clase intergrowth similar to that occurring in region (1) is present throughout the plagioclase. Thin veins in this region are enriched in Fe and Cl. The boundaries between the three regions are well defined, but regions (1) and (2) are interconnected by plagioclase crystals. In general, chondrules of this type are dominated by regions similar to (1) with varying amounts of (2).

Overall, inclusion KB2 clearly has an igneous texture. However, it is difficult to envision how the distinctly banded texture and complex mineralogy could arise during single-stage cooling of a molten droplet. If region (2) preceded region (1) in a crystallization sequence, it is not clear why metal and sulfide should be restricted to region (2). The nature of region (3) is also unclear. It may be a xenolith, but its plagioclase composition is similar to that in the rest of the inclusion: the question of the origin of such a xenolith then arises. Zoning of Fe/Mg in the spinels may result from metasomatic Fe infiltration, similar to zoning in olivine in region (2). Fe- and Cl-rich veins support this suggestion. If Na metasomatism accompanies Fe, and nepheline is replacing plagioclase, the process must proceed from the interior of the region outward, which appears unlikely. It is also unlikely that nepheline is replacing a more albitic plagioclase, as this would imply that the primary plagioclase had reverse zoning. Replacement of plagioclase with nepheline requires the transport of a large amount of Na into the inclusion and would generate a considerable silica excess, the product of which is not apparent. An alternative explanation is that nepheline may be primary, preceding plagioclase during fractional crystallization; however, the inclusion as a whole is silica-saturated. We intend to measure REE abundances in plagioclase and pyroxene in order to understand the mineralogical relationships better, and to determine whether the bulk composition of the inclusion is fractionated.

References: [1] Jones R. H. and Brearley A. J. (1994) *LPS XXV,* 641–642. [2] Hutcheon I. D. and Jones R. H. (1995) *LPS XXVI,* 647–648. [3] Kurat G. and Kracher A. (1980) *Z. Naturforsch., 35a,* 180–190.

THE ^{14}C AND STABLE ISOTOPIC COMPOSITION OF CARBONATES IN SNC METEORITES. A. J. T. Jull[1,2], S. Cloudt[1], and C. J. Eastoe[2], [1]National Science Foundation, Arizona AMS Facility, Tucson AZ 85721, USA, [2]Department of Geosciences, University of Arizona, Tucson AZ 85721, USA.

Some SNC meteorites [1] have been observed to contain minerals such as carbonates that result from aqueous alteration [2,3]. If we can show the carbonates are extraterrestrial and they have not subsequently exchanged with terrestrial CO_2, then the isotopic composition of C and O can provide important information about martian H_2O and CO_2 and about weathering processes on Mars. We have used cosmogenic ^{14}C as a label to identify the carbonate as a terrestrial or extraterrestrial alteration product. We will discuss the $\delta^{13}C$, $\delta^{18}O$, and ^{14}C compositions of CO_2 released from acid-etching experiments of Allan Hills 84001, Nakhla, and Zagami. Carbonates irradiated in space as small bodies will contain about 74 dpm/kg (3.2×10^8 atom ^{14}C/g) [4]. This activity corresponds to a $^{14}C/^{12}C$ ratio (atom/atom) of 5.0×10^{-14} or 4.3% of the ratio found in modern (~1950AD) C [4]. Twentieth-century, terrestrial carbonates formed prior to atmospheric nuclear tests will have a ^{14}C content of 98–100% modern. Samples formed after 1950 AD, or which equilibrated with atmospheric CO_2 later, will contain higher levels of ^{14}C, up to 180% modern [see 4]. Terrestrial weathering products introduced after the meteorite fall would lead to higher ratios of $^{14}C/^{12}C$ and values of $\delta^{13}C$ values of –10 to +10‰.

Previously, we have discussed the results of the isotopic measurements for ALH 84001 and Nakhla [4], which showed that $\delta^{13}C$ and ^{14}C correlated inversely. High $\delta^{13}C$ values up to 45‰ correspond with low ^{14}C, indicating an extraterrestrial carbonate; low values of $\delta^{13}C$ (<5‰) showed approximately modern terrestrial ^{14}C and imply a terrestrial source. This material had an ordinary composition of its O, $\delta^{18}O$ = 15–20‰. The lower $\delta^{13}C$ values in ALH 84001 etch samples corresponded to carbonates incorporating some terrestrial ^{14}C and were close to the earlier data for SNC meteorites [4–6]. Samples with the lowest ^{14}C compositions were highest in $\delta^{13}C$.

We have obtained new results on Zagami and sieve fractions of ALH 84001. Samples of crushed meteorite were treated with 100% H_3PO_4 at 25°C for times ranging from 1 to 4 days. The $\delta^{13}C$ and $\delta^{18}O$ were measured in purified CO_2 samples by stable isotope mass spectrometry and ^{14}C by accelerator mass spectrometry (AMS). The CO_2 released from acid etching of Zagami with the lowest values of ^{14}C has the lowest $\delta^{13}C$ of –20‰ and the data plot on a trend connecting $\delta^{13}C$ of –20‰ and low ^{14}C (indicating extraterrestrial origin) with carbonates ($\delta^{13}C$ of –5 to +5‰ and ^{14}C ~ modern) of terrestrial composition. The $\delta^{18}O$ values found for these samples were similar to those observed earlier [4].

Viking spacecraft measurements suggest that atmospheric CO_2 on Mars is isotopically heavy, about 50 ± 100‰ [7]. Models also predict a high $\delta^{13}C$ value for Mars CO_2 [8] and an atmospheric source could account for the heavy $\delta^{13}C$ values. Carbonates from three presumably random samples of martian rock indicate a $\delta^{13}C$ range of –20 to +45‰ prior to any terrestrial effects. The inorganic chemistry of Mars must include processes that allow a wider ranges of values of $\delta^{13}C$ than found in terrestrial carbonates.

References: [1] McSween H. (1994) *Meteoritics, 29,* 757–779. [2] Gooding J. L. et al. (1988) *GCA, 52,* 909–915. [3] Wentworth S. J. and Gooding J. L. (1990) *LPS XXI,* 1321–1322. [4] Jull A. J. T. et al. (1995) *Meteoritics, 30,* 311–318. [5] Romanek C. S. et al. (1994) *Nature, 372,* 655–657. [6] Wright I. P. et al. (1992) *GCA, 56,* 817–826. [7] Nier A. O. C. et al. (1976) *Science, 194,* 68–70. [8] Jakosky B. (1991) *Icarus, 94,* 14–31.

PONTLYFNI: NOT JUST ANOTHER WINONAITE. G. W. Kallemeyn, Institute of Geophysics and Planetary Physics, University of California, Los Angeles CA 90095-1567, USA.

Pontlyfni is a fall from Wales that was originally described as a "forsterite" chondrite along with Kakangari, Mount Morris (Wis), and Winona [1]. Although Tierra Blanca and several Yamato meteorites have joined this group under the moniker "winonaites," Kakangari was purged and became the prototype of a new grouplet [2]. A recent textural and mineralogical study showed that Pontlyfni has characteristics at the extreme of the winonaites [3]. It has the lowest values for fa (0.9) in olivine and fs (0.5) in low-Ca pyroxene. It is very fine grained, whereas the other winonaites are fine to coarse grained, with some being heterogeneous in grain size. Bulk compositional analyses of replicate samples of Pontlyfni by INAA were performed in order to see if its composition was also distinct from the other meteorites. Samples of Winona and Mount Morris (Wis) were also run concurrently with Pontlyfni. Previous analyses of Tierra Blanca were also used for compositional comparisons.

Refractory lithophile abundances (CI,Mg-normalized) in Pontlyfni are distinctly different from the other three winonaites in both magnitude and pattern. Pontlyfni has close to CI abundances of refractory lithophiles. The pattern is relatively flat except that the light REE are slightly enriched relative to the heavy REE, and there is a small positive Eu anomaly. The Ca/Al atom ratio (~0.7) is indistinguishable from the range of typical chondritic ratios. By comparison, Winona, Mount Morris, and Tierra Blanca have very fractionated refractory lithophile abundance patterns. They have fractionated REE patterns with the heavy REE enriched relative to light REE and strong positive Eu anomalies. Their Ca/Al atom ratios (~0.5) are lower than typical chondritic meteorite values. The overall lithophile element abundance patterns for Winona, Mount Morris (Wis), and Tierra Blanca are similar to those of silicate samples from the IAB Udei Station previously analyzed by this lab.

The siderophile/chalcophile element abundance pattern (CI,Mg-normalized) in Pontlyfni is relatively flat, with abundances generally a little higher than CI abundances. Only the highly volatile Zn is very low (0.2× CI). Winona, Mount Morris (Wis), and Tierra Blanca have highly variable siderophile/chalcophile element abundance patterns (2.0–0.2× CI). These meteorites are all weathered, so the variability may be due in part to the effects of weathering on metal and sulfides.

The differences in composition between Pontlyfni and the other winonaites, along with its outlying nature with regard to texture and mineralogy, would seem to preclude the classification of Pontlyfni with the other winonaites. Pontlyfni has an O isotopic composition similar to Winona [4]. The winonaites as a whole, though, encompass a relatively wide range on an O three-isotope plot, overlapping several other chondrite groups and unique meteorites (e.g., CR, CH, IAB, acapulcoites). Therefore, O isotopic composition alone is not a sufficient parameter for classification.

It has been suggested that all the winonaites except Pontlyfni have un-

dergone some degree of partial melting [3]. The relatively unfractionated abundance patterns for Pontlyfni, and the fractionated patterns for the other winonaites would seem to corroborate this notion (although the slight REE fractionation needs some explanation). Whether or not Pontlyfni originated on the same parent body is still unclear.

References: [1] Graham A. L. et al. (1977) *Min. Mag., 41,* 201–210. [2] Weisbery M. K. et al. (1996) *GCA,* submitted. [3] Benedix G. K. et al. (1995) *LPS XXVI,* 99–100. [4] Clayton R. N. and Mayeda T. K. (1978) *EPSL, 40,* 168–174.

AEM, XRD, AND IR ANALYSES OF AN AlSiO CONDENSATE ANNEALED FOR TWO HOURS AT ROOM TEMPERATURE UP TO 1100°C. J. M. Karner[1], F. J. M. Rietmeijer[1], and J. Janeczek[2], [1]Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque NM 87131, USA, [2]Department of Earth and Planetary Sciences, Silesian University, Miekzarskiego 60, 41-200 Sosnowiec, Poland.

The fluffy texture of vapor phase condensates will isolate its individual entities that during thermal annealing will behave as chemically closed systems [1]. To test this hypothesis we annealed an AlSiO condensate at 100°, 210°, 300°, 500°, 600°, 700°, 800°, and 1100°C, each for 2 hr. Assuming relevant diffusion rates in the Al_2O_3-SiO_2 system, and considering the small size (30–150 nm) of individual entities, diffusion-controlled reactions will be established during this time. If our hypothesis is correct, dusts in O-rich circumstellar environments may show a wide range of chemical signatures determined by allowable stable configurations in the Al_2O_3-SiO_2 system.

The original condensate was dominated by Al-O bonds and minor SiO features but, when the sample became fully oxidized during annealing in air, the IR data show changes in the length and bending modes of O-Si-O bonds and at 1100°C semicrystalline SiO_2 features. All samples are overwhelmingly X-ray amorphous except for tiny amounts of cristobalite between 210° and 500°C, but all traces of crystalline materials disappeared above 600°C. AEM analyses were performed on the original condensate and the sample annealed at 1100°C. All chemical and size data were submitted to statistical treatment in order to assess similarities and differences between the samples. Both samples have a fluffy texture consisting of (sub)circular grains with compositions ranging from 0 to ~70 wt% Al_2O_3. Two distinct types of grains are recognized in both samples.

1. Amorphous grains, 0–12 wt% Al_2O_3, have a well-defined 8.5-nm-thick rim of 0.7-nm lattice fringes (probably cristobalite). The rimmed grains, 32–79 nm (mean = 54 nm), have log-normal size distributions. Both samples have elongated strands of fused grains but with a single rim. Isolated rimmed grains in the unannealed sample have 0 and 6.9 wt% Al_2O_3, but in the annealed sample they occur mostly in clusters (~9 wt% Al_2O_3) wherein individual grains are only somewhat discernable.

2. The compositions of mottled grains show peaks at 23, 38.5, 51, and 59.5 wt% Al_2O_3 in the condensate and rare entities with a stoichiometric mullite composition (70 wt% Al_2O_3). Annealed mottled grains show peaks at 23, 39, and 58.5 wt% Al_2O_3. Mottled grains (30–150 nm) in both samples have log-normal size distributions with a mean of 90 nm. The grains are generally amorphous except for scattered diffraction maxima in grains with 40–60 wt% Al_2O_3 that are consistent wth sillimanite.

The grain size distributions, morphology, and chemistry in the condensate and the sample annealed at 1100°C are very similar. Differences between the samples include a compositional peak at 51 wt% Al_2O_3 and a higher abundance of mottled grains <60 nm, both in the condensate. We attribute the disappearance of this peak and the smallest grains to thermal annealing. The presence of two morphologically distinct grains can be explained using the SiO_2-Al_2O_3 equilibrium binary phase diagram [2] wherein compositions of the rimmed grains match those of the liquidus surface between pure SiO_2 and the eutectic composition at ~10 wt% Al_2O_3. The liquidus surface also constrains mottled grain compositions on the liquidus of the phase diagram between the eutectic composition and the mullite stability field. The compositional peaks in the condensate match those of the putative equilibrium and spinodal solvi postulated in this phase diagram. It suggests that condensation of liquid droplets occurred at preferred Al_2O_3/SiO_2 configurations during the gas-liquid transition. The preservation of compositional peaks in the annealed sample (1100°C) confirms that isolated entities were prevented from reacting to match compositions of the solvus crests. Subsolidus phase decomposition into sillimanite nanocrystals and an amorphous silica-rich aluminosilica matrix during autoannealing was preserved during thermal annealing.

Conclusion: Amorphous phase relationships during condensation of fluffy aluminosilica materials and subsequent thermal annealing are predictable by the phase diagram. These amorphous materials are observed in interplanetary dust particles, which suggests that these dusts could occur in O-rich circumstellar environments.

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References: [1] Rietmeijer F. J. M. (1996) *LPS XXVII,* 1071–1072. [2] MacDowell J. F. and Beall G. H. (1969) *J. Am. Ceram. Soc., 52,* 17.

RADIATION AND SHOCK-THERMAL HISTORY OF THE ZAGAMI METEORITE BY TRACK AND THERMOLUMINESCENCE INVESTIGATION. L. L. Kashkorov[1], A. I. Ivliev[1], G. V. Kalinina[1], and L. M. Bulgakova[1,2], [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Kosygin Street 19, Moscow, Russia, [2]Geology Department, Moscow State University, Moscow, Russia.

In this study we have examined heavy track and thermoluminescence (TL) parameters in six large (up to 800 μm in size) olivine crystals of the Zagami meteorite. This martian meteorite underwent shock pressures of 30–35 GPa [1] in the process of formation. Radiation- and shock-thermal effects in clear monomineral grains must be determined mainly by radiation and order-disorder crystal structure state.

The track density interval (1–3) × 10^6 cm^2 and essential shortening in the track-length distribution in some olivine grains indicate their remarkable heating. Thermoluminescence measurements were carried out using high-sensitivity equipment. The natural, γ-ray (^{137}Cs), and X-ray (55 KeV) induced TL were measured. Three types of glow curves with strongly different relations of TL intensity in the low-, middle-, and high-temperature intervals were observed. Thermoluminescence natural glow curves have at least three main peaks at 230°C, 320°C, and 400°C. the ratio values of TL intensity at<270°C, 270°–350°C, and >350°C are varied in the wide intervals. X-ray, artificially induced TL in all these olivine grains has the simplest glow curves, with the single peak 130°C. For γ-ray-induced (dose ~100 krad) TL glow curves have a number of peaks: the lowest near 130°–150°C in different grains and the some next T peak up to 300°C.

The present study supports the interpretation that (1) track density and length variations in different silicate grains can be due to a relatively short thermal annealing event at effective temperature up to 400°C; (2) TL parameters for the monomineral grains mainly reflect their shock-induced structure properties [2,3]; (3) the Zagami meteorite might have originated in the high-pressure-heating impact event that probably reflected in the specificity of the track and TL parameters for the large igneous origin olivine grains.

References: [1] Ostertag et. al. (1985) *LPS XVI,* 19–21. [2] Ivliev A. I. et al. (1993) *LPS XXIV,* 699–700. [3] Ivliev A. I. et al. (1995) *Geochimiya, N9,* 1367–1377, in Russian.

CONSTRAINTS ON THE ROLE OF IMPACT HEATING AND MELTING IN ASTEROIDS. K. Keil[1], D. Stöffler[2], S. G. Love[3], and E. R. D. Scott[1], [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, Honolulu HI 96822, USA, [2]Museum für Naturkunde, Humboldt University, 10115 Berlin, Germany, [3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena CA 91125, USA.

Imaging of asteroids Gaspra and Ida and laboratory study of asteroidal meteorites show that impacts undoubtedly played an important role in the histories of asteroids and resulted in shock deformation of minerals and the formation of shock veins, breccias, melt rocks, and melt breccias. However, in recent years, impact has also been called upon by numerous authors as a heat source for some of the major geological processes that took place on asteroids, such as global thermal metamorphism and a variety of melting and