IMPLANTED SOLAR NEON IN GREENLAND MICROMETEORITES;

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Measurements of neon isotopic compositions have been used to prove the extra-terrestrial origin of both melted and unmelted particles selected from polar sediments [1-3]. This was an important first result since prior theoretical calculations suggested that meteorites in this size range should not survive atmospheric entry without melting [4]. Further study of these micrometeorites is strongly motivated by the fact that their size range (~100μm) overlaps the peak of the meteoritic mass-flux distribution [5] and, therefore, may play an important role in better understanding our solar system. Correlations of trapped neon compositions with both gas concentration and grain size have become more apparent now that larger numbers of micrometeorites have been analyzed. These correlations yield new information about the trapping of solar wind (SW) Ne and solar energetic particle (SEP) Ne. They also suggest a possible short-term exposure chronometer for interplanetary particles.

Results--Figure 1 is a three-isotope plot of representative data from >100μm, unmelted Greenland micrometeorites. Some Greenland particles that were classified as extraterrestrial based on their neon compositions have clear spallation contributions, very few are dominated by planetary neon, and the vast majority are dominated by solar neon. Trapped solar compositions in these >100 μm, unmelted micrometeorites range from SEP Ne as defined by Wieler et al. [6], to SW Ne as deduced from the foil experiments of Geiss et al. [7]. Both melted and unmelted particles <100μm in size tend to contain very little SEP Ne, while >100μm, melted particles are frequently depleted in SW Ne (these subsets are omitted from Fig. 1 to avoid cluttering the plot).

Solar ions are implanted onto the surfaces of these particles during their exposure in space. Therefore, gas content is best described as a surface density of gas (σ) rather than a gas concentration, as is more common in noble gas studies. Surface area can be estimated from measured masses of these particles by assuming that they are spherical (which is only approximately true for most unmelted particles). Surface density of gas is then given, in arbitrary units, by the measured amount of gas divided by mass$^{2/3}$. Fig. 2 displays 1/σ vs. trapped $^{20}Ne/^{22}Ne$. The isotopic composition of neon in a hypothetical grain with infinite surface density of gas is, therefore, given by the y-intercept. Only unmelted Greenland micrometeorites containing solar Ne are plotted. Particles <100μm (triangles) were not weighed, so masses were estimated from dimensions obtained in SEM micrographs; errors in 1/σ reflect only counting statistics of the gas.

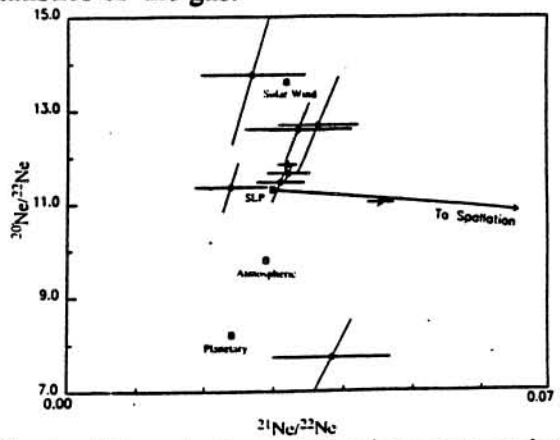

Fig. 1. Three-isotope plot of representative data from >100μm, unmelted Greenland micrometeorites.

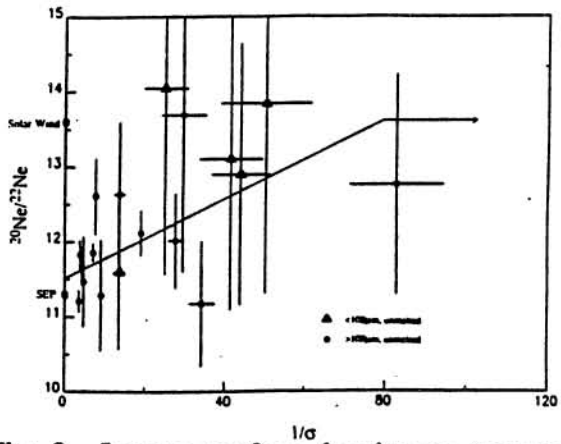

Fig. 2. Inverse surface density vs. trapped $^{20}Ne/^{22}Ne$ for unmelted Greenland micrometeorites.

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Discussion--Figure 2 shows that as σ increases, particles become more enriched in SEP Ne. This trend of increasing SEP/SW ratios with increasing surface density cannot be explained by atmospheric entry effects (either preferential loss of SW Ne or implantation of atmospheric neon) or by diffusive fractionation, and is inconsistent with the suggestion of Wieler et al. [6] that SEP Ne and SW Ne are implanted and retained contemporaneously with each other.

Preferential degassing of implanted SW Ne during atmospheric entry would produce a trend opposite to that in Fig. 2, with SEP/SW ratios decreasing as $1/\sigma$ increases. Diffusive fractionation of SW Ne [8] would similarly proceed in the wrong direction with respect to surface density (or concentration) of gas, and can not reach the enrichments of ^{22}Ne observed here. Implantation of atmospheric Ne would produce a positive slope, as in Fig. 2, but the line would be much steeper and would extend below SEP Ne for the required implanted concentrations. Finally, under the model of Wieler et al. [6], where SEP and SW Ne is incorporated in ratios directly related to their flux ratios, the variation from nearly pure SW Ne to nearly pure SEP Ne can not be explained. Thus, another mechanism must be active.

Saturation effects can accommodate the observed result. Reported SW Ne fluxes [7] and observed surface densities of neon in both lunar soils [6,7] and these samples suggest that micrometeorites can become saturated in SW Ne on the order of 100 years at 1 Au. However, SEP Ne is implanted up to two orders of magnitude deeper than SW Ne [6] and continues to accumulate after SW saturation is reached. Thus, the accumulated SEP/SW ratio increases, as does surface density (or concentration) of trapped neon, producing the observed trend in Fig. 2. The arrow indicates an assumption that implanted gas has approximately a SW composition until saturation is reached. Such dependance of the trapped SEP/SW ratios on exposure duration suggests that measured SEP/SW ratios can be exploited (at least qualitatively) as a relative exposure chronometer for micrometeorites which plot on the correlation line. Particles plotting to the left require longer exposure durations than particles plotting to the right. Samples plotting below the correlation line have presumably lost significant amounts of SW Ne during atmospheric entry (or contain significant planetary neon), as confirmed when melted particles are added to Fig. 2. In this latter case no chronometric information can be inferred.

Applying this chronometer to the particles analyzed, the micrometeorites <100μm in diameter generally have shorter exposure ages than the larger samples. This is consistent with the shorter Poynting-Robertson lifetimes expected for smaller micrometeorites. While such consistency does not prove the validity of this chronometer, it is an encouraging result.

Beyond suggesting chronometry of micrometeorite space exposure, this model can also explain isotopic differences in trapped solar neon between different lunar soils without resorting to the suggestions of Becker and Pepin [8] and Wieler et al. [6] that such differences are due to temporal variations in the SW Ne (or SEP Ne) composition. Variation in trapped composition of neon between bulk soils may, instead, simply reflect differences in average surface exposure duration of individual grains in the soils. Soils containing particles which have longer average surface exposures will have a higher trapped SEP/SW ratio than soils with shorter average surface residence times.

Conclusions--Trapped SEP/SW Ne ratios correlate with surface density of gases in Greenland micrometeorites, suggesting that trapped SEP/SW ratios depend on exposure duration of these particles. If correct, then this suggests 1) that smaller particles have a shorter space exposure (on the average) than larger particles, which is consistent with Poynting-Robertson lifetimes; and 2) that variation in trapped composition in bulk lunar soils may reflect differences in gardening conditions, not necessarily temporal variations in the composition of solar neon.

References: [1] Maurette et al. (1989) Lun. Planet. Sci. XX, pp. 640-641; [2] Olinger et al. (1989) Meteoritics (in press); [3] Olinger et al. (1989) E. P. Sc. L., submitted; [4] Whipple (1951) Proc. Nat. Acad. Sci. **36**, 687-695 [5] Hughes, (1978) Cosmic Dust, pp. 123-185; [6] Wieler et al. (1986) GCA **52**, pp. 1441-1448; [7] Geiss et al. (1972) Apollo 16: Prelim. Sci. Rep., pp. 14.1-14.9; [8] Becker and Pepin (1989) GCA **53**, pp. 1135-1146.

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