THE SHAPE OF MARS AND THE TOPOGRAPHIC SIGNATURE OF THE HEMISPHERIC DICHOTOMY; *David E. Smith[1] and Maria T. Zuber[2,1]*, [1]Laboratory for Terrestrial Physics, NASA/ Goddard Space Flight Center, Greenbelt MD 20771; [2]Dept. of Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge, MA 02139-4307.

Analysis of occultation data from the Mariner 9 and Viking Orbiter spacecraft has yielded the first accurate model for the shape of Mars. The hemispheric dichotomy, which was previously considered to be a relatively sharp 1-3 km change in height from the topographically high southern hemisphere to the low northern hemisphere, is not a fundamental feature of the shape of the planet. The dichotomy is a consequence of the ~3 km offset between the center of mass and center of figure of Mars, and the boundary along most of its length consists of broad, gradual surface slopes over distances of thousands of kilometers. This result is supported by analysis of high spatial resolution Earth-based radar topographic profiles. Any successful model for the origin of the dichotomy must explain a planet with an ellipsoidal shape and a long wavelength, gradual topographic transition between the northern and southern hemispheres.

The Martian hemispheric dichotomy [1,2] is characterized by a distinctive boundary between the hemispheres that is expressed as knobby and fretted terrains and detached plateaus [*e.g.* 2], distributed over a relatively limited width of ~700 km [3]. In the boundary region, elevations have been interpreted to decrease from south to north by ~1-3 km and the change in topography has been correlated with the geologic features [4]. Formation of the dichotomy has been attributed to internal processes such core formation, and crustal delamination/underplating by vigorous mantle convection. A massive impact or impacts to produce the low northern hemisphere has also been proposed. In addition, the boundary region has been hypothesized as the site of relic plate boundaries.

Most analyses of the origin of the dichotomy have been based on global topographic models with extremely poor long wavelength accuracy [4]. The topography has also been studied via higher spatial resolution measurements derived from photoclinometry, stereo-imaging and ultraviolet spectra. Although these methods yield information on relative heights within an individual image frame or mosaic, the heights cannot be placed in a global reference and are of limited utility in relating local to global structure.

Radio occultation measurements [*e.g.* 5,6] provide estimates of the radius at the time (and location) when the radio signal from a spacecraft is lost (occulted) behind the planet or emerges from behind the planet in its orbit. Occultation data have formed the basis of early determinations of Mars topography and were included in recent USGS digital elevation models (DEMs) [4], but these data have not been re-analyzed since the 1970's. We have improved the spatial location of occultation points on the Martian surface as well as the occultation radii with respect to Mars' center of mass (COM) by utilizing improved spacecraft orbital information, the latest planetary ephemerides and dynamical information, and revised atmospheric refraction corrections. In addition, we referenced the data to an equipotential surface, rather than a 6.1-mbar surface based on an early degree-4 gravity model.

The locations (latitude, longitude, radii) of the Viking 1 and 2 Lander sites were added to the occultation radii. Using the occultation and lander data we solved for a best fit topographic reference ellipsoid [7]. This ellipsoid has a root mean square (rms) fit of 1.9 km to all the data and its center is offset from Mars' COM by 3561±100 m of which 3081±60 m is down the *z*-axis, such that the south pole is further from COM than the north pole by ~6 km The radial accuracy varies between 200 and 1200 m with a rms error of 500 m with respect to Mars' COM, as compared to 1-3 km in the USGS DEMs.

To remove the rotation-induced oblateness from the global shape, we derived the ellipsoidal heights; the difference between the occultation radii and the best fit reference ellipsoid. Results show that there is no elevation difference between the northern and southern hemispheres. The ellipsoidal heights are unimodally distributed, with excursions due to Tharsis and Hellas. The distribution implies that there is no systematic difference in ellipsoidal heights between the N and S hemispheres. However, when the radius of the Martian geoid is subtracted from the occultation radii, the resulting geopotential topography shows a bimodal distribution

Results indicate that at the resolution of our model, the topography is smooth across the northern and southern hemispheres and across the mapped geologic boundary. Thus a topographic depression in the northern hemisphere is not a fundamental feature of the shape of Mars, but rather arises when the shape is referenced to the gravity field. The break in topography between the southern and northern hemispheres that arises in the geopotential reference frame does not everywhere correspond to the mapped geologic boundary, and it is not as spatially sharp. Instead, it is a gradual change in elevation.

A significant concern is that the number and distribution of occultation points near the dichotomy boundary suggests that any sharp elevation changes along the geologic boundary would not necessarily be resolvable from the occultation dataset alone. To determine whether the boundary defined by our model is a real feature of Mars, rather than a consequence of undersampling, we examined high spatial resolution radar-derived topographic profiles.

Earth-based radar observations [*e.g.* 8] provide a direct measure of the distance to the surface of Mars from the Earth and by inference the radius of Mars. The distance to the point on the surface normal to the incoming wave can be measured to within 10 to 30 km in longitude and 80 to 120 km in. Because of the limitations in the variation in geometry of the orbit of Mars and its spin axis direction, radar observations are generally limited to within ~25° of the Mars equator.

We examined all (>20) radar profiles collected at Mars oppositions during the period 1971-1982 that cross the geologic dichotomy. Of these, only two profiles display obvious topographic scarps, and even these features have relatively modest slopes. Analysis of our topographic model and the radar profiles indicates that the average slope in the north-south direction is ~0.1° between 15°N and 15°S. East-west slopes are slight with an rms of ~0.2° per 20° of longitude.

A long wavelength, gradual surface slope would be expected to result from the offset of the planet's COM from its center of figure (COF). A comparison of the occultation- and radar-derived topography as a function of latitude appears to fit such a long wavelength trend, except for deviations caused by major structures such as Tharsis and Hellas. Thus our results indicate that the apparent topographic difference between the northern and southern hemispheres reflects the COM/COF offset, and there is no surface depression in the northern hemisphere.

The distribution of geopotential topography may reflect the variations in the thickness of the crust, as plausible variations in crustal or mantle density cannot explain the observations. The topographic dichotomy is in most places a shallow surface sloping downwards to the north rather than a steep decline, even in areas where planet's geology changes abruptly. Small portions of the geologic boundary that display narrow, steeper scarps may define areas of localized erosion that may have occurred as much as an aeon after the dichotomy formed, and thus may not be directly relevant to the formation of the boundary. We note that a body with a 700-km wide, 3-km high scarp would not have the appearance of a broad, gradual and continuous slope when sampled at the resolution of our model.

Our new assessment of global topography must factor into future evaluation of models of the origin of N-S hemisphere difference on Mars. It is uncertain how the convection models produce a pattern of long wavelength topography and crustal thickness during contemporaneous accretion and core formation. Impact models must be consistent with virtually complete viscous relaxation of the impact depression(s) while maintaining a hemispheric-scale variation in crustal thickness. Plate tectonic models must explain relatively complex early plate arrangements in the context of the observed global-scale shape and lack of gravity anomalies associated with the boundary.

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