EFFECT OF THE DICHOTOMY ON MANTLE PLUME LOCATIONS

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Introduction: Martian crustal thickness is dichotomous [1]. As the crust is expected to be en-riched in heat-producing elements, the temperature at the base of the thicker crust of the southern highlands will be higher than at the base of the northern lowlands. This is analogous to an insulating lid on part of the mantle. It is also possible the martian mantle is compositionally layered [2]. These two effects strongly influence mantle dynamics, including the location and longevity of upwelling plumes [3]. We perform a series of analogue laboratory experiments to examine these effects.

Experimental methods: We perform the experiments in a glass-walled, aluminum-floored tank of aspect ratio ~4. The top boundary condition is set to be at a constant temperature by an inset glass tank, filled with well-stirred ice water. To simulate the thicker highland crust, for some experiments 60% of the floor of the inset tank is covered with a 1.27-cm thick acrylic insulating lid. The effective thermal conductivity of the insulated side is ~40% of that of the side with no insulating lid, equivalent to a crust about twice as thick under the southern highlands [1]. Working fluids are aqueous corn syrup solutions with highly temperature-dependent viscosity, with food dye added to the lower layer. Two opposite sides of the tank are insulated with 5.1-cm-thick polystyrene foam blocks. The two remaining sides are left open so that we can photograph and videotape the experiment. The experiments take one of two forms: (1) bottom heating and top cooling, or (2) secular cooling simulating internal heating. In the experiments with bottom heating, the fluids and the tank are initially at room temperature; the base of the tank is a hollow aluminum heat exchanger, through which hot water is pumped. In contrast, in the experiments with secular cooling the tank base is insulated. The fluids and the tank base are separately warmed and the fluids are then poured into the tank. We then bring the ice bath into contact with the top of the fluid, which results in thermal convection. The system cools over time as heat is lost to the ice bath. We quantify heat transfer during convection with timeseries of temperature and heat flux, measured with thermocouples and heat flux sensors on the tank roof and floor and thermocouple probes within the convecting interior.

Results: In the case with no insulating lid, the plume spacing is predicted from linear stability theory to be $L = C\cdot(\;/\mathrm{Ra})^{1/3}$, where C is a constant, is the ratio of viscosity in the fluid interior to that in the thermal boundary layer, and Ra is the Rayleigh number (e.g., [4]). The number of plumes (n) in the convecting layer is a proxy for the spacing: $L \sim n^{-1/2}$. The prediction then is that $n \sim \mathrm{Ra}^{2/3}$. We count the number of plumes visible in the shadowgraph videos and plot n as a function of Ra in Figure 1. The flow is transient by the nature of the secular cooling experiments, and scatter is greatest at earlier times (high Ra). Nevertheless, a clear trend is defined, with a slope in log(Ra)-log(n) space of 3, not 1.5 as predicted by theory. One effect of compositional layering is that the topography on the interface stabilizes the locations of upwelling plumes. We argue that the presence of compositional layering slows the reorganization of flow that accompanies a decrease in Ra. The result is that the number of plumes is higher than would otherwise be predicted at a given point in the planet's evolution.

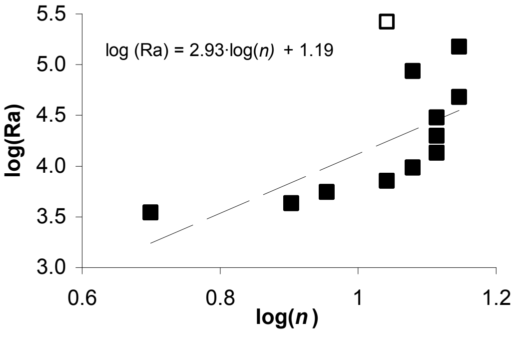

Figure 1: Log(Ra) v. log(n). Best-fit line excludes first point (open symbol). Slope of ~3 is different from predicted slope of 1.5.

In the case with both an insulating lid and layered convection, a strong hot upwelling forms under the lid and persists for the equivalent of many billions of years [3]. If the mantle upwelling leads to melting, volcanic material will be emplaced as crust over the upwelling. The thickening of the crust will reinforce the difference in insulation that localizes the upwelling—that is, there is a positive feedback between crustal thickness and mantle upwelling.

References: [1] Zuber M. T. et al. (2000) *Science, 287,* 1788-1793. [2] Elkins-Tanton, L. T. et al. (2003) *Meteoritics and Planet Sci., 38,* 1753-1772. [3] Wenzel, M. J. et al. (2004) *GRL, 31, L04702*. [4] Jellinek, A. M., and Manga, M., *Rev. Geophys., in press.*