LUNAR MARIA FIGURE, W. L. Sjogren, Jet Propulsion Laboratory, Pasadena, Calif., 91103, W. R. Wollenhaupt, Johnson Space Center, Houston, Texas, 77058

A compilation of 196 mare surface elevations have been extracted from a complete review of the Apollo 15, 16, and 17 laser altimeter measurements. They do not include every valid observation but consist of selected observations that are representative of a particular area. For Mare Smythii there are near-redundant data to show the data consistency between the three missions. Since there is such a scarcity of farside mare points, anything that could possibly be considered as a mare was included; however, many would never consider them as such. Oceanus Procellarum has the largest number of mare measurements, for the trajectory paths had a considerable spread of latitude over this area.

In Figure 1 the mare points are plotted in profile. Here one can see that the various surfaces deviate considerably from any spherical reference. If one fits an ellipsoid with an offset center to these 196 elevations, the values for the axes and offset components are shown in Table 1, line 1. The observations referenced to this solution are shown in Figure 2. The various groups of points are inconsistent with each other, and only Oceanus Procellarum and Mare Imbrium fall along the surface.

The next reduction included only circular mare points plus the dark maria of Tsiolkovsky and Grimaldi. Some 20 points were selected to give a relatively even distribution and still preserve stability in the solution. The resulting fit is shown in Figure 3 and tabulated parameters are listed in Table 1, line 2. The dots in Figure 3 represent the 20 points used in the estimation of the axes and offset. There seems to be some fair consistency; however, there are four groups of points that do deviate from the reference surface: farside craters, the crater Pasteur, and the Maria Pecunditatis and Tranquillitatis. The group of farside craters (longitude 150°E to 175°E) may be too small to have allowed a deep upwelling to produce a surface representative for a global mare reference. Evidence for this is the crater Langrenus on the eastern edge of Mare Pecunditatis. The floor of this crater is 5.3 kilometers (J. Love, private communication, 1974) below the 1738-kilometer reference sphere, which places it 2.3 kilometers below Mare Pecunditatis and 0.7 kilometer below Mare Crisium and Mare Smythii, the two deepest mare surfaces. Therefore, crater floors of this size do not necessarily reflect extensive mare surfaces. The crater Pasteur, somewhat larger than Langrenus, may at one time have been a global reference surface, but it appears to be a relatively old feature that has accumulated considerable surface ejecta. Likewise, Mare Tranquillitatis and Mare Pecunditatis, being older mare surfaces [Boyce], (Ref. 1), appears to have acquired additional elevation. The circular mare surfaces, though seem to be consistent and fit well to the reference ellipsoid. Brown (Ref. 2) obtained similar offset results for a spherical reference, using the Apollo 17 radar sounder data.

The remarkably good fit of the ringed mare surfaces (plus Grimaldi and Tsiolkovsky) to an ellipsoidal reference is one that stimulates some speculation for its existence. Were these surfaces once nearly hydrostatic and shaped by Earth's tidal effects? The 2.7-kilometer difference between the X and Y
axis of the ellipsoid (line 2, Table 1) reveals a bulge toward the Earth and revives the old contention that the Moon may have been closer to the Earth 3 billion years ago, when, according to most age dating specialists, the circular maria were formed. The Earth's gravitational effects can produce a bulge of 2' kilometers on a hydrostatic surface at approximately 100,000 kilometers (½ its present distance). This suggests that all the circular maria formed at approximately the same geologic time when this gravitational effect was constant, and that even at this close distance to the Earth, the Moon was rigid enough to support the mascons that we presently observe.

According to Boyce (Ref. 1), Oceanus Procellarum is a young mare surface whereas Mare Tranquillitatis and Mare Fecunditatis are old surfaces. The relation of these surfaces to the circular mare ellipsoid show Maria Tranquillitatis and Fecunditatis grossly anomalous (1 to 2 kilometers higher). These irregular maria also exhibit very small gravitational variations (i.e., no mascons), so one would conclude that they are near isostatic equilibrium. Possibly these surfaces were formed when the Moon was even closer to the Earth than previously mentioned and things were much warmer, so isostatic adjustment occurred over these mare.

Table 1. Estimates of lunar shape parameters

<table>
<thead>
<tr>
<th>Line</th>
<th>Data</th>
<th>X, km</th>
<th>Y, km</th>
<th>Z, km</th>
<th>ΔX, km</th>
<th>ΔY, km</th>
<th>ΔZ, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>196 maria</td>
<td>1736.6</td>
<td>1735.0</td>
<td>1732.7</td>
<td>-0.77</td>
<td>-1.03</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>20 circular maria</td>
<td>1737.3</td>
<td>1734.6</td>
<td>1733.8</td>
<td>-1.72</td>
<td>-1.23</td>
<td>0.0</td>
</tr>
</tbody>
</table>

X = axis toward the Earth in lunar equatorial plane.

Y = axis east in equatorial plane.

Z = north polar axis.

ΔX, ΔY, ΔZ are the offsets along the axes from the center of gravity to the optical center of the Moon.

ΔZ was not estimated due to high correlations with Z, and was held fixed at 0.0.


Figure 1.
Polar plot of mare observations relative to a 1738-kilometer sphere about the center of gravity.

Figure 2.
Polar plot of mare observations relative to ellipsoid fit to 196 points

Figure 3.
Polar plot of mare observations relative to ellipsoid fit to 20 circular mare points

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