CONSTRAINING IMPACT-INDUCED DEMAGNETIZATION IN MARTIAN CRUST WITH MAVEN SPHERICAL HARMONICS AND CURIE DEPTHS.

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Introduction: A planet's global magnetic field, or dynamo, is closely tied to the structure and evolution of its core, mantle, lithosphere, surface, and atmosphere. Many spacecraft have confirmed the absence of a presently-active strong core field on Mars, but analyses of fragmented Martian meteorites found on Earth show the Martian dynamo was Earth-like about 4 billion years ago. Along with other evidence, this suggests Mars once had a rich atmosphere and large bodies of surface water which might have hosted life, which were lost due to the demise of the dynamo.

The precise timing of the dynamo's demise is still debated, with estimates ranging from 4.2-bya to 3.6-bya. Large meteor impacts offer a unique window into the dynamo's earliest history as they involve the sudden heating of iron-bearing minerals past their Curie point, introducing a thermoremanent magnetization which reflects the background magnetic field present at the time of cooling which can be preserved for billions of years.

Discrepancies: Previous work with MGS data suggest relatively deep depth of magnetization in the crust and tight range for the dynamo's demise. However newer work applying forward-modeling techniques to high-resolution MAVEN data show compelling examples of shallow magnetization depths and significantly expand the uncertainty for the dynamo's cessation timing.

MAVEN Analysis: Here, we analyze newly acquired high-resolution magnetometer data from the NASA MAVEN orbiter collected at nighttime and altitudes less than 200 km in/around craters between 150-1,000 km diameter (n=855) [3]. The lack of widespread demagnetization signatures in larger craters (>300 km diameter) corroborate prior findings of deep depth of magnetization, but we find a few unexplained and notable examples of extremely strong demagnetization in smaller craters such as Henry crater (167 km diameter).

First, we use crater density dating techniques to corroborate newer dynamo cessation uncertainties, with a definite demise at 3.6-bya with the formation of Henry crater. Next, we construct local spherical harmonic models of the magnetic field with altitude-cognizant scalar Slepian functions in order to discriminate between crustal versus core magnetic field sources based on spherical harmonic degree.

To begin to associate shallow versus deep origins of magnetic field in the crust with certain spherical harmonic degrees, we begin by comparing craters in sites with known shallow magnetization (for example, Lucus Planum with pyroclastic flows and Henry crater in Arabia Terra) with sites of known deep magnetization (most larger craters).

Constraining the Deep-Crust with Curie Depths: Given the position and time of formation of a crater, we can calculate the heating due to radiogenic heat producing elements (U235, U238, Th232, and K40) in the crust using crustal thickness maps and GRS element concentration maps [4]. This gives us a temperature versus depth profile around the time of impact (excluding heating due to the impact itself), from which we can extract curie depths for the primary iron-bearing minerals in Martian crust. Past this depth, we assume no magnetization can exist in the lithosphere and mantle, which allows us to begin to associate spherical harmonic degrees in our previous model with specific deep-crust depths.

Constraining the Upper-Crust with Impact Demagnetization: We then turn our attention to demagnetization effects of the impact itself. For a given crater diameter and crustal excavation volume, we calculate impact energy, shock pressure produced, and depth of demagnetization in the crust using modified Holsapple-Schmidt-Housen method. Assuming craters that show clear demagnetization are primarily affected by these two processes (Curie depths due to HPEs and impact-induced demagnetization), we now associate spherical harmonic degrees in our previous model with specific shallow-crust depths.

Conclusions: Global analyses of MGS/MAVEN data have provided conflicting results on dynamo cessation estimates and magnetization depths. Our attempts to merge analytical techniques and spectral analysis models across all crater on Mars gives us a better understanding of magnetization anomalies and acute variations in crustal thermal conductivity, basal heat flow, and magnetic susceptibility. Furthermore, we draw attention to craters that remain unexplained by this work as possible sites for unique and/or hydrothermal processes.

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