3-4μm IMAGING SPECTROSCOPY OF MARS. D. R. Klassen[1] J. F. Bell III[1] R. N. Clark[2], W. Golisch[3], C. D. Kaminski[3], D. Griep[3] [1]Cornell University (Center for Radiophysics and Space Research, Space Sciences Building, Ithaca, NY 14853), [2]U. S. Geological Survey (Box 25046 Federal Center, Denver, CO 80225-0046) [3]NASA Infrared Telescope Facility (Institute for Astronomy, 2680 Woodlawn Dr., Honolulu, Hawaii 96822).

Near Infrared (NIR) multi-spectral images of Mars, taken at the NASA Infrared Telescope Facility (IRTF) at and near the 1995 opposition (01 and 04 FEB 1995) show interesting spectral absorptions at 3.33 and 3.40μm which appear to be confined to the Syrtis Major region. The bands show about 10% absorption in relative band depth maps. Based on their spatial extent the absorptions do not appear to be due to an atmospheric species. The absorption features also do not match any known atmospheric absorptions. The bands are similar to absorptions seen in band depth maps of CO_2 and H_2O ices, however we find no reason to believe these ices would exist in Syrtis Major in the early northern spring. There is a similarity between these absorptions and C-H features seen in the spectrum of CH_4, however there could be other explanations which we have yet to exclude before this possibility can be confirmed.

The 3.4μm band lies close to the shortest wavelength "Sinton Band". The "Sinton Bands" were first seen in NIR observations during 1958 on the Palomar 200" Hale Telescope [1]. Sinton obtained 36 disk-resolved spectra of bright and dark regions, calibrating them with solar observations the following day taken when the Sun was at the same airmass as Mars. Three distinct bands with depths of about 5% were seen at 3.43, 3.56 and 3.67μm. These band centers were later revised to 3.45, 3.58, and 3.69μm in a later paper [2] based on better wavelength calibration of the instrument. The bands were observed to be deeper and more prominent over the dark regions of Syrtis Major, Pandorae Fretum, Mare Sirenum and Mare Cimmerium and weaker by at least a factor of four in the bright regions of Arabia and Amazonis. The work stirred quite a controversy in the Mars community because the bands were interpreted as evidence of C-H absorptions due to vegetation or carbonates.

The organic interpretations of these absorption features was strengthened by the laboratory spectroscopy work of Colthup [3]. He agreed that the 3.43μm band could be due to any number of organic materials, all of which have a C-H absorption band. The longer wavelength bands could then be attributed to certain aldehydes such as acetaldehyde. This particular compound could be the result of an anaerobic metabolic process such as the fermentation of carbohydrates. Colthup [3] speculated that fermentation would be a reasonable method of energy production in an oxygen deprived environment such as Mars.

Rea *et al.* [4] re-analyzed Sinton's data after obtaining their own Solar spectra at the same humidity as the Sinton Mars spectra. They interpreted the two longer wavelength bands as terrestrial HDO absorptions, but no discussion or explanation of the 3.45μm band was given. Since this work, the nature of these enigmatic NIR bands has been left largely unexplored.

Our data were obtained at the NASA IRTF using the NSFCAM on 01 and 04 FEB 1995. The instrument has a 256x256 InSb array detector sensitive from 1 to 5.5μm and circular variable filters with a spectral resolution of about 1%. The image sets gathered include some taken at distinct wavelength subsets to search for mineralogic and volatile absorption features as well as some sets taken at full Nyquist sampling. The sets used for this work come from the full spectral sampling technique. The images have been remapped to a cylindrical projection to help register the images within a spectral set (Figures 1 and 2)

These multi-spectral image sets allow us to investigate spectral absorption features as a function of position on the visible disk of the planet. By normalizing the images to the disk average we are able to take out all terrestrial atmospheric effects, as well as any effects that are common to all regions of Mars. From these normalized images we create band-depth maps by ratioing the image at the band wavelength to a continuum image at that wavelength linearly interpolated between two local continuum images at wavelengths on either side of the absorption feature [5,6]. These relative band-depth maps show how the absorption feature varies across the disk of the planet relative to the average value of that feature. Regions with a value of 1.0 have the same amount of absorption in the particular band as the disk average.

In relative band depth maps centered at 3.331 and 3.401μm (Figures 1 and 2) we can see absorption differences of about 10% from the disk average in Syrtis Major and the north polar region. The band depth at the north polar region can be explained by water ice absorption [6]. Since this water ice absorption feature is so deep and broad, relative band depth maps almost anywhere in the 3μm region will easily produce 10-20% features.

The water ice interpretation could be invoked for the Syrtis Major region if we conclude that it is caused by a thick cloud covering the area. Clouds were seen around this time in Hubble Space Telescope images [7], however the clouds occurred primarily as large belts that were more extensive than the regions of absorption that we see confined to Syrtis Major.

The spectrum of Syrtis Major extracted from the image set shows the two absorptions at 3.33 and 3.4μm compared to the Sinton band spectra, water ice, a carbonate, a model Mars atmosphere, and Terrestrial HDO and CH_4 (Figure 3). Although the carbonate does show a 3.4μm absorption match, there is no evidence of the stronger 3.8- 4.0μm carbonate absorptions in the Syrtis Major spectrum.

The similarity between the CH_4 spectrum and the Syrtis Major data opens the possibility that the Mars features may be related to C-H absorption. However, other explanations exist that must be fully explored before this possibility could be confirmed. To date we have examined thousands of mineral and organic samples from the spectral libraries of Clark *et al.* [8] and others, but have found no satisfactory match to the Syrtis Major features. The fact that the bands are detected in independent data sets from different nights and under different viewing conditions, and using detection techniques designed to remove or minimize telluric or instrumental artifacts gives us confidence that they are in fact real and caused by material on the Martian surface. Our attempts to identify this material are continuing.

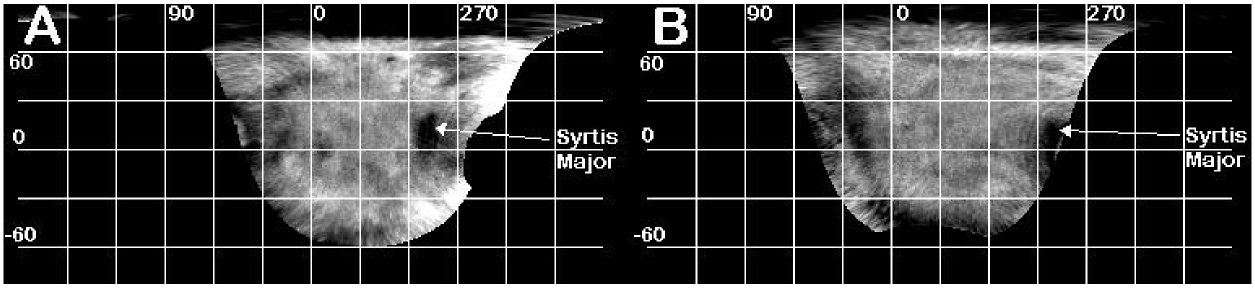

Figure 1 Relative band depth map from (A) 04 FEB 95 with band center at 3.401μm and (B) 01 FEB 95 with band center at 3.331μm. Local continuum points are at 3.194 and 3.497μm and the image stretch is ±10%. The grid lines are latitudes and longitudes in 30° increments. High absorption areas are the north polar region, due to water ice, and Syrtis Major.

References: [1] Sinton, W. M. (1959) Science, 130, 1234- 1237. [2] Sinton, W. M. (1961) Science, 134, 529. [3] Colthup, N. B. (1961) Science, 134, 529. [4] Rea. D. G., B. T. O'Leary, W. M. Sinton (1965) Science, 147, 1286-1288. [5] Bell, J. F., III, D. Crisp (1993) Icarus, 104, 2-19. [6] Klassen, D. R., J. F. Bell III, R. R. Howell, P. E. Johnson, W. Golisch, C. D. Kaminski, D. Griep (1998) submitted to Icarus. [7] James, P. B., J. F. Bell III, R. T. Clancy, S. W. Lee, L. J. Martin, M. J. Wolff (1996) JGR, 101, 18,883-18890. [8] Clark, R. N., G. A. Swayze, A. J. Gallagher, T. V. V. King, W. M. Calvin (1993) USGS Open File Report 93-592.

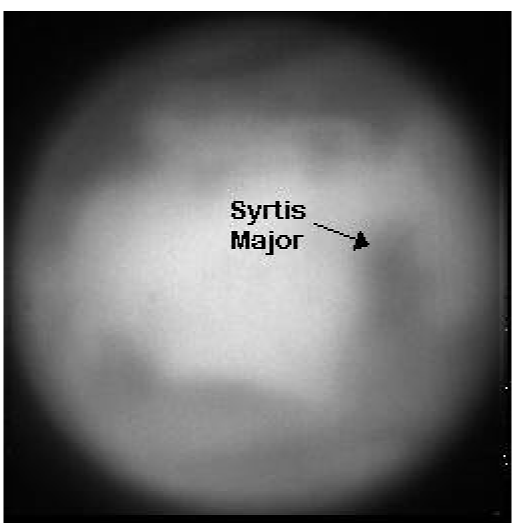

Figure 2 3.194μm image from 04 FEB 95 showing un-projected positions of classic albedo features.

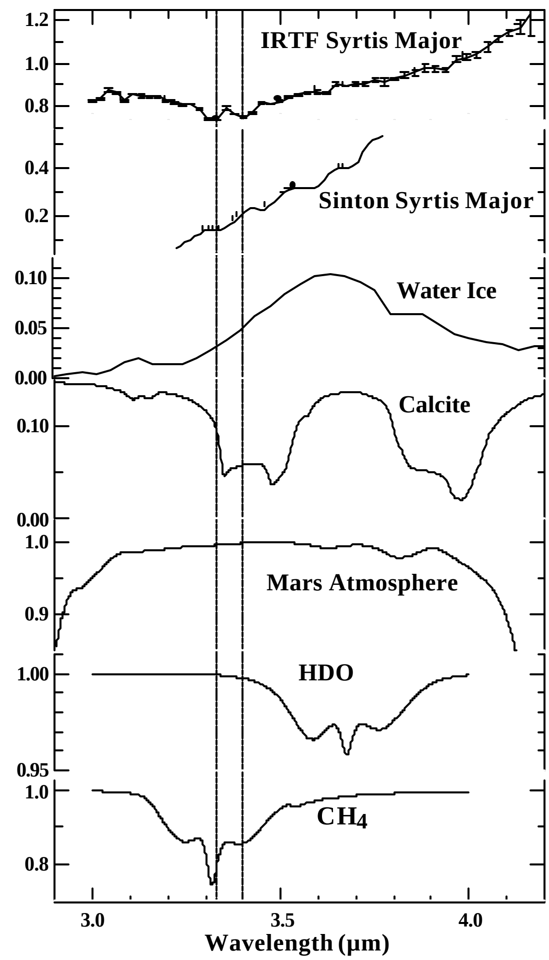

Figure 3 Spectrum of Syrtis Major extracted from 04 FEB 95 image set and normalized to disk average. For comparison the Sinton spectrum [1] is also presented. Spectra of water ice, calcite, an average Mars atmosphere, HDO and CH_4 spectra are presented for somparison of the 3.331 and 3.401μm absorption features seen in Syrtis Major.