LUNAR NITROGEN - SECULAR VARIATION or MIXING?

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The two current models to explain the nearly 40% variation of the lunar nitrogen isotopic composition (from $-210^o/oo$ (1) to $+170^o/oo$ (recorded by us from soil 73221) are (i) secular variation of solar wind nitrogen (2,3) and (ii) a two component mixing model having a constant, heavy solar wind ($+120^o/oo$) admixed with varying amounts of indigenous light lunar N - LLN (4). Both models need to explain the step pyrolysis extraction profile (Fig. 1). The secular variation model proposes that the low temperature (600^oC - 900^oC) release is modern day solar wind implanted into grain surfaces, the 900^oC - 1100^oC release is from grain surfaces which were once exposed to the ancient solar wind but which are now trapped inside agglutinates, and the $>1100^oC$ release as spallogenic N produced by cosmic rays. The mixing model ascribes the components to solar wind, indigenous lunar- and spallogenic N respectively. An extension of either interpretation is that the light N seen in lunar breccias or deep drill cores represent conditions when more ^{14}N was available to the lunar surface.

If the ancient solar wind was isotopically light then, according to the secular variation model, evidence for this ought to be found within agglutinate grains. This is not so (5), but (6) - Fig. 2 - and (7) have both shown that it can be found within mineral grains. Alternately, if light N is indigenous it ought to be resolved by stepped extraction of lunar rock material, this is not so from both our work (Fig. 3) and (8). Geiss and Bochsler (4) postulated that, because of the heavy, spallogenic component, LLN would be difficult to resolve by this method. To suggest that a two component extraction would be more difficult to resolve than the three component mixing seen in lunar soils seems unreasonable, as Fig. 1 shows a small, light component resolved from between two heavy components.

Work on acid resistant residues from the Allende and Murchison meteorites (9) has revealed the existence of an ultra light N (ULN) component (possibly the same as the one proposed by (4)). Pyrolysis of Allende (9,10) and residue BB (Fig. 4) shows that ULN is evolved around 900^oC , with a minimum isotopic value (in CC) of $-326^o/oo$ (9). As both volatile and trace element studies (11,12) show that 1-2% of carbonaceous chondrite material has survived impact and is now admixed with the lunar soil, it seems reasonable to suggest that some of this material could be similar to the acid- and heat-resistant phase that is found in Allende.

An extra-lunar but non-solar wind source for LLN has several advantages, thus ULN - (i) could survive impact whereas other C- and N-rich phases would volatilise, (ii) need only be added in very small quantities (<10ppm), (iii) could have been more abundant in the past as more meteorites abounded, (iv) may help explain the apparent "enrichment" of N compared to rare gases, (v) does not need a mechanism which only changes solar corona source for a single element. Since, in Allende, ULN is associated with C that is isotopically normal ($\delta^{13}C$ ca $-38^o/oo$) C isotope values need not exhibit (5) the same large isotopic variations seen for N. For the above model to work successfully the C/N ratio of the meteoritic phase which survived impact and was deposited in the lunar regolith would

need to be low.

Further detailed study of separates from lunar regolith breccias is needed before an explanation of the light N found within them can be put forward.

References:1) Clayton and Thiemens; The ANCIENT SUN; p.463 (1981).2) Kerridge; SCIENCE; 188 p.162 (1975). 3) Becker and Clayton; PLSC6; p.2131 (1975). 4) Geiss and Bochsler; GCA; 46; p.529 (1981). 5) Norris et al; PLPCS14; (1983). 6) Norris et al; METEORITICS; 18 (1983). 7) Frick et al; this volume; (1983). 8) Becker et al; PLSC7; p.441 (1976). 9) Lewis et al; NATURE; (1983 in press). 10) Theimens and Clayton; EPSL; 55; p.363 (1981). 11) Baedecker et al; P2LSC; p.1037; (1971). 12) Laul et al; P2LSC; p.1139; (1971).
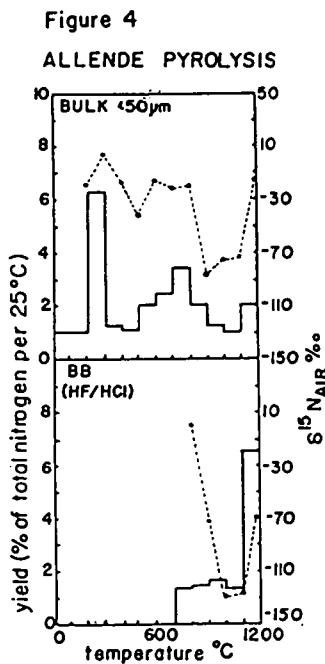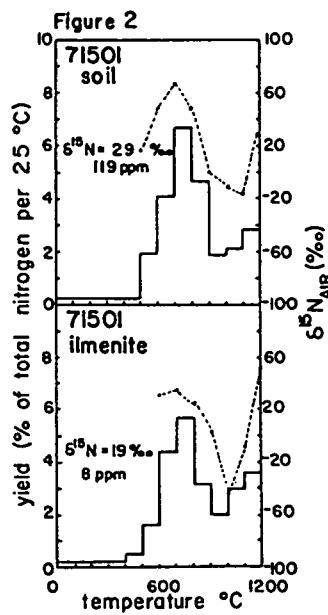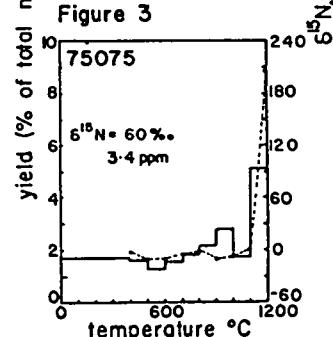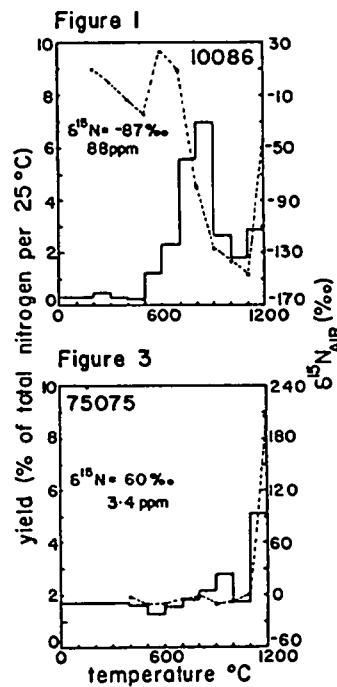

Figure 1. Pyrolysis of breccia pebble from soil 10086.

Figure 2. Pyrolysis of bulk soil and ilmenite fraction from sample 71501.
          Ilmenite sample donated by P. Signer and R. Wieler, ETH Zurich.

Figure 3. Pyrolysis of lunar basalt 75075.

Data for these three figures   from 600 to 1200°C inclusive.

Figure 4. Pyrolysis of Allende and Alende BB. Bulk data are:-

          Allende <50um $\delta^{15}N$ = -36°/oo, 17.2 ppm

          Allende BB $\delta^{15}N$ = -74°/oo, 2317 ppm. This data from (9).