LUNAR POWER DISSIPATED BY TIDES AND CORE-MANTLE INTERACTION.

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Introduction: Geophysical properties of the lunar interior are required to compute the dynamical contribution to the moon's heating. The heating is connected to development of solid convection in the mantle, fluid convection in the core, and generation of a lunar magnetic field.

Analysis of Lunar Laser Ranging data provides one opportunity to determine the moon's geophysical properties. Many lunar parameters, including bulk elastic and rotational dissipation parameters, are detected through their influence on lunar rotation. The Lunar Laser Ranging effort is reviewed in [1].

Dissipation Analysis: The present day 3.82±0.07 cm/yr expansion of the lunar orbit [1] is dominated by tidal dissipation on the earth, but is slightly affected (~1%) by dissipation in the moon. Dissipation effects in the moon are detectable through their influence on lunar rotation. Hence, sources of dissipation in the earth and moon are separable.

A study of dissipation signatures in the lunar rotation finds two sources of dissipation in the moon: solid-body tides and a molten-core/solid-mantle interaction [2, 3]. Tidal Q vs. frequency is determined; at 1 month the tidal Q is 37 and at 1 yr it is 60. The liquid core detection exceeds three times its uncertainty. The spin of the core is not aligned with the spin of the mantle and torque and energy dissipation arise from the velocity difference at the boundary. Yoder's turbulent boundary layer theory [4, 5] is used to compute the core radius. The core radius is ≤352 km for molten iron and ≤374 km for the Fe-FeS eutectic. Independent evidence for a (solid or liquid) core is presented in [6, 7].

Rotational Dissipation: The detection of two sources of rotational dissipation is quantitative, and there is an analytical theory for computation of dissipated power. For both dissipation mechanisms, power is drawn from the orbit and deposited in the moon. The present power generation from tides and core interaction contributes to heating the lunar interior, but it is minor compared to radiogenic heating. Under the assumption that the tidal Q and core radius, density, and viscosity are constant, the power generation for earlier times, when the moon was closer to the earth, is calculated. The total deposited energy contributes to lunar heating, but it is more difficult to calculate than the power since the deposited energy depends on how fast the lunar orbit evolves due to tides on earth. Slower expansion increases the heating. The past orbit evolution varies due to changing ocean response on earth [8].

Tidal Heating: Peale and Cassen [9] investigated lunar tidal heating while the lunar orbit expanded. Their calculations predate the measurement of Q and should be multiplied by 3.45 to match the lunar-laser-determined Love number and monthly Q. Tidal heating computations depend on orbit evolution rate and whether the tidal dissipation is localized. The measured dissipation is a bulk value. Where the energy is dissipated is subject to interpretation. Plausible assumptions lead to average heating in excess of 100° C and early central-region temperature increases of several hundred degrees. Most of the energy is deposited early in the moon's history and during this early time it is comparable to radiogenic energy.

Core Heating: The turbulent boundary layer theory allows a prediction of energy dissipated at the core-mantle boundary during orbit evolution. Under the assumption that the properties of the early core are the same as at present, the total energy dissipated by core-mantle interaction is about the same as for tidal dissipation, but it is deposited in a smaller volume. Like tidal heating, most of the energy is deposited early in the orbit evolution. This source of energy is available to promote convection in an early fluid core and to drive a dynamo. This is a transient phase with a duration depending on the rate of orbit evolution. Plausible assumptions lead to a duration of a few hundred million years. Thus, the remnant magnetization of many lunar rocks is compatible with a brief global magnetic field powered by dynamical energy dissipation.

Summary: Early in the lunar history dynamical sources of power generation may have rivaled radiogenic power. This dynamical source of energy may have powered core convection and a dynamo. These dynamical sources of energy dissipation operate at much smaller levels today. They are still strong enough to detect with analyses of Lunar Laser Ranging data.

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