MODELLING THE EVOLUTION OF N AND ^{15}N/^{14}N IN THE LUNAR REGOLITH

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Several explanations for the apparent long-term increase of ^{15}N/^{14}N in
the lunar regolith [1] have invoked mixing of solar-wind N with N from a
nonsolar source [2]. Possible sources have included indigenous lunar N [3],
interstellar components in meteorites [4] and magnetospheric ions from the
terrestrial atmosphere [5]. Two-component explanations have been criticised
[e.g. 1,6,7] on the grounds that the close relationship between regolith N
content and indices of solar-wind exposure appeared to preclude the presence
of a suitable quantity of nonsolar N. However, the only quantitative expres-
sion of that argument [1,6] employed a greatly oversimplified model for lunar
surface exposure. We are therefore subjecting a generalised two-component
mixing model to a more realistic series of tests incorporating multiple ex-
posures, long-term decreases in both solar-wind and micrometeorite fluxes,
and appropriate uncertainties in the various input parameters. Our aim is to
determine if there is a plausible range of input-parameter space that can
yield a reasonable simulation of the experimentally derived data for a suite
of Apollo regolith samples.

As measures of maturity and antiquity we use I_s/FeO [8] and trapped
^{40}Ar/^{36}Ar [9], respectively. Input parameters include the ^{15}N/^{14}N ratios of
both solar and nonsolar (= "planetary") N, number of surface exposures (ran-
domly generated), initial enrichment and rate of decay for the fluxes of
solar wind, planetary N and micrometeorites, and the uncertainties (including
short-term variabilities) assigned to those fluxes, as well as to that of
parentless ^{40}Ar. (Quoted values for uncertainties are the standard deviations
for the normally distributed population from which the model values were
randomly chosen.) Output parameters, used to test the model, are N content
and δ^{15}N value, ^{36}Ar content and trapped ^{40}Ar/^{36}Ar ratio, and I_s/FeO value.
In addition, we estimate the fraction of total N supplied by the planetary
component, inferred from the isotopic composition, PF(i), compared with the
analogous quantity estimated from the relationship between N content and
maturity, PF(N); see [1,10] for further details.

Inspection of existing lunar-sample data gave the broad ranges within
which the input-parameter values must fall. Subsequent refinement of those
values was achieved by trial and error. Given present assumptions, the opti-
mum match with a suite of Apollo 16 soil data is illustrated in Figs. 1a-d.
The model results correspond to the following input-parameter values:
$(^{15}$N/^{14}N$)_{solar}$ = 4.425x10^{-3} (δ^{15}N = +200°/oo)
$(^{15}$N/^{14}N$)_{planetary}$ = 2.25x10^{-3} (δ^{15}N = -390°/oo)
Early solar-wind flux enhancement = 3.5 X present.
Solar-wind flux decay constant (exponential) = 0.0015 Myr^{-1}
Early planetary-N flux = 4.5 X present solar-wind N flux.
Planetary-N flux decay constant = 0.0011 Myr^{-1}
Values for uncertainty and short-term variability of the input parameters
ranged from +/-5% to +/-30%.
Each simulated sample could be exposed at up to 5 different epochs.
No long-term change was imposed on the micrometeorite flux in the simulation
shown here; a long-term decrease of a factor of about two in that flux was
found to lead to an equivalent match to that illustrated in Fig. 1.
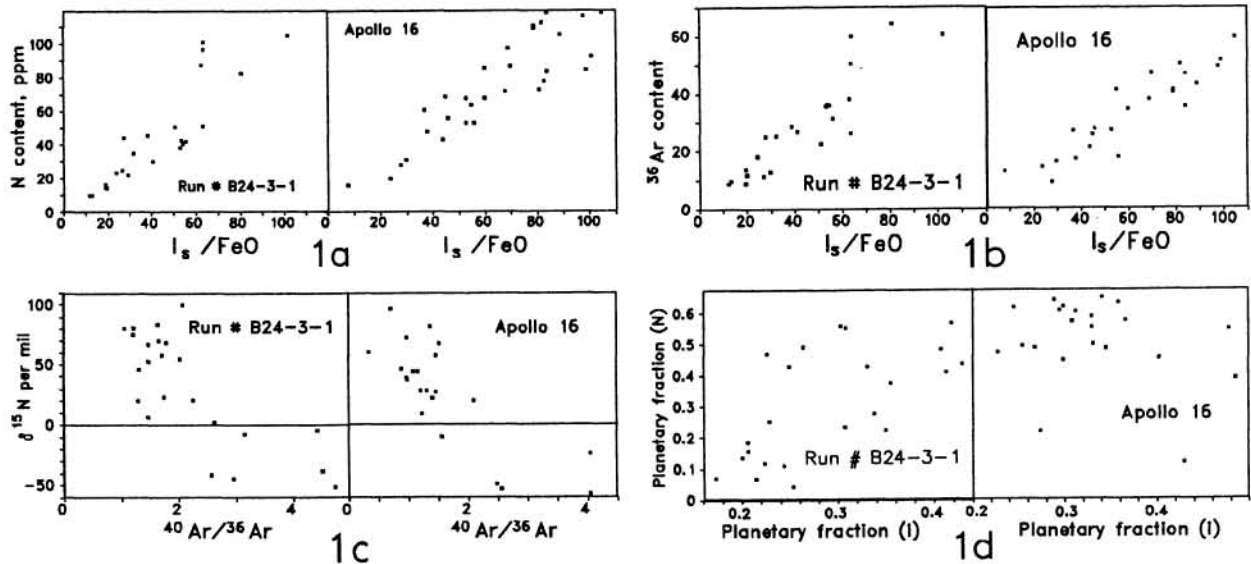(Note: solar-wind flux was considered to decay from its early enhanced value

Fig.1. Results from the optimum two-component simulation compared with data from a suite of Apollo 16 soil samples. (a) N content <u>vs</u> maturity (I_s/FeO): left, simulation; right, Apollo 16. (b) ^{36}Ar content <u>vs</u> maturity (I_s/FeO). (c) δ^{15}N <u>vs</u> antiquity (trapped ^{40}Ar/^{36}Ar). (d) Fraction of N attributable to "planetary" N estimated from relationship with maturity <u>vs</u> fraction estimated from N-isotopic data; for details, see [1,10].

to the present-day value, whereas the planetary-N flux was allowed to decay to zero on a roughly billion-year timescale.)

None of the input-parameter values appear to violate known constraints based on lunar data, though that does not mean they are consistent with all aspects of lunar history. In each of Figs. 1a-c, the real and simulated results are statistically indistinguishable from each other, and therefore consistent with a two-component model. In Fig. 1d, however, the correlation coefficient for parameters estimated from real data is $-0.301+/-0.198$, whereas the simulation yields $0.631+/-0.131$. (An earlier, oversimplified simulation yielded a perfect correlation in such a test [1]. For the Apollo-16 data, PF(N) was calculated assuming quantitative retention of solar-wind N and Xe in lunar soils.). This difference indicates that the two-component model, as tested here, is insufficient to explain the lunar data. One possibility may be the presence of more than two quantitatively significant components. These results are elaborated in [10].

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