ARE MAGNETIC ANOMALIES ASSOCIATED WITH MARTIAN VOLCANOES? AN ANALYSIS OF LOW-ALTITUDE MGS MAGNETOMETER DATA.
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Introduction: Magnetic anomalies associated with volcanic constructs on Mars can have important implications for the duration and history of the former martian core dynamo (e.g., [1,2]). In addition, they can potentially be applied to constrain the location and volume of magma intruded beneath a visible topographic construct (e.g., [2]). On a broader scale, the near absence of magnetic anomalies over the Elysium and Tharsis volcanic provinces has been interpreted to constrain the thermal history and evolution of the Tharsis region [3].

Possible magnetic signatures associated with a number of individual extinct martian volcanoes have been reported. These include positive anomalies associated with Apollinaris Patera (9°S, 174°E) [1] and Hadriaca Patera (31°S, 93°E) [4] as well as a demagnetization signature associated with Tyrrhena Patera (21°S, 107°E) [2]. In the case of Apollinaris Patera, whose active period is estimated to have ended ~ 3.7 Gyr ago [5], Mars Global Surveyor (MGS) magnetometer data acquired at all available altitudes were applied to infer the vector magnetization distribution using equivalent dipole source representations [1]. Model-estimated paleopole locations near the present rotational pole were obtained. These locations contrast with analyses of strong crustal field anomalies elsewhere on Mars, which yield preferred pole positions in the N.H. centered near 35°N, 210°E [6,7,8]. The preferred interpretation was that the magnetization was acquired near the end of the dynamo's life and after most polar wander had been completed [1].

In the cases of Hadriaca Patera and Tyrrhena Patera, magnetization signatures have been reported based primarily on MGS electron reflectometer (ER) data with an effective altitude of ~ 185 km [2,4]. Hadriaca Patera is younger than the Hellas basin and has earliest crater-count ages of ~ 3.7 – 3.9 Gyr [9]. Tyrrhena Patera has earliest ages of ~ 4.0 Gyr and possible resurfacing events occurred at ~ 3.5 and 1.6 Gyr ago [10].

In this paper, we report further analysis of low-altitude MGS magnetometer data from the aerobraking phase of the mission obtained in the near vicinities of these three volcanic constructs. The objectives are (a) to test the existence of detectable magnetic field signatures; (b) to apply forward modeling of positive field anomalies to estimate the horizontal dimensions and magnetization characteristics (e.g., direction) of the source; and (c) to evaluate further the implications of the results for the history of the former core dynamo.

Method of Data Analysis: We consider all available dayside and nightside aerobraking phase data acquired at altitudes of less than 210 km over Apollinaris Patera, Tyrrhena Patera, and Hadriaca Patera. To test for the existence of crustal magnetic field signatures, we compare data acquired along spatially adjacent orbit tracks at similar altitudes. Consistent signatures detected on adjacent passes identify permanent short-wavelength crustal fields and help to distinguish these fields from transient fields of ionospheric origin. Iterative forward modeling of magnetic anomalies to infer source properties is carried out using procedures described in ref. 7.

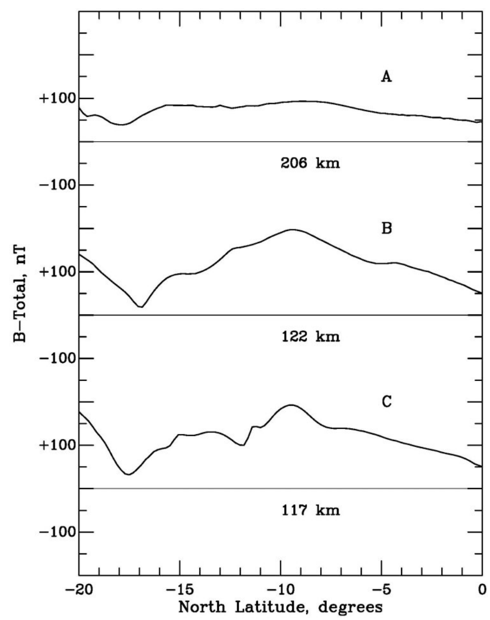

Figure 1

Results for Apollinaris Patera: Three orbit tracks that pass nearest to the Apollinaris Patera construct at altitudes of 206 km, 122 km, and 117 km were identified. Figure 1 compares the field magnitude measured along each of these tracks. For tracks B and C, which are at the lowest altitudes and pass closest to the construct and to one another, a repeatable broad maximum peaking at ~ 9.5°S is evident. Examinations of the three vector component plots confirm that field signatures are repeated on adjacent passes. Only the east component for track C contains significant transient field noise. The data therefore confirm the existence of an anomaly associated with this construct. Forward modeling of the anomaly using a single circular disk source yields a direction of magnetization and N.H. paleopole location (~ 64°N, 59°E) that is consistent with that obtained in ref. 1 for a single dipole source. Requiring that the source be centered exactly on the caldera yields a nearly southward magnetization direction and a N.H. paleopole near the present north pole. In general, results are therefore very consistent with those of ref. 1.

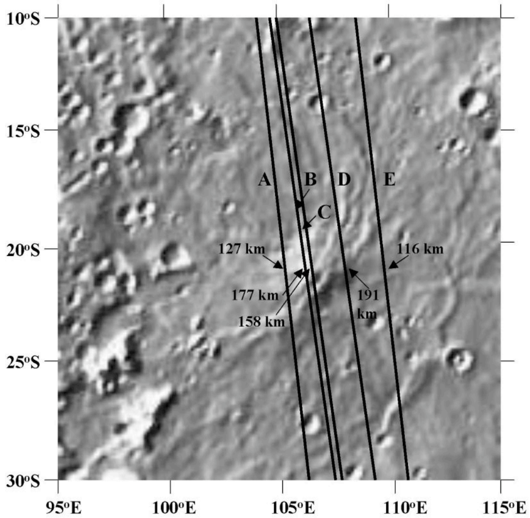

Figure 2

Figure 2 shows a series of orbit tracks near the Tyrrhena Patera construct. The altitudes above the surface at closest approach are also indicated. In particular, two tracks pass directly over the construct at minimum altitudes of 177 and 158 km, respectively. Figure 3 plots the field magnitude along each of the first 4 tracks nearest to the construct (labeled A, B, C, and D). No field signature (positive or negative) is evident at the location of the construct (21°S). One apparent minimum occurs along track A at this location with an amplitude of ~ 40 nT. Accounting for the altitude difference between track A and tracks B and C, one would expect a similar minimum with an amplitude of at least ~ 20 nT along these tracks but no minimum is present. The field variations along tracks B and C are, however, very consistent with one another when altitude differences are accounted for. Examinations of the three vector field component plots confirm that no demagnetization signature is detectable near Tyrrhena Patera.

A similar analysis of data from low-altitude passes near Hadriaca Patera also yields no evidence for a detectable positive anomaly or demagnetization signature associated with this volcanic construct.

Concluding Remarks: The available low-altitude MGS magnetometer data obtained over the three volcanoes studied here yield evidence for a magnetic signature only in the case of Apollinaris Patera. Preliminary modeling of this positive anomaly yields directions of magnetization and paleomagnetic pole locations that are consistent with those estimated in ref. 1. Results therefore generally support the conclusion of ref. 1 that the martian dynamo may have persisted to (or been regenerated) as late as 3.7 Gyr when this volcano is believed to have formed. The paleopole location indicates that major polar wander was complete at that time. The absence of detectable magnetization signatures associated with the other two constructs considered here imply that the available orbital data cannot be applied to constrain the location and volume of intruded magma beneath these volcanoes. Future lower-altitude data over martian volcanic and other magmatic features would be valuable.

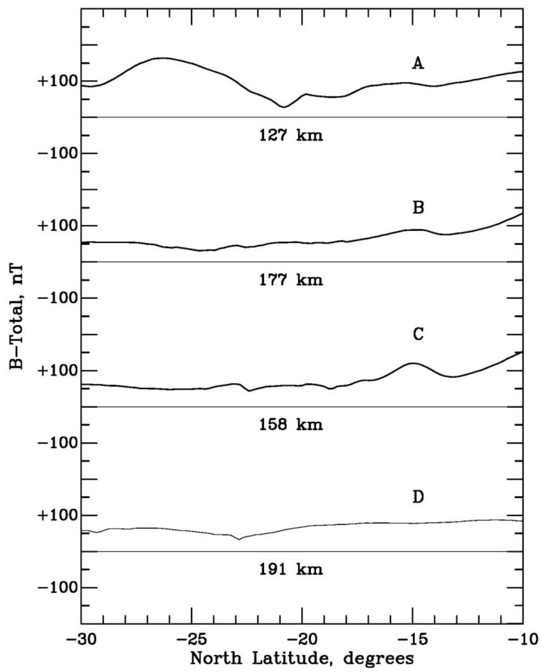

Figure 3

References: [1] Langlais, B. & M. Purucker (2007) *Planet. Space Sci.,, 55,* 270-279. [2] Lillis, R. J. et al. (2008) *Icarus,* in press. [3] Johnson, C. L. & R. J. Phillips (2005) *Earth Planet. Sci. Lett., 230,* 241-254. [4] Lillis, R. J. et al. (2006) *Geophys. Res. Lett., 33*, L03202, doi:10.1029/2005GL024905. [5] Werner, S. C. (2005), Ph. D. Thesis, Freie Universität Berlin. [6] Arkani-Hamed, J. & D. Boutin (2004) *J. Geophys. Res., 109*, doi:10.1029/2003JE002229, E03011. [7] Hood, L. L. et al. (2005) *Icarus, 177*, 144-173. [8] Hood, L. L. et al. (2007) *Icarus, 191*, 113-131. [9] Williams, D. A. et al. (2005*)* In: *Lunar Planet. Sci. XXXVI.,* Abstract #*147*. [10] Williams, D. A. et al. (2006) In *Lunar Planet. Sci. XXXVII,* Abstract #1306.