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Geologic Map of the Central-Southeast Flank of Mauna Loa Volcano, Island of Hawai‘i, Hawaii

By Frank A. Trusdell and John P. Lockwood

Pamphlet to accompany
Scientific Investigations Map 2932–B

Central-southeast flank of Mauna Loa volcano, Island of Hawai‘i, Hawaii. Photograph by Frank A. Trusdell, U.S. Geological Survey.

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Geologic Map of the Central-Southeast Flank of Mauna Loa Volcano, Island of Hawai‘i, Hawaii

By Frank A. Trusdell and John P. Lockwood

Mauna Loa

Mauna Loa, the largest volcano on Earth, has erupted 33 times since written descriptions became available in 1832. Some eruptions began with only brief seismic unrest, while others followed several months to a year of increased seismicity. Once underway, its eruptions can produce lava flows that may reach the sea in less than 24 hrs, severing roads and utilities. For example, lava flows erupted from the Southwest Rift Zone (SWRZ) in 1950 advanced at an average rate of 9.3 km/hr; all three lobes reached the ocean within approximately 24 hr (Finch and Macdonald, 1953). Near the eruptive vents, the flows must have traveled even faster. In terms of eruption frequency, pre-eruption warning, and rapid flow emplacement, Mauna Loa has great volcanic-hazard potential for the Island of Hawai‘i. Volcanic hazards on Mauna Loa may be anticipated, and risk substantially mitigated, by documenting the past activity to refine our knowledge of the hazards and by alerting the public and local government officials of our findings and their implications for hazards assessments and risk.

Mapping Project

The Mauna Loa project is generating detailed geologic maps and associated digital databases for the subaerial volcanic rocks of Mauna Loa (fig. 1). The temporal and spatial records of eruptive activity, traceable to approximately 30,000 yr B.P., provides a geologic framework for evaluating eruptive processes at large basaltic shield volcanoes and determining the long-term frequency and style of Mauna Loa eruptions. This framework can then be used as a guide for volcanic-hazard appraisals and land-use decisions (Trusdell, 1995).

The subaerial volcanic geology of Mauna Loa (fig. 1) is being mapped and digitally compiled on five maps at 1:50,000 scale, to show the extent of surface flows. Approximately 500 flows have been identified and their attributes compiled in a large database. This temporal and spatial record of eruptive activity for the last 30,000 years provides a geologic framework to interpret the long-term frequency and style of Mauna Loa eruptions. These data permit quantitative analysis of the distribution of eruptive products through time and improve evaluation of volcanic risk (Trusdell, 1995).

Central-Southeast Flank Mauna Loa

The map of the central-southeast flank of Mauna Loa shows the distribution and relations of volcanic and surficial sedimentary deposits. It incorporates previously reported work published in generalized small-scale maps (Lockwood and Lipman, 1987; Lockwood, 1995; Wolfe and Morris, 1996a).

Mapping Methods

Geological mapping was done by using vertical aerial photos taken in 1977 and 1978. Extensive fieldwork required walking the contacts to distinguish individual flow units and intraflow boundaries, including gradational morphologic transitions between pāhoehoe and ‘a‘ā flows. Where the terrain and jungle obscured contacts, we created a grid pattern of transects. The ensuing contacts were extrapolated between transects from aerial photo interpretation and from geological and botanical inferences. Details from aerial photos were transferred to a 1:24,000-scale base, using a photogrammetric stereoplotter (Kern model PG-2), scanned, and digitized with ArcInfo software to create the digital database.

Reliably correlating discontinuous exposures through heavily vegetated areas is a major challenge on a volcano that consists entirely of compositionally similar basalt. Criteria for correlation include phenocryst size, morphology, and proportion; groundmass texture; vesicle shape; vesicle linings (magnesioferrite); flow morphology; paleomagnetic pole directions; rock chemistry; and varied evidence on relative and absolute ages. Paleomagnetic poles are an indispensable tool for making correlations between flows over large distances and, especially, through dense jungle. Individual flows typically change from pāhoehoe near the vent to ‘a‘ā downslope, especially for high-discharge eruptions; low-discharge eruptions may result in the distal emplacement of pāhoehoe through efficient lava-tube systems.

The pre-1868 lava flows and tephra deposits are divided into 15 age groups by several methods. The map is largely chronostratigraphic. About half the flows were dated directly (102 radiocarbon ages), using carbonized organic material recovered from beneath flows (Lockwood and Lipman, 1980). For undated flows, relative ages are assigned on the basis of rock and mineral weathering or alteration, soil and tephra accumulation, vegetative cover, and stratigraphic relations with

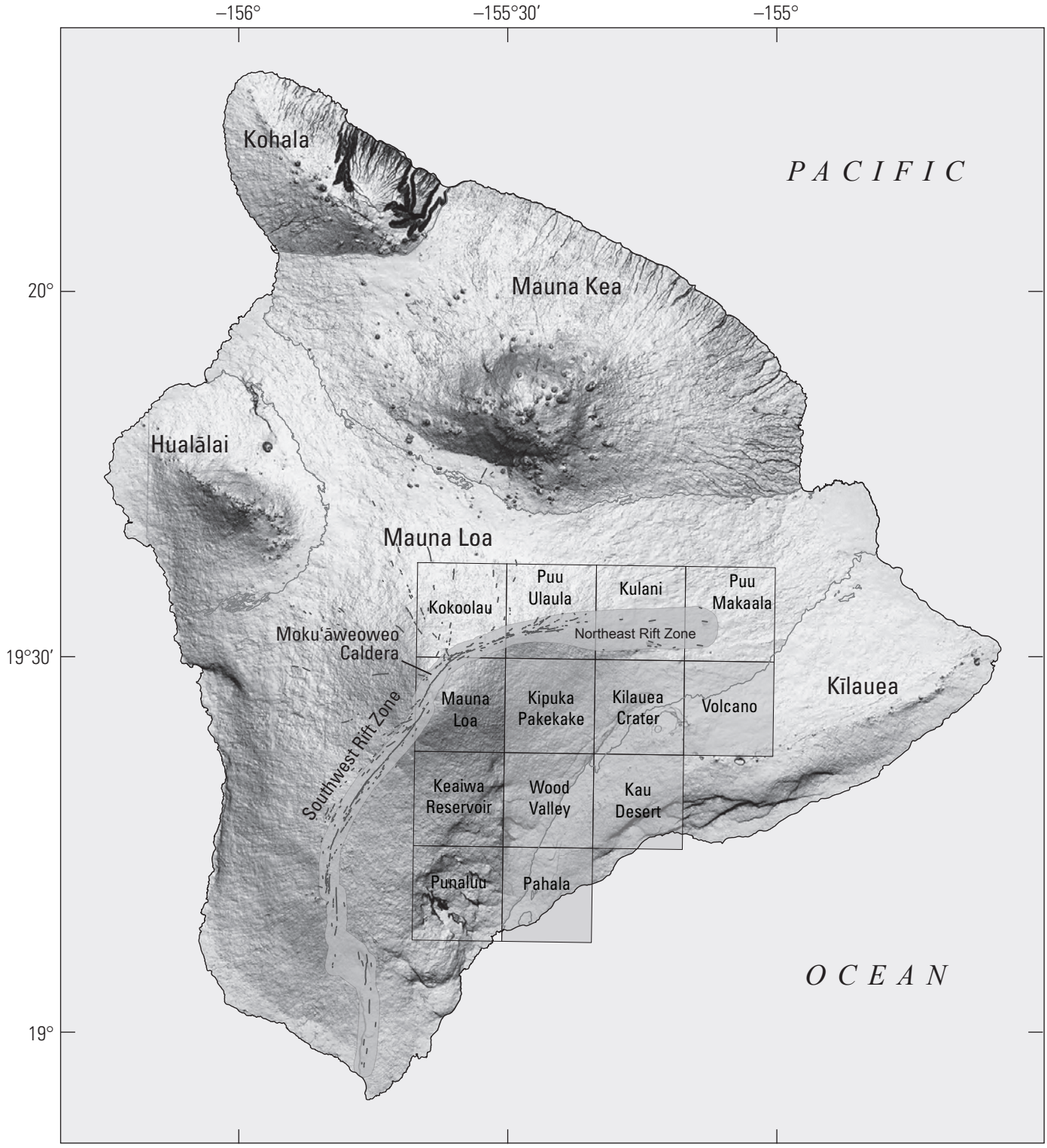

Figure 1. Map showing five subaerial volcanoes forming Island of Hawai'i, structures on Mauna Loa, and 7.5-minute topographic quadrangles in (shaded) and adjacent to map area.

adjoining dated flows. Surface color is an indirect indicator of age (Lipman, 1980, table 1). Young lava flows are initially black. As the rock is exposed to direct sunlight and becomes increasingly weathered, its color changes from black to dull black, then progresses to gray, brown, tan, orange, and, finally, reddish hues. The longer rock is weathered, the greater the color progression. Lipman and Swenson (1984) used this color scheme effectively to tentatively classify the ages of eruptive units within limited areas. The utility of this technique is influenced by elevation, rainfall, and shielding by forest and tephra cover. Soil and tephra accumulation are also an indirect indicator of age. The thickness of tephra also varies with proximity to the contributing source(s).

Database

The digital database contains all information in the printed publication at 1:50,000 scale, but it is accurate to 1:24,000 scale. A unique three-digit flow identification number (FID; for example, FID 831) is assigned to each flow unit mapped on Mauna Loa. The FIDs are unique descriptors in the database and are included in the Description of Map Units, as well as in the Correlation of Map Units. The database contains information on flow morphology, approximate age, exact age, mineralogy, data quality, unit names, rock chemistry, and any existing overburden type. Access the database for this map at https://doi.org/10.3133/sim2932B.

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Geology

Central-Southeast Flank Mauna Loa

Although most Mauna Loa eruptions begin in the summit area at the 12,000-ft elevation (Lockwood and Lipman, 1987), the central-southeast flank has not been the source of any activity. All flows originated from the summit or the upper reaches of the Northeast Rift Zone (NERZ) or the Southwest Rift Zone (SWRZ), shown in figure 1. The NERZ was the source of eight flank eruptions since 1843. The NERZ extends from the 13,680-ft-high summit towards Hilo (population ~43,000; second-largest city in State of Hawaii). The northern portion of the map area is built entirely on flows erupted from the NERZ. The SWRZ extends from the summit towards Kalae (South Point) at sea level. The southern portion of the map area is built entirely on flows erupted from the SWRZ.

The map area extends from the 10,350-ft elevation high on Mauna Loa's east flank toward the Hawaii Volcanoes National Park and the town of Volcano (population ~2,500) in the northeast. At the south boundary of the map area is the town of Pāhala (population ~1,350). This map includes areas adjacent to and downslope of the NERZ and regions east of and directly downslope of Moku'āweoweo, Mauna Loa's summit caldera (fig. 1).

In general, the northern part of the map, about 40 percent of the map area, is dominated by flows from the middle and upper reaches of the NERZ. The southern part contains flows from the upper reaches of the SWRZ (~2% of the map area); flows are generally narrow flow lobes.

One of the most significant findings, based on detailed geologic mapping and dating of lava flows, is that vast sheets of pāhoehoe originated from the summit of the volcano. The sustained summit activity, which lasted for about 900 years, occurred between A.D. 100 and 1,000. Flows from this period blanketed the southeast flank and reached the sea near Punalu'u.

Both morphologic flow types, 'a'ā and pāhoehoe, can be found. The center of the map, approximately 58 percent of the map area, contains flows from the summit of Mauna Loa. In contrast to the rift zones, the flows derived from the summit caldera form voluminous, broad, expansive sheets of pāhoehoe that cover large areas. 'A'ā occurs in this area but is inconsequential when compared to the pāhoehoe.

The geologic mapping and the radiocarbon ages indicate that there was a period of sustained summit activity from about 2,000 to 1,300 yr B.P. Lava flows of this age cover more than 75 percent of the area directly downslope from the summit. There are a few kīpuka of older flows, but they are limited in number and extent.

Volcanic Deposits

Flows

The map encompasses 506 km^2 of the southeast flank (fig. 1) of Mauna Loa from 10,350-ft elevation to sea level. It shows the distribution of eruptive units separated into 15 age groups ranging from a period greater than 50,000 yr B.P. to A.D. 1984.

Pāhoehoe, which covers more than 60% of the map area, is characterized by bulbous, smooth, and ropy surfaces, and the general topography can be described as hummocky. Lava tubes are common features in pāhoehoe flows. Most 'a'ā flows also start as pāhoehoe flow types near the vents and transition to 'a'ā downslope.

'A'ā flows are generally thicker and form broader units than pāhoehoe flows. 'A'ā flows are characterized by rubbly and (or) clinkery surfaces with a rough texture; they are typically 3 to 15 m thick.

Effusion rates and slope influence lava morphology. High effusion rates, combined with steep slopes, usually generate 'a'ā. Moderate to low effusion rates typically produce pāhoehoe. Not surprisingly, 'a'ā is abundant in the region, which has the highest effusion rates and some of the steepest slopes of any sector of Mauna Loa (Trusdell, 1995). The relation between high effusion rates and steep slopes has momentous implications for volcanic hazards and flow-advance rates. Historical flows from the SWRZ have reached the sea in a matter of hours to days (see individual eruption narratives in the Age Group 0 section for specific details).

Table 1. Summary statistics of historical (after A.D. 1843) eruptions on the central-southeast flank of Mauna Loa, Island of Hawai'i, Hawaii.

[S, Summit; NE, Northeast Rift Zone; SW, Southwest Rift Zone]

Year	Eruption begins (month/day)	Summit activity (days)	Flank activity (days)	Eruptive area of volcano	Area covered (km^2)	Volume (km^3)	Error in estimate (percent)	Closest reach to Kīlauea (km)
1984	March 25	<1	22	S, NE	48	0.220	±20	17.0
1880	November 5	0	280	NE, SW	51	0.130	±20 to 40	3.5
Total					**99 km^2**	**0.35 km^3**		

Vesicles are present in both pāhoehoe and ʻaʻā flows. In ʻaʻā flows, vesicles are generally fewer in number and volume (<35%), irregularly distributed, commonly deformed and subangular in shape, and larger in size than in pāhoehoe flows. In contrast, vesicles in pāhoehoe flows are smaller, more abundant, and voluminous (40–60%), moderately distributed to well distributed, and spherical to subrounded in form.

Age Groups

The age groups are arbitrary boundaries created by the authors. They are broken down into 1,000-year intervals until the latter age groups. The larger age groups represent time periods greater than 1,000 years. The age groups are defined based on radiocarbon years. Unless the flows are dated, the reliability of age determinations decreases with increasing age.

Age Group 0 (Historical period: A.D. 1843 and younger)

Lava erupted from A.D. 1880 to 1984 covers 1.1 percent of the map area (table 1). Eruptions occurred in 1880–81 and 1984. Soil or ash cover is absent except in forested areas, and surficial glass is common.

A.D. 1984—The 1984 eruption began on March 25 and continued for 22 days. It was Mauna Loa's fifth longest historical NERZ eruption; the erupted volume is 220 x 10^6 m^3 (Lockwood and others, 1985). Much of the lava is ʻaʻā. The vents were distributed along a 15-km segment of the NERZ between 9,350- and 12,400-ft elevation. Most fissures are north of the map area at higher elevations. The main fissure is located at approximately 9,600-ft elevation. The fissure that fed the flow in the map area is located at 11,185-ft elevation. The flows from this eruption came within 17 km of Kīlauea.

A.D. 1880–81—The eruption of 1880–1881 began on May 1, when a small, short-lived eruption at Mauna Loa's summit heralded the beginning of an eruptive sequence that was followed 6 months later by a voluminous flank eruption. This flank eruption would eventually threaten the Hilo area. The flank phase of the eruption began on November 5, 1880. The outbreak was located at the 11,000-ft elevation, about 1.5 km above Puʻuʻulaʻula. High lava fountains fed an ʻaʻā flow that moved swiftly down the north flank (north of the map area). Another branch of ʻaʻā flowed southeast, stopping within 3.5 km of Kīlauea Volcano. By early June, the flow was within 8 km of Hilo, and concern mounted. On June 26, 1881, the flow entered stream channels above Hilo and appeared to accelerate. By August 10, 1881, all forward progress ceased.

Age Group 1 (pre-A.D. 1843–1,000 yr B.P.)

Spatter and flows are typically slightly weathered and have negligible overlying soil or tephra except in forested areas. Surficial black glass is common. Eight flows have radiocarbon ages. All flows of Age Group 1 originate from the NERZ. Eruptions from this period cover approximately 20 percent of the map area.

Age Group 2 (1,000–2,000 yr B.P.)

Spatter and flows typically have some overlying soil or tephra at lower elevations, and any surficial glass shows slight mechanical degradation and color lightening to gray hues. Thirteen of twenty-five flows have radiocarbon ages. Eruptions from this period cover nearly 48.5 percent of the map area.

Age Group 3 (2,000–3,000 yr B.P.)

Spatter and flows are mildly weathered, and surficial glass is locally preserved. Four of ten flows have radiocarbon ages. Eruptions from this period cover 4.7 percent of the map area.

Age Group 4 (3,000–4,000 yr B.P.)

Spatter and flows are moderately weathered, and surficial glass is preserved only in protected places. One of twelve flows has a radiocarbon age. Eruptions from this period cover 2.4 percent of the map area.

Age Group 5 (4,000–5,000 yr B.P.)

Spatter and flows are moderately weathered, surficial glass is rare, and upper surfaces have moderate mechanical degradation. These flows commonly have as much as 0.4 m of overlying soil or ash when in close proximity to Kīlauea Volcano. One flow of eight has a radiocarbon age. Eruptions from this period cover 1.9 percent of the map area.

Age Group 6 (5,000–6,000 yr B.P.)

These rocks are increasingly weathered, surficial glass is gone, and upper surfaces have open vesicle texture. Units are typically covered with 0.2–0.3 m of ash or soil, especially at lower elevations. Eruptions from this period cover much less than 1 percent of the map area.

Age Group 7 (6,000–7,000 yr B.P.; not in map area)

Flows with dates of 6,000–7,000 radiocarbon yr B.P. were not identified within the map area. With so many undated flows, a few could fall into this age category. The absence of dates in this range suggests that eruptive activity may have been limited to the summit (lava lake activity) or the volcano's submarine flanks during this time interval (Lockwood, 1995).

Age Group 8 (7,000–8,000 yr B.P.)

The flows are weathered; upper surfaces have open-vesicle texture and are broken, and orange surfaces occur at higher elevations. Ash has accumulated in low areas. This age group is represented by a single dated flow. Eruptions from this period cover 2.1 percent of the map area.

Age Group 9 (8,000–9,000 yr B.P.)

The flows are deeply weathered, showing red-orange surfaces at higher elevations; mechanical disintegration of upper surfaces is almost complete. Ash has accumulated in low areas. Two of five flows have radiocarbon ages. Eruptions from this period cover 2.7 percent of the map area.

Age Group 10 (9,000–10,000 yr B.P.)

These flows and all older age groups are found only at the southeastern portion of the map area; they have been buried by younger flows closer to eruptive vents. Ash and soil fill low-lying areas; accumulations of as much as 0.5–1 m are common. Surface color approaches red. Three of six flows have radiocarbon ages. Eruptions from this period cover slightly more than 3 percent of the map area.

Age Group 11 (10,000–15,000 yr B.P.)

These flows have few original surfaces left. Upper surfaces are commonly stained red orange, probably due to hydration of glass. In the wet, windward regions, the rock is soft, and hammer impacts often leave a divot. Olivine is altered, yellow, and (or) brown green and looks slightly flaky. Units of this age have 1–3 m of soil or ash cover. Partly altered groundmass is often a dull gray and appears cryptocrystalline. Two of four flows have radiocarbon ages. Eruptions from this period cover 0.5 percent of the map area.

Age Group 12 (15,000–20,000 yr B.P.; not in map area)

Flows with dates of 15,000–20,000 were not identified within the map area. These flows have no original surfaces left. Upper surfaces are commonly stained red orange, probably due to hydration of glass. In the wet, windward regions, the rock is yielding and mushy; hydrated glass turns to clay. Olivine appears flaky and (or) cloudy and mostly altered. Units of this age have 2–4 m of soil and ash cover. Groundmass is altered and lined with alteration products (such as limonite).

Age Group 13 (20,000–30,000 yr B.P.)

These flows are exposed in drainages and include the only surface exposures of Pāhala Ash (unit pa) southeast of Nāʻālehu, at the coast near Kāhilipali Nui, and at the crest of the Kahuku Pali. The flows have no remaining original surfaces. Boundaries between individual flows are blurred. In the wet, windward regions, the rock is mushy; olivine phenocrysts are altered. Four units have radiocarbon ages. Eruptions from this period cover much less than 1 percent of the map area.

Age Group 14 (30,000–100,000 yr B.P.; not in map area)

These flows are exposed in fault scarps, sea cliffs, and drainages around Pāhala. Flows are commonly overlain by as much as 6 m of ash. Flows have lost all original surfaces, and boundaries between individual flows are blurred. In wet, windward regions, the rock is mushy; olivine phenocrysts are mostly altered and generally soft. Eruptions from this period cover less about 0.4 percent of the map area.

Age Group 15 (>100,000 yr B.P.)

Flows with dates of >100,000 yr B.P. were identified within the map area around Wood Valley. These flows are exposed in valley walls. The unit represents the oldest exposed rocks on Mauna Loa. These rocks are commonly overlain by as much as 6 m of ash and have no remaining original surfaces.

Surficial Sedimentary Deposits

Deposits were too small and transient to map. They consist chiefly of colluvial and alluvial deposits of basalt clasts and pebble- to cobble-sized gravel in drainages that occur locally within portions of the map area. We also include under this category unconsolidated sand along the coast.

Volcanic Ash

Pāhala Ash

Pāhala Ash includes beds of fallout and surge deposits that represent accumulation of deposits from numerous eruptions. Deposits include glassy ash and lapilli, now mostly altered to clay, crystals, and lithic fragments. Phenocryst abundance is difficult to estimate, owing to chemical decomposition, but ranges from aphanitic to moderately porphyritic, with as much as 8 percent olivine and fewer plagioclase phenocrysts. It is found chiefly in all quadrangles and in adjacent upslope areas, where it overlies lava flows ranging in age from 31,000 to 2,000 yr B.P.

There are two main subdivisions in this group: southern tephra (unit ts) and Pāhala Ash (unit pa). Southern tephra comprises beds of ashfall deposits in the map area. The source of the ashes is unknown but is considered to be primarily from Kīlauea Volcano, with likely contributions from Mauna Loa (Easton, 1987). All ash deposits ≤10,000 yr B.P. are included in this category and cover nearly 12.8 percent of the map area.

The term “Pāhala Ash,” named for the town Pāhala, was used with reference to ash deposits found along the northeast rift zone of Mauna Loa, northeast Kīlauea Volcano, and south and southwest of Kīlauea’s summit, including the eastern flank

of Mauna Loa. The bulk of the ash is presumed to be from Kīlauea, although Mauna Loa cannot be excluded as a source.

Pāhala Ash was described by Stone (1926), Stearns and Clark (1930), Wentworth (1938), Stearns and Macdonald (1946), Fraser (1960), Walker (1969), and Easton (1987). The term eventually came to be used for ashes from Kohala to Kalae at South Point. According to Easton (1987), Wolfe (verbal commun., 1986) determined that the ash deposits of Kohala, Waimea, Hāmākua, and North Hilo were derived locally and are chemically distinct from ashes near Kīlauea and on the east flank of Mauna Loa.

Wentworth (1938) and Stearns and Macdonald (1946) describe several sections of Pāhala Ash, yet, a type section was not identified. Easton (1987) proposed two well-exposed sections on the south flank of Kīlauea Volcano for the type locality of the Pāhala Ash.

The ash is a mixture of yellow-brown palagonite, rare vitric shards, Pele's hair, pumice, and olivine phenocrysts. It is derived from airfall deposits, weathered and reworked ash, and sediments. The ash is composed of mostly sand and silt-sized fractions. Ancient soil horizons are present in some localities.

The appearance of the ash is greatly influenced by climate. In dry areas, it is friable, in places compact, but it is mostly sandy, loose, and dusty. In higher-rainfall areas, the ash appears clay-like. The ash deposits from Kaʻaluʻalu to Kalae or South Point appear to be loess, reworked and redeposited by wind.

All ashes in the map area that are less than, and equal to, late Pleistocene (<16,000 yr B.P.) are incorporated into unit ts, which identifies a mostly Holocene ash deposit of sufficient thickness to mask the underlying flow(s) or the extent of the flow(s) cannot be mapped with a reasonable degree of certainty. In other places, where we are able to map ash-covered flows, <16,000 yr B.P. in age, with a high degree of certainty (see database for contact certainty), we chose to use a plus pattern. The overlying ashes are grouped with unit ts.

Our mapping demonstrates—and previous investigators noted (Stearns and Macdonald, 1946; Easton, 1987)—that the Pāhala Ash was a catch-all for all ash units from northeast Kīlauea Volcano, across Kīlauea's south flank, extending over Mauna Loa to (at least) Kalae to Kahuku Pali. This included ashes of all ages (0.2–25 ka; Stearns and Macdonald, 1946). The periodicity with respect to Pāhala Ash production was more infrequent than was previously recognized.

We are able to show that there have been at least eight ash events, where lava flows separate the younger ash layers (unit ts). Most of the individual ash horizons have not been studied well enough to be used as marker beds over a wide geographic area. We concur with previous investigators that the most likely source is Kīlauea, although Mauna Loa cannot be excluded as a source.

In order for Pāhala Ash to be recognized as a stratigraphic marker, its horizon needs to be recognizable over a large geographic region. Easton (1987) proposed a more restrictive age range of 25–10 ka for Pāhala Ash. Our preference would be to restrict the Pāhala Ash age even further, to approximately 31–16 ka, and possibly older, thereby providing a constraining period of time within which substantial ash accumulation occurred and is preserved, in places, on the flanks of Mauna Loa. The accumulated ash can then be used as a stratigraphic marker across a wide region. Unfortunately, this means that most type sections can only be found in drainages, arroyos, sea cliffs, and on top of Nīnole Hills above Punaluʻu.

Radiocarbon Data

Radiocarbon is obtained from under flow margins and usually dates the surface flow. This map includes some ages obtained from a vertical section (for example from a waterfall). Flows that are dated, in sections, from charcoal are represented by a solid black square on the map. In a few instances, we were able to obtain charcoal under the surface unit, but not at the contact between adjacent flows. The symbol is found inboard of the contact. In a few of these cases, heavy equipment broke through the flow (at a quarry), and we retrieved charcoal. In other instances, we obtained charcoal from arroyos, and the underlying outcrops were less than 5 m^2. Due to the limited exposure, we were not able to adequately characterize these units, and the map units were tiny; we do not show these units.

Table 2 reports 102 radiocarbon ages from 46 lava flows (Kelley, 1979; Kelley and others, 1979; Rubin and others, 1987; Buchanan-Banks and others, 1989; Buchanan-Banks, 1993; this study). Many are conventional ages determined at the U.S. Geological Survey (USGS) laboratory in Reston, Virginia. Thirty-six Accelerator Mass Spectrometer (AMS) ages were analyzed by USGS and other laboratories. For eruptive units at more locations, each age is weighted by the inverse of its variance to yield a mean age (Taylor, 1982).

All ages were calibrated to calendar years, using the CALIB 6.0 Radiocarbon Calibration Program (Stuiver and others, 2005). The calibrated age ranges in table 2 encompass the calendar years possible for a given radiocarbon age at two standard deviations; however, all ages shown on the map are radiocarbon yr B.P. Symbols in table 2 indicate reliability of age for stratigraphic interpretations. Rejected ages are reported in the appendix.

Fault Systems

The system of normal faults, which occurs on the southeast flank of the volcano, are the Kaʻōiki-Honuʻapo Fault System. Faults shown on the map were adapted from Wolfe and Morris (1996a). All faults within the map area are inactive and are draped by unfaulted, younger flows as old as 9,500 yr B.P. The concealed fault scarps are as much as 100 m high and traceable for as much as 10 km in an east-northeast direction.

In addition to the concealed faults on the southeast flank, there is a historically active tectonic zone. This area, known as the Kaʻōiki Fault Zone, is in the epicentral region for some recent large tectonic earthquakes. The Kaʻōiki Fault Zone has been active as recently as 1983 and prior to that in 1974 and 1962. In 1983, there was a 6.6 M_L earthquake on the southeast flank of Mauna Loa and there was discernible movement along this fault system. Ground rupturing took place, and displacements measured as large as 1.5 m in 1983 and as large as 0.5 m in 1974. Unlike the concealed faults of the Kaʻōiki-Honuʻapo Fault

System, which are buried normal faults, ground breakage in the Kaʻōiki Fault Zone is characterized by recent, left-stepping, en echelon ground cracks created by strike-slip motion along a fault system that strikes N. 40–50° E. (Jackson and others, 1992).

In the Wood Valley quadrangle, there are two graben that extend upslope. One graben cuts units p2e11 and p3e4; the second is found entirely within unit p3e4. Faults shown in the map area are adopted from Wolfe and Morris (1996a).

DESCRIPTION OF MAP UNITS

[Small areas on the printed or plotted map are not labeled, to avoid obscuring data; use unit color or the database (https://doi.org/10.3133/sim2932B) for unit identification. The simplified map unit label is not unique and provides quick access to flow morphology, flow age group, phenocryst mineralogy, and flow number in an age group (table 3, sheet 1); this non-unique unit label may be used for an entirely different unit on a different flank of Mauna Loa. We use the term "phenocryst" for any mineral ≥1 mm in maximum diameter. Pyroxene is not an abundant phenocryst in Mauna Loa lava flows and, therefore, it is not included in phenocryst mineralogy. Multiple labels for a unit are listed with the most abundant lithology first. In addition to the map unit label, a unique, three-digit, flow identification number (FID; for example, FID 831) is assigned to each mapped flow unit to facilitate use of the database; therefore, the FID is essential as a unique descriptor for unit identification in the database. No Age Group 7, 12, or 14 units were identified in the map area]

SEDIMENTARY DEPOSITS

mf **Mudflow deposits of A.D. 1868 (Holocene)**—In A.D. 1868, a large destructive earthquake caused a landslide in the back of Wood Valley and south of Ipuʻu Ridge. Rock lubricated by wet ash tumbled down from the hillside. Stearns and Macdonald (1946) originally mapped the mudflow, which we have included on our map. The original extent of the mudflow is no longer evident, because sugar cane companies spread out the deposits to enhance productivity

ls **Landslide deposits (Holocene)**—Landslides of unknown age, including some of the 1868 mudflow, are shown on the map in the region of Wood Valley. In recent mapping, we were only confident of landslide deposits at the foot of the valley walls and short distances downslope. The bulk of the deposits were spread out by sugar cane companies as media to grow cane

VOLCANIC DEPOSITS

LAVA FLOWS AND VENT DEPOSITS

Kaʻū Basalt

The Kaʻū Basalt includes historic and prehistoric members. The prehistoric units range in age from pre-A.D. 1843 to 30,000 yr B.P. The Kaʻū Basalt consists of tholeiitic basalt, vent deposits, and lava flows. The flows are mostly aphanitic and some have variable amounts of olivine and plagioclase phenocrysts. Pyroxene is rare in hand specimen. All but one of the map units are members of the Kaʻū Basalt.

Age Group 0 (A.D. 1843 and younger; Holocene)

a0a1 **A.D. 1984 flow**—Aphanitic ʻaʻā, with <1% olivine phenocrysts 1–2 mm in size. Vents were distributed along 15-km segment of NERZ between 9,350- and 12,400-ft elev. Most fissures are north and west of map area some at higher elevations. A flow from this eruption enters the north margin of the map area. The eruptive fissure that fed this flow is located at the 11,185-ft elev. FID 783

a0b2 **A.D. 1880–81 flow**—Flow is fresh and glassy, with 1–3% clear olivine phenocrysts and abundant, inconspicuous plagioclase microphenocrysts. An ʻaʻā flow enters from the north edge of the map and extends ~13 km in a southeasterly direction diagonally across the map. FID 787

Age Group 1 (pre-A.D. 1843–1,000 yr B.P.; Holocene)

a1g1 **Keʻāmuku Kīpukakēkake flow**—Dense, fine-grained, ʻaʻā in Kilauea Crater, Kau Desert, and Kipuka Pakekake quadrangles. Groundmass is sparkly, dark, and feldspathic. Small olivine phenocrysts (<1%) are widely scattered; 1–2% plagioclase is present as fine laths. Age, 288±36 radiocarbon yr B.P. FID 800

p1k2, a1k2, m1k2 **Kīpukamauna‘iu flow**—Pāhoehoe and ‘a‘ā, in contact with the lava flow of A.D. 1880, in Kipuka Pakekake quadrangle. Contains dense, well-crystallized, feldspathic groundmass. Surface is medium gray to black. Flow tops, locally glassy, are mostly weathered; surface glass is broken up. Flow contains 0–1% small olivine phenocrysts and 1–8% anhedral laths and clots of plagioclase, commonly intergrown with olivine. Vesicles are subrounded, commonly distorted, and may be lined with magnesioferrite. Age, 311±25 radiocarbon yr B.P. FID 801

p1a3, a1a3 m1a3 **Ke A Po‘omoku Lava Flow**—Massive pāhoehoe and ‘a‘ā that flooded Mauna Loa’s flank northeast of the caldera and southeast of the rift zone in northwestern Kipuka Pakekake quadrangle. Eruptive fissures of this eruption extend into the NERZ and are found outside of the map area to the northwest. Contains <1% olivine phenocrysts in medium-gray, fine-grained feldspathic groundmass. Age, 475±41 radiocarbon yr B.P. FID 274

p1g4 **Ke‘āmuku Kīpukakulalio flow**—Dense, dark-gray, nearly aphanitic pāhoehoe in northeastern Kipuka Pakekake and northwestern Kilauea Crater quadrangles. Flow contains <1%, widely scattered olivine phenocrysts and 2% plagioclase phenocrysts. Age, 569±53 radiocarbon yr B.P. FID 802

a1k5, m1k5, p1k5 **Ke‘āmuku Kīpukakulalio east flow**—Tube-fed pāhoehoe with some ‘a‘ā, in Kipuka Pakekake quadrangle. Glass is fresh where protected from mechanical weathering. Contains 2–6% olivine phenocrysts and from 5–10% plagioclase as laths, clumps, and intergrowths with olivine. Vesicles are mostly rounded and coated with magnesioferrite. Tree molds are exposed along Pu‘u‘ō‘ō Volcano Trail where not covered by ash. Abundant charcoal samples can be found where this unit overlies a5b7 (FID 870). Age, 575±38 radiocarbon yr B.P. FID 799

p1l6, a1l6 **Keauhou Ranch flow**—Large tube-fed pāhoehoe with minor ‘a‘ā north of Kīpukapuaulu, on Keauhou Ranch in central Kilauea Crater quadrangle. The 6–20% olivine forms phenocrysts and microphenocrysts; 4–6% plagioclase mostly microphenocrysts and groundmass. Age, 760±70 radiocarbon yr B.P. FID 833

a1b7, p1b7 **Flow northeast of A.D. 1880 lobe**—Mixed ‘a‘ā and pāhoehoe flows in northeastern Kipuka Pakekake quadrangle. Contains 4% inconspicuous round olivine phenocrysts. Age, 780±70 radiocarbon yr B.P. FID 840

p1e8, a1e8 **Pu‘uwahi picrite flow**—Dense picrite in northeastern Kipuka Pakekake and central Kilauea Crater quadrangles. Pāhoehoe and ‘a‘ā with a medium-gray groundmass, containing 10–20% clear, fresh olivine phenocrysts as much as 6 mm across. Weathered surfaces are orange brown, with protruding olivine minerals. Age, 955±24 radiocarbon yr B.P. FID 837

a1i9, p1i9 **Ke‘āmuku Kīpukakulalio west flow**—Both ‘a‘ā and pāhoehoe in northwestern Kilauea Crater quadrangle. Flow contains 3–8% subhedral, sugary olivine phenocrysts and 0–2% plagioclase phenocrysts. Vesicles are subrounded to elongate and may be magnesioferrite lined. FID 838

Age Group 2 (1,000–2,000 yr B.P.; Holocene)

a2g1 **Flow 300**—‘A‘ā flow in northwest quadrant of Kipuka Pakekake quadrangle. Flow contains 1–2% olivine microphenocrysts and abundant groundmass plagioclase to 2% as phenocrysts. The groundmass is dark gray and dense, with abundant plagioclase microlites. Unit overlies p2i3 (FID 298). FID 300

p2b2 **West Wood Valley flow**—Flow that forms floor of western side of Wood Valley. A spongy tube-fed pāhoehoe has 0–5% olivine phenocrysts in light-gray diktytaxitic groundmass. Flow is covered by variable amounts of soil ash that can be as thick as 1.5 m. Primary surfaces with black glass common; glass usually found in protected spots on surface and commonplace on base. Age, 1,281±66 radiocarbon yr B.P. Unit overlies p2b23 and p2b24 (FIDs 292 and 294). FID 293

p2i3, a2i3, m2i3 **Pahuamimi flow**—Major unit from summit region of Mauna Loa. Flow traverses Kipuka Pakekake from northwest to southeast in central and northeastern portions of the quadrangle. Flow is most common as tube-fed pāhoehoe. Tumuli are common, as are areas containing slabby pāhoehoe and fluid ‘a‘ā. Contains 5% plagioclase as blades and commonly intergrown with olivine. Unit contains 2% olivine phenocrysts and microphenocrysts. Age, 1,293±27 radiocarbon yr B.P. Unit overlies a2k13 (FID 347). FID 298

p2a4, a2a4 **Keakapulu Flat flow**—Young-looking tube-fed pāhoehoe unit in north-central Wood Valley and southwestern Kipuka Pakekake quadrangles. Unit has 3–8% inconspicuous olivine microphenocrysts. Due to their small size, the olivine could be easily overlooked. The groundmass is well crystallized and feldspathic with obvious plagioclase microlites. Unit is covered with as much as 30 cm of ash. Age, 1,428±38 radiocarbon yr B.P. FID 297

p2i5, a2i5 **Kapāpala flow**—Tube-fed pāhoehoe in central Wood Valley unit originated from summit. Flow contains 3–8% olivine phenocrysts and differs from its neighbors in that it has 2–3%

plagioclase. Upper surfaces usually orange stained and may be topped by a 6–8 mm glassy rind. Flow is characterized by hummocky terrain. Flow is often overlain by 10–50 cm of ash. Age, 1,469±32 radiocarbon yr B.P. FID 344

p2c6 **Kilohana flow**—Tube-fed pāhoehoe found in central Wood Valley quadrangle. This flow is distinctive in that the olivine has two habits: laths and equant phenocrysts. Flow contains 5–15% olivine phenocrysts and microphenocrysts. The groundmass is well crystallized and feldspathic. Flow has little to no ash cover. Age, 1,507±24 radiocarbon yr B.P. Unit overlies p2c25 (FID 340). FID 301

p2f7 **Waimuku flow**—Large tube-fed pāhoehoe in Wood Valley and Pahala quadrangles. This unit is distinctive in that the flow contains olivine with two habits: equant phenocrysts and laths. Flow has variable amounts of olivine, at 3–20%; flow tops are black and glassy. The groundmass is light gray, well crystallized, microcrystalline. Flow is covered by 10–50 cm of ash in places. Age, 1,511±24 radiocarbon yr B.P. Unit is overlain by p2b2 (FID 293). In addition, it overlies p2f9, p2b10, and p2b15 (FIDs 288, 290, and 336). FID 289

p2e8, a2e8, m2e8 **Pu‘u‘ele‘ele flow**—Expansive pāhoehoe flow field with minor ‘a‘ā and ash mantle, found in southwestern Kipuka Pakekake and northeastern Wood Valley quadrangles. Flow is distinctive in that olivines protrude through the glassy surface giving the flow a knobby appearance. Flow contains ~20% olivine and as much as 5% plagioclase. The olivines range in size from 4–8 mm and are clear and sugary. Subhedral plagioclase occurs as anhedral phenocrysts and microphenocrysts to 2 mm and is commonly intergrown with olivine. Vesicles are subrounded and magnesioferrite lined. Age, 1,530±37 radiocarbon yr B.P. FID 346

p2f9 **Ka‘ala‘ala Gulch flow**—Large tube-fed pāhoehoe in western Wood Valley and Ka‘ala‘ala Gulch. This extensive pāhoehoe is one of many similar flows of summit origin in this region. The unit contains 2–8% olivine phenocrysts and microphenocrysts in a diktytaxitic groundmass. The flow is covered by 10–50 cm of ash in places. Age, 1,574±25 radiocarbon yr B.P. FID 288

p2b10 **Kapāpala Ranch flow**—Tube-fed pāhoehoe, in Wood Valley quadrangle, contains 1–5% olivine. Also, found at the site of Kapāpala Ranch headquarters. Flow is covered with a veneer of ash as thick as 0.5 m. In low slope areas, tumuli and hummocky terrain dominate flow character. Flow tops orange stained with original flow surfaces common. Black vitreous glass only preserved in folds and creases on upper surfaces and glass is common on flow bottom. Age, 1,622±23 radiocarbon yr B.P. FID 290

a2k11, p2k11 **Upper Waiākea flow**—Mixed pāhoehoe and ‘a‘ā flows along the north edge, and in the center of, Kilauea Crater quadrangle. Contains 0–2% olivine phenocrysts, commonly as intergrowths with plagioclase, and 5–12% very fine plagioclase as laths and blebs. Vesicles are subrounded, elongate, and commonly magnesioferrite lined. ‘A‘ā is crumbly and weathered to a yellow orange. The flow is covered with a thin to thick layer of soil and ash; consequently, outcrops range from abundant to rare. This eruption sent flows over both sides of the rift zone, though the bulk of the lava flowed to the northeast. Age, 1,638±32 radiocarbon yr B.P. FID 864

a2a12, p2a12 **Flow 841**—Aphanitic ‘a‘ā, with minor pāhoehoe, found in the central portion of Kipuka Pakekake quadrangle. The ‘a‘ā is dense, fine-grained, and feldspathic. Flow is covered by deep soil. Unit overlies p2e14 (FID 343). FID 841

a2k13, p2k13 **Nāpu‘ukūlua Lava Flow**—‘A‘ā flow 10–12 m thick with distinctive mineralogy found in northwest quadrant of Kipuka Pakekake quadrangle. Contains 6–8% plagioclase laths and ~1% olivine phenocrysts in a dense medium-gray groundmass. Surface color is chocolate brown; minor yellow ash deposited in low areas. Unit overlies p2e14 (FID 343). FID 347

p2e14, a2e14 **Kauhiuhi flow**—Major tube-fed olivine-rich pāhoehoe at junction of Kilauea, Kipuka Pakekake, and Wood Valley quadrangles. This distinctive olivine-rich pāhoehoe has ~20–25% clear green phenocrysts in a dull gray cryptocrystalline groundmass. The upper flow surface appears to be knobby or warty owing to olivine protruding through the surface glass. The basaltic glass is common but mostly eroded away. Age, 1,640±150 radiocarbon yr B.P. Unit is overlain by a2a12 and a2k13 (FIDs 841, 347). FID 343

p2b15 **East Wood Valley flow**—Tube-fed pāhoehoe flow, which traverses the eastern portion of Wood Valley. Flow contains 1–3% olivine phenocrysts in a light-gray, well-crystallized plagioclase microlite-rich groundmass. Covered with variable amounts of ash, 0–1.5 m thick. Age, 1,708±50 radiocarbon yr B.P. Unit is overlain by p2b2 and p2f7 (FIDs 293, 289). FID 336

p2b16 **Moa‘ula flow**—Young-looking spongy pāhoehoe flow between Hi‘onamoa and Moa‘ula Gulches in Pahala quadrangle. Flow originates from the Southwest Rift Zone of Mauna Loa. The pāhoehoe has 0–2% olivine in a well-crystallized groundmass. The flow tops are black and glassy. Flow overlain by ash in low-lying areas. Age, 1,824±19 radiocarbon yr B.P. FID 540

p2j17, a2j17 **Flow 350**—Pāhoehoe in the northwest corner of Kipuka Pakekake quadrangle. Variable olivine mineralogy ~8–20%, subhedral, blades and phenocrysts. Olivines are dull, light green in color, inconspicuous, and range in size from 0.5–2.5 mm. Anhedral clots of plagioclase and olivine are common at 2–3%. The groundmass is medium gray and feldspathic. The surface color is tan gray; ash cover is thin at 0–0.14 m and concentrated in low-lying areas. Unit overlies a2a18 (FID 349). FID 350

a2a18, p2a18, m2a18 **Kauhiuhi Maluikeao flow**—Aphyric pāhoehoe with <1% fine olivine phenocrysts in a diktytaxitic, vesicular groundmass. Groundmass is bluish gray, dense, and occasionally feldspathic. Upper surfaces in places weathered to yellow orange; otherwise, color is tan gray. Flow is found in northwest corner of Kipuka Pakekake quadrangle. Age, 1,910±120 radiocarbon yr B.P. Unit is overlain by p2j17 (FID 350). FID 349

a2a19, p2a19 **Flow 989**—Aphanitic flow located in center of adjoining boundaries of Kilauea Crater and Kipuka Pakekake quadrangles. This pāhoehoe has a well-crystallized groundmass that contains plagioclase microlites. Flow is blanketed by ~20 cm of ash. Surface color is orange gray and original primary surface is almost nonexistent. Unit overlies p2k20 (FID 893). FID 989

a2k20, p2k20 **Kīpukalō‘ihi flow**—Blocky ‘a‘ā kīpuka east and southwest of A.D. 1880. Distal end of flow is 20–25 m thick near the boundaries of Kilauea Crater and Kipuka Pakekake quadrangles. Flow contains 4–10% plagioclase phenocrysts and 1–3% olivine phenocrysts in a medium-gray groundmass. Olivine commonly intergrown with plagioclase. Flow covered by a minor amount of ash. Unit overlies p2g22 (FID 883). FID 893

a2k21, p2k21 **Flow 900**—‘A‘ā flow along the west border of Kilauea Crater quadrangle. Flow contains 5% plagioclase laths as glomerocrysts and 2% olivine phenocrysts intergrown with plagioclase. The flow exhibits pāhoehoe-like character in places, with slabby plates and toothpaste-like morphologies. Unit overlies p2g22 (FID 883). FID 900

p2g22, a2g22 **Upper Strip Road flow**—Extensive pāhoehoe and related tube system, characterized by bulbous toes, south of Nāpu‘ukūlua in northwestern Kipuka Pakekake and Kilauea Crater quadrangles. Contains <1% olivine phenocrysts and ~2% plagioclase as microphenocrysts and phenocrysts. Vesicles are spherical to subrounded. Age, 1,993±43 radiocarbon yr B.P. Unit is overlain by a2k20 and a2k21 (FIDs 893, 900). FID 883

p2b23 **Pi‘ikea flow**—Pāhoehoe flows that form southwest valley floor and ridge of Wood Valley. Flow comprises multiply bedded pāhoehoe units containing 1–5% inconspicuous olivine phenocrysts in a light-gray microcrystalline groundmass. Unit is overlain by p2b2 (FID 293). FID 292

p2b24 **Keaīwa Gulch flow**—Another tube-fed pāhoehoe found along Ka‘ala‘ala Gulch in Wood Valley quadrangle. Flow contains 1–5% olivine phenocrysts and 0–1% plagioclase in a microcrystalline, gray, feldspathic groundmass. Flow is covered by 0.5–1.5 m of ash. Unit is overlain by p2b2 (FID 293). FID 294

p2c25 **Flow 340**—Pāhoehoe near highway along Pāhala-Volcano road in Wood Valley quadrangle. Pāhoehoe contains 5–7% olivine phenocrysts in a light-gray microcrystalline groundmass. Flow surface is orange-stained glassy top. The flow is covered by 0.2–1 m of ash. Unit is surrounded by p2c6 (FID 301) at the Kīlauea Volcano contact. FID 340

Age Group 3 (2,000–3,000 yr B.P.; Holocene)

a3a1 **Red Cone flow**—‘A‘ā flow of Keaīwa Gulch with 0–1% olivine phenocrysts in a well-crystallized feldspathic groundmass. Prominent flow, north and east of Pāhala town, planted in eucalyptus and macadamia. Unit is locally mantled by ash and is overlain by pāhoehoe flows of Wood Valley (p2f7, FID 289; p2f9, FID 288). Age, 2,072±37 radiocarbon yr B.P. FID 295

a3a2, p3a2 **Eastern Ka‘ōiki Pali flow**—Aphanitic ‘a‘ā and minor pāhoehoe found on Keauhou Ranch in Kilauea Crater quadrangle. Rock is distinctive in that the groundmass is well crystallized and feldspathic, full of plagioclase microlites. Age, 2,265±49 radiocarbon yr B.P. FID 889

a3i3 **Nīnole flow**—Massive ‘a‘ā flow at south edge of Pahala quadrangle. Flow forms the northeast edge of Punalu‘u Beach. An aphyric ‘a‘ā has 0–1% each of olivine and plagioclase phenocrysts. The groundmass is dense, finely crystalline, and feldspathic. Flow has little to no ash cover. Age, 2,365±30 radiocarbon yr B.P. FID 637

p3e4, m3e4, a3e4 **Cow Pasture picrite flow**—Pāhoehoe, mostly in north-central Kipuka Pakekake, outliers in northern Wood Valley quadrangle. Flow has a weathered red-orange rind. Rock contains 15–20% olivine phenocrysts, microphenocrysts. The groundmass is mildly feldspathic. Ash as thick as 0.5 m overlies this unit. Age, 2,826±32 radiocarbon yr B.P. FID 345

a3l5, p3l5 **Flow 891**—‘A‘ā found just southwest of the A.D. 1880 flow. A very distinctive rock that has glomerocrysts of plagioclase and olivine. Contains 9% plagioclase and 6% olivine phenocrysts. All these minerals are contrasted against a dark-gray groundmass. Surface color of this flow is tan gray. FID 891

a3a6 **Flow 357**—Tiny, composed (~1 acre) of a 5-m-high ‘a‘ā. Rock is dense, and the surface lichen covered. Flow is aphyric with sparse angular vesicles. Unit is found in contact with A.D. 1880 flow on the southwest side in central Kipuka Pakekake quadrangle. FID 357

m3a7 **‘Alili flow**—Mixed ‘a‘ā and pāhoehoe along the west boundary of Pahala quadrangle. Contains 0–1% olivine and 0–1% plagioclase phenocrysts in a light-gray, diktytaxitic groundmass. Flow is blanketed by 0.3–1 m of ash. FID 554

a3i8, p3i8, m3i8 **Flow 884**—Dense, weathered ‘a‘ā and tube-fed pāhoehoe, near the west margin of Kilauea Crater quadrangle. Contains dark-gray groundmass, 2–5% olivine phenocrysts, and 1–2% plagioclase as microphenocrysts and rare phenocrysts. Vesicles are subangular to subrounded and may be magnesioferrite lined. Surface is broken and weathered red. FID 884

p3a9 **Ka‘ala‘ala flow**—Pāhoehoe contains 0–1% olivine in a well-crystallized feldspathic to diktytaxitic groundmass. Found in southwestern Wood Valley quadrangle. Flow is very similar in mineralogy to those surrounding it. The difference being that this unit is buried by 1–3 m of ash and (or) colluvium. FID 291

p3b10 **Flow 296**—Tube-fed pāhoehoe of lower Keaīwa Gulch (northern Pahala quadrangle). Contains 0–3% olivine phenocrysts. The olivines are light green and sugary in appearance and are small and inconspicuous. The groundmass is well crystallized, feldspathic to diktytaxitic in texture. Flow is mantled by ash. FID 296

Age Group 4 (3,000–4,000 yr B.P.; Holocene)

p4a1 **‘Ōhaikea flow**—Pāhoehoe of ‘Ōhaikea (in southwest corner of Kilauea Crater quadrangle). Contains 2–3% plagioclase microphenocrysts. The plagioclases are fine grained, usually <0.5 mm. Rare olivine occasionally found. Unit is covered by 10–50 cm of ash. Age, 3,630±80 radiocarbon yr B.P. FID 892

p4g2, a4g2 **Flow 899**—Kīpuka in the northeast quadrant of Kipuka Pakekake quadrangle in contact with A.D. 1880 flow. Pāhoehoe contains 3–5% plagioclase phenocrysts in a well-crystallized light-gray groundmass. Unit is covered with 0.2–0.5 m of ash. FID 899

p4a3, a4a3 **Flow 401**—Small kīpukas in southwest corner of Kipuka Pakekake quadrangle. Flow is orange-weathered aphanitic pāhoehoe. Contains 0–1% olivine phenocrysts in well-crystallized light-gray groundmass. Unit here is covered with 0–0.5 m of ash in low-lying areas. FID 401

p4k4 **Flow 339**—Distinctive plagioclase pāhoehoe, in central Wood Valley quadrangle. Contains 5–8% plagioclase as anhedral snowflake clusters. In addition, unit contains 3–5% olivine phenocrysts in light-gray, well-crystallized groundmass. FID 339

p4l5 **Wai‘akaloa Gulch flow**—Distinctive plagioclase-bearing pāhoehoe flow containing 7–10% olivine as phenocrysts and microphenocrysts and 7–10% plagioclase as glomeroclasts in a diktytaxitic groundmass. Flow is overlain by ash as thick as 0.3 m. Unit is found in south-central Wood Valley quadrangle. FID 342

p4c6 **Flow 352**—Tan-orange-weathered pāhoehoe in west-central Kipuka Pakekake quadrangle, found as kīpuka in flow p2e8 (FID 346). Flow contains 8% olivine as very fine laths and phenocrysts in a gray groundmass. In contrast to knobby surface of p2e8 (FID 346), this unit has a smooth surface. Flow mantled by ash. FID 352

a4l7 **Flow 882**—‘A‘ā along west boundary of Kilauea Crater quadrangle. Contains 8–12% olivine phenocrysts, 8–15% plagioclase phenocrysts, and 5–6% olivine-plagioclase intergrowths. Plagioclase is more conspicuous than olivine. Unit covered by layers of yellow ash, probably from Kīlauea Volcano, in low-lying areas. FID 882

a4j8 **Flow 890**—Thick ‘a‘ā west of Ke‘āmuku Kīpukakēkake flow in central Kilauea Crater quadrangle. Rock is characterized by 6% olivine and 1–3% plagioclase phenocrysts. Groundmass is well crystallized and full of plagioclase microlites. FID 890

a4a9, p4a9 **Flow 351**—‘A‘ā with minor pāhoehoe in northwest corner of Kipuka Pakekake quadrangle. Unit nearly aphanitic yet contains 0.5% olivine-plagioclase glomeroclasts. Groundmass is medium dark gray. Upper surfaces are orange tan. FID 351

a4a10 **Flow 348**—Aphanitic ‘a‘ā, east of Napu‘ukūlua Lava Flow, in the northwest corner of Kipuka Pakekake quadrangle. Unit is a kīpuka in the younger p3e4 (FID 345). Surface color is

chocolate gray brown. Abundant ash fills all interstices between (mostly round) clinkers. Contains 0.5% plagioclase phenocrysts in a medium-light-gray groundmass. Olivine rare, usually intergrown with plagioclase. FID 348

p4a11, m4a11 **Flow 844**—Small pāhoehoe and mixed ʻaʻā and pāhoehoe kīpuka in the north-central portion of Kipuka Pakekake quadrangle. Units are aphanitic. Pāhoehoe contains 0–1% olivine phenocrysts in a well-crystallized light-gray groundmass. FID 844

p4a12 **Flow 895**—Pāhoehoe originates from spatter ramparts uprift of Puʻuʻulaʻula cone in Kokoolau quadrangle (west of map area). Represents only flows found in Kipuka Pakekake quadrangle. Nearly aphyric, with rare phenocrysts of olivine and plagioclase. Groundmass is medium gray, microcrystalline, and mildly feldspathic with abundant plagioclase microlites. A very large tube system lies within the pāhoehoe. Surface is tan. FID 895

Age Group 5 (4,000–5,000 yr B.P.; Holocene)

m5a1 **Halfway House flow**—Small kīpuka in southeastern Kipuka Pakekake and northeastern Wood Valley quadrangles. Unit under 1 m of ash is a dense aphanitic ʻaʻā and pāhoehoe. Groundmass is feldspathic, full of plagioclase microlites. Age, 4,378±42 radiocarbon yr B.P. FID 399

p5a2, m5a2 **Flow 880**—Aphanitic pāhoehoe and dense, fluid, ʻaʻā in contact with A.D. 1984 along north boundary of Kipuka Pakekake quadrangle. Flow is characterized by its well-crystallized, medium-gray, feldspathic groundmass. FID 880

a5b3 **ʻAhulili flow**—Kīpuka in southwest quadrant of Wood Valley quadrangle. ʻAʻā contains 5% olivine phenocrysts in microcrystalline, steely gray groundmass. Unit is blanketed by 2–3 m of ash. FID 379

p5h4, a5h4 **Flow 392**—Kīpuka in north-central Wood Valley and southwestern Kipuka Pakekake quadrangles. A distinctive coarse plagioclase-rich, tube-fed pāhoehoe. Contains variable plagioclase phenocrysts at 10–20%. Plagioclase comprises aggregates of euhedral plagioclase laths (to 3 mm) as glomerocrysts, all in a dark-gray glassy groundmass. Upper surface is orange stained, weathered, glass speckled by coarse plagioclase. Unit is covered by 0–30 cm of ash. FID 392

p5a5 **Kaʻiliʻula flow**—Large ash-covered kīpuka upslope of Kapāpala Ranch headquarters in Wood Valley quadrangle. Flow is sparsely olivine-phyric tube-fed pāhoehoe. Contains 0–1% olivine phenocrysts in light-gray, feldspathic to diktytaxitic groundmass. Unit overlain by 0.5–2 m of ash. FID 397

p5f6 **Uēwale Gulch flow**—Kīpuka in center of Wood Valley quadrangle. Pāhoehoe contains variable amounts of olivine at 5–15% phenocrysts. Groundmass is a bluish-gray color and cryptocrystalline. Flow differs from other nearby younger regional olivine pāhoehoe by the amount of ash cover, 1–4 m, and its more weathered, eroded upper surface. FID 378

a5b7, p5b7, m5b7 **Kīpukakēkake flow**—ʻAʻā and slabby, tube-fed pāhoehoe in north-central Kilauea Crater quadrangle. In contact with and isolated by Keʻāmuku Kīpukakēkake flow (a1g1, FID 800). Rare toothpaste and ʻaʻā phases exist in southernmost reach of the flow. Contains 0–2% widely scattered olivine phenocrysts in a gray feldspathic groundmass. Ash cover is nearly continuous. Abundant charcoal samples found where overlain by toes of Keʻāmuku Kīpukakulalio east flow (p1k5, FID 799). FID 870

s5a8 **Puʻukīpū cone**—Poorly exposed spatter cone at 4,274-ft elev in northeastern part of Kilauea Crater quadrangle. Spatter is fine grained and aphanitic. FID 871

Age Group 6 (5,000–6,000 yr B.P.; Holocene)

a6d1 **Flow 988**—ʻAʻā found at distal end and northeast of A.D. 1880 flow. Contains 8–12% olivine phenocrysts in a medium-gray groundmass. Unit is covered by 0.25 m of ash. FID 988

a6k2 **Kīpukapakēkakē flow**—Distinctive plagioclase-bearing ʻaʻā contains 5–7% plagioclase glomerocrysts (”snowflakes”) and 3–4% inconspicuous olivine phenocrysts. Olivine commonly associated with plagioclase. Groundmass medium to dark gray and feldspathic; vesicles are small and well sorted. Unit found in northwestern Kipuka Pakekake quadrangle and southwest of the distal end of A.D. 1880 flow, along the boundary between the Kilauea and Kipuka Pakekake quadrangles. FID 398

a6c3 **Flow 990**—Olivine-bearing ʻaʻā in northwest quadrant of Kilauea Crater quadrangle along Strip Road. Flow contains 8–10% sugary anhedral olivine phenocrysts and microphenocrysts. Groundmass is well crystallized and full of plagioclase microlites. Flow is mantled by ash. FID 990

a6a4 **Puʻu 4274 flow**—ʻAʻā in northwest corner of Kilauea Crater quadrangle. This unit is aphanitic. Flow is covered by 1–2 m ash. FID 986

Age Group 7 (6,000–7,000 yr B.P.; Holocene)

[No units of this age group are found at the surface in the map area]

Age Group 8 (7,000–8,000 yr B.P.; Holocene)

p8e1 **Palakea Flat flow**—Picritic pāhoehoe comprises all of the Mauna Loa flows in Volcano quadrangle and northeastern-most Kilauea Crater quadrangle. Characterized by 25–30% clear, large, subhedral to anhedral olivine and 0–2% plagioclase phenocrysts, mostly intergrown with olivine. Vesicles are highly irregular in distribution, subrounded, and commonly magnesioferrite lined. Flow is commonly covered with as much as 2 m of tan ash; outcrops are fairly common. Dzurisin and others (1995) map distal extent of Uwēkahuna Ash member of Puna Basalt to this unit, a distance of approximately 6 km from Kīlauea Volcano summit. Age, 7,960±110 radiocarbon yr B.P. FID 962

p8b2, a8b2 **Flow 400**—Spongy tube-fed pāhoehoe contains 2–5% inconspicuous olivine phenocrysts in a well-crystallized groundmass. Upper surfaces are deeply weathered and orange stained. Flow is found in extreme southwest corner of Kipuka Pakekake quadrangle and is covered by 0.2–1 m of ash. FID 400

m8k3, p8k3 **Flow 983**—‘A‘ā along boundary dividing Kipuka Pakekake and Kilauea Crater quadrangles. Flow surface severely broken and weathered, retaining very little surface glass and stained red orange. Minor olivine phenocrysts form 1–2% of rock and are mostly intergrown with plagioclase. Abundant, large plagioclase makes up 6–10% of rock. Rich soil/ash horizons support ‘ōhi‘a trees as tall as 4 m. FID 983

a8i4, p8i4 **Flow 979**—‘A‘ā and pāhoehoe in extreme northwest corner of Kilauea Crater quadrangle. Flow contains 1–2% of clear, inconspicuous olivine and 0–2% very fine plagioclase phenocrysts. Flow has no original surface glass, and deep orange rind is common. Overlain by pockets of yellow-brown ash as thick as 0.5 m. FID 979

p8e5 **‘Ua‘u flow**—Flow in northwestern and east-central Kipuka Pakekake quadrangle. Pāhoehoe containing 15–25% olivine phenocrysts. Groundmass is light gray and diktytaxitic. Surface is broken up and deep red. Unit represents some of the oldest rocks on this portion of the volcano. This unit harbors pockets of ash, as thick as 40 cm, in low-lying regions. FID 385

Age Group 9 (8,000–9,000 yr B.P.; Holocene)

p9h1 **Halfway House Kīpuka flow**—Pāhoehoe located in southeast corner of Kipuka Pakekake and northeastern Wood Valley quadrangles, with distinctive snowflakes or rosettes of plagioclase. Contains 18–20% euhedral blades intergrown to form glomeroclasts of plagioclase. Unit also contains minor olivine. Flow is covered by 0.5 to 1.5 m of ash. Age, 8,520±82 radiocarbon yr B.P. FID 395

p9g2, a9g2 **Pu‘u‘ula‘ula flow**—Pāhoehoe, and minor ‘a‘ā, from Pu‘u‘ula‘ula, one of largest cones on NERZ. Located in central part of Kilauea Crater quadrangle. Distinct unit, containing 3–4% fine plagioclase phenocrysts. Flow groundmass is light gray and orange stained, with many inconspicuous needles of plagioclase. Flow is commonly covered with as much as 1 m of tan ash, especially at lower elevations; outcrops are fairly common. Age, 8,645±71 radiocarbon yr B.P. FID 978

a9k3 **Flow 402**—‘A‘ā in northwest corner of Wood Valley quadrangle. Contains 8–10% anhedral plagioclase glomeroclasts and laths in a well-crystallized groundmass. Flow has 1% olivine phenocrysts. Upper surfaces are orange stained. Unit is covered by 0.5 m of ash. FID 402

p9b4 **Flow 393**—Tube-fed pāhoehoe found in northwest quadrant of Wood Valley and southeast corner of Kipuka Pakekake quadrangles. Unit has orange, weathered, glassy rind top and is characteristically overlain by 1 m of ash. Contains 5% olivine as inconspicuous anhedral phenocrysts and rare laths. FID 393

a9b5, p9b5 **Flow 944**—Old ‘a‘ā and tube-fed pāhoehoe, yellow stained and exposed only in gullies. Contains 1–2% anhedral olivine phenocrysts in a well-crystallized groundmass. Upper surfaces are orange stained. Flow is covered by 0.2–1 m of ash. Unit forms small kīpuka within largest p9g2 (FID 978) unit near Kīlauea Volcano contact in central Kilauea Crater quadrangle. FID 944

Age Group 10 (9,000–10,000 yr B.P.; Holocene)

m10b1, p10b1, a10b1 **Ka‘ū High School flow**—Tube-fed pāhoehoe that underlies the town of Pāhala. Contains 0–5% olivine phenocrysts in a well-crystallized groundmass. Flow tops are stained orange red. Flow is buried by 1.5–2 m of ash. Age, 9,121±46 radiocarbon yr B.P. FID 383

p10c2 **Lae‘opuhili flow**—Large regional pāhoehoe in Pahala quadrangle. Pāhoehoe contains 7–10% olivine phenocrysts in light-gray diktytaxitic groundmass. Unit is covered by 0.3 to 1 m of ash. Age, 9,218±79 radiocarbon yr B.P. FID 742

p10a3 **Flow 338**—Abandoned cane fields, ash covered, below Kapāpala Ranch Headquarters in southern Wood Valley quadrangle. Flow buried by 0.5–1.2 m of ash. Pāhoehoe has 0–1% olivine phenocrysts and microphenocrysts in a dull light-gray microcrystalline groundmass. Age, 9,680±70 radiocarbon yr B.P. FID 338

m10k4, p10k4, a10k4 **‘Iliokōloa flow**—Flow in Pahala quadrangle. Unit has both ‘a‘ā and pāhoehoe phases, informally known as the “plagioclase-rich flow” of Pahala quadrangle. Plagioclase ranges from 3–8% as anhedral clots and laths. Also contains 1–8% olivine as green phenocrysts and microphenocrysts. Unit is overlain by 0.5 to 5 m of ash. FID 382

a10i5 **Flow 943**—Small ash-covered ‘a‘ā kīpuka in southwestern part of Kilauea Crater quadrangle; surrounded by ash (ts) unit. Contains 5% plagioclase and 3% sugary olivine phenocrysts in a dense microcrystalline groundmass. Unit is covered by 2.5 m of ash. FID 943

p10g6 **Flow 942**—Small ash-covered pāhoehoe kīpuka in southwestern part of Kilauea Crater quadrangle, surrounded by ash (ts) unit. Contains 4–5% plagioclase in a dense microcrystalline groundmass. Unit is covered by 1.0–2.5 m of ash. FID 942

Age Group 11 (10,000–15,000 yr B.P.; Holocene and Pleistocene)

p11a1 **Kauhuhu‘ula flow**—Aphyric pāhoehoe of Kauhuhu‘ula Gulch, Pahala quadrangle. Contains rare olivine phenocrysts. The groundmass is full of plagioclase microlites. Surface color of flow is yellow orange. Unit is buried by 1.5 m of ash. Ka‘ū High School flow (m10b1, FID 383) overlies this unit. FID 390

a11a2, p11a2 **Pā‘au‘au flow**—Mixed ‘a‘ā and pāhoehoe of Pā‘au‘au Gulch in central Pahala quadrangle. Contains 0–1% olivine phenocrysts and microphenocrysts. Groundmass is dense and microcrystalline. Unit is buried by 1.0 m of ash. Age, 10,030±85 radiocarbon yr B.P. FID 388

p11b3 **Meyer Camp flow**—Very vesicular pāhoehoe with near-vent-type vesicularity in central Pahala quadrangle. Outcrop appears to be large tube system and (or) channel overbank deposit. Contains 2–3% olivine phenocrysts in microcrystalline gray groundmass. Unit is buried by 1–2 m of ash. Age, 10,600±150 radiocarbon yr B.P. FID 386

a11a4 **Wailoa flow**—Aphyric ‘a‘ā northeast of Pāhala town. Unit contains rare olivine phenocrysts. Groundmass is full of plagioclase microlites. Surface color of flow is yellow orange. Flow is buried by 1.5 m of ash. Ka‘ū High School flow (m10b1, FID 383) overlies this unit. FID 391

Age Group 12 (15,000–20,000 yr B.P.; Pleistocene)

[No units of this age group are found at the surface in the map area]

Age Group 13 (20,000–30,000 yr B.P.; Pleistocene)

m13b1 **Flow 387**—Mixed ‘a‘ā and pāhoehoe above town of Pāhala occurs as two kīpuka within Ka‘ū High School flow (m10b1, FID 383). Unit contains 0–3% olivine phenocrysts in a well-crystallized groundmass. Flow tops are stained orange red. Unit is buried by 1.5–2 m of ash. FID 387

a13b2 **Flow 384**—Lava flow in section at Hi‘onamoa Gulch. ‘A‘ā contains variable amounts of olivine phenocrysts from 1–7% in a microcrystalline bluish-gray groundmass. Flow is under Ka‘ū High School flow (m10b1, FID 383). Unit is covered by 0.5–1.0 m of ash. Age, 25,768±188 radiocarbon yr B.P. FID 384

a13f3, p13f3 **Lava flow of Hi‘onamoa Gulch**—‘A‘ā and pāhoehoe lining the floor of Hi‘onamoa and Moa‘ula Gulches near Highway 11 in Pahala quadrangle. Contains variable amounts of olivine, ranging from 0–8% as phenocrysts in a microcrystalline bluish-gray groundmass. Flow is overlain by the Ka‘ū High School flow (m10b1, FID 383). Unit is covered by 0.5–1.0 m of ash. Age, 28,140±590 radiocarbon yr B.P. FID 735

Kahuku Basalt

The Kahuku Basalt consists of units with an age range of 30,000 to 100,000 yr. The Kahuku Basalt is composed of tholeiitic basalt, tuffs, vent deposits, and lava flows that rest unconformably on the Nīnole Basalt. The flows are mostly aphyric and some have variable amounts of olivine and plagioclase phenocrysts. The Kahuku Basalt type locality is the Kahuku Pali or Kahuku Fault near Kalae (South Point).

Age Group 14 (30,000–100,000 yr B.P.; Pleistocene)

[No units of this age group are found at the surface in the map area]

Nīnole Basalt

The Nīnole Basalt, the oldest exposed rocks on Mauna Loa, is >100,000 yr B.P. These rocks are exposed in the Kaʻū District. The Nīnole Basalt consists of tholeiitic basalt, tuffs, vent deposits, and lava flows. The flows are mostly aphyric and some have variable amounts of olivine and plagioclase phenocrysts.

Age Group 15 (>100,000 yr B.P.; Pleistocene)

n **Nīnole Basalt**—Undivided units found in valley wall of Wood Valley. Flows are mostly aphyric and deeply weathered and have variable amounts of olivine and plagioclase phenocrysts. Lipman and others (1990) report a weighted mean age of 0.120±0.056 Ma for Nīnole Basalt. Whereas, Jicha and others (2012) constrain the Nīnole Basalts to have erupted from 0.227 to 0.108 Ma. FID 744

DISTAL TEPHRA DEPOSITS

Tephra (Holocene and Pleistocene)

ts **Southern tephra**—Beds of ashfall deposits in map area are chiefly from Kīlauea Volcano and likely include contributions from Mauna Loa (Easton, 1987). All ash deposits ≤10,000 yr B.P. are included in this category. Kīlauea deposits include ^{14}C ages of 2,110±120 yr B.P., 2,265±50 yr B.P., and 2,770±70 yr B.P., all dating Uwēkahuna Ash Member of Puna Basalt (Dzurisin and others, 1995). Other ages of 4,135±49 and 9,500±140 yr B.P. were obtained from ash layers on the east flank of the volcano. Distributions of ash near Kīlauea seem to be influenced by the inversion layer on the windward coast of the Island of Hawai'i. This meteoric phenomenon appears to limit distribution of ash to lower elevations; therefore, overlay patterns for ash deposits may vary with elevation within flows or on flows of similar age. Possibly, ash deposited at higher elevations (alpine and above) lack vegetative cover that preserves it, allowing combined wind and rainfall to strip ash deposits from higher elevations. FID 959

pa **Pāhala Ash—**Deep Pāhala Ash 5–8 m thick exposed at the surface. Unit comprises several kīpukas in northwest-central Pahala quadrangle. Unit is older than surficial ash deposits (ts; FID 959). Unit comprises multiply bedded airfall deposits whose origin is unknown. Most likely, Pāhala Ash has Kīlauea Volcano origin, although Mauna Loa cannot be excluded as a source. Unit is overlain by flows p11a1 (FID 390) and p11a2 (FID 388), dated at 12,500 and 10,030 radiocarbon yr B.P., respectively. Age, 31,020±310 radiocarbon yr B.P. FID 389

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Appendix

This appendix contains radiocarbon ages that were rejected and not used in the study of the central-southeast flank of Mauna Loa volcano, Island of Hawai‘i, Hawaii. Reasons for being rejected include age too old or too young, age not consistent with stratigraphy, and sample contaminated.

FID[1]	Field No.	Lab No.	Quadrangle name (1:24,000)	Age[2] (yr B.P.)	S.D.[2] (yr)	Data source[3]
289	9P74C	W5325	Pahala	1,370	200	1
289	L-01-501c	WW3711	Wood Valley	1,560	35	1
289	L-90-81	W6456	Wood Valley	1,820	80	1
289	L-91-143	W6460	Keaiwa Reservoir	1,850	80	1
289	L-91-191	W6462	Wood Valley	1,920	80	1
344	L-81-67	W5083	Mauna Loa	1,030	60	1
799	L-77-42A	W3879	Kilauea Crater	830	60	1
799	KUc-130	W4870	Kulani	1,100	70	2
801	77L-09	W3836	Kilauea Crater	2,830	60	2
801	L-80-126	W4801	Kilauea Crater	730	70	2
838	L-78-1	W4049	Kipuka Pakekake	420	70	2
838	PUd-135	W4571	Puu Ulaula	440	70	2
892	77L-08	W3855	Kilauea Crater	4,210	200	1

[1]Unique three-digit flow identification number (FID) assigned to each mapped flow unit is necessary to utilize associated database (https://doi.org/10.3133/sim2932B).

[2]Each age was calibrated to calendar years using CALIB 6.0 Radiocarbon Calibration Program (Stuiver and others, 2005); calibrated ages are for two standard deviations (S.D.). Samples were processed at U.S. Geological Survey, ^{14}C Laboratory, Reston, Va.

[3]Sources: 1, this study; 2, Kelley and others (1979).

Table 2. Radiocarbon ages of samples from the central-southeast flank of Mauna Loa volcano, Island of Hawai‘i, Hawaii.

[All ages are reported in radiocarbon years before present (yr B.P., before the calendar year datum of A.D. 1950). Materials dated include charcoal, roots, twigs, vegetative litter, or unaltered wood (rarely). See figure 1 for quadrangle locations]

Unit label[1]	FID[2]	Age[1] group	Unit name	Field No.	Lab No.[3]	Quadrangle name (1:24,000)
a1g1	800	1	Ke‘āmuku Kīpukakēkake flow	77L-24A	W3871	Kilauea Crater
a1g1	800	1	Ke‘āmuku Kīpukakēkake flow	L-78-26	W4360	Kilauea Crater
a1g1	800	1	Ke‘āmuku Kīpukakēkake flow	77L-24B	W4919	Kilauea Crater
p1k2	801	1	Kīpukamauna‘iu flow	77L-06	W3843	Kilauea Crater
p1k2	801	1	Kīpukamauna‘iu flow	77L-29	W4006	Kilauea Crater
p1k2	801	1	Kīpukamauna‘iu flow	L-78-14	W4183	Kipuka Pakekake
p1k2	801	1	Kīpukamauna‘iu flow	L-82-01	W5106	Kilauea Crater
p1k2	801	1	Kīpukamauna‘iu flow	F01-37-01c	WW3541	Kilauea Crater
p1a3	274	1	Ke A Po‘omoku Flow	L-80-100	W4790	Kipuka Pakekake
p1a3	274	1	Ke A Po‘omoku Flow	L-80-165	W4805	Kilauea Crater
p1a3	274	1	Ke A Po‘omoku Flow	L-87-07	W6001	Kipuka Pakekake
p1g4	802	1	Ke‘āmuku Kīpukakulalio flow	L-78-04[10]	W4118	Puu Ulaula
p1g4	802	1	Ke‘āmuku Kīpukakulalio flow	L-78-04R[10]	W4916	Puu Ulaula
a1k5	799	1	Ke‘āmuku Kīpukakulalio east flow	L-77-42B	W3880	Kilauea Crater
a1k5	799	1	Ke‘āmuku Kīpukakulalio east flow	MP-78-07	W4367	Kilauea Crater
a1k5	799	1	Ke‘āmuku Kīpukakulalio east flow	L-80-24	W4845	Kilauea Crater
p1l6	833	1	Keauhou Ranch flow	L-78-27	W4345	Kilauea Crater
a1b7	840	1	Flow northeast of 1880 lobe	L-80-90	W4863	Kipuka Pakekake
p1e8	837	1	Pu‘uwahi picrite flow	L-77-45	W4047	Kipuka Pakekake
p1e8	837	1	Pu‘uwahi picrite flow	L-77-45R	SUERC-5409	Kipuka Pakekake
p2b2	293	2	West Wood Valley flow	9WV2C	W4430	Wood Valley
p2b2	293	2	West Wood Valley flow	MJ-87-C5	W6037	Pahala
p2i3	298	2	Pahuamimi flow	L-93-119	USGS3466	Kipuka Pakekake
p2i3	298	2	Pahuamimi flow	KP-01	W3000	Wood Valley
p2i3	298	2	Pahuamimi flow	MJ-87-C2	W6014	Kipuka Pakekake
p2a4	297	2	Keakapulu Flat flow	MJ-87-C3	W6012	Wood Valley
p2a4	297	2	Keakapulu Flat flow	L-92-159	USGS3461	Wood Valley
p2i5	344	2	Kapāpala flow	MJ-87-C4	W5982	Wood Valley
p2i5	344	2	Kapāpala flow	L-92-181	WW323	Wood Valley
p2i5	344	2	Kapāpala flow	L-92-212	USGS3462	Kipuka Pakekake
p2c6	301	2	Kilohana flow	L-91-588[10]	WW319	Keaiwa Reservoir
p2c6	301	2	Kilohana flow	L-92-654	USGS3474	Wood Valley
p2c6	301	2	Kilohana flow	MJ-87-C1	W5679	Wood Valley
p2f7	289	2	Waimuku flow	L-84-06c	W5461	Wood Valley
p2f7	289	2	Waimuku flow	77L-63	W4359	Pahala
p2f7	289	2	Waimuku flow	L-01-501c	WW3711	Wood Valley
p2f7	289	2	Waimuku flow	77L-17A	W3857	Pahala
p2f7	289	2	Waimuku flow	77L-17B	W3858	Pahala
p2e8	346	2	Pu‘u‘ele‘ele flow	L-92-129	WW846	Wood Valley
p2e8	346	2	Pu‘u‘ele‘ele flow	L-93-242	WW852	Kipuka Pakekake
p2f9	288	2	Ka‘ala‘ala Gulch flow	L-92-2014	SUERC10374	Pahala
p2f9	288	2	Ka‘ala‘ala Gulch flow	L-92-507D	SUERC10382	Pahala
p2b10	290	2	Kapāpala Ranch flow	L-91-602[10]	USGS3468	Keaiwa Reservoir
p2b10	290	2	Kapāpala Ranch flow	L-99-553	WW2626	Wood Valley

Latitude[4] (degree)	Longitude[4] (degree)	Elev (ft)	Age[5] (yr B.P.)	S.D.[5] (yr)	Weighted average[6] (yr B.P.)	S.D.[6] (yr)	Quality[7]	Age range[8] (calendar years)	Source[9]
19.44321	-155.31630	4,200	230	60	288	36	+	1491 to 1953	1, 2
19.49084	-155.34227	5,500	300	60	288	36	+	1448 to 1951	2
19.44324	-155.31627	4,203	350	70	288	36	0	1433 to 1790	2
19.40565	-155.34085	3,500	290	50	311	25	—	1460 to 1950	1,2
19.40897	-155.33940	3,590	290	70	311	25	0	1447 to 1951	1,2
19.49261	-155.44146	8,360	300	60	311	25	+	1448 to 1951	1, 2
19.41252	-155.34698	3,825	300	80	311	25	+	1437 to 1952	2
19.41124	-155.34172	3,570	340	40	311	25	—	1462 to 1642	3
19.43715	-155.39977	5,280	540	70	475	41	+	1285 to 1464	2
19.39405	-155.36860	3,790	340	60	475	41	0	1445 to 1653	2
19.40651	-155.38265	4,350	720	100	475	41	0	1048 to 1422	3
19.50088	-155.38320	6,815	580	80	569	53	+	1274 to 1449	1,2
19.50088	-155.38320	6,815	560	70	569	53	+	1287 to 1446	3
19.45195	-155.28359	4,100	530	60	575	38	+	1296 to 1453	1,2
19.44277	-155.27337	4,060	570	70	575	38	+	1286 to 1442	2
19.46805	-155.29302	4,425	640	70	575	38	0	1262 to 1424	2
19.48993	-155.34121	5,450	760	70	—	—	+	1050 to 1392	2
19.48373	-155.41635	7,395	780	70	—	—	+	1045 to 1387	2
19.48408	-155.38352	6,350	910	70	955	24	+	1016 to 1259	1, 2
19.48408	-155.38353	6,350	961	25	955	24	+	1020 to 1155	3
19.26468	-155.48276	2,260	1,270	70	1,281	66	+	645 to 940	2
19.22045	-155.46248	1,180	1,290	120	1,281	66	+	543 to 994	3
19.38563	-155.38252	3,720	1,285	30	1,293	27	+	662 to 777	3
19.37141	-155.37367	3,000	1,330	70	1,293	27	+	597 to 876	1
19.37390	-155.37478	3,380	1,310	120	1,293	27	+	467 to 992	3
19.37075	-155.39729	3,680	1,360	120	1,428	38	+	428 to 948	3
19.33970	-155.42802	3,190	1,435	40	1,428	38	+	556 to 660	3
19.35599	-155.45361	4,280	1,460	100	1,469	32	+	386 to 775	3
19.33889	-155.45235	3,675	1,480	60	1,469	32	+	433 to 656	3
19.37196	-155.49370	6,180	1,465	40	1,469	32	+	475 to 657	3
19.36258	-155.50893	6,600	1,560	70	1,507	19	+	349 to 641	3
19.31153	-155.46132	3,250	1,505	20	1,507	19	+	470 to 614	3
19.28646	-155.43131	2,200	1,360	150	1,507	19	0	393 to 993	3
19.28060	-155.49265	3,160	1,510	110	1,511	24	+	258 to 765	—
19.22904	-155.45683	1,305	1,510	60	1,511	24	+	427 to 644	—
19.26165	-155.46675	1,930	1,560	34	1,511	24	+	420 to 572	—
19.22046	-155.46249	1,190	1,470	60	1,511	24	0	433 to 661	1,2
19.22046	-155.46249	1,190	1,400	60	1,511	24	0	541 to 770	1,2
19.35027	-155.39015	2,875	1,550	50	1,530	37	+	409 to 636	3
19.43314	-155.45902	7,060	1,510	50	1,530	37	+	427 to 649	3
19.23651	-155.47197	1,190	1,561	35	1,574	25	+	419 to 573	—
19.23551	-155.47158	1,518	1,586	35	1,574	25	+	406 to 533	—
19.32433	-155.52688	6,290	1,500	30	1,622	23	+	442 to 638	3
19.29682	-155.45998	2,940	1,585	60	1,622	23	—	341 to 603	3

Table 2. Radiocarbon ages of samples from the central-southeast flank of Mauna Loa volcano, Island of Hawai‘i, Hawaii.—*Continued*

[All ages are reported in radiocarbon years before present (yr B.P., before the calendar year datum of A.D. 1950). Materials dated include charcoal, roots, twigs, vegetative litter, or unaltered wood (rarely). See figure 1 for quadrangle locations]

Unit label[1]	FID[2]	Age[1] group	Unit name	Field No.	Lab No.[3]	Quadrangle name (1:24,000)
p2b10	290	2	Kapāpala Ranch flow	L-91-625[10]	W6480	Keaiwa Reservoir
a2k11	864	2	Upper Waiākea flow	HCB-83-15[10]	W5278	Hilo
a2k11	864	2	Upper Waiākea flow	L-92-237[10]	USGS3463	Piihonua
a2k11	864	2	Upper Waiākea flow	KUc-101[10]	W4344	Kulani
a2k11	864	2	Upper Waiākea flow	GAM-01[10]	W477	Piihonua
a2k11	864	2	Upper Waiākea flow	GAM-02[10]	W478	Piihonua
p2e14	343	2	Kauhiuhi flow	L-84-02	W5458	Wood Valley
p2b15	336	2	East Wood Valley flow	2WV1C	W5271	Wood Valley
p2b15	336	2	East Wood Valley flow	L-90-81	W6456	Wood Valley
p2b16	540	2	Moa‘ula flow	77L-04	W3850	Pahala
p2b16	540	2	Moa‘ula flow	9P77C	W5153	Pahala
p2b16	540	2	Moa‘ula flow	L-91-525	W6470	Pahala
p2b16	540	2	Moa‘ula flow	L-93-545[10]	USGS3475	Punaluu
p2b16	540	2	Moa‘ula flow	L-93-596[10]	USGS3478	Punaluu
p2b16	540	2	Moa‘ula flow	L-93-639[10]	WW347	Punaluu
a2a18	349	2	Kauhiuhi Maluikeao flow	L-86-330	W6004	Kipuka Pakekake
p2g22	883	2	Upper Strip Road flow	L-78-02	W4116	Kipuka Pakekake
p2g22	883	2	Upper Strip Road flow	L-86-02	W5815	Kilauea Crater
p2g22	883	2	Upper Strip Road flow	PUD-136[10]	W4579	Puu Ulaula
—	NAS	2	—	L-91-148	W6461	Wood Valley
a3a1	295	3	Red Cone flow	77L-56[10]	W4161	Keaiwa Reservoir
a3a1	295	3	Red Cone flow	77L-57[10]	W4163	Keaiwa Reservoir
a3a1	295	3	Red Cone flow	L-91-186[10]	W6349	Keaiwa Reservoir
a3a2	889	3	Eastern Ka‘ōiki Pali flow	L-77-41	W3876	Kilauea Crater
a3a2	889	3	Eastern Ka‘ōiki Pali flow	L-80-81	W4831	Kilauea Crater
a3a3	637	3	Nīnole flow	L-93-626[10]	USGS3479	Punaluu
p3e4	345	3	Cow Pasture picrite flow	77L-03	W3841	Wood Valley
p3e4	345	3	Cow Pasture picrite flow	77L-12	W3845	Wood Valley
p3e4	345	3	Cow Pasture picrite flow	L-92-137	WW322	Wood Valley
p4a1	892	4	‘Ōhaikea flow	L-81-18	W5086	Kilauea Crater
ts	959	5	Southern tephra	L-91-624[10]	W6477	Keaiwa Reservoir
ts	959	5	Southern tephra	77L-05	W3844	Wood Valley
m5a1	399	5	Halfway House flow	GAM	W1046	Wood Valley
m5a1	399	5	Halfway House flow	77L-05	W3844	Wood Valley
m5a1	399	5	Halfway House flow	L-92-149	WW848	Wood Valley
p8e1	962	8	Palakea Flat flow	KUc-177[10]	W4991	Kulani
p9h1	395	9	Halfway House Kīpuka flow	MJ-87-C6	W6038	Wood Valley
p9h1	395	9	Halfway House Kīpuka flow	L-80-163	W4821	Wood Valley
p9g2	978	9	Pu‘u‘ula‘ula flow	77L-10	W3853	Kilauea Crater
p9g2	978	9	Pu‘u‘ula‘ula flow	L-80-138	W4803	Kilauea Crater
m10b1	383	10	Ka‘ū High School flow	L-93-101	WW339	Pahala
m10b1	383	10	Ka‘ū High School flow	L-91-50	AA7656	Pahala
m10b1	383	10	Ka‘ū High School flow	L-91-680	W6482	Pahala
m10b1	383	10	Ka‘ū High School flow	L-93-533[10]	WW343	Punaluu

Latitude[4] (degree)	Longitude[4] (degree)	Elev (ft)	Age[5] (yr B.P.)	S.D.[5] (yr)	Weighted average[6] (yr B.P.)	S.D.[6] (yr)	Quality[7]	Age range[8] (calendar years)	Source[9]
19.33998	-155.52340	6,800	1,650	60	1,622	23	+	254 to 541	3
19.66731	-155.11106	660	1,740	100	1,638	32	+	78 to 535	2
19.64163	-155.16607	1,740	1,585	40	1,638	32	+	398 to 564	2
19.52973	-155.35102	6,440	1,690	70	1,638	32	+	143 to 539	2
19.67363	-155.11970	800	2,000	250	1,638	32	0	-748 to 558	2
19.67356	-155.11978	800	2,070	250	1,638	32	0	-769 to 428	2
19.36608	-155.37766	3,020	1,640	150	—	—	0	71 to 661	2
19.27681	-155.47994	2,370	1,700	80	1,708	50	0	138 to 535	3
19.27368	-155.48965	2,700	1,820	80	1,708	50	+	26 to 396	3
19.18410	-155.48308	450	1,810	80	1,824	19	+	28 to 414	1,2
19.16078	-155.49543	175	1,500	70	1,824	19	0	415 to 662	2
19.18386	-155.48119	420	1,830	30	1,824	19	+	86 to 317	3
19.19656	-155.51834	1,625	1,780	40	1,824	19	+	130 to 380	3
19.18940	-155.51213	1,320	1,885	30	1,824	19	+	34 to 227	3
19.19358	-155.50552	1,340	2,030	80	1,824	19	+	-348 to 130	3
19.44875	-155.43949	7,070	1,910	120	—	—	+	-193 to 390	3
19.48293	-155.38247	6,280	1,840	60	1,993	43	+	32 to 336	1,2
19.44964	-155.34664	4,770	2,270	130	1,993	43	+	-761 to -6	3
19.50618	-155.39308	7,260	2,120	70	1,993	43	+	-366 to 16	2
19.30584	-155.48280	3,680	2,000	85	—	—	+	-340 to 218	3
19.29351	-155.56723	6,760	2,000	70	2,072	37	+	-195 to 131	1,2
19.29749	-155.55876	6,680	1,980	80	2,072	37	+	-195 to 227	1,2
19.30734	-155.58595	7,520	2,150	50	2,072	37	+	-364 to -45	3
19.45210	-155.29076	4,100	2,190	70	2,265	49	+	-392 to -57	1,2
19.45208	-155.29081	4,120	2,340	70	2,265	49	+	-752 to -205	2
19.16975	-155.55796	1,920	2,365	30	—	—	+	-535 to -386	3
19.33072	-155.40527	2,600	2,950	80	2,826	32	+	-1405 to -920	1,2
19.36942	-155.39613	3,550	2,880	70	2,826	32	+	-1291 to -843	1,2
19.33486	-155.45218	3,540	2,890	60	2,826	32	+	-1287 to -903	3
19.42062	-155.34473	4,080	3,630	80	—	—	+	-2204 to -1758	2
19.33998	-155.52340	6,800	4,020	60	4,135	49	+	-2856 to -2352	3
19.36153	-155.38214	3,020	4,340	80	4,135	49	+	-3328 to -2710	3
19.36142	-155.38388	2,990	4,030	350	4,378	42	+	-3515 to -1639	2
19.36307	-155.38391	3,020	4,340	80	4,378	42	+	-3335 to -2705	1,2
19.36028	-155.38182	2,920	4,400	50	4,378	42	+	-3327 to -2905	3
19.50935	-155.32389	5,440	7,960	110	—	—	+	-7174 to -6593	2
19.36164	-155.38537	3,140	8,370	200	8,520	82	+	-7939 to -6780	3
19.36102	-155.38548	3,050	8,550	90	8,520	82	+	-7818 to -7361	1
19.41579	-155.33550	3,680	8,550	100	8,645	71	+	-7865 to -7379	1,2
19.43091	-155.32599	4,000	8,740	100	8,645	71	+	-8207 to -7581	2
19.20785	-155.47697	980	8,720	70	9,121	46		-8166 to -7589	3
19.20782	-155.47704	975	8,955	115	9,121	46	+	-8425 to -7715	3
19.20509	-155.48798	1,160	9,960	170	9,121	46	+	-10171 to -8878	3
19.21680	-155.50466	2,115	9,540	80	9,121	46	+	-9213 to -8653	3

Table 2. Radiocarbon ages of samples from the central-southeast flank of Mauna Loa volcano, Island of Hawai‘i, Hawaii.—*Continued*

[All ages are reported in radiocarbon years before present (yr B.P., before the calendar year datum of A.D. 1950). Materials dated include charcoal, roots, twigs, vegetative litter, or unaltered wood (rarely). See figure 1 for quadrangle locations]

Unit label[1]	FID[2]	Age[1] group	Unit name	Field No.	Lab No.[3]	Quadrangle name (1:24,000)
p10c2	742	10	Lae‘opuhili flow	9P70C1	W4419	Pahala
p10c2	742	10	Lae‘opuhili flow	78L-18[10]	W4201	Punaluu
ts	959	10	Southern tephra	77L-07	W3840	Kilauea Crater
p10a3	338	10	Flow 338	L-92-668	WW326	Wood Valley
NAS[11]	NAS	11	—	L-92-606	WW325	Pahala
a11a2	388	11	Pā´au´au flow	L-91-55	W7657	Pahala
p11b3	386	11	Meyer Camp flow	L-91-46	W6423	Pahala
a13b2	384	13	Flow 384	L-91-564R	WW240	Pahala
a13b2	384	13	Flow 384	L-91-548[10]	W6471	Punaluu
a13b2	384	13	Flow 384	L-92-582	USGS3471	Pahala
NAS[11]	NAS	13	—	L-92-588	USGS3473	Pahala
NAS[11]	NAS	13	—	L-92-576	USGS3470	Pahala
a13f3	735	13	Lava flow of Hi‘onamoa Gulch	L-91-555[10]	WW321	Punaluu
z13a4	389	13	Pāhala Ash	L-92-582D	USGS3472	Pahala

[1]See table 3 (sheet 1) for explanation of unit labels and definition of age groups.

[2]Unique, three-digit flow identification number assigned to each mapped surface-flow unit correlates with database (https://doi.org/10.3133/sim2932B).

[3]Initial letter(s) identifies analytical laboratory: AA, University of Arizona, Tucson, Ariz.; SUERC, NERC radiocarbon laboratory, Kilbride, Scotland, UK; USGS, U.S. Geological Survey ^{14}C laboratory, Menlo Park, Calif.; W, U.S. Geological Survey ^{14}C laboratory, Reston, Va. Initial letter(s) for Accelerator Mass Spectrometer (AMS) ages: A, WW, SUERC.

[4]Projection: decimal degrees. Datum: WGS84.

[5]Calibrated ages are for two standard deviations.

[6]Weighted avg., each age is weighted by the inverse of its variance before averaging (for example, Taylor 1982). A variance is reported as one standard deviation, in years.

[7]Quality: +, age considered meaningful; 0, age probably meaningful but accuracy may be poorer than indicated by the reported precision.

[8]Each age was calibrated to calendar years using CALIB 6.0 Radiocarbon Calibration Program (Stuiver and others, 2005); calibrated ages are for two standard deviations. Entire age range of calendar ages is possible for a given sample. Unspecified ages, A.D.; negative (-) ages, B.C.

[9]Sources: 1, Kelley and others, 1979; 2, Rubin and others, 1987; 3, this study.

[10]Radiocarbon sample collected outside of mapped area: Kulani, Piihonua, and Puu Ulaula quadrangles (SIM 2932–A); Punaluu quadrangle (SIM 2932–C), and Keaiwa Reservoir quadrangle (SIM 2932–D).

[11]NAS, flows not found at surface are exposed in drainages, fault scarps, and (or) sea cliffs.

[12]NAC, not able to calibrate ^{14}C age because too old for CALIB program.

Latitude[4] (degree)	Longitude[4] (degree)	Elev (ft)	Age[5] (yr B.P.)	S.D.[5] (yr)	Weighted average[6] (yr B.P.)	S.D.[6] (yr)	Quality[7]	Age range[8] (calendar years)	Source[9]
19.15966	-155.49475	210	9,300	130	9,218	79	+	-9118 to -8261	2
19.20450	-155.53528	2,140	9,170	100	9,218	79	+	-8694 to -8227	1,2
19.41515	-155.34106	3,750	9,500	140	—	—	+	-9252 to -8471	1,2
19.28410	-155.42982	2,120	9,680	70	—	—	+	-9279 to -8830	3
19.23768	-155.48886	1,980	10,010	70	—	—	+	-9858 to -9301	3
19.21949	-155.48103	1,380	10,030	85	—	—	+	-10009 to -9306	3
19.21947	-155.48614	1,460	10,600	150	—	—	+	-10908 to -10151	3
19.19938	-155.48648	990	25,000	460	25,768	188	+	NAC[12]	3
19.20977	-155.49981	1,610	25,570	600	25,768	188	—	NAC[12]	3
19.18879	-155.48278	575	25,970	220	25,768	188	+	NAC[12]	3
19.20514	-155.49645	1,400	26,450	120	26,532	88	+	NAC[12]	3
19.20026	-155.48893	1,060	26,630	130	26,532	88	+	NAC[12]	3
19.20966	-155.49983	1,605	28,140	590	—	—	+	NAC[12]	3
19.18873	-155.48278	575	31,020	310	—	—	+	NAC[12]	3