Press Releases

November 7, 2013
JAMSTEC

World’s First Samples of Primary Magma Discovered on Underwater Volcano

1. Overview

A survey team led by Dr. Yoshihiko Tamura, Principal Scientist of Institute for Research on Earth Evolution of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC; Asahiko Taira, President), using the remotely operated vehicle (ROV) *Hyper-Dolphin*, surveyed submarine volcanoes of the Mariana arc. Analysis of pillow lava samples recovered from the ocean floor during the survey were found to consist of primary magmas[*1] formed from subduction zone activity and which had retained its composition when brought to the surface in a lava flow. The discovery opens the door for detailed analyses of primary magma, which until now had only been identified in laboratory-based experiments. The findings are expected to shed further light on such internal dynamics as the mechanisms of volcanic formation and continental plate composition, and to contribute to disaster planning and damage mitigation during volcanic eruptions.

The findings were made in a survey funded in part by a Grant-in-Aid for Scientific Research (B) (23340166) from the Japan Society for the Promotion of Science; they were published in the November 7, 2013 (JST) digital volume of the *Journal of Petrology*.

Title: Mission Immiscible: Distinct subduction components generate two primary magmas of Pagan Volcano, Mariana arc
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*1Primary Magma
Magma is produced from the initial melting of the upper mantle; it is also known as primitive magma because it has not undergone differentiation. Until it erupts onto the surface as lava, primary magma changes in composition when the temperature decreases, as minerals crystallize and then separate from the surrounding magma (crystallization differentiation). The composition is also changed through the melting and assimilation of crust components from latent heat. If primary magma were an orange, differentiated magma would be like orange juice, meaning that just as studying an orange would require a whole orange and not the juice, primary rather than differentiated magma is needed to understand how magma forms.

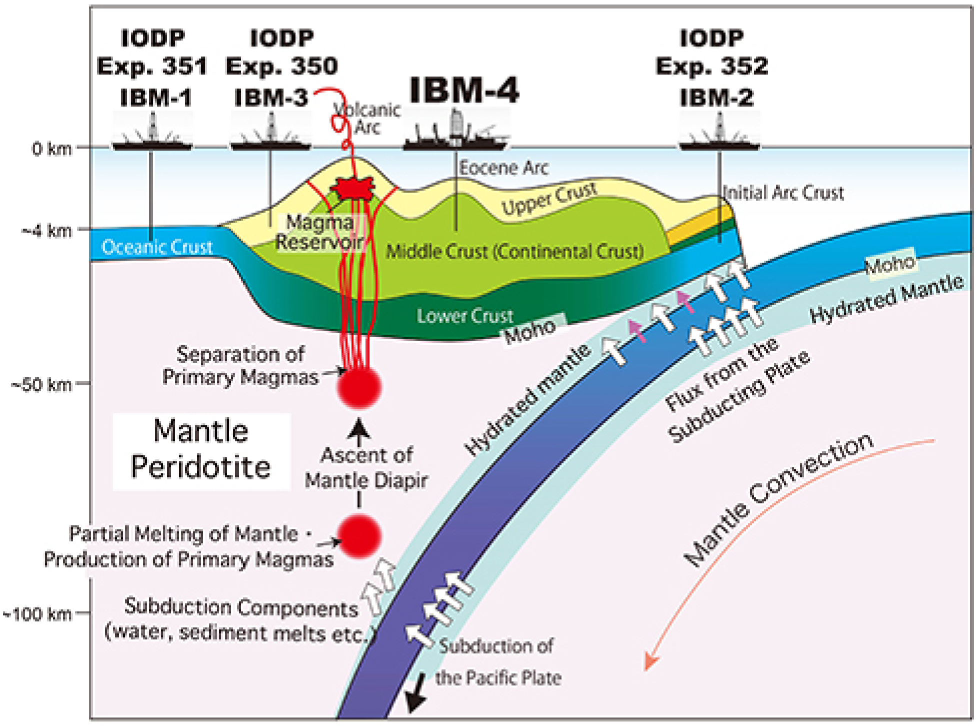

Figure 1: Conceptual diagram showing internal activity across a subduction zone. Water and sediment (liquid melt) from the subduction plate is released into the upper-mantle peridotite at depths of ~100 km. Although upper-mantle peridotite is largely solid, the melting temperature is lowered by the presence of water and melt, with primary magma being formed from the resulting partial melt. Melted peridotite containing 20-40 % primary magmas (mantle diapir) ascends through the mantle wedge and separates primary magmas out at depths of around 30–60 km. Primary magmas differentiate in crustal magma chambers, and solidify when they erupt onto the surface as lava flows or volcanic ash. Analysis of primary magmas collected during the survey is about to shed light on how this process occurs in detail.

(Note) One of the greatest geoscientific mysteries is how primary magma (basalt composition) formed in the mantle differentiates to produce continental crust (andesite composition). As part of the program called ‘Project IBM’ to understand the history from the onset of subduction to the present and the formation of continental crust in the Izu-Bonin-Mariana oceanic arc, the US DV JOIDES Resolution will take core samples of the Izu rear-arc (IBM-3), oceanic basement (IBM-1), and initial island arc crust (IBM-2) over the course of six months. In a future subsequent voyage, DV *Chikyu* will drill through the upper crust into the middle crust (IBM-4)and analyze mid-crust samples in an attempt to solve the mysteries behind the formation of continental crust.

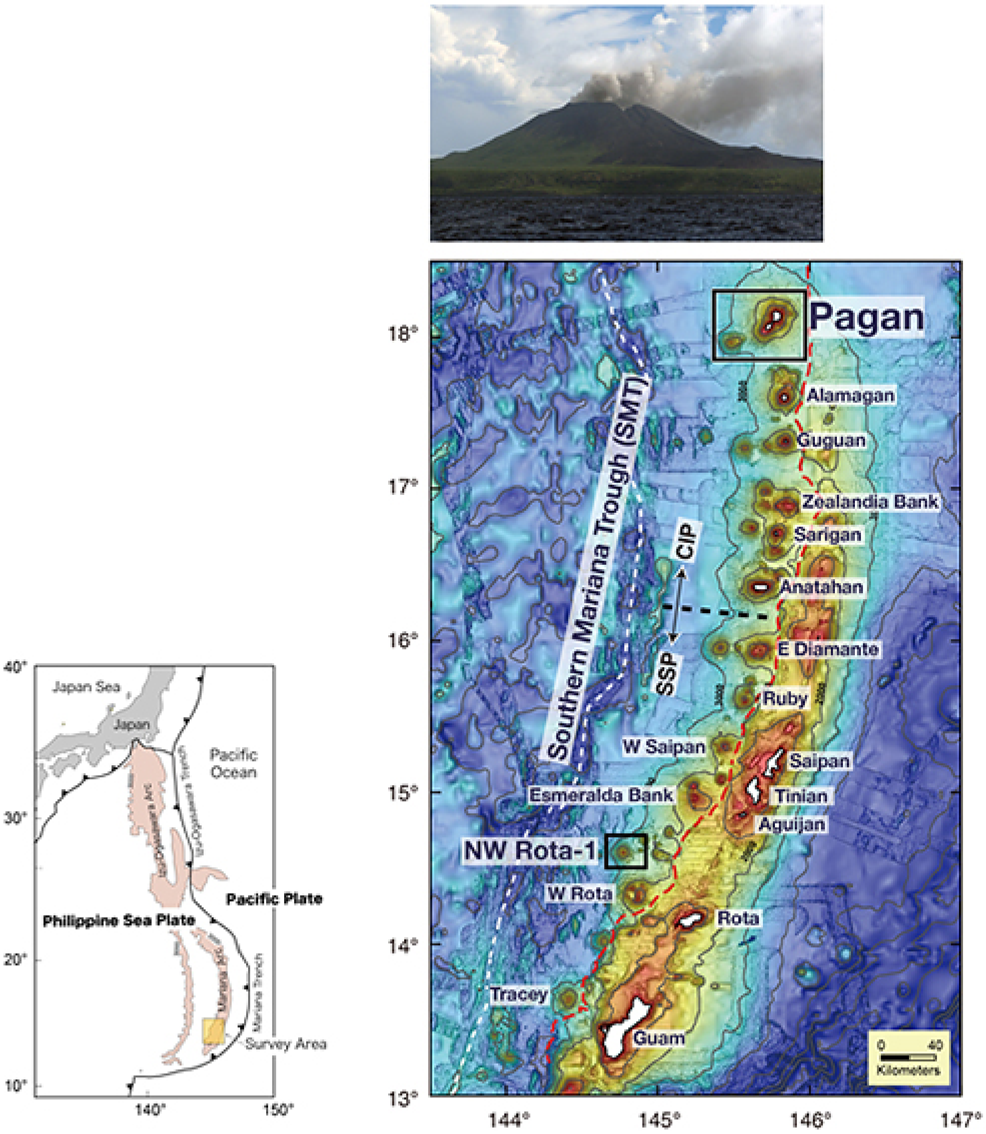

Figure 2: A regional map showing the Mariana Archipelago (Mariana arc), including the island of Pagan with the active Pagan volcano. The current volcanic front is seen west of the red dashed line (left). Subaerial volcanoes are clearly seen in the northern section of the Mariana arc (CIP: Central Island Province), whereas those in the south are all submarine (SSP: Southern Seamount Province). The limestone-covered islands of Saipan and Guam, located east (right) of the red dotted line, are ancient volcanic edifices formed from the Eocene to the Miocene. The white dotted line marks the Mariana Trough (back-arc basin axis).

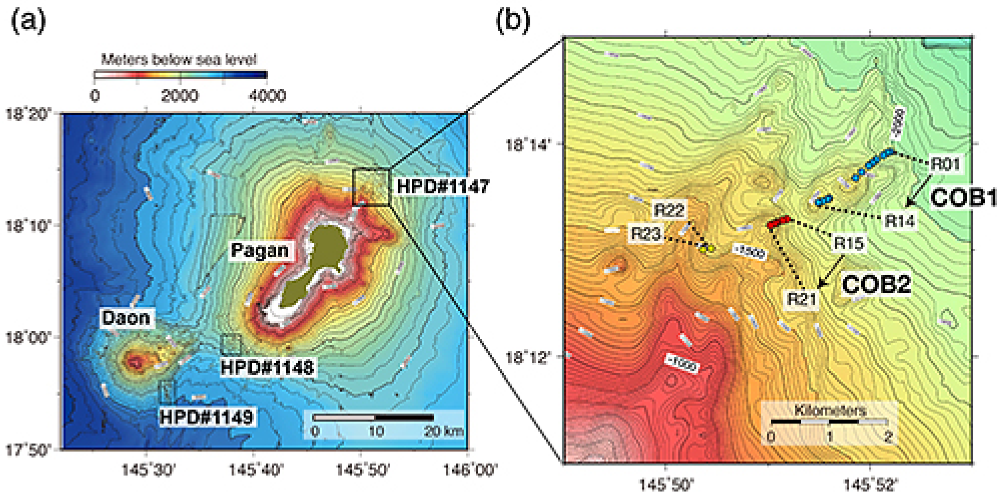

Figure 3: Topographical map showing the ocean floor around Pagan Island and sites of sample collection. (a) Diving points by ROV *Hyper-Dolphin* around Pagan Island. Samples of primitive magmas were collected at dive track HPD#1147. (b) Twenty-three samples of lava were collected at HPD#11147. The distinct compositional differences seen between lavas R01 to R14 (COB1) and lavas R15 to R21 (COB2) were found to be due to their formation from different types of primary magma.

Figure 4: Pillow lava flows freshly formed by primary magma on the ocean floor of Pagan Island. It is thought to be from a recent flow because there is no sediment on the surface of the lava.

(a) Water depth 1979 m
(b) Water depth 1830 m

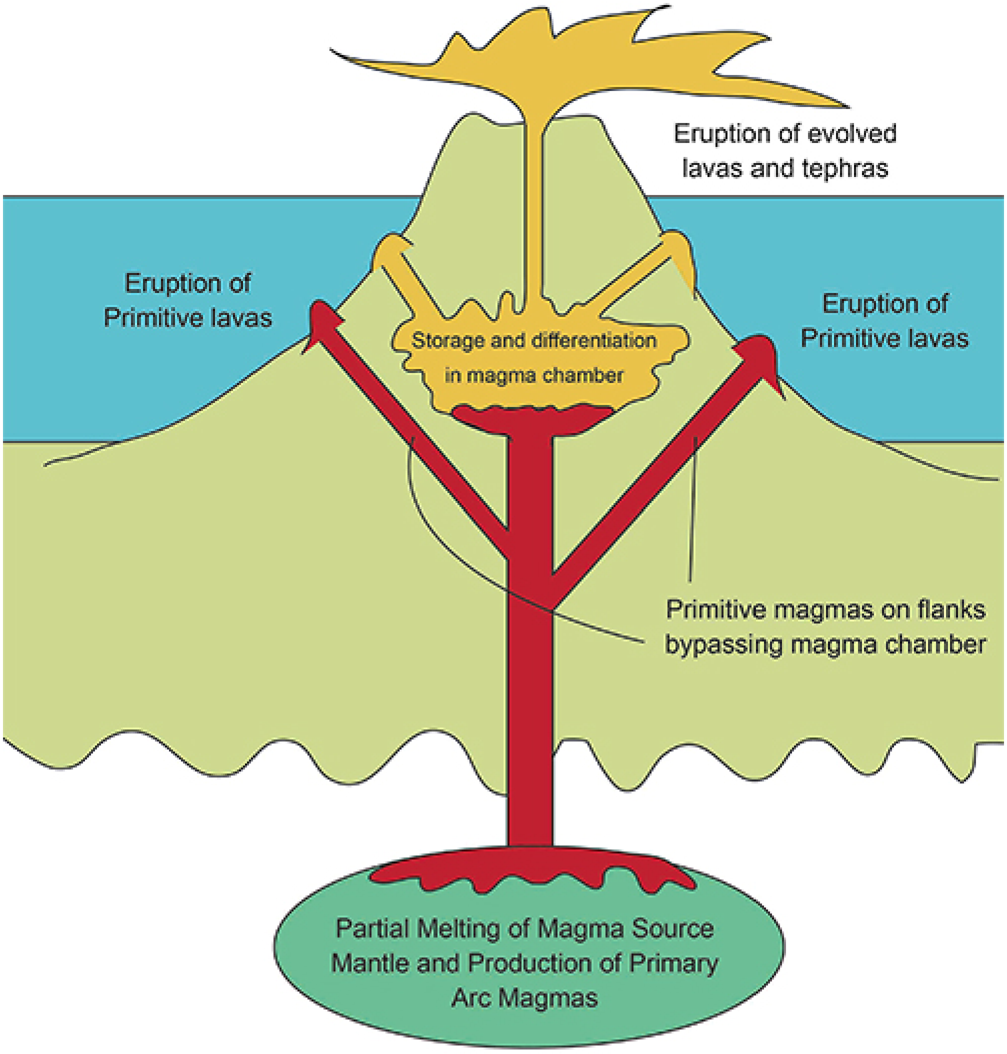

Figure 5: Conceptual diagram of Pagan volcano.
In this study, primitive lavas were discovered presumably because they directly erupted onto the ocean floor from deep mantle source over a short period of time without going through the magma chamber. Such primitive magmas may have followed peripheral conduits that allowed them to escape storage and differentiation in magma chambers existing below the summit of the volcanoes.

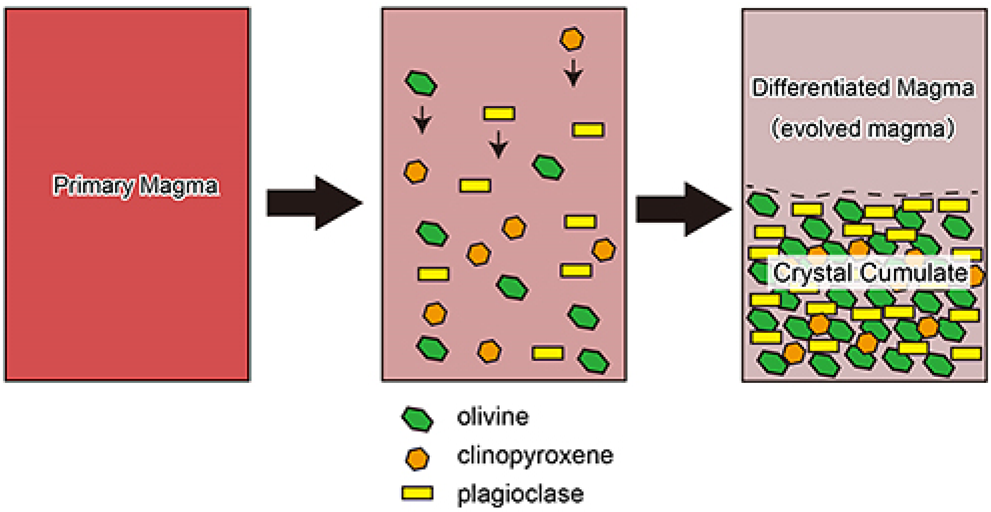

Figure 6: Concept of Fractional Crystallization
The arrows show a decrease in temperature, which results in the formation and separation of various crystals during cooling. The crystals differ in composition and density from their parent magmas. Hence, as they settle and separate, the composition of the remaining (differentiated or evolved) magma changes accordingly.

[Reference Video]

JST"Science News"

(YouTube)

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