COMPARATIVE STUDY OF NEAR- AND FAR-SIDE LUNAR SOILS: TOWARD THE UNDERSTANDING EARLY EVOLUTION OF THE EARTH.

Minoru Ozima[1], Qing-zhu Yin[2], Frank Podosek[3], and Yayoi Miura[4]. [1]Graduate School of Earth and Planetary Science, University of Tokyo, Tokyo 113-0033, Japan (EZZ03651@nifty.ne.jp), [2]Department of Geology, University of California, Davis, One Shields Avenue, Davis, CA 95616, USA, [3]Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130. USA, Earthquake Research Institute, University of Tokyo, 113-0032, Tokyo .

Introduction: Because of the almost total lack of geological record on the Earth for the time before 4 Ga, the history of the Earth during this period is still enigmatic. We propose that a comparative study of far- and near-side lunar soil would shed new light on this dark age of the Earth history.

Due to a strong dynamic coupling between the Earth and the Moon, theoretical studies of Earth-Moon dynamics have concluded that the Earth has been facing only to the near-side of the Moon since the formation of the Earth-Moon system about 4.5 billion year ago [e.g.1]. Also, theories have suggested that due to tidal energy dissipation, the Moon has been receding from the Earth. Recent theoretical studies concluded that the distance between the Earth and the Moon was about a half of the present distance about 4 Ga ago [2]. From these studies we infer that there may have been substantial interaction between the Earth through the atmosphere and the near-side lunar surface, especially in ancient time, whereas the far-side has remained essentially intact to the terrestrial atmospheric influence. Therefore, we suggest that the comparison of the far-side and near-side surface samples may impose unparalleled constraints on the evolution of the Earth such as the onset of the geomagnetic field, the evolution of a biotic oxygen atmosphere, and above all the dynamic evolution of the Earth-Moon system, a long standing fundamental problem, which has been strongly suggested by theoretical studies, but still requires observational confirmation.

Objectives: By analyzing isotopic ratios and elemental abundances of volatile elements (O, N, light noble gases) implanted on lunar mineral grains (preferably ilmenite grains and metallic particles for higher retentivity of these elements), we may tackle the following fundamental problems.

When did the geomagnetic field (GMF) first appear? Heber et al. [3] observed anomalous noble gas and nitrogen isotopic compositions in Apollo lunar ilmenites, which are quite different from the generally assumed solar components. Heber et al. [3] concluded that the anomalous isotopic composition could not be attributed to nuclear processes in the Sun, but was likely to be due to some fractionation during implantation process. However, Ozima et al. [4] showed that the isotopic compositions were attributable to the mixing of the Solar components with terrestrial atmospheric components. They suggested that the terrestrial components have been transported from the Earth and implanted on lunar soils during the period when the Earth had not fully developed the GMF (a non-magnetic Earth). Therefore, if their interpretation were correct, the youngest age of ilmenite grains which show terrestrial isotopic signature in N and light noble gases would impose a crucial constraint on the onset time of the GMF.

When did the biotic oxygen atmosphere form? Recently, Ireland et al. [5] reported oxygen implanted in lunar metal particles, which were mass-independently positively fractionated relative to the mean terrestrial oxygen. Since the isotopic ratio of this oxygen is very close to oxygen in the ozone layer, Ozima et al. [6] suggested that oxygen generated in the ozone layer was transported from the Earth to the Moon. The suggestion is consistent with the observation [7] that the amount of oxygen flux escaping from the present Earth at the Moon's orbit is comparable with the amount of the mass-independently fractionated oxygen (ozone-layer like oxygen) implanted in the lunar metal particles. Therefore, if the ozone-layer like oxygen indeed came from the Earth, the oldest record of this particular oxygen would constrain the initiation of the biotic Earth atmosphere. This issue is also directly relevant to the problem of the origin of life in the Earth.

Has the day length changed in geological time?

If the Moon has been receding from the Earth due to tidal energy dissipation as concluded by an Earth-Moon dynamic theory, we expect that the day length of the Earth should also have increased accordingly. To confirm the day length change in geological time has been a dream of Earth scientists over centuries, but a large number of studies of potential geological records such as the number of growth lines in coral has not so far been successful. We suggest that a final answer to this intriguing problem can be reached by examining the following two relevant problems by systematic comparison between far- and near-side lunar soils for terrestrial volatile components.

(a) We can identify the time when identical periods of rotation (Earth) and revolution (Moon) had taken place from the last appearance of terrestrial components in far-side soils. (b) We would expect a systematic decrease of terrestrial volatile components on the near-side soils, if the Earth-Moon distance has been increasing. Answers to these questions would add observational confirmation to the theory on the Earth-Moon dynamic system for the first time.

Methods: To tackle the above objectives, we need (i) systematic sampling of lunar soils both in the near- and far-side of the Moon, (ii) precise isotopic and elemental analyses of volatile elements such as N, O, light noble gases implanted in lunar soil minerals, and (iii) determination of surface exposure age of an individual mineral grain. We will discuss each issue below.

(i) Sampling: Sampling of lunar soils in a continuous vertical section of a few meter depths both from far- and near-side sites is required.

(ii) Elemental and isotopic analyses: The currently available experimental facility such as SIMS, ultra-high vacuum noble gas MS are quite satisfactory to carry out this requirement.

(iii) Surface exposure age of grains: We have a good reason [4] to believe that the surface exposure time of individual mineral grain is reasonably approximated by the time when a grain was first disintegrated from a bulk host rock. The latter event is very likely to have been caused by major impact event near the sampling site [8], and the disintegration time of an ilmenite grain from a host rock may reasonably be assigned to the age of impact melt minerals at the site. Therefore, by ^{40}Ar-^{39}Ar dating of impact melt minerals at or near a sampling site, we may infer the surface exposure time of an ilmenite grain.

In addition to this method, the direct application of ^{40}Ar-^{39}Ar dating to an ilmenite grain with a very carefully controlled step-heating procedure may enable us to resolve the disintegration time of ilmenite grains from their host rock.

Conclusions: Comparative study of lunar soils from near- and far-side of the moon will yield new insight on some of the most fundamental problems in Earth and planetary sciences such as the first appearance of the geomagnetic field, the evolution of oxygen in the atmosphere, and the dynamical evolution of the Earth-Moon system. Apart from the sampling from the far-side, all the objectives can be carried out with currently available experimental techniques.

References: [1] Murray C.D. and Dermott S.F. (1999) Solar System Dynamics, Cambridge Univ. Press, Cambridge. [2] Abe M. and Ooe M. (2001) *J. Geodetic Soc. Japan, 47,* 514-520. Bills B.G. and Ray R.D. (1999) *Geophysical Res. Lett. 26,* 3045-3048. [3] Heber V. et al. (2003) *Astrophys. J. 597,* 602-614. [4] Ozima M. et al. (2005), *Nature 436,* 655-659. [5] Ireland T.R. et al. (2006) *Nature 440,* 775-778. [6] Ozima M. et al (2007) LPSC XXXII (submitted). [7] Seki H. et al. (2001) *Science 291,* 1939-1941. [8] Dalrymple B. and Ryder G. (1996) *J. Geophys. Res. 101,* 26069-26084.