Fore-arc mantle alteration, fluid activity and fluid-rock interaction revealed from Serpentinite Mud Seamounts at the Mariana Convergent Margin System (IODP Expedition 366)

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The Mariana convergent margin provides the environment where a natural process brings materials from great depths directly to the surface. The Mariana forearc contains the only current active serpentine mud volcanism in a convergent margin setting. Here, serpentine mud volcanoes are numerous, large (averaging 30 km diameter and 2 km high) and active. They are composed principally of unconsolidated flows of serpentine muds containing clasts of serpentinized mantle peridotite and several other lithologies, such as blueschist materials derived from the subducting slab.

IODP Expedition 366 recovered cores from three serpentinite mud volcanoes at increasing distances from the Mariana trench subduction zone along a south-to-north transect: Yinazao (Blue Moon), Fantangisña (Celestial), and Asùt Tesoru (Big Blue). These cores consist of serpentinite mud containing lithic clasts and minerals derived from the underlying forearc crust and mantle, as well as from the subducting Pacific Plate. Fluids upwell within these mud volcanoes at a rate that is in excess of the mud matrix. Such fluids originate from the downgoing plate but are highly altered, are reducing and have pH values in the range of 9 to 12.5.

For the purposes of this study ultramafic and mafic rock clasts from the flanks and summits of both Asùt Tesoru and Fantangisña Seamounts were analyzed in order to reconstruct processes of fore-arc mantle alteration, fluid activity and fluid-rock interaction. Additionally, several samples from Asùt Tesoru Seamount consisting of cryptocrystalline serpentine mud with commonly occurring lithic clasts (>2 mm) in different amounts and size were investigated.

In general the mineral paragenesis of the serpentinized peridotite clasts, including mainly lizardite and chrysotile serpentine group minerals, along with brucite as well as andradite, and the apparent absence of high-temperature phases such as antigorite and anthophyllite, tentatively constrains an upper temperature limit of 200 – 300 °C. However, the presence of fine-grained matrix antigorite associated with lizardite suggests metamorphic temperature of at least 340 °C.

Hydrogarnet is a common secondary, hydrothermal mineral phase in the studied samples and it defines a serpentinization temperature of c. 230 °C. Garnet crystals with subhedral habitus and almost pure andraditic composition are found within a carbonate matrix. However, also Cr-rich garnets are common within the serpentine clasts. They are subhedral to anhedral and contain
chromite inclusions with similar composition to the unaltered chromites in the same sample. These textural observations suggest a secondary origin for the Cr-rich garnets as well, most probably related to hydrothermal fluids that infiltrated the ultramafic protolith. The formation of Cr-rich garnet after Cr-rich spinel is usually associated with hydrothermal or metasomatic reactions, although the precise mechanism of formation remains unclear. Generally Cr-rich hydrogarnets in serpentinites crystallize below 400 °C, which is in line with the obtained metamorphic conditions and indicate an overall evolution of a hydrothermal fluid from c. 350 °C (antigorite in serpentinites) to c. 100 °C and below.