Notes on a Study of the Moon.

BY

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SINCE Galileo directed his first telescope on to the Moon there have been immense improvements in instrumental equipment and in the methods of physical research. Thousands of observers have devoted their energies to a minute inspection of its rugged surface, innumerable details have been mapped and photographed, all the resources of astronomical science have been brought to bear on the question of solving the mystery of its surface features, yet to a large extent they still remain unexplained, though many theories have been advanced from time to time to account for them. It is, no doubt, this mystery which largely exercises the fascination which our satellite possesses for the observer.

Among the many theories put forward to account for the "Crateriferous" surface of the Moon two stand out prominently—the "Volcanic" and the "Bombardment" or "Meteoric" theories. Both theories as they stand are open to very serious objections.

I think it is generally recognised that the volcanic theory leaves too much to be explained, so much so, that an imaginary result of volcanic action had to be invented to account for the formations as we find them. For, as Proctor says,—"It is impossible to recognise a real resemblance between any terrestial feature and the crateriferous surface of the Moon. The volcanoes of the Moon are hollowed out like saucers, while those of the Earth rise up like mountain cones."

Although it is only reasonable to suppose that volcanic energy must have played its part in the formation of the crust during the process of its cooling down, still the absence of water in any large quantities favours the probability that volcanic activity was much less violent than on the Earth.

On the other hand, the majority of the "craters" are exactly what we should expect from what Proctor calls "the plash of meteoric rain." But there is an insurmountable objection to the theory of bombardment by meteorites from outside space in the fact that all the markings as far as can be seen, are such as must have been caused by impacts perpendicular to the Moon's surface, whereas it can be shown mathematically that vertical impacts would be almost impossible in the case of bodies arriving from outside space. They would almost always strike at considerable angles, as can be seen in the case of meteorites on our own planet.

But there is one source, and one only, which overcomes this objection, and that is the Earth. If we suppose, as is very probable, that the Earth in the earlier stages of its cooling down was subject to violent volcanic disturbances, ages before it settled down to produce the sedimentary rocks which at present form the greater part of its outer crust, then huge masses of matter must have been hurled out with tremendous velocity from its surface. After reaching great heights these would gradually lose their velocity, and the force of gravity would pull them back again to Earth. But if any happened to be ejected in the direction of our satellite to such a distance that the attractive force of the Moon overcame that of the Earth, then they would inevitably fall on to the former and—this is a most important point—they would fall vertically on to its surface under the force of gravity, just as they would have done on to the Earth if they hadn't been hurled quite so far.

That there is no serious objection to this theory of bombardment by the Earth, may be seen from the fact that Sir Robert Ball attributes the origin of meteorites to the same source. In his "Story of the Heavens" he says: "If a vast volume of ejected gases or vapours accompanied the more solid material, the effect of the resistance of the air might be completely eliminated." If volcanic activity was sufficient to eject matter beyond the influence of the Earth's gravitational force, how much easier it would have been to send it far enough to get within the sphere of the Moon's attractive force, especially as it is not improbable that our satellite was much closer at one time than it is now. It may be objected that bombardment from the Earth would only affect that part of the Moon which is continually turned towards us, whereas as far as can be observed the other hemisphere is also similarly marked. To this it may be replied that it is quite possible the Moon may have formerly rotated on its axis much quicker than it does now. To quote again from Sir Robert Ball........." if the Moon were to rotate faster on its axis than in its orbit again the tides would come furiously into play, but this time they would be engaged in retarding the Moon's rotation until they had reduced the speed of the Moon to one rotation for each revolution."

It seems to me then that the bombardment theory thus put forward is not open to any grave objection, and I propose very briefly to examine some of the formations of the Moon's surface in the light of a few experiments I have recently carried out. It is well known that very passable imitations of lunar "craters" can be produced by firing bullets into a target of soft lead. Commencing with a bath of molten lead 3 to 4 feet in diameter and about 2 feet deep, I allowed a solid crust to form on its surface, and then fired a ·303 inch bullet into its centre. The result was somewhat unexpected, yet instructive. A roughly circular piece of the crust about 18 inches in diameter was completely crushed in under the liquid interior leaving a depression with walls about 2 inches high—the crust itself was 2½ to 3 inches thick. When the crust had thickened another inch or so a similar bullet produced a depression of about 6 inches diameter. As long as the liquid interior could be tapped the floor of the crater was always flat.

Firing into a solid block of pure lead, I found the "craters" produced were entirely changed. They were all exactly circular and more or less saucer shaped; the bullets "mushroom" out evenly over the "craters" leaving their bases more or less intact in the centre. A round ball of pure lead spreads out evenly over the interior of the "crater" and leaves no trace of itself; but if the ball be hardened by the addition of a little tin or antimony a small residue is left in the centre of the crater. From further experiments to get metal of the right degree of cohesion, I have no doubt one could produce a "crater" with a typical cone in the centre.

The diameter of the "crater" was found to be from 2½ to 3 times that of the bullet which produced it.

On the analogy of these experiments it seems to me we might be able to classify the lunar "craters" into two main classes :—

I. Those in which the Moon's crust was broken in or pierced by the missile and the liquid interior tapped. All such have a flat flow. Those which were formed when the crust was thin are more of the nature of depressions and tend to be larger in area, *e.g.*, Clavius, Ptolemæus, etc. As the crust got thicker and offered more resistance, the area broken in would decrease, while the surrounding ramparts would become more pronounced, *e.g.*, Plato.

II. Those in which the missile failed to penetrate the crust, corresponding to the bullets fired into a solid block of lead. These are all saucer-shaped depressions, and have the surrounding walls more sharply defined and prominent. They may be sub-divided into two classes :—

(*a*) Those in which the missile "mushroomed" itself evenly over the interior of the "crater" leaving no trace of itself.

(*b*) Those in which the missile, being harder or more coherent left a typical cone or cones in the centre, *e.g.*, Tycho, Copernicus.

The gradual cooling and shrinking of the Moon's cone produced other changes in the crust, crumpling it up into Mountain chains in some cases and causing it to sink in huge depressions in others.. The liquid interior overflowing the sunken portions produced the dark areas which are called seas, and obliterated the marks of the previous bombardment over those areas. In some of the photographs in Pickering's Atlas the ramparts of some of the submerged "craters" show up plainly, for example, in the Mare Humorum. In other cases the sloping "craters" may be seen half submerged, *e.g.*, Frascatorius.

I regret that as the lantern is not in working order, we cannot examine a series of slides which Mr. Tomkins kindly lent me for this occasion. As they show details of the Moon's surface which are much more convincing to the eye than mere words can make them, I should like to postpone the remainder of my notes till our next meeting.

Notes and Queries.

A member sent the following queries. The answers are appended :—

Q. 1. In "Ball's Popular Guide to the Heavens" (3rd Ed., page 68) the equation to determine the distance of a star in light years is given as $\frac{3 \cdot 26}{\text{parallax}}$ = the distance. What does the constant 3·26 represent ?

A. The parallax of a star in circular measure is obviously given by the formula $\frac{R}{D}$ where R and D are the radius of the Earth's orbit and the distance of the star respectively both expressed in terms of the same unit. On inverting this, therefore, we get $D = \frac{R}{\text{parallax.}}$