSG3-52	14.5	63.5	85.3	0.74	0.0576	0.0053	0.4062	0.0367	0.0514	0.0012	0.2646	522	203	346	26	323	8	93%
PSG3-53	43.5	228	221	1.03	0.0553	0.0038	0.3586	0.0248	0.0474	0.0010	0.2958	433	156	311	19	299	6	95%
PSG3-54	13.2	62.3	87.9	0.71	0.0564	0.0049	0.3554	0.0311	0.0460	0.0010	0.2516	478	193	309	23	290	6	93%
PSG3-55	124	659	404	1.63	0.0507	0.0025	0.3256	0.0157	0.0470	0.0008	0.3516	233	118	286	12	296	5	96%
PSG3-56	5.70	28.6	42.5	0.67	0.0769	0.0083	0.4345	0.0458	0.0460	0.0016	0.3291	1120	217	366	32	290	10	76%
PSG3-57	22.8	107	135	0.79	0.0549	0.0043	0.3381	0.0265	0.0454	0.0010	0.2706	409	169	296	20	286	6	96%
PSG3-58	16.1	74.8	106	0.70	0.0535	0.0050	0.3261	0.0280	0.0458	0.0011	0.2683	350	209	287	21	289	7	99%
PSG3-59	17.6	79.3	118	0.67	0.0574	0.0044	0.3652	0.0254	0.0477	0.0009	0.2776	509	201	316	19	300	6	94%
PSG3-60	21.8	92.1	128	0.72	0.0557	0.0044	0.3517	0.0257	0.0475	0.0012	0.3385	443	178	306	19	299	7	97%

Table DR2. XRD mineralogical composition of the Lower Permian samples from southeastern North China

Samples	Depth (m)	Quartz	Feldspar	Calcite	Siderite	Clay minerals	Clay mineral assemblage		
							Chlorite	Illite	Kaolinite
ps5	1460	34	0	0	2	64	35	25	40
ps7	1465	27	0	0	46	27	5	20	75
ps8	1470.5	33	0	0	6	61	15	35	50
ps9	1471.1	38	0	0	2	60	15	25	60
ps10	1473.9	38	2	0	3	57	20	20	60
ps11	1476.3	32	0	0	2	66	15	15	70
ps12	1477.2	30	2	0	2	66	15	20	65
ps13	1479.4	40	6	2	2	50	20	25	55
ps14	1480.5	33	3	0	3	61	25	25	50
ps15	1482.2	33	3	0	3	61	25	25	50
ps16	1482.4	34	3	0	2	61	20	20	60
ps17	1483.1	32	2	0	2	64	15	15	70
ps19	1484.7	34	0	0	0	66	15	15	70
ps20	1488.5	29	0	0	16	55	10	10	80
ps21	1490	32	2	0	4	62	20	20	60
ps26	1505	10	0	2	0	88	10	10	80
ps27	1506	14	0	0	0	86	15	10	75
ps28	1514.7	38	0	0	2	60	15	10	75
ps29	1518.6	32	2	0	0	66	15	5	80
ps30	1522.8	32	0	0	2	66	15	10	75
ps31	1524.5	4	0	0	0	96	10	10	80
ps33	1527	2	0	0	32	66	30	0	70
ps34	1529.5	46	0	0	5	49	20	5	75
ps35	1529.6	4	0	0	0	96	35	10	55
ps36	1531.5	24	0	0	0	76	65	20	15
ps37	1532	29	0	0	2	69	55	15	30
ps38	1535.6	29	2	0	0	69	25	25	50
ps42	1545	39	3	0	2	56	25	25	50
ps52	1564.8	34	2	0	0	64	25	25	50
ps53	1585	35	0	0	0	65	20	25	55
ps54	1587.7	40	2	0	2	56	15	25	60
ps55	1587.8	43	2	0	2	53	15	30	55
ps58	1590	35	2	0	2	61	10	20	70

Table DR3. Whole-rock major element (%) and trace element (ppm) geochemistry of the Lower Permian samples from southeastern North China

Sample	Depth (m)	Lithology	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	LOI	Total	Rb	Sr	Ba	Zr
ps5	1460	mudstone	57.02	24.15	5.1	0.16	0.67	0.45	1.61	0.91	0.01	0.04	9.77	99.94	91.8	122.5	464	196
ps7	1465	siltstone	28.97	8.13	37.47	1.04	1.21	0.29	0.63	0.38	0.43	0.171	21.3	100.05	36.8	66.2	216	163
ps8	1470.5	mudstone	54.39	20.58	8.68	0.22	0.76	0.53	2.39	0.83	0.3	0.062	10.6	99.42	150.5	119.5	630	185
ps9	1471.1	mudstone	61.38	21.06	4.71	0.14	0.76	0.55	2.32	0.97	0.13	0.041	7.89	100	139	109.5	581	216
ps10	1473.9	mudstone	59.23	21.15	5.63	0.28	0.85	0.53	2.01	0.98	0.07	0.139	8.92	99.85	119.5	121	500	246
ps11	1476.3	mudstone	55.47	26.15	3.36	0.14	0.56	0.49	1.65	0.85	0.01	0.063	10.75	99.56	91.8	149	512	169
ps12	1477.2	mudstone	54.45	27.14	3.16	0.15	0.52	0.52	1.46	0.79	0.01	0.054	11.65	99.95	82.9	138	503	165
ps13	1479.4	siltstone	63.8	20.58	2.77	0.35	0.73	1.07	1.77	0.94	0.01	0.074	7.37	99.53	91.7	145	471	367
ps14	1480.5	siltstone	58.79	21.45	5.02	0.35	1.06	0.84	2.23	0.88	0.09	0.083	9.07	99.95	113.5	149.5	566	196
ps15	1482.2	mudstone	59	19.83	6.07	0.57	1.06	0.89	2	0.84	0.11	0.099	9.13	99.66	99.6	138.5	489	215
ps16	1482.4	mudstone	58.3	22.2	4.03	0.31	0.93	0.8	2.23	0.91	0.05	0.083	9.23	99.14	115	157.5	573	216
ps17	1483.1	mudstone	60.29	23.96	2.32	0.17	0.61	0.58	2.16	0.99	0.01	0.043	8.76	99.95	94.2	147	510	225
ps19	1484.7	mudstone	56.19	27	2	0.14	0.4	0.51	1.22	0.79	0.01	0.028	11.35	99.69	50.4	149.5	419	184
ps20	1488.5	mudstone	46.74	18.9	14.79	0.38	0.86	0.57	1.49	0.82	0.19	0.139	14.55	99.49	68.6	169.5	421	293
ps21	1490	mudstone	58.46	20.56	5.71	0.28	0.85	0.68	1.84	0.87	0.08	0.122	10.4	99.91	84.8	169.5	457	243
ps26	1505	mudstone	38.09	26.81	2.48	0.2	0.43	0.41	0.54	0.53	0.01	0.029	29.6	99.17	23.1	140.5	327	231
ps27	1506	mudstone	41.13	28.87	2.05	0.15	0.42	0.46	0.63	0.58	0.01	0.027	24.6	98.97	26.4	156.5	373	253
ps28	1514.7	mudstone	62.11	22.58	3.29	0.1	0.45	0.45	1.12	1.05	0.01	0.053	8.57	99.84	58.6	130.5	375	374
ps29	1518.6	mudstone	53.75	30.38	1.65	0.12	0.22	0.38	0.42	0.99	0.01	0.032	12.1	100.1	19.3	140	263	313
ps30	1522.8	mudstone	58.21	25.44	3	0.08	0.37	0.3	1.17	1.03	0.03	0.054	9.8	99.56	63.6	162	319	277
ps31	1524.5	mudstone	44.5	37.33	1.33	0.08	0.24	0.31	0.95	0.99	0.01	0.061	13.85	99.69	40.6	186	385	335
ps33	1527	mudstone	32.22	27.56	19.32	0.13	0.34	0.16	0.18	1.01	0.16	0.033	18.25	99.39	8.2	78.4	103	411
ps34	1529.5	mudstone	67.09	18.4	4.48	0.03	0.19	0.13	0.27	0.65	0.02	0.033	7.88	99.18	11.5	74	103.5	310
ps35	1529.6	mudstone	42.34	35.51	5.65	0.26	0.22	0.22	0.33	1.35	0.01	0.243	13.5	99.67	15.2	205	273	583
ps36	1531.5	mudstone	48.17	23.79	16.36	0.18	0.81	0.33	1.15	0.86	0.01	0.196	7.72	99.65	53.6	351	374	231
ps37	1532	mudstone	51.02	23.73	12.35	0.14	0.68	0.25	1.11	0.84	0.02	0.12	9.09	99.41	53.1	230	312	252
ps38	1535.6	mudstone	56.98	25.51	3.04	0.19	0.63	0.76	1.52	0.98	0.01	0.081	9.71	99.49	60	253	713	412
ps41	1538	fine–grained	63.02	20.29	3.25	0.91	0.7	1.8	1.96	0.75	0.01	0.132	6.96	99.89	65.9	265	704	207
ps42	1545	mudstone	60.76	23.51	1.98	0.08	0.49	0.75	1.8	0.9	0.01	0.048	8.98	99.39	83.9	171.5	551	296
ps52	1564.8	mudstone	53.63	26.74	1.48	0.07	0.49	0.69	1.94	0.74	0.01	0.056	13.85	99.74	89.5	130.5	431	210
ps53	1585	mudstone	46.65	23.11	1.32	0.07	0.39	0.43	1.37	0.72	0.01	0.071	25.5	99.68	65.9	142.5	285	224
ps54	1587.7	mudstone	62.46	23.16	1.17	0.1	0.36	0.44	2.06	0.91	0.01	0.027	8.96	99.71	79.3	121	526	482
ps55	1587.8	mudstone	62.32	22.4	1.29	0.12	0.37	0.4	2.14	1.02	0.01	0.031	9.13	99.29	83.3	119.5	520	579
ps58	1590	mudstone	60.55	22.12	1.31	0.05	0.4	0.4	1.88	0.69	0.01	0.038	12.35	99.85	68.5	94.9	432	279
ps60	1594.5	fine–grained	50.49	15.18	12.91	1.09	1.79	0.84	2.09	0.65	0.29	0.132	13.8	99.35	81.8	199	492	274

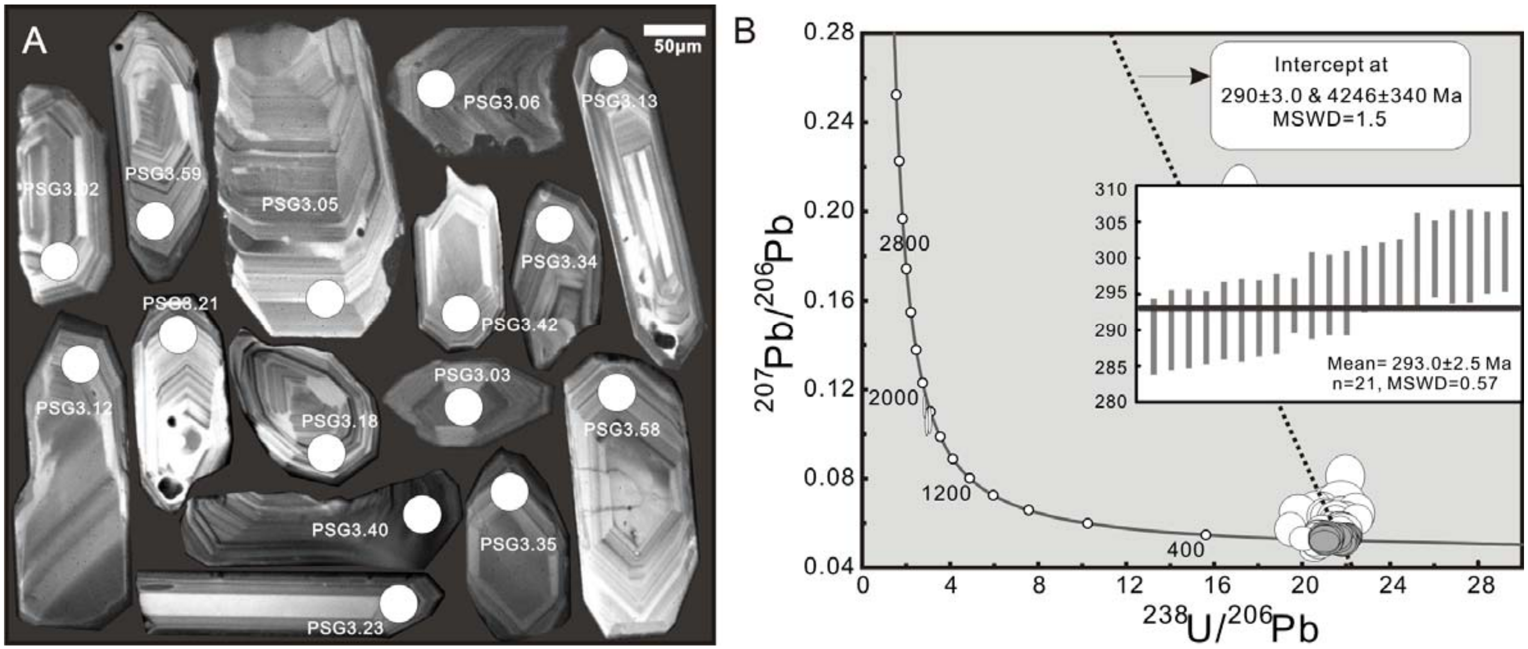

Figure DR1. A: Representative CL images for dated zircons; B: Tera-Wasserburg plot of zircon analyses from Sample PGS3, where the gray symbols mark the integrated analyses for calculating weighted average age [inset, 293.0 ± 2.5 Ma (n = 21, MSWD = 0.57)]. This average age is equal to the lower intercept age within error (290. 0 ± 3.0 Ma) and interpreted as the depositional age of this tuffaceous bed. Another three concordant analyses gave Paleoproterozoic $^{207}Pb/^{206}Pb$ ages (1832-1721 Ma, Table DR1), and are considered xenocrystic in origin.

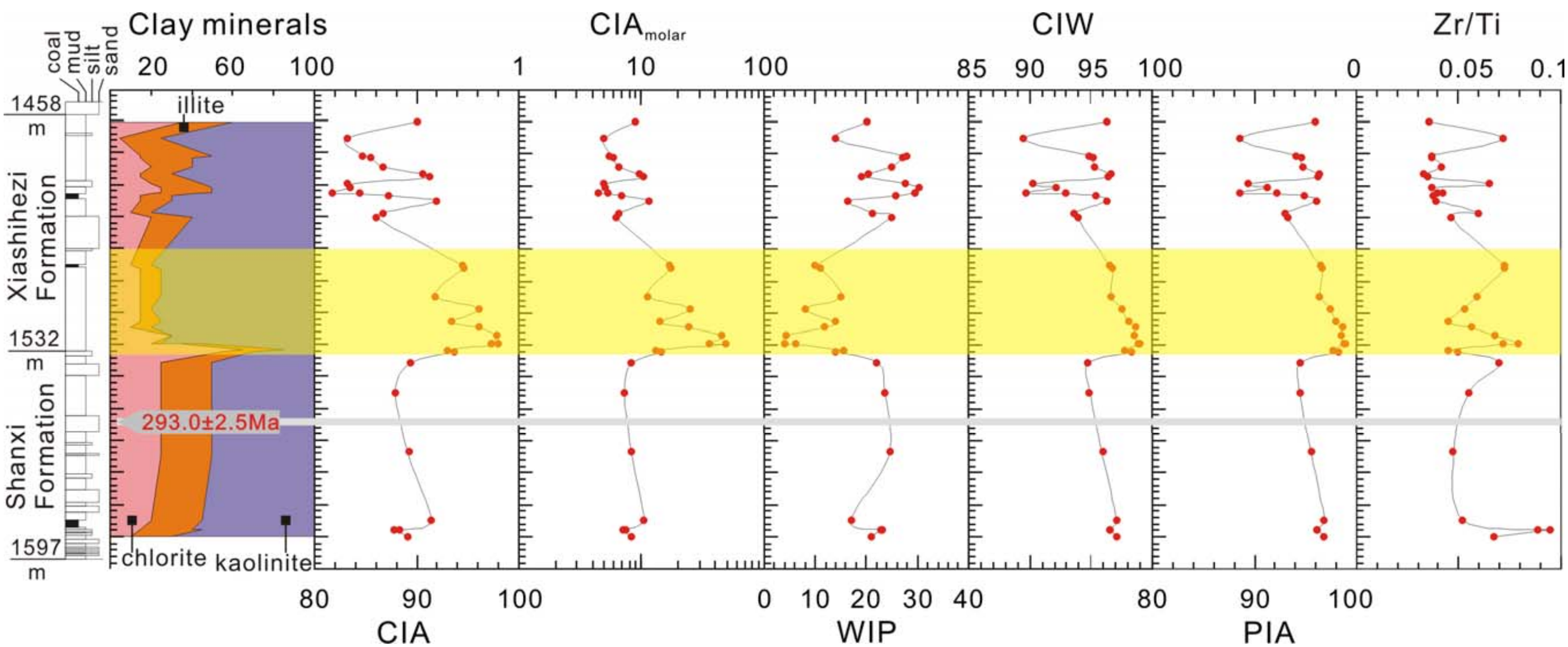

Figure DR2. Stratigraphic variations of CIA value (chemical index of alteration, Nesbitt and Young, 1982), clay mineral assemblage, and provenance chemical indicator Zr/Ti ratio for silt-mudstone samples. Other chemical weathering indices including weathering index of Parker (WIP, Parker, 1970), chemical index of weathering (CIW, Harnois, 1988), plagioclase index of alteration (PIA, Fedo et al., 1995) and CIA_{molar} (expressed as $Al_2O_3/(CaO^*+Na_2O+K_2O)$ mole ratio, Goldberg and Humayun, 2010) were also plotted for comparison. CaO* involved in index calculations represent only the Ca in silicate fractions.