Magma genesis model of the subduction zones based on hydrous melting experiments of a mantle peridotite

*Eiichi Takahashi[1], Jintuan Wang[1]

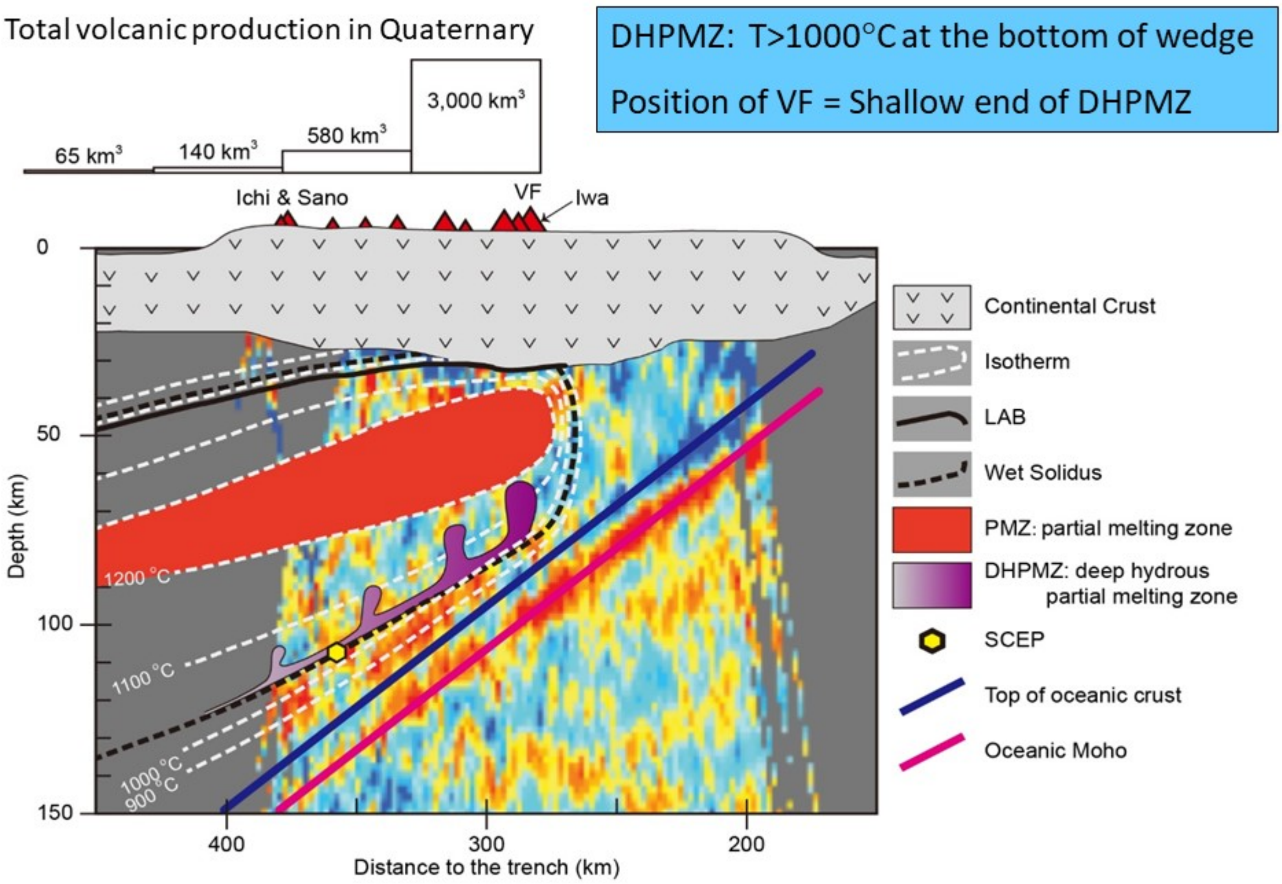
1. Guangzhou Institute of Geochemistry, Chinese Academy of Science

In order to understand the magma genesis beneath subduction zones, we carried out melting experiments of fertile peridotite KLB-1 with 10 wt.% H_2O at 3-6 GPa and 900-1200 ˚C using a large volume multi-anvil apparatus at Guangzhou Institute of Geochemistry (Wang et al, 2020, submitted to JGR). Compositions of the changing liquids (fluid + silicate melt at 3 GPa, super critical fluids SCFs at 4 and 6 GPa) have been determined by EDS analysis. At 3 GPa, quenched fluids are very rich in SiO_2 (>73 wt.%) and Al_2O_3 (>12 wt.%), but coexisting silicate melts are similar to boninite (SiO_2 =53-55 wt.%, MgO = 12-18 wt.%, TiO_2 = 0.3-0.5 wt.%) . Compositions of SCFs at 4 GPa are much higher in MgO than the melts at 3GPa, while SCFs at 6 GPa are further enriched in MgO and resembles komatiites or kimberlites (MgO = 22-25 wt.%). We discuss the role of DHPMZ (deep hydrous partial melting zone) and PMZ (partial melt zone in wedge mantle beneath arc volcanoes) in subduction zone magmatism based on our experimental results and some observation in geophysics, geochemistry and petrology in the North Honshu arc Japan.

Fine structures in the mantle wedge and subducted slab beneath North Honshu arc Japan have been studied using RF (receiver function) method by Kawakatsu and Watada (2007 Science), and they found a positive RF plane (indicating low velocity material) locating slightly above the top surface of the subducted plate at the depth of 90-120 km. Although they interpreted this low velocity layer as serpentinite but we propose that this is a hydrous partial melting zone judging from estimated temperature. According to our experiments, water-saturated solidus of mantle peridotite at 90 km depth is approximately 1000 ˚C which is consistent with the estimated mantle wedge temperature by Nakajima & Hasegawa (2003), while serpentinite is only stable below 650 ˚C at this depth.

We propose that the DHPMZ formed just above the subducted plate at 90-120km depth is the driving engine for subduction zone magmatism, although the magma derived from DHPMZ rarely appears on the surface. According to our experiments, melt at the top of the DHPMZ (˜90 km depth) should be similar to boninite and is very rich in H_2O (>20 wt.%). As partially molten diapirs separate from DHPMZ and moves upwards and are heated to ˜1200 ˚C in the shallower partial melt zone (PMZ), the partial melt compositions may become primitive olivine tholeiite beneath the volcanic front with 4-5 wt% of H_2O or water rich high-alumina basalt with 6-7 wt% H_2O in the rear arc side. It is possible that the location of the VF (volcanic front) is determined by the location of the shallowest end of the DHPMZ. In other word, wet mantle solidus possibly determines the position of VF. The very large volcanic production rate along the VF may be due to the coherent fluid transportation from the shallow end of the DHPMZ to PMZ. Spacing of arc volcanoes (Marsh, 1979) and hot mantle fingering (Tamura et al, 2002) may be explained by the spacing of wet diapirs from DHPMZ. We propose that role of boninite magma in arc magma genesis is significantly larger than previous thoughts. However, boninite magma can migrate to the surface only when PMZ has not been formed in the earliest stage of a subduction zone (e.g., Bonin arc) or PMZ terminates at the edge of a subduction zone (e.g., Tonga arc).

Keywords: subduction zone, magma genesis, wet mantle solidus, boninite magma


Total volcanic production in Quaternary
65 km³
140 km³
580 km³
3,000 km³
DHPMZ: T>1000°C at the bottom of wedge
Position of VF = Shallow end of DHPMZ
Ichi & Sano
VF
Iwa
0
50
100
150
Depth (km)
1200 °C
1100 °C
1000 °C
900 °C
400
300
200
Distance to the trench (km)
Continental Crust
Isotherm
LAB
Wet Solidus
PMZ: partial melting zone
DHPMZ: deep hydrous partial melting zone
SCEP
Top of oceanic crust
Oceanic Moho