Convection in Mercury's Mantle: Linear Upwellings Not Plumes

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To investigate the planform of convection in a thin silicate shell, applicable to Mercury, I use the finite element code CitcomS to solve the equations for 3D spherical, incompressible, convection with a free-slip surface and core mantle boundary and a core-mantle boundary radius of 0.75 times the planetary radius, giving a silicate mantle thickness of 600 km. The calculations run for several billion years model time from a hot, nearly-isothermal initial condition *(T=1880 K)* and include a core-cooling boundary condition. The viscosity temperature-dependent with an activation energy of 300 kJ mole^{-1}. I will present calculations using Rayleigh numbers ranging from $10^4 - 10^6$ and two end-member internal heat generation rates of no internal heating or an Earth-like value (0.0115 μW/m^3.) The results of more than fifteen 3D calculations with various Rayleigh numbers, internal generation rates, and initial conditions will be summarized. The heat flux at the core-mantle boundary from these calculations ranges from 4.8-15.8 mW/m^2, consistent with Mercury core dynamo and thermal history models.

While mantle convection on Venus, Earth and Mars takes the form of cylindrical upwellings, the upwellings on Mercury take the form of long, linear rolls (Figure 1a) or hemispherical sheet upwellings and cylindrical downwellings (Figure 1b). This convective planform is observed over the range of Rayleigh numbers relevant for Mercury ($10^4 - 10^6$) and with our without the inclusion of heat producing elements. It is a direct consequence of the thin silicate shell and the corresponding low Rayleigh number applicable to convection in Mercury's mantle and, the planform is dependent on the initial condition. Calculations with linear upwellings and downwellings (i.e., rolls) in the low-latitude regions of the spherical shell and a cylindrical upwelling (or downwelling) at the pole form within 300-500 Myrs of the initial condition and remain in this stable pattern through out the remained of the calculation except in cases with low-degree spherical harmonic initial conditions (e.g., Figure 1b). With low-degree initial conditions, a nearly-hemispherical pattern of upwelling and downwelling cylinders is observed throughout the calculation. In the other terrestrial planets, instabilities near the base of the mantle begin as linear, 2D features that quickly break into distinct cylindrical plumes as the instabilities rise. Sheets coalesce into plumes at the intersection of two or more linear sheets. The Mercurian mantle is too thin for the the basal boundary layer instabilities to break up into cylindrical plume structures and thus linear upwellings extend throughout the mantle.

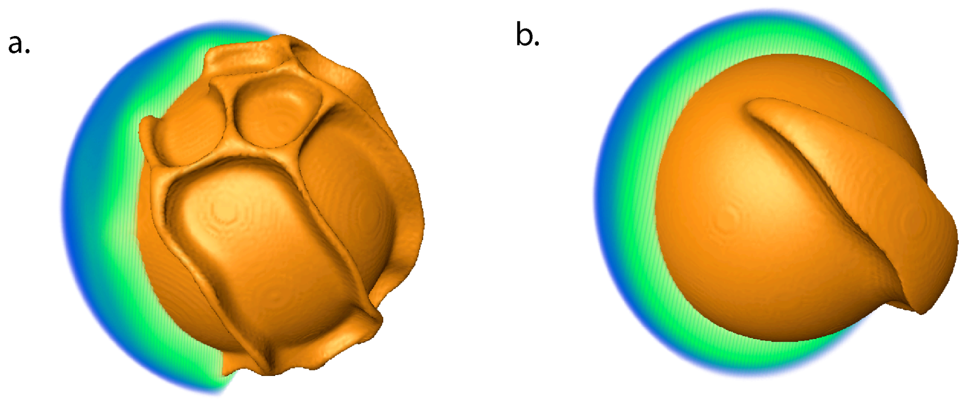

Figure 1: **Temperature field after 750 million years of model evolution. a.** calculation Merc LM1 **b.** calculation Merc L2. The orange surface represents the 0.9 (1804 °K) temperature isosurface. Note the transition between long, two-dimensional roll structures in the low latitudes to a more complicated hexagonal pattern in the high latitudes in **a.**