ASTRONOMY

Lunar Shroud

Moon Wears Thin Grayish-White Mantle of Volcanic Ash Which Serves as Insulation From the Sun's Great Heat

THE moon wears a thin grayish-white mantle—a marvelous garment woven of the ash of volcanic eruptions and the eternal rain of cosmic dust. This cloak shields its ancient rocks from the glaring heat of the sun and wraps in a chill of death the fleshless bones of that weird land whose face from over 200,000 miles away bewitches the dreams of men.

The existence of this strange shroud over a dead world is deduced from recent reports to the Carnegie Institution of Washington by the Committee on Study of the Surface Features of the Moon, composed of astronomers and geologists, and headed by Dr. F. E. Wright. This committee is attempting to extend as far as possible knowledge of the earth's little sister and constant companion, bound to her by the bonds of gravity.

So long as man has existed he has been fascinated by the moon. Some of the weirdest and loveliest legendry of all peoples has been inspired by the luminous orb of night. It has given rise to many persistent superstitions—such as those that relate to its influence in growing crops, which still are held in rural sections of the United States and Europe. Towards the moon's face Galileo turned his first telescope. His were the first eyes to look upon its awe-inspiring mountains and its great plains—far larger in area than any prairie or desert region on earth —which appeared to him to be oceans.

No other spot in the vast realms of space beyond his own planet can man hope to know so intimately. With the improvement of telescopes since Galileo's day the surface of the satellite can be brought to within what appears to be 200 to 300 miles. Details 500 feet apart can be distinguished with good seeing conditions. Every conspicuous detail of the visible face of the moon has been mapped. The altitudes of many of its mountains and the depths of its strange craters have been measured with an accuracy of a few hundred yards.

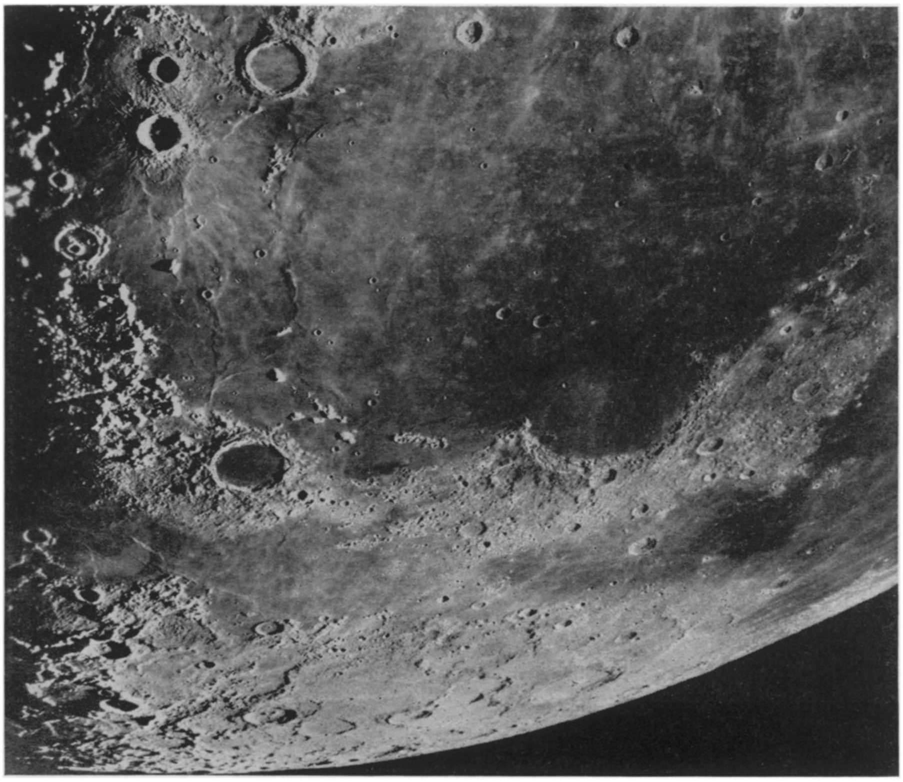
It is a laborious, time-consuming job to proceed beyond this—a job requiring new scientific tools and a vast accumulation of observations before sound deductions can be made. Already, however, Dr. Wright and his fellow members of the Carnegie Institution's Moon Committee have forged their tools and made notable contributions to knowledge of the satellite's surface.

The temperature of the moon's surface in full sunlight is close to 100° centigrade, or 212° Fahrenheit. It receives the full impact of solar radiation—heat rays, visible rays and ultraviolet—with no atmosphere to absorb any of it.

The temperature of its surface after an hour or so of darkness is approximately —98° centigrade or —140° Fahrenheit. From this rapid fall of 350° Fahrenheit it is obvious that different conditions of heat absorption and radiation exist on the lunar surface from those familiar on earth. Analysis of these differences leads scientists to far-reaching conclusions.

The rocks of the earth's mountains, when heated to the boiling point of water and set in a cool place, lose their temperature slowly. On the moon such rocks—if they exist, and there is every reason to believe they do exist since the satellite presumably is of a composition analogous to that of the earth—must be covered by something which acts as an almost perfect insulator. It absorbs very little heat permanently; but reflects back into space instantly most of the radiation which falls upon it. Thus one has the fantastic picture of a land which at noonday is at the boiling point of water on the surface but below freezing a short distance underneath.

There is such an insulating material—a pumice-like substance such as is belched from the boiling depths of the earth by volcanos. The picture may be reconstructed from the most delicate measurements ever made of lunar temperatures. They were carried out at Mount Wilson



FANTASTIC

This is the northern portion of the moon at last quarter photographed at the Mt. Wilson Observatory of the Carnegie Institution with the 100-inch reflector.

Observatory during the total eclipse of the moon on October 7, 1939, by Dr. Edison Pettit, using that delicate heat-measuring instrument, the thermocouple, upon which was concentrated by means of a 20-inch telescope the total radiation from a small point near the center of the moon's disk.

During the partial phase of the eclipse which preceded totality, the temperature dropped rapidly from +98° to —73° centigrade. After the start of the total phase it continued to fall at the rate of about 30° centigrade an hour, but by the end of the first hour this rate had declined to 7°. The low point reached was —98° centigrade.

Laboratory tests show, the Mount Wilson astronomers report, that this would be almost precisely the result to be expected from a layer of pumiceous material 2.6 centimeters thick under conditions such as obtain on the moon's surface. This leaves little doubt that such a film actually covers the moon, since the conclusion is supported by several lines of converging evidence.

Dr. Pettit's measurements also showed that the rate at which energy is radiated is very nearly proportional to that at which it is received on the moon's surface, except at very low temperatures when there is a considerable lag. The satellite, this shows, absorbs very little heat indeed.

Other conclusive evidence for this covering material is afforded by analysis of moonlight carried out by the Moon Committee. Moonlight is just reflected sunshine. The dead moon has little radiation of its own—less so than the earth. Almost like a mirror it reflects and scatters the rays of the sun which strike its surface. Some of this, however, is absorbed in the layer of pumiceous like material and re-radiated. In either case the moonlight which transforms spring nights on earth so magically is not quite the same as the sunlight which fell on the moon, or which falls on the earth. The changes to be expected, as described by Dr. Wright, are of three kinds, as follows:

"A large part of the energy of the incident sunlight penetrates a short distance into the surface and is absorbed, thereby heating the surface material; the heated surface, in turn, radiates the absorbed energy into space as heat waves, or 'planetary heat'.

"Different wave lengths or colors of the incident sunlight may be absorbed in different proportions, whereupon their relative intensities are altered slightly, thus coloring the scattered light. This is known as selective absorption.

"A certain amount of plane polarization is introduced on scattering and reflection. The amount depends on the character of the material and on its surface. In general, dark-colored, opaque substances polarize light much more than do non-opaque substances into which the incident light may enter and be returned in part by internal reflections."

This polarization, or change in the direction of light vibrations from the normal, can be measured quite precisely, largely with instruments brought to a high stage of perfection by Dr. Wright himself. In this way moonlight can be compared with sunlight reflected from materials easily available for laboratory study. There is no exact correspondence. But in general these studies indicate that the substances exposed at the surface of the moon are of the nature of volcanic ashes and pumice high in silica.

"The changes in the amount of polarization in the reflected light for different angles between incident and reflected rays," prove that the lunar surface is rough and not smooth. The changes in the intensity of light from different areas on the moon point to the same conclusion.

"It is true that the observations are restricted to materials at the actual surface and that in certain regions the cover of ashes and pumice may be quite thin and, like a light snowfall, may serve to blanket and conceal whatever is underneath."

More information might be obtained if some naked spot on the moon could be found—some area that has escaped the showers of ashes from the volcanic eruptions. Such might be a steep mountain slope or the inner wall of a deep crater. Efforts are being made with powerful equipment to measure the sunlight reflected from a few such spots.

The committee has also made many observations of the surface features of the moon and has sought to interpret them in terms of the conditions known to exist, such as the absence of atmosphere and water, rapid changes of temperature, and gravity only one-sixth that of the earth. It has made a detailed study of the trajectories of materials hurled out of the lunar volcanoes and found that they are from 20 to 50 times longer than those of materials ejected at the same initial velocity and angle of elevation on this planet.

For a muzzle velocity of 5,250 feet a second, equal to that of the Big Bertha used in the first World War, the range for an elevation angle of 50° was 75 miles. On the moon it would be 2,200 miles. Rays from one of the largest of the lunar craters, white lines extending in all directions from the center, have been traced for approximately 1,500 miles. This would have required, at an elevation angle of 26°, an initial velocity of 4,865 feet a second. Such velocities have been observed during eruptions of the volcano Cotopaxi in Ecuador.

This goes far towards solving one of the most puzzling features of the moon's surface—the great craters with their radiating white lines called rays which are scattered everywhere and some of which are as much as 24,000 feet in depth. During an eruption on earth the ejected material falls near and into the mouth of the crater. On the moon it is scattered far and wide. Lunar craters are cleaned out, as a rule, and thus are of the nature of immense, deep holes in the ground, with the floor of the crater below the level of the surrounding country. Terrestrial craters rise high above the level of the countryside.

It is even possible to make rough deductions on the age of these craters which pock-mark the face of the moon. The floors of the most recently formed ones are whiter and brighter than those of the older ones.

Study of the rays shows that they do not project as ridges above the land they traverse. They cast no appreciable shadows. But they reflect and scatter light more strongly than do the materials of the surfaces over which they extend. The most obvious interpretation is that they are streaks of fine dust or ashes carried along by jets of hot, escaping gases. They gradually settled out along the paths followed by these streams.

Not all the moon craters, Dr. Wright and his colleagues hold, need be volcanic. Both moon and earth are subjected to a constant bombardment of meteors. Here relatively few actually hit the surface. They are burned to ashes by the enormous heat engendered by the friction of the atmosphere through which they pass. The moon has no such atmospheric blanket. The objects from outer space crash into it at speeds of from 15 to 40 miles a second.

Such an impact not only would produce a crater-like hole, but its kinetic energy would be transformed into heat sufficient to melt and even to volatilize the invaded rock. This would give rise to actions that in their effects would resemble closely volcanic phenomena.

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