TIDAL DESPINNING AND THE HISTORY OF MERCURY Martin N. Ross[1] and Paul J. Thomas[2];
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The 3:2 resonance between spin angular velocity and orbital mean motion for Mercury almost certainly results from solar tidal interactions (1). Solar torques remove spin angular momentum from some unknown initial state until the spin reaches 58.65 days; moment of inertia asymmetries are then required to establish the 3:2 coupling (1). It has been suggested that the global system of escarpments are partly result from stresses accumulated during the despinning event (2,3,4,5). An alternative mechanism for scarp formation is global compression that accompanies inner core solidifiction and global cooling. Whatever the dominant mechanism of scarp formation, some portion of this geologic activity has likely been lost during the late bombardment of Mercury (6). In order to understand the origin the scarps, we must understand the relative timing of core solidification, global contraction, spin down, and end of bombardment on Mercury. It is commonly accepted that Mercury's cratering history is similar to the Moon's, with the most impact features dating from 3.9-4.0 Gyr. Detailed 'hot start' thermal evolution models show that a lunar-like cratering history is consistent with (a) magnetic field observations suggesting that a portion of the core remains molten and (b) the global contraction expected due to inner core growth by assuming Mercury's core initially consisted of an FeS alloy with about 2 wt. % sulfur (7). According to this scenario. most scarp formation due to inner core growth is erased by the late bombardment; only a few kilometers of contraction occurs post bombardment. Thermal models with a 'cold start', on the other hand, are inconsistent with the postulated lunar-like cratering history in that most core evolution occurs after heavy bombardment ends. Hot start thermal models obviate the need for the existence of a special late-stage impactor population unique to Mercury (9) and are favored based on general principles of planet formation (10).

Mercury's thermal and dynamical evolution are coupled through temperature and frequency dependent dissipation so that understanding the relative timing of important events requires a coupled thermal-dynamical model. We calculate Mercury's coupled tidal despinning and thermal evolution using realistic dissipation and rheological laws. We assume a hot start model with initial $Q = 10$, a rough upper bound. Results are not sensitive to the details of the dissipation law. We do not address the establishment of the spin-orbit lock except to assume it will occur if the spin rate equals 58.65 days and the moment of inertia is sufficiently asymmetric (e.g. (1)).

Assuming that the initial spin rate for Mercury equals the value derived from the angular momentum per unit mass from the rest of the solar system (about 8 h) we find that the despin time is about 100 Myr. Even for an initial rotation period of 4 h, the despin time is only about 800 Myr (Figure 1). The timescale for despin is comparable to the timescale for thermal evolution insuring that Mercury's Q remains relatively low throughout the despin period. Detailed thermal models of Mercury indicate that the lithosphere should be thick enough to sustain an asymmetric mass distribution (10-20 km) sufficient to insure establishment of the 3:2 resonance (11) after about 100 Myr (8). On the other hand, the despin time for initial spin rates exceeding 12 hours are less than about 35 Myr; it isn't clear if permanent mass asymmetries required for spin-orbit coupling could exist this early in Mercury's evolution.

We show that the tidal evolution of Mercury is extremely quick: most angular momentum loss occurs before the era of heavy bombardment ends. In contrast, global contraction continues beyond the end of bombardment. Thus the scarp formation due to stresses associated with despin are erased along with the bulk of the scarp formation due to inner core growth and global cooling. We conclude that despin stresses do not contribute to scarp formation; only contraction related features are preserved on the surface.

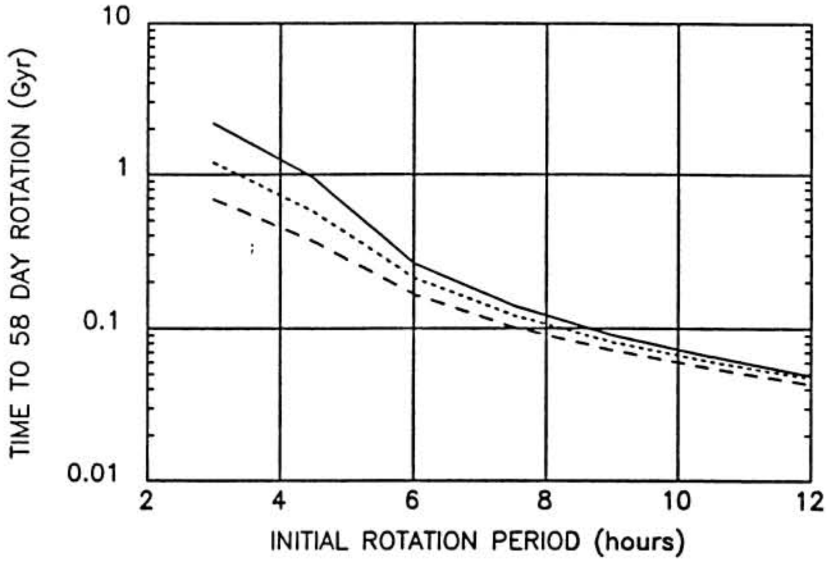

Figure 1. Time for Mercury to despin as a function of initial rotation period for three different dissipation laws. The solid, dotted and dashed lines represent models with dissipation factor Q = 400, 300 and 200, respectively, at a homologous temperature of 0.75.

<u>References</u>

1) Goldreich, P. and S. Peale (1966) A.J., **71**, 425-438.

2) Burns, J.A. (1976) Icarus, **28**, 453-458.

3) Melosh, H.J. (1977) Icarus, **31**, 221-243.

4) Melosh, H.J. and D. Dzurisin (1978) Icarus, **35**, 227-236.

5) Pechmann, J.B. and H.J. Melosh (1979) Icarus, **38**, 243-250.

6) Stevenson, D. J., Schubert, G., and T. Spohn (1983) Icarus, **54**, 466-489.

7) Solomon, S. (1976) Icarus, 28, 509-521.

8) Schubert, G., M.N. Ross, D. J. Stevenson and T. Spohn (1988) in *Mercury*, University of Arizona Press.

9) Leake, M.A. et al. (1987) Icarus, **71**, 350-375.

10) Basaltic Volcanism Study Project (1981) *Basaltic Volcanism on the terrestrial planets*, Pergamon, New York.

11) Schubert, G., P. Cassen and R.E. Young (1979) Icarus, **38**, 192-211.