TRACING OXYGEN FUGACITY IN ASTEROIDS AND METEORITES THROUGH OLIVINE COMPOSITION.

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Introduction: Olivine absorptions are known to dominate telescopic spectra of several asteroids [1]. Among the meteorite collection, three groups (excluding Martian meteorites), the pallasites, brachinites, and R group chondrites are plausible analogs to olivine-rich asteroids in that they are dominated by olivine. These meteorite groups have distinct petrologic origins. The primitive achondrite brachinites (which include both depleted and undeleted subgroups) are products of relatively minor differentiation and evolved in oxidizing environments [2-3]. R chondrites are also thought to have formed in high oxygen states, but are closely related to ordinary chondrites (yet with their own distinct compositions and oxygen isotopic signatures) [4, 5]. In contrast, pallasites, widely thought to be mantle components from much more evolved bodies, formed in more reducing environments [6, 2].

Petrologic indicators that are identifiable in spectral data must be used in order to infer the petrologic history of asteroids from surveys of their actual population. As discussed below, olivine composition (e.g. Fa#) can provide key constraints in exploring the origin and significance of olivine-dominated asteroids.

Oxygen Fugacity: All three groups of olivine-dominated meteorites contain 70-90% olivine; yet can readily be distinguished from each other in detailed petrological and geochemical studies. Fe-Ni metal content can be used, for example, to separate pallasites from brachinites. However, Fe-Ni cannot be uniquely identified in spectral surveys of the asteroid population, as similar spectral effects can be caused by space weathering [7].

There is also, however, compositional diversity among the olivine dominated meteorite groups. Brachinites and R-chondrites have relatively Fe-rich compositions (Fa_{35-40}), while the pallasite are Mg-rich (Fa_{10-20}). Thus, the olivine composition of olivine-dominated asteroids can be used to trace differences in oxygen fugacity in the asteroid population and thus in conditions within the solar nebula.

Meteorite Spectra: To test our ability to infer olivine composition and to provide a basis for comparison for asteroid spectra, we have begun a new program to collect reflectance spectra of well-characterized olivine-rich meteorite samples. In particular, we have collected new data on brachinites (EET99402 and NWA753), R-chondrites (Rumuruti), and are in the processes of collected new data on pallasites. Spectra of these samples and existing data on the Marjalahti pallasite [8] are shown in **Figure 1**. In all cases, quantitative analysis of these meteorite spectra are complicated by the presence of small absorptions in the 2 μm region that are due to terrestrial alteration and/or pyroxene.

Inferring Olivine Composition: Previous studies have successfully used absorption band modeling to infer composition from laboratory spectra of terrestrial olivines [9]. In this work, olivine absorption features are resolved into three individual absorption bands that arise from electronic transitions of Fe^{+2} within the M1 and M2 olivine crystallographic sites. As with the overall absorption feature [8], each of these bands is shown to move to longer wavelengths with increasing Fe content [7]. In addition, the relative strengths of M1/M2 absorptions are also observed to change with olivine composition. This combination of absorption band positions and relative strengths are strong indicators of olivine composition.

Preliminary Results for Meteorite Spectra:

We have begun our analyses with Fe-rich meteorites, as spectral studies have typically focused on terrestrial Mg-rich olivines. The spectrum of brachinite EET99402 (**Figure 1**) is almost devoid of features in the 2 μm region and includes a broad feature near 1 μm indicative of olivine. As shown in **Figure 2**, the spectrum of EET99402 is well modeled with olivine absorptions. Furthermore, based on results from terrestrial olivines [9], the position and relative strengths of the three absorption bands (shown in green) imply a composition of $Fa_{28\pm5}$. This result is in excellent agreement with the petrographic result of Fa_{35} [10].

The spectrum of the R chondrite Rumuruti clearly includes an absorption in the 2 μm region. This complication requires that we constrain our modeling to test various olivine compositions, while including two additional major absorptions for pyroxene (near 1 and 2 μm). Results (**Figure 3**) indicate the Rumuruti is Fe-rich, with an inferred composition of $Fa_{56\pm5}$ plus a Ca-rich pyroxene. This is broadly consistent with petrographic studies that indicate an olivine composition of Fa_{39} and 5% calcic pyroxene [5]. Our next efforts will focus on spectral studies of the Mg-rich pallasites.

Olivine-Rich Asteroids: Given the presence of olivine-dominated meteorites, it comforting that olivine absorptions are clearly present in previous generations of asteroid spectra [e.g. [1, 11]. Previous analyses of these data suggest that olivine on these asteroids are Mg-rich [*e.g.*, 1, 9, 12]. Our preliminary study using extended infrared data suggests at least one olivine-rich asteroid might be Fe-rich. On-going observations of asteroids with the recently developed SpeX instrument [*e.g.*, 13] include olivine-rich spectra with excellent signal-to-noise and spectral resolution that can better support the identification of the composition of olivine on these asteroids.

Preliminary results, taking into account the temperature variations of olivine absorptions [*e.g.*, 12, 14], indicate most of the olivine-rich SpeX asteroid spectra include some pyroxene absorptions and that most, but not all, of the olivine is Mg-rich.

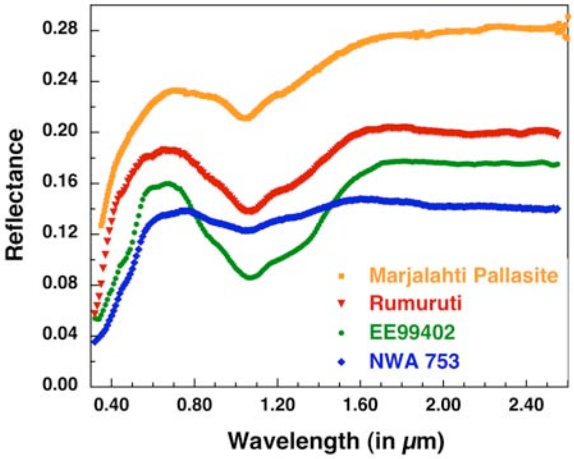

Figure 1: ***Laboratory Reflectance Spectra of Olivine-Dominated Meteorites***

(*Note, for display purposes, the spectrum of the Marjalahti Pallasite is scaled by 0.5.)*

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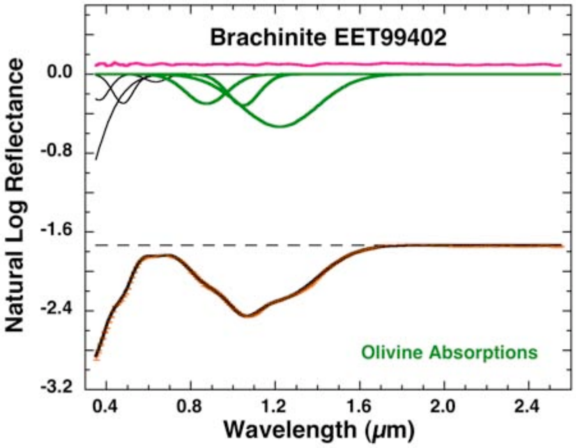

Figure 2: ***Absorption Band Model Fit to the Spectrum of Brachinite EET99402***

The position and relative strength of the three olivine absorptions (in green) are consistent with its known composition (Fa35) [10]. (The residual error (magenta) is offset 10% for clarity.)

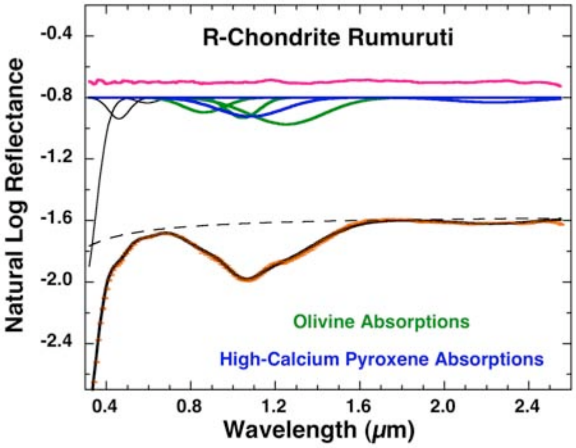

Figure 3: ***Absorption Band Model Fit to the Spectrum of Rumuruti, an R-Chondrite***

As in Figure 2, the position and relative strength of the three olivine absorptions (in green) are consistent with its known composition (Fa39) [5]. Absorptions from a high-calcium pyroxene (blue) are also present. (Note that for clarity, the modeled absorption bands and the residual error (magenta) are offset by -0.8, and -0.7, respectively.)

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