Lunar soils may tell us when the geomagnetic field first appeared.

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When did the Earth magnetic field first appear? This fundamental problem is still not resolved. It has been taken for granted that the development of the geomagnetic field was concomitant with the formation of the Earth core, but the time of core formation is not well known, nor is the role of the inner core in the generation of the geodynamo [1]. Paleomagnetic studies trace the geomagnetic field back only to about 3.5 Ga ago [2] that showed much weaker intensity than the present field. Since there is practically no crustal rock older than 4 Ga, we need an alternative approach to pursuit the record of the geomagnetic field in older time. We propose that lunar soils may be used to resolve this fundamental and urgent issue.

We show that the isotopic compositions of N (and possibly lighter noble gases) implanted in ancient lunar soils may reflect admixture of solar wind and terrestrial atmospheric components, suggesting transport of atmospheric components to the Moon. The geomagnetic field would prevent any effective ion loss from the atmosphere [3], but if the geomagnetic field was absent or much weaker in the early Earth as suggest by [2], the escape of ions from the ionosphere would be enhanced considerably, and a substantial amount of terrestrial atmospheric ions may have been transported to lunar soils. Therefore, the close examination of N (and possibly lighter noble gases) in ancient lunar soils may provide clues to resolve the time of the appearance of the geomagnetic field.

The PVO (Pioneer Venus Orbiter) observations at Venus have suggested the loss of 10E6-10E8 O+ cm-2s-1 from the Venus atmosphere (Table 2 of [4]). This substantial ion loss is understood to reflect direct interaction between the solar wind and the upper atmosphere in the absence of a permanent dipole field. For N+/O+ = 0.02 observed around the ionopause [5], we would expect N+ loss of about 2 x 10E5 cm-2s-1. Venus's atmosphere may serve as a proxy for the primitive atmosphere in the early Earth, which was likely to consist predominantly of CO2 [6]. We thus expect that a similar amount of N+ would escape from the Earth in the absence of the geomagnetic field. Also considering that the Earth was much closer to the Moon in the first several hundred Ma [7], we infer from simple geometrical considerations that a few percent of escaping ions from the Earth's ionosphere may have directly hit the lunar surface. Isotopic inventory considerations suggest that the implantation of about 10E4 cm-2s-1 of N of terrestrial origin would suffice to explain the hypothesized non-solar N in ancient lunar soils [8]. As discussed above, this much of non-solar N could be attributed to terrestrial N that was transported to the Moon, if the Earth did not have a geomagnetic field. However, it remains to see if substantial amounts of lighter noble gases can also be transported to the Moon from the Earth during diminishing geomagnetic field.

The above proposal can be tested by comparing ancient lunar soils from the far-side with those from the near-side. It is known that the dynamical coupling between the Earth and the Moon is so tight that the near side of the Moon has remained facing the Earth for nearly the whole history of the Earth-Moon system [9]. Therefore, if our hypothesis is correct, non-solar-terrestrial-like N and (possibly lighter noble gases) can only be observable in near-side lunar surface, but not in soils from the far-side.

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