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Arrival of extremely volatile-rich high-Mg magmas changes explosivity of Mount Etna

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Methods and calculations

Bulk rocks analyses were carried out by the Service d'Analyse des Roches et des Minéraux of CRPG – CNRS (Nancy, France) using ICP-AES for major elements and ICP-MS for trace elements.

Major element compositions of glassy melt inclusions were measured by a JEOL Superprobe JXA-8200 (Max-Plank Institute for Chemistry, Mainz) using wavelength dispersive spectroscopy, with 15kV, 12 nA beam current, 10 μm spot size, 60 sec counting time for each element, and typical external precision better then 0.5 rel%. Glass compositions were calculated off-line using ZAF correction and taking their H_2O content (measured by SIMS) into account. Compositions of trapped melts were calculated with PETROLOG software (Danyushevsky, 2001) from the analyses of melt inclusions, using corrections for post-entrapment olivine crystallisation on the walls and Fe-Mg exchange with the host mineral.

The same inclusions were analysed for water, carbon and trace elements. Water was determined by a CAMECA IMS3f ion microprobe (Max-Plank Institute for Chemistry, Mainz), using an O^- primary beam, 10 nA beam current, 15-20 μm beam size and ^{30}Si as internal standard. Synthetic glasses, matching natural Etnean magma compositions and

containing 1.19, 1.47, 3.04 and 3.60 wt % H_2O (B. Scaillet, ISTO, France) were used for calibration and as external standards. Carbon concentrations were determined with the nuclear microprobe (Laboratoire Pierre Süe, CNRS-CEA, Saclay), using the $^{12}C(d, p)^{13}C$ nuclear reaction. Analyses were made in the scanning mode (10×10 μm) in order to avoid beam damage. Carbon concentrations were calibrated against a scapolite standard (6800 ppm C) and a water-bearing Etna basaltic glass containing 300 ± 30 ppm C (Métrich et al., 2004).

Trace element concentrations were analysed by LA-ICPMS (New Wave Research UP213 Nd-YAG (213 nm) laser coupled to an Agilent 4500 quadrupole mass-spectrometer) at the University of Tasmania. Analyses were performed in a He atmosphere by ablating 30-80 μm diameter spots at a rate of 5 shots/sec. For data reduction the NIST612 standard glass and ^{43}Ca in the sample were used as a primary reference material and internal standard, respectively.

References:

Danyushevsky, L.V., 2001, The effect of small amounts of H_2O on crystallisation of mid-ocean ridge and backarc basin magmas: Journal of Volcanology and Geothermal Research, v. 110, p. 265-280.

Métrich, N., Allard, P., Spilliaert, N., Andronico, D., and Burton, M., 2004, 2001 flank eruption of the alkali- and volatile-rich primitive basalt responsible for Mount Etna's evolution in the last three decades: Earth and Planetary Science Letters, v. 228, p. 1-17.

Table DR1. Major (in wt%) and trace (in ppm) element compositions of the "FS" rocks and olivine-hosted melt inclusions

	ROCKS						Melt inclusions			
Sample	svp5	svp49	svp58	svp291-F	svp291-D	svp291-G	svp291-F	svp291-F	svp291-F	svp291-D
Grain							#457-7	#457-8	#457-9	#457-18
SiO_2	48.44	46.29	46.75	46.01	46.85	45.78	47.25	49.02	47.80	48.00
TiO_2	0.96	0.88	0.91	0.87	0.84	0.9	0.95	0.51	0.71	0.75
Al_2O_3	11.48	10.29	10.79	10.28	9.93	10.78	10.15	9.67	10.19	10.51
FeO	9.19	9.23	9.41	9.29	9.17	9.32	9.00	9.00	9.00	9.00
MnO	0.17	0.16	0.18	0.15	0.17	0.16	0.19	0.17	0.17	0.17
MgO	11.91	15.19	14.88	15.45	16.83	14.23	12.27	13.24	12.69	12.53
CaO	13.46	12.27	12.45	12.19	12.15	11.8	14.09	12.71	13.59	13.06
Na_2O	1.7	1.23	1.29	1.17	1.3	1.24	1.54	1.44	1.39	1.97
K_2O	0.93	0.58	0.62	0.54	0.61	0.61	0.67	0.46	0.72	0.69
P_2O_5	0.26	0.22	0.24	0.22	0.22	0.24	0.50	0.24	0.23	0.40
H_2O	0.45*	2.21*	1.84*	2.78*	0.99*	3.14*	3.22	3.39	3.36	2.71
CO_2							0.305	0.218	0.301	0.036
total	98.50	96.34	97.52	96.17	98.07	95.06	100.14	100.06	100.14	99.82
host olivine, Fo							90.4	90.7	90.6	90.5
Rb	22.0	13.7	14.5	13.4	14.5	15.3	13.0	8.6	18.6	13.4
Ba	314	248	254	228	240	269	479	340	239	451
Th	3.9	3.0	3.5	3.0	3.1	3.5	5.5	4.2	2.2	6.0
U	1.1	0.89	1.0	0.94	0.88	1.1	1.6	1.1	0.75	1.7
Nb	13.7	10.9	11.9	11.0	10.9	12.5	37.2	17.2	10.0	36.2
La	23.3	19.8	20.4	18.8	18.9	22.2	43.6	27.9	18.0	47.1
Ce	47.6	39.7	42.7	39.2	39.9	43.2	87.4	54.1	36.8	91.7
Pb	4.2	3.3	3.7	3.3	3.2	3.7	4.3	3.3	2.9	4.0
Sr	613	457	505	448	506	475	853	563	535	857
Nd	23.4	19.7	19.7	20.2	18.9	21.2	36.8	23.5	18.4	37.5
Sm	5.1	4.2	4.6	4.1	4.1	4.7	6.2	4.4	3.8	6.6
Zr	91.9	77.8	84.1	79.4	77.7	85.4	114	59.3	69.3	103
Eu	1.4	1.3	1.4	1.2	1.2	1.5	1.8	1.3	1.2	1.8
Gd	4.3	3.8	4.3	4.0	3.6	4.1	5.0	3.7	3.8	4.9
Dy	3.3	2.9	3.1	2.9	2.9	3.3	3.2	2.6	3.0	3.3
Li	6.3	4.5	n.d.	4.2	3.6	3.4	4.5	4.7	4.6	4.4
Y	17.9	16.0	16.3	16.1	15.3	17.4	15.4	13.4	14.9	16.2
Er	1.5	1.3	1.5	1.5	1.4	1.6	1.6	1.4	1.4	1.5
Yb	1.5	1.4	1.5	1.3	1.3	1.4	1.4	1.3	1.2	1.4
Sc	46.8	46.5	n.d.	40.0	48.1	54.3	42.9	37.3	41.1	42.7

	Melt inclusions								
Sample	svp291-D	svp291-D	svp291-D	svp291-D	svp49	svp49	svp49	svp49	svp291-G
Grain	#457-20	#457-22	#457-25	#457-32	#457-41	#457-46	#457-48	#457-49	#457-60
SiO_2	47.46	47.30	47.68	47.77	48.16	47.89	47.74	47.65	47.63
TiO_2	0.84	0.59	0.79	0.70	0.78	0.73	0.75	0.88	0.87
Al_2O_3	11.18	10.19	10.41	10.25	10.03	10.18	10.25	10.31	10.50
FeO	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MnO	0.14	0.20	0.16	0.19	0.18	0.15	0.15	0.16	0.15
MgO	12.43	12.42	12.62	13.01	12.59	12.53	12.52	12.32	12.82
CaO	13.17	14.15	13.30	13.19	13.88	13.86	13.72	13.83	12.99
Na_2O	1.64	1.23	1.54	1.47	1.47	1.46	1.36	1.42	1.54
K_2O	1.10	0.78	0.78	0.67	0.67	0.67	0.90	0.89	0.72
P_2O_5	0.27	0.24	0.21	0.24	0.24	0.25	0.29	0.26	0.27
H_2O	2.56	3.79	3.36	3.34	2.79	3.11	3.15	3.10	3.36
CO_2	0.058	0.328	0.277	0.286	0.071	0.252	0.304	0.311	0.279
total	99.82	100.21	100.12	100.12	99.86	100.07	100.13	100.13	100.12
host olivine, Fo	90.5	90.5	90.6	90.8	90.5	90.5	90.5	90.4	90.7
Rb	28.4	21.0	21.3	16.9	20.3	17.8	26.6	25.5	18.9
Ba	292	267	267	228	249	236	319	284	250
Th	3.0	2.5	2.6	2.0	2.1	2.1	3.2	2.9	2.5
U	1.0	0.83	0.82	0.67	0.67	0.72	1.1	0.93	0.78
Nb	11.9	10.5	11.8	9.3	9.7	10.0	14.9	12.9	11.4
La	23.0	19.6	19.8	16.9	17.2	17.4	24.8	21.6	19.0
Ce	46.9	41.4	40.7	35.5	36.2	36.0	50.8	45.0	39.5
Pb	3.3	3.2	3.0	2.6	2.5	2.9	3.8	3.5	3.4
Sr	583	562	587	531	531	538	619	582	565
Nd	23.7	20.0	19.7	18.0	17.2	17.6	23.9	21.0	19.0
Sm	4.9	4.3	4.2	3.9	4.3	3.8	4.6	4.6	4.3
Zr	83.1	68.2	76.9	65.4	68.8	63.8	77.3	77.4	76.3
Eu	1.5	1.3	1.3	1.2	1.1	1.1	1.4	1.4	1.3
Gd	4.8	3.9	4.1	3.7	3.6	3.4	3.9	3.9	4.0
Dy	3.6	3.0	3.0	2.7	2.8	2.9	2.8	3.0	3.2
Li	4.6	4.4	4.9	4.4	8.5	4.5	4.5	4.2	4.8
Y	17.6	15.2	15.2	14.7	14.8	14.4	15.1	14.8	15.3
Er	1.6	1.3	1.5	1.4	1.4	1.5	1.5	1.4	1.5
Yb	1.4	1.3	1.3	1.2	1.1	1.2	1.3	1.3	1.3
Sc	42.5	42.4	41.7	39.7	53.3	41.6	39.6	41.8	38.7

* - loss on ignition; n.d. - not determined. See Methods for details of analytical work

Table DR2. Representative compositions of clinopyroxene inclusions and host olivine from the "FS" roc

	Clinopyroxene inclusions in olivine						
Sample	svp291-F	svp291-F	svp291-D	svp291-D	svp291-D	svp49	svp291-G
Grain	#457-2	#457-3	#457-15	#457-29	#457-31	#457-50	#457-58
SiO_2	53.81	52.79	54.08	53.46	53.63	53.78	53.51
TiO_2	0.20	0.24	0.23	0.30	0.28	0.39	0.29
Al_2O_3	1.51	1.98	1.30	2.03	2.00	2.12	2.04
FeO	2.97	3.19	3.07	3.26	3.26	3.20	3.20
MnO	0.10	0.07	0.15	0.10	0.06	0.04	0.07
MgO	17.28	17.38	18.31	17.53	17.03	17.70	17.12
CaO	23.39	23.00	22.13	22.85	22.36	22.94	22.46
Na_2O	0.29	0.32	0.23	0.34	0.18	0.20	0.32
total	99.56	98.96	99.50	99.86	98.81	100.36	99.00
Mg#	91.2	90.7	91.4	90.6	90.3	90.8	90.5
	Host olivine						
SiO_2	41.24	41.24	41.52	41.08	40.82	40.70	40.55
FeO	9.46	9.35	9.29	9.43	9.27	9.31	9.44
MnO	0.16	0.14	0.13	0.16	0.16	0.14	0.19
MgO	50.36	50.49	50.90	50.31	49.83	50.16	50.02
CaO	0.23	0.21	0.20	0.22	0.22	0.20	0.23
NiO	0.17	0.18	0.22	0.19	0.19	0.19	0.19
Cr_2O_3	0.04	0.03	0.04	0.04	0.04	0.03	0.05
total	101.67	101.65	102.30	101.43	100.52	100.73	100.67
Fo	90.5	90.6	90.7	90.5	90.6	90.6	90.4

Table DR3. Representative compositions of Cr-spinel inclusions and host olivine from the "FS" rocks

	Cr-spinel inclusions in olivine						
Sample	svp49	svp49	svp49	svp291-G	svp5	svp5	svp291-D
Grain	#454-14	#454-31	#454-35	#454-63	#454-65	#454-78	#454-161
SiO_2	0.26	0.33	0.21	0.28	0.22	0.32	0.25
TiO_2	0.75	0.93	1.22	0.71	0.67	0.83	0.60
Al_2O_3	10.02	10.47	13.40	9.98	10.70	10.67	10.18
Cr_2O_3	52.12	51.59	46.27	52.85	52.69	52.17	53.04
Fe_2O_3	8.73	8.83	11.48	8.69	8.51	8.51	8.50
FeO	13.25	13.51	13.82	13.92	12.92	13.71	13.56
MnO	0.22	0.24	0.21	0.20	0.22	0.20	0.24
MgO	13.47	13.64	14.01	13.26	13.85	13.59	13.37
NiO	0.11	0.09	0.12	0.09	0.12	0.09	0.10
ZnO	0.04	0.06	0.05	0.03	0.04	0.05	0.05
V_2O_3	0.03	0.02	0.03	0.05	0.01	0.02	0.04
Total	98.99	99.72	100.80	100.06	99.94	100.16	99.94
Mg#, mol%	64.4	64.3	64.4	62.9	65.6	63.9	63.7
Cr#, mol%	77.7	76.8	69.9	78.0	76.8	76.6	77.7
Fe2+/Fe3+	1.69	1.70	1.34	1.78	1.69	1.79	1.77
	Host olivine						
SiO_2	40.52	40.35	40.47	41.14	40.90	40.69	40.92
FeO	9.11	9.26	9.65	10.30	9.03	9.16	9.14
MnO	0.15	0.15	0.14	0.17	0.15	0.15	0.17
MgO	49.52	49.67	49.61	49.51	50.01	49.33	49.49
CaO	0.23	0.23	0.24	0.28	0.20	0.20	0.23
NiO	0.19	0.19	0.18	0.13	0.24	0.19	0.19
Cr_2O_3	0.08	0.09	0.06	0.12	0.15	0.11	0.12
Total	99.81	99.94	100.36	101.65	100.66	99.82	100.27
Fo	90.6	90.5	90.2	89.5	90.8	90.6	90.6