POTENTIAL CORRELATION BETWEEN COMPOSITION AND CRUSTAL MAGNETISM IN TERRA SIRENUM, MARS.

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Introduction: Mars has no dynamo and thus no global magnetic field today. However, scientists learned that a significant magnetic field once existed, at least locally, from the remanent magnetization in Martian meteorite ALH84001 [1]. Evidence for an ancient global magnetic field came when Mars Global Surveyor (MGS) discovered large regions of magnetized crust in Magnetic field experiment/Electron Reflectometer (Mag/ER) data [2]. An internally generated magnetic field, which is now extinct, is required to explain how a steady ambient field persisted for a few hundred million years to produce the observed large-scale distribution of the magnetization [3].

The magnetic field above the Terra Sirenum region is the strongest observed on Mars (Figure 1). At orbital altitudes (~100 km), the MAG/ER investigation measured magnetic fields up to ~1600 nT [2], which are an order of magnitude stronger than intrinsic fields on Mercury and Ganymede and the remanent magnetic anomalies observed on the rest of Mars and Earth's Moon [4,5].

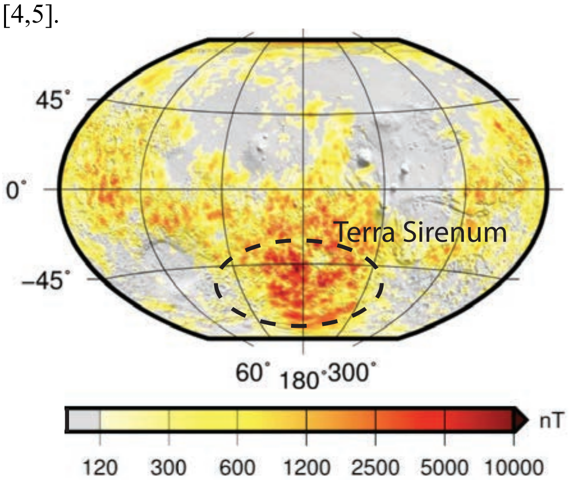

Figure 1. Crustal magnetic field strength on Mars with Terra Sirenum indicated. Modified from Langlais et al. (2019).

Based on the measured magnetic field from orbit, ~600 kA must be accounted for through the product of magnetization of the crust and its volume [6]. Given the associated Curie point isotherm depths and the saturation magnetization of the candidate magnetic phases (magnetite, pyrrhotite, and hematite as end members, plus hemoilmenite, maghemite, and titanomagnetite as intermediate components), the amount of magnetic material required ranges from ~0.4 to 6 weight percent [6]. These proportions are feasible given measurements made on the Martian surface (e.g.,[7]), and the composition of some (albeit few) Martian meteorites [8].

While the basic existence of magnetic anomalies has been explained in theory through modeling and lithologic observations, the relationship between the magnetization and the composition on the surface of Mars has not previously been explored. This study compares various compositional datasets for the Martian crust including elemental abundance, mineralogical indicators, and thermophysical properties with magnetic field measurements to quantify any potential relationships.

Methods and datasets: The Langlais et al. [9] model for crustal magnetism uses all available data on the Martian magnetic field detected from orbit, condensing Mag/ER from the Mars Global Surveyor (MGS) and Mag from MAVEN. The model represents the magnetic field strength and direction at the location of measurement through spherical harmonics and is thus capable of propagating magnetic field values to the Martian surface yielding a surface resolution of ~160 km. The Moore & Bloxham model [10] takes a different approach by determining the minimum amount of surface magnetization ("sparsity") required to represent the MGS Mag/ER results. This model is fundamentally different from Langlais et al. [9] and finds a best-fit sparsity of 85%. We utilize both models as endmembers for what the Martian surface magnetization could be.

For the majority of the datasets we propose to use (all except GRS; Table 1), the dataset is either from a push-broom spectrometer or a spectrometer that produces a discrete observation resulting in a stamp or spectle. Some of the instruments, e.g., CRISM, have a spatial resolution that is far above that of the magnetization model. In these instances, we bin the data provided in the global maps to match a crustal magnetization model with the approximate maximum resolution of the instrument (i.e., 160 km). While using the Moore & Bloxham model we sample our datasets at the discrete points specified by the sparse models (98% and 85%). We will note the associated error and precision of the instruments when comparing datasets to ensure validated results.

We exclude all regions where the crustal magnetization is below 50 nT. This still allows study of >90% of Terra Sirenum. Some of the datasets (e.g., the Vis-NIR spectrometers) are sensitive to thin surface layers and in regions of high dust are not an accurate representation of the underlying bedrock. To account for this, we exclude regions where the Lambert albedo of the surface (from TES) is above 0.25.

Once the datasets have each been sampled at the appropriate resolution, we perform regional calculations on the correlation between magnetization and each measured property. The regions are determined both through a sampling within set radiuses and also through previously mapped geologic units [11]. We use the Student's T-Test slope of a regression line [12] to determine the confidence that the measured property and magnetization are correlated or not.

Table 1: Datasets used

Data Product	Instrument	Ref.	Res.
Crustal Magnetic Field	Mag, ER	[9,10]	160 km/px
Elemental Concentration	GRS	[13,14]	219 km/ 5°/px
Mineral abundances:	TES	[15]	1°/px
Rock Type Abundance	TES	[16]	1°/px
Surface Types 1-4	TES	[17]	1°/px
Surface Class 1-8	multiple	[18]	various
Fe^{3+}, Ferric nanophase	OMEGA	[19]	2 km/px
BD1000	CRISM	[20]	18 m/px
OLINDEX	CRISM	[20]	18 m/px
Thermal Inertia	TES, THEMIS	[21]	100 m/px

Results: We generated scatter plots of the magnetization model after down-sampling it to the resolution of GRS Fe, Si, and THEMIS thermal inertia. We observe that the majority of the planet is uncorrelated, however a population of points exists where a positive (Fe, thermal inertia) or negative (Si) correlation exists (Figure 2). When the points that are correlated are selected, we observed that they cluster in discrete regions, primarily in Terra Sirenum. The Pearson correlation coefficients are shown in Figure 2.

We did not observe correlations using geologic units either by age or by individual units. However, the geologic units were typically too small to contain a statistically robust number of data points.

Discussion: The correlations between iron, silica, and thermal inertia and crustal magnetization may indicate there is mineralogical enhancement of the magnetization in this region. One possible scenario to explain this observation is an iron-rich igneous intrusion in the shallow subsurface of Terra Sirenum.

It is possible that in some Martian crustal regions the rocks may be exceptionally good magnetic recorders (due to iron content or particular magnetic phase) and therefore the magnetization may be locally enhanced.

Future Work: We will modify our technique after [14], which specifically deals with studies combining different data types and resolutions.

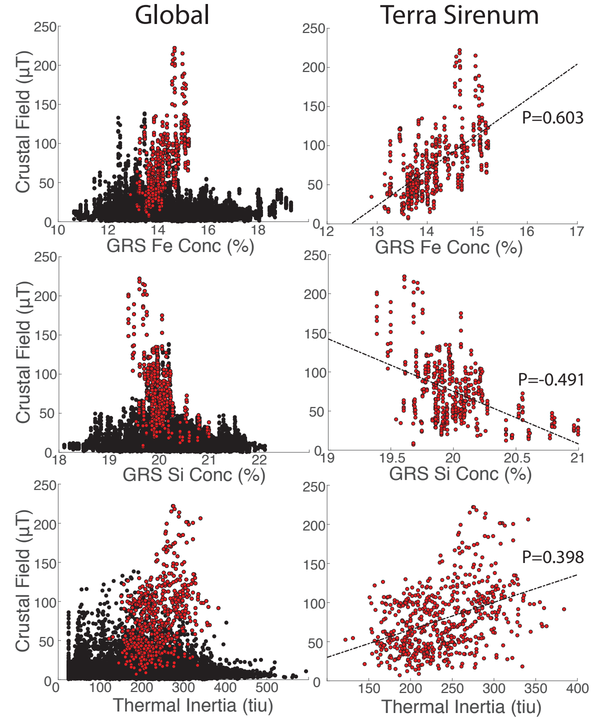

Figure 2. Scatter plots of Fe (top), Si (middle), and TI (bottom) against crustal magnetism. When Terra Sirenum is selected (red), some correlations appear (right).

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