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JAMSTEC

Two Types of Primary Magma Found at Underwater Volcano - New Implication for Magma Genesis at Subduction Zones -

Overview

Yoshihiko Tamura and his colleagues at JAMSTEC conducted a series of geochemical analysis of the rock samples from NW Rota-1 volcano, an active submarine volcano in the southern part of the Mariana arc, and discovered that the rocks come from two types of magmas of different nature and origin.

The study suggests the possible presence of heterogeneous peridotite in the uppermost mantle as a magma source at the subduction zone, which may contribute to the genesis of two types of primary magmas (*1). The findings provide significant implications for better explaining the magmatic diversity on the surface, and may urge the development of a model to explain deep mantle flow in the volcanic arcs.

The study will be published online on June 3rd as an advance access of the Journal of Petrology and will be included in the July issue.

Title:	Two primary basalt magma types from Northwest Rota-1 volcano, Mariana arc, and its mantle diapir or mantle wedge plume.
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Results

Magmas of NW Rota-1 volcano (Fig. 1) are little modified by fractional crystallization (*2) and thus represent melts of the near-primitive magmatic stage. Researchers analyzed the rock samples collected from this volcano, using microscopic observations and chemical analysis (e.g. major element analysis, trace element analysis, and Sr-Nd-Pb-Hf isotope analysis), and explored the origin and differentiation of magmas. The results showed the existence of two types of primary magmas; a magma containing significant water and elements derived from the subducting slab (wet magma), and a magma containing little water and less subduction components (dry magma).

These results, however, do not support the conventional theory that magmas of a single volcano are derived from partial melting of nearly homogenous peridotite in the mantle wedge. Researchers reexamined the processes of the plate subduction, mantle convection and associated magma genesis at the Mariana arc and presented a new model as shown in Figure 2.

The process of magma genesis is:

1) Water released from the subducting peridotite causes flush melting of sediment on the subducting plate and produces hydrous sediment melt. The hydrous sediment melt , which is then mixed into the overlying mantle peridotite, triggers the partial melting of the mantle peridotite and forms a semi-liquid mass called mantle diapir (*3). The partial melting gives the diapir buoyancy and makes it move upward.

2) The mantle peridotite and the sediment melt, however, are not expected to mix well within the diapir. Such difference of the amounts of sediment melt results in the formation of two magma types within the mantle diapir; one poor and another rich in sediment melt.

3) Decompression melting caused by the ascending diapir produces more magmas.

The existence of two primary magma types within a volcano suggests the possibility to generate diverse magmas by fractional crystallization. The findings could thus provide rational explanation to the actual magmatic diversity, and moreover, would urge redesigning of mantle structure models below volcanic arcs.

Background and future perspectives
Understanding the formation of the continental crust is one of the major scientific challenges for earth scientists. The continental crust has an average composition of andesite, thus the production of andesitic magma is the main issue. " How can andesitic magmas be produced from mantle-derived primary magmas and how do they evolve into continental crust?" To answer these questions, scientists need to explore both primary magmas and magma differentiation processes.

At NW Rota-1 volcano, the lavas are little modified by fractional crystallization and thus record compositions analogous to those of near-primary magmas. Using JAMSTEC's ROV, the researchers collected rock samples from NW Rota-1 volcano (reported on May 22, 2006) and analyzed their petrological and geochemical properties. The results revealed the existence of two primary magma types with different compositions.
This also indicates that fractional crystallization of two primary magma types can result in greater diversity of magmas.
Such processes may help researchers to develop a new theory in magma genesis and continental crust formation.

The results of this study will be referenced to the core analysis in the Project IBM(Izu-Bonin-Mariana), a project led by JAMSTEC and planned for the future Integrated Ocean Drilling Program (IODP). The project aims to reveal the arc magma genesis, arc crust evolution and continental crust formation by drilling ocean floor of the Izu-Bonin-Mariana (IBM).

***1. Primary magma**
A melt first derived from partial melting of the upper mantle. As primary magma ascends toward the surface and cools, minerals crystallize out of magma and change the composition of residual magmas.

***2. Fractional crystallization**
As magma cools, it begins to crystallize minerals. Heavier than the magma, crystals accumulate at the base of the magma chamber. As such, the composition of magma changes during the crystallization. The process is called fractional crystallization.

3. Mantle diapir
A mush formed by partial melting of the mantle. Partial melting induces buoyancy and makes a diapir ascend through the mantle wedge. Mantle diapirs are likely to be involved in the origin of arc magmas beneath the volcanoes.

Appendix

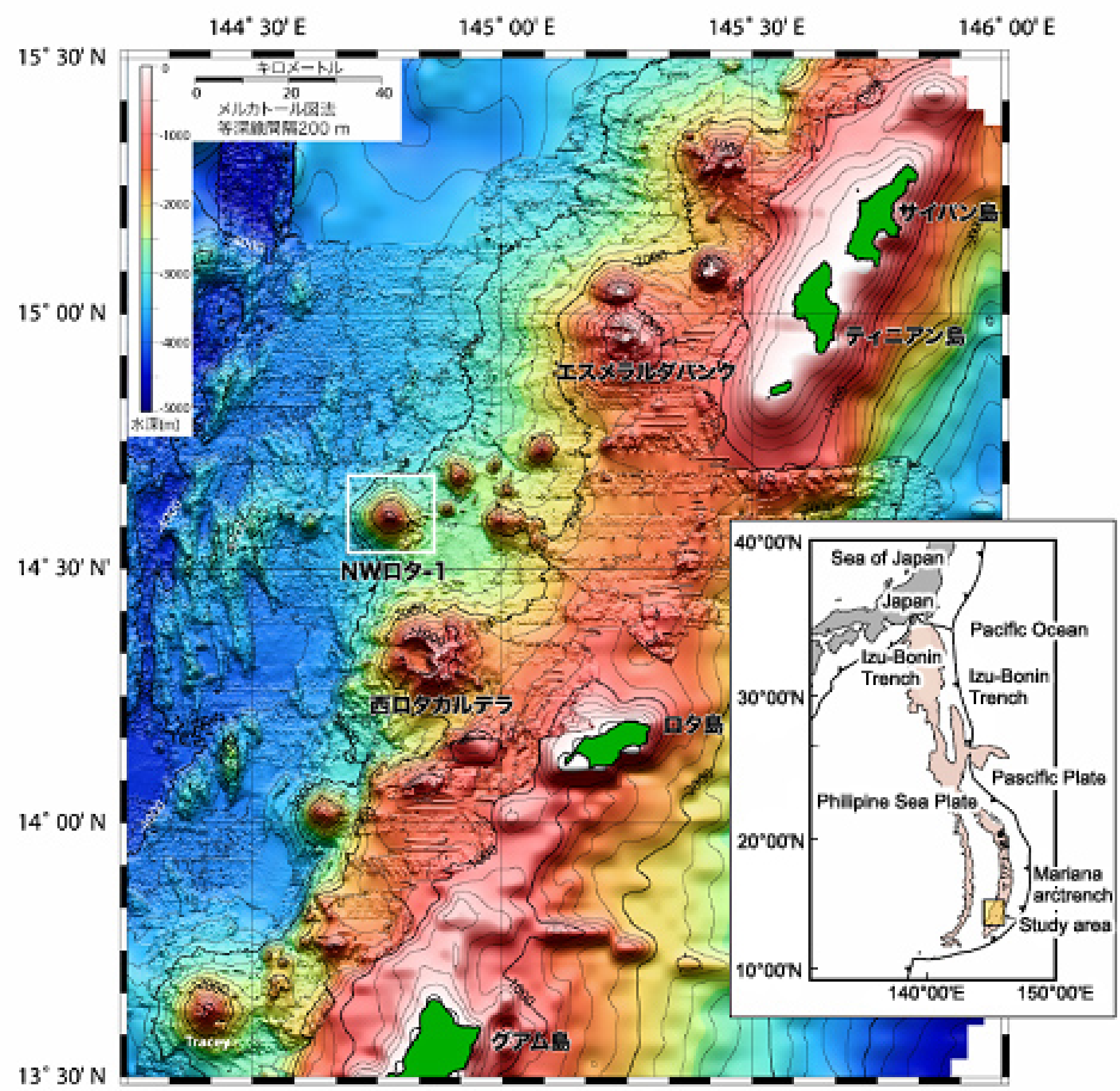

Figure 1. Location of NW Rota-1 volcano

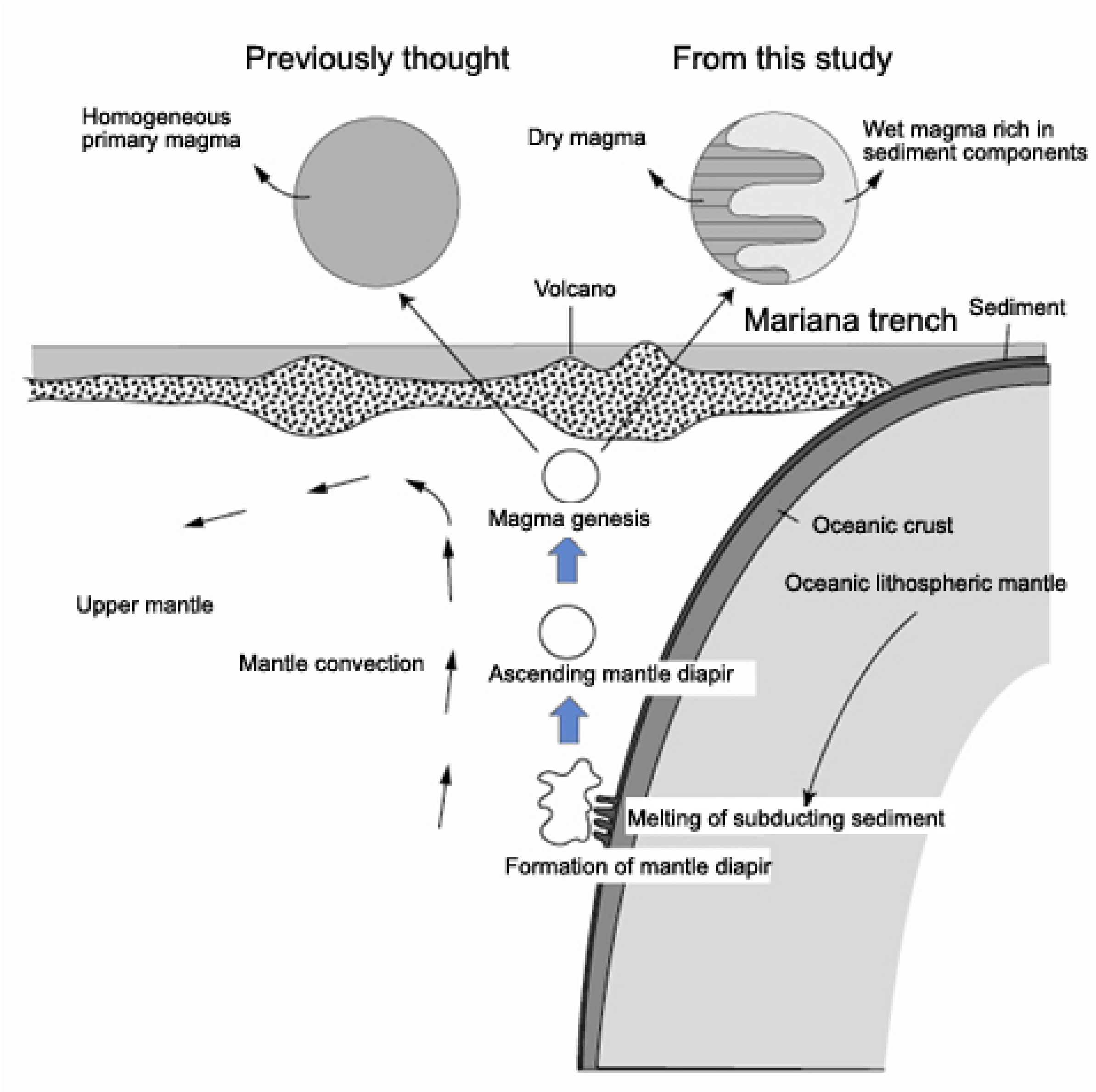

Figure 2. Magma genesis model involving a mantle diapir consisting of two magma types

Magmas are thought to originate from partial melting of a homogenous peridotite in the mantle wedge. The findings from this study suggest that the mantle wedge at the subduction zone contains heterogeneous peridotite and partial melting of it contributes to different magma compositions.

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