GENERATION OF BASALTIC CRUST ON VENUS; R.J. Phillips and R.E. Grimm, Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275

Introduction. Terrestrial basaltic magmas are generated at divergent plate margins by pressure-release partial melting of ascending mantle material. A by-product of this melting is a relatively magnesium-rich residuum due to the preferential fractionation of iron into basaltic magmas. This residuum is more buoyant than its parent undepleted mantle [1,2]. In the Earth's ocean basins, the residuum is attached to the mechanical plate and, along with newly-created basaltic crust, is moved away from sites of partial melting. Significant crustal generation is ongoing because fresh material is continuously drawn to high levels (i.e., low pressure regions) of the mantle.

On Venus, two factors may inhibit crustal generation. If the lithosphere is unable to subduct and therefore unable to drive significant horizontal motion and lithospheric divergence, easy access to the surface will be lost. Furthermore, the residuum generated by partial melting may accumulate in the upper mantle, where it is buoyantly stable. If the ascending mantle cannot penetrate this residuum, then the melting process will eventually shut down as the residuum (and basaltic crust) limit the minimum depth to which mantle can rise. To first order, convection will not penetrate the residuum if the chemical density anomaly of the residuum exceeds the thermal density anomaly of the ascending mantle material. Here we show how this process works and apply it to Venus.

Method. We have combined a global parameterized convection calculation [3] with solutions to the differential equation for the mass fraction of partial melting as a function of temperature and pressure [4,5]. The lateral extent of partial melting is governed by the horizontal velocity of an upper boundary layer. The velocity is obtained by equating the heat delivered by convection to the heat lost by thermal diffusion out of the boundary layer, assuming unit aspect ratio to the convection cell. The convecting temperature of the mantle is obtained by integrating the energy conservation equation with time, and the upper-mantle temperature is obtained by extrapolating upward along an adiabat. The system was calibrated by finding the value of A in $\mu = \mu_0 \exp(A/T)$ for the Earth such that at t = 4.6 Ga, the heat flux is 84 mW/m^2 and the upper-mantle temperature is 1300°C. The value obtained for A is 65,000 K with μ_0 = 165 m^2s^{-1}. For Venus, 0.6 Ma passes before basaltic crust is allowed to accumulate, supposing that it would be remixed into the mantle before that. The crustal accumulation will be only modestly diminished if the starting point is moved forward in time. At each 5 Ma increment, the amount of accumulated crust and residuum is calculated, heat sources are preferentially removed from the mantle, and the outer radius of the convecting mantle is reset according to the crust and residuum thicknesses. We assume that heat can diffuse from the crust at the same rate it is delivered, so that the temperature T_L at the top of the boundary layer does not build up. A simple diffusion calculation shows that this is true to first order, and, in any event, the crustal accumulation is insensitive to T_L (Figure 1).

Results. Figure 1 shows the results of our calculations for Venus with varying values of T_L. Each calculation was run until the change in crustal thickness in a 5-Ma increment was less than 10 m. As expected, the process shuts down, here at about 16 km of crust and in about 100 Ma. The temperature T_L affects the rate of crustal buildup but has only a small influence on the asymptotic value. Higher temperatures lead to faster buildup.

In Figure 1 it was assumed the mantle did not penetrate the residuum at all. In Figure 2, we compare for T_L = 1300 K, the effects of 0%, 25%, and 50% penetration. That is, this is the fraction of residuum that is entrained in the convective

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flow and does not stabilize at the top of the mantle. For 50% assimilation, a 40-km-thick crust accumulates in 300 Ma.

Discussion. The residuum density can be calculated from the mass fraction of partial melt [6]. The magnitude of the average density contrast is at a maximum early in the melting sequence, when most of the magma is being generated. For T_L = 1300 K, the average residuum density contrast $\Delta\rho_c$ for the first 10 of 16 km is 16 kg m^{-3}. For a coefficient of thermal expansion of $\alpha = 3 \times 10^{-5}$ K^{-1}, this corresponds to a thermal density contrast of about 160 K. In an internally-heated mantle, the temperature contrast of ascending material might be less than 100 K. Whole-mantle plumes might have temperature anomalies in excess of 300 K [7], reflecting the hot boundary layer at the core-mantle interface. Thus in the calculations here, plumes would penetrate the residuum, but possibly not the upper part if the residuum is stably stratified. On Earth, hot rising mantle plumes are predicted to generate large amounts of basalt [8]. Our calculations show that increasing the upper-mantle temperature from the mean convecting temperature (as might be expected in a plume) will not have strong effect on the final crustal thickness: with higher temperatures both thicker crust and thicker residuum will be generated, leading to a shutdown. For example, a 200° increase in upper-mantle temperature leads to a crustal thickness of 23 kilometers for T_L = 1300 K and a 300° difference will actually decease the final crustal thickness. We have not taken into account the role of melting in removing heat from the boundary layer. This effect would lower the horizontal velocity of the layer and decrease the lateral extent of melt, which will decrease the average crustal thickness. The residuum density contrast estimates may increase when this effect is considered.

Conclusions. Because of various assumptions and approximations used at this point, the absolute magnitudes of the numbers in Figures 1 and 2 should not be taken too seriously. The results do show, however, the self-limiting nature in basaltic crustal generation on a planet without seafloor spreading. Clearly, the most sensitive parameter here is the fraction of assimilation of residuum into the convecting mantle. Future work will include a quantitative look at penetration of the residuum by convection, as well as the stability of the residuum.

References. [1] O'Hara, M.J., *Nature, 253*, 708, 1975; [2] Jordan, T.H., in Boyd *et al.* (eds.), *The Mantle Sample: Inclusions in Kimberlites and Other Volcanics*, AGU, 1, 1979; [3] Phillips, R.J., and M.C. Malin, in Hunten *et al.* (eds.), *Venus*, 159, 1983; [4] McKenzie, D.P., *J. Petrol., 25*, 713, 1984; [5] McKenzie D., and M.J. Bickle, *J. Petrol., 29*, 625, 1988; [6] Finnerty, A.A., *et al., JGR, 93*, 10225, 1988; [7] Richards, M.A., and B.H. Hager, *JGR, 93*, 7690, 1988; [8] White, R., and D. McKenzie, *JGR, 94*, 7685, 1989.

Figure 1

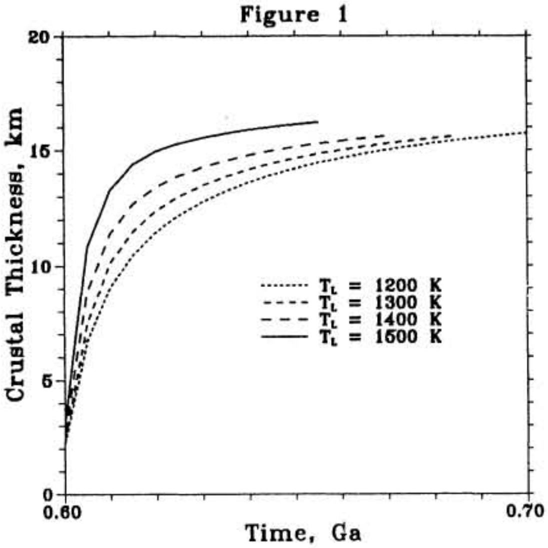

Figure 2