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**Introduction:** We are working to develop a set of compositional and textural characteristics that would allow us to find and identify achondrite micrometeorites. To this end we made elemental measurements of 18 micrometeorites (MMs) whose relict grain compositions can indicate differentiation of the precursor material in the hope of matching specific textures or relict minerals to achondritic compositions. We also analyzed five MMs for oxygen isotopes. The oxygen isotopic data provide an independent criterion for linking micrometeorites to specific meteorite types and for assessing assignments of a micrometeorite to a meteorite type based on isotopic and elemental data.

**Materials and Methods:** All MMs studied were collected from the bottom of the South Pole water well [1]. We used an FEI XL-30 field scanning electron microscope and energy dispersive X-ray system at Dartmouth College for preliminary characterization and a JEOL 8200 electron microprobe at Rutgers University for quantitative analyses. We calibrated the electron microprobe on standard silicates and reduced the data using conventional ZAF corrections. If the phase was large we took an average of 8-15 spots and excluded all analyses that summed to less than 96% or more than 104%.

The oxygen isotopic composition of relict olivine and pyroxene crystals in five MMs was analyzed using the IMS 1280 at WiscSIMS. We used a 15 \(\mu\)m Cs\textsuperscript{+} primary beam at ~3nA on multi-collection Faraday Cup detectors for all three isotopes \((^{18}\text{O} \sim 3 \times 10^6 \text{cps})\) [2]. Reproducibility (2SD) of analyses were 0.3‰ and 0.7‰ for \(^{18}\text{O}\) and \(^{17}\text{O}\), respectively.

**Results and Discussion:** Of the 18 MMs analyzed for elements, 10 had feldspar or quartz relict grains; seven had relict olivine or pyroxene grains, thought to be Fe-bearing based on the observation of magnetite zones formed around their edges; and one MM had an interesting texture with olivine poikilitically enclosed in pyroxene (Fig. 1). The five MMs analyzed for oxygen isotopes had previously been analyzed for elemental composition [3].

**Fe/Mg-Fe/Mn Ratios.** The Fe/Mg-Fe/Mn ratios of asteroids and planets differ from one another and can help classify and identify the sources of meteorites [4] and of melted MMs[5, 6]. In Fig. 2 we plot the bulk Fe/Mg and Fe/Mn ratios of several different kinds of asteroidal and planetary samples along with the ratios of olivines, pyroxenes and glasses in our samples (best to compare bulk to bulk and mineral to mineral).

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Fig. 1 Backscattered electron images of the micrometeorites studied here.

Fig. 2. Plot showing the bulk Fe/Mg and Fe/Mn ratios of several different kinds of asteroidal and planetary samples along with the ratios of olivines, pyroxenes and glasses in our samples.
One major source of uncertainty in using Fe/Mg/Mn systematics to match MM relict grains to chondrite types is the Fe/Mg to Fe/Mn ratios of chondrules, whose minerals may not plot within the chondritic field demarcated by their host meteorite [7]. When we plotted the Fe/Mg-Fe/Mn ratios of chondrules [8] with those from the MMs analyzed here the datasets show some overlap, indicating that coarse-grained unmelted MMs that derive from chondrules could be mistaken for achondrites based on their Fe/Mg to Fe/Mn ratios.

Ca content of Plagioclase. Seven of the MMs have relict plagioclase grains and five others have areas of glass that suggest they were once feldspars (lower backscatter than surrounding glass, presence of Ca, Na and K or a combination). The plagioclase relict grains have calcium contents that range from An$_{10}$ to An$_{87}$; none are anorthites. Anorthite can be an indicator for achondrites although it is found in CAIs in CV meteorites and in chondrules in carbonaceous chondrites. The Moon, HED meteorites and angrite meteorites also have high Ca plagioclases whereas Martian meteorites have plagioclases with ~An$_{50}$ [10].

Oxygen Isotope Data. Fig. 3 shows oxygen isotope analyses for five MMs. The three MMs with Mg-rich relict grains (SP00D-9, -16, & -18) have negative $\Delta^{18}$O values that decrease with increasing Mg# (96.4, 97.5 and 98.9, respectively). This trend is observed in chondrules from Acfer094 [11], Y-81020 [12] and CR3 chondrites [13]. These MMs have textures similar to those of chondrules and their oxygen isotope ratios are consistent with their being chondrule fragments from carbonaceous chondrites.

D-50 has pyroxenes and olivines in a feldspathic glass, which was classified as a fragment of an H-chondrite on the basis of its texture and elemental composition [3]. Oxygen isotope ratios of D-50 overlap with those of chondrules in H chondrites [14] that show positive $\Delta^{18}$O values.

D-2 has Fe-rich olivines and pyroxenes unlike most known chondrites. Although D-2 seemed a good compositional match for a mare basalt its oxygen isotope composition does not match that of lunar materials (Fig. 3), which plot on the terrestrial fractionation line between $\delta^{18}$O =0 and +5‰ and $\delta^{18}$O= 0 and +2‰. The isotopic ratios of D-2 are consistent with those of chondrules in carbonaceous chondrites, which generally fall below the terrestrial fractionation line [11-13, 15], and its low Mg#, 61.8, falls within the range for type II chondrules in carbonaceous chondrites [11, 13]. D-2, however, is texturally different from these chondrules and has low-Ca pyroxene surrounded by olivine, FeO-rich olivines and pyroxenes, and Ca-rich (An$_{79}$Ab$_{5}$O$_{10}$) plagioclase. The only object known to us that matches all D-2’s characteristics is NWA011, a unique basaltic meteorite [16].

Conclusion: Despite their small sizes and elemental losses or gains during atmospheric entry heating, MMs retain information that can link them to meteorite groups and may be a repository for new types of meteoritic materials. A combination of data, textural, elemental and isotopic, will best constrain the sources of MMs as evidenced for the five MMs where these types of data were available. For coarse-grained unmelted MMs the Fe/Mg – Fe/Mn ratios of their relict minerals should be coupled with oxygen data to distinguish possible achondrites from chondrule fragments.