Lithospheric structure and composition of the Southern Marianas

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The 3000 km long Izu-Bonin-Mariana (IBM) arc system is an outstanding example of an intraoceanic convergent plate margin. The IBM forearc is a typical nonaccretionary convergent plate margin; the inner trench slope exposes lithologies found in many ophiolites including several km of mantle. To more clearly delineate the geology of the forearc, we have been investigating a ~700 km long region of the Mariana forearc south of ~13°N near Guam to the Yap Trench junction in 6 expeditions with the DSV Shinkai 6500 and deep-tow camera since 2006. Except for a few expeditions in 1970's, there have been no studies of the southern Mariana forearc west of the Challenger Deep. Data from our expeditions therefore provide a new perspective on the lithospheric structure and composition of the southern Mariana forearc. Most strikingly, mantle peridotite extensively crops out and has been sampled from the inner trench wall along the southernmost Mariana forearc.
Peridotites from the southwesternmost Mariana forearc near the Yap Trench junction area are strikingly fresh and have fertile compositions similar to those from the Parece Vela backarc basin [Ohara et al., 2003, G3]. The freshness of the peridotites indicates continuing protrusion of backarc-basin peridotite along the inner trench slope near the Yap Trench junction, possibly as a result of continuing backarc extension or collision of the Caroline Ridge.
Peridotites from near the Challenger Deep are exposed below the Moho as shallow as ~4500 m bsl and are heterogeneous, ranging from fertile lherzolites (i.e., backarc basin-like) to depleted harzburgites (i.e., forearc-like). In addition, we found that the forearc northeast of the Challenger Deep experienced rifting unusually close to the trench axis, exposing young (~ 3 Ma) basaltic lava with Mariana Trough backarc basin affinity [Ribeiro et al., 2013, Island Arc]. Earthquake foci also indicate that the forearc northeast of the Challenger Deep is a region of strong extension, and bathymetric data indicate that multiple tectonic rifts dissect it, indicating that diffuse extension occurs in the forearc.
We now argue that the southern Mariana forearc northeast of the Challenger Deep has heterogeneous lithospheric structure and composition, a mixture of those of backarc and forearc. A serpentinite-hosted ecosystem, the Shinkai Seep Field [SSF; Ohara et al., 2012, PNAS] is located in this area. SSF is a diffuse cold seep, serpentinite-hosted system that hosts an ecosystem mainly consisting of vesicomyid clams. We have tried to find other such seeps along the southern Mariana forearc during 2013 to 2015 expeditions, but no such seeps have yet been found, partly because these seeps are low-T and do not provide much of a thermochemical plume in the water column. We hypothesize that SSF vent fluid originated from seawater circulated within the shallow crust driven by the heat of young backarc-like magmatic intrusions. This mechanism is similar to that proposed for the Lost City hydrothermal field in the Mid-Atlantic Ridge [Allen and Seyfried, 2004, GCA]. We hypothesize that lithospheric mantle associated with forearc rifting is necessary for SSF-type seeps. This in turn suggests that finding where recent igneous activity has occurred in the southern Mariana forearc northeast of the Challenger Deep is the best strategy for finding new SSF-like seeps.

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