WHAT WE HAVE LEARNED ABOUT THE MINERALOGY OF COMET WILD 2 IN TWO YEARS

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Introduction: The nature of cometary solids is of fundamental importance to our understanding of the early solar nebula and protoplanetary history. Samples of Comet Wild 2 have now been examined in terrestrial labs for two years, and we have been very surprised by the phenomenal variety of materials present in the comet. We have compared the observed composition ranges of the critical phases olivine, pyroxene and Fe-Ni sulfides in Wild 2 grains (recovered by the Stardust spacecraft) with those from chondritic interplanetary dust particles (IDPs) and chondrite classes to explore whether these data suggest affinities to known astromaterials.

Mineralogy: Olivine and pyroxene are present in the majority of Wild 2 particles, with an extremely wide composition range, from Fo_{4-100} with a pronounced frequency peak at Fo_{99}. Wild 2 olivines include some with very elevated MnO, Al_2O_3 and Cr_2O_3 contents, up to 6.45, 0.71 and 1.46 wt%, respectively [1]. The wide Mg-Fe composition range of Wild 2 olivine is similar to that for anhydrous chondritic IDPs. However, the range of these olivine compositions is also similar to that found in the matrix of the chondrites Murchison (CM2), and Orgueil (CI1), which have experienced significant-to-pervasive aqueous alteration (Figure 1). The resemblance of Wild 2 olivine to CI and CM chondrite matrix olivine with pronounced forsterite peaks, suggests that a more detailed search for possible aqueous alteration products should be undertaken, but thus far no phyllosilicates have been reported. Both low- and high-calcium pyroxenes are present among the Wild 2 grains, with the former being dominant. Orthoenstatite is present, requiring slow cooling for these particular samples. High calcium pyroxene is also present in some grains, including at least one where it has exsolved as a high temperature phase separated into intergrown diopside and enstatite [2] with falling temperature. The composition range displayed by the low-calcium pyroxene is very extensive, from En_{52} to En_{100}, with a significant frequency peak centered at En_{95}. Low-calcium pyroxene usually coexists with olivine in the Wild 2 grains, but the Mg/Fe ratios for coexisting phases are not always similar. The extreme compositional range of low-Ca pyroxene is again similar to the anhydrous chondritic IDPs, and significantly broader than that observed in most chondrites, including Murchison and Orgueil.

Fe-Ni sulfides are ubiquitous in the Wild 2 grains, grading from sulfides which apparently melted during collection and separated into a mixture of sulfide and metal [2,3], all the way to apparently unmodified FeS and pentlandite ($(Fe,Ni)_9S_8$) grains. Several tracks (e.g. Track 59) have FeS- or pentlandite-dominated terminal grains. Here we collectively refer to troilite (stoichiometric FeS) and pyrrhotite ($Fe_{1-x}S$) collectively as "FeS" because the exact stoichiometry and structure is unknown in most instances. A plot of analyses of Wild 2 Fe-Ni sulfides shows that many have compositions close to that of FeS, with less than 2 atom % Ni. A few pentlandite grains have been found among the Wild-grains suggesting that this mineral is not abundant. The complete lack of compositions between FeS and pentlandite (with intermediate solid solution compositions) suggests (but does not require) that FeS and pentlandite condensed as crystalline species, i.e. did not form as amorphous phases, which later became annealed [4]. The few verified pentlandite crystals in Wild 2 tracks are intriguing since this phase is frequently an indicator of low-temperature metamorphism under oxidizing conditions, and/or aqueous alteration [5,6]. So far we have not observed tochilinite nor the intermediate Fe-Ni phase, which are hallmarks of the hydrated CM2s and a few hydrous chondritic IDPs [7,8]. Therefore, at face value the presence of these few Ni-rich sulfides suggests that some Wild 2 particles could have experienced a limited degree of aqueous alteration, as also supported by the reports of vary rare Ca-Fe-Mg carbonates [9,10].

When we add in the results for oxides, metals, refractory phases [1] and organics enriched in ^2H and ^{15}N [11], it is clear that the components of Wild 2 formed in many environments across the entire protosolar disk.

References: [1] Zolensky M. et al. (2006) *Science* 314, 1735-1740. [2] Leroux H. et al. *GCA* 72, in press. [3] Rietmeijer F. et al. *GCA* 72, in press. [4] Vaughan D., Craig J. (1978) *Mineral Chemistry of Metal Sulfides*. Cambridge Univ. Press. [5] Zolensky M.E. and Thomas K. (1995), *GCA* 59, 4707-4712. [6] Bullock E.S. et al. (2005) *GCA* 69, 2687-2700. [7] Bradley J.B. and Brownlee D.E. (1991) *Science* 251, 549-552. [8] Zolensky M.E. et al. (1993) GCA 57, 3123-3148. [9] Wirick S. et al (2007) Lunar And Planetary Science XXXVIII. [10] Mikouchi T. et al. (2007) *Lunar And Planetary Science XXXVIII*. [11] Sandford S. et al. (2006) *Science* 314, 1720-1724.

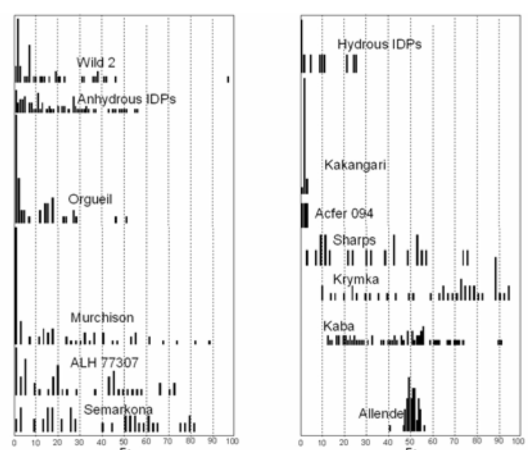

Figure 1 Compositional range of olivine in Wild 2 grains compared with matrix olivines in chondrites and chondritic IDPs