LITHOSPHERIC THICKNESS VARIATIONS FROM GRAVITY AND TOPOGRAPHY IN AREAS OF HIGH CRUSTAL REMANENT MAGNETIZATION ON MARS, S. E. Smrekar, and C. A. Raymond, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., MS 183-501, Pasadena CA 91109 (ssmrekar@cythera.jpl.nasa.gov).

Introduction: Large regions of intense crustal remanent magnetization were fortuitously discovered on Mars [1] by the Mars Global Surveyor (MGS) spacecraft. The somewhat linear pattern of positive and negative regions led to the initial hypothesis that plate tectonics may organized crustal formation in a process analogous to seafloor spreading early in the geologic history of Mars [2]. Other hypotheses include rifting and reheating of the crust by dyke intrusion [2,3]. Little correlation is observed between surface geology and the pattern of magnetization, indicating subsequent reworking of the surface by impact cratering and erosion. A possible exception is the location of several channels along the boundaries of positive and negatively magnetized crust. However, this may indicate structural control on the location of the channels as well as on the pattern of magnetization.

A basic question about the magnetized regions is why are only some areas magnetized, and in particular, why only some regions of the southern highlands where the majority of the magnetized regions occur. Another question is whether regions with different magnetic polarities represent reversals or if negative (or positive) regions are produced by gaps between the positively (or negatively) magnetized zones. Gaps might consist of regions with high frequency variations in polarity that sum to zero at the observation altitude, or unmagnetized regions. If the time scale of reversals on Mars is of the order of hundreds of millions of years, then a difference in elastic thickness could be expected between regions with different polarity, given the expected rapid early cooling of the lithosphere on Mars. Rifting and major dike intrusion would both be expected to rehear and locally thin the lithosphere.

In this study we use the admittance technique, in which the ratio of the gravity to the topography is examined as a function of topography to look at the response of the elastic lithosphere and crust to loads emplaced near the surface (top loading) and those emplaced at depth (bottom loading) [e.g. 3,4,5]. This method permits the estimation of elastic thickness, T_e, at the time of loading, and the product of the crustal density, ρ_c, and crustal thickness, Z_c. The loading history, whether there is a load causing flexure of the elastic lithosphere, and whether it is emplaced at the surface or at depth. In this way we can determine if variations in crustal structure exist within the highly magnetized regions and if they have a relationship to the pattern of magnetization.

Data Analysis: The relationship between gravity and topography is examined using the MGS75d 75 degree and order spherical harmonic gravity field and the corresponding topography field [7]. Both are referenced to the ellipsoid approximation for the shape of Mars. As the complete magnetic field data have not been released to the community, we use the magnetic anomaly field produced at an altitude of 200 km by [8]. This study focuses on the highly magnetized area of the southern highlands within 0-90S and 90-250 E; the highest degree of magnetization occurs near the center of this region. We first examine the correlation between the free air gravity and the magnetic pattern. The free air gravity does not appear to be correlated with the magnetic pattern, but it does correlate in many locations with the topography, indicating a strong influence of surface erosional features on the gravity field within the southern highlands area examined. However, the Bouguer anomaly, which is calculated by subtracting the gravity predicted from the topography from the observed gravity, does show a correlation with the magnetic pattern in many regions. Often there is a small offset, likely indicating that vertical magnetization assumed in the model of [8] is incorrect at least locally. This indicates that subsurface total density variations are correlated with the magnetic pattern. Total density variations may represent changes in the thickness or the actual density of the magnetized regions.

Admittance spectra for 7 subregions have also been examined (Table 1). These subregions have been chosen to contain primarily positively or negatively magnetized portions of the crust with the goal of determining whether variations exist in lithospheric structure. Models of top, bottom, and a combined load were fit to each area. With the exception of 1 area, all spectra indicate the presence of bottom loading, with varying degrees of top loading. In the one case that could be well fit by a top load alone, a bottom loading model could also provide a good fit, giving somewhat thicker values of T_e and Z_c. All models assume a crustal density of 2900 kg/m^3, and a mantle density of 3300 kg/m^3, as adopted in earlier Mars gravity studies [9]. Derived values of elastic T_e and Z_c are given in Table 1.

As large coherent regions of negatively polarized magnetization are rare, the majority of the regions examined have a positive magnetization. Areas 2, 3, and 4 have lower values of T_e and Z_c than others in the study. These regions also contain very high amplitude positive anomalies. Although regions 5 and 6 are also positively magnetized, these areas straddle the dichotomy boundary, and may have been affected by other processes. The two regions of negatively magnetized crust have the largest values of T_e and Z_c.

Area	Lat. (S)	Lon. (E)	T_e (km)	Z_c (km)	Polarity
1	28-43	169-182	35	70	N
2	43-56	170-190	15	10	P
3	20-35	156-169	20	30	P
4	25-38	187-206	20	10	P
5	10-23	188-201	30	75	P
6	11-24	158-173	25	35	P
7	5-20	127-142	40	110	N

Table 1. Results from regional admittance studies. Magnetic anomaly polarity is negative (N) or positive (P). Values of T_e and Z_c have an uncertainty of approximately ±5 km.

Discussion: These preliminary results suggest that variations exist in the crustal/lithospheric structure between areas of positively and negatively magnetized crust. Positively magnetized crust has smaller values of T_e and Z_c, with those regions entirely on the southern highlands having the most extreme values. If we assume these results indicate true variations in Z_c and T_e, there are two possible interpretations. One is that positively magnetized crust formed earlier, when T_e and Z_c were likely to have been thinner. Negatively magnetized crust formed later, following a magnetic field reversal and after lithospheric cooling and additional crustal production. Alternatively, positively magnetized crust formed later in a reheating event, giving lower values of T_e and a thinned Z_c. In this context, the thinner Z_c values are more consistent with an extensional environment, such as rifting, than a crustal underplating event, as occurs for some plumes.

The apparent variations in T_e and Z_c could instead be interpreted in terms of density variations. Using an extreme 'crustal' density of 3500 kg/m^3 rather than 2900 kg/m^3 for the regions with the smallest values of T_e and Z_c gives more intermediate ranges for these parameters. For example, the admittance spectrum for area 2 can also be fit using rc equal to 3500 kg/m^3, T_e equal to 20 km, and Z_c equal to 30 km. Although such a large density is not consistent with a crustal composition, it might reflect an extremely iron-rich mineralogy, consistent with extreme values of crustal magnetization observed [10]. Similarly, use of crustal density values less than 2900 kg/m^3 would give smaller values of T_e and Z_c. In reality both density variations and changes in thickness likely contribute to the differences in derived parameters. If sufficient variability of crustal density is allowed,

The fact that many, if not all, of these regions exhibit a bottom loading signature is consistent with subsurface intrusions pushing up on the elastic lithosphere at the time of loading.

Conclusions and Further Work: Constraints on the structure of the lithosphere are preliminary at present. However, it appears that there are differences between positively and negatively polarized crust. This indicates that the formation processes, subsequent evolution, and/or timing of the formation of the two types of regions differ. Regions beyond the intensely magnetized zones will also be examined to attempt to distinguish whether timing or genetic and evolutionary processes are dominant in creating variations in structure between crustal regions with different magnetization.

Additional work will include direct modeling of the magnetic field to determine if gaps in the magnetized regions could be consistent with the observed negative and positive patterns [11]. Preliminary results suggest that this may be a viable interpretation. The degree of correlation between the Bouguer gravity and the intensity of the magnetization will also be examined. Once the magnetic field data become available, a joint inversion of the gravity, topography, and magnetic field data will be attempted to distinguish between density variations and thickness variations.

The current results are consistent with several interpretations, and do not discriminate between mechanisms of formation. Further work on density structure and magnetic intensity may help eliminate hypotheses.

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