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LUNAR ORBITER SELENODESY STUDIES

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1. Analysis of Lunar Orbiter Tracking Data

The nine satellite orbits being utilized have been set up as two duplicating sets of arcs, one limited to arc lengths of 7 days and the other using arc lengths up to 28 days. The set of gravitational coefficients being solved for was extended up through the 12th degree, taking advantage of 360/75 core capacity. Different magnitudes of a priori weighting of coefficients have been tried. Solutions were still not satisfactory, however, in the sense of giving a reasonable gravitational field for the back of the moon. Since May 1 progress has been slight because of hardware difficulties in the 360/91 installed at UCLA.

2. Analysis of Laser Ranging to the Moon

Additional error sources were allowed for in the error analysis, to make the complete list:

1] instrumental random error;
2] constant bias;
3] zenith angle dependent random error;
4] zenith angle dependent bias;
5] sun-moon angle dependent random error;
6] sun-moon angle dependent bias;
7] cloudy weather, random day-to-day

A standard reference was calculated which assumed:

1] observations 3 times a day for 437 days, weather permitting, at the extremes of allowable zenith angle and the meridian;

2] maximum zenith angle of 60°;
3] minimum sun-moon angle of 30°;
4] two telescopes:

Maui (21°N, 204°E, 60% clear weather);
Pic-du-Midi (43°N, 0°, 40% clear weather);

5] one reflector:

Mare Tranquilitatis (2°N, 34°E);

6] random error

$\pm$ (10. + 10. sec Z + 12. $\cos^6\psi/2$)cm, where Z is zenith angle and ψ is sun-moon angle;

7] a priori sigma of bias

$\pm$ (5. + 5. sec Z + 6. $\cos^6\psi/2$)cm;

8] a priori sigmas of lunar orbit elements:

$\Omega = \pm\ 5. \times 10^{-6}$
$I =\ 5. \times 10^{-6}$ radians
$\omega = 100. \times 10^{-6}$
$a = 10^{-10}$ earth radii
$e =\ 5. \times 10^{-6}$
$M =\ 15. \times 10^{-6}$
scale = 2.5×10^{-6} earth radii.

The Fourier components of the wobble and rotation which were solved for were for the periods 13.251, 13.665, 14.106, and 27.330 days.

Eight different variations from this standard program were tested. The main changes from the conclusions given in Quarterly Reports Nos. 9 & 10 were:

a. the maximum allowable zenith distance should be retained at 60°;

b. an additional station in the southern hemisphere would improve significantly determination of the action elements of the orbit (a, e, I), telescope coordinates, and monthly oscillations in the earth's rotation & wobble;

c. tracking over 18.6 years is desirable to determine bodily tide parameters of the moon as well as orbital parameters.

The results still yield appreciably smaller uncertainties than P.L. Bender's, whose analysis appears to neglect the effect of the telescopes' 24^h varying location with respect to the moon. In addition, to duplicate his results would require assuming ad hoc systematic errors at the critical periodicities, rather than having them arise as a consequence of error dependence on zenith distance and sun-moon angle.

The program for the error analysis is to be used as a basis for the actual data analysis.

3. Interpretation of Lunar Mass Concentrations

Considerable further work was done on this subject. The problem was divided into three parts:

1] how was mass transferred to create the mass excess;

2] how has the mass excess been supported since it was transferred;

3] are there any mechanisms besides those associated with the mass transfer which would make the ringed maria denser?

In regard to the first problem, the lunar "mascons" appear to be too big to be caused primarily by the infalling bodies which created the ringed maria: however, this inference depends on scaled extrapolation from explosion data rather than direct calculation. Any other mechanism requires that the moon have differentiated, or acquired, a lighter crust, so that the ringed maria remained topographic lows after isostatic compensation. Mass transfer over the moon's surface requires erosion and sedimentation mechanisms several orders-of-magnitude stronger than are now observed. Mass transfer internal to the moon requires excess pressures generated dynamically (as in the earth) or passively. A dynamic interior to the moon makes it implausible that the mascons would be so closely correlated with ancient surface features. The passive mechanism proposed by Wise & Yates, of lava extruded by the pressure of surrounding highlands, requires a rather thick crust and the simultaneous occurrence of local temperatures high enough to generate lava ($\geq 1100^\circ C$) and general temperatures low enough to allow strength to support the load ($\lesssim 700^\circ C$).

It therefore seems worthwhile investigating whether sufficient pressure could be generated by thermal contraction, such as would have occurred if the outermost layer of the moon was hot enough to differentiate a crust while the interior was colder. The obvious objection is that the lithosphere would fail by a localized cracking. However, the process need only be about 0.1% efficient to produce sufficient pressure, and would still continue when the moon had cooled enough to have a lithosphere several tens of kilometers thick. So the question becomes whether shallow-focus type earthquakes would eventually remove the 10 bars tensile stress required.

In regard to the second problem, the mechanism of support could be the elastic strength of the lithosphere, which would be about 160 km thick for the estimated temperature gradients of 5°C/km. The close correlation of mascons with ringed maria makes dynamic support implausible.

The most significant densification mechanism was probably the outgassing of water after impact, which resulted in the ringed maria not being serpentinized to the same extent as other parts of the moon. Higher thermal conductivity of the mare material may also have lead to a lower temperature gradient and hence some increase in density due to thermal contraction. This dehydration of the ringed maria is most strongly indicated by the distribution of sinuous rilles.

Lectures on interpretation of the mascons were given at UC Santa Barbara, UC Berkeley, Jet Prop. Lab., COSPAR, and NASA-Goddard Inst. A paper has been accepted by <u>Physics of the Earth and Planetary Interiors</u>.

(This work has now been transferred to NASA Grant No. NGL 05-007-002).

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