Oceanic hornfels: Records of heat transport near axial magma chamber roofs

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The transfer of heat from the lower to upper ocean crust is the most fundamental process shaping the morphology of mid-ocean ridges and determining the mechanism of accretion of the lower crust. At fast-spreading mid-ocean ridges, the heat that drives high temperature hydrothermal systems is focused at the top of axial magma chambers (AMCs) that reside 1–2 km beneath the seafloor. Theoretical models predict that heat is exchanged across thin (<100 m), hot (>650°C), impermeable conductive boundary layers (CBLs) sandwiched between AMCs and permeable upper crust. The thickness of the CBL is predicted to vary with time, in response to magmatic activity and would have a finite life that is dependent upon the longevity of an AMC. Thus, CBLs are not static features, but rather should vary in thickness and position, depending on the magma supply and frequency of diking. While conceptually robust, there is sparse evidence in support of these predictions, perhaps because CBLs are transient and short-lived, thus preventing their preservation.

The expected characteristics for CBLs were recognized within *hornfelsic* dikes found within a contact aureole at the base of the sheeted dike complex in the Troodos opholite (Gillis and Roberts, 1999), and dikes intruding the uppermost gabbros in the Oman opholite and two regionally extensive tectonic escarpments of young fast-spreading East Pacific Rise crust exposed at Pito and Hess Deeps. These very fine-grained, granoblastic hornfels occur either as *in situ* dikes or xenoliths in the gabbro sequence. Where *in situ*, they form massive, indurated outcrops that lack the common ladder-like fracture patterns of sheeted dikes. Hydrothermally altered dikes are partially to completely recrystallized to pyroxene and/or hornblende hornfels, recording episodes of re-heating at 750–1050°C. Field relationships and temperture constraints indicate that the heat flux across the CBLs is 12–33 Wm^{-2}, similar to the latent heat of crystallization released to build a vertical thickness of 6 km crust. These are also similar to normalized values for hydrothermal plumes (20–40 MW/km), indicating that the heat that drives hydrothermal convection is transferred across a conductive boundary layer.

Collectively, widespread distribution of hornfelsic dikes at or just below the sheeted dike – gabbro transition indicate that thermally metamorphosed rocks are common feature in ocean crust. I will argue that these thermally metamorphosed rocks are remnants of preserved CBLs that record the migration of magma–hydrothermal boundaries, thus providing tangible evidence for AMC dynamics.

Assimilation of the plutonic roots of the Andean arc: Evidence from CO_2-rich fluid inclusions in olivines

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Assimilation of young plutonic rocks by magmas of similar compositions is not easily seen in isotopic signatures because of their low isotopic contrast with the magmas. However, variability of trace element ratios in Tatara-San Pedro basalts (SVZ of the Andes) suggests assimilation (Dungan *et al*., 2001). Mineral inclusions and healed microfractures (HMF, Dungan and Davidson, 2004) show the xenocrystic nature of their crystals.

We compare olivine xenocrysts from a basaltic unit with amphibole- and phlogopite-bearing gabbroic xenoliths from a Holocene dacite (Costa *et al*., 2002) and analyse the contents of their HMFs using SEM, electron microprobe, Raman spectroscopy, microthermometry and LA-ICP-MS.

The better preserved fluid inclusions and textures in xenoliths reflect interactions between CO_2-rich, saline H_2O-bearing fluids and gabbroic intrusions. This subsolidus history then influences the partial melting and assimilation of the gabbros at the contact of the dacite host. The presence of hydrous minerals, especially micas, favours melting even at moderate magmatic temperatures.

In olivine xenocrysts from the basaltic units, most of the healed microfractures have been reopened upon ascent or eruption, thereby partly destroying the subsolidus signal. Diffusion modeling on iron-rich zones along the HMFs give a very short residence times (a few hours) suggesting syn- or post-eruptive healing. This is easily explained by the higher temperature of the basaltic host compared to the dacite. However some fluid inclusions are preserved and their similarity with those found in the xenoliths suggests similar origins for the xenocrysts.

Distinct mineralogical assemblages between xenocrysts-bearing basalts (olivine + plagioclase + clinopyroxene) and the gabbroic xenoliths (lacking clinopyroxene) show the diversity of the plutonic crust that was sampled by these magmas. Variable amounts of micas and amphiboles in the original gabbro will influence the chemical effect of assimilation on the bullk rock chemistry of the host magma.

References

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