AM-85-264

American Mineralogist, Volume 70, pages 288–303, 1985

Fluid inclusion geobarometry from ejected Mt. Somma-Vesuvius nodules

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Abstract

The Mt. Somma-Vesuvius volcano (Naples, Italy), part of the Italian-Tyrrhenian volcanic province, has erupted lavas and tephra that are silica-undersaturated and unusually potassium-rich. Ejected nodules, usually related to explosive activity, have been subdivided into four varieties: cumulate, "skarn," hornfels, and hypabyssal lava equivalents. The results of a microthermometric study of fluid inclusions from seven cumulate and three "skarn" nodules collected from the pyroclastics of three non-Plinian eruptive episodes are presented in this paper. Two primary inclusion types, formed by trapping of immiscible fluids, are commonly present: silicate melt (now glass in part crystallized to various daughter mineral(s) plus a shrinkage bubble) and essentially pure CO_2 (now liquid and vapor) $\pm$ glass. Three inclusions in one nodule (N81) contain water in addition to CO_2 and glass. The homogenization temperature (*Th*) of two-phase CO_2 inclusions was determined with a CHAIXMECA stage and used to derive the trapping density. In the seven cumulate nodules the CO_2 inclusion density ranged from 0.32 to 0.60 g/cm^3; those in the three "skarn" nodules ranged from 0.31 to 0.72 g/cm^3. *Th* of silicate melt inclusions, determined using a LEITZ 1350 stage, averaged ~1200°C in cumulate and ~1000°C in "skarn" nodules. CO_2 inclusion densities plus calculated *P–V–T* data on CO_2 at 1200° or 1000°C provide an estimate, with certain limitations, of the pressure during silicate melt and CO_2 inclusion trapping. These estimates range from ~1200 to ~3050 bars for seven cumulate nodules and from ~925 to ~3550 bars for the three "skarn" nodules. Assuming a density of 2.7 g/cm^3 for the magma column, the depth of trapping of both CO_2 and silicate melt inclusions was ~4.5 to ~11.0 km for the seven cumulate and ~3.5 to ~13.0 km for the three "skarn" nodules. Based on the presence of primary silicate-melt inclusions, both the cumulate and "skarn" nodules appear to have crystallized from a silicate melt. Two types of silicate-melt inclusions can be distinguished in the "skarn" nodules based on quenching behavior after homogenization; one quenches to glass, and the other readily crystallizes on quench. These two types suggest that melts of different composition were present in the "skarn" nodule environment. Cumulate and "skarn" nodules appear to be crystallization products from a silicate melt containing an emulsion of supercritical CO_2 globules. Most nodules contain CO_2 inclusions with a narrow density range but three nodules (N30, N13, N45) contain CO_2 inclusions that have an inexplicable bimodal distribution and wide density range.

0003-004X/85/0304-0288$02.00

[1]Nodule	Inclusion Number	Size µm	[2]Th°C	[3]density gm/cm^3	[4]homogenization behavior	[5]host	Remarks	Trapping conditions [6]Pressure (bars)	[7]depth (km)
N81	1	61.0	30.8	0.375	V	px	contains liquid H_2O at RT upon freezing formed CO_2 clathrate that melted at +6.5°C (fig.22A,B,C,D,E,F)	1485	5.5
N81	2	15.0	30.1	0.340	V	px		1300	4.8
N81	3	6.5	30.6	0.364	V	ap	5 others with similar behavior	1430	5.3
N81	4	41.0	30.6	0.364	V	px	contains liquid H_2O at RT upon freezing formed CO_2 clathrate that melted at +7.8°C Tm-CO_2 = -57.1°C	1430	5.3
N81	5	38.0	30.3	0.349	V	px	contains liquid H_2O at RT CO_2 clathrate melted at +7.2°C	1350	5.0
N81	6	36.0	30.7	0.370	V	px		1460	5.4
N1	1	14.0	30.4	0.355	V	ap	3 other with similar behavior	1375	5.1
N1	2	27.0	30.4	0.355	V	px	optics poor, negative xl. shape	1375	5.1
N1	3	19.0	30.6	0.364	V	px	negative xl. shape. optics poor	1430	5.3
N1	4	28.0	30.4	0.355	V	px	TmCO_2 = -56.9°C	1375	5.1
N1	5	12.0	30.4	0.355	V	ap	3 others with similar behavior	1375	5.1
N34	1	80.0	30.6	0.364	V	px	negative xl. shape	1430	5.3
N34	2	15.0	30.2	0.345	V	px	attached to a mica xl. (fig. 11)	1325	4.9
N34	3	32.0	30.2	0.345	V	px		1325	4.9
N34	4	41.0	30.3	0.349	V	px		1350	5.0
N34	5	14.0	30.1	0.340	V	px	attached to a mica xl.	1300	4.8
N34	6	19.0	30.2	0.345	V	px	negative crystal shape	1325	4.9

N67	1	31.0	30.6	0.364	V	sp	near edge of a 18μm xl. included in mica	1150	4.4
N67	2	13.0	30.4	0.355	V	sp	negative crystal shape	1100	4.3
N67	3	12.1	30.5	0.359	V	sp	inclusions 3-7 in same crystal	1125	4.4
N67	4	9.3	30.5	0.359	V	sp		1125	4.4
N67	5	9.3	30.5	0.359	V	sp		1125	4.4
N67	6	7.4	30.5	0.359	V	sp		1125	4.4
N67	7	8.4	30.5	0.359	V	sp		1125	4.4
N67	8	25.0	30.8	0.375	V	px		1200	4.6
N45	1	17.0	30.1	0.340	V	px	negative xl. shape	1300	4.8
N45	2	19.0	30.4	0.355	V	px	20 others in same xl. with similar behavior	1375	5.1
N45	3	85.0	30.4	0.355	V	px		1375	5.1
N45	4	24.0	30.0	0.600	L	px	$TmCO_2$ = -56.9°C	3025	11.2
N45	5	32.0	30.6	0.565	L	px	$TmCO_2$ = -56.9°C	2725	10.1
N45	6	32.0	30.2	0.590	L	px		2940	10.8
N45	7	38.0	30.8	0.550	L	px	optics poor	2625	9.6
N45	8	32.0	30.5	0.570	L	px		2775	10.2
N45	9	47.0	30.8	0.375	V	px	$TmCO_2$ = -57.0°C (fig. 15A,B,C)	1485	5.5
N45	10	42.0	30.2	0.345	V	px		1325	4.9
N45	11	34.0	30.1	0.595	L	px	another in area with similar Th, $TmCO_2$ = -57.1°C	2980	11.0
N45	12	32.0	30.5	0.570	L	px		2775	10.2
N62	1	18.0	30.2	0.590	L	px	attached to a mica crystal (fig. 8)	2940	10.8
N62	2	27.0	30.7	0.555	L	px		2650	9.8
N62	3	24.0	30.7	0.555	L	px	optics poor	2650	9.8
N62	4	19.0	30.8	0.550	L	px		2625	9.6
N62	5	15.0	30.4	0.580	L	px		2850	10.5
N42	1	17.0	29.5	0.320	V	px		1180	4.4
N42	2	34.0	30.2	0.345	V	px	optics not good	1325	4.9
N13	1	12.0	30.5	0.359	V	sp	in center optics not good	1125	4.4
N13	2	29.0	30.7	0.555	L	px	optics not good	2250	8.3
N13	3	31.0	30.5	0.570	L	px	optics not good	2300	8.7
N13	4	35.0	31.1	0.465	CP	sp	3 others with the same Th	1650	6.3
N13	5	90.0	28.9	0.308	V	sp	edge of spinel	925	3.5
N13	6	33.0	30.2	0.590	L	px	2 others nearby with same Th, negative xl. shape $TmCO2$ = -57.2°C	2450	9.2
N13	7	29.0	30.3	0.349	V	sp		1100	4.2

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[1] Nodule	Inclusion Number	Size µm	[2] Th°C	[3] density gm/cm^3	[4] homogenization behavior	[5] host	Remarks	Trapping conditions [6] Pressure (bars)	[7] depth (km)
N13	8	73.0	30.1	0.340	V	sp	near edge of crystal	1050	4.0
N13	9	19.0	30.7	0.555	L	sp	near edge of crystal	2250	8.3
N13	10	10.0	29.6	0.615	L	sp	in a spinel crystal included in mica (fig. 18)	2650	9.8
N13	11	37.0	31.0	0.465	CP	sp	near edge of crystal	1650	6.3
N13	12	16.0	29.6	0.325	V	ol		1000	3.8
N13	13	18.0	30.2	0.345	V	px	negative crystal shape	1075	4.1
N13	14	31.0	29.8	0.330	V	sp	near edge of crystal negative crystal shape	1025	3.9
N30	1	17.0	24.0	0.720	L	sp	in center of spinel grain (fig. 19)	3550	13.2
N30	2	7.0	24.0	0.720	L	sp	in center of spinel grain neg. xl. shape	3550	13.2
N30	3	4.5	25.0	0.707	L	sp	in center of spinel grain, neg. xl. shape	3425	12.7
N30	4	35.0	31.1	0.465	CP	px	TmCO_2 = -57.1°C	1650	6.3
N30	5	15.0	25.2	0.703	L	sp	in center of spinel grain	3375	12.6
N30	6	58.0	30.8	0.375	V	px	TmCO_2 = -56.0°C	1200	4.6
N30	7	12.0	25.9	0.690	L	sp	in center of spinel grain, neg. xl. shape	3275	12.2
N30	8	23.0	30.9	0.540	L	sp	near edge of grain, very near critical point	2100	8.0
N30	9	7.0	25.2	0.703	L	sp	in center of grain	3375	12.6
N30	10	6.0	25.2	0.703	L	sp	in center of grain	3375	12.6
N30	11	4.5	26.6	0.680	L	sp	in center of grain	3175	11.8
N30	12	58.0	30.7	0.555	L	sp		2250	8.3
N30	13	32.0	30.7	0.555	L	sp	optics fair	2250	8.3
N30	14	8.0	25.1	0.705	L				

N30	11	4.5	26.6	0.680	L	sp	in center of grain	[illegible]	[illegible]
N30	12	58.0	30.7	0.555	L	sp		2250	8.3
N30	13	32.0	30.7	0.555	L	sp	optics fair	2250	8.3
N30	14	8.0	25.1	0.705	L	sp		3400	12.65
N30	15	9.0	26.5	0.683	L	sp		3200	11.9
N30	16	10.0	30.4	0.580	L	sp	negative xl. shape	2375	8.9
N30	17	16.0	30.8	0.550	L	sp	neg. xl. shape, in center grain	2150	8.2
N30	18	14.0	29.5	0.620	L	sp	near edge of grain	2775	10.2
N30	19	12.0	30.5	0.359	V	sp	near edge of grain (fig. 16A,B)	1125	4.4
N30	20	11.4	29.6	0.615	L	sp	neg. xl. shape (fig. 17)	2650	9.9
N30	21	49.0	30.5	0.359	V	px		1125	4.4
N30	22	11.2	30.7	0.370	V	sp	near edge of grain	1175	4.5
N30	23	25.0	30.2	0.345	V	px	(fig. 14A,B)	1075	4.1
N30	24	27.0	29.4	0.625	L	sp	neg. xl. shape, in center of grain 2 others with the same Th	2700	10.1
N48	1	28.0	31.1	0.465	CP	px	negative xl. shape	2000	7.4
N48	2	26.0	30.8	0.375	V	px		1485	5.5
N48	3	10.5	30.7	0.370	V	px	optics fair	1460	5.4
N48	4	35.0	30.8	0.375	V	px	negative xl. shape	1485	5.5
N48	5	11.2	30.9	0.380	V	px		1520	5.6

[1] Nodule numbering from Hermes and Cornell (1978).

[2] The estimated temperature uncertainty is ±0.1°C.

[3] This CO_2 density is derived from Fig. 24.

[4] The homogenization behavior records the nature of the meniscus disappearance; V = vapor, L = liquid, and CP = critical point phenomenon.

[5] ap = apatite, px = pyroxene, sp = spinel, ol = olivine.

[6] This trapping pressure value was obtained from the (dashed-line) isobars of Kerrick and Jacobs (1981) at 1000°C for "skarn" and 1200°C for cumulate nodules.

[7] This depth of trapping value is determined from Fig. 27. Cumulate nodules--1200°C; "skarn" nodules--1000°C curve.

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[1]Nodule	Inclusion Number	Size	[2]Th°C	[3]Intensity	[4]homogene