THERMAL EVOLUTION OF PLUTO AND IMPLICATIONS FOR SURFACE TECTONICS AND A SUBSURFACE OCEAN. F. Nimmo, G. Robuchon, *Dept. Earth & Planetary Sciences, U.C. Santa Cruz, Santa Cruz CA 95064 (fnimmo@es.ucsc.edu, grobucho@ucsc.edu).*

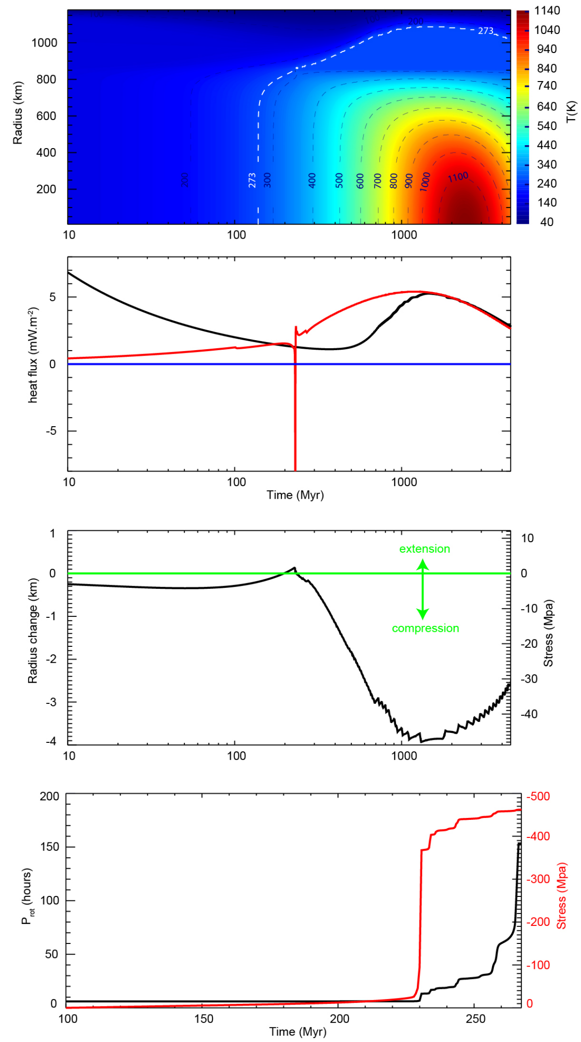

Figure 1: a) Evolution of temperature as a function of time and radial position for a differentiated, conductive Pluto. White line denotes 273 K isotherm. An ocean develops beneath the ice shell because of the heat generated by radioactive decay within the silicates. b) Surface heat flux (black line) and heat flux out of the silicate core, evaluated at the surface (red line). The negative excursion for the red line is due to tidal heating in the ice shell accompanying despinning. c) Change in radius as a function of time. The large negative excursion (resulting in compression) occurs because of the conversion of ice to water. d) Rotation period and equatorial stress as a function of time, demonstrating the effect of despinning.

Determining whether or not Pluto possesses, or once possessed, an ocean is crucial to understanding its astrobiological potential. We have used a 3D convection model [1] to investigate Pluto's thermal and spin evolution, and the present-day observational consequences of different evolutionary pathways. We assume an initially differentiated structure [2] with no liquid water present. We test the sensitivity of our model results to different initial temperature profiles, initial spin periods, silicate potassium concentration and ice reference viscosity; in this study we have not examined the role of ammonia, which may be important [3,4].

Figure 1 shows a set of results for a high-viscosity case. Radioactive heat is generated within the silicate core and conducted to the base of the ice shell (Fig 1a). The ice is too viscous to convect, so the heat conducted into the base of the ice shell exceeds the heat transported by the shell (Fig 1b). An ocean begins to form at about 200 Myr and persists to the present day. The ice shell thickness decreases then increases as the radiogenic heat production evolves. The conversion of ice to water results in volume reduction and large compressional stresses (Fig 1c). Despinning occurs rapidly once the ice becomes warm enough to dissipate tidal energy (Fig 1d).

Despinning occurs in all cases we examined, owing to the relatively dissipative ice shell. While a minor source of heat [cf. 5], despinning stresses will contribute significantly to the overall tectonic pattern [6]. The potassium content and the ice reference viscosity control whether or not an ocean develops, and whether that ocean survives to the present day. Low ($\leq 10^{15}$ Pa s) reference viscosities can transport sufficient heat that the ice shell remains frozen throughout. High ($\geq 10^{16}$ Pa s) reference viscosities are incapable of transporting heat generated within the silicates, and a subsurface ocean results. Convection typically implies the absence of a present-day ocean, and vice versa.

If Pluto never developed an ocean, predominantly extensional surface tectonics and a fossil rotational bulge should be present. For the cases which possess, or once possessed, an ocean, no fossil bulge should exist. A present-day ocean implies that compressional surface stresses should dominate, perhaps with minor recent extension. Reorientation is a possible additional source of stress, because Pluto's slow rotation makes it unstable [7]. These predictions may be tested by the *New Horizons* mission.

References

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