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Southern Mariana Forearc: geology and chemosynthetic biological community of a serpentinite terrain

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It has been considered that the hydrogen formation and the resultant abiotic formation of methane in serpentinite-hosted hydrothermal systems may have played important roles in the emergence of life on the Earth, and may have astrobiological implications for the presence of life on other planets and solar systems. Cold seeps and hydrothermal vents associated with serpentinized mantle have been known for 15 years. In 1997, an alkaline cold seep associated with Bathymodiolus mussel communities was discovered from the South Chamorro Seamount (a serpentinite mud volcano) in the Mariana forearc. In 2001, a serpentinite-hosted, low-temperature, alkaline hydrothermal system, the Lost City hydrothermal field, was discovered along the Mid-Atlantic Ridge. In September 2010, the YK10-12 cruise with Shinkai 6500 discovered chemosynthetic biological communities (principally vesicomyid clams) that feed on serpentinized peridotite in the southern Mariana forearc. Here we report the background and overview of the discovery.

A number of serpentinite mud volcanoes exist in the northern Mariana forearc, however none is known from the southern Mariana forearc, which faces the Challenger Deep. Instead, serpentinized peridotite crops out extensively in the inner trench slope there, forming a serpentinite terrain. The peridotite there includes amphibole and high-temperature type serpentine (i.e., antigorite) as well as low-temperature type serpentine (i.e., crysotile and/or lizardite). Since antigorite is rarely reported from abyssal peridotite, the southern Mariana forearc provides an important opportunity to study a different style of peridotite serpentinization. The YK10-12 cruise was designed to study unmapped regions of the southern Mariana forearc.

Abundant chemosynthetic communities, principally consisting of vesicomyid clams, associated with serpentinized peridotite were discovered during Shinkai 6500 dive #1234 (observer: T. Ishii) in the southern Mariana forearc, about 80 km northeast of the Challenger Deep. More than 30 live vesicomyid clams were collected, along with serpentinized peridotite, subordinate gabbro and a fragment of a potential vent chimney. Although no active fluid venting was observed, it is likely that fluids responsible for nourishing the communities come from cold seeps associated with serpentinization. We therefore named our discovery the Shinkai Seep Field (SSF).

This is the first description of vesicomyid clams anywhere in the Mariana forearc. Furthermore, the SSF vesicomyid clam community is the first live example described from a low-temperature serpentinite-hosted hydrothermal system from either convergent or divergent plate margins. The SSF vesicomyid clam is likely a new species, closely related genetically to the vesicomyid clam described from the high-temperature serpentinite and gabbro-hosted Logatchev hydrothermal field.

Serpentinite-hosted hydrothermal systems are thought to be unable to sustain high-biomass communities, based on the small-biomass communities observed at the Lost City hydrothermal field. However, the SSF vesicomyid clam communities are probably larger than those reported from the Nankai Trough and/or Sagami Trough, demonstrating that these serpentinite-hosted low-temperature systems can sustain high-biomass communities.

The SSF is a new class of seep system hosted by exposed upper mantle. The deep geology of the southern Mariana forearc is dominated by peridotite and is heavily faulted, suggesting that more SSF-type seeps exist in this region. Similar vents may also exist in other convergent margins like the Tonga forearc where extensive peridotite exposures in the inner trench wall also are known. Our discovery supports the prediction that serpentinite-hosted vents are widespread on the ocean floor. We hope to return to the SSF to better understand the workings of this natural laboratory as soon as possible.

Keywords: serpentinite, peridotite, upper mantle, chemosynthetic community, vesicomyid clam, Shinkai Seep Field