



**A compilation of whole-rock and glass major-element  
geochemistry of Kīlauea Volcano, Hawai‘i, near-vent  
eruptive products: January 1983 through September  
2001**

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## Introduction

This report presents major-element geochemical data from 652 glasses (~6,520 analyses) and 795 whole-rock aliquots from 1,002 fresh samples of olivine-tholeiitic lava collected throughout the near-continuous eruption of Kīlauea Volcano, Hawai‘i, from January 1983 through September 2001. The data presented herein provide a unique temporal compilation of lava geochemistry that best reflects variations of pre-eruptive magma compositions during prolonged rift-zone eruption. This document serves as a repository for geochemical data referred to in U.S. Geological Survey Professional Paper 1676 (Heliker, Swanson, and Takahashi, eds., 2003) which includes multidisciplinary research papers pertaining to the first twenty years of Pu‘u ‘Ō‘ō-Kūpaianaha eruption activity. Details of eruption characteristics and nomenclature are provided in the introductory chapter of that volume (Heliker and Mattox, 2003). Geochemical relations among all or portions of this data set are depicted and interpreted by Thornber (2003), Thornber and others (2003) and Thornber (2001). Trace element compositions and Nd, Sr and Pb isotopic analyses of representative samples of this select eruption suite will be provided in a separate and complimentary open file report.

From 1983 to October 2001, approximately 2,500 eruption samples were collected and archived by the U.S. Geological Survey’s Hawaiian Volcano Observatory (HVO). Geochemical data for 1,002 of these samples are included here. Previous reports present bulk-lava major-element chemistry for eruption samples collected from 1983 to 1986 and from 1990 to 1994 (Neal and others, 1988 and Mangan and others, 1995, respectively). Major element glass chemistry and thermometry data for samples collected from 1983 to 1994 is reported by Helz and Hearn (1998) and whole-rock and glass chemistry for samples collected from September 1994 to October 2001 is provided by Thornber and others (2002). This report is a compilation of previously published data along with unpublished whole-rock data for the 1986-1990 eruptive interval (episode 48, see Heliker and Mattox, 2003).

The geochemical data in this report is mostly limited to well-quenched samples collected at or near their respective vents. The samples include tephra and spatter, in addition to lava dipped from lava lakes, lava tubes, and surface lava flows. The details of sample collection techniques as described by Thornber and others (2002) are generally applicable for this entire sampling interval.

Specifically excluded from this database are samples of distal surface flows, many of which were collected for topical studies of emplacement dynamics (for example, Cashman and others, 1999). Samples of sluggish or crystal-laden tube flows collected during eruptive pauses were also excluded, because they bear visual, petrographic and geochemical evidence for crystal accumulation during surface-flow stagnation. In addition, the pre-1992 whole-rock major element data reported here has been corrected to compensate for minor analytical discrepancies between pre- and post-1991 XRF analyses. These discrepancies resulted from a change in instrumentation at the USGS Denver analytical laboratories (see below). This select suite of time-constrained geochemical data is suitable for constructing petrologic models of pre-eruptive magmatic processes associated with prolonged rift zone eruption of Hawaiian shield volcanoes.

## Acknowledgments

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## Analytical Methods

### Electron Microprobe Glass Analysis

The facilities, instrument settings, data reduction methods, and standard reproducibility pertaining to electron microbeam analyses of glasses and glass geothermometry results reported here are detailed in earlier open-file reports by Helz and Hearn (1995) for 1983-1994 samples and by Thornber and others (2001) for 1994-2001 samples.

### X-ray Fluorescence Whole-Rock Analysis

Pre-October 1994 samples were powdered by USGS Denver analytical labs for whole-rock analysis using an alumina-plated pulverizer. Post-1994 samples were prepared for whole-rock geochemical analysis at HVO and were crushed using a ceramic alumina rocker and platen and powdered in an alumina shatterbox device.

Whole-rock concentrations of major elements were measured at the U.S. Geological Survey's Denver XRF Laboratory by David Siems and Joe Taggart using wavelength-dispersive spectrometry X-ray fluorescence (WDS-XRF) techniques. In January 1992, the USGS Denver analytical laboratories implemented a new WDS-XRF instrument. Techniques for these respective eras of XRF analyses are described by Taggart and others (1987 and 2002).

Repeated XRF analyses of four USGS Kilauea standards were performed as analytical control in each of 19 sample analysis batches conducted from 1994 - 2001 (see Table 2 of Thornber and others, 2002). 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. A comparison of USGS Kilauea basalt standard (BVO-1) analyses before and after the instrument change (i.e., "OLD XRF" versus "NEW XRF", Table 1) reveals significant differences in some elements (particularly calcium, potassium, titanium, and phosphorous). In this database, the whole-rock major element analyses from the older instrument were corrected based upon the post-1991 change in BHVO-1 analyzed values (Table 1).

### **Table 1. "Old" versus "new" whole-rock analyses of USGS Kilauea standard BHVO-1.**

Analyses by X-ray fluorescence spectroscopy at U.S. Geological Survey's Denver analytical laboratory. Oxides reported in weight percent (wt%). For all XRF data reported here, 10 element analyses are normalized to 100 with total iron as FeO after removal of volatile loss on ignition (LOI = 0.33+/- .03 wt%). The reported precision of oxide concentrations (tenths, hundredths or thousandths of weight percent) is based upon overall standard reproducibility.

		<b>BHVO-1 "Old" XRF</b>									
Date Analyzed	Sample	SiO2	Al2O3	FeOT	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO
May 17, 1988	BHVO-1	50.1	13.63	11.27	7.31	11.72	2.14	0.521	2.846	0.281	0.1
June 26, 1990	BHVO-1	50.1	13.62	11.27	7.33	11.72	2.18	0.511	2.825	0.290	0.1
February 25, 1991	BHVO-1	50.1	13.69	11.23	7.28	11.67	2.25	0.513	2.798	0.282	0.1
February 15, 1991	BHVO-1	50.0	13.72	11.26	7.30	11.71	2.27	0.511	2.813	0.280	0.1
February 25, 1991	BHVO-1	50.1	13.72	11.17	7.30	11.72	2.24	0.511	2.824	0.280	0.1
December 30, 1991	BHVO-1	50.0	13.71	11.22	7.30	11.71	2.24	0.510	2.822	0.280	0.1
	average	50.1	13.68	11.24	7.30	11.71	2.22	0.513	2.821	0.282	0.1
	std dev	0.1	0.04	0.04	0.02	0.02	0.05	0.004	0.016	0.004	0.0

		<b>BHVO-1 "New" XRF</b>									
Date Analyzed	Sample	SiO2	Al2O3	FeOT	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO
February 12, 1996	BHVO-1	50.1	13.88	11.16	7.27	11.56	2.22	0.536	2.794	0.296	0.1
February 13, 1996	BHVO-1	50.3	13.77	11.10	7.30	11.49	2.23	0.533	2.789	0.288	0.1
February 26, 1996	BHVO-1	50.3	13.79	11.09	7.30	11.48	2.24	0.531	2.780	0.291	0.1
June 5, 1996	BHVO-1	50.3	13.82	11.12	7.25	11.48	2.27	0.530	2.775	0.295	0.1
August 4, 1996	BHVO-1	50.3	13.84	11.09	7.26	11.49	2.28	0.533	2.778	0.296	0.1
September 24, 1996	BHVO-1	50.3	13.87	11.13	7.25	11.47	2.24	0.530	2.777	0.297	0.1
October 18, 1996	BHVO-1	50.3	13.80	11.10	7.25	11.47	2.27	0.530	2.779	0.298	0.1
February 5, 1997	BHVO-1	50.2	13.87	11.11	7.26	11.52	2.26	0.528	2.781	0.297	0.1
March 17, 1997	BHVO-1	50.3	13.83	11.09	7.32	11.46	2.22	0.531	2.778	0.288	0.1
June 4, 1997	BHVO-1	50.2	13.80	11.11	7.35	11.51	2.22	0.522	2.779	0.299	0.1
August 14, 1997	BHVO-1	50.3	13.83	11.11	7.25	11.49	2.28	0.531	2.783	0.302	0.1
November 10, 1997	BHVO-1	50.2	13.79	11.15	7.27	11.51	2.27	0.526	2.777	0.307	0.1
April 4, 1998	BHVO-1	50.3	13.84	11.12	7.31	11.45	2.24	0.531	2.768	0.301	0.1
September 28, 1998	BHVO-1	50.2	13.79	11.12	7.34	11.50	2.29	0.535	2.777	0.302	0.1
July 20, 1999	BHVO-1	50.3	13.81	11.17	7.14	11.53	2.23	0.531	2.799	0.319	0.1
May 17, 2000	BHVO-1	50.3	13.83	11.17	7.30	11.51	2.11	0.525	2.806	0.323	0.1
August 25, 2000	BHVO-1	50.5	13.79	11.12	7.26	11.52	2.06	0.523	2.785	0.315	0.1
July 19, 2001	BHVO-1	50.3	13.77	11.12	7.34	11.46	2.19	0.523	2.793	0.301	0.1
November 8, 2001	BHVO-1	50.2	13.82	11.07	7.34	11.50	2.24	0.524	2.784	0.323	0.1
	<b>Average</b>	<b>50.3</b>	<b>13.82</b>	<b>11.12</b>	<b>7.28</b>	<b>11.49</b>	<b>2.23</b>	<b>0.529</b>	<b>2.783</b>	<b>0.302</b>	<b>0.1</b>
	<b>Std. dev</b>	<b>0.1</b>	<b>0.03</b>	<b>0.03</b>	<b>0.05</b>	<b>0.03</b>	<b>0.06</b>	<b>0.004</b>	<b>0.009</b>	<b>0.011</b>	<b>0.0</b>

<b>Correction Factor: "Old" to "New" XRF</b>	<b>Percent difference in averages</b>	<b>0.4</b>	<b>0.99</b>	<b>-1.06</b>	<b>-0.27</b>	<b>-1.85</b>	<b>0.28</b>	<b>3.121</b>	<b>-1.359</b>	<b>6.750</b>	<b>-0.3</b>
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## Explanation of the Data Spreadsheet

Average major-element compositions for glasses and whole rocks are presented in chronological order in Table 2. Explanations for each of the categories of sample information provided are as follows:

**Sample Number:** The sample number prefix (for example, “KE53-”) designates the Kīlauea episode number (see Heliker and Mattox, 2003). Each sample number is followed by a “T”, “S,” “F,” or “P” suffix, which denotes a lava sample as tephra, spatter, flow, or pond respectively.

**Geochemical Type:** “Hybrid” samples (episodes 1 -30, 54 and early 55) have petrologic characteristics suggesting mixing with fractionated rift-stored magma bodies (Garcia and Wolfe, Garcia and others, 1989 and 1992; Thornber and others, 2003). Samples of “Open System” type are typically olivine-phyric and most were collected during intervals of prolonged near-continuous eruption (episodes 48-53 and 55).

**Deposit Type:** Tephra samples are categorized as Pele’s tears, Pele’s hair, or reticulite. Samples of spatter from vents or from upper-elevation skylights are listed as spatter. Lava-flow samples in the table are mostly pāhoehoe lava, with a few of ‘a‘ā. These are further categorized as “tube” for tube-contained flow, “surface” for near-vent surface flows of pāhoehoe or ‘a‘ā morphology, and “pond” for samples of near-vent ponded lava.

**Date Collected, Date Formed, Hour Formed:** Dates are in mm/dd/yy format. Many flow samples were collected from active lava flows, and some spatter 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.

**Decimal Date Formed:** Decimal equivalents to the year, month, day and hour of sample formation are provided to facilitate temporal data plots of eruption chemistry.

**Vent:** The location of the source-vent for each lava sample is designated in accordance with vent designations of Wolfe and others (1988), Heliker and others (1998), and Heliker and Mattox (2003).

**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 Hawai'i 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 Pu'u 'Ō'ō cone (below 2,300-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 2,300-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 lava tube sample altitudes are reported more precisely because we needed unique identifiers for the skylights that provided sampling opportunities. 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.

**Vent Distance:** The distance from vent to sample location, in kilometers, is reported for samples of tube-contained lava and vent-proximal surface flows. These distances were used to apply a temperature correction to the glass thermometry values. For tube samples, distance 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 indicated as  $<90$  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 ( $\text{MgO}$   $T^\circ\text{C}$ ):** Eruptive temperature of glasses is calculated from the average weight percent  $\text{MgO}$  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 flow samples in the database has been adjusted to account for cooling of  $0.9^\circ\text{C}$  per kilometer of distance from the vent (Thornber, 2001).

**Whole Rock Chemistry (XRF):** For sample numbers designated with an asterisk (\*), "old" XRF analyzed values are corrected by those factors shown in Table 1. All values are in weight percent, normalized to 100 with all iron as  $\text{FeO}$ . The whole-rock ferric to ferrous iron ratio can be calculated assuming a  $\text{FeO}/\text{FeO}_T$  ratio of 0.9 (Thornber, 2001).

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