Implantation of solar wind ions has in principle left in the lunar soils a fossil record of the composition, energy, and flux of the wind—and thus a measure of the physical and chemical characteristics of its source regions—extending back to the early history of the sun. In practice, the record has been exacting to read and difficult to interpret. Apart from the central chronological problem (when and for how long were particular soil grains exposed to the wind?), just the relatively simple task of deducing in part the composition(s) of the primary ion flux from relative abundances of solar wind nuclides now trapped in lunar soils is complicated by questions concerning alteration of primary abundance patterns during or after irradiation by mass- and mineral-dependent trapping efficiencies, saturation effects, and sputtering and diffusion losses, and by formation of constructional particles by agglutination and brecciation. Best estimates of solar wind composition do not involve data from natural lunar detectors. They are based either on light noble gases trapped in foils(1), or on average solar system abundances compiled from solar and meteoritic data(2). Uncertainties in the data, and some of the lunar measurements discussed below, suggest that these relative elemental abundances may represent the composition of the wind to within a factor 1.5-2, at least for noble gases. The fact that all He-Ne-Ar-Kr-Xe elemental abundance patterns measured so far in lunar soil materials are discordant with these estimates of solar wind composition by factors >4 for one or more of the noble gases is evidence for alteration of the regolithic record by some combination of the mechanisms noted above.

In recent papers(3,4) the Zürich group has argued for the superiority of primary regolith particles as solar wind recorders. Volatile elements in minerals are free of the possible fractionations involved in formation of the secondary glasses, agglutinates, and breccias that carry the major fraction of solar-derived gases in bulk soils. From extensive study of He, Ne and Ar in sized mineral and composite particle separates, Signer, Wieler, Etique and coworkers conclude that mineral grains, lightly loaded with typically a few % of the concentrations in agglutinates, are unsaturated macroscopically and in most cases microscopically with respect to implanted noble gases. Subsequent losses, particularly of He and Ne from plagioclase, are attributed to diffusion, but these are thought to be small for heavier species: <30% for Ar from plag, and negligible for Ar-Kr-Xe from pyroxene and ilmenite. They thus consider mineral grains to be accurate recorders of the solar flux for heavy gases, and for He and Ne as well in retentive substrates (e.g., ilmenite).

Combined nitrogen and noble gas analyses add two dimensions to interpretation of the solar wind record in minerals. Solar N appears to be well retained in the regolith(5), so N/Xe ratios in trapped solar gases are potential monitors of relative noble gas losses. And, given evidence for secular variation of solar wind δ15N(6,7), nitrogen isotopes could yield qualitative information on when the minerals were irradiated by the wind. We are measuring elemental and isotopic abundances of N and noble gases released from separated minerals by stepwise heating. Pure separates from soil 71501 were prepared for us by R. Wieler of the Zürich laboratory. We report here results for plagioclase; ilmenite and pyroxene experiments are in progress.

N and Ar release profiles are shown in Fig.1. Ar release is typical for surface-sited solar wind, but that of N is not: N yield/step increased up to the highest temperature attainable in our quartz oven. Repeat heating at 1200° yielded no additional noble gases, including Xe (max release at 1000°), but 50% of the 1200° N, implying a significant untapped reservoir of firmly bound N. Isotopically labelled N implanted at 15KeV into Apollo 15 fines(8) was released much like solar
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wind Ar; its profile, normalized to the $800^\circ$ plag N fraction, is shown in Fig.1. Release of solar N from 71501 ilmenite, which has been carried to $1150^\circ$, also closely follows that of Ar. We conclude that this plagioclase contains nonsolar indigenous N, retentively sited in grain volumes and amounting to several ppm. N isotopic compositions (Fig.2) are not inconsistent with this interpretation. Contaminant N, with $\delta^{15}\text{N} = 2\%$, was released at $600^\circ$; this step was repeated until the extraneous N vanished. There may be an isotopic signature of recent solar N (high $\delta^{15}\text{N}$) at $800^\circ$, the characteristic temperature of initial release from bulk soils(9), but the analysis, on $<400\text{pgN}$, is so imprecise that within $2\sigma$ it is nondiagnostic. Assuming that this is in fact solar wind N, and from the $^{15}\text{N}_2$ profile in Fig.1 that a comparable amount of solar N appears at $1000^\circ$, superimposed on indigenous N, $\delta^{15}\text{N}$ of indigenous N is $\approx 15\%$, within the range of an earlier estimate(10). Spallation elevates $\delta^{15}\text{N}$ above this level in the final steps. Removal of spallation N was clearly incomplete; the fraction released amounts to $\approx 100\text{ my}$. of cosmic ray exposure.

Integrated abundances normalized to Xe are plotted in Fig.3, relative to solar values(2). Noble gases follow a plag pattern, also shown by the $<4\mu$ fraction of the plag-rich soil 67701(11), in which He and Ne are severely depleted. But Ar is also depleted, by 60%, and Kr by 35%. If the solar estimates are correct, the plag has lost heavy noble gases. The $400^\circ$ release from 67701, shown in Fig.3, is closely solar for Ne,Ar,Kr/Xe, but only weakly supports the validity of the solar values since, although this was the first release after acid etch(11) and the gases were probably lightly held in the damaged substrate, we cannot rule out fractionation during outgassing. Low temperature release in the current ilmenite run shows solar composition for all noble gases to $\pm 40\%$. Our best estimate is that the plag has lost $\approx 20-60\%$ Ar (assuming no Xe loss), close to the Zürich estimate(4). Interpretation of the N/Xe ratio is complicated by the indigenous N. If we assume that the $600-800^\circ$ N is entirely solar, and that half the total solar component is released in this interval as it was for $^{15}\text{N}_2$ (Fig.1), then the solar wind N/Xe ratio in the plag is solar, implying quantitative retention of both. A reasonable upper limit might be to take the $1000^\circ$ N release as solar wind also, yielding N/Xe = 2.9x solar. In this case either the solar ratio(2) is wrong by a substantial factor, or up to 65% of the Xe (and 85% of the Ar) has been lost from the plag; or, we are dealing with some combination of both possibilities. REFS. (1)Geiss J. et al. (1972)NASA SP-315,14-1; (2)Cameron A.G.W. (1980)preprint; (3)Signer P. et al. (1977)Proc.Lun.Sci.Conf.8th. 3657; (4)Wieler R. et al. (1980)Proc.Lun.Pl.Lun.Sci.Conf.11th,1569; (5)DesMarais D.J. et al. (1974)Lun.Sci.V,168; (6)Clayton R.N.,M.H.Thiemens (1980)Proc.Conf.An.Sun,463; (7)Kerridge J.F. (1980)ibid; (8)Chang S. et al. (1973)Proc.Lun.Sci.Conf.4th,1509; (9)Becker R.H.,R.N.Clayton(1977)Proc.Lun.Sci.Conf.8th,3685; (10)Becker R.H.et al. (1976)Proc.Lun.Sci.Conf.7th,441; (11)Frick U.,R.O.Pepin(1981)Lun.Plan.Sci.XII,303.