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The Puʻu ʻŌʻō - Kūpaianaha Eruption of Kīlauea, November 1991–February 1994: Field Data and Flow Maps

by

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INTRODUCTION

The Puʻu ʻŌʻō - Kūpaianaha eruption on the east rift zone of Kīlauea, which began in January 1983, is the longest-lived rift zone eruption of the last two centuries. By 1994, a broad field of lava, nearly 1 km^3 in volume and 12 km wide at the coast, had buried 87 km^2 of the volcano's south flank. The initial six months of fissure eruptions (episodes 1-3) were followed by three years of episodic lava fountaining from the Puʻu ʻŌʻō vent (episodes 4–47). In July 1986, after two days of fissure eruptions up- and downrift from Puʻu ʻŌʻō (episodes 48a and 48b), the eruption shifted to a new vent, Kūpaianaha, 3.5 km downrift. For the next five-and-a-half years (episode 48), Kūpaianaha was the site of nearly continuous low-level effusion. The 49th episode occurred in November 1991, when several fissures opened between Puʻu ʻŌʻō and Kūpaianaha (see Mangan and others, 1995, Bulletin of Volcanology, v. 57, p. 127-135). This three-week-long outburst was the result of the waning output of the Kūpaianaha vent, which finally died in February 1992 (see Kauahikaua and others, 1996, Bulletin of Volcanology, v. 57, p. 641-648).

The third epoch of the eruption began ten days later, when vents opened on the uprift slope of the Puʻu ʻŌʻō cone. Several flank vents erupted over the next two years (episodes 50-53). In the first year, from February 1992 through February 1993, the low-level effusion was interrupted by 21 brief pauses. These ended with the beginning of episode 53 in February 1993, and for the next year, lava effusion was continuous. Episode 53 was ongoing at the end of the interval covered by this report.

During the years that Kūpaianaha was active, the Puʻu ʻŌʻō conduit gradually evolved into a crater 300 m in diameter as the conduit walls collapsed. Beginning in 1987, an active lava pond was intermittently visible in the bottom of the crater; from 1990 on, the pond was almost continuously present. The Puʻu ʻŌʻō pond drained at the beginning of episode 49 in November 1991, and the crater floor collapsed. Lava was visible in the crater by early December, and pond overflows resurfaced the crater floor, raising it to its former level of 35 m below the rim by the end of January 1992.

This report includes flow-field maps and a table giving a) start and stop times of the eruptive episodes and of pauses in the eruption, b) Puʻu ʻŌʻō lava pond and crater-floor elevations, and c) elevations of the episode 50-53 vents and of the floors of the collapse pits that subsequently formed over these vents. A chronology of this interval of the eruption and an interpretation of the data included in this report can be found in Heliker and others (1998, Bulletin of Volcanology, v. 59, p. 381-393).

METHODS

Flow-field maps

The first of the four flow field maps on plates 1 and 2 shows the final form of both the Kūpaianaha (episode 48) flow field and the episode 49 flows. The other three maps show the progressive development of the Kamoamaoa (episode 50-53) flow field during 1993.

The two maps on plate 1 were compiled from vertical air photographs, and the contacts were transferred to a 7.5-minute composite of the eruption site. The maps on plate 2 were produced by mapping on outdated aerial photographs that didn't show the current contacts. Consequently, the contacts of the episode 53 flows on these maps are less detailed than the earlier ones.

Astute readers of the map legends will note that episode 48 continued after episode 49 had ended; likewise, episode 51 continued after episode 52 was over. The convention at that time was to declare that a new episode had started when a new vent began to erupt. If the new vents died and the ones from the previous episode were still erupting, we reverted to the previous episode number. In the case of episodes 51- 53, the episode 52 vents erupted for three weeks; thereafter, the episode 51 vents were the sole vents active until episode 53 began several months later. Both the episode 51 and episode 53 vents were active during much of episode 53.

Eruptive episode and pause start-and-end times

Exact times are often known from field observations, but in many cases start-and-end times of eruptive activity were determined on the basis of tremor amplitude recorded by the STC seismometer near the eruption site. As indicated, these times are approximate.

Elevation measurements

Elevations of the surface of the Pu‘u ‘Ō‘ō lava pond, the crater floor, the flank vents, and floor of collapse pits were determined by a variety of means. The datum for most of these measurements was the "North Spillway Rebar," located in the spillway on the northeast rim of Pu‘u ‘Ō‘ō cone. The elevation of this rebar (866 m ASL) was determined from surveys conducted in 1988 and 1990.

Pond and crater-floor elevations

The various methods to measure pond-level, listed by the abbreviations given in Table 1, are described below. Crater-floor depths were determined by lowering a cable from the north spillway.

AO Aerial observations were usually made by helicopter pilots flying tours over the eruption site. Since they were in the area almost every day, their reports are a valuable addition to our record, even though this is the least accurate method of estimating pond level. Only those observations made by observers we deemed reliable are preserved in this document. At times pilots reported that the pond was rising or falling, without attempting to estimate its depth; these observations are also included here. Aerial observations were our only recourse during periods when the pond drained to a depth that wasn't visible from the crater rim.

RO Rim observations were made from the north rim of the crater at the site of our time-lapse camera. The depth of the pond could be estimated relative to the position of some feature, usually the crater floor, for which the depth was known. During periods of little change, this method was relatively accurate.

MC Mauro Coltelli, a visiting scientist from Italy, made many observations from the north rim in early 1992 using a rangefinder and inclinometer.

TL Time-lapse 8-mm movie cameras, situated on the north rim, took a picture of the pond every 1-3 minutes during much of the interval covered in this report. Pond level could sometimes be judged from these films, given good visibility and some feature of known depth with which to compare the pond level.

RT The rock toss was a sophisticated technique in which one person dropped a rock from the north spillway while an observer timed its descent to the lava pond.

RF Rangefinder measurements with the available instruments produced variable results and were rarely attempted.

BM Brunton compass measurements (using the inclinometer) from the north rim were the preferred method from September 1, 1992, through the end of the interval covered in this report. We obtained distance measurements via EDM from our time-lapse camera site on the north rim to the south spillway across the crater. Thereafter, we took inclinometer measurements to the level of the pond surface beneath the south spillway and calculated the depth. The estimated accuracy of these measurements is ±5 m.

Flank vent elevations

Elevations of the episode 50-53 vents were determined by leveling from known points on the crater rim, using the North Spillway Rebar as a datum, and, less frequently, by altimeter measurements. The leveling method employed a Leitz 2x hand level mounted on a monopod and lightweight fiberglass leveling rods. The estimated error of this method is ≤1 m.

In one instance, the depth to active lava beneath the sealed-over episode 51 vent was estimated using Very Low Frequency (VLF) measurements (see Kauahikaua and others, 1996, Bulletin of Volcanology, v. 57, p. 641-648), which are accurate to ± 3-5 m.

Collapse-pit elevations

The longer-lived vents were soon sealed over and hidden from view as lava fed directly into tubes. As the tubes cut down into the underlying tephra, the vents progressively lowered, and collapse pits formed over the vents. The elevation of the pit floor gives a maximum elevation for the underlying vent. Pit depths were determined by lowering a cable to the pit floor or by the rock-toss method.

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Tables

1. Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and episode 50-53 vent and collapse pit elevations.

Plates

1. Flows emplaced through February 8, 1992 and February 19, 1993, Pu‘u ‘Ō‘ō - Kūpaianaha eruption of Kīlauea Volcano

2. Flows emplaced through April 13, 1993 and September 21, 1993, Pu‘u ‘Ō‘ō - Kūpaianaha eruption of Kīlauea Volcano

Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and 50-53 vent and collapse pit elevations. Bold italic type indicates date/time when effusion paused or restarted. Datum for pond elevations is North Spillway Rebar, 866 m ASL.

Date	Time HST	*Pause start*	*Pause end*	Pond elev (m ASL) & method	Crater floor elev/depth	Vent or collapse pit elev (m ASL)	Comments
							Pond-depth estimation methods:
							AO = aerial observation, RO = rim observation
							MC = M. Coltelli data, TL = timelapse camera,
							RT = rock toss, RF = rangefinder,
1/17/1992				799 AO			BM = Brunton measurement
1/18/1992				806 RO			
1/24/1992				822 RO	831 / 35*		*Measured w/ cable from N spillway
2/7/1992				826 MC			***Kūpaianaha vent shuts down***
2/12/1992				824 MC			
2/16/1992				826 MC			
2/17/1992	***~1930***						***Episode 50 begins***
2/18/1992				781 RO		NE end 50 fissure=788*	*Measured by altimeter
2/19/1992				797 MC			
2/21/1992				796 RO			
2/22/1992				796 RO			
2/23/1992				796 RO			
2/28/1992				796 RO			
3/3/1992	45						UPPER EAST RIFT ZONE INTRUSION
	130	***1***					***Eruption stops, end of episode 50***
	1330			~766 AO*			*Rough estimate
3/7/92	***1245***		***1***	pond rising AO			***Episode 50 fissure extends--Episode 51 begins***
	1431			823 TL			
	2100	***2***					
	2400		***2***				
3/9/1992	900			821 RO			
	1530			811 MC			
3/10/1992	1100			806 MC			
3/11/1992	850			811 RO			
	1730			809 MC			
3/12/1992	***1519***	***3***					
3/13/1992	500			811 RO			
	1200			816 AO			
3/14/1992	***1130***		***3***	814 RO			
3/15/1992	***1800***	***4***					

Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and 50-53 vent and collapse pit elevations. Bold italic type indicates date/time when effusion paused or restarted. Datum for pond elevations is North Spillway Rebar, 866 m ASL.

Date	Time HST	***Pause start***	***Pause end***	Pond elev (m ASL) & method	Crater floor elev/depth	Vent or collapse pit elev (m ASL)	Comments
	1846			825 TL			
3/16/1992	1100			816 AO			
	2137			825 TL			
3/17/1992	***600***		***4***				
	1000			831 AO			
	1621			831 TL			
	2315			829 MC			
3/18/1992	***300***	***5***					
	600		***5***	824 MC			
	1233			829 TL			
3/19/1992	730			829 MC			
	1230			831 MC			
	1402			831 TL			
3/20/1992	708			825 TL			
	1235			824 TL			
3/21/1992	1200			822 MC			
3/23/1992	1630			828 AO			
3/24/1992	1200			828 AO			
3/26/1992	***1400***	***6***					
3/27/1992	~1100			822 RF	826 / 40*	NE end 51 fissure=817#	*Measured with cable from N spillway
							#Leveled from Spillway Rebar
3/29/1992	***930***		***6***				
3/30/1992	***2400***	***7***					
3/31/1992	***1230***		***7***				
4/3/1992	1215			821 RT		NE end 51 fissure=819*	*Leveled from Spillway Rebar
	2334			826 RO			
4/5/1992	907			821 RO			
4/9/1992	1200			813 RT			
4/16/1992	1138			813 RO	829 / 37*		*RO--assumes overflows of last week are ~3 m thick
4/17/1992	1549			826 TL			
4/19/1992	***2000***	***8***					
4/22/1992	1000			825 AO			
4/23/1992	337			826 TL			
	1100		***8***	826 AO			

Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and 50-53 vent and collapse pit elevations. Bold italic type indicates date/time when effusion paused or restarted. Datum for pond elevations is North Spillway Rebar, 866 m ASL.

Date	Time	***Pause***	***Pause***	Pond elev	Crater floor	Vent or collapse pit	Comments
	HST	***start***	***end***	**(m ASL)**	**elev/depth**	**elev (m ASL)**	
				& method			
	all day			826 TL			
4/24/1992	1030			823 RT	830 / 36*		*Rock toss
4/25/1992	1130			822 AO			
4/28/1992	A.M.			826 AO			
	1130	***9***					
4/30/1992	1300			829 RO			
5/3/1992	1757			830 AO			
5/4/1992	***539***		***9***				
5/5/1992				829 AO			
5/7/1992	1300			806 RO			
5/10/1992	1600			794 AO			
5/14/1992	1400			806 RO			
5/22/1992	1340			796 RO			
	1400	***10***					
5/24/1992	all day			796 AO			
5/26/1992				pond rising			
5/27/1992	***320***		***10***				
	811			dropping TL			
5/28/1992	***2020***	***11***					
5/29/1992	1220			811 RO			
6/2/1992	***~0530***		***11***				
	midday			831 AO			
	1720			822 AO			
6/3/1992	400			831 RO			
	1600			818 RO			
6/5/1992	***~1700***	***12***					
6/6/1992	***400***		***12***				
	1400			820 RO			
6/7/1992	***~0630***	***13***					
6/10/1992	***1325***		***13***	828 AO			
6/11/1992	1400			811 RO			
6/13/1992				820 RO			
6/16/1992	***~0500***	***14***					
6/18/1992	1200			828 RO			

Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and 50-53 vent and collapse pit elevations. Bold italic type indicates date/time when effusion paused or restarted. Datum for pond elevations is North Spillway Rebar, 866 m ASL.

Date	Time	*Pause*	*Pause*	Pond elev	Crater floor	Vent or collapse pit	Comments
	HST	*start*	*end*	(m ASL)	elev/depth	elev (m ASL)	
				& method			
6/20/1992	1435			830 AO			
	2121-2206			830 TL			
	2314		***14***				
6/21/1992	800			dropping AO			
	1630			816 AO			
6/27/1992				818 RO			
7/2/1992	1200			801 RO			
7/5/1992	1200			815 AO			
7/13/1992				799 RO			
7/21/1992				806 RO			
7/22/1992	***PM***	***15***					
7/23/1992	1030			796 AO			
7/24/1992	AM			<794 AO			
7/26/1992	1300			<790 AO			
7/27/1992	***1030***		***15***				
7/28/1992	1657			824 AO			
7/29/1992	1130			816 RT			
7/31/1992	1500			806 AO			
8/3/1992	1000			801 RO			
8/6/1992	1000			794 AO			
8/11/1992	***~2000***	***16***					
8/15/1992	800-1100			pond rising AC			
	~1300		***16***				
8/18/1992	1300			804 RO			
8/27/1992	1150			803 RO			
8/29/1992	***~0800***	***17***					
9/1/1992	1200			815 BM			
9/2/1992	***1400***		***17***	830 AO			
9/8/1992	1200			820 AO			
9/9/1992	***900***	***18***					
9/10/1992	1130			pond low AO			
9/12/1992	1100			pond rising AC			
	1700		***18***				
9/18/1992	1100			796 BM			

Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and 50-53 vent and collapse pit elevations. Bold italic type indicates date/time when effusion paused or restarted. Datum for pond elevations is North Spillway Rebar, 866 m ASL.

Date	Time	*Pause*	*Pause*	Pond elev	Crater floor	Vent or collapse pit	Comments
	HST	*start*	*end*	(m ASL)	elev/depth	elev (m ASL)	
				& method			
9/24/1992				815 BM			
9/27/1992	***~0600***	***19***					
10/2/1992	1025-1500			pond rising AO			
	1951						Earthquake--S. flank Kīlauea, M 4.3, 7 km deep
10/3/1992	***~0330***		***19***				***New fissure erupts--Episode 52 begins***
	1530					E end of 52 fissure=806*	***51 vent restarts***
							*Leveled from West Flank Rebar
	1600			796 BM			
10/7/1992	1000			801 BM			
10/12/1992	1300			786 RO*			*Pond too low for Brunton measurement
10/16/1992	1300			791 RO*			*ditto
	p.m.						***Last observed activity at 52 vent***
10/21/1992	1200			789 RO*			*Pond too low for Brunton measurement
10/22/1992	1200			789 RO*			*ditto
10/28/1992	1100			794 AO			
10/29/1992	930			794 AO		51 vent = 789*	*VLF measurement
11/5/1992	1045			794 AO			
11/21/1992	1600			796 RO			
12/15/1992	1000			<791 RO			
1/3/1993	***1600***	***20***					
1/4/1993	***1528***		***20***				
1/12/1993	1300			791 AO			
1/25/1993	1200			791 AO			
1/26/1993						51 pit = 798*	*Measured by rock toss (20 m deep)
2/7/1993	2325						UPPER EAST RIFT ZONE INTRUSION
2/8/1993	***400***	***21***					
	late p.m.						Pond drained & crater floor collapsed, time unknown
2/9/1993	1040			~766*	781 / 85 RO		*Pond not visible from rim, rough estimate
2/10/1993	1530			pond rising AO*			*Fresh overflows on crater floor rubble
2/12/1993	1200			781 RO		52 pit=794*	*Measured by cable & leveling
2/16/1993	***1200***		***21***				
2/18/1993	1000			785 RO			

Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and 50-53 vent and collapse pit elevations. Bold italic type indicates date/time when effusion paused or restarted. Datum for pond elevations is North Spillway Rebar, 866 m ASL.

Date	**Time**	***Pause***	***Pause***	**Pond elev**	**Crater floor**	**Vent or collapse pit**	**Comments**
	HST	***start***	***end***	**(m ASL)**	**elev/depth**	**elev (m ASL)**	
				& method			
2/20/1993	AM			rising AO			
	1450			801 BM			***New vent erupts--Episode 53 begins***
	PM			dropping AO		53 vent=792*	*Leveled from 52 vent
2/21/1993	1230			789 BM			
2/26/1993	1200			799 BM	806 / 60*		*Brunton measurement. Sometime between 2-21 and
							2-26, the pond rose to 806 m, building the new floor
3/4/1993	1200			799 BM			
3/7/1993	1600			806 A0			
3/10/1993	1500			800 AO			
3/12/1993	1200			795 BM			
3/18/1993	1200			792 BM			
3/25/1993	1000			799 BM			
4/1/1993	1200			789 BM			
4/9/1993	1000			793 BM			
4/16/1993	1000			789 BM			
4/27/1993	1000			789 BM			
5/12/1993	1200			789 BM			
5/20/1993	1000			791 BM			
5/27/1993	1000			782 BM			
6/3/1993	1000			782 BM			
6/8/1993	257						Earthquake--S. flank Kīlauea M 4.9, 7.6 km deep
6/10/1993	1000			772 BM			
6/25/1993	1000			772 BM			
7/1/1993	1000			788 BM			
7/8/1993	900			792 BM			
7/29/1993	900			786 BM			
8/5/1993	1000			787 BM			
8/20/1993	1000			785 BM		51 pit = 787*	*Measured by rock toss (31 m deep)
8/27/1993	900			785 BM			
9/2/1993	830			782 BM			
9/9/1993	800			779 BM			
9/21/1993	900			784 BM			
9/28/1993	830			779 BM			
10/7/1993	900			785 BM			

Pause start and end times, Pu‘u ‘Ō‘ō pond and crater floor elevations, and 50-53 vent and collapse pit elevations. Bold italic type indicates date/time when effusion paused or restarted. Datum for pond elevations is North Spillway Rebar, 866 m ASL.

Date	**Time**	***Pause***	***Pause***	**Pond elev**	**Crater floor**	**Vent or collapse pit**	**Comments**
	HST	***start***	***end***	**(m ASL)**	**elev/depth**	**elev (m ASL)**	
				& method			
10/14/1993	1000			783 BM			
10/29/1993	900			783 BM			
11/4/1993	900			782 BM			
11/16/1993	900			782 BM			
12/9/1993	1130			782 BM			
12/27/1993	930			782 BM		53 pit = 776*	*Meaured by cable (16 m deep)
1/6/1994	930			782 BM			
1/25/1994	1000			782 BM			
2/8/1994	1000			~782 AO			
2/23/1994	1400			~782 AO			
3/4/1994	900			776 RO*			*Pond too low for Brunton measurement
3/9/1994	930			771 RO*			*ditto
3/13/1994	1200			771 AO*			*ditto
3/29/1994	900			776 RO*			*ditto