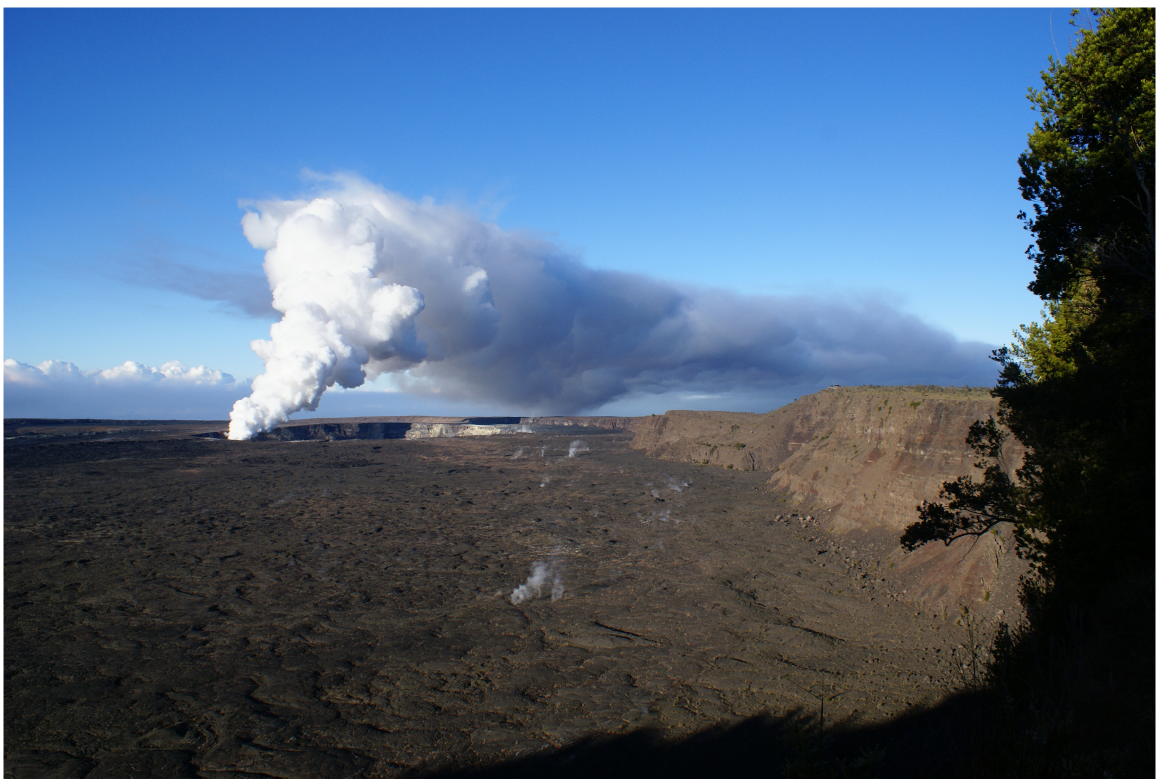
# Catalog of Tephra Samples from Kīlauea's Summit Eruption, March–December 2008

By Kelly M. Wooten, Carl R. Thornber, Tim R. Orr, Jennifer F. Ellis, and Frank A. Trusdell



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Cover. Photograph of the billowing plume rising from the Halemaʻumaʻu Overlook vent inside Halemaʻumaʻu Crater, taken from the north rim of Kīlauea caldera, July 9, 2008 (USGS photograph by J.P. Kauahikaua).

## Contents

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By Kelly M. Wooten[1], Carl R. Thornber[2], Tim R. Orr[1], Jennifer F. Ellis[1], and Frank A. Trusdell[1]

## Introduction

The opening of a new vent within Halema'uma'u Crater in March 2008 ended a 26-year period of no eruptive activity at the summit of Kīlauea Volcano. It also heralded the first explosive activity at Kīlauea's summit since 1924 and the first of eight discrete explosive events in 2008. At the onset of the eruption, the Hawaiian Volcano Observatory (HVO) initiated a rigorous program of sample collection to provide a temporally constrained suite of tephra samples for petrographic, geochemical, and isotopic studies. Petrologic studies help us understand conditions of magma generation at depth; processes related to transport, storage, and mixing of magma within the shallow summit region; and specific circumstances leading to explosive eruptions.

This report provides a catalog of tephra samples erupted at Kīlauea's summit from March 19, 2008, through the end of 2008. The Kīlauea 2008 Summit Sample Catalog is tabulated in the accompanying Microsoft Excel file, of2009-1134.xls. The worksheet in this file provides sampling information and sample descriptions. Contextual information

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for this catalog is provided below and includes (1) a narrative of 2008 summit eruptive activity, (2) a description of sample collection methods, (3) a scheme for characterizing a diverse range in tephra lithology, and (4) an explanation of each category of sample information (column headers) in the Microsoft Excel worksheet.

## Eruption Narrative

Starting in November 2007, the seismic tremor level and sulfur dioxide ($SO_2$) emission rate at Kīlauea's summit began to climb. By March 2008, the $SO_2$ emission rate had reached 10 times the long-term background value, prompting Hawai‘i Volcanoes National Park to close the Halema‘uma‘u area to visitors. The tremor and $SO_2$ increases were accompanied by the appearance of a new, vigorously fuming gas vent low on the southeast wall of Halema‘uma‘u Crater on March 12 (fig. 1). The new gas vent was about 70 m below the crater rim, almost directly below the visitor overlook on Halema‘uma‘u's southeast rim, and has been informally designated as the "Halema‘uma‘u Overlook vent." The crater rim at that location stands about 85 m above the crater floor. Incandescence, which was visible only at night, was first observed at the vent on March 13. Overnight on March 16-17, the size of the incandescent area began to increase, and, by March 18, the incandescent area had expanded to 30 m in diameter.

**Figure 1.** Aerial photograph of the heavily fuming gas vent on the southeast wall of Halema‘uma‘u Crater on March 14, 2008, Hawai‘i Volcanoes National Park (USGS photograph by A.J. Sutton).

At 0258 (all times are reported in Hawai‘i standard time unless otherwise noted) on March 19, the collapse of the incandescent rubble capping the gas vent was accompanied by an explosive eruption that scattered coarse rock debris over an area of about 50 hectares, opening and widening the vent to a diameter of about 35 m. Dense rock fragments and blocks were deposited up to 175 m beyond the Halema‘uma‘u Crater rim above the vent, and the visitor overlook and fence sustained damage from falling blocks (fig. 2), the largest of which measured 90 cm in length. Ash and lapilli were distributed downwind toward the southwest, covering the Halema‘uma‘u parking area and adjacent section of Crater Rim Drive (fig. 3). Fine ash was reported as far away as Pāhala, 30 km downwind of the vent. No juvenile material was identified in the tephra generated during this initial explosive eruption, but an incandescent source was revealed in reflections off the base of the plume after the vent opened.

**Figure 2.** Photograph showing damage to the visitor overlook fence caused by lithic blocks ejected during the March 19, 2008, explosive eruption, Hawai‘i Volcanoes National Park. Photo taken April 14, 2008.

The ejection of incandescent tephra was first captured overnight by a time-lapse camera on March 22–23. By the evening of March 23, nearly continuous ejection of incandescent particles was observed after dark from HVO about 2 km away. The following day, a sparse deposit of Pele’s tears, fresh-looking glassy black spatter, and glass-coated lithic fragments was observed at the visitor overlook. This deposit constituted the first lava erupted at Kīlauea’s summit since September 1982.

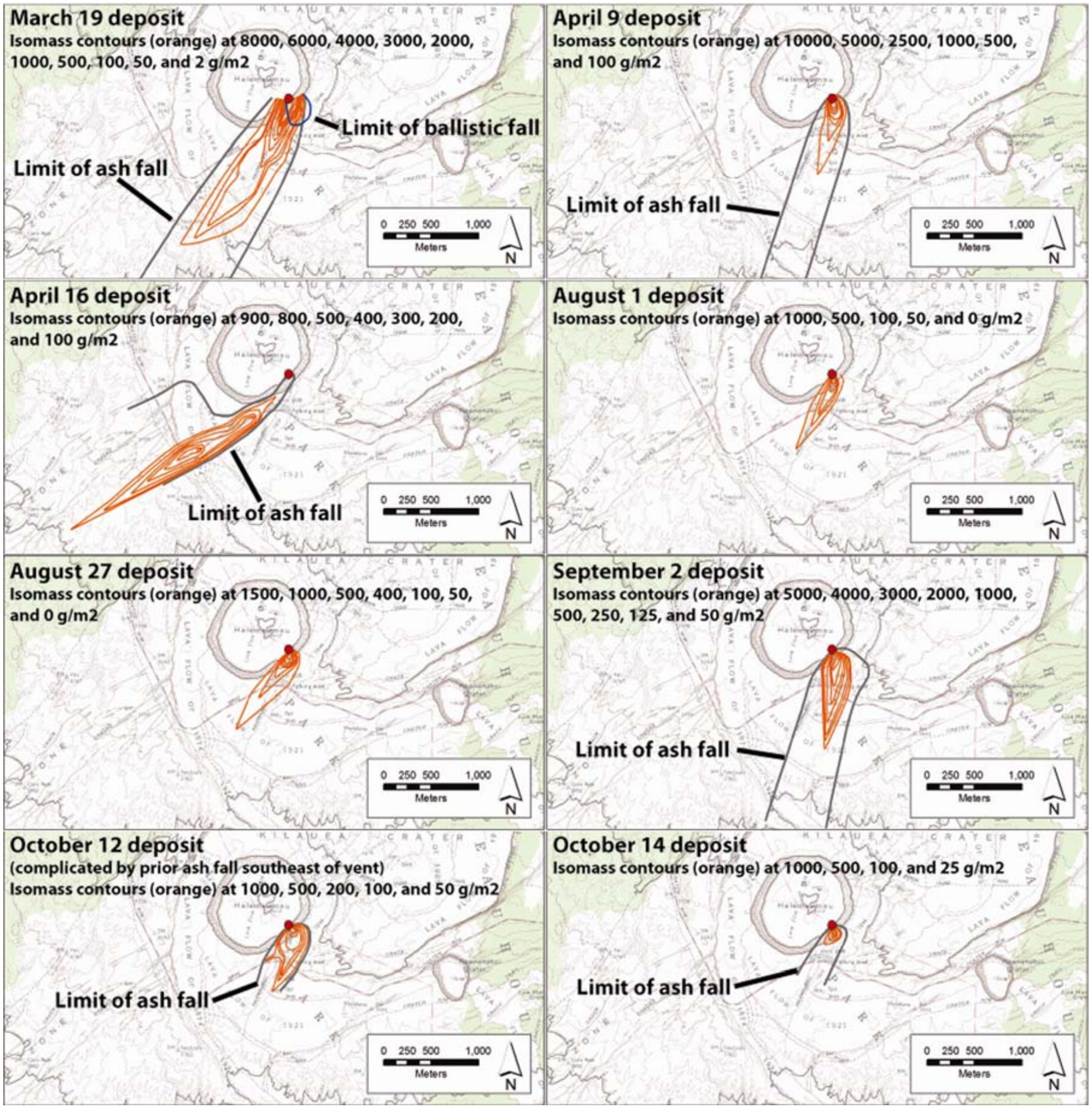


**Figure 3.** Preliminary isomass maps prepared by D. Swanson in cooperation with B. Houghton (University of Hawai‘i), showing the isomass contours for the eight explosive eruption deposits from the Halema‘uma‘u Overlook vent in 2008, Hawai‘i Volcanoes National Park.

A more significant deposit of white to dark gray rock dust with a sparse vitric component was erupted at about 2200 on March 23, just as glow at the base of the plume was suddenly extinguished by the ash-rich plume. The brown to gray, ashy plume continued for 4 days, depositing ash near the crater rim. The ash was heavily reworked by wind and accumulated behind rocks. By 0755 on March 27, the plume began to change back to a typical white, relatively ash-poor plume. There were two more periods in late

March when the plume was relatively ash-rich for an extended period of time—from 1626 on March 27 to 1406 on March 28, and at 0800–1001 on March 30. There were hundreds of brief, tephra-bearing plumes after March 19 that were associated with collapses of the vent rim and walls. For the most part, these plumes deposited relatively minor amounts of ash.

Between March 31 and April 9, tephra contained a significant component of Pele’s tears that peaked on April 3–4 and declined through April 8. On April 2–3, Pele’s hair was found accumulating on the downwind side of curbs in the Halema‘uma‘u parking area (fig. 4).

**Figure 4.** On April 3, 2008, Pele’s hair was found accumulating on the downwind side of curbs in the Halema‘uma‘u parking area, Hawai‘i Volcanoes National Park (USGS photograph by D. Swanson).

A second explosive eruption occurred at 2308 on April 9 and deposited lithic debris and juvenile tephra on the crater rim. This was followed by a third explosive eruption, intermediate in size between the previous two, on April 16 (fig. 3). The vent was obscured by clouds during the April 16 eruption, but seismic signals recorded its onset at 0357. The explosive eruption produced pinkish-gray lithic ash and fine lapilli (less than 4 mm in diameter), with small amounts (~5 percent) of Pele’s hair and tears, glassy spheres, and shards.

Following a period of relative quiet that lasted through July, the fourth, fifth, and sixth explosive eruptions at the summit occurred in August and early September and were associated with continued widening of the vent by successive collapses of its rim and walls. The fourth eruption occurred at 2245 on August 1, ejecting a mixture of lithic and juvenile tephra, with clasts up to several centimeters in diameter, onto the crater rim. At 0737 on August 27, the fifth explosive eruption also deposited a mixture of lithic and juvenile tephra, with clasts up to several centimeters in diameter, on the crater rim. Following these two explosive eruptions, the vent measured 60 m across. Both of the August eruptions produced only small amounts of tephra (fig. 3).

The following week, the sixth—and largest—explosive eruption in 2008 occurred at 2013 on September 2. Both lithic and juvenile material was erupted during this event, but the magmatic component overshadowed the minor lithic component of 10–15 percent. Oblate bombs up to 20 cm in length were found along the crater rim above the vent, and lapilli up to 10 cm across were found ~350 m away in the Halema‘uma‘u parking area. After this explosion, the vent diameter had increased by 12 m, bringing its diameter to 72 m across. The increase in vent diameter improved the view into the vent and, on September 5, the top of the lava column was first seen from the air; it was sighted several more times during the following weeks.

The largest seismic signal produced during the explosive eruptions in 2008 accompanied the seventh explosive eruption, which occurred at 0728 on October 12. This event produced a small component of lithic tephra, but was dominated by glassy scoria fragments up to several centimeters in diameter and mixed with lithic fragments. The eighth and final explosive eruption of 2008 occurred only two days later at 1607 on October 14. Again, the deposit was a mixture of both lithic and juvenile tephra, with a predominant juvenile component. There are two broadly distinct variants of juvenile tephra (1) scoriaceous lapilli and small bombs up to 10 cm across, with a dull gray surface coating of rock dust, and (2) bombs up to nearly 1 m long, which often consist of clots of lava interconnected by long, thick strands of Pele's hair. Following this explosive eruption, the vent diameter was 84 m.

In the weeks following the October 14 explosive eruption, collapses from the vent rim and walls continued to produce frequent dusty plumes (fig. 5). On December 4, a relatively large collapse partially blocked the conduit beneath the vent. By the time the dusty plume from the collapse had dissipated, the plume had become very weak. Low-level ash production from the vent, present throughout the eruption, dropped to insignificant levels, and all hint of nighttime glow vanished. Small collapses of the vent rim and walls continued through December, and, by the end of the month, the vent had reached a diameter of 104 m (fig 6). Views into the vent using an infrared camera to see through the weak plume showed that the vent had become choked with rubble at a depth of about 200 m.

**Figure 5.** Time-lapse camera photograph from the northeast rim of Halemaʻumaʻu Crater showing a typical ash event at 1542 Hawaiʻi standard time on August 20, 2008, Hawaiʻi Volcanoes National Park.


**Figure 6.** Comparison photographs from a time-lapse camera in the observation tower at the Hawaiian Volcano Observatory showing east-to-west widening of the overlook vent in 2008, Hawaiʻi Volcanoes National Park. *Left:* The vent on March 19, 2008, with an approximate width of 35 m. *Right:* The vent on December 30, 2008, with an approximate width of 104 m.

## Collection Methods

Most of the summit lava samples collected during 2008 were simply picked from the ground by hand. In addition, wooden boxes (referred to as “tear catchers”) were placed on the ground near the rim of Halemaʻumaʻu Crater within a few days of the opening of the vent. The tear catchers, with areas of 0.21 $m^2$, 0.27 $m^2$, and 0.34 $m^2$, provide a collection surface for material ejected from the vent. One tear catcher was on the crater rim directly in front of the visitor overlook (TC1; fig. 7 right, fig. 8), and another was placed about 200 m southwest of the overlook in a position directly under the plume during typical trade-wind conditions (TC3; fig. 7 left, fig. 8). The third tear catcher, mounted on a tripod at a height of about 1 m, was briefly located next to the box under the plume (TC3) to compare the effects of eolian contamination, but the strong winds quickly destroyed the tripod mount on the box. This tear catcher was then moved to a ground position near the crater rim about 20 m west of the overlook (TC2; fig. 8). Though a fixed location is assigned to each box, the actual locations of individual boxes within these three areas shifted up to 20 m over time to accommodate changing conditions.


**Figure 7.** *Left:* A tear catcher (TC3), deployed after the initial explosive eruption on March 19, was located approximately 200 m southwest of the vent, Halema‘uma‘u Crater, Hawai‘i Volcanoes National Park. Photograph taken March 27, 2008, looking northeast. *Right:* The overlook tear catcher (TC1) is on the crater rim in front of the visitor overlook fence, directly above the vent. The blue bucket attached to the fence is part of D. Swanson’s tephra-collection array. Photograph taken March 10, 2009, looking southwest.

A 4 by 6 foot tarp was deployed on August 6, approximately 20 m west of the visitor overlook, with rocks placed around the edges to keep it in place. This tarp was used as a clean surface on which to collect tephra fallout from the explosive eruptions. After the August 27 explosive eruption, the tephra was collected from the tarp, which had been melted through by the hot ejecta. The September 2 explosive eruption ejected more hot material that melted most of the remaining tarp. A new tarp was laid over the original on September 3, but no samples were collected from it before it was completely destroyed in the subsequent explosive eruption on October 12.

A 10-station network of plastic buckets was also set up under the direction of D. Swanson to collect tephra fallout from the eruptive plume. Tephra was collected from the buckets nearly every day and used to calculate daily accumulation rates, background ash-production mass flux, and explosive eruption mass flux. These calculations, however, are not addressed in this report.

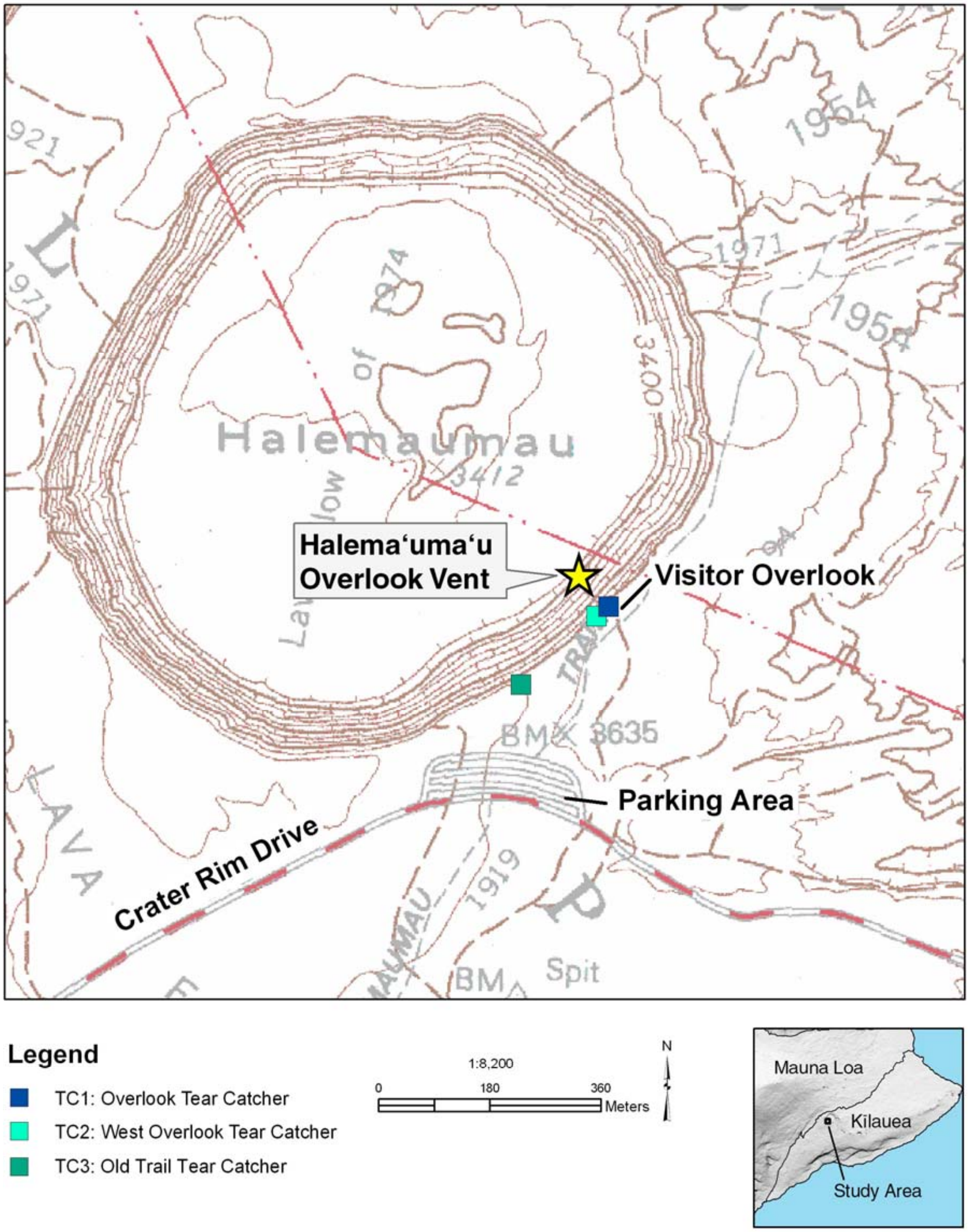


**Figure 8.** Map showing the location of the March 2008 eruptive vent and tear catcher (collection box) deployments in relation to Halema‘uma‘u Crater, Crater Rim Drive, and the Halema‘uma‘u parking area, Hawai‘i Volcanoes National Park. TC3 was removed mid-August, but TC1 and TC2 continued to be used through the end of the year.

## General Description and Classification of the 2008 Kīlauea Summit Sample Suite

Tephra deposited by the 2008 explosive eruptions includes lithic blocks, lapilli, and ash from the collapsed crater floor and conduit walls. This is mixed with a relatively small proportion of bombs, spatter, and Pele's hair and tears that were molten or partly molten when erupted. Samples collected for petrologic study were mostly limited to those of apparent juvenile character. Most collection forays yielded only small amounts of Pele's hair and tears, tiny glassy spheres or broken rods, shards of bubble walls, and bits of frothy pumice. Larger juvenile pyroclasts were associated with the larger explosive events and include discrete globules of vesicle-rich spatter and pumice, angular chunks of fresh or oxidized scoria, and glass-coated bombs and lapilli. Most of these specimens are either cored by, or mixed with, coarse to very fine foreign fragments, including juvenile components of crystal-mush clots, oxidized or unoxidized pumice and scoria, as well as anhydrite and holocrystalline, aphanitic basalt fragments. The predominant juvenile component in the 2008 summit tephra is sparsely olivine-phyric (less than 2 volume percent) with variable microphenocryst of plagioclase and clinopyroxene that are likely to have developed shortly before and during eruption and emplacement. Scarce but significant, small (up to 1 cm), open-textured gabbroic mush clots are found as cores to lapilli and also are mixed into the pumice and scoria tephra (fig. 9).

**Figure 9.** Photograph of a thin section containing a crystal mush clot of open-textured gabbro coring a 1-cm glassy lapilli (KS08-2S).

## Kīlauea Summit Sample Descriptions

The Kīlauea summit samples have labels, such as “KS08-01M,” that begin with an identifying prefix “KS” with a two-digit year and a hyphen (for example, KS08-). This is followed by a unique numeric sample identifier (for example, “01”), representing a group of material collected at a particular time and (or) place, and a single alpha character (for example, “M”) corresponding to a “type” designation. The type designation is used to distinguish lithologic categories based upon bulk macroscopic characteristics. Ten categories were established for the tephra collected in 2008—types A, B, C, D, E, H, I, M, Y, and Z. Each of these categories is briefly described and depicted below.

**Type A—**Apparently pure, glassy juvenile tephra. These samples are black and include Pele's hair, Pele's tears, small glass spheres, shards and rods, small lapilli without dense lithic cores, pure glassy spatter, and pumice (fig. 10).


**Figure 10.** Photograph of type A lava sample KS08-02A.

**Type B—**Glassy tephra with a mixed juvenile and lithic component. This includes pristine glassy-coated lapilli and small bombs cored either with dense foreign lithics (such as holocrystalline, aphanitic basalt) or with crystal-mush clots, pumice, and scoria (fig. 11).


**Figure 11.** Photograph of type B lava sample KS08-02B.

**Type C—**Apparently juvenile scoriaceous bombs and lapilli. These samples consist of clean black vesicular and microcrystalline scoria. No lithics or ash are apparent in the primary fabric, and the sample may or may not be glassy (fig. 12).


**Figure 12.** Photograph of type C lava sample KS08-62C.

**Type D—**Dust- or anhydrite-coated scoriaceous bombs and lapilli. These bombs have surfaces with a secondary yellow or white coating. The interior is clean, black scoria, and the samples are vesicular and microcrystalline. There are no lithics or ash in the primary fabric, and the sample may or may not be glassy (fig. 13).


**Figure 13.** Photograph of type D lava sample KS08-62D.

**Type E—**Pumiceous bombs and lapilli thoroughly mixed with coarse to very fine accidental lithic and juvenile fragments (fig. 14).


**Figure 14.** Photograph of type E lava sample KS08-100E.

**Type H—**Scoriaceous bombs and lapilli thoroughly mixed with coarse to very fine accidental lithic and juvenile fragments. These samples are microcrystalline or glassy black scoria and differ from types C and D because of the mixed accidental fragments contained in the sample (fig. 15).


**Figure 15.** *Left:* Photograph of type H lava sample KS08-66H. *Right:* Thin section of a scoriaceous-to-pumiceous bomb, containing a mush clot and fragments of oxidized scoria, unoxidized pumice, anhydrite, and aphanitic basalt in a sparsely olivine-phyric pumiceous matrix (KS08-66H).

**Type I—**Scoriaceous bombs and lapilli with lithic cores. These samples are large, angular lithic fragments with a thin coating of pasty, but mostly non-glassy microcrystalline spatter (fig. 16).


**Figure 16.** Photograph of type I lava sample KS08-02I.

**Type Y—**Lithic debris and ash with no apparent juvenile component (fig. 17).


**Figure 17.** Photograph of type Y lava sample KS08-40Y.

**Type Z—**Tear catcher (collection box) sample. Fragments in this category can vary in size (from ash to bombs) and in lithology. Most samples contain both a juvenile and a lithic component. Samples in this category may also contain material deposited earlier during the eruption and reworked by wind (fig. 18).


**Figure 18.** Photograph of type Z lava sample KS08-99Z.

**Type M—**Type M is the miscellaneous, or "catch all" category for anything that did not fit neatly in the other 9 categories or warrant its own type designation.

# Explanation of the Kīlauea Summit Sample Catalog, March–December 2008

The Kīlauea summit sample catalog is found in the Microsoft Excel spreadsheet of2009-1134.xls. This table provides general information about each of the samples in the KS08 sample series, separates each sample into one or more lithologic groups, and provides a detailed description of each. The column headers for the table are explained below.

## Table 1. Sampling Information and Descriptions

- **Location Number—**All sample numbers begin with the KS08- prefix and are followed with a numeric sample identifier. This number represents a single collected sample prior to being separated into its different "types." See the Sample Number heading below.
- **Original Sample Number—**Either a "T" or an "S" follows the location number, differentiating between a tephra (solid) or spatter (liquid or pasty) sample. Original sample numbers are listed here to prevent any confusion resulting from sample distribution during the early stages of the eruption, but these sample numbers are no longer used as of May 24, 2008.
- **Location—**The general location where the sample was collected. If collected from a tear catcher, the tear catcher is specified. Refer to figure 8 for a location map of the tear catchers.
- **Latitude/Longitude—**The latitude and longitude in WGS84, measured using a hand-held GPS instrument (error ~3-5 m), at the sample location. The GPS locations are

exact (within error) for most of the samples, but represent a general area in some cases. Some of the samples were collected by walking a specific area and collecting ejecta from the ground. Only one GPS point was assigned to each of those areas. If the sample from two or more tear catchers was mixed, only one GPS point was assigned to that sample.

- **Date Collected—**The date of sample collection.
- **Time Collected—**The time of sample collection, Hawaiʻi standard time (24-hour clock).
- **Deposited Time/Time Interval—**The time or time span during which the sample was erupted.
- **Sample Number—**The location number, with a letter designation for each lithologic type within the sample suite. Each sample is categorized as one of 10 lithologies ejected from the vent—types A, B, C, D, E, H, I, M, Y, and Z [see Kīlauea Summit Sample Descriptions].
- **Sample Weight—**Weight in grams of bulk sample on hand at HVO.
- **Sample Description and Sampling Notes—**The description of the letter designation given to each lithologic group within the individual sample. A detailed sample description from field and laboratory observations, specific notes about sampling techniques, and any other pertinent sample information are also included.

## Acknowledgments

We would like to thank Hawai‘i Volcanoes National Park for giving us full access to all closed areas for observations and sample collection.

HVO staff scientist Don Swanson spent numerous early mornings collecting samples, while conducting his research on the eruption, and also provided a technical review of the report. Larry Mastin (CVO staff scientist) and Jim Kauahikaua (HVO scientist-in-charge) also provided technical reviews to help clarify the report. Jane Takahashi (HVO) edited this report.