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Rapid mass wasting following nearshore submarine volcanism on Kilauea volcano, Hawaii

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Abstract

The rapid mass wasting of shallow submarine basalts was documented during SCUBA dives along the flanks of Kilauea volcano, Hawaii during the Kii lava entry of the current eruption (19°20.5′N, 154°59.8′W). Lava entered the ocean at this site from mid-February to late March 1990, with several pauses. Dives on 19–20 March 1990 confirmed the widespread formation of lava pillows at this site over a water depth range of 20–40 m, and visual observations suggested that the resulting volcanic deposits were generally stable, despite the steep (~40°) incline of the seafloor. (The pre-eruptive nearshore seafloor slope was ~14°.) However, dives on 2 April 1990 revealed that nearly all submarine volcanic features had been subject to mass wasting, as the offshore area had been transformed into a debris field composed of material ranging in size from fine sand to boulder fragments. This generally featureless seascape extended uniformly to beyond the visual range of divers (~60 m water depth). High-resolution multibeam bathymetry and sidescan imaging indicate that steeply sloped coarse sediment extends down the flanks of Kilauea in this area to abyssal depths, implying a linkage between nearshore submarine volcanism and deep-water deposits.

Keywords: lava; submarine; Kilauea; pillow; hyaloclastite; debris

1. Introduction

In this paper we discriminate between two types of coastal volcanic activity: *shoreline* volcanism (which occurs at or near the waterline along the shore) and *nearshore* volcanism (which occurs under water within a few hundred meters of shore). It is well known that shoreline volcanic activity can produce large quantities of glassy debris that can be transported along- or offshore (e.g., Moore et al., 1973; Peterson, 1976; Sansone and Resing, 1995). In this paper we demonstrate that nearshore submarine volcanism can also be a significant source of debris over very short time scales. The rapid mass wasting of shallow submarine basalts was documented during SCUBA dives along the flanks of Kīlauea volcano, Hawai'i.

This work, combined with other observations at Kīlauea, suggests that nearshore submarine volcanism does not generally result in the generation of stable submarine rock formations. Thus, observations of deep-water volcanic flows (e.g., Ballard et al., 1979; Davis, 1982; Embley et al., 1990; Chadwick et al., 1998), which describe the formation of coherent, stable rock formations, do not appear to apply to the nearshore Hawaiian environment.

2. Kīlauea shoreline and nearshore volcanic activity

Shoreline volcanism on Kīlauea has been described in detail by Moore et al. (1973), Peterson (1976), and

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Mattox and Mangan (1997). Molten lava is rapidly quenched and fractured by its contact with relatively cool seawater, resulting in the copious production of hyaloclastic debris, particularly where the shoreline is steep or significant surf is present (both are typical conditions along this shore). A large portion of the debris is black sand that is either transported by longshore currents to form black sand beaches or is discharged downslope as debris flows (Sansone and Resing, 1995). Mechanical abrasion of black beach sands produces fine suspended particles that can be transported long distances along- and/or off-shore, though it is unlikely that these particles are volumetrically significant to the overall sediment budget. Shoreline lava flows can also release numerous steaming rocks (typically a few tens of centimeters in length) that float offshore and sink to the bottom (Sansone et al., 1990; Sansone and Resing, 1995), contributing to the nearshore debris field. Finally, shoreline volcanism frequently results in the construction of lava benches (deltas) which are prone to catastrophic collapse (Kauahikaua, 1993; Mattox and Mangan, 1997). Such structures may be significant contributors to offshore debris flows, particularly during episodes of extended or highly active shoreline volcanism.

Nearshore volcanism on Kīlauea consists of two major extrusive processes fed by submarine lava tubes: pillow lava formation and the release of highly fluid, channelized lavas. Pillow lava formation at Kīlauea has been described in detail by Moore et al. (1973), Moore (1975), and Moore and Lockwood (1978), and are illustrated in Movie 1 in the Appendix of this paper. Tribble (1991) estimated that cooled pillows generally covered 10–20% of the bottom during nearshore eruptions, although coverage of 60–80% was observed on one occasion. Channelized submarine flows, which result from the underwater release of highly fluid lava from submarine lava tubes, were described by Tribble (1991) and can be seen in the video by Sansone et al. (1990) and in Movie 2. Hydrogen explosions within these thin submarine flows (Sansone and Resing, 1995) add to the production of rock fragments.

3. Observations

In this paper, visual observations by SCUBA divers during and after a nearshore extrusive event are used to describe the near-term fate (day-to-week scale) of the extruded pillow basalts. These observations were documented using an underwater 8-mm video camera; data files containing edits of the video documentation are available for downloading via the Appendix of this paper. The photographs presented in this paper (except Fig. 3) are video frame grabs, and consequently are not high resolution images.

This work was done during the Ki'i lava entry during Episode 48 (Kauahikaua et al., 1996) of the current Kīlauea eruption. Lava entered the ocean at this site (19°20.5'N, 154°59.8′W) (Fig. 1) from mid-February to late March 1990, with several pauses. Dives on 19–20 March 1990 confirmed the widespread formation of lava pillows over a water depth range of 20–40 m, with less than half of the bottom covered with talus (Sansone and Resing, 1995). Lava production rate at Kīlauea this time was ~3×10^5 m^3 d^{-1} (Kauahikaua et al., 1996), with a highly variable amount entering the ocean.

Visual observations suggested that the resulting volcanic deposits were generally stable, despite the steep (~40°) incline of the seafloor; the latter was consistent with previous estimates of 25–40° (Tribble, 1991), ~30° (Kelly et al., 1989) and 30–45° (Moore et al., 1973) at other sites offshore of Kīlauea. The pre-eruptive nearshore seafloor slope at Ki'i was ~14°, as measured by a July, 1989 bathymetric survey (data not shown).

However, dives on 2 April 1990, two weeks after the end of the submarine volcanism episode, revealed that nearly all of the expansive submarine volcanic deposits had been subject to mass wasting, having been transformed into a debris field composed of material ranging from fine sand to large boulder fragments (Fig. 2). This generally featureless seascape extended uniformly to beyond the visual range of divers (~60 m water depth). The debris field was close to the angle of repose, as evidenced by the immediate sliding of surface material after any disturbance by divers (Movie 3).

Occasional intact rock outcrops were seen; some of these were intact lava pillows, but most were large, partially fractured basalt blocks (Fig. 3). However, none of these rocks were of a stable, coherent nature, in contrast to the pāhoehoe which dominates the subaerially extruded lava flows at Kīlauea. Instead, the outcrops were composed of friable rock with weak tensional strength (Fig. 4). Presumably this fragility is the cause of the "gravitational collapse" of pillow lavas originally noted by Jones (1966). It also contrasts with the greater apparent coherence of deeper basalts, suggesting that it is related to the shallow depth of our field site or the steepness of the seafloor.

4. Discussion

New observational techniques, such as high-resolution multibeam bathymetry, sidescan imagery and