

MAFIC MINERALOGY OF MARTIAN VOLCANICS: VARIATIONS IN SPACE AND TIME: J. F. Mustard¹ and J. M. Sunshine² (1) Dept. Geol. Sci., Box 1846, Brown University, Providence RI, 02912, (2) SETS Tech. Inc., 300 Kahelu Ave., Miliani, HI 96789.

Introduction: The high spatial resolution, spectral coverage, and high signal to noise of the ISM data have permitted the determination of a mineralogic basis for the spectral properties of weakly altered regions of Mars [1]. Through the use of the Modified Gaussian Model (MGM)[2], it was demonstrated that weakly altered mafic materials are dominated by two-pyroxene basalts, analogous to the basaltic SNC meteorites. In addition, differences in spectral properties between Eos Chasma and Nili Patera were best modelled as a change in relative modal abundance of low (LCP) and high (HCP) calcium pyroxene, with Nili Patera enriched in high-calcium pyroxene relative to Eos Chasma. There is a great deal of diversity within other spectra of weakly altered crust identified thus far, and some of this diversity is due to mixing with dust and alteration products, and some to mineralogic variations. We have examined the mineralogic basis for this diversity to determine how regionally extensive these mineralogic differences are, the degree of homogeneity of surface compositions, and if other compositional units can be identified. For all areas examined, the weakly altered materials on Mars are best modelled as two-pyroxene basalts enriched in HCP. Syrtis Major, a low relief, Early Hesperian, shield volcano, has a homogeneous composition with the highest relative abundance of HCP. Ophir Planum, a region of ridged, volcanic(?) plains, is also enriched in HCP, but has $\approx 12\%$ less than Syrtis, while the floor of Valles Marineris is the $\approx 20\text{-}25\%$ less HCP than Syrtis. These differences can be interpreted to indicate a change in source mantle composition from relatively fertile (Syrtis Major, Ophir Planum) to depleted (Valles Marineris), which would be consistent with the relative ages and environments of formation.

Mineralogic Determinations with the MGM: On the basis of several spectral criteria discussed previously [1,2], spectra of weakly altered regions have been identified and through simple analysis of the position of the minima of the 1 and 2 μm pyroxene absorption features, three primary classes have been identified: 1) Plateau Plains (longest wavelength band minima, Syrtis Major, Ophir Planum), 2) Valles Marineris (intermediate wavelength band minima), and 3) Western Arabia/ southeastern Oxia Palus (shortest wavelength band minima). For each of these major groups, our goal is to characterize the mafic mineralogy with the MGM of each group. These results can then be used to determine if the different terrains represent distinct and unique compositions and thus related to the environment of formation, or are part of a continuum of compositions related in some other way.

The MGM has been used to deconvolve overlapping absorptions in mafic mineral mixtures, solid solution series, and natural lithologic samples [3,4,5]. A strength of the MGM is that it is apparently not affected by particle size variations [5]. Spectra are modelled as a series of absorption bands superimposed on a baseline or continuum. These computations were done in energy (cm^{-1}) and natural log reflectance (absorption processes are symmetric in energy and strength is an exponential function of absorption coefficient) where superimposed, overlapping absorptions are additive and can be modelled using linear inverse theory. With lithologies that contain several mineral components and weak bands, the model calculations are constrained by stochastic inversion methods [6] that include general limits on the wavelengths of band minima, absorption widths, and/or mathematical coupling of absorption strengths.

For the spectra of Mars, we have determined the optimum set of starting conditions for the MGM model (appropriate continuum slope, initial band positions, strengths, and widths for a ferric component, low (LCP), and high calcium pyroxene (HCP))[1]. The model is applied with a consistent methodology for each spectrum. The same starting conditions are used for each application. First the continuum slope is fit, with the band parameters set to initial, starting values. Then the continuum slope is fixed and all the band parameters are allowed to vary until the improvement to the fit is minimal. Finally, the continuum and all band parameters are allowed to vary, again until the improvement to the fit is minimal. Each result is critically evaluated in the context of existing mineralogic data bases and modelling experience (e.g. [4,7,8]) to assess the

validity of the solutions. Solutions that are consistent are accepted, those rejected will be examined to assess whether this is due to unmodelled mineralogy or calibration.

Results: It is necessary to perform these calculations one spectrum at a time, and thus progress is slow. Of the 50+ spectra examined thus far, 21 spectra (11 from the floor of Valles Marineris, 7 from the surface of Syrtis Major, and 4 from the surface of Ophir Planum) satisfy the criteria for weakly altered properties, and also provide acceptable solutions from the MGM. The parameters defining the absorption bands (center, strength, width) provide the essential information for analyzing the mineralogies. For pyroxene mixtures, the ratio of the strength of the LCP to the HCP pyroxene bands has been shown to be a quantitative measure of the relative abundance of these minerals. This ratio for the 2 μm region of the 21 spectra analyzed is shown in Figure 1. Though the LCP/HCP ratio for the 1 μm band is consistent, we use the 2 μm ratio because it is not affected by overlapping absorptions from ferric materials.

It is clear from Figure 1 that these three areas have distinct differences in the ratio of LCP to HCP. The volcanics in Syrtis Major are enriched in HCP relative to the materials on the floor of Valles Marineris, while the plateau plains of Ophir Planum are intermediate between these. The relationship between LCP:HCP ratio and relative abundance of these pyroxenes presented by [3] was used to calculate the change in relative pyroxene abundance of these areas. This is shown in Figure 2, using the mean values from each area, with the error bars showing the variability to 1-standard deviation. It is evident from this, and previous analyses [1], that that two-pyroxene basalts with a high proportion of HCP are common on Mars. In addition, the low albedo and strong bands imply that pyroxenes make up a large fraction of the modal mineralogic abundances. These compositions are comparable to the basaltic SNC meteorites that are thought to have crystallized from magmas with major element composition analogous to terrestrial basaltic komatiites [9]. Thus the variability in the relative modal abundances of pyroxenes is likely associated with bulk CaO content. We hypothesize that the volcanics on the floor of Valles Marineris came from depleted sources relative to the plains volcanics represented by Syrtis Major and Ophir Planum. If true, these compositions may reflect the evolution of the composition of the martian mantle from enriched (source materials for early plains volcanism) to slightly depleted (source regions for later volcanism on floor of Valles Marineris).

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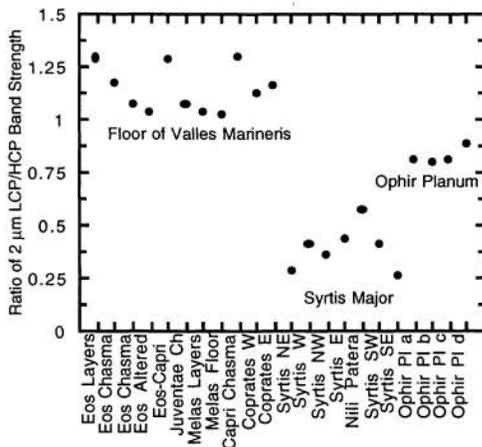


Figure 1. Relative band strength of low calcium (LCP) to high calcium (HCP) pyroxene from MGM analysis of ISM spectra for regions indicated along the bottom of figure.

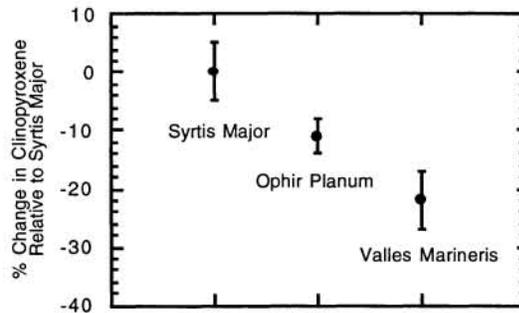


Figure 2. Difference in %HCP/(HCP+LCP) for each of the major areas analyzed with ISM and the MGM. The %HCP change is derived from relationships presented in [3].