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**Oxygen Isotope Analyses of 166 Rock Samples from Medicine  
Lake Volcano, California**

by

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# Oxygen Isotope Analyses of 166 Rock Samples from Medicine Lake Volcano, California

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This report lists oxygen isotope data for 166 rock samples from at least 45 eruptive units on and adjacent to Medicine Lake volcano, northern California (table 1). Locations of the samples are indicated by latitude and longitude in table 1 and shown on figures 1 and 2.

Sixty-three of the samples are inclusions collected from lava flows. Most of these (54) are from late Holocene flows, including 7 from mafic flows and 47 from silicic flows (see fig. 2). Inclusion type is indicated in table 1, based on petrographic criteria.

Of the 102 samples that are not inclusions, 24 are from late Holocene flows and 17 others are from post-glacial lava flows erupted about 10,600 years B.P. (Donnelly-Nolan and others, 1990). All late Holocene eruptions are represented in the data set, and all but two of 17 known post-glacial eruptions are included. Four samples are thought to be of Pleistocene age but erupted prior to initiation of Medicine Lake volcano; these are identified in table 1. The remaining 57 samples were collected from Pleistocene lavas in all sectors of the volcano.

Previous oxygen isotope data for lavas from Medicine Lake volcano were published by Taylor (1968). Taylor's data are in generally good agreement with the data presented here in table 1, where it is possible to correlate units.

Analytical work was conducted at U.S. Geological Survey laboratories in Menlo Park, California, between 1982 and 1995. Initially, a BrF<sub>5</sub> extraction process was used, subsequently replaced by a ClF<sub>3</sub> process. The resultant CO<sub>2</sub> gas was analyzed by the method reported in Bacon and others (1989, p. 201). The data are reported here in the familiar  $\delta$ -notation relative to VSMOW (Coplen, 1994).

## Acknowledgments

J. Beall provided the drillhole samples. J. Brophy collected sample LGM13; T.L. Grove collected samples 85-15b, 85-17, 85-25, and 86-1a. D. Champion facilitated the laboratory work. M. Olea, W. Loskutoff, O. Guracar, E. Lougee, and R. Sickler made mineral separates. J. Fierstein and J.G. Moore are thanked for reviewing this report.

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## FIGURE CAPTIONS

- Figure 1. Location map of Medicine Lake volcano showing locations of oxygen isotope samples. Rectangle indicates outline of Figure 2. Post-glacial lavas are shown with patterns: gray (late Holocene silicic lavas containing >62.9 wt. % SiO<sub>2</sub>), diagonal lines (late Holocene mafic lavas), and cross-hatch pattern (mafic lavas erupted about 10,600 years ago). Dotted lines are topographic contours for 5000, 6000, and 7000-foot elevations. Sample numbers for inclusions are shown in *italic*.
- Figure 2. Enlarged map of the central part of Medicine Lake volcano showing locations of oxygen isotope samples. The late Holocene silicic lava flows are shown in gray. Only site numbers are shown, e.g. site 554M is represented in table 1 by 554M (host rhyolite) plus 554M-a and 554M-g (inclusions). Sample numbers for inclusions are shown in *italic*. The location of the deep drill hole 17A-6 is indicated by the star. Elevation contours are shown with dotted lines.



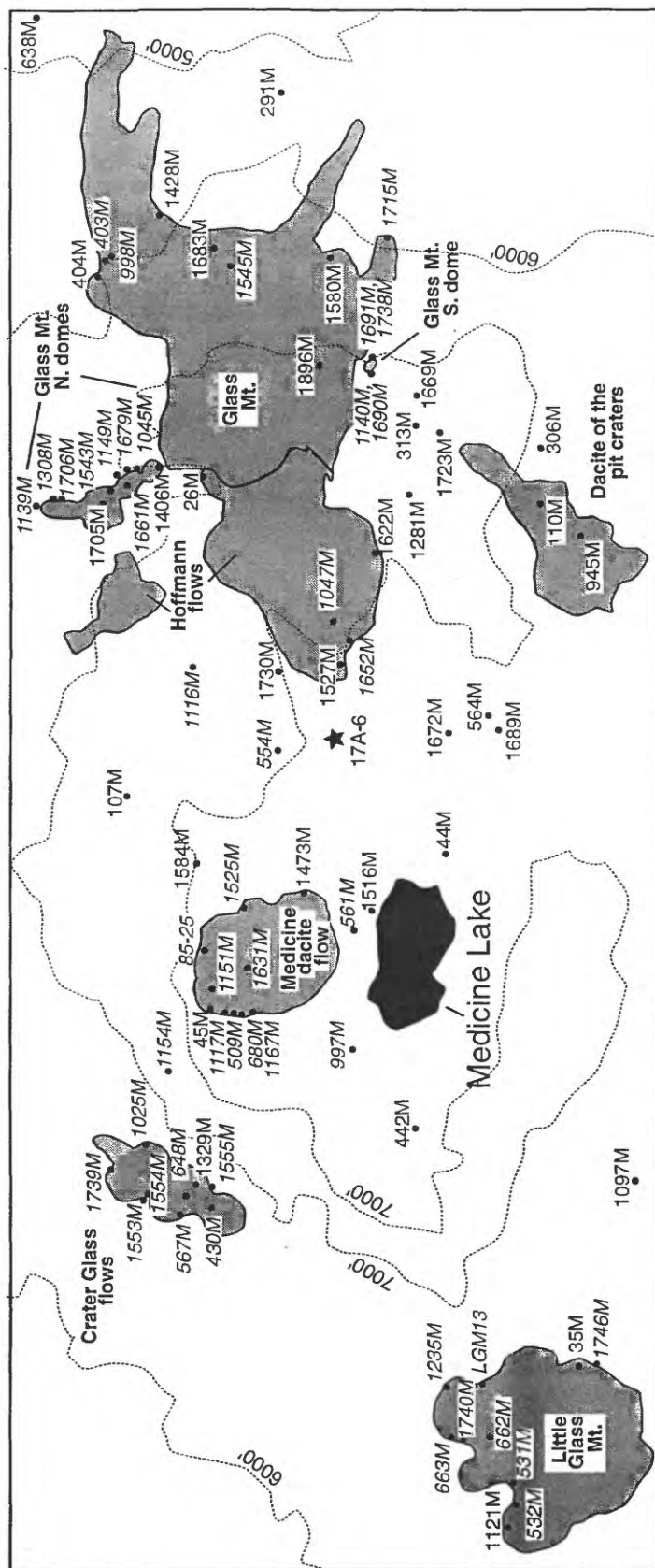


Figure 2

Table 1. Oxygen isotope data, Medicine Lake volcano

	A	B	C	D	E	F	G	H	I	J	K
	Sample No.	Description	Inclusion Type	Unit Code	Age Code	$\delta^{18}\text{O}$ WR	$\delta^{18}\text{O}$ Plag	$\delta^{18}\text{O}$ Qtz	Wt% $\text{SiO}_2$	Latitude	Longitude
1	18M	Older rhyolite SE of Callahan flow			p		6.0		72.6	40.8	35.4
2	26M	Larger of the Hoffmann flows		hf	lh			8.1	71.8	36.4	30.9
3	35M	Little Glass Mt.		lgm	lh			6.6	73.7	33.7	40.2
4	41M	Basalt of Paint Pot Crater			lh			6.9	52.9	31.5	42.4
5	44M	Lake Basalt			p			5.9	50.6	34.7	35.1
6	45M	Medicine dacite flow		md	lh			8.5	68.5	36.4	36.4
7	107M	North caldera rim porphyritic lava			p			5.1	62.7	37.1	34.3
8	110M	Dacite of the pit craters		dpc	lh			7.5	63.4	33.8	31.6
9	133M	Dacite flow near Dock Well			p			5.7	69.7	38.6	42.1
10	142M	Older rhyolite W. of Callahan flow			p			5.8	75.7	41.7	38.9
11	146M	Callahan flow			lh			7.3	57.6	42.0	34.3
12	155M	Older rhyolite near Cougar Butte			p			6.3	77.2	39.7	27.4
13	158M	Porphyritic basalt, NW sequence			p			5.8	50.5	41.1	43.3
14	183M	Basaltic andesite W. of Callahan flow			p			4.8	53.4	40.5	38.2
15	192M	Older rhyolite near Lost Iron Well			p			6.2	75.4	28.1	43.2
16	194M	Pumice, Andesite tuff			p			5.2	63.6	32.6	43.4
17	253M	Older rhyolite, Grasshopper Flat			p			5.8	75.2	31.2	42.0
18	291M	Older rhyolite E. of Glass Mt.			p			5.9	76.4	35.8	27.1
19	306M	Eastern caldera rim lava			p			4.3	63.4	33.9	30.9
20	313M	Lyons Peak, aphyric			p			5.1	55.7	34.8	30.6
21	324M	Pumice, older silicic ash-flow tuff			Pre-MLV			7.5	68.9	47.1	37.0
22	328M	Glant Crater flow at quarry			em			5.4	51.2	25.2	39.3
23	328M-A	Megacryst, Glant Crater flow at quarry			em			5.9	51.2	25.2	39.3
24	381M	Older rhyolite, small dome near Dock Well			p			6.3	72.3	38.2	43.1
25	387M	Andesite flow, NW sequence			p			5.1	59.5	40.4	42.9
26	388M	Basaltic andesite W. of Callahan flow			p			4.8	53.7	41.1	41.3
27	403M	Glass Mt. flow		gm	lh			7.1	67.9	37.2	28.8
28	403M-e	Inclusion, Glass Mt. flow	magmatic	gm	lh			6.4	57.0	37.2	28.8
29	404M	Glass Mt. flow		gm	lh			7.5	73.8	37.2	28.8
30	430M-b	Inclusion, small Crater Glass flow	magmatic	lgm	lh			6.3	57.0	36.5	38.5
31	442M	Older silicic flow W. of Medicine Lake			p			5.9	67.9	35.0	37.8
32	480M	Small hill NE of Tamarack Lake			p			7.2	60.8	33.0	46.6
33	504M	Small hill N of Tamarack Lake			p			7.4	59.7	33.1	47.6
34	505M	Typhoon Mesa			p			7.3	60.1	32.5	48.2
35	509M-a	Inclusion, Medicine dacite flow	magmatic	md	lh			7.9	60.8	36.3	36.4
36	509M-b	Inclusion, Medicine dacite flow	lithic	md	lh			7.0	50.3	36.3	36.4
37	531M-a	Inclusion, Little Glass Mt.	magmatic	lgm	lh			6.8	58.8	34.2	41.3
38	532M-a	Inclusion, Little Glass Mt.	cumulate	lgm	lh			6.0	54.3	34.2	41.6
39	554M	Rhyolite of Mt. Hoffmann			p			6.3	71.7	35.9	34.1
40	554M-a	Inclusion, rhyolite of Mt. Hoffmann	magmatic		p			6.5	61.9	35.9	34.1
41	554M-g	Inclusion, rhyolite of Mt. Hoffmann	magmatic		p			7.7	62.9	35.9	34.1
42	561M	Inclusion, Lake Basalt	granitic		p			9.2	71.0	35.4	35.7



Table 1. Oxygen isotope data, Medicine Lake volcano

1	A	B	C	D	E	F	G	H	I	J	K
	Sample No.	Description	Inclusion Type	Unit Code	Age Code	$\delta^{18}\text{O}$ WR	$\delta^{18}\text{O}$ Plag	$\delta^{18}\text{O}$ Qtz	Wt% $\text{SiO}_2$	Latitude	Longitude
44	564M	Eastern caldera rim lava			p	4.7			62.3	34.3	33.6
45	567M-a	Inclusion, large Crater Glass flow	lithic	lgm	lh	5.7			53.3	36.7	38.4
46	598M	North caldera rim lava			p	5.3			60.3	39.0	33.9
47	620M	Porphyritic andesite, N. flank			p		6.1		58.6	40.4	33.0
48	631M	Basalt of Tionesta			p		5.8		48.1	38.9	19.6
49	631M	Basalt of Tionesta			p		6.0		48.1	38.9	19.6
50	638M	Andesite of Indian Butte			p		5.7		58.0	37.7	26.3
51	646M	Near Mammoth Crater			p		6.2		55.2	41.9	32.7
52	648M-c	Inclusion, large Crater Glass flow	magmatic	lgm	lh	6.5			57.0	36.7	38.3
53	649M	Basalt of the tree molds			em	5.6			51.9	38.2	36.4
54	662M	Inclusion, Little Glass Mt.	magmatic	lgm	lh	6.4			62.2	34.4	40.9
55	663M-a	Inclusion, Little Glass Mt.	lithic	lgm	lh	5.7			52.8	34.7	40.9
56	663M-c	Inclusion, Little Glass Mt.	granitic	lgm	lh	8.2		9.7	73.6	34.7	40.9
57	680M	Inclusion, Medicine dacite flow	granitic	md	lh			8.8	74.2	36.3	36.4
58	691M	Basalt of the ribbon flows			em	6.1			50.1	27.7	29.6
59	692M	Burnt Lava flow			lh		6.1		56.9	27.8	29.5
60	693M	Basalt of Yellowjacket Butte			p		6.9		49.7	27.2	28.5
61	708M	Inclusion, Paint Pot Crater flow	granitic		lh			7.1	74.3	31.5	42.4
62	716M-a	Inclusion, Burnt Lava flow	magmatic		lh	5.9			49.3	31.1	31.8
63	716M-b	Inclusion, Burnt Lava flow	granitic		lh			6.5	78.2	31.1	31.8
64	726M	Andesite of Schonchin Butte			p		5.2		57.3	44.2	31.1
65	732M	Basalt of The Castles			p		5.6		48.6	44.2	32.2
66	753M	Ross Chimneys			lh		4.8		48.3	46.9	32.4
67	761M	Basalt of Devils Homestead			em		6.1		51.3	48.3	33.6
68	826M-b	Dead Horse Gulch tephra, white			Pre-MLV	6.0			66.9	45.1	17.9
69	826M-c	Dead Horse Gulch tephra, black			Pre-MLV	6.5			54.0	45.1	17.9
70	851M	Basalt at top of Gillem Bluff			Pre-MLV		6.0		47.7	47.2	34.0
71	863M-B	Megacryst, Chimney Crater			em		5.8		53.2	30.9	37.6
72	879M	Megacryst, spatter cone SE of Giant Crater			em		6.0		52.2	30.3	37.7
73	880M	Giant Crater group 6 vent			em	5.8			47.8	30.0	37.9
74	881M	Giant Crater group 4 lava			em	5.2			49.1	30.0	38.0
75	900M	Pumice, Andesite tuff			p	5.6			65.5	32.6	43.4
76	942M	South caldera rim lava			p	5.7			61.5	32.1	35.0
77	945M	Dacite of the pit craters		dpc	lh	7.6			63.4	33.5	31.8
78	997M-a	Inclusion, Andesite tuff	lithic		p	2.0			53.4	35.4	36.9
79	997M-c	Inclusion, Andesite tuff	lithic		p	0.5			72.0	35.4	36.9
80	997M-d	Inclusion, Andesite tuff	lithic		p	2.2			63.1	35.4	36.9
81	997M-f	Inclusion, Andesite tuff	lithic		p	0.5			67.7	35.4	36.9
82	998M	Inclusion, Glass Mt. lava	magmatic	gm	lh	6.3			54.5	37.2	28.8
83	1025M-j	Inclusion, large Crater Glass flow	lithic	lgm	lh	5.9			52.7	37.1	37.8
84	1045M-a	Inclusion, Glass Mt. dome 7	lithic	gm	lh	5.1			50.0	37.1	31.2
85	1047M-b	Inclusion, larger of the Hoffmann flows	magmatic	hf	lh	5.8			49.6	35.4	32.7

Table 1. Oxygen isotope data, Medicine Lake volcano

	A	B	C	D	E	F	G	H	I	J	K
1	Sample No.	Description	Inclusion Type	Unit Code	Age Code	$\delta^{18}\text{O}$ WR	$\delta^{18}\text{O}$ Plag	$\delta^{18}\text{O}$ Qtz	Wt% SiO <sub>2</sub>	Latitude	Longitude
86	1097M	South caldera rim lava			p	5.9			62.0	33.2	38.3
87	1116M-aD	Inclusion, rhyolite of Mt. Hoffmann	magmatic		p	6.3			61.7	36.6	33.1
88	1117M	Inclusion, Medicine dacite flow	magmatic	md	lh	7.4			59.0	36.3	36.4
89	1121M	Little Glass Mt.		lgm	lh	7.6			74.2	34.3	41.8
90	1139M-a	Inclusion, Glass Mt. dome 10	cumulate	gm	lh		7.1		54.1	37.6	31.3
91	1140M-h	Inclusion, Glass Mt. south dome	granitic	gm	lh			5.8	75.4	35.1	29.7
92	1149M-b	Inclusion, Glass Mt., dome 7	cumulate	gm	lh	6.6			54.2	37.0	31.0
93	1151M-a	Inclusion, Medicine dacite flow	cumulate	md	lh	7.8			56.3	36.5	36.2
94	1151M-c	Inclusion, Medicine dacite flow	magmatic	md	lh	7.6			61.6	36.5	36.2
95	1154M-a	Inclusion, north caldera rim	magmatic		p	5.6			55.2	36.8	37.1
96	1155M	Inclusion, Burnt Lava flow	magmatic		lh	6.0			48.0	30.4	32.0
97	1157M-a	Inclusion, Burnt Lava flow	granitic		lh			6.4	76.4	30.4	32.0
98	1167M-a	Inclusion, Medicine dacite flow	lithic	md	lh	5.9			51.1	36.3	36.5
99	1229M	Basaltic andesite of Black Mt.			p	6.2			55.1	32.1	26.0
100	1235M	Inclusion, Little Glass Mt.	magmatic	lgm	lh	6.1			59.8	34.7	40.5
101	1276M	Megacryst, Giant Crater group 2 flow			em		6.2		51.7	28.2	40.8
102	1281M	Red Shale Butte			p	5.7			53.7	34.9	31.3
103	1308M	Inclusion, Glass Mt. dome 10	lithic	gm	lh	5.5			54.6	37.6	31.3
104	1329M	Large Crater Glass flow		lgm	lh	7.2			74.2	36.7	38.3
105	1344M	Lake Basalt SE of Old Camp One			p	6.2			54.8	33.9	23.2
106	1375M	Basalt of vent 5			em	5.5			52.7	28.9	41.8
107	1392M	Basalt of the ribbon flows			em	5.5			49.2	32.5	31.3
108	1406M	Glass Mt. dome 1		gm	lh	7.0			74.6	36.6	30.9
109	1415M	Lake Basalt NE			p	6.0			54.0	39.3	21.5
110	1428M	Glass Mt. flow		gm	lh	7.3			65.9	36.7	28.3
111	1443M	Lake Basalt, Long Bell			p	6.0			51.1	28.3	24.9
112	1455M	Megacryst, Giant Crater group 4 vent			em		6.0		49.6	29.8	37.3
113	1466M	Giant Crater group 5 lava			em		6.0		48.2	14.6	30.3
114	1466M-a	Segregation vein, Giant Crater group 5 lava			em		6.7		50.0	14.6	30.3
115	1471M-A	Lake Basalt NE of Burnt Lava flow			p	5.6			51.5	31.9	30.2
116	1471M-B	Lake Basalt NE of Burnt Lava flow			p	5.7			52.1	31.9	30.2
117	1473M	Medicine dacite flow		md	lh	8.1			68.8	35.7	35.3
118	1484M	Giant Crater group 6 lava			em		6.3		47.7	19.9	35.0
119	1509M	Basalt of Valentine Cave			em	5.7			52.9	41.0	31.9
120	1513M	Callahan flow			lh	5.8			51.8	40.7	36.8
121	1516M	Lake Basalt, campground			p	5.7			50.1	35.2	35.5
122	1525M	Inclusion, Medicine dacite flow	granitic	md	lh	8.0		9.0	73.6	36.2	35.5
123	1527M	Larger of the Hoffmann flows		hf	lh	7.2			68.4	35.4	33.1
124	1543M	Inclusion, Glass Mt. dome 8	granitic	gm	lh			6.9	76.9	37.2	31.2
125	1543M-a	Inclusion, Glass Mt. dome 8	magmatic	gm	lh	5.4			62.8	37.2	31.2
126	1545M	Inclusion, Glass Mt.	magmatic	gm	lh	6.6	7.0		57.8	36.2	29.0
127	1553M	Inclusion, large Crater Glass flow	lithic	lgm	lh	5.8			52.2	37.0	38.3



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	A	B	C	D	E	F	G	H	I	J	K
1	Sample No.	Description	Inclusion Type	Unit Code	Age Code	$\delta^{18}\text{O}$ WR	$\delta^{18}\text{O}$ Plag	$\delta^{18}\text{O}$ Qtz	Wt% $\text{SiO}_2$	Latitude	Longitude
128	1554M	Inclusion, large Crater Glass flow	magmatic	lgm	lh	6.5			55.8	37.0	38.3
129	1555M	Inclusion, Crater Glass tephra	cumulate	lgm	lh	6.6			53.4	36.4	38.3
130	1580M	Glass Mt. flow		gm	lh	7.1			68.0	35.5	28.8
131	1584M	North caldera rim lava			p	5.1	5.6		64.3	36.6	35.0
132	1622M	Larger of the Hoffmann flows		hf	lh	7.4			72.4	35.1	32.0
133	1631M	Inclusion, Medicine dacite flow	magmatic	md	lh	6.8			57.9	36.2	36.0
134	1650M-A	Pumice, Andesite tuff			p	5.5			64.9	39.8	36.3
135	1650M-B	Pumice, Andesite tuff			p	5.8			64.2	39.8	36.3
136	1652M	Inclusion, larger of the Hoffmann flows	magmatic	hf	lh	6.1			51.6	35.3	32.9
137	1661M	Glass Mt. dome 7		gm	lh	7.3	6.9		73.4	37.1	31.3
138	1661M-a	Inclusion, Glass Mt. dome 7	cumulate	gm	lh	6.6			50.8	37.1	31.3
139	1669M	Lyons Peak porphyritic			p	4.9			53.1	34.8	30.3
140	1672M	Lake Basalt, caldera cone			p	5.9			50.0	34.6	33.8
141	1679M	Inclusion, Glass Mt. dome 7	magmatic	gm	lh	6.4	6.1		60.7	37.1	31.2
142	1683M-A	Glass Mt. flow		gm	lh	7.5			74.5	36.3	28.7
143	1683M-B	Glass Mt. flow		gm	lh	7.0			68.5	36.3	28.7
144	1689M	Eastern caldera rim lava			p	5.4			62.8	34.2	33.7
145	1690M	Inclusion, Glass Mt. south dome	granitic	gm	lh	3.0		5.1	71.2	35.1	29.8
146	1691M	Inclusion, Glass Mt. south dome	cumulate	gm	lh	6.1	6.2		54.9	35.1	29.8
147	1705M	Glass Mt. dome 8		gm	lh	7.5			73.3	37.3	31.4
148	1706M-a	Inclusion, Glass Mt. dome 10	cumulate	gm	lh	6.2	7.1		53.8	37.7	31.3
149	1715M	Inclusion, Glass Mt. flow	magmatic	gm	lh	6.1			58.7	34.9	28.6
150	1723M	Eastern caldera rim lava			p	4.9			63.5	34.6	30.7
151	1730M	Rhyolite of Mt. Hoffmann			p	5.5			71.9	35.9	32.8
152	1738M	Inclusion, Glass Mt. south dome	cumulate	gm	lh	6.4	6.6		55.3	35.2	29.7
153	1739M	Inclusion, large Crater Glass flow	granitic	lgm	lh			9.8	73.4	37.3	38.2
154	1740M	Inclusion, Little Glass Mt.	granitic	lgm	lh			9.8	73.4	34.6	40.9
155	1746M	Inclusion, Little Glass Mt.	cumulate	lgm	lh		6.4		55.3	33.6	40.2
156	1764M	Black Crater			lh		6.0		50.6	45.7	33.1
157	1774M	Ross Chimneys			lh		6.3		48.8	47.0	32.3
158	1896M	Glass Mt. tephra		gm	lh	6.7			61.3	35.5	30.0
159	LGM-13	Inclusion, Little Glass Mt.	cumulate	lgm	lh		6.9		56.3	34.4	40.3
160	85-15b	Inclusion, Burnt Lava flow	granitic		lh			7.1	73.4	30.6	31.8
161	85-17	Inclusion, Chimney Crater	granitic		em			7.0	72.8	30.8	37.5
162	85-25	Inclusion, Medicine dacite flow	granitic	md	lh	8.2		9.8	73.9	36.4	35.6
163	86-1a	Inclusion, High Hole Crater	granitic		lh			7.5	76.0	30.6	31.8
164	17A-6-6580	Drill hole sample			?	-2.7			74.1	35.5	33.8
165	17A-6-8210	Drill hole sample			?	-0.8			73.1	35.5	33.8
166	17A-6-9620	Drill hole sample			?	-3.3			72.7	35.5	33.8

## Explanation for Table 1

### Column C. Inclusion Type

Four types of inclusions are indicated:

(1) Magmatic -- typically fine-grained, these commonly display chilled cusped margins and are also called enclaves or blobs. Similar to those described by Bacon (1986). (2) Cumulate -- crystal-rich, commonly with glass in the interstices between mm-size crystals. Cumulate inclusions from Little Glass Mountain were described by Grove and Donnelly-Nolan (1986). (3) Lithic -- accidental fragments of unknown origin. They are typically completely crystalline and do not contain glass. Many of them have plutonic textures and may be intrusive equivalents of Medicine Lake volcano lavas. (4) Granitic -- a subset of the lithic inclusions. Glass can be found along grain boundaries or in cracks, depending on the extent of melting.

### Column D. Unit Codes

Unit codes are given for the five late Holocene silicic units: gm (Glass Mt. and co-erupted domes to north and south), lgm (Little Glass Mt.; includes co-erupted Crater Glass flows), hf (Hoffmann flows), md (Medicine dacite flow), and dpc (dacite of the pit craters).

### Column E. Age Codes

lh -- late Holocene; lavas erupted since 5000 years ago; em -- early mafic; post glacial lavas erupted about 10,600 yrs B.P. (Donnelly-Nolan and others, 1990); p -- Pleistocene; Pre-MLV -- pre-Medicine Lake volcano, but probably Pleistocene in age; ? -- ages of the three drill hole samples are unknown. These samples probably represent intrusive equivalents of erupted Medicine Lake lavas; depth beneath surface is indicated by the second part of the sample number (i.e. 6580 feet, 8210 feet, 9620 feet). All three samples are from cuttings.

### Columns F, G, and H

$\delta^{18}\text{O}$  WR -- whole-rock samples were analyzed;  $\delta^{18}\text{O}$  Plag -- plagioclase separates were analyzed;  $\delta^{18}\text{O}$  Qtz -- quartz separates were analyzed. All values are positive except as noted. Data are reported relative to VSMOW. Analyses in *italic* by W. Hildreth (single determinations). All other samples were analyzed by L. Adami and are averages of at least two determinations.

### Column I -- Wt% $\text{SiO}_2$

Analyses are normalized to 100%, volatile-free. XRF analyses were performed in U.S. Geological Survey laboratories in Lakewood, Colorado. The two analyses in *italics* (158M and 324M) were done on samples different from the ones from which plagioclase was separated for oxygen isotope analysis. In both cases, the chemically analyzed samples were collected nearby the two oxygen isotope samples.

### Column J -- Latitude

Minutes north of 41°N latitude are given to nearest tenth

### Column K -- Longitude

Minutes west of 121°W longitude are given to nearest tenth