Journal of Volcanology and Geothermal Research 183 (2009) 139–156

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

The length of channelized lava flows: Insight from the 1859 eruption of Mauna Loa Volcano, Hawai'i

Jenny M. Riker [a,*,1], Katharine V. Cashman [a], James P. Kauahikaua [b], Charlene M. Montierth [c]

[a] Department of Geological Sciences, University of Oregon, Eugene, OR 97403, USA
[b] U.S.G.S. Hawaiian Volcano Observatory, Hawai'i Volcanoes National Park, HI 96718, USA
[c] Clark College, Vancouver, WA 98663, USA

ARTICLE INFO

Article history:
Received 6 October 2008
Accepted 2 March 2009
Available online 16 March 2009

Keywords:
lava flow
Mauna Loa
crystallization
channels
geothermometry

ABSTRACT

The 1859 eruption of Mauna Loa Volcano, Hawai'i, produced paired 'a'ā and pāhoehoe flows of exceptional length (51 km). The 'a'ā flow field is distinguished by a long (>36 km) and well-defined pāhoehoe-lined channel, indicating that channelized lava remained fluid to great distances from the vent. The 1859 eruption was further unusual in initiating at a radial vent on the volcano's northwest flank, instead of along the well-defined rift zone that has been the source of most historic activity. As such, it presents an opportunity both to examine controls on the emplacement of long lava channels and to assess hazards posed by future flank eruptions of Mauna Loa. Here we combine evidence from historical chronicles with analysis of bulk compositions, glass geothermometry, and microlite textures of samples collected along the 1859 lava flows to constrain eruption and flow emplacement conditions. The bulk compositions of samples from the 'a'ā and pāhoehoe flow fields are bimodally distributed and indicate tapping of two discrete magma bodies during eruption. Samples from the pāhoehoe flow field have bulk compositions similar to those of historically-erupted lavas (<8 wt.% MgO); lava that fed the 'a'ā channel is more primitive (>8 wt.% MgO), nearly aphyric, and was erupted at high temperatures (1194–1216 °C). We suggest that the physical properties of proximal channel-fed lava (i.e., high-temperature, low crystallinity, and low bulk viscosity) promoted both rapid flow advance and development of long pāhoehoe-lined channels. Critical for the latter was the large temperature decrease (~50 °C) required to reach the point at which plagioclase and pyroxene started to crystallize; the importance of phase constraints are emphasized by our difficulty in replicating patterns of cooling and crystallization recorded by high-temperature field samples using common models of flow emplacement. Placement of the 1859 eruption within the context of historic activity at Mauna Loa suggests that the formation of radial vents and eruptions of high-temperature magma may not only be linked, but may also be a consequence of periods of high magma supply (e.g., 1843–1877). Flank eruptions could therefore warrant special consideration in models and hazard mitigation efforts.

1. Introduction

On January 23, 1859, an eruption of Mauna Loa Volcano, Hawai'i, initiated at several vents high on the mountain's northwest flank (Fig. 1). During the first 8 days of the eruption, a channelized 'a'ā flow traveled 51 km to the western coast of the Island of Hawai'i, producing not only the longest lava flow in the volcano's historic record, but also a long and well-developed pāhoehoe-lined channel (36 km). A parallel tube-fed pāhoehoe flow formed over the following 10 months, making the 1859 eruption one of several historic eruptions to generate paired 'a'ā and pāhoehoe flows (e.g., Rowland and Walker, 1990). This eruption was unusual in many respects. First, its flows initiated at a radial flank vent, instead of along the two rift zones that have been the source of most other historic eruptions (Fig. 1). Second, it produced magma of heterogeneous composition (Rhodes, 1983); this contrasts with the remarkable compositional homogeneity that has typified Mauna Loa's historic and prehistoric eruptions (Powers, 1955; Wright, 1971; Rhodes, 1983; Rhodes, 1995; Rhodes and Hart, 1995). Third, it produced anomalously long channelized 'a'ā and tube-fed pāhoehoe flows. Finally, the 1859 eruption occurred during an uncommonly active four-decade period at Mauna Loa (1843–1877; Lockwood and Lipman, 1987). Here we suggest that these seemingly disparate characteristics (flow location, composition, length, and timing) may be related. Moreover, we demonstrate ways in which an improved understanding of this eruption can aid assessment of lava flow hazards related to rare radial vent eruptions on the flanks of Mauna Loa Volcano.

The unique hazards posed by flank eruptions have been studied at Mount Etna, Italy (Acocella and Neri, 2003), where they may initiate along rift zones or at isolated radial vents and tend to have both higher eruption rates and larger total volumes than summit eruptions. Flows

* Corresponding author. Tel.: +44 29 2087 4573; fax: +44 29 2087 4326.
E-mail address: jenny.riker@gmail.com (J.M. Riker).
[1] Present address: Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol, BS8 1RJ, United Kingdom.

0377-0273/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.jvolgeores.2009.03.002

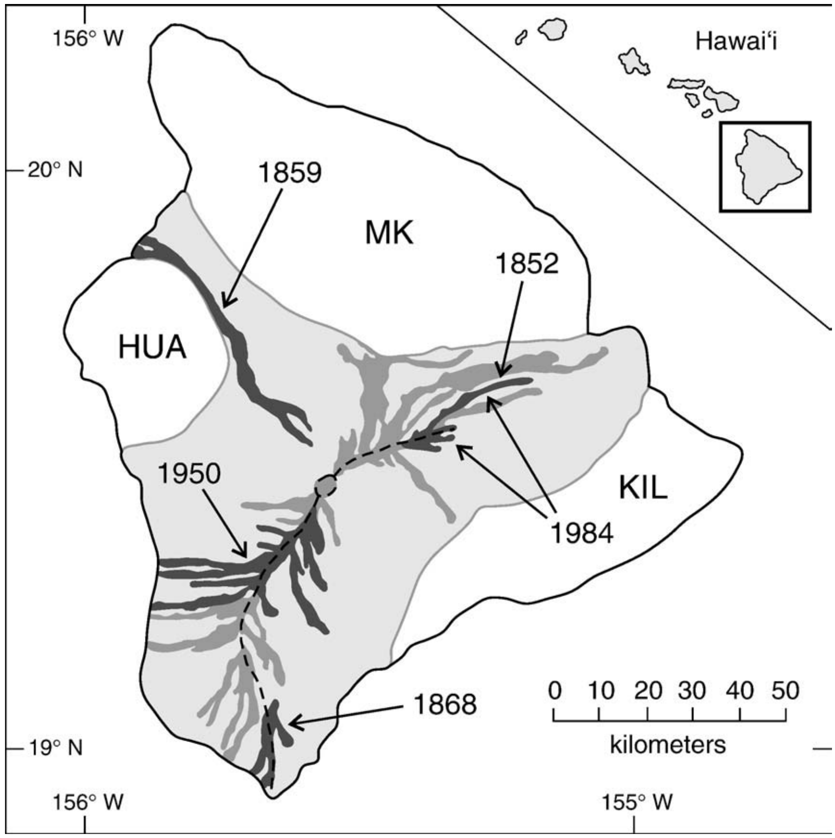

Fig. 1. Simplified map of Mauna Loa Volcano (shaded region) on the Island of Hawai'i, showing lava flows produced since 1843 ('historic eruptions'). Dashed lines show approximate location of summit caldera and rift zones. Labeled eruptions (dark grey) are discussed in this paper. Lava flows from the 1859 eruption are distinguished by their exceptional length (51 km) and off-axis vent location. HUA = Hualālai, MK = Mauna Kea, and KIL = Kīlauea.

with high eruption rates tend to travel farther than those with lower ones (Walker, 1973), while flows of large volume may cover more area than smaller flows. Combined with the effect of flank vents being displaced from the summit (toward population centers), it is clear that flank events at Mount Etna pose greater risks than typical summit eruptions. Is the same true for Hawaiian volcanoes?

Unlike Mount Etna, the overwhelming majority of Mauna Loa's eruptive vents form along two well-established rift zones. The rarity of historic eruptions on the northwest flank (hereafter termed 'flank,' 'radial,' or 'off-axis' eruptions) prevents an equivalent analysis of the hazards they pose. However, displacement of radial vents from the summit and upper rift zones toward populated coastlines clearly increases hazard, both because of increased probability that flows will invade populated areas, and because proximal flow advance rates are generally higher than those in distal regions (e.g., Kauahikaua et al., 2003; Soule et al., 2004). Additionally, the exceptional length of the 1859 'a'ā flow, along with its well-formed, pāhoehoe-lined channel, give evidence of sustained lava fluidity, raising questions about the nature of flank vent eruptions. This is of particular concern as it relates to channelized lava flows, which advance rapidly (up to 4 m/s; Kauahikaua et al., 2003) and may transport lava at very high speeds (up to 15 m/s; Lipman and Banks, 1987). Of the 29 flows produced by historic eruptions of Mauna Loa (Fig. 1), 23 were channel-fed (Rowland et al., 2005). Understanding controls on the emplacement of channelized lava flows is therefore critical to effective hazard assessment and response.

Over the past few decades, studies have established key factors governing the lengths and advance rates of lava channels including effusion rate (e.g., Walker, 1973; Pinkerton and Wilson, 1994; Kauahikaua et al., 2003), topography (e.g., Kilburn, 1990; Kilburn, 1993; Pinkerton and Wilson, 1994), and cooling and crystallization (e.g., Crisp et al., 1994; Cashman et al., 1999; Soule et al., 2004). Effusion rate is generally considered to exert a primary control on final flow length (Walker, 1973; Pinkerton and Wilson, 1994; Kauahikaua et al., 2003), although effusion rate alone is a poor predictor of the lengths of lava channels at Mauna Loa and Kīlauea (Fig. 2), which may be better correlated with flow volume or eruption duration (Malin, 1980; Pinkerton and Wilson, 1994). Moreover, none of these

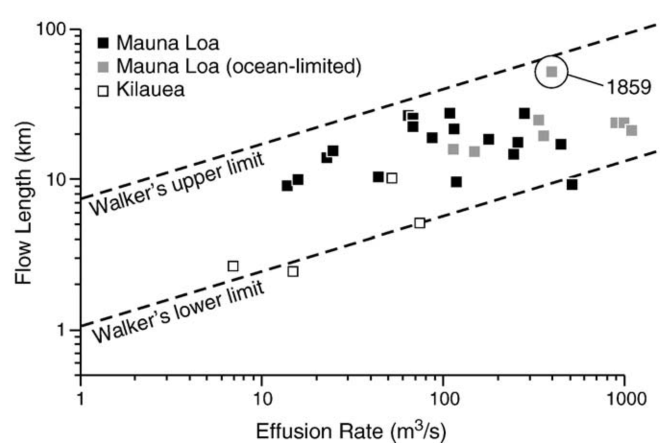

Fig. 2. Length versus effusion rate for channel-fed Hawaiian lava flows (modified from Pinkerton and Wilson 1994). All data except those for the 1859 and 1984 eruptions are from Malin (1980). For consistency with Malin (1980), effusion rates are 'actual effusion rates' (flow volume divided by the length of time the flow was actively fed). Dashed lines are flow length limits empirically defined by Walker (1973) based on a global data set. The effusion rate estimate for the 1859 channel is discussed in the text. Effusion rates for 1984 flow lobes 1 and 1A were estimated from the cumulative flow volumes and durations given by Lipman and Banks (1987). Flows less than 45 h in duration are assumed to be supply-limited and are excluded (e.g., Pinkerton and Wilson, 1994).