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Major and trace elements of a peat core from Yunnan, Southwest China: Implications for paleoclimatic proxies

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ABSTRACT

This study examines the accumulation of major and trace elements in peat deposits in central Yunnan Province, southwestern China. The ashes of an approximately 2 m long core spanning 32.7–11.4 ka are analyzed to assess the elemental contributions of organic materials and to identify elemental paleoclimatic proxies in peats. Peat ash, which is mainly composed of silicate materials, makes up 20–80% of each of the samples. The analysis shows that organic materials are a significant source of many of the elements in the ashes. Among these elements, P and V are the most typical, with their concentrations in the ashes closely correlating to the total organic carbon (TOC) content of the peats. Al, Na, Sc, Cr, Co, Ni, Cu, Ge, Pb, and Th are also associated with biogenic materials, particularly in the lower section (below 122 cm) of the core, where the organic material content is high. Ca, Sr, Mg, and Mn appear to have been part of carbonate deposits, such as authigenic $FeCO_3$ and $MnCO_3$ in the anoxic peats, whereas, K, Ti, Zn, Ga, Rb, Y, rare earth elements (REEs), Zr, Hf, Nb, Ta, Ba, and U are mainly associated with silicate materials. Local weathering products, rather than dust from northern China, are the main sources for the silicate materials in these peats. Some elemental ratios such as K/Rb and K_2O/Na_2O can reliably indicate changes in local chemical weathering intensity, and their variation patterns match the changes in the East Asian summer monsoon (EASM) very well. The less intensive chemical weathering indicated by lower K/Rb and K_2O/Na_2O ratios generally corresponds to weaker EASM strength during ~30 to ~10 ka, which is consistent with the fact that weaker summer monsoons may arouse drier climates, and do not favor intense chemical weathering. This suggests that select elemental ratios in peats/organic rich sediments may be informative proxies for monsoon climate changes.

1. Introduction

Peats are valuable archives of climate and environment changes, and proxies in peats have been used to reconstruct paleoclimatic and paleoenvironmental records for more than a century (Bindler, 2006). Most of these proxies are associated with biogenic materials, such as pollen, peat-forming fossils, elements and isotopes of organic matter, and some newly developed molecular biomarkers (Bindler, 2006). Inorganic materials in peats, however, can also provide plentiful information about climate and environment changes. In ombrotrophic peat bogs, inorganic materials are believed to be mainly atmospheric deposits, and their elemental and isotopic compositions probably indicate changes in atmospheric inputs. Numerous studies in the past decades have described the changes in atmospheric imported heavy metals, such as lead and mercury, during industrial eras or during pre-industrial periods in Europe and North America (Farmer et al., 2006; Kamenov et al., 2009; Kempter et al., 1997; Kylander et al., 2005, 2007; Le Roux et al., 2004; Martinez-Cortizas et al., 1999, 2002; Roos-Barraclough et al., 2002; Shotyk et al., 1998, 2001, 2005; Weiss et al., 1997, 1999). These studies of natural and anthropogenic inputs from the atmosphere are important in the evaluation of the impact of human activities on the environment. The geochemistry of inorganic materials in minerotrophic peat bogs are also believed to be informative proxies for climate and environment changes, even though inorganic materials carried by water flow can conceal materials imported from the atmosphere. Not only human activities (Monna et al., 2004a,b), but also natural climate changes (Kylander et al., 2007; Muller et al., 2006, 2008) can be reflected in the elemental and isotopic compositions of the inorganic materials in minerotrophic peat bogs.

Peat can generally be considered as a special type of sediment comprising a large amount of biogenic materials transformed from

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Table 1
LOI and TOC contents of the peats and the major element contents of the ashes (unit: %).

Sample ID	Depth (cm)	Age (ka)	LOI	TOC	Al_2O_3	CaO	FeO(T)[a]	K_2O	MgO	MnO	Na_2O	P_2O_5	TiO_2
BX-21	42	11.42	21.84	6.92	27.22	2.02	4.95	3.07	1.19	0.03	0.18	0.06	0.90
BX-22	44	11.84	20.63	6.64	26.95	1.87	4.90	3.09	1.19	0.03	0.16	0.06	0.96
BX-23	46	12.26	30.14	11.38	28.49	3.67	6.67	2.62	1.39	0.05	0.19	0.12	0.88
BX-24	48	12.68	28.33	8.94	28.82	2.87	5.96	2.80	1.31	0.03	0.15	0.10	0.90
BX-25	50	13.10	30.95	11.33	28.64	3.03	6.09	2.76	1.35	0.04	0.18	0.11	0.89
BX-26	52	13.51	34.81	14.02	26.54	3.77	6.01	2.56	1.43	0.04	0.27	0.16	0.90
BX-27	54	13.93	38.24	16.84	23.89	4.02	6.69	2.34	1.33	0.06	0.27	0.20	0.88
BX-28	56	14.35	38.61	15.60	23.52	3.97	7.14	2.36	1.34	0.06	0.25	0.24	0.93
BX-29	58	14.77	40.29	16.79	24.33	4.33	7.69	2.49	1.45	0.06	0.26	0.30	0.97
BX-30	60	15.19	44.60	20.17	25.67	4.67	7.06	2.48	1.46	0.05	0.24	0.27	0.89
BX-31	62	15.61	47.40	21.79	26.93	4.85	7.38	2.61	1.51	0.05	0.20	0.31	0.89
BX-32	64	16.03	45.14	19.96	27.65	4.09	6.29	2.78	1.46	0.04	0.18	0.25	0.93
BX-33	66	16.45	46.39	23.28	27.29	4.05	5.48	2.65	1.53	0.03	0.22	0.30	0.94
BX-34	68	16.87	45.50	22.16	26.10	3.21	5.53	2.61	1.37	0.03	0.22	0.29	0.97
BX-35	70	17.29	48.19	21.26	24.99	3.61	5.82	2.39	1.34	0.03	0.27	0.38	0.98
BX-36	72	17.71	50.21	24.63	24.69	3.88	5.34	2.18	1.34	0.03	0.32	0.43	0.96
BX-37	74	18.13	50.93	24.35	24.19	3.81	5.40	2.07	1.30	0.03	0.29	0.45	0.93
BX-38	76	18.38	52.76	25.46	24.98	3.96	5.31	2.03	1.36	0.03	0.29	0.50	0.93
BX-39	78	18.85	51.66	25.55	25.19	3.81	5.08	2.09	1.38	0.03	0.32	0.46	0.93
BX-40	80	19.31	50.03	24.56	24.80	3.21	4.94	2.11	1.30	0.03	0.29	0.41	0.93
BX-41	82	19.78	47.98	23.39	24.20	2.85	4.69	2.11	1.24	0.03	0.28	0.39	0.90
BX-42	84	20.24	49.83	23.76	25.32	3.07	4.89	2.28	1.33	0.03	0.27	0.36	0.92
BX-43	86	20.71	51.70	25.63	25.77	3.10	4.95	2.31	1.33	0.03	0.26	0.37	0.90
BX-44	88	21.18	43.31	20.96	26.74	2.63	5.08	2.56	1.30	0.03	0.23	0.31	0.89
BX-45	90	21.64	43.95	18.93	27.05	2.55	4.89	2.70	1.30	0.03	0.23	0.29	0.89
BX-46	92	22.11	41.13	18.64	25.72	2.28	4.82	2.68	1.21	0.03	0.22	0.29	0.89
BX-47	94	22.57	41.44	19.88	26.65	2.35	4.81	2.86	1.25	0.03	0.23	0.27	0.93
BX-48	96	23.04	38.18	18.83	26.95	2.28	4.48	3.11	1.30	0.02	0.21	0.22	0.91
BX-49	98	23.42	35.67	16.51	26.61	1.85	4.33	3.39	1.23	0.02	0.18	0.17	0.95
BX-50	100	23.81	38.18	18.42	26.46	2.15	4.40	3.24	1.28	0.02	0.19	0.20	0.89
BX-51	102	24.19	39.55	19.77	26.29	2.01	4.17	3.24	1.25	0.03	0.18	0.16	0.92
BX-52	104	24.57	44.44	22.17	26.80	2.53	4.43	3.12	1.37	0.03	0.19	0.19	0.87
BX-53	106	24.95	51.27	25.21	26.15	2.36	4.62	3.12	1.32	0.03	0.19	0.20	0.87
BX-54	108	25.34	50.92	25.91	27.28	2.44	4.50	3.26	1.41	0.03	0.19	0.21	0.83
BX-55	110	25.72	47.99	24.56	26.30	2.02	4.25	3.49	1.29	0.03	0.18	0.18	0.83
BX-56	112	26.10	42.36	21.58	26.81	1.73	4.20	3.77	1.28	0.02	0.17	0.16	0.87
BX-57	114	26.48	44.32	19.80	26.91	1.71	4.14	3.66	1.31	0.02	0.18	0.16	0.86
BX-58	116	26.87	41.44	20.84	26.05	1.31	3.87	3.82	1.25	0.02	0.17	0.12	0.87
BX-59	118	27.25	41.38	19.53	25.88	1.36	3.95	3.79	1.25	0.02	0.17	0.14	0.83
BX-60	120	27.63	51.16	25.55	27.29	2.11	4.64	3.51	1.43	0.03	0.20	0.21	0.84
BX-61	122	27.68	57.18	29.67	26.06	3.13	5.69	2.90	1.48	0.04	0.21	0.32	0.80
BX-62	124	27.74	56.29	29.14	26.62	3.62	6.13	2.87	1.61	0.05	0.22	0.35	0.80
BX-63	126	27.79	63.76	33.39	26.69	3.69	6.68	2.68	1.56	0.05	0.23	0.39	0.79
BX-64	128	27.84	73.81	35.19	27.41	4.27	6.65	2.50	1.70	0.05	0.25	0.40	0.80
BX-65	130	27.90	70.33	37.98	27.61	3.83	6.76	2.44	1.56	0.05	0.23	0.41	0.81
BX-66	132	27.95	59.47	39.83	27.86	3.81	6.76	2.48	1.66	0.05	0.25	0.42	0.79
BX-67	134	28.00	70.52	40.40	27.86	3.68	6.95	2.60	1.68	0.05	0.27	0.44	0.82
BX-68	136	28.06	80.43	44.46	27.46	3.87	7.34	2.46	1.69	0.05	0.27	0.49	0.84
BX-69	138	28.11	66.21	35.35	26.98	2.87	6.29	2.87	1.45	0.04	0.23	0.32	0.88
BX-70	140	28.16	61.14	31.90	26.44	2.78	5.98	2.83	1.40	0.04	0.20	0.30	0.88
BX-71	142	28.22	57.21	29.88	26.68	2.85	5.95	2.89	1.40	0.04	0.21	0.29	0.87
BX-72	144	28.27	62.73	40.51	25.35	2.99	6.36	2.70	1.38	0.04	0.22	0.30	0.87
BX-73	146	28.32	52.94	26.81	26.27	3.05	6.02	2.99	1.42	0.05	0.19	0.26	0.90
BX-74	148	28.38	49.86	24.41	23.92	3.25	6.39	2.43	1.31	0.05	0.19	0.25	0.89
BX-75	150	28.43	50.61	25.63	23.20	3.47	6.31	2.38	1.34	0.05	0.19	0.26	0.91
BX-76	152	28.48	49.66	26.00	24.13	3.49	6.47	2.61	1.41	0.05	0.18	0.25	0.92
BX-77	154	28.54	51.52	25.69	24.09	2.71	5.83	2.60	1.27	0.04	0.17	0.22	0.95
BX-78	156	28.59	50.14	25.57	22.46	2.25	5.23	2.66	1.22	0.04	0.16	0.20	0.96
BX-79	158	28.64	50.32	25.61	25.34	2.01	4.99	3.10	1.29	0.03	0.16	0.19	1.00
BX-80	160	28.70	48.07	25.30	25.06	1.84	4.80	3.13	1.26	0.03	0.16	0.18	1.00
BX-81	162	28.75	42.99	21.45	25.15	1.36	4.39	3.20	1.20	0.02	0.16	0.15	1.05
BX-82	164	28.96	40.95	19.53	25.08	1.10	3.87	3.36	1.17	0.02	0.15	0.13	1.03
BX-83	166	29.17	55.59	29.93	25.65	1.49	4.54	3.22	1.25	0.02	0.17	0.17	1.01
BX-84	168	29.37	46.97	23.59	25.33	1.30	4.24	3.26	1.20	0.02	0.15	0.14	1.02
BX-85	170	29.58	49.31	25.70	25.65	1.34	4.22	3.36	1.25	0.02	0.15	0.14	1.02
BX-86	172	29.79	43.41	21.80	24.90	1.10	4.08	3.30	1.21	0.02	0.15	0.11	1.03
BX-87	174	30.00	46.35	23.44	25.45	1.16	4.23	3.39	1.25	0.02	0.16	0.12	1.05
BX-88	176	30.20	41.44	21.69	25.46	1.06	3.92	3.41	1.24	0.02	0.14	0.11	1.02
BX-89	178	30.41	42.86	21.17	26.17	1.10	4.20	3.52	1.27	0.02	0.16	0.11	1.08
BX-90	180	30.62	41.79	20.86	25.52	1.09	4.03	3.40	1.24	0.02	0.14	0.10	1.02
BX-91	182	30.83	40.17	19.69	24.76	1.02	4.00	3.21	1.19	0.02	0.14	0.10	1.01
BX-92	184	31.03	39.26	18.45	25.11	1.04	4.04	3.23	1.20	0.02	0.14	0.10	1.01
BX-93	186	31.24	39.97	19.63	22.42	1.03	4.10	3.10	1.09	0.02	0.14	0.10	0.99
BX-94	188	31.45	51.39	26.49	26.46	1.47	4.70	3.17	1.32	0.03	0.16	0.15	0.94

(*continued on next page*)