Press Releases

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JAMSTEC
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Carbon Dioxide Induces Partial Melting in the Asthenosphere - A big step to settle arguments on plate tectonics -

Overview

Dr. Shiki Machida at Research and Development Center for Submarine Resources, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) carried out high-pressure melting experiments to define magma genesis of petit-spot[*1] in the flexed region of the northwestern Pacific plate. The results revealed that the petit-spot magmas are originated in the asthenosphere[*2] in the upper mantle. The work was carried out in collaboration with Dr. Tetsu Kogiso, Professor at Graduate School of Human and Environmental Studies, Kyoto University (Juichi Yamagiwa, President) and Dr. Naoto Hirano, Associate Professor at Tohoku University (Susumu Satomi, President).

It has already been known that the primary petit-spot magma includes approximately 10% carbon dioxide (CO_2), which is much higher amount of that in magmas for the other type of volcanism. In this study, scientists demonstrated that 1) CO_2 induces partial melting in the asthenosphere; and 2) plate flexure allows these magmas to intrude into the lower part of plate, which are then in equilibrium with surrounding mantle peridotites before eruption to form petit spot volcanoes. Here, petit-spot is a definitive evidence for partial melting in the asthenosphere caused by CO_2.

According to the plate tectonic theory, plates move on top of the weak asthenosphere. Subduction of these plates causes earthquakes, volcanic activities and orogeny. Thus, the asthenosphere plays a critical role on the movement of plates across the Earth's surface, and is an important layer to characterize the Earth having active surface and continent, which is a unique planet in the solar system. Since the establishment of the plate tectonic theory, there have been arguments whether the weak asthenosphere is caused by partial melting of mantle rocks or not. These results strongly support the partial melting hypothesis, providing a big clue to further elucidate the mechanism of plate movements and mantle convection.

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Title: Petit-spot as definitive evidence for partial melting in the asthenosphere caused by CO_2

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*1 Petit-spots
Petit-spots or petit-spot volcanoes are young volcanoes discovered on the seafloor or near the trench. They're not classified in typical three types of volcanoes erupting in three tectonic settings: mid-ocean ridges; subduction zones where a continental and oceanic plate collides; and a hot spot where mantle plumes is upwelling. Compared to these three types, petit-spots are a new type, in which plate flexure causes magma eruption, forming much smaller volcanoes.
Since the group of such small volcanoes or petit spot volcanoes was discovered (Hirano et al., 2006, Science), they have been ubiquitously found around the world such as off the coasts of Chile and Tonga, off Greenland, and the Sunda Trench.

*2 Asthenosphere and plates (lithosphere)
The asthenosphere is the weak layer of the mantle of the Earth, lying beneath the lithosphere, which is the solid and rigid outer-most layer of our planet. It extends from about 100 km to 300 km below Earth’s surface. Asthenosphere comes from the Greek word "astheno," which means "weak," while “litho” means rocky.

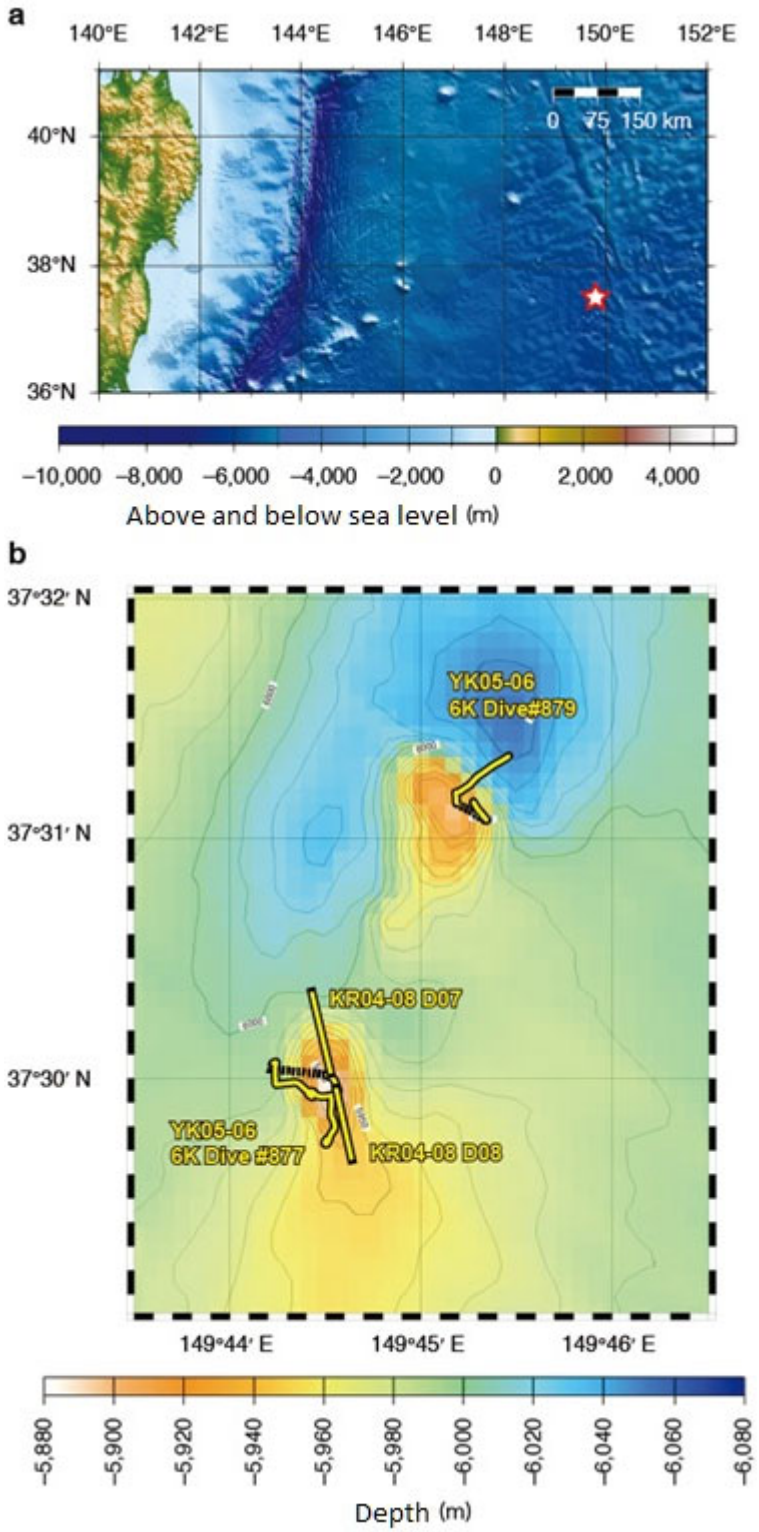

Figure 1. Bathymetric maps for the northwestern Pacific showing the position of the petit-spot volcanoes investigated in this study. The open red star corresponds to the region shown in b).
The yellow bars in b) mark the positions of the survey lines around the sampling sites. YK05-06 6K Dive #877 & #879 were carried out by *Shinkai 6500* during Yokosuka YK05-06 cruise; and KR04-08 D07 & D08 by dredge surveys during *Kairei* KR04-08 cruise.

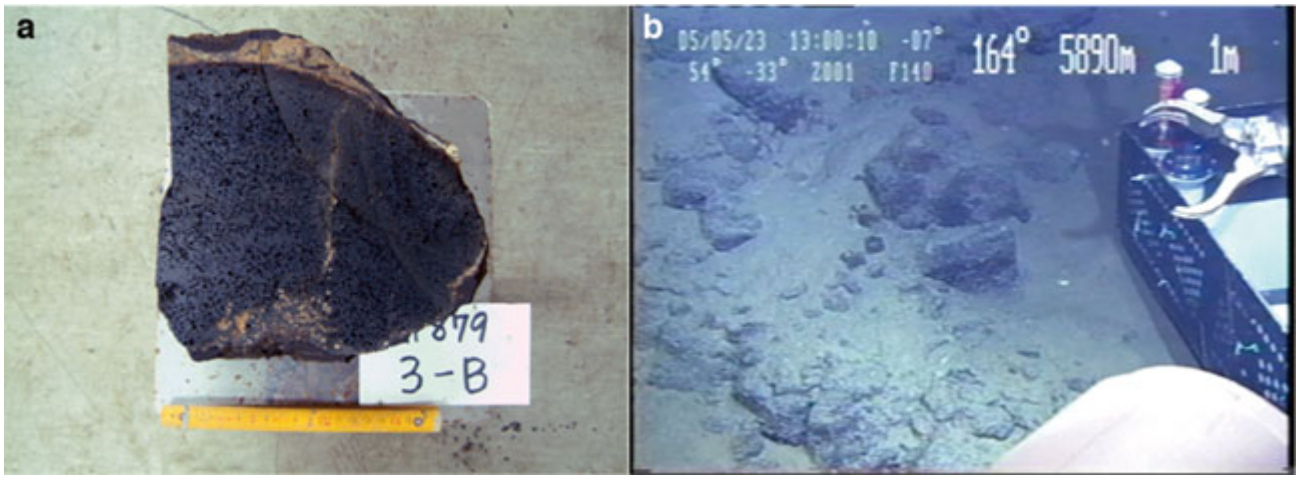

Figure 2. (a) One of sample basalts used for high-pressure melting experiments. Its chemical composition is likely to be very similar to those of primary magmas. (b) Sampling carried out by *Shinkai 6500* Dive 879 during YK05-06 cruise.

Figure 3. Mixture of pre-dried reagents of oxides, hydroxides, phosphate and carbonates, which represents the major elements, CO_2 and H_2O composition of the primary magma for petit-spot volcano. This mixture is used as starting material of the melting experiments.

Figure 4. Boyd–England-type 1/2-in-diameter piston–cylinder apparatus used for the melting experiments at Kyoto University.

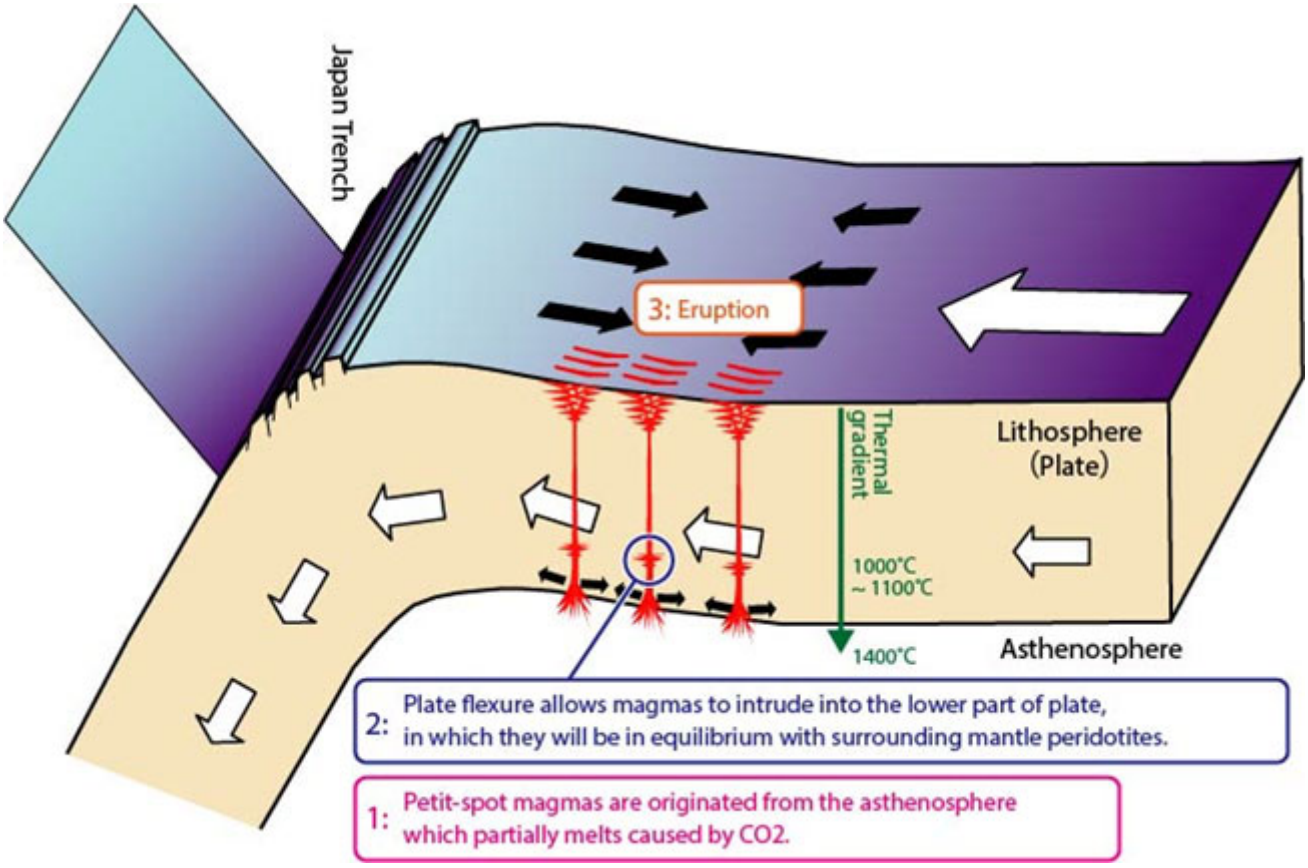

Figure 5. Model for petit-spot volcanism in the northwest Pacific (modified Fig. 3C in Hirano et al. (2006) based on results of this study).

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