論文の内容の要旨

論文題目

Observational and numerical studies of melt generation beneath the Petit-spots in the northwestern Pacific

（北西太平洋プチスポットメルト生成場の観測的研究と数値シミュレーション）

氏名　　高橋　亜夕

In recent years, some intraplate volcanoes that clearly do not form above a fixed hot spot have been found in the Pacific plate. Of these, the Petit-spot volcanoes occur on an old part of the northwestern Pacific, being far away from either mid-ocean ridges or hotspots. Deciphering the origin of the Petit-spot volcanoes, therefore, is important for understanding the uncategorized volcanoes.

Petit-spot volcanoes on the north western Pacific Plate were first reported by Hirano et al. (2001, 2006). Until now the Petit-spot-like volcanoes are observed in the north western Pacific Plate and near the Tonga and Chile Trenches (Hirano et al., 2008; Ranero et al., 2005). Hirano et al. (2006) suggested "the flexure model", in which melt in the asthenosphere may have escaped along plate fractures that occur in the flexed outer rise. The flexure model provides insights into the mechanism of melt ascent and distribution of knolls, still it does not explain how partial melting occurs in the asthenosphere beneath the old part of the Pacific Plate. The thermal structure beneath the Petit-spot is particularly of great interest. This comprehension would provide constraints on the P-T and compositional condition of asthenosphere under the western part of the Pacific Plate, being independent of seismology.

The main aim of this study is to elucidate the melting mechanism beneath the Petit-spots in the northwestern Pacific, where a 130 Ma oceanic lithosphere, hence a relatively cold plate, could suppress melting. The geological, petrological and geophysical observations of the Petit-spots have been collected through scientific cruises and geochemical analyses of the recovered samples. The bathymetry and age data have revealed that the Petit-spots were active in an extensive area from the top of the Hokkaido Rise to a region about 650 km east from the Rise. The isotope compositions and trace elements spidergram patterns indicate that the extremely low degree of melting of the MORB-like source with enrichment of specific elements such as Pb and K. The measured regional heat flow values are slightly higher than the typical value for a 130 Ma ocean basin. The flow-melting model has been constructed based on these bathymetry and heat flow data. In order to reproduce the trace element compositions of the lavas with this flow-melting regime, averaged DMM and an aqueous fluid that has geochemical affinities with a slab-derived fluid in subduction zones were assumed as source materials of the Petit-spot magmas. Combination of DMM and the fluid may also explain the isotopic characteristics including Sr, Nd, Pb and He isotopes. The results were shown as a function of the melting and fluid parameters.

If the thickness of lithosphere is assumed within a range from 60 km to 90 km depth, as suggested from the seismological observations, no melting occurs under the dry condition. Although the water content necessary for incipient melting varies with the assumed thickness of lithosphere, only the extremely low degree of near-incipient melting can reproduce the steeply downward pattern of trace element spidergram.

The best fit model (the case with a fluid fraction that was added to DMM source is ~0.14 wt.%, the melting depth is 78 km, the temperature is ~1150℃, the averaged melting degree is 0.19 %, and the spinel – garnet proportion involved in melting X_{gt} = garnet lherzolite / [garnet lherzolite + spinel lherzolite] in melt weight is 0.91) exhibits a good agreement with most of the observations as follows:

(1) Aqueous fluid as a solidus-reducing agent can cause melting in the condition of averaged observed surface heat flow value (54 mW/m^2). The depth of calculated molten layer (78 km) and its melting degree (0.19 %) and residual mineralogy reasonably reproduce the steep trend of trace element spidergram with strong depletion of HREE, together with enrichment of Pb and K which can be transported by the aqueous fluid.

(2) Existence of a DMM source, which has been fluxed by and aqueous fluid, is supported by both Sr-Nd-Pb and noble gas isotope systematics. In addition the Petit-spot samples show a high 'anciently subducted fluid-component' (i.e., high IC2 component, Iwamori et al., 2010). Furthermore, Iwamori (2010) suggested that dehydration-hydration reactions that occurred in the past subduction zones are responsible for the origin of IC2

involved in the Petit-spot magmas.

(3) The Petit-spot lavas are characterized by high vesicularity. The estimated extremely low degree of partial melting (0.19 % with ~0.14 wt.% H_2O) concentrates ~ 11.7 wt.% of H_2O in the melt, which obviously exceeds the water solubility in basaltic melts at melt generation depths (Iwamori, 1998).

(4) Although the partially molten layer is limited at a depth of ~ 80 km, large velocity drop at a depth of 80 – 210 km is observed in the northwestern Pacific (e. g. Kawakatsu et al., 2009). Sub-solidus velocity reduction should occur due to presence of H_2O for the thick low velocity zone, with an overlying thin partially molten layer that defines the sharp lithosphere-asthenosphere boundary.

Addition of the aqueous fluid to a depleted MORB mantle (DMM) source offers internally consistent explanations for the key observations as above. Taking the high IC2 component into consideration with the evolved pseudo isochron ages (1.78 – 2.08 Ga, assuming ~ 0.19 % melting) in the U-Th-Pb isotope space, an anciently subducted 'slab-fluid' like component is suggested in the source, and such fluids could have been delivered vertically from the depths to the melting source region of the Petit-spot.