THE MINERALOGY OF COMET WILD 2

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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, provided by the Stardust Mission, have now been examined in terrestrial labs for two years, and are very surprising! Here we describe mainly the critical phases olivine, pyroxene and Fe-Ni sulfides in Wild 2 grains, as a guide to the general mineralogy of the returned comet samples.

Ferromagnesian Silicates: 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 (Zolensky et al., 2006). The wide Mg-Fe composition range of Wild 2 olivine is similar to that for anhydrous chondritic IDPs (Zolensky and Thomas, 1995). However, the range is also similar to that found in the matrix of the chondrites Murchison (CM2), and Orgueil (CI1) (Zolensky et al., 1993), which have experienced significant-to-pervasive aqueous alteration. This resemblance suggests that a detailed search for possible aqueous alteration products should be undertaken, but thus far no phyllosilicates have been reported from Wild 2. Both low- and high-calcium pyroxenes are present among the Wild 2 grains, with the former being dominant. Orthoenstatite is present, requiring rather slow cooling for these particular samples. It is clear that some Wild 2 grains have an igneous origin. High calcium pyroxene is also present in some grains, including at least one which has exsolved at high temperature into a mix of diopside and enstatite (H. Leroux, personal communication, 2008). The composition range displayed by the low-calcium pyroxene in Wild 2 is also 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.

Sulfides: 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 (Leroux et al., in press a, b}, all the way to unmodified FeS and pentlandite grains. The complete lack of compositions between FeS and pentlandite 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 (Vaughn and Craig, 1978). 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 (Zolensky et al., 1993; Zolensky and Thomas, 1995; Bullock et al., 2005). We have not observed tochilinite nor the strange intermediate Fe-Ni phase, which are hallmarks of many hydrated chondritic materials (Bradley and Brownlee, 1991; Zolensky et al., 1993). The presence of rare pentlandite suggests that some Wild 2 particles could have experienced a limited degree of aqueous alteration, as supported by the reports of vary rare Ca-Fe-Mg carbonates (Wirick et al., 2007; Mikouchi et al., 2007). However, no actual water-bearing species have been located among the returned samples, and indeed may simply not be present.

Summary: When we add in the reported results for other important Wild 2 phases, including oxides, metals, refractory phases (Zolensky et al., 2006) and organics enriched in ^{2}H and ^{15}N (Sandford et al., 2006) it is clear that the components of Wild 2 formed in many environments across the entire protosolar disk, containing unequilibrated materials that formed in very cold environments all the way to grains that formed right up next to the early Sun. Add to this the rare occurrence of presolar grains among the Wild 2 samples (McKeegan et al., 2006) and we appear to have in this one body the widest possible selection of early solar system materials.

References:

Bullock S. et al. (2005) *Geochim. Cosmochimica Acta* 69, 2687-2700.
Bradley J. and Brownlee D.E. (1991) *Science* 251, 549-552.
Leroux H. et al. (2008a). *Meteoritics and Planetary Science,* in press.
Leroux H. et al. (2008b). *Meteoritics and Planetary Science,* in press.
McKeegan K. et al., (2006) *Science* 314, 1724-1728.
Mikouchi T. et al. (2007) *Lunar and Planetary Science XXXVIII*.
Sandford S. et al., (2006) *Science* 314, 1720-1724.
Vaughan D. and Craig J. (1978) *Mineral Chemistry of Metal Sulfides*. Cambridge Univ. Press., 493.
Wirick S. et al. (2007) *Lunar and Planetary Science XXXVIII*.
Zolensky M. et al. (1993) *Geochim. Cosmochimica Acta* 57, 3123-3148.
Zolensky M. et al. (2006) *Science* 314, 1735-1740.
Zolensky M. and Thomas K. (1995) *Geochim. Cosmochim. Acta* 59, 4707-4712.