OLIVINE-METAL MIXTURES: SPECTRAL REFLECTANCE PROPERTIES AND PHASE DETERMINATIONS ; Edward A. Cloutis, Department of Geology, University of Alberta, Edmonton, Alberta, Canada T6G 2E3

A systematic study of the spectral reflectance properties of olivine-meteoritic metal mixtures was undertaken in order to develop procedures for extracting quantitative information on metal and silicate grain sizes, abundances and chemistries. In order to obtain the greatest amount of compositional information, a number of spectral parameters must be examined sequentially.

Experimental Technique: A series of 25 wt. % interval mixtures of olivine-metal were spectrally characterized in the 0.35-2.6μm range, in addition to olivine-carbon and olivine-magnetite series. The olivine is from San Carlos, AZ and contains 9.6 mole % FeO. The metal was ground from a fresh, rust-free interior piece of the Odessa, TX iron meteorite. The metal shavings were magnetically separated to remove grinding wheel contaminants, and beaten to reduce their filamentary shape to a more equidimensional habit. Additional olivine spectra were assembled from the literature *(1-4)*.

Results: A large number of spectral parameters were examined in order to search for characteristics which could be easily applied to the analysis of suspected olivine-metal assemblages. The first step in the analysis is to determine whether the reflectance spectrum to be deconvolved is consistent with olivine-metal mixtures. It must show an absorption band between ~1.04 and 1.09μ, and no appreciable band near 2μm (Figure 1). The reflectance ratio 2.5μm/1.8μm is a sensitive indicator of the metal abundance and its particle size. All clean, naturally occuring olivines are relatively flat in this wavelength region regardless of particle size (Figure 2). The addition of meteoritic metal, which has a red slope, systematically increases this ratio. Although mixtures of large metal-small olivine were not run, extrapolations from pure metal spectra suggest that a four fold increase in metal size results in only a 10% overestimation of metal abundance. There is some overlap between fayalitic olivines and metal-olivine mixtures but the latter show a marked decrease in reflectance at decreasing wavelength. A horizontal continuum constructed tangent to the local maximum between ~0.5 and 0.7μm intersects the long wavelength wing of the major Fe^{2+} at progressively shorter wavelengths with increasing metal content. In the pure olivines, this intersection point is independent of chemistry and particle size (Figure 3). The intersection point can be used to determine metal abundance with a high degree of accuracy. A fourfold increase in metal grain size would result in a ~15% overestimation of metal abundance. The latter two criteria (2.5μm/1.8μm ratio; intersection point) can be used to determine metal abundance and grain size irrespective of the olivine properties, provided the 1μm Fe^{2+} absorption band is resolvable.

The olivine grain size may differ from the metal due to their different material properties. The reflectance ratio 1.8μm/ 1μm band minimum is sensitive to olivine grain size (Figure 4). Increasing grain size is accompanied by an increase in this ratio until band saturation is reached near a ratio of 10:1. A number of vertical lines representing olivine metal mixtures can be superimposed on Figure 4. Since the grain size and abundance of the metal have been previously determined, an appropriate amount of metal can be subtracted from this ratio to yield the olivine grain size.

The remaining criterion which can be established is the ferrous iron content of the olivine. A similar procedure to that used in Figure 4 is applied. A series of vertical lines can be constructed on Figure 5 representing different metal-olivine grain sizes. By placing the 1.8/~0.7μm peak reflectance ratio in the field at the previously determined metal abundance/grain size, the intersection of the vertical line with the least squares fit to the olivine data can yield a rough estimate of the olivine's iron content. In the absence of high quality spectral data this calibration may be the only method suitable for constraining the olivine chemistry. Where high quality spectral data is available, the wavelength position of the band minimum can be used for iron content determination. Perhaps surprisingly the wavelength position of the major olivine band does not vary substantially with metal abundance (Figure 6). The available laboratory data for clean, naturally occuring olivines and the metal olivine mixtures show a high degree of linearity. The position of the band minimum can be used to determine the iron content to within ±~10%.

One possible source of ambiguity arises from olivine-amorphous carbon mixtures. A lab spectrum of 99.5:0.5 olivine:carbon is virtually identical to an interpolation between 75:25 and 50:50 olivine:metal spectra. The amorphous carbon which is spectrally flat, or even slightly blue imparts a red slope to the olivine at low abundances along with reducing the overall reflectance (3). Magnetite-olivine mixtures were also examined and show a number of differences from the olivine-metal spectra which can be used to easily separate these two types of assemblages (2).

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OLIVINE-METAL SPECTRA
Cloutis, E.A.

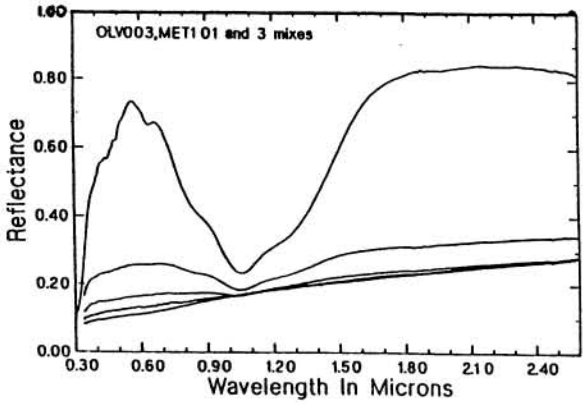

Figure 1. Reflectance spectra of different wt. % mixtures of olivine and meteoritic metal.

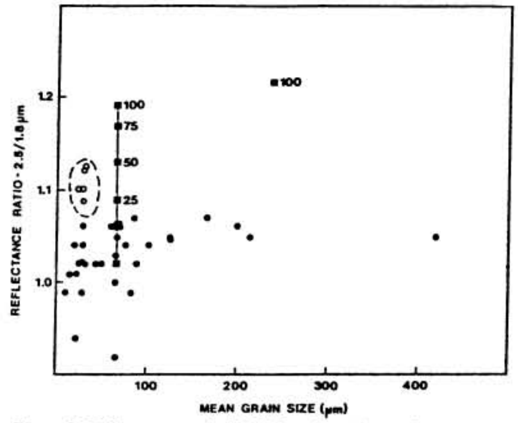

Figure 2. Reflectance ratio 2.5/1.8µm for olivines (filled circles selected fayalitic olivines (open circles), and olivine-met mixtures (squares) versus mean grain size. Numbers indica metal abundance in the olivine-metal mixtures.

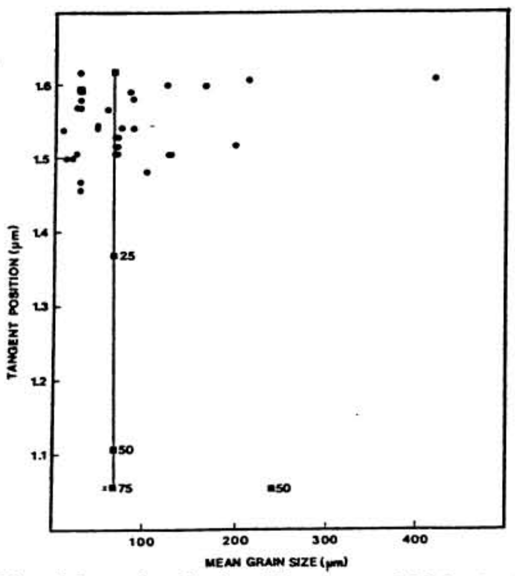

Figure 3. Intersection of horizontal line tangent to 0.5-0.7µm local maximum with the long wavelength wing of the major olivine absorption band versus particle size. Symbols are the same as in Figure 2.

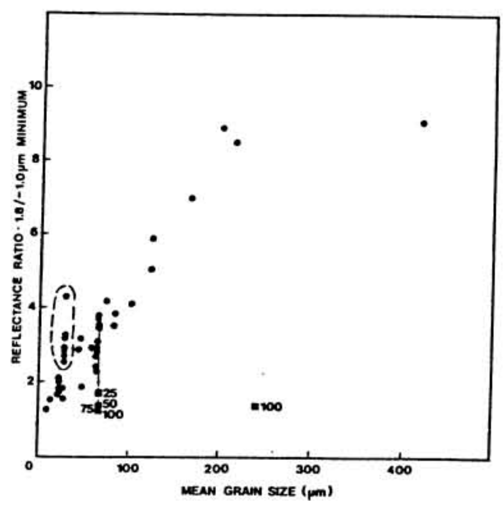

Figure 4. Reflectance ratio 1.8µm/1µm band minimum versus grain size. Symbols are the same as in Figure 2.

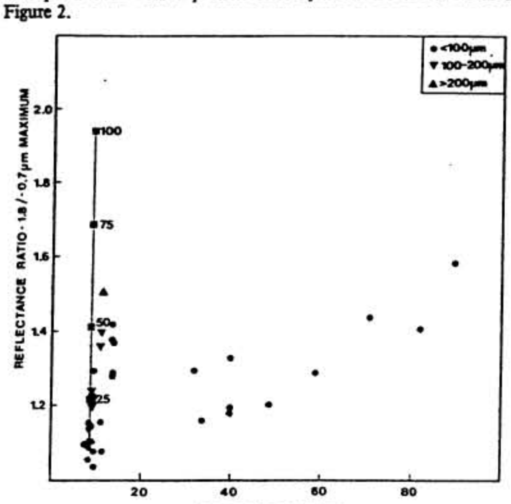

Figure 5. Reflectance ratio 1.8µm/0.5-07µm-local maximum versus olivine iron content. Symbols are the same as in Figure 2.

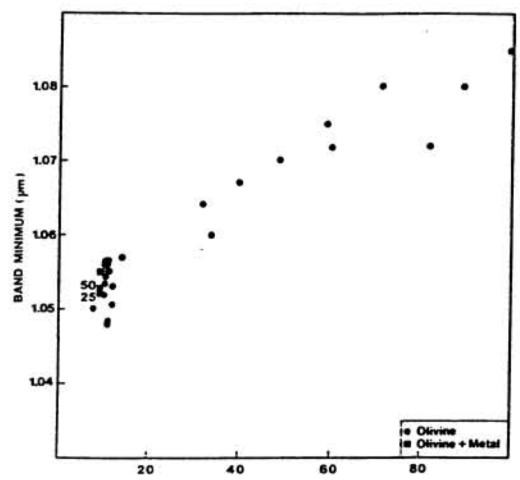

Figure 6. Wavelength position of the olivine band minimum versus olivine iron content. There is no systematic variation with increasing iron content. Symbols are the same as in Figure 2.