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Further Evidence of Vegetation on Mars

The presence of large organic molecules is indicated by recent infrared-spectroscopic tests.

William M. Sinton

There has long been evidence pointing to the presence of vegetation on Mars. Photographs taken by E. C. Slipher at Lowell Observatory for decades have shown a seasonal variation in the intensity of the dark regions. Every spring and summer, coinciding with the melting of the ice caps, a wave of darkening spreads from the polar regions toward the equator (1). In addition to the seasonal variation there have been nonsystematic changes: areas that were never dark have become dark, and a few dark areas have become light and have blended into the desert regions. A striking case of the appearance of a dark region occurred in 1954, when an area of 580,000 square miles at longitude 240° and latitude 20° was newly dark

(2). The region in which it is situated has, however, been undergoing development for many years.

Some visual observers have often reported the dark regions as green or bluish, while others have found them neutral in color. Spectroscopic tests have also failed to find them green. The green color that is often seen may be only a complementary hue produced by the bright orange colors of the deserts.

Until recently there has not been a successful direct test for the presence of plants. Tests for the presence of chlorophyll have all been negative (3; 4, p. 362). These tests, which sought to find the high reflectivity characteristic of terrestrial plants in the near infrared, do not necessarily exclude chlorophyll. They can be explained if supposed

Martian plants possess a pigment that absorbs the near infrared.

Using the 61-inch telescope of the Harvard College Observatory during the 1956 opposition, I made a new test for the presence of organic molecules on Mars (5). Organic molecules possess strong absorption bands at 3.5 μ as a result of the resonance of their carbon-hydrogen bonds. It was found that in the plants tested this band was double, most likely as a result of interaction between a pair of hydrogen atoms attached to the same carbon atom, as occurs in paraffin molecules.

The results of the 1956 observations indicated the presence of the band in the light reflected from Mars, but they left some doubt about the reality of the absorption. Furthermore, the regions of Mars which produced the absorption were not ascertained in this work. At the 1958 opposition the test was made again with improved equipment, and the reality and distribution of the band were established.

Instrumentation

As in 1956 the infrared from Mars was analyzed spectrally with a monochromator. A great improvement in sensitivity was obtained with a new liquid-nitrogen-cooled lead sulfide detector that was custom made by Infrared Industries, Inc. A further improvement was obtained by alternating the dispersed radiation from Mars between two separate detecting areas incorpo-

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rated within this cell. The alternation was produced by moving the image of Mars from one to another of two apertures at the entrance slit of the monochromator. Moreover, the loss of light that aberrations produced in the condensing optical system used in 1956 was eliminated by use of a better condenser.

Through the courtesy of the Mount Wilson and Palomar Observatories, the 200-inch Hale telescope was made available during morning twilight hours for 2 weeks near new moon in October. The coudé focus was employed because its use would cause a minimum of interference to the scheduled observer at the prime focus. Conversion of the telescope from prime focus to coudé may be made in 10 minutes. With these technical improvements (6) investigations of different areas of the disk were made with approximately 10 times the sensitivity achieved in 1956.

Solar spectra were obtained in the afternoons with the equipment moved outside by the west door of the dome. A scattering plate of ground aluminum was placed in sunlight with its surface perpendicular to the earth's axis. It was viewed by the monochromator from a point toward the south pole. With this arrangement no tracking mechanism was required. The scattering properties of the plate have been tested to make certain that no distortions were introduced into the solar spectrum.

Observations

Spectra were obtained on 13 mornings in the period 7 to 21 October and also during the first half of the night of the 21st, when strong moonlight prevented observations of nebulae with the telescope.

For the most part two combinations of slit widths and apertures were employed. In one set a pair of apertures 1 mm in diameter was placed in front of the entrance slit to restrict observation to a part of the 2-mm image of Mars. The width of the exit slit of the monochromator was 2 mm and gave a band pass of 0.11μ . For most of the other observations no aperture other than the 1 mm width of the entrance slit limited the observed part of Mars. The exit slit was also 1 mm, giving a band pass of 0.056μ at the expense of loss of resolution on the disk.

Thirty-two spectra were obtained of

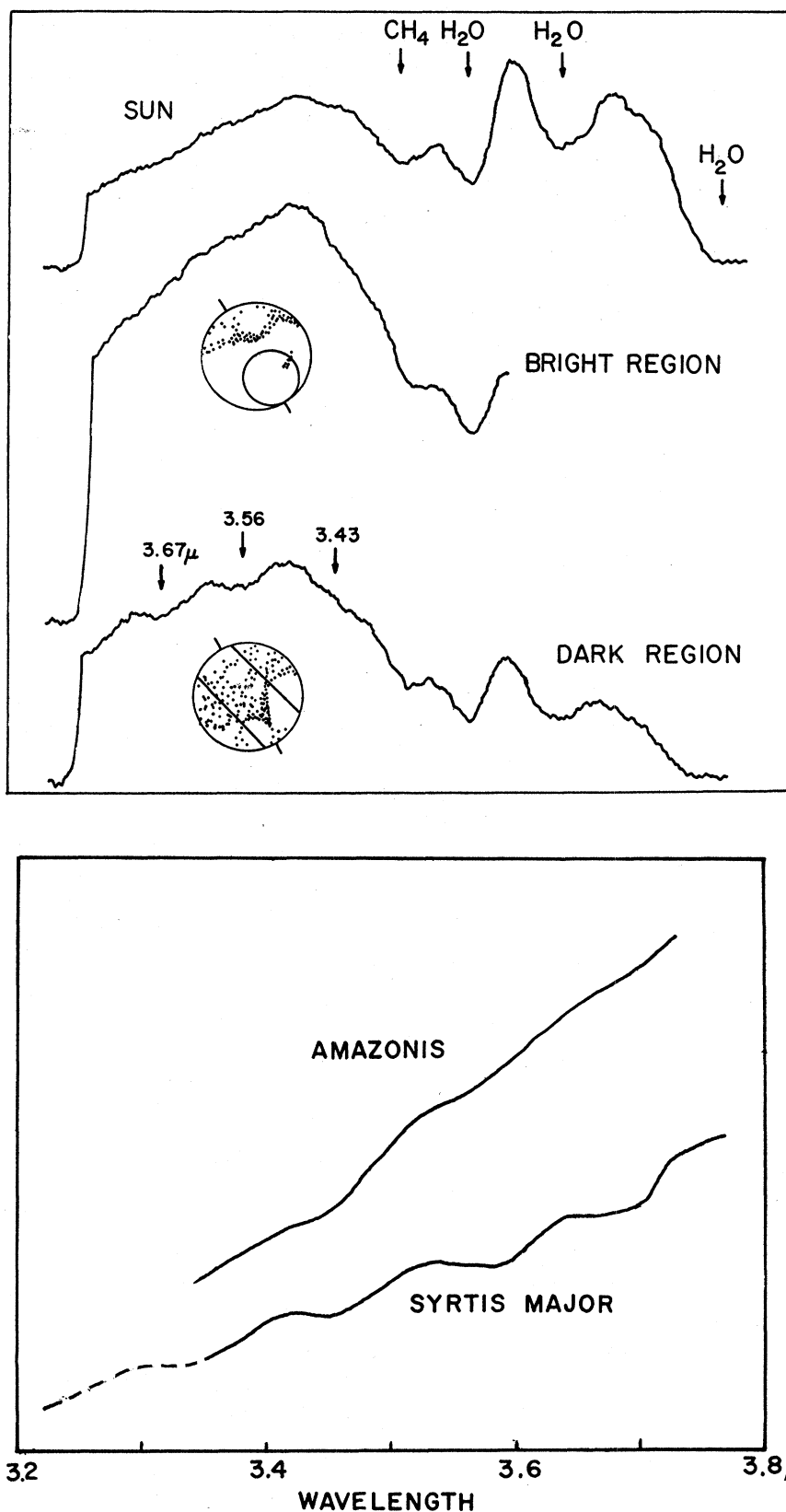
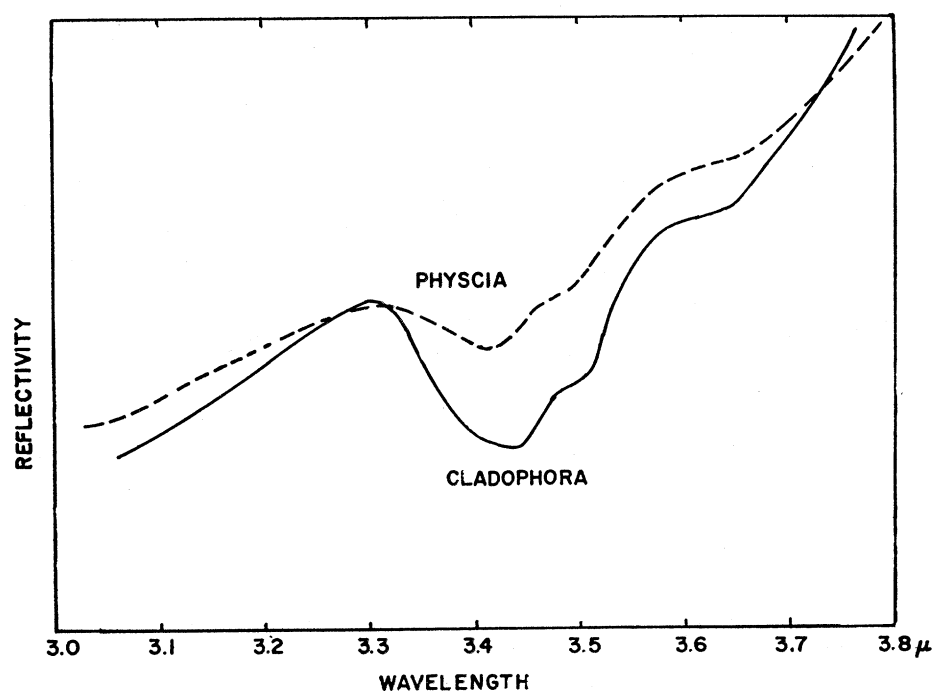
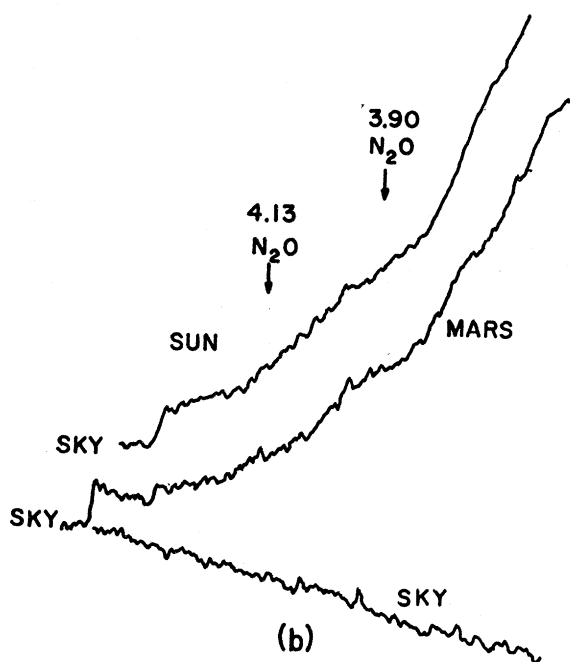
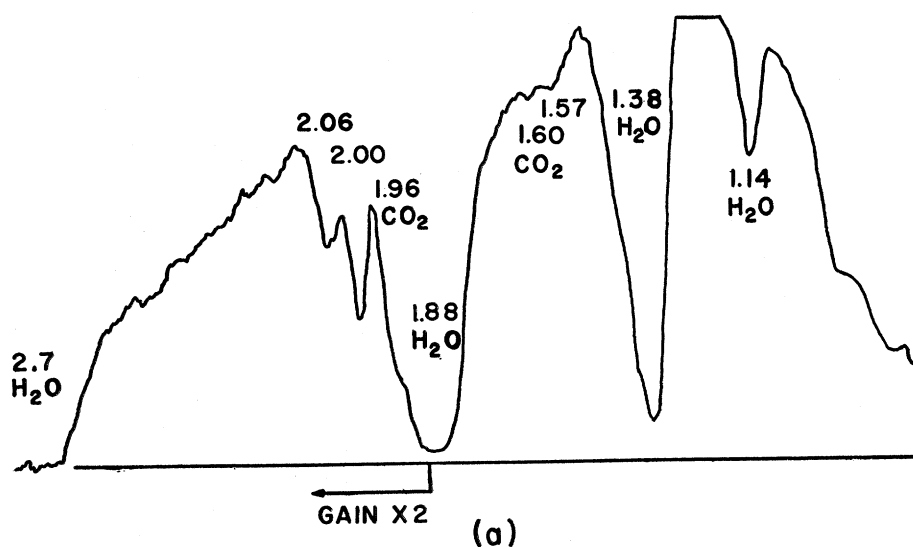


Fig. 1 (Top). Infrared spectra of Mars and the sun. The upper curve shows the spectrum of the sun with absorptions produced by water and methane in the earth's atmosphere. The middle curve is the spectrum of Amazonis, the desert region within the circle in the sketch. The bottom curve shows the spectrum of a strip across Mars as shown in the sketch and includes Syrtis Major. The last spectrum shows the absorptions supposedly due to organic molecules. Fig. 2 (Bottom). The spectra of Amazonis and Syrtis Major after division by the solar spectrum. The dashed portion of the curve is the region through strong methane and water-vapor absorption. The variations are not believed to be significant.



various regions of Mars with the 1-mm apertures. Five spectra were obtained of the region of Syrtis Major with the aperture removed and with 1-mm entrance and exit slit widths. The above spectra included only the wavelengths 2.7 to 3.8 μ or 3.1 to 3.8 μ .

Figure 1 shows a spectrum obtained with 1-mm slits that traversed the region of Syrtis Major as shown in the inset. Besides absorptions produced by water vapor and methane in the earth's atmosphere it has additional absorptions at 3.43, 3.56, and 3.67 μ which appear to be peculiar to the dark regions of Mars. A solar spectrum is shown in this figure for comparison, as is a spectrum of the region Amazonis, an area nearly free of dark markings. In Fig. 2 the spectra of these regions have been divided by the solar spectrum, taken at nearly the same air mass, to remove atmospheric absorptions and to derive the variation in albedo with wavelength. Thermal emission becomes increasingly important at longer wavelengths and may contribute a third of the radiation at 3.8 μ . Consequently Fig. 2 does not give the albedo variation accurately.

The intensity of the band in five regions of Mars was studied with the 1-mm aperture (8 sec of arc diameter). Table 1 gives qualitative intensities of the three absorptions together in these regions. In general the band was found to be present in four mostly dark regions centered on Syrtis Major, Pandora Fretum, Mare Sirenum, and Mare Cimmerium. It was absent or weak in the bright regions surrounding Arabia and Amazonis. From this we conclude that the absorbing material is on the surface and that it is associated with the dark regions.

In addition to the spectra that were made in the region of the organic band, other spectra (Fig. 3) were obtained in the regions 1 to 2.7 μ and 3.8 to 4.2 μ , the extent of the detector's sensitivity. In the first range are bands of CO_2

Fig. 3. (Top) Spectra of Mars in the regions 1 to 2.7 μ (a) and 3.8 to 4.2 μ (b). In a the ordinates of the portion of the curve to the left of the 1.88- μ absorption have been amplified by twofold. In b the spectrum of the sun is shown for comparison. The lowest curve marked "sky" is to be taken as the zero for the Mars spectrum. The nitrous oxide bands are equally strong in the spectra of the sun and Mars. Fig. 4. (Bottom) Laboratory reflection spectra of the lichen *Physcia* and the alga *Cladophora*. They show absorption at 3.67 μ due to carbohydrate constituents.

Table 1. Intensity of organic band in different regions of Mars.

Region	Relative intensity	No. of spectra
Amazonis	0.3	2
Arabia	0.5	13
Mare Cimmerium	2	1
Mare Sirenum	2	2
Pandorae Fretum	2	7
Syrtis Major	2.5	11

previously reported by Kuiper (4, p. 358). These are shown quite well here, particularly the ones at $2\ \mu$, which were in a region of low detector sensitivity in Kuiper's spectra.

No new absorptions, other than the organic bands, were found on Mars. The N_2O bands at 3.90 and $4.13\ \mu$ were no stronger in Mars spectra than in sun spectra. The CH_4 band at $3.3\ \mu$ was likewise equally strong in Mars and in solar spectra. The effective path length of CH_4 on Mars is four times a vertical path (two paths through the atmosphere each with a factor of 2 coming from the average over slant heights). For N_2O the effective path length is less than this because an appreciable fraction of the energy is emitted by the surface. However the ability to detect these gases is reduced by nearly tenfold relative to detection in the earth's atmosphere because of the low pressure on Mars. The amounts of CH_4 and N_2O , if present, are probably

less than the amounts in the earth's atmosphere.

The presence or absence of these gases, and of oxygen too, is important to the question of biological life on Mars, for on the earth these gases are formed chiefly by biological activity. Oxygen results from photosynthesis, methane is formed by the decay of organic matter, and nitrous oxide is produced by bacteria in the soil (7).

Conclusions

The presence of the bands near $3.5\ \mu$ is confirmed. These bands are most probably produced by organic molecules, but carbonates also possess bands in this region (8). Their absorption is strongest at 3.4 and $3.9\ \mu$ with practically no absorption at $3.7\ \mu$. Though carbonates are eliminated because of the disagreement in the details of the absorptions, it probably cannot be assumed that no inorganic molecule can explain the observed bands. The observed spectrum fits very closely, however, that of organic compounds and particularly that of plants (see Fig. 4).

It is tempting to assume, though this has not been demonstrated, that the dark regions that have appeared during the history of planetary observing also contain organic molecules. If this is true, then organic molecules are produced in localized regions in relatively

short spans of time. Growth of vegetation certainly seems to be the most logical explanation for the appearance of organic molecules.

At first the band at $3.67\ \mu$ seemed to be an enigma, for it had not been found in any terrestrial plants. However it has now been found in the alga *Cladophora* (Fig. 4). It is apparently produced by carbohydrate molecules present in the plant. The attachment of an oxygen atom to one of the carbon atoms shifts the resonance of a hydrogen atom attached to the same carbon to a longer wavelength. Thus the evidence points not only to organic molecules but to carbohydrates as well. The strength of the band at $3.67\ \mu$ compared to its weakness or absence in plants may indicate a significant difference in plants that may be present on Mars and perhaps indicates a larger storage of food.

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Science in the News

National Standards for Teacher Certification To Be Studied under Carnegie Grant to AAAS

The American Association for the Advancement of Science has received an \$81,000 grant from the Carnegie Corporation of New York to support an 18-month study of certification requirements for teachers of secondary-school science and mathematics. The grant was made in response to a proposal that

was submitted to Carnegie by the National Association of State Directors of Teacher Education and Certification, an independent group that is made up of the chief certification officer in each of the states. Since the organization is not incorporated, and therefore not directly eligible for a Carnegie award, the AAAS will hold the funds and administer them in cooperation with NASDTEC. Work will commence on 1 December at headquarters that are being established in

the AAAS building in Washington, D.C.

John R. Mayor, AAAS director of education, is part-time director of the new study. He will provide some leadership, but full-time responsibility for the investigation will be carried by the associate director, William Viall, who has just resigned his post as chief of the Bureau of Teacher Education and Certification for the state of New York.

Viall, immediate past president of NASDTEC, has been on the staff of the New York State Education Department since 1951. His experience there, and his earlier career, provide him with outstanding qualifications for his present assignment. He has served as teacher in a one-room country school, as instructor in a small-town junior high school, as assistant principal in a practice school for teachers, as professor of education and director of demonstration schools and student teaching in a teachers college, as director of elementary schools