Estimation of the thermal state of NW Kyushu mantle using primitive basalts

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The critical aspect of the debate regarding whether a mantle plume exists or not is temperature. If a plume exists it should have temperature higher than convecting upper mantle since it comes from deeper parts of the mantle *e.g.*, the 660-km discontinuity or the core-mantle boundary. If intraplate basalts are formed by mantle plumes, as many authors assume, primitive basalts should have melting temperatures higher than MORB and subduction zone basalts formed by shallow mantle convection. The results of previous melting experiments of peridotites and pyroxenites suggest that the compositions of partial melts depend on temperature. Thus, the petrochemistry of primitive intraplate basalts can tell us whether their source is abnormally hot or not. My colleague and I have estimated source temperatures of the northwest Kyushu basalts, southwest Japan (*Higo & Mashima*, 2004; *Mashima*, 2005).

Northwest Kyushu is located in the backarc region where the Philippine Sea plate subducts beneath the Eurasian plate (Figure 1). Seismic observations suggest that the subducting Philippine Sea plate does not extend beneath the Eurasian plate (Figure 2).

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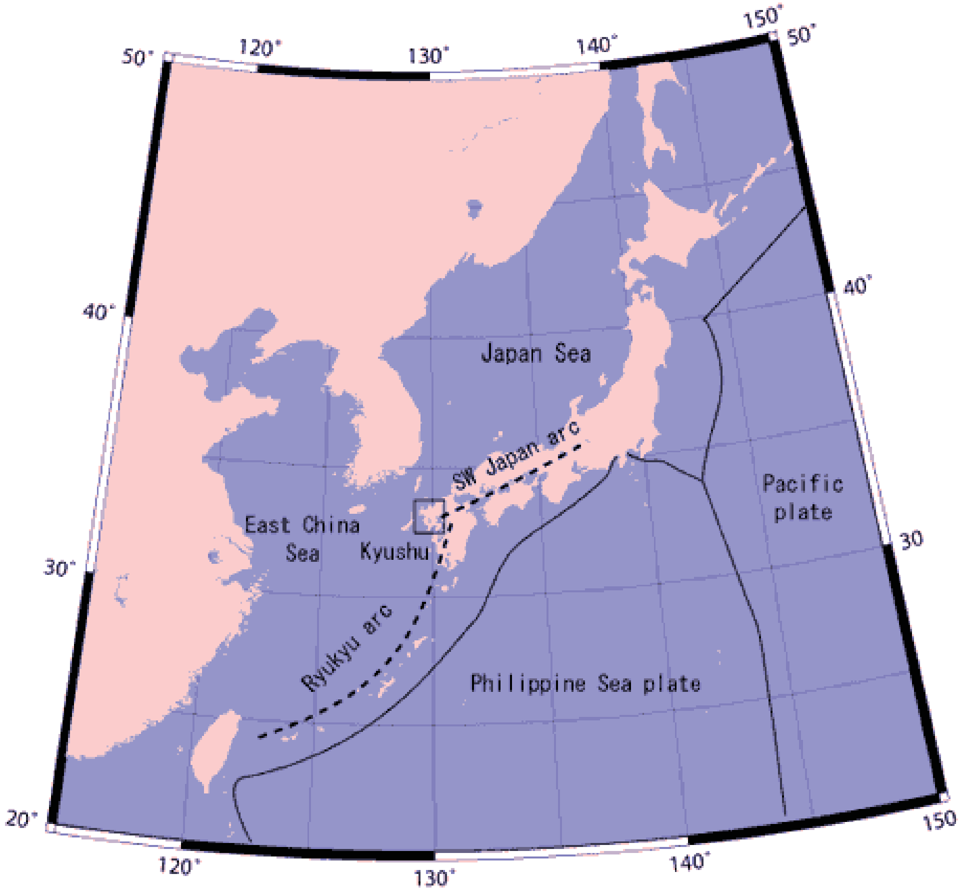

Figure 1: Map showing the tectonic setting of NW Kyushu. NW Kyushu is at the junction of the SW Japan arc and the Ryukyu arc, and the junction of the Japan Sea and the East China Sea.

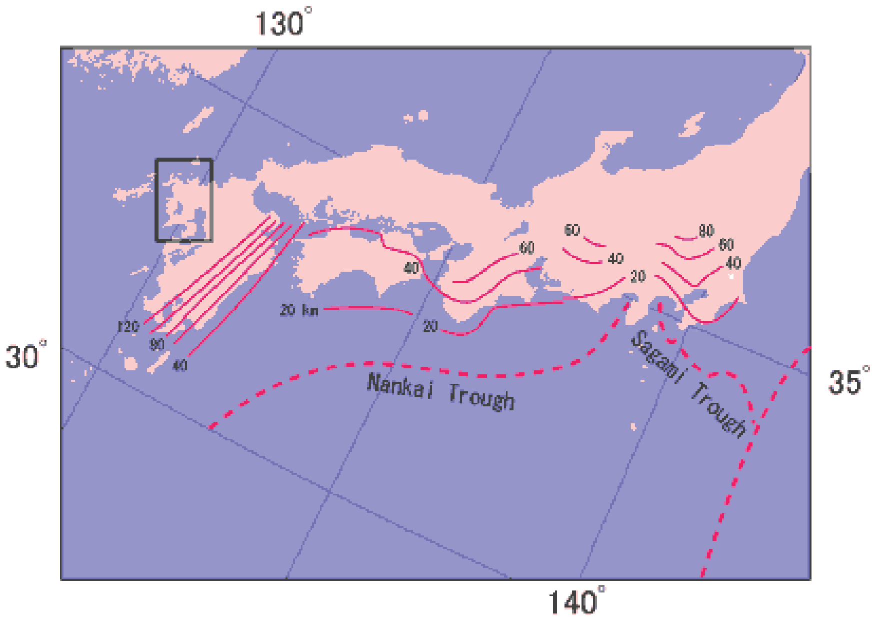

Figure 2: Map showing depth of the subducting Philippine Sea plate (after Yamazaki & Ooida, 1985; Ishida, 1992). The subducting Philippine Sea plate does not extend beneath NW Kyushu.

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NW Kyushu is also the junction of the southwest Japan arc and the Ryukyu arc and of the Japan Sea and the East China Sea. Mantle plumes are generally believed to come from a thermal boundary at the 660-km discontinuity or the core-mantle boundary. Tomographic images, however, suggest that subducted Pacific plate stagnates at the 660-km discontinuity beneath NE Asia (F*ukao et al.,* 1992), which means that the 660-km discontinuity beneath NW Kyushu is cold. Normal faults in NW Kyushu (Figure 3) suggest that the stress field there is essentially tensional. Volcanism in NW Kyushu is characterized by the eruption of basaltic lava flows since 10 Ma. Prior to this basaltic volcanism, formation of inner arc sedimentary basins and their uplift occurred. Because of petrochemical similarities, *Nakamura et al.* (1985) suggested that NW Kyushu volcanism is caused by plumes from the deep mantle.

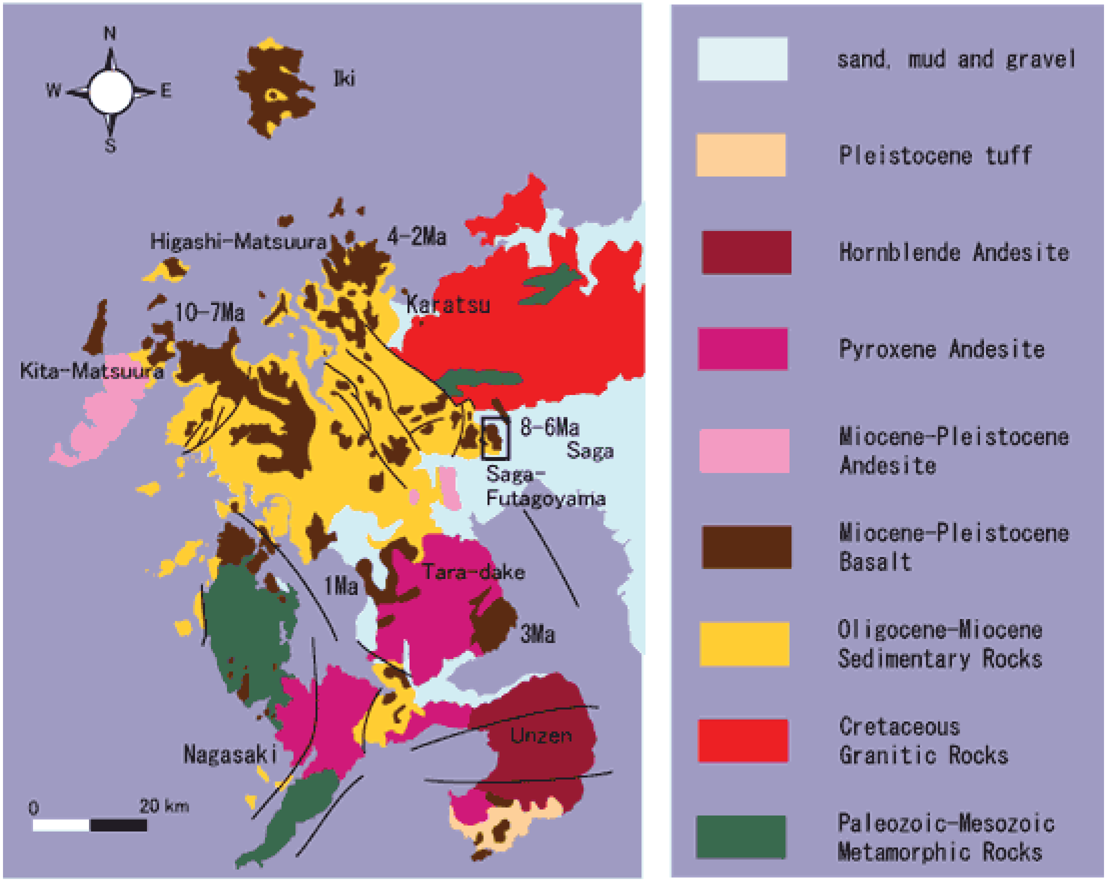

Figure 3: Simplified geological map of NW Kyushu. Basalts erupted at 10-1 Ma are distributed in NW Kyushu.

We estimated melting temperatures of primitive NW Kyushu basalts by comparison with the results of high-pressure melting experiments of peridotites. First, we selected primitive NW Kyushu basalts using bulk rock Mg-Fe-Ni relationships (Figure 4). We calculated olivine compositions in equilibrium with bulk rock compositions of analyzed samples (details of the methods of calculation are given in *Higo & Mashima*, 2004). Some of calculated olivines have Mg-Fe-Ni compositions similar to mantle olivines (*Takahashi*, 1986; *Arai et al.*, 2001), which means that the samples used for those calculations could have been equilibrated with the mantle. Selected samples show a negative Al_2O_3 – MgO correlation and a positive CaO – MgO correlation similar to those observed in melting experiments (Figure 5). This suggests that our estimation of primitive melts is reasonable.

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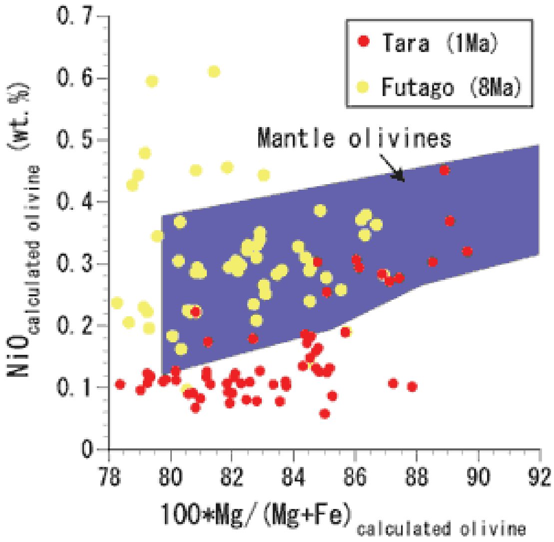

Figure 4: Mg-Fe-Ni relationships of calculated olivines in equilibrium with NW Kyushu basalts. Detailed methods of calculation are given in Higo & Mashima (2004). Compositions of mantle olivines were obtained from Takahashi (1986) and Arai et al. (2001).

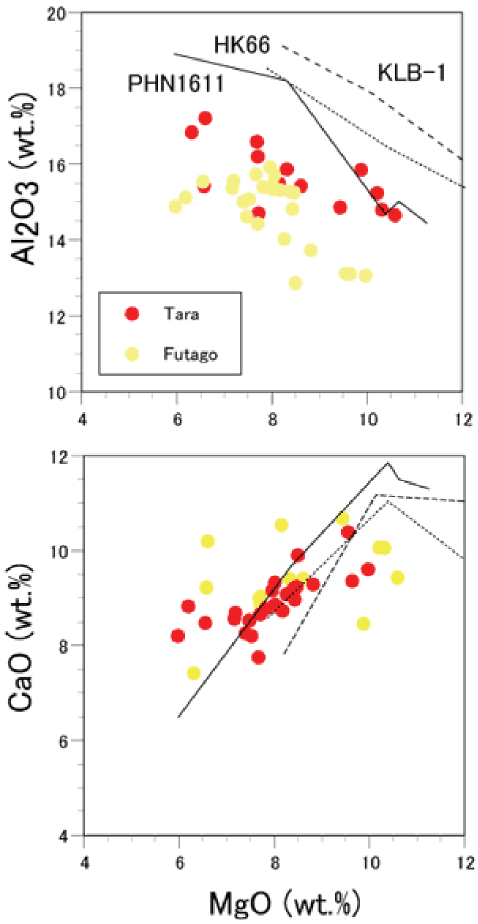

Figure 5: Relationships between Al2O3, CaO and MgO. Results of melting experiments were obtained from Hirose & Kushiro (1993) [samples KLB1 and HK66] and Kushiro (1996) [sample PHN1611].

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Second, the pressure at which primitive basalts were last in equilibrium with the mantle is also estimated since the compositions of partial melts in melting experiments also depend on pressure. Primitive samples are plotted on a cotectic line at 1 GPa (Figure 6), which is consistent with the average depth of the Moho beneath NW Kyushu (Murakoshi, 2003).

Finally, the melting temperatures of the primitive basalts were estimated using the temperature-MgO relation from previous melting experiments of peridotites. The estimated melting temperature range is 1200-1300°C (Figure 7), which is similar to that of MORB (*Hirose & Kushiro*, 1993) and subduction zone basalts (*Tatsumi et al.*, 1983).

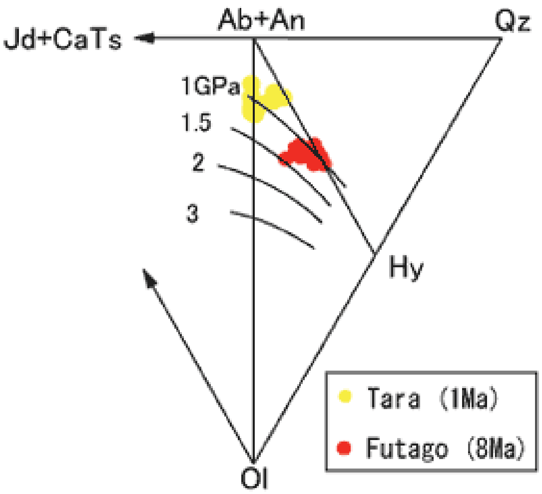

Figure 6: Normative ol-qz-Jd+CaTs diagram. Cotectic lines were obtained from Falloon & Green (1988).

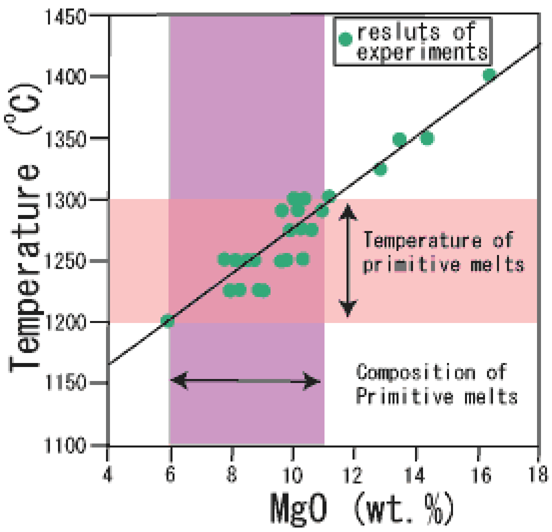

Figure 7: Relationship between temperature and MgO in melts. The results of melting experiments of peridotites at 1 GPa were obtained from Takahashi & Kushiro (1983), Hirose & Kushiro (1993) and Kushiro (1996).

Thus, the petrochemistry of primitive NW Kyushu basalts suggests that they were formed by upwelling of shallow mantle, as is the case for MORB and subduction zone basalts. Upwelling forming NW Kyushu basalts is probably caused by mechanical interaction of the Philippine Sea plate and the Eurasia plate since Cenozoic SW Japan basalts are concentrated in NW Kyushu, the junction of the southwest Japan arc and the Ryukyu arc, and of the Japan Sea and the East China Sea.

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