THE GLOBAL DISTRIBUTION OF MARTIAN CRUSTAL MAGNETIC FIELDS: INTERPRETATION AND IMPLICATIONS. L. L. Hood, N. C. Richmond, *Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721-0092, USA, (lon@lpl.arizona.edu)*, J. Halekas, *Space Science Laboratory, University of California, Berkeley, CA 94720, USA.*

Introduction. To date, comparisons of the global distribution of martian crustal field anomalies with surface geology (Figure 1) have revealed several basic characteristics (e.g., Acuña et al. (1,2)). First, the strongest anomalies occur over the older southern highland terrane and are relatively weak over the younger, resurfaced northern lowlands. Second, a zone of especially strong anomalies occurs in the southern hemisphere over Noachian terrane centered approximately on the 180° longitude meridian. Third, anomalies are especially weak in the near vicinities of the large southern hemisphere impact basins, Hellas and Argyre. In this paper, we discuss the interpretation and implications of these characteristics for the most probable geologic sources of the crustal anomalies and the relative chronology of the former Mars core dynamo magnetic field.

Interpretation. The first characteristic implies that the martian dynamo must have been operative during the earliest (Noachian) times (2). However, as discussed in ref. 3, the time of cessation of the core dynamo, i.e. whether it continued to be operative during early Hesperian times, is not yet known with accuracy. It is possible, for example, that the creation of highly susceptible sources of magnetization (e.g., hydrothermally altered igneous materials) was limited to the first several hundred Myr. In this case, strong magnetic anomalies would not have been produced at later times even if the core dynamo had continued to operate. If no highly susceptible materials were produced as a result of the Hellas and Argyre impacts, then no detectable magnetic anomalies would be present even if the underlying crust had cooled in the presence of a steady magnetic field.

The second and third characteristics listed above (the concentration of anomalies in the Southern Hemisphere near the 180° longitude meridian and the lack of significant anomalies in the near vicinities of Hellas and Argyre) are most simply explained by a combination of two assumptions: First, shock effects associated with these basin-forming impacts demagnetized a substantial portion of the previously inhomogeneously magnetized Noachian crust. Second, the resurfacing event that resulted in the formation of the northern lowlands altered the crust in such a way as to have weakened or eliminated most magnetic anomalies in this region.

Demagnetization signatures of impact craters with diameters ranging from 50 to 400 km are clearly observed on the Moon (4). These signatures extend to $\sim$ 2-4 crater radii, suggesting shock as the demagnetization process rather than thermal effects. In addition, major lunar basins (e.g., Imbrium, Orientale, Serenitatis, and Crisium) are characterized by relatively weak surface fields while fields near the antipodes of these basins are especially large (5,6). Experimental evidence shows that shock pressures of $\sim$ 10 kbar or less can remove magnetic remanence while smaller pressures of a few kbar can reduce it (7,8,9). Magnetic susceptibility can also be reduced by shock effects (10). Using pressure attenuation curves and

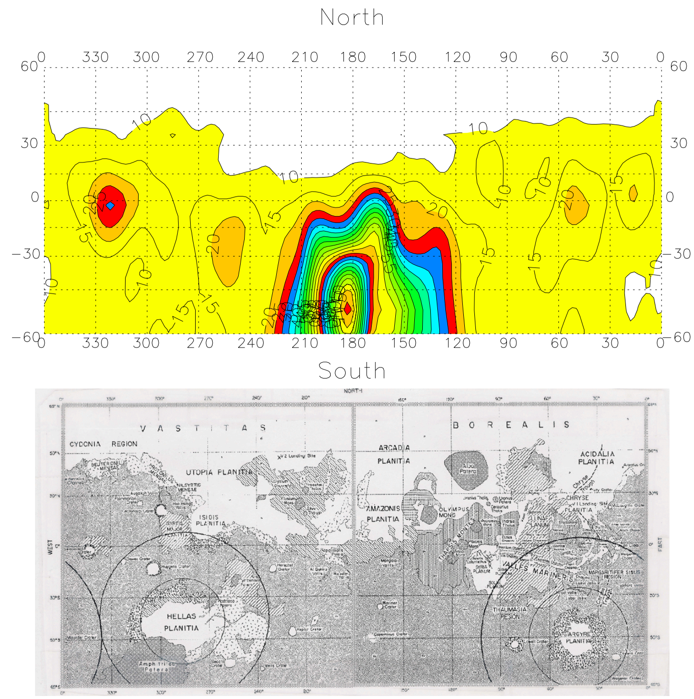

Figure 1: Comparison of the crustal field magnitude (in nT) at the mapping altitude (370 - 438 km) with a geologic map of Mars (after Scott and Carr [1978; ref. 16). The contour interval on the field map is 5 nT. The circles indicate probable zones of demagnetization associated with the Hellas and Argyre impacts (see the text).

approximate scaling laws (11,12), it can be estimated that an impact that would produce a large lunar crater or basin could produce shock pressures of 10 kbar at a distance up to several crater or basin radii. By extension, it may be expected that large basin-forming impacts on Mars would also produce such shock pressures, thereby demagnetizing much of the crust out to 1.5-2 basin radii. Reduced magnetization may continue out to as much as 4 basin radii. The Hellas basin is centered near 42°S, 65°E and has a diameter of approximately 1500 km while the Argyre basin is near 50°S, 45°E and has a total diameter, including all associated geologic units, exceeding that of Hellas. As shown in Figure 1b, if the demagnetization radius is assumed to be $\sim$ 2 basin radii (inner circles) and the reduced magnetization radius is assumed to be $\sim$ 4 basin radii (outer circles), then these two basin-forming impacts can explain a majority of the relative weakness of the southern highland anomalies in the longitude sector centered on 0°.

Although the origin of the northern lowlands is not well understood, recent interpretations of MGS topography and gravity data have indicated that the northern hemisphere was a zone of high heat flow early in martian history (13). The same data indicate that martian crustal thickness does not correlate with the dichotomy boundary as expected if one or more giant impacts were responsible for the formation of the northern lowlands. These results tend to favor the main alternative model, which hypothesizes that a single mantle convection cell eroded the lower crust in what is now the northern zone of Mars (14). According to this model, the lowland plains resulted from foundering of the upper crust and later lava flooding and erosion (see also ref. 15). A further speculation is that this single mantle cell was initiated by the antipodal effects of the Hellas and/or Argyre impacts. In any case, the anomalous heat flow and lower crustal erosion predicted by this model would be more than sufficient to explain the weakening of pre-existing crustal magnetization in this zone.

Conclusions. The stronger anomalies near 180° in the Southern Hemisphere may represent a surviving remnant of the early Noachian crust that escaped both the shock demagnetization effects of later basin-forming impacts in this hemisphere and the thermal demagnetization effects of the northern resurfacing event. Confirmation of the existence of a core dynamo during the early Noachian can be obtained by estimating bulk directions of magnetization for isolated sources, corresponding paleomagnetic pole positions, and searching for evidence of clustered pole positions (3,17). An accurate determination of the time of cessation of the hypothesized core dynamo will require a better understanding of the origin of strongly magnetized anomaly sources on Mars. If no strongly magnetic anomaly sources formed after the early Noachian, a final determination of the end of the dynamo era on Mars may not be possible until the return of dated samples.

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WHY ARE SOME MARTIAN TERRANES STRONGLY MAGNETIC AND SOME NON-MAGNETIC?

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Introduction: Strongly magnetic crust at Mars is restricted to a broad sinuous region (Figure 1), extending southward from the crustal dichotomy for several thousand km. There are two large non-magnetic terranes, one centered at Noachis Terra in the south (Figure 2) and one centered on the northern lowlands. Old, large impact craters such as Hellas, Isidis, and Argyre (Figures 1 and 2) show up as non-magnetic circular features, and the magnetic boundaries correspond to the outermost ring. The southern non-magnetic terrane is enigmatic because the age of the rocks at the surface is little different from those in the adjacent, strongly magnetic region. And the boundaries of the non-magnetic terrane in the south do not correspond to any obvious geologic or structural feature. Using a newly developed magnetic map that retains only features common to all three global magnetic maps of Mars [1,2,3], the nature of the boundary between the magnetic and non-magnetic terranes is examined, especially in the more enigmatic southern region.

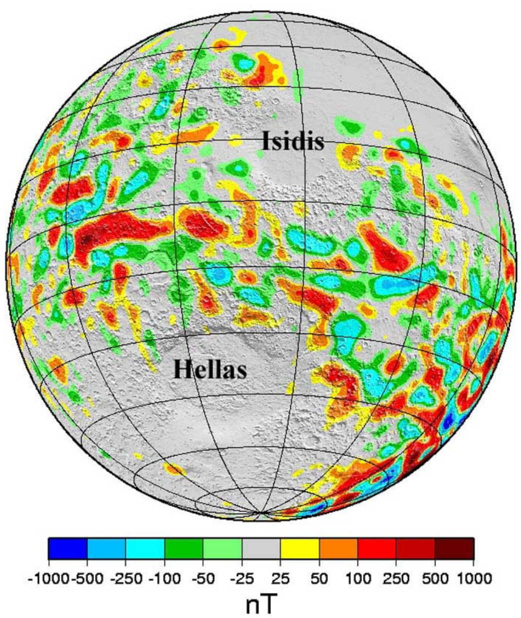

Figure 1. The radial component of the magnetic field at 120 km altitude in an orthographic projection centered at 80 degrees E longitude, 15 degrees S latitude.

Models and Techniques: Three global models, two using a spherical harmonic basis [2,3] and one using an equivalent source basis [1] are now available to describe the Martian magnetic field of internal origin. The models use either radial component data only [1], so as to minimize external field contributions, or all three components [2,3]. The spherical harmonic models are of degree 90 [3] and degree 60 [2]. The dipoles in the equivalent source basis have an average spacing of 111 km. The maps (Figures 1 and 2) have been combined by simple averaging in the spatial domain but will soon be combined in the spherical harmonic domain [4].

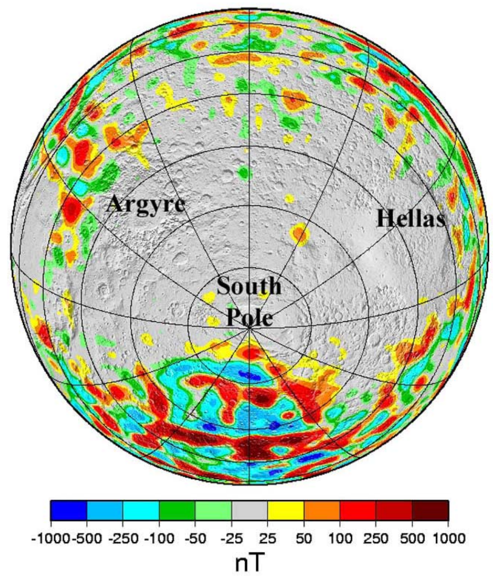

Figure 2. The radial component of the magnetic field at 120 km altitude in an orthographic projection centered at 0 degrees longitude, 70 degrees S latitude.

Results: The boundaries of the southern non-magnetic region can be characterized as gradational between longitudes 0-120 and 240-360 E longitude. In the intervening region the boundary is sharp, such as might characterize a fault block. Parts of the southern non-magnetic region are associated with the Argyre and Hellas impact basins, but one or more additional large impacts or thermal events would be necessary to produce such a large non-magnetic region.

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