MODELS OF LUNAR EVOLUTION, D. W. Strangway and

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Many workers have presented models of lunar evolution which involve an initially cold moon and which was heated from the outside during the terminal stages of lunar accretion. We have examined a model which has the following constraint imposed on it.

1. The presence of a well-defined crustal structure, implying differentation of at least the outer 150 kilometers. (1)

2. The seismic evidence for a core which will not transmit S-waves implying partial melting at a depth of about 1,000 kilometers. (2)

3. Heat flow observations which imply that the global heat flow is about 30 ergs/cm^2 sec. (3)

4. The presence of mascons and low order gravity harmonics implying that the outer part of the moon at least has been relatively rigid since 3 by. ago.

5. The delay of up to 500 million years in the time between the giant impact and subsequent mare filling.

6. The presence of a magnetic remanence in most returned lunar samples and lunar magnetic anomalies implying the presence of an ancient magnetic field. This may be due to an early dynamo, to transient phenomena associated with shock or to a cold lunar interior carrying the memory of an ancient field. In this latter case the moon would have warmed up after most of the activity of mare formation and lost this memory. We have chosen to consider the implications of this model for the origin of the field. This keeps much of the interior below 770°C, the Curie point of iron, for the first 1-1.4 by. of its history. (4)

If we consider these constraints we are faced with a maze of conflicting requirements, which at first glance appear to be mutually exclusive.

We have followed the procedures used by others in developing a model of thermal evolution. (5) This model involves an initial thermal, accretional pulse on the outer part of the moon as shown in figure 1. The K/U ratio was chosen to be 2,000, corresponding to lunar values and a variety of evolution models calculated on the assumption that thermal transport is by conduction and by radiation and by convection in the fluid state. The uranium concentration and lattice conductivity were permitted to vary and the solidus of a model lunar pyroxenite was chosen.

Figures 2, 3, and 4 show a few of the results. In figure 2 the heat flow value implies that the overall uranium concentration is around 50-70 ppb and the lattice conductivity

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around 9×10^5 ergs/cm sec deg. In figure 3, the radius of the partially molten core is given and assuming it is between 500 and 1000 kilometers an acceptable band can be defined. Finally in figure 4 the acceptable region to keep the moon below the Curie point at 1 by. is shown. The only region in which all three of these constraints can be met is for a U content of about 50 ppb and a conductivity of 9×10^5. Moreover the initial temperature chosen must be very close to 0°C with only a small surface pulse, reaching the melting point, but not penetrating to great depth.

A moon which had a history of this type would still have a rather specific difficulty in that the outer parts would cool rapidly and it would be difficult to generate the mare basalts. One method of creating the basalts is to consider the thermal effect of a giant impact. This would tend to remove the radioactivity from the vicinity of the basin (since this is concentrated in the upper layers) and to generate a thermally insulating ejecta blanket. Temperature differences up to 500°C at a depth of 100-200 kilometers can be attained in this way in the ring surrounding the ejecta blanket. This effect could lead to the generation of basalt at depth beneath the highlands (6) while allowing the impact site to cool and become strong enough to sustain the gravity effect due to the loading by basalt. This can also account for the negative rings surrounding the mascons. The large negative gravity anomaly associated with Mare Orientale in this model (7) is due to the fact that by the time this impact formed (3.6 by.) the crust had cooled enough to become rigid so there was little isostatic compensation and little basalt formed.

There are many possible thermal evolution models for the moon. This is only one of these, but it can account for many of the observed constraints by having a relatively cool moon which had only a thin molten layer early in time and has only recently become warm enough in the deep interior to approach the melting point.

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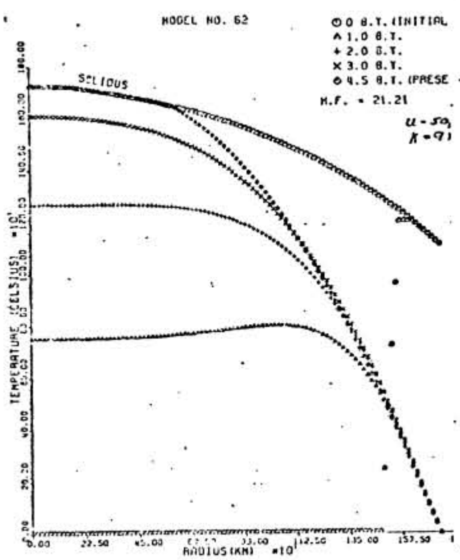

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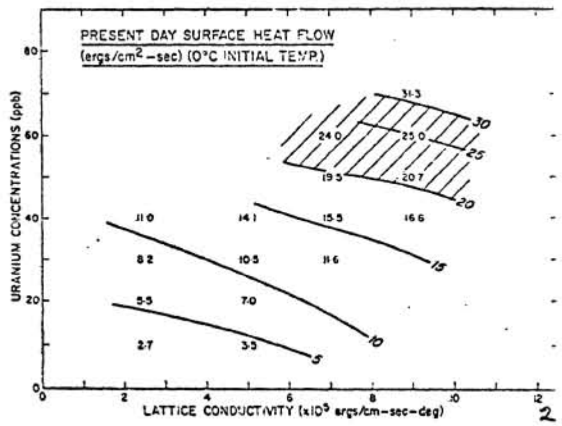

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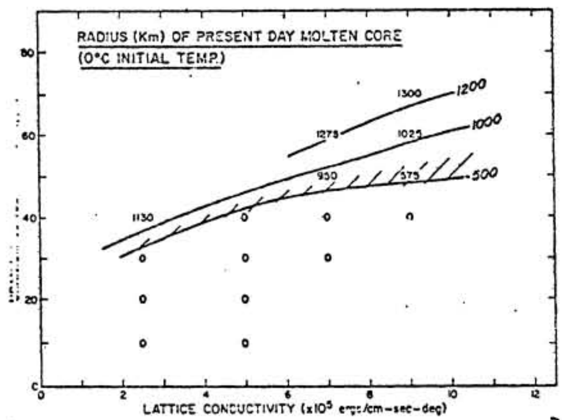

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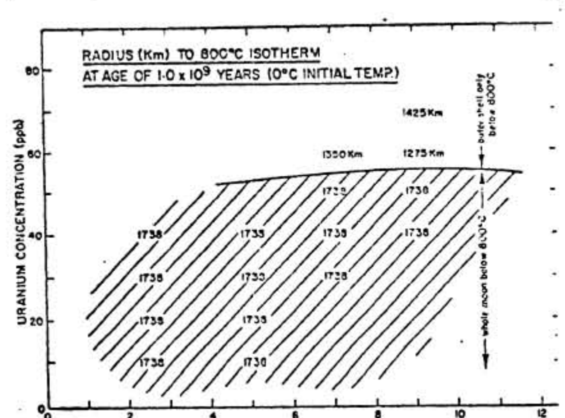

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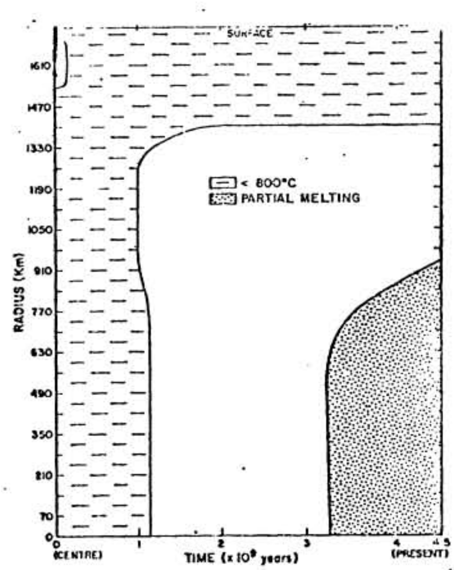

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