International Research: **Back Arc Basins**

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-spreading 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).

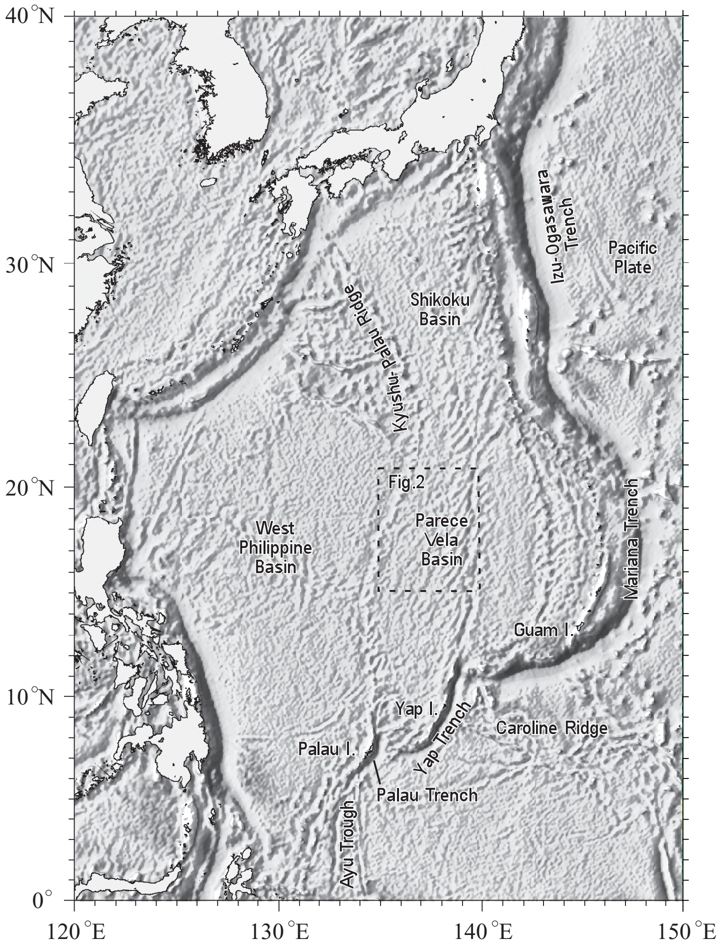

Figure 1. Satellite altimetry map showing the tectonic feature of the Philippine Sea. Dotted box indicates the location of Fig. 2.

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).

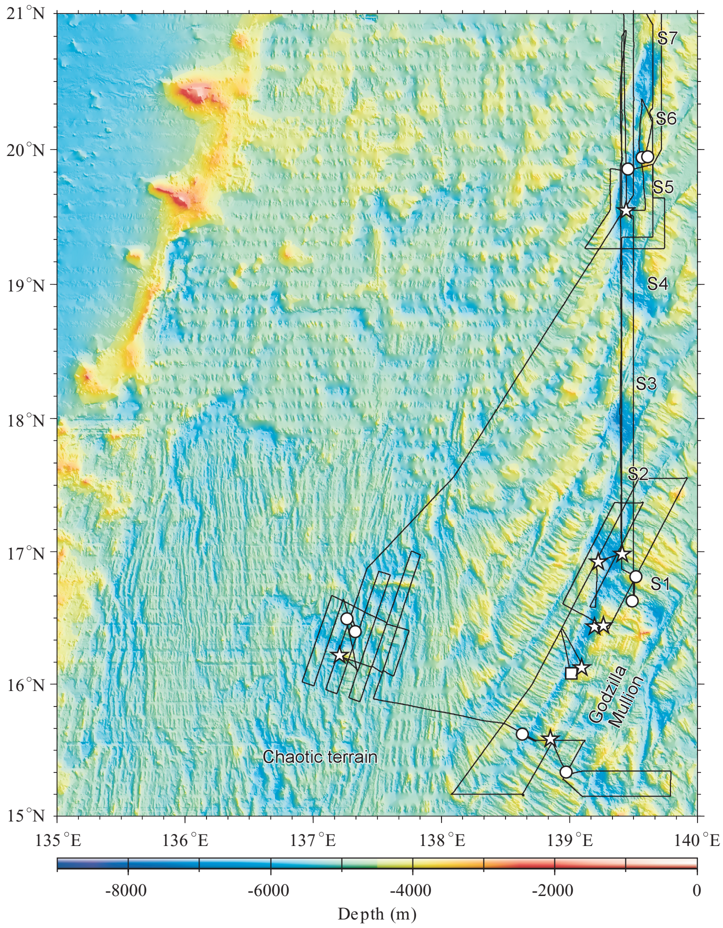

Figure 2. Shaded bathymetry of the Parece Vela Basin showing the cruise tracks of *R/V Kairei* during the KR03-01 cruise. Bathymetric data are from this cruise as well as previous cruises (Ohara *et al.*, 2001). The short, first-order segments are labeled S1-S7 from south to north. Asterisks indicate dredge hauls containing peridotites, circles indicate dredge hauls containing mostly basalts. A square indicates an empty dredge haul. Our mapping confirmed the presence of several megamullions in the chaotic terrain, yielding mantle peridotite from a single dredge haul. The Godzilla Mullion yields peridotites from the entire length of over 125 km (4 dredges). Some dredge hauls from the Godzilla Mullion contain plagio-granite. A voluminous axial blocky ridge in the rift valley of S6 yields peridotites, indicating this structure is possibly a remnant inside-corner high massif. "Crab-leg ridges" are clearly seen in the southern off-axis of S6.

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 Yokosuka on January 25, 2003. The expedition to the southern Philippine Sea was incredibly successful, resulting in 18 dredge hauls and extensive geophysical mapping (bathymetry and magnetic surveys; gravity data were not recorded) during the 20-days cruise, mainly focused on the chaotic terrain and the ridge-transform intersections (RTI) of segments S1, S2, S6 and S7. Some of the remarkable results can be summarised as follows (Fig. 2):

1) Extensive swath mapping oblique to the chaotic terrain confirmed that it is actually composed of several individual megamullions. Dredging on one of the several megamullions recovered mantle peridotites and gabbros, documenting an extremely thin crust with extensive tectonic dismemberment.
2) Four dredge hauls on the Giant Megamullion revealed it to be composed nearly entirely of mantle peridotite along its entire length of over 125 km. This suggests a peridotite exposure of some ~ 7000 km^2, confirming this structure is the largest exposure of amagmatic or nearly amagmatic ocean crust in the world. We thus renamed it “Godzilla Mullion”, since it deserves to have the name of the world-famous Japanese monster.
3) Although oceanic plagio-granite has been very rarely reported (*e.g.*, Engel and Fisher, 1975), we recovered plagio-granites associated with mantle peridotites from the Godzilla Mullion surface, suggesting small volumes of melt were highly fractionated in this magma-starved spreading environment.
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 is 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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