P. 475

THE APOLLO 15 LUNAR HEAT FLOW MEASUREMENT: Marcus G. Langseth, Jr. of Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964, Sydney P. Clark, Jr., Department of Geology, Yale University, New Haven, Connecticut 06520, and John Chute, Jr. and Stephen Keihm of Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964.

The Heat Flow Experiment is one of the instruments in the Apollo Lunar Surface Experiments Package (ALSEP) emplaced on the moon during Apollo 15. This instrument is designed to measure the heat flow from the lunar interior by determining the vertical gradient of mean temperature and the thermal conductivity in the upper few meters of the regolith.

The essential measurements are made by slender, meter-long temperature sensing probes that are placed in hollow, thin-walled fiberglass borestems. These borestems are drilled into the regolith by the Apollo Lunar Surface Drill. The instrument is designed to make two independent measurements of heat flow with two probes buried about 10 m apart.

The relatively high density of the regolith at Hadley Rille prevented full penetration of either of the two fiberglass borestems to the planned 3 m depth. Both borestems were driven about 1.6 m into the subsurface; however, one of the probes, designated #2, could not pass to the bottom of the borestem because of an obstruction. The bottom of this probe is only one meter below the surface.

Data received during the first 1 1/2 months after the probes were emplaced has been analyzed. During this period the initially warmer probe and borestem cooled slowly toward the initial undisturbed temperature distribution in the regolith. The mean temperature at 100 cm below the surface is 252.3° K at probe #1 and 250.7° K at probe #2. These values are nearly 30° K higher than the average surface temperature over a lunation cycle which is about 217° K. Most of this increase in mean temperature is due to the high dependence of heat transfer on ambient temperature in the upper several cm of the lunar soil.

Eight temperature sensors below 70 cm were uneffected by the large variations of surface temperature during the first 30 days after emplacement. The cooling histories of these thermometers were extrapolated to their equilibrium values using the theory of cooling of a cylinder in an infinite medium. After applying appropriate corrections for the shunting effect of the probe and borestem, these extrapolated temperatures yield an accurate determination of the temperature field that existed in the subsurface before the probes were inserted. This analysis indicated that the undisturbed vertical temperature gradient below 70 cm is 1.75 ± 0.09° C/M.

Each of the heat-flow probes has heaters surrounding four of the thermometers. These heaters can be turned on by command from earth to conduct in situ experiments to determine the thermal properties of the soil surrounding the borestem. Six such experiments were conducted in August and September. The analysis of these experiments indicated that the conductivity of the regolith is not uniform with depth. The values obtained from three experiments are tabulated below:

Depth, cm	Conductivity,* W/cm-°K
49	1.4×10^{-4}
91	1.7×10^{-4}
138	2.5×10^{-4}

*Estimated error of these measurements is ±10%.

An independent estimate of thermal conductivity can be made from the cool down history of the thermometers. Such estimates are dependent on knowledge of the initial temperature and consequently are not very accurate (±50%). Analysis of the first 100 hours of data indicate that the conductivity increases with depth at a rate similar to that shown by in situ measurements, the value at 91 cm is $1.5 \times 10^{-4} \pm 50\%$ and at 138 cm is $2.7 \times 10^{-4} \pm 50\%$. These values are in good agreement with the in situ determinations.

The conductivity data combined with the gradient determination indicate that the average heat flow through the regolith is 3.3×10^{-6} watts/cm^2 (0.79×10^{-6} cal/cm^2sec) at the probe #1 site. For comparison this value is about 1/2 the average heat flow from the earth.

The shallow emplacement of probe #2 prevents an accurate estimate of the mean gradient with only 1000 hours of data. When several lunations of data become available, the heat flow at this site can be calculated with suitable accuracy.

Because of the proximity of the heat flow measurement to the surface, it is susceptible to a number of disturbances. The principal ones are caused by topography and refraction of heat flow associated with sloping interfaces between materials of differing thermal conductivity. The effects of the most important topographic features, Hadley Rille and the Apennine Front, have been estimated by modelling them with very simple geometries. These preliminary estimates indicate that positive corrections on the order of 10 to 20% should be applied to the observed heat flow value.

Realizing that future measurements may produce major changes in our conclusions, we will here consider briefly the implications of the observed heat flow taking it at face value. For a planetary body the size of the moon very little heat flow results from initial temperatures even if they were at the solidus. Most of the present heat flow must result from the decay of long

P.477

lived radioisotopes. Isotopic abundances appropriate for ordinary chondrites would result in present rates of heat loss of 1.0 to 2.0 x 10^{-6} watt/cm^2. A moonwide heat flow of 3.3 x 10^{-6} watts/cm^2 would require much higher rates of heat production at present than "chondritic" bulk composition for the moon can provide.