Supplementary Information:
Magnetite record of repose after recharge leading to the Plinian eruptions at Sakurajima

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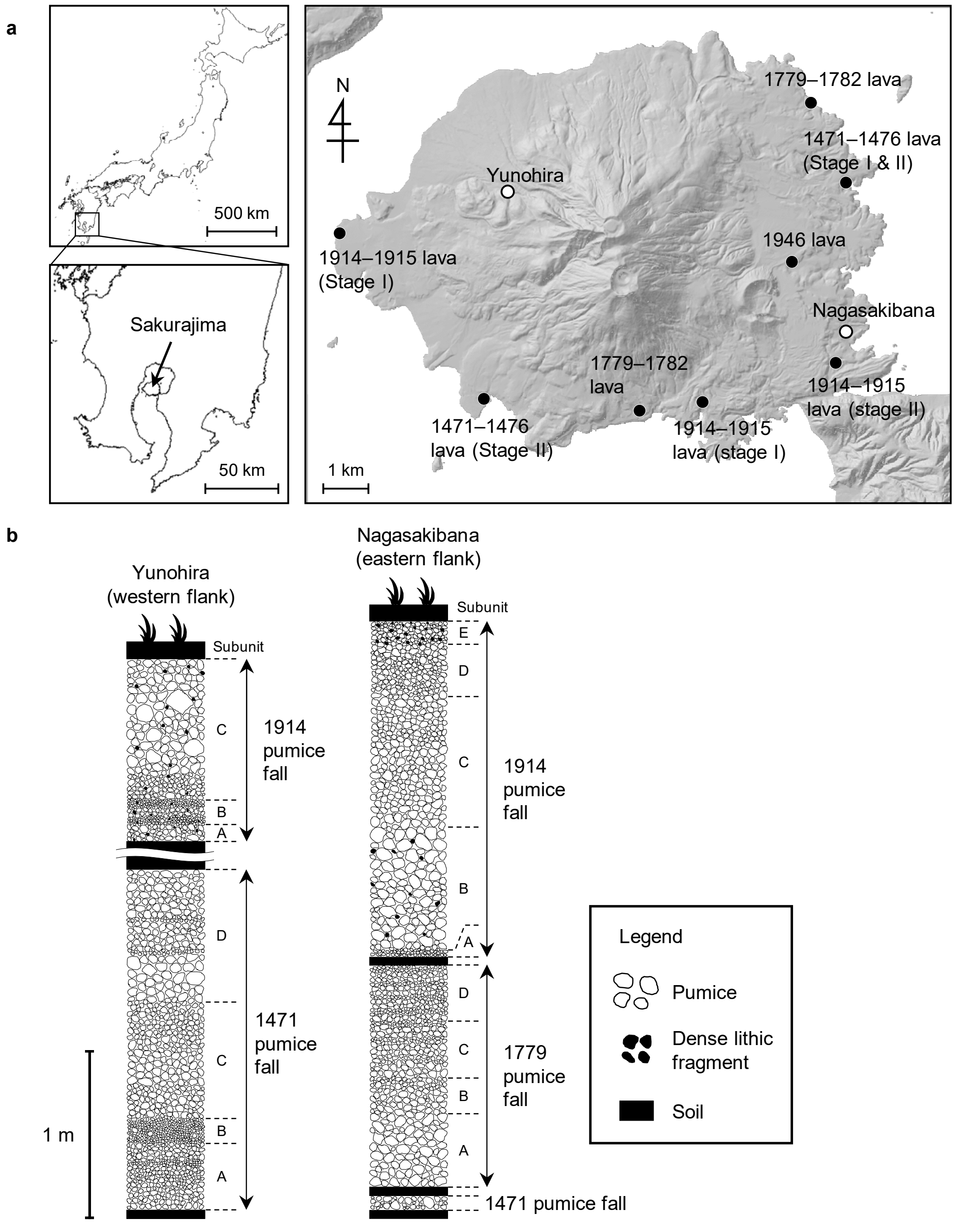
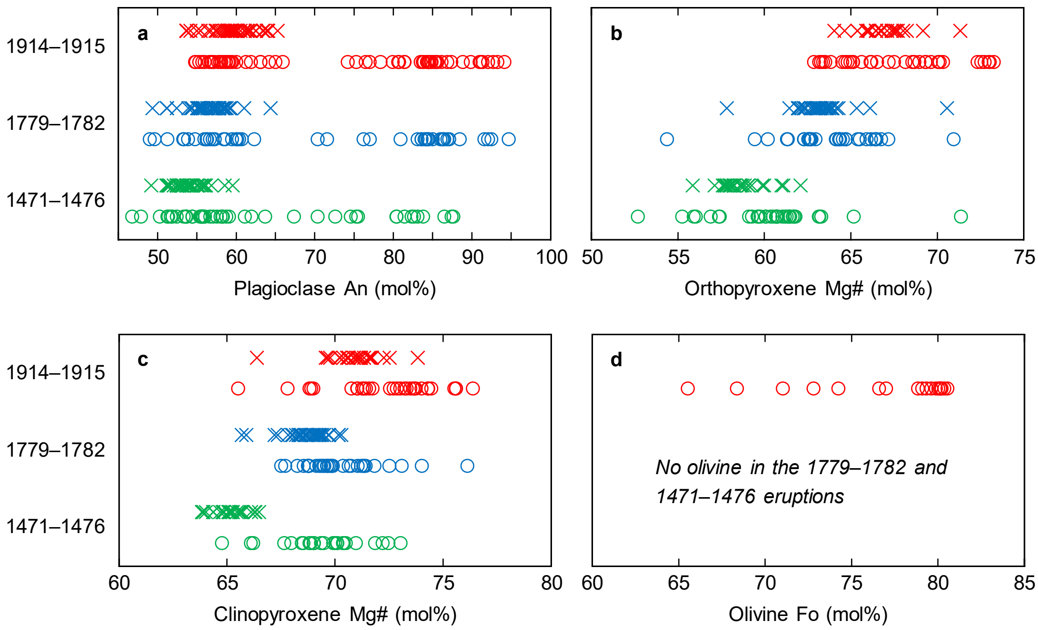
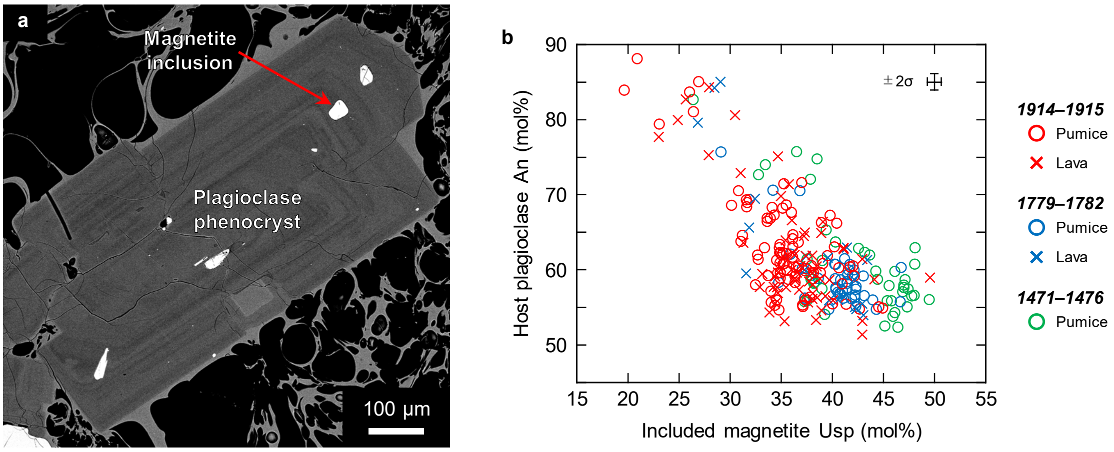
Supplementary Figures



Supplementary Figure S1. (**a**) Index maps and sampling points of the Sakurajima volcano. The localities for pumices and lavas are shown as open and solid circles, respectively. Eruptive stages of the 1471–1476 and 1914–1915 lavas were obtained from Kobayashi et al.[1]. (**b**) Columnar sections of historical pumice falls at Yunohira (left) and Nagasakibana (right).



Supplementary Figure S2. Solid solution compositions of (**a**) plagioclase, (**b**) orthopyroxene, (**c**) clinopyroxene, and (**d**) olivine phenocrysts in the pumices and lavas (open circle, core; cross, rim). The rim compositions of plagioclase phenocrysts were obtained from Araya et al.[2].



Supplementary Figure S3. (**a**) Back-scattered electron image of magnetite inclusions in a plagioclase phenocryst and (**b**) compositional relationship between magnetite inclusions and their host plagioclases. When a magnetite was located in multiple zones of the hosting plagioclase, we analyzed the outermost zone, which crystallized when the magnetite was entrapped entirely.

Supplementary Table S1. Core compositions of magnetite phenocrysts.

	1471–1476 eruption		1779–1782 eruption		1914–1915 eruption			
					High-Usp		Low-Usp	
	Pumice (*n*[a]=63)	Lava (*n*=31)	Pumice (*n*=59)	Lava (*n*=70)	Pumice (*n*=330)	Lava (*n*=32)	Pumice (*n*=5)	Lava (*n*=1)
SiO_2	0.08 ± 0.02	0.10 ± 0.03	0.08 ± 0.02	0.08 ± 0.02	0.07 ± 0.02	0.09 ± 0.03	0.03 ± 0.01	0.08
TiO_2	16.25 ± 0.32	16.04 ± 0.77	14.35 ± 0.24	13.37 ± 1.36	12.41 ± 0.65	12.41 ± 0.81	9.23 ± 0.04	8.99
Al_2O_3	2.30 ± 0.09	2.37 ± 0.17	2.50 ± 0.09	2.67 ± 0.18	2.80 ± 0.12	2.84 ± 0.20	3.84 ± 0.04	4.00
V_2O_3	0.36 ± 0.08	0.48 ± 0.16	0.37 ± 0.11	0.39 ± 0.15	0.49 ± 0.11	0.65 ± 0.04	1.12 ± 0.16	0.71
Cr_2O_3	0.03 ± 0.03	0.03 ± 0.03	0.03 ± 0.03	0.01 ± 0.02	0.04 ± 0.03	0.03 ± 0.03	0.08 ± 0.02	-
Fe_2O_3[b]	35.79 ± 0.67	35.23 ± 1.44	39.13 ± 0.52	40.13 ± 2.81	42.44 ± 1.25	42.21 ± 1.50	47.59 ± 0.62	48.22
FeO[b]	43.28 ± 0.45	43.83 ± 1.01	40.94 ± 0.40	41.24 ± 1.01	38.92 ± 0.73	39.87 ± 1.12	35.40 ± 0.17	35.07
MnO	0.65 ± 0.04	0.65 ± 0.05	0.61 ± 0.04	0.53 ± 0.06	0.48 ± 0.04	0.49 ± 0.05	0.39 ± 0.02	0.31
MgO	1.91 ± 0.09	1.34 ± 0.23	2.24 ± 0.12	1.46 ± 0.31	2.47 ± 0.12	1.95 ± 0.38	3.13 ± 0.09	3.26
Total	100.64 ± 0.57	100.08 ± 1.02	100.25 ± 0.73	99.87 ± 0.96	100.11 ± 0.73	100.55 ± 0.76	100.82 ± 0.68	100.64
Usp (mol%)	48.01 ± 1.03	48.84 ± 2.22	42.26 ± 0.74	40.84 ± 4.12	36.69 ± 1.97	37.50 ± 2.46	27.69 ± 0.43	26.65
O=	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
Si	0.003 ± 0.001	0.004 ± 0.001	0.003 ± 0.001	0.003 ± 0.001	0.003 ± 0.001	0.003 ± 0.001	0.001 ± 0.001	0.003
Ti	0.448 ± 0.008	0.447 ± 0.021	0.396 ± 0.006	0.373 ± 0.040	0.343 ± 0.018	0.343 ± 0.021	0.251 ± 0.003	0.245
Al	0.099 ± 0.004	0.103 ± 0.007	0.108 ± 0.004	0.117 ± 0.008	0.121 ± 0.005	0.123 ± 0.009	0.164 ± 0.001	0.171
V	0.011 ± 0.002	0.014 ± 0.005	0.011 ± 0.003	0.011 ± 0.004	0.014 ± 0.003	0.019 ± 0.001	0.033 ± 0.005	0.021
Cr	0.001 ± 0.001	0.001 ± 0.001	0.001 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001	0.002 ± 0.001	-
Fe^{3+}	0.987 ± 0.018	0.981 ± 0.037	1.081 ± 0.012	1.119 ± 0.072	1.173 ± 0.033	1.165 ± 0.037	1.296 ± 0.009	1.314
Fe^{2+}	1.327 ± 0.011	1.356 ± 0.030	1.257 ± 0.009	1.279 ± 0.038	1.195 ± 0.021	1.224 ± 0.038	1.072 ± 0.005	1.062
Mn	0.020 ± 0.001	0.020 ± 0.002	0.019 ± 0.001	0.017 ± 0.002	0.015 ± 0.001	0.015 ± 0.001	0.012 ± 0.001	0.010
Mg	0.104 ± 0.005	0.074 ± 0.012	0.123 ± 0.006	0.080 ± 0.017	0.135 ± 0.006	0.107 ± 0.020	0.169 ± 0.004	0.176
Total	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000

[a]Number of analyzed samples.

[b]The ferric/ferrous ratio was calculated based on the oxide formula recalculation model of Stormar[3].

Supplementary Table S2. Diffusion time of the low-Usp magnetite in the 1914 Plinian pumice.

Sample ID	Radius (μm)	Usp (mol%)		MgO (wt.%)		Diffusion time (hour)	
		Core	Rim	Core	Rim	Fe–Ti	Mg
20110725Ng-Ts5-B1_4	133	27.2	28.5	3.19	2.44	7	5
20110725Ng-Ts5-B1_10	89	27.3	28.6	3.28	2.53	28	13

Supplementary Table S3. Chemical compositions of touching magnetite and ilmenite pairs in 1471 Plinian pumices.

Sample ID	20080516Yn-0603-b_19		20080516Yn-0603-b_12		20150321Yn-BmA_20	
	Core	Rim	Core	Rim	Core	Rim
Magnetite						
SiO_2	0.08	0.09	0.08	0.08	0.11	0.13
TiO_2	16.04	16.02	16.49	15.55	16.08	16.36
Al_2O_3	2.42	2.24	2.30	2.40	2.23	2.30
V_2O_3	0.35	0.34	0.34	0.33	0.51	0.44
Cr_2O_3	0.00	0.01	0.03	0.03	0.00	0.02
Fe_2O_3[a]	36.12	34.39	35.47	36.94	35.50	34.69
FeO[a]	43.04	42.25	43.55	42.57	43.02	43.20
MnO	0.64	0.64	0.66	0.68	0.67	0.64
MgO	1.95	1.89	1.90	1.91	1.83	1.87
Total	100.63	97.89	100.81	100.50	99.95	99.64
Usp (mol%)	47.47	48.63	48.61	46.07	48.03	49.11
Ilmenite						
SiO_2	0.03	0.05	0.03	0.00	0.06	0.05
TiO_2	47.15	46.86	47.35	47.09	48.23	48.35
Al_2O_3	0.20	0.23	0.23	0.25	0.19	0.26
V_2O_3	0.13	0.18	0.12	0.14	0.19	0.17
Cr_2O_3	0.04	0.00	0.06	0.06	0.02	0.00
Fe_2O_3[a]	12.99	12.63	12.49	12.89	11.31	11.18
FeO[a]	36.36	36.07	36.69	36.20	37.58	37.64
MnO	0.79	0.78	0.75	0.74	0.83	0.82
MgO	2.97	3.01	2.91	3.04	2.83	2.85
Total	100.64	99.81	100.63	100.39	101.24	101.32
Ilm (mol%)	86.45	86.87	87.14	86.72	88.52	88.71
T (°C)[b]	938	941	937	924	912	917
$\log_{10} f_{O_2}$[b]	-11.3	-11.3	-11.4	-11.5	-11.9	-11.9
ΔNNO	-0.1	-0.1	-0.2	-0.1	-0.3	-0.3

[a]The ferric/ferrous ratio was calculated based on the oxide formula recalculation model of Stormar[3].

[b]Calculated with the thermometer of Anderson and Lindsley[4].

Supplementary References

1. Kobayashi, T. et al. *Geological Map of Sakurajima Volcano* (2nd edition). Geological Survey of Japan (in Japanese with English abstract, 2013).
2. Araya, N. et al. Shallow magma pre-charge during repeated Plinian eruptions at Sakurajima volcano. *Sci. Rep.* **9**, 1979 (2019).
3. Stormer, J. C. The effects of recalculation on estimates of temperature and oxygen fugacity from analyses of multi-component iron-titanium oxides. *Am. Mineral.* **68**, 586–594 (1983).
4. Andersen, D. J. & Lindsley, D. H. New (and final!) models for the Ti-magnetite/ilmenite geothermometer and oxygen barometer. *Trans. Am. Geophys. Union* **66**, 416 (1985).