

Metal-induced stress in survivor plants following the end-Permian collapse of land ecosystems

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Borehole ZK4703

The borehole ZK4703 (25.54151°N, 104.28994°E) was drilled 15 km south of Fuyuan County, Xuanwei City, Yunnan Province in summer of 2014 by Coal Geology Bureau. It was one of dozens of boreholes drilled to explore the Permian coal reserves. It consists of Carboniferous, Permian and Early Triassic strata. The core of Xuanwei Formation (Late Permian), Kayitou Formation (Permian-Triassic transition) and lower part of Dongchuan Formation (Early Triassic) are currently stored at State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences (Wuhan).

Palynological analysis

36 samples have been collected from core ZK4703 of South China, across the Permian-Triassic transition. And all of them have been processed with the standard palaeopalynological method without the oxidation process. The residues were then mounted on permanent slides (ten slides for each sample) by using the medical neutral gum. The quantitative palynological analysis on 19 productive samples were counted as around 100 sporomorphs per sample (Table DR2). Those processes were carried on a Zeiss Axio Scope A1 microscope. All residues in sealed tubes with the antifungal process and permanent slides were stored at State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences (Wuhan).

Trace element analysis

Al and Cu contents of whole rock were conducted on Agilent 7700x ICP-MS at the Wuhan Sample-Solution Analytical Technology Co., Ltd.. NH₄HF₂-open-vessel acid digestion technique was

used in this study in order to complete dissolve refractory minerals. The detailed sample-digesting procedure was as follows: (1) Sample powder (200 mesh) are placed in an oven at 105 °C for drying of 12 hours; (2) 50 mg sample powder is accurately weighted and mixed with 200 mg pure NH₄HF₂ powder in a 7-mL screw-top PFA vial; (3) The vials are then capped and heated at 230 °C in an electric oven for 3 hours; (4) After cooling, 2 mL HNO₃ are added, and the vials are capped and placed on a hot plate at 160 °C. After 1 hour, the vials are opened and evaporated to near dryness at 160°C on the hot plate; (5) The final residue is then taken up in 1 mL HNO₃, 1 mL MQ water, and 1 mL internal standard solution of 1 ppm In. The vials are recapped and heated for 6 hours at 120 °C to obtain a clear solution; (6) The final solution was transferred to a polyethylene bottle and diluted to 100 g by the addition of 2% HNO₃ before ICP-MS analysis. The accuracy of Al and Cu of international standards BCR-2, BHVO-2 and AGV-2 are better than 5% .

Table DR1. Hg, Cu, TOC and Al concentrations, and Hg/TOC, Hg/Al and Cu/ Al ratios from ZK4703.

Sample	Height (m)	Al (ppm)	Cu (ppm)	TOC (%)	Hg (ppb)	Hg/TOC (ppb/%)	Hg/Al*10 ⁸	Cu/Al*10 ⁴	Cu/TOC (ppm/%)	Ni (ppm)	Pb (ppm)	Cr (ppm)	Zn (ppm)
ZK-3	1.5	92690	158	1.49	31	21	34	17	106	94	9	167	196
ZK-5	2.5	113623	241	1.55	30	19	27	21	155	95	11	137	200
ZK-8	4	103762	224	1.51	24	16	23	22	148	95	12	127	164
ZK-10	5	96706	223	1.43	36	25	37	23	156	92	18	138	168
ZK-12	6	80291	186	1.00	32	32	40	23	186	82	10	122	164
ZK-14	7	86305	182	3.17	26	8	30	21	57	128	11	236	185
ZK-17	11	90801	176	1.07	21	20	24	19	164	85	10	142	166
ZK-20	12.5	94372	214	0.87	19	22	20	23	246	84	11	113	131
ZK-22	13.5	91816	191	1.02	28	27	30	21	187	91	19	139	173
ZK-23	14	86026	182	1.10	37	34	43	21	165	90	10	115	168
ZK-26	15.25	79826	171	1.17	29	25	36	21	146	86	12	129	156
ZK-27	15.5	102655	209	0.86	43	50	42	20	243	77	9	88	157
ZK-28	15.75	109131	221	0.89	43	49	40	20	248	78	9	88	158
ZK-30	16.25	116885	260	1.37	23	17	20	22	190	74	12	87	184
ZK-32	16.75	120010	274	1.62	24	15	20	23	169	86	9	75	145
ZK-35	17.5	114482	281	0.66	38	58	34	25	426	85	10	110	202
ZK-37	18	75576	168	0.20	40	199	53	22	840	67	6	122	153
ZK-39	18.25	97538	219	0.32	29	90	29	22	684	81	6	140	207
ZK-41	18.75	96043	411	0.28	42	150	44	43	1468	81	11	114	156
ZK-42	19.25	95809	417	0.28	70	250	73	44	1489	78	10	107	171
ZK-43	19.5	107655	246	0.40	124	310	115	23	615	81	13	83	241
ZK-45	19.75	114811	271	0.21	324	1544	282	24	1290	79	16	76	129
ZK-47	20.25	106907	250	0.30	42	141	39	23	833	94	6	123	230
ZK-50	21	92401	209	0.45	39	87	42	23	464	93	7	161	162
ZK-52	21.5	97483	253	0.76	24	31	24	26	333	81	7	122	135
ZK-54	22	94306	241	0.72	26	37	28	26	335	79	7	105	148
ZK-56	22.5	89934	220	0.44	36	82	40	24	500	83	8	118	161
ZK-58	23	94185	237	0.41	14	35	15	25	578	82	10	111	168
ZK-61	23.75	72446	171	0.30	21	72	30	24	570	46	7	98	92
ZK-63	24.25	89518	203	0.26	42	161	47	23	781	98	8	164	180
ZK-65	24.75	90395	265	0.26	16	60	17	29	1019	86	10	148	157
ZK-67	25.25	85811	182	0.51	6	12	7	21	357	80	7	130	149
ZK-70	26	89655	207	0.26	8	29	8	23	796	82	9	155	166
ZK-72	26.5	82691	188	0.25	11	43	13	23	752	77	10	178	162
ZK-74	27	89460	213	0.52	11	21	12	24	410	75	8	118	159
ZK-77	27.75	92990	219	0.57	14	25	15	24	384	72	10	92	153

Table DR2. Counts of total and tetrad spores from ZK4703.

Sample	Height(m)	Total	Spore	Spore/total	Tetrads	Tetrads/total	Tetrad/spore
ZK-5	2.50	199	190	0.9548	0	0.0000	0.0000
ZK-7	3.50	70	67	0.9571	0	0.0000	0.0000
ZK-10	5.00	74	72	0.9730	0	0.0000	0.0000
ZK-12	6.00	81	79	0.9753	0	0.0000	0.0000
ZK-14	7.00	90	90	1.0000	0	0.0000	0.0000
ZK-17	11.00	168	168	1.0000	0	0.0000	0.0000
ZK-26	15.25	74	66	0.8919	0	0.0000	0.0000
ZK-28	15.75	204	194	0.9510	0	0.0000	0.0000
ZK-30	16.25	195	193	0.9897	0	0.0000	0.0000
ZK-34	17.25	196	164	0.8367	1	0.0051	0.0061
ZK-37	18.00	298	168	0.5638	1	0.0034	0.0060
ZK-40	18.50	339	301	0.9066	21	0.0633	0.0698
ZK-41	18.75	340	326	0.9588	64	0.1882	0.1963
ZK-42	19.25	204	200	0.9804	36	0.1765	0.1800
ZK-43	19.50	152	121	0.7961	1	0.0066	0.0083
ZK-45*	19.75	61	51	0.8360	2	0.0327	0.0392
ZK-53	21.75	87	49	0.3793	0	0.0000	0.0000
ZK-65	24.75	147	34	0.2313	0	0.0000	0.0000
ZK-77	27.75	171	48	0.2807	0	0.0000	0.0000
ZK-79	28.25	142	45	0.3169	1	0.0070	0.0222

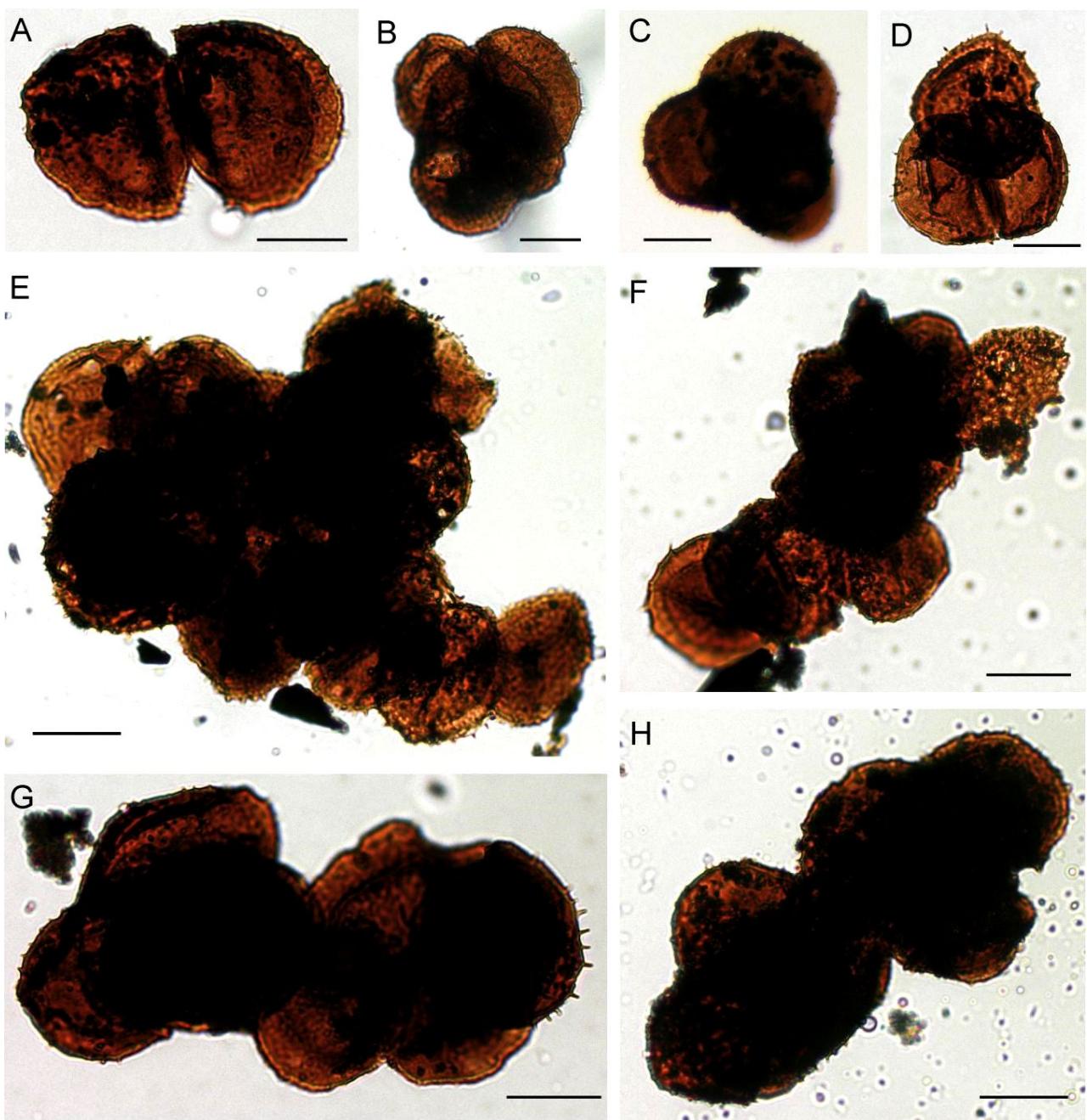


Figure DR1. A-D, Spore tetrads from ZK4703; E-H, masses of spores and tetrads stuck together. A-E are from sample ZK-41; F-H are from ZK-42. The scale bar is 20 μm .