Lunar heat flux is important for constraining both the temperature models (and the composition) of the interior of the Moon in terms of the average uranium abundances. Recently, the observed heat flux values have been revised (1). Also, convective models that have been calculated indicate a more rapid cooling of the interior (2). To evaluate the effects of these developments on earlier models (3 and others) we undertook a new set of conductive-convective calculations of the thermal history of the Moon.

In these calculations we start with the initial condition that the Moon was heated very early in its history. This is required for the formation of the lunar crust and early volcanism. Relative abundances of heat sources are determined from the measured values of lunar samples with K/U = 2,000 and Th/U = 3.7. Heat source re-distribution is accomplished by melting and differentiation processes. Seismic velocity and attenuation models and electrical conductivity profiles are used to constrain the present day temperatures.

In the calculations we start from the initial temperature profile shown in Figure 1. A steady state solution for convection within the partially molten spherical shell is used as an initial flow field. Figure 1 shows the angularly averaged temperature versus depth for various times as shown. This model implies that after its formation, the interior of the Moon starts to heat up. At about 1.5 b.y. most of the body is partially molten. Convection then cools off the center almost immediately to nearly the present temperature. The lithospheric thickness increases to about 300 km at about 2-2.5 b.y. At this time, the differentiation process is completed. At the present, the interior of the Moon is about 1200°C. A convective region exists below 700 km with a convection speed of about 0.1 cm/year, much lower than the values estimated for the earth. Figure 2 shows the evolution of convective cells within the lunar interior. Initially, the Moon is at a higher temperature and requires more convective cells to transport the heat. Before 2 b.y., convection is concentrated within the outer region. After 2.5 b.y. a thick lithosphere is formed, and convection shrinks towards the center. The computed present day heat flux of 17 ergs/cm²/sec is in agreement with the revised values. The average present day uranium concentration implied by this model is 37 ppb.
EVOLUTION OF THE MOON - REVISITED

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References

(2) Schubert, G., R.E. Young and P. Cassen, to be published, 1975.

Figure 1 - Temperature as a function of depth in the Moon for various times after origin (b.y.) as noted next to each curve. The model starts with an accretion temperature profile (labelled 0 b.y.) and has a present day bulk uranium concentration of 37 ppb. The calculated heat flow is 17 ergs/cm²/sec.
Figure 2 - The evolution of convective cells within the lunar interior as a function of time. One quadrant of the flow field is shown, the other quadrants being mirror images of this one. Solid lines are stream lines and the dots are location of absolute maximum stream functions. Only one stream line is given for each convective cell and all stream lines are of equal strength within a quadrant. Dashed lines indicate the bottom of the lithosphere.