



**Whole-rock and glass major-element geochemistry of  
Kilauea Volcano, Hawaii, near-vent eruptive products:  
September 1994 through September 2001**

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**U.S. GEOLOGICAL SURVEY  
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## Introduction

This report presents major-element geochemical data from 392 glasses (3,920 analyses) and 387 whole-rock aliquots among 523 lava samples collected on Kilauea's east rift zone between September 1994 and October 2001. This period of time comprises the final 2.5 years of episode 53, all of episode 54 (January 30, 1997), and the first 4.5 years of episode 55. See Thornber (2001) for a description of eruptive activity during this time period and an interpretation of the data presented herein. Other reports have described major-element chemistry for the period from 1990 to 1994 (Mangan and others, 1995) and glass chemistry and thermometry for the period from 1983 to 1994 (Helz and Hearn, 1998).

Petrologic sampling of eruption products is accomplished as part of comprehensive volcano monitoring by the U.S. Geological Survey's Hawaiian Volcano Observatory (HVO). One goal of this sampling program is to assess changing magmatic conditions through time. This goal is achieved through frequent sampling and analysis of vent tephra and spatter, tube-contained lava flows, and surface lava flows at or near the vent. The data presented in this report are limited to such near-vent samples. Since tephra samples are typically of insufficient volume for XRF analysis, whole-rock analyses are limited to flow and spatter samples. Excluded from this database are distal surface flows that were sampled for topical studies of emplacement dynamics (for example, Cashman and others, 1999) and any sluggish or crystal-laden tube flows collected during brief intermittent pauses in the eruption. Of 713 eruption samples collected and archived for various purposes during this interval, geochemical data for 523 are included here.

Pele's tears, hair and reticulite (tephra) and spatter from lava splashes within Pu'u 'O'o were collected using wooden "tear catcher" trays (30cm x 60cm x 10cm) placed downwind of the lava pond on the rim of the active crater. There is uncertainty of 2 to 4 days in the time of deposition of most tephra collected in "tear catchers" and such samples are limited to times when there was an active lava pond within the crater. Vent spatter samples obtained during active fountaining were usually retrieved by hand within seconds after their fall. Near-vent surface flow samples were collected with geological picks from the leading edges of lava flows or using cable-strung hammer heads tossed over levees into near-vent flow channels. Samples of tube-contained lava flows were taken at skylights created by roof collapses along the active tube system. These tube samples were routinely obtained at elevations above 600 m and over a distance ranging from roughly 1 to 6 km from the vent. The tube-flow sampling device consisted of a 1.4 kg hammer head secured to the end of a 20-m length of 0.8-cm stainless-steel cable. In most cases, the cable-strung hammer head was tossed over a log positioned across the skylight in order to facilitate optimal positioning over the center of the flow and to avoid sample contamination by tube-roof material at the edge of the skylight. Using this technique, up to 0.5-kg samples of lava were retrieved from the tube flow.

While tephra or tears were quickly air-quenched during deposition, spatter and lava tube samples were retrieved as quickly as possible and quenched in water in order to preserve the phases present before collection. Well-quenched glass compositions in near vent samples allow for reasonable assessment of pre-eruptive magma temperatures using the MgO glass thermometer of Helz and Thornber (1987). As established by analysis of same-day, down-tube sampling experiments (Thornber, 2001), a 0.9°C per kilometer "vent-correction" is applied to glass thermometry temperatures of lava tube samples collected at variable distance from the vent.

## **Acknowledgments**

The 518 samples described herein were collected by the following HVO staff and visiting scientists: Christina Heliker (176 samples), Carl Thornber (171 samples), David Sherrod (111 samples), Jim Kauahikaua (22 samples), Frank Trusdell (8 samples), Ken Hon (8 samples), Tari Mattox (7 samples), Jennifer Reynolds (7 samples), Laszlo Keszthelyi (4 samples), Don Swanson (4 samples), Tamar Elias (2 samples), Maggie Mangan (2 samples), and Bob Tilling (1 sample). Many samples were obtained with the able assistance of David Okita (Volcano Helicopters). We acknowledge the vision of Ken Hon, who in 1992 originated the HVO eruption database as an ongoing depository of geochemical analyses from the then nine-year-old eruption on Kilauea Volcano's east rift zone. HVO volunteers are gratefully acknowledged for their efforts in sample preparation and data archiving.

## **Analytical Methods and Standard Reproducibility**

### **Electron Microprobe Glass Analysis**

Microbeam analyses of glasses for 1994 to 1999 samples were accomplished by Carl Thornber and Gregory Meeker at the USGS Denver Microbeam Facility using a JEOL 8900 electron microprobe. Glass analyses for 1999 to September 2001 samples were obtained by Robert Oscarson at the USGS Menlo Park electron microprobe lab using an identical instrument and similar analysis routine. In Denver, glasses were analyzed at 15 keV, 20 nanoampere beam current and using a Phi-Rho-Z data reduction routine. In Menlo Park, analyses were conducted using 25 nanoampere beam current and ZAF correction parameters for data reduction. In both labs, a 20- $\mu\text{m}$ -diameter beam was used to minimize loss of alkalis during analyses of glasses. Data for major and minor elements were collected using 20-second peak-count intervals. A longer peak-count interval of 80 seconds was used for all sulfur determinations. The precision of electron microprobe results is estimated on the basis of counting statistics and reproducibility of USNM basaltic glass standards (Jarosewich and others, 1979) that bracket the compositional range of most eruption glasses. The average and standard deviation of 418 analyses of VG-A99 and 114 analyses of USNM-113716, analyzed repeatedly during probe analysis sessions between May 1995 and January 1999, are listed in Table 1. Both glass standards were reproducible within the estimated precision in multiple electron-probe sessions over the four-year period, and no additional corrections to the data were made based upon standard values obtained in each analysis session (as was done by Helz and others, 1995).

The analyses of 1999 to September 2001 samples were conducted in August 2000 and November 2001. The average and standard deviation of 203 analyses of USNM basaltic glass standard VG-2 (Jarosewich and others, 1979) are listed in Table 1. Similar to the USGS Denver results, this glass standard was reproducible within estimated precision, so no further corrections were made.

Despite limitations in the absolute accuracy of the Helz-Thornber glass thermometer associated with experimental uncertainty of 10°C, the relative temperatures estimated by this method are comparable within limits of analytical precision. An average standard deviation (one-sigma error) of 1.4 percent in the measured MgO concentration in glass standards yields an average estimated glass thermometry precision of 1.4°C. The average standard deviation of MgO per ten replicate analyses of glasses in all samples of this study was 1.4 weight percent, demonstrating that unknown glasses were homogeneous within the precision of analysis. Sulfur values were reproducible at about 10 percent standard deviation in the higher concentrations of the USNM-113716 and VG-2 standards

but not in the roughly 100-ppm concentrations of the VG-A99 standard, which was considered as the detection limit for unknown glasses.

**Table 1. Average electron microprobe analyses of basalt glass standards VG-A99, USNM-113176 and VG2.**

	<u>USGS Denver</u> <u>VG-A99</u> <u>Kilauea basalt glass</u> MAY-95 to JAN-99 418 analyses			<u>USGS Denver</u> <u>USNM 113716</u> <u>Indian Ocean basalt glass</u> MAY-95 to JAN-99 114 analyses			<u>USGS Menlo Park</u> <u>VG-2</u> <u>Juan de Fuca basalt glass</u> AUG-00 & NOV-01 203 analyses			USNM *
	avg	std.dev	USNM*	avg	std.dev	USNM*	avg	std.dev	USNM*	
SiO <sub>2</sub>	51.06	0.46	50.94	51.77	0.39	51.52	50.81	0.25	50.81	
Al <sub>2</sub> O <sub>3</sub>	12.44	0.13	12.49	15.13	0.10	15.39	14.00	0.20	14.06	
FeO <sub>T</sub>	13.15	0.16	13.30	9.04	0.09	9.13	11.84	0.25	11.84	
MgO	5.04	0.10	5.08	8.03	0.12	8.21	6.66	0.18	6.71	
CaO	9.04	0.11	9.30	11.12	0.14	11.31	11.06	0.20	11.12	
Na <sub>2</sub> O	2.72	0.16	2.66	2.78	0.06	2.48	2.62	0.07	2.62	
K <sub>2</sub> O	0.82	0.03	0.82	0.08	0.01	0.09	0.19	0.08	0.19	
TiO <sub>2</sub>	3.95	0.09	4.06	1.29	0.03	1.30	1.89	0.23	1.85	
P <sub>2</sub> O <sub>5</sub>	0.43	0.03	0.38	0.12	0.02	0.12	0.20	0.03	0.20	
MnO	0.19	0.02	0.15	0.16	0.02	0.17	0.21	0.02	0.22	
TOTAL	98.84		99.18	99.51		99.72	99.49		99.62	
S (ppm)	96	63		875	88		1305	135		

\* Values of Jarosewich and others (1979)

### X-ray Fluorescence Whole-Rock Analysis

Concentrations of major elements were measured in whole rocks at the U.S. Geological Survey's Denver XRF Laboratory by David Siems using wavelength-dispersive spectrometry X-ray fluorescence techniques described by Taggart and others (1987). Samples were prepared for whole-rock geochemical analysis at HVO. Samples were crushed using a ceramic alumina rocker and platen and powdered in an alumina shatterbox.

Repeated XRF analyses of four USGS Kilauea standards were performed as analytical control in each of 19 sample analysis batches conducted from 1994 - 2001 (Table 2). Standard reproducibilities (at one-sigma error) are less than 0.01 weight percent for K<sub>2</sub>O and MnO, 0.02 for TiO<sub>2</sub> and P<sub>2</sub>O<sub>5</sub>, 0.03 for CaO and Na<sub>2</sub>O, 0.05 for Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub>\* (total-iron) and 0.13 for SiO<sub>2</sub>.

Reproducibility for MgO (one-sigma error) was less than 0.04 weight percent in standards with less than 7.3 percent MgO and less than 0.7 weight percent in the standard with 14.28 percent MgO.

**Table 2. Analyses of Kilauea whole-rock standards BHVO-1, DAS-6912-5, KL-77-15, and KL-77-9.** [Analyses by X-ray fluorescence spectroscopy at U.S. Geological Survey's Denver analytical laboratory. Oxides reported in weight percent. Loss on ignition (LOI) is reported for each standard analysis, and determined as specified by Taggart and others (1987). The reported precision of oxide concentrations (tenths, hundredths or thousandths of weight percent) is based upon overall standard reproducibility.]

													<b>BHVO-1</b>	
<b>Date Analyzed</b>	<b>LAB#</b>	<b>SiO<sub>2</sub></b>	<b>Al<sub>2</sub>O<sub>3</sub></b>	<b>Fe<sub>2</sub>O<sub>3</sub>*</b>	<b>MgO</b>	<b>CaO</b>	<b>Na<sub>2</sub>O</b>	<b>K<sub>2</sub>O</b>	<b>TiO<sub>2</sub></b>	<b>P<sub>2</sub>O<sub>5</sub></b>	<b>MnO</b>	<b>LOI</b>	<b>Total</b>	
2/12/1996	V-001087	49.7	13.76	12.30	7.21	11.47	2.20	0.532	2.771	0.294	0.168	-0.34	100.1	
2/13/1996	V-001102	49.8	13.62	12.20	7.22	11.36	2.21	0.527	2.759	0.285	0.168	-0.3	99.9	
2/26/1996	V-001150	49.9	13.66	12.21	7.23	11.37	2.22	0.526	2.754	0.288	0.168	-0.35	99.9	
6/5/1996	V-001455	49.9	13.69	12.24	7.19	11.37	2.25	0.525	2.750	0.292	0.168	-0.29	100.0	
8/4/1996	V-001710	50.0	13.77	12.26	7.23	11.43	2.27	0.530	2.765	0.295	0.168	-0.31	100.4	
9/24/1996	V-001964	49.8	13.74	12.25	7.17	11.36	2.22	0.525	2.749	0.294	0.168	-0.34	99.9	
10/18/1996	V-001983	49.9	13.67	12.22	7.18	11.36	2.25	0.525	2.752	0.295	0.166	-0.25	100.0	
2/5/1997	V-002403	49.8	13.77	12.25	7.20	11.43	2.25	0.524	2.759	0.295	0.168	-0.36	100.1	
3/17/1997	V-002504	49.8	13.70	12.21	7.25	11.35	2.20	0.526	2.752	0.285	0.168	-0.35	99.9	
6/4/1997	V-002674	49.7	13.65	12.22	7.27	11.39	2.19	0.516	2.749	0.296	0.167	-0.34	99.8	
8/14/1997	V-002874	49.7	13.67	12.20	7.16	11.36	2.26	0.525	2.751	0.299	0.168	-0.31	99.8	
11/10/1997	V-002994	49.5	13.59	12.22	7.17	11.35	2.23	0.519	2.738	0.303	0.167	-0.34	99.5	
4/4/1998	V-003559	49.8	13.71	12.24	7.24	11.34	2.22	0.526	2.742	0.298	0.168	-0.32	100.0	
9/28/1998	V-004246	49.7	13.67	12.25	7.28	11.40	2.27	0.530	2.752	0.299	0.169	-0.31	100.0	
7/20/1999	V-005586	49.7	13.64	12.26	7.05	11.39	2.20	0.524	2.765	0.315	0.169	-0.3	99.7	
5/17/2000	C-169667	49.8	13.70	12.30	7.23	11.40	2.09	0.520	2.780	0.320	0.170	-0.35	100.0	
8/25/2000	C-173306	50.0	13.68	12.26	7.20	11.43	2.05	0.519	2.762	0.312	0.168	-0.39	100.0	
7/19/2001	C-188700	50.1	13.70	12.30	7.30	11.40	2.18	0.520	2.780	0.300	0.170	-0.35	100.4	
11/8/2001	C-199227	49.8	13.70	12.20	7.28	11.40	2.22	0.520	2.760	0.320	0.170	-0.35	100.0	
	<b>Average</b>	<b>49.8</b>	<b>13.69</b>	<b>12.24</b>	<b>7.21</b>	<b>11.39</b>	<b>2.21</b>	<b>0.524</b>	<b>2.757</b>	<b>0.299</b>	<b>0.168</b>	<b>-0.33</b>	<b>100.0</b>	
	<b>Std. dev</b>	<b>0.14</b>	<b>0.05</b>	<b>0.03</b>	<b>0.06</b>	<b>0.03</b>	<b>0.06</b>	<b>0.004</b>	<b>0.011</b>	<b>0.011</b>	<b>0.001</b>	<b>0.03</b>		

**Table 2. (continued)**

<b>DAS-6912-5</b>													
Date Analyzed	LAB#	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub> *MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	MnO	LOI	Total	
2/12/1996	V-001085	48.0	11.02	13.01	14.28	9.31	1.83	0.422	2.121	0.234	0.171	-0.8	99.6
2/13/1996	V-001100	48.1	10.98	12.97	14.26	9.25	1.87	0.410	2.121	0.229	0.173	-0.84	99.5
2/26/1996	V-001148	48.3	11.03	13.02	14.41	9.27	1.85	0.408	2.118	0.229	0.175	-0.81	100.0
6/5/1996	V-001453	48.2	10.96	12.93	14.24	9.21	1.85	0.408	2.103	0.233	0.171	-0.8	99.5
8/4/1996	V-001708	48.3	11.06	13.07	14.35	9.27	1.89	0.410	2.136	0.240	0.174	-0.81	100.1
9/24/1996	V-001962	48.2	11.06	13.07	14.29	9.26	1.85	0.412	2.121	0.237	0.174	-0.84	99.9
10/18/1996	V-001981	48.3	11.07	13.02	14.27	9.29	1.88	0.413	2.111	0.233	0.171	-0.88	99.9
2/5/1997	V-002401	48.2	11.06	13.06	14.18	9.29	1.86	0.409	2.123	0.242	0.172	-0.84	99.8
3/17/1997	V-002502	48.4	11.04	13.06	14.27	9.27	1.85	0.414	2.127	0.233	0.174	-0.85	99.9
6/4/1997	V-002672	48.1	11.03	13.03	14.36	9.28	1.81	0.400	2.114	0.239	0.172	-0.86	99.7
8/14/1997	V-002872	48.0	10.96	13.01	14.15	9.25	1.87	0.409	2.126	0.248	0.172	-0.95	99.2
11/10/1997	V-002992	48.0	10.97	13.05	14.21	9.26	1.85	0.407	2.122	0.243	0.173	-0.86	99.4
4/4/1998	V-003557	48.2	11.04	13.00	14.27	9.26	1.86	0.409	2.100	0.239	0.172	-0.85	99.7
9/28/1998	V-004244	48.0	10.96	13.01	14.36	9.27	1.91	0.415	2.117	0.246	0.174	-0.76	99.7
5/17/2000	C-169666	47.9	11.00	12.90	14.10	9.23	1.70	0.400	2.130	0.260	0.170	-0.83	99.0
8/25/2000	C-173304	48.3	11.00	13.04	14.19	9.30	1.67	0.403	2.118	0.262	0.172	-0.81	99.6
	<b>Average</b>	<b>48.1</b>	<b>11.01</b>	<b>13.02</b>	<b>14.26</b>	<b>9.27</b>	<b>1.84</b>	<b>0.409</b>	<b>2.119</b>	<b>0.240</b>	<b>0.173</b>	<b>-0.84</b>	<b>99.6</b>
	<b>Std. dev</b>	<b>0.14</b>	<b>0.04</b>	<b>0.05</b>	<b>0.08</b>	<b>0.02</b>	<b>0.06</b>	<b>0.006</b>	<b>0.009</b>	<b>0.010</b>	<b>0.001</b>	<b>0.04</b>	

<b>KL-77-15</b>													
Date Analyzed	LAB#	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub> *MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	MnO	LOI	Total	
2/12/1996	V-001084	50.8	13.51	13.60	5.45	9.43	2.75	0.781	3.551	0.434	0.176	-0.76	99.8
2/13/1996	V-001099	51.1	13.48	13.55	5.42	9.40	2.77	0.774	3.539	0.426	0.176	-0.9	99.8
2/26/1996	V-001147	50.9	13.57	13.50	5.42	9.37	2.80	0.771	3.530	0.433	0.176	-0.89	99.6
6/5/1996	V-001452	51.3	13.48	13.56	5.41	9.35	2.81	0.770	3.532	0.433	0.175	-0.89	99.9
8/4/1996	V-001707	51.0	13.50	13.60	5.44	9.40	2.85	0.774	3.542	0.439	0.175	-0.76	100.0
9/24/1996	V-001961	51.1	13.50	13.57	5.46	9.38	2.80	0.773	3.523	0.439	0.176	-0.82	99.8
10/18/1996	V-001980	51.2	13.48	13.57	5.46	9.39	2.83	0.776	3.533	0.446	0.176	-0.81	100.0
2/5/1997	V-002400	51.0	13.51	13.61	5.45	9.42	2.81	0.775	3.535	0.447	0.176	-0.86	99.9
3/17/1997	V-002501	51.2	13.52	13.59	5.48	9.39	2.79	0.776	3.554	0.432	0.176	-0.82	100.1
6/4/1997	V-002671	51.1	13.47	13.57	5.47	9.40	2.80	0.768	3.519	0.444	0.175	-0.83	99.8
8/14/1997	V-002871	51.1	13.50	13.57	5.47	9.40	2.84	0.782	3.533	0.448	0.176	-0.84	99.9
11/10/1997	V-002991	50.7	13.41	13.57	5.42	9.37	2.82	0.770	3.517	0.446	0.174	-0.81	99.4
4/4/1998	V-003556	51.1	13.48	13.66	5.43	9.35	2.79	0.774	3.524	0.444	0.177	-0.89	99.8
9/28/1998	V-004243	50.7	13.41	13.49	5.48	9.35	2.84	0.775	3.498	0.453	0.176	-0.85	99.3
5/17/2000	C-169665	50.9	13.50	13.50	5.44	9.37	2.67	0.770	3.550	0.460	0.180	-0.86	99.5
8/25/2000	C-173304	51.3	13.50	13.61	5.47	9.41	2.64	0.764	3.535	0.469	0.176	-0.85	100.1
7/19/2001	C-188701	51.1	13.40	13.60	5.47	9.39	2.72	0.770	3.540	0.430	0.170	-0.84	99.8
11/8/2001	C-199226	50.9	13.40	13.50	5.44	9.38	2.80	0.770	3.520	0.460	0.180	-0.84	99.5
	<b>Average</b>	<b>51.0</b>	<b>13.48</b>	<b>13.57</b>	<b>5.45</b>	<b>9.39</b>	<b>2.78</b>	<b>0.773</b>	<b>3.532</b>	<b>0.444</b>	<b>0.176</b>	<b>-0.84</b>	<b>99.8</b>
	<b>Std. dev</b>	<b>0.17</b>	<b>0.05</b>	<b>0.05</b>	<b>0.02</b>	<b>0.02</b>	<b>0.06</b>	<b>0.004</b>	<b>0.014</b>	<b>0.012</b>	<b>0.002</b>	<b>0.04</b>	

**Table 2. (continued)**

		<u>KL-77-9</u>											
Date Analyzed	LAB#	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub> *MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	MnO	LOI	Total	
2/12/1996	V-001086	50.6	13.79	13.05	5.93	10.05	2.67	0.710	3.289	0.381	0.171	-0.4	100.2
2/13/1996	V-001101	50.7	13.75	12.97	5.84	9.97	2.67	0.695	3.269	0.372	0.171	-0.46	99.9
2/26/1996	V-001149	50.7	13.81	12.97	5.86	10.00	2.64	0.695	3.278	0.390	0.171	-0.5	100.1
6/5/1996	V-001454	50.8	13.74	12.97	5.84	9.96	2.68	0.691	3.262	0.384	0.169	-0.5	100.0
8/4/1996	V-001709	50.7	13.77	13.02	5.89	10.00	2.74	0.700	3.287	0.391	0.171	-0.4	100.2
9/24/1996	V-001963	50.7	13.76	13.01	5.88	9.95	2.68	0.697	3.254	0.384	0.170	-0.45	100.1
10/18/1996	V-001982	50.9	13.81	13.03	5.84	9.98	2.70	0.705	3.250	0.388	0.172	-0.45	100.3
2/5/1997	V-002402	50.8	13.80	13.06	5.87	10.02	2.70	0.700	3.263	0.386	0.172	-0.5	100.2
3/17/1997	V-002503	50.9	13.84	13.01	5.90	9.99	2.62	0.697	3.260	0.381	0.172	-0.44	100.3
6/4/1997	V-002673	50.8	13.86	13.04	5.97	10.02	2.61	0.691	3.261	0.395	0.171	-0.51	100.3
8/14/1997	V-002873	50.5	13.70	12.94	5.88	9.96	2.68	0.696	3.237	0.396	0.170	-0.41	99.7
11/10/1997	V-002993	50.5	13.70	13.07	5.88	9.97	2.64	0.698	3.258	0.396	0.171	-0.5	99.8
4/4/1998	V-003558	50.6	13.80	12.98	5.90	9.94	2.66	0.687	3.243	0.392	0.171	-0.46	100.0
9/28/1998	V-004245	50.4	13.72	12.94	5.92	9.97	2.72	0.701	3.244	0.396	0.169	-0.45	99.7
5/17/2000	C-169664	50.7	13.80	13.00	5.93	10.00	2.52	0.690	3.290	0.400	0.170	-0.44	100.1
8/25/2000	C-173305	50.8	13.71	13.00	5.87	10.01	2.45	0.692	3.275	0.403	0.171	-0.44	99.9
7/19/2001	C-188702	51.0	13.80	13.10	6.00	10.00	2.61	0.690	3.290	0.390	0.170	-0.49	100.6
11/8/2001	C-199225	50.8	13.80	13.00	5.93	10.00	2.67	0.690	3.270	0.410	0.170	-0.47	100.3
	<b>Average</b>	<b>50.7</b>	<b>13.78</b>	<b>13.01</b>	<b>5.89</b>	<b>9.99</b>	<b>2.65</b>	<b>0.696</b>	<b>3.266</b>	<b>0.391</b>	<b>0.171</b>	<b>-0.46</b>	<b>100.1</b>
	<b>Std. dev</b>	<b>0.16</b>	<b>0.05</b>	<b>0.04</b>	<b>0.05</b>	<b>0.03</b>	<b>0.07</b>	<b>0.006</b>	<b>0.017</b>	<b>0.009</b>	<b>0.001</b>	<b>0.04</b>	

### Explanation of the Data Spreadsheet

Average major-element compositions for glasses and whole rocks are presented by order of sample number (approximate chronological order) in Table 3. Explanations for each of the categories of sample information provided are as follows:

**Sample Number:** The sample number prefix (for example, “KE53-”) designates the Kilauea episode number. Each sample number is followed by a “T”, “S,” or “F” suffix, which denotes a lava sample as tephra, spatter, or flow, respectively.

**Deposit Type:** Tephra samples are categorized as Pele’s tears, hair, or reticulite. Samples of lava spatter from vents or from upper-elevation skylights are listed as spatter. All flow samples in the table are pahoehoe lava. These are further categorized as “tube” for tube-contained flow, “surface” for near-vent surface flow, and “pond” for near-vent ponded lava.

**Date Collected, Date Formed, and Hour Formed:** Dates are in mm/dd/yy format. Many flow samples were collected from active lava flows, and some tephra samples were collected immediately after impact. These samples were water quenched by the collector, and the date collected is the same as the date formed. The time of formation is roughly the time of quenching, reported as hours and minutes in 24-hour clock format, Hawaii Standard Time (HST). For most tephra samples, which were deposited as fallout on collection trays and gathered roughly once a week, the date formed is assigned as the midpoint date of each collection interval. “**Sample Interval**” specifies the collection interval, in days, for Pele’s tears, or the uncertainty in estimated times of formation of other samples that were not collected in the molten state.

**Vent:** The location of the source-vent for each lava sample is designated as Pu`u `O`o Crater or Pu`u `O`o Flank for episode 53 and episode 55. Fissure designations A through F indicate eruptive sources for samples collected during fissure-fed episode 54. These samples had an eruptive origin in the vicinity of Napau Crater, about 1 to 4 km uprift of Pu`u `O`o (Thornber, 2001).

**Longitude and Latitude:** The geographic coordinates of each sample are referable to the World Geodetic System datum, 1984 (WGS84). Latitude is positive (north) and longitude is negative (west). Beginning in October 1997, high-precision portable GPS receivers were used to measure sampling locations. In these cases, positional accuracy is generally better than 12 m and 2D precision error is better than 6 m.

Prior to October 1997, sample locations were plotted on topographic maps or air photos by standard field techniques, a difficult task given the changing nature of the lava-flow field and the quickly outdated topographic maps and yearly photographic coverage. For those samples, positional accuracy probably ranges from 25 to 50 m or more. The coordinate grid system used previously to describe sample locations (Mangan and others, 1995) relied on a UTM metric grid referable to the International ellipsoid for earth geometry. These eastings and northings were converted to the Old Hawaiian datum, which is based on the 1866 Clarke ellipsoid, then reprojected to the WGS84 datum. This anomalous mapping scheme of using different ellipsoids for UTM and latitude-longitude grids persisted on several USGS topographic quadrangle maps in Hawaii until the release of a new map edition in the 1990s.

**Altitude, in feet,** was determined as follows. For sampling sites farther than 1 km from the P`u`u `O`o cone (below 2300-ft altitude) the pre-1983 orthometric altitude was read from topographic quadrangle maps. Some locations may stand as much as 50 m higher than shown on the maps, owing to lava buildup along the axis of the lava-flow field. Altitudes for samples collected within 1 km of the cone (above 2300-ft altitude) are reported according to their approximate actual altitude. These altitudes were determined from generalized or detailed topographic maps made periodically as the eruption progressed.

No altitude is more precise than  $\pm 10$  ft, and many have errors larger than  $\pm 50$  ft. Nonetheless, many skylight sample altitudes are reported more precisely because we needed unique identifiers for these sites. The assigned altitude became the skylight's moniker, which could not be duplicated when a skylight at similar altitude opened later. As a result, the names for one or two skylights indicate attitudes that differ significantly from their plotted altitude.

**Tube Distance:** The along-tube distance from vent to sample location, in kilometers, is reported for samples of tube-contained lava. These distances were used to apply a temperature correction to the glass thermometry values. Tube paths were determined from periodic infrared images of the lava-flow field, electromagnetic mapping, and observations of skylights and collapse pits.

**Glass Chemistry:** Analyses reported for ten major and minor oxide components and sulfur (parts per million) are the average of ten glass analyses per sample with total iron oxide reported as total ferrous-iron oxide ( $\text{FeO}_T$ ). Sulfur concentrations below detection limits ( $\sim 100$  ppm) are generally indicated as  $<100$  ppm, except for those that are close to detection limits and with measured values of 90 to 99 ppm. As detailed by Thornber (2001) the ferric to ferrous iron ratio of glasses can be calculated assuming a  $\text{FeO}/\text{FeO}_T$  ratio of 0.9.



**Glass Thermometry (MgO T°C):** Eruptive temperature of glasses is calculated from the average weight percent MgO of glass using the formula  $T^{\circ}\text{C} = 20.1 * \text{wt}\% \text{MgO} + 1014^{\circ}\text{C}$  (Helz and Thornber, 1987). The temperature of “Tube” samples in the database has been adjusted to account for cooling of 0.9°C per kilometer of actual tube distance (Thornber, 2001).

**Whole Rock Chemistry (XRF):** All values are in weight percent, normalized to 100 with all iron as FeO. The whole-rock ferric to ferrous iron ratio can be calculated assuming a FeO/Fe<sub>T</sub> ratio of 0.9 (Thornber, 2001).

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