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# Modeling gravity and magnetic field anomalies at Tyrrhenus Mons and Syrtis Major, Mars: Evidence for polar wander, excursions, and the death of the dynamo

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## Abstract

We model a collection of correlated gravity and magnetic anomalies distributed throughout the areas surrounding Tyrrhenus Mons and Syrtis Major, Mars. Our work differs from past studies in that we model a large number of magnetic anomalies, including relatively small anomalies and those that are contiguous with other anomalies. We select only anomalies that also have gravity signatures, which we use as inputs to the magnetic analysis to reduce the non-uniqueness in the horizontal position of the magnetic source. In contrast, most other studies have focused on the largest, most isolated magnetic anomalies. Our motivation is to attempt to constrain the continuous history of the magnetic field as recorded in the crust and to do so in a statistically robust manner.

## 1. Introduction

Understanding the magnetic signature of volcanoes can provide insight into the timing of the paleodynamo, the location of the magnetic paleopole and the overall evolution of the planet. Studies of the magnetic signature of volcanoes on Mars [1-3] support the view that the dynamo was active after the formation of the major impact basins (4.0 Ga) [4,5] and call into question the view that the Martian dynamo ceased activity before 4.0 Ga [6].

## 2. Methods

The isostatic anomaly field is inverted to determine the depths and thicknesses of the layers that fit the gravity data best. The gravity data are inverted first since the observed gravity anomalies do not have the same horizontal ambiguity that the unknown paleopole introduces into the position of the magnetic anomalies, thereby better constraining the anomaly location. The magnetic field data (see Figure 1) are inverted over an array of paleopole positions in order to find the paleopole position of each source that fits the data best. The root mean square (rms) difference between the magnetic observation and predicted field (at each pole location) is determined for each inversion, and is given by $\epsilon = \sum_{i=1}^{n} \frac{1}{n}|B_i - F_i|$, where $i$ is the index, $n$ is number of magnetic field observations, $B_i$ is one of the components of the observed magnetic field, and $F_i$ is one of the components of the predicted magnetic field. We use the following equation to determine a range of paleopoles that fit the data best: $\epsilon_{bf} = 0.1 * (\epsilon_{max} - \epsilon_{min})$. Geologic analysis of the regions around the studied volcanoes provides a temporal framework for interpreting the dynamo history from the derived paleopoles. The magnetic sources are expected to reside at depth in the crust, so surface ages may not date the processes which created the magnetic anomalies. However, we adopt the assumption that the age of the magnetization is the same as the surface age as a simplifying assumption in the interpretation.

## 3. Results

We find two populations of paleomagnetic poles generally fit the data: paleopoles that cluster near the equator and near the geographic poles (see Figure 2). Magnetic sources that favor low to middle latitude paleopoles are generally located below or immediately adjacent to Noachian surface units and sources that favor middle to high latitude paleopoles are located below or immediately adjacent to Hesperian features. The correlation of magnetic sources located below Noachian (Hesperian) aged crust with paleopoles distributions near the equator (geographic poles) supports the hypothesis that true polar wander occurred on Mars roughly consistent with the polar wander path near the 330° E meridian determined by Perron et al. [7]. We also interpret the results as suggesting that the dynamo underwent an excursion during the Hesperian. Figure 2 shows that the paleopole distributions associated with Hesperian age crust cluster in the NW/SE and NE/SW quadrants as well as the geographic poles. This clustering of pale-

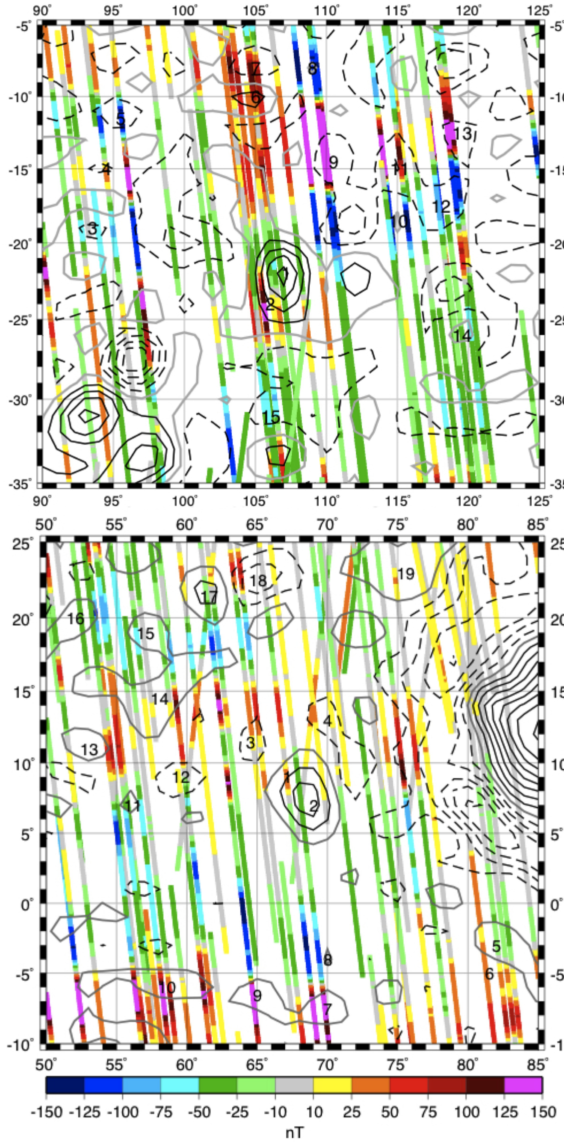


Figure 1: Map of the radial component of AB/SPO magnetic field data for Tyrrhenus Mons (top) and Syrtis Major (bottom). The density is contoured at intervals of 50 kg m$^{-3}$, solid black lines represent positive anomalies, dashed black lines represent negative anomalies and the solid gray line is the zero line. The numbers represent the magnetic sources modeled here.

opole locations implies that the dynamo traveled over the rotation pole as it traveled from the NE/SW quadrant to the NW/SE quadrant during an excursion.

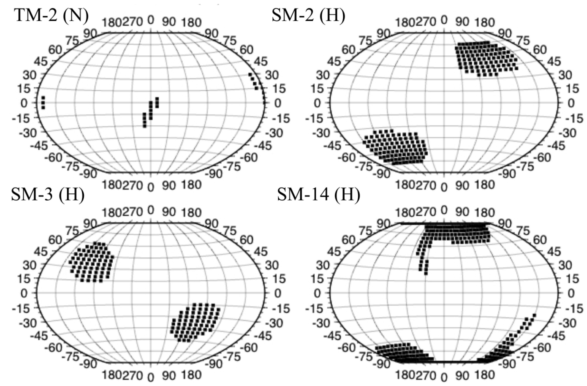


Figure 2: Best fitting paleopoles $\epsilon_{bf}$ and corresponding antipodes determined by the magnetic inversions. The numbers to the upper left indicate the anomaly modeled, TM/SM indicates the anomaly is in the Tyrrhenus Mons/Syrtis Major study region, and (H) or (N) indicate that the anomaly is below Hesperian or Noachian age crust.

## 4. Summary and Conclusions

Analysis of gravity and magnetic anomalies in the regions surrounding Tyrrhenus Mons and Syrtis Major provide insight into the activity and timing of the dynamo from the late Noachian through the Hesperian, the period when they were geologically active. Evidence of magnetization of Tyrrhenus Mons, Nili Patera, Meroe Patera, and reversals of the field are presented. The paleopole distributions determined for the magnetic sources below Hesperian crust show that the dynamo likely underwent reversals and/or excursions during the Hesperian when geologic data show that these areas were volcanically active. Since the Tharsis volcanic province and Elysium, which were active in the Amazonian, are not significantly magnetized this demonstrates that the dynamo likely ceased activity sometime in the late Hesperian to early Amazonian.

## References

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