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FURTHER NOTES ON MARTIAN FEATURES

DEAN B. McLAUGHLIN

Observatory of the University of Michigan

INTRODUCTION

In a previous paper¹ the Martian maria of the tropical girdle were interpreted as composed chiefly of dark volcanic ash drifted by the prevailing winds, which must be strongest during the summer of the southern hemisphere, when the winds cross the equator and become anti-trade winds. The vertices of the pointed bays were identified as active volcanoes, the sources of the ash. The curved flow pattern of the maria and intervening lighter strips was shown to be consistent with the expected deflection of the winds by the rotation of the planet. Canals that meet the maria in the pointed bays were interpreted as drifts of ash from the source volcanoes during the period of weaker reversed winds of the northern summer.

OTHER EXPLANATIONS OF CANALS

There is always a great temptation to overwork a new hypothesis by using it to explain everything in sight. Perhaps this has been done already in the present case. But it is certain that many canals cannot be explained as ash drifts by any *ad hoc* combination of prevailing winds and local irregularities of circulation. Nor should we expect all canals to be explicable by a single mechanism. Any linear dark feature that is not too wide is called a "canal," and might be formed in a variety of ways.

Linear chains of small volcanoes, along major crustal fractures, are the most obvious possibility. Their individual ash deposits, a few miles in extent, might nearly merge to produce apparent continuity. The canal Casius, northeast of Syrtis Major,

seems to be a chain of larger spots or blotches, each of which might contain several minor vents.

Major fault zones are a second possibility. Within the past few years much important work has been done in the mapping of "linears" in the Canadian Shield.² Some of these have lengths of several hundred miles. Such features as the zone of thrust faults known as the Grenville front might produce effects on the surface that would be visible from the earth. The crushed and sheared rock could produce surface irregularities too small to be detected as topographic features, yet capable of trapping drifted ash, so that a discolored strip would appear. Or, *if* vegetation occurs on Mars, the crushed zones might weather to produce a more hospitable soil.

Allied to fault zones are rift valleys³ such as those of Africa. Their widths of some thirty miles and lengths of a couple of thousand miles are comparable with those of Martian canals. Volcanoes are associated with the African rift valleys⁴ and might occur with similar structures on Mars.

Igneous dikes may be a remote possibility. The lengths of canals far exceed those of known terrestrial dikes. If aqueous sedimentation and erosion and folded mountain structures occurred on Mars, we could add other features to the list. It is practically certain, however, that these have to be ruled out.

SOME ANOMALIES OF ATMOSPHERIC CIRCULATION

The wind pattern is disturbed in and about Sabaeus Sinus. This linear "sea" and associated lighter bands trend nearly east and west. They are, however, definitely part of the normal anti-trade wind flow pattern. The abnormality consists of a greater leftward deflection than that which has affected most of the bands.

The disturbance can be attributed to the large "islands" of Noachis and Hellas, respectively south and southeast of Sabaeus Sinus. Both are light-colored and therefore would heat up less than surrounding darker regions. This could result in their being the sites of semipermanent anticyclones. The southeast trades blowing off Noachis would be developed more strongly than those of some other regions and the anti-trades would thereby be forced to flow closer to the equator, hence the nearly due eastward flow of Sabaeus Sinus. Hellas is very probably a high plateau, since

it is often snow-covered, and in winter forms a vast extension of the polar cap down to latitude 30° .⁵ Anticyclonic winds sliding down its western slope and being deflected to the left by the planet's rotation, produce a southwestward flow of air along the Hellespontus and also deflect winds coming from both west and north. This is believed to be the explanation of the sharp southwestward bend of the eastern end of Sabaeus Sinus.

The great promontory of Thaumasia probably produces an equally great disturbance of the circulation. The pattern southeast of it is quite chaotic in appearance.

POSSIBLE HEIGHT OF MARTIAN VOLCANOES

The oft-quoted statement that elevations higher than 2500 feet would surely have been detected on Mars seems to be based on a calculation by Lowell.⁶ On examination, this is seen to involve the assumption that the mountains are of lunar type: long ranges or crater walls of great extent. The determining factor as regards visibility of a Martian mountain is not height (except in so far as height *implies* breadth of base), *but the illuminated area beyond the terminator or the area of surface that it puts in shadow*. Considered from this point of view, the limiting height for a *steep volcanic cone* would far exceed Lowell's limit. Quite possibly cones as large as Mounts Rainier and Shasta have been missed! Some rough calculations, whose details need not be elaborated here, indicate that peaks of those dimensions should be visible, *once we know just where to look*. This we do know now, but it was not known until the vertices of the bays were recognized as probable sites of volcanoes. On the other hand, a cone equal to that of Vesuvius might escape detection even if sought with the 200-inch telescope!

Possibly the activity is so violently explosive that cones are demolished before they reach large dimensions. This seems unlikely for such uniformly active vents as those at the vertices of Dawes's forked bay and other apparently permanent "estuaries."

THE COLOR OF THE MARIA

The greenish color of the maria is often cited as evidence of vegetation, especially as it changes seasonally. The negative result of the spectroscopic test for chlorophyll⁷ seems not to have altered

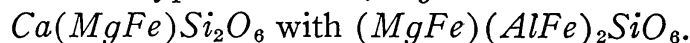
this prevailing belief. Lichens would not show a sufficient effect to be detected. In spite of Kuiper's very cautious statement concerning lichens as a *possible* form of Martian vegetation, occasional statements in "popular" writings have been so phrased as to suggest that the spectroscopic test *supports* the presence of lichens, which it most emphatically does not.

If the maria are drifts of ash, are they covered annually by a growth of primitive plants? This appears very unlikely. If the volcanic hypothesis is correct, there must be some other explanation of the color and its changes. Arrhenius⁸ suggested it might be due to hydration and dehydration of salts in the Martian soil. The hypothesis was presented rather vaguely, however, and appeared far from convincing.

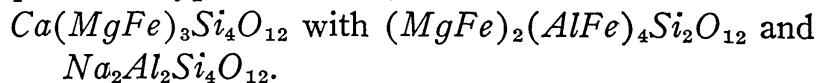
The green color may be entirely consistent with the chemical composition of common types of volcanic ash on the one hand and of the Martian atmosphere on the other. The following outline is intended to be suggestive, and it cannot now be claimed that it is certainly the correct, or complete, explanation.

Since the deposits appear quite dark, the ash is probably basaltic or andesitic. Both types consist chiefly of ferromagnesian silicates and plagioclase feldspars. Chemical compositions of these minerals are indicated below. None of them have fixed compositions, but show a considerable range. Parentheses indicate that the ratio of the elements enclosed may vary between wide limits.

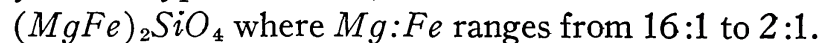
Pyroxenes : typical mineral, *augite*



Amphiboles : typical mineral, *hornblende*



Chrysolites : typical mineral, *olivine*



Plagioclase Feldspars : mixtures of *albite* and *anorthite* in ratios that cover a great range.



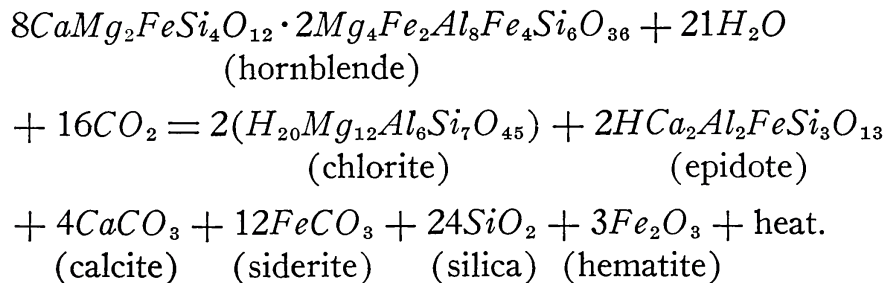
The first stage of weathering of pyroxenes and amphiboles yields chlorite, epidote, and talc, while the chrysolites alter to

serpentine.⁹ The second stage is described by Van Hise¹⁰ as follows:

“Under extreme and long-continued conditions of the belt of weathering the serpentines, chlorites, and epidotes are likely to further degenerate, breaking up into carbonates of the alkalies and alkaline earths, anhydrous or hydrous oxides of aluminum and iron, quartz, and kaolin. *Or in the belt of weathering these end products may directly develop from the metasilicates without the serpentines, chlorites, and epidotes as intermediate products.*”

The italics are mine. Van Hise is, of course, describing processes that take place *on the earth, where the atmosphere contains abundant oxygen*. The end products include iron oxide and hydroxide which impart to the soil strong reddish, yellowish, or brown tints, submerging the feebler coloring of other components. The italicized statement in the quotation applies especially to the surface, where oxygen has ready access to the minerals. Below the surface, percolating water-carrying carbon dioxide causes the first stage of alteration, while the second stage occurs much more slowly.

At the surface of Mars the first stage of weathering should occur readily in the presence of moisture and carbon dioxide. For the weathering of augite, Van Hise¹¹ gives a reaction that involves some free oxygen and is, therefore, not applicable to Mars. However, on inspection, it is seen that if additional carbon dioxide is substituted for oxygen, the composition of the original mineral and its alteration products can be varied by small but allowable amounts to make the equation balance. (We recall that none of these minerals has a rigidly fixed composition.) The result is very similar to a reaction that Van Hise¹² gives for the weathering of hornblende:



Under the same conditions plagioclase feldspars yield kaolin, silica, aluminum hydroxide, sodium carbonate, and epidote.¹³

Enough detail has been presented to show that, when exposed to the Martian atmosphere, common types of volcanic ash would weather to a soil in which epidote and chlorite would be abundant, and in which the strongly colored iron oxide and hydroxide would be scant or absent. If olivine were abundant, as it is in some basalts, serpentine would form. *Chlorite, epidote, and serpentine are strongly green in color, while the other products are chiefly light-colored.*

One apparent difficulty with this suggestion is the probable dry powdery form of the minerals under Martian conditions. They are green in compact crystalline form, but appear light-colored as powder. Chlorite, however, is greenish as a powder, and it develops authigenically¹⁴ as crystalline particles in clays. That is, the crystals grow in place. Since chlorite is, by weight, the most abundant alteration product, authigenic crystals may cause the green color.

The time element also needs to be considered. One season probably would be too short for development of strong coloration in a fresh fall of ash. When we recognize that the ash film a thousand miles from the volcanoes must be very thin, this difficulty appears less formidable. What we see is the drifted and winnowed accumulation of many years, and the annual darkening may be due in greater measure to *moistening* than to chemical change. H. C. Urey¹⁵ suggests that the darkening may be due to moisture that has come out of the volcanoes.

Terrestrial soils at all times are a complex mixture of green intermediate and yellow-brown end products. On earth, a fresh fall of ash, exposed to the air, would yield brownish soil, in part directly without passing through the intermediate green minerals. On Mars the progress toward brown is delayed by lack of oxygen, and the soil may remain long in the greenish stage. The explanation here suggested may require considerable modification, but it has every appearance of being "on the right track."

THE SEASONAL CHANGES

The annual darkening appears to be intimately connected with the arrival of moisture migrating from the dissolving polar cap

to the growing one. Possibly we have a combination of two effects that coincide in time because both result from the change of winds. (1) Moistening would darken the surface. (2) A new fall of ash must occur, though it need be only a thin film. As Opik¹⁶ points out, the maria must be continually renewed; otherwise they would be obliterated by drifting dust from the deserts. Our hypothesis provides a natural mechanism for the renewal without plant growth.

The later reversal of the change may also be a composite effect. Drying out of the maria would tend to make their color lighter. Some material, even in the absence of free oxygen, would change to limonite (iron hydroxide). Dollfus¹⁷ has suggested this is the coloring matter of the deserts. Perhaps the most potent effect is that of reversal of the winds. This would result in desert dust being spread as a thin film over the maria, reducing their contrast with the deserts, though not entirely obliterating them.

THE DESERTS

Kuiper¹⁸ found that the spectral reflection of the reddish areas did not match that of hematite (the red ferric oxide) but resembled that of a brownish felsitic lava. The sample of felsite may have been colored in part by limonite. Possibly the deserts are in part solid lava and in part covered by drifted dust whose color is due to limonite and the mixed and pulverized minerals of the lavas.

Some of the light areas are high ground. Hellas is an outstanding example. Rudely circular patterns can be discerned, both in the "islands" of the southern hemisphere and between the intersecting canals of the northern. Perhaps these are great flat domes formed by extrusion of flow upon flow of lava about a center. It is interesting in this connection to note that Solis Lacus, a group of merging dark spots, is central in the elliptical area of Thaumasia, and that there is a vague darkish spot in the center of Hellas.

This suggests another tentative interpretation of some canals as due to deposition of dark ash in topographic depressions between adjoining broad lava domes. But we are already speculating far beyond the facts. Interpretation of the light-colored areas should await accumulation of more data on their actual relief.

CONCLUSION

In this paper and the one that preceded it,¹ an account has been given of numerous Martian features in terms of well-known terrestrial processes. The morphology of the markings is the crucial evidence. Many facts of orientation and form have hitherto been almost totally neglected. But all fit into a scheme that "makes sense." Even the color of the maria and the seasonal changes, long attributed to vegetation, appear consistent. Evidently the vegetation hypothesis has a heavy burden of proof placed upon it.

One of the most frequent statements about Mars in "popular" writings, and even in textbooks, refers to it as an old, desiccating, and dying planet. We are told that it has been eroded level, and that mountain building has ceased. There are now good reasons to challenge these statements.

Urey¹⁹ has pointed out that Mars's internal development should have been much slower than the earth's, because of lower temperature of formation and lower gravity. He remarks that convection probably has not yet occurred in the Martian interior, and for that reason Mars has no strong central condensation and has never had folded mountains.

I would modify this view slightly by suggesting that Mars has "just now" reached a stage in which internal melting has been accomplished and convection is beginning. The violent volcanism we see today may be the expression of internal turmoil that will give Mars an earthlike structure. Urey¹⁵ indicates that in all of geologic time radioactive heating would have raised the temperature of Mars only between 1000° and 1500° C, so that volcanoes may just be possible now, but were not very far in the past.

Speculating further, along the most attractive of several possible lines, Mars may acquire oceans in the future, as they are believed to have developed on earth in Pre-Cambrian time, through the slow accumulation of water brought up by volcanism.²⁰ The earth's oldest known rocks are dominantly volcanic. The ancient Keewatin "greenstones" are a thick series of lava flows whose structure is obscure in many places. But in the Noranda district of Quebec, where deformation has been less extreme, the lavas lie, flow upon flow, to the thickness of 25,000

feet with no bottom in sight.²¹ Perhaps our present view of Mars is a miniature of the earth in very early Pre-Cambrian time.

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- ¹ D. B. McLaughlin, *Pub. A.S.P.*, **66**, 161, 1954.
² J. Tuzo Wilson, *Trans. Am. Geophys. Union*, **29**, 691, 1948.
³ Russell, Dugan, and Stewart, *Astronomy* (1926), p. 343.
⁴ A. Holmes, *Principles of Physical Geology* (1945), pp. 432-41.
⁵ P. Lowell, *Mars and Its Canals* (1908), p. 58.
⁶ *Ibid.*, p. 99.
⁷ G. P. Kuiper, *The Atmospheres of the Earth and Planets* (1949), p. 339.
⁸ S. Arrhenius, *The Destinies of the Stars* (1918), pp. 218 ff.
⁹ C. R. Van Hise, *Treatise on Metamorphism*, U.S. Geol. Surv. Monograph No. 47, p. 353, 1904.
¹⁰ *Ibid.*, p. 354.
¹¹ *Ibid.*, p. 276.
¹² *Ibid.*, p. 287.
¹³ *Ibid.*, pp. 261, 264.
¹⁴ F. J. Pettijohn, *The Sedimentary Rocks* (1949), p. 503.
¹⁵ H. C. Urey, personal communication, 1954.
¹⁶ E. Opik, *Irish Astron. J.*, **1**, 46, 1950 (Armagh Leaflet No. 4).
¹⁷ A. Dollfus, *Comptes rendus*, **223**, 467, 1951.
¹⁸ G. P. Kuiper, *loc. cit.*, p. 335.
¹⁹ H. C. Urey, *Proc. Nat. Acad. Sci.*, **39**, 943, 1953.
²⁰ W. W. Rubey, *Geol. Soc. Amer. Bull.*, **62**, 1111, 1951.
²¹ M. E. Wilson, *Geol. Surv. Canada, Memoir*, No. 229, 1941.