CONVECTIVE COOLING OF LARGE IMPACT BASINS. *E.M. Parmentier*, Department of Geological Sciences, Brown University, Providence, RI 02912; *R.A.F. Grieve*, Dept. of Energy, Mines, and Resources, Ottawa, CANADA; and *M.J. Cintala*, NASA Johnson Space Center, Houston, TX 77058.

The formation and evolution of large impact basins may have important consequences for the early crustal and internal evolution of planetary bodies. Both impact heating and adiabatic decompression beneath the excavation cavity can cause partial melting and chemical differentiation with possibly important implications for the formation of an early crust (1,2). The amount of impact-generated heat retained within a growing planet will depend on the rate of cooling of an individual impact basin and the time before it is buried by the ejecta of later impacts. Large impacts both heat the interior and enhance the rate of heat transfer from the interior to the surface. Factors affecting the thermal evolution of an impact basin will determine which effect is the more important. Previous studies (3,4) have considered only conductive cooling. In this study we examine the role of solid-state thermal convection for large impacts which excavate to depths comparable to the lithosphere thickness.

The thermal anomaly generated by a large impact can be separated into two parts, one due to shock waste heat and the other due to uplift associated with rebound of the excavation cavity. For our model calculations, the pre-uplift and excavation thermal anomaly was based shock heating calculations (5) for an 80 km diameter chrondritic body, modelled as basalt with a density of 3.58 gm/cm^3, impacting a basaltic target at 15 km/sec. The pre-uplift transient cavity was assumed to be parabolic in crossection with a diameter of one-half the final basin diameter. The extent and distribution of uplift was based on the amount of observed structural uplift and geometric reconstructions of post-excavation modifications at large terrestrial craters (6). On this basis the uplift of a 1000 km diameter basin would be about 120 km and the radius of the excavation cavity, R, would be 250 km.

Since shock heating is most concentrated at shallow depths, we examine, for simplicity, the convective cooling of the thermal anomaly generated only by adiabatic, viscous flow beneath the uplifted excavation cavity. The thermal anomaly depends on the depth of excavation and the thermal structure of the planet prior to impact. We assume $T(z)=T_m \mathrm{erf}(z/\delta)$, where z is depth, δ is the thermal boundary layer thickness, and T_m is the deep interior temperature. The initial thermal anomaly for $\delta=.2R$ is shown in Figure 1. For this δ/R, the maximum initial temperature anomaly $\Delta T \simeq .4T_m$.

The subsequent cooling of this anomaly due to thermal convection is calculated using finite difference solutions of the equations for viscous flow and thermal energy conservation (7). Because rock at low temperature does not flow, the temperature dependence of viscosity is an important factor in the cooling. For temperatures less than a prescribed value T_l, we assume that no flow occurs and for higher temperatures that the viscosity ν is uniform. In the examples considered here $T_l=.5T_m$. The convective cooling rate depends on the Rayleigh number $Ra=\alpha\Delta T g R^3/\kappa\nu$ where α is the coefficient of thermal expansion, g is the acceleration of gravity, and κ is the thermal diffusivity. As shown by Figure 2, convection will significantly enhance cooling if Ra exceeds about 10^4. For a 1000 km diameter impact basin on the fully accreted earth ($g=980$ cm/sec^2) with $T_m=1500°C$, convective cooling will be important if the viscosity is less than about 10^{21} poise. The viscosity of an olivine-rich planetary mantle at 1500°C, based on laboratory data, may be less than 10^{20} poise (8). If the interior approaches its melting temperature, due either to sufficiently rapid accretion or other heat sources, convective cooling should be an important factor in the evolution of large impact basins and may affect the amount of accretional energy retained by the planet.

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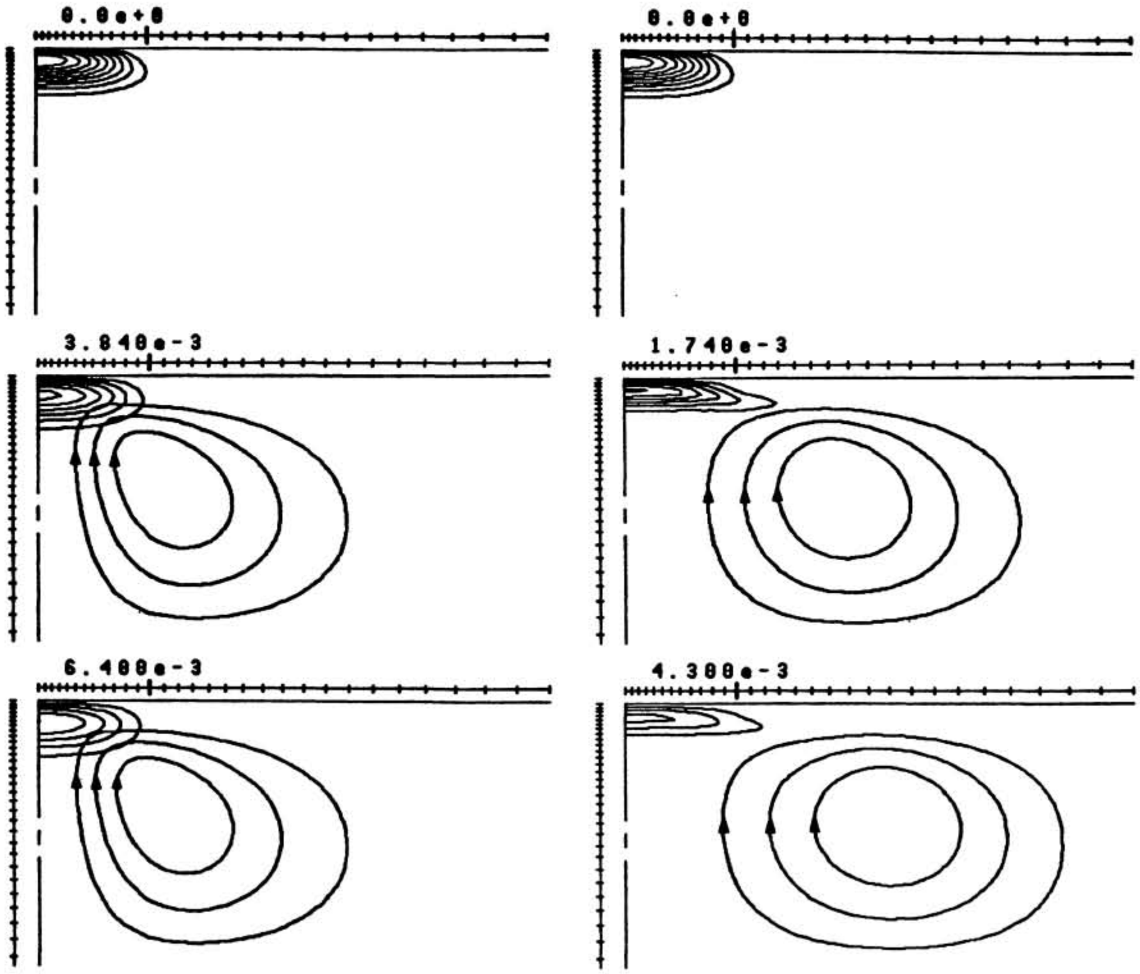

Figure 1. Isotherms and streamlines for the cooling of a thermal anomaly beneath a large impact basin. The cooling history is shown for $Ra \ll 1$ (left) and $Ra = 10^6$ (right). Each diagram shows a vertical section of a cylindrical geometry with the axis of symmetry on the left. Isotherms are plotted at intervals of one-tenth the maximum initial temperature anomaly. Time is given in units of R^2/κ. Tick-marks show the location of grid points in the finite difference solution. The heavier tick-mark along the top shows the radius of the excavation cavity.

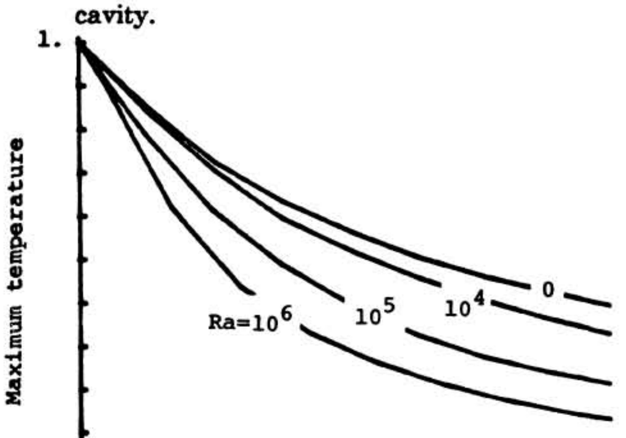

Figure 2. Maximum temperature in the thermal anomaly, expressed as a fraction of the initial maximum temperature, as a function of time for a range of Ra-values.