

**Lost Apollo Heat Flow Data suggest a different lunar bulk composition.** Y. Saito<sup>1,2</sup>, S. Tanaka<sup>2</sup>, J. Takita<sup>1,2</sup>, K. Horai<sup>2</sup>, A. Hagermann<sup>3</sup>, <sup>1</sup>The University of Tokyo (saito@planeta.sci.isas.jaxa.jp), <sup>2</sup>Institute of Space and Astronautical Science (tanaka@planeta.sci.isas.jaxa.jp), <sup>3</sup>Open University (a.hagermann@open.ac.uk).

**Introduction:** Because heat flow measurements provide the most direct method of estimating the bulk abundance of refractory elements such as U and Th, an accurate determination of the global average of lunar heat flow is essential for a better understanding of the origin and evolution of the moon.

Lunar surface heat flow values were measured directly during the Apollo missions. These experiments were carried out on Apollo 15 and 17 for about six years between July 7, 1971 and September 30, 1977. The heat flow values derived from these two measurement sites using the annual temperature change (for about first 3 years) at various depths were 21 mW/m<sup>2</sup> and 14 mW/m<sup>2</sup> respectively [1].

However, as we discuss below, a significant “long-term” temperature change was recognized at the depth below 130cm where the annual temperature change might be smaller than 0.01 degree. Langseth et al. (1976) speculated this phenomenon to reflect the process of approaching the stationary state (without sufficient evidence) and they did not make any modification of the heat flow values that reflected this effect. Therefore, it is worthwhile to re-investigate what caused this long-term variation and to examine whether any modification of the heat flow values is required or not.

Recently, Saito et al. (2006) succeeded in archiving the heat flow data from March 1 1976 until September 30th 1977 [2]. These data are very useful for identifying this very long-term variation because we could extend the period of data almost by a factor of two (from 3 years to 6 years) compared to the data archived previously. In this paper, we preliminarily report a new insight to explain this temperature variation and propose new heat flow values modified by this effect.

**Discovery of the lost heat flow data set:** All of the Apollo Science data were processed and compiled at NASA’s JSC, and delivered to each principal investigator of the scientific instrument by February 29th 1976. As for the heat flow experiment (HFE) data, the compiled data sets were delivered to Dr. M. Langseth and analyzed by him. Then, the data obtained until December 31st 1974 were submitted to NSSDC (National Space Science Data Center) after some editing

of the data (data extraction, reduction, etc). Although the data set might have been delivered, the data acquired from January 1st 1975 to February 29th 1976, seemed not to have been submitted to NSSDC.

However the processing system was changed on March 1st 1976. Dr. Y. Nakamura of Texas University had archived all of the science data from Apollo Stations until September 30th 1977. We analyzed most telemetry data and the electrical circuits of HFE, and then extracted the HFE data from them. Even though there are no data between the beginning of 1975 and February 29th 1976, the data set is still very useful for identifying this long-term variation because we could extend the period of data almost by a factor of two (from 3 years to 6 years).

**The characteristics of the long-term temperature change:** All of the HFE data (temperature profiles) obtained by Apollo 17 are shown in Figure 1. We found three major characteristics of the temperature profiles as follows; (1) temperature differences among the sensors have decreased continuously throughout the observation period, (2) all of the temperatures profiles have local minimum points after the deployment. And, (3) the minimum points seem to propagate from the upper to the lower part of the sensors with a time lag. After that, the temperatures increased continuously.

Langseth et al. (1976) interpreted that ‘aperiodic’ temperature rise as a process to reach thermal equilibrium state, they indicated that these transients were initiated by astronaut activity. They estimated that, for the deepest sensors, 5-7 years would be needed to re-equilibrate.

However, this explanation cannot be reconciled with the characteristics of the temperature profiles mentioned above. The new set of archived data also contradicts this interpretation since the temperature field was not approaching equilibrium after 5 years of deployment.

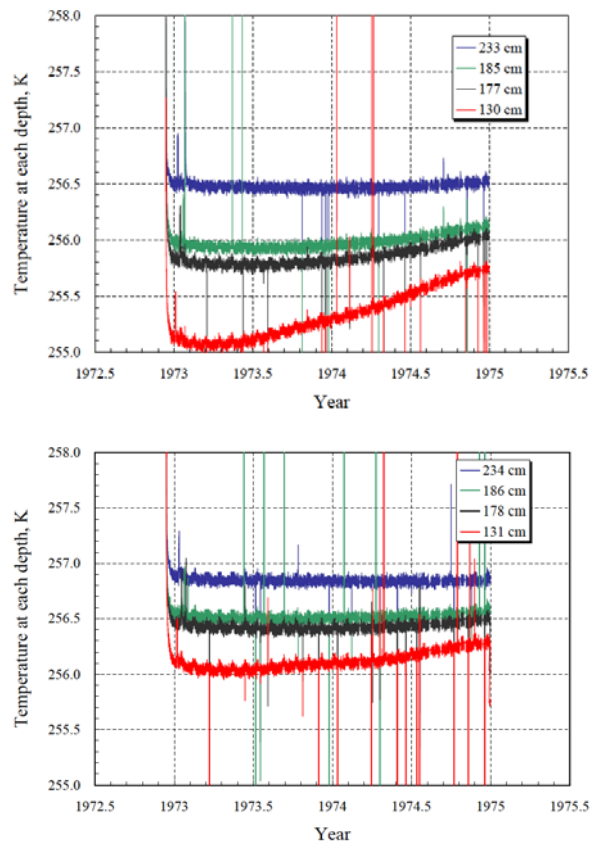
We will introduce the new set of archived data, solve the above three problems in our presentation, and revise the temperature gradient in the lunar regolith to 0.312 K/m (at Apollo 17 landing site). Assuming the thermal conductivity of the lunar regolith

equals  $0.012 \text{ W/m/K}$  [1], lunar heat flow value is to be  $3.7 \text{ mW/m}^2$ .

**Lunar and terrestrial material:** If this is the global mean value and the moon is in steady state, the bulk abundance of U, an incompatible element, would be 9.5 ppb. This assumes abundance ratios to be  $\text{Th/U}=3.8$  and  $\text{K/U}=2000$  [3] and requires these distribution in the moon to be uniform. This abundance is only half as much as that of ordinary chondrite (about 16 ppb; [4]) and the earth's silicate shell (20 ppb; [5-6]).

**References:** [1] M. G. Langseth et al., *Proc. Lunar Sci. Conf., 7th*, pp.3143, 1976; [2] Y. Saito et al., *Japan Geosci. Union Abstracts #P232-P008*, 2006; [3] M. N. Toksoz and D. H. Johnston, *Presented at the Sov.-Am. Conf. on the Cosmochem. of the Moon and Planets*, 1974; [4] B. Mason, *Cosmochem., Part 1, Meteorite*, U.S. Geol. Surv. Prof. Pap., 1979; [5] A. E. Ringwood, *New York, Springer-Verlag New York, Inc.*, 1979; [6] S. R. Taylor, *Planet. Sci.*, 1982

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**Figure 1.** Apollo heat flow Experiment data obtained by Apollo 17 probe 1 (Upper) and 2 (Lower). As each probe has four Pt absolute thermometers, temperature profiles in time series are measured at four depth points.