GRAVITY, TOPOGRAPHY, AND TECTONIC SEGMENTATION OF THE MARTIAN HEMISPHERIC DICHOTOMY: EVIDENCE FOR MULTIPLE FORMATION MECHANISMS

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Introduction The hemispheric dichotomy of Mars is one of the most prominent topographic structures on the planet. The typical offset of 3-4 km in elevation between the southern highlands and northern lowlands [1,2] corresponds to a difference in crustal thickness of about 25 km [3]. Crater densities indicate that the dichotomy formed very early in martian history [4]. Both internal processes related to mantle convection [5-7] and external processes related to one or more large impact basins [8,9] have been proposed as formation mechanisms. In this work, I focus on regional variations in the gravity, topography, and tectonic patterns along the hemispheric dichotomy. These observations indicate that the dichotomy is segmented into at least two distinct segments. In turn, this suggests that at least two different processes were involved in forming or significantly modifying the dichotomy boundary.

Topographic Segmentation Based on its topography and morphology, the hemispheric dichotomy can be divided into three distinct segments [10]. In Arabia Terra, 320°-50° East, the transition is best marked morphologically as the transition between heavily cratered terrain in the south and much less cratered terrain to the north. Topographically, the transition between highland and lowland occurs over a distance of 2000 to 3000 km of gently sloping terrain. In eastern Mars, 50°-210° E, the dichotomy has a more scarp-like morphology, with the transition from highland to lowland occurring over just a few hundred km. Finally, between 210° and 320° E, the dichotomy's location and morphology are obscured by young lava flows in Tharsis.

Gravity Anomaly Segmentation The gravity anomalies shown in Figure 1 are based on model MGS-95J [11] interpreted up to spherical harmonic degree 72 [12], corresponding to a half-wavelength resolution of 150 km. In order to assess the existence and nature of possible buried mass anomalies, I calculate the residual gravity anomaly by removing the effects of both the topography and its compensating roots from the gravity field [10]. Figure 1a shows the results for the region east of Isidis, 105°-165° E. The map is similar to that in [10] but with 20% higher spatial resolution. The strong positive anomaly, 80-160 mGal, is nearly continuous for more than 3000 km along the dichotomy, implying the existence of high density subsurface material. Northwest of Isidis, a similar ~800 km long positive buried anomaly has also been identified along the dichotomy boundary [13].

In contrast, Figure 1b shows the residual anomaly along the dichotomy boundary in Arabia Terra, 330°-30° E. As in eastern Mars, a strong residual gravity anomaly parallels the morphologic dichotomy boundary, but in this case the anomaly is negative, from -100 to -130 mGal, indicating a low-density subsurface structure. In both cases, the residual gravity anomalies were calculated using an elastic lithosphere thickness of 5 km, consistent with the generally small values in the southern highlands [10,14]. However, the sign and basic structure of the residual anomalies along the dichotomy in these regions are insensitive to the specific choice of elastic thickness between 0 and 90 km [10].

Tectonic Segmentation In eastern Mars, tectonic structures (compressional in the highlands, extensional in the lowlands) commonly parallel the dichotomy boundary [15]. Similar boundary-parallel structures are not observed along the morphologic dichotomy in Arabia Terra. The structures in eastern Mars are thought to be at least partially due to flexural stresses associated with the large change in topography [15]. The absence of similar structures in Arabia Terra may reflect the much longer wavelength topographic structure in that region, which will modify the elastic stress field.

Implications These observations indicate there are spatially correlated lateral variations in the gravity, topography, and tectonic signatures of the hemispheric dichotomy. These correlated changes subdivide the dichotomy into at least two distinct segments, Arabia Terra and eastern Mars. This segmentation suggests that at least two distinct processes were involved in the formation and major modification of the dichotomy. One non-unique possibility is that the dichotomy initially formed by mantle convection and was subsequently strongly modified in some places by large impact basins such as Utopia. To make further progress, models for dichotomy formation need to make specific predictions about quantities such as the topographic gradient and the nature of the gravity anomalies that would occur along the dichotomy boundary. Comparison of such predictions with the observations summarized here would provide important tests of the various models.

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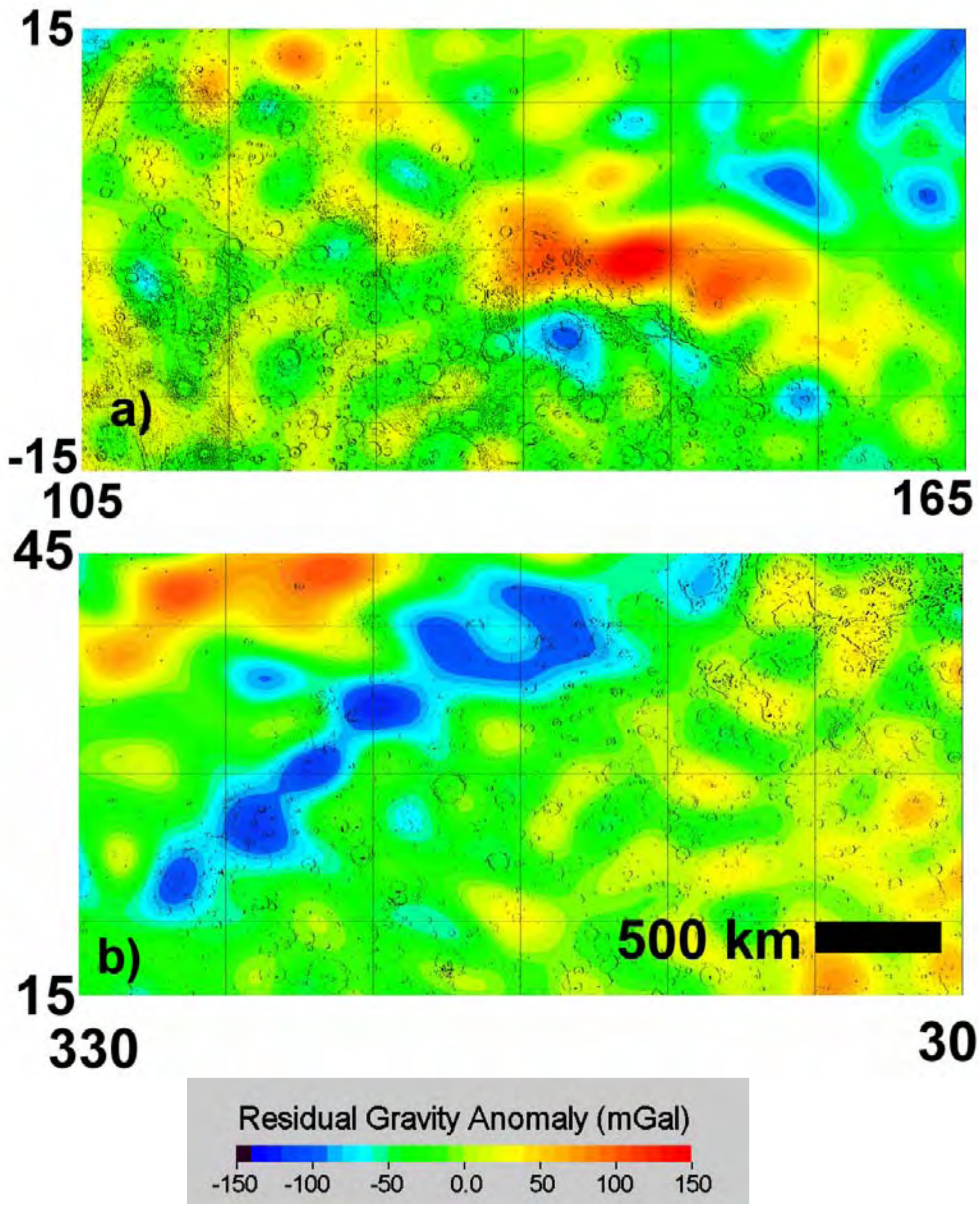

Figure 1. (a) The residual gravity anomaly in eastern Mars, 15° South – 15° North, 105° – 165° East. (b) The residual gravity anomaly in Arabia Terra, 15-45° North, 330-30° East. In both images, the underlying shaded relief image is a Viking MDIM mosaic, processed to emphasize shadowed regions such as impact crater rims. In eastern Mars (a), the morphologic boundary defined by the impact craters closely corresponds to the topographic dichotomy boundary. The major residual gravity anomaly is positive (yellows and reds) and stretches along the dichotomy boundary for more than 3000 km. In Arabia Terra (b), the major negative gravity anomaly (blue) is closely associated with the morphologic boundary as defined by the distribution of impact craters. Simple cylindrical projections.