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Factors goverining the structure of the upper oceanic crust formed at intermediate-fast-spreading rate

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UPPER CRUSTAL STRUCTURE AND AXIAL MAGMA CHAMBER (AMC) DEPTH

The upper crustal structure is defined by the thickness (=AMC depth), ratio of thicknesses of the extrusive to intrusive rocks (Re/i), lithology, mode of occurrences, and mutual relationships among each lithology, density and bulk chemistry, distribution of fractures and faults. An inverse correlation between AMC depth below intermediate-fast spreading ridges and spreading rate is interpreted by balance between heat supplied by magma input to and removal by hydrothermal cooling from the AMCs (Phipps Morgan and Chen, 1993).

Re/is for the East Pacific Rise (EPR) (11-14 cm/a) and the Galapagos Spreading Center (GSC) (4.9-5.5 cm/a) show negative correlations with AMC depth. Thickness of lavas emplaced on the EPR axis is constant irrespective to the AMC depth. In contrast, axial flows on the GSC become thicker with increasing AMC depth. Total extrusive thicknesses are inversely correlated with AMC depth for both ridges. These observations can be explained that the EPR does not have axial troughs which trap thick lavas and most overflow downslope and deposits off-axial flanks. On the contrary, the GSC with deep AMCs develops axial troughs, which trap thick axial flows (Blacic et al., 2004). Then, questions arise 1) why axial troughs are more developed as AMC deepens, and 2) why total extrusive rocks are thicker as AMC becomes shallower.

WHAT DETERMINES AMC DEPTH?

Efficiency of hydrothermal cooling depends on the development of pathways of hydrothermal fluids. The most effective mechanisms to produce fluid pathways are faults and tension fractures formed by strain due to plate spreading. The mode of upper crustal extension by faulting and dike intrusions depends on the presence or absence of level of neutral buoyancy (LNB) and the amount of available magma (Umino et al., 2008). Like ODP Hole 1256D, fast-spread upper crust has no LNB because it essentially consists of dense sheet flows and sheeted dikes. This makes more magma to extrude once a dike intrusion occurs. Magma solidified along the conduit forms a dike by which the upper crust extends. In contrast, LNB is present in the intermediate-spread upper crust like ODP Hole 504B. Dikes are emplaced in and around the LNB, above which faults and tension cracks develop to form axial troughs. The brittle crust without an AMC extends only by faults and tension cracks.

WHAT DETERMINES THE TOTAL EXTRUSIVE THICKNESSES?

The conditions to terminate an eruption on fast-spreading ridges are: 1) exhaustion of magma in the AMC, 2) closure of conduit by lowering excess pressure of AMC, 3) stagnation of magma in the conduit due to viscosity increase (Wylie et al., 1999) and solidification (Bruce and Huppert, 1990) of magma as it cools during ascent through the conduit. Case 1 is discarded because typical eruptive volume on the EPR is an order of magnitude smaller than the average AMC volume. Case 2 is also negative as pressure reduction of AMCs at the end of a typical eruption on the EPR is only 0.02 MPa.

Most common basaltic eruptions are Strombolian, which usually last for a few to 10 hr (case 3)

(Wylie et al., 1999). Volume and fissure length of typical lobate sheet flows on the EPR are 0.01-0.1 km^3 and 1-18 km, respectively (Sinton et al., 2002). An eruptive period of 10-20 hr produces a typical volume of lobate sheet flows. Consequently, the eruptive volume of magma is governed by an eruption period which terminates by viscosity increase and solidification of magma within a conduit upon cooling. Deeper AMCs yield longer conduits which cool magma more efficiently, giving shorter eruptive periods. It also reduces pressure gradient and lowers extrusion rate of magma, resulting in smaller eruptive volumes.

Keywords: Mid-ocean ridges, Oceanic crust, Ocean drilling, East Pacific Rise,
Galapagos Spreading Center