CHEMISTRY AND TEMPERATURES AT THE ENTRANCE OF TRACK #80. Frans J. M. Rietmeijer, Department of Earth and Planetary Sciences, MSC03 2040, 1-University of New Mexico, Albuquerque, NM 87131-0001, U.S.A; fransjmr@unm.edu

Introduction: The clumps of silica-rich glass extracted from the walls in the upper parts of Stardust tracks receive little attention and yet they contain information on the nanometer scale grains of comet Wild 2 [1,2]. These clumps are dominated by the now familiar vesicular low-Mg silica stardust glass with embedded nanometer low-Ni FeS and Fe,Ni-metal compounds and occasionally GEMS-like objects. This glass formed when pyrrhotite grains decelerated from 6.1 km/s and commingled with hot silica melt [3]. Understanding the thermal regime(s) and responses of the underdense aerogel during hypervelocity capture will only come from laboratory studies of the materials that formed when these comet grains interacted with a hot silica melt. Much of the kinetic energy of Wild 2 particles was probably disseminated in the upper part of tracks that caused a plethora of physiochemical responses. It was reported that very small amounts of Fe are found at the track entrance in all track types [4].

Here I report data on the TEM sections #4, #8, #10 and #12 of allocation C2092,2,80,46,1 that was taken from the track entrance. These ~70-nm thin serial sections are a ~500nm transect carved by the impacting Wild 2 particle which represents the onset of physiochemical interactions between the particle and silica aerogel. The entrance hole of this bulbous, type B track is ~410 microns in diameter. All data were corrected for the chemical background of this allocation caused by the *chemical impurities* present in silica aerogel [5] but not for particulate impurities in aerogel.

Observations: Most sections contain vesicular low-Mg glass with scattered Fe-Ni-S compound inclusions. Clean, *i.e*. inclusion-free, low-Mg,Al,Ca (in variable relative proportions) silica glass forms (1) a (partial) rim between vesicular glass and silica aerogel and (2) inclusions in vesicular glass. The sections here discussed contain generally more clean glass, *i.e*. Fe- and Ni-free, silica glass, than the typical vesicular glass. Some sub-micron glass forms "ropey glass" and 'schlieren'-like shards.

Section #4. A few Ca-rich silica glass inclusions are present in the typical vesicular glass matrix. The Fe-normalized matrix and glass abundances show CI-like Mg, Al, S, Mn and Ni abundances but 10-times CI calcium. Nanometer scale Fe-Ni-S compound and low-S Fe,Ni-metal inclusions are present in vesicular glass.

Section #8. A mostly non-vesicular glass matrix with CI-like Fe-normalized Mg and S (trace Al) contains tiny opaque inclusions. Glass spheres are (1) pure silica (Mn trace) and (2) low-Mg GEMS-like globules with sub-CI Fe-normalized S, Mn and Ni abundances. Patches of vesicular glass contain mostly Ni-free sulfides; low-Ni sulfide compositions show a continuous trend to low-Ni Fe,Ni-metal grains.

Section #10. Texturally and chemically this section resembles section #6 but it contains Al, Ti and Cr (Fig 1). The glass matrix and vesicular glass matrix contain similar Ni-free and low-Ni sulfides, and low-S Fe,Ni metal inclusions. There is a ~100nm rounded pure enstatite crystal grain. GEMS-like objects are present.

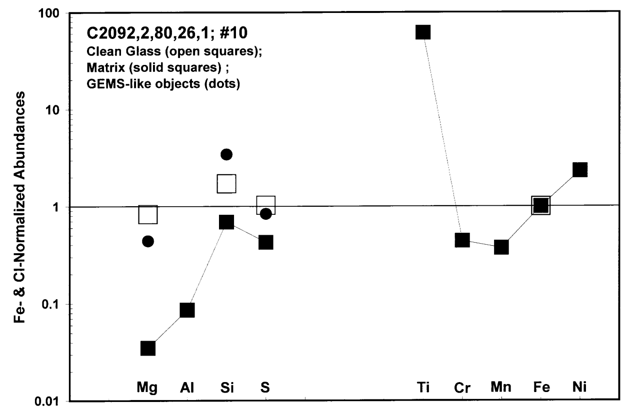

Figure 1: Fe- & CI normalized abundances in clean glass, vesicular matrix and GEMS-like objects of section #10.

Section #12. This section is dominated by non-vesicular glass with Fe,S compound and (rare) metal inclusions. The Fe- and CI normalized abundance patterns show high Al, Ca and Ti abundances for the glass matrix and GEMS-like globules (Fig. 2). High Ti abundance is due to assimilation of melted TiO_2 grains (see below), suggesting slightly higher temperatures

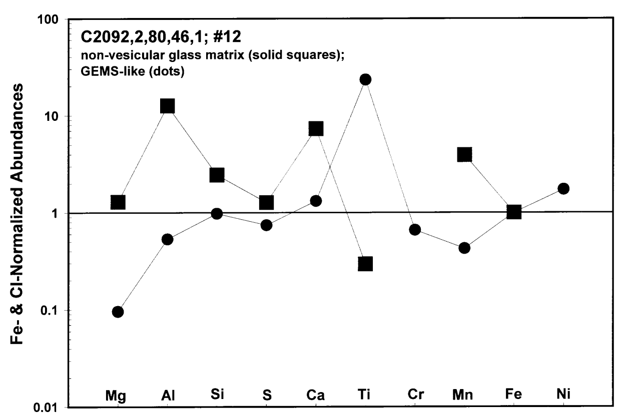

Figure 2: Fe- & CI normalized abundances in non-vesicular glass and GEMS-like objects in section #12.

than the glass matrix. The glass has randomly distributed Ni-free and low-Ni Fe-Ni-S compound and low-S, low-Ni, metal inclusions.

The "ropey glass" and 'schlieren'-like shards are pure (Mg,Al,Ca)-bearing silica glass. The compositional trend plotted in the MgO-Al_2O_3-SiO_2 (Fig. 3) and CaO-Al_2O_3-SiO_2 systems show how an original glass phase becomes increasingly more silica rich when the temperatures increased. The original glass composition resembles garnet, which is not evidence that Wild 2 contained a garnet grain. More likely, Ca and Al in this glass were derived from CaO and Al_2O_3 aerogel contaminant particulates (see below).

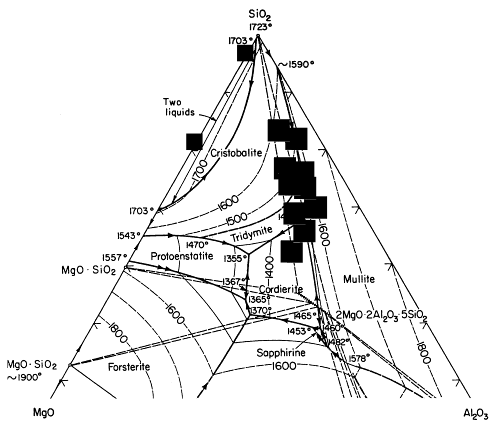

Figure 3: Truncated MgO-Al_2O_3-SiO_2 diagram with the clean glass compositions in #6 (small squares and in #12 (large squares) showing increased mixing with silica glass at increasing temperatures.

Particulate aerogel contaminants: Nanometer scale angular, platy CaO (m.p. 2614^{o}C) grains encased in low-Mg ferromagnesiosilica glass are present in section #3. They might be from calcite dissociation into CaO and CO_2. Impact induced dolomite dissociation yielded globules with a CaO or MgO core and carbon rim [6] but such spheres were not found. A few TiO_2 nanograins occur in section #6. Its presence in silica-rich glasses in #10 and #12 suggests TiO_2 assimilation during hypervelocity capture. Section #6 also contains a globular aluminosilica glass particle [SiO_2 =69; Al_2O_3 =31 el%]. Whether it shows particulate alumina of Al metal reacting with silica melt or melting of an AlSi(O) Wild grain cannot be ascertained.

Post-collection contaminants: Sections #4, #6 and #12 contain fuzzy patches, irregularly shaped patches and 'bands' of finely dispersed Na and K containing Ca,Cl droplets (K/Cl <0.1; Na/Cl: 0.2 – 0.7) and (rare) cubic crystallites. They could be chloride or perchlorate compounds. There is no evidence that they reacted with silica melt and melted Wild 2 materials.

Discussion: It is reassuring that contaminants can be recognized although their origin is not always obvious. Some are linked to known chemical and particulate aerogel contaminants, others cannot. The source of the Na,K bearing Ca,Cl droplets is unknown but they were probably introduced after hypervelocity capture.

The Fe-normalized Mg abundance in the clean (non-vesicular) and vesicular glasses is less than the CI value. They are compositionally simple with close to chondritic element abundances, except for >CI Al, Ca and Ti. Titanium is a known particulate contaminant; both Ca and Al might also be contaminants (Occam's rule). The Mg,Al,Ca-silica glasses (#12) may be unique artifacts but they offer insight of rising temperatures in the melting aerogel as do other low-Mg and low-Al-bearing silica and the compositions of the Fe-Ni-S compound and low-S Fe,Ni-metal inclusions.

Neither glasses nor the nanometer scale inclusions are equilibrium phases but because of their surface free energy they may be treated as such. The equilibrium temperatures (Table 1) show a coherent pattern along a ~500 nm part of the track. The glass temperatures are consistently higher than those indicated by the Fe-Ni-S compounds, suggesting that sulfur was able to separate and move away as melts or vapors.

Table 1: Estimated equilibrium temperatures track 80,46

Section	Clean glass	Fe-Ni-S compounds
#4	~1700	~1200 - ~1350
#6	~1700 - ~1800	None present
#8	~1700	~1200 - ~1500
#10	No data	~1100 - ~1500
#12	~1400 - ~1550	~1300 - ~1450

Conclusion: At the penetration hole the typical low-Mg vesicular matrix with Fe-Ni-S compound and Fe,Ni-metal inclusions is not dominant feature. Instead the matrix is mostly a non-vesicular low-Mg glass with similar inclusions and GEMS-like globules. Impact produced vapors were not trapped inside glass in a dynamic environment that was conducive to globular glass particle formation between ~1100^{o}C and 1800^{o}C.

References: [1] Leroux H. et al. (2008) *Meteoritics & Planet. Sci., 43*, 97-120 [2] Rietmeijer F. J. M. (2009) *Meteoritics & Planet. Sci., 44*, 1707-1715. [3] Ishii H. A. et al. (2008) *Science, 319*, 447-450 [4] Iida Y. et al. (2010) *Meteoritics & Planet. Sci., 45*, 1302-1319. [5] Rietmeijer F. J. M. (2009) *Meteoritics & Planet. Sci., 44*, 1121-1132. [6] Rietmeijer F. J. M. et al. (2003) *Chem. Phys. Lett, 374*; 464-470. This work was supported by NNX07AM65G through the NASA Stardust Analyses Program