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The Meishucun phosphorite succession (SW China) records redox change in shallow water of the early Cambrian ocean

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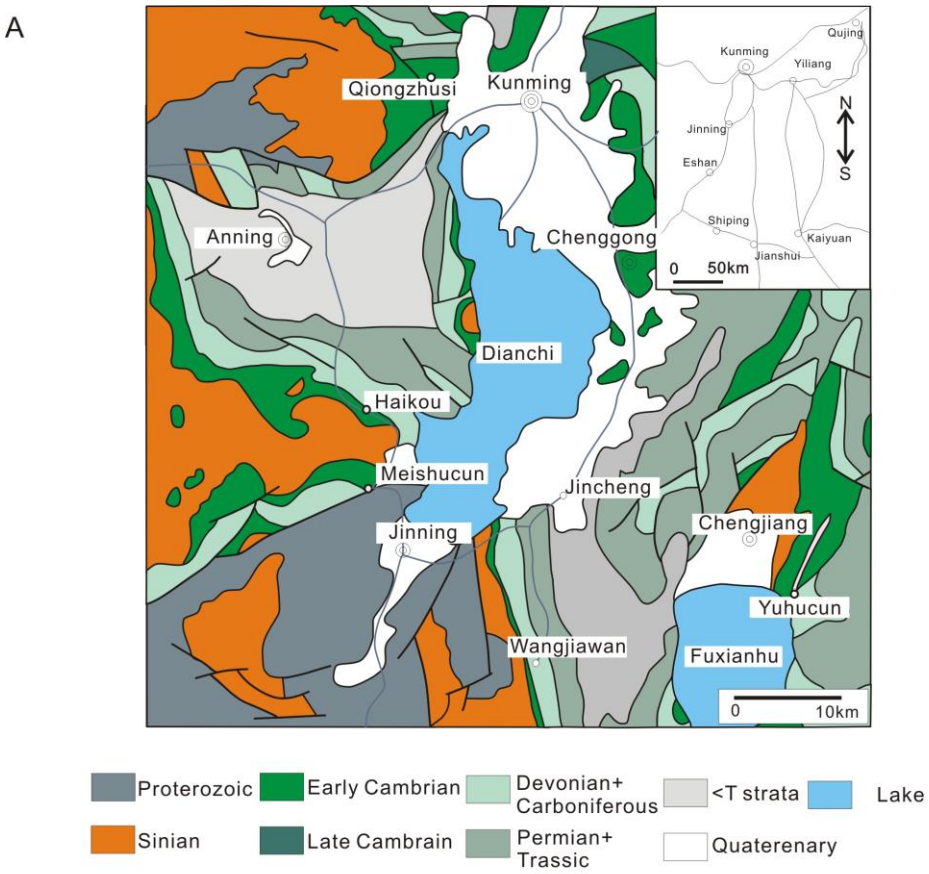
Section 1. Supplementary Figures



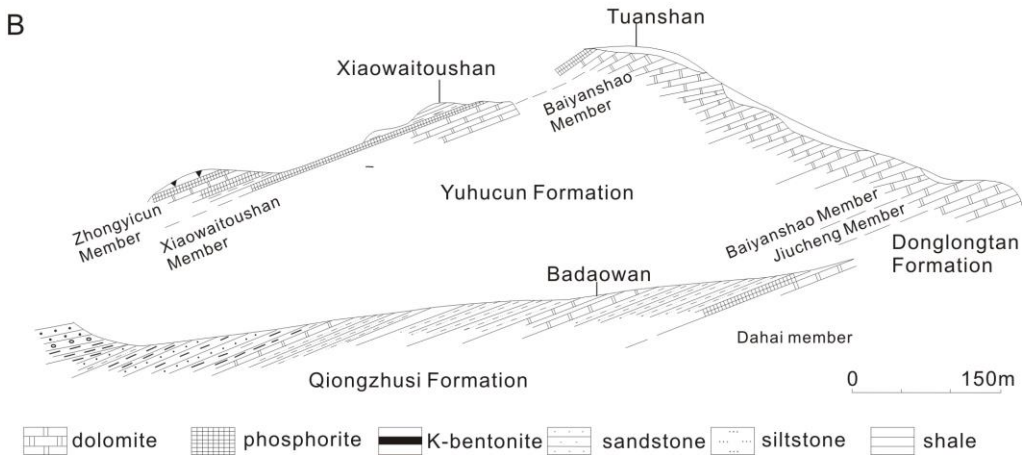


Figure A1 A simplified geological map of the Kunming region, Yunnan province, showing the location of phosphorite in Meishucun (a) and the Meishucun cross sections (b), southwest Kunming (midified from Pašava et al. (2010)).

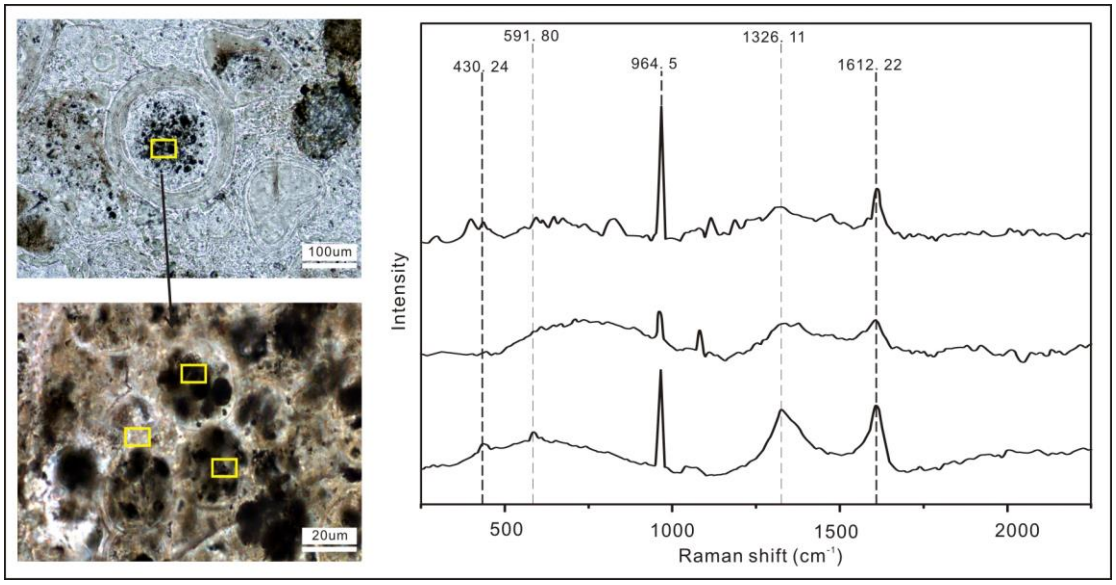


Figure A2 Representative Raman images and spectra.

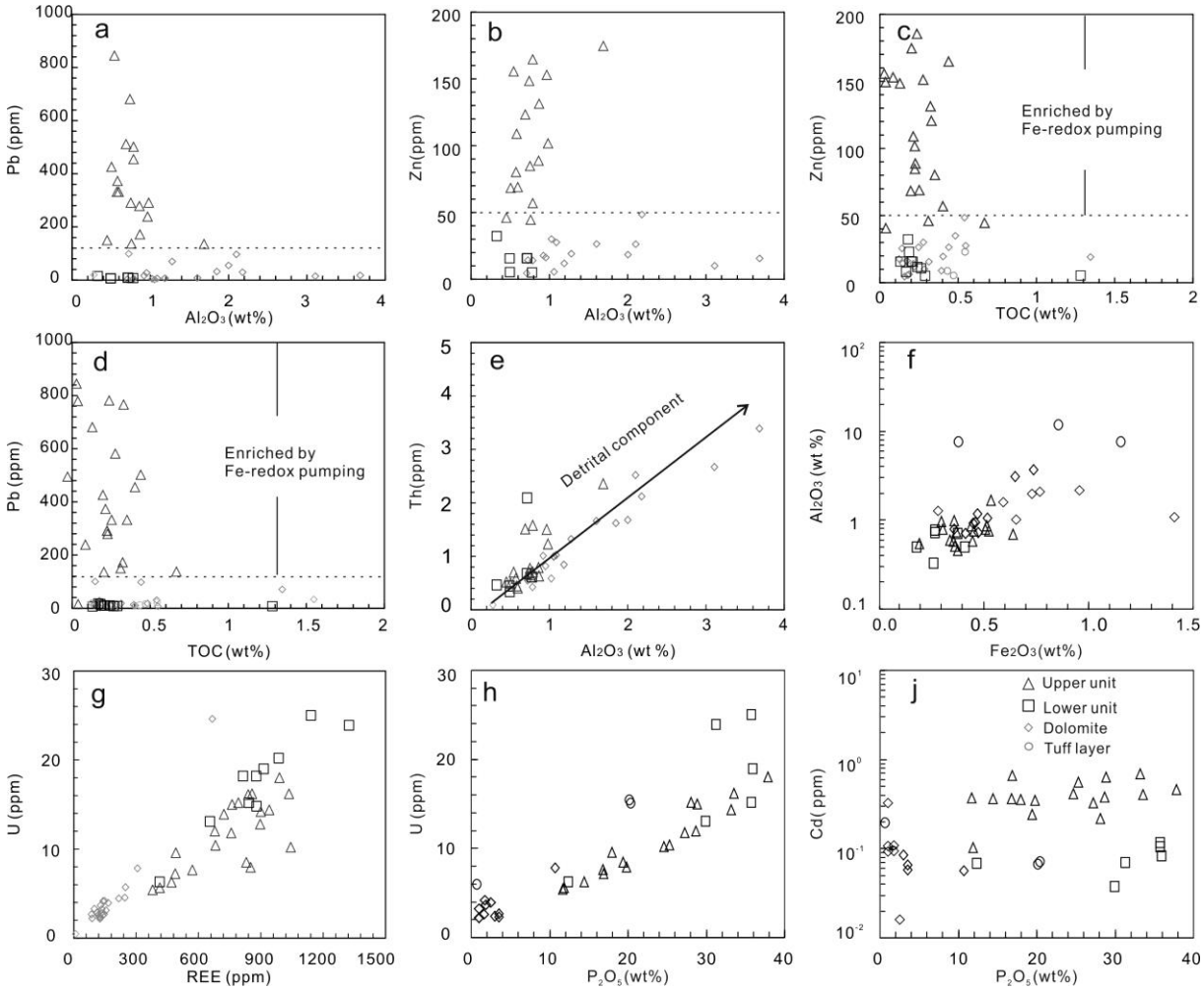


Figure A3 Multi-elements diagrams comparing the composition of the dolostones from the Baiyanshao and Xiaowaitoushan Members, phosphorites from the lower and upper units and tuff layer of the Zhongyicun Member

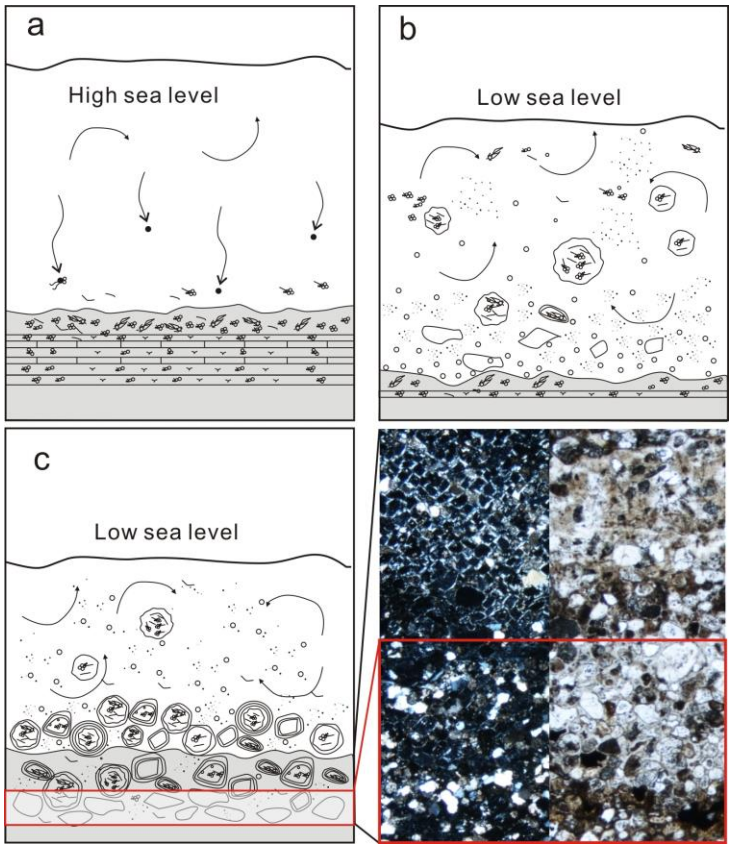


Figure A4 Reworking process of the lower unit of phosphorites in Meishucun: (a) In-situ growth of phosphorus layers under a high sea level, (b) phosphorite crashed by high energy water and mixing with terrigenous clasts in the intertidal zone, (c) density differentiation, (d) petrographic image.

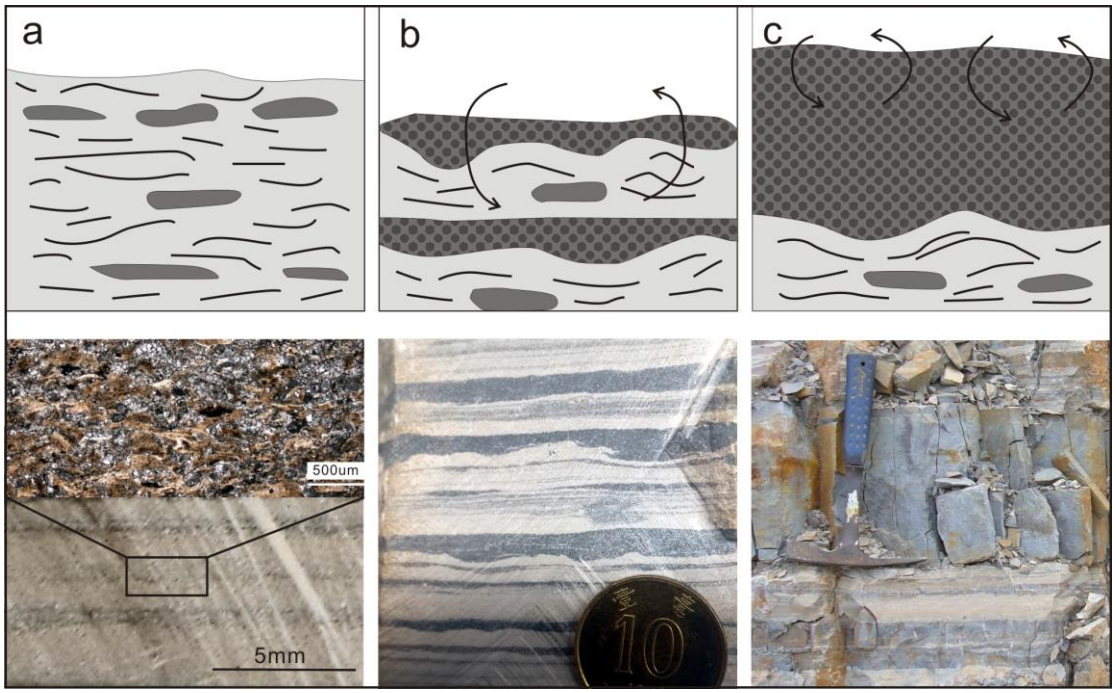


Figure A5 Reworking process of the upper unit of phosphorite in Meishucun: (a) laminated layer, (b) ripple mark, (c) massive layer modified from Soudry et al. (2013)

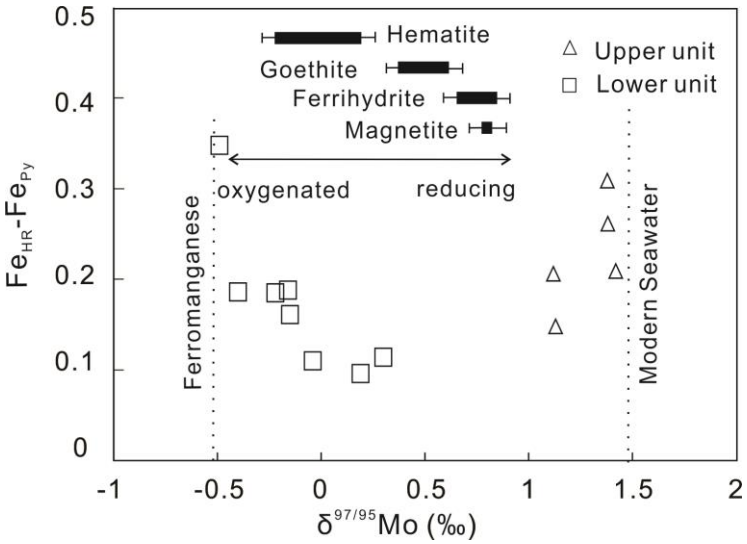


Fig. A6 Fe_{HR} – Fe_{Py} vs. $\delta^{97/95}$Mo diagrams (data from Wen et al., 2011). Ferromanganese from oxic sink of Pacific and Atlantic nodules (Barling et al., 2001) and modern seawater cited from (Siebert et al., 2003), Hematite, Goethite, Ferrihydrite and magnetite form Goldberg et al. (2009). Fe_{HR} = Fe in highly reactive mineral species, Fe_{Py} = Fe in pyrite

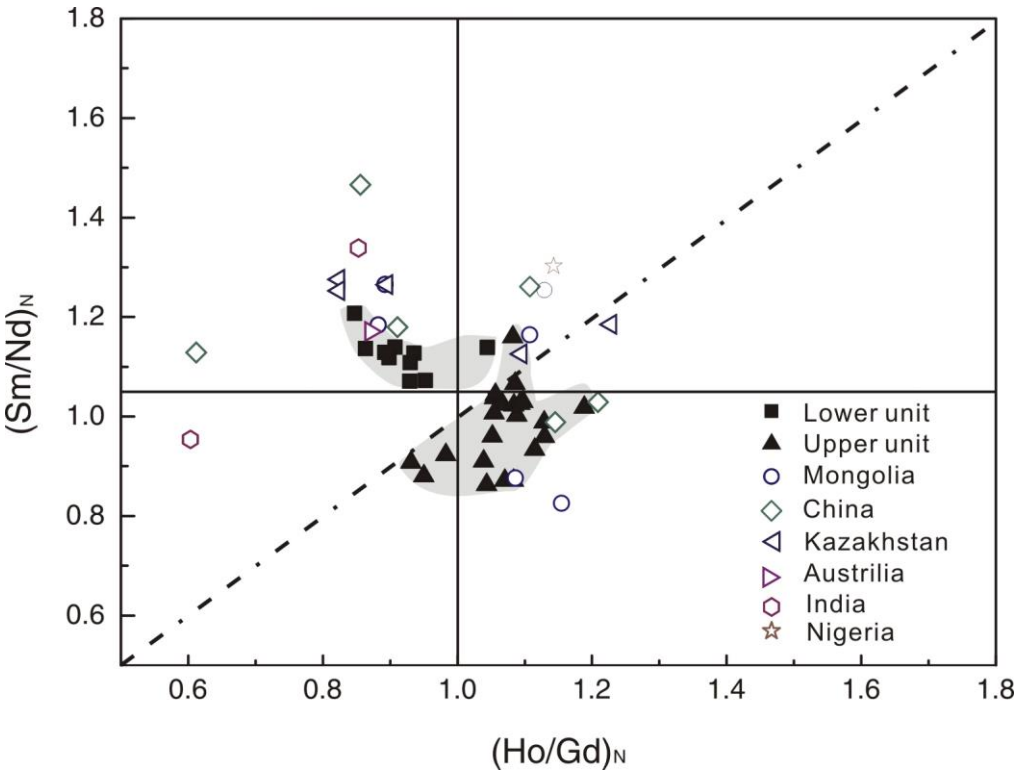


Figure A7 Variation of NASC shale-normalized Sm/Nd and Ho/Gd of the early Cambrian phosphorite from different basins (referenced data from Ilyin (1998))

References

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Wen, H. J., Carignan, J., Zhang, Y. X., Fan, H. F., Cloquet, C., and Liu, S. R., 2011, Molybdenum isotopic records across the Precambrian-Cambrian boundary: Geology, v. 39, no. 8, p. 775-778.

Section 2. Analytical methods

Petrographic Observations

Petrographic data were collected with both optical microscope and electron microscopes. Larger scale (tens of micrometers to a few millimeters) was were performed on polished thin sections with an Olympus BX51 petrographic microscope, while delicate textures and mineralogical structures at micro- and even nanoscales was performed on both thin sections and freshly broken chips of samples, using electron microscopes at Queen Mary Hospital. Freshly broken chips of samples were cleaned, rinsed with DI water, and dried in air. The electron microscopes used in this study include a Hitachi S-4800 FEG and a Hitachi S-3400N variable pressure scanning electron microscope (SEM) equipped with Energy dispersive X-ray spectroscopy (EDS) detectors. EDS was operated at 5 kV and 20 kV and was applied to determine mineral chemical compositions (c.f. Sun et al., 2015). Organic matters were observed and analyzed using a Thermo Scientific DXR dispersive Raman micro-spectrometer at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan). The Olympus M plan-BD 100X objective was used. The laser beam with an output power of 24mW irradiated the sample with a maximum power of 10mW and an estimated spot size of 1μm (c.f. Xiong et al., 2011).

Major and Trace Element Analyses

All samples were cut into ~2 cm^3 pieces, ultrasonically cleaned with distilled water and dried at 50 °C in oven before powdering in a stainless steel puck mill. Major element oxides were determined using X-ray fluorescence (XRF) on fused glass beads at the University of Hong Kong. Trace elements, including REE, were analyzed on a VG PQ Excell ICP-MS at

Institute of Geochemistry, Chinese Academy of Sciences (CAS), Guiyang, China. Samples were digested with a mixture of HF and HNO_3 in closed beakers in high-pressure bombs heated at 190°C for 2 days to ensure complete digestion (Qi et al. 2000). We used pure elemental standards for external calibration and BHVO-1 (basalt) and SY-4 (syenite) as reference materials. Accuracies of the XRF analyses are estimated to be better than 1% for SiO_2, 2% for other major oxides present in concentration greater than 0.5 % and 5% for trace elements. The ICP-MS analyses have accuracies better than 5%.

Total Organic Carbon Content Analysis

The total organic carbon content was measured using a Multi EA 4000 carbon/sulfur analyzer with a high temperature furnace and acidification module (Eltra, Germany). Firstly, inorganic carbon was removed by adding 4 mol/L HCl into about 2g powder. Then, ~100 mg of the solid residue was weighed into a ceramic boat and combusted in pure (99.95%) O_2 at 1350 °C for ~3 mins to measure TOC. Analytical errors are ± 0.1 wt%, based on analysis of carbonate standard, AR4007 (Alpha, USA).

Whole Rock Inorganic C-O Isotope Analyses

Carbon and oxygen isotope compositions ($\delta\ ^{13}C_{carb}$ and $\delta\ ^{18}O_{carb}$) of whole rock carbonates were determined using a Thermo Fisher Scientific carbonate-preparation device and Gas Bench II connected to a Delta Plus XL isotope ratio mass spectrometer (IRMS) that was operated in the continuous He flow mode, at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan). The CO_2 was extracted from carbonates with 100% phosphoric acid at 70 °C for calcite and 90 °C for dolomite. The stable C and O isotope ratios are reported in the delta (δ) notation as the per

mil (‰) deviation relative to the Vienna Pee Dee belemnite (VPDB) standard. The analytical reproducibility estimated from replicate analyses of the laboratory standards Carrara marble and Binn dolomite was better than ±0.05‰ for $\delta^{13}C_{carb}$ and ±0.1‰ for $\delta^{18}O_{carb}$.

Whole Rock Organic C Isotope Analysis

About 7 gram of sample powder was decarbonated with 6 M HCl until reactions ceased. The residue was rinsed with deionized water until neutral pH was achieved, then centrifuged and freeze-dried for 24 h. The tubes were evacuated, sealed and combusted at 850° for 4h. The $\delta^{13}C_{org}$ value was analyzed using a MAT 253 isotope-ratio mass spectrometer (IR-MS) at the State Key Laboratory of Geological Processes and Mineral Resources in China University of Geosciences (Wuhan). C-isotope results are reported relative to the Vienna Pee Dee belemnite (V-PDB) standard with a precision better than ± 0.1‰ based on duplicate analyses of national standards GBW04407 ($\delta^{13}C = -22.4$‰) and GBW04408 ($\delta^{13}C = -36.9$‰).

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Section3 . Supplementary Tables

Table C1. C-O isotopic and Geochemical data of rocks from Meishucn section, South China.

Member	Baiyan shao											Xiaowai toushan
Unit												
Analysis	B4-1	B4-2	B3-1	B3-2	B3-3	B2-1	B2-2	B2-P	B1-1	B1-2	B1-3	X1-1
C-O isotopes (‰, VPDB)												
δ^{13}Ccarb	-2.07	-2.45	-2.23	-2.10	-1.96	-2.05	-2.08	-2.22	-2.00	-2.13	-2.59	-2.22
δ^{18}Ocarb	-10.7	-10.7	-9.76	-9.77	-9.95	-9.98	-9.87	-9.84	-9.77	-9.03	-7.67	-7.65
δ^{13}Corg	-31.21	-32.05	-31.07	-30.4	-29.39	-28.66	-29.83	-26.68	-28.94	-28.99	-28.24	-28.94
Major elements (wt %)												
SiO_2	12.4			19.0		18.9	18.0	78.0	12.1	11.5		20.3
TiO_2	0.06			0.13		0.13	0.13	0.07	0.07	0.10		0.20
Al_2O_3	1.09			2.18		2.10	2.00	1.28	1.03	1.60		3.68
Fe_2O_3	1.41			0.96		0.76	0.73	0.28	0.65	0.59		0.74
MnO	0.12			0.10		0.14	0.14	0.02	0.12	0.09		0.06
MgO	17.5			16.2		15.9	15.1	2.64	18.0	17.4		13.8
CaO	26.8			24.0		25.1	23.9	7.71	27.1	27.6		25.8
Na_2O	0.00			0.07		0.03	0.03	0.03	0.00	0.01		0.06
K_2O	0.14			0.46		0.48	0.45	0.30	0.17	0.27		0.96
P_2O_5	0.95			1.01		1.75	1.67	2.50	1.04	1.82		3.73
LOI	39.5			35.5		34.7	36.8	6.0	39.7	38.7		30.2
TOC	0.5			0.5		0.4	3.6	1.3	0.3	0.2		0.3
Total	100.6			100.2		100.4	102.6	100.2	100.3	99.9		99.8
Trace elements(ppm)												
V	13.6	12.6	13.9	23.5	12.5	30.2	16.9	11.4	13.7	16.9	11.3	30.6
Cr	21.4	10.9	14.4	22.9	16.1	17.6	16.5	13.6	14.4	14.8	9.1	25.5
Zn	27.5	34.8	8.88	48.4	19.4	26.3	18.4	19.1	30.0	26.4	25.5	15.6
Pb	7.12	18.1	12.5	30.4	9.44	97.4	55.4	70.4	5.43	8.92	15.0	18.0
Mo	1.48	1.45	1.34	1.06	1.04	0.53	0.31	0.38	0.35	0.46	1.09	0.61
Cd	0.11	0.13	0.10	0.33	0.08	0.10	0.10	0.02	0.10	0.11	0.85	0.09
Zr	18.8	12.5	23.9	37.0	23.7	48.4	37.0	24.4	27.3	34.8	10.7	62.7
Sr	52	74	55	53	49	66	57	59	56	74	71	108
Y	9.84	14.1	8.57	11.8	8.76	14.3	11.3	15.5	7.57	11.0	15.8	20.8
Ba	43.7	64.0	39.2	71.9	41.2	72.4	56.0	91.1	45.3	58.8	32.6	121.6
Th	1.02	0.68	1.14	2.12	1.26	2.52	1.68	1.32	0.58	1.66	1.01	3.39
U	2.16	2.50	3.27	3.23	2.65	4.17	2.59	3.94	2.20	3.66	2.76	5.70
La	9.00	9.95	7.11	9.65	6.12	10.6	8.46	11.9	6.36	9.23	9.47	17.8
Ce	13.2	12.9	11.3	17.5	10.6	19.6	14.7	17.4	11.0	15.8	13.5	29.7
Pr	1.29	1.46	1.24	1.71	1.08	2.16	1.55	2.10	1.19	1.64	1.62	3.16
Nd	4.57	5.53	4.28	6.59	4.31	8.70	5.89	8.40	4.68	6.30	7.10	11.1
Sm	0.87	1.04	0.84	1.20	0.76	1.55	1.10	1.53	0.88	1.15	1.44	2.07
Eu	0.17	0.21	0.18	0.21	0.15	0.30	0.21	0.30	0.17	0.20	0.27	0.39
Gd	1.01	1.22	0.96	1.36	0.93	1.73	1.11	1.70	0.83	1.14	1.60	2.30
Tb	0.14	0.17	0.14	0.19	0.12	0.26	0.17	0.22	0.14	0.18	0.21	0.32
Dy	0.80	0.99	0.74	1.16	0.78	1.33	1.04	1.32	0.77	1.05	1.19	1.84
Ho	0.18	0.21	0.16	0.23	0.15	0.27	0.22	0.24	0.16	0.20	0.27	0.36
Er	0.48	0.61	0.47	0.66	0.47	0.81	0.60	0.64	0.45	0.58	0.71	1.09
Tm	0.06	0.08	0.05	0.09	0.07	0.11	0.09	0.07	0.05	0.09	0.08	0.15
Yb	0.40	0.41	0.34	0.50	0.35	0.55	0.49	0.42	0.36	0.47	0.45	0.85
Lu	0.05	0.06	0.05	0.08	0.05	0.08	0.07	0.06	0.05	0.07	0.05	0.11

Table C1. Continued

	Xiaowai toushan									Zhongyicun		
										Lower unit		
Sample	X1-2	X1-3	X1-4	X1-5	X2-1	X2-2	X2-3	X2-4	X2-P	Z3-1	Z3-2	Z3-3
C-O isotopes (‰, VPDB)												
δ^{13}Ccarb	-2.18	-2.44	-2.58	-2.43	-2.13	-2.18	-2.01	-2.05	-3.32	-2.94		-2.43
δ^{18}Ocarb	-7.63	-7.92	-8.17	-7.94	-7.87	-7.74	-7.89	-8.20	-9.11	-8.38		-8.77
δ^{13}Corg	-29.08	-30.44	-29.7	-30.69	-26.22	-23.67	-27.15	-28.81	-33.65	-31.94	-25.93	-31.21
Major elements (wt %)												
SiO_2	18.5	6.13	9.40	6.22	6.47	7.11	6.19	4.31		9.95	5.66	
TiO_2	0.12	0.03	0.05	0.03	0.04	0.03	0.02	0.03		0.04	0.08	
Al_2O_3	3.11	0.79	1.06	0.71	0.95	0.92	0.73	1.19		0.78	0.33	
Fe_2O_3	0.65	0.36	0.51	0.41	0.46	0.45	0.47	0.47		0.27	0.26	
MnO	0.06	0.07	0.09	0.09	0.09	0.11	0.13	0.11		0.02	0.00	
MgO	15.5	18.4	21.3	18.7	19.0	18.7	19.0	15.4		3.98	1.83	
CaO	24.5	29.8	31.4	29.9	29.3	29.4	29.5	34.5		44.3	49.6	
Na_2O	0.10	0.07	0.12	0.07	0.00	0.00	0.00	0.00		0.22	0.31	
K_2O	0.74	0.11	0.23	0.12	0.15	0.15	0.09	0.07		0.12	0.06	
P_2O_5	3.37	4.25	2.79	3.99	3.00	3.58	3.56	10.7		29.9	35.7	
LOI	32.5	38.8	32.2	39.1	39.9	38.8	39.6	32.3		9.51	5.60	
TOC	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.2		0.3	0.2	
Total	99.4	99.1	99.2	99.5	99.5	99.4	99.4	99.4		99.4	99.6	
Trace elements(ppm)												
V	25.0	7.90	10.8	9.15	8.72	8.81	7.74	63.3	42.3	18.0	11.1	11.0
Cr	30.4	20.0	11.1	16.4	13.6	12.5	14.7	37.4	44.6	14.2	11.8	7.22
Zn	10.1	14.0	5.54	4.46	16.3	17.6	14.2	11.9	6.08	5.06	32.2	8.07
Pb	15.4	5.43	2.47	3.60	28.0	17.3	99.6	7.53	11.0	7.64	15.4	10.4
Mo	0.78	0.33	0.45	0.54	0.43	0.58	0.55	0.64	1.10	1.15	0.98	0.95
Cd	0.06	0.07	0.03	0.11	0.08	0.06	0.07	0.06	0.04	0.04	0.11	0.06
Zr	44.7	9.39	33.8	12.9	10.3	11.5	6.49	14.8	11.1	15.5	9.6	10.9
Sr	100	94	70	89	63	77	76	241	604	615	791	605
Y	19	20	14	18	15	19	18	42	93	89	149	104
Ba	98	106	32	26	32	34	24	67	139	219	244	170
Th	2.67	0.42	1.00	0.60	0.81	1.01	0.55	0.84	0.85	0.61	0.47	0.52
U	4.44	3.10	2.86	4.14	2.41	2.68	2.31	7.83	24.6	13.1	25.0	18.2
La	15.5	11.1	8.02	10.1	8.72	10.5	9.11	21.9	47.6	46.8	81.5	58.2
Ce	25.3	15.0	11.2	12.4	12.1	14.6	11.3	19.8	36.7	34.4	58.0	54.2
Pr	2.62	2.04	1.35	1.57	1.36	1.74	1.43	3.17	6.59	6.33	13.7	9.94
Nd	9.79	8.50	4.80	6.46	5.79	6.75	5.97	12.7	27.6	29.1	61.1	45.5
Sm	1.88	1.51	1.00	1.24	1.12	1.34	1.09	2.33	4.69	5.11	11.40	8.99
Eu	0.37	0.30	0.20	0.22	0.22	0.31	0.24	0.48	1.09	1.18	2.58	1.85
Gd	2.03	1.79	1.15	1.49	1.29	1.76	1.42	2.96	6.75	6.77	15.2	11.0
Tb	0.27	0.24	0.17	0.21	0.18	0.23	0.21	0.39	0.83	0.95	2.07	1.47
Dy	1.69	1.42	0.98	1.17	1.07	1.36	1.21	2.36	5.24	6.16	13.4	9.03
Ho	0.35	0.29	0.21	0.25	0.22	0.27	0.25	0.52	1.23	1.37	2.93	1.98
Er	0.92	0.75	0.58	0.66	0.63	0.71	0.68	1.42	3.45	3.87	7.66	5.00
Tm	0.13	0.08	0.08	0.07	0.08	0.09	0.08	0.17	0.37	0.43	0.83	0.56
Yb	0.72	0.41	0.42	0.39	0.36	0.45	0.39	0.72	1.65	1.92	3.76	2.28
Lu	0.09	0.05	0.07	0.05	0.05	0.05	0.05	0.09	0.20	0.24	0.42	0.27

Table C1. Continued

Zhongyicun

	Lower unit							Tuff			Upper unit	
Sample	Z3-4	Z3-5	Z3-6	Z4-1	Z4-2	Z4-3	Z4-4	Z5-1	Z5-2	Z5-3	Z6-1	Z6-2
C-O isotopes (‰, VPDB)												
δ^{13}Ccarb	-2.70	-2.69			-3.87						-0.30	-0.29
δ^{18}Ocarb	-9.11	-8.99			-9.81						-5.96	-5.54
δ^{13}Corg	-31.44		-28.29	-30.96	-30.67	-30.62	-31.31	-28.99	-28.68		-30.9	-31.04
Major elements (wt %)												
SiO_2	8.97		7.82			3.14	66.4	36.5	36.3	72.2	4.30	4.56
TiO_2	0.08		0.10			0.08	0.04	0.05	0.07	0.10	0.02	0.08
Al_2O_3	0.72		0.71			0.49	0.50	7.63	7.56	11.90	0.45	0.60
Fe_2O_3	0.26		0.37			0.18	0.41	0.38	1.15	0.86	0.37	0.34
MnO	0.02		0.00			0.04	0.01	0.00	0.00	0.01	0.09	0.07
MgO	3.42		1.12			2.38	0.31	0.78	0.76	2.13	13.6	10.6
CaO	44.9		48.8			50.1	17.3	27.4	26.9	2.43	37.2	40.0
Na_2O	0.28		0.35			0.41	0.21	0.28	0.28	0.06	0.09	0.14
K_2O	0.10		0.08			0.05	0.06	3.35	3.35	5.16	0.06	0.06
P_2O_5	31.3		35.9			35.7	12.3	20.4	20.2	0.67	14.4	19.8
LOI	8.70		3.57			6.83	1.87	2.42	2.49	4.14	28.5	22.6
TOC	0.2		0.2			0.1	1.3	0.4	0.5	0.5	0.3	0.3
Total	98.9		99.1			99.6	100.7	99.6	99.4	100.2	99.5	99.1
Trace elements(ppm)												
V	12.7	15.6	13.6	7.56	8.05	6.21	3.26	7.29	7.07	4.25	23.0	23.1
Cr	19.0	10.9	11.6	8.50	19.8	8.80	8.01	9.49	9.45	10.6	23.8	30.8
Zn	15.8	11.7	15.7	22.9	10.7	15.7	5.3	8.7	5.3	22.9	46.1	68.9
Pb	9.0	17.4	9.6	7.5	9.7	6.4	7.2	11.2	15.6	22.2	150	332
Mo	1.21	1.53	2.38	1.59	1.83	2.24	3.25	1.06	2.30	3.83	0.53	0.39
Cd	0.07	0.09	0.08	0.08	0.08	0.12	0.07	0.07	0.07	0.20	0.36	0.35
Zr	10.4	25.4	29.7	11.8	9.89	8.69	7.06	76.9	77.6	126.0	7.72	7.02
Sr	692	658	713	865	874	863	407	692	710	41	247	371
Y	166	116	129	140	111	107	50	116	117	39	88	149
Ba	182	174	236	265	280	253	232	322	332	238	75	125
Th	2.09	0.87	0.68	0.33	0.53	0.44	0.34	14.2	15.2	24.7	0.52	0.41
U	23.9	18.2	19.0	20.2	14.8	15.2	6.30	15.1	15.5	5.98	6.26	7.94
La	94.6	62.7	65.3	70.4	62.8	60.2	29.5	72.0	72.6	19.9	33.6	60.8
Ce	70.5	53.3	43.6	43.2	55.1	58.2	35.1	121.0	122.0	43.7	18.3	30.8
Pr	15.7	10.1	9.81	9.29	8.51	8.79	4.71	16.60	17.30	4.66	4.40	7.65
Nd	73.2	46.4	45.3	42.8	38.4	34.4	19.0	67.2	70.0	17.4	19.5	35.7
Sm	13.40	8.63	8.36	7.98	6.73	6.24	3.51	13.90	14.50	3.63	3.27	5.61
Eu	3.26	1.97	1.94	1.89	1.53	1.28	0.59	1.27	1.34	0.19	0.84	1.39
Gd	17.3	11.5	11.3	10.9	9.52	8.81	4.19	15.15	16.03	3.83	5.12	8.83
Tb	2.35	1.52	1.57	1.54	1.27	1.14	0.60	2.28	2.38	0.67	0.70	1.20
Dy	14.80	9.41	10.0	10.1	8.14	7.72	3.78	13.90	14.80	5.20	4.92	8.28
Ho	3.31	2.11	2.25	2.43	1.88	1.74	0.80	2.85	2.99	1.26	1.16	2.12
Er	8.88	5.47	5.96	6.37	4.98	4.49	2.04	7.26	7.87	4.20	3.29	5.74
Tm	0.97	0.61	0.66	0.74	0.54	0.53	0.25	0.90	0.97	0.68	0.40	0.68
Yb	4.28	2.66	2.82	3.32	2.69	2.49	1.12	5.00	5.15	4.47	1.98	2.98
Lu	0.48	0.31	0.34	0.39	0.31	0.30	0.14	0.66	0.66	0.64	0.25	0.39

Table C1. Continued

	Zhongyicun												
	Upper unit												
Sample	Z6-3	Z6-4	Z6-5	Z6-6	Z6-7	Z6-8	Z6-9	Z6-10	Z6-11	Z6-12	Z6-13	Z6-14	Z6-15
C-O isotopes (‰, VPDB)													
δ^{13}Ccarb	-0.69	0.24	0.12	-3.33	-2.87		-3.47	-3.32	-0.59	-0.13	-0.02	-0.28	
δ^{18}Ocarb	-5.32	-5.86	-5.93	-7.79	-7.20		-7.79	-7.18	-5.60	-5.91	-7.46	-6.11	
δ^{13}Corg	-30.45	-30.63	-29.16	-32.5	-31.88	-31.64	-32.58	-32.22	-30.92	-31.23	-30.27	-30.54	-32.69
Major elements (wt %)													
SiO_2	4.42	9.09	9.49	6.85		3.03	4.77		4.47	3.41	9.16	5.87	
TiO_2	0.07	0.04	0.05	0.04		0.10	0.06		0.05	0.06	0.04	0.03	
Al_2O_3	0.58	0.75	0.86	0.74		0.54	0.97		0.98	0.51	0.76	0.58	
Fe_2O_3	0.35	0.45	0.51	0.36		0.19	0.30		0.36	0.36	0.52	0.44	
MnO	0.05	0.07	0.10	0.04		0.03	0.05		0.04	0.04	0.08	0.07	
MgO	8.0	11.1	13.7	3.03		1.39	3.04		6.56	11.3	13.5	11.9	
CaO	43.1	37.0	33.2	47.1		51.4	48.0		45.0	40.2	33.7	38.0	
Na_2O	0.15	0.14	0.13	0.35		0.33	0.27		0.17	0.18	0.17	0.14	
K_2O	0.04	0.14	0.16	0.10		0.09	0.17		0.15	0.06	0.12	0.07	
P_2O_5	24.6	16.8	11.7	33.2		37.9	33.6		27.2	19.4	11.9	16.9	
LOI	17.6	23.7	29.1	7.65		4.56	7.79		14.7	23.7	29.0	25.2	
TOC	0.2	0.2	0.2	0.1		0.0	0.1		0.2	0.2	0.7	0.4	
Total	99.1	99.5	99.2	99.6		99.5	99.1		99.9	99.4	99.7	99.6	
Trace elements(ppm)													
V	23.2	21.7	21.1	34.3	36.1	37.7	34.3	33.8	49.0	22.9	18.8	22.1	37.6
Cr	34.6	28.0	22.7	52.9	55.4	62.1	55.1	43.0	43.4	28.1	20.5	28.5	60.1
Zn	109	85	89	149	185	156	153	151	102	68	44	80	149
Pb	373	291	279	681	781	845	239	581	291	426	137	332	779
Mo	0.70	0.46	0.40	0.66	0.54	0.91	0.47	0.37	0.30	0.33	0.30	0.35	0.73
Cd	0.41	0.36	0.38	0.68	0.66	0.46	0.40	0.43	0.33	0.24	0.10	0.67	0.65
Zr	10.4	19.0	15.3	15.7	18.1	13.0	42.6	37.0	13.9	7.4	25.7	11.8	27.1
Sr	432	344	247	795	734	878	776	672	462	355	258	293	866
Y	171	97	68	108	102	118	113	97	136	141	74	93	122
Ba	154	127	90	301	282	319	314	273	158	112	96	80	296
Th	0.45	0.77	0.79	0.69	0.73	0.70	1.50	1.18	1.23	0.50	0.65	0.59	0.84
U	10.2	7.64	5.40	14.4	12.8	18.0	16.2	13.9	11.8	8.51	5.64	7.22	16.2
La	74.6	40.8	27.1	67.2	64.1	70.7	61.3	51.6	54.1	59.3	29.6	34.9	74.0
Ce	40.9	34.6	23.5	52.4	50.4	51.7	39.9	33.1	37.5	34.9	27.3	22.9	66.8
Pr	10.10	6.43	4.34	7.34	6.59	7.72	6.68	5.48	7.74	8.11	4.88	4.95	9.61
Nd	43.5	26.2	18.2	28.3	25.3	30.5	27.7	22.0	33.5	35.6	20.7	22.0	38.0
Sm	7.14	4.45	3.00	4.00	3.77	4.35	4.64	3.56	6.36	5.98	3.54	3.71	5.48
Eu	1.63	1.01	0.67	0.91	0.84	1.00	0.99	0.83	1.44	1.36	0.81	0.88	1.13
Gd	10.8	6.24	4.25	6.04	5.84	6.81	6.60	5.04	9.26	9.00	4.81	5.87	8.08
Tb	1.48	0.91	0.61	0.82	0.76	0.95	0.92	0.73	1.31	1.27	0.72	0.84	1.04
Dy	10.1	5.78	4.05	5.45	5.03	6.23	6.16	4.91	9.21	8.20	4.49	5.70	6.89
Ho	2.49	1.40	0.95	1.34	1.29	1.55	1.52	1.21	2.13	2.09	1.08	1.37	1.63
Er	7.06	3.91	2.73	4.01	3.72	4.55	4.52	3.62	6.35	5.72	3.08	3.93	4.62
Tm	0.80	0.47	0.32	0.47	0.42	0.55	0.55	0.44	0.83	0.67	0.37	0.47	0.53
Yb	3.66	2.36	1.61	2.22	2.03	2.54	2.59	2.25	4.25	3.11	1.89	2.38	2.47
Lu	0.43	0.29	0.22	0.27	0.26	0.31	0.35	0.28	0.61	0.38	0.23	0.30	0.31

Table C1. Continued

	Zhongyicun							Dahai	
	Upper unit								
Sample	Z6-16	Z6-17	Z6-18	Z6-19	Z6-20	Z7-1	Z7-2	D8-1	D8-2
C-O isotopes (‰, VPDB)									
δ^{13}Ccarb		-2.35	-3.02		-2.16	-1.07	-2.49	0.63	-0.31
δ^{18}Ocarb		-7.24	-7.71		-6.01	-7.05	-6.48	-7.04	-8.41
δ^{13}Corg	-31.88	-32.52	-32.4	-32.45	-31.96	-31.31	-31.94	-32.45	-30.14
Major elements (wt %)									
SiO_2		13.1	15.9		9.61	4.42	4.28	2.41	18.2
TiO_2		0.04	0.03		0.10	0.09	0.04	0.01	0.09
Al_2O_3		0.79	0.87		1.69	0.69	0.79	0.28	1.85
Fe_2O_3		0.50	0.44		0.53	0.64	0.30	0.58	0.72
MnO		0.04	0.04		0.04	0.08	0.05	0.17	0.08
MgO		5.55	3.22		3.99	11.2	6.1	20.4	13.4
CaO		40.6	41.3		43.5	38.9	45.5	29.5	27.7
Na_2O		0.28	0.44		0.65	0.15	0.18	0.07	0.12
K_2O		0.14	0.11		0.52	0.10	0.13	0.00	0.56
P_2O_5		25.3	28.6		28.8	18.0	28.1	0.39	7.85
LOI		12.8	8.0		10.0	24.6	14.0	45.9	28.3
TOC	0.3	0.4	0.3	0.0	0.2	0.0	0.4	0.1	0.0
Total	0.3	99.6	99.3	0.0	99.8	98.8	99.8	99.8	98.9
Trace elements(ppm)									
V	28.2	38.1	26.4	32.1	55.0	29.1	46.7	5.80	29.4
Cr	46.9	43.7	45.6	38.7	57.1	30.0	48.6	8.05	20.1
Zn	121	165	131	41	175	123	57	134	141
Pb	766	502	172	15	136	512	455	19.8	32.6
Mo	0.67	0.85	0.69	0.73	0.69	0.55	0.55	0.92	0.51
Cd	0.53	0.56	0.38	0.15	0.64	0.36	0.22	0.40	0.80
Zr	14.1	12.5	11.3	19.6	39.8	17.3	25.0	1.02	40.7
Sr	737	596	676	895	765	454	452	33	166
Y	112	83	89	101	99	75	135	2	42
Ba	269	211	276	311	288	181	162	10	121
Th	0.60	0.71	0.63	0.70	2.36	1.51	1.58	0.09	1.62
U	14.2	10.4	12.0	16.1	15.0	9.58	15.20	0.45	4.53
La	64.3	48.7	48.5	60.0	54.4	35.1	56.6	0.67	17.6
Ce	57.7	47.4	34.3	38.8	35.3	31.2	41.7	1.21	23.8
Pr	8.55	6.57	5.34	5.80	5.45	5.01	8.78	0.16	3.20
Nd	34.0	25.3	21.2	23.2	22.2	22.0	38.9	0.84	13.2
Sm	5.14	3.76	3.24	3.31	3.70	3.46	6.79	0.17	2.42
Eu	1.06	0.72	0.69	0.78	0.84	0.82	1.60	0.03	0.51
Gd	7.47	5.21	4.73	5.26	5.31	4.83	9.93	0.22	3.13
Tb	0.97	0.70	0.66	0.68	0.73	0.64	1.40	0.03	0.44
Dy	6.43	4.35	4.45	4.60	5.23	4.38	9.60	0.15	2.78
Ho	1.56	1.03	1.12	1.21	1.34	1.08	2.29	0.04	0.61
Er	4.52	2.93	3.24	3.53	4.06	2.99	6.55	0.09	1.85
Tm	0.54	0.33	0.38	0.42	0.51	0.36	0.81	0.01	0.25
Yb	2.38	1.68	1.83	1.95	2.70	1.72	4.37	0.09	1.49
Lu	0.30	0.20	0.23	0.25	0.36	0.22	0.57	0.01	0.20