LETTERS TO THE EDITOR

ASTRONOMY

Evidence that the Dark Areas on Mars are Elevated Mountain Ranges

In the communication under the above title[1], Dr. Wells makes a good point in reference to Lowell's conclusion regarding Martian topography. It agrees in part with the phenomena I have often observed, namely, that the migration of portions of some maria and gradual shading off of some low-cloud or frost areas implies very gradual slopes[2]. But even in the case of abrupt topographic differences, I think Lowell was over-optimistic in his value of 2,500 ft. It must be remembered that the maximum phase occurs at about twice the oppositional distance. At that time the terrain slopes away from the observer at about 45°. Furthermore, the colour contrasts of both maria and deserts show a marked drop at about half the radius from the centre of the planet's disk, apparently from the Martian atmosphere. There is also the troublesome factor of irradiation. Mars has some twilight effects, further lessening the contrast. The total of these effects and the limitation of detail under the best 'seeing conditions' makes an abrupt topographic difference of 20,000 ft. or less impossible to detect.

I cannot reconcile the statement that the dark areas are elevated land. On the contrary, our observations show that the formation of localized clouds on Mars is a common occurrence, not a rare one. Many desert areas behave this way, such as: Elysium, Hellas, Isidis-Neith, Aeria, Edom, Nix Tanaica, Nix Olympica, Ogygis, and some other 'islands in the south'. In addition, there are some other areas exhibiting less whiteness and persistence. Meteorologically, the aforenamed regions must be the high-elevation areas and this is the basis for my topographic mapping of Martian desert relief. The white areas strongly avoid the maria. Radiometric measurements show the maria to be warmer, which could be due to lower reflective power alone, but it is of the right sign to favour lower topographic altitude. The temperatures of our dark mountain forests are certainly lower than those of the brighter lowlands.

Recently, I presented evidence for the absence of folded mountain ranges on Mars[3]. Such mountains are of geosynclinal origin, in which erosional sediments are deposited into sedimentary rocks. There are good reasons why such conditions never prevail on Mars. On the other hand, the desert areas which are observed to whiten must represent plateaux. While most of these are round or oval in outline, at least two (Elysium and eastern Aeria) are definitely angular, suggesting fault-block terrain.

The relatively small number of minute white spots suggests that volcanism has operated on a much lesser scale than on the Earth. To my mind, and as I suggested in 1950, the round dark oases represent asteroid impact craters, which are much more numerous than the small white spots[4]. Fifteen years later this was confirmed by the *Mariner* 4 pictures.

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[1] Wells, R. A., *Nature*, **207**, 735 (1965).
[2] Tombaugh, C. W., *Provisional Topographic Maps of Mars—Mariner 4 Region*, Publ. New Mexico State Univ. Obs. *TN*-701-66-8, *NASA* (1965).
[3] Tombaugh, C. W., *The Absence of an Aqueous Morphology on Mars and some Geologic Consequences*, Publ. New Mexico State Univ. Obs. *TN*-557-65-6, *NASA* (1960).
[4] Tombaugh, C. W., *Astro. J.*, **55** (1950).

Dr. Tombaugh's communication raises some interesting points about the topography of Mars. In view of the brevity of my earlier communication[1] I could only mention the most salient features of the proposed model for the dark maria. A more detailed discussion is now in preparation for publication.

One can scarcely doubt the rarity of Martian cloud phenomena if a comparison is made with some standard, say, one week's cloud occurrence on Earth. It is of interest to note that only one possible indication of the presence of a cloud was recorded by *Mariner* 4 although, admittedly, less than 1 per cent of the Martian surface was photographed.

Furthermore, the phenomena in the desert areas to which Dr. Tombaugh refers are quite different from those I gave as examples of lee-wave clouds. He has listed areas of possible hoar frost deposits on the surface which could imply elevated plateaux. (In my previous report I gave one example each of a possible mountain and plateau revealed by surface deposits of snow or hoar frost.) It is questionable that these areas participate in surface frost formation as frequently as has been observed. A powerful means of distinguishing between surface hoar frost and white clouds is by use of the polarimeter. For the past decade such observations at the Pic-du-Midi and Meudon have revealed that atmospheric clouds are as frequent a cause of brightening, particularly in the equatorial regions mentioned. The few instances that Dr. Tombaugh and others[2] have mentioned need not, of course, imply that all the bright areas (nearly three-quarters of Mars is bright desert area) are elevated. Since dust storms are considerably widespread occurrences, it would seem more natural that low areas would be dust covered and bright. Hence if the dark maria are depressions, why do they exhibit themselves at all? One would think that they would have been filled with dust and obliterated long ago. Application of Öpik's[3] 'rejuvenation' theory at this point would find even more stringent demands.

Figs. 29–31 of a recent publication by Dollfus[4] show the initial developments of the great dust storm of 1956. The dust clouds formed and spread along the bright regions between the dark maria without transgressing the boundaries. Later, of course, most of the maria became enveloped in some of the dust clouds. This phenomenon is certainly not consistent with the maria as depressions.

It may be that Dr. Tombaugh's "white areas strongly avoid the maria", but the white clouds (atmospheric phenomena) to which I have referred behave otherwise. They form at the interface of a bright and dark area, although they remain over the bright region and do not seem to penetrate the boundary into the mare. It was this peculiar 'stabilization' that caused me to suggest the similarity to lee-wave clouds on Earth. These Martian clouds are stationary but not unduly persistent, dissolving after several hours to re-form again the next day. One of the finest examples of these phenomena is depicted in Plates 33 and 34 in an article by Dollfus[5], where he describes them as: ". . . of the same nature as the bright formations observed at the top of the mountains surrounding the polar cap . . . and are probably also due to surface elevations". The bright formations in the polar regions to which Dollfus refers are ". . . bright, small clouds [which] appear in late spring each day at the same locations"[6].

In view of the mounting interest in the wind-blown formation theory of the dark maria beginning with McLaughlin[7], amended by Kuiper[8], and re-modelled by Rea[9], it appears that the interpretation of the dark maria