NOBLE GAS CONTENTS OF UNMELTED CAP-PRUDHOMME "GIANT MICROMETEOROTIES".

C. T. Olinger[1], M. Maurette[2], J. P. Das[3,4], A. Meshik[3], [1]Physics Division, Los Alamos National Laboratory (colinger@lanl.gov), [2]CSNSM Bat. 104 91405 Orsay-Campys, France, [3]Laboratory for Space Sciences and Physics Dept., Campus Box 1105, Washington University, St. Louis, MO 63130, USA, [4]Currently at Department of Earth Sciences, Syracuse University, NY.

Introduction: The extraterrestrial origin of unmelted micrometeorite collections in Greenland[1] and Antarctica[2] have been demonstrated by implanted solar and cosmogenic ^{21}Ne, but generally the heavier noble gas content in this size range is right at the margin of measurement. Since these original studies, Sarda et al. measured the elemental composition in one large (230 mg) micrometeorite providing additional isotopic constraints[3]; Baecker et al. placed additional constraints noble gas isotopic and elemental content[4],[5].

During a collection in 1994 near the margin of the Cap-Prudhomme ice field, team glaciologists with Maurette recommended sampling of a specifc 1500 m^2 section of ice (out of a 50,000 m^2 surface) that was under compression, blocking vertical turbulence, and therefore likely free of moreinic debris. In this collection ~ one grain out of every five was a micrometeorite, providing favorable conditions to search for large unmelted micrometeorites.[6]

Likely micrometeorites in sieve fractions 100-400 micron and > 400 micron were selected from this collection based on experience from previous work[1-3]. In both of these size ranges samples were optically selected in France based on dark color, very limited fusion crust (irregular surface texture) and in many cases light magnetism. Fourteen samples in the 100-400 micron size range and seven samples in the > 400 micron size range were then selected in St. Louis for noble gas analyses. Figure 1 is an example of SEM and EDX data collected for the smaller samples; SEM data were not collected on the larger samples due to communication errors. A subset of samples were fragmented between glass microscope slides for possible follow-up in nana-SIMS measurements, but otherwise whole particles were weighed on a Cahn microbalance and loaded into laser extraction cells drilled into an aluminum SEM microscope slide.

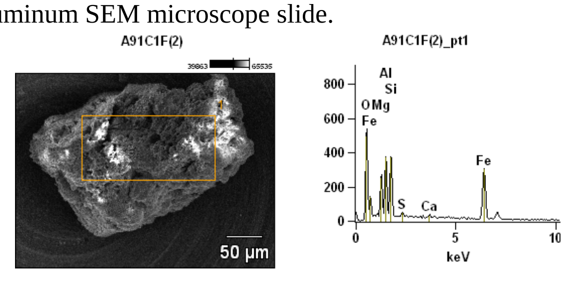

Figure 1. "Typical" SEM image and EDX spectrum from the 100-400 micron size fraction of this collection.

Summary of results: Results for the two different size fractions are summarized separately.

100-400 micron -- Fourteen samples were analyzed. Ne: four of these 14 samples have Ne characterized by implant-fractionated solar wind, and two additional samples have ^{20}Ne several times above blank but had insufficient Ne to unambiguously distinguish the isotopics between terrestrial and solar. All of these range from 1e-7 to 1e-5 ccSTP/g ^{20}Ne. He: each of the particles with Ne above blank also had He well above blank (ranging from 8 to 340 times the blank level) and ^{3}He/^{4}He ratios ranging from 2.5-5.7 $x10^{-4}$, consistent with the expected range of implanted solar wind. Ar: five of the six samples with implanted solar He or Ne had clearly measurable ^{36}Ar and ^{38}Ar, with ^{40}Ar/^{36}Ar ratios ranging from ~10-30 (compared to air at ~297). Kr/Xe: three of the samples with implant-fractionated solar Ne also have measurable Kr and Xe.

>400 micron -- Seven samples were analyzed. Ne: Four of these samples had ^{20}Ne that was clearly above blank, two were 2-3 times blank and one was 17 times blank level. ^{20}Ne concentrations range from 1e-9 to 1e-8 ccSTP/g, systematically lower than the 100-400 micron samples, strongly suggesting partial outgassing or shorter exposure to solar wind. At these gas quantities CO_2^{++} interference on the measurement of ^{22}Ne makes uncertainties on ^{20}Ne/^{22}Ne too large to distinguish terrestrial from solar gas. However, excesses in ^{21}Ne from spallation (^{21}Ne/^{20}Ne > .003) provide unambiguous classification of these four samples as extraterrestrial. He: All except two of the samples show clear ^{3}He excesses (and ^{3}He/^{4}H > 1e-2), strongly suggesting spallogenic He and therefore exposure to cosmic rays. Ar: In contrast to the 100-400 micron size fraction, three of the four > 400 micron samples with spallogenic Ne have ^{40}Ar/^{36}Ar *higher* than air, and the fourth has uncertainties that overlap atmospheric composition. Three of the four samples with Ne above blank also have Kr and Xe that are well above blank; one of these, is clearly distinct from the others in that it is dominated by radiogenic Ar and Xe, with larger amounts of ^{4}He, ^{3}He and ^{21}Ne than any of the others; the ^{4}He is likely from alpha decay associated with the parent of the radiogenic Xe and the large ^{3}He and ^{21}Ne (both spallogenic) demonstrate exposure to cosmic rays.

Discussion: At least half of the samples that selected for noble gas work were extraterrestrial, based on implanted solar Ne and possibly all of the >400 micron samples were extraterrestrial based on $^{3}He/^{4}He$ ratios. Elemental ratios are shown in Figure 2, normalized to the Lunar ilmenite ratios[7], for all samples where each gas was measurably above blank; Xe isotopic delta values for the >400 micron samples are shown in Figure 3, normalized to surface-correlated Xe in Lunar soils (SUCOR)[8]. Enrichments in favor of heavy elements and heavy isotopes likely reflect a combination of solar wind implantation as well as partial degassing during atmospheric entry, both of which would favor retention of the heavy gases. Similar to Baecker et al., a high degree of variability is seen in the noble gas elemental abundances.

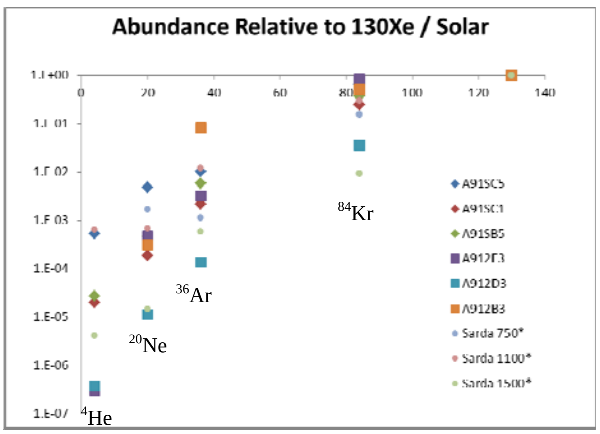

Figure 2. Noble gas distributions ($^{4}He/^{130}Xe$, $^{20}Ne/^{130}Xe$, $^{36}Ar/^{130}Xe$, and $^{84}Kr/^{130}Xe$ normalized by 125 micron Lunar Ilemenite ratios[7] Gas/$^{130}Xe_{solar}$) measured in the 100-400 micron size fraction (diamond shape), > 400 micron size fraction (squares) from Antarctica, compared to the three temperature steps reported in Sarda et al. (circles).

In the 100-400 micron samples, the correlation between large concentrations of solar Ne and comparatively large amounts of heavy gases suggest that these are all reliably from implanted solar wind, although with variable fractionation from implant and diffusive loss. The > 400 micron fraction in this collection shows clear differneces in $^{40}Ar/^{36}Ar$ ratio (greater than atmospheric) from both the smaller samples in this study and the larger samples (600-800 micron samples[5] from Transantarctic Mountains[9]) in Becker et al, suggesting that different collections and even different size fractions from a single collection may represent significantly different solar system sources.

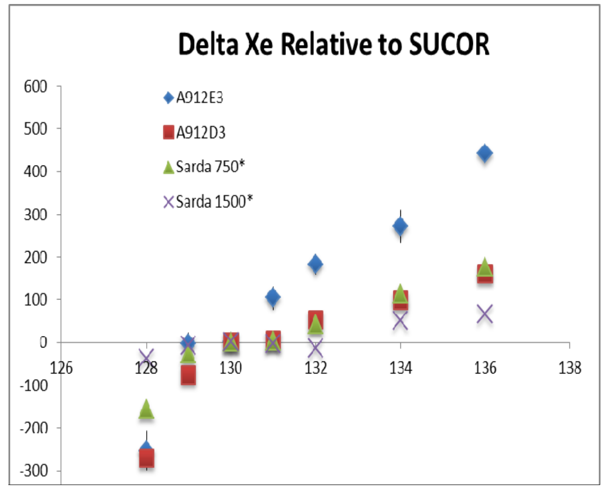

Figure 3. Delta values of Xe relative to SUCOR for the two non-radiogenic >400 micron samples compared to results from Sarda et al.'s temperature steps on one large Greenland micrometeorite. Note that the radiogenic sample in this study has $^{132}Xe/^{130}Xe$, $^{134}Xe/^{130}Xe$ and $^{136}Xe/^{130}Xe$ that are progressively off scale on this plot.

Acknowledgements: This work was made possible by the noble gas lab developed by Charles Hohenberg and benefitted from discussions with Olga Pravdivtseva, Christne Floss and Frank Stadermann at Washington University. Glaciologists M. Pourchet and D. Daunou at LGCC provided envaluable guidance for the meteorite collection at Cap-Prudhomme. Public release is approved by LANL: LA-UR-13-20045.

1 Olinger, C. et al. (1990) EPSL **100**, 77-93
2 Maurette M. et al. (1991) Nature **351** 44-47
3 Sarda, Ph. et al. (1992) LPSC XXII 1165.
4 Baecker, B. et al. (2012) MAPS 5044.
5 BaeckerB. et al. (2012) 43rd LPSC, 1824.
6 Maurette, M. (2006) Micrometeorites and the Mysteries of our Origins, Springer-Verlag, pp. 1-330.
7 Eberhardt et al. (1972) Proceedings 3rd LSC **2** 1821-1856.
8 Podosek, F. et al. (1971) EPSL **10** 199-216.
9 Rochette P. et al., (2008) PNAS 105, pp. 18206-11.