Supplemental Material 1: Methods for *in situ*-produced ^{36}Cl cosmic ray exposure dating

Basaltic whole rock samples were processed at CEREGE, Aix-en-Provence, France, for *in situ*-produced ^{36}Cl cosmic ray exposure (CRE) dating, following the method described in Schimmelpfennig *et al.* (2011). We first took bulk rock aliquots for analyses of the major and trace element concentrations at the Service d'Analyse des Roches et des Minéraux (SARM, Nancy, France) (Tables S1 I & II). These analyses later allow estimating the contribution of the capture of low-energy neutrons on ^{35}Cl to the production of ^{36}Cl, which is difficult to constrain (Schimmelpfennig *et al.* 2009). Regarding our samples, this reaction contributes to only ~ 3% to ~21% to the total ^{36}Cl production due to their relatively low Cl concentrations (10-84 ppm, Table II in the main text). Samples were crushed and sieved to obtain a grain size fraction of 250-500 µm. They were then shaken in a HF/HNO_3 acid mixture to remove atmospheric ^{36}Cl and potential Cl-rich contaminants (Schimmelpfennig *et al.* 2009). This first dissolution removed about 40% of the initial samples weight. A 2 g aliquot of the rinsed and dried sample grains was then sent to SARM for major elements concentrations analysis by ICP-OES (Table S1 II), in order to analyse the major element concentrations, including Ca, K, Ti and Fe, which are the target elements for spallogenic/muogenic ^{36}Cl production. Finally, a ^{35}Cl-enriched spike (~99%) was added for isotope dilution (Ivy-Ochs *et al.* 2004) and totally dissolved the samples in a HF/HNO_3 acid mixture. The further steps strictly followed those described in Schimmelpfennig *et al.* (2011). $^{36}Cl/^{35}Cl$ and $^{35}Cl/^{37}Cl$ ratios were measured by isotope dilution accelerator mass spectrometry (AMS) at the French AMS national facility ASTER after normalization to the inhouse standard SM-CL-12, using an assigned value of 1.428 (± 0.021) x 10–12 for the $^{36}Cl/^{35}Cl$ ratio (Merchel *et al.* 2011) and assuming a natural ratio of 3.127 for the stable ratio $^{35}Cl/^{37}Cl$. After correction for the average number of atoms of the three chemistry blanks processed during the joint preparation of the samples from Jomelli *et al.* (2017, 2018), the ^{36}Cl and Cl concentrations were calculated (Table II in the main text) (Sharma *et al.* 1990). ^{36}Cl ages were computed with the Excel® spreadsheet published by Schimmelpfennig *et al.* (2009), taking into account the chemical composition of each sample (Tables S1 I & II). The ^{36}Cl production rates, referenced to sea level and high latitude (SLHL), used for the calculations are: 42.2 ± 4.8 atoms of ^{36}Cl (g Ca)$^{-1}$ yr^{-1} for Ca spallation (Schimmelpfennig *et al.* 2011), 148.1 ± 7.8 atoms of ^{36}Cl (g K)$^{-1}$ yr^{-1} for K spallation (Schimmelpfennig *et al.* 2014), 13 ± 3 atoms of ^{36}Cl (g Ti)$^{-1}$ yr^{-1} for spallation of Ti (Fink *et al.* 2000), 1.9 ± 0.2 atoms of ^{36}Cl (g Fe)$^{-1}$ yr^{-1} for Fe spallation (Stone *et al.* 2005), and 696 ± 185 neutrons (g air)$^{-1}$ yr^{-1} for the rate of epithermal neutron production from fast neutrons in the atmosphere at the earth/atmosphere interface (Marrero *et al.* 2016). These production rates were corrected considering sample thickness, topographic shielding and geographical location (Table I in the main text). The scaling factor used is based on the time-invariant "St" method (Stone 2000) (Table II in the main text). We applied a high-energy-neutron attenuation length value of 160 g cm^{-2} and a bulk rock density of 2.4 g cm^{-3} for the calculation of all samples.

Table S1 I: Chemical compositions of the bulk rock samples before chemical treatment. Analysis performed at the SARM-CRPG (Nancy, France) by ICP-OES (major elements), ICP-MS (trace element), atomic absorption (Li), colorimetry (B) and spectrophotometry (Cl).

Sample Name	CaO %	K2O %	TiO2 %	Fe2O3 %	Cl (ppm)	SiO2 %	Na2O %	MgO %	Al2O3 %	MnO %	P2O5 %	CO2 %	Li (ppm)	B (ppm)	Sm (ppm)	Gd (ppm)	Th (ppm)	U (ppm)
Ker-42	2.28	5.99	0.5	7.1	125	59.79	5.73	0.44	17.91	0.19	0.18	0.47	18.1	6.1	9.58	7.18	13.7	2.94
Ker-44	3.51	5.05	1.67	9.05	245	51.15	3.94	1.81	17.08	0.19	0.76	4.63	22.2	6.4	10.2	7.99	7.68	2.15
Ker-45	6.33	2.93	2.19	10.00	215	48.93	3.88	2.94	17.94	0.18	0.85	1.82	12.3	4.3	11.1	8.96	7.08	1.6
Ker-47	6.88	2.69	2.75	11.19	220	47.57	3.87	3.39	17.62	0.17	0.93	2.89	10.9	5.0	9.93	8.11	6.97	1.61
Ker-49	7.54	2.79	2.79	10.92	120	49.35	3.88	3.41	17.67	0.17	0.96	0.83	5.45	5.4	10.5	8.57	6.48	1.48
Ker-50	6.14	3.29	1.62	8.27	86	49.96	4.06	2.1	18.79	0.16	0.8	5.90	9.46	2.9	9.63	7.64	6.82	1.08
Ker-56	9.9	1.58	3.45	11.79	195	44.28	2.86	3.95	16.88	0.17	1.49	1.37	5.88	3.3	10.8	9.03	3.68	0.7
Ker-57	9.29	1.1	2.67	13.66	80	44.09	2.09	8.38	13.75	0.18	0.47	0.89	6.51	2.3	6.05	5.45	2.86	0.6
Ker-58	7.5	2.56	2.78	11.24	83	48.8	4.13	3.62	17.05	0.17	0.99	1.28	8.42	4.2	11.1	9.13	6.81	1.51
Ker-65	7.04	2.66	3.26	12.02	185	45.03	3.27	4.09	16.13	0.16	0.76	7.62	6.85	4.6	8.44	6.85	6.69	1.5
Ker-66	7.77	2.51	2.61	10.55	360	49.91	4.05	3.49	17.8	0.16	0.93	0.79	7.71	4.2	9.49	7.82	5.88	1.32
Ker-67	7.77	2.55	2.49	10.2	135	49.36	4.11	3.4	17.95	0.16	0.92	0.98	8.20	3.5	9.87	8.0	5.97	1.23
Ker-68	6.19	3.49	1.77	8.68	66	51.46	4.22	2.14	18.78	0.15	0.84	2.71	10.1	2.2	9.72	7.65	6.97	0.92

Table S1 II: Concentrations of the major element oxides, determined in splits taken from the samples after the chemical pre-treatment (acid etching). Analysis performed at the SARM-CRPG (Nancy, France) by ICP-OES.

Sample Name	CaO %	K_2O %	TiO_2 %	Fe_2O_3 %	SiO2 %	Na2O %	MgO %	Al2O3 %	MnO %	P2O5 %
G2										
Ker-42	2.17 ± 0.33	6.10 ± 0.31	0.55 ± 0.11	5.03 ± 0.50	62.0 ± 1.2	5.28 ± 0.26	0.320 ± 0.064	16.97 ± 0.33	0.095 ± 0.019	0.0300 ± 0.0045
Ker-44	3.38 ± 0.51	4.87 ± 0.49	2.30 ± 0.23	9.09 ± 0.91	57.1 ± 1.1	3.90 ± 0.19	1.06 ± 0.11	15.61 ± 0.31	0.130 ± 0.026	0.120 ± 0.018
Ker-45	6.04 ± 0.30	3.11 ± 0.31	2.52 ± 0.25	9.16 ± 0.92	54.3 ± 1.1	3.98 ± 0.20	2.26 ± 0.23	16.49 ± 0.33	0.140 ± 0.028	0.250 ± 0.038
G1										
Ker-47	7.21 ± 0.36	2.27 ± 0.23	3.06 ± 0.31	9.87 ± 0.99	51.1 ± 1.0	3.84 ± 0.19	2.46 ± 0.25	18.48 ± 0.37	0.130 ± 0.026	0.150 ± 0.023
Ker-49	7.68 ± 0.38	2.22 ± 0.22	3.03 ± 0.30	9.60 ± 0.96	50.9 ± 1.0	3.72 ± 0.19	2.89 ± 0.29	18.46 ± 0.37	0.120 ± 0.024	0.160 ± 0.024
Ker-50	6.61 ± 0.33	2.96 ± 0.30	1.65 ± 0.17	5.98 ± 0.60	55.3 ± 1.1	4.24 ± 0.21	1.33 ± 0.13	20.33 ± 0.41	0.087 ± 0.017	0.140 ± 0.021
Ker-56	9.28 ± 0.46	1.71 ± 0.17	4.27 ± 0.43	9.15 ± 0.92	51.6 ± 1.0	2.94 ± 0.15	2.45 ± 0.25	15.72 ± 0.31	0.150 ± 0.030	0.690 ± 0.035
Ker-57	10.00 ± 0.20	1.08 ± 0.11	3.04 ± 0.30	11.70 ± 0.23	50.1 ± 1.0	2.09 ± 0.10	8.20 ± 0.41	12.00 ± 0.24	0.150 ± 0.030	0.180 ± 0.027
Ker-58	8.45 ± 0.42	1.85 ± 0.19	2.86 ± 0.29	9.30 ± 0.93	50.9 ± 1.0	3.78 ± 0.19	3.22 ± 0.32	19.11 ± 0.38	0.130 ± 0.026	0.210 ± 0.032
Ker-65	6.93 ± 0.35	2.72 ± 0.27	3.53 ± 0.35	11.19 ± 0.22	50.7 ± 1.0	3.30 ± 0.16	3.25 ± 0.33	15.98 ± 0.32	0.140 ± 0.028	0.390 ± 0.059
Ker-66	7.87 ± 0.39	2.10 ± 0.21	3.11 ± 0.31	9.86 ± 0.99	50.3 ± 1.0	3.68 ± 0.18	3.11 ± 0.31	18.50 ± 0.37	0.130 ± 0.026	0.220 ± 0.033
Ker-67	6.87 ± 0.34	2.36 ± 0.24	3.25 ± 0.36	10.96 ± 0.22	50.4 ± 1.0	3.68 ± 0.18	3.12 ± 0.31	17.21 ± 0.34	0.140 ± 0.028	0.130 ± 0.020
Ker-68	6.41 ± 0.32	2.91 ± 0.29	1.70 ± 0.17	6.53 ± 0.65	54.6 ± 1.1	4.22 ± 0.21	1.54 ± 0.15	19.93 ± 0.40	0.094 ± 0.019	0.150 ± 0.023

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