OLIVINE AND PYROXENE COMPOSITIONS IN FINE-GRAINED CHONDRITIC MATERIALS

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Introduction: Our analyses of the Wild-2 samples returned by the Stardust Mission have illuminated critical gaps in our understanding of related astromaterials. There is a very large database of olivine and low-calcium pyroxene compositions for coarse-grained components of chondrites, but a sparse database for anhydrous silicate matrix phases. In Figure 1 we present comparisons of Wild-2 olivine with the available chondrite matrix olivine major element data (from [1]), as a baseline for what needs to be done next. Analogous low-Ca pyroxene data are given in [1].

The wide Mg-Fe compositional range of Wild-2 olivine is similar to anhydrous chondritic IDPs [1] (Fig. 1). However, the range of these olivine compositions is also similar to what is found in the matrix of the chondrites Murchison (CM2), and Orgueil (CI1), which have experienced significant aqueous alteration. The presence of the pronounced peak in forsterite seen in Murchison and Orgueil could be due to the preferential survival of Mg-rich olivine during aqueous alteration, since Fe-rich olivine is most susceptible to dissolution and alteration [1]. However, there are still very few good olivine and pyroxene analyses from the Wild-2 samples. For some major meteorite types matrix analyses are not even available.

The dearth of minor element analyses of chondrite matrix and IDP silicates is another major problem. Wild 2 olivines include varieties with very elevated MnO, Al_2O_3 and Cr_2O_3 contents, up to 6.45, 0.71 and 1.46 wt%, respectively [2]. About 1/4 of these Mn- and Cr-rich olivines contain <<1% FeO. Olivines with enrichments in these elements have been reported in carbonaceous chondrites, micrometeorites, and chondritic IDPs, though they are rare [3-7]. However, when we tried to compare minor element compositions of Wild-2 olivine and low-Ca pyroxene to chondrite matrix and chondritic IDPs we were stymied by the lack of reliable analyses. We thus have begun a long-term project measuring minor as well as major element compositions for chondrite matrix and chondritic IDPs, and Wild 2 grains.

Finally, we wish to re-investigate the changes to fine-grained olivine and low-Ca pyroxene composition with progressive thermal metamorphism. We have examined the LL3-4 chondrites which because of the Hayabusa Mission have become very interesting.

Techniques: We are making WDS measurements where possible using a Cameca SX2000 electron microprobe using a focused beam. But for most samples, diminutive grain sizes require us to make 500 sec long EDX analyses using a JEOL 2000FX STEM with a Link EDX system. We use natural mineral standards in both techniques to achieve measurement errors of 2% and 5-6%, respectively.

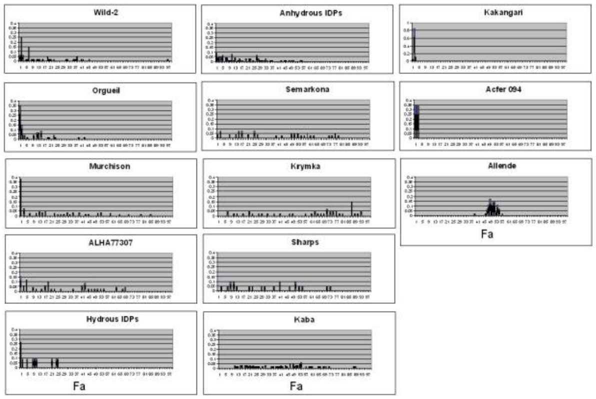

Figure 1. Composition ranges of olivine (Fa) in grains from 9 Wild-2 particles ([1] – these data were collected by many people!), compared with those for primitive chondrite matrix olivine from [8-15]. Vertical scale is number of analyses normalized to a total of 1. See [1] for other data references.

Results for Wild 2 vs. Chondrites: As a start, in the past year we have made many new analyses of Wild 2 grains and the CI chondrites Orgueil and Ivuna. In Figure 2 we show a new comparison between olivine major element compositions in Wild 2 and Orgueil. In Figs 3-5 we show comparisons of our newly-measured minor element concentrations in Wild 2 grains vs. CI (Orgueil and Ivuna), CM (Murchison, Mighei, Murray) and CV chondrites (Vigarano). The correspondence between CI and Wild 2 is fairly good, especially when one understands that the few high Mn and Cr olivines in CI chondrites in our dataset are mainly analyses from different regions in only 2 zoned grains. However, we will revisit this result after we have collected data from more meteorites. We also will compare these new data to existing minor element data [2].

Results for LL Chondrites: In Figure 6 we present our new data for matrix in 7 LL chondrites ranging from grades 3.0 to 4. We tried to analyze only falls, but in the end had to include a couple of less-weathered finds (Wells and NWA 4522, for which we took appropriate precautions). We don't have room to present results of minor element comparisons in this abstract, and we need to make additional analyses, but we can offer some preliminary conclusions.

Preliminary Conclusions: (1) Wild 2 olivine and low-Ca pyroxene are similar to those in CI chondrites, which is strange since there is as yet no indication that Wild 2 experienced significant aqueous alteration. (2) The bulk of mineralogical changes to LL chondrite matrix olivine and low-Ca pyroxene occurred in the range 3.5 to 3.6. (3) The olivine and pyroxene equilibrated at different rates. Conclusions (2) and (3) are of course already known from studies of coarser components of chondrites, but now we can compare equilibration rates between different grain size components in the same chondrite.

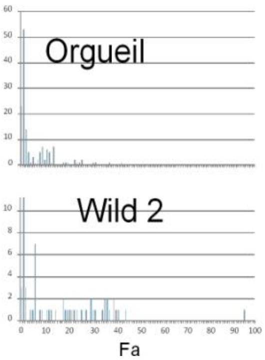

Figure 2. Comparison between matrix olivine in Orgueil and Wild 2 grains. Orgueil data are from [10, 11, 16, 17] and new data from us. Wild 2 from [1] and new data from us.

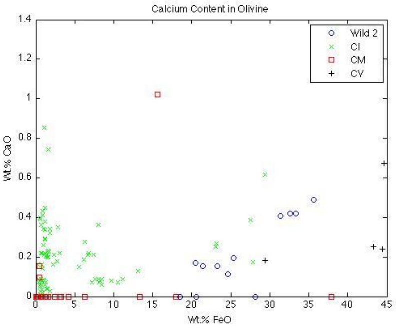

Figure 3. Our new data for CaO vs. FeO for Wild 2, CI, CM and CV chondrites.

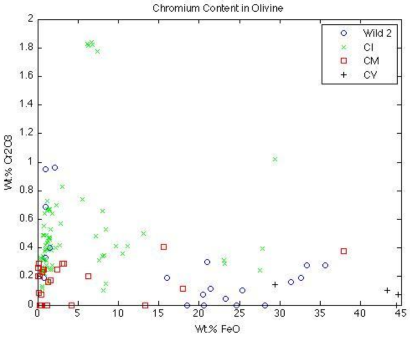

Figure 4. Our new data for Cr_2O_3 vs. FeO for Wild 2, CI, CM and CV chondrites.

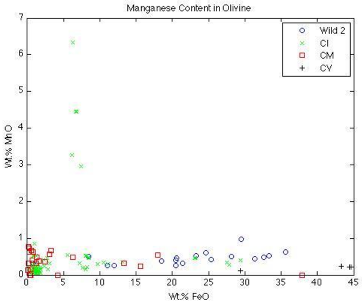

Figure 5. Our new data for MnO vs. FeO for Wild 2, CI, CM and CV chondrites.

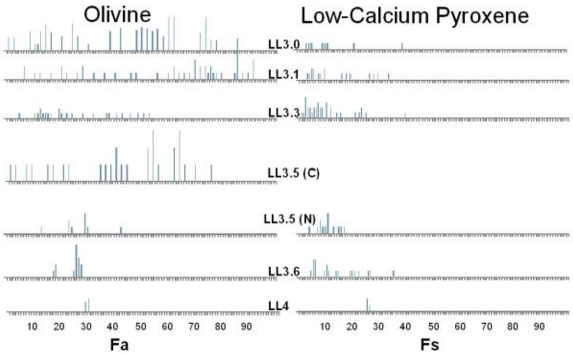

Figure 6. Matrix olivine and low-Ca pyroxene compositional ranges for a metamorphic suite of LL chondrites, including LL3.0 (Semarkona), LL3.1 (Krymka), LL3.3 (Wells), LL3.5 (C is Chainpur, N is NWA 4522), LL3.6 (Parnallee), and LL4 (Savtschenskoje).

References: [1] Zolensky et al. (2008) *MAPS* **43**, 261-272;. [2] Zolensky et al. (2006) *Science* **314**, 1735-1740; [3] Klöck et al. (1989) *Nature* **339**, 126-128; [4] Rietmeijer (1998), in *Planetary Materials*, Papike, Ed., MSA, 95; [5] Gounelle et al. (2002) *MAPS* **37**, A55; [6] Simon and Grossman (2003) *MAPS* **38**, 813-825; [7] Weisberg et al. (2004) *MAPS*, **39**: 1741-1753; [8] Greshake (1997) *GCA* **61**, 437-452; [9] Brearley (1993) *GCA* **57**, 1521-1550; [10] Reid et al. (1970) *GCA* **34**, 1253-1255; [11] Kerridge and MacDougal (1976) *EPSL* **29**, 341-348; [12] Krot et al. (1995) *Meteoritics* **30**, 748-775; [13] Fuchs et al. (1973) *Smithsonian Contribs. Earth Sci.* **10**, 39p; [14] Nagahara (1984) *GCA* **48**, 2581-2595; [15] Matsunami et al. (1990) *Proc NIPR Symp. Antarct. Mets*. **3**, 147-180; [16] Leshin et al. (1997) *GCA* **61**, 835-845; [17] Steele (1990) *Meteoritics* **25**, 301-307.