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Onset of the Indian Ocean isotopic signature in the Philippine Sea Plate: Hf and Pb isotope evidence from Early Cretaceous terranes

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Abstract

Basalts from Paleocene–recent back arc basins within the Philippine Sea Plate have the Pb and Hf–Nd isotopic characteristics of Indian Ocean mid-ocean ridge basalts (MORB). We examined the isotopic composition of rocks from Early Cretaceous terranes within the Philippine Sea Plate, in order to understand the onset and origin of the Indian MORB isotopic signal. Igneous rocks from the Huatung Basin, a fragment of Early Cretaceous oceanic lithosphere sutured to the Paleocene–Oligocene West Philippine Basin, have an Indian MORB Hf–Nd isotopic signature, but Pb isotope ratios are intermediate between those of Indian and Pacific MORB. West Philippine Basin basalts have a stronger Indian Pb isotope signature than Huatung Basin rocks. Pre-subduction mantle sources for igneous rocks from the Amami Plateau, an Early Cretaceous island arc in the northernmost Philippine Sea Plate, have isotopic characteristics of Pacific MORB, and subducted components added to the mantle sources also have isotopic characteristics of Pacific MORB, plus sediment.

The Indian MORB characteristics of Early Cretaceous Huatung Basin rocks lend support to the idea that mantle sources with this signature existed prior to the opening of the present day Indian Ocean and that Tethyan oceanic basalts, now found throughout southern Eurasia, shared them. As the West Philippine Basin opened, basalts formed from mantle sources with a more pronounced Indian Pb isotope signature than those tapped by the older Huatung Basin. Results for the Amami Plateau indicate that the Philippine Sea Plate also contains Pacific-type lithosphere, perhaps scattered within subduction terranes, such as the Philippine Islands, that were disrupted by basin opening. Taken together, results indicate that the lithosphere on which the proto-Izu-Bonin-Mariana arc formed was diverse, containing Pacific and Indian oceanic lithosphere, and old, depleted and subduction-conditioned arc mantle wedge.

Keywords: oceanic basalts; island arc basalts; isotopic data; Early Cretaceous; Philippine Sea Plate; Izu-Bonin-Mariana arc

1. Introduction

The Philippine Sea Plate (Fig. 1) is the earth's tenth largest lithospheric plate, covering some 5.4×10^6 km^2 (Bird, 2003). It is bounded by the Eurasian, Pacific and Indo-Australian Plates, thus, its tectonic development is an important part of the large-scale plate reorganization affecting the western Pacific region since the Mesozoic. The plate consists mainly of oceanic and oceanic island arc lithosphere of Early Cretaceous to recent age. Four large well-defined basins within the Philippine Sea Plate are floored by oceanic lithosphere (Fig. 1): the Paleocene–Oligocene West Philippine Basin, the Oligocene Parece Vela and Shikoku basins, and the Miocene–recent Mariana Trough. A notable geochemical feature of basalts from these basins is that they have isotopic characteristics like those of Indian Ocean MORB, rather than Pacific MORB. This feature has been tracked back in time to Eocene basalts drilled from the West

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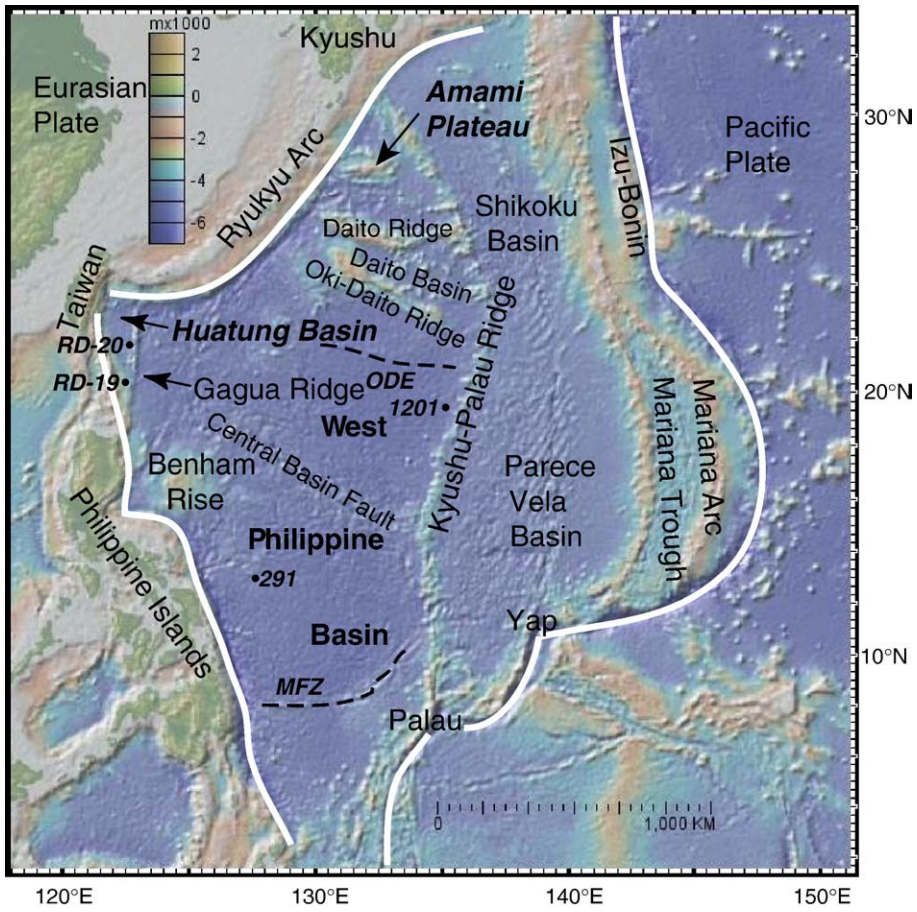

Fig. 1. Map of the Philippine Sea Plate showing locations mentioned in the text. The boundaries of the Philippine Sea Plate are outlined in white. Dots with numbers are dredge and drill sites mentioned in the text. ODE is the Oki Daito Escarpment (Okino et al., 1999) and MFZ is the Mindanao Fracture Zone (Taylor and Goodliffe, 2004). The map was constructed using GeoMapApp (http://www.marine-geo.org/geomapapp/).

Philippine Basin at DSDP Site 291 and at ODP Site 1201 (Fig. 1) (Hickey-Vargas, 1998a, 1991; Savov et al., 2006) and it continues as a feature of recent back arc basin basalts from the Mariana Trough (Volpe et al., 1990; Gribble et al., 1996, 1998). Since these are back arc basin basalts, the Indian MORB signature is a feature of the asthenosphere that is robust enough to have survived several epochs of subduction, arc building and rifting, and renewed back arc spreading. Some competing hypotheses for the Indian Ocean-type signature in Philippine Sea Plate basin basalts are: 1) that Philippine Sea Plate asthenosphere formed in at the periphery of an expanding Indian Ocean asthenospheric domain, and subsequently migrated northward to its present location with the moving lithospheric plate (Hickey-Vargas, 1998a; Pearce et al., 1999); 2) that the plate formed within a larger and older Tethyan asthenospheric domain, with isotopic characteristics similar to the Indian Ocean domain (Xu and Castilo, 2004); or 3) that the chemical signature developed in situ, by processes analogous to those that geochemically affected the sub-Indian Ocean mantle (Tu et al., 1992).

In this paper, we report isotopic data for rocks from the oldest known sections of the Philippine Sea Plate: the Amami Plateau and the Huatung Basin (Fig. 1), in order to understand better the origin and timing of the Indian MORB isotopic signature. Our results show that these ancient terranes are not entirely Indian or Pacific in character, based on present day definitions. They are also distinct from the West Philippine and younger Philippine Sea Plate basins, and, therefore, provide information about the tectonic history and development of the plate.

2. Geologic background

2.1. History of the Philippine Sea Plate

The West Philippine Basin is the oldest of large basins forming the Philippine Sea Plate. The basin is now subducting beneath Japan, Taiwan and the Philippines along its northern and western margins (Fig. 1), and it is bounded on the east the by the Kyushu–Palau ridge, which is the Paleocene–Eocene remnant of the Izu-Bonin-Mariana (IBM) island arc. Basins and ridges east of the Palau–Kyushu ridge formed since about 48 Ma when subduction began (Cosca et al., 1998), through a series of arc building, arc rifting and back arc spreading events that ultimately led to the present day IBM arc. Fragments of West Philippine Basin lithosphere have been found in the IBM arc basement (DeBari et al., 1999), and much of the IBM forearc is presumed to have formed within proto- and early IBM arcs coincident with the Kyushu–Palau ridge (Fig. 1).