A NEW THEORY FOR THE FORMATION OF THE MARIA AND CAYLEY TYPE LUNAR REGIONS

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Abstract. A new 'liquefaction' theory for the origin of the flat marial and Cayley areas on the lunar surface is described. It is supposed that the flat terrain in these areas resulted from periods in the development of the Moon when these regions, although not liquid, had a sufficiently low viscosity for the surfaces to relax more or less completely to a level form. To account for this low viscosity a model is developed in which, within these regions and for relatively short periods in the early history of the Moon, preferentially high temperatures were maintained close to the lunar surface. The paper examines in some detail the possibility that these high temperatures may have resulted from instabilities in the lunar heat flow pattern caused by the presence of a surface layer of very low thermal conductivity produced by the debris of early meteorite impacts.

A comparison is made between current models for the formation of the lunar surface and the theory here proposed: the advantages of the latter are enumerated and discussed.

1. Introduction

This paper presents a new theory for the origin of the flat areas on the lunar surface. It is based on the idea that all of these areas have, at some time early in the Moon's history, been subject to temperatures which were sufficiently high for the surface to relax to an approximately equipotential form on a time scale small or very small compared with the lunar age. This process will be referred to as liquefaction. As a mechanism for producing such high temperatures close to the Moon's surface instabilities in the pattern of heat flow from within the Moon will be considered. It will be shown that such instabilities can result from the presence of a highly insulating layer of pulverized rock which covered the lunar surface early in its history.

The idea that the insulating properties of the lunar surface layer might act to increase the lunar subsurface temperatures is naturally not new. In 1958 Muncey concluded, from a comparison of infrared and microwave lunar observations, that the mean temperature at a small fraction of a meter below the lunar surface was less than the mean surface temperature. This result he showed to be consistent with an increase with temperature of the product of conductivity (K) and specific heat (c). Fremlin (1959a, b) considered the effect of a very low conductivity on the outward flow of heat of internal origin. He concluded that the blanketing of the outer layers of the Moon could possibly produce temperatures of 1000 K at depths as small as 25 m. Almost immediately Jaeger (1959) correctly criticized the values of the thermal parameters chosen by Fremlin but it was nevertheless clear that a considerable vertical tempera-

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ture gradient would be expected in the upper layers of the lunar surface. More recent examination of the problem has been carried out by Clegg *et al.* (1966), Linsky (1966) and by Winter and Saari (1969).

It now seems clear that we must distinguish two distinct mechanisms which cause the subsurface temperature to be greater than the mean surface temperature:

(i) the top surface layer acts as a rectifier to heat flow allowing heat to enter more readily duiing the lunar day than it escapes during the lunar night (Muncey effect). The effect depends on the increase of either of both the conductivity and specific heat with temperature. Probably the most important cause of this increase is the large contribution to the effective conductivity by radiative transfer – a process which has a tempeıature-cubed dependence. This effect would still exist in the absence of any outward flux of internal origin. It causes the mean temperature to increase with depth throughout the top fraction of a meter of the surface layer within which the diurnal thermal wave is propagated. Comparison of microwave and infrared lunar brightness temperatures showed that the total temperature difference is in the range 20–50 K (Muncey, 1958; Linsky, 1966). Recently this has been confirmed by thermocouple measurements at the Apollo 15 and 17 sites (Langseth *et al.*, 1972; Keihm and Langseth, 1973) which indicate the temperature difference to be about 40 K.

(ii) The second and more obvious cause of higher subsurface temperatures is the thermal flux of internal (probably radioactive) origin. In passing through the immediate surface layer of the Moon this flux produces an appreciable temperature gradient because of the low conductivity of the uppermost material (Fremlin effect). Keihm and Langseth (1973) have estimated this effect alone to produce a drop of about 6 K in the top meter of the lunar soil whilst microwave measurements (Krotikov and Troitsky, 1964) indicate a change of about 25 K in the top 10 m. If the conductivity increases with depth only because of a pressure-induced increase in the point contact areas of particles, then it is found from a model first considered by Fremlin (1959a) that the conductivity varies as the root of the depth in the top pulverized layer. Such a model predicts appreciable porosity to depths of many kilometeıs, and whilst it seems unlikely that the lunar layer at present approximates to such a model it is possible that the Fremlin effect gave very high temperatures ($\sim$1000 K) at depths as little as a few kilometers at some stage in lunar history.

In 1971 Urey, Marti, Hawkins and Liu suggested that an insulating layer was formed on the lunar surface by the debris from the large meteorites which formed the circular basins, and that, as a consequence of this insulation, a subsurface melting occurred which produced the marial basalts. Their model has similarities to that presented here and forms an interesting parallel. It is more detailed and explicit in its description of chemical evolution. However it does not contain the idea of thermal instabilities and differs in the mechanism which it proposes for the formation of the horizontal aıeas of the lunar terrain. More ıecently other suggestions that the poor conductivity of the lunar surface has had an appreciable effect on lunar evolution have been made both by Mizutani and Newbigging (1973) and Bastin (1973). It is the purpose of this paper to extend these suggestions and to give a detailed account of how the surface layer could produce thermal instabilities which would result in high temperatures close to the lunar surface.

2. Theory

The model which will be described in this section refers to the origin of all the flat, and usually dark areas on the Moon: it does not refer to the formation of the circular basins, nor does it specifically require that we should chose either an internal or impact origin for these basins. More precisely, the aim is to explain the formation of those areas of the lunar surface which satisfy the following criteria:

(a) they have albedae below the average for the lunar surface,

(b) they are extremely level on a kilometer and subkilometer scale size,

(c) compared with highland areas they have a low density of large size craters and thus have an age of formation less than about 4.0×10^9 yr.

As is well known this definition corresponds to some but not all of the areas within the circular basins; to some areas within large craters (e.g., Ptolemaeus) and to some areas such as Oceanus Procellarum which are not contained within any obvious circular feature: and in this definition is also included those areas which are often referred to as Cayley formations.

The model can be described by the following sequence of events. It is assumed in common with current opinion that early in its history, the Moon was covered with a surface layer of anorthositic material probably of thickness in the range 20–100 km and of low radioactive content. I assume this layer was then chaotically broken by meteorite impact to a depth of several kilometers, a process which could have lasted for as long as 0.5×10^9 yr and produced material which had a considerably lower thermal conductivity than the present upland regions. The material beneath this anorthositic crust had previously been enhanced in radioactive content by the differentiation process which formed the crust. During the pulverization of the surface, the material below the crust came fairly rapidly to a high temperature probably within the range 1200–1700 K. The heating of this deep layer resulted partly as a consequence of its high radiactive content, partly because of the efficient thermal blanket being formed above it and partly because it was doubtless still hot as a consequence of those earlier processes which produced sufficient heat to cause the earlier crustal differentiation.

Naturally the heating process cannot go on indefinitely and in particular the thermal conductivity of the lower layers of the anorthositic crust will increase with time as they approach the solidus temperature. This increase of conductivity with time is a result of local welding of particle contacts – a process often referred to as sintering. It allows more heat to pass through the thermal blanket, progressively heating the higher layers, which will in turn increase in conductivity, thus producing a cooperative phenomena eventually resulting in a heat surge through the outer lunar crust. In this way most of the top surface layer heats to a temperature close to or above the solidus although because of the efficiency of radiation to space for the lunar surface, the top meters or tens of meters of the surface still remain relatively cool. Such a model can obviously give rise to spatial instability, i.e. the possibility that the heat loss will take place in selected areas, and the probability of such an instability will be greatly enhanced if there is an efficient means of horizontal heat transport at any level within the system. The regions at which this preferentially large heat loss has taken place from the lunar surface I wish to identify with the flat marial and Cayley type areas of the Moon. I do not suppose that within these areas the whole of the crustal layer melted as a result of such a localized heat flow. By this I mean that the layer did not in any sense become magmatic as a whole, and the majority of the minerals retained their long range lattice ordering throughout the process. It is enough to suppose simply that the temperature of the broken material was sufficiently raised for its conductivity to increase appreciably with time, and that this rise in conductivity then produced a temperature increase in the top few kilometers of the surface resulting in a viscosity low enough for the surface topography to relax completely. If τ is the time for which the heat surge effectively occupies the upper surface terrain they it can be shown (see, for example, Scott, 1967) that surface formations of scale size l will become essentially flat if

$$\tau \gg \frac{\eta}{\varrho g l}, \tag{1}$$

where ϱ is the crustal density of the local gravitational field and η the mean viscosity of the surface material throughout the thermal surge.

3. Calculations

The results of some preliminary calculations will now be described. An essential element in all these is that I assume that the conductivity K increases with time in accordance with

$$\frac{\mathrm{d}K}{\mathrm{d}t} = A e^{-(H/T)}, \tag{2}$$

where A and H are constants the latter chosen in the range 20–35000 K. The conductivity was in all cases given an upper bound equal to the conductivity of basalt ($\sim 3\text{Wm}^{-1}\text{K}^{-1}$, Tőksoz *et al.*, 1972), but initially set at all points less than this by a factor G so as to represent the low initial conductivity of the blanket. Calculations were made with G between 1/3 to 1/300 this being well within the range indicated by theory and experiment for pulverized lunar surface material (Fremlin, 1959a; Cremers *et al.*, 1970; Ade *et al.*, 1971; Langseth *et al.*, 1972).

I have considered two models both having vertical axial symmetry so that the conductivity and temperature are a function time, depth and radial distance but not azimuthal direction.

Figure 1 shows some isotherms for the first model, a circular basin in which because

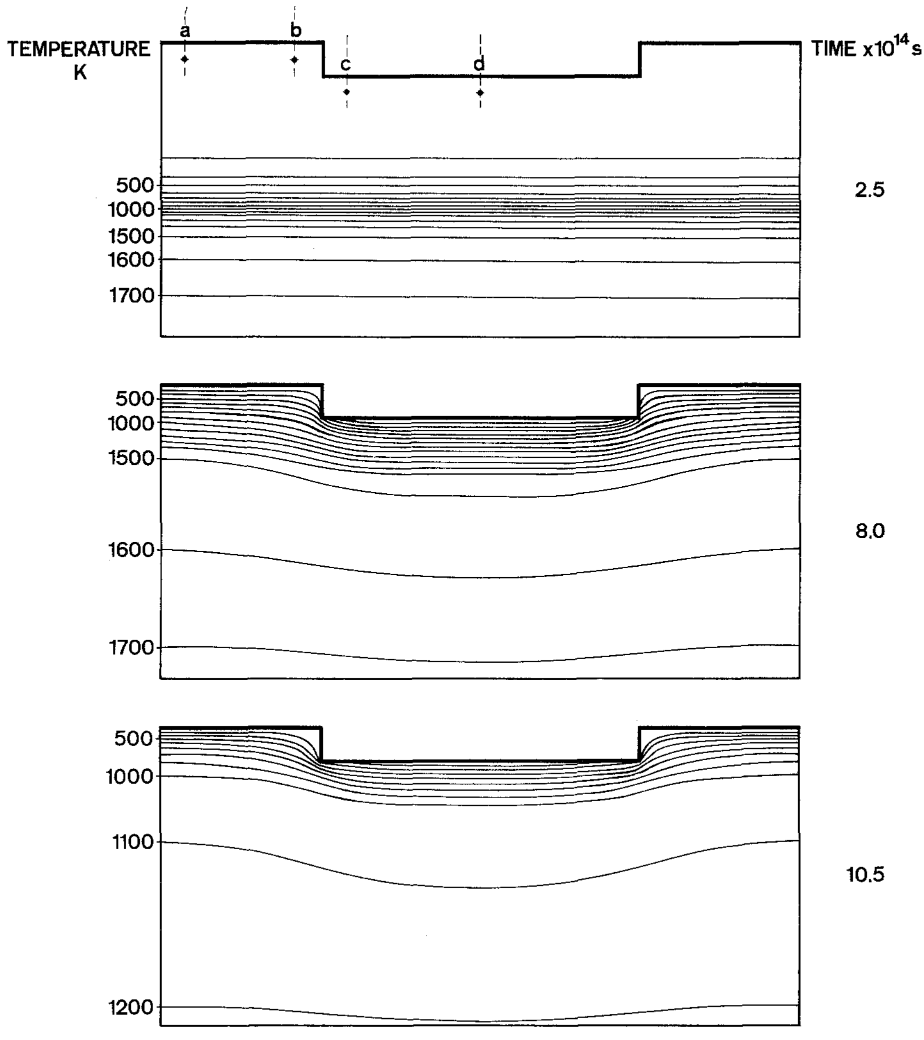

Fig. 1. Isotherms during the development of the thermal history of a model surface with a circular horizontal depression (Model 1). The thick line in each case represents the surface of the model. For clarity the horizontal scale has been contracted by a factor of five. Initially the model was set with the temperature of the whole volume equal to 240 K and throughout the history a constant flux of 3.3×10^{-2} Wm^{-2} was supplied to the base elements. The diagrams represent a sequential development of the model, the corresponding times after the model has been set into operation being shown on the right of each diagram. The depth of the model was chosen to be 20 km and the diam. 200 km. It is seen that a strongly shouldered temperature function is propagated to the surface, and that after it reaches the surface, the interior cools in spite of the constant basal source. The model is axially symmetric, and changes in horizontal dimensions do not radically affect its properties. An increase in depth of the model serves mainly to lengthen the time taken for the heat surge to reach the surface. The values of constants defined in the text for these particular calculations were $G = 0.03$, $A = 3.5 \times 10^{-6}$ $Wm^{-1}K^{-1}s^{-1}$, and $H = 30000K$.

of the difficulty of drawing clearly in such a flat slab the horizontal scale has been contracted by a factor of five. As boundary conditions I assume black body radiation from the surface, and at the base a flux of thermal energy equal to that measured by the Apollo surface-based experiments (Langseth, 1972). It is seen from Figure 1 that a heat surge is propagated towards the surface: as soon as it reaches the surface, heat is relatively qiuckly lost by radiation and the subsurface layers cool although the rate of cooling is affected appreciably by the details of what happens in a thin surface layer and this is in turn dependent on the values assumed for the constants defining the time dependence of the conductivity. Figure 2 shows a plot as a function of time of the temperature at points 1 km below the surface both within the basin and in the raised upland area. It is clear that there is a very considerable difference between the temperature maxima of the uplands and basin regions. Much larger temperature differences are found if the basin depth is increased but this is hardly necessary to suppose since a change of temperature in rock of as little as 100 K can cause viscosity changes by a factor between $10^2 \times 10^3$ (see, for example, Hardin, 1966). Figure 3 shows similar results for a second model in which an axially symmetric cylinder at the base of the layer is given an initial high conductivity corresponding to that of basalt. In this model there is no central basin and the top surface is all at the same level. The model relates to the development of a maria (or a region of Cayley patches), in areas where the broken surface layer is of less than average thickness.

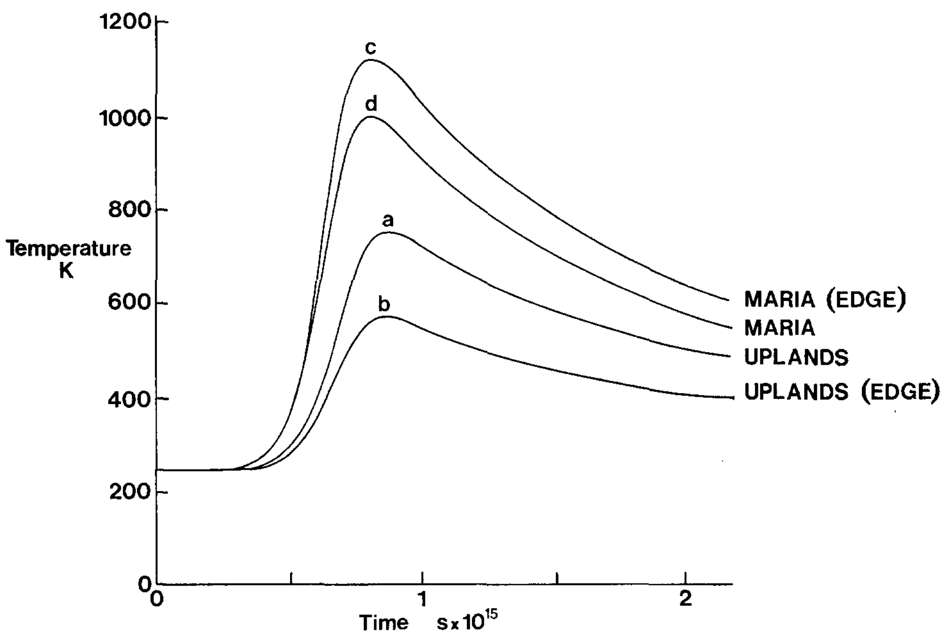

Fig. 2. Model 1. Temperatures shown as a function of time at points 1 km below the surface in the circular basin model. The letters a, b, c, and d indicate respectively the positions in Figure 1 to which the curves refer.

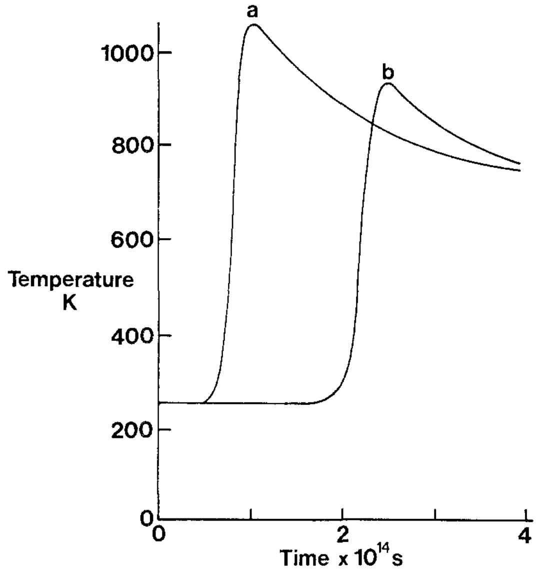

Fig. 3. Model 2. Temperatures shown as a function of time at points 1 km below the surface: (a) above a region only 10 km deep with material initially of low conductivity overlying an equal depth of high conductivity material. (b) in the outer annulus of the model consisting of a single layer 20 km thick of initially low conductivity material. The diameter of the inner highly conductive layer is 100 km, and there is no central basin. The constants and dimensions of the model are in all other respects identical to that of the first model illustrated in Figures 1 and 2.

4. Discussion

There are two basic elements in the ideas described here. First that the marial and Cayley regions of the Moon have resulted from processes which have caused these areas to behave to a depth of many kilometers and for a relatively short time essentially as a liquid; and secondly that the cause of this behavior is a heating which has resulted from instabilities in the Moon's thermal flow pattern. The first of these ideas I wish to refer to as the liquefaction theory: it does not logically require the idea of thermal instabilities as its *cause*, although at present this is the only mechanism which I can show to be physically reasonable.

We must of course at least suppose that isolated or localized regions in the maria became liquid in the sense that basaltic rocks were able to crystallize from the melts and we will refer to this magmatization process as melting. For chemical reasons we require in the maria considerable transport of liquid magma to the surface from deeper levels below the crust. However, as a result of the high latent heat of fusion of lunar rocks, the different melting temperatures of lunar mineral types, possible localization of the radioactive heat sources, spatial inhomogeneity of the thermal conductivity and other thermal parameters which affect the local temperature, it is very reasonable to suppose that such melting is a strictly localized phenomena occurring mainly at isolated regions throughout the maria. The difference between the maria regions and Cayley formations then appears as one of degree. The maria regions we regard as ones in which localized magmatic regions occur frequently and make their influence felt in the surface topography and chemistry. In the Cayley regions the temperatures have in general not been so high: they have been high enough to produce level surfaces but the magmatization has occurred infrequently or only at depths where its production has not greatly affected the topography and chemical composition of the surface. They thus represent less energetic forms of the phenomenon that produced the maria.

In order to consider the advantages of the present theory I first list the hypotheses which are currently used to explain the origin of the flat dark areas on the Moon:

(a) the marial areas have been covered by lava flows coming from deep within the moon through a relatively, small number of fissures and then spreading horizontally,

(b) the maria represent solidified magmatic lakes many kilometers deep,

(c) the marial basalts were formed as a direct result and at the same time as the meteorite impacts which formed the circular basins,

(d) the marial material and Cayley regions were formed by impact-produced dust migrating from upland areas, and

(e) the Cayley regions result from ash flows formed by meteorite impact.

These will be referred to respectively as the lava-flow, lava-lake, impact, migration and ash flow hypotheses. It is recognized of course that whereas these theories all compete to a greater or lesser extent with the present hypothesis they are not necessarily all mutually inconsistent. Thus for example the lava flow and ash flow hypotheses are mutually consistent and probably represent together the current favoured hypotheses for the origin of the features I am considering.

The advantages of the hypothesis put forward in this paper will now be enumerated and discussed briefly.

1. Because the flat areas on the Moon have numerous features in common we might expect a common mode of formation, and this is provided by the present theory.

2. It is now often assumed that the heating required to produce the upland breccias in their present form came from the kinetic-energy of large impacting meteorites. However, it would be expected that such melting would be scale-invariant so that, irrespective of the size of the meteorite, the same fractions of the kinetic energy of the incoming meteorite would be converted into heating rocks, into giving the ejecta kinetic energy and in producing seismic energy. On the ash flow hypothesis it is, therefore, surprising that in the marial regolith we do not find the same evidence of impact produced heating as in the uplands. The present liquefaction theory predicts very considerable heating of the *upland* areas without any additional ad-hoc hypotheses.

3. Examination of upland breccia types indicates that they were subject to temperatures almost sufficient to cause complete magmatization. If the impact origin of such heat treatment is to be believed, we would also expect considerable quantities of rock which have been completely melted. The present theory accounts for this upper temperature boundary. The heat is of internal origin; had it been sufficient to melt an appreciable fraction of the rocks completely the area would have undergone

liquefaction in the sense defined above and become of a marial or Cayley type. Of course the larger impacting meteorites do produce some molten rock. The playa regions close to the crater Tycho clearly seen in Orbiter photography were probably liquid pools formed in this way. However their total volume does not represent a large fraction of the material excavated by the Tycho event.

4. The explanation of many of the upland breccias as having been heated as a result of meteorite impact requires a blanket of thermally insulated material above the breccias during their initial cooling (Simonds *et al.*, 1973). It seems very difficult

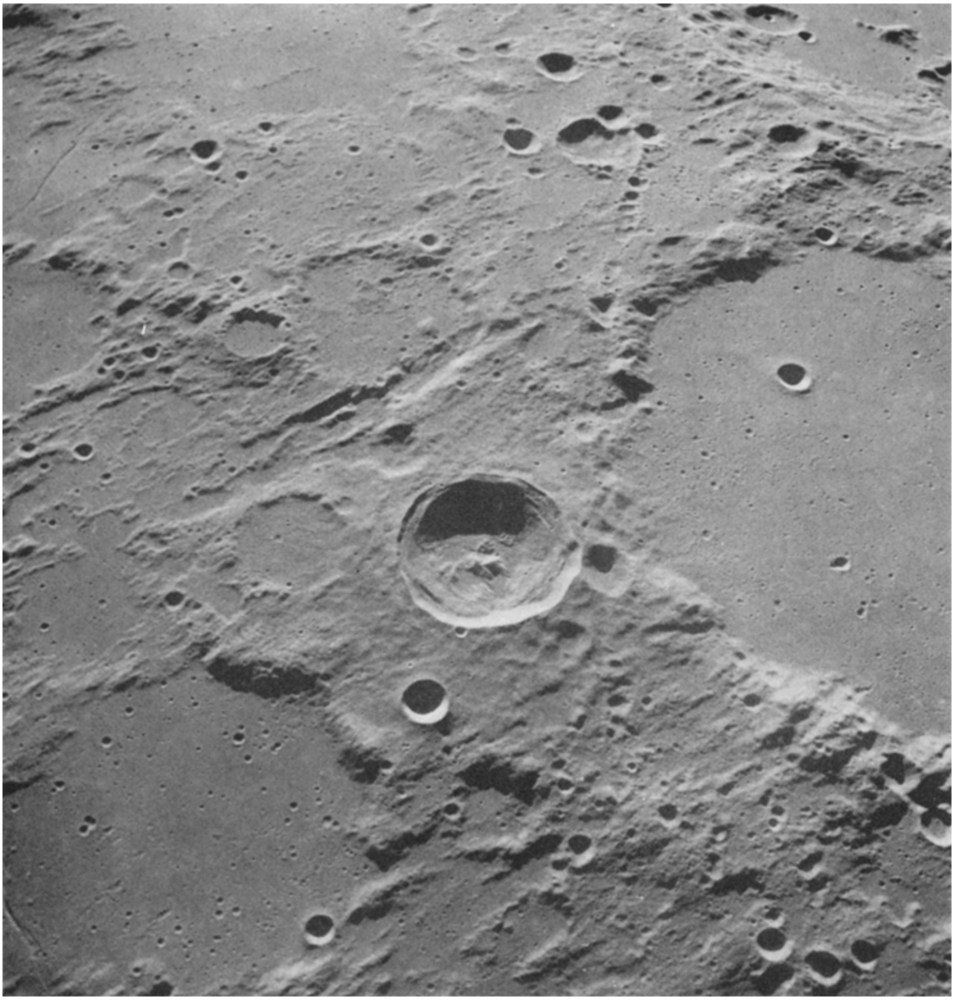

Fig. 4. An Apollo 12 photograph (NASA AS12-50-7431) showing the craters Herschel (center) and Flammarion right. The center of the frame corresponds to a point 4° S and 6.5° W of the center of the lunar disc. Notice the large number of flat lowlying areas all at about the same height yet unconnected by any surface features.

to imagine an impact model which could produce such a blanket at the same time as heating the breccia.

5. If the Cayley formations are meteorite ash flows why are they often darker than the surrounding uplands?

6. If the Cayley formations are meteorite produced ash flows why are their surfaces all apparently at above the same level within a given general area as is seen in Figures 4 and 5?

7. If the Cayley formations are ash flows why are they located in groups?

These last three problems are all well explained by the liquefaction hypothesis. Such a group of Cayley areas can be regarded as a system similar to that which formed the maria but having a smaller heat source or flux so that the process never went so far as in the case of the maria.

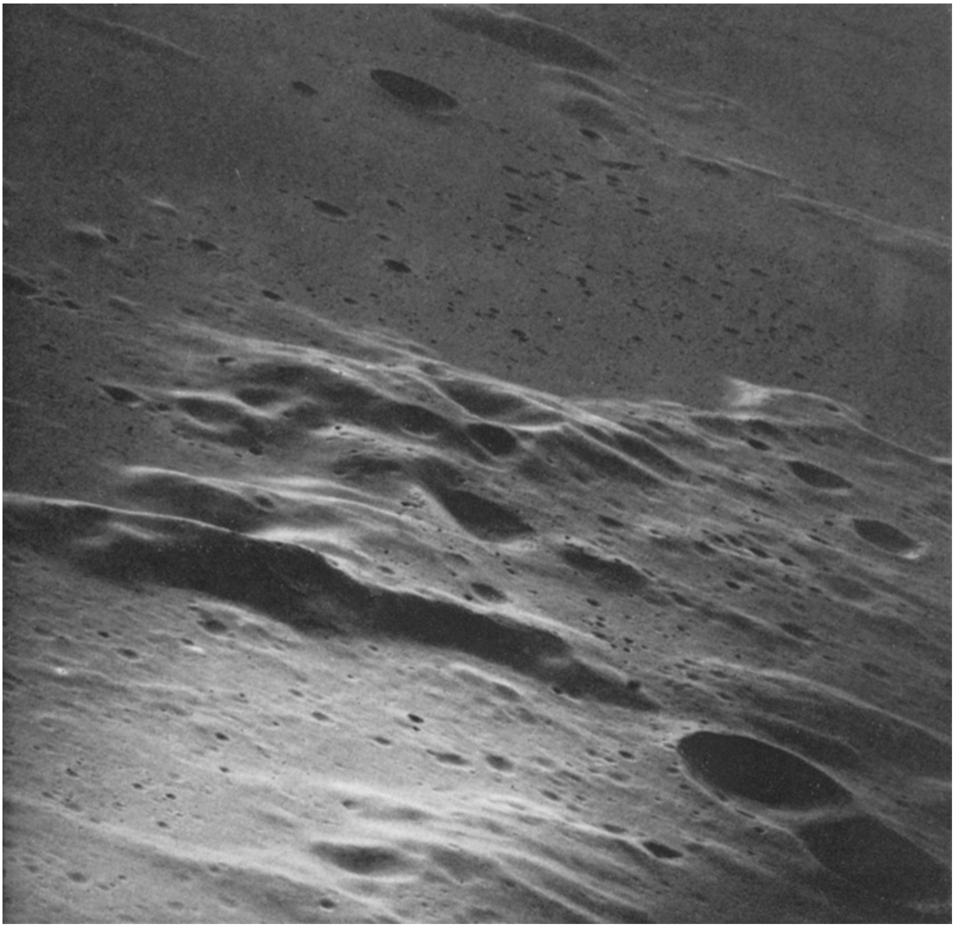

Fig. 5. Apollo 14 photograph (NASA AS14-69-9576) centered 15° W and 4° S of the lunar center. Note as in Figure 4 the apparent flatness and uniform height of the various low lying areas. Craters Fra Mauro H and Fra Mauro HA appear at the bottom right hand.

8. The seismic results require inhomogeneities to a depth of many kilometers and of about a kilometer scale size within the marial areas. This does not seem possible with the lava-lake model and would require additional ad hoc postulates in the case of the lava-flow theory.

9. The presence of a continuous bedrock layer a few meters below the maria surfaces is difficult to reconcile with radar reflection data. However the more recent orbital radar sounder experiments show the presence of high density regions at depths both up to and in excess of one kilometer (Phillips *et al.*, 1973).

The last two points find a simple explanation on the liquefaction model which

Fig. 6. Apollo 14 photograph (NASA AS14-70-9837) centered on the lunar equator at a point 30° W of the disc centre. The large crater Lansberg G appears near the top of the photograph. The crater Lansberg G referred to in the text is on the plate about a third of the way from the main crater to the bottom right hand corner of the plate.

requires localized melting; this would produce spatial density variations and could thus account for both the seismic and electromagnetic reflection observations.

10. The variations in density produced at depth within the maria by localized melting would be expected to give rise to various faults and stresses which could be propagated to the immediate lunar surface and produce those surface features which we now see on the maria. These features cannot be explained on the lava-lake model and do not all have exact and well-agreed detailed explanations on the lava flow model.

11. The marial basalts show great spatial inhomogeneity in chemical and mineral composition even within a given rock which would not be expected on the lava lake model. Similarly the lava flow model would be expected to produce considerable homogeneity in the magma after flow over great distances.

12. There are no strong flow lines or obvious surface gradients on the surface of maria at the points where the lava flow model would require the greatest flow rates. Notice for example in Figure 6 the absence of flow lines in the bottleneck entrance to crater Lansberg G.

13. Ghost craters and surface coloration within the maria are often associated with little change in the local surface gradient yet they clearly show the presence of premare craters and the continuation by albedo contrast of upland features into the flat marial areas. Both of these effects are expected with this liquefaction model and yet are hard to explain on either the lava flow or lava lake hypotheses.

14. There seems to be no case of the kind illustrated in Figure 7 where marial material has been *in*sufficient to fill a given crater thus resulting in a lower level of mare fill within the crater than in the adjacent maria. One would expect many instances of this type in the lava flow model.

15. Another objection to the lava flow model is that it is very difficult to imagine that the hydrostatic lava pressure would always be just sufficient to fill the lowest

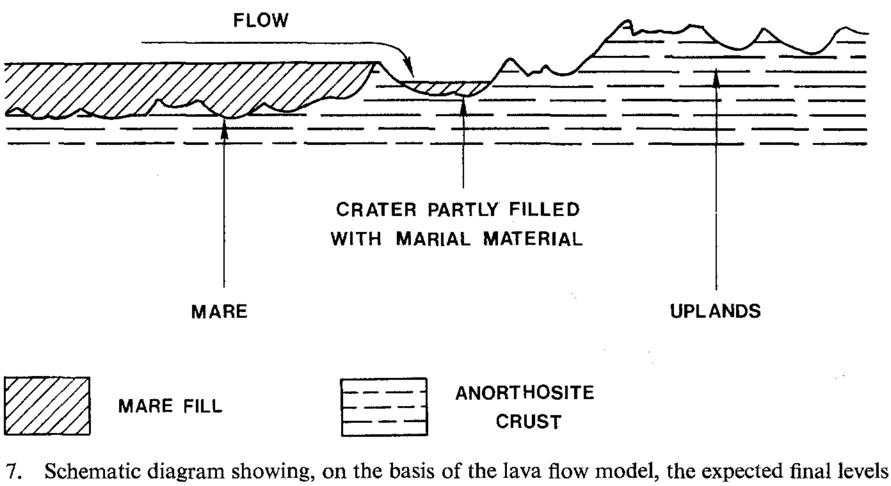

Fig. 7. Schematic diagram showing, on the basis of the lava flow model, the expected final levels of some partially filled craters at the boundaries of lunar maria.

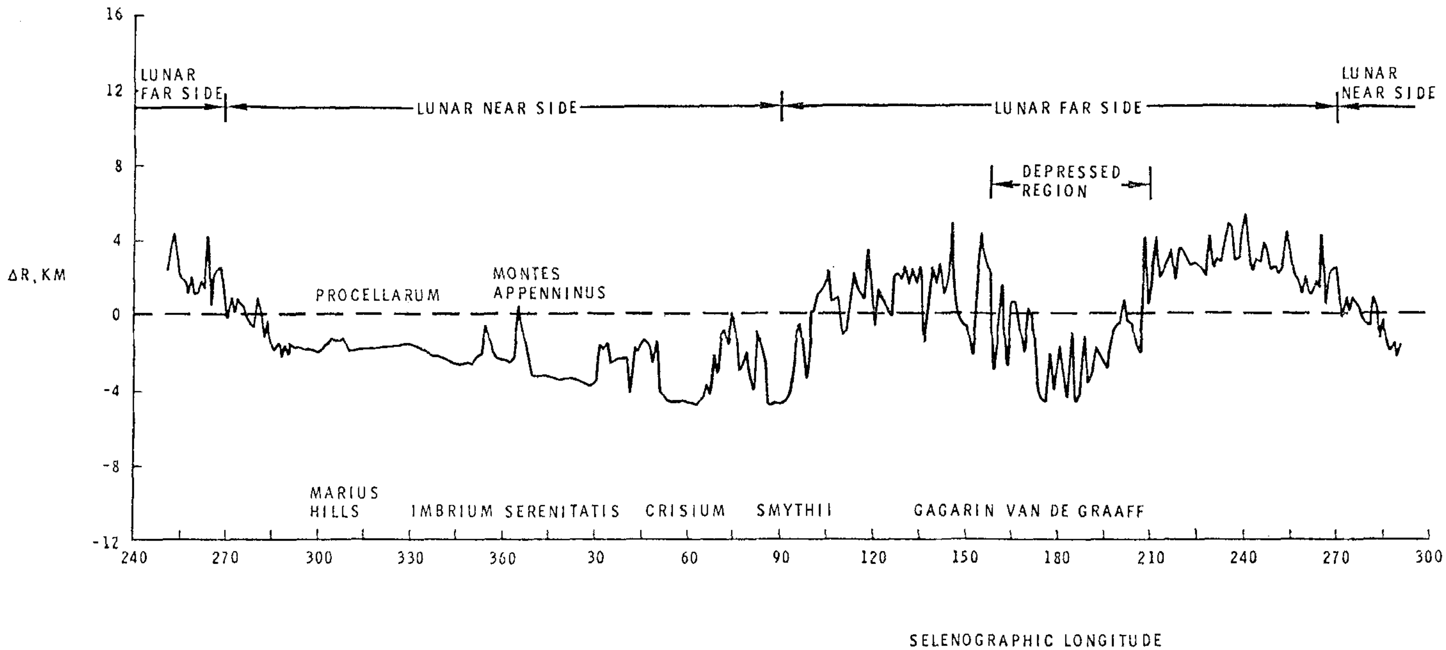

Fig. 8. Lunar height determinations (Wollenhaupt and Sjogren, 1972) made using laser reflection measurements based on the Apollo 15 lunar orbiting spacecraft. Notice the strong correlation between terrain flatness and depth.

levels of the lunar terrain (see Figure 8) and never produce flows coming from higher levels. Measurements of the profiles of the marial surfaces do not show exact correspondence with the present lunar gravitational equipotential surfaces. However, it seems probable from these measurements that some degree of hydrostatic connection

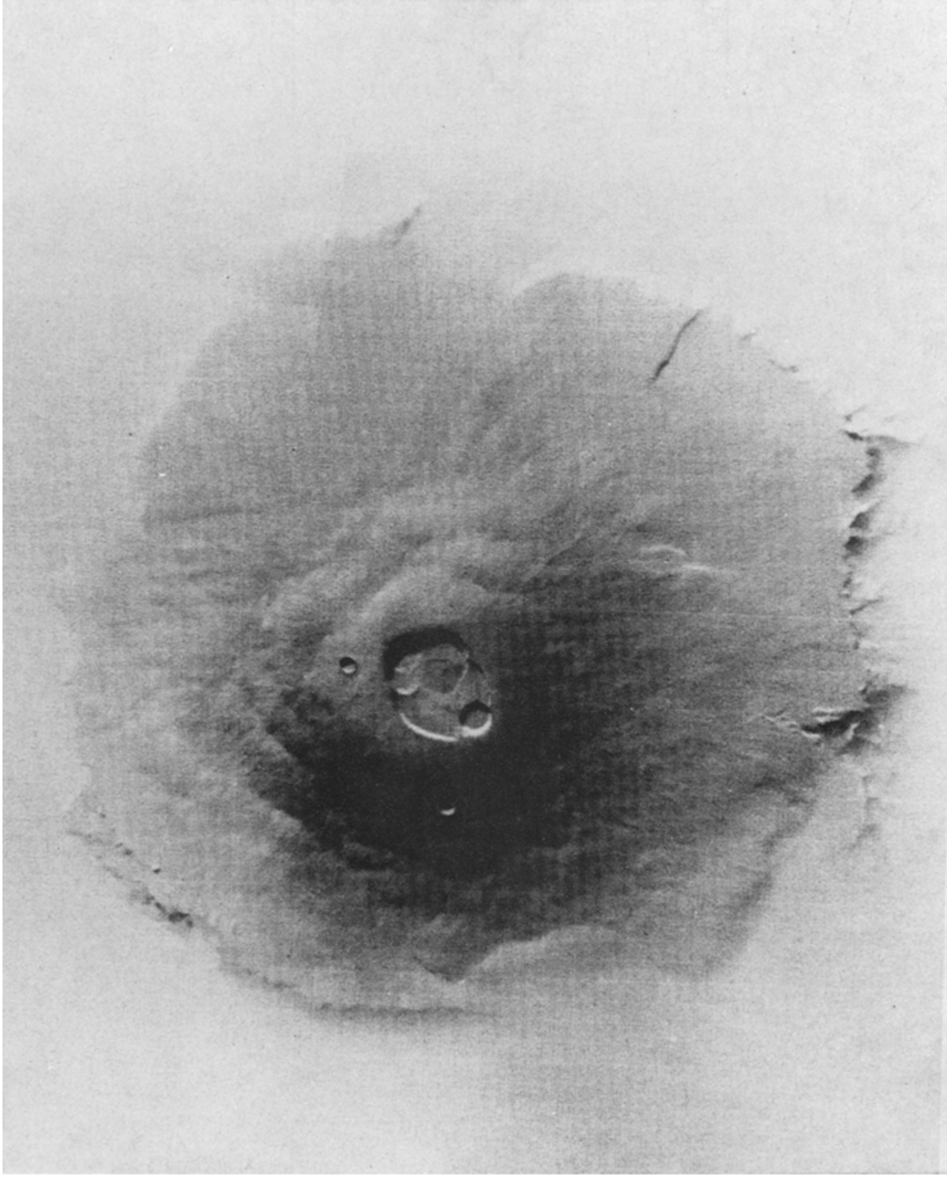

Fig. 9. Nix Olympica photographed by the Mariner 9 Martian orbiter (J.P.L. Photo 13074). The flat laval lakes near the summit of the mountain are about 24 km above the mean level of the Martian surface.

has existed. The slopes and difference in absolute height could be explained by different mean densities of material in the various regions or by the different times at which the various maria solidified, either effect being coupled with a high viscosity. In this context it seems possible that an increase with time of the height of the maria could result from the assumption of a relatively rigid crust and a lunar interior whose mean temperature was increasing during the formation of the various maria. If we compare the terrestrial and Martian cases we find flows at places many kilometers above the mean surface level. Figure 9 for example shows lava lakes on the summit of Nix Olympica on Mars. Indeed comparing Mars and the Earth on the one hand with the Moon on the other, the Moon alone has no atmosphere and thus has a

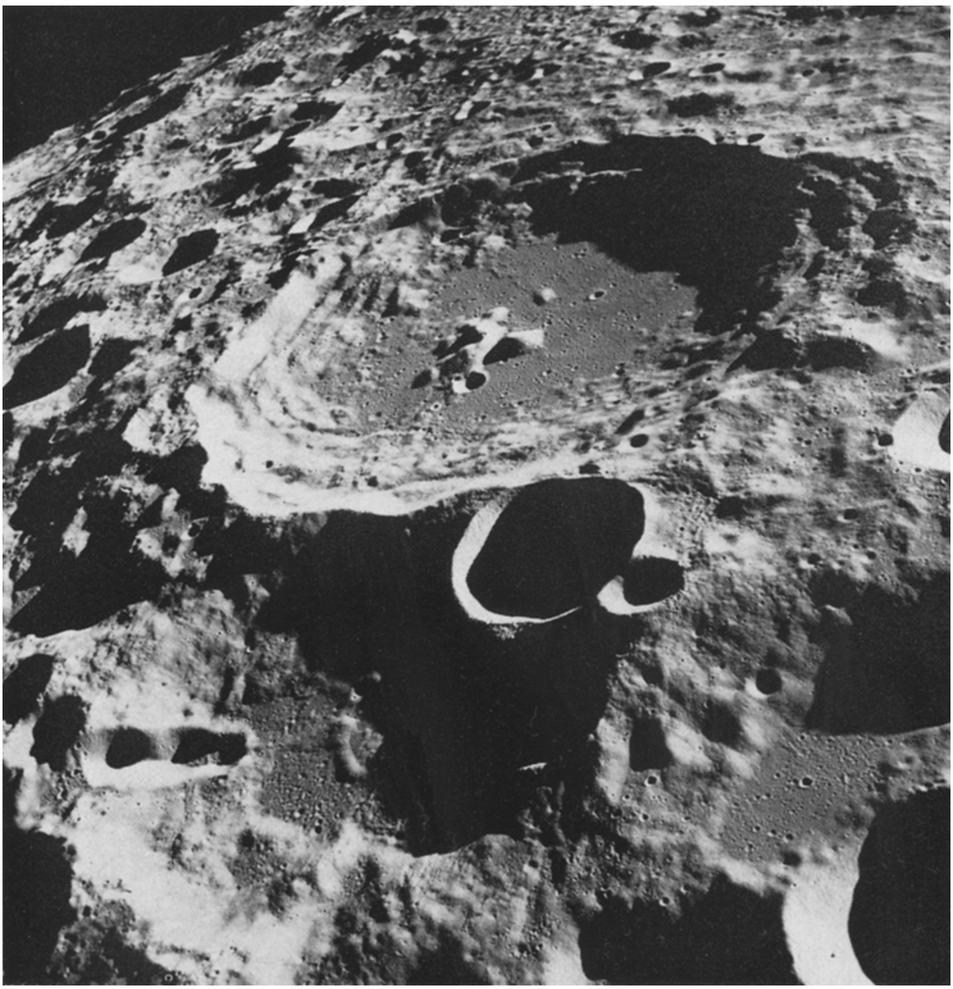

Fig. 10. An area on the far side of the Moon, including the large crater Daedalus, photographed during the Apollo 11 mission (NASA AS11-44-6611). The frame center is 4° S of the lunar equator and 179° to the east of the center of the visible disc. Notice the very low level of all the flat Cayley areas.

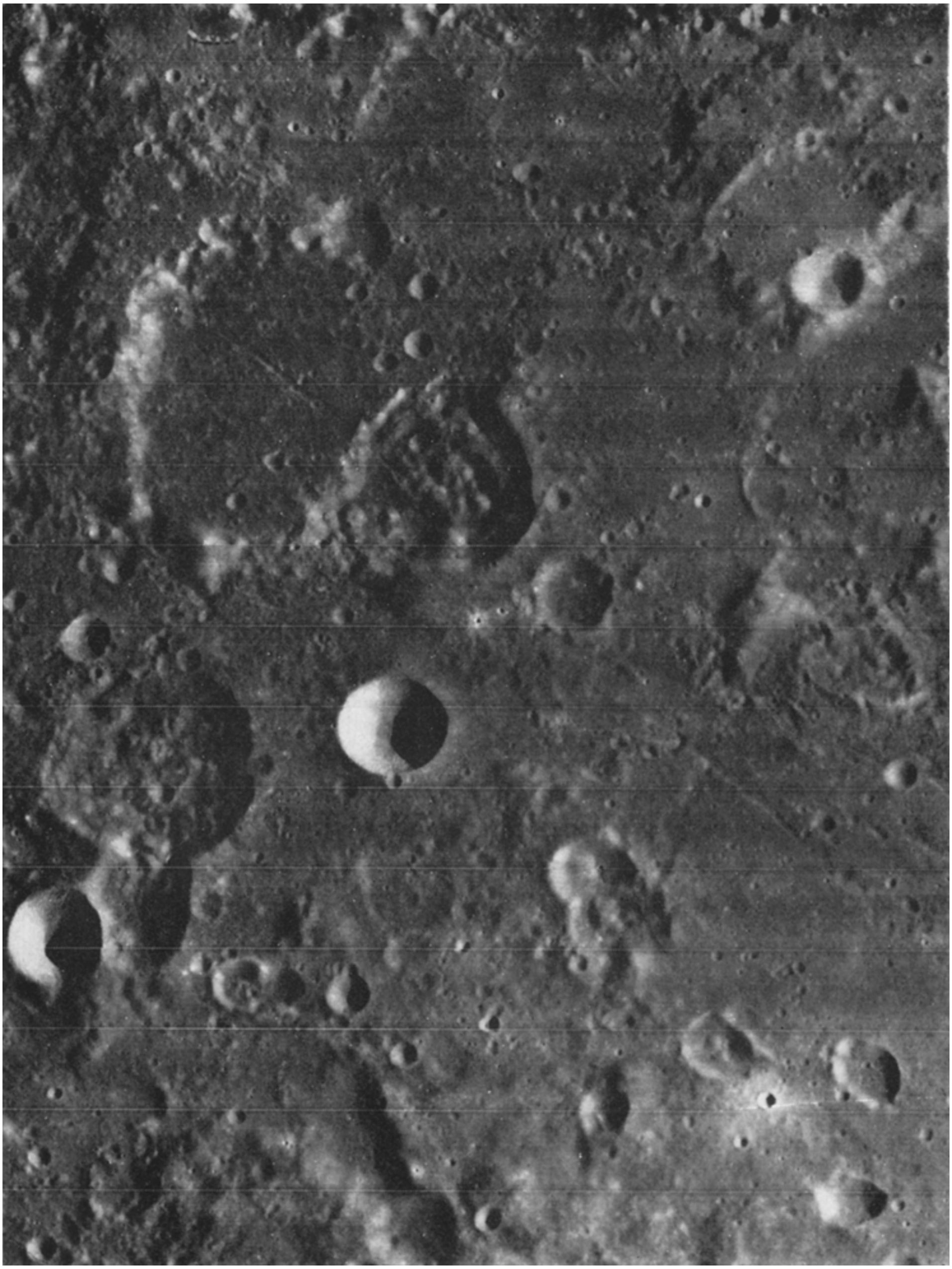

Fig. 11. Orbiter photograph (NASA Orbiter IV-72-H3) at lunar longitude 38° E and latitude 5° S. The horizontal striations result entirely from the photographic process and should be disregarded. Notice the highly relaxed appearance of most of the large craters. The Sun angle was 66° and the length of the base of the photograph represents 140 km on the lunar surface.

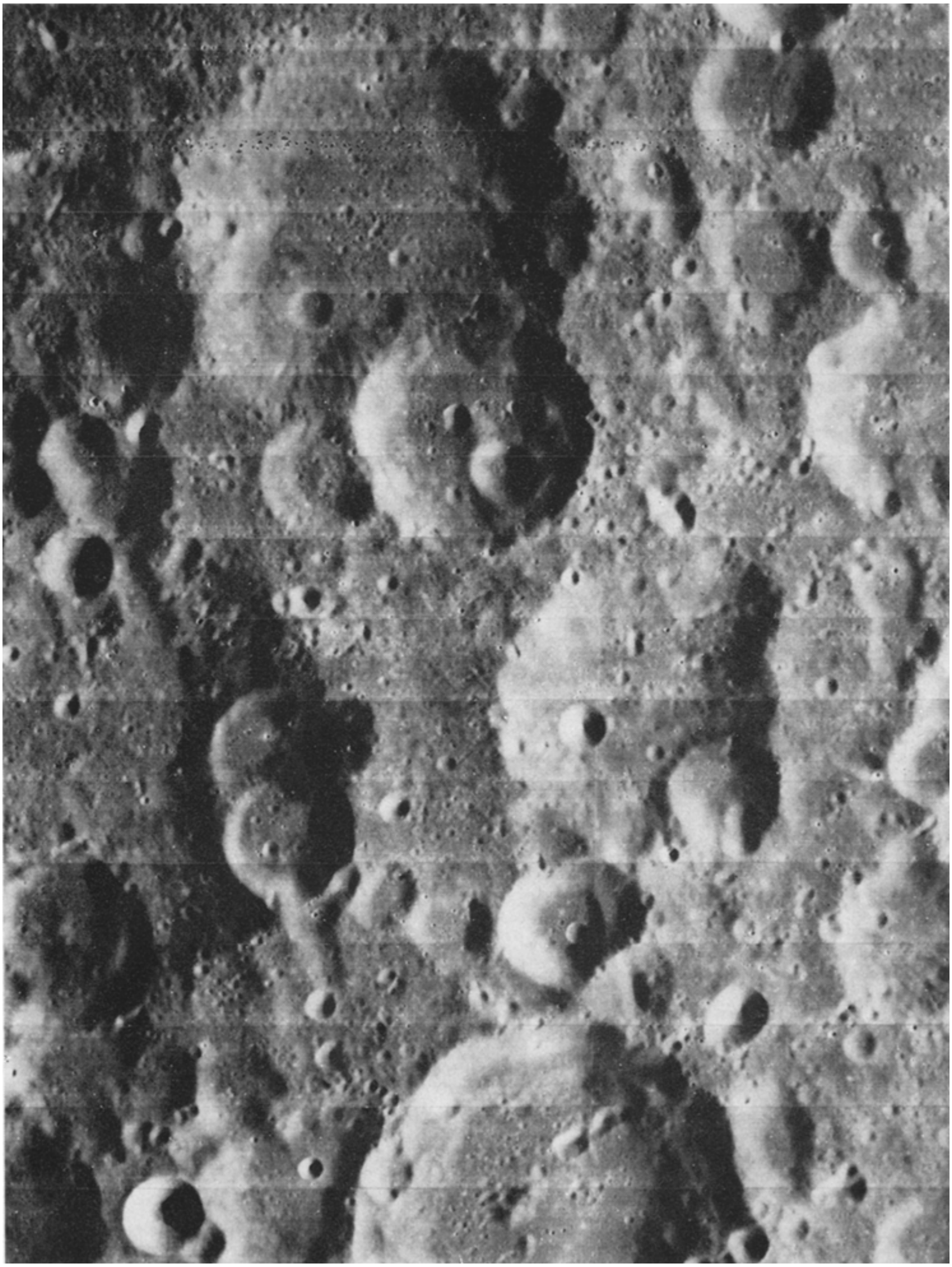

Fig. 12. Orbiter photograph (NASA Orbiter IV-52-H2) of a region of the Southern uplands centered at longitude 64° E and latitude 43° S. The scale and Sun angle are close to those in the previous figure (base 140 km: Sun angle 65°). Notice however that in contrast to the previous figure the terrain is dominated by craters in the 10–100 km diam. range.

very low thermal conductivity of the broken surface material which could give rise to thermal instabilities leading to liquefaction. A general low level of maria and Cayley formations on the Moon is implied by the present liquefaction theory and this is illustrated in Figure 10.

16. The classification of the lunar surface into upland and marial regions is not an exact one and there are many intermediate cases. A comparison of the Orbiter photographs in the two upland areas shown in Figures 11 and 12 suggests that both regions could well be accounted for by the same initial large-scale cratering densities with however a much greater viscous relaxation in one case. Of course the lower viscosity required to produce the more relaxed case could be the result of compositional differences, but it would also result from a relatively small temperature difference between the two regions. Such temperature differences would be expected on the basis of the present model. It would be very difficult to account for the different degrees of relaxation on the basis of the currently accepted hypotheses.

17. There seems to be evidence to suggest that within the upland regions there is an increasing concentration at the lunar poles of kilometer-sized craters (Hartmann, 1968). Such a variation would be expected from the present model since the subsurface temperatures depend on the mean surface temperature and this decreases with increasing latitude.

18. For the reasons stated in the previous paragraph an equatorial concentration of marial and Cayley areas would be expected on the basis of the liquefaction model and this is in fact observed.

19. The occurrence of marial regions preferentially in the circular basins is not unreasonable on the present model since in these areas we could well expect either subsurface rock of greater conductivity, or a thinner insulating poor conductivity layer or even both of these.

20. Large scale photographs of the Moon as a whole (Figure 13) show that the marial and Cayley group areas are located in an approximately cell-like arrangement and with their centers more or less regularly spaced from each other. Such a structure would be expected as a consequence of the liquefaction model if, as seems likely, appreciable horizontal heat transport in the deep layers can occur. Each region of liquefaction would thus tend to drain the surrounding areas of heat and cause these regions of liquefaction to be more or less uniformly spaced.

5. Conclusion

The theory developed in this paper represents an essentially new approach to many of the processes which have given rise to the lunar topography in its present form. The mechanisms which have been considered will have implications in a number of different branches of lunar science. The development of these implications and their subsequent comparison with observation should provide a number of tests for the theory.

The mathematical heat flow calculations were only carried out for a simplified set

Fig. 13. Apollo 11 photograph (NASA S11-44-6664) of the Moon centered at the point latitude 65° E longitude 9° N. Notice the almost regular cell-like arrangement of the darker marial and Cayley type areas.

of conditions. I intend to extend these to cases which are likely to correspond more closely to the actual situation on the lunar surface. In particular I hope to investigate models in which the initial thermal conductivity increase continuously with depth, and tends asymptotically to a limiting value at great depths.

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