IRON OXIDE MINERALOGY ON MARS: NEW RESULTS BASED ON HIGH RESOLUTION IMAGING SPECTROSCOPY DURING 1988; James F. Bell III, Thomas B. McCord, and Paul G. Lucey (Planetary Geosciences, Univ. Hawaii, Honolulu 96822)

"Mars differs from other planets in showing strong, fixed markings. We do not need to imagine; we can actually observe what takes place."
—E.C. Slipher (1962)

Introduction: Approximately every 13-15 years, groundbased astronomers are afforded brief yet unusually rich opportunities to observe Mars from a distance of only ~ 60 million km and at a maximum angular diameter of ~ 25 arcseconds. At times such as these, the planet can be studied at spatial scales as small as 150 km. The late summer/early fall perihelic opposition of Mars in 1988 provided one such opportunity. Significant advances over the last two decades in telescopic instrumentation and detector technologies, most notably the advent of widespread use of CCD's in observational astronomy and the construction of remote, high-altitude observatories has brought about a huge leap in our ability to (1) Obtain digital images and spectra of the planet at small spatial scales, (2) Acquire these data in an extremely large number of wavelengths ranging from the near-UV out to the mid-IR (roughly 0.3 to 12 μm), and (3) Be assured that these data are of high signal-to-noise (S/N) and high reliability because of specifically designed, well-focused observing strategies and low atmospheric water vapor content over observatories such as Mauna Kea.

Measurements discussed here were obtained through an observing program which emphasized the acquisition of high spectral resolution data in the visible to near-IR (0.3-1.07 μm), specifically concentrating on the identification and analysis of spectral absorption features characteristic of Iron oxides and hydroxides long known to occur in this wavelength region (see Table I). Previous remote sensing datasets, obtained at typical spectral resolution of 2-5% have indicated the presence of ferrosilicate and ferric oxide bands near and shortward of 1.0 μm [1,2,3]. These previous spectra have not, however, revealed the existence of specific Fe^{3+} ligand field transitions, and this fact has been generally interpreted to indicate that the surface soils (and airborne dust) are relatively free of crystalline ferric oxides.

Dataset: The new 1988 measurements reported here include ~ 10,000 individual spectra at both medium (1.5%) and high (0.3%) spectral resolution, as well as full disk images (spectral image cubes) in nearly 250 colors from 0.4 to 1.07 μm. Details of the spectrographic instrumentation and data acquisition methods are discussed elsewhere [4]. The data underwent standard photometric reductions using the stars η Psc and α Aqr. Further reductions need to be performed, particularly in terms of martian atmospheric correction, to produce finalized normal reflectance spectra and cylindrical projection albedo maps.

Results: The moderate resolution point spectra obtained in mid-August (L_s 250°) are very much like those published previously [2,3] in their broad, spectral shape in the visible, however they exhibit much more structure than the previously published data due to (1) higher spectral resolution (2) low telluric atmospheric water vapor content, and (3) unusually low dust opacity in the martian atmosphere, as inferred from the striking visibility of even the most subtle surface albedo features during most of the opposition. The most exciting new result is the identification of a rather strong 0.65 μm Fe^{3+} absorption [3,5,6] which appears to vary in magnitude between classical bright and dark regions (Fig. 1). Continued reduction of these data will concentrate on attempts to distinguish the reflectance signature of the airborne dust from that of the actual surface soils.

The high resolution point spectra (at 5 times the resolution of the data in Fig. 1), provide verification of the 0.65 μm Fe^{3+} feature and its variation with surface albedo. Additionally, the resolution of these data allows a much more detailed determination of exact band positions associated with minor bands and inflections shortward of 0.6 μm (Fig. 2). These spectra are accompanied by 14 sets of 250 color full disk images representing nearly 65% coverage of the planet from roughly 40°N to 90°S and for 220° of longitude, centered on the zero meridian.

Summary and Implications: It appears that for the first time, crystalline bands in the visible to near-IR have been detected on Mars through imaging spectroscopic methods. The presence of these absorptions strongly suggests that there is some crystalline iron oxide component in the martian surface material. Band positions and strengths, once fully quantified, can be mapped across the regions observed. An important part of this analysis will be the attempt to untangle the surface soil reflectance and its spectral characteristics from that of the small but nontrivial airborne dust load (which is known to vary at least in its distribution). Final data products will include spectral images, high S/N point spectra, cylindrical projection normal albedo maps, color ratio images, and 2-D histogram spectral unit maps. Future laboratory studies will concentrate on the identification and analysis of more potential Mars soil analogs which are consistent with the new data, as well as the mixing model systematics of the new Mars data, which almost certainly represent a complex blend of a number of pure Fe-bearing endmembers.

References: [1] McCord, T.B. and J.A. Westphal (1971) *Astrophys. J.*, **168**, 141. [2] McCord, T.B. *et al.*, (1978) *J.G.R.*, **83**, 5433. [3] Singer, R.B. (1982) *J.G.R.*, **87**, 10159. [4] Bell III, J.F. and P.G. Lucey, in preparation. [5] Hunt, G.R. and J.W. Salisbury (1971) *Mod. Geol.*, **2**, 195. [6] Sherman, D.M. and T.D. Waite (1985) *Amer. Mineralogist*, **70**, 1262.

Table I. Mauna Kea Observing Parameters

Date (UT)	Telescope	L_s	Phase Ang.	Instrument
5/1/88	U.H. 88"	188°	44°	0.5-1.0μm spectrograph
8/13/88	U.H. 24"	250°	34°	0.3-1.0μm CVF
8/25/88	U.H. 88"	259°	27°	0.3-1.0μm spectrograph
9/24/88	"	278°	5°	"
9/28/88	"	280°	3°	"

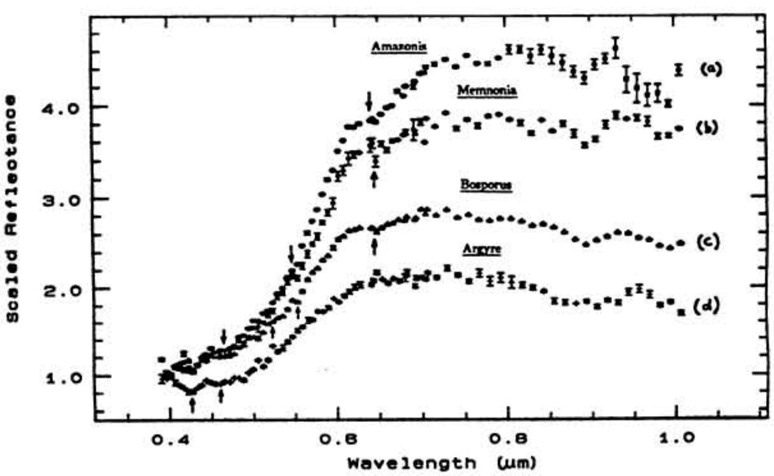

Figure 1: Moderate spectral resolution (1.5% channel to channel) circular variable filter (CVF) spectra of 200-300 km size spots on the martian surface. These 4 spots (of the 22 sampled) show several minor bands or inflections (arrows) associated with the intense near-UV absorption edge and interpreted as Fe^{3+} bands. Note the weakening of the 0.65 μm band with decreasing surface albedo.

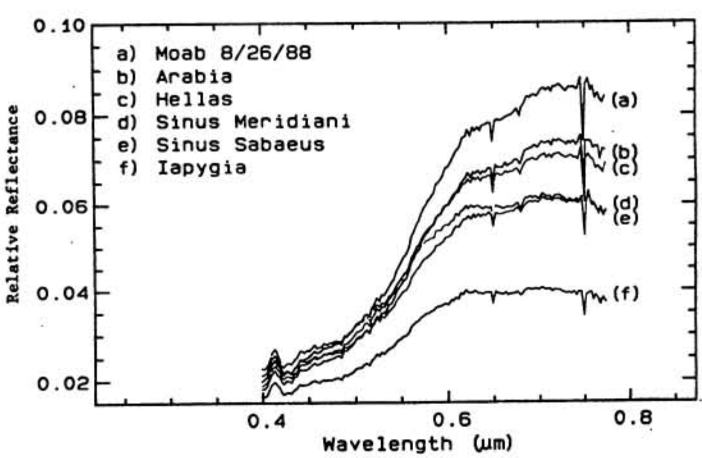

Figure 2: High spectral resolution (0.3% channel to channel) grism spectra of selected 150-200 km size regions on the martian surface. The 0.65 μm Fe^{3+} band is again detected, and minor bands and inflections shortward of 0.6 μm are more accurately determined due to the high resolution and S/N of the dataset. The feature at 0.42 μm is an artifact of the standard star, and the small "spikes" near 0.65 and 0.75 μm are caused by telluric atmospheric absorptions.