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Evidence for metasomatism due to melt migration within deep oceanic crust: Implications from IODP Hole U1309D, Mid-Atlantic Ridge

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We found the "high-temperature microscopic veins" (HTMVs) in lower crustal gabbroic rocks recovered from 1400-m-long IODP Hole U1309D, the Mid-Atlantic Ridge (30 N). The HTMVs are very thin (0.3-0.6 mm in thickness) with very diffuse boundaries and are mainly composed of high-temperature silicate minerals. Very similar veins were reported by Maeda et al. (2002) from lower crustal gabbros in ODP Hole 735B, the Southwest Indian Ridge. These HTMVs yield information on mass and heat transportation during the latest stage of magmatism within deep oceanic crusts beneath mid-ocean spreading ridges.

An important feature of the HTMVs is the "along-vein variation" in mineralogy, which is correlated with the magmatic minerals that they penetrate (Maeda et al. 2002). Within grains of magmatic clinopyroxene, the HTMV consists of secondary clinopyroxene + orthopyroxene + plagioclase + pargasitic amphibole. In plagioclase, the veins are composed of secondary plagioclase. In olivine grains, the veins are composed of orthopyroxene + plagioclase. The mode of occurrence indicates that the HTMV minerals were not crystallized from migrating agents (silicate melts, for example) but were formed by metasomatic replacement of primary magmatic minerals. Here we report trace and major element concentrations of clinopyroxene and plagioclase in gabbroic rocks from Hole U1309D and discuss the origin of the HTMVs.

We detected gradational increase in incompatible element concentrations from intact portion of the minerals toward center of the HTMV. The metasomatic process responsible for formation of the HTMVs was divided into two stages (Stage 1 and Stage 2). Clinopyroxene of Stage 1 is characterized by strong enrichment in Hf and Zr (HFSE) and also moderate enrichment in REE compared to magmatic clinopyroxene. No substantial increase in Ba and K (LILE) is observed. On the contrary, Stage 2 clinopyroxene shows strong enrichment in Ba and K compared to Stage 1 clinopyroxene with no sign of HFSE enrichment. LREE-enrichment compared to HREE is also remarkable. Based on these observations, we conclude that migrating agent is silicate melt-dominant in Stage 1 and aqueous fluid-dominant in Stage 2. This conclusion is supported by across-HTMV compositional variation of plagioclase. Transition from Stage 1 to Stage 2 may be due to differentiation of the agent from melt-dominant to fluid-dominant with gradational decrease in temperature. Thus, the fluid-dominant agent in Stage 2 may be magmatic in origin and penetration of high temperature seawater into deep oceanic crust may not be plausible. In some HTMVs, tiny grains of apatite and/or zircon are observed, suggesting that the melt phase in Stage 1 was not primitive but rather evolved one. Although our results support a proposal that migrating evolved melts have a potential to modify primary mineral compositions within deep oceanic crust, the extent of metasomatic effects is very limited, in sub-millimeter-order in general. If high-temperature seawater circulation within deep oceanic crust is not likely as mentioned above, the role of the HTMV should be evaluated as an agent for mass and heat transportation in mid-ocean spreading ridge systems.