ON THE ISOTOPIC SIGNATURE OF RECENT SOLAR-WIND NITROGEN
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Recently exposed lunar surface samples must contain N atoms implanted by the recent solar wind, but because of the isotopic complexity of lunar regolith N, both between different samples and within individual samples, it has proven difficult to identify the signature of such recent N. We therefore have little knowledge of the isotopic composition of recently implanted solar-wind N. Furthermore, no such information is currently available from direct spacecraft measurements of the present solar wind. A knowledge of the isotopic make-up of N in the present solar wind appears to be essential for an understanding of the nature of the long-term isotopic variation [1]. We are addressing this problem by studying N in well-documented samples which have been recently exposed to solar wind on the lunar surface.

Estimates of the isotopic composition of recently implanted solar N (often identified with solar wind) have ranged from +105°/oo (from stepwise etching [2]), through +120°/oo (from stepwise pyrolysis [3]) to +200°/oo (from stepwise combustion of a metal separate [4]). (It is not clear whether in the last of these, the isotopic signature could have been affected by presence of extralunar, i.e., meteoritic, metal which reveals a variability in $^{15}$N of at least a factor of two [e.g. 5].)

North Ray Crater at Apollo 16 was formed 49Myr ago [6], a recent event on the lunar or solar timescale. Rim soils from North Ray contain abundant fresh ejecta from the 49Myr event, though significantly contaminated with soil mixed in by lateral transport from the surrounding Cayley terrain [7]. Such "country fines" [8] would be predominantly mature regolith with considerably greater average antiquity than 50Myr. In fact, bulk analyses of North Ray rim soils reveal a significant range in both N contents and $^{15}$N values, from 19 to 47ppm and from +44 to +96°/oo, respectively. This variability could well be due to variable proportions of mature regolith and North Ray ejecta. Concentrating true North Ray ejecta is most readily achieved by employing coarse pristine plagioclase grains. R.L.Korotev [Pers. Comm.] has suggested that such material is unlikely to have been transported in significant quantities to North Ray from distant locations. As a first step towards our stated goal, we have analysed aliquots of three grain-size fractions (90-125, 125-175 and 175-250μm) of plagioclase hand picked from soil 67601, analysed previously at Zurich for He, Ne and Ar [9].

Analysis of N released by stepwise heating of grain-size fractions was designed to aid discrimination between trapped and cosmogenic components. Nitrogen analysis involved some modification of our earlier procedure [10]. All samples were combusted at 400°C to remove possible terrestrial contamination. For the medium and coarse fractions, this was followed by pyrolysis in 5 or 6 steps to 1040°C. Then, a combustion step was added at 700°C, followed by further pyrolysis steps to 1065°C. (Unfortunately, after the first 1040°C pyrolysis, the medium grain-size fraction in its gold foil container made contact with the Au foil of a previously analysed sample and became vacuum-welded to it. Although we disqualify the subsequent results from our interpretation, our data suggest that any perturbation of 67601 results was small.) The significant N release in the 700°C combustion step and the negative $^{15}$N signature which followed, prompted us to change the schedule for the fine fraction. In this case, the combustion was carried out before heating the sample to temperatures above 700°C.

Results are shown in Fig. 1 (excluding those for the 400°C combustion).
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Fig. 1. $^{15}\text{N}$ as function of N release for grain-size
fractions of 67601. P denotes pyrolysis, C combustion.

Several features are noteworthy. First, our results for the fine fraction
yielded less N (5.0 ppm) than anticipated based on concentrations observed in
the other fractions (5.0 ppm [coarse]; 10.8 ppm [medium]), though isotopic
values are rather similar. A shorter solar-wind exposure for the fine frac-
tion appears inconsistent with the noble-gas data [9]. All size fractions
exhibit the two-step release pattern characteristic of trapped regolith N
(relatively low $^{15}\text{N}$ values at the lowest temperatures are probably due to
traces of terrestrial N). The low-temperature maxima, in the 700-850°C range,
plausibly interpretable as recently implanted solar wind, are $+48$ (coarse)
$+53$ (medium) and $+70$ (fine), significantly lower than found for bulk 67601,
$+120^\circ$/oo [3]. The intermediate-temperature minima, possibly resulting from
higher-energy implantation [11], are $+1$, $+18$ and $+23^\circ$/oo, compared with
$+36^\circ$/oo for the bulk [3].

Interestingly and importantly, all grain sizes reveal evidence for an
isotopically light ($^{15}\text{N} = -57, -76^\circ$ and $-52^\circ$/oo) component (*the medium
fraction needs to be disqualified, as discussed earlier). This N component,
apparently made mobile, though not directly released, by the 700°C combustion
step has not previously been recognised, presumably because it has always
been masked by other components. Its source and significance are still far
from clear, but it represents an additional minor N component, apparently
distinct from indigenous lunar N [10].

Concerning our search for recently implanted solar-wind N, the low-tem-
perature release from 67601 plagioclase reveals no evidence for N with $^{15}\text{N} > +100^\circ$/oo as previously found for bulk material. Although there is evidence
for transported material in bulk North Ray soils [7], the cause of this ap-
parent discrepancy is not clear. It is striking that a sample with a presumed
recent and relatively short lunar-surface exposure nonetheless exhibits mar-
ked complexity in its N-isotope systematics.