Glazner et al. left behind by extraction of erupted liquids (e.g., Bachmann and Keller et al. and solidified at depth (e.g., Miller et al.). Related to this temporal association-disassociation of discrete magma pulses. The rhyolite dike preserves an evolved fraction segregated from these discrete magmas. Synchronous with plutonism was a volcanic eruption of trachyte magma derived from the same source, which may have stalled at a relatively shallow depth prior to eruption. Stalling occurred at least above the amphibole stability zone because amphibole-compatible Sc and Ti were not depleted in the trachyte melt resulting in elevated values of these in volcanic compared to plutonic zircon. Identifying smaller episodic magma pulses in a larger magmatic complex places constraints on potential magma fluxes and eruptible volumes. High-flux, large volume, plume-related ocean island magmatic systems may have extensive vertically distributed multi-stage magmatic reservoirs and subduction-related systems transcrustal magma reservoirs. By contrast, Oki-Dōzen was a low-flux system with incremental pluton growth and small- to moderate-scale eruptions.

**Keywords:** U-Th-Pb dating, zircon trace elements, O isotopes, Hf isotopes, amphibole

**INTRODUCTION**

Unerupted magma preserved as plutonic and hypabyssal rocks may provide a window deep into the timing and origins of magma storage architecture and dynamics. Zircon provides a window deep into the timing and origins of magma storage architecture and dynamics. Zircon is ubiquitous in all samples; our aim is to determine what its age and composition can reveal about the plutonic-volcanic connection. Here we show magma source characteristics are recorded in zircon Hf isotopes; source composition and assimilation of heterogeneous hydrothermally altered crust in zircon O isotopes; and extensive fractional crystallization in zircon trace elements. Combined with new U-Th-Pb SHRIMP zircon ages, 6.4–5.7 Ma, compositional data show pluton formation was by protracted amalgamation of discrete magma pulses. The rhyolite dike preserves an evolved fraction segregated from these discrete magmas. Synchronous with plutonism was a volcanic eruption of trachyte magma derived from the same source, which may have stalled at a relatively shallow depth prior to eruption. Stalling occurred at least above the amphibole stability zone because amphibole-compatible Sc and Ti were not depleted in the trachyte melt resulting in elevated values of these in volcanic compared to plutonic zircon. Identifying smaller episodic magma pulses in a larger magmatic complex places constraints on potential magma fluxes and eruptible volumes. High-flux, large volume, plume-related ocean island magmatic systems may have extensive vertically distributed multi-stage magmatic reservoirs and subduction-related systems transcrustal magma reservoirs. By contrast, Oki-Dōzen was a low-flux system with incremental pluton growth and small- to moderate-scale eruptions.

**Abstract**

The relationship between plutonic and volcanic components of magmatic plumbing systems continues to be a question of intense debate. The Oki-Dōzen Islands, Sea of Japan, preserve outcrops of temporally associated plutonic, hypabyssal, and volcanic rocks. Post-intrusion uplift juxtaposed Miocene syenites in inferred faulted contact with volcanic trachytes that are cut by rhyolite hypabyssal dikes. This provides a window deep into the timing and origins of magma storage architecture and dynamics. Zircon is ubiquitous in all samples; our aim is to determine what its age and composition can reveal about the plutonic-volcanic connection. Here we show magma source characteristics are recorded in zircon Hf isotopes; source composition and assimilation of heterogeneous hydrothermally altered crust in zircon O isotopes; and extensive fractional crystallization in zircon trace elements. Combined with new U-Th-Pb SHRIMP zircon ages, 6.4–5.7 Ma, compositional data show pluton formation was by protracted amalgamation of discrete magma pulses. The rhyolite dike preserves an evolved fraction segregated from these discrete magmas. Synchronous with plutonism was a volcanic eruption of trachyte magma derived from the same source, which may have stalled at a relatively shallow depth prior to eruption. Stalling occurred at least above the amphibole stability zone because amphibole-compatible Sc and Ti were not depleted in the trachyte melt resulting in elevated values of these in volcanic compared to plutonic zircon. Identifying smaller episodic magma pulses in a larger magmatic complex places constraints on potential magma fluxes and eruptible volumes. High-flux, large volume, plume-related ocean island magmatic systems may have extensive vertically distributed multi-stage magmatic reservoirs and subduction-related systems transcrustal magma reservoirs. By contrast, Oki-Dōzen was a low-flux system with incremental pluton growth and small- to moderate-scale eruptions.

**Keywords:** U-Th-Pb dating, zircon trace elements, O isotopes, Hf isotopes, amphibole

**Introduction**

Unerupted magma preserved as plutonic and hypabyssal rocks may provide a window deep into the plumbing system architecture and dynamics of related volcanic rocks (e.g., Lipman 1984; Barth et al. 2012; Deering et al. 2016). Plutonic magmatism may accumulate over protracted periods of time, whereas magma from associated volcanic systems may assemble rapidly before eruption (e.g., Mills and Coleman 2013; Caricchi et al. 2014; Coleman et al. 2016). Related to this temporal association-disassociation is a key question regarding components of magmatic complexes, do plutons preserve: (1) the erupted magma counterpart stalled and solidified at depth (e.g., Miller et al. 2011; Metcalf 2004; Keller et al. 2015; Lipman and Bachmann 2015) or (2) the residue left behind by extraction of erupted liquids (e.g., Bachmann and Bergantz 2004; Eichelberger et al. 2006; Gelman et al. 2014; Glazner et al. 2015; Lundstrom and Glazner 2016; Cashman et al. 2017). Irrespective of details of their petrogenetic relationship with volcanic deposits, plutonic bodies record physical properties and compositions of magmas that did not erupt, e.g., viscosities, temperatures, volatile contents, and crystal cargoes. These may be compared and contrasted with extrusive products. These considerations are important in assessing potential connections in temporally associated plutonic and volcanic rocks; rarely, though, are systems dissected to reveal such relationships.

The Oki-Dōzen Islands, Sea of Japan, preserve outcrops of temporally associated plutonic, hypabyssal, and volcanic rocks (Fig. 1). Brenna et al. (2015) studied the petrogenesis of the magmatic complex mafic and felsic volcanic rocks and exposed syenite. They presented a new hypothesis for the volcanic-plutonic connection in an intraplate context: the volumetrically significant proportion of felsic deposits (Fig. 1, Tiba et al. 2000) reflected a low magmatic flux coupled with crustal plumbing system heterogeneity that filtered magmas and permitted fractionation. Specifically, thermal destabilization and eruption triggered by injection of mafic magma into shallow, evolved syenite magma bodies were impeded by a central network of vertically separated crustal reservoirs. This prevented large explosive eruptions.