CONSTRAINTS ON THE MARTIAN PLATE TECTONIC HYPOTHESIS FROM GRAVITY AND TOPOGRAPHY DATA.

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The Mars Global Surveyor Magnetic Fields Experiment/Electron Reflectometer (MGS MAG/ER) experiment serendipitously discovered unanticipated and unprecedented regions of high amplitude crustal magnetic anomalies [1], indicating strong sources of remanent crustal magnetism. In one area of the southern hemisphere, the anomalies appear lineated and alternate in direction, resembling the stripes formed at terrestrial oceanic spreading regions [2]. However, many significant differences exist. The inferred magnetizations are easily an order of magnitude greater in strength than terrestrial counterparts. The width of the anomalies appears to be approximately 200 km, in comparison to a variable width of order 10-1000 km at terrestrial spreading centers. However, the spacecraft altitude of 100-200 km may be such that narrower anomalies are simply unresolved. Although the majority of strong anomalies are found in the southern highlands, there is no clear correlation with landforms at the surface. The lack of a correlation between magnetism and topography hinders the confident interpretation of magnetic sources.

Several hypotheses have been put forward to explain the magnetic lineations observed by Mars Global Surveyor [2]. The first and favored is that they are comparable to a seafloor spreading signature and represent isochrons of a spreading center that cooled during different magnetic field orientations. Another is that the lineations represent numerous rifts and intrusions formed under different field orientations. A third possibility is that a uniformly magnetized crust was folded such that the field orientation appears to reverse. Connerney et al. [2] point out that this hypothesis is unlikely due to the length scale of the required folds.

Each of these hypotheses has a predicable gravity signature. It is apparent from the distribution of magnetic anomalies that the ridge would have ceased activity billions of years ago. Thus, for the spreading ridge hypothesis, no thermal density contrasts would contribute to a gravity signature. However, variations in crustal thickness would likely be preserved. Estimates of crustal thickness on Mars range from 30 to 100 km [3]. At terrestrial spreading centers, the crustal thickness goes from 0 km at the spreading axis to approximately 6 km within about 20 km of the ridge axis, depending on the spreading rate. If we assume formation, at a spreading center, of a 30 km crust on Mars (at the low-end of the thickness spectrum), then a comparably larger magma chamber would be

required and the crust might take longer to achieve its full thickness. As an example, a crustal thickness of 30 km might be reached at 300 km from the axis. Although Acuna et al. [1] suggest that there is some correlation of magnetic and gravity anomalies in the northern hemisphere that suggests dense, perhaps iron-rich bodies, it would be difficult to generate crust at a ridge that is negatively buoyant. We assume that if the magnetic anomalies were created at a spreading center, then the crust generated would be positively buoyant. After dissipation of the thermal anomaly, a positive gravity anomaly would occur due to the relatively thin crust and thick mantle as compared to regions off the ridge crest with larger crustal thicknesses.

If the magnetic anomalies formed through rifting of the lithosphere followed by later intrusions, gravity anomalies should be associated with the graben structures. The magnitude of the gravity anomaly is proportional to the throw and angle of the bounding faults, the change in density, if any, between the graben walls and fill, and the depth to which the grabens were filled. Gravity lows are produced on the downdropped sides of the faults, and highs on the flanks. Only in the case where the grabens were uniformly filled to the top with materials of the same density would there be no resulting gravity anomaly.

Uniform folding of a magnetized crust should produce a uniform variation in the gravity signature. The large amplitudes of the magnetic anomalies indicates that the fold amplitudes must also be large. Given that the magnetic anomalies are not uniform, the amplitude of the folds may not be uniform, or the thickness of the original layer may not have been uniform. The expected gravity signal would be a clear correlation between gravity highs and lows and reversals in the magnetic field.

An initial examination of the gravity [4] and topography [5] does not show a correlation to individual magnetic lineations. This is expected as the gravity data from Viking was acquired at 400 km altitude, as was the data acquired by MGS, except for a region near the north pole where gravity data was recorded at approximately 200 km during aerobraking [6]. Thus, the gravity resolution is a factor of 2 to 3 worse than that of the magnetic data. Complicating the gravity interpretation for all of the above hypotheses is the fact that the original structures are buried under an unknown thickness of younger sediments that have been disrupted by impact craters. However, the

observed amplitudes of the magnetic anomalies, -1389 nT to 1476 nT [2] suggest sources of very large volume, which increases the chance of correlated magnetic and gravity anomalies.

Despite the relatively low resolution in the gravity data, there are some gravity highs associated with magnetic lineations. Lineations near -55°S and above -70° S have positive free air and bouger gravity anomalies associated with them. If we consider this observation in terms of the spreading center hypothesis, the highs would indicate fossil spreading centers, where the crust is thin. However, some additional compensation, perhaps flexural, would also be required since these region are topographic highs. If these regions were isostatically compensated fairly near the surface, there would be no Bouger anomaly. The individual rift and folding hypotheses do not appear to fit the gravity data. However this may be simply an artifact of the gravity resolution. More detailed forward models of these processes will be formulated, using the magnetic anomalies as constraints to place bounds on these two models. Thus the maximum possible rift relief or fold amplitude and density constrasts permissible can be determined. The gravity signature of lithospheric loading will also be examined. Although the MGS gravity data was acquired at the same altitude as that of Viking, the improved tracking accuracy may improve the gravity field in this region. Further the MOLA data set will provide much more accurate topography data in the region [7]. Thus new data may slightly improve the resolution of possible correlations with specific features, although individual lineations will still not be resolved.

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