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Induction Vector Analysis of InSight Magnetic Data to Constrain Martian Mantle Structure

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Recent discoveries have challenged the long-held view that Mars has been geologically dormant since the Amazonian period. While Mars experienced intense volcanism and tectonics before and during the Hesperian period (~3.5 – 3.2 Ga), the Amazonian period (<3.2 Ga) has been characterized by relative inactivity with only limited volcanism. However, Horvath et al. (2021) identified young volcanic deposits in the Cerberus Fossae region of Elysium Planitia, suggesting eruptions occurred as recently as 210 to 50 ka. Broquet and Andrews-Hanna (2022) further demonstrated that such recent volcanic activity cannot be explained by conventional passive mechanisms, and instead proposed a geophysical low-density anomaly model of an active mantle plume beneath Elysium Planitia, supported by integrated analyses of gravity and topography. Nevertheless, substantial uncertainty remains regarding the detailed properties of the plume head, including its diameter (3,600 – 4,000 km), depth (25 – 200 km), and thickness (200 – 500 km). Additional constraints on the plume head properties are necessary and important for advancing our understanding of Martian interior dynamics.

To further constrain the shape and properties of the mantle plume in this region, we analyzed nightside magnetic field data from NASA's InSight lander, located on the inner side of the western boundary of the proposed plume head. We observed a systematic anti-clockwise rotation in the real part of induction vectors—from southeast to northeast—across periods ranging from 500 to 10,000 seconds. These vectors, expressed as (– Tx, – Ty) from the relationship Bz = Tx· Bx + Ty· By, point toward regions of anomalously low resistivity. Therefore, this result suggests the presence of a localized conductive anomaly several hundred kilometers beneath the eastern side of the InSight landing site, consistent with the influence of the proposed mantle plume.

To quantitatively interpret the result above, we conducted numerical simulations using the edge-based finite element method (Minami et al., 2018), incorporating Martian real topographic data. We tested a range of low-resistivity anomaly models with horizontally rectangular geometries and uniform thicknesses to evaluate their consistency with the observed induction vector behavior. Preliminary results indicate that the anomaly's western edge lies east of the InSight landing site, with its northern boundary extending further north and its southern edge located just a few hundred kilometers to the south. These findings support the mantle plume hypothesis and suggest that its structure may be more complex than a simple cylindrical form. Our study demonstrates the effectiveness of magnetic sounding techniques in revealing subsurface mantle structures and constraining the thermal and structural evolution of Mars.