COOPERATOR REPORT TO HAWAII COUNTY CIVIL DEFENSE

Preliminary Analysis of the ongoing Lower East Rift Zone (LERZ) eruption of Kīlauea Volcano: Fissure 8 Prognosis and Ongoing Hazards

Prepared by the U.S. Geological Survey Hawaiian Volcano Observatory

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Introduction

In late April 2018, the long-lived Puʻu ʻŌʻō vent collapsed, setting off a chain of events that would result in a vigorous eruption in the lower East Rift Zone of Kīlauea Volcano, as well as the draining of the summit lava lake and magmatic system and the subsequent collapse of much of the floor of the Kīlauea caldera. Both events originated in Lava Flow Hazard Zone (LFHZ) 1 (Wright et al, 1992), which encompasses the part of the volcano that is most frequently affected by volcanic activity.

We examine here the possible and potential impacts of the ongoing eruptive activity in the lower East Rift Zone (LERZ) of Kīlauea Volcano, and specifically that from fissure 8 (fig. 1). Fissure 8 has been the dominant lava producer during the 2018 LERZ eruption, which began on May 3, 2018, in Leilani Estates, following intrusion of magma from the middle and upper East Rift Zone, as well as the volcano's summit, into the LERZ. The onset of downrift intrusion was accompanied by collapse of the Puʻu ʻŌʻō vent, which started on April 30 and lasted several days. Kīlauea Volcano's shallow summit magma reservoir began deflating on about May 2, illustrating the magmatic connection between the LERZ and the summit. Early LERZ fissures erupted cooler lava that had likely been stored within the East Rift Zone, but was pushed out in front of hotter magma arriving from farther uprift. This hotter magma, similar in composition to lava that had been erupting at Pu`u `O`o, arrived in mid-May, coincident with an increase in discharge from the fissures.

The volume of lava erupted during the current activity exceeds that of many past eruptions. Given this volume and the sustained withdrawal of magma from the summit reservoir without appreciable deformation in the lower East Rift Zone, it is most likely that the LERZ eruption may continue for months to years. While additional fissures may form either uprift or downrift of the current activity, the continued focus of activity within the current fissure system after 10 weeks of activity (as of July 15, 2018) makes this scenario increasingly unlikely. This document reviews current activity, focusing on the fissure 8 vent, channel, and ocean entry. It describes a credible set of future scenarios for fissure 8 and discusses uncertainties. This document is meant as a guide for managing hazards and risks in Kīlauea's East Rift Zone.

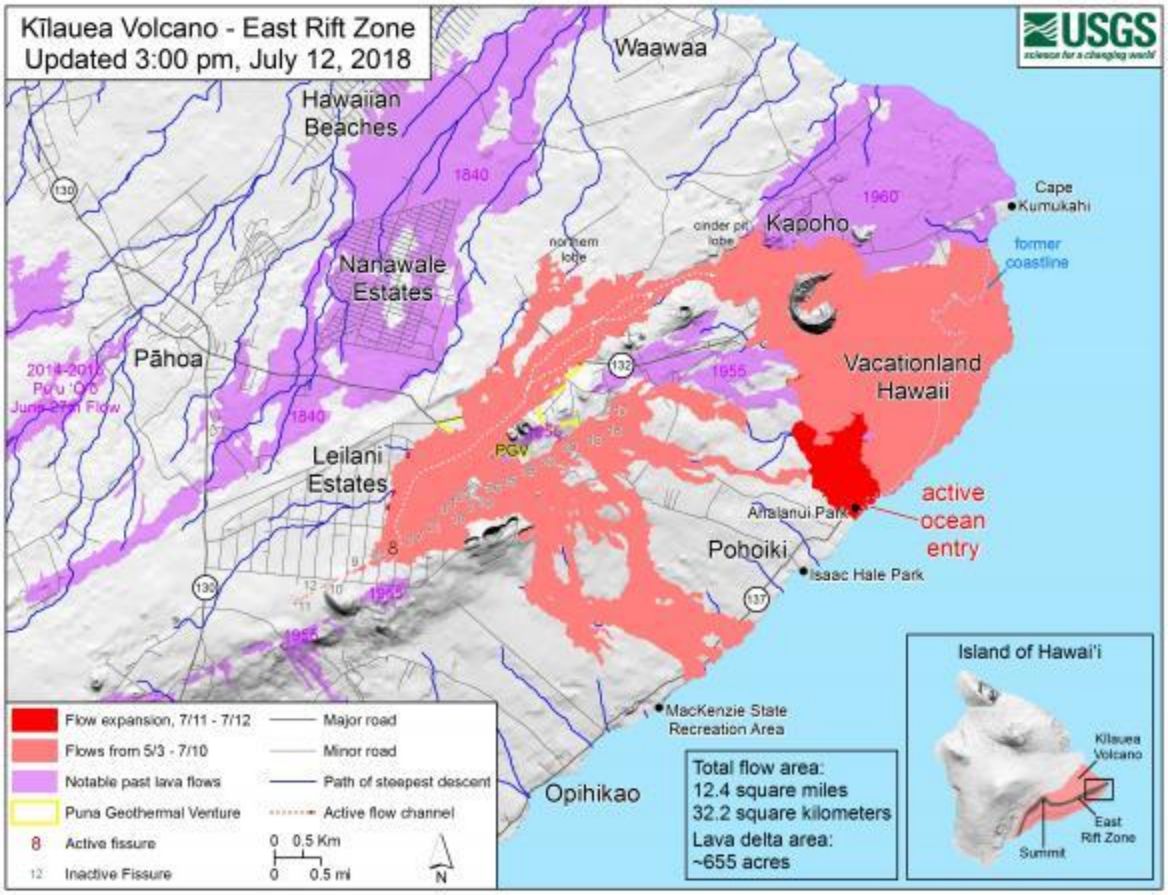

Figure 1. Map of the 2018 eruption as of July 12 (pink and red) with lava flows from the 1840, 1955,1960, and 2014-2015 eruptions in purple.

Summary of Activity April 30 – July 15

In early 2018, the lava lake in a small pit crater within Halemaʻumaʻu crater rose to high levels, overflowing a few times. On April 30, the Puʻu ʻŌʻō vent in the middle East Rift Zone began to collapse, and seismicity and deformation migrated downrift signifying an intrusion of magma into the LERZ beneath Leilani Estates subdivision. Cracks began to form within the subdivision during the next few days.

An eruption started on May 3 with brief spattering from a fissure in the southeastern portion of the subdivision. Additional short-lived fissures opened along a 6.7 km (4.2 mi) stretch of the lower East Rift Zone and erupted sporadically, both uprift and downrift over the following week, with only relatively small, viscous flows being produced.

There was a marked increase in the vigor of the eruption starting on May 18, coincident with the production of more fluid lava. Activity became longer-lived, and large, fast-moving channelized flows were produced that first reached the ocean along Kīlauea's southeast coast on May 20 but only remained active for a few days. Activity eventually coalesced at fissure 8, and the other fissures became inactive or sporadically weakly active through June.

Fissure 8 was first active May 5, but reactivated during the third week of May with episodic spattering, and began to erupt with a vigorous fountain late in the day on May 27, producing a relatively fast moving channelized flow that travelled northeast. The fountain abruptly stopped the following morning (May 28), and the flow it fed stalled after crossing Pohoiki Road. Fissure 8 restarted later the same day, however, and began feeding a new fast-moving, channelized flow northeast and depositing tephra downwind. This new flow crossed Pohoiki Road early the next morning (May 29) and Highway 132 in the afternoon, isolating Puna Geothermal Ventures (PGV).

The fissure 8 channelized flow continued to advance rapidly downslope over the following days, reaching the ocean at Kapoho Bay late in the day on June 3. The flow filled the bay and spread along the coast quickly, destroying hundreds of homes and the tide pools south of Kapoho Bay.

Fountaining and spattering from fissure 8 began constructing a spatter cone (fig. 2), which by the end of June was about 55 m (180 ft) high and open to the northeast. Discharge from the vent continues to feed directly into the relatively stable channel, which carries lava 13 km to the ocean. Although difficult to measure, the most plausible estimates of the eruption rate from fissure 8 range from 50 to 150 m^3/s.

After several blockages and subsequent clearing or channel rerouting around the blockage to keep the channel flowing to the north and east of Kapoho Crater, the channel overflowed just northwest of Kapoho Crater and a new lobe advanced southward along the west margin of the previous flow and entered the ocean on July 12. This diversion of the channel flow was the first major change in the fissure 8 channel. Even though the channel no longer directly fed the massive lava delta to the southeast of Kapoho Crater, lava continues to ooze out of the flow front into the ocean in many locations.

Ongoing fissure 8 hazards

Figure 2. Fissure 8 fountains within a cinder and spatter cone feeding a wide channelized flow.U.S. Geological Survey (USGS) Photo taken on June 22, 2018.

The upper four kilometers of the channel (fig. 3) stands 16 to 22 m above ground level and is as much as 400 m wide. Its middle section is braided and relatively narrow, while its lower section merges again into a single channel feeding a gradually thickening and spreading ʻaʻā flow at the coast. The main hazard from the source cone and the channel system is failure of the cone or channel walls or blockage of the channel where it divides in narrower braids. Either could divert most, if not all, of the lava to a new course depending on where the breach occurs.

Figure 3. Upper part of the fissure 8 channel. USGS photo taken on June 22, 2018. Lava is flowing from lower right to upper center of the photo.

LERZ areas potentially threatened by fissure 8 channel blockages or failures

Estimates of future potential flow paths will be made for three areas along the north edge of the fissure 8 channel system using drainage areas and the steepest descent lines calculated from a 10 m digital elevation model. The drainage areas, here called lavasheds (fig. 4; Kauahikaua et al, 2003), define the areas in which fluids flow toward a steepest descent line (fig. 4; Kauahikaua et al, 2017).

Only flows to the north of the existing channel system will be considered because, as of the date of this report, residents to the south have been evacuated while residents to the north have not been evacuated.

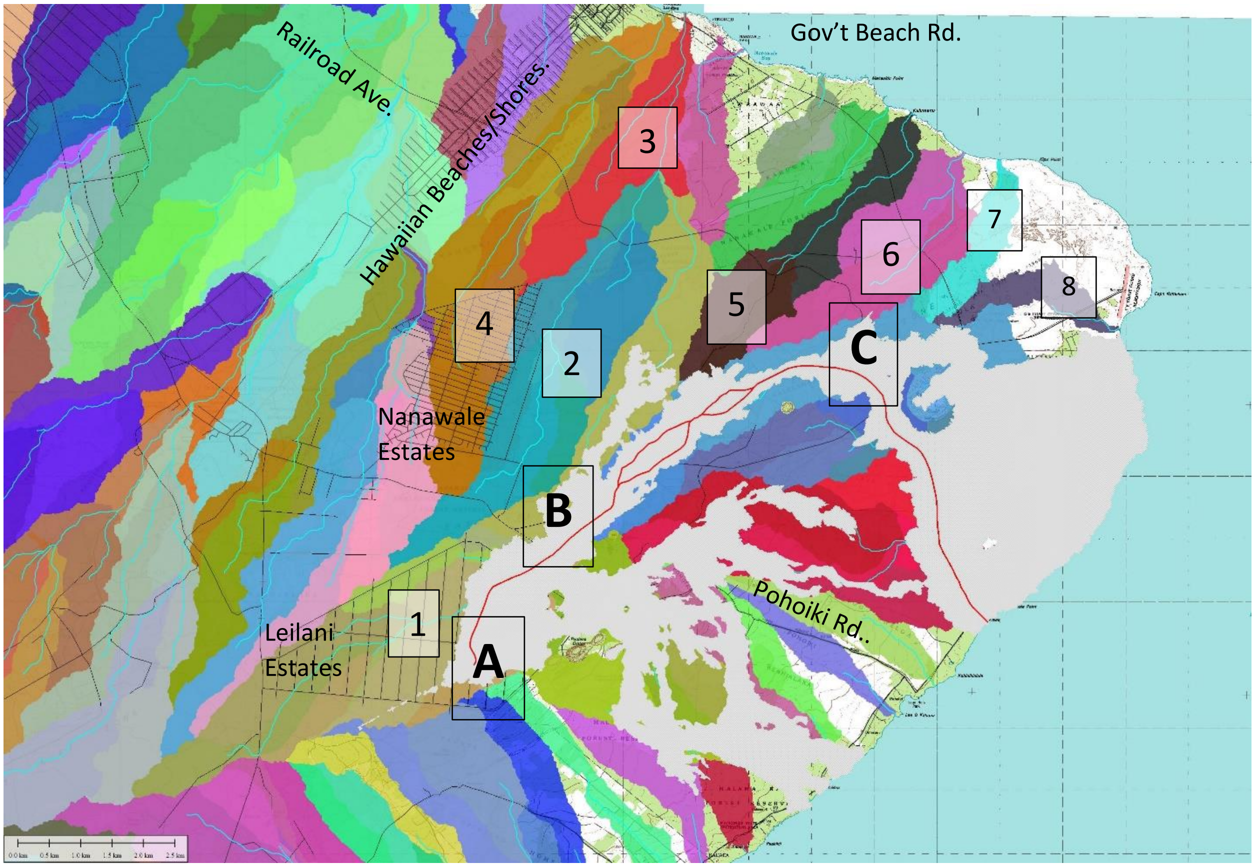

Figure 4. Map of lavasheds that drain through steepest descent lines (light blue). The numbered lavasheds are described in the text. The grey cross-hatched lava flow polygon is the erupted lava from all fissures as of July 12, 2018. The red line within the July 12 lava flow polygon represents the fissure 8 channel system on that same date.

Upper channel (A – B)

Any major flow caused by a breach of the west wall of the channel between the vent (A) and the intersection Pohoiki Road and Highway 132 (B) is likely to advance northeast into lavashed 1, hugging the northeast edge of the existing flow. Beyond Highway 132, the flow may enter lavashed 2 and become captured by steepest descent lines that pass along the eastern boundary of the Nanawale Estates subdivision (along Road A and possibly Seaview Road). If the flow continues to advance, it will ultimately cross Railroad Avenue and Government Beach Road, enter lavashed 3, and reach the ocean between 1.3 and 2.3 km southeast of Kahakai Boulevard (Hawaiian Beaches). If the flow enters lavashed 2 and stalls, subsequent lava flows advancing along the west side of the stalled flow could enter lavashed 4 in Nanawale Estates subdivision and ultimately reach the coast slightly closer to the Hawaiian Beaches and Hawaiian Shores subdivisions.

Middle channel (B – C)

The fissure 8 channel becomes braided northeast of B, with narrower sections that could form choke points. If one of the narrower sections becomes blocked by large collapse fragments from the channel wall or spatter cone, lava could be diverted out of the channel. If, in this scenario, part of the channel is redirected to the north, lava could feed into lavasheds 5 or 6 and threaten homes and infrastructure in the Noni Farms area, Railroad Ave., Papaya Farms Rd., and Government Beach Rd. before entering the ocean between Kalamanu and the northern edge of the 1960 lava flow.

Lower channel (below C)

The ‘a‘ā channel has been unstable in the area of Kapoho Crater (C) and beyond to the ocean. Most recently on July 9-10, a channel overflow in the area northwest of Kapoho Crater created a new lobe that advanced south along the west margin of the existing flow and entered the ocean on July 12 destroying a school and a beach park; however, the previous flow to the northeast continued to ooze lava into the ocean along its entire front. Although not fed by any surface flow, the earlier flow north and east of Kapoho Crater to the ocean is still oozing lava into the ocean from its front and could potentially thicken and widen beyond the current flow margins as it has in the past several weeks. Flows advancing from a breach in the northeast side of the channel near Kapoho Crater may enter lavasheds 7 or 8 and again threaten the the handful of remaining structures in the Kapoho Ag Lots and Beach Lots, structures built on the eastern section of the 1960 lava flow, and the Cape Kumukahi Lighthouse.

Gas and Tephra Hazards

Vog

Volcanic gas emissions from the fissure 8 vent (fig. 5) have continued to be unusually high since mid-May (over 30,000 metric tons per day—more than 4 times the average daily amount from Kīlauea’s summit lava lake prior to May 3), coincident with the increase in eruptive vigor. This has caused a significant increase in vog in downwind areas including the Kona coast. When trade winds slacken, easterly and southeasterly winds can blow gases into areas on the east side of the Island of Hawai‘i. Fissure 8 is now the dominant producer of volcanic gas on the Island of Hawai‘i and will remain so as long as current rates of eruption continue.

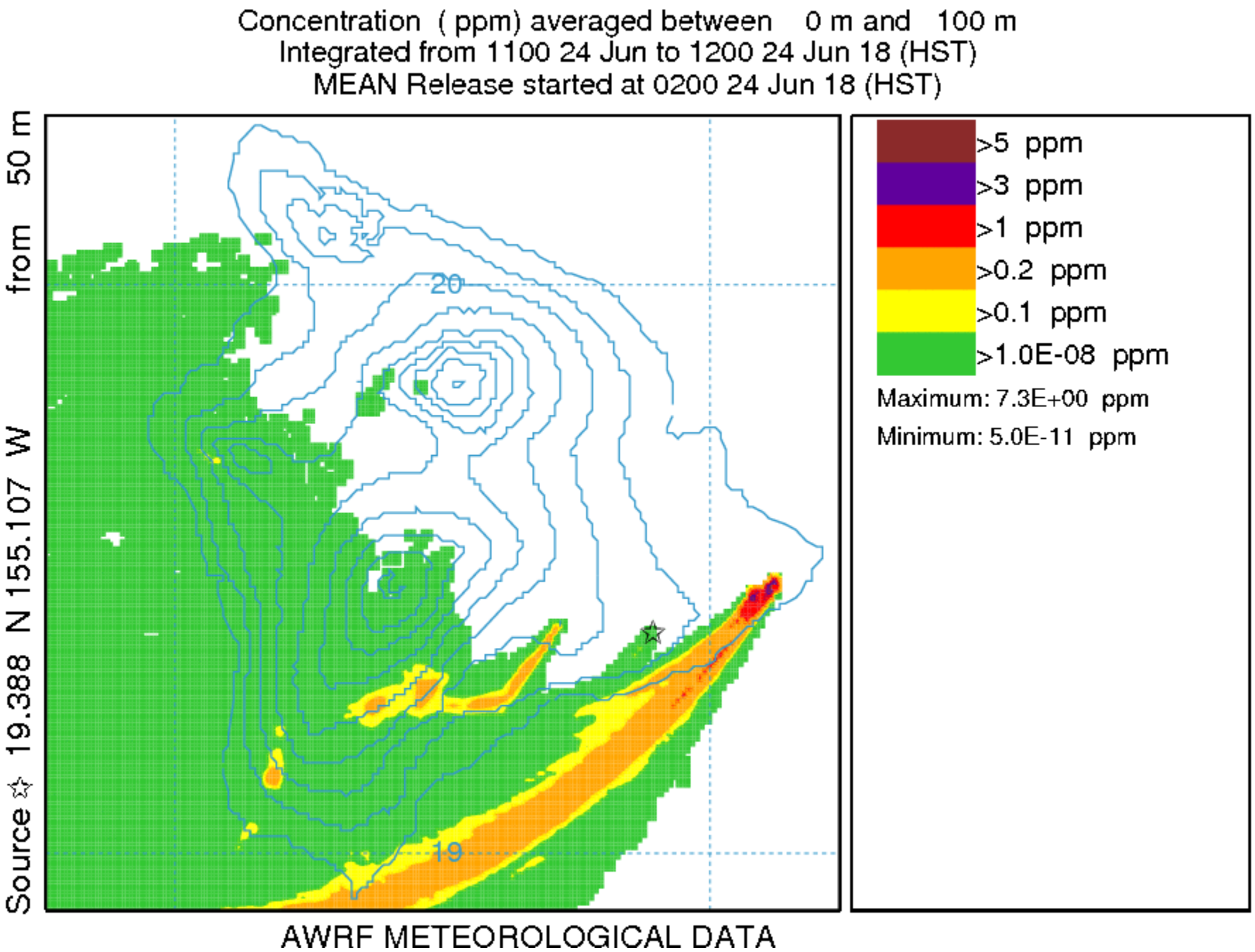

Figure 5. Example map from the SO2 forecast available at https://weather.hawaii.edu/vmap/hysplit/

Increased distribution of tephra fall

At the moment, lava from fissure 8 erupts from a 60–80-m-long fissure segment. Discharge from the fissure was initially characterized by relatively steady low fountaining but has evolved into more chaotic Strombolian (large bubble bursts) activity. If the eruption begins to coalesce into single point along the fissure, higher fountains (100-300 m) could be produced. This would result in more widespread deposition of Pele's hair and cinder. Pele's hair has already been reported several times in Pāhoa (about 5 km or 3 mi northwest of fissure 8 fountains) during slack or southerly winds. Both the 1955 and 1960 eruptions in the same general area produced fountains much higher than what has been seen thus far during the current eruption.

Tephra fall from 100-300 m fountains could produce a 30 cm (1 ft) deposit several hundred meters (yards) downwind. This deposit may be thinner if the wind is variable and spreads the tephra laterally. Previous eruptions produced a 30 cm (1 ft) thick deposit up to 625 m (2,000 ft) downwind from the vent at Kīlauea Iki, 1.6 km (1 mi) downwind from the vent at Mauna Ulu, and 900 m (3,000 ft) from the vent at Puʻu ʻŌʻō.

Ocean entry hazards (from Hawaiian Volcano Observatory, 2017)

Figure 6. The lava delta (looking south) built by lavas traveling 8 miles from fissure 8 (erupting in the distance). USGS photo taken on June 18, 2018.

Delta collapse

The entry of lava into the ocean at Kapoho (fig. 6) has made 6-km-wide lava delta that now extends up to 800 m (0.5 mi) from the pre-eruption coastline outside Kapoho Bay. As with any lava delta, there is the potential for collapse without warning, which could lead to explosions caused by the interaction of seawater with hot rock exposed by the collapse.

Hydrovolcanic explosions

Boat tours, as well as observers in the air, have reported hydrovolcanic explosions occurring without warning up to 100 m offshore. These events, which last 10–15 seconds, have been observed rarely, but may occur several times per day. They burst through the water, sending fragments of lava and hot water as high as 25 m up to hundreds of meters. It is likely they are caused by the underwater emplacement of ʻaʻā lava where large amounts of molten lava suddenly come in contact with seawater during collapse of a lava conduit.

Both delta collapse and hydrovolcanic explosions are hazards primarily to boats and other water craft , as this area is currently closed to foot traffic. Based on an extensive study of these coastal hazards during the 35-year eruption of the Puʻu ʻŌʻō vent, a zone of radius 300 m is considered a minimum high hazard around pāhoehoe lava deltas (Mattox and Mangan, 1997; Hawaiian Volcano Observatory, 2017). The 2018 Kapoho lava delta is composed of ʻaʻā lava and more study will be required to ascertain whether this high hazard margin needs to be modified.

Figure 7. Photo of the laze plume from the fissure 8 ocean entry (leftmost incandescence) lit by the source fountain (rightmost incandescence) and lava channel. White lights to the far right are from Pāhoa. Photo taken on the evening of June 20, 2018 by Klaus Hodapp.

Laze (lava haze) plume

The large laze plume (fig. 7) produced at the ocean entry poses a health risk to those exposed to it. It will continue as long as lava enters the ocean. The composition of the plume is the result of the interaction between molten basaltic lava and sea water and includes hydrochloric acid, hydrofluoric acid, and halide precipitate. It is not known how far downwind harmful constituents drift in a laze plume of this size. At times onshore winds carry the laze plume an unknown distance inland.

How long will this eruption last?

The current eruption started with 23 days of sporadic eruption from 24 different fissures covering a distance of 6.7 km (4.2 mi), some composed of multiple segments, before focusing at fissure 8, which has been erupting continuously since May 27. More than 430 × 10^6 m^3 of lava has been erupted so far (as of July 15). Most of this volume has come from fissure 8, which is discharging lava at an estimated rate of about 100 m^3/s. This exceeds the duration (38 days), erupted volume (122 × 10^6 m^3 of lava), and peak time-averaged eruption rate (38 m^3/s; for the first 2 week) of the 1960 eruption. While the current eruption has not yet lasted as long as the 1955 eruption (88 days, including pauses), it has erupted far more lava at a higher rate—the 1955 eruption produced 81 × 10^6 m^3 of lava at a peak time-averaged discharge rate of 31 m^3/s (for the first phase of the 1955 eruption). In this regard, the current eruption may be more similar to the 1840 eruption, which, though only lasting for 26 days, erupted 210 × 10^6 m^3

of lava at a time-averaged discharge rate (for the entire eruption) of 94 m^3/s. (See Appendix A for brief overviews of the 1840, 1955, and 1960 eruptions, as well as the 1924 intrusion.)

A glance around the LERZ finds numerous large pyroclastic cones indicating repeated activity in this area. Puʻu Kaliu, which borders the southern edge of Leilani Estates, and a younger vent complex which overlies it, are both very close to the location of the current fissures. Both of these older eruptions are thought to have produced about 200×10^6 m^3 of lava (Moore, 1992). Other eruptions in the area, including flows erupted in the late 1700s, may have similar volumes. Perhaps eruptions in the LERZ only continue until pressure in the magmatic system, partly controlled by vent elevation, becomes too low to keep the eruption going. The volume of the current eruption has exceeded that of these older nearby eruptions. The steady discharge from fissure 8 shows no sign of waning supply, suggesting relatively constant magma pressure; the lack of significant ground deformation in this area shows that there is neither storage nor withdrawal from the May intrusion since its initial emplacement.

If the ongoing eruption maintains its current style of activity at a high eruption rate, then it may take months to a year or two to wind down. While this seems to be the most likely outcome, a pause in the eruption, followed by additional activity, cannot be ruled out, nor can an abrupt cessation or a transition to steady, longer-lived activity at a lower effusion rate.

The shield complex of Heiheiahulu, 9.5 km (6 mi) upslope, represents a more voluminous eruption that could have lasted several years (Moore, 1992), similar to the 35-year-long eruption of Puʻu ʻŌʻō. Both of these eruptions started with several short ʻaʻā flows erupted along a 3.5 km (2.2 mi-) and 7 km-(4.3 mi-) long fissure system, respectively, before centralizing to a single vent (Moore, 1992; Wolfe et al, 1988) and eventually erupting tube-fed pahoehoe flows. The 2018 LERZ eruption has erupted only ʻaʻā flows so far but the eruption rate is high and a stable channel system is being elevated by frequent spillovers of pāhoehoe flows above Kapoho Crater. The flow maintains its ʻaʻā character below that point to the ocean with a more pasty lava oozing from its interior along its edges. The change in the character of the channel toward pahoehoe may signal a gradual change of eruption style and a potentially longer eruption with more destruction of infrastructure.

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Appendix: Comparisons to other eruptions along the LERZ

The ongoing LERZ eruption is occurring in a similar location to the 1840, 1955, and 1960 LERZ eruptions, as well as the location of intrusive activity in 1924. Discharge or effusion rates during the peak phases of the 1955 and 1960 eruptions are very similar to that occurring now. The onset of the current activity, with fissures opening both uprift and downrift from the initial outbreak, shifting back and forth amongst these fissures, and starting and stopping erratically, was similar to the 1955 and the 1960 eruptions, although the 1960 fissure system was considerably shorter so the effects of the eruption were more focused. The start of the current eruption prior to the continuous eruption of fissure 8 that started on May 27, resembles the opening of the 1955 eruption, but ramped up more slowly and was more chaotic. The current eruption has not produced high (>50 m?) fountains of 1955 and 1960 eruption, and instead has evolved into a relatively steady eruption at fissure 8 characterized by low fountaining and Strombolian activity that feeds a large-volume channelized flow.

1840 LERZ eruption: May 30-June 24 (See Coan, 1841)

The 1840 eruption started in the upper East Rift zone and quickly migrated to a fissure just west of present day Pāhoa. “On Monday, June 1st, the stream began to flow off in a northeasterly direction and on the following Wednesday, June 3d, at evening, the burning river reached the sea having averaged about half a mile an hour in its progress. . . Sometimes it is supposed to have moved five miles an hour, and at other times, . . . make no apparent progress. . . For three weeks this terrific river disgorged itself into the sea with little abatement.”

The fissure sources extended about 6.1 km (3.8 mi) along a NE-SW trend parallel to, and 2.6 km (1.6 mi) northwest of, the 2018 fissure system. The volume of the 1840 flow was more recently estimated to be 210 x 10^6 m^3 at an average rate of 94 m^3/s over 26 days of the eruption. The distance from fissure vent to coast is about 11 km (7 mi) for an average initial advance rate of 150-230 m/hr (170-250 yds/hr).

Also of interest were the changes at Kīlauea summit just before this eruption started. “For several years past the great crater of Kilauea [sic] has been rapidly filling up, by the rising of the superincumbent crust, and by the frequent gushing forth of the molten sea below. In this manner the great basin below the black ledge, which has been computed from three to five hundred feet deep, was long since filled up by the ejection and cooling of successive masses of the fiery fluid. These silent eruptions continued to occur at intervals, until the black ledge was repeatedly overflowed, each cooling, and forming a new layer from two feet thick and upwards, until the whole area of the crater was filled up, at least fifty feet above the original black ledge, and thus reducing the whole depth of the crater to less than nine hundred feet. This process of filling up continued till the latter part of May, 1840, when . . . the whole area of the crater became one entire sea of ignifluous matter, raging like old ocean when lashed into fury by a tempest. For several days the fires raged with fearful intensity, exhibiting a scene awfully terrific. For several days . . The infuriated waves sent up infernal sounds, and dashed with such maddening energy against the sides of the awful caldron, as to shake the solid earth above, and to detach huge masses of overhanging rocks, which, leaving their ancient beds, plunged into the fiery gulf below. So terrific was the scene that no one dared to approach near it, and travellers [sic] on the main road, which lay along the verge of the crater, feeling the ground tremble beneath their feet, fled and passed by at a distance . . . Every thing [sic] within the caldron is new. Not a particle of lava remains as it was when I last visited it. All has been melted down and re-cast. All is new."

While the summit and rift zone activities bear some similarities to 2018 events, the chronological order is reversed with the summit's apparent collapse preceding the LERZ eruption in 1840 while the 2018 summit collapse started after the LERZ eruption began.

1924 LERZ intrusion (HVO website)

After years of rising lava levels within, and overflows from, Halemaʻumaʻu crater, the lava lake dropped out of sight in February 1924. It was followed by an earthquake swarm that began in early April, reaching a peak on April 23 with ground cracking, faulting, at least 3.6 m (12 ft) of coastal subsidence, and hundreds of felt earthquakes indicating the intrusion of magma from the summit into the LERZ. Ultimately, no lava was erupted.

"Halemaʻumaʻu Crater was 115 m (377 ft) deep following the draining of the lake. As seismicity waned in lower Puna, the crater floor began to collapse on April 29, deepening to more than 150 m (490 ft) on May 1 and nearly 210 m (690 ft) on May 7. Frequent dust clouds indicated continuing collapse in the following days."

". . . more than 50 explosive events during a 2.5-week period in May 1924. The explosions were then, and remain today, the most powerful at Kīlauea since the early 19th century, throwing blocks weighing as much as 14 tons from the crater. Halemaʻumaʻu doubled in diameter, deepened to about 400 m (1300 ft), and drastically changed in behavior—for the next 85 [sic; 84] years it no longer hosted a long-lived lava lake, until one returned in 2008."

Although there was no LERZ eruption due to this activity, the subsidence and plentiful earthquakes suggested an intrusion similar to the 2018 intrusion and it was followed by summit collapse and explosive events. No evidence of an offshore eruption has been found after several submarine expeditions in the area.

1955 LERZ eruption: February 28–May 26 (see Macdonald and Eaton, 1964)

The 1955 LERZ eruption lasted for 88 days, but consisted of three eruptive periods separated by pauses in activity.

The first period of the eruption lasted from February 28 to March 7 (8 days), and consisted of fissures that extended 5.7 km (3.5 mi) from Puu Honuaula to Kapoho Crater, along a trend overlapping the eastern part of the 2018 fissure system, but north of it. The 1955 fissures generally propagated to the northeast, but chaotically, with activity starting and stopping and shifting back and forth along the rift zone. This behavior was similar to that displayed during the early part of the current activity, but ramped up more quickly, with longer-lived fissures, higher fountains and spattering, and more voluminous lava flows. There was also considerable steam and ash venting, which has only been a very minor part of the current activity. The lava erupted in 1955 was among the most differentiated lavas on Kīlauea.

The first eruptive period in 1955 ended abruptly on March 7, but seismicity continued southwest of the initial breakout point near the current site of the PGV facility. The second period of the eruption began March 12 in the area where the continued seismicity was occurring. This area is south of Puu Kaliu, which is on the southern edge of Leilani Estates. The second set of 1955 fissures overlap with the western part of the current fissure system, but are south of it. This lava was less evolved (fresher) than the magma erupted during the first eruptive period that had been stored underground for at least decades.

Activity associated with the second period of the eruption (34 days) along a 7 km (4.3 mi) long fissure system to the southwest of the first eruption period fissure system, also ramped up quickly, producing fountains within a few days that were higher than any that have occurred during the current activity, and sending lava to the ocean. Outbreaks continued to occur progressively farther southwest, with some exceptions, producing fast-moving flows. Fountaining exceeded 250 m (820 ft) by the end of the first week. Most of the fissures were short-lived (hours to a few days), and a few vents started and stopped repeatedly. The activity stopped on April 7.

After a pause of 16 days, during which seismicity continued, the third period of the eruption started unexpectedly on April 24 with a resumption of activity at the western fissures. The eruption was episodic and relatively weak initially, but its vigor gradually increased through mid-May. On May 16, there was a sudden increase in output near the west end of western fissure system, with fountaining and new fast-moving flows. After 32 days of activity, fountaining ended abruptly on May 26, accompanied by a marked decrease in subsequent absence of notable seismicity.

About 81×10^6 m^3 of lava erupted (dense rock equivalent using 25% void space). The time-averaged dense rock equivalent (DRE) discharge rate of 14 m^3/s over the 66 days of actual eruption. Considered separately, the three eruptive periods equate to time-averaged DRE discharge rates of 31 m^3/s (period 1), 18 m^3/s (period 2), and 7 m^3/s (period 3).

1960 LERZ eruption: January 13–February 19 (see Richter et al., 1970)

The 1960 eruption, which lasted for about 5 weeks, opened along nearly the entire 1.4 km (0.9 mi) length of its fissure system at the onset of the eruption. These fissures behaved erratically for the first few days, often starting and stopping, but coalesced around a few points and began feeding fountains more than 400 m high by the end of the first week of activity. Early activity often included phreatic steam and ash venting. The high fountaining was accompanied by heavy tephra fall, and a large tephra cone was built.

A few weeks later, after a substantial edifice, filled with ponded lava, had grown around the dominant vents, two new fissures opened to the east of, and along the same trend as, the initial line of fissures. This may have been due to an increase in head pressure in the magmatic system in response to construction of the tephra cone complex and ponded lava.

The lava chemistry changed from more-evolved (stored magma) to fresher (directly from the summit reservoir) about half way through the eruption. This did not seem to cause a change in eruptive behavior. The dying phase of the eruption lasted from Feb 7 to 20, with a marked reduction in discharge. While slow deflation at the summit began about 4 days after the eruption started, summit collapse really began in earnest on about February 7, coincident with the start of the dying phase of the eruption.

About 122×10^6 m^3 of lava was erupted. The time-averaged discharge rate was about 38 m^3/s during the first two weeks of the eruption.