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Age and geochemistry of volcanic clasts from DSDP Site 445, Daito Ridge and relationship to Minami-Daito Basin and early Izu-Bonin arc magmatism

Rosemary Hickey-Vargas [a,*], Osamu Ishizuka [b], Michael Bizimis [c]

[a] Department of Earth and Environment, Florida International University, Miami, FL 33199, USA
[b] Institute of Geology and Geoinformation, Geological Survey of Japan, AIST, Central 7, 1-1-1 Higashi, Ibaraki, Tsukuba 305-8567, Japan
[c] Department of Earth and Ocean Sciences, University of South Carolina, Columbia, SC 29208, USA

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ABSTRACT

The age and character of volcanism on the Daito Ridge is important for understanding the tectonic evolution of the Philippine Sea plate and the initiation of subduction that formed the Izu-Bonin-Mariana Island arc at about 50 Ma. We report new major, trace element and Nd, Sr, Pb and Hf isotope data for basaltic clasts from volcaniclastic sediments drilled at DSDP Site 445 on the Daito Ridge, and new Ar–Ar ages for minerals from the same location. Ages indicate that volcanic material in the core is as young as 47–49 Ma, similar in age to OIB-like basaltic sills from the adjacent Minami-Daito Basin and similar in age to the earliest volcanic rocks from the Izu-Bonin-Mariana (IBM) Island arc. The basaltic clasts have the major and trace element character of subduction-related rocks from mature island arc settings, and are unlike boninites or other rocks formed in proposed arc initiation sequences. Isotopic compositions are consistent with melting of mantle wedge with an Indian Ocean signature (i.e., elevated $^{208}Pb/^{204}Pb$ relative to $^{206}Pb/^{204}Pb$ and $^{177}Hf/^{176}Hf$ relative to $^{143}Nd/^{144}Nd$), containing subduction components derived from seawater altered Pacific Ocean MORB. Isotopic compositions overlap with those for boninites from the early northern IBM arc, suggesting that extraction of arc magma during Cretaceous–Eocene magmatism on the Daito Ridge and adjacent remnant arcs in the northern Philippine Sea, formed part of the depleted mantle wedge that was remelted during the initiation of IBM arc magmatism. Based on tectonic models, the Daito arc mantle wedge was probably isolated and cut-off from volatile replenishment by the initiation of subduction along the orthogonal trend of the proto-IBM arc. Collision of the Oki Daito Ridge may also have contributed to the waning of arc volcanism on the Daito Ridge and the contemporaneous eruption of OIB-like basalts in the Minami-Daito Basin.

1. Introduction

The Daito Ridge is located in the northern section of the Philippine Sea plate within a cluster of ridges and basins called the Amami–Daito Province (Fig. 1). The Amami–Daito Province is interpreted as a terrane of mixed arc and oceanic lithosphere that is significantly older than the adjacent West Philippine Basin (Shiki, 1985; Hickey-Vargas, 2005; Ohara et al., 2007). The Daito and Oki-Daito Ridges are linear features oriented at oblique angles to the north–south trending northern Kyushu-Palau Ridge (Fig. 1), and are separated from each other by the Minami-Daito Basin. The Amami Plateau lies to the north, immediately adjacent to the Nansei Shoto Trench, and separated from the Daito and Kyushu-Palau Ridges by the Kita Daito and Amami-Sankaku Basins. The probable southern boundary of the Amami–Daito Province is the south-facing Oki-Daito Escarpment, along which relief exceeds 1 km and seafloor spreading fabric changes from that of the West Philippine Basin (Okino et al., 1999).

The Amami–Daito Province was explored and sampled by dredging during the Japanese Geodynamics Project of 1973–1978 (Shiki, 1985) and by dredging, drilling and Shinkai 6500 submersible dives during more recent United Nations Law of the Sea related research (Ohara et al., 2007). In addition, three Deep Sea Drilling Project (DSDP) sites are located there: Leg 31 Site 294/5 is located just south of the Oki-Daito Ridge, and Leg 58 Sites 445 and 446, are on the Daito Ridge and in the Minami-Daito Basin, respectively (Fig. 1). A future Integrated Ocean Discovery Program (IODP) site has been proposed for drilling in the Amami-Sankaku basin. To date, basement rocks have been drilled only at Site 294/5; sediments and basaltic sills were drilled at Site 446 and volcaniclastic sediments at Site 445.

* Corresponding author. Tel.: +1 305 348 3471; fax: +1 305 348 3877.
E-mail addresses: hickey@fiu.edu (R. Hickey-Vargas), o-ishizuka@aist.go.jp (O. Ishizuka), mbizimis@geol.sc.edu (M. Bizimis).

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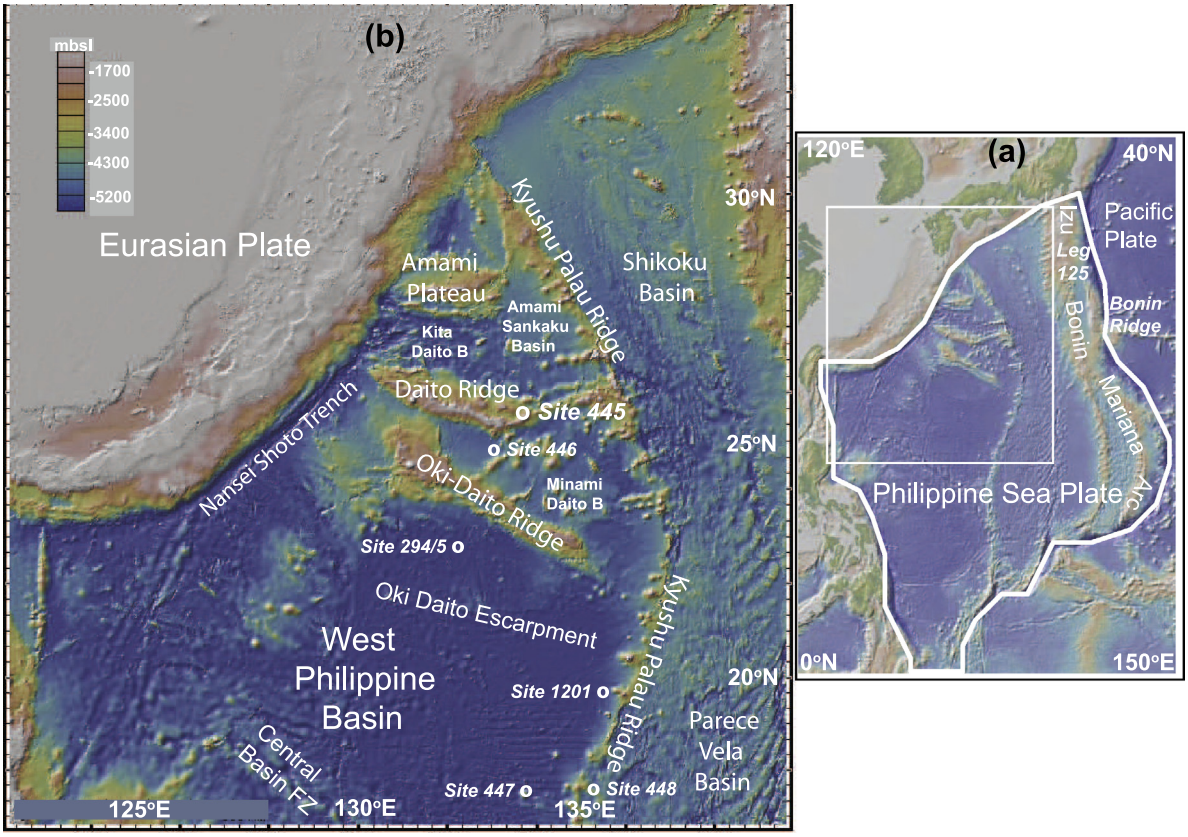

Fig. 1. Map of the northern Philippine Sea plate showing bathymetric features and the locations of DSDP and ODP drilling sites mentioned in the text. The area enclosed in the white square in (a) is expanded in (b).

The focus of this study is volcanic rocks from the Daito Ridge, specifically, the major, trace element and Sr, Nd, Pb and Hf isotope geochemistry of mafic volcanic clasts and Ar–Ar ages of minerals from coarse volcaniclastic sediments recovered from the lowermost part of DSDP Site 445. The specific objective is to develop an understanding of the age and chemical relationship of volcanic rocks from the Daito Ridge to those from adjacent areas, particularly the Minami-Daito Basin, West Philippine Basin, the northern Kyushu-Palau Ridge and Izu-Bonin forearc.

2. Background

2.1. Regional background and context

The Philippine Sea plate (Fig. 1) is bounded by a convergent and transform margin on the east and south, along which the Pacific plate is subducted, and convergent margins to the west and north, where the Philippine Sea plate is subducted beneath the Philippine archipelago and the Ryukyu islands, Kyushu and Honshu, Japan. The Amami–Daito Province abuts the West Philippine Basin, a feature formed by seafloor spreading along an extinct spreading ridge now marked by the Central Basin Fracture Zone (CBFZ) (Fig. 1). Magnetic anomalies parallel to the CBFZ indicate a spreading history from 35 Ma to greater than 45 Ma(Hilde and Lee, (1984), while exploration of the CBFZ suggests magmatism and amagmatic spreading lasted until as late as 26 Ma (Fujioka et al., 1999). On the east, the Amami Daito Province is bounded by the Kyushu-Palau Ridge, which is a remnant section of an island arc once contiguous with arc lithosphere underlying the active Izu-Bonin-Mariana Island arc (Fig. 1). The proto-Izu-Bonin-Mariana Island arc began to form at about 50 Ma when Pacific plate subduction was initiated beneath the Philippine Sea plate (Stern and Bloomer, 1992; Stern, 2004). After about 20 Ma of arc development, the early IBM arc was rifted while the Shikoku and Parece Vela Basins opened (Fig. 1), shifting part of the older arc basement eastward and stranding the remnant Kyushu Palau ridge. Therefore, volcanic and plutonic rocks formed in the early IBM are found both in the IBM forearc and on the Kyushu-Palau Ridge.

Philippine Sea plate locations have been widely sampled by the Deep Sea Drilling Project and Ocean Drilling Program, and the contrasting geochemistry of drilled igneous rocks elucidates the tectonic history and evolution of the plate. The West Philippine Basin contains five sites where igneous basement was reached: DSDP Leg 31 Sites 290, 291, 292, and Leg 59 Site 447, and ODP Leg 195 Site 1201, in addition to Leg 31 Site 294/5 and Leg 58 Site 446 in the Amami–Daito Province (Fig. 1). Geochemical studies of Leg 58 and Leg 59 rocks were conducted by researchers participating in the cruises (Marsh et al., 1980; Mattey et al., 1981), and were extended, together with rocks from Leg 31 sites, to include Sr, Nd, and Pb isotopic data by Hickey-Vargas (1991, 1998a,b). Hf-isotope data for Leg 31, 58 and 59 rocks were provided by Pearce et al. (1999) and Hickey-Vargas et al. (2006). Savov et al. (2006) published geochemical and Sr, Nd, Pb and Hf isotopic data for ODP Leg 195 Site 1201. Geochemical results and ages for these areas were presented in a synthesis of West Philippine Basin magmatism by Hickey-Vargas et al. (2006). In summary, West Philippine Basin floor basalts from Sites 447 and 1201 are indistinguishable from depleted, normal-MORBs, whereas Site 291 basalts show some enrichment in incompatible elements and isotopic characteristics, and basalts from DSDP Site 292 (the Benham Rise) are strongly incompatible element enriched and resemble oceanic island basalts (OIB). An important finding relevant to the present study is that basalts forming sills in sediments of the Minami-Daito Basin