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EDITORIAL

The historic events at Kīlauea Volcano in 2018: summit collapse, rift zone eruption, and M_w 6.9 earthquake: preface to the special issue

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Kīlauea Volcano (Fig. 1), on the Island of Hawai'i, has had a prominent role in the science of volcanology and a long history of generating new insights into how volcanoes operate (Tilling et al. 2014; Garcia 2015). Native Hawaiians shared ideas on the behavior of the volcano with early Western visitors to Kīlauea, addressing the basic geometry of magma storage and transport (Ellis 1825; Bishop 1827). The lava lake activity at Kīlauea's summit in the 1800s and early 1900s fascinated early geologists, such as Dana (1890), who published one of the first inquiries into the fundamental processes of Hawaiian volcanoes. The sustained activity led to the 1912 founding of the Hawaiian Volcano Observatory, one of the world's first volcano observatories, by Thomas Jaggar (Tilling et al. 2014). Kīlauea's activity in the twentieth century contributed to the development of many modern volcano monitoring techniques (Tilling et al. 2014), which helped refine conceptual models of how volcanoes behave (Eaton and Murata 1960).

The foundation for these efforts has been the frequent and accessible effusive activity that has enabled robust field observations and the testing of ideas and methods (Tilling et al. 2014; Garcia 2015) (Fig. 1). The early lava lake activity that extended into the early 1900s, and terminated with explosive eruptions in 1924, helped uncover the basic relationships between seismicity, ground deformation, and the magmatic system, as well as the potential role of the hydrothermal system (Jaggar 1947). The 1959, 1963, and 1965 eruptions at Kīlauea Iki, 'Alae, and Makaopuhi provided fundamental constraints on cooling of shallow, closed-system magma bodies and their differentiation (Wright and Okamura 1977; Peck 1978; Helz and Thornber 1987). The 1955 and 1960 eruptions highlighted the importance of magma transport and storage along the East Rift Zone (Wright and Fiske 1971), as well as the vulnerability of residential areas on Kīlauea's flanks even tens of kilometers away from the summit (Macdonald and Eaton 1964; Richter et al. 1970). The Mauna Ulu (1969–1974) and Pu'u 'Ō'ō (1983–2018) eruptions demonstrated the nature of sustained magma supply to the rift zones (Cervelli and Miklius 2003; Poland et al. 2014), the character of summit and rift zone outgassing (Gerlach and Graeber 1985), development of lava tubes and compound lava flow fields (Kauahikaua et al. 2003), transition between pāhoehoe and 'a'ā (Peterson and Tilling 1980; Hon et al. 2003), and the behavior and hazards of tube-fed pāhoehoe flows (Hon et al. 1994; Kauahikaua et al. 2003; Orr et al. 2015). The Pu'u 'Ō'ō eruption also served as a testing location for new geophysical, remote sensing and physical volcanology tools for better measuring, tracking and understanding effusive activity. Examples include very low frequency (VLF) lava tube measurements (Kauahikaua et al. 1996), satellite thermal monitoring (Harris and Thornber 1999), and petrologic monitoring (Thornber et al. 2015). More recently, the 2008–2018 summit eruption in Halema'uma'u has provided modern insights into lava lake behavior, highlighting the well-developed hydraulic connection between the summit magma reservoir and rift zones (Poland et al. 2014; Patrick et al. 2019).

Of these landmark Kīlauea eruptions of the past 200 years, the 2018 activity is among the most significant. The 2018 activity consisted of a large effusive eruption on the lower

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This paper constitutes part of a topical collection:

The historic events at Kilauea Volcano in 2018: summit collapse, rift zone eruption, and Mw6.9 earthquake

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East Rift Zone (LERZ) that was accompanied by caldera floor collapse at the volcano's summit, 40-km uprift (Neal et al. 2019). The 4-month LERZ eruption extruded over 1 km^3 of lava, surpassed in the past 200 years at Kīlauea only by the Puʻu ʻŌʻō eruption, which erupted 4.4 km^3 over nearly four decades (Neal et al. 2019). Worldwide, lava flow eruptions greater than 1 km^3 are rare; in the past 100 years, these include Holuhraun (2014–2015; Pedersen et al. 2017), and Tolbachik (1975–1976; Fedotov et al. 1980), in addition to the 2018 LERZ and Puʻu ʻŌʻō eruptions on Kīlauea. The summit collapse that occurred during May–August was one of the largest of the past 200 years at Kīlauea and arguably the best observed collapse worldwide.

The 2018 sequence began with inflation of the magmatic system in March 2018 which affected the ongoing eruptions at Halemaʻumaʻu crater, at Kīlauea's summit (active since 2008), and Puʻu ʻŌʻō, on the East Rift Zone (active since 1983) (Neal et al. 2019) (Fig. 1). This pressurization of the magmatic system was expressed as rapidly rising lava levels in the Halemaʻumaʻu lava lake as well as in the lava pond in Puʻu ʻŌʻō crater. An intrusion that began at Puʻu ʻŌʻō on April 30 migrated 20 km eastward into the LERZ over the subsequent few days, terminating the Puʻu ʻŌʻō eruption. Lava began erupting from fissures in the LERZ, in Leilani Estates subdivision, on May 3. The next day, a M_w 6.9 earthquake on the décollement south of the East Rift Zone likely promoted further migration of summit magma releasing compressive stress on the rift zone. A total of 24 fissures opened in the LERZ over the next month, with effusion focusing on fissure 8 in late May. Fissure 8's large channelized flow reached the ocean in early June and fed an ocean entry that persisted for 2 months. The lava erupted during 2018 was more diverse in composition than that of any other historical Kīlauea eruption, with old rift-stored evolved basalt and andesite progressively flushed out to give way to hotter, more mafic basalt (Gansecki et al. 2019).

Deflation of Kīlauea's summit magma reservoir began days after the April 30 collapse of Puʻu ʻŌʻō crater, accompanied by the descent of the summit lava lake and increasing earthquake activity (Neal et al. 2019). Widening of the crater that hosted the lava lake produced explosions that were common in mid to late May. On May 16, the first collapse event occurred, characterized by co-event inflationary signals in geodetic data, sudden reductions in the earthquake rate, and ash-bearing plumes reaching more than 3 km above ground level. Between collapses, deflationary deformation continued and the earthquake rate recovered to increasingly higher levels.

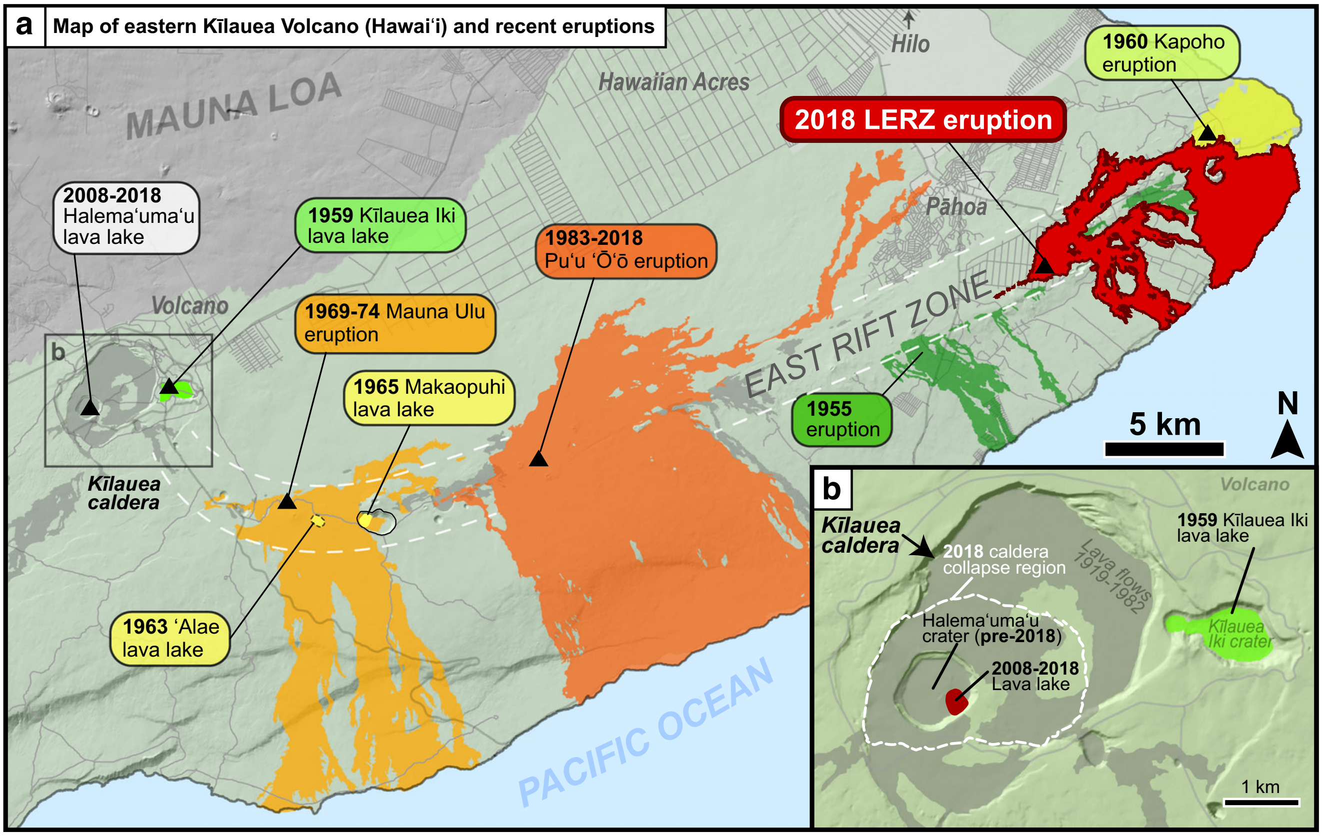

Fig. 1 (**a**) Key locations, lava lakes and flow fields from the last 100 years Kilauea Volcano mentioned in the text, and (**b**) enlargement of the summit area. Other eruptions and flow fields of the 20th century (1906-1982) are shown in light gray. LERZ: Lower East Rift Zone. Digital elevation model and flow units outlines from the USGS

Starting on May 29, the collapse events became less explosive, producing less ash but larger inflationary deformation signals. The earthquake rate continued to be cyclic, with rates decreasing dramatically following a collapse event. However, the maximum rate just prior to collapse continued to increase through late June, when it plateaued. From May 16 until August 2, 62 collapse events were recorded at the summit, with a total volume change of 825 million m^3. The last summit collapse event occurred on August 2, and major effusion in the LERZ ended on August 4–5, with minor LERZ vent activity continuing until September 5.

In addition to the scale of the eruption, the 2018 activity stands out for its societal impacts; the LERZ eruption has the unfortunate distinction of being the most destructive eruption in Hawaiʻi in the past 200 years (and the USA since 1980). The eruption destroyed over 700 structures, covered dozens of farms and miles of highway, covered portions of a geothermal well field and power plant, and destroyed numerous iconic local landmarks (Neal et al. 2019). It is impossible to quantify the emotional toll that the eruption had on the thousands of residents whose lives were disrupted, in many cases for far longer than the 4-month duration of the eruption. The level of destruction reflects not only the scale of the event but also the increasing vulnerability on the Island of Hawaiʻi, due to the rising demand for affordable residential property in zones of high lava flow hazard.

The studies in this special issue address a wide range of topics related to the 2018 eruption. Among these, Flinders et al. use ambient noise interferometry to characterize the state of the summit and East Rift Zone in the years-to-months prior to the eruption onset and the ensuing eruption-related changes. Dietterich et al. analyze unoccupied aircraft systems data to measure the effusion rates and dynamics in the dominant lava channel on the LERZ. Kern et al. show the challenges of measuring SO_2 emissions during an eruption of this scale, requiring modification of conventional techniques. Lerner et al. address the petrologic underpinnings of these high SO_2 emissions on the LERZ, and storage depths of the magma. Johanson et al. examine coseismic and postseismic deformation fields from the M_w 6.9 earthquake on May 4, 2018, and how the event impacted the East Rift Zone and the ongoing eruption.

Many previous eruptions on Kīlauea, such as Kīlauea Iki, Mauna Ulu and Puʻu ʻŌʻō, have spurred decades of research and evolving ideas (Garcia 2015). We hope and expect that the research presented in this special issue represents a foundation for many future studies in the coming years.

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