A POST-STARDUST MISSION VIEW OF JUPITER FAMILY COMETS. M. Zolensky, ARES, KT, NASA Johnson Space Center, Houston, TX 77058, USA (michael.e.zolensky@nasa.gov).

Introduction: Before the Stardust Mission, many persons (including the mission team) believed that comet nuclei would be geologically boring objects. Most believed that comet nucleus mineralogy would be close or identical to the chondritic interplanetary dust particles (IDPs), or perhaps contain mainly amorphous nebular condensates or that comets might even be composed mainly of preserved presolar material [1]. Amazingly, the results for Comet Wild 2 (a Jupiter class comet) were entirely different. Whether this particular comet will ultimately be shown to be typical or atypical will not be known for a rather long time, so we describe our new view of comets from the rather limited perspective of this single mission.

Nucleus Geology: Wild 2 displayed dozens of active vents during its brief fly-by of the Stardust Spacecraft [2]. Far from being geologically boring, the face of Wild 2 was covered with km-sized depressions – some with overhanging walls, abundant possible impact craters, 100m tall pinnacles, landslides, and normal faults. There is evidence that some vents originate well below the nucleus' surface. It is difficult to account for all of this geological activity.

Basic Mineralogy: Researchers have by now harvested Wild 2 grains from approximately 150 separate particle capture tracks [3,4]. Approximately 33% of the tracks are dominated by olivine, 24% by low-calcium pyroxene, 10% by a fairly equal amount of olivine and pyroxene, and the remaining 33% are dominated by other minerals, mainly the Fe-Ni sulfides pyrrhotite and pentlandite. These results reveal that crystalline materials are abundant in Wild 2. Our current model for the structure of the nucleus grains is one of very fine-grained (sub-micrometer), loosely-bound aggregates with a bulk chondritic composition, with most aggregates also containing one or more much larger individual crystals (most commonly) of olivine, pyroxene and Fe-Ni sulfides [3,4], which probably served to nucleate the cometary particles at the earliest stage of accretion. This physical structure is consistent with some chondritic materials, including chondritic IDPs and primitive chondrites [4]. There are hints of the possible transient liquid water within the nucleus, from a few Mg-Ca carbonates [5], and a single occurrence of orthorhombic cubanite [6], but it is possible that these phases formed in an aqueous environment before incorporation into the nucleus.

Presolar Grains: Presolar grains are present within Wild 2, but in an abundance far lower than that in most primitive chondrites [4].

High Temperature Minerals: The presence of calcium and aluminum-rich inclusions (CAI) and chondrules in Wild 2 was a shock to most people. These require high temperature formation, up to 1600-2000K [3,7], and are thought to be the earliest condensates in the hot inner solar nebula. Previously, CAI and chondrules were found only in primitive meteorites. Since the oxygen isotope compositions of these Wild-2 CAI and chondrules are identical to the meteorite analogues, both sampled a common oxygen reservoir during formation, probably the Sun [7,8]. This in turn requires that some solar system wide dynamic process was operating to carry inner solar system solids out to the comet assembly region.

Organics: Amazingly, a wide range of organic species survived collection by the spacecraft. Among these are indigenous aliphatic hydrocarbons with longer chain lengths than those observed in the diffuse interstellar medium [9,10], and the amino acid glycine [11]. Some organics have excesses of 15N, a signature of formation at the very edge of the solar nebula, if not in interstellar space [8,9].

Search for Evidence of Radiogenic Aluminum: Thus far, Wild 2 grains do not appear to contain evidence of ^{26}Al [12], which implies mineral crystallization well after the formation of the oldest solar system solids. This means that material from the inner solar system must have traveled to the outer solar system, across a period of at least two million years, raising questions regarding the timescale of the formation of comets and the relationship between Wild 2 and other primitive objects.

References: [1] Brownlee et al. (2006) Science 314, 1710; [2] Brownlee et al. (2004) Science 304, 1764; [3] Zolensky et al. (2006) Science 314, 1735; [4] Hanner and Zolensky (2010) In Astromineralogy, T. Henning, Ed., p. 203-232; [5] Mikouchi et al. (2007) Lunar and Planetary Science XXXVIII; [6] Berger et al. (2011) Geochimica et Cosmochimica Acta 75, 3501; [7] Nakamura et al. (2008) Science 321, 1664; [8] McKeegan et al. (2006) Science 314, 1724; [9] Sandford et al. (2006) Science 314,1720; [10] Cody et al. (2007) Lunar And Planetary Science XXXVIII, Abstract 2286; [11] Elsila et al. (2009) Meteoritics and Planetary Science 44, 1323; [12] Matzel et al. (2010) Science 328, 483.