MAGMA PRODUCTION AND MIGRATION WITHIN THE MOON, D.L. Turcotte and J.L. Ahern, Department of Geological Sciences, Cornell University, Ithaca, N.Y. 14853

Substantial melting of the moon must have occurred very early in its evolution in order to have generated the lunar highlands. Subsequent partial melting must have occurred between about 3.8 BYbp and 3.0 BYbp in order to have produced the mare basalts. In this paper we consider alternative mechanisms for producing the magma and the influence of magma migration. We conclude that radioactive heating is unlikely to have produced the magmas associated with the mare basalts.

Melting within the moon could have occurred with or without solid state convection. Without solid state convection localized or general heating of the lunar interior would have been necessary. One source of heat was the accretionary process itself. This could have been responsible for the early melting which resulted in the formation of the highlands. It has been suggested (1) that the initial temperature distribution in the moon combined with heating due to the decay of radioactive isotopes could have been responsible for the second melting episode associated with the mare basalts.

There is also a substantial potential source of heating from tidal dissipation. If at any time the moon had a moderately elliptical orbit the tidal dissipation associated with the reduction of the elliptic orbit to a circular orbit could have produced substantial partial melting (2).

On the earth, a substantial fraction of the present volcanism is associated with ascending, solid-state mantle convection. Similar convective processes within the moon could have been responsible for the generation of the mare basalts (3).

Once the solidus of the lunar mantle rocks is reached magna is produced on the intersections of grain boundaries. This liquid fraction can be considered to be an equivalent liquid filled porosity within a solid, crystalline matrix. Once the degree of partial melting reaches several per cent the porosity on the grain boundaries becomes interconnected, resulting in an effective permeability (4). The permeability of the magma within the crystalline matrix is easily calculated using tubular models.

Because the magma is lighter than the crystalline residue, it will be driven upwards by the lunar gravitational field. At temperatures above the solidus the rigidity of the crystalline matrix is so low that negligible stresses are required to deform it as the magma is removed by the vertical migration. Using Darcy's law (5, 6) the concentration and velocity of the magma have been determined for a wide range of conditions.

Once the degree of partial melting has reached a few per cent the magma will migrate upwards as rapidly as it is produced. If a stationary lunar interior is being heated the low temperature melt fractions will migrate vertically first followed at later times by the higher temperature melt fractions. A similar surface sequence of flows might be expected.

It is expected that the radioactive elements, uranium, thorium and potassium, will be concentrated in the early melt fraction. These will then migrate upwards and will not be available for further melting. It is therefore concluded that radioactive heating cannot produce degrees of partial melting greater than a few per cent.

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If, alternatively, steady ascending convection occurred within the lunar interior the low temperature melt fractions would be produced at greatest depths with higher temperature melt fractions being produced at shallower depths. However, the liquids would mix to form a completely mixed magma as they migrated upwards. Surface flows would appear to be the result of the simultaneous melting of the low and high temperature components. Since we have concluded that the high degrees of partial melting associated with the lunar basalts could not have been produced directly by radioactive heating, we favor either tidal heating or pressure release melting associated with solid-state convection.

In that portion of the lunar interior in which the temperature exceeded the solidus (i.e., the asthenosphere), the magma would migrate freely upwards by the porous flow mechanism. When the magma reached the cooler lithosphere it would either freeze of form an extensive magma chamber depending upon the rate of magma generation and the thickness of the lithosphere. The pooled magma at the base of the lithosphere could penetrate the lithosphere either by diapiric mechanisms (7) or hydraulic fracturing mechanisms (8).

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