WATER CONTENT OF NOMINALLY ANHYDROUS MINERALS IN THE IBITIRA EUCRITE. T. H. Burbine[1], M. D. Dyar[1], S. J. Seaman[2], and T.J. McCoy[3], [1]Department of Astronomy, Mount Holyoke College, South Hadley, MA 01075, USA (tburbine@mtholyoke.edu), [2]Department of Geosciences, University of Massachusetts, Amherst, MA, 01002, USA, [3]Dept. of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0119, USA.

Introduction: The Ibitira eucrite is a chemically and petrologically anomalous member of the basaltic eucrite suite [1]. Chemically, Ibitira contains among the most anorthitic (calcic) plagioclase observed in eucrites and has a mean Fe/Mn ratio for low-Ca pyroxenes significantly higher than other basaltic eucrites [1]. Ibitira also slightly deviates from the mass fractionation line defined by other HEDs in oxygen isotopic space [2]. Based on its geochemical anomalies, Mittlefehldt [1] concluded that Ibitira is derived from a basaltic parent body that is different from the parent body of most other HEDs, which is often assumed to be 4 Vesta [3]. Petrologically, Ibitira is unusual in that it contains abundant vesicles (~3 vol.%) [4,5], which are rare among HEDs (howardites, eucrites, and diogenites). It also exhibits a granoblastic texture testifying to a long period of thermal metamorphism [6].

McCoy et al. [5] investigated the nature of the gas that formed the vesicles in Ibitira by modeling the growth of bubbles from CO, CO_2 and H_2O in basaltic magma ascending through the crust in dikes. Only small amounts of CO and/or CO_2 would be needed to create the observed bubbles: they argued that a mixed CO-CO_2 gas with concentrations between ~50-100 ppm would be needed to create the vesicles in Ibitira.

On the other hand, H_2O is highly-soluble and nucleates only at very shallow depths. Thus, H_2O concentrations in excess of 3,000 ppm are necessary to nucleate bubbles below the cold, outer 5 km of the crust of an asteroid, where magmas quench rapidly and bubble growth is stopped. McCoy et al. [5] argue that such H_2O concentrations are too high to be consistent with the "dryness" of Ibitira and the absence of hydrous minerals [4].

In the Earth, and potentially in other terrestrial planetary interiors, the majority of H is contained within the crystal structures of nominally anhydrous minerals. CO and CO_2 can also be present.

Many different minerals can incorporate trace amounts of H in their structures, especially feldspar and pyroxene. In order to quantify the possible presence of CO, CO_2, and H_2O in nominally anhydrous minerals in Ibitira, we have used Fourier transform infrared (FTIR) spectroscopy.

Methods: For transmission FTIR analysis, we prepared a doubly-polished ~60 μm slice of Ibitira that was supported on the edges only by Crystal Bond adhesive. The sample was analyzed using the infrared radiation generated by the UV-IR synchrotron at the National Synchrotron Light Source at Brookhaven National Laboratory. Transmission spectra were obtained from ~700 to ~4000 cm^{-1} on single grains. Plagioclase and pyroxene grains could be distinguished by color differences in the section and had different spectral characteristics. Analysis techniques are similar to those used by Seaman et al. [7].

Results: CO_2 has an absorption feature centered near 2350 cm^{-1}, but it was found to be present barely at detection limits. However, both CO_2 and CO are extremely important for understanding the vesicles in this meteorite, so further work is in progress to characterize and quantify those bands (Figure 1).

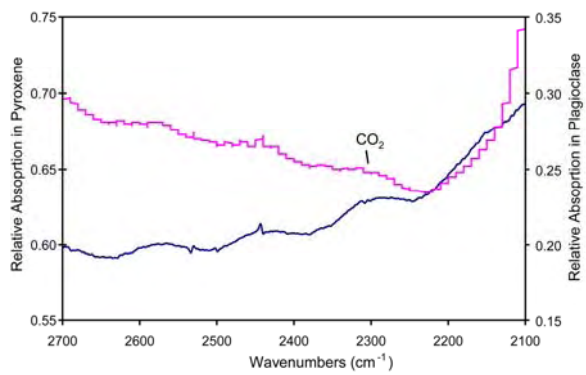

Figure 1. FTIR data near the CO_2 absorption at 2350 cm^{-1}. Pyroxene is in pink and plagioclase is in blue.

The conspicuous water bands of interest are found between 3000 and 3700 cm^{-1}; they are observed in both pyroxene and olivine. FTIR spectroscopy has previously been used to determine the absence of water in minerals found in lunar samples [8], and absorption coefficients for H are readily available.

The following form of the Beer-Lambert Law was used to calculate water concentrations in the analyzed crystals [10]:

$$c(wt.\%\ H_2O) = \frac{A\ (cm^{-1}) \cdot 1.8}{t(cm) \cdot D(g/cm^3) \cdot \varepsilon_i(L \cdot cm^{-2}/mol\ H_2O)}$$

where c is the concentration of the species, A is the area under the absorption peak, t is the thickness of the sample, D is the density, and ε_i is the integrated molar absorption coefficient. The ε_i for feldspar is assumed

to be 107,000 ± 5,000 L· cm^{-2}/mol H_2O [9], and the ε_i value for pyroxene varies significantly as a function of composition. To determine the concentration in ppm, the concentration in wt.% must be multiplied by 10,000.

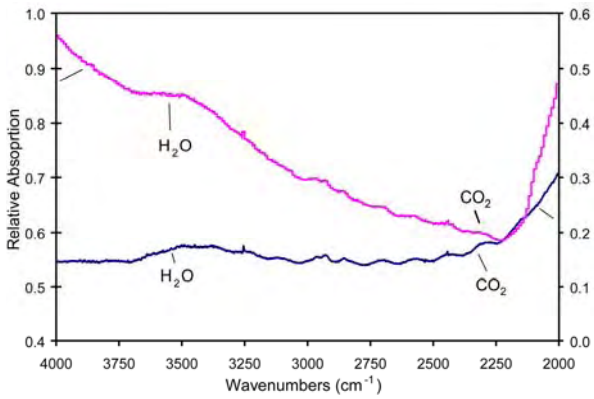

Figure 2. FTIR spectra of Ibitira showing both the H_2O and CO_2 absorption regions. Pyroxene is in pink and plagioclase is in blue.

There is significant uncertainty in the calculated concentrations of H. Because the orientations of the measured crystals are unknown and total water concentration should be calculated using the sum of values from analyses of spectra taken from three mutually perpendicular orientations, all calculated concentrations should be thought of as lower limits. Seaman et al. [7] estimates uncertainties of ±30% for calculated water concentrations that are the sum of the concentrations calculated from collecting spectra in three orientations. Because we do not know the orientation of the crystals that we analyzed, we estimate the uncertainty of our measurements to be ±30-50%.

FTIR spectra were obtained on five pyroxene grains, and work is in progress to analyze their major element compositions and thus determine the appropriate ε_i values to use to quantify their H contents.

Because of limitations imposed by the small size of the section that could be placed in the beam, FTIR spectra were obtained only on five plagioclase grains. The H_2O concentrations derived for the plagioclase grains ranged from 56 to 233 ppm with a mean value of 127±71 ppm and a median value of 131 ppm. As stated earlier, the large range of estimated concentrations and the large standard deviation are most likely due to the range of orientations that were most likely measured.

Seaman et al. [7] finds that there is an approximately 10:1 ratio between H_2O concentrations in melt inclusions and plagioclase grains in felsic melts. If this ratio were to apply to the plagioclase grains in Ibitira, the H_2O concentration of the melt would be inferred to be at least ~1,300 ppm. However, the partitioning of H, like other trace elements, is known to vary as a function of the composition of the host minerals and melts so this estimate is highly conjectural.

The high anorthite content of Ibitira compared to other basaltic eucrites would be consistent with Ibitira forming in a region with a "high" volatile concentration, such as due to water. "Wet" magmas tend to produce feldspar grains with higher anorthite contents than "dry" grains since H_2O tends to lower the temperature of both the liquidus and solidus, which results in the formation of more anorthite-rich grains [11].

Conclusions: Our FTIR analyses of plagioclase grains in Ibitira indicate that H_2O was present during the formation of the vesicles. H is also present in pyroxene, and work is underway to quantify those spectra. Although our inferred H_2O concentration of the melt does not appear to have been high enough to actually have created the vesicles in Ibitira [4], some combination of H and as-yet unquantified CO_2 may well be sufficient for their nucleation. Alternatively, the long period of thermal metamorphism experienced by Ibitira [6] may have affected the minor element concentrations observed in the plagioclase crystals.

Future Work: A number of future FTIR measurements are planned to confirm these calculated water concentrations and explore CO and CO_2 contents of Ibitira. To confirm that the inferred H_2O concentrations are not due to adsorbed terrestrial water, we plan on analyzing feldspar grains in another basaltic eucrite that does not contain vesicles and pyroxene grains in an aubrite, which formed in an exceedingly "dry" environment. We would expect that the H_2O contents of the feldspars in a basaltic eucrite without vesicles to be lower than those found in Ibitira and that the pyroxene grains in the aubrite would not have absorption bands due to water.

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