LUNAR CRUSTAL DENSITY PROFILE FROM AN ANALYSIS OF DOPPLER GRAVITY DATA, A. W. Gerhard Kunze, NASA/Johnson Space Center, Houston, Texas (NRC research associate).

Line-of-sight gravity residuals obtained from Doppler radio tracking data of various Apollo missions over lunar highland terrain correlate unmistakeably with major lunar topographic features (1, 2, 3). If local lunar gravity anomalies over a given region are indeed caused entirely by topographic inequalities, then these anomalies should reflect crustal densities and density gradients sampled by crustal topography. The present study investigates the usefulness of planetary gravity anomalies as a remote sensing tool for the determination of crustal density gradients.

Line-of-sight gravity observations are valid estimators of radial (vertical) gravity components only near the center of the lunar disk. Consequently, in this study, available line-of-sight gravity data were converted to radial gravity components over selected lunar highland regions utilizing a method similar to the equivalent source technique used in geoexploration (4). The resulting equispaced radial gravity net was normalized to an altitude of 20 km above the lunar surface. As expected, the larger lunar craters are clearly associated with pronounced negative gravity anomalies. However, highpass filtering of the gravity data revealed almost no additional anomalies that could be correlated with smaller craters. Smaller features are apparently beyond resolution due to noise either present in the data or introduced by conversion and filtering operations. The specific gravity anomalies that correlate clearly with individual craters are listed in column 2 of table 1.

The gravity anomaly produced by a crater shaped mass (or mass deficit) of radius R is similar to that of a disk shape of the same radius and of thickness t, where t is one half of the crater depth, and is given approximately by

$$\Delta g = 2\pi \cdot G\bar{\rho} \cdot t \cdot (1 - H/\sqrt{H^2 + R^2}).$$

G is the gravitational constant, $\bar{\rho}$ is the mean density of the disturbing mass, and H is the height of observation. Solving for $\bar{\rho}$ yields

$$\bar{\rho} = \Delta g \cdot \sqrt{H^2 + R^2} \; / 2\pi G t \cdot (\sqrt{H^2 + R^2} - H)$$

This expression indicates the mean crustal density corresponding to a given negative anomaly for a given crater geometry. The mean densities thus obtained for craters analysed in this study are listed in column 6 of table 1. Figure 1 is the corresponding plot of mean density versus crater depth. The error bars reflect a standard error of approximately 0.2 in crater depths.

In spite of the prohibitive scatter of the data presented in fig. 1, a general trend of increasing density with depth is evident. The trend to

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be expected is of quasi-logarithmic nature (5,6), and a least squares fit of a logarithmic curve to the data (dashed line in fig. 1) has the parameters

$$\bar{\rho}(z) = 1.05 + 0.48 \text{ LOG}(z+1)$$

where the depth z is expressed in meters. The mean density $\bar{\rho}(z)$ in this relationship may be defined as

$$\bar{\rho}(z) = 1/z \int_0^z \rho(z')dz'$$

and, consequently, the actual density with depth is given by

$$\rho(z) = 1.25 + 0.48 \text{ LOG}(z+1)$$

This expression predicts a crustal density increase in the lunar highlands from 1.73 g/cc near the surface (10 m depth) to 2.69 g/cc at 1 km depth. The density reaches a value of 3.00 g/cc at approximately 5 km depth with progressively smaller increases thereafter.

These predictions are in good agreement with other sources of density data for the lunar highland crust (5,6); however, in view of the paucity of data points used in deriving the above relationship it must be concluded that the excellent result may be largely fortuitous, and that further studies with additional data are needed.

Table 1. Correlatable Lunar Gravity Anomalies

Crater	Anomaly (mgals)	Diameter (km)	Depth (km)	Effective Depth t (km)	Mean Density (g/cc)
Ptolomaeus	-134	153	2.9	1.45	2.9
Hipparchus	-42	150	1.0	0.50	2.7
Theophilius	-293	100	6.8	3.40	3.3
Cyrillius	-111	93	3.2	1.60	2.7
Macrobius	-54	64	3.2	1.60	1.7
Kant	-36	32	2.7	1.35	2.9

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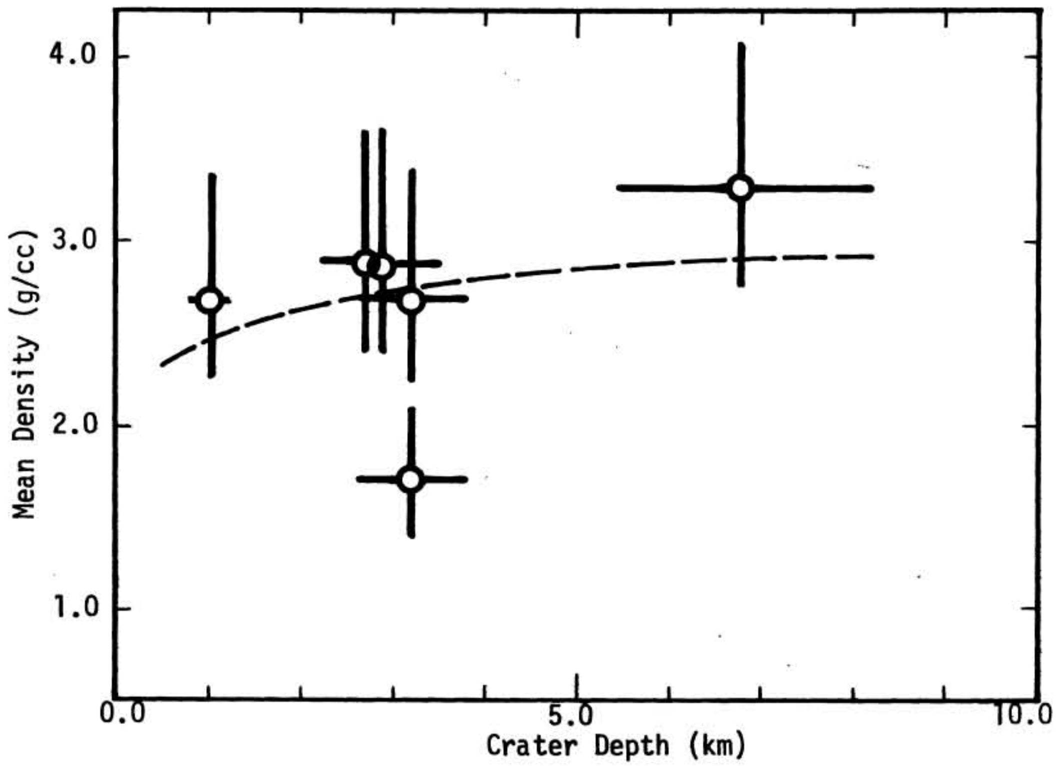

Figure 1. Mean Crustal Density versus Crater Depth

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