ASSOCIATION OF PRESOLAR GRAINS WITH MOLECULAR CLOUD MATERIAL IN IDPS. S. Messenger[1] and L. P. Keller[1], , [1]Robert Walker Laboratory for Space Science, NASA Johnson Space Center, Mail Code KR, 2101 NASA Parkway, Houston TX 77059, scott.r.messenger@nasa.gov.

Introduction: Anhydrous interplanetary dust particles (IDPs) collected in the stratosphere appear chemically, mineralogically, and texturally primitive in comparison to meteorites [1]. Particles that escape significant atmospheric entry heating have highly unequilibrated mineralogy, are volatile element rich, and, overall, appear to have escaped significant parent body hydrothermal alteration [2]. These IDPs are comprised of the building blocks of the solar system.

The strongest evidence that anhydrous IDPs are primitive is that they contain abundant stardust and molecular cloud material. In particular, presolar silicates were first identified in IDPs and are present in abundances (450 – 5,500 ppm) that are well above that observed in primitive meteorites (<170 ppm); [3-7]. The most fragile (cluster) IDPs also commonly exhibit large H and N isotopic anomalies that likely originated by isotopic fractionation during extremely low temperature chemical reactions in a presolar cold molecular cloud [8]. The D/H ratios exceed that of most primitive meteorites, and in rare cases reach values directly observed from simple gas phase molecules in cold molecular clouds [9]. The most extreme D- and ^{15}N-enrichments are usually observed at the finest spatial scales (0.5 – 2 μm) that can be measured.

These observations suggest that D and ^{15}N 'hotspots' are in fact preserved nuggets of molecular cloud material, and that the materials within them also have presolar origins [10]. The advanced capabilities of the NanoSIMS ion microprobe now enable us to test this hypothesis. Here, we report two recent examples of presolar silicates found to be directly associated with molecular cloud material.

Methods: The two samples discussed here followed different experimental protocols. The first sample discussed (B10) is a 10 μm fragment of cluster #6 from collection flag L2011, two other fragments of which are enriched in D and ^{15}N [8]. This IDP was embedded in low viscosity epoxy and thin (40 – 70 nm) sections were obtained by ultramicrotomy. Thin sections of this IDP were placed on TEM grids for both TEM and NanoSIMS analysis. The second sample (D11) was a 20 μm fragment of cluster 13 from collection flag L2009. This IDP was pressed into a gold substrate for analysis with the Washington University IMS-3f ion microprobe. Following D/H measurements, the IDP was extracted from the Au substrate by hand with a scalpel, attached to an epoxy bullet and embedded in elemental sulfur for microtomy. TEM and spectroscopic analyses show that the elevated D/H in D11 is hosted by hydrocarbons in the carbonaceous matrix of the IDP [11]. Both samples were analyzed with the Washington University NanoSIMS ion microprobe following detailed mineralogical mapping by TEM. For most samples we acquired 6-10 image layers of $^{16,17,18}O^-$, $^{24}Mg^{16}O^-$, and $^{28}Si^-$, in multidetection, using a 2 pA, 50 nm Cs^+ primary ion beam. For one slice of B10 we instead acquired images of $^{16,18}O^-$,$^{12}C^{14}N^-$,$^{12}C^{15}N^-$,and $^{32}S^-$.

Results: *Supernova olivine:* IDP L2011B10 was found to contain an isotopically unusual (^{18}O-rich, ^{17}O-poor) presolar olivine grain that probably originated from a type II supernova [12]. Since this (500 nm) grain appeared in several consecutive slices of the IDP, we were able to perform complementary O, Si, and N isotopic imaging of the particle. A TEM image of the IDP containing the grain is shown in Fig 1, where the presolar grain is identified by the ^{18}O-rich region (Fig 1B), while the adjacent GEMS and FeS grains are identified in an overlain ^{32}S map acquired by NanoSIMS (Fig 1C). The presolar olivine grain is partially rimmed with ^{15}N-rich organic matter (Fig 1D).

Deuterium hotspot: The D/H ratio map of IDP D11 is shown in Fig 2A where the values range from 3 to at least 10 x the terrestrial ratio. The prominent D hotspot is 3-4 μm in size. The hotspot contains mineral and glassy grains embedded in a carbonaceous matrix. Grains at least 200 nm in size were large enough for isotopic measurements, including 12 grains of enstatite, 12 olivine, 3 anorthite, 5 diopside, and one each of pyrrhotite and chromite. In addition to the crystalline components, we observed 12 GEMS grains and 2 aluminosilicate glass grains. The crystalline silicates have abundant solar flare tracks. All of the silicates within the primary D-hotspot are found to have O isotopic compositions that are indistinguishable from solar within 100 ‰ or less. However, a ^{17}O-rich presolar silicate was found nearby in a small region of D-rich carbonaceous matter (Fig. 2D).

Discussion: Interstellar dust grains accrete coatings of mixed H_2O/organic ices in cold molecular clouds (13), and these ices may undergo extensive chemical processing driven by UV photolysis (e.g. 14) to become protective mantles of refractory organic matter

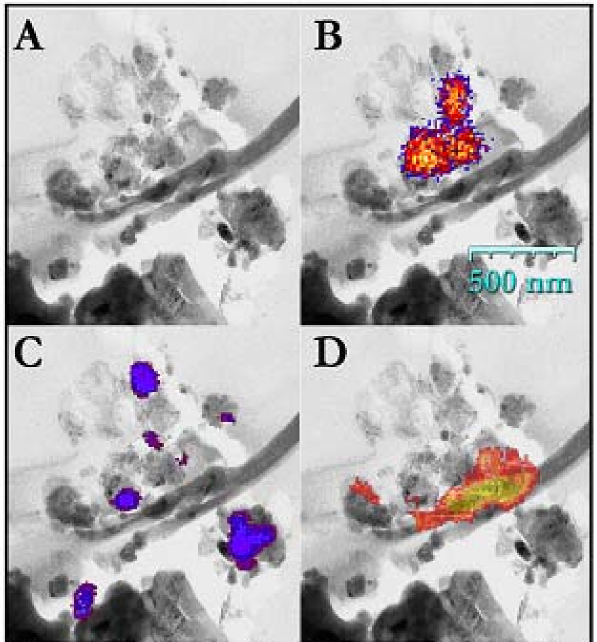

Figure 1 (A) TEM brightfield image of IDP L2011 B10A containing forsterite, enstatite, GEMS grains and carbonaceous matter (B) overlay of ^{18}O-rich region identifying a supernova olivine grain (C) ^{32}S hotspots show the location of FeS and GEMS grains (D) ^{15}N-rich carbonaceous matter associated with the presolar olivine.

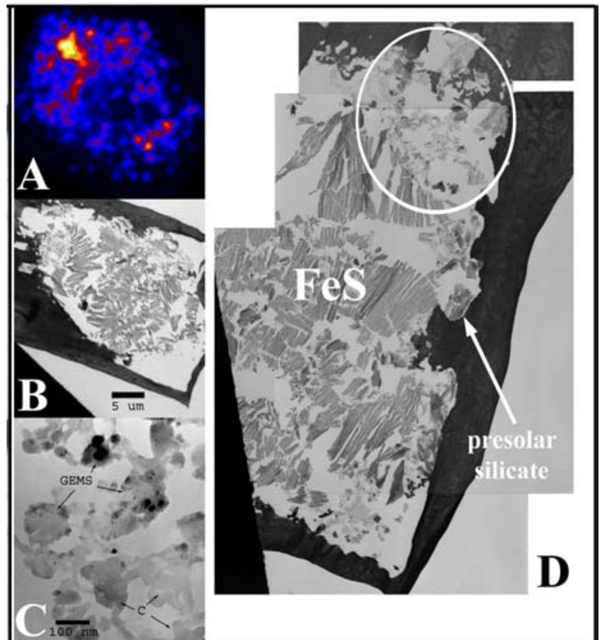

Figure 2 (A) D/H ratio image of IDP L2011 d11 where D/H ratios reach 10 x terrestrial (B) TEM brightfield image of particle extracted from gold substrate (C) TEM view of materials found within the D-hotspot, including GEMS grains, forsterite, enstatite, FeS and carbonaceous matter (D) Presolar silicate grain found by NanoSIMS. Location of D hotspot circled

(15). The ^{15}N-rich organic coating observed on the supernova olivine grain B10A is a clear example of the expected association of stardust with molecular cloud matter. These results reinforce the previously observed general trend that presolar grains are most abundant in ^{15}N-rich IDPs [4].

The D hotspot in IDP D11 is among the most deuterium rich objects ever studied in the laboratory. It is therefore surprising that most of the material within it appears to be of solar system origin. This implies that dust grains in the outer solar nebula accreted volatile organic mantles similar to that of grains in the interstellar medium. The grains within the D hotspot include high temperature nebular condensates that likely formed in the inner, warmer regions of the disk. It is possible that this material was ejected by the early active sun in a bipolar outflow or that this material migrated outward in a turbulent nebular disk [16]. All of this must have occurred prior to the association of the presolar organic matter with the nebular grains.

References: [1] Bradley J.P. *et al.* (1988) in *Meteorites ant the Early Solar System*, 861-898. [2] Flynn G. J. *et al.* (1996) in Physics, Chemistry, and Dynamics of Interplanetary Dust (eds Bo A. S. Gustafson and M. S. Hanner) ASP Conf. Proc **104**, 291-296. [3] Messenger S. et al. 2003. *Science* **300**, 105 [4] C. Floss, F. J. Stadermann (2004), *LPS* **35**, Abstract #1281 (2004) [5] A. Nguyen, E. Zinner (2004), *Science* **303**, 1496 [6] K. Nagashima, A. N. Krot, H. Yurimoto (2004), *Nature* **428**, 921. [7] S. Mostefaoui, P. Hoppe (2004) *ApJ* **613**, L149. [8] S. Messenger (2000) *Nature* **404**, 968 [9] S. Messenger, R. M. Walker, in *Astrophysical Implications of the Laboratory Study of Presolar Materials*, T. J. Bernatowicz and E. Zinner, Eds. (AIP Conf. Proc. **402**, American Inst. of Phys., Woodbury, NY, 1998), pp. 545-564 [10] L.P. Keller, S. Messenger, J. P. Bradley (2000), JGR **105**, 10397 [11] Keller L. P. et al. (2004) *GCA* **68**, 2577. [12] Messenger S. and Keller L. P. (2004) *Met Planet Sci* **39**, Abstract #5185 [13] E. L. Gibb *et al.* (2000), *Astrophys. J.* **536**, 347 [14] M. P. Bernstein (2002), *Astrophys. J.* **576**, 1115 [15] A. Li, J. M. Greenberg (1997), *Astron. Astrophys*. **323**, 566 [16] van Boekel et al. (2004) *Nature* **432**, 479.