COMPOSITION OF WEAKLY ALTERED MARTIAN CRUST:

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Introduction: The mineralogic and chemical composition of weakly altered crust remains an unresolved question for Mars. Dark regions hold clues to the composition since they are thought to comprise surface exposures of weakly altered crustal materials (e.g. 1,2). Understanding the in situ composition of relatively pristine crustal rocks in greater detail is important for investigating basic volcanic processes. Also, this will provide additional constaints on the chemical pathways by which pristine rocks are altered to produce the observed ferric iron-bearing assemblages and inferred clay silicate, sulphate, and magnetic oxide phases. Reflectance spectra of dark regions obtained with the ISM instrument are being used to determine the basic mineralogy of weakly altered crust for a variety of regions on Mars. The first results of this analysis are presented here.

Spectral Data: High spatial resolution (22 km/pixel) imaging spectrometer data were acquired in 1989 by the ISM instrument onboard the Phobos 2 spacecraft for 9 different areas near the equatorial regions on Mars (3,4). The data windows are $\approx$300 km wide and 2000 km long and sample a wide variety of terrain and surface morphologies. The surface in the Tharsis plateau and Valles Marineris regions were well sampled with additional coverage in the Arabia and the Syrtis Major-Isidis regions. A 128 channel reflectance spectrum from 0.76 to 3.16 μm was obtained for each pixel of which 64 channels are used in these analyses. The signal to noise ratio is > 300:1 across most of the detector elements and the absolute radiometric accuracy is $\approx$10%. Details of data reduction and calibration are presented elsewhere (4,5).

Composition of "Fresh Crustal Materials": Surfaces that are weakly altered, or relatively "fresh", are identified and the basis of several spectral properties (albedo, spectral slope, wavelength of band minimum, band area) that have been discussed previously (5). A relatively fresh surface is typically low in albedo, has a flat to slightly negative continuum slope, large band area, and a band minimum at wavelengths longer than $\approx$0.9 μm. The entire ISM data set has been transformed into a suite of spectral parameters that characterize these properties . From the parameter maps, many regions have been identified that contain spectra that meet the freshness criteria. A subset of these spectra, with continuua removed, are shown in **Figure 1**.

These spectra sample geologic units of different age and surface morphology. The general geographic region is listed along the left margin of **Fig. 1**. All show a strong, well-defined absorption near 1.0 μm and an absorption of variable strength and definition near 2.1 μm. The shape, position, symmetry, and strength of these absorptions provide unambiguous identification of calcic pyroxene as a mineral phase on the Martian surface (5). However, the spectra also show diversity in the shape, position and relative strengths of these two dominant absorptions suggesting that additional mineral phases are present or that the compositions of the pyroxenes differ. Since pyroxene reflectance spectra exhibit variations in the wavelength position of absorption band minima that are systematic with composition (6,7,8), band minima provide a simple tool for deriving initial estimates of the pyroxene chemistry for these surfaces. The wavelength position of absorption band minima for the 1.0 and 2.0 μm bands of the spectra shown in **Fig. 1** were determined and are presented in **Table 1**. A plot of the wavelength of the 1.0 vs 2.0 μm band minima for these areas (**Figure 2**) illustrates that most conform to the experimentally determined pyroxene trend and these spectra are likely to be dominated by pyroxene of a unique composition. For those that fall off the main trend (e.g. Coprates Chasma) one or both bands is probably modified by other, currently unresolved, mineral components. Using the results of (7), estimates of pyroxene chemistry were derived and are presented in **Figure 3**. The validity of these estimates depend on the completeness of the analysis of (7) and that the band parameters are dominated by the absorption properties of a single pyroxene. Nevertheless, regional variations in pyroxene, and therefore rock composition, are strongly suggested by these results.

Discussion The results obtained thus far show: 1) Relatively unaltered crustal material is well exposed in several areas on the surface over the spatial scale of an ISM pixel ($\approx$500 km^2). They contain well crystalized pyroxenes of augitic composition and are of moderate iron content, consistent with SNC meteorites (9). 2) Surface morphology and pyroxene composition indicate a volcanic origin and basaltic composition for many of the areas studied. 3) Clearly defined variations in pyroxene absorption bands imply differences in pyroxene composition and/ or whole rock mineralogy and composition for different geographic regions on Mars.

Direct evidence of additional mineral phases is not immediately evident from a qualitative examination of **Fig. 1**. Feldspar is certainly an expected phase and may be responsible for the shoulder of variable intensity between 1.1 and 1.3 µm. However clino-pyroxene can have a well defined band in this wavelength region (e.g. 10) and olivine may contribute as well. In order to address the question of complete mineralogy, we are currently pursuing the application of more sophisticated mineralogic modelling approaches (e.g. 11). However, this will require some restructuring of the approaches to include the expected mineral compliments and effects of grain size distributions expected in the natural system (12). In addition to continuing the mineralogic modelling we are examining high resolution images of the surface to better understand surface morphology and possible clues to the differences in composition.

References: (1) Arvidson, R., E., (1989)*J. Geophys. Res.*, *94*, 1573-1587 (2) Singer, R. B., (1980) *(abstr) Lun. Plan. Sci.* XI, 1048-1050 (3) Bibring, J-P., *et al.*, (1989) *Nature*, 341, 591-592 (4) Erard, S. *et al.*, (1991) *Proc. Lun. Plan. Sci.* 21, 437-456 (5) Mustard, J. F., *et al*, (1992) The surface composition of Syrtis Major: (*in press*) *JGR-Planets* (6) Adams, J. B. (1974) *J. Geophys. Res.*, 79, 4829-4836. (7) Cloutis, E.A. and M. J. Gaffey (1991) *J. Geophys. Res.* 96, 22809-22826. (8) Hazen, *et al.*, (1978) *Proc. Lun. Plan. Sci.* VIII, 2919-2934. (9) McSween, H. Y (1985) *Rev. Geophys. 23*, 391-416. (10) Besancon, J. R. *Am. Mineral. 53*, 965-973. (11) Sunshine *et al.*, (1990) *J. Geophys. Res.*, 95, 6955-6966. (12) Mustard, J. F., *et al.*, (1993) *(abstr) Lun. Plan. Sci.* XXIV (this volume).

Table 1

Location	1.0 µm^1	2.0 µm^2
Arabia	0.925	2.05
Coprates	0.938	2.18
Juventae	0.976	2.16
Melas Ch.	0.972	2.20
Melas Cap	0.969	2.14
Eos Ch.	0.964	2.20
Capri Ch.	0.996	2.21
Nili Patera	0.995	2.20

1) ± 28 nm 2) ±50 nm

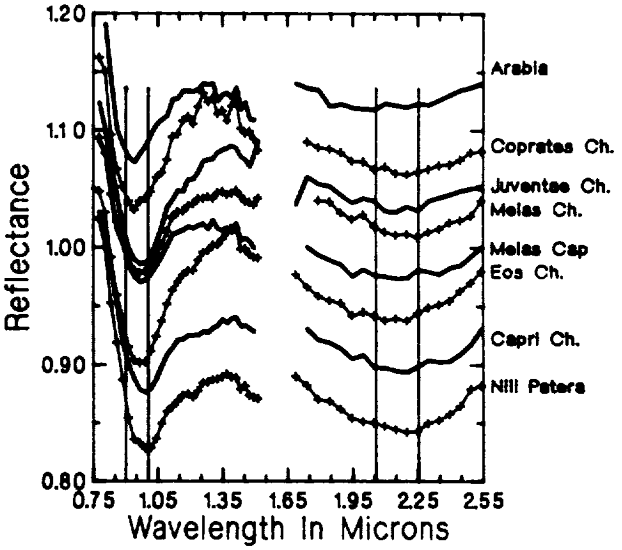

Figure 1

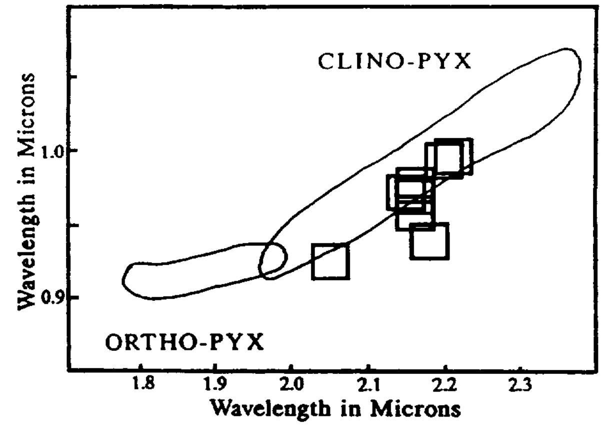

Figure 2
Band minima from Table 1 plotted on the 1.0 vs 2.0 µm band minima plot. Boundaries of pyroxene fields after (7).

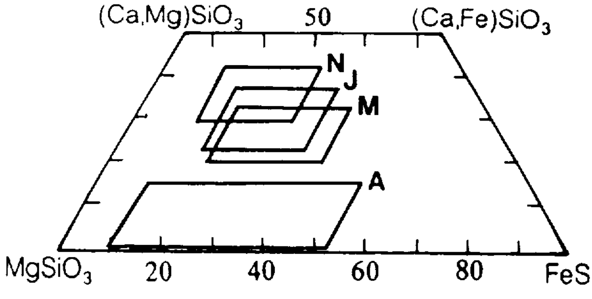

Figure 3
Estimated pyroxene compositions for Arabia (A), Melas Cap (M), Juventae Chasma (J) and Nili Patera (N)