Terrestrial atmospheric components in lunar soils: Records of early Earth evolution.

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Solar wind (SW) implanted in lunar soils contains not only components from the Sun, but also non-solar components including N and some other light elements. With the use of published data, we show that non-solar components of N (1) and He, Ne, Ar (2) can be attributable to the terrestrial atmospheric components; the observed data for these elements are well explained in terms of the mixing between the terrestrial components and solar components. We propose that the examination of these terrestrial components would serve as unique tracer of the early Earth evolution. In the present Earth, there is little interaction between the SW and ionosphere constituents due to the shielding effect of the geomagnetic field (GMF). However, if the GMF is absent, the SW directly interacts with the ionosphere. Seki et al. (3) showed that substantial amount of terrestrial ions will be picked up from the ionosphere and can be transported to the Moon, if GMF were absent. Therefore, the existence of terrestrial atmospheric components in some lunar soils suggests that at the time when the terrestrial components were implanted in the lunar soils, GMF was absent. Hence, if we find that the majority of lunar soils older than a certain age were systematically endowed with a disproportionately large fraction of terrestrial components, we may conclude that GMF did not exist before this age. Also, the close examination of terrestrial components in lunar soils may impose constraint on the relative elemental abundance and isotopic composition of light elements in the ancient terrestrial atmosphere. Assuming that the non-solar components in lunar soils are terrestrial, we estimated the flux of the terrestrial components (hereafter Earth Wind or EW) from mixing diagrams between the SW and terrestrial components. The absolute value was scaled to the 4He flux (= 6.3 x 10^6 ions/cm^2s; (4)) in the SW measured at lunar surface. The ancient atmosphere must have been depleted in oxygen and the early Sun was likely to be more active. Taking account of these effects, Seki et al. (3) made a theoretical estimate of EW flux which would hit the Moon. In Table 1, we compare this theoretical estimate with the EW flux estimated from the non-solar components observed in lunar soils. From Table 1, we infer that N and 36Ar can be accounted for by terrestrial components transported from a putative non-magnetic Earth, but barely for Ne (about 10%). If SW flux in ancient time was more intense, Ne may also be accounted for by EW.

References. (1) Hashizume K. et al. (2000) Science, 290, 1142-1145. (2) Heber V.S. et al. (2003) Astrophysical J. 597, 602-614. (3) Seki K. et al. (2005) (this volume). (4) Geiss J. (1973) Conf. Paper 13th Intl. Cosmic Ray Conf. 3375-3398.

Table 1.
Non-solar flux (observed) and EW flux (theoretical) on the Moon.

Ions	Non-solar flux ($ions/cm^2s$)	EW flux [3] ($ions/cm^2s$)
^{14}N	$>2 \times 10^3$	2×10^6
^{4}He	2×10^6	6×10^4
^{20}Ne	3×10^3	5×10^2
^{36}Ar	10	13