SAMPLING

Shanmenhai section

The Shanmenhai section is situated at 24°24'51.90"N and 107°2'27.50"E northwest of Bama in the province Guangxi, South China. Sample SHA-I was taken in the Triassic Luolou Fm. ca. 12 m above the Permian-Triassic boundary (PTB) and indicates the base of a 5 m thick volcanogenic sandstone which is situated directly on top of the microbial limestone interval in Shanmenhai.

Nanem section

The Nanem section is exposed at 24°24'3.70"N and 107°19'29.20"E at a roadcut north of Bama in the province Guangxi, South China. The base of a ca. 40 cm thick volcanogenic sandstone (NAN-3) situated 8.8 m above the PTB on top of the microbial limestone interval in Nanem was sampled in the Triassic Luolou Fm.

Wuzhuan section

The Wuzhuan section outcrops at 24°21'44.6" N and 107°20'02.00" E at a roadcut north of Bama in the province Guangxi, South China. Two volcanogenic samples were taken, one in the Permian Heshan Fm. and one in the Triassic Luolou Fm. WUZ-4 is a 15 cm thick ash bed directly underlying the PTB. WUZ-7 represents a 10 cm thick volcanogenic sandstone and is situated 9.5 m above the PTB directly on top of the microbial limestone interval in Wuzhuan.

Tienbao section

The Tienbao section is located at 24°50'3.40"N and 106°29'20.90"E northwest of Leye in the province Guangxi, South China. The ash bed TIE-6 was sampled in the Permian Heshan Fm. and represents a 10 cm thick fine-grained ash bed which is situated directly below the PTB.

Penglaitan section

The Penglaitan section is exposed at 23°41'48.40"N and 109°18'21.00"E at the riverbank of the Hongshui River, east of Laibin in the province Guangxi, South China. Two volcanogenic samples were taken, one in the Permian Dalong Fm. and one in the Triassic Luolou Fm. PEN-28 represents the base of a 30 cm thick volcanogenic sandstone (PEN-28) directly underlying the PTB. In order of bracketing the PTB at Penglaitan, one 2 mm thin argillaceous ash bed (PEN-22) just 50 cm above the PTB was sampled, too.

Dongpan section

The Dongpan section is situated at 22°16'11.80"N and 107°41'31.30"E, north-east of Liuqiao in the province Guangxi, South China. Two volcanogenic samples were taken in the Triassic Luolou Fm. DGP-21 was sampled just 10 cm above the PTB and represents a 1 cm thick argillaceous ash bed just 10 cm above the PTB. DGP-18 is a thin-bedded volcanogenic sandstone 40 cm further above.

ANALYTICAL METHODS

Electron microprobe analysis of apatite

Electron microprobe (EMP) analyses of apatite were performed on a JEOL® Superprobe JXA-8200 at the Institute of Earth Sciences, University of Lausanne. Equipped with five wavelength- and one energy-dispersive spectrometer, it provides the simultaneous analysis of major (Ca, P, and F) and trace elements (Cl, S, Sr, Si, Mg, Fe, Y, La, Ce). For standardization and calibration, miscellaneous native and synthetic phosphate, silicate, sulphate and oxide phases were used (Tab. DR1). An acceleration voltage of 15 kV and a nominal probe current of 100 nA were used for standardization and analysis of all apatite samples. The spatial resolution of the electron microprobe was adjusted to 10 μm to reduce beam-induced halogen volatility. Raw data for apatite analyses were reduced with the ZAF matrix correction by

Armstrong (1984). Given that no substantial intra-grain variability was detected in the apatite samples by backscattered electron imaging and repeated grain profile measurements, one spot per apatite grain was routinely analyzed in the inner core domain. Detection limits for minor and trace elements are typically in the range of 10-50 ppm except for Sr with ~100 ppm (Tab. DR1). Limits of detection for major elements are ranging from ~60 ppm (Ca), over ~200 ppm (P), to ~400 ppm (F) (Tab. DR1). Analytical precision was assessed by repeated analyses of the natural Durango apatite (Cerro de Mercado, Durango, Mexico), typically in the range of ≤1% for Ca and P, and of ≤3% for F (Fig. DR1). Relative analytical precision for minor and trace elements was invariably below 10-15% except for Sr bearing evidence of chemical zoning in the Durango apatite. The resulting structural formula for each sample was typically within 1% of the expected stoichiometry for P and 1.5% for Ca (Durango apatite: 0.7% for P and 1% for Ca), giving confidence that the resulting atomic ratios were reliable. As several authors have documented strong dependency of fluorine X-ray count rates as a function of crystallographic orientation during EMP analysis of apatite (e.g., Stormer et al., 1993; Goldoff et al., 2012) special attention was drawn to the orientation of each individual apatite grain. Slightly elevated F concentrations of 3.73 ± 0.09 wt% of the Durango apatite (Tab. DR2) compared to previous studies (Young et al., 1969; Roeder et al., 1987; Streck and Dilles, 1998; Henderson, 2011) are related to the fact that the measurement protocol was optimized for accurate trace element determination, especially Fe and Mg, involving high-energy beam conditions. Additionally, the Durango apatite exhibits intracrystalline inhomogeneity by showing various degrees of zoning in Cl, Si, S, Y, and Ce (Boyce and Hodges, 2005; Henderson, 2011) plus compositional inhomogeneity between crystals (Streck and Dilles, 1998). A summary of all EMP analyses is provided in Table DR3 and a graphical description in terms of their F, Cl, FeO and MgO content in Figures DR2-DR4.

Armstrong, J.T., 1984, Quantitative analysis of silicate and oxide minerals: A reevaluation of ZAF corrections and proposal for new Bence-Albee coefficients, *in* Proceedings, 19th Annual Conference of the Microbeam Analysis Society, Bethlehem, Pennsylvania, July 1984, Microbeam analysis - 1984: San Francisco, San Francisco Press, p. 208-212.

Boyce, J.W., and Hodges, K.V., 2005, U and Th zoning in Cerro de Mercado (Durango, Mexico) fluorapatite: insights regarding the impact of recoil redistribution of radiogenic ^{4}He on (U-Th)/He thermochronology: Chem. Geol., v. 219, p. 261-274, doi:10.1016/j.chemgeo.2005.02.007.

Goldoff, B., Webster, J.D., and Harlov, D.E., 2012, Characterization of fluorchlorapatites by electron probe microanalysis with a focus on time-dependent intensity variation of halogens: Am. Mineral., v. 97, p. 1103-1115, doi:10.2138/am.2012.3812.

Henderson, C.E., 2011, Protocols and pitfalls of electron microprobe analysis of apatite [M.Sc. thesis]: Ann Arbor, University of Michigan, 33 p.

Roeder, P.L., MacArthur, D., Ma, X.P., Palmer, G.R., and Mariano, A.N., 1987, Cathodoluminescence and microprobe study of rare-earth elements in apatite: Am. Mineral., v. 72, p. 801-811.

Stormer, J.C. Jr., Pierson, M.L., and Tacker, R.C., 1993, Variation of F and Cl X-ray intensity due to anisotropic diffusion in apatite during electron microprobe analysis: Am. Mineral., v. 78, p. 641-648.

Streck, M.J., and Dilles, J.H., 1998, Sulfur evolution of oxidized arc magmas as recorded in apatite from a porphyry copper batholith: Geology, v. 26, p. 523-526, doi:10.1130/0091-7613.

Young, E.J., Myers, A.T., Munson, E.L, and Conklin, N.M., 1969, Mineralogy and geochemistry of fluorapatite from Cerro de Mercado, Durango, Mexico: USGS Professional Paper, v. 650-D, p. 84-93.

Table DR1. Element selection and measurement conditions for EMP analyses of apatite.

Apatite *15 kV, 100 nA, 10 µm*			*Measurement time [s]*		
Element	**Crystal**	**Reference Material**	**Peak**	**Background**	**Limit of Detection**
Si	TAP	Olivine	20	10	~50 ppm
Mg	TAP	Olivine	300	150	~10 ppm
Ca	PETJ	Apatite Durango	20	10	~60 ppm
P	PETJ	Apatite Durango	20	10	~200 ppm
Sr	PETJ	$SrSiO_3$ (synth.)	300	150	~100 ppm
F	LDE1	Topaz	3	1	~400 ppm
Cl	PETH	Scapolite	30	15	~20 ppm
S	PETH	Baryte	150	75	~30 ppm
Y	PETH	YPO_4 (synth.)	150	75	~50 ppm
Fe	LIFH	Fayalite	60	30	~40 ppm
La	LIFH	$LaPO_4$ (synth.)	150	75	~50 ppm
Ce	LIFH	$CePO_4$ (synth.)	150	75	~50 ppm

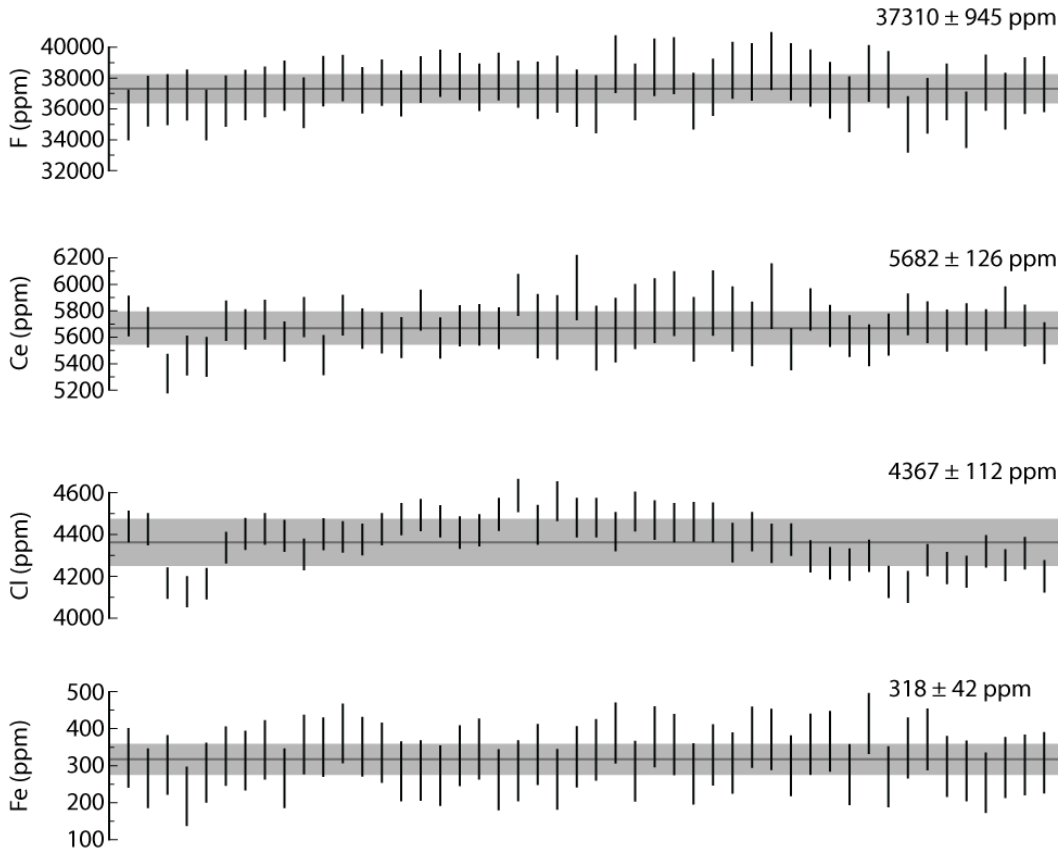

Figure DR1. EMP analyses of F, Ce, Cl, Fe of the Durango reference apatite. Each vertical bar represents a single EMP analysis including its 1σ analytical (internal) uncertainty. The horizontal line through the middle of each population represents the mean, which is surrounded by its 1σ uncertainty (in grey).

Table DR2. Comparison of Durango fluorapatite chemistry measured in this study and taken from the literature.

	This study	*Young et al. 1969*	*Roeder et al. 1987*	*Streck & Dilles 1998*		*Henderson 2011*
	EMPA (1σ)	*XRF/AAS*	*EMPA*	*EMPA (1σ)*	*EMPA (1σ)*	*EMPA (3σ)*
F	3.73 (0.09)	3.53	3.53	3.56 (0.23)	3.37 (0.38)	3.40 (0.09)
Cl	0.44 (0.01)	0.41	0.36	0.39 (0.04)	0.35 (0.07)	0.46 (0.02)
SiO_2	0.37 (0.01)	0.34	0.04	0.37 (0.02)	0.42 (0.03)	0.32 (0.02)
P_2O_5	40.84 (0.36)	40.78	40.90	40.30 (0.69)	40.80 (0.45)	41.04 (0.68)
FeO	0.03 (0.004)		0.03	0.04 (0.016)	0.04 (0.034)	0.04 (0.01)
Fe_2O_3		0.060				
SO_3	0.30 (0.02)	0.37		0.44 (0.08)	0.32 (0.05)	0.44 (0.04)
MgO	n.d.					0.02 (0.01)
CaO	54.35 (0.38)	54.02	54.05	54.10 (0.70)	54.40 (0.27)	54.22 (0.53)
Ce_2O_3	0.57 (0.01)	0.42	0.51	0.61 (0.06)	0.72 (0.08)	0.62 (0.02)
Y_2O_3	0.10 (0.01)	0.10	0.07			0.09 (0.01)
SrO	0.03 (0.02)	0.07	0.06			0.09 (0.01)
La_2O_3	0.43 (0.04)	0.49	0.41			0.43 (0.02)
Total [wt%]	101.18	101.56	100.55	99.81	100.42	101.82
–O(F,Cl)	*1.67*	*1.58*	*1.57*	*1.59*	*1.50*	*1.54*
Corr. Total [wt%]	*99.51*	*99.98*	*98.98*	*98.22*	*98.92*	*100.35*

Cathodoluminescence microscopy of apatite

Epoxy mounted apatite crystals were investigated by cathodoluminescence (CL) microscopy. The CL examinations were performed on a cold cathode CITL 8200 Mk 5-1 mounted on a Leitz Orthoplan petrological microscope at 15 kV and with a current density of ~10 μA/mm^2. Luminescence images were captured 'on-line' during CL operations by means of an adapted digital video-camera. A graphical summary of the most representative crystals of each sample is given in Figs. DR2 to DR4.

Several studies demonstrate that internal structures of apatite revealed by CL can be related to variations in the crystal chemistry (e.g., Bouzari et al., 2014; Kempe and Götze, 2002). In a study of porphyry copper deposits, Bouzari et al. (2014) show that apatite in fresh rocks displays yellow, yellow-brown and brown luminescence, whereas in K-silicate altered rock displays characteristic green luminescence and grey luminescence with muscovite alteration. The green-luminescent apatite often replaces yellow- or brown-luminescent apatite and locally overgrows it. Their study revealed high concentrations of Mn (0.3-0.5%) and high

Mn/Fe (>1) of the yellow-luminescent apatite, while the brown-luminescent apatite has low Mn, but higher concentrations of Cl, S and REE. Green-luminescent apatite bears lower Mn/Fe ratio (ca. 1) and a depletion of Cl, S and Na, whereas grey-luminescent apatite shows Mn and trace element loss (Mn:Fe of <0.3).

In a study of different rare-metal deposits, Kempe and Götze (2002) demonstrate that apatite from alkaline rocks and carbonatites typically exhibits relatively homogeneous blue to violet luminescence probably due to activation by trace quantities of rare earth elements such as Ce, Eu, Sm, Dy and Nd. In contrast, apatite from P-rich altered granites and pegmatites shows yellow-greenish luminescence, partially with distinct oscillatory zoning, and higher Mn concentrations.

Bouzari, F., Hart, C.J.R., Bissig, T., and Barker, S., 2014, Hydrothermal Alteration Revealed by Apatite Luminescence and Chemistry: An Indicator for Covered Porphyry Copper Deposits: Goldschmidt Conference, 24th, Sacramento, Abstracts, abstract 254.

Kempe, U., and Götze, J., 2002, Cathodoluminescence (CL) behaviour and crystal chemistry of apatite from rare-metal deposits: Mineralogical Magazine, v. 66, p. 151–172, doi: 10.1180/0026461026610019.

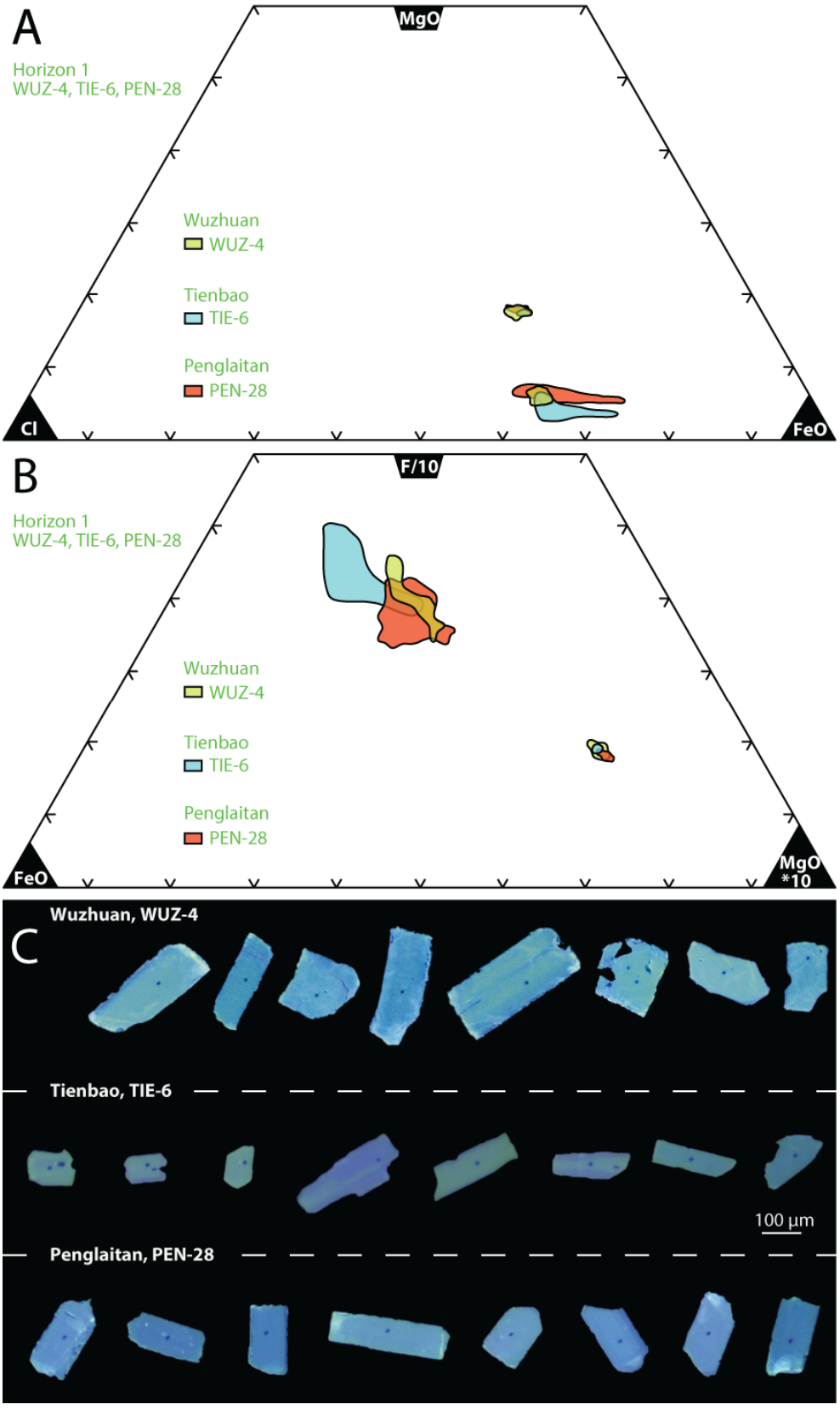

Figure DR2. Apatite chemistry ternary diagrams showing in A and B: Cl, F, FeO, MgO content of the volcanogenic beds of Horizon 1 in Wuzhuan, Tienbao and Penglaitan. For better visibility F concentration is divided by 10 and MgO concentration multiplied with 10 in B. C: Cathodoluminescence microscopy of representative apatite crystals of Horizon 1. Black dots indicate the position of the electron microprobe beam (10 µm spot size).

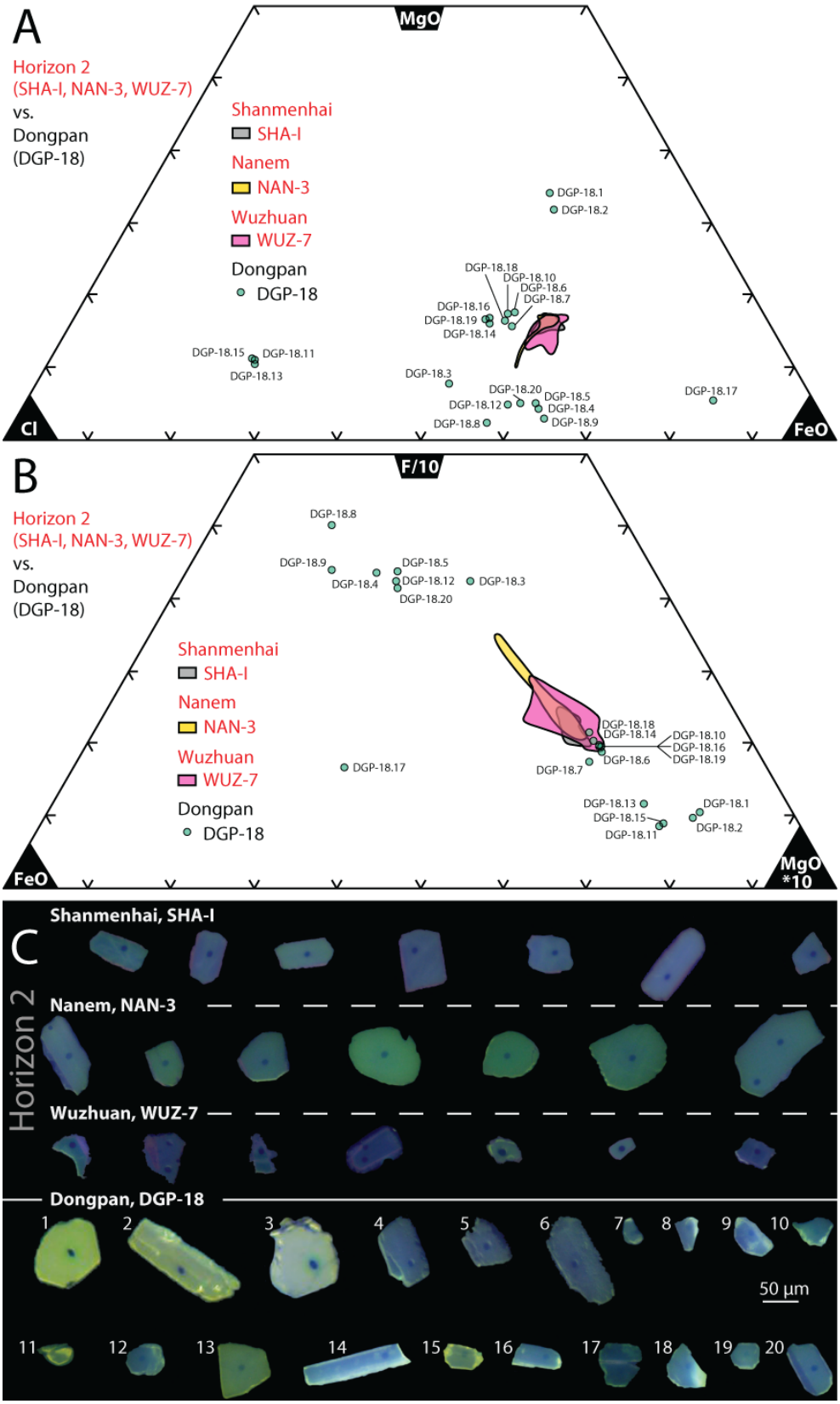

Figure DR3. Apatite chemistry ternary diagrams showing in A and B: Cl, F, FeO, MgO content of the volcanogenic beds of Horizon 2 in Shanmenhai, Nanem and Wuzhuan, and of DGP-18 in Dongpan. For better visibility F concentration is divided by 10 and MgO concentration multiplied with 10 in B. C: Cathodoluminescence microscopy of representative apatite crystals of Horizon 2 and DGP-18. Black dots indicate the position of the electron microprobe beam (10 µm spot size).

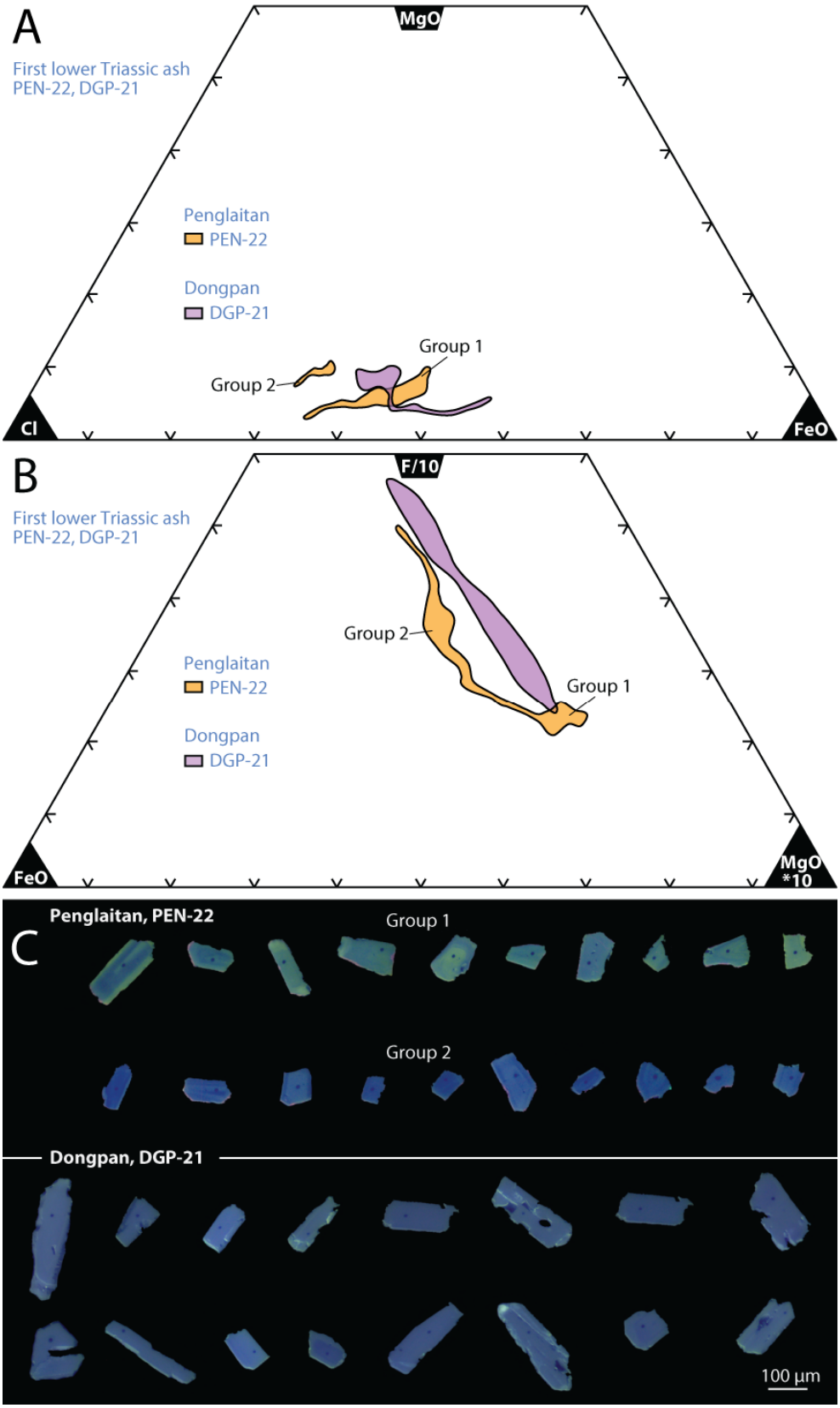

Figure DR4. Apatite chemistry ternary diagrams showing in A and B: Cl, F, FeO, MgO content of the volcanogenic beds of PEN-22 in Penglaitan and DGP-21 in Dongpan. For better visibility F concentration is divided by 10 and MgO concentration multiplied with 10 in B. C: Cathodoluminescence microscopy of representative apatite crystals of PEN-22 and DGP-21. Black dots indicate the position of the electron microprobe beam (10 µm spot size).

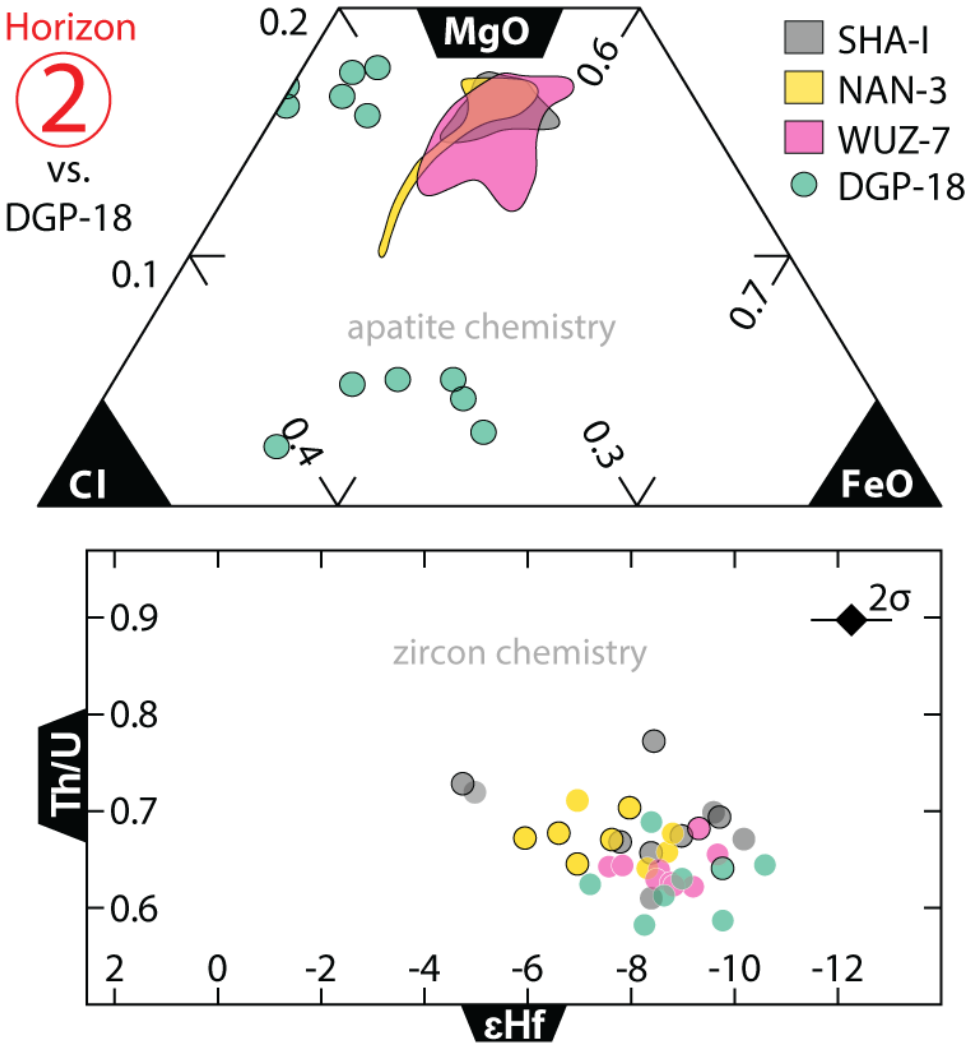

Figure DR5. Apatite Cl-MgO-FeO ternary diagram, zircon U-Pb dates, and zircon Th/U vs. εHf plot are presented for Horizon 2 and DGP-18. Though zircon dates and chemistry might reveal cogeneity of Horizon 2 and DGP-18, apatite chemistry refutes an identical origin. External reproducibility of the Hf isotope analyses of 0.78 εHf (2σ) corresponds to the reproducibility of the Plešovice reference zircon measurements (Tab. DR5; Fig. DR6).

Table DR3. Electron microprobe analyses of apatite.

Section: Dongpan Ash Bed: DGP-18

Crystal	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
F	3.63	2.95	3.65	3.41	3.61	3.49	3.16	3.34	3.24	3.76	1.70	3.40	1.93	3.57	1.73	3.43	2.85	3.77	3.35	3.29
Cl	0.14	0.13	0.17	0.14	0.14	0.20	0.22	0.17	0.15	0.21	0.87	0.16	0.74	0.22	0.85	0.21	0.12	0.20	0.21	0.15
SiO_2	0.19	0.15	0.11	0.20	0.23	0.36	2.29	0.20	0.12	0.13	0.05	0.14	0.07	0.20	0.05	0.31	0.13	0.15	0.13	0.12
P_2O_5	41.90	42.29	42.31	42.23	42.37	41.90	39.53	40.48	40.94	41.07	41.64	40.12	40.47	41.53	40.42	40.57	41.42	41.73	40.61	41.45
FeO	0.39	0.37	0.20	0.26	0.25	0.35	0.38	0.24	0.29	0.35	0.34	0.25	0.29	0.34	0.32	0.32	0.87	0.33	0.32	0.25
SO_3	0.12	0.13	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.04	0.01	0.03	0.01	0.05	0.02	0.01	0.00	0.01	0.01
MgO	0.27	0.24	0.03	0.02	0.02	0.12	0.11	0.01	0.01	0.12	0.15	0.02	0.12	0.11	0.15	0.11	0.06	0.11	0.11	0.02
CaO	56.25	54.96	56.51	53.00	52.89	53.16	50.67	53.18	54.00	53.47	54.00	52.79	51.97	54.69	53.42	52.67	54.16	53.96	53.45	54.17
Ce_2O_3	0.00	0.12	0.00	0.39	0.48	0.43	0.43	0.33	0.23	0.26	0.18	0.29	0.20	0.31	0.17	0.37	0.13	0.27	0.26	0.27
Y_2O_3	0.00	0.09	0.00	0.19	0.24	0.24	0.29	0.18	0.14	0.15	0.04	0.16	0.03	0.18	0.03	0.24	0.10	0.17	0.14	0.15
SrO	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.03	0.00
La_2O_3	0.40	0.05	0.62	0.09	0.01	0.15	0.19	0.12	0.08	0.10	0.09	0.10	0.07	0.12	0.09	0.16	0.04	0.10	0.09	0.10
Total [wt%]	*103.28*	*101.52*	*103.59*	*99.94*	*100.24*	*100.40*	*97.28*	*98.26*	*99.21*	*99.65*	*99.09*	*97.45*	*95.91*	*101.26*	*97.30*	*98.41*	*99.89*	*100.79*	*98.71*	*99.98*
-O(F)	1.53	1.24	1.54	1.44	1.52	1.47	1.33	1.41	1.36	1.58	0.72	1.43	0.81	1.50	0.73	1.44	1.20	1.59	1.41	1.39
-O(Cl)	0.03	0.03	0.04	0.03	0.03	0.04	0.05	0.04	0.03	0.05	0.20	0.04	0.17	0.05	0.19	0.05	0.03	0.05	0.05	0.03
Corr. Total [wt%]	*101.72*	*100.25*	*102.02*	*98.47*	*98.69*	*98.89*	*95.90*	*96.82*	*97.81*	*98.02*	*98.18*	*95.99*	*94.93*	*99.71*	*96.38*	*96.92*	*98.66*	*99.16*	*97.25*	*98.56*
Atomic proportions on the basis of 25 oxygens																				
P	5.89	5.97	5.94	6.07	6.08	6.02	5.83	5.96	5.96	5.98	6.00	5.96	6.03	5.95	5.95	5.97	5.97	6.00	5.96	5.98
Si	0.03	0.03	0.02	0.03	0.04	0.06	0.40	0.03	0.02	0.02	0.01	0.02	0.01	0.03	0.01	0.05	0.02	0.02	0.02	0.02
S	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
P-position	*5.94*	*6.02*	*5.95*	*6.10*	*6.12*	*6.08*	*6.23*	*6.00*	*5.98*	*6.01*	*6.01*	*5.99*	*6.04*	*5.98*	*5.97*	*6.02*	*5.99*	*6.02*	*5.98*	*6.01*
Ca	10.01	9.82	10.03	9.64	9.60	9.66	9.45	9.91	9.95	9.86	9.85	9.93	9.79	9.92	9.96	9.81	9.87	9.82	9.93	9.90
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.00	0.01	0.00	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.00	0.01	0.00	0.02	0.00	0.02	0.01	0.02	0.01	0.01
Ce	0.00	0.01	0.00	0.02	0.03	0.03	0.03	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.02
La	0.02	0.00	0.04	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01
Mg	0.07	0.06	0.01	0.00	0.01	0.03	0.03	0.00	0.00	0.03	0.04	0.01	0.03	0.03	0.04	0.03	0.01	0.03	0.03	0.01
Fe	0.05	0.05	0.03	0.04	0.04	0.05	0.06	0.03	0.04	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.12	0.05	0.05	0.04
Ca-position	*10.15*	*9.96*	*10.11*	*9.73*	*9.70*	*9.80*	*9.60*	*10.00*	*10.03*	*9.98*	*9.96*	*10.01*	*9.89*	*10.03*	*10.07*	*9.94*	*10.03*	*9.93*	*10.04*	*9.98*
F	1.91	1.56	1.91	1.83	1.93	1.87	1.74	1.84	1.76	2.05	0.92	1.89	1.07	1.91	0.95	1.88	1.53	2.02	1.84	1.77
Cl	0.04	0.04	0.05	0.04	0.04	0.06	0.07	0.05	0.04	0.06	0.25	0.05	0.22	0.06	0.25	0.06	0.04	0.06	0.06	0.04
F, Cl, OH-position	*1.95*	*1.59*	*1.96*	*1.87*	*1.97*	*1.93*	*1.81*	*1.89*	*1.81*	*2.11*	*1.17*	*1.94*	*1.29*	*1.97*	*1.20*	*1.95*	*1.57*	*2.08*	*1.90*	*1.82*

Table DR3. Electron microprobe analyses of apatite.

Section: Dongpan Ash Bed: DGP-21

Crystal	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
F	3.66	3.04	3.16	3.35	3.55	3.15	3.25	3.49	3.18	3.39	3.28	3.22	3.22	3.24	3.21	3.20	3.51	3.27	3.18	3.27	3.01	3.16
Cl	0.11	0.30	0.33	0.13	0.21	0.29	0.30	0.28	0.30	0.12	0.30	0.30	0.30	0.31	0.30	0.31	0.29	0.32	0.27	0.30	0.39	0.29
SiO_2	0.23	0.34	0.24	0.34	0.33	0.17	0.24	0.23	0.22	0.20	0.17	0.31	0.23	0.24	0.17	0.30	0.23	0.26	0.22	0.25	0.23	0.35
P_2O_5	41.63	41.68	41.63	41.45	41.59	42.06	41.80	41.73	41.54	41.51	41.62	41.36	41.30	41.16	41.57	41.09	41.25	41.45	41.23	41.58	41.36	41.12
FeO	0.16	0.26	0.26	0.15	0.18	0.23	0.24	0.22	0.25	0.16	0.25	0.25	0.25	0.24	0.25	0.25	0.24	0.23	0.22	0.22	0.27	0.25
SO_3	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
MgO	0.02	0.05	0.06	0.01	0.02	0.04	0.05	0.04	0.05	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.04	0.05	0.07	0.05
CaO	53.88	53.63	53.70	53.97	54.03	54.12	53.97	54.07	53.76	53.80	54.36	53.43	54.11	53.75	53.67	53.88	54.39	53.84	54.02	53.61	53.63	53.41
Ce_2O_3	0.34	0.41	0.34	0.39	0.34	0.28	0.34	0.34	0.33	0.32	0.28	0.39	0.33	0.33	0.30	0.38	0.34	0.30	0.32	0.34	0.33	0.41
Y_2O_3	0.22	0.26	0.21	0.27	0.25	0.18	0.21	0.21	0.20	0.20	0.18	0.25	0.20	0.20	0.18	0.24	0.22	0.21	0.21	0.22	0.20	0.27
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.12	0.15	0.13	0.14	0.11	0.10	0.13	0.13	0.12	0.11	0.11	0.14	0.13	0.12	0.12	0.14	0.30	0.10	0.13	0.13	0.13	0.16
Total [wt%]	*100.37*	*100.12*	*100.06*	*100.22*	*100.62*	*100.64*	*100.54*	*100.74*	*99.94*	*99.83*	*100.60*	*99.73*	*100.13*	*99.64*	*99.83*	*99.85*	*100.83*	*100.04*	*99.85*	*99.98*	*99.63*	*99.47*
-O(F)	1.54	1.28	1.33	1.41	1.49	1.33	1.37	1.47	1.34	1.43	1.38	1.36	1.36	1.36	1.35	1.35	1.48	1.38	1.34	1.38	1.27	1.33
-O(Cl)	0.02	0.07	0.07	0.03	0.05	0.06	0.07	0.06	0.07	0.03	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.07	0.09	0.07
Corr. Total [wt%]	*98.81*	*98.78*	*98.65*	*98.78*	*99.08*	*99.25*	*99.10*	*99.21*	*98.54*	*98.38*	*99.15*	*98.31*	*98.71*	*98.21*	*98.41*	*98.43*	*99.29*	*98.60*	*98.45*	*98.54*	*98.27*	*98.08*
Atomic proportions on the basis of 25 oxygens																						
P	6.00	5.99	6.00	5.97	5.98	6.02	6.00	5.99	6.00	6.00	5.98	5.99	5.96	5.97	6.01	5.95	5.95	5.98	5.97	6.00	5.99	5.97
Si	0.04	0.06	0.04	0.06	0.06	0.03	0.04	0.04	0.04	0.03	0.03	0.05	0.04	0.04	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.06
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.04*	*6.05*	*6.04*	*6.03*	*6.04*	*6.05*	*6.04*	*6.03*	*6.03*	*6.03*	*6.01*	*6.04*	*6.00*	*6.01*	*6.04*	*6.01*	*5.98*	*6.03*	*6.00*	*6.04*	*6.03*	*6.03*
Ca	9.82	9.76	9.79	9.84	9.83	9.80	9.80	9.83	9.82	9.84	9.88	9.79	9.89	9.87	9.81	9.88	9.92	9.84	9.89	9.79	9.82	9.81
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ce	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Mg	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Fe	0.02	0.04	0.04	0.02	0.03	0.03	0.03	0.03	0.04	0.02	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04
Ca-position	*9.90*	*9.87*	*9.89*	*9.92*	*9.91*	*9.88*	*9.90*	*9.92*	*9.91*	*9.91*	*9.97*	*9.89*	*9.98*	*9.96*	*9.90*	*9.98*	*10.03*	*9.92*	*9.98*	*9.88*	*9.93*	*9.92*
F	1.97	1.63	1.70	1.80	1.91	1.68	1.74	1.87	1.71	1.83	1.76	1.74	1.74	1.76	1.73	1.73	1.89	1.76	1.72	1.76	1.63	1.71
Cl	0.03	0.09	0.09	0.04	0.06	0.08	0.08	0.08	0.09	0.04	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.09	0.08	0.09	0.11	0.08
F, Cl, OH-position	*2.00*	*1.72*	*1.80*	*1.84*	*1.97*	*1.77*	*1.83*	*1.95*	*1.80*	*1.87*	*1.85*	*1.83*	*1.82*	*1.85*	*1.82*	*1.82*	*1.97*	*1.86*	*1.80*	*1.85*	*1.74*	*1.80*

Table DR3. Electron microprobe analyses of apatite.

Section: Dongpan Ash Bed: DGP-21

Crystal	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*
F	3.33	3.08	3.19	3.26	3.14	3.15	3.16	3.39	3.21	3.20	3.43	3.09	3.16	3.20	3.30	3.18	3.38	3.16	3.44	3.26	3.22	3.18
Cl	0.30	0.30	0.33	0.29	0.29	0.24	0.32	0.23	0.29	0.33	0.15	0.38	0.30	0.31	0.31	0.30	0.24	0.31	0.15	0.27	0.28	0.30
SiO_2	0.17	0.21	0.24	0.23	0.23	0.17	0.18	0.17	0.18	0.20	0.16	0.29	0.21	0.20	0.37	0.17	0.13	0.23	0.32	0.20	0.31	0.25
P_2O_5	41.39	41.26	40.63	40.53	41.41	40.56	41.70	41.53	41.19	41.06	40.91	41.27	40.72	40.85	40.69	41.33	40.99	40.82	40.96	41.10	40.95	40.80
FeO	0.25	0.23	0.26	0.25	0.24	0.20	0.27	0.19	0.23	0.25	0.15	0.27	0.25	0.25	0.26	0.22	0.19	0.27	0.16	0.22	0.23	0.24
SO_3	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01
MgO	0.05	0.05	0.06	0.05	0.04	0.03	0.06	0.03	0.05	0.05	0.01	0.06	0.05	0.05	0.05	0.05	0.04	0.06	0.01	0.04	0.05	0.05
CaO	54.03	54.01	53.91	53.39	53.75	53.36	53.97	53.91	53.12	53.90	53.65	53.59	53.78	53.28	53.65	53.80	53.98	53.63	53.74	53.87	53.66	53.73
Ce_2O_3	0.27	0.31	0.34	0.33	0.33	0.30	0.32	0.29	0.31	0.32	0.28	0.38	0.31	0.31	0.42	0.28	0.27	0.33	0.41	0.31	0.37	0.34
Y_2O_3	0.18	0.19	0.21	0.21	0.20	0.18	0.19	0.18	0.19	0.19	0.19	0.24	0.19	0.20	0.27	0.17	0.15	0.21	0.27	0.20	0.23	0.21
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.10	0.12	0.12	0.13	0.12	0.12	0.12	0.11	0.13	0.12	0.11	0.15	0.11	0.10	0.17	0.11	0.10	0.11	0.14	0.11	0.13	0.13
Total [wt%]	*100.08*	*99.76*	*99.29*	*98.68*	*99.75*	*98.33*	*100.30*	*100.03*	*98.91*	*99.63*	*99.06*	*99.72*	*99.10*	*98.77*	*99.50*	*99.62*	*99.49*	*99.13*	*99.60*	*99.59*	*99.44*	*99.24*
-O(F)	1.40	1.30	1.34	1.37	1.32	1.33	1.33	1.43	1.35	1.35	1.44	1.30	1.33	1.35	1.39	1.34	1.42	1.33	1.45	1.37	1.36	1.34
-O(Cl)	0.07	0.07	0.07	0.07	0.06	0.05	0.07	0.05	0.07	0.07	0.03	0.08	0.07	0.07	0.07	0.07	0.05	0.07	0.03	0.06	0.06	0.07
Corr. Total [wt%]	*98.61*	*98.39*	*97.87*	*97.24*	*98.37*	*96.95*	*98.90*	*98.55*	*97.49*	*98.21*	*97.58*	*98.34*	*97.70*	*97.35*	*98.04*	*98.22*	*98.01*	*97.73*	*98.12*	*98.16*	*98.02*	*97.83*
Atomic proportions on the basis of 25 oxygens																						
P	5.98	5.97	5.93	5.95	5.99	5.96	6.00	6.00	6.01	5.96	5.97	5.98	5.95	5.98	5.93	5.99	5.97	5.96	5.95	5.97	5.96	5.95
Si	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.03	0.06	0.03	0.02	0.04	0.05	0.03	0.05	0.04
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.01*	*6.01*	*5.97*	*5.99*	*6.03*	*5.99*	*6.03*	*6.03*	*6.04*	*6.00*	*6.00*	*6.03*	*5.98*	*6.01*	*6.00*	*6.02*	*5.99*	*6.00*	*6.01*	*6.00*	*6.01*	*5.99*
Ca	9.88	9.89	9.96	9.92	9.84	9.93	9.82	9.85	9.80	9.90	9.92	9.82	9.94	9.87	9.90	9.86	9.94	9.90	9.89	9.90	9.88	9.92
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.02
Ce	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01
Fe	0.04	0.03	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.02	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.02	0.03	0.03	0.03
Ca-position	*9.97*	*9.98*	*10.06*	*10.02*	*9.93*	*10.01*	*9.92*	*9.93*	*9.89*	*10.00*	*9.98*	*9.93*	*10.03*	*9.96*	*10.01*	*9.95*	*10.02*	*10.00*	*9.97*	*9.99*	*9.97*	*10.01*
F	1.80	1.66	1.74	1.79	1.70	1.73	1.70	1.83	1.75	1.74	1.87	1.67	1.72	1.75	1.80	1.72	1.84	1.72	1.87	1.77	1.75	1.73
Cl	0.09	0.09	0.09	0.08	0.08	0.07	0.09	0.07	0.08	0.09	0.04	0.11	0.09	0.09	0.09	0.09	0.07	0.09	0.04	0.08	0.08	0.09
F, Cl, OH-position	*1.88*	*1.75*	*1.83*	*1.87*	*1.78*	*1.80*	*1.79*	*1.89*	*1.83*	*1.83*	*1.92*	*1.78*	*1.81*	*1.84*	*1.89*	*1.81*	*1.91*	*1.81*	*1.91*	*1.85*	*1.83*	*1.82*

Table DR3. Electron microprobe analyses of apatite.

Section: Dongpan Ash Bed: DGP-21						*Section: Penglaitan Ash Bed: PEN-22*															
Crystal	*45*	*46*	*47*	*48*	*49*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
F	3.28	3.15	3.31	3.05	3.49	2.70	2.37	2.47	3.05	3.00	2.94	2.74	2.89	2.57	2.51	2.81	2.63	3.00	2.74	3.04	2.64
Cl	0.27	0.32	0.31	0.30	0.28	0.28	0.53	0.32	0.43	0.45	0.45	0.27	0.45	0.26	0.31	0.26	0.37	0.46	0.27	0.44	0.28
SiO_2	0.15	0.31	0.22	0.15	0.25	0.26	0.06	0.05	0.25	0.08	0.02	0.22	0.19	0.04	0.22	0.05	0.02	0.21	0.23	0.09	0.20
P_2O_5	41.27	41.24	41.13	40.26	40.86	40.53	40.47	40.67	40.03	40.65	40.95	40.98	40.57	41.06	41.14	41.29	41.16	40.47	40.60	41.30	41.02
FeO	0.19	0.27	0.23	0.23	0.22	0.17	0.27	0.26	0.27	0.24	0.26	0.28	0.27	0.14	0.28	0.23	0.25	0.26	0.23	0.26	0.20
SO_3	0.00	0.01	0.01	0.02	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MgO	0.04	0.06	0.05	0.05	0.05	0.02	0.06	0.04	0.07	0.06	0.08	0.04	0.07	0.01	0.04	0.03	0.04	0.07	0.02	0.07	0.03
CaO	54.01	53.47	53.50	53.04	54.19	53.58	52.92	53.66	52.56	53.02	53.29	53.56	53.12	53.98	53.62	53.81	53.41	53.03	53.17	53.62	53.79
Ce_2O_3	0.24	0.38	0.33	0.28	0.37	0.21	0.20	0.18	0.40	0.28	0.23	0.17	0.35	0.10	0.22	0.12	0.18	0.40	0.25	0.28	0.21
Y_2O_3	0.16	0.25	0.21	0.17	0.25	0.23	0.10	0.09	0.19	0.12	0.09	0.16	0.15	0.12	0.20	0.11	0.14	0.17	0.19	0.12	0.14
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.09	0.14	0.10	0.10	0.67	0.07	0.07	0.04	0.14	0.10	0.08	0.06	0.14	0.03	0.07	0.04	0.06	0.14	0.09	0.10	0.07
Total [wt%]	*99.70*	*99.59*	*99.41*	*97.65*	*100.63*	*98.05*	*97.08*	*97.79*	*97.39*	*98.01*	*98.39*	*98.48*	*98.22*	*98.32*	*98.60*	*98.75*	*98.27*	*98.23*	*97.81*	*99.33*	*98.58*
-O(F)	1.38	1.33	1.39	1.28	1.47	1.14	1.00	1.04	1.28	1.26	1.24	1.15	1.22	1.08	1.06	1.18	1.11	1.26	1.15	1.28	1.11
-O(Cl)	0.06	0.07	0.07	0.07	0.06	0.06	0.12	0.07	0.10	0.10	0.10	0.06	0.10	0.06	0.07	0.06	0.08	0.10	0.06	0.10	0.06
Corr. Total [wt%]	*98.26*	*98.19*	*97.95*	*96.30*	*99.09*	*96.85*	*95.96*	*96.68*	*96.01*	*96.64*	*97.05*	*97.27*	*96.90*	*97.18*	*97.47*	*97.51*	*97.08*	*96.86*	*96.60*	*97.95*	*97.41*
Atomic proportions on the basis of 25 oxygens																					
P	5.98	5.98	5.98	5.96	5.92	5.95	5.99	5.97	5.95	5.99	6.00	5.98	5.97	5.99	5.98	6.00	6.01	5.96	5.97	6.00	5.97
Si	0.03	0.05	0.04	0.03	0.04	0.04	0.01	0.01	0.04	0.01	0.00	0.04	0.03	0.01	0.04	0.01	0.00	0.04	0.04	0.02	0.03
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.01*	*6.03*	*6.02*	*5.99*	*5.96*	*5.99*	*6.00*	*5.98*	*6.00*	*6.01*	*6.01*	*6.02*	*6.00*	*6.00*	*6.02*	*6.01*	*6.02*	*6.00*	*6.01*	*6.02*	*6.01*
Ca	9.91	9.81	9.85	9.94	9.94	9.95	9.91	9.97	9.89	9.89	9.89	9.89	9.89	9.96	9.87	9.90	9.87	9.89	9.89	9.86	9.91
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01
Ce	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.03	0.02	0.02	0.01
La	0.01	0.01	0.01	0.01	0.04	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Mg	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.01
Fe	0.03	0.04	0.03	0.03	0.03	0.02	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.02	0.04	0.03	0.04	0.04	0.03	0.04	0.03
Ca-position	*9.98*	*9.92*	*9.94*	*10.02*	*10.07*	*10.02*	*9.99*	*10.04*	*10.00*	*9.98*	*9.97*	*9.97*	*9.99*	*10.00*	*9.95*	*9.96*	*9.95*	*9.99*	*9.97*	*9.95*	*9.98*
F	1.78	1.71	1.80	1.69	1.89	1.48	1.31	1.35	1.69	1.65	1.61	1.49	1.59	1.40	1.36	1.53	1.43	1.65	1.50	1.65	1.44
Cl	0.08	0.09	0.09	0.09	0.08	0.08	0.16	0.09	0.13	0.13	0.13	0.08	0.13	0.08	0.09	0.07	0.11	0.14	0.08	0.13	0.08
F, Cl, OH-position	*1.85*	*1.80*	*1.89*	*1.77*	*1.97*	*1.56*	*1.47*	*1.45*	*1.82*	*1.79*	*1.74*	*1.57*	*1.72*	*1.48*	*1.45*	*1.60*	*1.54*	*1.79*	*1.58*	*1.78*	*1.52*

Table DR3. Electron microprobe analyses of apatite.

Section: Penglaitan Ash Bed: PEN-22																		*Section: Penglaitan Ash Bed: PEN-28*			
Crystal	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*1*	*2*	*3*	*4*
F	2.74	2.45	2.85	2.99	2.85	2.73	3.29	3.41	2.76	2.88	2.92	2.85	2.82	3.01	2.59	2.44	2.48	3.22	3.24	3.29	3.46
Cl	0.27	0.32	0.30	0.45	0.29	0.28	0.42	0.44	0.34	0.48	0.45	0.33	0.27	0.46	0.28	0.30	0.32	0.14	0.14	0.14	0.13
SiO_2	0.31	0.05	0.07	0.26	0.31	0.12	0.10	0.19	0.10	0.27	0.16	0.26	0.33	0.07	0.27	0.02	0.14	0.33	0.19	0.17	0.12
P_2O_5	40.71	41.29	41.13	40.29	40.14	40.66	41.07	41.03	41.35	40.75	40.91	40.54	40.30	40.89	40.27	40.82	40.85	41.47	41.75	41.85	42.03
FeO	0.26	0.27	0.20	0.26	0.31	0.29	0.26	0.27	0.31	0.27	0.28	0.31	0.20	0.25	0.25	0.21	0.25	0.30	0.27	0.34	0.24
SO_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.07	0.01
MgO	0.03	0.04	0.02	0.07	0.07	0.06	0.08	0.08	0.05	0.07	0.07	0.06	0.02	0.07	0.03	0.02	0.03	0.03	0.03	0.03	0.02
CaO	53.58	53.73	53.98	52.92	52.55	53.02	53.95	54.22	53.73	53.37	53.20	53.92	53.36	53.26	53.22	53.73	52.65	54.62	54.87	54.95	54.70
Ce_2O_3	0.32	0.16	0.17	0.42	0.32	0.17	0.28	0.37	0.17	0.41	0.35	0.26	0.25	0.26	0.27	0.12	0.12	0.43	0.32	0.32	0.31
Y_2O_3	0.20	0.10	0.09	0.19	0.20	0.13	0.13	0.15	0.18	0.18	0.15	0.32	0.23	0.11	0.19	0.05	0.36	0.27	0.20	0.20	0.18
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.03
La_2O_3	0.10	0.04	0.06	0.16	0.12	0.06	0.00	0.37	0.06	0.16	0.13	0.16	0.07	0.11	0.08	0.03	0.03	0.17	0.11	0.11	0.13
Total [wt%]	*98.52*	*98.44*	*98.87*	*98.01*	*97.16*	*97.52*	*99.59*	*100.54*	*99.16*	*98.85*	*98.61*	*99.00*	*97.85*	*98.51*	*97.46*	*97.74*	*97.24*	*101.02*	*101.15*	*101.47*	*101.36*
-O(F)	1.15	1.03	1.20	1.26	1.20	1.15	1.39	1.44	1.16	1.21	1.23	1.20	1.19	1.27	1.09	1.03	1.04	1.36	1.36	1.39	1.46
-O(Cl)	0.06	0.07	0.07	0.10	0.07	0.06	0.09	0.10	0.08	0.11	0.10	0.07	0.06	0.10	0.06	0.07	0.07	0.03	0.03	0.03	0.03
Corr. Total [wt%]	*97.30*	*97.34*	*97.60*	*96.65*	*95.89*	*96.31*	*98.11*	*99.00*	*97.92*	*97.53*	*97.28*	*97.73*	*96.60*	*97.14*	*96.31*	*96.64*	*96.12*	*99.63*	*99.75*	*100.05*	*99.88*
Atomic proportions on the basis of 25 oxygens																					
P	5.95	6.00	5.99	5.95	5.96	5.99	5.97	5.94	6.00	5.96	5.99	5.92	5.94	5.99	5.94	5.99	6.01	5.94	5.96	5.96	5.99
Si	0.05	0.01	0.01	0.05	0.05	0.02	0.02	0.03	0.02	0.05	0.03	0.04	0.06	0.01	0.05	0.00	0.02	0.06	0.03	0.03	0.02
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
P-position	*6.00*	*6.01*	*6.00*	*6.00*	*6.01*	*6.01*	*5.99*	*5.97*	*6.01*	*6.00*	*6.01*	*5.97*	*5.99*	*6.01*	*5.99*	*5.99*	*6.04*	*5.99*	*5.99*	*5.99*	*6.01*
Ca	9.91	9.89	9.94	9.89	9.87	9.89	9.93	9.93	9.86	9.87	9.85	9.97	9.95	9.88	9.94	9.97	9.81	9.90	9.91	9.90	9.87
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.03	0.02	0.01	0.02	0.00	0.03	0.02	0.02	0.02	0.02
Ce	0.02	0.01	0.01	0.03	0.02	0.01	0.02	0.02	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.03	0.02	0.02	0.02
La	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01
Mg	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fe	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.05	0.03
Ca-position	*10.00*	*9.96*	*10.00*	*10.00*	*9.98*	*9.97*	*10.02*	*10.05*	*9.96*	*9.98*	*9.95*	*10.08*	*10.02*	*9.97*	*10.02*	*10.02*	*9.89*	*10.01*	*10.01*	*10.00*	*9.95*
F	1.50	1.33	1.55	1.65	1.58	1.50	1.79	1.84	1.50	1.57	1.60	1.55	1.55	1.65	1.43	1.34	1.36	1.72	1.73	1.75	1.84
Cl	0.08	0.09	0.09	0.13	0.09	0.08	0.12	0.13	0.10	0.14	0.13	0.10	0.08	0.14	0.08	0.09	0.09	0.04	0.04	0.04	0.04
F, Cl, OH-position	*1.57*	*1.42*	*1.64*	*1.78*	*1.67*	*1.59*	*1.91*	*1.97*	*1.59*	*1.71*	*1.73*	*1.65*	*1.63*	*1.78*	*1.51*	*1.42*	*1.46*	*1.76*	*1.77*	*1.79*	*1.88*

Table DR3. Electron microprobe analyses of apatite.

Section: Penglaitan Ash Bed: PEN-28

Crystal	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*
F	3.39	2.96	3.33	3.31	3.14	3.37	3.23	3.27	3.40	3.16	3.27	3.23	3.28	3.22	3.67	3.17	3.29	3.35	3.37	3.29	3.32	3.25
Cl	0.13	0.12	0.19	0.14	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.14	0.13	0.14	0.14	0.14	0.14	0.11	0.14	0.13	0.14
SiO_2	0.16	0.19	0.18	0.14	0.16	0.10	0.12	0.19	0.19	0.20	0.18	0.18	0.16	0.09	0.11	0.14	0.21	0.12	0.20	0.23	0.16	0.17
P_2O_5	42.23	41.54	42.04	41.95	41.97	42.01	42.29	42.23	41.98	41.89	41.98	42.28	42.31	41.92	42.84	42.11	41.74	42.54	41.75	41.92	42.13	42.35
FeO	0.25	0.30	0.36	0.27	0.25	0.27	0.26	0.27	0.28	0.27	0.27	0.30	0.26	0.29	0.26	0.28	0.30	0.27	0.24	0.28	0.24	0.27
SO_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.03	0.01	0.02	0.02	0.01	0.01
MgO	0.02	0.02	0.12	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.03
CaO	55.14	55.02	54.73	54.64	55.11	55.01	54.75	54.78	54.60	55.08	55.18	54.83	54.87	55.24	55.08	55.17	54.82	55.23	54.62	55.08	54.69	54.66
Ce_2O_3	0.33	0.29	0.30	0.29	0.31	0.28	0.27	0.34	0.32	0.33	0.35	0.30	0.30	0.26	0.28	0.30	0.35	0.28	0.33	0.37	0.36	0.32
Y_2O_3	0.20	0.18	0.20	0.19	0.19	0.16	0.17	0.21	0.20	0.20	0.21	0.18	0.18	0.18	0.17	0.18	0.22	0.18	0.27	0.22	0.21	0.19
SrO	0.02	0.02	0.03	0.00	0.02	0.02	0.02	0.03	0.02	0.00	0.02	0.03	0.03	0.05	0.02	0.00	0.03	0.02	0.08	0.04	0.00	0.00
La_2O_3	0.13	0.11	0.12	0.12	0.11	0.10	0.11	0.13	0.12	0.13	0.11	0.12	0.12	0.10	0.11	0.11	0.14	0.10	0.12	0.14	0.14	0.11
Total [wt%]	*102.00*	*100.77*	*101.62*	*101.09*	*101.43*	*101.52*	*101.42*	*101.65*	*101.30*	*101.45*	*101.76*	*101.61*	*101.71*	*101.51*	*102.70*	*101.66*	*101.30*	*102.27*	*101.12*	*101.75*	*101.40*	*101.50*
-O(F)	1.43	1.25	1.40	1.39	1.32	1.42	1.36	1.38	1.43	1.33	1.38	1.36	1.38	1.36	1.55	1.33	1.39	1.41	1.42	1.39	1.40	1.37
-O(Cl)	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Corr. Total [wt%]	*100.54*	*99.49*	*100.17*	*99.66*	*100.08*	*100.07*	*100.03*	*100.24*	*99.84*	*100.09*	*100.35*	*100.22*	*100.30*	*100.12*	*101.13*	*100.29*	*99.88*	*100.82*	*99.68*	*100.33*	*99.97*	*100.10*
Atomic proportions on the basis of 25 oxygens																						
P	5.98	5.94	5.98	5.99	5.97	5.98	6.00	5.99	5.98	5.96	5.96	5.99	6.00	5.96	6.02	5.97	5.96	6.00	5.97	5.95	5.99	6.01
Si	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.04	0.02	0.03	0.04	0.03	0.03
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.01*	*5.98*	*6.01*	*6.01*	*6.00*	*6.00*	*6.03*	*6.02*	*6.02*	*5.99*	*5.99*	*6.03*	*6.02*	*5.98*	*6.04*	*6.00*	*5.99*	*6.02*	*6.00*	*6.00*	*6.02*	*6.04*
Ca	9.88	9.96	9.85	9.87	9.92	9.91	9.84	9.83	9.85	9.92	9.92	9.84	9.84	9.95	9.80	9.90	9.90	9.86	9.88	9.90	9.85	9.81
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Y	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ce	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fe	0.03	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.04
Ca-position	*9.97*	*10.05*	*9.97*	*9.96*	*10.00*	*9.99*	*9.92*	*9.93*	*9.95*	*10.01*	*10.01*	*9.93*	*9.93*	*10.04*	*9.88*	*9.99*	*10.00*	*9.94*	*9.98*	*10.00*	*9.94*	*9.90*
F	1.79	1.58	1.77	1.77	1.67	1.79	1.71	1.73	1.81	1.68	1.73	1.71	1.74	1.71	1.93	1.68	1.75	1.76	1.80	1.75	1.76	1.72
Cl	0.04	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04
F, Cl, OH-position	*1.83*	*1.62*	*1.82*	*1.81*	*1.71*	*1.83*	*1.75*	*1.77*	*1.85*	*1.72*	*1.77*	*1.75*	*1.78*	*1.75*	*1.97*	*1.72*	*1.80*	*1.80*	*1.83*	*1.79*	*1.80*	*1.76*

Table DR3. Electron microprobe analyses of apatite.

Section: Penglaitan Ash Bed: PEN-28

Crystal	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*
F	3.25	3.32	3.30	3.34	3.29	3.28	3.18	3.35	3.33	3.36	3.30	3.24	3.28	3.20	3.22	3.39	3.06	3.28	3.34	3.30	3.26	3.24
Cl	0.14	0.14	0.13	0.13	0.19	0.14	0.13	0.19	0.14	0.13	0.20	0.20	0.13	0.13	0.20	0.17	0.13	0.14	0.14	0.14	0.14	0.14
SiO_2	0.13	0.16	0.25	0.16	0.14	0.16	0.18	0.17	0.16	0.17	0.17	0.15	0.16	0.18	0.21	0.22	0.11	0.12	0.17	0.12	0.21	0.18
P_2O_5	41.89	41.83	42.11	42.04	42.39	41.83	41.84	42.09	41.84	41.86	42.21	42.16	42.31	41.93	41.96	42.09	42.03	41.82	42.19	41.90	41.63	42.06
FeO	0.30	0.27	0.26	0.26	0.34	0.26	0.30	0.35	0.33	0.31	0.35	0.35	0.25	0.30	0.34	0.27	0.34	0.27	0.37	0.26	0.28	0.27
SO_3	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.05	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MgO	0.03	0.03	0.02	0.02	0.12	0.03	0.02	0.12	0.03	0.02	0.12	0.12	0.02	0.03	0.12	0.03	0.02	0.03	0.03	0.03	0.03	0.03
CaO	54.84	54.81	54.92	55.08	54.77	55.16	54.95	54.90	55.16	55.09	54.58	54.75	55.12	55.07	54.92	54.70	55.11	55.11	54.52	55.00	54.88	55.20
Ce_2O_3	0.26	0.33	0.36	0.33	0.27	0.33	0.33	0.28	0.33	0.35	0.28	0.28	0.32	0.29	0.28	0.33	0.25	0.29	0.31	0.30	0.34	0.32
Y_2O_3	0.16	0.20	0.22	0.20	0.20	0.20	0.21	0.19	0.18	0.21	0.19	0.19	0.20	0.17	0.20	0.21	0.15	0.17	0.19	0.17	0.21	0.19
SrO	0.02	0.02	0.02	0.00	0.02	0.02	0.03	0.02	0.05	0.03	0.00	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.00
La_2O_3	0.10	0.12	0.13	0.12	0.11	0.12	0.13	0.11	0.13	0.13	0.11	0.11	0.12	0.11	0.10	0.13	0.10	0.10	0.11	0.12	0.13	0.13
Total [wt%]	*101.11*	*101.24*	*101.74*	*101.67*	*101.85*	*101.54*	*101.29*	*101.79*	*101.72*	*101.74*	*101.51*	*101.58*	*101.93*	*101.44*	*101.60*	*101.57*	*101.33*	*101.37*	*101.41*	*101.37*	*101.16*	*101.78*
-O(F)	1.37	1.40	1.39	1.41	1.39	1.38	1.34	1.41	1.40	1.41	1.39	1.36	1.38	1.35	1.36	1.43	1.29	1.38	1.41	1.39	1.37	1.36
-O(Cl)	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Corr. Total [wt%]	*99.71*	*99.81*	*100.32*	*100.24*	*100.42*	*100.13*	*99.92*	*100.33*	*100.28*	*100.30*	*100.08*	*100.17*	*100.52*	*100.07*	*100.20*	*100.11*	*100.02*	*99.96*	*99.97*	*99.95*	*99.75*	*100.38*
Atomic proportions on the basis of 25 oxygens																						
P	5.98	5.97	5.97	5.97	6.00	5.96	5.96	5.97	5.95	5.95	6.00	5.99	5.99	5.96	5.96	5.98	5.97	5.96	6.00	5.97	5.95	5.97
Si	0.02	0.03	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.03	0.02	0.04	0.03
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.00*	*6.00*	*6.02*	*6.00*	*6.02*	*5.98*	*5.99*	*6.00*	*5.98*	*5.99*	*6.02*	*6.01*	*6.01*	*6.00*	*6.00*	*6.02*	*5.99*	*5.98*	*6.03*	*5.99*	*5.99*	*6.00*
Ca	9.90	9.90	9.86	9.90	9.81	9.94	9.91	9.86	9.93	9.91	9.81	9.84	9.87	9.91	9.88	9.84	9.91	9.94	9.81	9.92	9.93	9.91
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
Ce	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.01	0.01	0.01	0.00	0.03	0.01	0.01	0.03	0.01	0.01	0.03	0.03	0.00	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fe	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.05	0.05	0.03	0.04	0.05	0.04	0.05	0.04	0.05	0.04	0.04	0.04
Ca-position	*9.99*	*9.99*	*9.95*	*9.99*	*9.93*	*10.03*	*10.01*	*9.98*	*10.03*	*10.01*	*9.93*	*9.96*	*9.96*	*10.01*	*10.00*	*9.94*	*10.01*	*10.03*	*9.92*	*10.01*	*10.03*	*10.00*
F	1.73	1.77	1.75	1.77	1.74	1.74	1.69	1.78	1.77	1.78	1.75	1.72	1.73	1.70	1.71	1.80	1.62	1.75	1.77	1.76	1.74	1.72
Cl	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.06	0.06	0.04	0.04	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04
F, Cl, OH-position	*1.77*	*1.81*	*1.79*	*1.81*	*1.79*	*1.79*	*1.73*	*1.83*	*1.81*	*1.82*	*1.81*	*1.77*	*1.77*	*1.74*	*1.77*	*1.85*	*1.66*	*1.79*	*1.81*	*1.80*	*1.78*	*1.76*

Table DR3. Electron microprobe analyses of apatite.

Section: Penglaitan Ash Bed: PEN-28											*Section: Nanem Ash Bed: NAN-3*									
Crystal	*49*	*50*	*51*	*52*	*53*	*54*	*55*	*56*	*57*	*58*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
F	3.21	3.41	3.57	3.16	3.28	3.11	3.20	3.24	3.70	3.26	3.44	3.78	3.56	3.13	3.45	3.50	3.58	3.68	3.06	3.59
Cl	0.14	0.13	0.14	0.13	0.20	0.13	0.14	0.12	0.13	0.15	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.15
SiO_2	0.15	0.18	0.17	0.17	0.16	0.18	0.07	0.14	0.21	0.18	0.19	0.14	0.30	0.20	0.13	0.19	0.38	0.10	0.19	0.18
P_2O_5	41.99	42.02	41.77	42.00	41.72	42.09	42.42	42.40	41.82	41.63	40.37	40.78	41.11	41.32	40.99	41.42	40.61	41.21	40.92	41.50
FeO	0.27	0.31	0.28	0.26	0.34	0.30	0.26	0.31	0.27	0.27	0.32	0.25	0.33	0.28	0.34	0.33	0.33	0.32	0.30	0.35
SO_3	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.00	0.03	0.01	0.02	0.01	0.02	0.01	0.00
MgO	0.03	0.03	0.03	0.02	0.12	0.02	0.03	0.02	0.02	0.03	0.10	0.05	0.09	0.06	0.10	0.09	0.09	0.09	0.07	0.10
CaO	54.99	54.99	55.35	54.92	54.96	55.29	55.08	55.31	55.92	54.90	52.19	54.30	53.51	53.82	54.68	53.92	53.60	53.32	54.87	55.28
Ce_2O_3	0.32	0.32	0.33	0.32	0.28	0.28	0.26	0.22	0.36	0.31	0.27	0.33	0.38	0.26	0.23	0.27	0.38	0.20	0.27	0.29
Y_2O_3	0.18	0.19	0.20	0.20	0.20	0.18	0.15	0.14	0.22	0.21	0.16	0.16	0.23	0.16	0.14	0.16	0.25	0.12	0.16	0.13
SrO	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.11	0.12	0.13	0.13	0.12	0.10	0.10	0.08	0.00	0.12	0.10	0.14	0.13	0.10	0.10	0.11	0.16	0.09	0.10	0.00
Total [wt%]	*101.44*	*101.73*	*101.99*	*101.32*	*101.38*	*101.68*	*101.72*	*102.02*	*102.66*	*101.09*	*97.31*	*100.08*	*99.78*	*99.52*	*100.31*	*100.16*	*99.55*	*99.31*	*100.11*	*101.57*
-O(F)	1.35	1.44	1.50	1.33	1.38	1.31	1.35	1.36	1.56	1.37	1.45	1.59	1.50	1.32	1.45	1.47	1.51	1.55	1.29	1.51
-O(Cl)	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Corr. Total [wt%]	*100.05*	*100.26*	*100.46*	*99.96*	*99.96*	*100.35*	*100.34*	*100.63*	*101.07*	*99.68*	*95.83*	*98.45*	*98.25*	*98.17*	*98.82*	*98.65*	*98.01*	*97.72*	*98.78*	*100.02*
Atomic proportions on the basis of 25 oxygens																				
P	5.97	5.97	5.94	5.98	5.95	5.96	6.00	5.99	5.92	5.95	6.00	5.93	5.97	5.98	5.93	5.98	5.92	6.00	5.91	5.93
Si	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.02	0.04	0.03	0.03	0.02	0.05	0.03	0.02	0.03	0.06	0.02	0.03	0.03
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.00*	*6.00*	*5.97*	*6.01*	*5.98*	*6.00*	*6.02*	*6.01*	*5.96*	*5.99*	*6.03*	*5.96*	*6.02*	*6.02*	*5.95*	*6.01*	*5.99*	*6.02*	*5.95*	*5.96*
Ca	9.90	9.89	9.97	9.89	9.92	9.92	9.87	9.88	10.02	9.94	9.81	10.00	9.83	9.86	10.01	9.85	9.90	9.83	10.03	10.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Ce	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Mg	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.03	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
Fe	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.05
Ca-position	*9.99*	*9.99*	*10.06*	*9.98*	*10.04*	*10.00*	*9.95*	*9.96*	*10.10*	*10.03*	*9.92*	*10.09*	*9.95*	*9.95*	*10.12*	*9.96*	*10.03*	*9.93*	*10.13*	*10.10*
F	1.71	1.81	1.90	1.68	1.75	1.65	1.69	1.71	1.96	1.74	1.91	2.05	1.93	1.69	1.86	1.89	1.95	2.00	1.65	1.92
Cl	0.04	0.04	0.04	0.04	0.06	0.04	0.04	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.04
F, Cl, OH-position	*1.75*	*1.85*	*1.94*	*1.72*	*1.80*	*1.68*	*1.73*	*1.74*	*1.99*	*1.78*	*1.95*	*2.10*	*1.97*	*1.74*	*1.91*	*1.93*	*2.00*	*2.05*	*1.70*	*1.96*

Table DR3. Electron microprobe analyses of apatite.

Section: Shanmenhai Ash Bed: SHA-I

Crystal	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
F	3.49	3.53	3.51	3.52	3.45	3.62	3.50	3.50	3.60	3.69	3.45	3.55	3.40	3.61	3.95	3.53
Cl	0.16	0.16	0.16	0.15	0.16	0.15	0.15	0.16	0.16	0.15	0.16	0.15	0.16	0.16	0.16	0.17
SiO_2	0.13	0.45	0.23	0.32	0.20	0.15	0.12	0.14	0.49	0.26	0.38	0.33	0.39	0.16	0.31	0.44
P_2O_5	41.72	41.53	41.42	41.80	41.72	41.88	41.83	41.40	40.79	41.98	41.55	41.18	41.46	41.01	41.76	41.07
FeO	0.34	0.36	0.35	0.36	0.35	0.33	0.33	0.33	0.35	0.34	0.35	0.34	0.34	0.34	0.34	0.35
SO_3	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.02
MgO	0.09	0.10	0.09	0.10	0.09	0.09	0.09	0.10	0.10	0.09	0.10	0.09	0.10	0.09	0.09	0.10
CaO	55.00	54.38	54.71	54.60	54.66	54.84	55.03	54.29	54.21	54.76	54.63	54.68	54.46	55.00	54.56	53.84
Ce_2O_3	0.23	0.46	0.30	0.37	0.29	0.25	0.23	0.23	0.50	0.31	0.42	0.36	0.40	0.25	0.38	0.46
Y_2O_3	0.13	0.29	0.17	0.22	0.18	0.16	0.12	0.15	0.31	0.20	0.26	0.22	0.25	0.15	0.22	0.27
SrO	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.08	0.18	0.09	0.13	0.14	0.10	0.09	0.10	0.19	0.12	0.17	0.13	0.15	0.11	0.15	0.17
Total [wt%]	*101.39*	*101.46*	*101.04*	*101.59*	*101.25*	*101.61*	*101.50*	*100.42*	*100.70*	*101.92*	*101.49*	*101.06*	*101.13*	*100.90*	*101.93*	*100.43*
-O(F)	1.47	1.49	1.48	1.48	1.45	1.52	1.47	1.47	1.52	1.55	1.45	1.49	1.43	1.52	1.66	1.49
-O(Cl)	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.04	0.04
Corr. Total [wt%]	*99.89*	*99.94*	*99.53*	*100.07*	*99.76*	*100.05*	*100.00*	*98.91*	*99.15*	*100.33*	*100.00*	*99.53*	*99.67*	*99.34*	*100.23*	*98.91*
Atomic proportions on the basis of 25 oxygens																
P	5.96	5.93	5.94	5.96	5.96	5.97	5.96	5.97	5.89	5.97	5.93	5.92	5.93	5.91	5.96	5.93
Si	0.02	0.08	0.04	0.05	0.03	0.02	0.02	0.02	0.08	0.04	0.06	0.06	0.07	0.03	0.05	0.07
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*5.98*	*6.01*	*5.98*	*6.01*	*6.00*	*6.00*	*5.99*	*5.99*	*5.98*	*6.01*	*6.00*	*5.97*	*6.00*	*5.94*	*6.01*	*6.01*
Ca	9.94	9.83	9.93	9.85	9.89	9.89	9.93	9.90	9.91	9.85	9.87	9.94	9.87	10.03	9.85	9.84
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.01	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.02
Ce	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.03
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03
Fe	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ca-position	*10.04*	*9.97*	*10.04*	*9.97*	*10.00*	*10.00*	*10.03*	*10.01*	*10.06*	*9.97*	*10.01*	*10.07*	*10.00*	*10.14*	*9.97*	*9.98*
F	1.86	1.88	1.88	1.87	1.84	1.93	1.86	1.88	1.94	1.96	1.84	1.91	1.82	1.94	2.10	1.90
Cl	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.05	0.05
F, Cl, OH-position	*1.91*	*1.93*	*1.93*	*1.92*	*1.89*	*1.97*	*1.91*	*1.93*	*1.99*	*2.00*	*1.89*	*1.95*	*1.86*	*1.99*	*2.15*	*1.95*

Table DR3. Electron microprobe analyses of apatite.

Section: Shanmenhai Ash Bed: SHA-I

Crystal	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*
F	3.78	3.39	3.73	3.74	3.69	3.88	3.38	3.53	3.63	3.81	3.68	4.07	3.67	3.62	3.82	3.41	3.54	3.71	3.32	3.45	3.67	3.67
Cl	0.16	0.15	0.16	0.16	0.15	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.15	0.17	0.15	0.16	0.15	0.16	0.16
SiO_2	0.21	0.16	0.25	0.15	0.15	0.21	0.32	0.40	0.28	0.15	0.33	0.14	0.17	0.34	0.35	0.25	0.35	0.34	0.44	0.28	0.39	0.14
P_2O_5	41.19	41.99	41.21	41.23	41.69	41.40	41.36	41.13	41.43	41.94	41.39	41.69	41.70	40.86	40.84	41.74	41.17	41.16	40.97	41.21	41.10	41.37
FeO	0.35	0.33	0.34	0.31	0.35	0.35	0.35	0.35	0.35	0.33	0.34	0.33	0.36	0.36	0.36	0.35	0.35	0.34	0.37	0.35	0.37	0.34
SO_3	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
MgO	0.10	0.09	0.09	0.08	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
CaO	54.84	55.23	54.87	54.99	54.79	54.82	54.59	54.42	54.85	55.05	54.46	55.56	54.66	54.58	54.53	54.62	54.58	54.46	54.42	54.77	54.46	54.81
Ce_2O_3	0.29	0.27	0.35	0.30	0.23	0.29	0.36	0.42	0.33	0.26	0.37	0.30	0.29	0.39	0.40	0.33	0.38	0.39	0.45	0.33	0.42	0.24
Y_2O_3	0.17	0.16	0.19	0.19	0.14	0.16	0.21	0.25	0.20	0.14	0.22	0.17	0.16	0.21	0.23	0.18	0.22	0.22	0.25	0.18	0.25	0.14
SrO	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
La_2O_3	0.11	0.10	0.12	0.12	0.11	0.10	0.15	0.16	0.13	0.10	0.15	0.00	0.11	0.16	0.15	0.12	0.14	0.15	0.17	0.12	0.16	0.10
Total [wt%]	*101.20*	*101.89*	*101.31*	*101.29*	*101.43*	*101.50*	*100.99*	*100.93*	*101.47*	*102.06*	*101.19*	*102.53*	*101.39*	*100.79*	*100.95*	*101.27*	*101.01*	*101.03*	*100.68*	*100.96*	*101.10*	*101.08*
-O(F)	1.59	1.43	1.57	1.57	1.55	1.63	1.42	1.49	1.53	1.60	1.55	1.71	1.55	1.52	1.61	1.44	1.49	1.56	1.40	1.45	1.55	1.55
-O(Cl)	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.04
Corr. Total [wt%]	*99.58*	*100.43*	*99.71*	*99.68*	*99.84*	*99.83*	*99.53*	*99.41*	*99.90*	*100.42*	*99.61*	*100.78*	*99.81*	*99.23*	*99.31*	*99.80*	*99.48*	*99.44*	*99.25*	*99.48*	*99.52*	*99.50*
Atomic proportions on the basis of 25 oxygens																						
P	5.92	5.96	5.92	5.92	5.96	5.94	5.93	5.92	5.93	5.97	5.94	5.93	5.96	5.90	5.90	5.96	5.92	5.92	5.90	5.92	5.91	5.94
Si	0.04	0.03	0.04	0.03	0.02	0.04	0.05	0.07	0.05	0.03	0.06	0.02	0.03	0.06	0.06	0.04	0.06	0.06	0.07	0.05	0.07	0.02
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*5.96*	*5.99*	*5.96*	*5.95*	*5.99*	*5.97*	*5.99*	*5.99*	*5.98*	*5.99*	*5.99*	*5.95*	*5.99*	*5.96*	*5.96*	*6.00*	*5.98*	*5.98*	*5.98*	*5.97*	*5.98*	*5.97*
Ca	9.98	9.92	9.97	10.00	9.92	9.95	9.91	9.91	9.94	9.91	9.89	10.00	9.89	9.97	9.97	9.87	9.93	9.92	9.92	9.96	9.91	9.97
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Ce	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.02
Fe	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Ca-position	*10.10*	*10.03*	*10.09*	*10.11*	*10.03*	*10.06*	*10.03*	*10.04*	*10.06*	*10.02*	*10.01*	*10.11*	*10.01*	*10.10*	*10.10*	*9.99*	*10.06*	*10.05*	*10.06*	*10.08*	*10.05*	*10.07*
F	2.03	1.80	2.00	2.01	1.97	2.08	1.81	1.90	1.94	2.02	1.97	2.16	1.96	1.95	2.06	1.82	1.90	1.99	1.79	1.85	1.97	1.97
Cl	0.04	0.04	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.05	0.05
F, Cl, OH-position	*2.08*	*1.84*	*2.05*	*2.05*	*2.01*	*2.13*	*1.86*	*1.94*	*1.99*	*2.07*	*2.02*	*2.21*	*2.01*	*2.00*	*2.11*	*1.86*	*1.95*	*2.04*	*1.83*	*1.89*	*2.02*	*2.02*

Table DR3. Electron microprobe analyses of apatite.

Section: Shanmenhai	*Ash Bed: SHA-I*													*Section: Tienbao*	*Ash Bed: TIE-6*							
Crystal	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
F	3.97	3.63	3.55	3.50	3.62	3.48	3.63	3.50	3.40	3.48	3.76	3.56	3.43	3.57	3.22	3.52	3.51	3.56	3.38	3.52	3.53
Cl	0.17	0.16	0.16	0.16	0.16	0.16	0.17	0.15	0.16	0.16	0.16	0.17	0.16	0.14	0.14	0.13	0.14	0.19	0.13	0.14	0.12
SiO_2	0.64	0.09	0.14	0.23	0.22	0.58	0.21	0.43	0.15	0.15	0.26	0.38	0.55	0.10	0.14	0.17	0.14	0.29	0.28	0.45	0.18
P_2O_5	40.38	41.55	41.50	41.62	41.42	40.59	41.07	40.94	41.61	41.25	40.99	40.71	40.33	41.58	40.90	40.68	40.70	41.12	41.57	41.53	40.77
FeO	0.39	0.34	0.33	0.34	0.34	0.37	0.35	0.36	0.34	0.35	0.36	0.36	0.36	0.27	0.26	0.24	0.27	0.35	0.26	0.29	0.24
SO_3	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MgO	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.10	0.03	0.02	0.01	0.03	0.11	0.02	0.03	0.01
CaO	54.02	54.63	55.02	54.63	54.70	54.21	54.85	54.37	54.77	54.53	54.74	54.64	54.37	53.93	54.36	52.97	53.66	53.42	55.03	54.29	54.34
Ce_2O_3	0.60	0.21	0.24	0.31	0.29	0.53	0.29	0.39	0.25	0.25	0.32	0.41	0.54	0.22	0.29	0.31	0.27	0.36	0.43	0.50	0.33
Y_2O_3	0.37	0.12	0.13	0.18	0.17	0.31	0.16	0.22	0.14	0.14	0.19	0.23	0.32	0.12	0.14	0.15	0.15	0.25	0.23	0.29	0.18
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.23	0.09	0.09	0.12	0.13	0.21	0.11	0.14	0.10	0.10	0.12	0.14	0.20	0.09	0.13	0.13	0.11	0.14	0.17	0.19	0.12
Total [wt%]	*100.87*	*100.93*	*101.28*	*101.19*	*101.17*	*100.56*	*100.94*	*100.61*	*101.04*	*100.53*	*101.00*	*100.70*	*100.37*	*100.06*	*99.64*	*98.32*	*98.99*	*99.81*	*101.51*	*101.24*	*99.82*
-O(F)	1.67	1.53	1.49	1.47	1.52	1.47	1.53	1.47	1.43	1.47	1.58	1.50	1.44	1.50	1.36	1.48	1.48	1.50	1.42	1.48	1.49
-O(Cl)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03
Corr. Total [wt%]	*99.17*	*99.36*	*99.75*	*99.69*	*99.61*	*99.06*	*99.37*	*99.10*	*99.57*	*99.03*	*99.39*	*99.17*	*98.89*	*98.52*	*98.25*	*96.81*	*97.48*	*98.26*	*100.06*	*99.72*	*98.31*
Atomic proportions on the basis of 25 oxygens																					
P	5.86	5.97	5.94	5.96	5.94	5.87	5.92	5.91	5.96	5.95	5.91	5.89	5.85	6.01	5.94	5.99	5.96	5.97	5.93	5.94	5.93
Si	0.11	0.01	0.02	0.04	0.04	0.10	0.04	0.07	0.02	0.03	0.04	0.06	0.09	0.02	0.02	0.03	0.02	0.05	0.05	0.08	0.03
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*5.97*	*5.98*	*5.97*	*6.00*	*5.98*	*5.97*	*5.95*	*5.98*	*5.98*	*5.97*	*5.96*	*5.95*	*5.95*	*6.02*	*5.97*	*6.02*	*5.98*	*6.02*	*5.98*	*6.02*	*5.96*
Ca	9.92	9.93	9.97	9.89	9.93	9.93	10.00	9.93	9.92	9.95	9.99	10.00	9.99	9.86	9.99	9.87	9.95	9.81	9.94	9.83	10.00
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.03	0.01	0.01	0.02	0.02	0.03	0.01	0.02	0.01	0.01	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.02
Ce	0.04	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.01	0.01	0.00	0.01	0.03	0.00	0.01	0.00
Fe	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.03
Ca-position	*10.09*	*10.03*	*10.07*	*10.01*	*10.05*	*10.08*	*10.11*	*10.06*	*10.03*	*10.06*	*10.11*	*10.13*	*10.14*	*9.93*	*10.08*	*9.95*	*10.03*	*9.95*	*10.04*	*9.95*	*10.09*
F	2.15	1.95	1.90	1.87	1.94	1.88	1.95	1.89	1.82	1.87	2.03	1.92	1.86	1.93	1.75	1.94	1.92	1.93	1.80	1.88	1.92
Cl	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.06	0.04	0.04	0.03
F, Cl, OH-position	*2.20*	*1.99*	*1.94*	*1.92*	*1.99*	*1.93*	*2.00*	*1.93*	*1.86*	*1.92*	*2.07*	*1.97*	*1.91*	*1.97*	*1.79*	*1.97*	*1.96*	*1.99*	*1.84*	*1.92*	*1.95*

Table DR3. Electron microprobe analyses of apatite.

Section: Tienbao Ash Bed: TIE-6

Crystal	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*
F	3.83	3.43	3.62	3.35	3.31	3.68	3.47	3.61	3.23	3.33	3.34	3.48	3.53	3.53	3.51	3.21	3.28	3.27	3.31	3.27	3.80	3.33
Cl	0.13	0.13	0.13	0.14	0.14	0.13	0.14	0.13	0.12	0.14	0.13	0.15	0.18	0.14	0.19	0.11	0.13	0.14	0.14	0.14	0.12	0.12
SiO_2	0.16	0.19	0.23	0.12	0.22	0.13	0.13	0.13	0.13	0.19	0.20	0.20	0.09	0.43	0.18	0.16	0.14	0.16	0.18	0.16	0.14	0.12
P_2O_5	42.19	41.57	40.93	42.50	41.91	41.85	41.81	42.01	42.04	41.76	41.53	42.13	42.00	40.80	41.58	41.48	41.71	41.50	40.96	41.65	41.78	41.90
FeO	0.26	0.25	0.27	0.26	0.27	0.25	0.27	0.26	0.31	0.29	0.30	0.29	0.34	0.29	0.37	0.33	0.30	0.28	0.28	0.27	0.31	0.26
SO_3	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01
MgO	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.03	0.11	0.02	0.12	0.02	0.02	0.02	0.03	0.02	0.01	0.02
CaO	54.99	53.79	54.53	55.57	55.11	55.49	55.42	55.23	55.57	55.27	53.98	54.63	54.68	54.56	54.85	55.11	55.13	54.80	54.79	54.96	55.14	55.00
Ce_2O_3	0.37	0.37	0.37	0.27	0.37	0.31	0.29	0.30	0.22	0.32	0.30	0.33	0.24	0.52	0.31	0.22	0.21	0.31	0.32	0.32	0.19	0.25
Y_2O_3	0.18	0.20	0.19	0.15	0.18	0.17	0.17	0.16	0.12	0.17	0.18	0.18	0.15	0.27	0.17	0.11	0.12	0.16	0.16	0.16	0.10	0.12
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.13	0.15	0.13	0.12	0.13	0.09	0.08	0.12	0.07	0.11	0.12	0.13	0.09	0.21	0.12	0.08	0.08	0.12	0.13	0.11	0.08	0.08
Total [wt%]	*102.25*	*100.09*	*100.43*	*102.52*	*101.67*	*102.11*	*101.81*	*101.98*	*101.82*	*101.59*	*100.11*	*101.55*	*101.40*	*100.75*	*101.40*	*100.84*	*101.11*	*100.78*	*100.29*	*101.08*	*101.68*	*101.22*
-O(F)	1.61	1.44	1.52	1.41	1.39	1.55	1.46	1.52	1.36	1.40	1.41	1.47	1.49	1.49	1.48	1.35	1.38	1.38	1.39	1.38	1.60	1.40
-O(Cl)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Corr. Total [wt%]	*100.61*	*98.62*	*98.88*	*101.07*	*100.25*	*100.53*	*100.32*	*100.43*	*100.44*	*100.16*	*98.67*	*100.05*	*99.88*	*99.24*	*99.88*	*99.46*	*99.70*	*99.37*	*98.87*	*99.67*	*100.05*	*99.79*
Atomic proportions on the basis of 25 oxygens																						
P	5.99	6.00	5.92	5.98	5.96	5.95	5.95	5.97	5.96	5.95	5.99	5.99	5.99	5.89	5.95	5.94	5.96	5.95	5.92	5.96	5.96	5.98
Si	0.03	0.03	0.04	0.02	0.04	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.07	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.02
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.01*	*6.03*	*5.97*	*6.00*	*6.00*	*5.97*	*5.97*	*5.99*	*5.98*	*5.98*	*6.02*	*6.03*	*6.01*	*5.97*	*5.98*	*5.97*	*5.98*	*5.98*	*5.95*	*5.98*	*5.99*	*6.00*
Ca	9.87	9.82	9.99	9.90	9.91	9.98	9.98	9.93	9.97	9.96	9.85	9.83	9.87	9.97	9.93	9.99	9.97	9.95	10.02	9.95	9.96	9.93
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ce	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00
Mg	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.03	0.00	0.03	0.00	0.00	0.01	0.01	0.01	0.00	0.00
Fe	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
Ca-position	*9.96*	*9.91*	*10.08*	*9.98*	*10.00*	*10.06*	*10.06*	*10.01*	*10.04*	*10.05*	*9.94*	*9.93*	*9.98*	*10.09*	*10.05*	*10.07*	*10.04*	*10.04*	*10.11*	*10.03*	*10.03*	*10.00*
F	2.03	1.85	1.96	1.76	1.76	1.95	1.84	1.92	1.71	1.77	1.80	1.85	1.88	1.90	1.88	1.72	1.75	1.75	1.79	1.75	2.03	1.77
Cl	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.05	0.04	0.05	0.03	0.04	0.04	0.04	0.04	0.03	0.04
F, Cl, OH-position	*2.07*	*1.89*	*2.00*	*1.80*	*1.80*	*1.99*	*1.88*	*1.95*	*1.74*	*1.81*	*1.84*	*1.89*	*1.93*	*1.94*	*1.93*	*1.75*	*1.79*	*1.79*	*1.83*	*1.79*	*2.06*	*1.81*

Table DR3. Electron microprobe analyses of apatite.

Tienbao	*Section: Wuzhuan*			*Ash Bed: WUZ-7*																
Crystal	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
F	3.46	3.45	3.94	3.62	3.88	3.85	3.51	3.55	3.62	3.33	3.85	3.41	3.51	3.49	3.51	3.47	3.52	3.63	3.52	3.44
Cl	0.16	0.18	0.14	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.16	0.14	0.14	0.17	0.15	0.14	0.16	0.15	0.19
SiO_2	0.36	0.43	0.08	0.33	0.40	0.35	0.18	0.20	0.20	0.20	0.28	0.17	0.12	0.18	0.57	0.31	0.15	0.44	0.16	0.21
P_2O_5	41.95	41.93	42.86	42.31	41.84	41.20	41.52	41.01	41.32	41.22	41.26	42.20	42.09	40.86	40.55	39.99	41.69	40.53	41.29	41.25
FeO	0.35	0.36	0.33	0.35	0.34	0.37	0.34	0.33	0.27	0.33	0.34	0.34	0.33	0.31	0.35	0.32	0.34	0.34	0.33	0.33
SO_3	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
MgO	0.09	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.06	0.09	0.10	0.10	0.09	0.09	0.10	0.09	0.09	0.09	0.09	0.11
CaO	54.72	54.36	54.58	54.60	54.49	54.95	55.27	53.96	53.43	53.96	54.93	54.92	55.03	53.09	52.85	52.56	54.83	53.04	54.03	54.28
Ce_2O_3	0.38	0.49	0.21	0.38	0.47	0.38	0.26	0.27	0.35	0.28	0.36	0.27	0.23	0.26	0.54	0.34	0.27	0.37	0.26	0.29
Y_2O_3	0.24	0.31	0.12	0.22	0.29	0.24	0.18	0.16	0.19	0.17	0.19	0.15	0.13	0.16	0.33	0.21	0.15	0.27	0.15	0.18
SrO	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.16	0.19	0.07	0.15	0.19	0.16	0.10	0.11	0.13	0.12	0.13	0.11	0.09	0.10	0.22	0.14	0.09	0.17	0.09	0.13
Total [wt%]	*101.87*	*101.81*	*102.44*	*102.23*	*102.16*	*101.76*	*101.60*	*99.84*	*99.73*	*99.87*	*101.58*	*101.82*	*101.77*	*98.68*	*99.18*	*97.58*	*101.27*	*99.05*	*100.08*	*100.44*
-O(F)	1.46	1.45	1.66	1.52	1.63	1.62	1.48	1.49	1.52	1.40	1.62	1.44	1.48	1.47	1.48	1.46	1.48	1.53	1.48	1.45
-O(Cl)	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.04
Corr. Total [wt%]	*100.37*	*100.32*	*100.75*	*100.67*	*100.49*	*100.10*	*100.09*	*98.31*	*98.18*	*98.43*	*99.92*	*100.35*	*100.26*	*97.18*	*97.67*	*96.09*	*99.76*	*97.48*	*98.56*	*98.95*
Atomic proportions on the basis of 25 oxygens																				
P	5.96	5.96	6.05	5.98	5.95	5.90	5.93	5.95	6.00	5.96	5.92	5.98	5.98	5.99	5.93	5.94	5.96	5.94	5.97	5.95
Si	0.06	0.07	0.01	0.06	0.07	0.06	0.03	0.03	0.03	0.03	0.05	0.03	0.02	0.03	0.10	0.05	0.03	0.08	0.03	0.04
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.02*	*6.03*	*6.06*	*6.04*	*6.02*	*5.96*	*5.96*	*5.99*	*6.03*	*6.00*	*5.96*	*6.01*	*6.00*	*6.02*	*6.03*	*6.00*	*5.99*	*6.02*	*6.00*	*5.99*
Ca	9.83	9.78	9.74	9.77	9.81	9.96	9.99	9.91	9.81	9.88	9.97	9.86	9.89	9.84	9.78	9.89	9.92	9.84	9.89	9.91
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.03	0.01	0.02	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.02	0.01	0.03	0.01	0.02
Ce	0.02	0.03	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02
La	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Fe	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05
Ca-position	*9.96*	*9.92*	*9.84*	*9.90*	*9.95*	*10.10*	*10.10*	*10.02*	*9.91*	*9.99*	*10.09*	*9.96*	*10.00*	*9.95*	*9.94*	*10.01*	*10.03*	*9.97*	*10.00*	*10.03*
F	1.84	1.83	2.08	1.91	2.06	2.06	1.87	1.93	1.96	1.80	2.06	1.81	1.86	1.91	1.92	1.93	1.88	1.99	1.90	1.85
Cl	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.05
F, Cl, OH-position	*1.88*	*1.88*	*2.12*	*1.96*	*2.10*	*2.10*	*1.92*	*1.97*	*2.01*	*1.84*	*2.10*	*1.85*	*1.90*	*1.95*	*1.97*	*1.97*	*1.92*	*2.03*	*1.95*	*1.91*

Table DR3. Electron microprobe analyses of apatite.

Section: Wuzhuan Ash Bed: WUZ-7								*Section: Wuzhuan Ash Bed: WUZ-4*													
Crystal	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
F	3.31	3.35	3.61	3.44	3.50	3.60	3.46	3.37	3.31	3.40	3.54	3.35	3.38	3.54	3.62	3.33	3.30	3.45	3.29	3.31	3.38
Cl	0.15	0.16	0.16	0.18	0.15	0.16	0.14	0.18	0.14	0.14	0.19	0.20	0.19	0.19	0.13	0.20	0.14	0.15	0.13	0.19	0.19
SiO_2	0.32	0.46	0.11	0.23	0.48	0.26	0.26	0.21	0.19	0.16	0.15	0.13	0.19	0.14	0.22	0.20	0.15	0.15	0.13	0.17	0.19
P_2O_5	41.49	40.47	41.22	41.01	40.90	41.19	41.87	41.13	41.67	41.60	41.86	41.80	41.48	41.45	41.42	41.41	41.55	41.05	41.19	41.40	41.87
FeO	0.35	0.36	0.31	0.39	0.37	0.34	0.28	0.35	0.27	0.27	0.35	0.33	0.35	0.35	0.26	0.36	0.27	0.27	0.24	0.34	0.35
SO_3	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
MgO	0.10	0.11	0.09	0.08	0.10	0.10	0.06	0.11	0.03	0.03	0.12	0.12	0.12	0.12	0.02	0.12	0.03	0.03	0.02	0.12	0.12
CaO	54.87	53.99	54.03	53.64	54.22	55.06	54.81	53.39	53.57	53.71	53.55	53.43	53.69	53.52	54.11	53.26	53.62	53.64	53.53	53.52	53.32
Ce_2O_3	0.35	0.45	0.22	0.34	0.48	0.33	0.32	0.29	0.34	0.33	0.28	0.28	0.30	0.28	0.40	0.32	0.33	0.31	0.36	0.29	0.32
Y_2O_3	0.21	0.28	0.12	0.22	0.28	0.19	0.20	0.18	0.17	0.17	0.18	0.17	0.19	0.16	0.23	0.19	0.17	0.16	0.18	0.19	0.19
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.15	0.20	0.07	0.13	0.18	0.13	0.11	0.11	0.14	0.11	0.11	0.11	0.11	0.11	0.08	0.11	0.14	0.11	0.14	0.11	0.13
Total [wt%]	*101.30*	*99.82*	*99.95*	*99.66*	*100.68*	*101.36*	*101.52*	*99.34*	*99.84*	*99.93*	*100.35*	*99.92*	*100.02*	*99.87*	*100.49*	*99.51*	*99.70*	*99.32*	*99.22*	*99.64*	*100.07*
-O(F)	1.39	1.41	1.52	1.45	1.47	1.52	1.46	1.42	1.39	1.43	1.49	1.41	1.42	1.49	1.52	1.40	1.39	1.45	1.39	1.39	1.42
-O(Cl)	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.05	0.03	0.03	0.03	0.04	0.04
Corr. Total [wt%]	*99.87*	*98.37*	*98.39*	*98.17*	*99.17*	*99.81*	*100.04*	*97.88*	*98.42*	*98.46*	*98.82*	*98.46*	*98.55*	*98.34*	*98.94*	*98.06*	*98.28*	*97.84*	*97.81*	*98.20*	*98.60*
Atomic proportions on the basis of 25 oxygens																					
P	5.93	5.89	5.97	5.96	5.90	5.91	5.96	5.98	6.01	6.01	6.02	6.03	5.99	6.00	5.97	6.00	6.01	5.98	5.99	6.00	6.03
Si	0.05	0.08	0.02	0.04	0.08	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.02	0.04	0.03	0.03	0.03	0.02	0.03	0.03
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*5.98*	*5.97*	*5.99*	*6.00*	*5.98*	*5.95*	*6.01*	*6.02*	*6.05*	*6.03*	*6.05*	*6.05*	*6.02*	*6.03*	*6.01*	*6.04*	*6.03*	*6.01*	*6.02*	*6.03*	*6.06*
Ca	9.92	9.94	9.91	9.87	9.90	10.00	9.88	9.83	9.78	9.82	9.75	9.75	9.81	9.81	9.87	9.77	9.81	9.89	9.86	9.81	9.71
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.03	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ce	0.02	0.03	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
La	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.03	0.01	0.01	0.03	0.03	0.03	0.03	0.01	0.03	0.01	0.01	0.01	0.03	0.03
Fe	0.05	0.05	0.04	0.06	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.03	0.05	0.05
Ca-position	*10.05*	*10.09*	*10.01*	*9.99*	*10.05*	*10.12*	*9.98*	*9.95*	*9.88*	*9.90*	*9.87*	*9.87*	*9.94*	*9.92*	*9.97*	*9.90*	*9.90*	*9.98*	*9.94*	*9.93*	*9.84*
F	1.77	1.82	1.95	1.87	1.89	1.93	1.84	1.83	1.78	1.83	1.90	1.80	1.82	1.91	1.95	1.80	1.78	1.88	1.79	1.79	1.82
Cl	0.04	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.04	0.06	0.06	0.06	0.06	0.04	0.06	0.04	0.04	0.04	0.05	0.05
F, Cl, OH-position	*1.81*	*1.87*	*2.00*	*1.92*	*1.93*	*1.97*	*1.88*	*1.88*	*1.83*	*1.87*	*1.96*	*1.86*	*1.88*	*1.97*	*1.99*	*1.86*	*1.82*	*1.92*	*1.83*	*1.85*	*1.87*

Table DR3. Electron microprobe analyses of apatite.

Section: Wuzhuan Ash Bed: WUZ-4

Crystal	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*
F	3.41	3.46	3.55	3.56	3.88	3.39	3.30	3.36	3.61	3.10	3.36	3.45	3.36	3.43	3.86	3.48	3.30	3.60	3.63	3.51	3.39	3.32
Cl	0.14	0.19	0.20	0.13	0.19	0.15	0.14	0.19	0.19	0.14	0.20	0.13	0.19	0.14	0.16	0.19	0.14	0.20	0.13	0.13	0.20	0.20
SiO_2	0.23	0.14	0.16	0.14	0.16	0.30	0.27	0.20	0.19	0.24	0.27	0.14	0.22	0.13	0.16	0.14	0.21	0.17	0.18	0.15	0.19	0.17
P_2O_5	41.32	41.61	41.42	41.22	41.16	41.13	40.67	41.26	40.94	41.18	40.89	40.96	40.97	41.29	41.20	41.71	41.35	41.90	41.01	41.56	41.24	41.64
FeO	0.27	0.35	0.36	0.25	0.35	0.28	0.26	0.34	0.35	0.28	0.35	0.24	0.36	0.28	0.28	0.35	0.28	0.35	0.24	0.24	0.36	0.36
SO_3	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
MgO	0.03	0.12	0.12	0.02	0.12	0.03	0.02	0.12	0.12	0.03	0.12	0.02	0.12	0.03	0.03	0.12	0.03	0.11	0.02	0.02	0.12	0.12
CaO	53.64	53.59	53.45	53.41	54.09	53.16	53.46	53.33	53.19	53.47	53.40	53.39	53.32	53.52	53.80	53.61	53.52	53.44	53.56	53.68	53.20	53.41
Ce_2O_3	0.36	0.28	0.30	0.33	0.30	0.43	0.44	0.29	0.31	0.37	0.37	0.35	0.32	0.32	0.32	0.27	0.35	0.30	0.39	0.32	0.32	0.29
Y_2O_3	0.19	0.17	0.19	0.17	0.18	0.24	0.24	0.20	0.21	0.19	0.25	0.18	0.19	0.17	0.18	0.17	0.18	0.19	0.21	0.17	0.20	0.19
SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
La_2O_3	0.14	0.11	0.12	0.11	0.00	0.16	0.17	0.11	0.11	0.13	0.14	0.13	0.13	0.11	0.13	0.12	0.13	0.11	0.14	0.13	0.12	0.11
Total [wt%]	*99.73*	*100.02*	*99.88*	*99.34*	*100.42*	*99.29*	*98.98*	*99.41*	*99.21*	*99.14*	*99.36*	*99.01*	*99.20*	*99.44*	*100.12*	*100.18*	*99.50*	*100.36*	*99.52*	*99.92*	*99.34*	*99.83*
-O(F)	1.44	1.46	1.49	1.50	1.63	1.43	1.39	1.41	1.52	1.31	1.41	1.45	1.41	1.44	1.63	1.47	1.39	1.52	1.53	1.48	1.43	1.40
-O(Cl)	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.04
Corr. Total [wt%]	*98.26*	*98.53*	*98.34*	*97.81*	*98.75*	*97.83*	*97.56*	*97.95*	*97.65*	*97.80*	*97.90*	*97.53*	*97.74*	*97.96*	*98.46*	*98.67*	*98.08*	*98.80*	*97.96*	*98.41*	*97.87*	*98.39*
Atomic proportions on the basis of 25 oxygens																						
P	5.99	6.01	6.00	6.00	5.96	5.99	5.95	5.99	5.98	5.98	5.96	5.99	5.97	6.00	5.98	6.01	6.00	6.03	5.97	6.01	6.00	6.01
Si	0.04	0.02	0.03	0.02	0.03	0.05	0.05	0.03	0.03	0.04	0.05	0.02	0.04	0.02	0.03	0.02	0.04	0.03	0.03	0.03	0.03	0.03
S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.03*	*6.03*	*6.03*	*6.03*	*5.99*	*6.04*	*6.00*	*6.03*	*6.01*	*6.03*	*6.01*	*6.01*	*6.01*	*6.02*	*6.01*	*6.04*	*6.03*	*6.06*	*6.01*	*6.03*	*6.03*	*6.04*
Ca	9.83	9.79	9.80	9.84	9.91	9.79	9.90	9.80	9.83	9.83	9.85	9.87	9.84	9.84	9.88	9.78	9.82	9.73	9.88	9.82	9.79	9.76
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ce	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
La	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.01	0.03	0.03	0.01	0.03	0.01	0.01	0.03	0.03	0.01	0.03	0.01	0.03	0.01	0.01	0.03	0.01	0.03	0.01	0.00	0.03	0.03
Fe	0.04	0.05	0.05	0.04	0.05	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.04	0.05	0.04	0.05	0.03	0.03	0.05	0.05
Ca-position	*9.93*	*9.91*	*9.92*	*9.92*	*10.03*	*9.90*	*10.00*	*9.92*	*9.96*	*9.93*	*9.98*	*9.96*	*9.96*	*9.93*	*9.97*	*9.90*	*9.91*	*9.85*	*9.97*	*9.90*	*9.92*	*9.88*
F	1.85	1.87	1.92	1.94	2.10	1.84	1.80	1.82	1.97	1.68	1.83	1.88	1.83	1.86	2.09	1.87	1.79	1.93	1.98	1.90	1.84	1.79
Cl	0.04	0.05	0.06	0.04	0.05	0.04	0.04	0.06	0.06	0.04	0.06	0.04	0.06	0.04	0.05	0.06	0.04	0.06	0.04	0.04	0.06	0.06
F, Cl, OH-position	*1.89*	*1.92*	*1.98*	*1.97*	*2.15*	*1.89*	*1.84*	*1.88*	*2.03*	*1.72*	*1.89*	*1.92*	*1.88*	*1.90*	*2.14*	*1.93*	*1.83*	*1.99*	*2.01*	*1.93*	*1.90*	*1.85*

Table DR3. Electron microprobe analyses of apatite.

Section: Wuzhuan Ash Bed: WUZ-4

Crystal	*37*	*38*	*39*	*40*	*41*	*42*
F	3.64	3.27	3.38	3.48	3.58	3.62
Cl	0.19	0.13	0.19	0.20	0.13	0.20
SiO_2	0.17	0.20	0.16	0.22	0.16	0.14
P_2O_5	41.78	41.51	41.90	41.53	41.72	41.93
FeO	0.34	0.26	0.35	0.35	0.25	0.35
SO_3	0.01	0.01	0.01	0.01	0.01	0.01
MgO	0.12	0.02	0.12	0.12	0.02	0.12
CaO	53.60	53.64	53.39	53.19	53.73	53.48
Ce_2O_3	0.28	0.36	0.29	0.33	0.35	0.26
Y_2O_3	0.18	0.19	0.17	0.20	0.19	0.17
SrO	0.00	0.00	0.01	0.00	0.00	0.02
La_2O_3	0.10	0.14	0.11	0.14	0.14	0.11
Total [wt%]	*100.41*	*99.73*	*100.08*	*99.77*	*100.27*	*100.39*
-O(F)	1.53	1.38	1.42	1.47	1.51	1.52
-O(Cl)	0.04	0.03	0.04	0.04	0.03	0.04
Corr. Total [wt%]	*98.83*	*98.32*	*98.61*	*98.26*	*98.73*	*98.82*
Atomic proportions on the basis of 25 oxygens						
P	6.01	6.00	6.03	6.01	6.01	6.03
Si	0.03	0.03	0.03	0.04	0.03	0.02
S	0.00	0.00	0.00	0.00	0.00	0.00
P-position	*6.04*	*6.03*	*6.06*	*6.05*	*6.04*	*6.06*
Ca	9.77	9.81	9.72	9.74	9.80	9.73
Sr	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.02	0.02	0.02	0.02	0.02	0.02
Ce	0.02	0.02	0.02	0.02	0.02	0.02
La	0.01	0.01	0.01	0.01	0.01	0.01
Mg	0.03	0.01	0.03	0.03	0.00	0.03
Fe	0.05	0.04	0.05	0.05	0.04	0.05
Ca-position	*9.88*	*9.90*	*9.85*	*9.87*	*9.89*	*9.85*
F	1.96	1.77	1.82	1.88	1.93	1.95
Cl	0.05	0.04	0.06	0.06	0.04	0.06
F, Cl, OH-position	*2.01*	*1.80*	*1.87*	*1.94*	*1.97*	*2.00*

Table DR3. Electron microprobe analyses of apatite.

Durango Apatite

Analysis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
F	3.56	3.65	3.66	3.69	3.56	3.65	3.69	3.71	3.75	3.64	3.78	3.80	3.72	3.77	3.70	3.79	3.83	3.81	3.74	3.81	3.76	3.72
Cl	0.44	0.44	0.42	0.41	0.42	0.43	0.44	0.44	0.44	0.43	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.44	0.44	0.45	0.46	0.44
SiO_2	0.38	0.37	0.36	0.36	0.36	0.37	0.37	0.38	0.37	0.38	0.38	0.36	0.35	0.37	0.37	0.35	0.37	0.37	0.36	0.36	0.39	0.37
P_2O_5	41.26	41.19	40.95	41.33	41.30	41.18	40.82	41.29	41.37	40.97	41.17	40.55	41.27	40.36	40.65	41.17	41.06	40.94	40.56	41.20	41.44	40.60
FeO	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
SO_3	0.29	0.29	0.25	0.25	0.26	0.29	0.29	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.28	0.28	0.29	0.29	0.28	0.28	0.33	0.33
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	54.74	54.83	54.86	54.92	55.05	55.08	54.96	54.92	54.89	54.92	55.00	54.10	53.97	53.94	54.46	54.83	53.86	53.65	53.68	54.13	53.62	54.36
Ce_2O_3	0.58	0.57	0.53	0.55	0.55	0.57	0.57	0.57	0.56	0.58	0.55	0.58	0.57	0.56	0.56	0.58	0.56	0.57	0.57	0.57	0.59	0.57
Y_2O_3	0.11	0.12	0.12	0.12	0.11	0.12	0.10	0.12	0.12	0.11	0.12	0.12	0.10	0.10	0.11	0.11	0.11	0.10	0.11	0.11	0.11	0.08
SrO	0.06	0.06	0.04	0.04	0.06	0.06	0.07	0.04	0.05	0.06	0.04	0.00	0.00	0.02	0.02	0.00	0.02	0.03	0.01	0.02	0.02	0.01
La_2O_3	0.43	0.42	0.40	0.40	0.41	0.42	0.42	0.43	0.43	0.42	0.42	0.25	0.44	0.46	0.44	0.35	0.44	0.44	0.35	0.38	0.48	0.44
Total [wt%]	*101.89*	*101.97*	*101.61*	*102.08*	*102.09*	*102.20*	*101.77*	*102.22*	*102.29*	*101.83*	*102.22*	*100.52*	*101.18*	*100.34*	*101.06*	*101.95*	*101.01*	*100.67*	*100.15*	*101.34*	*101.22*	*100.96*
-O(F)	1.50	1.54	1.54	1.55	1.50	1.54	1.55	1.56	1.58	1.53	1.59	1.60	1.57	1.59	1.56	1.60	1.61	1.60	1.57	1.60	1.58	1.57
-O(Cl)	0.10	0.10	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Corr. Total [wt%]	*100.29*	*100.33*	*99.98*	*100.43*	*100.50*	*100.57*	*100.12*	*100.55*	*100.61*	*100.20*	*100.53*	*98.82*	*99.51*	*98.66*	*99.40*	*100.25*	*99.30*	*98.97*	*98.47*	*99.63*	*99.53*	*99.29*
Atomic proportions on the basis of 25 oxygens																						
P	5.90	5.89	5.88	5.90	5.89	5.88	5.86	5.89	5.90	5.87	5.88	5.89	5.93	5.88	5.88	5.89	5.92	5.93	5.91	5.92	5.95	5.87
Si	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06
S	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
P-position	*6.00*	*5.99*	*5.97*	*5.99*	*5.98*	*5.98*	*5.96*	*5.99*	*6.00*	*5.97*	*5.98*	*5.99*	*6.03*	*5.98*	*5.97*	*5.99*	*6.02*	*6.03*	*6.00*	*6.02*	*6.06*	*5.98*
Ca	9.90	9.92	9.97	9.92	9.94	9.95	9.99	9.92	9.90	9.96	9.94	9.94	9.82	9.95	9.96	9.93	9.84	9.83	9.89	9.85	9.75	9.95
Sr	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ce	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.04
La	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.03	0.03
Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca-position	*9.98*	*10.00*	*10.05*	*10.00*	*10.02*	*10.03*	*10.07*	*10.00*	*9.99*	*10.05*	*10.02*	*10.01*	*9.90*	*10.03*	*10.04*	10.01	9.91	9.91	9.97	9.92	9.83	10.03
F	1.90	1.95	1.96	1.97	1.90	1.95	1.98	1.98	2.00	1.95	2.02	2.06	2.00	2.05	2.00	2.03	2.06	2.06	2.03	2.05	2.02	2.01
Cl	0.13	0.13	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
F, Cl, OH-position	*2.03*	*2.08*	*2.08*	*2.09*	*2.02*	*2.07*	*2.11*	*2.10*	*2.12*	*2.07*	*2.14*	*2.19*	*2.12*	*2.18*	*2.13*	2.16	2.19	2.19	2.16	2.18	2.15	2.14

Table DR3. Electron microprobe analyses of apatite.

Durango Apatite

Analysis	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*
F	3.76	3.67	3.63	3.89	3.71	3.87	3.88	3.65	3.74	3.85	3.84	3.91	3.84	3.80	3.72	3.63	3.83	3.79	3.50	3.62	3.71	3.53
Cl	0.46	0.45	0.45	0.44	0.45	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.43	0.43	0.43	0.43	0.42	0.41	0.43	0.42	0.42
SiO_2	0.38	0.39	0.37	0.37	0.38	0.39	0.38	0.38	0.38	0.40	0.38	0.38	0.37	0.37	0.36	0.36	0.37	0.37	0.36	0.37	0.36	0.37
P_2O_5	41.00	40.23	40.63	40.32	40.85	40.37	40.39	40.71	41.08	40.36	40.17	40.15	41.17	40.61	40.64	41.07	40.93	41.09	41.18	41.02	40.71	40.75
FeO	0.03	0.03	0.03	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.03	0.03
SO_3	0.33	0.33	0.33	0.32	0.33	0.34	0.34	0.33	0.35	0.33	0.33	0.34	0.29	0.30	0.30	0.29	0.30	0.30	0.30	0.30	0.30	0.30
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	54.27	54.13	54.28	54.19	54.19	54.19	54.14	54.48	54.42	54.26	54.11	54.24	54.19	54.22	54.32	54.07	54.21	54.08	54.45	54.29	54.19	54.35
Ce_2O_3	0.57	0.60	0.56	0.57	0.58	0.58	0.59	0.57	0.59	0.57	0.56	0.59	0.55	0.58	0.57	0.56	0.55	0.56	0.58	0.57	0.57	0.57
Y_2O_3	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.09	0.11	0.10	0.10	0.12	0.10	0.10	0.10	0.09	0.09	0.10	0.10	0.10	0.09	0.11
SrO	0.03	0.01	0.02	0.01	0.01	0.03	0.01	0.01	0.05	0.02	0.02	0.02	0.02	0.02	0.00	0.04	0.01	0.01	0.01	0.04	0.04	0.02
La_2O_3	0.45	0.45	0.47	0.45	0.45	0.46	0.44	0.45	0.44	0.47	0.45	0.44	0.44	0.43	0.44	0.43	0.45	0.43	0.45	0.44	0.44	0.43
Total [wt%]	*101.37*	*100.40*	*100.87*	*100.68*	*101.08*	*100.82*	*100.74*	*101.15*	*101.63*	*100.83*	*100.44*	*100.66*	*101.44*	*100.89*	*100.90*	*101.00*	*101.21*	*101.17*	*101.37*	*101.21*	*100.86*	*100.87*
-O(F)	1.58	1.55	1.53	1.64	1.56	1.63	1.63	1.54	1.57	1.62	1.62	1.65	1.62	1.60	1.57	1.53	1.61	1.60	1.47	1.52	1.56	1.49
-O(Cl)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.10	0.10	0.10
Corr. Total [wt%]	*99.69*	*98.75*	*99.24*	*98.94*	*99.42*	*99.09*	*99.01*	*99.52*	*99.95*	*99.11*	*98.73*	*98.92*	*99.73*	*99.19*	*99.24*	*99.38*	*99.50*	*99.48*	*99.80*	*99.59*	*99.21*	*99.29*
Atomic proportions on the basis of 25 oxygens																						
P	5.90	5.86	5.88	5.86	5.89	5.86	5.87	5.87	5.89	5.86	5.86	5.85	5.92	5.88	5.88	5.92	5.90	5.92	5.91	5.90	5.89	5.88
Si	0.06	0.07	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
S	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
P-position	*6.01*	*5.97*	*5.98*	*5.97*	*6.00*	*5.97*	*5.98*	*5.98*	*6.00*	*5.97*	*5.96*	*5.96*	*6.02*	*5.98*	*5.98*	*6.02*	*6.00*	*6.02*	*6.01*	*6.00*	*5.99*	*5.99*
Ca	9.88	9.97	9.94	9.97	9.89	9.96	9.95	9.95	9.88	9.97	9.98	10.00	9.86	9.94	9.95	9.86	9.89	9.86	9.88	9.89	9.92	9.93
Sr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ce	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04
La	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Ca-position	9.96	10.06	10.02	10.05	9.97	10.04	10.03	10.02	9.97	10.05	10.07	10.08	9.93	10.02	10.02	9.94	9.97	9.93	9.96	9.97	10.00	10.01
F	2.02	2.00	1.96	2.11	2.00	2.10	2.11	1.97	2.00	2.09	2.09	2.13	2.06	2.06	2.01	1.95	2.06	2.04	1.88	1.95	2.01	1.90
Cl	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
F, Cl, OH-position	2.15	2.13	2.09	2.24	2.13	2.23	2.24	2.10	2.13	2.21	2.22	2.25	2.19	2.18	2.13	2.08	2.19	2.16	1.99	2.07	2.13	2.03

Table DR3. Electron microprobe analyses of apatite.

Durango Apatite

Analysis	*45*	*46*	*47*	*48*	*(N=48)*	*Mean*	1σ
F	3.77	3.65	3.75	3.76	F	0.31	0.05
Cl	0.43	0.43	0.43	0.42	Cl	0.04	0.00
SiO_2	0.37	0.36	0.37	0.37	SiO_2	0.03	0.00
P_2O_5	40.53	40.37	40.80	40.46	P_2O_5	3.38	0.16
FeO	0.03	0.03	0.03	0.03	FeO	0.00	0.002
SO_3	0.29	0.31	0.30	0.30	SO_3	0.02	0.01
MgO	0.00	0.00	0.00	0.00	MgO	0.00	0.000
CaO	54.12	54.16	54.05	54.22	CaO	4.51	0.06
Ce_2O_3	0.57	0.58	0.57	0.56	Ce_2O_3	0.05	0.01
Y_2O_3	0.09	0.09	0.10	0.09	Y_2O_3	0.01	0.00
SrO	0.04	0.03	0.02	0.03	SrO	0.00	0.006
La_2O_3	0.43	0.44	0.43	0.44	La_2O_3	0.04	0.00
Total [wt%]	*100.67*	*100.45*	*100.84*	*100.67*	*Total [w*	*8.39*	*0.14*
-O(F)	1.59	1.54	1.58	1.58	-O(F)	0.13	0.02
-O(Cl)	0.10	0.10	0.10	0.09	-O(Cl)	0.01	0.00
Corr. Total [wt%]	*98.98*	*98.82*	*99.17*	*98.99*	*Corr. To*	*8.25*	*0.12*
Atomic proportions on the basis of 25 oxygens							
P	5.88	5.87	5.90	5.87			
Si	0.06	0.06	0.06	0.06			
S	0.04	0.04	0.04	0.04			
P-position	*5.98*	*5.97*	*6.00*	*5.97*			
Ca	9.94	9.97	9.89	9.96			
Sr	0.00	0.00	0.00	0.00			
Y	0.01	0.01	0.01	0.01			
Ce	0.04	0.04	0.04	0.03			
La	0.03	0.03	0.03	0.03			
Mg	0.00	0.00	0.00	0.00			
Fe	0.00	0.00	0.00	0.00			
Ca-position	10.02	10.05	9.97	10.04			
F	2.04	1.98	2.03	2.04			
Cl	0.13	0.12	0.12	0.12			
F, Cl, OH-position	2.17	2.11	2.15	2.16			

U-Pb geochronology of zircon

Sample preparation and U-Pb chemical abrasion isotope-dilution thermal ionization mass spectrometry (CA-ID-TIMS) analysis of zircon were carried out at the University of Geneva. The rock samples were crushed and milled, and the powders were wet-sieved to remove the clay fraction. Heavy minerals were isolated using methylene iodide. Populations of euhedral to subhedral zircon grains with maximum diameters ≤ 250 μm were microscopically inspected and euhedral crystals were picked for annealing at 900°C for ~48 h, followed by chemical abrasion with 40% HF and trace HNO_3 in pressurized dissolution 200 μl Ludwig-style capsules in a PARR vessel at 180°C for 18 h to minimize Pb loss effects (Mattinson, 2005). After several washing steps with water, 6 N HCl, and 3 N HNO_3, single crystals were loaded in the same 200 μl Ludwig-style capsules, spiked with ~4 mg of the EARTHTIME ^{202}Pb-^{205}Pb-^{233}U-^{235}U tracer solution (hereafter referred to as ET2535; Condon et al., 2015) and dissolved in ~70 μl 40% HF and trace HNO_3 at 210°C for 48 h. After dissolution, samples were dried, dissolved again in 6 N HCl at 180°C for 12 h, dried down and dissolved again in 3 N HCl. U and Pb were collected in 3 ml Savillex beakers after separation in a modified single 50 μl column anion exchange chemistry (Krogh, 1973) and dried down with a drop of 0.05 M H_3PO_4. They were loaded on a single outgassed Re filament with a Si-gel emitter modified from Gerstenberger and Haase (1997). Measurements of U and Pb isotopes were performed on a Thermo TRITON thermal ionization mass spectrometer utilizing the ET2535 tracer calibration version 3.0 defined by Condon et al. (2015). Pb isotopes were measured in dynamic mode on a MasCom secondary electron multiplier with a deadtime of 23 ns. Instrumental mass fractionation was corrected using the fractionation factor derived from the measured $^{202}Pb/^{205}Pb$ ratio relative to a true value of 0.99924. $BaPO_2$ interferences on mass 202 to 205 were corrected by determining $^{138}Ba^{31}P^{16}O^{16}O$ concentration on mass 201 assuming natural abundance of ^{138}Ba of 71.7%. No correction was applied for isobaric interference of Tl on mass 205 (natural abundance of ^{205}Tl = 70.48% and ^{203}Tl = 29.52%)

since routine check of Re filaments yielded negligible concentrations on mass 203. U isotopes were measured in static mode on Faraday cups equipped with 10^{12} Ω resistors as UO_2^+ and measured ratios were corrected for isobaric interferences of $^{233}U^{18}O^{16}O$ on $^{235}U^{16}O^{16}O$ using $^{18}O/^{16}O$ of 0.0020, measured on large U500 loads, and for mass fractionation using the measured $^{233}U/^{235}U$ ratio relative to a value of 0.99506, assuming a sample $^{238}U/^{235}U$ ratio of 137.818 ± 0.045 (2σ; Hiess et al., 2012). Raw data were statistical filtered by using the Tripoli program, followed by data reduction including correct uncertainty propagation and online data visualization using U-Pb_Redux software (Bowring et al., 2011; McLean et al., 2011). U-Pb ratios and dates were calculated relative to a tracer $^{235}U/^{205}Pb$ ratio of 100.23 ± 0.046% (2σ; Condon et al., 2015). All common Pb in the analyses was assumed to be procedural blank yielding a long-term average $^{206}Pb/^{204}Pb$ of 18.469 ± 0.458, $^{207}Pb/^{204}Pb$ of 15.471 ± 0.320, $^{208}Pb/^{204}Pb$ of 38.011 ± 0.484 (uncertainties are given as 2σ) and an average of 0.50 pg during the course of this study. All uncertainties associated with weighted mean $^{206}Pb/^{238}U$ ages are at the 95% confidence level and reported as ±x, with x as analytical uncertainty. The tracer calibration uncertainty (y) of 0.03% has to be added if the calculated dates are to be compared with other U-Pb laboratories not using the EARTHTIME tracer solution. The ^{238}U decay constant uncertainty of 0.05% should be used if compared with other chronometers such as Ar-Ar. All $^{206}Pb/^{238}U$ single grain ages have been corrected for initial ^{230}Th-^{238}U disequilibrium assuming Th/U_{magma} of 3.00 ± 1.00 (2σ). Th-corrected $^{206}Pb/^{238}U$ dates are on average 80 ka older than the equivalent uncorrected dates when applying this correction. The U-Pb isotopic results are presented in Table DR4.

Bowring, J.F., McLean, N.M., and Bowring, S.A., 2011, Engineering cyber infrastructure for U-Pb geochronology: tripoli and U-Pb_Redux: Geochem. Geophy. Geosy., v. 12, Q0AA19, doi:10.1029/2010GC003479.

Condon, D.J., Schoene, B., McLean, N.M., Bowring, S.A., and Parrish, R.R., 2015, Metrology and traceability of U-Pb isotope dilution geochronology (EARTHTIME Tracer Calibration Part I): Geochim. Cosmochim. Ac., v. 164, p. 464-480, doi:10.1016/j.gca.2015.05.026.

Gerstenberger, H., and Haase, G., 1997, A highly effective emitter substance for mass spectrometric Pb isotope ratio determination: Chem. Geol., v. 136, p. 309-312, doi:10.1016/S0009-2541(96)00033-2.

Hiess, J., Condon, D.J., McLean, N.M., and Noble, S.R., 2012, $^{238}U/^{235}U$ Systematics in terrestrial uranium-bearing minerals: Science, v. 335, p. 1610-1614, doi:10.1126/science.1215507.

Krogh, T.E., 1973, A low contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determination: Geochim. Cosmochim. Ac., v. 37, p. 485-494, doi:10.1016/0016-7037(73)90213-5.

Mattinson, J.M., 2005, Zircon U-Pb chemical abrasion ("CA-TIMS") method: combined annealing and multi-step partial dissolution analysis for improved precision and accuracy of zircon ages: Chem. Geol., v. 220, p. 47-66, doi:10.1016/j.chemgeo.2005.03.011.

McLean, N.M., Bowring, J.F., and Bowring, S.A., 2011, An algorithm for U-Pb isotope dilution data reduction and uncertainty propagation: Geochem. Geophy. Geosy., v. 12, Q0AA18, doi:10.1029/2010GC003478.

Table DR4. U-Pb single-grain zircon dates and isotopic data.

	Dates (Ma)					Composition			Isotopic Ratios						
Fraction and sample	206Pb/238U *a °°	±2σ (absolute)	207Pb/235U *a	±2σ (absolute)	Disc. (%) *b	Th/U *c	Pb (pg) *d	Pbc (pg) *e	206Pb/204Pb *f	206Pb/238U *g	±2σ (%)	207Pb/235U *g	±2σ (%)	207Pb/206Pb *g	±2σ (%)
Wuzhuan-7															
WUZ-7.2	253.252	0.162	252.886	0.361	-1.17	0.66	18.77	0.19	5889	0.0401	0.07	0.2828	0.16	0.0512	0.14
WUZ-7.3	253.382	0.515	252.327	0.874	-4.11	0.64	12.83	0.25	2959	0.0401	0.21	0.2821	0.39	0.0511	0.32
WUZ-7.4	254.305	0.566	255.638	5.070	5.37	0.63	19.35	4.04	299	0.0402	0.23	0.2863	2.24	0.0516	2.24
WUZ-7.5	253.861	0.299	253.731	0.494	-0.19	0.64	20.94	0.27	4572	0.0402	0.12	0.2839	0.22	0.0513	0.19
WUZ-7.6	253.384	0.345	253.234	0.498	-0.27	0.63	25.14	0.25	6031	0.0401	0.14	0.2833	0.22	0.0513	0.16
WUZ-7.7	252.554	0.301	252.375	0.585	-0.40	0.68	16.73	0.17	5711	0.0399	0.12	0.2822	0.26	0.0513	0.21
WUZ-7.8	253.099	0.849	252.577	1.004	-1.82	0.64	18.35	0.34	3190	0.0400	0.34	0.2824	0.45	0.0512	0.26
WUZ-7.9	254.452	0.622	252.894	0.958	-6.32	0.62	15.86	0.23	4000	0.0402	0.25	0.2828	0.43	0.0510	0.33
WUZ-7.10	253.086	0.338	252.495	0.525	-2.11	0.62	23.37	0.19	7332	0.0400	0.14	0.2823	0.23	0.0512	0.16
Wuzhuan-4															
WUZ-4.1	252.455	0.107	252.435	0.857	0.22	0.92	13.32	0.40	1827	0.0399	0.04	0.2822	0.38	0.0513	0.37
WUZ-4.2	251.985	0.183	252.096	1.614	0.79	0.62	29.74	1.93	925	0.0398	0.07	0.2818	0.72	0.0513	0.72
WUZ-4.4	252.066	0.269	252.046	1.366	0.26	0.62	8.28	0.39	1278	0.0399	0.11	0.2818	0.61	0.0513	0.58
WUZ-4.5	252.013	0.157	251.899	0.720	-0.11	0.52	20.73	0.45	2791	0.0399	0.06	0.2816	0.32	0.0513	0.29
WUZ-4.6	252.025	0.657	252.115	0.704	0.68	0.80	54.63	0.43	7218	0.0399	0.27	0.2818	0.32	0.0513	0.17
WUZ-4.7	252.024	0.096	251.949	0.521	0.03	0.64	23.62	0.37	3720	0.0399	0.04	0.2816	0.23	0.0513	0.21
WUZ-4.8	253.288	0.194	253.084	1.741	-0.50	0.70	6.79	0.45	892	0.0401	0.08	0.2831	0.78	0.0513	0.77
WUZ-4.9	254.205	0.189	254.031	0.507	-0.40	0.86	12.19	0.14	4771	0.0402	0.08	0.2843	0.23	0.0513	0.19
WUZ-4.10	252.140	0.195	252.226	0.414	0.67	0.71	15.85	0.17	5485	0.0399	0.08	0.2820	0.19	0.0513	0.15
WUZ-4.11	253.131	0.101	253.197	0.667	0.57	0.82	7.43	0.16	2696	0.0400	0.04	0.2832	0.30	0.0513	0.28
Shanmenhai-I															
SHA-I.3	252.429	0.193	252.467	0.936	0.48	0.70	13.62	0.45	1775	0.0399	0.08	0.2823	0.42	0.0513	0.40
SHA-I.4	252.342	0.123	252.262	0.697	0.00	0.69	19.17	0.46	2436	0.0399	0.05	0.2820	0.31	0.0513	0.30
SHA-I.6	253.160	0.171	253.195	0.824	0.46	0.72	19.16	0.49	2267	0.0400	0.07	0.2832	0.37	0.0513	0.35
SHA-I.7	252.380	0.122	252.326	0.389	0.12	0.61	39.98	0.47	5062	0.0399	0.05	0.2821	0.17	0.0513	0.15
SHA-I.8	252.489	0.147	252.500	0.623	0.37	0.67	31.62	0.70	2641	0.0399	0.06	0.2823	0.28	0.0513	0.26
SHA-I.9	252.481	0.135	252.416	0.951	0.06	0.73	19.04	0.60	1839	0.0399	0.05	0.2822	0.43	0.0513	0.41
SHA-I.10	252.848	0.090	252.817	0.539	0.20	0.70	26.15	0.46	3300	0.0400	0.04	0.2827	0.24	0.0513	0.23
SHA-I.13	252.536	0.074	252.625	0.481	0.68	0.77	28.23	0.46	3524	0.0399	0.03	0.2825	0.21	0.0513	0.21
SHA-I.14	253.587	0.360	253.519	0.985	0.06	0.67	15.62	0.45	2034	0.0401	0.14	0.2836	0.44	0.0513	0.39
SHA-I.15	252.363	0.135	252.486	0.398	0.83	0.67	36.42	0.48	4436	0.0399	0.05	0.2823	0.18	0.0513	0.16
Nanem-3															
NAN-3.3	252.406	0.279	251.361	0.562	-4.10	0.67	15.89	0.21	4381	0.0399	0.11	0.2809	0.25	0.0511	0.20
NAN-3.4	253.104	0.171	252.419	0.422	-2.52	0.68	16.44	0.18	5349	0.0400	0.07	0.2822	0.19	0.0512	0.16
NAN-3.5	252.563	0.142	252.159	0.416	-1.33	0.64	26.11	0.31	4950	0.0399	0.06	0.2819	0.19	0.0512	0.17
NAN-3.6	252.507	0.187	252.878	0.563	1.81	0.65	27.00	0.47	3354	0.0399	0.08	0.2828	0.25	0.0514	0.22
NAN-3.7	253.276	0.146	252.785	0.446	-1.70	0.71	24.31	0.29	4909	0.0401	0.06	0.2827	0.20	0.0512	0.17
NAN-3.8	252.386	0.095	252.135	0.289	-0.70	0.67	20.02	0.16	7496	0.0399	0.04	0.2819	0.13	0.0512	0.12
NAN-3.10	252.350	0.207	252.067	0.472	-0.83	0.70	22.91	0.32	4170	0.0399	0.08	0.2818	0.21	0.0512	0.18

Table DR4. U-Pb single-grain zircon dates and isotopic data.

	Dates (Ma)					Composition			Isotopic Ratios						
Fraction and sample	206Pb/238U *a °°	±2σ (absolute)	207Pb/235U *a	±2σ (absolute)	Disc. (%) *b	Th/U *c	Pb (pg) *d	Pbc (pg) *e	206Pb/204Pb *f	206Pb/238U *g	±2σ (%)	207Pb/235U *g	±2σ (%)	207Pb/206Pb *g	±2σ (%)
NAN-3.11	252.581	0.126	252.631	0.793	0.53	0.66	31.29	0.97	1886	0.0399	0.05	0.2825	0.35	0.0513	0.35
NAN-3.12	252.220	0.507	252.329	0.760	0.77	0.68	34.28	0.57	3521	0.0399	0.21	0.2821	0.34	0.0513	0.26
Tienbao-6															
TIE-6.1	251.916	0.297	251.953	0.352	0.48	0.67	48.95	0.35	8239	0.0398	0.12	0.2816	0.16	0.0513	0.14
TIE-6.2	251.954	0.194	252.237	0.988	1.48	0.57	15.35	0.56	1649	0.0398	0.08	0.2820	0.44	0.0514	0.41
TIE-6.3	253.049	0.129	259.628	0.526	21.00	0.59	18.46	0.31	3486	0.0400	0.05	0.2914	0.23	0.0528	0.21
TIE-6.4	253.679	0.152	261.145	0.945	23.03	0.60	12.22	0.36	2017	0.0401	0.06	0.2933	0.41	0.0530	0.38
TIE-6.5	252.655	0.146	252.944	1.062	1.49	0.64	12.90	0.47	1607	0.0400	0.06	0.2829	0.47	0.0514	0.46
TIE-6.6	252.044	0.085	252.006	0.521	0.16	0.82	16.26	0.22	4224	0.0399	0.03	0.2817	0.23	0.0513	0.22
TIE-6.7	252.381	0.139	252.248	0.795	-0.20	0.61	9.50	0.22	2612	0.0399	0.06	0.2820	0.36	0.0513	0.34
TIE-6.8	253.942	0.314	254.012	2.145	0.62	0.56	3.26	0.22	906	0.0402	0.13	0.2842	0.95	0.0513	0.87
Dongpan-21															
DGP 21.2	252.677	0.241	252.499	0.494	-0.38	0.59	52.48	0.51	6089	0.0400	0.10	0.2823	0.22	0.0513	0.18
DGP 21.4	252.715	0.084	252.668	0.412	0.15	0.55	42.44	0.52	4883	0.0400	0.03	0.2825	0.18	0.0513	0.17
DGP 21.5	252.265	0.163	252.503	0.442	1.25	0.95	29.07	0.38	4114	0.0399	0.07	0.2823	0.20	0.0513	0.18
DGP 21.6	252.586	0.117	252.523	0.339	0.07	0.69	43.39	0.44	5721	0.0399	0.05	0.2824	0.15	0.0513	0.13
DGP 21.8	251.908	0.134	251.934	0.875	0.45	0.61	19.59	0.57	2053	0.0398	0.05	0.2816	0.39	0.0513	0.39
DGP 21.10	252.145	0.120	252.108	0.438	0.19	0.62	29.98	0.41	4356	0.0399	0.05	0.2818	0.20	0.0513	0.18
DGP 21.12	251.969	0.229	251.711	0.720	-0.73	0.67	26.37	0.46	3340	0.0398	0.09	0.2813	0.32	0.0512	0.25
DGP 21.13	251.975	0.077	252.032	0.715	0.58	0.52	17.62	0.49	2206	0.0398	0.03	0.2817	0.32	0.0513	0.33
DGP 21.14	252.240	0.157	252.369	0.850	0.84	0.77	13.19	0.40	1877	0.0399	0.06	0.2822	0.38	0.0513	0.37
DGP 21.15	251.929	0.080	251.955	0.694	0.46	0.53	19.68	0.54	2197	0.0398	0.03	0.2816	0.31	0.0513	0.31
DGP 21.17	251.945	0.113	251.963	0.480	0.42	0.56	39.56	0.63	3736	0.0398	0.05	0.2816	0.22	0.0513	0.20
DGP 21.18	251.896	0.230	251.998	1.429	0.75	0.61	11.49	0.61	1119	0.0398	0.09	0.2817	0.64	0.0513	0.60
DGP 21.20	251.976	0.074	252.081	0.523	0.77	0.57	29.35	0.59	2997	0.0398	0.03	0.2818	0.23	0.0513	0.23
DGP 21.21	251.940	0.172	252.109	1.486	1.02	0.62	10.01	0.58	1028	0.0398	0.07	0.2818	0.67	0.0513	0.65
Penglaitan-22															
PEN 22.2	251.909	0.073	251.819	0.444	0.00	0.44	36.92	0.50	4573	0.0398	0.03	0.2815	0.20	0.0513	0.20
PEN 22.3	251.405	0.174	251.671	0.358	1.44	0.43	46.73	0.53	5494	0.0398	0.07	0.2813	0.16	0.0513	0.13
PEN 22.4	251.895	0.080	252.071	0.360	1.09	0.35	38.18	0.46	5207	0.0398	0.03	0.2818	0.16	0.0513	0.14
PEN 22.6	251.910	0.055	252.004	0.366	0.77	0.28	29.59	0.46	4155	0.0398	0.02	0.2817	0.16	0.0513	0.16
PEN 22.7	251.964	0.237	251.667	1.108	-0.86	0.48	13.37	0.51	1614	0.0398	0.10	0.2813	0.50	0.0512	0.46
PEN 22.8	252.166	0.123	252.092	1.220	0.10	0.17	8.09	0.44	1248	0.0399	0.05	0.2818	0.55	0.0513	0.54
PEN 22.9	252.166	0.123	252.210	1.229	0.53	0.55	13.03	0.63	1252	0.0399	0.05	0.2820	0.55	0.0513	0.54
PEN 22.10	251.939	0.156	252.332	1.313	1.93	0.51	14.37	0.72	1229	0.0398	0.06	0.2821	0.59	0.0514	0.57
PEN 22.11	251.891	0.082	251.861	0.715	0.25	0.40	20.94	0.62	2139	0.0398	0.03	0.2815	0.32	0.0513	0.31
PEN 22.12	251.913	0.157	251.527	0.818	-1.19	0.18	6.21	0.14	2866	0.0398	0.06	0.2811	0.37	0.0512	0.33
PEN 22.13	251.923	0.205	251.163	1.490	-2.82	0.35	4.24	0.14	1895	0.0398	0.08	0.2806	0.67	0.0511	0.63
Penglaitan-28															
PEN 28.1	252.511	0.198	251.772	1.001	-2.75	0.60	18.86	0.67	1668	0.0399	0.08	0.2814	0.45	0.0511	0.43

Table DR4. U-Pb single-grain zircon dates and isotopic data.

	Dates (Ma)					Composition			Isotopic Ratios						
Fraction and sample	206Pb/238U *a °°	±2σ (absolute)	207Pb/235U *a	±2σ (absolute)	Disc. (%) *b	Th/U *c	Pb (pg) *d	Pbc (pg) *e	206Pb/204Pb *f	206Pb/238U *g	±2σ (%)	207Pb/235U *g	±2σ (%)	207Pb/206Pb *g	±2σ (%)
PEN 28.2	252.078	0.083	252.151	0.760	0.64	0.59	22.29	0.64	2081	0.0399	0.03	0.2819	0.34	0.0513	0.34
PEN 28.3	252.057	0.106	252.080	0.597	0.43	0.65	25.69	0.52	2916	0.0399	0.04	0.2818	0.27	0.0513	0.25
PEN 28.4	252.096	0.086	252.096	0.536	0.35	0.57	25.37	0.52	2913	0.0399	0.03	0.2818	0.24	0.0513	0.23
PEN 28.5	252.364	0.156	252.603	1.227	1.25	0.96	10.94	0.47	1277	0.0399	0.06	0.2825	0.55	0.0513	0.54
PEN 28.6	252.045	0.119	251.936	1.366	-0.10	0.58	14.53	0.82	1074	0.0399	0.05	0.2816	0.61	0.0513	0.62
PEN 28.7	251.989	0.144	252.023	0.676	0.49	0.56	28.93	0.62	2784	0.0399	0.06	0.2817	0.30	0.0513	0.28
PEN 28.8	252.174	0.367	251.129	2.321	-4.10	0.59	4.11	0.37	680	0.0399	0.15	0.2806	1.04	0.0511	1.02
PEN 28.9	252.430	0.286	252.213	1.763	-0.56	0.69	6.03	0.40	898	0.0399	0.12	0.2820	0.79	0.0512	0.77
PEN 28.10	252.413	0.245	252.919	2.130	2.32	0.80	6.63	0.53	724	0.0399	0.10	0.2829	0.95	0.0514	0.94
PEN 28.11	251.994	0.167	252.168	0.996	1.04	0.63	10.75	0.39	1621	0.0399	0.07	0.2819	0.45	0.0513	0.43
PEN 28.12	252.403	0.284	252.540	1.982	0.89	0.61	6.77	0.52	789	0.0399	0.11	0.2824	0.89	0.0513	0.87
PEN 28.13	253.090	0.375	252.838	2.764	-0.69	0.64	3.87	0.42	559	0.0400	0.15	0.2828	1.24	0.0513	1.22

a Isotopic dates calculated using the decay constants λ238 = 1.55125E-10 and λ235 = 9.8485E-10 (Jaffey et al., 1971).

*b % discordance = 100 - (100 * (206Pb/238U date) / (207Pb/206Pb date)).*

c Th contents calculated from radiogenic 208Pb and the 207Pb/206Pb date of the sample, assuming concordance between U-Th and Pb systems.

d Total mass of radiogenic Pb.

e Total mass of common Pb.

f Measured ratio corrected for fractionation and spike contribution only.

g Measured ratio corrected for fractionation, tracer and blank.

°° Corrected for initial Th/U disequilibrium using radiogenic 208Pb and Th/Umagma = 3.00.

Hafnium isotope analysis in zircon

Hafnium isotope analyses were conducted on a Thermo «Neptune Plus» multicollector-inductively coupled plasma mass spectrometer (MC-ICP-MS) equipped with nickel cones (Thermo "X series") at the University of Geneva, under dry plasma conditions using a Cetac "Aridus 2" desolvation unit and a Teflon nebulizer (~70 µl*min^{-1} uptake rate). The nine Faraday cups were configured to measure the following masses at low mass resolution (m/Δm~450): 172 (L4), 173 (L3), 175 (L2), 176 (L1), 177 (C), 178 (H1), 179 (H2), 180 (H3), 181 (H4). All analytes were diluted in 2% HNO_3 with traces of HF in order to minimize memory effects during analyses and stabilize Hf ions in solution. The certified JMC475 standard used as a reference was run at a concentration of ~10 ppb at the beginning of each measurement campaign. They were doped with variable amounts of Yb (ICP-MS standard solution, Merck KGaA, Germany) with concentrations ranging from 0.5 to 5 ppb (i.e. $0.001<{}^{173}Yb/{}^{177}Hf<0.5$) in order to control the accuracy of the main ^{176}Yb interference correction and monitor the instrument drift. During sample measurement runs, Plešovice zircon (Sláma et al., 2008), dissolved to a 10 ppb Hf concentration and doped with Yb to ca. $^{173}Yb/^{177}Hf\leq0.5$, was used as a reference material in order to account for existing matrix effects (D'Abzac et al., 2016). Samples were prepared from the washes of U-Pb column chemistry after zircons digestion that were dried out and brought into solution using the same batch of 2% HNO_3 than that used for analytes dilution and wash cycles (~400 s between analytes). Measurements included a 60-80 s uptake, baseline control over ~30 s and 330 s (80 cycles of 4.2 s) of analysis, for a total consumption of ~450 µl. The β_{Yb} and β_{Hf} mass bias coefficients were calculated using an exponential law (Albarède et al., 2004) respectively from the measured $^{172}Yb/^{173}Yb$ and $^{179}Hf/^{177}Hf$ and using natural abundances reference values: $^{172}Yb/^{173}Yb=1.3534$ and $^{179}Hf/^{177}Hf=0.7325$ (Blichert-Toft and Albarède, 1997). Mass bias correction on Lu was calculated using β_{Yb} (Yuan et al., 2008) and the isobaric interference of ^{176}Lu was removed using the natural abundances of ^{175}Lu (0.97416) and ^{176}Lu

(0.02584). The isobaric interference of ^{176}Yb is the most significative and was evaluated from Yb doped Plešovice solutions by calculating $^{176}Yb/^{173}Yb$ using β_{Yb} and using a reference value that is chosen for each run by minimizing the drift in corrected $^{176}Hf/^{177}Hf$ ratios for increasing $^{173}Yb/^{177}Yb$, as shown by Fisher et al. (2014). The optimized value for $^{176}Yb/^{173}Yb$ always stays within 0.02% of the Yb isotopic composition measured by Thirwall and Anczkiewicz (2004) (*i.e.* $^{176}Yb/^{173}Yb=0.786956$). Correction for ^{176}Hf in-growth due to ^{176}Lu β^--decay has been calculated using $\lambda^{176}Lu=1.87\times10^{-11}$ $year^{-1}$ (Söderlund et al., 2004; Iizuka and Hirata, 2005) and the age determined in this study by U-Pb dating on the analyzed zircons. The $^{176}Hf/^{177}Hf$ ratio for all Plešovice zircon measurements over the whole campaign is 0.282477 ± 0.000043 (2SD, n=83) which is -0.20 εHf off from the recommended value of 0.282482 (Fig. DR6). The residual offset of the Plešovice zircon was calculated after each measurement session to normalize the εHf values obtained with unknown samples (shown as εHf offset corrected values in Tab. DR5). The external reproducibility (2SD) on Plešovice corresponds to 0.78 εHf and is considered as the most representative uncertainty over the whole dataset (see Tab. DR5).

Albarède, F., Telouk, P., Blichert-Toft, J., Boyet, M., Agranier, A., and Nelson, B., 2004, Precise and accurate isotopic measurements using multiple-collector ICPMS: Geoch. Cosmochim. Ac., v. 68, p. 2725-2744, doi:10.1016/j.gca.2003.11.024.

Blichert-Toft, J., and Albarède, F., 1997, The Lu-Hf isotope geochemistry of chondrites and the evolution of the mantle-crust system: Earth Planet. Sc. Lett., v. 148, p. 243-258, doi:10.1016/S0012-821X(97)00040-X.

D'Abzac, F.X., Davies, J., Wotzlaw, J.F., and Schaltegger, U., 2016, Precise and accurate Hf isotope analysis of small zircon and baddeleyite grains by conventional Multi Collector – Inductively Coupled Plasma – Mass Spectrometry: Chem. Geol., v. 433 p. 12-23, doi:10.1016/j.chemgeo.2016.03.025.

Fisher, C.M., Vervoort, J.D., and Hanchar, J.M., 2014, Guidelines for reporting zircon Hf isotopic data by LA-MC-ICPMS and potential pitfalls in the interpretation of these data: Chem. Geol., v. 363, p. 125-133, doi:10.1016/j.chemgeo.2013.10.019.

Iizuka, T., and Hirata, T., 2005, Improvements of precision and accuracy in in situ Hf isotope microanalysis of zircon using the laser ablation-MC-ICPMS technique: Chem. Geol., v. 220, p. 121-137, doi:10.1016/j.chemgeo.2005.03.010.

Sláma, J., Košler, J., Condon, D.J., Crowley, J.L., Gerdes, A., Hanchar, J.M., Horstwood, M.S.A., Morris, G.A., Nasdala, L., Norberg, N., Schaltegger, U., Schoene, B., Tubrett M.N., and Whitehouse, M.J., 2008, Plešovice zircon - A new natural reference material for U-Pb and Hf isotopic microanalysis: Chem. Geol., v. 249, p. 1-35, doi:10.1016/j.chemgeo.2007.11.005.

Söderlund, U., Patchett, P.J., Vervoort, J.D., and Isachsen, C.E., 2004, The ^{176}Lu decay constant determined by Lu-Hf and U-Pb isotope systematics of Precambrian mafic intrusions: Earth Planet. Sc. Lett., v. 219, p. 311-324, doi:10.1016/S0012-821X(04)00012-3.

Thirlwall, M.F., and Anczkiewicz, R., 2004, Multidynamic isotope ratio analysis using MC-ICP-MS and the causes of secular drift in Hf, Nd and Pb isotope ratios: Int. J. Mass Spectrom., v. 235, p. 59-81, doi:10.1016/j.ijms.2004.04.002.

Yuan, H.-L., Gao, S., Dai, M.-N., Zong, C.-L., Günther, D., Fontaine, G.H., Liu X.-M., and Diwu, C., 2008, Simultaneous determinations of U-Pb age, Hf isotopes and trace element compositions of zircon by excimer laser-ablation quadrupole and multiple-collector ICP-MS: Chem. Geol., v. 247, p. 100-118, doi:10.1016/j.chemgeo.2007.10.003.

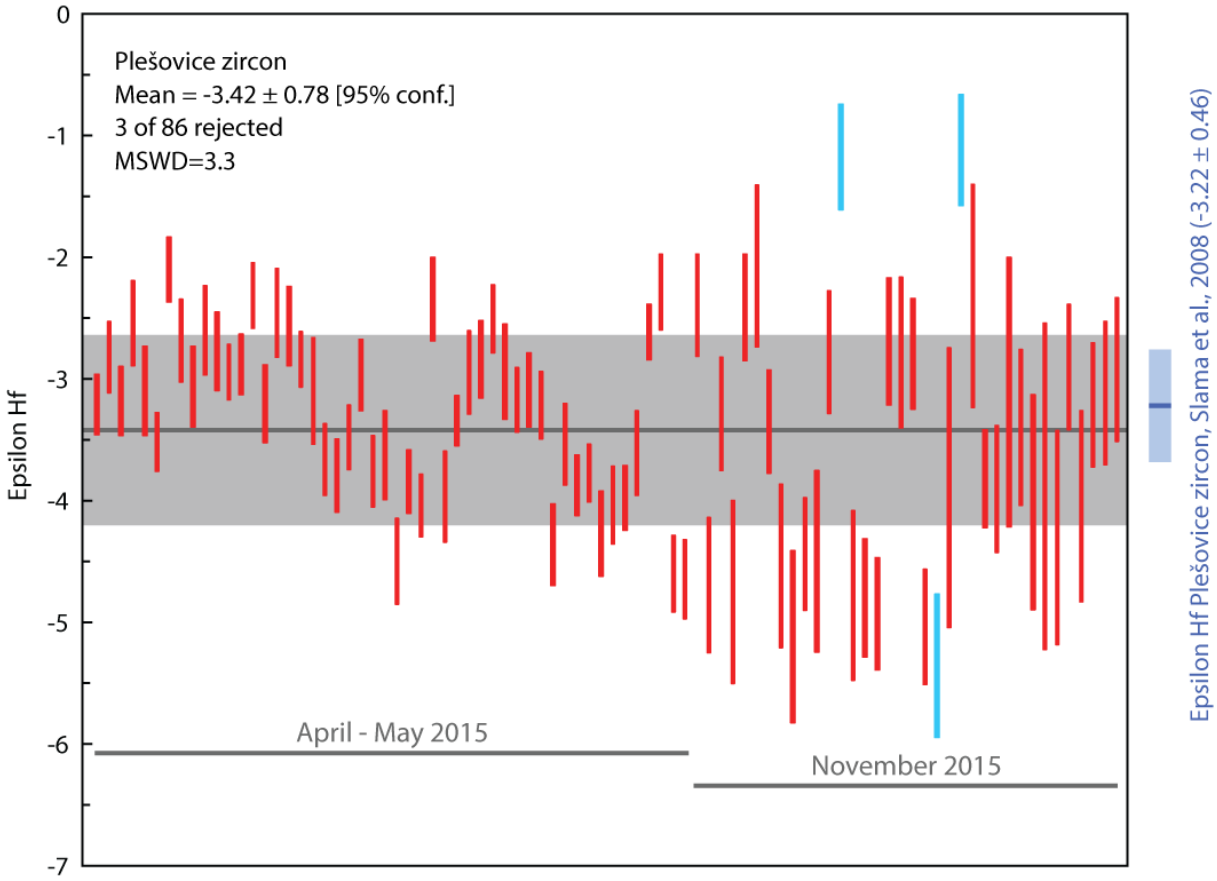

Figure DR6. Hf isotopes analyses of Plešovice reference zircon. Each vertical red bar represents a single analysis including its 2σ analytical uncertainty. The horizontal line through the middle of the population represents the mean, which is surrounded by its 2σ uncertainty (in grey).

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Section: Wuzhuan Ash Bed: WUZ-7										*Section: Wuzhuan Ash Bed: WUZ-4*			
Crystal	*WUZ-7.2*	*WUZ-7.3*	*WUZ-7.4*	*WUZ-7.5*	*WUZ-7.6*	*WUZ-7.7*	*WUZ-7.8*	*WUZ-7.9*	*WUZ-7.10*	*WUZ-4.1*	*WUZ-4.2*	*WUZ-4.4*	*WUZ-4.5*
β Yb	1.809	1.769	1.783	1.807	1.797	1.802	1.774	1.784	1.789	1.772	1.781	1.770	1.771
2σ	1.09E-02	2.45E-02	1.98E-02	1.65E-02	2.06E-02	1.60E-02	1.93E-02	2.12E-02	2.41E-02	1.93E-02	2.06E-02	2.31E-02	1.53E-02
β Hf	1.2700	1.2844	1.2752	1.2778	1.2778	1.2839	1.2860	1.2830	1.2679	1.2890	1.2951	1.2839	1.2910
2σ	1.46E-03	2.40E-03	2.58E-03	1.65E-03	1.76E-03	1.83E-03	1.89E-03	1.88E-03	2.13E-03	2.48E-03	1.41E-03	2.07E-03	2.07E-03
$^{179}Hf/^{177}Hf$	0.7430442	0.7431652	0.7430880	0.7431102	0.7431100	0.7431612	0.7431780	0.7431535	0.7430272	0.7432039	0.7432544	0.7431613	0.7432203
2σ	1.22E-05	2.00E-05	2.16E-05	1.38E-05	1.47E-05	1.53E-05	1.58E-05	1.58E-05	1.78E-05	2.07E-05	1.18E-05	1.73E-05	1.73E-05
$^{178}Hf/^{177}Hf$	1.4884071	1.4885943	1.4884531	1.4884788	1.4884589	1.4886082	1.4886344	1.4885630	1.4883437	1.4887094	1.4887678	1.4886160	1.4887360
2σ	1.82E-05	3.22E-05	2.92E-05	2.40E-05	2.23E-05	2.37E-05	2.96E-05	2.81E-05	2.01E-05	3.02E-05	1.95E-05	2.93E-05	3.67E-05
$^{172}Yb/^{173}Yb$	1.3440327	1.3443463	1.3442374	1.3440497	1.3441279	1.3440827	1.3443052	1.3442281	1.3441905	1.3443212	1.3442478	1.3443351	1.3443255
2σ	8.55E-05	1.91E-04	1.55E-04	1.29E-04	1.61E-04	1.25E-04	1.50E-04	1.65E-04	1.88E-04	1.51E-04	1.61E-04	1.81E-04	1.20E-04
$^{173}Yb/^{177}Hf$	0.0594410	0.0715780	0.0530491	0.0420193	0.0269598	0.0688332	0.0514287	0.0410223	0.0317981	0.0567508	0.0218207	0.0471831	0.0788915
2σ	4.24E-05	4.70E-05	3.14E-05	2.59E-05	1.89E-05	4.01E-05	2.89E-05	2.34E-05	3.92E-05	3.50E-05	1.96E-05	2.82E-05	4.17E-05
$^{176}Lu/^{177}Hf$	0.0014795	0.0018242	0.0014426	0.0011703	0.0007769	0.0018214	0.0014127	0.0011329	0.0009028	0.0015492	0.0005695	0.0012586	0.0020616
2σ	5.86E-07	7.39E-07	6.01E-07	6.30E-07	4.30E-07	1.03E-06	6.17E-07	4.92E-07	1.06E-06	5.86E-07	3.35E-07	3.90E-07	6.94E-07
$^{176}Hf/^{177}Hf$	0.2823554	0.2824148	0.2823879	0.2823854	0.2823776	0.2823676	0.28240718	0.28237691	0.28235738	0.2824222	0.2823644	0.2823334	0.2823873
2σ	6.86E-06	1.37E-05	1.08E-05	9.14E-06	6.36E-06	9.97E-06	9.14E-06	9.80E-06	9.27E-06	1.02E-05	6.23E-06	7.96E-06	1.06E-05
U/Pb Age [Ma]	253.25	253.38	254.30	253.86	253.38	252.55	253.10	254.45	253.09	252.45	251.98	252.07	252.01
$^{176}Hf/^{177}Hf$ (t)	0.2823484	0.2824062	0.2823810	0.2823799	0.2823739	0.2823590	0.2824005	0.2823715	0.2823531	0.2824149	0.2823617	0.2823274	0.2823775
εHf	-9.82	-7.77	-8.64	-8.69	-8.91	-9.46	-7.98	-8.97	-9.65	-7.48	-9.37	-10.58	-8.81
2σ	0.24	0.48	0.38	0.32	0.23	0.35	0.32	0.35	0.33	0.36	0.22	0.28	0.37
εHf corrected	*-9.68*	*-7.63*	*-8.50*	*-8.55*	*-8.77*	*-9.32*	*-7.84*	*-8.83*	*-9.20*	*-7.03*	*-8.92*	*-10.13*	*-8.36*
2 σ	*0.24*	*0.48*	*0.38*	*0.32*	*0.23*	*0.35*	*0.32*	*0.35*	*0.33*	*0.36*	*0.22*	*0.28*	*0.37*

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Section: Wuzhuan Ash Bed: WUZ-4							*Section: Shanmenhai Ash Bed: SHA-I*						
Crystal	*WUZ-4.6*	*WUZ-4.7*	*WUZ-4.8*	*WUZ-4.9*	*WUZ-4.10*	*WUZ-4.11*	*SHA-I.3*	*SHA-I.4*	*SHA-I.6*	*SHA-I.7*	*SHA-I.8*	*SHA-I.9*	*SHA-I.10*
β Yb	1.765	1.700	1.845	1.712	1.755	1.799	1.775	1.826	1.759	1.782	1.724	1.715	1.823
2σ	1.50E-02	2.26E-02	2.98E-02	2.61E-02	2.54E-02	2.41E-02	2.97E-02	1.99E-02	2.00E-02	1.22E-02	2.58E-02	1.19E-01	2.02E-02
β Hf	1.2893	1.2942	1.2819	1.2773	1.2855	1.2870	1.2848	1.2897	1.2928	1.2897	1.2875	1.2743	1.2856
2σ	1.85E-03	1.98E-03	3.84E-03	2.72E-03	2.33E-03	2.01E-03	3.45E-03	2.03E-03	2.50E-03	1.52E-03	1.91E-03	7.64E-03	2.14E-03
$^{179}Hf/^{177}Hf$	0.7432061	0.7432475	0.7431439	0.7431058	0.7431745	0.7431870	0.7431685	0.7432098	0.7432352	0.7432094	0.7431910	0.7430803	0.7431750
2σ	1.55E-05	1.65E-05	3.21E-05	2.28E-05	1.95E-05	1.68E-05	2.88E-05	1.70E-05	2.09E-05	1.27E-05	1.60E-05	6.39E-05	1.79E-05
$^{178}Hf/^{177}Hf$	1.4886900	1.4887624	1.4886070	1.4884641	1.4886393	1.4886485	1.4886250	1.4886793	1.4888033	1.4886825	1.4886417	1.4884569	1.4886375
2σ	2.48E-05	2.33E-05	4.49E-05	2.87E-05	3.67E-05	2.30E-05	3.34E-05	3.06E-05	4.18E-05	1.75E-05	2.10E-05	1.11E-04	2.88E-05
$^{172}Yb/^{173}Yb$	1.3443783	1.3448827	1.3437528	1.3447891	1.3444560	1.3441113	1.3442957	1.3438983	1.3444225	1.3442441	1.3446931	1.3447672	1.3439201
2σ	1.17E-04	1.76E-04	2.33E-04	2.04E-04	1.98E-04	1.88E-04	2.32E-04	1.55E-04	1.56E-04	9.55E-05	2.02E-04	9.27E-04	1.58E-04
$^{173}Yb/^{177}Hf$	0.0450503	0.0309313	0.0674588	0.0378075	0.0564104	0.0386065	0.0575105	0.0495966	0.0728613	0.0360579	0.0249542	0.0786606	0.0474587
2σ	2.17E-05	1.63E-05	3.60E-05	2.09E-05	4.38E-05	4.97E-05	2.58E-05	2.92E-05	5.11E-05	1.74E-05	2.31E-05	7.11E-05	2.99E-05
$^{176}Lu/^{177}Hf$	0.0011907	0.0007950	0.0018691	0.0010383	0.0014692	0.0010671	0.0015806	0.0013405	0.0019552	0.0009529	0.0006329	0.0020677	0.0012479
2σ	5.04E-07	2.12E-07	1.05E-06	3.91E-07	9.71E-07	6.49E-07	1.06E-06	1.22E-06	2.54E-06	3.20E-07	3.60E-07	1.51E-06	6.54E-07
$^{176}Hf/^{177}Hf$	0.2823262	0.28240502	0.28225614	0.28248226	0.28239894	0.28242926	0.2823842	0.2823455	0.2824816	0.2823808	0.2823964	0.2824892	0.2823480
2σ	9.52E-06	9.25E-06	2.00E-05	1.11E-05	1.38E-05	9.71E-06	1.49E-05	1.20E-05	1.32E-05	7.11E-06	7.91E-06	5.60E-05	9.84E-06
U/Pb Age [Ma]	252.02	252.02	253.29	254.21	252.14	253.13	252.43	252.34	253.16	252.38	252.49	252.48	252.85
$^{176}Hf/^{177}Hf$ (t)	0.2823206	0.2824013	0.2822473	0.2824773	0.2823920	0.2824242	0.2823768	0.2823391	0.2824723	0.2823763	0.2823935	0.2824795	0.2823421
εHf	-10.83	-7.97	-13.39	-5.23	-8.30	-7.14	-8.83	-10.16	-5.43	-8.85	-8.24	-5.19	-10.05
2σ	0.34	0.33	0.71	0.39	0.49	0.34	0.53	0.42	0.47	0.25	0.28	1.98	0.35
εHf corrected	*-10.38*	*-7.52*	*-12.94*	*-4.78*	*-7.85*	*-6.69*	*-8.38*	*-9.71*	*-4.98*	*-8.40*	*-7.79*	*-4.74*	*-9.60*
2 σ	*0.34*	*0.33*	*0.71*	*0.39*	*0.49*	*0.34*	*0.53*	*0.42*	*0.47*	*0.25*	*0.28*	*1.98*	*0.35*

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Section: Shanmenhai Ash Bed: SHA-I					*Section: Nanem Ash Bed: NAN-3*								
Crystal	*SHA-I.10*	*SHA-I.13*	*SHA-I.14*	*SHA-I.15*	*NAN-3.3*	*NAN-3.4*	*NAN-3.5*	*NAN-3.6*	*NAN-3.7*	*NAN-3.8*	*NAN-3.10*	*NAN-3.11*	*NAN-3.12*
β Yb	1.823	1.808	1.867	1.809	1.781	1.790	1.769	1.689	1.733	1.721	1.773	1.792	1.644
2σ	2.02E-02	2.25E-02	2.07E-02	1.73E-02	2.45E-02	2.10E-02	2.41E-02	2.48E-02	1.39E-02	1.59E-02	1.48E-02	1.19E-02	1.79E-02
β Hf	1.2856	1.2924	1.2914	1.2911	1.2979	1.2892	1.2944	1.2989	1.2966	1.2957	1.2958	1.2712	1.1905
2σ	2.14E-03	2.07E-03	1.96E-03	1.70E-03	2.40E-03	1.98E-03	2.00E-03	1.60E-03	1.50E-03	1.74E-03	1.61E-03	1.26E-03	4.06E-03
$^{179}Hf/^{177}Hf$	0.7431750	0.7432319	0.7432239	0.7432211	0.7432784	0.7432050	0.7432486	0.7432865	0.7432671	0.7432599	0.7432607	0.7430543	0.7423800
2σ	1.79E-05	1.73E-05	1.64E-05	1.42E-05	2.01E-05	1.65E-05	1.67E-05	1.34E-05	1.25E-05	1.45E-05	1.35E-05	1.05E-05	3.39E-05
$^{178}Hf/^{177}Hf$	1.4886375	1.4887428	1.4887014	1.4886933	1.4888224	1.4886623	1.4887721	1.4888387	1.4887775	1.4887848	1.4887712	1.4884198	1.4868424
2σ	2.88E-05	2.56E-05	2.96E-05	2.29E-05	3.34E-05	3.04E-05	1.99E-05	2.38E-05	1.98E-05	2.27E-05	2.48E-05	1.61E-05	3.36E-05
$^{172}Yb/^{173}Yb$	1.3439201	1.3440393	1.3435823	1.3440301	1.3442469	1.3441809	1.3443447	1.3449728	1.3446276	1.3447223	1.3443096	1.3441665	1.3453231
2σ	1.58E-04	1.75E-04	1.62E-04	1.35E-04	1.92E-04	1.64E-04	1.88E-04	1.93E-04	1.08E-04	1.24E-04	1.16E-04	9.32E-05	1.40E-04
$^{173}Yb/^{177}Hf$	0.0474587	0.0392275	0.0450859	0.0457893	0.0482352	0.0506411	0.0252071	0.0235290	0.0361678	0.0512659	0.0404975	0.0373252	0.0882636
2σ	2.99E-05	2.14E-05	1.95E-05	2.11E-05	5.10E-05	3.78E-05	1.11E-05	1.53E-05	1.90E-05	3.80E-05	1.69E-05	3.02E-05	1.49E-04
$^{176}Lu/^{177}Hf$	0.0012479	0.0010270	0.0011926	0.0011620	0.0012824	0.0013685	0.0006768	0.0006243	0.0009451	0.0013501	0.0010560	0.0010126	0.0022157
2σ	6.54E-07	4.86E-07	4.51E-07	3.58E-07	2.22E-06	5.16E-07	2.44E-07	3.14E-07	5.45E-07	8.73E-07	5.54E-07	8.83E-07	2.40E-06
$^{176}Hf/^{177}Hf$	0.2823480	0.2823796	0.2823302	0.2823653	0.2824127	0.2823794	0.2823904	0.2824287	0.2824295	0.2824612	0.2824015	0.2823824	0.2824283
2σ	9.84E-06	9.75E-06	1.01E-05	8.59E-06	1.16E-05	1.04E-05	8.00E-06	9.15E-06	6.43E-06	8.05E-06	7.79E-06	5.62E-06	1.08E-05
U/Pb Age [Ma]	252.85	252.54	253.59	252.36	252.41	253.10	252.56	252.51	253.28	252.39	252.35	252.58	252.22
$^{176}Hf/^{177}Hf$ (t)	0.2823421	0.2823747	0.2823245	0.2823598	0.2824067	0.2823729	0.2823872	0.2824258	0.2824250	0.2824548	0.2823965	0.2823777	0.2824178
εHf	-10.05	-8.90	-10.65	-9.43	-7.77	-8.95	-8.46	-7.10	-7.10	-6.07	-8.13	-8.80	-7.38
2σ	0.35	0.35	0.36	0.30	0.41	0.37	0.28	0.32	0.23	0.28	0.28	0.20	0.38
εHf corrected	*-9.60*	*-8.45*	*-10.20*	*-8.98*	*-7.63*	*-8.81*	*-8.32*	*-6.96*	*-6.96*	*-5.93*	*-7.99*	*-8.66*	*-6.60*
2 σ	*0.35*	*0.35*	*0.36*	*0.30*	*0.41*	*0.37*	*0.28*	*0.32*	*0.23*	*0.28*	*0.28*	*0.20*	*0.38*

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Section: Tienbao Ash Bed: TIE-6						*Section: Dongpan Ash Bed: DGP-18*							
Crystal	*TIE-6.1*	*TIE-6.2*	*TIE-6.3*	*TIE-6.4*	*TIE-6.6*	*DGP-18.1*	*DGP-18.2*	*DGP-18.3*	*DGP-18.4*	*DGP-18.5*	*DGP-18.6*	*DGP-18.7*	*DGP-18.8*
β Yb	1.456	1.379	1.808	1.552	1.701	1.792	1.768	1.780	1.703	1.793	1.792	1.716	0.861
2σ	8.16E-02	2.60E-01	3.41E-02	4.72E-02	5.68E-02	2.44E-02	8.71E-02	3.81E-02	4.84E-02	3.74E-02	1.91E-02	5.02E-02	9.20E-01
β Hf	1.3341	1.3558	1.3433	1.3438	1.3406	1.3161	1.3159	1.3214	1.3069	1.3126	1.3103	1.3040	1.2717
2σ	3.20E-03	8.82E-03	3.11E-03	4.24E-03	3.23E-03	2.94E-03	4.23E-03	3.54E-03	4.67E-03	2.92E-03	2.40E-03	3.45E-03	7.84E-03
$^{179}Hf/^{177}Hf$	0.7435804	0.7437626	0.7436578	0.7436619	0.7436355	0.7434300	0.7434286	0.7434744	0.7433533	0.7434013	0.7433818	0.7433288	0.7430587
2σ	2.67E-05	7.38E-05	2.60E-05	3.55E-05	2.71E-05	2.46E-05	3.54E-05	2.96E-05	3.90E-05	2.44E-05	2.01E-05	2.89E-05	6.55E-05
$^{178}Hf/^{177}Hf$	1.4891379	1.4898700	1.4891129	1.4896431	1.4891252	1.4891301	1.4891393	1.4892470	1.4889847	1.4891075	1.4890251	1.4889544	1.4883433
2σ	5.56E-05	1.14E-04	4.68E-05	5.86E-05	5.79E-05	3.74E-05	6.05E-05	3.90E-05	5.83E-05	4.87E-05	3.12E-05	5.67E-05	1.02E-04
$^{172}Yb/^{173}Yb$	1.3467926	1.3473935	1.3440420	1.3460378	1.3448734	1.3441662	1.3443493	1.3442543	1.3448586	1.3441574	1.3441650	1.3447556	1.3514533
2σ	6.38E-04	2.03E-03	2.66E-04	3.69E-04	4.44E-04	1.91E-04	6.80E-04	2.97E-04	3.78E-04	2.92E-04	1.49E-04	3.92E-04	7.23E-03
$^{173}Yb/^{177}Hf$	0.0195355	0.0316433	0.0602414	0.0417401	0.0397529	0.0633242	0.0361433	0.0551858	0.0553807	0.0613056	0.0693336	0.0477197	0.0092296
2σ	1.68E-04	8.89E-05	4.74E-04	1.88E-04	3.28E-04	7.07E-05	7.19E-05	4.78E-05	3.17E-05	5.70E-05	3.07E-05	4.59E-05	5.07E-05
$^{176}Lu/^{177}Hf$	0.0004225	0.0007601	0.0012788	0.0010293	0.0008688	0.0017198	0.0009963	0.0015059	0.0015396	0.0016674	0.0017878	0.0013109	0.0002443
2σ	1.60E-06	1.82E-06	6.31E-06	2.77E-06	3.24E-06	1.19E-06	1.31E-06	1.21E-06	8.12E-07	1.53E-06	5.07E-07	1.26E-06	8.35E-07
$^{176}Hf/^{177}Hf$	0.2823984	0.2823275	0.2822952	0.2824408	0.2823294	0.2823867	0.2823607	0.2823990	0.2824328	0.2823418	0.2823656	0.2823917	0.2823964
2σ	1.43E-05	4.28E-05	1.91E-05	2.00E-05	2.10E-05	1.39E-05	2.69E-05	1.66E-05	2.80E-05	1.94E-05	1.16E-05	2.28E-05	3.93E-05
U/Pb Age [Ma]	251.92	251.95	253.05	253.68	252.04	253.253	254.900	257.274	255.159	254.752	252.559	256.837	253.456
$^{176}Hf/^{177}Hf$ (t)	0.2823964	0.2823240	0.2822891	0.2824359	0.2823253	0.2823785	0.2823559	0.2823917	0.2824255	0.2823339	0.2823572	0.2823854	0.2823952
εHf	- 8.15	-10.71	-11.92	-6.71	-10.66	-8.75	-9.51	-8.19	-7.04	-10.29	-9.52	-8.43	-8.15
2σ	0.50	1.51	0.68	0.71	0.74	0.49	0.95	0.59	0.99	0.69	0.41	0.81	1.39
εHf corrected	*- 7.95*	*-10.51*	*-11.72*	*-6.51*	*-10.46*	*-9.09*	*-9.85*	*-8.53*	*-7.38*	*-10.63*	*-9.86*	*-8.77*	*-8.39*
2 σ	*0.50*	*1.51*	*0.68*	*0.71*	*0.74*	*0.49*	*0.95*	*0.59*	*0.99*	*0.69*	*0.41*	*0.81*	*1.39*

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Section: Dongpan Ash Bed: DGP-21

Crystal	*DGP-21.2*	*DGP-21.4*	*DGP-21.5*	*DGP-21.6*	*DGP-21.8*	*DGP-21.10*	*DGP-21.12*	*DGP-21.13*	*DGP-21.14*	*DGP-21.15*	*DGP-21.17*	*DGP-21.18*	*DGP-21.20*	*DGP-21.21*
β Yb	1.747	1.749	1.757	1.766	1.794	1.828	1.791	1.765	1.790	1.760	1.732	1.775	1.705	1.804
2σ	1.03E-02	1.30E-02	1.67E-02	1.40E-02	6.84E-02	1.69E-02	2.92E-02	2.45E-02	3.33E-02	2.51E-02	3.70E-02	2.70E-02	1.94E-02	2.82E-02
β Hf	1.2223	1.2299	1.2366	1.2652	1.3018	1.2668	1.3066	1.3176	1.2777	1.2684	1.3187	1.3119	1.3245	1.3104
2σ	4.13E-03	4.60E-03	4.29E-03	5.53E-03	4.66E-03	3.54E-03	2.34E-03	2.46E-03	6.34E-03	3.82E-03	1.84E-03	2.75E-03	1.62E-03	2.52E-03
$^{179}Hf/^{177}Hf$	0.7426458	0.7427098	0.7427653	0.7430049	0.7433105	0.7430183	0.7433507	0.7434430	0.7431088	0.7430314	0.7434519	0.7433954	0.7435006	0.7433829
2σ	3.45E-05	3.84E-05	3.59E-05	4.63E-05	3.90E-05	2.96E-05	1.96E-05	2.06E-05	5.30E-05	3.19E-05	1.54E-05	2.30E-05	1.35E-05	2.11E-05
$^{178}Hf/^{177}Hf$	1.4873854	1.4875106	1.4876433	1.4881891	1.4889182	1.4882587	1.4889486	1.4891400	1.4885629	1.4883837	1.4891175	1.4890605	1.4891983	1.4890437
2σ	4.08E-05	4.51E-05	4.31E-05	5.97E-05	6.05E-05	4.45E-05	3.94E-05	3.60E-05	7.10E-05	5.04E-05	2.60E-05	3.51E-05	2.28E-05	4.02E-05
$^{172}Yb/^{173}Yb$	1.3445168	1.3445009	1.3444343	1.3443638	1.3441459	1.3438840	1.3441704	1.3443764	1.3441804	1.3444113	1.3446356	1.3443002	1.3448438	1.3440677
2σ	8.07E-05	1.01E-04	1.31E-04	1.10E-04	5.34E-04	1.32E-04	2.28E-04	1.92E-04	2.60E-04	1.96E-04	2.89E-04	2.11E-04	1.52E-04	2.20E-04
$^{173}Yb/^{177}Hf$	0.0648259	0.0800283	0.0696894	0.1035678	0.0467718	0.0564602	0.0413647	0.0418073	0.0762746	0.0894097	0.0186431	0.0468706	0.0309819	0.0643277
2σ	1.19E-04	1.71E-04	1.60E-04	3.35E-04	3.51E-05	1.53E-04	4.27E-05	1.91E-05	2.50E-04	3.76E-05	1.30E-05	4.36E-05	3.13E-05	6.37E-05
$^{176}Lu/^{177}Hf$	0.0016146	0.0019985	0.0017335	0.0023520	0.0013067	0.0012879	0.0011209	0.0011665	0.0018873	0.0024236	0.0005192	0.0012708	0.0008458	0.0017728
2σ	2.67E-06	2.45E-06	3.62E-06	4.24E-06	1.27E-06	2.46E-06	9.38E-07	7.46E-07	3.79E-06	1.29E-06	3.62E-07	7.69E-07	9.18E-07	1.09E-06
$^{176}Hf/^{177}Hf$	0.2825167	0.2825599	0.2823154	0.2826019	0.2825514	0.2824913	0.2826666	0.28263641	0.28252955	0.28242724	0.28262492	0.28258612	0.28263412	0.28261116
2σ	7.18E-06	8.64E-06	9.71E-06	1.18E-05	2.37E-05	8.82E-06	1.49E-05	9.54E-06	2.23E-05	1.84E-05	7.93E-06	1.35E-05	7.76E-06	1.33E-05
U/Pb Age [Ma]	252.677	252.715	252.265	252.586	251.908	252.145	251.969	251.975	252.240	251.929	251.945	251.896	251.976	251.940
$^{176}Hf/^{177}Hf$ (t)	0.2825091	0.2825505	0.2823072	0.2825908	0.2825452	0.2824852	0.2826613	0.2826309	0.2825206	0.2824158	0.2826225	0.2825801	0.2826301	0.2826028
εHf	-4.14	-2.68	-11.29	-1.25	-2.88	-5.00	1.23	0.15	-3.74	-7.46	-0.15	-1.64	0.13	-0.84
2σ	0.25	0.31	0.34	0.42	0.84	0.31	0.53	0.34	0.79	0.65	0.28	0.48	0.27	0.47
εHf corrected	*-3.36*	*-1.90*	*-10.51*	*-1.05*	*-3.22*	*-4.80*	*0.89*	*-0.19*	*-3.54*	*-7.70*	*-0.49*	*-1.98*	*-0.21*	*-1.18*
2 σ	*0.25*	*0.31*	*0.34*	*0.42*	*0.84*	*0.31*	*0.53*	*0.34*	*0.79*	*0.65*	*0.28*	*0.48*	*0.27*	*0.47*

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Section: Penglaitan Ash Bed: PEN-28

Crystal	*PEN-28.1*	*PEN-28.2*	*PEN-28.3*	*PEN-28.4*	*PEN-28.5*	*PEN-28.6*	*PEN-28.7*	*PEN-28.8*	*PEN-28.9*	*PEN-28.10*	*PEN-28.11*	*PEN-28.12*	*PEN-28.13*
β Yb	1.739	1.780	1.812	1.833	1.813	1.673	1.789	1.717	1.851	1.720	1.866	1.842	1.776
2σ	3.70E-02	2.80E-02	2.16E-02	1.53E-02	2.50E-02	3.87E-02	2.44E-02	5.01E-02	3.21E-02	3.84E-02	3.30E-02	3.34E-02	3.75E-02
β Hf	1.3116	1.3184	1.3132	1.3176	1.3067	1.3146	1.3081	1.3163	1.2927	1.2935	1.2980	1.2929	1.2839
2σ	1.71E-03	1.98E-03	2.65E-03	1.76E-03	2.54E-03	2.34E-03	2.45E-03	3.10E-03	3.49E-03	2.84E-03	3.07E-03	2.48E-03	2.93E-03
$^{179}Hf/^{177}Hf$	0.7433928	0.7434496	0.7434060	0.7434432	0.7433513	0.7434175	0.7433635	0.7434322	0.7432349	0.7432415	0.7432785	0.7432359	0.7431607
2σ	1.43E-05	1.66E-05	2.22E-05	1.48E-05	2.12E-05	1.96E-05	2.05E-05	2.60E-05	2.92E-05	2.38E-05	2.57E-05	2.07E-05	2.45E-05
$^{178}Hf/^{177}Hf$	1.4890216	1.4891295	1.4890750	1.4891374	1.4890359	1.4890306	1.4889958	1.4891122	1.4888011	1.4887399	1.4888714	1.4887417	1.4885866
2σ	2.91E-05	2.49E-05	3.46E-05	2.20E-05	2.81E-05	2.79E-05	3.09E-05	4.74E-05	5.19E-05	4.70E-05	4.36E-05	3.18E-05	4.19E-05
$^{172}Yb/^{173}Yb$	1.3445751	1.3442604	1.3440062	1.3438457	1.3440034	1.3450944	1.3441855	1.3447505	1.3437025	1.3447244	1.3435834	1.3437712	1.3442882
2σ	2.89E-04	2.18E-04	1.68E-04	1.20E-04	1.95E-04	3.02E-04	1.91E-04	3.92E-04	2.51E-04	3.00E-04	2.58E-04	2.61E-04	2.93E-04
$^{173}Yb/^{177}Hf$	0.0219946	0.0327752	0.0538741	0.0480723	0.0488917	0.0276061	0.0436691	0.0507510	0.0751884	0.0541319	0.0573603	0.0404139	0.0561263
2σ	1.73E-05	1.99E-05	3.71E-05	3.69E-05	1.75E-05	2.08E-05	2.46E-05	2.77E-05	4.04E-05	3.55E-05	5.52E-05	2.55E-05	1.15E-04
$^{176}Lu/^{177}Hf$	0.0006058	0.0008810	0.0014320	0.0012786	0.0013557	0.0007572	0.0011860	0.0013995	0.0020324	0.0015373	0.0015521	0.0011128	0.0015730
2σ	3.64E-07	4.13E-07	1.01E-06	5.86E-07	3.70E-07	3.55E-07	4.30E-07	6.48E-07	9.13E-07	7.03E-07	1.05E-06	8.15E-07	1.16E-06
$^{176}Hf/^{177}Hf$	0.2823544	0.2824179	0.2823662	0.2823812	0.2824197	0.2824425	0.2823489	0.28245026	0.28227462	0.28248675	0.28232967	0.28233005	0.28233097
2σ	9.38E-06	9.37E-06	1.27E-05	9.54E-06	1.08E-05	1.18E-05	1.15E-05	2.37E-05	2.22E-05	1.83E-05	1.76E-05	1.30E-05	1.68E-05
U/Pb Age [Ma	252.51	252.08	252.06	252.10	252.36	252.04	251.99	252.17	252.43	252.41	251.99	252.40	253.09
$^{176}Hf/^{177}Hf$ (t)	0.2823515	0.2824137	0.2823594	0.2823752	0.2824133	0.2824389	0.2823433	0.2824437	0.2822650	0.2824795	0.2823223	0.2823248	0.2823235
εHf	-9.72	-7.53	-9.45	-8.89	-7.54	-6.64	-10.02	-6.47	-12.78	-5.20	-10.77	-10.67	-10.70
2σ	0.33	0.33	0.45	0.34	0.38	0.42	0.41	0.84	0.79	0.65	0.62	0.46	0.59
εHf corrected	*-10.06*	*-7.87*	*-9.79*	*-9.23*	*-7.88*	*-6.98*	*-10.36*	*-6.81*	*-12.64*	*-5.06*	*-10.63*	*-10.53*	*-10.56*
2 σ	*0.33*	*0.33*	*0.45*	*0.34*	*0.38*	*0.42*	*0.41*	*0.84*	*0.79*	*0.65*	*0.62*	*0.46*	*0.59*

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Section: Penglaitan Ash Bed: PEN-22

Crystal	*PEN 22.2*	*PEN 22.3*	*PEN 22.4*	*PEN 22.6*	*PEN 22.7*	*PEN 22.8*	*PEN 22.9*	*PEN 22.10*	*PEN 22.11*	*PEN 22.12*	*PEN 22.13*
β Yb	1.686	1.537	1.806	1.383	1.431	1.729	1.495	1.633	1.723	1.431	1.673
2σ	3.24E-02	9.22E-02	2.83E-02	1.10E-01	4.89E-01	9.48E-02	1.01E-01	4.25E-02	3.42E-02	2.45E-01	1.71E-01
β Hf	1.2850	1.2897	1.2994	1.3077	1.3224	1.3144	1.3145	1.3131	1.3164	1.3075	1.3077
2σ	2.18E-03	4.27E-03	1.91E-03	2.76E-03	5.20E-03	4.04E-03	5.96E-03	2.93E-03	2.96E-03	1.06E-02	8.24E-03
$^{179}Hf/^{177}Hf$	0.7431705	0.7432092	0.7432907	0.7433597	0.7434830	0.7434162	0.7434170	0.7434053	0.7434332	0.7433582	0.7433601
2σ	1.82E-05	3.57E-05	1.60E-05	2.31E-05	4.35E-05	3.38E-05	4.98E-05	2.45E-05	2.48E-05	8.84E-05	6.90E-05
$^{178}Hf/^{177}Hf$	1.4886215	1.4886956	1.4888607	1.4889940	1.4892232	1.4890907	1.4892369	1.4891067	1.4891373	1.4887140	1.4891021
2σ	3.20E-05	3.00E-05	2.40E-05	3.65E-05	5.41E-05	6.01E-05	7.54E-05	3.58E-05	4.04E-05	1.41E-04	1.15E-04
$^{172}Yb/^{173}Yb$	1.3449946	1.3461537	1.3440553	1.3473658	1.3512154	1.3446540	1.3464859	1.3454084	1.3447004	1.3482212	1.3450976
2σ	2.53E-04	7.21E-04	2.21E-04	8.61E-04	3.84E-03	7.40E-04	7.90E-04	3.33E-04	2.67E-04	1.92E-03	1.34E-03
$^{173}Yb/^{177}Hf$	0.0249165	0.0058316	0.0423179	0.0107878	0.0075305	0.0272089	0.0493208	0.0262059	0.0507895	0.0406888	0.0432775
2σ	4.59E-05	2.86E-05	1.77E-05	7.23E-06	2.65E-05	2.24E-05	8.88E-05	2.97E-05	4.52E-05	1.88E-04	1.28E-04
$^{176}Lu/^{177}Hf$	0.0006034	0.0001496	0.0011776	0.0003017	0.0002175	0.0007383	0.0014693	0.0007149	0.0013822	0.0012289	0.0012321
2σ	5.65E-07	1.66E-07	6.17E-07	1.36E-07	4.43E-07	6.50E-07	1.66E-06	1.03E-06	1.36E-06	1.53E-06	1.26E-06
$^{176}Hf/^{177}Hf$	0.2823666	0.2823216	0.2823340	0.2823729	0.2823470	0.282291	0.2824303	0.282391	0.2823974	0.2824488	0.2823355
2σ	1.03E-05	1.54E-05	8.75E-06	1.33E-05	2.82E-05	2.68E-05	3.50E-05	1.43E-05	1.51E-05	6.61E-05	5.93E-05
U/Pb Age [Ma]	251.82	251.31	251.80	251.81	251.88	251.85	252.07	252.08	251.80	251.81	251.83
$^{176}Hf/^{177}Hf$ (t)	0.2823638	0.2823209	0.2823284	0.2823715	0.2823460	0.2822875	0.2824233	0.2823876	0.2823909	0.2824430	0.2823297
εHf	-9.30	-10.83	-10.55	-9.03	-9.93	-12.00	-7.19	-8.45	-8.34	-6.50	-10.51
2σ	0.36	0.54	0.31	0.47	1.00	0.95	1.24	0.51	0.53	2.34	2.10
εHf corrected	*-9.64*	*-11.17*	*-10.89*	*-9.37*	*-10.27*	*-12.34*	*-7.53*	*-8.79*	*-8.68*	*-6.84*	*-10.85*
2 σ	*0.36*	*0.54*	*0.31*	*0.47*	*1.00*	*0.95*	*1.24*	*0.51*	*0.53*	*2.34*	*2.10*

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Plešovice Zircon

Analysis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
β Yb	1.588	1.703	1.727	1.728	1.741	1.687	1.754	1.775	1.790	1.812	1.797	1.685	1.693	1.754
2σ	6.36E-02	1.40E-02	9.18E-03	5.66E-03	5.70E-03	6.11E-02	1.50E-02	7.99E-03	4.85E-03	4.18E-03	7.11E-03	5.16E-02	5.96E-02	1.53E-02
β Hf	1.2343	1.2101	1.2277	1.2266	1.2369	1.2429	1.2720	1.2864	1.2892	1.3100	1.3015	1.3136	1.2930	1.2798
2σ	1.79E-03	1.85E-03	1.66E-03	1.81E-03	1.45E-03	1.50E-03	1.51E-03	1.64E-03	1.55E-03	1.39E-03	1.57E-03	1.60E-03	1.61E-03	1.93E-03
$^{179}Hf/^{177}Hf$	0.7427461	0.7425437	0.7426913	0.7426821	0.7427675	0.7428177	0.7430617	0.7431821	0.7432052	0.7433796	0.7433084	0.7434090	0.7432374	0.7431268
2σ	1.50E-05	1.55E-05	1.38E-05	1.52E-05	1.21E-05	1.26E-05	1.26E-05	1.37E-05	1.30E-05	1.16E-05	1.32E-05	1.34E-05	1.35E-05	1.61E-05
$^{178}Hf/^{177}Hf$	1.4878025	1.4873865	1.4877143	1.4876692	1.4878415	1.4879637	1.4884115	1.4886753	1.4887068	1.4890540	1.4889121	1.4890939	1.4887991	1.4885640
2σ	2.15E-05	1.99E-05	2.50E-05	2.19E-05	2.25E-05	2.00E-05	2.26E-05	2.11E-05	1.83E-05	2.30E-05	2.07E-05	2.18E-05	1.82E-05	2.32E-05
$^{172}Yb/^{173}Yb$	1.3457585	1.3448601	1.3446760	1.3446610	1.3445653	1.3449873	1.3444642	1.3442936	1.3441815	1.3440106	1.3441243	1.3450043	1.3449404	1.3444618
2σ	4.97E-04	1.09E-04	7.17E-05	4.42E-05	4.45E-05	4.77E-04	1.17E-04	6.24E-05	3.79E-05	3.27E-05	5.55E-05	4.03E-04	4.65E-04	1.19E-04
$^{173}Yb/^{177}Hf$	0.0077441	0.0470355	0.1186119	0.2294550	0.2295059	0.0076444	0.0484950	0.1220400	0.2374410	0.2432124	0.1264653	0.0082343	0.0079544	0.0487011
2σ	8.43E-06	3.54E-05	6.30E-05	9.11E-05	4.81E-05	1.00E-05	1.56E-05	3.56E-05	4.64E-05	1.36E-04	9.13E-05	8.70E-06	1.28E-05	6.16E-05
$^{176}Lu/^{177}Hf$	0.0001382	0.0001503	0.0001477	0.0001443	0.0001447	0.0001396	0.0001461	0.0001451	0.0001461	0.0001456	0.0001422	0.0001421	0.0001411	0.0001532
2σ	6.34E-08	1.84E-07	7.76E-08	5.77E-08	6.03E-08	5.40E-08	5.69E-08	4.81E-08	4.83E-08	6.39E-08	9.57E-08	1.17E-07	6.55E-08	7.01E-08
$^{176}Hf/^{177}Hf$	0.2824832	0.2824942	0.2824840	0.2825021	0.2824864	0.2824745	0.2825145	0.2824981	0.2824873	0.2825005	0.2824956	0.2824908	0.2824925	0.2825087
2σ	7.11E-06	8.32E-06	8.02E-06	9.91E-06	1.03E-05	6.76E-06	7.51E-06	9.65E-06	9.40E-06	1.04E-05	9.07E-06	6.44E-06	7.12E-06	7.60E-06
U/Pb Age [Ma]	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00
$^{176}Hf/^{177}Hf$ (t)	0.2824823	0.2824932	0.2824830	0.2825012	0.2824855	0.2824736	0.2825136	0.2824972	0.2824864	0.2824996	0.2824947	0.2824899	0.2824916	0.2825077
εHf	-3.21	-2.82	-3.18	-2.54	-3.10	-3.51	-2.10	-2.68	-3.06	-2.60	-2.77	-2.94	-2.88	-2.31
2σ	0.25	0.29	0.28	0.35	0.37	0.24	0.27	0.34	0.33	0.37	0.32	0.23	0.25	0.27

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Plešovice Zircon

Analysis	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*
β Yb	1.792	1.780	1.778	1.667	1.766	1.779	1.777	1.678	1.748	1.768	1.769	1.789	1.758	1.803
2σ	9.15E-03	4.21E-03	4.93E-03	4.47E-02	4.72E-03	1.40E-02	7.34E-03	5.79E-02	1.42E-02	8.87E-03	5.82E-03	5.85E-03	5.58E-02	1.68E-02
β Hf	1.2993	1.2894	1.2870	1.2811	1.2658	1.2659	1.2601	1.2674	1.2528	1.2637	1.2679	1.2817	1.2800	1.2844
2σ	1.78E-03	1.83E-03	1.83E-03	1.75E-03	1.66E-03	1.66E-03	1.78E-03	1.94E-03	1.58E-03	1.54E-03	1.41E-03	1.74E-03	1.53E-03	1.68E-03
$^{179}Hf/^{177}Hf$	0.7432901	0.7432071	0.7431866	0.7431375	0.7430093	0.7430102	0.7429622	0.7430226	0.7429007	0.7429922	0.7430275	0.7431424	0.7431284	0.7431654
2σ	1.49E-05	1.53E-05	1.53E-05	1.46E-05	1.39E-05	1.39E-05	1.49E-05	1.62E-05	1.32E-05	1.29E-05	1.18E-05	1.45E-05	1.28E-05	1.40E-05
$^{178}Hf/^{177}Hf$	1.4888878	1.4887396	1.4886624	1.4885960	1.4883186	1.4882944	1.4882542	1.4883365	1.4881082	1.4882900	1.4883529	1.4885786	1.4885832	1.4886163
2σ	1.87E-05	2.55E-05	2.13E-05	2.32E-05	2.19E-05	2.22E-05	2.06E-05	2.29E-05	2.13E-05	2.06E-05	2.07E-05	2.00E-05	2.28E-05	1.84E-05
$^{172}Yb/^{173}Yb$	1.3441631	1.3442543	1.3442703	1.3451376	1.3443677	1.3442643	1.3442826	1.3450584	1.3445101	1.3443541	1.3443446	1.3441911	1.3444274	1.3440801
2σ	7.15E-05	3.29E-05	3.85E-05	3.49E-04	3.69E-05	1.09E-04	5.73E-05	4.53E-04	1.11E-04	6.93E-05	4.54E-05	4.57E-05	4.36E-04	1.31E-04
$^{173}Yb/^{177}Hf$	0.1227522	0.2373126	0.2363191	0.0077616	0.2340964	0.0514773	0.1276029	0.0078398	0.0508333	0.1212636	0.2341606	0.2357839	0.0077494	0.0534392
2σ	9.41E-05	1.04E-04	1.09E-04	5.69E-06	8.25E-05	8.89E-05	1.79E-04	8.87E-06	2.97E-05	5.45E-05	9.15E-05	1.28E-04	8.10E-06	1.80E-05
$^{176}Lu/^{177}Hf$	0.0001496	0.0001475	0.0001473	0.0001423	0.0001445	0.0001407	0.0001374	0.0001390	0.0001456	0.0001439	0.0001458	0.0001467	0.0001418	0.0001393
2σ	3.49E-07	7.90E-08	6.94E-08	8.22E-08	7.10E-08	2.42E-07	8.05E-08	6.06E-08	7.80E-08	1.27E-07	5.80E-08	9.13E-08	6.75E-08	6.62E-08
$^{176}Hf/^{177}Hf$	0.2824835	0.2825045	0.2825015	0.2824937	0.2824863	0.2824704	0.2824666	0.2824756	0.2824901	0.2824677	0.2824714	0.2824468	0.2824653	0.2824598
2σ	8.97E-06	1.02E-05	9.23E-06	6.48E-06	1.24E-05	8.37E-06	8.47E-06	7.57E-06	8.34E-06	8.33E-06	1.02E-05	1.01E-05	7.30E-06	7.32E-06
U/Pb Age [Ma]	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00
$^{176}Hf/^{177}Hf$ (t)	0.2824825	0.2825036	0.2825006	0.2824928	0.2824854	0.2824695	0.2824657	0.2824747	0.2824892	0.2824668	0.2824705	0.2824459	0.2824644	0.2824589
εHf	-3.20	-2.45	-2.56	-2.83	-3.10	-3.66	-3.79	-3.48	-2.96	-3.76	-3.62	-4.50	-3.84	-4.04
2σ	0.32	0.36	0.33	0.23	0.44	0.30	0.30	0.27	0.30	0.29	0.36	0.36	0.26	0.26

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Plešovice Zircon

Analysis	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*
β Yb	1.793	1.803	1.820	1.791	1.791	1.769	1.786	1.614	1.744	1.763	1.781	1.779	1.858	1.808
2σ	8.82E-03	5.68E-03	5.20E-02	5.22E-03	7.46E-03	1.37E-02	5.33E-03	5.46E-02	1.16E-02	7.83E-03	5.15E-03	5.40E-03	5.60E-02	1.23E-02
β Hf	1.2964	1.2992	1.2867	1.2892	1.2927	1.2890	1.2844	1.2678	1.2565	1.2658	1.2772	1.2808	1.2827	1.2805
2σ	1.59E-03	1.74E-03	1.51E-03	1.40E-03	1.74E-03	1.66E-03	1.80E-03	1.71E-03	1.98E-03	1.89E-03	1.74E-03	1.73E-03	1.38E-03	1.67E-03
$^{179}Hf/^{177}Hf$	0.7432655	0.7432893	0.7431842	0.7432051	0.7432349	0.7432039	0.7431655	0.7430262	0.7429317	0.7430094	0.7431052	0.7431346	0.7431506	0.7431324
2σ	1.33E-05	1.46E-05	1.26E-05	1.17E-05	1.45E-05	1.39E-05	1.50E-05	1.43E-05	1.65E-05	1.58E-05	1.46E-05	1.45E-05	1.15E-05	1.40E-05
$^{178}Hf/^{177}Hf$	1.4888424	1.4888832	1.4886778	1.4887239	1.4887685	1.4886826	1.4886281	1.4883456	1.4881741	1.4883385	1.4885117	1.4885610	1.4886102	1.4885508
2σ	2.14E-05	1.99E-05	2.09E-05	2.36E-05	2.13E-05	2.17E-05	2.41E-05	2.06E-05	2.61E-05	2.31E-05	2.23E-05	2.10E-05	2.21E-05	2.10E-05
$^{172}Yb/^{173}Yb$	1.3441594	1.3440756	1.3439436	1.3441692	1.3441700	1.3443437	1.3442106	1.3455585	1.3445392	1.3443896	1.3442513	1.3442624	1.3436488	1.3440404
2σ	6.89E-05	4.44E-05	4.06E-04	4.07E-05	5.82E-05	1.07E-04	4.16E-05	4.27E-04	9.07E-05	6.11E-05	4.02E-05	4.21E-05	4.37E-04	9.59E-05
$^{173}Yb/^{177}Hf$	0.1305957	0.2412471	0.0080888	0.2410325	0.1284044	0.0531713	0.2403339	0.0079137	0.0529354	0.1237704	0.2377654	0.2374507	0.0078505	0.0540904
2σ	8.36E-05	1.13E-04	9.35E-06	1.22E-04	8.01E-05	5.19E-05	1.12E-04	5.72E-06	2.94E-05	7.67E-05	1.22E-04	1.04E-04	1.30E-05	3.27E-05
$^{176}Lu/^{177}Hf$	0.0001399	0.0001470	0.0001383	0.0001443	0.0001360	0.0001372	0.0001431	0.0001388	0.0001419	0.0001419	0.0001460	0.0001463	0.0001420	0.0001369
2σ	5.72E-08	7.02E-08	1.04E-07	1.13E-07	1.21E-07	3.76E-07	6.10E-08	8.54E-08	1.77E-07	7.54E-08	6.97E-08	8.19E-08	6.34E-08	9.86E-08
$^{176}Hf/^{177}Hf$	0.2825076	0.2824618	0.2824795	0.2824907	0.2824937	0.2825031	0.2824908	0.2824843	0.2824865	0.2824830	0.2824506	0.2824740	0.2824644	0.2824673
2σ	9.65E-06	1.06E-05	5.80E-06	9.67E-06	8.92E-06	7.82E-06	1.10E-05	7.46E-06	8.63E-06	7.77E-06	9.50E-06	9.53E-06	6.99E-06	6.71E-06
U/Pb Age [Ma]	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00
$^{176}Hf/^{177}Hf$ (t)	0.2825067	0.2824609	0.2824786	0.2824898	0.2824928	0.2825022	0.2824899	0.2824834	0.2824856	0.2824821	0.2824497	0.2824731	0.2824635	0.2824665
εHf	-2.34	-3.96	-3.34	-2.94	-2.84	-2.50	-2.94	-3.17	-3.09	-3.21	-4.36	-3.53	-3.87	-3.77
2σ	0.34	0.38	0.21	0.34	0.32	0.28	0.39	0.26	0.31	0.27	0.34	0.34	0.25	0.24

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Plešovice Zircon

Analysis	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*52*	*53*	*54*	*55*	*56*
β Yb	1.797	1.788	1.880	1.790	1.758	1.791	1.801	1.802	1.167	1.642	1.509	1.773	1.332	1.655
2σ	6.10E-03	4.91E-03	5.52E-02	4.50E-03	1.19E-02	5.58E-03	5.72E-03	5.75E-03	1.36E-01	1.21E-01	1.05E-01	1.14E-02	1.30E-01	8.82E-03
β Hf	1.2779	1.2841	1.2834	1.2840	1.2783	1.2943	1.2918	1.2905	1.2317	1.2467	1.2577	1.2716	1.2897	1.1785
2σ	1.40E-03	1.61E-03	1.81E-03	1.29E-03	1.80E-03	1.69E-03	1.45E-03	1.40E-03	8.62E-03	7.03E-03	7.76E-03	6.84E-03	7.69E-03	5.02E-03
$^{179}Hf/^{177}Hf$	0.7431105	0.7431623	0.7431566	0.7431614	0.7431141	0.7432476	0.7432266	0.7432163	0.7427241	0.7428496	0.7429418	0.7430580	0.7432094	0.7422802
2σ	1.17E-05	1.35E-05	1.51E-05	1.08E-05	1.50E-05	1.42E-05	1.21E-05	1.17E-05	7.21E-05	5.88E-05	6.49E-05	5.72E-05	6.43E-05	4.19E-05
$^{178}Hf/^{177}Hf$	1.4885172	1.4886205	1.4886081	1.4886218	1.4885319	1.4888061	1.4887487	1.4887525	1.4875440	1.4878014	1.4879786	1.4882027	1.4885330	1.4866687
2σ	1.84E-05	1.95E-05	2.13E-05	1.78E-05	1.94E-05	2.51E-05	1.94E-05	1.98E-05	8.63E-05	7.17E-05	7.76E-05	6.59E-05	8.00E-05	4.67E-05
$^{172}Yb/^{173}Yb$	1.3441279	1.3441948	1.3434803	1.3441810	1.3444308	1.3441691	1.3440942	1.3440855	1.3490563	1.3453400	1.3463796	1.3443138	1.3477588	1.3452315
2σ	4.76E-05	3.83E-05	4.30E-04	3.51E-05	9.26E-05	4.36E-05	4.47E-05	4.49E-05	1.06E-03	9.44E-04	8.21E-04	8.88E-05	1.02E-03	6.90E-05
$^{173}Yb/^{177}Hf$	0.1287078	0.2397128	0.0081103	0.2402594	0.0534420	0.2438758	0.2429259	0.2420215	0.0085593	0.0088083	0.0085745	0.2490464	0.0083867	0.2318967
2σ	4.24E-05	1.33E-04	4.96E-06	1.09E-04	2.95E-05	1.67E-04	1.39E-04	1.24E-04	3.91E-05	3.64E-05	3.71E-05	9.87E-04	4.17E-05	4.42E-04
$^{176}Lu/^{177}Hf$	0.0001384	0.0001455	0.0001368	0.0001424	0.0001343	0.0001445	0.0001455	0.0001454	0.0001674	0.0001718	0.0001662	0.0001704	0.0001617	0.0001611
2σ	6.75E-08	6.31E-08	7.90E-08	9.98E-08	1.06E-07	6.56E-08	7.08E-08	6.77E-08	4.64E-07	3.76E-07	4.72E-07	4.24E-07	4.60E-07	2.34E-07
$^{176}Hf/^{177}Hf$	0.2824532	0.2824599	0.2824615	0.2824719	0.2825000	0.2825094	0.2824439	0.2824426	0.2825064	0.2824414	0.2824812	0.2824398	0.2825059	0.2825154
2σ	9.87E-06	8.97E-06	7.50E-06	9.82E-06	6.42E-06	8.79E-06	8.90E-06	9.18E-06	1.19E-05	1.58E-05	1.32E-05	2.13E-05	1.24E-05	1.88E-05
U/Pb Age [Ma]	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00
$^{176}Hf/^{177}Hf$ (t)	0.2824523	0.2824589	0.2824607	0.2824710	0.2824991	0.2825085	0.2824430	0.2824417	0.2825053	0.2824403	0.2824802	0.2824388	0.2825049	0.2825144
εHf	-4.27	-4.03	-3.97	-3.61	-2.61	-2.28	-4.60	-4.64	-2.39	-4.69	-3.28	-4.75	-2.41	-2.07
2σ	0.35	0.32	0.27	0.35	0.23	0.31	0.32	0.33	0.42	0.56	0.47	0.75	0.44	0.67

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Plešovice Zircon

Analysis	*57*	*58*	*59*	*60*	*61*	*62*	*63*	*64*	*65*	*66*	*67*	*68*	*69*	*70*
β Yb	1.714	1.719	1.817	1.871	1.644	1.249	1.563	1.728	1.778	1.828	1.825	1.829	1.626	1.812
2σ	1.09E-01	8.77E-03	1.27E-02	1.24E-01	2.25E-01	1.11E-01	1.31E-01	1.24E-02	1.02E-02	1.13E-02	7.76E-03	8.13E-03	2.76E-02	2.21E-02
β Hf	1.2645	1.2243	1.3180	1.2163	1.2135	1.2017	1.3411	1.2160	1.2715	1.3354	1.3464	1.3398	1.1816	1.2671
2σ	5.11E-03	4.46E-03	6.06E-03	5.74E-03	4.98E-03	9.67E-03	3.20E-03	7.33E-03	5.09E-03	3.12E-03	2.54E-03	2.67E-03	6.22E-03	8.21E-03
$^{179}Hf/^{177}Hf$	0.7429988	0.7426624	0.7434460	0.7425958	0.7425725	0.7424740	0.7436393	0.7425933	0.7430576	0.7435919	0.7436836	0.7436288	0.7423061	0.7430206
2σ	4.27E-05	3.73E-05	5.07E-05	4.80E-05	4.17E-05	8.08E-05	2.68E-05	6.12E-05	4.26E-05	2.61E-05	2.12E-05	2.24E-05	5.19E-05	6.86E-05
$^{178}Hf/^{177}Hf$	1.4881451	1.4874137	1.4891662	1.4873121	1.4872336	1.4870236	1.4896011	1.4872452	1.4882838	1.4894591	1.4896747	1.4895189	1.4866907	1.4882217
2σ	4.84E-05	5.42E-05	6.28E-05	5.94E-05	6.35E-05	9.11E-05	4.61E-05	8.05E-05	5.85E-05	3.88E-05	3.27E-05	3.66E-05	6.71E-05	9.07E-05
$^{172}Yb/^{173}Yb$	1.3447731	1.3447342	1.3439687	1.3435441	1.3453190	1.3484144	1.3459560	1.3446633	1.3442717	1.3438809	1.3439039	1.3438745	1.3454586	1.3440080
2σ	8.49E-04	6.85E-05	9.94E-05	9.66E-04	1.76E-03	8.72E-04	1.02E-03	9.69E-05	7.96E-05	8.79E-05	6.06E-05	6.35E-05	2.16E-04	1.73E-04
$^{173}Yb/^{177}Hf$	0.0081018	0.2321625	0.2370940	0.0080859	0.0081229	0.0078233	0.0089455	0.2321248	0.2372552	0.2516121	0.2616159	0.2641965	0.0512810	0.0529815
2σ	2.35E-05	4.45E-04	8.89E-04	2.20E-05	2.23E-05	3.02E-05	3.11E-05	7.98E-04	7.02E-04	7.78E-04	7.48E-04	7.31E-04	1.16E-04	2.45E-04
$^{176}Lu/^{177}Hf$	0.0001560	0.0001602	0.0001589	0.0001574	0.0001594	0.0001518	0.0001640	0.0001591	0.0001608	0.0001640	0.0001695	0.0001702	0.0001612	0.0001636
2σ	2.81E-07	2.26E-07	4.86E-07	2.84E-07	1.96E-07	3.61E-07	4.77E-07	3.25E-07	3.05E-07	4.95E-07	3.59E-07	3.58E-07	2.50E-07	3.74E-07
$^{176}Hf/^{177}Hf$	0.2824793	0.2824458	0.2824294	0.2824486	0.2824469	0.2824954	0.2825408	0.2824390	0.2824384	0.2824348	0.2824981	0.2824955	0.2824951	0.2824317
2σ	1.20E-05	1.90E-05	2.00E-05	1.30E-05	2.10E-05	1.43E-05	1.22E-05	1.97E-05	1.37E-05	1.30E-05	1.47E-05	1.75E-05	1.29E-05	1.33E-05
U/Pb Age [Ma]	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00
$^{176}Hf/^{177}Hf$ (t)	0.2824783	0.2824448	0.2824284	0.2824476	0.2824459	0.2824944	0.2825398	0.2824380	0.2824373	0.2824337	0.2824970	0.2824945	0.2824941	0.2824306
εHf	-3.35	-4.54	-5.11	-4.43	-4.50	-2.78	-1.17	-4.77	-4.80	-4.93	-2.69	-2.78	-2.79	-5.04
2σ	0.42	0.67	0.71	0.46	0.74	0.51	0.43	0.70	0.49	0.46	0.52	0.62	0.46	0.47

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Plešovice Zircon

Analysis	*71*	*72*	*73*	*74*	*75*	*76*	*77*	*78*	*79*	*80*	*81*	*82*	*83*	*84*
β Yb	1.720	1.780	1.786	1.821	1.370	1.683	1.537	1.757	1.776	1.799	1.809	1.811	1.812	1.816
2σ	2.15E-02	2.35E-02	1.30E-01	1.40E-02	1.12E-01	1.87E-02	3.34E-02	1.00E-02	1.45E-02	1.61E-02	1.21E-02	7.43E-03	1.00E-02	8.68E-03
β Hf	1.2060	1.2817	1.3454	1.3453	1.1522	1.1835	1.0470	1.2652	1.2840	1.2984	1.3005	1.3167	1.3216	1.3215
2σ	7.82E-03	8.86E-03	2.72E-03	3.57E-03	5.78E-03	5.15E-03	1.44E-02	3.28E-03	5.54E-03	4.24E-03	4.55E-03	2.96E-03	3.44E-03	2.75E-03
$^{179}Hf/^{177}Hf$	0.7425096	0.7431426	0.7436752	0.7436744	0.7420601	0.7423221	0.7411820	0.7430041	0.7431615	0.7432819	0.7432995	0.7434355	0.7434764	0.7434751
2σ	6.54E-05	7.41E-05	2.27E-05	2.99E-05	4.83E-05	4.30E-05	1.20E-04	2.74E-05	4.63E-05	3.54E-05	3.81E-05	2.47E-05	2.88E-05	2.30E-05
$^{178}Hf/^{177}Hf$	1.4870938	1.4885341	1.4895702	1.4896027	1.4862948	1.4868628	1.4845129	1.4882558	1.4886220	1.4888693	1.4889697	1.4891861	1.4892808	1.4892384
2σ	8.12E-05	1.01E-04	3.75E-05	4.39E-05	5.09E-05	5.53E-05	1.69E-04	3.90E-05	6.41E-05	6.81E-05	4.31E-05	3.63E-05	4.77E-05	3.75E-05
$^{172}Yb/^{173}Yb$	1.3447259	1.3442546	1.3442138	1.3439383	1.3474670	1.3450177	1.3461601	1.3444366	1.3442892	1.3441074	1.3440347	1.3440123	1.3440107	1.3439790
2σ	1.68E-04	1.84E-04	1.02E-03	1.09E-04	8.76E-04	1.46E-04	2.61E-04	7.84E-05	1.13E-04	1.26E-04	9.46E-05	5.80E-05	7.81E-05	6.78E-05
$^{173}Yb/^{177}Hf$	0.1035724	0.1062317	0.0087091	0.2614669	0.0076383	0.0988399	0.2105974	0.2287763	0.2327867	0.2378562	0.2400314	0.2470835	0.2476646	0.2636931
2σ	3.77E-04	4.97E-04	2.52E-05	7.71E-04	1.95E-05	1.76E-04	8.73E-04	5.74E-04	8.91E-04	7.39E-04	1.24E-03	5.97E-04	1.11E-03	1.10E-03
$^{176}Lu/^{177}Hf$	0.0001601	0.0001613	0.0001597	0.0001696	0.0001519	0.0001565	0.0001511	0.0001587	0.0001600	0.0001616	0.0001627	0.0001663	0.0001669	0.0001732
2σ	3.91E-07	5.16E-07	5.04E-07	4.35E-07	2.09E-07	2.04E-07	2.70E-07	2.60E-07	3.57E-07	5.20E-07	4.89E-07	2.78E-07	5.91E-07	4.49E-07
$^{176}Hf/^{177}Hf$	0.2824226	0.2824640	0.2825423	0.2825086	0.2824660	0.2824638	0.2824861	0.2824780	0.2824607	0.2824643	0.2824525	0.2824921	0.2824597	0.2824833
2σ	1.67E-05	3.25E-05	1.29E-05	2.60E-05	1.13E-05	1.48E-05	3.13E-05	1.82E-05	2.49E-05	3.79E-05	2.48E-05	1.46E-05	2.21E-05	1.44E-05
U/Pb Age [Ma]	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00
$^{176}Hf/^{177}Hf$ (t)	0.2824216	0.2824630	0.2825413	0.2825075	0.2824651	0.2824628	0.2824852	0.2824770	0.2824597	0.2824632	0.2824515	0.2824910	0.2824587	0.2824822
εHf	-5.35	-3.89	-1.12	-2.31	-3.82	-3.90	-3.11	-3.39	-4.01	-3.88	-4.30	-2.90	-4.04	-3.21
2σ	0.59	1.15	0.45	0.92	0.40	0.52	1.11	0.64	0.88	1.34	0.88	0.51	0.78	0.51

Table DR5. Multi-Collector Inductively Coupled Plasma Mass Spectrometry of Hafnium Isotopes in Zircon.

Plešovice Zircon

Analysis	*85*	*86*
β Yb	1.815	1.811
2σ	9.43E-03	8.23E-03
β Hf	1.3322	1.3223
2σ	2.45E-03	2.13E-03
$^{179}Hf/^{177}Hf$	0.7435649	0.7434823
2σ	2.05E-05	1.78E-05
$^{178}Hf/^{177}Hf$	1.4894181	1.4892800
2σ	3.19E-05	2.58E-05
$^{172}Yb/^{173}Yb$	1.3439820	1.3440131
2σ	7.36E-05	6.42E-05
$^{173}Yb/^{177}Hf$	0.2491759	0.2630746
2σ	1.27E-03	6.48E-04
$^{176}Lu/^{177}Hf$	0.0001603	0.0001658
2σ	5.88E-07	2.96E-07
$^{176}Hf/^{177}Hf$	0.2824860	0.2824915
2σ	1.66E-05	1.67E-05
U/Pb Age [Ma]	337.00	337.00
$^{176}Hf/^{177}Hf$ (t)	0.2824850	0.2824904
εHf	-3.11	-2.92
2σ	0.59	0.59