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REMOTE-CONTROLLED STUDY OF THE HISTORY OF LUNAR VOLATILES; J. H. Fremlin, Department of Physics, University of Birmingham, England.

Since the formation of the moon, very large quantities of volatile materials must have been evolved from the interior. If the moon was originally formed nearer the sun as its high refractory content would suggest, most of these must be permanently lost. This could also be true if it formed in association with the earth, but had for a long time a high surface temperature internally generated. For most of the time since it was established in its present orbit, however, it must have had a surface temperature determined as now by the dynamic equilibrium between the input of energy from sunlight and the loss from thermal radiation. During this period some further loss of volatiles, including small quantities of water derived from interaction between solar wind protons and surface oxides must have continued.

It is well known that the gravitational field of the moon is inadequate to hold an atmosphere at its average surface temperature of around 250°K, but if areas exist on the moon sufficiently cold to freeze out volatiles, some of these may still persist. Such areas may exist near the poles. If the moon were perfectly smooth an area near one of its poles would be calculably cooler than the equator, but not cool enough. The axis of the moon's orbit and of its rotation is inclined at just over 5° to the axis of the earth's orbit round the sun and hence in the polar 'summer' there will be six months insolation rising to a maximum with the sun just over 5° above the horizon.

The rate of input of solar energy will then be reduced to about 1/11 of that at midday at the equator and, since thermal radiation varies as T^4 the maximum temperature reached will be only about 210°K. At this temperature the vapour pressure of water is still high enough for it to be lost quite quickly but 210°K is the temperature that would be reached if the moon were perfectly smooth. It is not in fact perfectly smooth. Even a micro-roughness in which some dust particles projected to reach near-equatorial temperatures and hence lost thermal radiation at eleven times the local average rate would enable temperatures well below 210°K to be permanently maintained by much of the surface, although estimation of the magnitude of the effect would be difficult. The moon's surface, however, is rough on a major as well as on a minor scale. A range of hills at a latitude just under 85° (5° from the pole) and with a poleward slope of over 10° would leave an area in permanent shadow; hills of only 200 metres high would shadow a strip a kilometre wide. Near the pole craters or parallel ranges of hills with internal slopes over 5° will give permanently shaded areas. Thermal conduction from the sunlit areas, themselves having average round-the-year temperatures of only 170°K or so, would be negligible over even a few hundred metres - much less than the thickness of the hills or crater walls.

We can, therefore, confidently expect that there will be areas of significant size near the lunar poles in which the surface temperature has for extended periods been almost entirely determined by the amount of heat from the interior reaching the lunar surface. This has been found from Apollo studies to be 2×10^{-6} watts/cm^2. At the equator we have a daytime absolute temperature of about 390°K with a solar heat input of 1.4 kw/m^2. The equilibrium temperature on a dark area near the pole should then be in the region of $390 \div (0.14/2 \times 10^{-6})^{0.25}$ or 26° K.

This would be low enough to hold water, ammonia or carbon dioxide indefinitely, probably together with oxygen and nitrogen. Only a fraction of volatile gases evolved from the interior would, of course, reach such areas; most on the day side may be ionised at once and swept away by the solar wind, but any large emissions, especially on the dark side, should have left frozen layers in the polar craters. In the long term it is even possible that there could be enough water ice to be of practical value to a lunar colony, but my present concern is with the possible scientific value of the "sedimentary" layers in offering us a record of volatile emissions over a very long period of lunar history. Careful analysis of a core from such sediments, on the lines of the examination of deep ocean cores, should enable us to reconstruct this history.

My specific proposal is that a mobile unmanned remote-controlled unit should be landed at a suitable point at polar midsummer when the permanently dark areas could readily be identified. The unit would carry a core-digger, an evaporator and a recording or on-line mass spectrograph which could transmit results periodically to a lunar satellite in polar orbit. The unit should have sensors capable of measuring surface temperatures so that it could first survey the surface temperature distribution in the chosen area and then be directed to the coldest point for its analysis of volatiles as a function of depth. If more convenient, the motion of the unit could be self-controlled to follow surface temperature gradients downwards until it reached a minimum.

If the results were interesting, a later version of the unit could include a recoverable module either to return a complete core suitably cooled or at least a sample of the underlying rock which might be dated by fission-track analysis to determine the time at which the crater itself was formed and hence the length of time over which the sediments were collected.