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## DERIVATION OF A GLOBALLY AVERAGED LUNAR HEAT FLOW FROM THE LOCAL HEAT FLOW VALUES AND THE THORIUM DISTRIBUTION AT THE SURFACE: EXPECTED IMPROVEMENT BY THE LUNAR-A MISSION

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**Introduction:** Lunar heat flow values have been measured at two sites so far; Apollo 15 and 17 heat flow values of 21 and 16 mW/m<sup>2</sup> respectively. By assuming that the difference in heat flow between the two sites is caused by the difference in the total abundance of radioisotopes below the two region, Langseth et al. [1] estimated average lunar heat flow values of 14 to 18 mW/m<sup>2</sup>, on the basis of two heat flow values and the distribution of thorium concentration of the lunar surface. The thorium distribution at the surface was measured by the orbital gamma-ray experiments on Apollo 16 and 17, but the vertical distribution (total amount) in the crust could only be inferred from the relationship between heat flow values and thorium abundances at the surface of the two sites. Therefore more heat flow measurements at different geological settings are desirable to derive a reliable global heat flow average.

**Heat flow measurements using the LUNAR-A penetrators:** In situ lunar heat flow measurements will be carried out during the LUNAR-A mission [2]. Two penetrators will be deployed on the near and far side of the lunar surface. The most feasible candidates of landing sites are near the Apollo 12 landing site (near-side) and almost at the center of the Mendeleev crater (far-side), where rugged rocky terrain or steep slopes are not likely to be encountered. These topographic features are favorable not only for the proper penetration but also for the heat flow measurements in the sense that topographic effects of the sloping surfaces will be less than those of the Apollo sites.

**Thorium abundances at the surface and heat flow values:** The thorium distribution at the surface is now globally known from the results of the LUNAR PROSPECTOR gamma-ray spectrometer [3]. We use the high-resolution data for the discussion below. At the Apollo 15 and 17 sites, the thorium concentrations are about 3.6 ppm and 1.9 ppm. At the LUNAR-A landing sites the thorium concentrations are about 6.0 ppm (near-side) and 1.0 ppm (far-side) respectively. A larger difference in heat flow than that between the two Apollo values will be detected in the LUNAR-A heat flow measurements. Together with the Apollo heat flow data, the relationship between heat flow values and thorium abundances in such a wide range will give us a clue to the vertical thorium distribution (amount) in the crust, and therefore better estimate of the averaged heat flow value. In Figure 1 the relationship between the thorium abundance and the measured and esti-

ated heat flow values are plotted at the Apollo sites and the LUNAR-A sites respectively. The method for inferring these values is similar to that used by Langseth et al. [1]. It is assumed that the surface heat flow is equal to the heat production of the total abundance of radioisotopes below any given region on the moon. The local heat flow value  $Q$  is assumed to be  $Q_M + Q_{add} (+Q_C)$ . Here  $Q_M$  is the heat flow from the mantle and is assumed to be uniformly 4 mW/m<sup>2</sup>, Langseth et al. estimated.  $Q_{add}$  is the heat flow from the thorium rich crust layer, whose depth is universally  $h$  km.  $Q_C$  is the background heat flow from the crust. In the estimation of Langseth et al.  $Q_C$  has the value of about 8 mW/m<sup>2</sup> derived from 1 ppm of thorium uniformly distributed in the crust and the value of  $h$  is 19 (km). We assume that the value of  $Q_C$  is 0, so that the total thorium abundance below a region is equal to a surface concentration multiplied by  $h$ , which can be called "effective depth". It is assumed that the value of Th/U is 3.7, the value of K/U is 2000. The slope of the line (Figure 1.) is steeper as the assumed  $h$  is larger. By adopting the value of 30 km from the heat flow values of the Apollo landing sites, heat flow values of the LUNAR-A landing sites are estimated to be about 30 mW/m<sup>2</sup> (near-side) and 8 mW/m<sup>2</sup> (far-side). This assumption that  $h$  is a constant at any region may not be valid because of the different process of crust formation of each area. The near-side landing site of the penetrator is the most thorium-rich region, which is inside the High-Th Oval Region named by Haskin [4], who indicated that 'h' at this site might be 20 to 50 km. The determination of the heat flow value within 20% error will make us estimate the value of  $h$  within 8 km error. The heat flow measurement at this site will allow us to determine whether thorium is (1) only concentrated at the surface as thorium-rich In-brium ejecta, (2) distributed to a depth of 19 km as Langseth et al. [1] estimated, or (3) concentrated to the depth of 50 km as Haskin [4] indicated. The accuracy of the heat flow measurement using the LUNAR-A penetrator will be able to indicate which is more probable [5]. The far-side landing site is a thorium-poor region. It is difficult to estimate the value of  $h$  from a heat flow value only, but it is likely that the measured heat flow value indicates mainly the heat flow from the mantle  $Q_M$ , or the background heat flow  $Q_M + Q_C$ . As is shown in Figure 2, the heat flow measurement at this site is also of importance for the estimation of the averaged heat

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flow, because the thorium concentration of most of the lunar surface is about 1 ppm.

**References:** [1]Langseth et al. (1976) LPSC 3143  
 [2]Mizutani et al. (2000) ESA **SP462** [3]Lawrence et al. (2000) JGR **105** 20307 [4]Haskin (1998) JGR **103** 1679  
 [5]Tanaka et al. (2001) (this vol.)

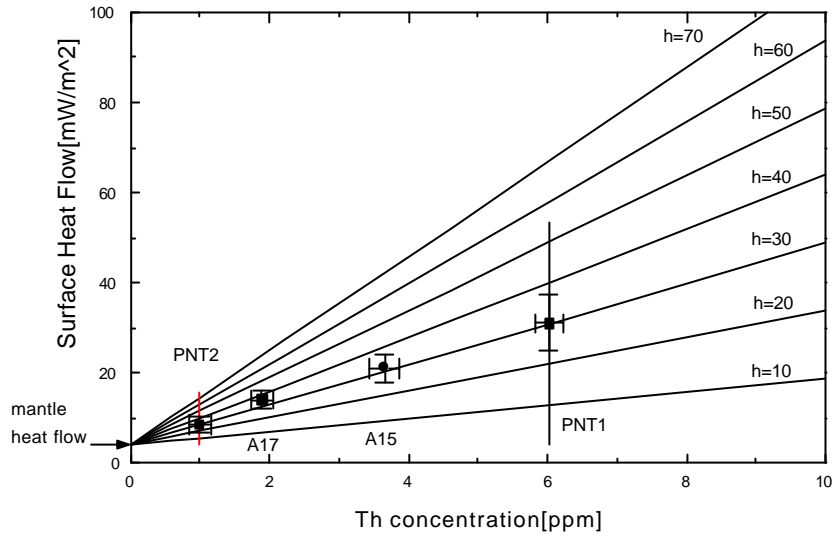


Figure 1. Surface heat flow vs. thorium concentration. The lines show the expected heat flow if thorium is uniformly distributed from the surface to a depth of h km. A15, A17 is Apollo 15, 17 heat flow value. PNT1, PNT2 shows the expected heat flow value of the landing site of the penetrator, assuming that h is 30 km.

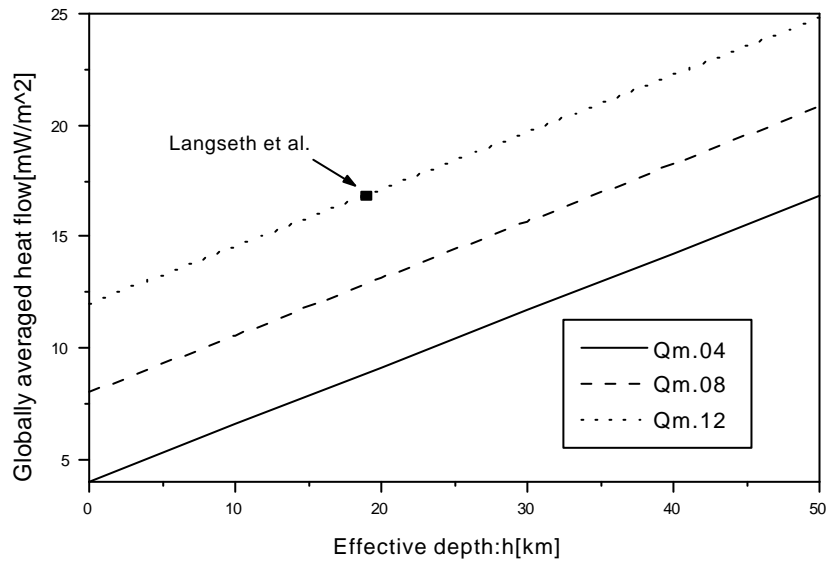


Figure 2. Effective depth h vs. estimated globally averaged heat flow.  $Q_M (+Q_C)$  is assumed to be 4, 8, 12  $mW/m^2$ . The estimate of Langseth et al. [1] is also shown. The value of  $Q_M (+Q_C)$  is 12  $mW/m^2$  and the value of h is 19km.