LETTERS TO THE EDITOR

ASTRONOMY

Photographs of Mars taken by *Mariner IV*

NINETEEN close-up pictures of Mars, showing details down to a few kilometres across, were recorded by *Mariner IV* before the cameras crossed the terminator into the night hemisphere. The first seven pictures are not rich in detail because the Sun was less than 30° from zenith and shadows were absent. Later pictures, taken under a lower Sun, show progressively more relief: what may be afternoon shadows occur even on the ninth frame, composed at a solar altitude of more than 50°.

Contrasts between the shadows and the brightly lit parts of the surface of Mars show that the planet is mountainous and packed with craters and ring-structures strikingly like those of the Moon. Some of the craters have well-developed central eminences: by analogy with the central peaks of lunar craters, they may be volcanoes. Both the central eminences and the walls of the Martian craters appear to slope at steeper angles than those of the Moon. Whereas the mean inner slope of the wall of a well-developed lunar ring structure is 20° or 30°, the corresponding slope on Mars seems to be at least 40°.

Ring structures ranging up to 170 km in diameter are apparent on the eleventh frame recorded by *Mariner IV*. The largest is remarkably similar to the same-sized lunar feature Lacus Mortis, which is probably a lava-flooded, fault-bounded graben structure. The martian ring has a dark floor with crateriform or scalloped edges and may also be a lava-flooded collapse structure.

At present, it is difficult to say whether the majority of the newly discovered craters are the result of impact or volcanism. However, the *Mariner IV* pictures suggest to me that Mars has a volcanic terrain. The pictures are scored by ridge and depression lineaments that are similar to those on the Moon[1], and there is strong evidence[2] for the growth of the lunar lineaments by volcanic extrusion from fractures and faults. Evidently, Mars has a fracture system of its own, and the indurated ridges may best be explained on the volcanic hypothesis.

The canals drawn on the older maps of Mars are not evident on those *Mariner IV* frames that might have registered them, but I have found a correlation between the trends of the recently photographed martian lineaments and the directions of the mapped canals. A possible explanation is that, as some observers[3] thought previously, the linear canals appear to form under certain conditions of poor seeing by the (subjective) connexion of many discrete patches of dark material arranged linearly on the surface of Mars. The patches might be widely separated ring structures, or groups of craters, arranged in linear chains, with floors of low albedo like many of the large lunar rings. These isolated features might well avoid the particular point in a 'canal' traversed by *Mariner IV*; and, even if they did appear in a picture, one would not necessarily associate them with a canal extending beyond the bounds of the frame.

On the Moon, chains of craters of a given type bear a close relation to the less readily seen Moon-wide lineament system. As, therefore, Mars seems to present volcanic phenomena like the Moon's, it is surely not surprising to find that the lineaments in small patches of Martian surface have trends similar to those of the coarser, larger-scale, canals.

Though full photometric and colorimetric calibration will be necessary before the *Mariner IV* pictures can be interpreted with confidence, it is possible to propose tentatively that the craters are not necessarily impact phenomena, and that the canals are not continuous markings as drawn on the older maps but may be indicative of fractures or faults that dissect the solid surface of Mars.

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[2] Fielder, G., *Lunar Geology*, Sec. 6–4, 108 (Lutterworth Press, London, 1965).
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Lunar Hot Spots

I SUGGEST that the thermal anomalies found recently in infra-red lunar observations[1,2] could be due to lunar roughness on a centimetre scale rather than due to changes in the thermal composition of lunar rock or localized thermal sources. The idea of roughness of centimetre dimensions[3] has now been directly verified by radar reflexion measurements. In fact, some protagonists of the dust hypothesis now incorporate this type of roughness in their models of the lunar crust.

Infra-red measurements at 11μ of lunar surface temperatures which range from 90° K to 400° K correspond respectively to values of 14·8 and 3·3 for the parameter $x = h\nu/kT$ so that throughout the lower part of the temperature range Wein's law:

$$F_\lambda = 2\pi hc^{-2}\nu^3 \exp(-h\nu/kT)$$

is a good approximation to the correct radiation law connecting the radiative energy density $E\nu$ from the lunar surface at frequency ν with the temperature T. This result shows that lunar night-time and eclipse observations made through the 8–14μ atmospheric window are extremely sensitive to small temperature changes of the lunar surface. Because of the highly non-linear variation of $E\nu$ with T the brightness temperature, measured by an instrument which sees simultaneously a number of surfaces, will be considerably higher than the mean temperature especially if the surfaces have widely differing temperatures.

Using the model previously proposed[3] and shown in Fig. 1, I have calculated from approximate heat flow considerations the temperatures T_1 and T_2 at the middle of an eclipse in the case for which a smooth surface composed of the same material would give a temperature of 200° K. Values of $T_1 = 275°$ K and $T_2 = 195°$ K are obtained from the calculation and these give a brightness temperature of 240° K for telescope observations at zero lunar zenith angle. An increase in the radiative density by a factor of nearly 3 is thus expected when rough and smooth regions are compared during an eclipse. The existence of preferential roughness of centimetre dimensions should thus show up clearly in scans across the lunar disk during an eclipse. It is interesting that the eclipse measurements recently made by Shorthill and Saari[1] show regions of radiation enhancement both greater and less than that calculated from this simple model.

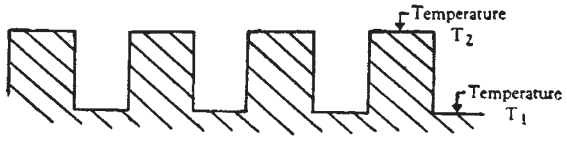

Fig. 1