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Highlights and Breakthroughs

Hydrous LABZ Beneath a Subduction Zone was Reconstructed for the First Time

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Introduction

The lithosphere asthenosphere boundary zone (LABZ) has been of great interest in recent decades, for the simple reason that understanding the LABZ - how it is defined, how it forms, how it evolves with time - is crucial to understanding mantle dynamics. In the framework of plate tectonics, the LABZ represents a boundary layer having a certain thickness (McKenzie and Bickle, 1988; see "thermal boundary layer in their Fig. 3), where heat, momentum, and materials are exchanged between conductive mantle (lithosphere) and underlying convective mantle (asthenosphere and below). Our knowledge about the composition and material properties of the LABZ is limited to areas overlain by continental cratons. Under thick continental cratons we can sample garnet lherzolite mantle xenoliths, and for such mineral assemblages, we have well-calibrated geothermometers and geobarometers (e.g., Boyd, 1973). The pressure-temperature conditions of the deep sub-continental mantle lithosphere can thus be obtained, and from such estimates, several petrologic models for the LABZ have been proposed (e.g., O'Reilly and Griffin, 2010; Agashev et al., 2013). In contrast, the LABZ under oceanic plates, young continents and subduction zones has remained largely in question, due to the lack of proper geobarometry for mantle xenoliths that record spinel (rather than garnet) lherzolite facies equilibrium.

Study on xenolith suites from Ichinomegata maar

Yuto Sato and Kazuhito Ozawa for the first time describe the petrologic features of the LABZ beneath a subduction zone, in their paper entitled "Reconstruction of the lithosphere-asthenosphere boundary zone beneath Ichinomegata maar, Northeast Japan, by geobarometry of spinel peridotite xenoliths" (Sato and Ozawa, this volume). In this paper, Sato and Ozawa successfully estimated depths of equilibration for nine spinel lherzolite xenoliths, collected from the Ichinomegata maar, in Northeast Japan. According to their estimates, these xenoliths last equilibrated at depths of 28 to 55 km, at temperatures of 829 to 1081°C, prior to their transport to the surface via host andesite magma. They also show that these mantle xenoliths exhibit clear changes in texture (granular to porphyroclastic) and phase assemblage (hornblende bearing to hornblende absent but partially molten) that represent a transition from lithosphere, to a lithosphere-asthenosphere boundary zone (see their Fig. 8).

The xenoliths from the Ichinomegata maar have received attention by many previous workers because they are rare samples derived from the crust and the upper mantle beneath an active subduction zone (e.g., Kuno 1967; Takahashi, 1980, 1986; Arai et al. 2004). In such prior studies, it has been revealed that the Ichinomegata xenoliths show complex thermal histories before final entrapment, and display evidence of hydration/dehydration and partial melting. However, the geologic implications of these petrologic features have not been entirely clear: due to a lack of proper geobarometry, their equilibration depths have been unknown. In this new study, not only do the authors estimate P-T equilibration conditions, but the authors make use of olivine and pyroxene grains (that show chemical zonings) in order to reconstruct episodes of cooling and heating on different time scales. Sato and Ozawa (this volume) carefully analyzed these zoning patterns and evaluated the equilibrium chemical composition of coexisting minerals just prior to the final xenolith transportation, using the thermo-barometry models of Nickel and Brey (1984).

Reconstructed LABZ beneath a subduction zone

A reconstructed LABZ beneath Ichinomegata is similar to those reported from the bottom of the subcratonic lithospheric mantle in various aspects, but the boundary layer beneath Ichinomegata is much shallower (40-60 km) and colder (~1050°C). What is particularly compelling is the coincidence of the depth of the rheological transition (granular to porphyroclastic textures) and that of the hydrous melting of peridotite. This remarkable feature of the boundary zone beneath Ichinomegata indicates that a rheological boundary zone in subduction zone is governed by the wet mantle solidus and also that the underlying asthenosphere is partially molten.

Sato and Ozawa (this volume) compared their results with seismological observation for

Northeast Japan arc. The mean depth of LAB beneath the Japan Sea is estimated to be 60 km by shear-wave tomography studies (e.g., Yoshizawa et al.,2010), which tends to decrease towards the Northeast Japan arc. Under volcanic front, depth of LAB is estimated to be <40km and it coincides with that of MOHO (e.g., Nakajima and Hasegawa, 2001). Ichinomegata maar is located about 80km from the volcanic front on the back-arc side. According to Sato and Ozawa (this volume), upper boundary of the LABZ is estimated to be around 40km in depth and the lower boundary to be >55km in depth. Combining this information with those by seismology, Sato and Ozawa (this volume) estimated a cross section of Northeast Japan Arc (see their Fig.10).

Nature of the LAB has been discussed from various aspects and it has been attributed to changes in either temperature, chemical compositions, water contents, or partial melting (e.g., Hirth and Kohlstedt, 1996; O'Reilly and Griffin, 2006; Green et al., 2010; Hirschmann, 2010; Karato, 2012). Paper by Sato and Ozawa (this volume) demonstrated that partial melting is the most crucial factor at least in the wet LABZ beneath subduction zones. Detailed petrologic information obtained by Sato and Ozawa (this volume) for LABZ beneath Northeast Japan arc should have great implications for understanding LABZ in other tectonic environments. Clearly, this paper is a breakthrough in mantle xenolith studies and it may have a profound influence on geodynamic studies of subduction zones.

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