SUBSURFACE STRUCTURE OF THE ISMENIUS AREA AND IMPLICATIONS FOR EVOLUTION OF THE MARTIAN DICHOTOMY AND MAGNETIC FIELD. S. E. Smrekar[1], C.A. Raymond[1], and G.E. McGill[2], [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.

Introduction: The Martian dichotomy divides the smooth, northern lowlands from the rougher southern highlands. The northern lowlands are largely free of magnetic anomalies, while the majority of the significant magnetic anomalies are located in the southern highlands. An elevation change of 2-4 km is typical across the dichotomy, and is up to 6 km locally [1,2]. We examine a part of the dichotomy that is likely to preserve the early history of the dichotomy as it is relatively unaffected by major impacts and erosion. This study contains three parts: 1) the geologic history, which is summarized below and detailed in McGill et al. [5], this volume, 2) the study of the gravity and magnetic field to better constrain the subsurface structure and history of the magnetic field (this abstract), and 3) modeling of the relaxation of this area (Guest and Smrekar, [6], this volume). Our overall goal is to place constraints on formation models of the dichotomy by constraining lithospheric properties. Initial results for the analysis of the geology, gravity, and magnetic field studies are synthesized in Smrekar et al. [7].

Geologic History: Our study area (50°-90°E) is characterized by steep scarps, a fairly rapid change in crustal thickness [3,4], and large magnetic field anomalies in the adjacent lowlands. The area includes a series of 10 graben with slopes of 13° to 21° bounding the rim of the plateau with >3.5% horizontal strain. A topographic bench separates the highlands from the lowlands. The northeastern edge of the bench is defined by the abrupt disappearance of topographic knobs and parallels graben along the dichotomy boundary to the south. These observations support the interpretation that the boundary marks a buried fault, with the lowlands dropped down to the north. Additionally, crater counts indicate that the basement material in the lowlands is likely similar in age to the highlands material [8]. Finally, 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. 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 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. Our modeling of the admittance signature of this area [7] indicates that the highlands regions are isostatically compensated, as is found elsewhere [9-11]. To determine what additional density anomalies remain once both topographic and isostatic effects are modeled, we remove the effect of a 50 km thick crust to produce the isostatic anomaly. Modeling the isostatic anomaly along a profile (50°E, 33°N to 75°E, 49.5°N) perpendicular to the buried fault and dichotomy boundary we find that each of the two main peaks in the isostatic and magnetic field anomalies are offset by approximately 200 km and have a lower peak to the south (Fig. 1). 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 along the same profile, examining a range of possible paleopole positions consistent with prior estimates [12,13]. In each model the intensity is held constant. The position and thickness of each block is varied to fit the observed data. All of the models in Figure 2 provide a reasonably good fit to the data, except for the model with a 0° paleopole inclination (Fig. 2b). For an inclination of –30°, gaps in the magnetic field are aligned with the locations of the isostatic gravity anomalies (Fig. 2c). For a 30° magnetic inclination (Fig. 2d) the isostatic anomalies are aligned with magnetized crustal blocks.

One possible interpretation of the large positive isostatic anomalies is that they are due to subsurface magmatic intrusions. Both Martian meteorites [e.g. 14] and estimates of volcano densities from gravity studies [9,10,15-17] are consistent with the presence of high-density intrusions. Although no volcanism is visible at the surface, there is a plausible mechanism to produce intrusions in this location. King and Anderson [18] 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.

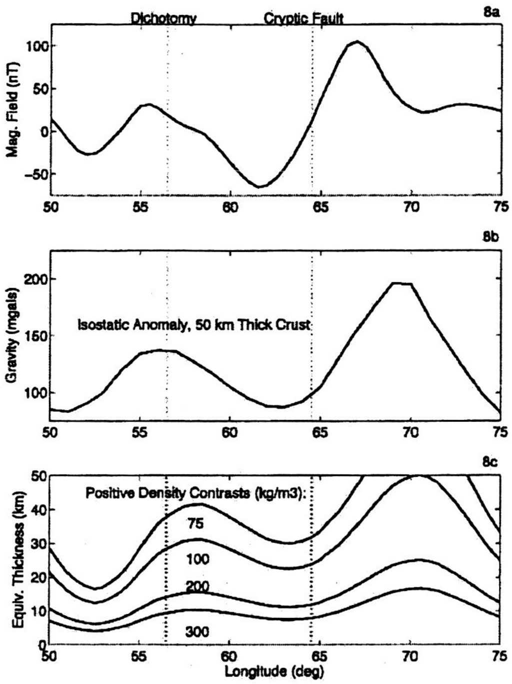

Figure 1. Profiles through the magnetic field (a), and the isostatic gravity anomaly (b), and thicknesses of layers with that would produce an equivalent gravity anomaly(c).

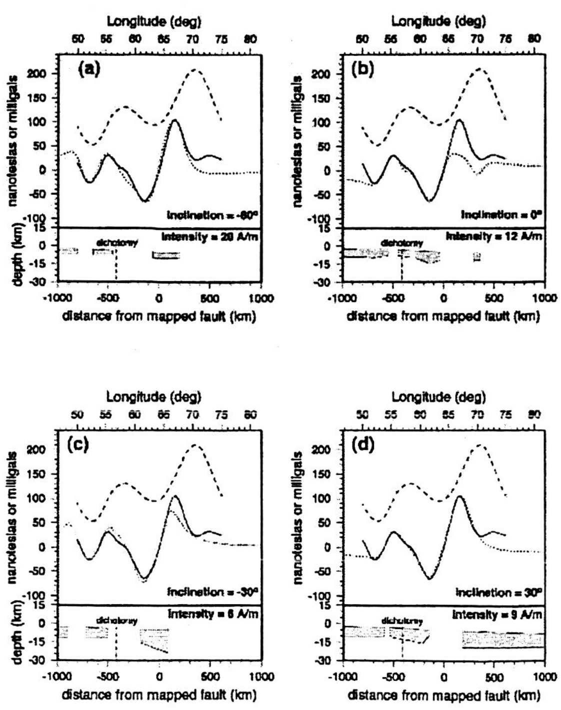

Figure 2. Model fits (dotted lines) to the observed magnetic field in nT (dashed lines) along with the isostatic gravity anomaly in mgals (dashed lines). The source blocks are shown at the bottom of each panel as a function of distance from the buried fault and depth. Intensity and field inclination assumed for each model are indicated on the figure.

In the magnetic field model shown in Fig. 2c, the gaps in the magnetic field would be caused by magmatic intrusions that both demagnetized the crust and emplaced high-density bodies at depth. An intriguing aspect of this model is that the magnetized crust stops at approximately the location of the buried fault. In an alternate model (Fig. 2d), in which there is a common source for the gravity and magnetic anomalies, the intrusions would have been emplaced in the presence of a magnetic field. An interesting implication of this model is that the plains to the north of the magnetic anomalies are magnetized.

Preliminary Conclusions and Follow-on Work

The modeling results offer interesting possible interpretations but are non-unique. The next step is to develop a 3D model of the gravity and magnetic field for those anomalies associated with the dichotomy boundary and down dropped block. Objectives include better defining the extent of magnetized material at depth, placing narrower bounds on paleopole position, and determining if there is strong evidence for either correlation or anticorrelation of the gravity and magnetic anomaly source regions. Results will be used to test two alternative hypotheses: 1) magnetic anomalies in the lowlands along the boundary represent highlands crust that has been dropped down via extension across the boundary, and 2) the lowlands are in fact magnetized at a low level. We will continue our study of the dichotomy by examining the geology, gravity, and magnetic field data for additional areas of the dichotomy. Our initial examination of the boundary to the east, in the Amenthes area, indicates a pattern of gravity and magnetic field anomalies with similar magnitude and frequency content.

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