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GRAIL and the Legacy of Apollo

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Abstract

The Apollo landings provided the first samples of the lunar regolith for analysis back on Earth. The samples unlocked many secrets of the crust while also providing data about the deep interior from seismic measurements and from laser reflector observations of lunar rotation. The Apollo observations were point observation made from sites on the lunar near-side but were more global in their contribution to the lunar interior. But it was not until the GRAIL mission, launched 40 years after the first Apollo landings, that a truly global picture of the crust on a scale and resolution that could be compared with the Apollo data that would reveal the differences between the lunar nearside and farside and the crustal variations that exist across the lunar surface.

GRAIL

GRAIL measured the lunar gravity field from orbital altitudes of 50 and 23 km, and as low as a few km during its last few orbits, and together with high accuracy topographic measurements from LOLA on LRO enabled a global Bouguer gravity map of mass anomalies and gravity variations across the complete lunar surface. By assuming uniform crust and mantle density, Bouguer gravity was downward continued to an interface corresponding to the crust-mantle boundary to produce a map of crustal thickness. Apparent in the map is the nearside-farside asymmetry in crustal thickness that was known from the Apollo era but was unreliable on the farside due to the lack of an accurate gravity field model. Not until the GRAIL mission was an accurate global crustal thickness map possible. What GRAIL data showed were variations on crustal thickness across the lunar surface with the thickest crust in the farside highlands and the thinnest crust under several of the large mass anomalies, mascons, originally detected by the Apollo Orbiter missions. From the shorter wavelengths of Bouguer gravity the crustal density was derived as a function of depth and the results showed an increase of about 10% between the surface and a depth of 20 km, where the mean crustal mass density is about 2550 kg m^{-3}.

Knowing the grain density at the surface from Apollo samples the average porosity of the surface was shown to be over 15% and decreased steadily with depth in the crust. The conclusion is that at least the outer 20 km of the lunar crust had undergone even more bombardment during its early history than the surface expression of craters had suggested.

GRAIL's global view and Apollo's local views of the Moon have provided a complementary picture of the lunar crust.