JOINT INVERSION AND FORWARD MODELING OF GRAVITY AND MAGNETIC DATA IN THE ISMENIUS REGION OF MARS.

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Introduction: The unexpected discovery of remanent crustal magnetism on Mars was one of the most intriguing results from the Mars Global Surveyor mission. The origin of the pattern of magnetization remains elusive. Correlations with gravity and geology have been examined to better understand the nature of the magnetic anomalies. In the area of the Martian dichotomy between 50 and 90 degrees E (here referred to as the Ismenius Area), we find that both the Bouguer and the isostatic gravity anomalies appear to correlate with the magnetic anomalies and a buried fault, and allow for a better constraint on the magnetized crust [1].

Ismenius Area: 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 [2]. Topographic knobs cover the 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 [2].

In order to gain more insight into the geologic evolution and subsurface structure in this area, we perform an inversion of the gravity and magnetic anomaly data, focusing on two major anomalies on either side of the mapped buried fault, using the fault to guide the placement of the source array. The magnetic field changes polarity across the fault, which is indicative of some type of edge effect in the subsurface magnetized material. A large positive gravity anomaly occurs northeast of the fault, in the same general area as the magnetic anomaly. Southeast of the fault, a small negative gravity anomaly is aligned with the magnetic anomaly.

An initial examination of possible correlation between the gravity and magnetic anomaly sources explored different hypotheses by modeling a 1-D profile across the dichotomy boundary, the buried fault, and the 2 gravity and magnetic anomalies described above [2]. We tested two types of models. In the first model the sources for the magnetic and gravity anomalies are the same and are therefore correlated. For this model, the correlations between the magnetic anomalies and positive density variations are most likely to be a result of subsurface magmatic intrusions. The second model assumes that the bodies are anticorrelated. This model has gaps in the magnetization (relative to the highlands source layer) that are approximately aligned with the isostatic gravity anomalies. These gaps are consistent with discrete, high density intrusions causing demagnetization of the crust. Paleopole estimates for Mars which have been previously derived place both normal and reversed polarity poles in a region centered at 230E, 25N [3], or in a region centered at 225W, 50N [4]. The uncertainties on the paleopole estimates allow a wide range of possible inclinations for the study area, but exclude steep paleofield inclinations (>±60º). The estimated range of paleolatitudes expected across the sampled profile for is 10º–30º ± 30º [3] or 25º to 40º [4]. Given this large range of paleopole position, it was not possible to distinguish between the two models on the basis of 2-D forward modeling.

Gravity and Magnetic Field Data: Both the free air and Bouguer gravity fields exhibit anomalies with a similar wavelength and amplitude variation as the magnetic field anomalies. We use the isostatic anomaly, which removes the gravity signature of a subsurface crustal layer from the Bouguer gravity, assuming that the layer provides isostatic compensation of the topography. For the magnetic data we take advantage of the full resolution available in the 3-component magnetic measurements of the MGS orbiter. Individual profiles are selected and the data are then processed. This includes selecting high and low altitude data and eliminating noisy data via a combination of visual inspection, track-to-track comparison, and examination of the power spectrum for effects of aliasing.

Inversion: We base the 3D joint inversion method on the approach developed by [5] and references therein. This approach is one of the few that allow a full 3-D joint inversion, the subsurface is represented as a series of rectangular prisms. The inversion solves for susceptibility, remanent magnetization, paleopole inclination, density, and depths to the top and bottom of the prisms [5]. Our approach modifies the method of [5] in several ways. We have eliminated the calculation of the induced magnetic field and inversion for susceptibility from the original code to reflect the lack of an active field on Mars. The new code is based in Martian coordinates. In addition, the steepest descent inverse approach has also been replaced by a Bayesian approach, motivated primarily by the non-uniqueness of models that fit the data (as observed for 1D models in [1]). The Bayesian figure of merit for various models is the *posterior probability*, given in terms of prior probabilities for the models (chosen to reflect physical constraints on the models) and the likelihood of observing the data in the context of a given model. The likelihood of observing the data in the context of a model is determined by the instrument noise – it is the negative log-likelihood, also known as χ^2“chi-squared” (for the case of Gaussian noise) which is typically minimized in traditional approaches to the inverse problem (usually through steepest descent, or other optimization algorithms). Our emphasis has shifted from finding a single “best” model to quantifying the collection of models with similar values of the Bayesian posterior probability – providing a generalization of the notion of “error bars”. While more expensive than steepest decent, a Bayesian approach provides a more complete picture of what has been learned from the data, and allows the quantification of our uncertainty (through samples from the Bayesian posterior).

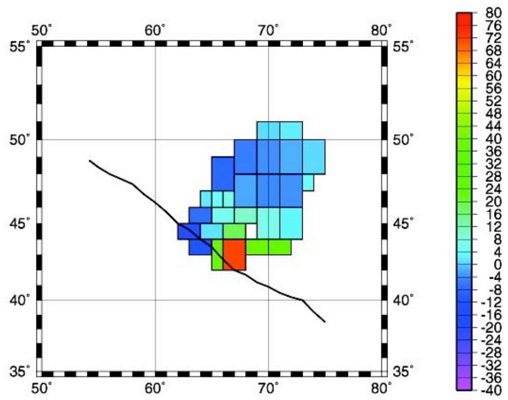

Figure 1. Location of model prisms, buried fault and model inversion results for magnetization intensity (A/m).

Source prisms are defined as 4 different types. Prisms that allow for inversion of: 1) remnant magnetization only, 2) density only, 3) magnetization and density, or 4) magnetization or density. Figure 1 below shows an example inversion of magnetization intensities obtained assuming a paleopole at 230E, 25N [3], for a set of prisms where all prisms are inverted for magnetization and density. Densities are not shown. The scale bar is magnetization in A/m, and the mapped buried fault is the black curve. In separate forward modeling trials, prisms closer to the fault match the magnetic field data better than those that are farther away, and the prisms farther from the fault better fit the gravity data. In this inversion, prisms located closer to the fault exhibit higher magnetization values than those that are further from the fault, consistent with the intrusion model mentioned previously.

This same set of prisms was inverted with the far group of prisms being selected as density only prisms, and the near group selected as magnetic only prisms. This resulted in a posterior probability lower than the first. This shows that a better fit is obtained allowing all prisms to have magnetic and density variations, even if they are relatively low.

Future Work: We find the best fitting solutions for source dimension, density and paleopole based on assumption that gravity and magnetic anomalies are caused by the same sources (prisms). Initial prism locations will be defined based on the location of the isostatic anomalies. To test for anticorrelation, we will constrain the solution such that those prisms defined by the isostatic anomalies will have magnetization set to 0, and the magnetic prisms will have density set to 0. Additional prisms will be added in which the magnetization can vary. To test if the sources are largely uncorrelated, we will blanket the region with small prisms and let the density and magnetization vary within reasonable bounds. We will compare the best-fit solutions to determine which hypothesis provides the best, and most reasonable, fit. A key aspect of the study will be an examination of how the inversion changes with paleopole location. As discussed in the context of 1D models, determining whether or not the gravity and magnetic source regions are correlated or anticorrelated has important implications for the local history of the crust. If magnetic and gravity anomalies here and elsewhere can be correlated, it will be possible to better constrain paleopole positions.

References: [1] Smrekar, S. E. et al. (2004), JGR, 109, E11002, doi:10.1029/2004JE002260. [2] Dimitriou A.M. (1990) Masters Thesis, Univ. Mass. Amherst. [3] Arkani-Hamed, J. (2001), Geophys. Res. Lett., 28, 3409–3412. [4] Hood L.L. and Zakharian A. (2001) JGR, 106, 14601-14619. [5] Zeyen, H., and J. Pous, Geophys. J. Int., 112, 244-256, 1993. [6] Jewell et al. (2004) Trans. Am. Geophys. Union, Fall Mtg, Abstract NG34A-02.