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Introduction

This supporting information contains all of the Supplementary Figures with captions for this manuscript.
Table captions for Supplementary Tables also contains. Supplementary Tables are included as separated spreadsheets (.xlsx).

Supplementary figures

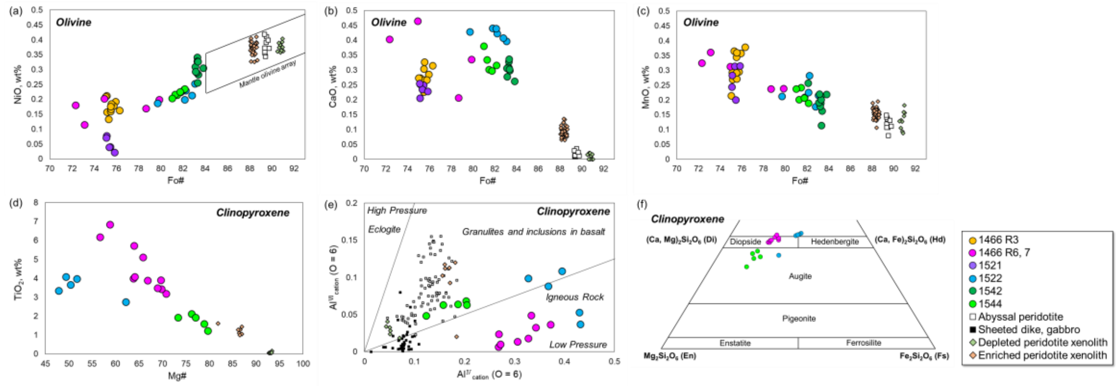

Fig. S1. Mineral compositions of olivine (a)–(c) and clinopyroxene (d)–(f) in this study. (a) Forsterite number (Fo#: Mg# = $Mg/(Mg+Fe^{2+})$ for cation ratio of olivine) vs NiO content of olivine. Mantle olivine array is after Takahashi et al. (1987). (b) Fo# vs CaO content of olivine. (c) Fo# vs MnO content of olivine. (d) Mg# vs TiO_2 content of clinopyroxene. (e) Al^{IV} vs Al^{VI} (cation ratio when total oxygen is six) of clinopyroxene. (f) Ca–Mg–Fe pyroxene classification diagram from Morimoto (1988). The compiled abyssal peridotite is from Regelous et al. (2016), sheeted dike–gabbro by ODP Hole 1256D is from Yamazaki et al. (2009), peridotite xenoliths from the petit-spot knoll of 6K#1466R6-001 and R7-003 in this study is from Mikuni et al. (2022).

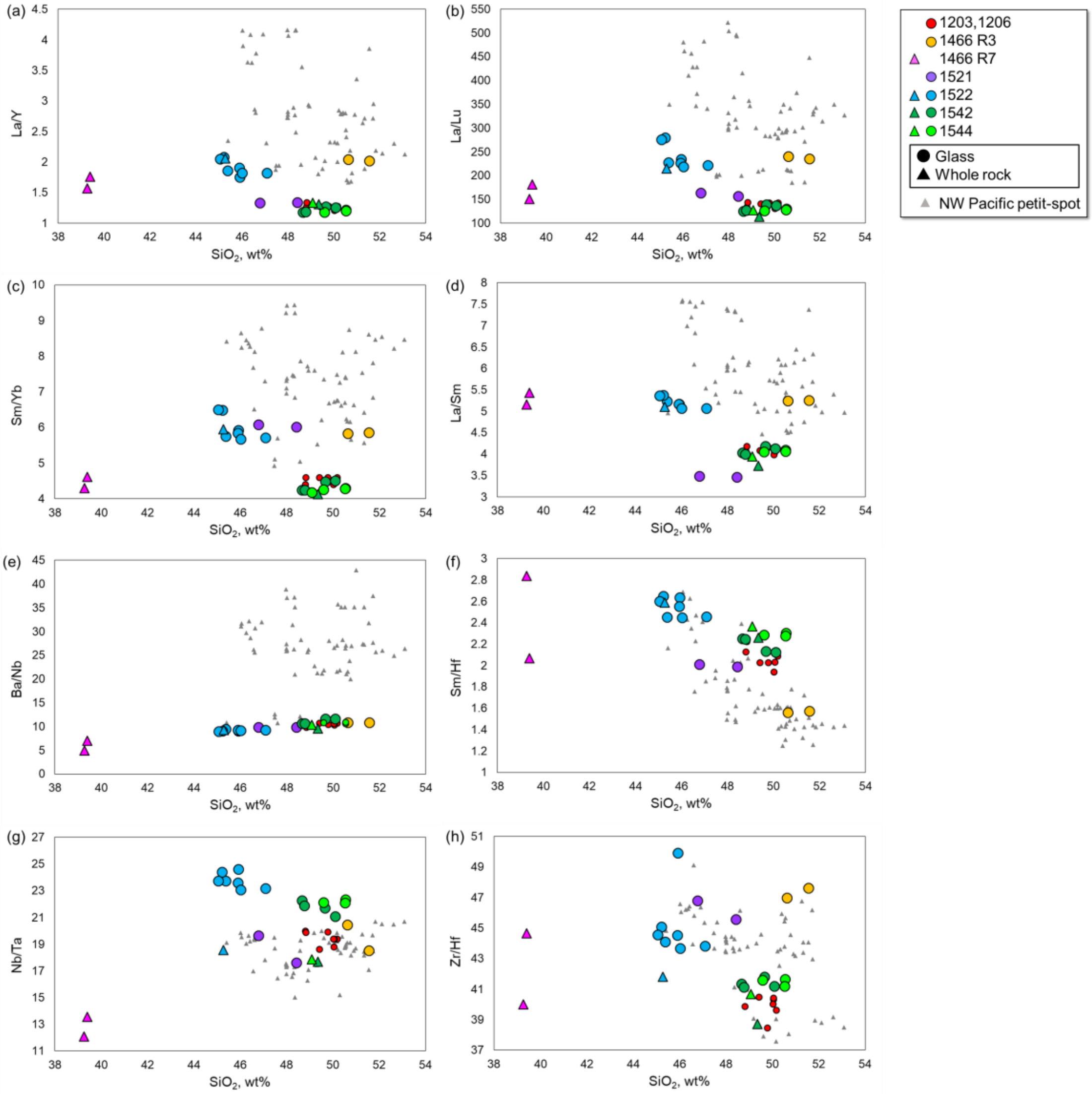

Fig. S2 Selected trace-element ratios against SiO_2 content.

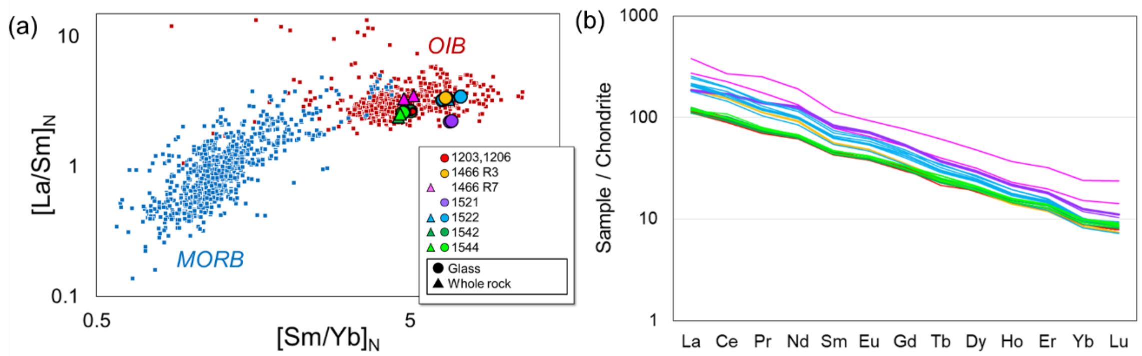

Fig. S3 The REEs characteristics of the western Pacific petit-spot basalts. (a) CI Chondrite normalized Sm/Yb and La/Sm variations. Chondrite value is after Sun and McDonough (1989). (b) CI Chondrite normalized REE patterns. The color of each line corresponds to that of the symbols in (a). The data of OIB and MORB are from Stracke et al. (2022) as “Expert datasets” in GEOROC database (https://georoc.eu/georoc/new-start.asp).

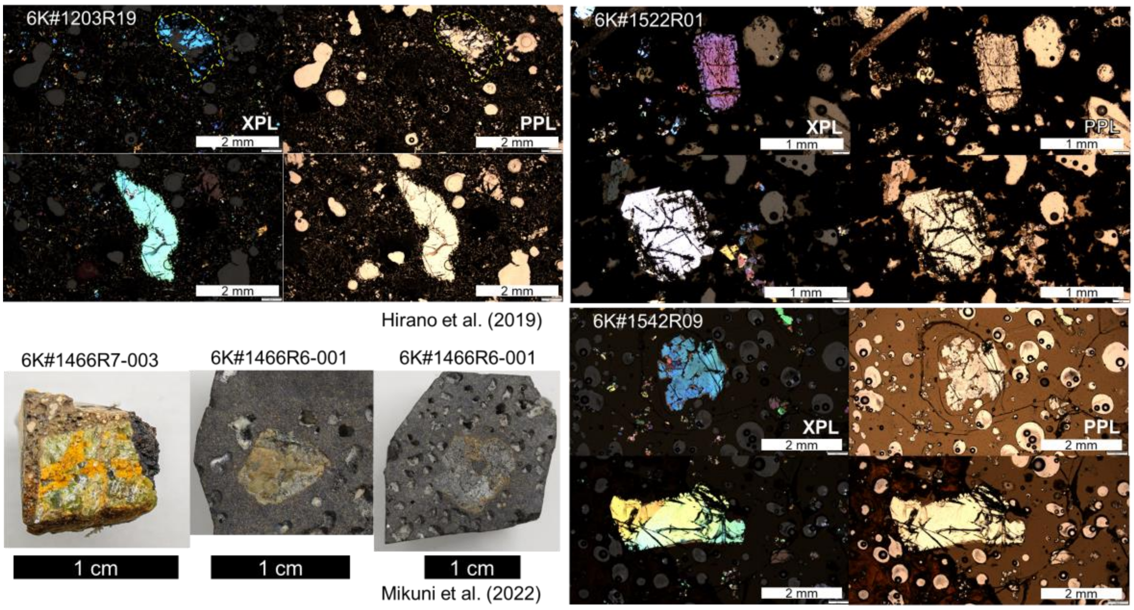

Fig. S4 Photomicrographs and photos of xenocrysts and xenoliths in this study samples.

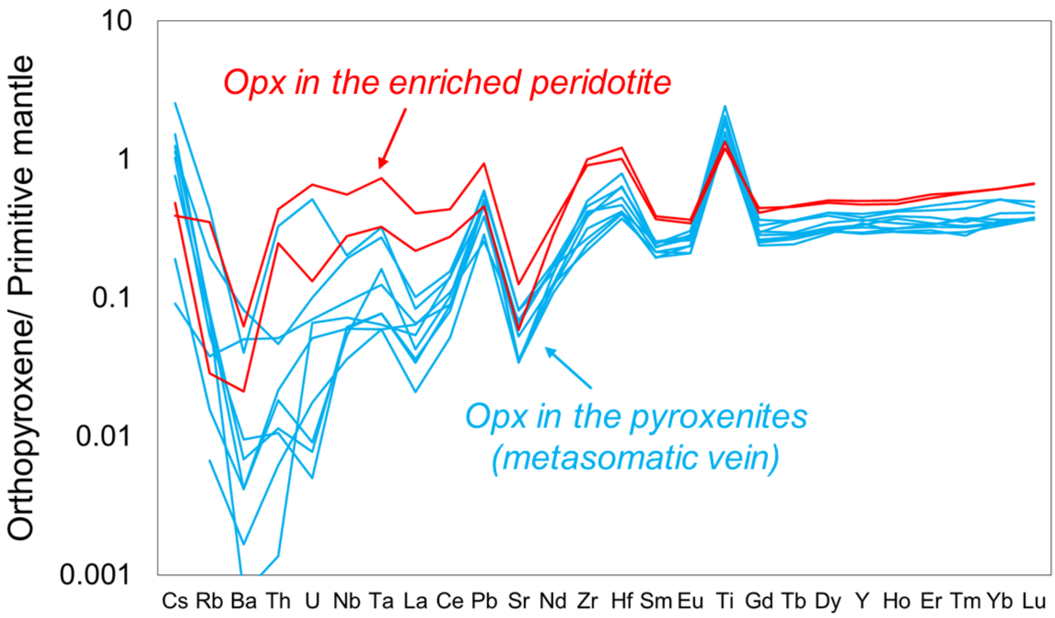

Fig. S5 Primitive mantle-normalized trace-element compositions of orthopyroxene in the metasomatized ultramafic xenoliths. The enriched peridotite and the pyroxenite xenoliths were reported from the petit-spot knoll in this study area (investigated by the 6K#1466R6-001, R7-001 and R7-003 dives). The data are provided in Mikuni et al. (2022).

Olivine maximum fractionation model

Primary composition of selected samples were calculated based on "olivine maximum fractionation model" generally based on the method of Machida et al. (2008) to check the primitiveness of the 6K#1522 petit-spot basalts. First, we calculated the composition of olivine in equilibrium with the analyzed melt (glass) composition based on the exchange partition coefficients of Fe–Mg ($K_d^{Fe-Mg}{}_{\text{olivine-melt}}$) and Ni–Mg ($K_d^{Ni-Mg}{}_{\text{olivine-melt}}$) from Takahashi (1986) as described below. Then, the calculated composition of olivine were added to the analyzed melt composition in a weight ratio of 1:99. This procedure was repeated until the NiO content and Fo# of olivine reached the "mantle olivine array" (Takahashi, 1986). Assumption in the calculation are as follows: $K_d^{Fe-Mg}{}_{\text{olivine-melt}} = 0.27+0.03(N^{MgO}{}_{melt} + 0.33N^{FeO}{}_{melt})$, $K_d^{Ni-Mg}{}_{\text{olivine-melt}} = 2.8 - 0.033(N^{MgO}{}_{melt} + 0.33N^{FeO}{}_{melt})$, $Fe^{3+}/(Fe^{2+} + Fe^{3+})$ is constant of 0.1. $N^{MgO}{}_{melt}$ and $N^{FeO}{}_{melt}$ are molar fraction of MgO and FeO of melt, respectively.

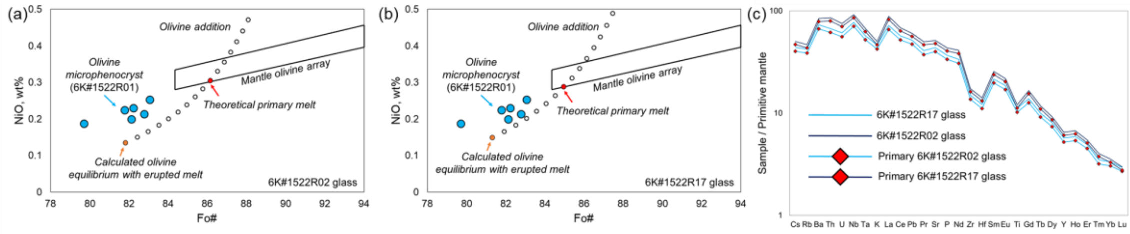

Fig. S6 The olivine maximum fractionation model. Selected two samples of 6K#1522R02 (a) and 6K#1522R17 (b) were back-calculated to "mantle olivine array" by addition of olivine. (c) Primitive mantle normalized trace-element patterns of analyzed values and calculated primary magma.

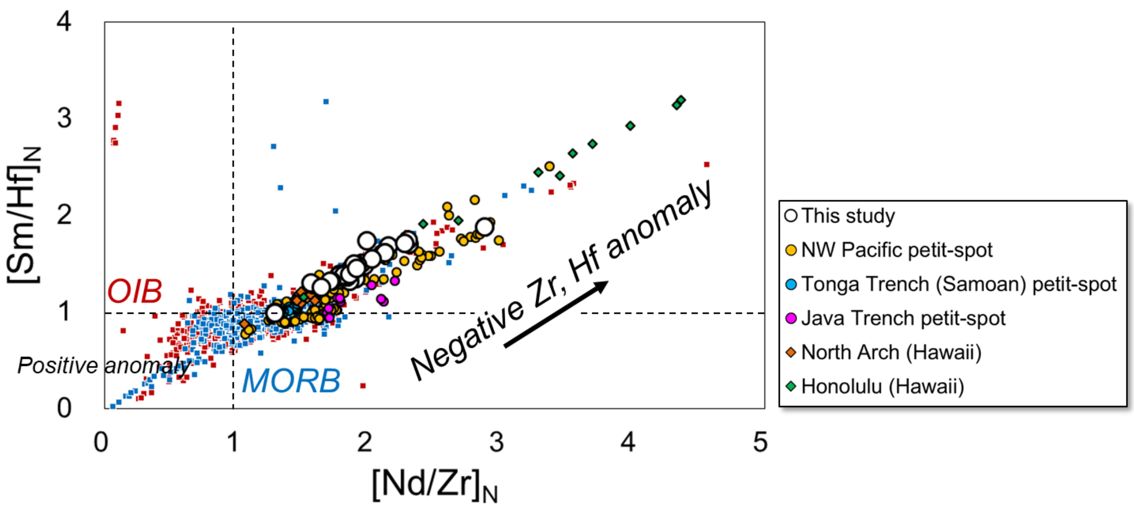

Fig. S7 Primitive mantle normalized Nd/Zr vs. Sm/Hf diagram. This study samples were showed as white circles. Compiled data and references are as follows: NW Pacific petit-spots (yellow circles); Hirano and Machida (2022), petit-spots off Tonga Trench (blue circles); Reinhard et al. (2019), petit-spots off Java Trench (pink circles); Taneja et al. (2016) and Falloon et al. (2022), Hawaiian North Arch lavas and Honolulu volcanics (blown and green diamonds, respectively); Clague and Frey (1982), Clague et al. (1990), and Yang et al. (2003). Data of OIB and MORB (red and blue cubes, respectively) are from Stracke et al. (2022) as "Expert datasets" in GEOROC database (https://georoc.eu/georoc/new-start.asp).

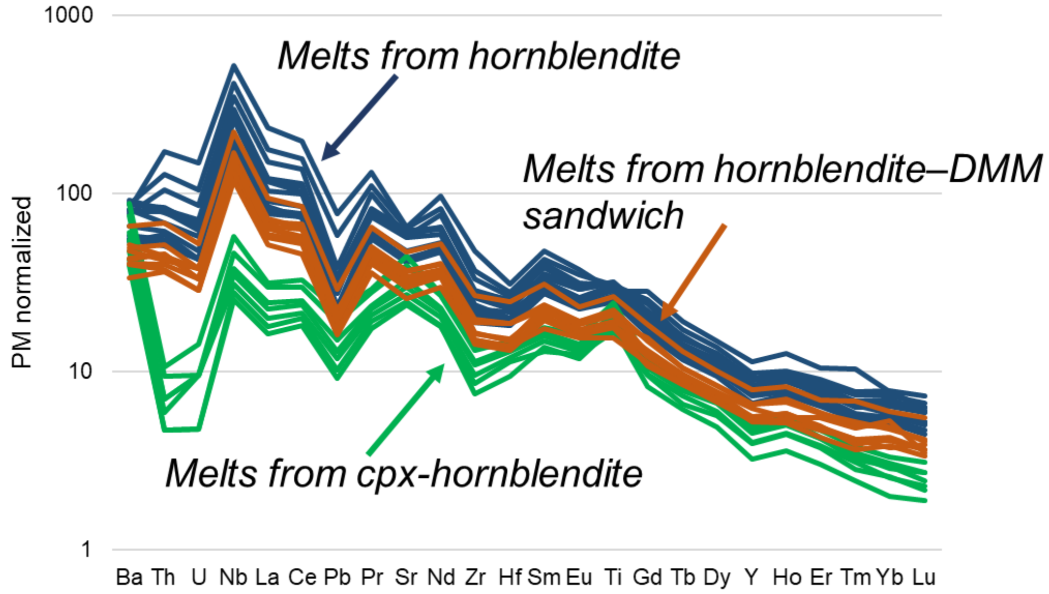

Fig. S8 Primitive mantle normalized trace-element patters of the produced melts from experiments of Pilet et al. (2008). Dark blue lines, green lines, and brown lines are melts from hornblendite, cpx-hornblendite, and hornblendite–DMM sandwich, respectively. Details are provided in Pilet et al. (2008).

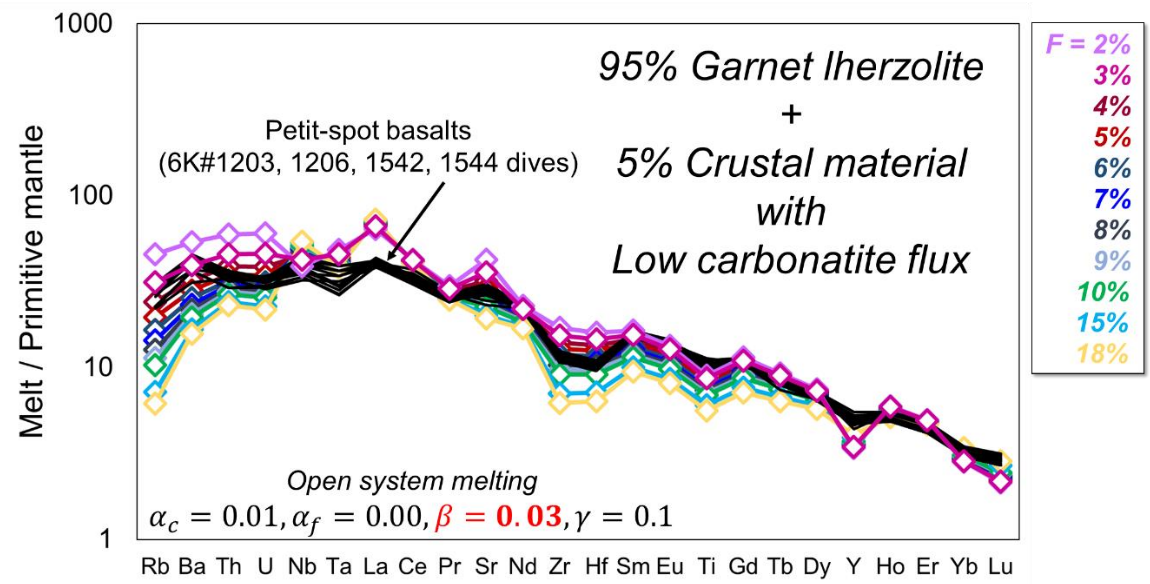

Fig. S9 Geochemical modeling for the primitive mantle (PM)-normalized trace-element pattern for each degree of melting. The calculated hypothetical melts are partial melts of 5% crustal component-bearing garnet lherzolite with carbonatite influx. Carbonatite influx rate (β) of 0.03 is lower than those consistent with 6K#1522 basalts (Figs. 11a and b). A melt-separation rate (γ) is 0.1. The trace-element composition of the western Pacific petit-spot basalts from the 6K#1203, 1206, 1542, and 1544 dives are shown as black lines for comparison. Used parameters were same as Fig. 11.

Supplementary Tables

Table S1

Mineral compositions: Olivine

Cruise	YK16-01											YK16-01				
Sample name	6K#1466R3-001											6K#1466R6-001				
No.	5	6	7	9	10	12	13	14	15	16	17	29	30	38	41	43
SiO_2	38.83	36.72	36.10	38.62	38.61	38.02	37.81	38.12	38.15	38.07	38.36	36.68	38.17	37.34	36.22	38.58
TiO_2	0.05	0.07	0.05	0.00	0.05	0.00	0.01	0.02	0.00	0.10	0.04	0.13	0.05	0.90	0.07	0.06
Al_2O_3	0.02	0.04	0.05	0.03	0.04	0.04	0.01	0.01	0.02	0.04	0.04	0.56	0.03	2.40	1.59	0.06
Cr_2O_3	0.01	0.01	0.02	0.02	0.04	0.01	0.02	0.04	0.01	0.00	0.00	0.02	0.01	0.04	0.00	0.01
FeO	22.52	22.35	21.99	22.74	22.21	22.67	22.26	22.78	22.02	22.28	22.50	22.51	19.74	21.35	23.59	18.52
MnO	0.37	0.36	0.38	0.27	0.35	0.29	0.36	0.22	0.30	0.27	0.29	0.31	0.24	0.36	0.33	0.24
MgO	38.48	39.51	39.69	38.55	38.34	38.37	38.50	38.35	38.56	38.58	38.86	37.71	40.84	32.55	34.56	41.16
CaO	0.25	0.29	0.32	0.27	0.23	0.25	0.27	0.27	0.27	0.33	0.30	0.47	0.21	4.29	0.40	0.34
Na_2O	0.00	0.04	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.01	0.10	0.01	0.19	0.26	0.02
K_2O	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.07	0.00	0.08	0.13	0.00
NiO	0.13	0.19	0.16	0.16	0.16	0.21	0.17	0.21	0.18	0.19	0.18	0.20	0.17	0.12	0.18	0.20
Total	100.66	99.59	98.75	100.67	100.01	99.87	99.42	100.01	99.52	99.87	100.60	98.75	99.47	99.61	97.33	99.18
cation ratio (O=4)																
SiO_2	1.004	0.966	0.958	1.000	1.004	0.994	0.992	0.995	0.998	0.994	0.994	0.974	0.989	0.983	0.980	0.996
TiO_2	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.002	0.001	0.003	0.001	0.018	0.001	0.001
Al_2O_3	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.017	0.001	0.074	0.051	0.002
Cr_2O_3	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
FeO	0.487	0.492	0.488	0.492	0.483	0.496	0.489	0.497	0.482	0.486	0.488	0.500	0.427	0.470	0.534	0.400
MnO	0.008	0.008	0.009	0.006	0.008	0.006	0.008	0.005	0.007	0.006	0.006	0.007	0.005	0.008	0.007	0.005
MgO	1.484	1.550	1.570	1.488	1.487	1.496	1.506	1.493	1.503	1.501	1.502	1.492	1.577	1.278	1.394	1.584
CaO	0.007	0.008	0.009	0.008	0.006	0.007	0.008	0.008	0.007	0.009	0.008	0.013	0.006	0.121	0.012	0.009
Na_2O	0.000	0.002	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.005	0.000	0.010	0.014	0.001
K_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.000	0.003	0.004	0.000
NiO	0.003	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.004	0.004
total cation	2.994	3.033	3.040	2.999	2.994	3.005	3.008	3.004	3.002	3.004	3.005	3.018	3.010	2.968	3.002	3.002
Fo# = $100(Mg/Mg+Fe^{2+})_{cation}$	75.29	75.91	76.29	75.14	75.48	75.11	75.51	75.01	75.74	75.54	75.49	74.91	78.67	73.10	72.31	79.85

Table S1 continued

YK18-08					YK18-08						YK19-05S									
6K#1521R04					6K#1522R01						6K#1542R06									
45	48	53	54	55	56	57	58	59	60	67	5	6	7	8	11	12	18	19	20	21
38.43	38.54	38.82	37.64	37.30	39.51	38.65	38.90	38.87	38.67	38.83	40.07	39.78	39.88	40.47	39.11	38.82	39.48	39.63	39.89	39.95
0.11	0.30	0.05	0.03	0.12	0.01	0.05	0.01	0.00	0.00	0.00	0.00	0.05	0.03	0.12	0.02	0.01	0.01	0.01	0.03	0.00
0.03	0.02	0.04	0.03	0.11	0.02	0.34	0.05	0.03	0.06	0.03	0.03	0.01	0.04	1.18	0.06	0.03	0.03	0.03	0.03	0.05
0.04	0.00	0.03	0.00	0.00	0.03	0.03	0.06	0.06	0.02	0.03	0.05	0.03	0.04	0.10	0.08	0.02	0.02	0.00	0.16	0.07
22.24	22.77	22.73	22.16	22.48	16.59	18.41	16.94	16.68	15.99	16.10	15.61	16.01	15.97	16.31	15.78	15.80	15.83	16.00	15.92	16.11
0.20	0.31	0.28	0.32	0.24	0.28	0.21	0.21	0.23	0.22	0.18	0.22	0.21	0.19	0.26	0.16	0.18	0.19	0.20	0.22	0.11
38.33	39.03	38.47	38.99	37.99	43.05	40.53	42.65	43.02	43.99	43.43	45.33	44.70	44.62	41.96	44.39	43.92	44.39	44.11	44.57	44.55
0.25	0.24	0.21	0.23	0.26	0.42	0.43	0.44	0.44	0.40	0.41	0.26	0.33	0.31	0.76	0.30	0.31	0.31	0.34	0.28	0.30
0.00	0.01	0.00	0.02	0.02	0.03	0.04	0.03	0.00	0.00	0.01	0.03	0.00	0.00	0.22	0.01	0.00	0.00	0.01	0.00	0.00
0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.09	0.03	-0.01	0.00	0.00	0.01	0.02
0.04	0.04	0.08	0.02	0.07	0.23	0.19	0.22	0.20	0.25	0.21	0.31	0.34	0.33	0.23	0.28	0.29	0.31	0.26	0.29	0.33
99.68	101.26	100.70	99.44	98.62	100.18	98.89	99.52	99.54	99.60	99.22	101.90	101.47	101.41	101.71	100.22	99.37	100.57	100.58	101.40	101.48
1.003	0.992	1.004	0.987	0.988	1.000	1.000	0.994	0.992	0.984	0.991	0.992	0.991	0.994	1.005	0.987	0.988	0.992	0.996	0.994	0.995
0.002	0.006	0.001	0.000	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.001	0.000
0.001	0.001	0.001	0.001	0.004	0.001	0.010	0.002	0.001	0.002	0.001	0.001	0.000	0.001	0.035	0.002	0.001	0.001	0.001	0.001	0.001
0.001	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.000	0.000	0.000	0.003	0.001
0.485	0.490	0.491	0.486	0.498	0.351	0.398	0.362	0.356	0.340	0.344	0.323	0.334	0.333	0.339	0.333	0.336	0.333	0.336	0.332	0.335
0.004	0.007	0.006	0.007	0.005	0.006	0.005	0.005	0.005	0.005	0.004	0.005	0.004	0.004	0.005	0.003	0.004	0.004	0.004	0.005	0.002
1.490	1.498	1.483	1.524	1.500	1.624	1.563	1.624	1.636	1.668	1.652	1.673	1.660	1.657	1.554	1.670	1.667	1.663	1.652	1.656	1.654
0.007	0.006	0.006	0.006	0.007	0.011	0.012	0.012	0.012	0.011	0.011	0.007	0.009	0.008	0.020	0.008	0.008	0.008	0.009	0.007	0.008
0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001	0.000	0.000	0.000	0.000	0.001
0.001	0.001	0.002	0.000	0.002	0.005	0.004	0.005	0.004	0.005	0.004	0.006	0.007	0.007	0.005	0.006	0.006	0.006	0.005	0.006	0.007
2.995	3.002	2.994	3.013	3.008	3.000	2.995	3.005	3.007	3.015	3.009	3.008	3.007	3.005	2.981	3.012	3.011	3.007	3.004	3.004	3.004
75.44	75.34	75.11	75.82	75.08	82.22	79.70	81.78	82.13	83.07	82.79	83.81	83.27	83.28	82.10	83.38	83.21	83.33	83.09	83.31	83.14

Table S1 continued

YK19-05S				
6K#1544R04				
27	28	29	30	31
39.89	39.65	39.79	40.25	39.83
0.03	0.05	0.01	0.08	0.00
0.05	0.04	0.04	0.15	0.04
0.03	0.03	0.07	0.06	0.10
17.20	17.68	17.95	18.08	17.51
0.19	0.24	0.20	0.24	0.21
44.37	43.56	43.70	43.23	43.95
0.32	0.30	0.34	0.38	0.30
0.00	0.02	0.00	0.02	0.00
0.01	0.00	0.01	0.02	0.01
0.24	0.21	0.22	0.20	0.23
102.32	101.77	102.32	102.70	102.17
0.990	0.992	0.991	0.998	0.991
0.001	0.001	0.000	0.001	0.000
0.001	0.001	0.001	0.004	0.001
0.001	0.001	0.001	0.001	0.002
0.357	0.370	0.374	0.375	0.364
0.004	0.005	0.004	0.005	0.004
1.642	1.624	1.622	1.598	1.631
0.008	0.008	0.009	0.010	0.008
0.000	0.001	0.000	0.001	0.000
0.000	0.000	0.000	0.000	0.000
0.005	0.004	0.004	0.004	0.005
3.008	3.007	3.008	2.998	3.007
82.14	81.46	81.27	81.00	81.74

Table S1
Mineral compositions: Clinopyroxene

	YK16-01 6K#1466R6-001								YK18-08 6K#1521R04					YK19-05S 6K#1544R04				
No.	31	32	33	34	36	37	39	40	61	70	71	72	73	22	23	24	25	26
SiO_2	45.07	42.27	42.67	43.23	44.53	43.76	45.12	42.67	40.59	39.39	38.95	41.29	42.56	48.52	51.39	48.99	50.07	47.98
TiO_2	3.19	3.89	3.99	4.08	3.44	3.90	3.49	5.11	3.34	4.08	3.97	3.66	2.74	2.12	1.22	1.92	1.60	1.92
Al_2O_3	6.06	8.13	7.47	8.41	6.17	7.00	6.46	9.09	10.80	10.26	9.87	9.77	9.21	6.21	3.99	5.75	5.08	6.07
Cr_2O_3	0.01	0.00	0.00	0.02	0.00	0.01	0.04	0.00	0.06	0.07	0.07	0.08	0.04	0.24	0.51	0.36	0.47	0.06
FeO	9.16	9.49	10.66	10.32	9.30	9.14	9.36	9.56	13.75	13.85	13.40	13.26	12.19	8.04	7.94	8.21	7.33	9.43
MnO	0.22	0.19	0.16	0.14	0.12	0.09	0.10	0.14	0.18	0.14	0.13	0.11	0.24	0.09	0.17	0.20	0.17	0.19
MgO	12.44	10.72	10.54	10.33	12.04	11.77	11.65	10.34	7.07	7.58	8.05	7.55	11.24	14.45	17.48	15.46	15.40	14.57
CaO	22.03	22.04	21.60	21.83	21.62	21.87	22.06	22.45	21.75	22.09	21.99	21.49	17.95	20.28	17.55	18.75	19.96	19.15
Na_2O	0.45	0.58	0.58	0.60	0.44	0.51	0.50	0.61	0.85	0.68	0.72	0.73	0.66	0.40	0.36	0.45	0.36	0.39
K_2O	0.03	0.04	0.05	0.02	0.07	0.01	0.03	0.02	0.05	0.01	0.05	0.15	0.15	0.01	0.05	0.03	0.00	0.02
NiO	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.01	0.03	0.01	0.04	0.01	0.04
Total	98.67	97.34	97.74	98.99	97.76	98.07	98.80	100.00	98.45	98.16	97.20	98.09	96.98	100.39	100.66	100.15	100.43	99.81
cation ratio (O=6)																		
SiO_2	1.73	1.66	1.67	1.67	1.73	1.69	1.73	1.63	1.61	1.57	1.57	1.63	1.67	1.80	1.88	1.81	1.84	1.80
TiO_2	0.09	0.11	0.12	0.12	0.10	0.11	0.10	0.15	0.10	0.12	0.12	0.11	0.08	0.06	0.03	0.05	0.04	0.05
Al_2O_3	0.27	0.38	0.35	0.38	0.28	0.32	0.29	0.41	0.50	0.48	0.47	0.46	0.43	0.27	0.17	0.25	0.22	0.27
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00
FeO	0.29	0.31	0.35	0.33	0.30	0.30	0.30	0.31	0.45	0.46	0.45	0.44	0.40	0.25	0.24	0.25	0.23	0.29
MnO	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01
MgO	0.71	0.63	0.62	0.59	0.70	0.68	0.67	0.59	0.42	0.45	0.48	0.45	0.66	0.80	0.95	0.85	0.84	0.81
CaO	0.91	0.93	0.91	0.90	0.90	0.91	0.91	0.92	0.92	0.94	0.95	0.91	0.76	0.80	0.69	0.74	0.79	0.77
Na_2O	0.03	0.04	0.04	0.05	0.03	0.04	0.04	0.04	0.07	0.05	0.06	0.06	0.05	0.03	0.03	0.03	0.03	0.03
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
NiO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total cation	4.06	4.06	4.06	4.05	4.05	4.05	4.04	4.04	4.08	4.09	4.11	4.06	4.06	4.02	4.01	4.02	4.01	4.03
$Mg\# = 100(Mg/Mg+Fe^{2+})_{cation}$	70.77	66.83	63.81	64.09	69.78	69.64	68.93	65.84	47.83	49.40	51.70	50.39	62.17	76.22	79.70	77.06	78.92	73.36

Table S1
Mineral compositions: Plagioclase, FeTi oxide, spinel

	YK16-01 6K#1466R3-001								YK16-01 6K#1466R6-001				
No.	8	11	18	19	20	21	22	23	24	25	26	27	28
SiO_2	0.11	1.38	0.09	0.07	0.11	51.18	52.35	53.15	0.11	0.13	15.01	0.19	0.13
TiO_2	10.68	11.09	11.29	10.70	10.73	0.08	0.16	0.17	16.19	16.98	13.20	17.69	16.81
Al_2O_3	7.16	6.41	6.83	7.18	7.17	28.37	28.08	27.88	5.22	5.05	8.40	4.99	5.10
Cr_2O_3	9.43	6.15	6.72	9.20	8.94	0.00	0.00	0.00	1.08	0.06	0.80	0.04	0.16
FeO	63.10	65.08	64.81	62.66	62.54	0.78	0.73	0.75	69.02	70.32	50.96	69.08	69.50
MnO	0.27	0.29	0.34	0.24	0.29	0.03	0.00	0.00	0.47	0.38	0.50	0.45	0.50
MgO	6.60	7.65	6.50	6.39	6.58	0.12	0.14	0.12	5.27	4.83	4.98	4.20	4.93
CaO	0.07	0.05	0.03	0.11	0.20	12.05	11.55	11.64	0.04	0.11	4.37	0.16	0.10
Na_2O	0.00	0.00	0.00	0.00	0.00	4.29	4.50	4.49	0.04	0.05	0.98	0.03	0.00
K_2O	0.04	0.01	0.02	0.01	0.04	0.33	0.36	0.37	0.02	0.00	0.64	0.07	0.04
NiO	0.20	0.20	0.15	0.22	0.20	0.01	0.03	0.00	0.06	0.04	0.04	0.04	0.05
Total	97.66	98.29	96.78	96.79	96.79	97.24	97.88	98.55	97.52	97.96	99.88	96.93	97.31
Mineral species	FeTi ox	FeTi ox	FeTi ox	FeTi ox	FeTi ox	Pl	Pl	Pl	FeTi ox	FeTi ox	Spl	FeTi ox	FeTi ox
cation ratio (O=24)													
SiO_2	0.02	0.32	0.02	0.02	0.03	7.19	7.29	7.34	0.03	0.03	2.95	0.05	0.03
TiO_2	1.87	1.92	2.01	1.89	1.89	0.01	0.02	0.02	2.89	3.03	1.95	3.18	3.01
Al_2O_3	1.96	1.74	1.90	1.99	1.98	4.70	4.61	4.54	1.46	1.41	1.94	1.40	1.43
Cr_2O_3	1.73	1.12	1.26	1.71	1.66	0.00	0.00	0.00	0.20	0.01	0.12	0.01	0.03
FeO	12.27	12.52	12.81	12.30	12.26	0.09	0.08	0.09	13.69	13.93	8.37	13.79	13.84
MnO	0.05	0.06	0.07	0.05	0.06	0.00	0.00	0.00	0.09	0.08	0.08	0.09	0.10
MgO	2.29	2.62	2.29	2.23	2.30	0.03	0.03	0.02	1.86	1.71	1.46	1.49	1.75
CaO	0.02	0.01	0.01	0.03	0.05	1.81	1.72	1.72	0.01	0.03	0.92	0.04	0.03
Na_2O	0.00	0.00	0.00	0.00	0.00	1.17	1.21	1.20	0.02	0.02	0.37	0.01	0.00
K_2O	0.01	0.00	0.01	0.00	0.01	0.06	0.06	0.07	0.01	0.00	0.16	0.02	0.01
NiO	0.04	0.04	0.03	0.04	0.04	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Total cation	20.26	20.34	20.40	20.25	20.27	15.06	15.03	15.00	20.27	20.24	18.33	20.09	20.23

Table S1 continued

YK18-08					YK18-08					YK19-05S					
6K#1521R04					6K#1522R01					6K#1542R06					
46	47	49	51	52	62	63	64	65	66	9	37	13	14	15	16
0.02	0.10	0.04	0.10	0.13	2.56	2.89	0.91	8.43	0.19	0.07	0.13	0.10	0.10	0.10	0.12
48.43	47.81	48.05	17.43	17.41	4.90	4.07	4.79	3.81	4.70	1.86	2.80	3.20	2.76	3.34	2.98
0.64	0.65	0.63	5.02	5.00	11.62	9.53	10.45	9.65	10.42	11.02	12.34	13.25	12.20	13.29	12.75
0.00	0.00	0.00	0.01	0.00	24.50	25.17	24.62	21.86	25.01	44.12	36.88	36.26	39.16	36.63	37.61
43.39	43.26	43.69	67.93	67.96	42.64	43.76	44.59	40.09	44.71	30.58	33.50	35.63	33.96	35.56	35.15
0.19	0.31	0.28	0.32	0.33	0.26	0.25	0.37	0.29	0.32	0.27	0.29	0.23	0.17	0.22	0.27
7.16	6.99	7.24	6.52	6.49	10.41	12.65	10.90	19.02	9.89	10.45	10.72	10.67	10.44	11.02	10.62
0.09	0.09	0.09	0.17	0.23	1.15	0.09	0.11	0.17	0.07	0.16	0.00	0.06	0.15	0.03	0.16
0.02	0.00	0.01	0.00	0.00	0.03	0.01	0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.01
0.00	0.01	0.00	0.01	0.03	0.00	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01
0.02	0.04	0.02	0.13	0.09	0.24	0.21	0.23	0.27	0.22	0.15	0.19	0.22	0.17	0.21	0.16
99.96	99.26	100.05	97.63	97.67	98.32	98.64	96.98	103.62	95.56	98.66	96.83	99.62	99.10	100.40	99.85
ilmenite	ilmenite	Ilmenite	FeTi ox	FeTi ox	Spl	Spl	Spl	Spl	Spl	Spl	Spl	Spl	Spl	Spl	Spl
0.00	0.02	0.01	0.02	0.03	0.53	0.60	0.20	1.58	0.04	0.01	0.03	0.02	0.02	0.02	0.02
7.21	7.18	7.16	3.07	3.07	0.77	0.64	0.78	0.54	0.78	0.29	0.44	0.49	0.43	0.51	0.46
0.15	0.15	0.15	1.39	1.38	2.86	2.35	2.67	2.13	2.72	2.68	3.05	3.19	2.96	3.17	3.07
0.00	0.00	0.00	0.00	0.00	4.04	4.17	4.21	3.24	4.39	7.19	6.12	5.85	6.36	5.85	6.07
7.18	7.22	7.24	13.32	13.32	7.45	7.67	8.07	6.28	8.29	5.27	5.88	6.08	5.84	6.01	6.00
0.03	0.05	0.05	0.06	0.07	0.05	0.04	0.07	0.05	0.06	0.05	0.05	0.04	0.03	0.04	0.05
2.11	2.08	2.14	2.28	2.27	3.24	3.95	3.52	5.31	3.27	3.21	3.35	3.25	3.20	3.32	3.23
0.02	0.02	0.02	0.04	0.06	0.26	0.02	0.03	0.03	0.02	0.03	0.00	0.01	0.03	0.01	0.03
0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01
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	0.01	0.00	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.02	0.03	0.04	0.03	0.03	0.03
16.72	16.73	16.76	20.21	20.21	19.25	19.49	19.59	19.20	19.62	18.76	18.95	18.97	18.89	18.96	18.96

Table S2 Results of Ar-Ar dating

6K#1466 R6-001

T (℃)	^{36}Ar/^{40}Ar	^{37}Ar/^{40}Ar	^{38}Ar/^{40}Ar	^{39}Ar/^{40}Ar	%^{39}Ar	%^{40}Ar*	Ca/K	^{40}Ar*/^{39}Ar$_K$	Age(Ma)
600	0.00246 ± 0.00046	0.021 ± 0.053	0.01438 ± 0.00033	0.08495 ± 0.00085	0.4	27	0.24	3.2 ± 1.6	109 ± 53
700	0.002803 ± 0.000051	0.243 ± 0.012	0.2062 ± 0.0013	1.2682 ± 0.0076	5.5	27	0.19	0.135 ± 0.012	4.73 ± 0.42
780	0.002128 ± 0.000055	0.780 ± 0.019	0.7162 ± 0.0074	4.450 ± 0.046	18.7	37	0.18	0.0834 ± 0.0039	2.91 ± 0.14
860	0.002004 ± 0.000055	0.970 ± 0.023	0.7977 ± 0.0090	4.747 ± 0.053	19.9	41	0.20	0.0859 ± 0.0038	3.00 ± 0.13
940	0.00200 ± 0.00011	0.684 ± 0.024	0.4289 ± 0.0042	3.918 ± 0.037	16.6	41	0.17	0.1042 ± 0.0083	3.64 ± 0.29
1020	0.00218 ± 0.00026	0.605 ± 0.042	0.2045 ± 0.0019	2.987 ± 0.025	12.8	36	0.20	0.120 ± 0.026	4.18 ± 0.91
1100	0.00320 ± 0.00027	1.748 ± 0.062	0.2874 ± 0.0024	1.858 ± 0.014	8.0	5	0.94	0.029 ± 0.042	1.0 ± 1.5
1200	0.00257 ± 0.00027	11.00 ± 0.25	0.4245 ± 0.0038	2.563 ± 0.022	11.0	24	4.3	0.094 ± 0.032	3.3 ± 1.1
1300	0.00367 ± 0.00087	101.7 ± 2.1	0.2383 ± 0.0018	1.518 ± 0.011	6.6	0	67	-0.06 ± -0.17	-2.0 ± 6.0
1400	0.00314 ± 0.00059	23.71 ± 0.57	0.00459 ± 0.00053	0.0766 ± 0.0013	0.3	7	309	0.9 ± 2.3	32 ± 78
1500	0.03226 ± 0.00065	4.69 ± 0.18	0.00888 ± 0.00040	0.04832 ± 0.00082	0.2	0	97	-176.6 ± -5.0	n.d. ±

* Irradiation for 6.6 days at the Kyoto University Reactor (KUR), Kyoto University.
* Analysis after 322 days from the irradiation.
* J-value: 0.01939 ± 0.00012

6K#1522 R01

T (℃)	^{36}Ar/^{40}Ar	^{37}Ar/^{40}Ar	^{38}Ar/^{40}Ar	^{39}Ar/^{40}Ar	%^{39}Ar	%^{40}Ar*	Ca/K	^{40}Ar*/^{39}Ar$_K$	Age(Ma)
600	0.00314 ± 0.00027	0.021 ± 0.049	0.01990 ± 0.00021	0.06776 ± 0.00052	0.3	7.4	0.32	1.1 ± 1.2	38 ± 41
700	0.003269 ± 0.000031	0.3441 ± 0.0094	0.2834 ± 0.0017	0.8565 ± 0.0049	3.7	3.4	0.40	0.040 ± 0.011	1.41 ± 0.38
760	0.003393 ± 0.000064	1.418 ± 0.049	1.250 ± 0.010	3.393 ± 0.028	14.3	0	0.42	-0.0008 ± 0.0056	-0.03 ± 0.20
820	0.003416 ± 0.000081	2.260 ± 0.067	1.869 ± 0.020	4.564 ± 0.050	19.1	0	0.50	-0.0021 ± 0.0053	-0.07 ± 0.19
880	0.003478 ± 0.000081	2.142 ± 0.052	1.629 ± 0.016	3.782 ± 0.037	15.9	0	0.57	-0.0074 ± 0.0063	-0.26 ± 0.22
940	0.003146 ± 0.000070	1.944 ± 0.048	1.1673 ± 0.0098	2.763 ± 0.022	11.8	7.0	0.70	0.0255 ± 0.0075	0.90 ± 0.27
1000	0.003014 ± 0.000089	1.224 ± 0.037	0.6198 ± 0.0040	1.4423 ± 0.0091	6.2	10.9	0.85	0.076 ± 0.018	2.67 ± 0.64
1100	0.002477 ± 0.000044	2.388 ± 0.054	1.1159 ± 0.0082	2.306 ± 0.017	9.9	26.8	1.0	0.1163 ± 0.0058	4.10 ± 0.20
1200	0.002965 ± 0.000087	4.49 ± 0.10	0.6427 ± 0.0042	1.593 ± 0.010	6.9	12.4	2.8	0.078 ± 0.016	2.74 ± 0.57
1300	0.0030 ± 0.0012	131.4 ± 2.8	0.3841 ± 0.0033	2.309 ± 0.018	9.9	12.2	57	0.05 ± 0.15	1.9 ± 5.2
1400	0.00301 ± 0.00030	14.62 ± 0.33	0.05251 ± 0.00063	0.3550 ± 0.0031	1.5	11.0	41	0.31 ± 0.25	10.9 ± 8.8
1500	0.00319 ± 0.00021	2.809 ± 0.079	0.01304 ± 0.00020	0.12375 ± 0.00080	0.5	5.8	23	0.47 ± 0.50	17 ± 17

* Irradiation for 6.6 days at the Kyoto University Reactor (KUR), Kyoto University.
* Analysis after 327 days from the irradiation.
* J-value: 0.01957 ± 0.00012

* All errors shown in 1-sigma, not including the decay contant uncertainties.
* All data using 295.5 of ^{40}Ar/^{36}Ar ratio for air standard correction.
  Nier, A. (1950) A redetermination of the relative abundances of the isotopes of carbon, nitrogen, oxygen, argon, and potassium. Physical Review 77, 789-793.
* All data using the decay contants referred from:
  Stoenner, R.W., Schaeffer, O.A., & Katcoff, S. (1965) Half-lives of argon-37, argon-39, and argon-42. Science 148, 1325-1328.
* The age of flux monitor is 91.4 +/- 0.5 Ma (JB1 biotite) referred from:
  Iwata, N. (1998) Geochronological study of the Deccan volcanism by the ^{40}Ar-^{39}Ar method. Ph.D. thesis, University of Tokyo, Tokyo.
* All data described after the corrections from interfering isotopes from Ca & K as below:

(^{36}Ar/^{37}Ar)$_{Ca}$	0.0002683	± 0.0000059
(^{38}Ar/^{37}Ar)$_{Ca}$	0.0000709	± 0.0000020
(^{39}Ar/^{37}Ar)$_{Ca}$	0.000794	± 0.000016
(^{38}Ar/^{39}Ar)$_K$	0.01093	± 0.00013
(^{40}Ar/^{39}Ar)$_K$	0.0098	± 0.0018

Table S3

Result of olivine maximum fractionation model

Cruise	YK18-08				YK18-08			
Sample name	6K#1522R02				6K#1522R17			
Sample type	Glass				Glass			
	Original	100 normalized original	Primary	Olivine equilibrium with primary melt	Original	100 normalized original	Primary	Olivine equilibrium with primary melt
wt%								
SiO_2	45.90	47.04	46.42	40.16	45.06	46.20	45.75	39.96
TiO_2	2.51	2.57	2.35	0.00	2.67	2.74	2.55	0.00
Al_2O_3	12.82	13.14	12.01	0.00	12.55	12.87	12.00	0.00
Cr_2O_3	0.02	0.02	0.02	0.00	0.02	0.02	0.02	0.00
FeO*	11.64	11.93	12.22	13.25	11.89	12.19	12.45	14.33
MnO	0.16	0.17	0.15	0.00	0.18	0.18	0.17	0.00
MgO	7.33	7.51	10.73	46.28	7.24	7.42	9.91	45.42
CaO	10.81	11.07	10.12	0.00	11.19	11.47	10.69	0.00
Na_2O	4.16	4.27	3.90	0.00	4.28	4.39	4.09	0.00
K_2O	1.40	1.43	1.31	0.00	1.51	1.55	1.44	0.00
NiO	0.01	0.01	0.03	0.31	0.01	0.01	0.02	0.29
P2O5	0.80	0.82	0.75	0.00	0.95	0.97	0.90	0.00
Total	97.56	100.00	100.00	100.00	97.54	100.00	100.00	100.00
μg/g								
Li	7.69		7.03		8.42		7.85	
B	2.34		2.13		2.94		2.74	
Sc	20.6		18.8		20.6		19.2	
V	208		190		209		195	
Cr	218		199		203		189	
Co	46.8		42.7		46.8		43.6	
Rb	26.9		24.6		29.7		27.7	
Sr	924		845		1086		1012	
Y	26.0		23.7		29.6		27.6	
Zr	168		153		194		181	
Nb	55.3		50.5		65.7		61.2	
Cs	0.35		0.32		0.40		0.37	
Ba	512		468		590		550	
La	49.6		45.3		60.9		56.7	
Ce	101		92		122		113	
Pr	11.3		10.3		13.8		12.8	
Nd	45.5		41.6		55.7		51.9	
Sm	9.60		8.77		11.4		10.58	
Eu	3.13		2.86		3.67		3.42	
Gd	8.27		7.55		9.92		9.25	
Tb	1.08		0.99		1.27		1.19	
Dy	5.94		5.42		6.81		6.35	
Ho	0.97		0.88		1.10		1.03	
Er	2.37		2.17		2.63		2.45	
Tm	0.26		0.24		0.30		0.28	
Yb	1.64		1.50		1.75		1.63	
Lu	0.22		0.20		0.22		0.21	
Hf	3.76		3.44		4.36		4.07	
Ta	2.34		2.14		2.77		2.58	
Pb	3.68		3.36		4.29		4.00	
Th	5.73		5.23		7.29		6.79	
U	1.28		1.17		1.58		1.48	

FeO* is total iron content as Fe^{2+}.

Table S4 Modelling parameters and results

Modelling parameters

Mineral proportion in solid and melt modes of hypothetical garnet lherzolite

	Olivine	Orthopyroxene	Clinopyroxene	Garnet
Source*[a]	0.55	0.20	0.15	0.10
Melt*[b]	0.08	-0.19	0.81	0.30

*a Mineralogy of source peridotite is from Johnson et al. (1990)

*b Melting reaction at 3GPa is after Walter (1998)

Trace element concetration of references and partition coefficients

Concentrations					Partition coefficients*[e, f, g]			
μg/g	PM*[c]	N-MORB*[c]	Carbonatite*[d]	5% N-MORB + 95% PM	Ol	Opx	Cpx	Grt
Rb	0.635	0.56	18.72	0.63	0.00018	0.0006	0.011	0.0007
Ba	6.989	6.3	2628	6.95	0.0003	0.0001	0.0005	0.0005
Th	0.085	0.12	54.25	0.09	0.0001	0.0001	0.00026	0.0001
U	0.021	0.047	12.16	0.02	0.0001	0.0001	0.00036	0.0001
Nb	0.713	2.33	1344	0.79	0.01	0.02	0.05	0.07
Ta	0.041	0.132	49.79	0.05	0.005	0.005	0.02	0.04
La	0.687	2.5	1666	0.78	0.0004	0.002	0.054	0.01
Ce	1.775	7.5	2250	2.06	0.0005	0.003	0.098	0.021
Pr	0.276	1.32	190.5	0.33	0.0008	0.0048	0.15	0.054
Sr	21.1	90	10088	24.55	0.00019	0.007	0.067	0.0011
Nd	1.354	7.3	535.4	1.65	0.001	0.0068	0.21	0.087
Zr	11.2	74	67.76	14.34	0.01	0.03	0.1	0.32
Hf	0.309	2.05	0.61	0.40	0.01	0.01	0.233	0.23
Sm	0.444	2.63	55.3	0.55	0.0013	0.01	0.26	0.217
Eu	0.168	1.02	13.19	0.21	0.0016	0.013	0.31	0.32
Ti	1300	7600	323.6	1615	0.006	0.024	0.4	0.6
Gd	0.596	3.68	31.48	0.75	0.0015	0.016	0.3	0.498
Tb	0.108	0.67	3.67	0.14	0.0015	0.019	0.31	0.75
Dy	0.737	4.55	17.21	0.93	0.0017	0.022	0.33	1.06
Y	4.55	28	90.06	5.72	0.005	0.01	0.4	3.1
Ho	0.164	1.01	2.99	0.21	0.0016	0.026	0.31	1.53
Er	0.48	2.97	7.27	0.60	0.0015	0.03	0.3	2
Yb	0.493	3.05	5.24	0.62	0.0015	0.049	0.28	4.03
Lu	0.074	0.455	0.71	0.09	0.0015	0.06	0.28	5.5

*c Trace element concentration of PM (primitive mantle) and N-MORB are from Sun and McDonough (1989)

*d Trace element concentration of carbonatite is from "Average carbonatite" of Bizimis et al. (2003)

*e Partition coefficients of each mineral are from McKenzie and O'Nions (1991), *f Ti for Cpx and Grt are from Kelemen et al. (2003), :g Y for each mineral are from White (2013)

Results of melting model using the OSM-4 of Ozawa et al. (2001)*h

Situation	Source: 0.05 N-MORB + 0.95 PM, carbonatite influx rate (β): 0.1, melt separation rate (γ): 0.1										
Degree of	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.15	0.18
μg/g											
Rb	28.6	19.9	15.4	12.7	10.9	9.6	8.7	7.9	7.3	5.4	4.8
Ba	450	378	343	322	308	298	291	285	280	266	262
Th	6.68	6.08	5.79	5.61	5.50	5.42	5.36	5.31	5.27	5.16	5.12
U	1.63	1.45	1.36	1.31	1.28	1.25	1.23	1.22	1.21	1.17	1.16
Nb	48.5	63.7	74.2	81.7	87.5	92.0	95.6	98.6	101.1	109.3	112.2
Ta	3.05	3.45	3.70	3.86	3.97	4.06	4.12	4.17	4.22	4.35	4.40
La	81.8	101.6	113.3	121.0	126.4	130.5	133.6	136.1	138.2	144.5	146.7
Ce	116.2	138.7	153.3	163.6	171.2	177.1	181.7	185.5	188.6	198.6	202.2
Pr	10.88	12.35	13.41	14.21	14.83	15.33	15.74	16.08	16.37	17.33	17.68
Sr	1096	1064	1044	1031	1021	1014	1008	1004	1000	989	985
Nd	36.9	39.8	42.0	43.8	45.2	46.4	47.5	48.3	49.1	51.7	52.7
Zr	190	170	155	142	131	122	114	107	100	78	69
Hf	4.89	4.45	4.08	3.77	3.50	3.27	3.06	2.88	2.72	2.13	1.89
Sm	7.71	7.62	7.54	7.47	7.42	7.37	7.32	7.29	7.25	7.13	7.08
Eu	2.33	2.29	2.25	2.22	2.19	2.17	2.15	2.13	2.11	2.04	2.01
Ti	11623	11158	10729	10331	9960	9614	9291	8987	8702	7502	6923
Gd	6.98	6.83	6.70	6.58	6.47	6.38	6.29	6.21	6.13	5.84	5.70
Tb	1.02	1.00	0.98	0.97	0.95	0.94	0.92	0.91	0.90	0.86	0.84
Dy	5.55	5.49	5.43	5.37	5.32	5.26	5.21	5.17	5.12	4.93	4.83
Y	15.7	16.0	16.3	16.6	16.9	17.2	17.5	17.8	18.1	19.8	20.8
Ho	0.99	0.98	0.98	0.97	0.97	0.97	0.96	0.96	0.96	0.94	0.93
Er	2.39	2.39	2.40	2.40	2.40	2.41	2.41	2.41	2.42	2.43	2.44
Yb	1.40	1.42	1.44	1.46	1.48	1.51	1.53	1.55	1.58	1.70	1.78
Lu	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.18	0.19	0.21	0.22

	Source: 0.05 N-MORB + 0.95 PM, carbonatite influx rate (β): 0.1, melt separation rate (γ): 1.0										
	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.15	0.18
μg/g											
Rb	29.0	20.3	15.8	13.0	11.1	9.7	8.7	7.9	7.3	5.4	4.8
Ba	451	379	343	322	308	298	291	285	280	266	262
Th	6.68	6.08	5.79	5.61	5.50	5.42	5.36	5.31	5.27	5.16	5.12
U	1.63	1.45	1.36	1.31	1.28	1.25	1.23	1.22	1.21	1.17	1.16
Nb	45.5	58.6	68.4	76.1	82.2	87.3	91.5	95.0	98.0	107.8	111.2
Ta	2.99	3.37	3.61	3.79	3.91	4.01	4.08	4.14	4.19	4.34	4.39
La	78.9	97.8	109.8	118.2	124.2	128.8	132.3	135.1	137.4	144.3	146.6
Ce	112.2	132.5	146.9	157.8	166.3	173.0	178.4	182.8	186.5	198.0	202.0
Pr	10.59	11.84	12.81	13.61	14.27	14.83	15.30	15.71	16.05	17.22	17.64
Sr	1102	1071	1051	1036	1026	1017	1011	1006	1002	989	985
Nd	36.3	38.6	40.5	42.2	43.7	45.0	46.1	47.1	48.0	51.2	52.5
Zr	194	179	166	155	145	136	128	120	113	87	75
Hf	4.98	4.65	4.35	4.09	3.85	3.62	3.41	3.22	3.04	2.33	2.01
Sm	7.73	7.66	7.60	7.54	7.49	7.44	7.40	7.35	7.32	7.16	7.09
Eu	2.34	2.31	2.28	2.26	2.23	2.21	2.19	2.17	2.15	2.06	2.02
Ti	11722	11394	11090	10796	10509	10228	9951	9679	9411	8133	7416
Gd	7.01	6.90	6.81	6.72	6.63	6.54	6.46	6.38	6.31	5.97	5.79
Tb	1.02	1.01	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.88	0.85
Dy	5.57	5.52	5.48	5.44	5.40	5.36	5.32	5.28	5.24	5.05	4.93
Y	15.6	15.8	16.0	16.2	16.4	16.6	16.8	17.0	17.2	18.4	19.3
Ho	0.99	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.95	0.94
Er	2.39	2.39	2.39	2.40	2.40	2.40	2.40	2.41	2.41	2.42	2.43
Yb	1.39	1.41	1.42	1.43	1.45	1.46	1.48	1.49	1.51	1.59	1.66
Lu	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.18	0.19	0.20

These results were "total melt" as a value considering of instantaneous melt and accumulated melt.

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Results of melting model using the OSM-4 of Ozawa et al. (2001)*h

	Source: PM, carbonatite influx rate (β): 0.1, melt separation rate (γ): 0.1										
	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.15	0.18
μg/g											
Rb	28.8	20.0	15.5	12.8	11.0	9.7	8.7	7.9	7.3	5.5	4.8
Ba	452	379	344	322	308	298	291	285	280	267	262
Th	6.59	6.03	5.75	5.58	5.47	5.39	5.34	5.29	5.25	5.15	5.11
U	1.57	1.41	1.33	1.29	1.26	1.23	1.22	1.21	1.20	1.17	1.16
Nb	46.6	62.2	72.9	80.6	86.5	91.1	94.8	97.9	100.5	108.8	111.8
Ta	2.90	3.35	3.61	3.78	3.91	4.00	4.07	4.13	4.18	4.32	4.38
La	78.7	99.3	111.5	119.5	125.1	129.4	132.6	135.2	137.4	144.0	146.2
Ce	108.5	132.6	148.3	159.3	167.5	173.8	178.8	182.8	186.2	196.9	200.8
Pr	9.78	11.44	12.63	13.52	14.22	14.78	15.24	15.62	15.94	17.02	17.42
Sr	987	981	978	976	974	973	972	971	970	968	967
Nd	31.8	35.4	38.1	40.3	42.1	43.6	44.8	45.9	46.8	50.0	51.2
Zr	148	133	121	111	103	96	89	84	79	62	55
Hf	3.81	3.47	3.19	2.94	2.73	2.55	2.40	2.26	2.13	1.67	1.48
Sm	6.32	6.36	6.39	6.41	6.43	6.45	6.47	6.48	6.49	6.54	6.56
Eu	1.89	1.88	1.87	1.86	1.85	1.85	1.84	1.84	1.83	1.82	1.81
Ti	9356	8983	8638	8318	8020	7741	7481	7237	7008	6043	5578
Gd	5.60	5.53	5.47	5.42	5.37	5.33	5.28	5.25	5.21	5.08	5.01
Tb	0.81	0.80	0.79	0.78	0.78	0.77	0.76	0.76	0.75	0.73	0.72
Dy	4.43	4.40	4.37	4.34	4.31	4.29	4.26	4.24	4.22	4.12	4.07
Y	12.5	12.8	13.1	13.4	13.7	14.0	14.3	14.6	14.9	16.5	17.5
Ho	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Er	1.90	1.91	1.92	1.93	1.94	1.94	1.95	1.96	1.97	2.00	2.02
Yb	1.11	1.13	1.15	1.17	1.19	1.21	1.23	1.25	1.27	1.39	1.46
Lu	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.17	0.18

	Source: PM, carbonatite influx rate (β): 0.1, melt separation rate (γ): 1.0										
	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.15	0.18
μg/g											
Rb	29.2	20.4	15.9	13.0	11.1	9.8	8.8	8.0	7.4	5.5	4.8
Ba	452	380	344	323	309	299	291	285	281	267	262
Th	6.60	6.03	5.75	5.58	5.47	5.39	5.34	5.29	5.25	5.15	5.11
U	1.57	1.41	1.33	1.29	1.26	1.23	1.22	1.21	1.20	1.17	1.16
Nb	43.6	57.0	67.0	74.8	81.2	86.3	90.6	94.2	97.3	107.3	110.8
Ta	2.84	3.25	3.52	3.71	3.84	3.95	4.03	4.10	4.15	4.31	4.37
La	75.7	95.4	107.9	116.6	122.9	127.6	131.3	134.2	136.6	143.7	146.2
Ce	104.2	126.0	141.4	153.1	162.2	169.4	175.2	180.0	183.9	196.3	200.5
Pr	9.45	10.85	11.95	12.84	13.59	14.21	14.75	15.20	15.59	16.90	17.37
Sr	988	983	979	976	975	973	972	971	970	968	968
Nd	31.1	34.0	36.3	38.4	40.2	41.7	43.1	44.4	45.5	49.5	51.0
Zr	152	140	130	122	114	107	100	95	89	69	60
Hf	3.89	3.63	3.40	3.19	3.01	2.83	2.67	2.52	2.38	1.82	1.58
Sm	6.32	6.34	6.37	6.39	6.41	6.42	6.44	6.45	6.47	6.52	6.55
Eu	1.89	1.88	1.87	1.87	1.86	1.86	1.85	1.85	1.84	1.82	1.81
Ti	9436	9173	8928	8691	8461	8234	8012	7793	7578	6550	5974
Gd	5.62	5.57	5.52	5.48	5.44	5.40	5.36	5.33	5.29	5.14	5.06
Tb	0.81	0.81	0.80	0.79	0.79	0.78	0.78	0.77	0.77	0.74	0.73
Dy	4.44	4.42	4.40	4.38	4.36	4.34	4.32	4.30	4.28	4.18	4.12
Y	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	14.0	15.2	16.0
Ho	0.79	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Er	1.90	1.91	1.91	1.92	1.92	1.93	1.93	1.94	1.95	1.98	2.00
Yb	1.11	1.12	1.13	1.14	1.16	1.17	1.18	1.20	1.21	1.29	1.35
Lu	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.16

Results of melting model using the OSM-4 of Ozawa et al. (2001)*h

	Source: 0.05 N-MORB + 0.95 PM, carbonatite influx rate (β): 1.0, melt separation rate (γ): 0.1										
	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.15	0.18
μg/g											
Rb	25.8	19.5	16.7	15.1	14.1	13.4	12.8	12.4	12.1	11.2	10.9
Ba	1097	1183	1221	1241	1255	1264	1271	1276	1280	1292	1296
Th	20.89	23.38	24.45	25.04	25.42	25.68	25.88	26.02	26.14	26.48	26.59
U	4.78	5.30	5.52	5.64	5.72	5.78	5.82	5.85	5.87	5.95	5.97
Nb	267.9	381.4	447.1	489.9	520.0	542.4	559.6	573.3	584.4	618.8	630.6
Ta	13.48	17.35	19.30	20.48	21.27	21.84	22.26	22.59	22.86	23.65	23.92
La	448.3	583.6	651.1	691.6	718.6	737.8	752.3	763.5	772.4	799.3	808.2
Ce	532.1	720.5	823.7	888.8	933.6	966.3	991.2	1010.9	1026.7	1075.0	1091.4
Pr	39.27	54.79	64.19	70.50	75.01	78.41	81.06	83.18	84.91	90.34	92.23
Sr	3083	3762	4109	4321	4462	4564	4641	4700	4748	4892	4941
Nd	102.1	142.5	169.1	187.9	201.8	212.7	221.3	228.3	234.1	252.8	259.5
Zr	177	152	135	122	113	105	98	93	89	74	69
Hf	4.46	3.80	3.33	2.96	2.68	2.45	2.26	2.11	1.97	1.52	1.36
Sm	12.53	15.70	17.99	19.72	21.07	22.16	23.05	23.80	24.43	26.54	27.33
Eu	3.25	3.88	4.37	4.75	5.06	5.32	5.53	5.72	5.87	6.42	6.63
Ti	10942	9970	9158	8469	7878	7365	6915	6518	6165	4858	4315
Gd	8.78	10.03	11.02	11.82	12.49	13.05	13.53	13.95	14.31	15.59	16.10
Tb	1.18	1.29	1.39	1.47	1.53	1.59	1.64	1.69	1.73	1.88	1.94
Dy	6.13	6.56	6.94	7.27	7.56	7.81	8.05	8.25	8.44	9.16	9.48
Y	17.4	19.4	21.2	23.1	24.8	26.5	28.1	29.7	31.3	38.2	41.9
Ho	1.07	1.13	1.19	1.25	1.30	1.34	1.39	1.42	1.46	1.60	1.66
Er	2.55	2.70	2.85	2.98	3.10	3.21	3.31	3.41	3.50	3.89	4.07
Yb	1.47	1.56	1.66	1.74	1.83	1.92	2.00	2.08	2.16	2.54	2.74
Lu	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.25	0.26	0.31	0.34

	Source: PM (non-modal batch melting*i)						
	0.001	0.01	0.02	0.05	0.1	0.15	0.2
μg/g							
Rb	216.7	53.6	29.2	12.3	6.3	4.2	3.2
Ba	5337	678	344	139	70	47	35
Th	75.64	8.40	4.22	1.70	0.85	0.57	0.42
U	18.44	2.07	1.04	0.42	0.21	0.14	0.10
Nb	28.6	21.3	16.6	10.0	6.0	4.3	3.4
Ta	3.50	2.00	1.36	0.69	0.38	0.26	0.20
La	64.4	35.7	23.9	12.0	6.5	4.5	3.4
Ce	95.5	66.2	49.3	28.0	16.3	11.5	8.8
Pr	9.15	7.28	5.93	3.81	2.39	1.74	1.37
Sr	1673	999	690	358	198	137	105
Nd	31.6	27.0	23.3	16.4	11.0	8.3	6.7
Zr	189	168	149	112	79	61	50
Hf	4.67	4.24	3.85	3.01	2.21	1.75	1.44
Sm	6.92	6.28	5.70	4.45	3.26	2.58	2.13
Eu	2.03	1.90	1.77	1.46	1.14	0.93	0.79
Ti	10109	9767	9413	8491	7299	6400	5699
Gd	5.99	5.68	5.37	4.61	3.73	3.13	2.70
Tb	0.85	0.82	0.79	0.71	0.60	0.53	0.47
Dy	4.57	4.47	4.36	4.05	3.64	3.30	3.01
Y	12.1	12.2	12.3	12.6	13.0	13.5	14.0
Ho	0.80	0.79	0.78	0.74	0.70	0.66	0.62
Er	1.90	1.89	1.88	1.85	1.79	1.74	1.69
Yb	1.08	1.09	1.10	1.14	1.19	1.26	1.33
Lu	0.12	0.12	0.13	0.13	0.14	0.16	0.17

Results of melting model using the OSM-4 of Ozawa et al. (2001)*h

ɔurce: 0.05 N-MORB + 0.95 PM, carbonatite influx rate (β): 0.03, melt separation rate (γ): 0.1

	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.15	0.18
μg/g											
Rb	28.9	19.9	15.3	12.4	10.5	9.1	8.1	7.2	6.6	4.6	3.9
Ba	376	276	226	196	176	162	151	143	136	117	110
Th	5.05	3.88	3.31	2.96	2.73	2.56	2.44	2.35	2.27	2.04	1.96
U	1.27	0.96	0.81	0.72	0.66	0.61	0.58	0.56	0.54	0.48	0.46
Nb	27.7	30.2	31.9	33.2	34.2	35.0	35.6	36.1	36.5	38.0	38.5
Ta	1.99	1.86	1.79	1.74	1.70	1.68	1.66	1.64	1.63	1.58	1.57
La	43.9	45.6	46.7	47.4	47.9	48.2	48.5	48.8	48.9	49.5	49.7
Ce	75.5	74.6	74.1	73.7	73.4	73.2	73.0	72.9	72.7	72.4	72.2
Pr	8.23	7.94	7.73	7.57	7.44	7.34	7.26	7.19	7.13	6.93	6.85
Sr	894	755	669	611	569	537	512	492	476	424	406
Nd	31.0	29.6	28.4	27.5	26.8	26.1	25.6	25.2	24.8	23.4	22.8
Zr	191	172	157	144	133	124	115	108	102	79	70
Hf	4.92	4.51	4.15	3.85	3.59	3.36	3.16	2.98	2.82	2.22	1.96
Sm	7.29	6.86	6.49	6.17	5.90	5.66	5.45	5.26	5.09	4.46	4.20
Eu	2.25	2.14	2.05	1.96	1.89	1.82	1.76	1.70	1.65	1.45	1.36
Ti	11679	11262	10874	10511	10170	9849	9547	9262	8993	7842	7276
Gd	6.83	6.55	6.29	6.06	5.85	5.66	5.48	5.32	5.17	4.55	4.27
Tb	1.00	0.97	0.94	0.92	0.89	0.87	0.85	0.83	0.81	0.73	0.69
Dy	5.51	5.40	5.29	5.19	5.10	5.01	4.92	4.84	4.76	4.41	4.22
Y	15.5	15.7	15.9	16.0	16.2	16.4	16.5	16.7	16.9	17.8	18.4
Ho	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.86	0.84
Er	2.38	2.37	2.36	2.35	2.34	2.33	2.32	2.32	2.31	2.27	2.24
Yb	1.39	1.41	1.42	1.44	1.45	1.47	1.49	1.50	1.52	1.62	1.68
Lu	0.16	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.18	0.20	0.21