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Hydrothermal circulation deduced from the thermal structure of the upper oceanic crust

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We have restored the thermal structures in the upper oceanic crust by using geothermometers based on crystal size and metamorphic minerals of the sheeted dikes from the Oman Ophiolite, which gives ambient temperatures at the time of dike intrusions and subsequent hydrothermal alteration. The Oman Ophiolite is regarded as an analog of fast-spreading ridge system. Samples were collected along transects through the sheeted dikes in a paleoridge segment from northern Oman. Pervasive hydrothermal alteration yielded metamorphic mineral assemblages of typical greenschist facies with some relict secondary hornblende, indicating that some sheeted dikes experienced amphibolite facies metamorphism, which was overprinted by greenschist facies alteration. In spite of pervasive alteration, primary igneous textures are generally preserved.

The crystal-size geothermometer is based on the models of Toramaru (2001) and Toramaru et al. (2008), which show the number density of crystals N is proportional to the 3/2 power of cooling rate of magma. Cooling rate in a dike at a distance of D from the dike margin is ˜(Tm ? Th)/Tm/D^2, where Tm and Th are temperatures of the magma and the host rock at the time of the dike intrusion. Volumetric fraction F of a specified crystal phase depends on the bulk magma composition and can be assumed to be almost identical to the sheeted dikes of interest. Then, F = rL3N, r is aspect ratio of the crystal with a dimension L X L X rL. Th = AD^2/L + Tm, where A is a constant relevant to F and r. By taking a reference dike whose host rock temperature Th0 is known, A is eliminated from the equation; Th = (Th0 ? Tm)$\{(L0/D0)/(L/D)\}^2$ + Tm

The estimated geotherm through the dikes at a paleoridge segment end shows constantly low but variable temperatures in the upper dikes and a remarkably high gradient in the lower dikes toward the gabbros. The thermal structure at the segment end indicates advective heat transfer by hydrothermal circulation of cold seawater in the upper dikes and conductive heat transfer in the lower dikes. The estimated geotherm at the segment center is 800-900 C, much higher than that at the segment end and does not show any stratigraphic variation. The high geotherm in the segment center cannot be reconciled with heating by hydrothermal fluids but requires high heat supply by repeated dike intrusions.

On the contrary, metamorphic mineral assemblages and chlorite and hornblende geothermometer give consistently lower temperatures than the crystal-size geothermometer, indicating that low-T hydrothermal alteration continued as the crust moves off-ridge.

Keywords: Mid-ocean ridges, Oceanic crust, Oman Ophiolite, Sheeted dikes, Thermal structure, Crystal size