in the rainfall, which is occasionally mentioned in the meteorological literature, is that of "overseeding." Ordinarily, it is discounted as a practical impossibility. An alternative hypothesis, informally suggested to us by J. Hughes (5), depends upon the presumption that the dispersal of silver iodide smoke causes widespread cloudiness. If this is so, then the ground temperatures at midday and early afternoon on days with seeding are likely to be lower than on days without seeding, with the consequent difference in the cumuli formation in the late afternoon. Primarily, the above explanation applies to period T_2, and the tapering off of the effect in T_3 to zero in T_4 appears as an intuitive possibility. The differences between the seeded and the natural precipitation observed in T_5, amounting to some 20 percent of the latter, are not very large, but the shapes of the two curves in Fig. 1 are suggestive, and the question arises whether the general cloudiness generated by seeding on the preceding day could continue to affect cumuli formation, for example, between 8 and 9 a.m. of the next day.

The hypothesis of early effects of seeding requires confirmation, possibly through cloud-chamber experiments and certainly through the analysis of observations in the free atmosphere. At this time we wish to point out that the hypothesis tends to explain certain of our findings relating to the Swiss experiment Grossversuch III.

Motivated by certain considerations not related to the present problems, we subdivided (6) the experimental days of Grossversuch III into three roughly defined categories: days of "incipient" storm periods, days of "middle" storm periods, and days of "dissipating" storms. Because of the tendencies of some experimenters to seed summer clouds ahead of the anticipated period of convection, we expected that the precipitation on incipient storm days with seeding will be much larger than that on days without seeding. To our surprise we found the contrary to be true; for the incipient category the precipitation on seeded days was significantly less than that without seeding. In the middle of the target (zone 3) the indicated loss in the rainfall due to seeding was 62 percent of what might have fallen without seeding ($P = .021$). It is just possible that this phenomenon is a simple consequence of the mechanism hypothesized by Hughes: The seeding from 7:30 a.m. on, in the absence of well-developed clouds, could have created widespread cloud cover that prevented the heating of the ground at midday and thus attenuated the development of cumuli.

JEANNE L. LOVASICH
JERZY NEYMAN
ELIZABETH L. SCOTT
JEROME A. SMITH
Statistical Laboratory, University of California, Berkeley 94720

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Mars: Water Vapor in Its Atmosphere

Abstract. *With the use of newly obtained spectrograms of Mars in the region of the water vapor band at 8200 angstroms, we have derived a value of 35 ± 15 microns for the amount of precipitable water in a vertical column in the Martian atmosphere.*

We have made a new determination of the abundance of water in the atmosphere of Mars, based on observations of the planet during February and March 1969. Since the discovery of water vapor lines in the spectrum of Mars (*1*) and their subsequent evaluation (*2*), only one other study of this problem has been reported (*3*). Both sets of observations were obtained at reciprocal dispersions in excess of 4 Å/mm, and in each case the quality of the data was considered to be the limiting factor in the abundance determination. The amount of precipitable water in the Martian atmosphere was found to be about 15 μ in both investigations.

The importance of a reliable determination of the abundance of water vapor cannot be overemphasized. If the Martian atmosphere is the result of crustal outgassing like the atmosphere of Earth, 18 times more water than carbon dioxide by mass may have been evolved, and there are several possible fates for the water (*4*). The suggestion that the polar caps and some of the ground deposits are actually solid carbon dioxide has raised the possibility that earlier estimates of the abundance of atmospheric water vapor might be too large (*5*). Moreover, the amount and distribution of Martian water is important for biological considerations.

To redetermine the amount of atmospheric water, we used the coudé spectrograph of the 82-inch (208-cm) telescope at the McDonald Observatory to record the spectrum of Mars at 2 Å/mm in the region of the 8200-Å water vapor band. The projected slit width varied from 0.020 to 0.030 mm. A preliminary spectrogram obtained

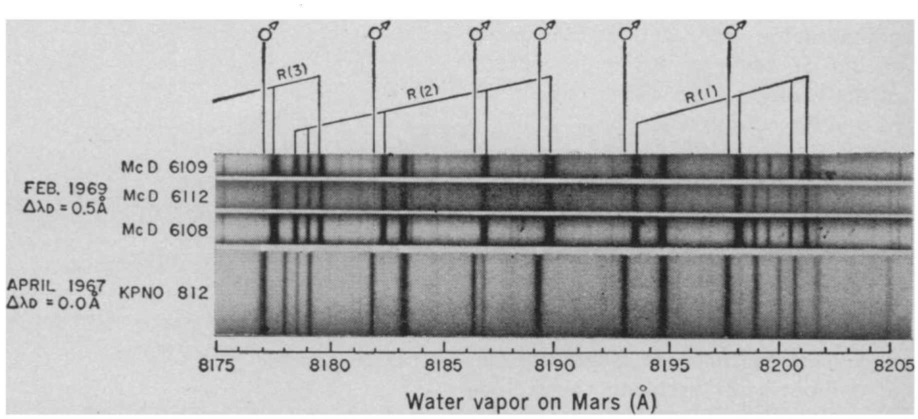

Fig. 1. Spectrum of Mars near 8200 Å. The McDonald (*McD*) and Kitt Peak (*KPNO*) plate numbers of the spectrograms are given, as well as the approximate Doppler shift ($\Delta\lambda_D$) at the time of observation. Martian water vapor lines are indicated by the symbol ♂; the strong lines for terrestrial water are identified by their rotational quantum numbers *R*.

with the 84-inch (215-cm) reflector at the Kitt Peak National Observatory on 2 February had established that this improvement in plate scale would lead to a much better record of the water vapor absorptions than had been possible in the past. At the time of our observations at the McDonald Observatory (25 February to 5 March), the relative motions of Earth and Mars resulted in a Doppler shift of 0.5 Å for lines formed in the Martian atmosphere. The planet's large southerly declination (−19°) offset this advantage somewhat by forcing us to observe at relatively large zenith angles, thereby increasing the amount of absorption from terrestrial water vapor.

Considerable image motion as a result of atmospheric turbulence prevented the exact registration of the spectrograph slit on the planetary disk. Instead, we essentially integrated over a meridional strip having the approximate central longitude of 140° and a sub-Earth latitude of +8°. Thus we were looking primarily at light areas on the tropical and north-temperate regions of the planet during a time when it was early summer in the Northern Hemisphere.

Figure 1 illustrates sections of three of the resulting spectograms compared with a record of the planet's spectrum obtained at opposition in 1967 at the Kitt Peak National Observatory. Solar lines appearing in both sets of spectrograms are aligned so that the strong terrestrial water vapor lines are displaced in the upper three spectra (*6*). In this representation, water vapor lines formed in the Martian atmosphere appear in the upper three spectra directly above the terrestrial lines in the reference spectrum. Even with the loss of detail inherent in photographic reproductions, the reader should be able to distinguish several of the stronger water vapor lines in the Martian spectrograms.

To obtain a value for the abundance of water, we first determined the equivalent widths (a measure of the total absorption) of the Martian lines. Weak solar lines whose equivalent widths were measured in a standard atlas (*7*) were used to calibrate the three best Martian spectrograms. This is a nontrivial problem, since one must try to account for overlapping of the Martian lines by the far wings of the terrestrial water vapor lines which will also obscure the true level of the continuum. A summary of our results

Table 1. Water vapor lines in the spectrum of Mars.

Rest wavelength (Å)	Equivalent width (mÅ)
8176.98*	5.0
8181.85	4.0
8186.37	4.0
8189.27*	5.5
8193.11	5.5
8197.70	4.0
8226.96*	5.5
8282.02*	5.5

* Lines whose strengths were determined in the laboratory.

for the strongest lines is given in Table 1, where all values have been rounded to the nearest 0.5 Å. Attempting to allow for possible systematic errors, we estimate the uncertainty in these values as ± 30 percent.

The absorption coefficients for four of the lines have been measured in the laboratory (*8*). Correcting these values to a temperature of 230°K (*2*) and using a Voigt profile to determine the true amount of absorption (*9*), we obtain a value of 105 μ for the precipitable water in the total atmospheric path. We adopt an effective slant path of three times the vertical path length to allow for the average in the zenith angles of the sun and Earth over the observed strip of the Martian disk. The final result for the amount of precipitable water in a vertical column is then 35 ± 15 μ or 0.0035 ± 0.0015 g cm^{-2}.

It should not be too surprising that this value is larger than earlier determinations. Even though it is possible that the difference is the result of

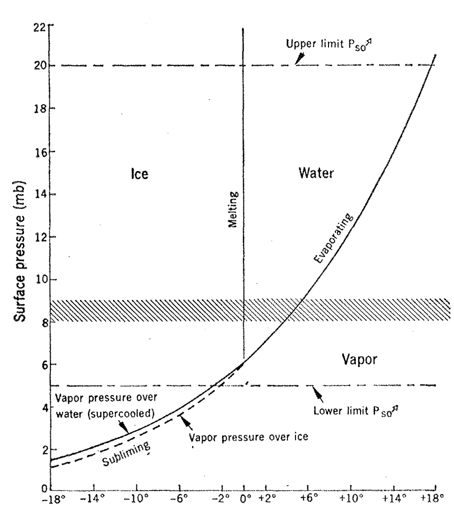

Fig. 2. A phase diagram of water. The hatched area corresponds to a Martian surface pressure $P_{s♂}$ of approximately 8.5 mb.

a genuine secular variation in the amount of water in the Martian atmosphere, most of the apparent increase is probably an instrumental effect. The same situation occurred when increased resolution was used to investigate the Martian carbon dioxide lines (*2, 4, 10*); this effect has also been noticed for weak, sharp lines observed in the laboratory (*11*).

This amount of water vapor requires that the mean temperature in the region of the atmosphere where these lines are formed is considerably higher than the value of 200°K associated with the carbon dioxide lines and the Mariner 5 occulation (*10, 12*). This result follows from a calculation of the mixing ratio, which is 2.5×10^{-4}, if we assume a carbon dioxide abundance of 75 m-atm (*10*). If we assume that the atmosphere is isothermal and saturated, the corresponding temperature is 205°K. The comparative rarity of Martian clouds indicates that the atmosphere must be well below saturation, and hence the mean temperature of the region containing the water vapor must be well above 205°K. One would anticipate that the water vapor would be confined to the lower, warmer layers of the atmosphere, as on Earth, and not uniformly mixed with the carbon dioxide; thus this is a reasonable result.

The abundance derived here has little bearing on the problem of the evolution of the Martian atmosphere, except to reaffirm that some water is present at the current epoch. If we take 35 μ as the average value, the total amount of water in the Martian atmosphere is 5×10^{15} g. The entire atmosphere has a mass roughly 10^4 times larger; thus the relative amount of water it contains is not much different from average terrestrial values. Most of the terrestrial water is in the oceans, however, and if one assumes that Mars has outgassed like Earth relative to the observed abundance of carbon dioxide, the total amount of Martian water must be about 200,000 times larger than the amount present in the planet's atmosphere. There are at least three hypotheses that can explain this discrepancy, and they are not mutually exclusive: (i) dissociation and subsequent thermal escape; (ii) retention as permafrost (a 7-m column is required if all the missing water is in this form); and (iii) invalidity of the assumption that Mars has outgassed like Earth. With respect to the latter, very large comets may have masses on the order of 10^{19} g and could thus make a significant contribution to the content of the Martian atmosphere, given suitable impacts (*4*).

Finally, the presence of water vapor in the atmosphere of Mars does not imply that liquid water exists on the planet's surface. The reason is evident from inspection of Fig. 2, which is a phase diagram of water. At the likely range of values for the Martian surface pressure (5 to 12 mb) there is only a very restricted temperature domain in which liquid water will be stable.

TOBIAS OWEN*
Illinois Institute of Technology Research Institute, Chicago 60616, and Kitt Peak National Observatory, Tucson, Arizona 85717

HAROLD P. MASON
Illinois Institute of Technology Research Institute

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6. Actually, of course, it is the solar lines that are displaced as a result of reflection by the moving planet. The terrestrial lines have identical positions in the two sets of observations since they are formed in our own atmosphere, at rest with respect to the observer. There is no evidence on these spectrograms for a Fraunhofer line at 8189 angstroms, suspected in earlier work on Venus [T. Owen, *Astrophys. J.* **150**, L121 (1967)]. Such a line would have to have an equivalent width less than 2 milliangstroms, to escape detection and thus seems an unlikely explanation for observations of water vapor absorption on Venus reported at this wavelength.
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* Visiting Astronomer, 1969, Kitt Peak National Observatory.

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Glossopterid Leaves from the Middle Jurassic of Oaxaca, Mexico

Abstract. *Leaves indistinguishable from those of the late Paleozoic genus* Glossopteris *occur in Middle Jurassic beds in the State of Oaxaca, Mexico. If they are biologically related to the Permo-Carboniferous* Glossopteris, *the occurrence in Mexico is the latest report of the genus. Alternatively, these leaves may have belonged to another group of plants with foliage similar to that of* Glossopteris, *but with a different reproductive structure.*

Plants of the genus *Glossopteris* are important constituents of the late Paleozoic Gondwanaland floras, now found as fossils in Southern Hemisphere continents and India. The disjunct distribution of *Glossopteris*, along with that of other plant and animal genera, is one of the pieces of evidence used to indicate that once continuous biota became separated by a pulling apart of continental masses.

According to some workers, the distribution of fossil *Glossopteris* is not confined only to those regions cited above. There are reports of the occurrence of *Glossopteris* leaves from the Upper Permian of northern Russia (*1*) and the Rhaetian (uppermost Triassic) of Tonkin (*2*) and east Greenland (*3*). Florin (*4*) and Harris (*5*) subsequently suggested a cycadean relation of the Rhaetic leaves.

Wieland (*6*) reported on a flora from the Mixteca Alta in the State of Oaxaca, Mexico; he considered these deposits to be Liassic (Lower Jurassic) in age. Among the plant remains, the most abundant are leaves of cycadophytes, principally of the genera *Otozamites* and *Pterophyllum*. Williamsonian cones were also found, as well as ferns of the genera *Sphenopteris*, *Coniopteris*, *Cladophlebis*, and others. In his report Wieland figured entire, spatulate leaves that he tentatively identified as *Glossopteris*. He had only a few leaves, and his identifications were uncertain, as witnessed by the question marks used with the generic name. In fact, it is impossible to determine the nature of the venation in his specimens. In addition to the presumed *Glossopteris*, Wieland also figured a few foliar structures identified as *Sagenopteris*. In no case, however, was there more than one blade attached to a compound leaf.

I have recently resumed collecting plant fossils in localities quite close to those of Wieland (*7*). Plants are derived from coarse sandy shales of the Zorrillo and Simón formations, both Middle Jurassic and separated by the Taberna Formation which includes Jurassic ammonites (*8*). The flora is also typically Middle Jurassic, comparable to that reported by Wieland. These recent collections yielded hundreds of compressed leaves of the *Glossopteris* type. Preservational details are fine enough to allow a precise comparison with *Glossopteris*. The longest complete leaf measures close to 40 cm in length (Fig. 1A), although certain incomplete specimens (Fig. 1B) suggest that some of the leaves are even longer. The smallest entire specimen is 7 cm long (Fig. 1C), and slightly more than 2 cm wide at the broadest part. Some of the large leaves may exceed 7 cm in width. Lateral veins diverge from the midrib at angles ranging from almost 90° to about 45°. There is considerable variation in this angle even in the same leaf, with those near the base and apex arising at a steeper angle than those near the middle of the leaf. Anastomoses are not frequent, but are consistent (Fig. 1D).

There is a range in shape as well, but in all instances the leaf is broadest above the middle. Tips may range from rounded obtuse to acuminate. Intergradations in size and shape are close and it is impossible to detect more than one distinct morphological type. Variation most likely was influenced by age and by the position on the parent plant. It is not possible to recognize more than one grouping of characters, and quite likely only one species is represented. There is no mistaking these glossopterid leaves for the Rhaetic ones from Greenland and Sweden that are now called *Anthrophyopsis* (*5*). Leaves of the latter genus are like those of the cycadean *Ctenis*, except that *Ctenis* is pinnately divided.

An alternative explanation, of course,