N94- 33204

Regional wind regimes are important because the wind distributes sand over an area, removes material from a source, and forms deposits such as dunes. Sand has been or is being distributed in the classical albedo regions of Mars in different ways. In Hellespontus, for example, there appears to be a considerable volume of sand present, but it is entirely piled up into large transverse dunes. In Hellespontus, there appears to be little dark material that is not piled up in dunes. This is in contrast with craters in low-albedo regions like Mare Cimmerium or Margaritifer Sinus, where there are many extracrater dark deposits. The configuration of dunes in Hellespontus might have resulted from winds that were strong enough to strip loose sand from the surrounding areas and deposit the sand in craters.

In contrast, some of the sand from small barchans in Oxia has been removed from the craters to form dark streaks [20]. In places, the streaks coalesce to make larger, low-albedo units like Oxia Palus (9°N, 16°W). Barchans indicate that the amount of loose sand available for transport in Oxia is small relative to Hellespontus, yet the winds might have been more vigorous in order to facilitate the movement of sand in and out of craters and prevent the accumulation of fine, bright dust over the whole region. The coalescence of dark streaks forming Oxia Palus may provide a model for the formation of low-albedo regions like Mare Cimmerium, Mare Sirenum, or Margaritifer Sinus, where the winds may be stronger [21] and the sand supply might be greater than in Oxia, thus causing sand to be more widely distributed. Alternatively, the sources of sand in low-albedo regions might be more ubiquitous. Perhaps sediment beds are currently eroding and feeding the present-day dark eolian deposits found throughout the low-albedo regions.

Which of the two influences, broadly termed "wind regime" and "sand supply," has had the greatest influence on the nature of eolian sediment deposition and removal in different martian regions remains to be understood. One additional factor is the question of climatic change; for example, were the huge piles of sand in the Hellespontus craters deposited under climate conditions that were different from the present?

References: [1] Sagan C. et al. (1972) *Icarus, 17,* 346–372. [2] Cutts J. A. and Smith R. S. U. (1973) *JGR, 78,* 4139–4154. [3] Arvidson R. E. (1974) *Icarus, 21,* 12–27. [4] Peterfreund A. R. (1981)*Icarus, 45,* 447–467. [5] Christensen P. R. (1983)*Icarus, 56,* 496–518. [6] Edgett K. S. (1990) M.S. thesis, Arizona State Univ. [7] Edgett K. S. and Christensen P. R. (1991)*LPSC XXII,* 335–336. [8] Edgett K. S. and Christensen P. R. (1992)*LPSC XXIII,* 325–326. [9] Edgett K. S. and Christensen P. R. (1993) *JGR,* submitted. [10] Haberle R. M. and Jakosky B. M. (1991)*Icarus, 90,* 187–204. [11] Paige D. A. et al. (1993)*JGR,* submitted. [12] Martin T. Z. and Richardson M. I. (1993) *JGR, 98,* 10941–10949. [13] Thomas P. (1984)*Icarus, 57,* 205–227. [14] Edgett K. S. and Christensen P. R. (1991) *JGR, 96,* 22765–22776. [15] Pye K. and Tsoar H. (1990) *Aeolian Sand and Sand Dunes,* 218–220, Unwin and Hyman, London. [16] Lancaster N. (1989) *The Namib Sand Sea,* 111–112, A. A. Balkema, Rotterdam. [17] Wasson R. J. and Hyde R. (1983)*Nature, 304,* 337–339. [18] Rubin D. M. (1984) *Nature, 309,* 91–92. [19] Zimbelman J. R. (1986)*Icarus, 66,* 83–93. [20] Thomas P. et al. (1981) *Icarus, 45,* 124–153. [21] Greeley R. et al. (1993)*JGR, 98,* 3183–3196.

AEROSOLS SCATTERING AND NEAR-INFRARED OBSERVATIONS OF THE MARTIAN SURFACE.   S. Erard, IAS-Planetologia, viale dell'Universita 11, 00185 Roma, Italy.

Introduction: The presence of a scattered contribution in the atmosphere of Mars is a major problem for spectroscopic observations of the surface in the infrared since the main mineralogical absorptions have a typical depth of 1% and could be easily masked or subdued by atmosphere scattering. An estimate of the aerosol contribution between 0.77 and 2.6 μm was previously derived above Tharsis from ISM imaging spectroscopic data acquired from the Phobos 2 spacecraft in 1989 [1]. It is used here to investigate the effect of the scattering on the criteria that allow the mineralogical characterization of the surface.

Aerosols Contribution: Under low opacity and near-normal viewing geometry (the conditions of ISM observations) multiple atmospheric scattering can be neglected. Because the martian aerosols are very bright and strongly forward-scattering in the near-IR, the radiance factor can be further approximated as the sum of the surface reflectance and the backscattering [2]. This model was used to derive an estimate of the scattered spectrum, taking advantage of the overlap between two image cubes in the region of Pavonis Mons
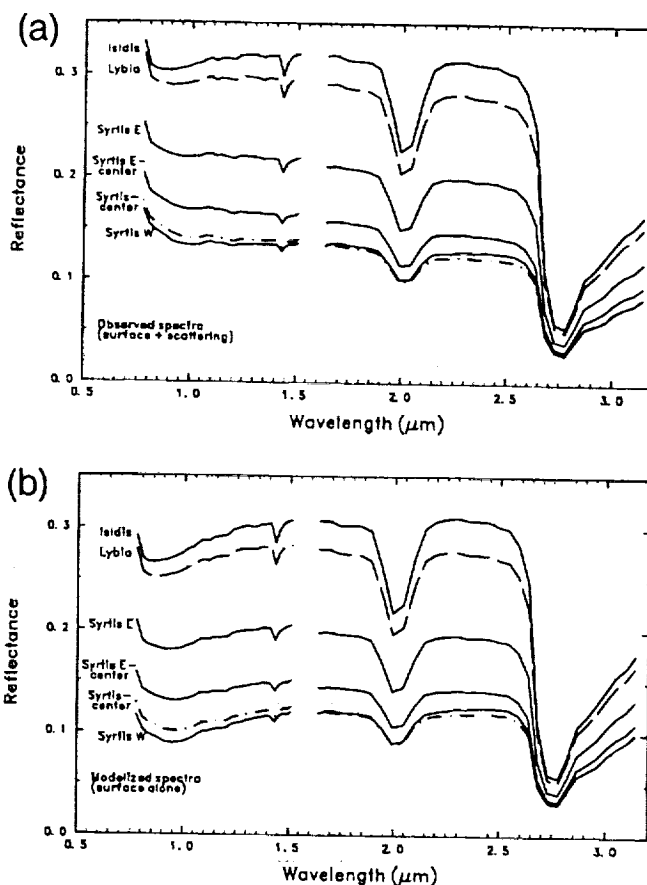

Fig. 1.   Average spectra of the six main spectral units in the Syrtis Major-Isidis Planitia image-cube: (a) calibrated spectra; (b) after removal of the estimated scattering.

TABLE 1.   Range of variation of the spectral criteria in the Syris-Isidis image cube.

	Surface + Scattering (Measured)			Surface Alone (Modeled)		
	Min	Max	Range/rms Noise	Min	Max	Range/rms Noise
Reflectance at 1.09 µm	0.115	0.33	1200	0.08	0.30	1200
Spectral slope reflectance units/µm	−0.025	0.0002	35	−0.010	0.020	30
2-µm pyroxenes (band depth)	0.97	1.00	20	0.98	1.01	20
0.9-µm Fe^{3+} (band depth)	0.965	1.055	50	0.955	1.055	60
1-µm Fe^{2+} (band depth)	0.0	0.40	85	0.0	0.70	150

[1]. The main hypotheses in this procedure are that (1) the aerosol contribution is assumed to be zero at 2.6 µm, (2) the photometric function of the surface is assumed independent of the wavelength, and (3) the difference between extinction and forward scattering is supposed to be small compared to backscattering. Although there is some uncertainty about the absolute level of the spectra, the result is reasonable in terms of opacity ($\tau \approx 0.23$ at 1.9 µm) and is consistent with the efficace radius of 1.2 µm derived from Phobos 2/ Auguste [3].

The image cube covering Syrtis Major and Isidis Planitia (400 × 3000 km^2), which is the more contrasted one, was used to test the effect of the scattering on the spectra. Statistical analysis of these 3000 spectra showed that the vertical scattering contribution can be considered uniform on the whole region, with a value of 0.75× the estimate derived on Tharsis, and no altimetric dependence. This correction is probably overestimated on the darkest areas.

Surface Properties: The six main spectral criteria related to the surface materials are the reflectance at 1.09 µm; the spectral slope, estimated here as the derivative between 1.84 and 2.35 µm; the strength of the 2-µm pyroxene band; an equivalent of the depth of the 0.88-µm ferric oxide band; and the surface of the Fe^{2+} band, integrated from 0.86 to 1.09 µm. They were computed on the whole image cube for the calibrated spectra and for the spectra corrected from scattering (estimate of the surface alone); their values are given in Table 1. The last three criteria were also used to establish a classification of the calibrated spectra [4]; the main spectral types are given in Fig. 1a. The spectra of the same pixels were averaged after subtraction of the aerosols contribution, and are given in Fig. 1b.

Discussion: The level of the scattered spectrum below 2 µm ranges from 0.02 to 0.05, which represents 5–15% of the albedo of the bright areas and 15–30% of that of the dark regions. This large contribution of scattering is similar to that infered for "clear atmosphere" from IRTM observations [5] and independent ISM analysis [6]. The negative spectral slope often ascribed to dark materials appears to be largely due to the aerosol scattering continuum, although intrinsic variations are recognized on the data. The opposition between the eastern and western parts of Syrtis Major is enhanced by the correction.

The three criteria measuring the main surface absorptions are relatively insensitive to the addition of a low-opacity scattered component. Although they are subdued and slightly shifted to longer wavelengths, their spatial distribution and relative contrast are not deeply modified. The Fe^{3+} and 2-µm pyroxene bands appear to be very insensitive to small variations of opacity. Conversely, the Fe^{2+}

band area is reduced by almost a factor of 2, although the transformation is almost a linear stretch of the scale. This reduction may help explain why the mafic features are not always observed from the ground.

We measured the centers of the 1-µm band on the spectra of Fig. 1. On the corrected spectra they are systematicaly shifted by some tens of nanometers toward the short wavelengths, but the shift is not large enough to change dramatically the mineralogical interpretation of the surface: The absorptions are still compatible with hematite on bright regions (center at 0.86 µm) and with calcic pyroxenes in Syrtis Major (center at 0.94 µm), though probably less rich in Ca than previously inferred from ISM [7] (Ca/(Fe + Ca + Mg) $\approx 0.20 \pm 0.08$ instead of 0.275 ± 0.075). Very calcic pyroxenes could have their bands shifted up to 1.05 µm by the addition of a steep scattered component. In this case they could be mistaken for olivine, so no detection of this mineral could be validated unless made under very low opacity.

References: [1] Erard et al. (1993) *LPS XXIV*, 445. [2] Drossart et al. (1991) *Annal. Geophys., 9*, 754. [3] Korablev et al. (1993) *Icarus, 102*, 76. [4] Erard et al. (1993) *LPS XXIV*, 443. [5] Clancy and Lee (1991) *Icarus, 93*, 135. [6] Erard et al. (1992) *LPS XXIII*, 335. [7] Mustard et al. (1993) *JGR* 98 3387.

A MODEL FOR THE EVOLUTION OF CO_2 ON MARS.   R. M. Haberle[1], D. Tyler[2], C. P. McKay[1], and W. L. Davis[1], [1]NASA Ames Research Center, Moffett Field CA 94035-1000, USA, [2]San Jose State University, San Jose CA 95192, USA.

Our MSATT work has focused on the evolution of CO_2 on Mars. We have constructed a model that predicts the evolution of CO_2 on Mars from a specified initial amount at the end of the heavy bombardment to the present. The model draws on published estimates of the main processes believed to affect the fate of CO_2 during this period: chemical weathering, regolith uptake, polar cap formation, and atmospheric escape. Except for escape, the rate at which these processes act is controlled by surface temperatures that we calculate using a modified version of the Gierasch and Toon [1] energy balance model. The modifications account for the change in solar luminosity with time, the greenhouse effect, and an equatorial (as well as polar) energy budget. Using published estimates for the main parameters, we find no evolutionary scenario in which CO_2 is capable of producing a warm (global mean temperatures >250K) and wet (surface pressures >30 mbar) early climate, and then evolves to present