

TERRESTRIAL ATMOSPHERIC COMPONENTS IN LUNAR SOILS: RECORD OF EARLY EARTH EVOLUTION.

M. Ozima¹, K. Seki², N. Terada², Y.N. Miura³, F.A. Podosek⁴, and H. Shinagawa²

¹Dept. Earth Planetary Science, University of Tokyo, Tokyo, Japan (EZZ03651@nifty.ne.jp).

²Solar-Terrestrial Environment Lab. Nagoya University, Toyokawa, Japan. ³Earthquake Research Inst., University of Tokyo, Tokyo, Japan. ⁴Dept. Earth Planetary Sciences, Washington University, St. Louis, MO 63130, USA.

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 and He, Ne, Ar 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 (Fig. 1 and 2). We propose that the examination of these terrestrial components would serve as unique tracer of the early Earth evolution. In this paper we focus our discussion mainly on the case of the geomagnetic field (GMF).

In the present Earth, there is little interaction between the SW and ionospheric constituents due to the shielding effect of GMF. However, if GMF is absent, the SW directly interacts with the ionosphere. Seki et al. [1] 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 plausible 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.

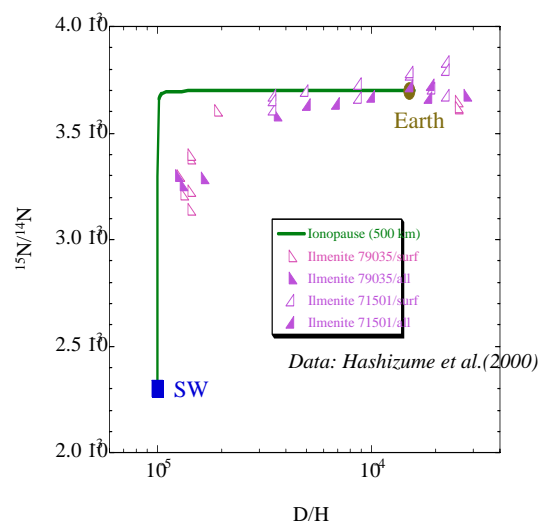


Figure 1: H-N mixing diagram. Data for individual ilmenite grains from Apollo 17 breccias are from [2]. A mixing curve between the SW component and terrestrial component was constructed with three independently estimated parameters, i.e. two end member isotopic compositions [2] and the ratio of elemental ratios of the end members, i.e. $r = (^{14}\text{N}/\text{H})/(^{14}\text{N}/\text{H})_{\text{SW}}$ at ionopause height 500 km [1].

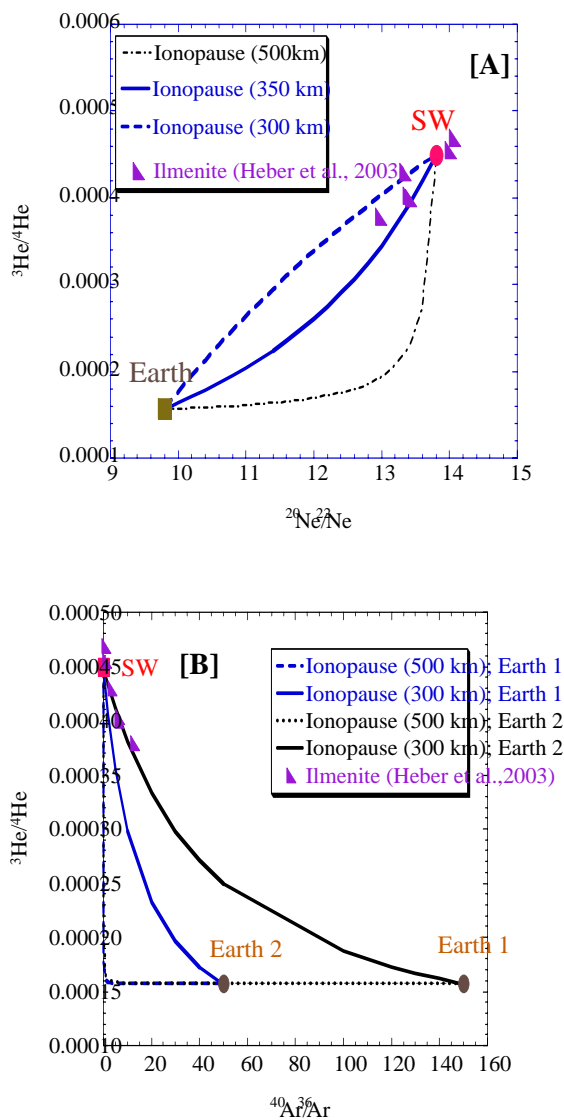


Figure 2: Mixing diagrams He-Ne [panel A] and He-Ar [panel B] for ilmenite grain ensembles from lunar breccias [3]. For SW, we assume $^3\text{He}/^4\text{He} = 4.5 \times 10^{-4}$, $^{20}\text{Ne}/^{22}\text{Ne} = 13.8$, $^{22}\text{Ne}/^4\text{He} = 1.12 \times 10^{-4}$, $^{40}\text{Ar}/^{36}\text{Ar} = 10^{-4}$, $^{36}\text{Ar}/^4\text{He} = 3.27 \times 10^{-5}$, respectively. For atmospheric components, we assume $^3\text{He}/^4\text{He} = 1.57 \times 10^{-4}$, $^{20}\text{Ne}/^{22}\text{Ne} = 9.8$, and two cases for Ar, i.e. $^{40}\text{Ar}/^{36}\text{Ar} = 50$ and 150. Elemental ratios are calculated at ionopause altitude 500, 350, 300 km for $^{22}\text{Ne}/^4\text{He}$ and at 500, 300 km for $^{36}\text{Ar}/^4\text{He}$ (Fig. 1 in [1]).

Assuming that the non-solar components in lunar soils are terrestrial, we estimated the flux of the terrestrial components (hereafter Earth Wind or EW). The absolute value was scaled to the ^4He flux ($= 6.3 \times 10^6$ ions/cm²s; [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. [1] made a theoretical estimate of EW flux which would hit the Moon. In Table 1, we compared 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 ^{36}Ar 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.

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

Ions	Non-solar flux (ions/cm ² s)	EW flux [1] (ions/cm ² s)
¹⁴ N	$> 2 \times 10^3$	2×10^6
⁴ He	$\sim 2 \times 10^6$	$\sim 10^5$
²⁰ Ne	$\sim 3 \times 10^3$	$\sim 5 \times 10^2$
⁴⁰ Ar	~ 10	~ 13

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