by the fact that Sr^{89} and Ba^{140} both have gaseous precursors:

$$\mathrm{Br}^{89} \xrightarrow[4.5\text{ sec}]{\beta^-} \mathrm{Kr}^{89} \xrightarrow[3.2\text{ min}]{\beta^-} \mathrm{Rb}^{89} \xrightarrow[15\text{ min}]{\beta^-} \mathrm{Sr}^{89} \xrightarrow[50.4\text{ days}]{\beta^-} ;$$

$$\mathrm{Xe}^{140} \xrightarrow[16\text{ sec}]{\beta^-} \mathrm{Cs}^{140} \xrightarrow[66\text{ sec}]{\beta^-} \mathrm{Ba}^{140} \xrightarrow[12.8\text{ days}]{\beta^-} .$$

These fission products of mass numbers 89 and 140 remain in gaseous state for some time after the fallout particles begin to form and hence Sr^{89} and Ba^{140} would tend to become enriched in smaller particles. This means that Sr^{89} and Ba^{140} would be depleted in larger particles, which are deposited preferentially as a local fallout in the vicinity of the nuclear test site. Smaller particles may tend to remain in the atmosphere for a longer period, traveling longer distances and then being deposited at greater distances from the test site. The phenomenon of the atmospheric fractionation of nuclear debris is well known (*4, 6*).

The area in Fig. 1 below the mass-yield curve due to the Chinese nuclear explosion adds up to approximately 200 $\times 10^6$ atoms, whereas the area below the mass-yield curve due to older debris adds up to at least 10,000 $\times 10^6$ atoms. Thus the percentage of the contribution from the Chinese bomb to the total fallout of the fission products in the rain collected on 26 October 1964 is of the order of a few percent.

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13 January 1965

Mars: The Origin of the 3.58- and 3.69-Micron Minima in the Infrared Spectra

Abstract. *The 3- to 4-micron spectra of Mars, recorded with the 200-inch telescope in 1958, were reexamined in order to ascertain whether the minima at 3.58 and 3.69 microns are due to telluric HDO molecules. Solar spectra obtained at Denver and water vapor abundances derived from radiosonde flights during the observing period were used. There seems to be a correlation between the intensities of the 3.58- and 3.69-micron features and the amount of telluric water vapor in the optical path. An important corollary is that there is no evidence for attributing these spectral features to Mars.*

In 1956 and 1958, one of us (Sinton) detected spectral features in the 3- to 4-μ spectra of Mars (*1, 2*). With an infrared spectrometer on the 200-inch (500-cm) Hale telescope at Mount Palomar these features appeared to be more pronounced for the dark than for the bright areas and were identified as minima at 3.43, 3.56, and 3.67 μ. These minima are significant because they are in the general region where organic C-H bonds absorb, so that, taken together with other observations of Mars, they strongly suggest that life is present on the dark areas; this was the tentative interpretation at that time. The assignment was modified by Colthup (*3*), who concluded that the 3.67-μ minimum had to be due to an aldehyde C-H, and most probably to acetaldehyde (CH_3CHO). At the same time Sinton reexamined the original spectra and changed the minima to 3.45, 3.58, and 3.69 μ, with a probable error of $\pm$ 0.02 μ (*4*). The origins of these bands were further investigated at Berkeley by Rea *et al.* (*5*). Rea *et al.* were not satisfied with previous interpretations but could find no new attractive possibilities and reluctantly concluded: "At present we know of no satisfactory explanation of the Martian bands."

This was the situation until recently when similarity between the 3.58- and 3.69-μ bands and those of D_2O-HDO-H_2O mixtures was noted by Shirk *et al.* (*6*). In particular, these workers believed the spectra could best be reproduced by a gas mixture in which the D/H ratio is approximately one. This represents a phenomenal enrichment of deuterium over the D/H ratio of less than 1 : 4500 for the interstellar medium (*7*) and demands an explanation. Shirk *et al.* raised the possibility that extensive fractionation had occurred during the escape of H and D atoms from the planet's gravitation field, but they presented no calculations to indicate that this is a plausible mechanism. Moreover, no mechanism was advanced to explain the preferential location of water vapor over the dark areas. Because of these factors, we regard the identification of the 3.58- and 3.69-μ minima with Martian water vapor having a D/H ratio near one as improbable.

However, this proposal did suggest to Rea that the explanation may lie in our own atmosphere. It has been known for many years that the ν_1 band of HDO (the O-D stretching vibration) is present in solar spectra with *P*, *Q*, and *R* minima at about 3.75, 3.67, and 3.57 μ, respectively (for example, see *8*, *10*). To determine whether this telluric HDO could be the source of the absorption at 3.58 and 3.69 μ in the spectra of Mars we conducted the following investigation.

We remeasured the original infrared spectra obtained at Mount Palomar and estimated for all of the spectra the percentage absorption at 3.58 and 3.69 μ. In doing this we had to make a more-or-less subjective estimate of the background envelope, the curve which would be observed for no absorption. This could introduce errors of a few percent, so that absorptions of this magnitude are not very meaningful. If the absorption was estimated to be less than the noise, it was given a value of zero.

The next step was to obtain solar spectra which could be used for comparison. Fortunately, during 1954–55 D. M. Gates had spent several days at the University of Denver (elevation 1615 m) recording solar spectra with a double-pass Perkin-Elmer model 112 monochromator equipped with a NaCl prism. The resulting widths of the spectral slits were less than those used by Sinton, but the difference was much less than for the high resolution spectra in the solar atlases (*8*). In addition, Gates's spectra were obtained for a wide range of zenith angles with a resulting broad range of precipitable water vapor in the path. The actual amount of water vapor could also be calculated for each spectrum with the aid of the peak or integrated intensities of the near-infrared water-vapor bands which were

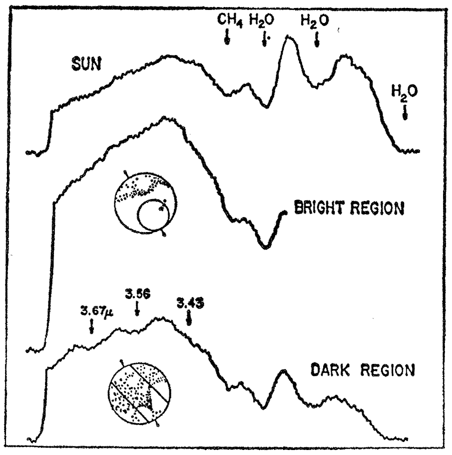

Fig. 1. Spectra of the Sun and Mars recorded at Mount Palomar in October 1958.

also recorded. In doing this we used the procedure outlined by Gates (*10*).

Finally, to estimate the amount of water vapor in the path for the Mars observations we obtained radiosonde data for the San Diego station from the National Weather Records Center, Asheville, North Carolina. From the relative humidity and temperature as a function of altitude we calculated the amount of water vapor in a vertical path above 1706 m, the elevation of Mount Palomar. Radiosondes were launched twice per day, at approximately 03:00 and 15:00 Pacific Standard Time, so that the amount of water vapor in the vertical path was known, at times, only a few hours from the time of observation. The value for the closest radiosonde was multiplied by the computed air mass from the Mars observation to obtain the amount of water vapor in the path. Since San Diego is only 77 km from Mount Palomar, water values so computed should be indicative of the values above the mountain. This course was followed because San Diego is the closest radiosonde station and because there are no measurements of this quantity from the mountain itself.

Three of the spectra recorded by Sinton are reproduced in Fig. 1 (taken from *2*). The spectrum of the sun was taken on 19 October at 11:47 P.S.T. (estimated water vapor, 7.3 mm), of the bright region (Amazonis) at 23:16 P.S.T. on 20 October (estimated water vapor, 11.5 mm), and of the dark region (Syrtis Major) at 05:02 P.S.T. on 15 October (estimated water vapor, 11.4 mm). The wavelengths marked on the curves are the original estimates. The widths of the spectral slits at 3.67 μ were 0.049, 0.074, and 0.049 μ, respectively. For comparison, solar spectra recorded by Gates at Denver are shown in Figs. 2 and 3, plotted on the same wavelength scale as the spectra in Fig. 1. The water vapor values for Gates's spectra were calculated with the area of the φ band at 1.13 μ (*10*).

The similarity between the minima at 3.56 and 3.67 μ in the Syrtis Major spectra (Fig. 1) and those at 3.57 and 3.67 μ in the solar spectra (Figs. 2 and 3) is very striking. The similarity would be further enhanced had the solar spectra been recorded with a spectral slit width of 0.049 μ, since then the relative intensity of the 3.67-μ band would decrease and its width would increase to approach the width of the 3.57-μ feature.

The values for the percentage absorption at 3.58 and 3.69 μ for the 1958 Martian and solar spectra were examined; the precipitable water vapor from the San Diego radiosondes was used as a guide. A one-to-one correlation was not observed, but we believe that a correlation does exist after allowance is made for the various uncertainties involved. It then follows that there is no evidence for the presence on Mars of substances absorbing at 3.58 and 3.69 μ.

We wish to emphasize that the measurement of these bands, especially for different regions of the planet, is extremely difficult. The depth of the bands is but 5 percent, and their great breadth makes determination of the location of the continuum if the bands were absent rather uncertain. It is also generally difficult to guide the telescope on a small part of a planetary disc and, in so doing, to avoid imposing spurious structure in a scanned spectrum through errors in guiding. Perhaps too much emphasis has been placed on the association of the bands with organic molecules as was too strongly suggested in a previous report (*2*).

A further conclusion from our reexamination is that solar spectra are not adequate for monitoring the amount of water vapor in the path for the Mars observations. Significant variations were observed in the HDO absorption for night and day spectra recorded during a particular 24-hour interval. It is therefore mandatory to carry out the monitoring during the observation period. This can best be realized by 3.5- to 3.8-

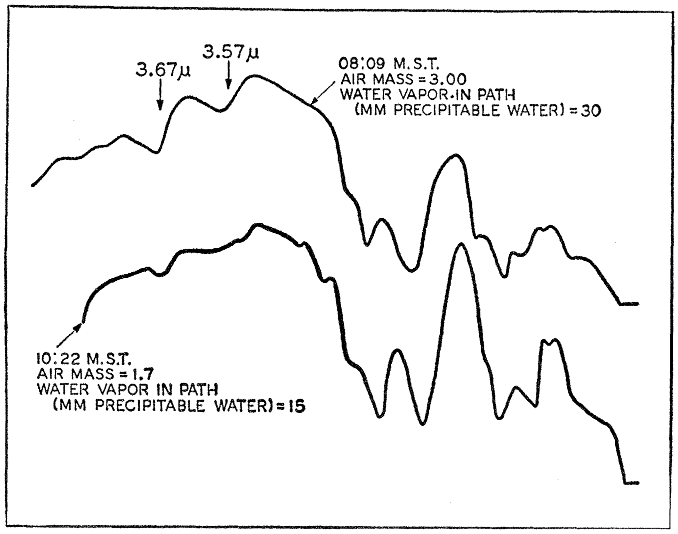

Fig. 2. Spectra of the Sun recorded at Denver on 21 October 1954. The spectral slit width at 3.67 μ was 0.014 μ (M.S.T., Mountain Standard Time).

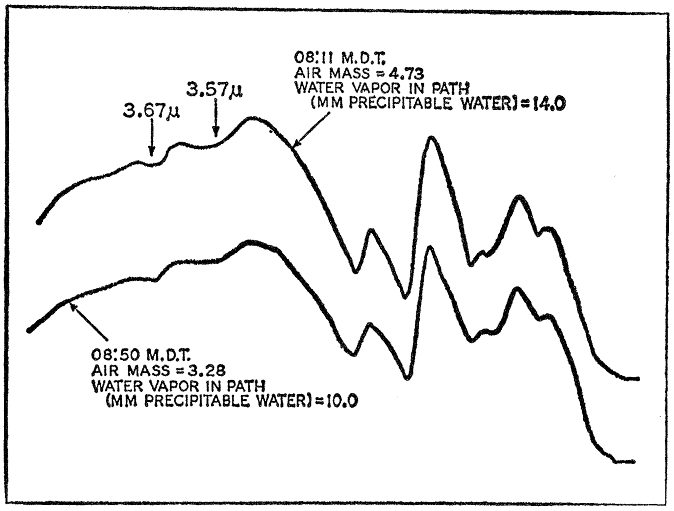

Fig. 3. Spectra of the Sun recorded at Denver on 12 May 1955. The spectral slit width at 3.67 μ was 0.03 μ (M.D.T., Mountain Daylight Time).

μ observations of a star or of the moon for an air mass close to that of Mars. It is expected that the observations planned for the 1965 opposition, when this technique will be used, will permit positive conclusions to be drawn about Martian absorption features in the 3.5- to 3.8-μ region (*11*).

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12. We thank D. M. Gates for the loan of his solar spectra and for discussion of the vagaries of absorption by our own atmosphere. Supported in part by NASA contract NAS r 220.

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Mazama and Glacier Peak Volcanic Ash Layers: Relative Ages

Abstract. *Physiographic and stratigraphic evidence supports the regional correlation of two volcanic ash layers with extinct Mount Mazama at Crater Lake, Oregon, and Glacier Peak in the northern Cascade Range of Washington. A radiocarbon age of 12,000 ± 310 years confirms geological evidence that ash derived from the Glacier Peak eruption is substantially older than ash from the Mazama eruption of 6600 years ago.*

The potential use of widespread volcanic ashfalls as time-stratigraphic marker horizons in the Pacific Northwest is great, for lenses of volcanic ejecta are present locally, and in some cases regionally, in sediments from early Pleistocene to Recent age. The best preserved, most widespread, and consequently most valuable as tools in the development of a postglacial regional chronology, are the pumice and ash from eruptions of Mount Mazama at Crater Lake, Oregon, and Glacier Peak in the northern Cascade Range of Washington.

Powers and Wilcox (*1*) recently have provided techniques for petrographic correlation of the pumice deposits from these and other (*2*) eruptions. My own field studies have yielded stratigraphic and radiocarbon data indicating the age and distribution of these deposits. It now is possible to reconfirm an age of about 6600 years for the Mazama eruption; to place an age of about 12,000 years for the Glacier Peak eruption; and to estimate the minimum areas of fallout for Mazama ash at about 900,000 km^2 and for Glacier Peak at more than 260,000 km^2 (Fig. 1).

Wide distribution of pumice from the destruction of Mount Mazama was demonstrated by Williams (*3*) within Oregon, and ash deposits as far north and east as Walla Walla, Washington were correlated with the Mazama blast by Moore and Carithers (*4*). Hansen (*5*) reported the presence of several pumice and ash horizons in bog sediments throughout the northwest, and noted the almost universal presence of a layer of volcanic ash in sediments thought by him to have been deposited during the "Thermal Maximum" (Altithermal) climatic interval between 8000 and 4000 years ago. Included in Hansen's field studies and those of Rigg (*6*) were many bogs in northeastern Washington and the Puget Sound area, nearly all of which included ash layers of Altithermal age. Rigg and Gould (*7*) adopted Hansen's earlier suggestion as to the source of the ash, and correlated these lenses of ash with an eruption of Glacier Peak known from thick deposits of pumice on its flanks and in the Entiat and Methow valleys.

Radiocarbon dates placed the age of the Mazama eruption at about 6500 years (*8*); those associated with volcanic ash attributed to the Glacier Peak eruption indicated an age of about 6700 years (*7*). Thus it became evident that the Altithermal ash deposits represented either two almost contemporaneous ashfalls or a single blanket of ash mistakenly attributed to two sources. I found late Wisconsin ash, too coarse to have been derived from Mount Mazama and stratigraphically lower than the Altithermal ash, at several localities reported by Carithers (*4*) and at the Nat Cave and Park Lake archeological sites in Lower Grand Coulee, Washington.

Most recently, Powers and Wilcox (*1*) have used petrographic and chemical characteristics to correlate the Altithermal ashfall throughout the Pacific Northwest with the catastrophic Mazama eruption and to correlate the older, coarser ash with Glacier Peak. These two ash layers were found superposed at Creston Bog by R. E. Wilcox and me during the summer of 1963, and by others as far southeast as Birch Creek Valley, Idaho (*1*, *9*).

The coarse pumice of the immediate Glacier Peak area thins rapidly eastward, grading to grains of about 0.25 mm maximum diameter at Creston Bog. Although this size still is coarse enough and distinctive enough, because of its "tapioca-like" appearance, to be megascopically distinguishable from Mazama ash in this area, remnants of the older Glacier Peak ash disappear for the most part beneath the accumulation of younger sediment and the blanket of more recent Mazama ash. Thus in a transect from Glacier Peak eastward across the Columbia Plateau, the obvious thick deposits of Glacier Peak pumice and coarse ash appear to grade smoothly to those of the finer Mazama ash blanket, which provides the most prominent series of ash deposits east of the Okanogan and Columbia rivers. Without detailed stratigraphic information, the transition from prominent exposures of Glacier Peak ash to prominent exposures of the Mazama overlay is not apparent.

At least ten radiocarbon dates, including some obtained from wood buried by the Mazama eruption (*8*, *10*), place the age of the Mazama eruption at about 6600 years. Shells of freshwater molluscs collected from an abandoned quarry in Glacier Peak ash at the east wall of Lower Grand Coulee about 8 km north of Soap Lake have