Preliminary report of Kairei KR03-01 cruise: amagmatic tectonics and lithospheric composition of the Parece Vela Basin

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Introduction
Recent mapping studies by our group (Kasuga and Ohara, 1997; Okino et al., 1998; 1999; Ohara et al., 2001) revealed that the Parece Vela Basin (PVB) in the Philippine Sea (Fig. 1) has the geodynamic characteristics expected for amagmatic extension, thus providing a rare opportunity to study the architecture and composition of backarc basins. The study of backarc spreading systems has a strong bearing on two important aspects of the Earth’s evolution, as it relates to both subduction zone and mid-ocean ridge dynamics. Study of backarc basins thus has strong impact on both the InterRidge and MARGINS communities.

The KR03-01 cruise aboard the Japan Marine Science and Technology Center’s R/V Kairei was thus scheduled to better understand the lithospheric architecture and composition of this unique backarc basin (Ohara et al., 2002). In this article, we report the preliminary results of the cruise.

Geodynamic background
The Philippine Sea occupies a large part of the western Pacific and is composed of three large basins separated by the Kyushu-Palau and West Mariana ridges (both are remnant arcs; Fig. 1). Situated east of the Kyushu-Palau Ridge, the Shikoku Basin and the PVB are extinct backarc basins. The central PVB is characterized by a N-S trending chain of right-stepping en-echelon depressions (the Parece Vela Rift; Mrozowski and Hayes, 1979) bordered by escarpments extending ~ N20°E from the depressions into the surrounding basin floor (Fig. 2). The escarpments and depressions (maximum depth ~ 7500 m) are fossil fracture zones and extinct segmented-spraying axes (first-order segments), respectively (Kasuga and Ohara, 1997). Each segment is labeled as S1-S7 from south to north (Ohara et al., 2001). The PVB has a two-stage spreading history (Kasuga and Ohara, 1997; Okino et al., 1998; 1999), initial E-W rifting and spreading with spreading axes trending N-S began at ~ 29 Ma (spreading rate: 8.8 cm/y full-rate) (Okino et al., 1998; 1999). The second stage involved counter-clockwise rotation of spreading axes from N-S to NW-SE at ~ 19 Ma (spreading rate: 7.0 cm/y full-rate) (Ohara et al., submitted).

Figure 1. Satellite altimetry map showing the tectonic feature of the Philippine Sea. Dotted box indicates the location of Fig. 2.
Spreading ceased at ~ 12 Ma (Ohara et al., submitted).

Ohara et al. (2001) mapped distinct rough topographic features in the PVB, suggesting amagmatic extension in the basin, in spite of the basin’s relatively fast-spreading rate (8.8-7.0 cm/y full-rate). The most distinct topographic feature is a set of megamullions in the Parece Vela Rift (PVR). Recently discovered “megamullions” found along slow-spreading ridges have been interpreted as exhumed footwalls of low-angle normal faults, characterized by distinct corrugations normal to the spreading axis (Cann et al., 1997; Blackman et al., 1998; Mitchell et al., 1998; Tucholke et al., 1998). One of the PVR megamullions is the largest seafloor megamullion known. Ohara et al. (2001) named it the Giant Megamullion, as it is ~ 10 times larger in area than the Mid-Atlantic Ridge (MAR) megamullions. The other distinct topographic feature is a rugged “chaotic terrain” in the off-axis region of the western PVB. This terrain consists of isolated and elevated blocks (maximum relief is ~ 1500 m), capped by corrugated axis-normal lineations, and associated deeps (maximum depth ~ 6000 m). The chaotic terrain has a mantle Bouguer anomaly distinctly higher than the surrounding ocean basin, about 30 mgal, indicating a thinner crust beneath the area (Okino et al., 1998). The morphology and gravity signature of these individual blocks are also similar to MAR megamullions. Similar off-axis rugged topography has been documented at the “high” intermediate-spreading Australian-Antarctic Discordance (7.4 cm/y full-rate) and reflects a long-term magma deficiency associated with a mantle cold spot (Christie et al., 1998).

Before the KR03-01 cruise, mantle peridotites were sampled in only two previous dredge hauls in the PVR; no bottom samples were obtained from the chaotic terrain. However, the limited sample suites revealed fundamental characteristics of the backarc basin lithospheric composition (Ohara et al., in press). The most notable characteristic of PVR peridotites is the existence of fertile peridotite (spinel Cr # (= Cr/Cr+Al ratio) ~ 0.17), accompanied by melt-impregnated peridotite with more depleted composition. The existence of fertile peridotite indicates that PVR peridotite experienced only minor melting (4% near-fractional melting of a MORB-type mantle), most likely due to inhibited mantle melting caused by closely-spaced fracture zones (Ohara et al., submitted). The extreme water depth of the PVR (maximum depth ~ 7500 m) also supports cold magma. The estimated low degree of melting of the PVB upper mantle is, to a first approximation, consistent with bathymetric features suggesting amagmatic extension.

**Preliminary results**

The Kairei left Yokosuka on January 6, 2003 and returned to Yokosu-
4) We mapped the northern segments (S6 and S7) which were previously poorly mapped. The rift valley of S6 and S7 are both oblique to the fracture zones, indicating oblique extension was dominant during the final phase of the basin evolution. A minor elongated ridge and a voluminous blocky ridge (~1600 m relief) are located in the rift valley of S6. Dredging the former recovered a large volume of basalt, whereas the latter yielded a large volume of peridotite. We interpret the former as a “normal” neovolcanic ridge in S6, whereas the latter may be a remnant inside-corner high massif.

5) The southern off-axis region of S6 is characterised by prominent curved abyssal hills that look like “crab legs”. We interpret these as extreme expressions of “hooked ridge”, well described along mid-ocean ridge RTI. Compared to normal hooked ridges, the PVR crab-leg ridges are anomalous due to their abrupt changes in orientation along axis and in the length of the “hooks”.

We interpret that these observations reveal a dramatic magmatic undersupply more typical of an ultraslow-spreading ridge than of a fast- or intermediate-spreading ridge in a backarc basin. The results imply that the morphologic and petrologic characteristics of ridges we normally assume to be a direct function of spreading rate are in fact solely a function of magmatic supply.

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References


