GEOLOGIC EVOLUTION OF THE MARTIAN DICHOTOMY AND PLAINS MAGNETIZATION IN THE ISMENIUS AREA OF MARS. S. E. Smrekar[1], G.E. McGill[2], C.A. Raymond[1], and A.M. Dimitriou[3], [1]Jet Propulsion Lab, California Inst. of Technology, M.S. 183-501, 4800 Oak Grove Dr., Pasadena, CA 91109; ssmrekar@jpl.nasa.gov; [2]Univ. of Massachusetts, Dept. of Geosciences, Amherst, MA 01003; [3]SLR Alaska, 2525 Blueberry Rd., Suite 206, Anchorage, AK 99503.

Introduction: The global dichotomy divides the northern lowlands from the southern highlands, except where interrupted by relatively young volcanic provinces and impact basins. An elevation change of 2-4 km is typical across the dichotomy, and more than 6 km locally, over distances of several 100s km to as much as 1300 km [1,2]. A variety of exogenic and endogenic formation models have been proposed. Distinguishing between these models would help constrain the overall thermal evolution of the planet, possibly timing of core formation, and the associated mantle heat flux over time. A first step is to determine whether or not gravitational relaxation plays a role in modifying the boundary. Nimmo and Stevenson [3] examined 10 profiles across the dichotomy and used models of gravitational relaxation to conclude the relaxation has not occurred. In this study we begin by considering the geologic history in detail as inputs for modeling [4].

Geologic History: We examine a section of the dichotomy between 50 and 90E. A series of 10 graben with slopes of 13° to 21° bound the rim of the plateau. We estimate a lower bound of 3.5% horizontal strain across these graben using the measured apparent vertical offset from MOLA profiles (corrected for intersection angle) and assuming an original fault dip of 60°. The highlands in this area are separated from the lowlands by a topographic bench. We interpret the bench as a down faulted highlands block based on both age constraints and evidence for faults on either side. Topographic knobs cover the topographic bench, but disappear abruptly to the north under plains fill. This transition is parallel to graben along the dichotomy boundary and is interpreted as a cryptic normal fault [5].

Age Constraints: The count for the highlands craters ≥ 16 km in diameter yields a late Early Noachian age. If only craters superposed on the plateau surface material are included, the age is Middle Noachian. Counts from two large areas in the topographic bench yielded crater ages ranging from Middle Noachian to Late Noachian. The greater tectonic disruption and thicker plains cover on the bench result in loss of many of the oldest and most degraded. We thus infer that the basement beneath the lowland bench as most likely Early Noachian in age, similar to the basement beneath the highland plateau. A Late Hesperian age has been estimated for adjacent plains [6].

Origin of the Boundary Scarp: The 2.5 km of relief at the dichotomy could not have been a result of erosion. Given the similarity in age between the highlands and the bench, erosion would have had to have occurred in the Early Noachian. However, the scarp separating the highlands and the bench cuts Middle Noachian deposits, and could not have survived early bombardment. Nor could erosion have occurred subsequently as 2.5 km of erosion would have erased all but the largest craters.

Gravity and Magnetic Field Data: The free air and Bouguer gravity, which has the effect of topography removed, both have anomalies with a similar frequency and amplitude variation as that of the magnetic field anomalies. In order to gain more insight into the geologic evolution and subsurface structure in this area, we examine the hypothesis that both the magnetic and gravity anomalies are due to the same source regions. We focus on two major anomalies on either side of the cryptic fault. The magnetic field changes polarity across the cyptic fault, which is indicative of some type of edge effect in the subsurface magnetized material. The Bouguer gravity is more positive in the topographic shelf area adjacent to the cryptic fault. To the north of the cryptic fault, there is another major positive anomaly in the Bouguer gravity, offset by approximately 200 km from the peak in a comparably sized magnetic anomaly. Both our modeling of the admittance signature of this area and other studies of the compensation of the highlands in general [3,7-9] find that the highlands regions are isostatically compensated. To determine what additional density anomalies remain once both topographic and isostatic effects are modeled, we remove the effect of an 80 km thick crust [10] (see Figure 1). Each of the two main peaks in the isostatic gravity anomaly and magnetic field are offset by approximately 200 km and have a lower peak to the south. For an intrusion 100 kg/m^3 denser than the surrounding crust, a layer roughly 30 km thick is needed to match the observed gravity anomalies. The more dense the intrusion, the thinner the required layer.

We next model the total magnetic field, assuming that the magnetic and isostatic gravity anomalies are caused by the same source region. Two possible solutions using inclinations of 30 and –60° provide the best fit. These inclinations are consistent with paleopole estimates [11,12]. We model the anomalies using gaps in the magnetized material. Equivalently, gaps can be filled in with oppositely polarized material, and the intensities increased by a factor of 2. For an inclination of –60°, gaps in the magnetic field are aligned with the locations of the isostatic gravity anomalies (Figure 2). Other field inclinations were also examined for this case, but did not provide as good a fit. We also considered a second case in which magnetized blocks, rather than gaps in the magnetization, are aligned with the isostatic gravity anomalies. For a 30° magnetic inclination this also provides a good fit to the magnetic field.

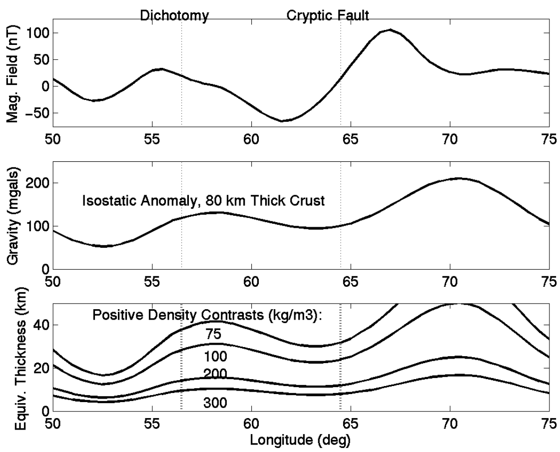

Figure 1. Profiles from 33N, 50E to 50.5N, 75E across the dichotomy, the topographic shelf, and into the plains through the magnetic field (top), and the isostatic gravity anomaly (middle). The thicknesses of layers with varying density contrasts that would produce an equivalent gravity anomaly are shown on bottom.

We interpret the magnetic and gravity field modeling as most likely due to subsurface volcanic intrusions. Both Martian meteorites [e.g. 13] and estimates of volcano densities from gravity studies [7,8,14-16] are consistent with the presence of high-density intrusions. In the model shown in Figure 2, the gaps in the magnetic field would be caused by magmatic intrusions that both demagnetized the crust and emplaced high-density bodies at depth. In the alternate model, where the source region for the magnetic and gravity anomalies is magnetized crust, the intrusions would have been emplaced into nonmagnetic crust in the presence of a magnetic field from Purucker (pers. com.). Although neither case can be ruled out, the first scenario is simpler. Although no volcanism is visible at the surface, there is a plausible mechanism to produce intrusions in this location. King and Anderson [17] model the effects of a transition in lithospheric thickness on a convecting system and find that localized upwelling is produced at the transition. The extension across the boundary may also be related to the volcanism. Future work will investigate other locations across the dichotomy to further test these hypotheses.

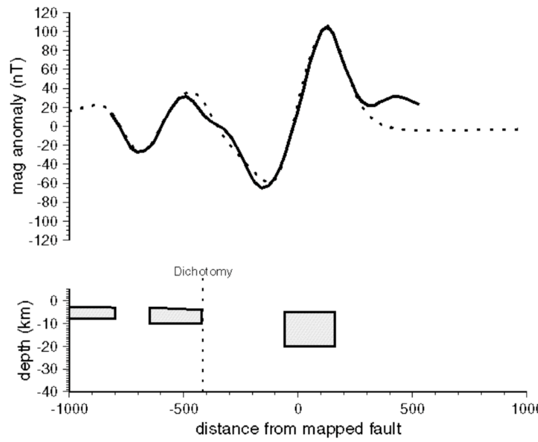

Figure 2. The solid line in the top plot is a profile of the total magnetic field calculated as an average of three field models [Purucker, pers. Com.]. The dashed line is the magnetic anomaly in nanaoteslas (nT) predicted from the magnetized blocks of crust shown on the bottom. The magnetic inclination is -60° and the intensity of each block is 6 A/m. The cryptic fault is located at 0 km.

References: [1] Frey H. A. et al. (1998) GRL, 25, 4409-4412. [2] Smith D. E. et al. (1999) Science, 284, 1495-1503. [3] Nimmo F. and Stevenson D. J. (2001) JGR, 106, 5085-5098. [4] Guest A. and S.E. Smrekar. (2004) *LPS XXXV,* Abstract #1362. [5] Dimitriou A.M. (1990) Masters Thesis, Univ. Mass. Amherst. [6] Frey H.V. et al. (1988) *Geophys. Res. Let., 25*, 4409. [7] McGovern P.J. et al. (2002) *JGR 107*, doi: 10.1029/2002JE001854. [8] McKenzie D. et al. (2002) *EPSL 196*, 1. [9] Nimmo F. (2002) *JGR 107*, doi:10.1029/2000JE001488. [10]Zuber M.T. et al. (2000*) Science, 287*, 1788. [11] Cain J. C. et al. (2003) *JGR, 108,* doi: 10.1029/2000JE001487. 1151-1154. [12] Hood L.L. and Zakharian A. (2001) JGR, 106, 14601-14619. [13] Britt D.T and G.J. Consolmagno (2003) *Meteorit. Planet. Sci. 38,* 1161. [14] Arkani-Hamed (2000) *JGR 105*, 26,712. [15] Kiefer W.S. (2002) Trans. Am. Geophys. Union, Fall Mtg, Abstact # P71B-463. [16] Kiefer W.S. (2003) LPS XXXIII, Abstract #1234. [17] King S.D. (1998) *Earth Planet. Sci., 160*, 289.