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Reduced radio tracking data from the Command and Service Module (CSM) during ten orbits just prior to the Lunar Module descent (20 km periapsis altitude) reveal gravity information for Grimaldi, Copernicus, Mare Procellarum, the Appenines, Mare Serenitatis, Littrow and Mare Crisium. These line-of-sight velocity data, processed as described in reference 1, produce a band of gravity contours approximately 60 km wide from 70°W longitude to 70°E longitude. The areas of redundant coverage with the Apollo 14, 15 and 16 missions agree to 10 milligals or better.

Various models were tested to match the gravity profile for Grimaldi, Copernicus and Mare Serenitatis. In figure 1 there are six solution results plotted against the real gravity profile (heavy line) for Grimaldi. They include a point mass at 100 km depth, a disk at 50 km depth, surface disks where parameters such as the latitude and longitude of the disk were also estimated. They all do a rather poor job except for the last solution in which three surface masses were estimated (dots). The mass centered in Grimaldi is 7.6×10^{16} kg ($1.M_{☾} = 7.355 \times 10^{22}$ kg) distributed over a 54 km radius surface disk or a loading of 1240 kg/cm^2 (average area for mass distribution is $.67\pi r^2$ for ellipsoidal disk). This is higher than the Mare Serenitatis and Mare Crisium loadings obtained with Apollo 15 data, making Grimaldi the smallest known mascon, but the largest for mass per unit area.

The gravity anomaly for Copernicus is just the opposite of Grimaldi in that it is negative and consistent with some twenty other crater anomalies (Ref. 2, 3, 4). Again various solution results are shown in comparison with the real gravity profile (figure 2). Notice that the point mass estimate (.3 km radius) could not produce gradients steep enough to match the real data. A fairly good match was obtained when three masses were estimated. One mass was placed in the optical center of Copernicus while the others were placed in the rim deposits where the trajectory crossed over them. The mass deficiency is 3.24×10^{16} kg. If one uses Baldwin's dimensions of Copernicus (Ref. 5) and computes a volume for the crater, a density of 3.57 g/cm^3 is obtained. To reduce the density to 3.00 g/cm^3, there must be a 550 m increase in crater depth, a $.6 \times 10^{16}$ kg error in the mass, or a combination. The first two inferences and possibly the third seem to be outside known error bounds. This implies that the lunar crust to a depth of 3 km has a density near the average lunar density of 3.34 g/cm^3, say closer to 3.10 g/cm^3 than 2.90 g/cm^3.

A prediction for the Apollo 17 Mare Serenitatis anomaly was made from the best Apollo 15 model. The prediction was 40% too small. This inconsistency was resolved when gravity contours were obtained from the Apollo 15 subsatellite data that revealed two peaks in the Serenitatis anomaly. The Apollo 17 gravity profile was fit very well with a 221 km radius surface disk located at 22.9°N and 18.6°E, consistent with the lower peak. The mass solution yielded the same loading per unit area as the Apollo 15 data (Ref. 6). The Mare Crisium gravity profiles from Apollo missions 15 and 17 agreed very well for their trajectories passed over essentially the same area of the

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basin.

The Apollo 17 landing site at Littrow was gravity sampled by a surface gravimeter (Ref. 7) which read 162,695 ± 5 milligals. The absolute gravity at the landing site (1734.8 km from center of gravity) for a completely homogeneous sphere would be 162,908 ± 6 milligals. This implies a -213 ± 8 milligal anomaly. The results from the orbital data show a -205 ± 10 milligals anomaly - very consistent with the surface gravimeter. Sources other than those in the data itself which can contribute 20-40 milligal variations are the absolute elevation (19 milligals/100 m), local topography, and downward continuation from the 20 km spacecraft altitude. This large negative anomaly is not due solely to the large positive anomaly in Mare Serenitatis. Simulations with surface slabs the size of the Mare Serenitatis mascon produce only -50 milligal edge effects for these trajectories. The implication is that this area has a real mass deficiency probably at depths of 10-50 km. Possibly in the Littrow area some of the denser material at depth was transported to the Serenitatis basin and lower density material took its place.

A more elaborate report of the Apollo 17 gravity results is given in Ref. 8.

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GRAVITY PROFILES OVER GRIMALDI
(APOLLO 17 ORBIT 6)

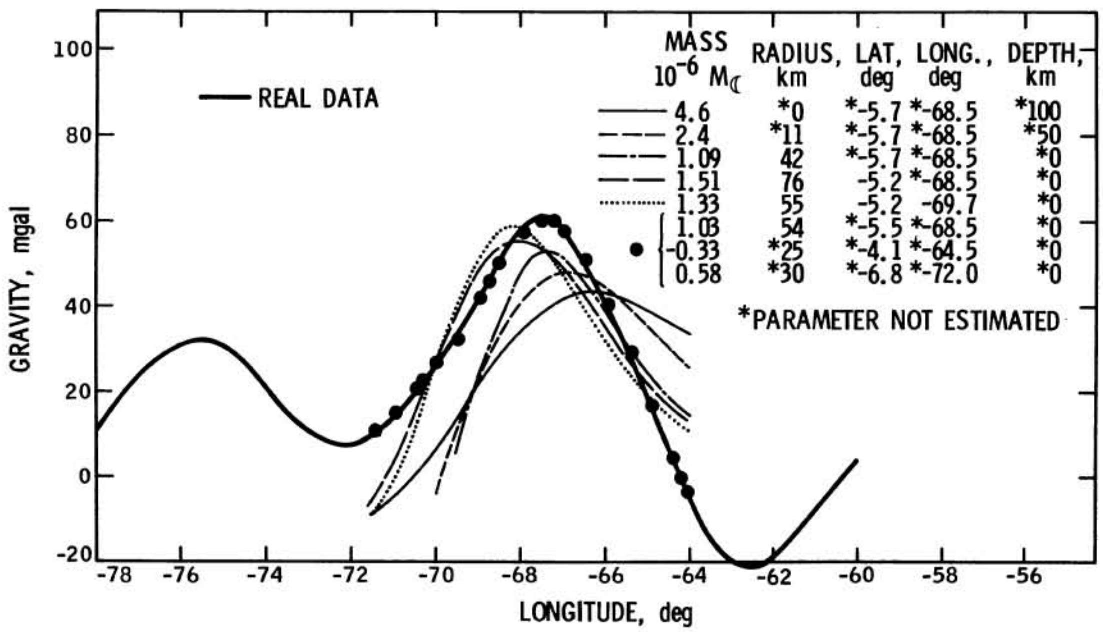

Figure 1

COPERNICUS GRAVITY PROFILES

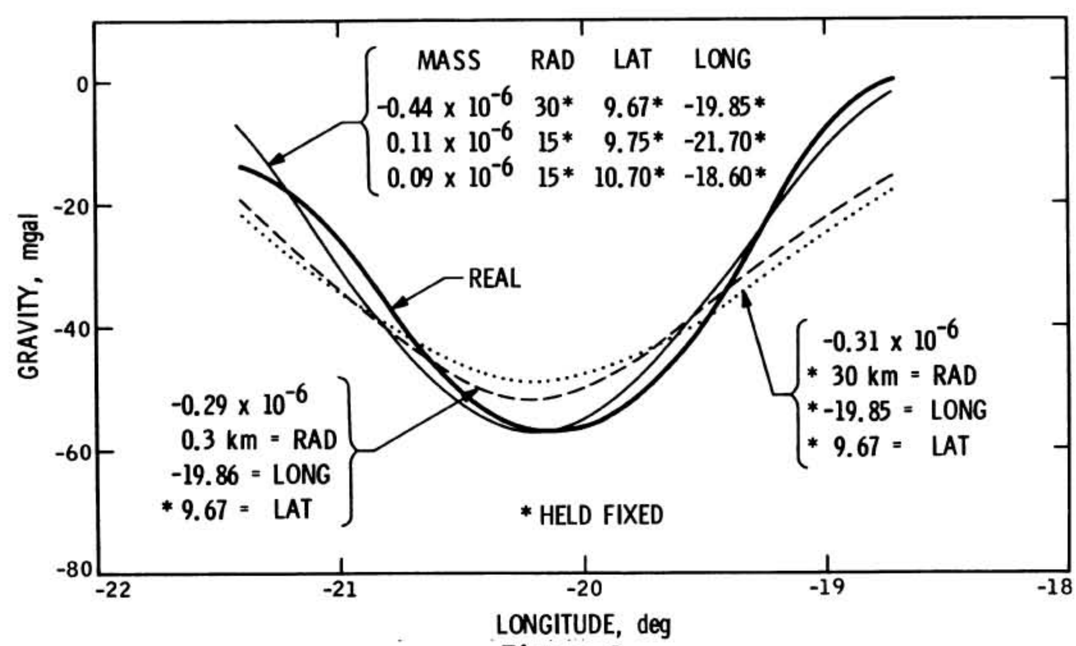

Figure 2