THE AGE OF LUNAR CRATERS

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The currently accepted uniformitarian views on the origin and age of lunar features are contradicted by the facts of the rheology of materials. In view of the nature of the material at the surface of the Moon, the craters, in particular, could not be older than a few thousand to a few million years. But the craters are there; hence they must be far younger than the uniformitarian view would allow.

Current views of the history of the moon hold that the major period of cratering on the lunar surface ended four billion years ago. This conclusion is inferred from radioactive age measurements from the various Apollo landing sites. Wood says,

> The concentration of highland rock ages at about 4.0×10^9 years points either to an epoch of specially intense meteoroid bombardment at that time, or . . . a bombardment rate during the first 0.6×10^9 years of solar history so intense that virtually all rocks at the lunar surface had their radiometric clocks repeatedly reset until the bombardment tapered off 4.0×10^9 years ago.[1]

Everyday experience teaches us the difference between a liquid and a solid. Liquids flow out until their surfaces are relatively level. Solids on the other hand remain basically in the same geometrical shape in which they were fashioned. For instance, water is a liquid and when placed on an inclined plane, will flow down slope. Ice is the solid phase of water. When it is placed on an inclined plane, it may slide but will not flow down the slope.

This easy distinction between solids and liquids becomes blurred when extended periods of time are considered. In the above example, ice is a solid, but when enough ice is placed on an inclined surface, it will flow just like water. The only difference is the speed with which it flows. With water one can see the movement down a mountain in a matter of minutes, but with ice, it may take a year to detect the flow. If it were not for this phenomenon of a solid acting like a liquid, glaciers would be impossible.

The difference in speed between the flow of ice in a glacier and the flow of water is due to the friction generated between one molecule of ice and another and the far less friction generated by two liquid water molecules. The greater friction in the case of ice causes it to flow very slowly. The property due to this type of friction is called viscosity, and is measured in a unit called poise. The range of measured viscosity varies from less than one poise for water to over 10^{22} poise for the mantle of the earth. Table 1 gives values of viscosity for several materials.

Glass, in ordinary experience appears as a solid and yet over a century the lower edge of a window pane noticeably thickens. The glass flows in response to the pull of gravity. Salt, too, is considered as a solid in everyday experience but when subjected to forces which endure for several centuries, it will flow just as water or ice. But once again, due to the greater viscosity, it flows very slowly. This movement can be seen in salt domes, some of which appear to be moving today,[2] and in the salt glaciers in Iran.[3] Granite, an igneous rock, has also been observed to flow, albeit exceptionally slowly. N. Kumagai and H. Ito cut long bars of granite and supported them at each end. They then measured the deformation in the granite bars over a period of several years. The deformation was enough to prove that granite had a viscosity of 10^{20} poise.[4]

At the other time extreme, liquids can act as solids. In solids pressure waves travel with a velocity of $[(k + 4\gamma/3)/\rho]^{1/2}$ where k is the bulk modulus, γ is the rigidity of the solid, and ρ is the density. In liquids, the rigidity is zero; so sound travels with a velocity of $(k/\rho)^{1/2}$. Glycerine is a liquid in everyday experience and the velocity of sound through it obeys the latter law. However, when the frequency of the sound becomes high enough, the liquid no longer obeys the liquid velocity law. With (ultra) sound waves of 10^{10} cycles per second, the speed obeys the velocity law for solids.[5] Raman and Venkateswaran conclude,

> Our observations thus seems to establish that for mechanical disturbances of sufficiently high frequencies, a liquid behaves essentially as a solid."[6]

Thus when considering whether a material behaves as a solid or a liquid, the time over which the forces persist must also be considered.

When considering the lunar surface it is reasonable to assume that the surface prior to meteoric impact is in isostatic equilibrium. This means that the basaltic surface is essentially level. The impact and subsequent crater formation alters this equilibrium. Part of the surface, the crater rim, is above the former level. The crater depression is below the former surface. This change from a level surface to an uneven topography

Table 1. Viscosities of various materials.

Material	Viscosity (poise)
Earth's Mantle	10^{22}
Limestone	10^{21}
Granite	10^{20}
Mudstone	10^{18}
Salt	10^{18}
Rubber	10^{15}
Ice	10^{13}
Silicone Putty	10^{7}
Glycerine	10^{0}
Water	10^{-2}

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produces stress in the crust. Gravity will tend to pull the structure down and hydrodynamic forces will push the crater depression up. Over a long enough period of time, the lunar crust will flow to reduce the stress.

The equation which describes this restoration of isostatic equilibrium is given by Officer:[7]

$$H = H_0 \exp -(\rho g t / 2\mu k) \quad (1)$$

where ρ is the density, g is the acceleration of gravity, μ is the viscosity, t is the time, H is the height above or below the isostatic level, and H_0 is the initial distance the crater surface is away from the equilibrium level. k is defined as; $k^2 = l^2 + m^2$, where $l = \pi/a$ and $m = \pi/b$ where a and b are the orthogonal dimensions of the load. For a crater $a = b = 2R$ where R is the crater radius. Substituting, we have

$$H = H_0 \exp -(\rho g R t / 2^{1/2} \pi \mu) \quad (2)$$

Rearranging,

$$t = \ln \left(\frac{H}{H_0}\right)\left[\frac{2^{1/2}\pi\mu}{\rho g R}\right] \quad (3)$$

The density of basalt is 2.9 gm/cm^3 and the gravitational acceleration on the lunar surface is 163 cm/sec.^{2}. However, the viscosity of basalt is the most uncertain parameter in this equation. Both manual and computer assisted literature searches revealed that no measurement of the viscosity of basalt at the applicable temperatures has ever been made. However, even without this measurement, it is possible to define an upper limit to the viscosity of lunar basalts. It must first be noted that the chemical composition of lunar basalts is very close to terrestrial basalts.[8] Table 2 shows the average composition of terrestrial and lunar basalts. Because of this similarity, we may use what we know of terrestrial basalts. One of the things that we know about terrestrial basalts is that the viscosity over all temperature ranges over which it has been measured is always less than granitic material.[9] This is because the viscosity increases as the igneous rock contains more silicon. Granitic rocks contain an average of 70 percent SiO_2 while basalts contain only 40 percent. Thus we can use the viscosity of 10^{20} poise measured for cold granite as an upper limit for the viscosity of basalt.

Another limiting factor is the lack of any *measured* viscosities larger than the 10^{22}-10^{23} poise value which is ascribed to the earth's mantle. Thus we can be rather confident that the lunar viscosities are definitely below 10^{23} poise and most likely below 10^{20} poise.

Since the value of the viscosity involved in this flow is absolutely critical to the validity, or lack thereof, of this argument, it would be useful to discuss these measurements in more detail. In looking over the literature one can make an interesting observation. Authorities when talking about terrestrial materials seldom cite values greater than 10^{23} poise. The values they cite are taken from laboratory measurements and terrestrial measurements.[10, 11, 12] However it is not exceptionally difficult to find values cited as high as 10^{30} poise but upon investigation, these cases turn out to be extrapolations from lower values.[13] Solomon, Comer and Head[14] when discussing the viscous flow of lunar craters include two graphs showing extremely high viscosities. They include these charts as "examples" but fail to adequately explain to the reader that the higher viscosities are extrapolations.

Table 2. Composition of Terrestrial and Lunar Basalts.

Mineral	Terrestrial %	Lunar %
SiO_2	40	42
Al_2O_3	10	13
FeO	18	16
MgO	7	8
CaO	11	12
TiO_2	11	8

The problem is that in discussing lunar craters, one must know two facts: the age of the crater and the viscosity. Laboratory measurements give us the surface viscosity within certain limits; but using these values yields ages that contradicts the current accepted chronology. Thus, many investigators have chosen to assume the age and solve for the viscosity. J. Arkani Hamed in an article on the viscosity of the moon[15] derives a viscosity of 10^{27} poise. This value was not derived from measurement of the physical properties of lunar basalts but from the assumption that the lunar crust is billions of years old. If the viscosity were lower than that then certain lunar features could not have lasted the necessary 3 billion years. In this paper we will use the laboratory measurements since they are the only firm information available.

In using equation 3 to determine how long it will take for a crater to flow back to the original surface level, we will assume that when 99 percent of the structure is gone, equilibrium is restored. This is identical to setting H/H_0 equal to 0.01. Table 3 shows how long it would take for craters of various sizes to be reduced in height by 99 per cent due to hydrodynamic flow. As can be seen, the lunar craters can not last longer than a few million years for any reasonable value of the viscosity. If the viscosity of granite is the upper limit for the viscosity of basalt, then lunar craters can not be more than a few thousand years old.

Should the objection be made that these rates are too fast and we should see these effects in old earth structures or mountains, it can be shown that this is not so. In the case of mountains, they are in isostatic balance (or close to it); so the mountain as a whole would not sink. Mountains are supported by a low-density root which keeps them floating far above normal elevations. Because they are in isostatic balance, equation (3) is not strictly applicable to describing the flow.

The only type of flow which an isostatically supported mountain would undergo is for it to flow out

Table 3. Time for Re-Establishment of Isostatic Balance for Various Viscosities (time in Years).

Crater Radius Km	Viscosity (poise) 10^{20}	10^{21}	10^{22}	10^{23}	10^{24}
450	3,050	30,500	305,000	3,050,000	30,500,000
125	10,980	109,800	1,098,000	10,980,000	109,800,000
50	27,000	270,000	2,700,000	27,000,000	270,000,000
25	55,000	550,000	5,500,000	55,000,000	550,000,000

and fill up the valleys. In this case the hydrodynamic equations must be derived differently. Following Hubbert's approach[16] we have

$$\frac{\partial V_z}{\partial z} = \frac{\sigma_{zz}}{3\mu} \quad (4)$$

where V_z is the velocity in the vertical direction (z axis), σ_{zz} is the stress parallel to the z axis and μ is the viscosity. With the origin fixed at the base of the mountain, the velocity as a function of z can be found by integrating the above equation.

$$V_z = \frac{\sigma_{zz}}{3\mu} z + C \quad (5)$$

where $C = O$ since $V_z = 0$ at $z = 0$.

To determine how far a given particle has moved in a given time, we integrate equation (5) with respect to time remembering that $V_z = dz/dt$. This yields

$$t = \frac{3\mu}{\sigma_{zz}} \ln(z/z_0) \quad (6)$$

For a cliff $\sigma_{zz} = \rho gz$ where ρ is the density of the rock, 2.5 gm/cc, g is the acceleration of gravity, 980 cm/sec.[2] A 3000 foot cliff would have a stress of approximately 2×10^8 dynes/cm^2. Using a vsicosity of 10^{22} poise we find that it would take 47,000 years for the cliff to be shortened by 1 percent or thirty feet. The important question is: would we ever be able to observe this flow? Unfortunately we wouldn't. The rates of erosion in mountainous areas is exceptionally rapid. The overall rate of erosion averaged over the entire continent is 1 inch every thousand years. But in the Transverse Range in California, the USGS reported an erosion rate of 25 feet per thousand years.[17] Thus while flow would lower the cliff by 30 feet over 47,000 years, erosion would lower that same cliff by nearly 1200 feet. Thus we would never observe the flow.

In the case of old human structures, they too are generally flowing at too slow a rate for it to be observed. For instance, the Great Pyramid of Egypt is made of limestone which has a viscosity of 10^{21} poise. Following Hubbert's method, which is more applicable to the case of a pyramid than equation (3) we find that it would take over 26,000 years for it to shorten by four feet. In the 4,600 year history of the pyramid, the original 481 feet height has been reduced to 451 feet by weathering and plundering. Thus once again we would be unable to detect flow in a small object.

Equation (3) was first derived by Z. F. Danes of the United States Geological Survey. In a short report on this work, the USGS stated,

> The history of a circular crater in a highly viscous medium is derived from the hydrodynamic equations of motion by Z. F. Danes . . . Correspondence between theoretical crater shapes and observed ones is good. However, the time constant, T, is surprisingly short if commonly accepted viscosity values are used. Thus, if the present analysis is valid and if lunar craters are of the order of 10^9 years, lunar rock viscosities must be of the order of 10^{25} to 10^{26} poises. If viscosities of lunar rocks were around 10^{21} to 10^{22} poises, the ages of large craters would have to be only 10^4 to 10^7 years.[18]

Table 4. Crater Radii.

Crater	Radius (kms.)
Oriental Basin	450
Clavius	120
Grimaldi	120
Copernicus	50
Plato	48
Tycho	40
Krafft	26
Cardanus	25
Hansteen	23
Zupus	19
Damoiseau	18
Harpalus	17
Giordano Bruno	10

Considering the time at which this was written (1966) it was perfectly within the right of the investigator to speculate that the lunar material was extremely viscous. In 1966 we really had no idea of the exact chemical composition of the moon's surface. However, since the Apollo missions have shown that the lunar surface is merely a basalt with a very similar composition to terrestrial basalts, such speculation is no longer reasonable. In spite of this, such speculation continues to the present.

In a recent article, Binder and Lange remarked,

> Meissner assumed in his discussions of the present viscosity of the moon that n_0 and g are the same as for terrestrial mantle materials and hence that [the viscosity equals] 10^{21} [poise] at the solidus, the value found for the earth's upper mantle from the rebound of the Fennoscandian and Canadian shields. However, our results indicate that these assumptions lead to viscosities which are too low to be consistent with certain boundary conditions.[19]

Among the boundary conditions listed by Binder and Lange is the assumption that the moon separated from the earth 3 to 4 billion years ago.[20] This extremely old age for the moon is the only boundary condition in their list which could possibly be violated by low viscosity values.

Because the laboratory measurements on terrestrial materials indicate that viscosities could not be much more than 10^{23} poise, the lunar craters can not possibly have lasted the three to four billion years assumed by secular lunar theories. The evidence presented here demonstrates that the lunar surface and the craters on it are relatively young structures.

Postscript

Even though it is normal for the erosion rate to be faster than the rate of fluid flow under most conditions, fluid flow has been observed in recent man-made structures. This fact simply verifies the youth of the craters in the solar system. L. L. Nettleton gives several examples of fluid flow in hard rocks in his classic paper on salt dome formation. He stated,

> There are several lines of evidence showing that hard rocks will flow under small stresses maintained for long times. Bingham calls attention to

the deformation of tombstones under their own weight in a cemetery in Washington, D.C., and quotes several instances of rock flow from ancient structures in the old World. In an old cemetery in Richmond, Virginia, the writer has noticed a pronounced concavity of tombstones which consisted of horizontal slabs mounted on brick pillars at the four corners. Slow flow and 'elastic after effect' has been determined on bars of rock cut from the coal measures of England. Bingham and Reiner have shown that long slender bars (about 1 inch square by 33 inches long) of thoroughly cured cement mortar bend appreciably under their own weight in a few months. Flow of marble slabs, probably from forces arising from diurnal temperature changes, has been noticed in a cemetery in Havana, Cuba. All the evidence quoted on the flow of rocks shows only small deformations, but they were caused by small forces (in most cases, of the order of the weight of the rock) and for times which are infinitesimal in comparison with geological time.[21]

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ARE THE BRISTLE-CONE PINE TREES REALLY SO OLD?

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Various treatments were given to 8-month-old bristle-cone pine seedlings; and it was found that supplementing the winter day length with a 250-watt heat lamp in order to give a total of 16 hours of illumination proved most effective. The lamp was placed about three feet above the seedlings, and the temperature in the growth chamber was kept at about 70°F. Those which received a short (circa 21 days) drought stress period in August of the third growing season showed up having one more growth ring than the control seedlings, that is four growth rings instead of three.

Also seedlings which received a two week drought stress period in August of the fourth growing season showed a similar extra growth ring.

The bearing of this on the estimates of the age of the bristle-cone pine forest is discussed. Under the San Francisco type of both spring and fall rainfall with a relatively dry period in the summer the young forests on the White Mountains would have grown an extra ring per year quite often. Accordingly it is believed that the presumed 7100 year age postulated for these trees by Ferguson would be reduced to about 5600 years, on the assumption that extra rings would be formed by stress during about 50% of the years between the end of the Flood and about 1200 A.D.

Introduction

In his paper, "Bristlecone Pine: Science and Esthetics," C. W. Ferguson points out that in some species of conifers one season's growth increment may be composed of two or more flushes of growth, each of which may strongly resemble an annual ring. Such multiple growth rings are extremely rare in the bristlecone pine, especially in the White Mountain area, according to Ferguson.[1] Now this range of mountains is located east of the Sierra Nevada and separated from

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