

In situ ^{238}U - ^{230}Th disequilibrium dating of pyrochlore at sub-millennial precision**FLORIAN WETZEL, AXEL K. SCHMITT, ANDREAS KRONZ, AND GERHARD WÖRNER****TABLE 1.** Major element compositions (oxides in wt%) of pyrochlores from Laacher See carbonatite (564-L) and Amis granite (AM206). EMP detection limits (d.l.) for Th and U are ~0.02 wt%.

Grain #	Laacher See Pyrochlore											Amis Pyrochlore							
	2 1	2 2	2 3	2 4	3 1	4 1	4 2	6 1	9 1	11 1	1 1	1 2*	1 3b	1 4	2 6†	2 7†	3 1‡	3 2‡	
Nb2O5	40.43	46.99	47.16	47.32	49.91	48.79	48.62	43.48	48.34	48.94	51.11	47.83	48.41	47.24	47.95	50.26	48.16	47.08	
Ta2O5	0.85	0.90	0.97	0.78	0.90	0.99	0.95	1.00	1.05	1.58	1.71	4.15	2.15	2.11	3.38	3.39	2.05	2.12	
SiO2	d.l.	d.l.	d.l.	d.l.	d.l.	d.l.	d.l.	d.l.	d.l.	0.04	0.08	0.07	0.10	d.l.	0.11	0.12	0.08	0.07	
TiO2	11.23	10.24	10.40	10.05	9.15	9.45	9.30	9.55	9.91	9.03	8.69	9.31	10.28	10.34	9.20	9.04	10.18	10.60	
ThO2	1.83	6.56	6.00	6.65	4.67	8.06	7.81	2.96	6.73	3.97	1.17	0.26	0.26	0.23	0.30	0.41	0.23	0.22	
UO2	15.57	1.92	3.40	1.56	2.45	0.51	0.59	11.04	2.68	4.70	3.83	5.17	3.63	3.88	5.39	5.43	3.88	3.64	
HfO2	0.11	0.04	0.12	0.07	0.04	0.07	0.09	0.12	0.05	0.04	d.l.	0.03	0.04	0.03	d.l.	0.05	d.l.	0.04	
ZrO2	1.79	0.71	0.51	0.60	0.40	0.46	0.45	3.01	0.32	0.37	d.l.	0.12	0.59	0.73	0.13	d.l.	0.67	0.80	
La2O3	0.53	0.81	0.78	0.88	0.76	0.82	0.74	0.77	0.72	0.64	3.49	3.27	3.39	3.37	3.12	3.33	3.47	3.47	
Ce2O3	1.64	2.81	2.52	2.87	2.21	2.22	2.10	1.82	1.96	1.56	8.95	8.09	8.70	8.53	8.10	8.53	8.86	8.67	
Pr2O3	0.16	0.20	0.20	0.26	0.15	0.20	0.19	0.12	0.17	0.18	0.89	0.90	0.92	0.76	0.87	0.79	0.85	1.00	
Nd2O3	0.25	0.58	0.47	0.51	0.36	0.38	0.32	0.36	0.32	0.26	2.16	2.33	2.41	2.43	2.32	2.33	2.41	2.50	
FeO*	0.74	0.41	0.32	0.42	0.36	0.42	0.43	0.64	0.34	0.27	d.l.	d.l.	d.l.	d.l.	0.12	d.l.	d.l.		
CaO	14.46	15.93	16.00	16.29	16.64	16.42	16.34	15.00	16.15	16.23	2.51	2.89	2.99	3.05	2.56	0.60	2.87	2.93	
MnO	0.29	0.51	0.45	0.48	0.36	0.53	0.49	0.29	0.43	0.29	d.l.	d.l.	d.l.	d.l.	d.l.	d.l.	d.l.		
Na2O	5.78	6.13	6.03	6.11	6.54	6.44	6.34	6.22	6.34	6.54	0.37	7.21	7.68	7.64	1.02	0.46	7.08	7.10	
Sum	95.65	94.76	95.34	94.85	94.90	95.75	94.75	96.38	95.50	94.64	84.97	91.63	91.55	90.34	84.45	84.86	90.79	90.25	
Th/U	0.12	3.49	1.80	4.36	1.95	16.03	13.51	0.27	2.57	0.86	0.31	0.05	0.07	0.06	0.06	0.08	0.06	0.06	
Nb/Ta	79.47	86.36	80.43	100.69	92.22	82.06	85.11	72.61	76.61	51.49	49.69	19.16	37.43	37.22	23.58	24.65	39.06	36.92	
$^{238}\text{U}/^{232}\text{Th}$	8.26	0.28	0.55	0.23	0.51	0.06	0.07	3.62	0.39	1.15	3.18	19.03	13.80	16.38	17.72	13.01	16.17	16.06	
Th (EMP)																			

* Note: For the texturally much more homogenous Laacher See pyrochlores every EMP spot has an equivalent SIMS analysis (compare with Table 2). Due to heterogeneity and visible alteration in AM206 pyrochlores it was sometimes neither possible nor recommended to target the same SIMS spot with the EMP. Therefore, for some SIMS analyses of AM206 no spatially equivalent EMP analyses exist. We used the zonation and grey scale visible in BSE pictures to interpolate U and Th abundances for the equivalent SIMS spot. In this case, we used the U and Th data of grain 1 #2 also for grain 1 #5 (compare with Table 2).

† U and Th average of grain 2 #6 and #7 was used as equivalent for SIMS analysis grain 2 #1

‡ U and Th average of grain 3 #1-7 was used as equivalent for SIMS analysis grain 3 #1

§ U and Th abundances were used as equivalent for SIMS analysis grain 4 #1

U and Th average of grain 5 #2,3, and 6 was used as equivalent for SIMS analysis grain 5 #1

TABLE 1.—EXTENDED

Amis Pyrochlore								
3	3	3	3	3	4	5	5	5
3 ‡	4 ‡	5 ‡	6 ‡	7 ‡	5 §	2 #	3 #	6 #
48.21	48.47	48.06	46.68	49.42	47.90	48.31	48.62	49.59
1.95	1.99	2.22	2.04	2.28	2.13	1.83	4.22	4.35
d.l.	0.12	0.08	0.12	0.29	0.09	0.10	0.09	0.35
9.91	9.60	10.62	10.52	10.63	10.20	9.83	8.89	9.27
0.22	0.21	0.27	0.24	0.26	0.26	0.23	0.25	0.29
3.76	3.70	3.46	3.62	3.46	3.88	4.32	5.48	5.83
0.03	d.l.	d.l.	d.l.	0.07	0.06	0.04	d.l.	d.l.
0.70	0.73	0.77	0.70	0.79	0.60	0.79	0.09	0.11
3.51	3.39	3.46	3.39	3.56	3.35	3.34	3.12	3.08
8.88	8.79	8.91	8.88	9.10	8.63	8.68	8.18	8.43
0.82	0.81	0.83	0.81	0.91	0.94	0.84	0.78	0.83
2.41	2.38	2.41	2.43	2.61	2.43	2.34	2.26	2.39
d.l.	d.l.	d.l.	d.l.	0.14	d.l.	d.l.	d.l.	0.06
2.94	2.90	2.79	2.77	0.80	2.82	2.71	2.73	1.04
d.l.	d.l.	d.l.	d.l.	0.06	d.l.	d.l.	d.l.	d.l.
6.27	0.81	0.77	0.98	0.42	0.55	0.47	0.32	d.l.
89.61	83.92	84.65	83.19	84.79	83.84	83.83	85.03	85.62
0.06	0.06	0.08	0.07	0.08	0.07	0.05	0.05	0.05
41.10	40.49	35.99	38.04	36.04	37.39	43.89	19.15	18.95
16.47	16.72	12.28	14.39	13.08	14.60	18.11	20.89	19.29

Supplementary data continues next page

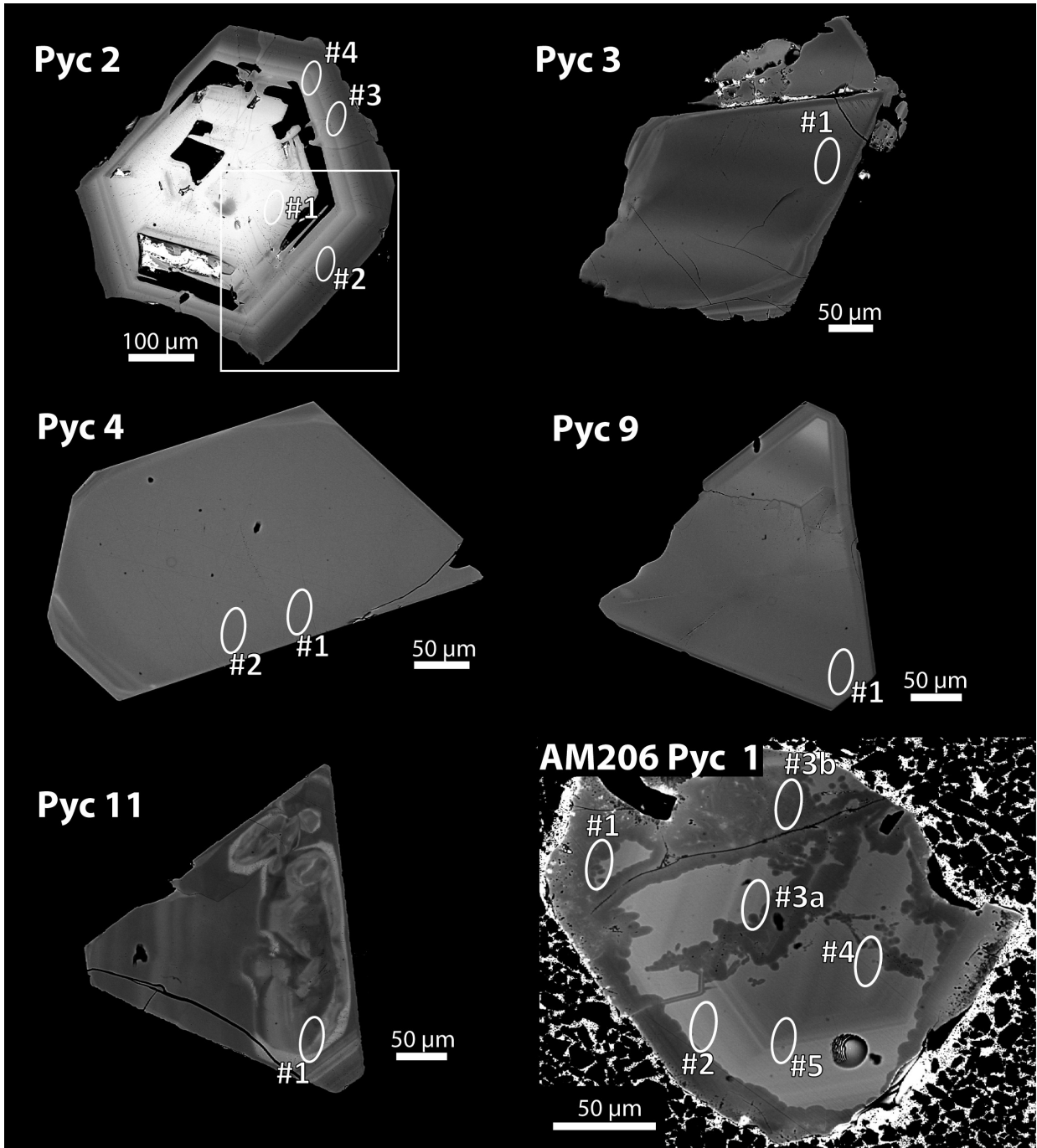


FIGURE 1. Backscattered electron (BSE) images of selected pyrochlore crystals from the Laacher See carbonatite (sample 564-L) and Amis peralkaline granite (sample AM206; white frame). SIMS spots are marked by white ellipses. The area within the white frame was mapped for U and Th with EMP (Fig. 2).