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MODELLED AND MEASURED STRAIN IN MASCON BASINS ON THE MOON

M. P. Golombek and B. J. Franklin, Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109

The close association of wrinkle ridges and grabens with mascon basins on the Moon has suggested that the responsible compression and extension resulted from basin subsidence and peripheral flexing of the lithosphere. The distribution of grabens and wrinkle ridges associated with mascon basins has been further used along with elastic plate bending models to constrain the thickness of the lithosphere at the time of their formation (1). Kinematic models for basin subsidence have also been developed and compared with strains inferred from grabens and wrinkle ridges (2, 3). Note that kinematic models may be preferable to dynamic models because the strain associated with tectonic features can be compared directly with model predictions and because fewer assumptions are required for their calculation, such as perfect elasticity and specific values of the elastic moduli. In addition, if the results from kinematic models compare favorably with the strain estimated across tectonic features on the Moon, then a global strain (or stress) field, proposed by a number of workers, may not be necessary. In this abstract, the strain inferred for wrinkle ridges and grabens has been compared to that calculated from a simple kinematic subsidence model for mascon basins on the Moon.

The kinematic model used is conservative [model 1 described in (3)]. Briefly, the model assumes an initial basin that is a couple of kilometers deep (2.5 km) at its center, tapering toward the edges (approximated by a segment of a sphere with a larger radius of curvature than the original lunar surface). The basin center is assumed to subside 1-2 km from loading of the lithosphere, which is 25-150 km thick (1), with all points moving towards the center of the Moon. The radial strain due to shortening of the arc (membrane) and that due to unbending are calculated for the interior of the basin. Hoop strains are calculated from the corresponding decrease in circumference of interior small circles around the basin center. Radial extensional bending strains at the edge of the basin are calculated from the flexure of the lithosphere over the width of the graben zone (typically about 50 km) due to subsidence of the basin. Because most wrinkle ridges and grabens associated with mascon basins are concentric, the total radial compressional strain across a basin (edge to edge) and the peripheral radial extensional bending strain are the quantities most easily compared with model calculations.

Determining the extension across grabens on the Moon is straightforward. The bounding faults dip about 60° (4), so the extension on each fault is a simple function of the depth of the graben floor [see (4) for method]. Calculations are based on specific measurements already made (where topographic data exist) or by an estimate based on the apparent depth of a graben (where topographic data does not exist).

Determining the shortening across wrinkle ridges is less well constrained. A number of different methods have been used to obtain the compressional strain, and most methods suggest between a fraction of a percent to a few percent (2, 5, 6, 7). For this application, the method of Golombek et al. (7) is used, which is based on topographic profiles across wrinkle ridges and the presence of an elevation offset, assumed due to motion on a thrust fault at depth. Wherever adequate topographic data exist, we calculate the shortening directly by unfolding the ridge profile and by slip on a 25° dipping thrust fault to produce the observed elevation offset. Because many basins do not have adequate topographic coverage, a general relationship is used between the hill width (the part of the ridge most easily identified on most images) and shortening, based on a set of 31 lunar ridges with detailed topographic data (7) and shortening estimates that suggest wider ridges have more shortening than smaller ridges. This relationship equates shortening with the hill width times 0.016 plus 122 m; it is derived from linear regression analysis and has a correlation coefficient of 0.66. Because this relationship includes uncertainties from a variety of sources and the correlation coefficient is not optimal, we choose the most sensitive parameter that affects the relationship (the fault dip) and vary it by 10° from the nominal 25°. Tests in basins where detailed topographic data do exist (Serenitatis and Crisium) show that this method adequately bounds the measured shortening.

For each basin, a number of transects were drawn to maximize the observed strain. Shortening within the basin and extension peripheral to the basin were measured using the above methods. For each basin we calculated the total radial shortening across the basin and the total peripheral radial extension for lithosphere thicknesses most appropriate for the basin (1). Reported below are the maximum measured and calculated shortenings and extensions across the eight mascon basins on the Moon. Models assume 2 km of subsidence and a lithosphere thickness of 50 km for peripheral flexure, unless otherwise noted. Symbols are: r=radius of basin, not including zone of peripheral grabens (50 km wide unless otherwise noted); sh=maximum shortening across basin (range in model results are for different lithosphere thicknesses, range in measured results are for 15-35° fault dips); ex=maximum extension across periphery; T=lithosphere thickness from (1).

For Humorum (r=200 km) model results indicate sh=1212-2210 m for T=50-100 km and ex=505 m; measured sh=1005-2185 m and ex=475 m. For Serenitatis (r=275 km), model results indicate sh=1076-1800 m for T=50-125 km and ex=366 m; measured sh=815-1760 m and ex=330 m. For Smythii (r=175 km, no graben zone) model results are sh=1874-2446 m for T=75-100 km; measured sh=365-790 m. For Crisium (r=225 km, no graben zone) model results are sh=1590-2920 m for T=75-150 km; measured sh=1040-2540 m. For Grimaldi (r=75 km, initial depth 1 km and 1 km subsidence) model results are sh=670-1338 m for T=25-50 km and ex=335 m for T=25 km; measured sh=340-730 m and ex=200 m. For Orientale (r=150 km, 100 km graben zone) model results are sh=1172-1440 m for T=40-50 km and ex=537 m for T=40 km; measured sh=400-900 m and ex=300 m. For Nectaris (r=160 km, 150 km graben zone) model results are sh=2002-2628 m for T=75-100 km and ex=944 m; measured sh=390-850 m and ex=205 m. For Imbrium (r=540 km) model results indicate sh=1148-1864 m for T=50-150 km and ex=278 m for T=75 km; measured sh=1090-2410 m and ex=250 m.

Results of a conservative and fairly simple kinematic model of mascon basin subsidence indicate modest radial shortening of 0.6-3 km across the basins and extension of 0.2-1 km along the basin margins. Estimates of the cumulative shortening across wrinkle ridges (0.3-2.5 km) and the cumulative extension across grabens (0-0.5 km) in transects across the basins are very similar to subsidence model calculations. In all cases the models can account for the cumulative measured extension and compression. These results argue that the superposition of global strains to account for the strain accommodated by the wrinkle ridges and grabens in mascon basins is not required. There are, however, many wrinkle ridges and a few grabens that do not appear directly related to mascon basin subsidence on the Moon, and it is possible that these features formed from a global strain. To quantify this possibility, the length of all non-mascon grabens and mare wrinkle ridges were summed, an average extension (3, 4) applied to the grabens and an average shortening applied to the wrinkle ridges (7) to calculate a change in lunar surface area. If all of this surface area change is due to a radius change, the total increase in radius needed to account for the non-mascon grabens is trivial (<5 m); the total decrease in radius needed to account for the non-mascon wrinkle ridges is <80 m. It seems reasonable that many if not all of these features are due to non-mascon related processes such as local cooling and contraction, minor settling or subsidence, so that no change in lunar radius is necessary.

References:

(1) Solomon, S., and Head, J., 1979, J. Geophys. Res. 87, 1667-1682. 1980, Rev. Geophys. Space Phys. 18, p. 107-141.
(2) Bryan, W., 1973, Proc. 4th Lunar Sci. Conf., 93-106.
(3) Golombek, M., and McGill, G., 1983, J. Geophys. Res., 88, 3563-3578.
(4) Golombek, M., 1979, J. Geophys. Res. 84, 4657-4666.
(5) Muehlberger, W., 1974, Proc. 5th Lunar Sci. Conf., 101-110.
(6) Watters, T., 1988, J. Geophys. Res. 93, 10,236-10,254.
(7) Golombek, M., Plescia, J., and Franklin, B., 1991, Proc. 21st Lunar Planet. Sci. Conf.