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Argon geochronology of Kilauea's early submarine history

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Abstract

Submarine alkalic and transitional basalts collected by submersible along Kilauea volcano's south flank represent early eruptive products from Earth's most active volcano. Strongly alkalic basalt fragments sampled from volcaniclastic deposits below the mid-slope Hilina Bench yield $^{40}Ar/^{39}Ar$ ages from 212 ± 38 to 280 ± 20 ka. These ages are similar to high-precision 234 ± 9 and 239 ± 10 ka phlogopite ages from nephelinite clasts in the same deposits. Above the mid-slope bench, two intact alkalic to transitional pillow lava sequences protrude through the younger sediment apron. Samples collected from a weakly alkalic basalt section yield 138 ± 30 to 166 ± 26 ka ages and others from a transitional basalt section yield 138 ± 115 and 228 ± 114 ka ages. The ages are incompatible with previous unspiked K–Ar studies from samples in deep drill holes along the east rift of Kilauea. The submarine birth of Kilauea volcano is estimated at <300 ka. If the weakly alkalic sequence we dated is representative of the volcano as a whole, the transition from alkalic to tholeiitic basalt compositions is dated at ~150 ka.

Keywords: Kilauea; $^{40}Ar/^{39}Ar$; submarine; geochronology; alkalic; transitional; basalt

1. Introduction

Volcanoes along the Hawaiian Ridge are Earth's best examples of intraplate hotspot volcanism. In the commonly accepted model for Hawaiian magmatism, as the Pacific Plate moves over a mantle melting anomaly, an individual volcano first erupts comparatively small-volume alkalic composition lavas followed by larger volumes of tholeiite, and ending with a small volume of alkalic composition lavas (e.g. Moore et al., 1982; Clague, 1987). Early-erupted products of Hawaiian volcanoes are mostly covered by younger submarine and subaerial lavas, or are only exposed at great water depth, making the early stages difficult to sample.

Kīlauea, a young tholeiitic shield volcano on the island of Hawai'i (Fig. 1), is among the most active volcanoes on earth. The deep offshore region south of Kīlauea was explored and sampled by submersible and remotely operated vehicle (ROV) dives during joint Japan–USA cruises in 1998–2002, supported by the Japan Marine Science and Technology Center (JAMSTEC). The offshore flank consists of a steep upper slope, the prominent mid-slope Hilina Bench with a closed depression at ~3000 m water depth, and a lower scarp descending to the 5000 m Cretaceous ocean floor (Chadwick et al., 1993; Smith et al., 1999). Southwest of the bench is the active alkalic to transitional Lō'ihi Seamount—Hawai'i's youngest volcano. Lō'ihi erupts alkalic, transitional and tholeiitic lavas and is considered to be in the transition between its alkalic and tholeiitic stages (Moore et al., 1982; Garcia et al., 1995). Submarine observations and chemistry of turbidite sandstones and debris-flow deposits show that

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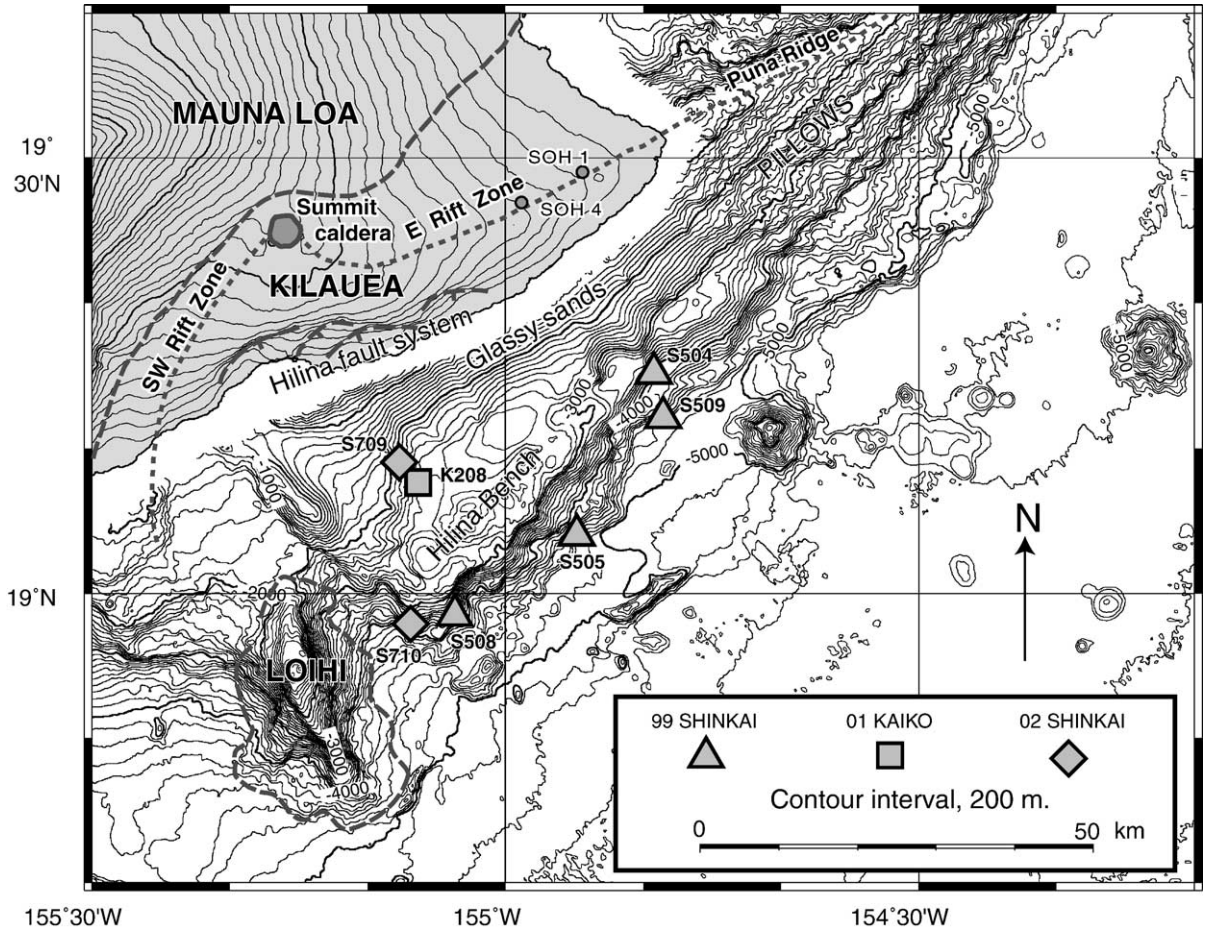

Fig. 1. Location map of Kīlauea volcano on the southeast portion of Hawai'i Island after Lipman et al. (2006-this issue). Locations of dives described in text, Lō'ihi and Mauna Loa boundaries are from Lipman et al. (2006-this issue), and SOH drill sites of Guillou et al. (1997) and Quane et al. (2000).

ancestral Kīlauea shed large amounts of coarse alkalic and transitional debris as it grew, and those deposits are intercalated with tholeiitic sand from Mauna Loa, and possibly Mauna Kea (Lipman et al., 2002). The isotopic ages presented here on fragments of alkalic pillow lavas and intrusive rocks date the early alkalic phase, near the time of Kīlauea's inception. In-place sections of weakly alkalic and transitional pillow lavas were sampled in 2001–2002 from landslide scarps above the mid-slope bench (Coombs et al., 2006-this issue). These samples allow us to determine the timing of the transition to Kīlauea's tholeiitic phase.

2. Stratigraphic context of geochronology samples

All geochronology samples were collected using the manned submersible *Shinkai 6500* (S sample prefix) or the ROV *Kaiko* (K sample prefix) south of the Hilina Fault System (dives S505, S508, S509, S710, K208) or south of Kīlauea's east rift (S504) (Fig. 1). Following Coombs et al. (2006-this issue), samples are grouped by their alkalinity, defined as the difference in weight percent of total alkalis above or below the alkalic–tholeiitic division of Macdonald and Katsura (1964). Strongly alkalic samples have alkalinity >1.5 and tholeiitic samples have alkalinity <-1. Intervening samples are termed "weakly alkalic to transitional".

2.1. Clasts from volcaniclastic sections

Observed portions of the 3-km-deep, mid-slope Hilina Bench and its lower scarp leading to the Cretaceous sea floor consist entirely of well-bedded volcaniclastic material derived from Kīlauea and Mauna Loa (Lipman et al., 2000, 2002; Sisson et al., 2002; Coombs et al., 2006-this issue). Massive sandstone, with abundant Mauna Loa glass grains, is interbedded with debris-flow breccia, siltstone and mudstone. Debris-flow breccia deposits are bedded, heterogeneous,