# BASIN MAGNETIC SIGNATURES AND CRATER RETENTION AGES: EVIDENCE FOR A RAPID SHUTDOWN OF THE MARTIAN DYNAMO

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**Introduction**: Present-day Mars does not possess an active core dynamo and associated global magnetic field. However, the discovery of intensely magnetized crust in Mars' Southern hemisphere [1] implies that a Martian dynamo has existed in the past [2,3]. Resolving the history of the Martian core dynamo is important for understanding the evolution of the planet's interior. Moreover, because the global magnetic field provided by an active dynamo can shield the atmosphere from erosion by the solar wind[4], it may have influenced past Martian climate.

**Electron Reflection (ER) Magnetometry** is based on the magnetic mirror effect, that is, the reflection of charged particles from regions of increased magnetic field strength. By comparing the pitch angle distribution of electrons moving toward the planetary surface with the distribution of those electrons reflected from the surface, the increase in the magnetic field strength can be determined. Here ~2.9 million measurements of 90-400 eV electrons over 7 years have been combined to produce a map of the field magnitude $|\boldsymbol{B}|$, due to *crustal* sources only, at 195 km altitude (the mean altitude at which the electrons' scattering depth reaches unity) It has an intrinsic resolution of ~200 km and a global detection threshold for unambiguously crustal fields of ~3 nT [5]. It is shown in figure 1, overlaid on MOLA topography and with all craters >200 km shown with white circles [6].

**Magnetic Signatures of Basins:** The heating and shock from a large meteorite impact can demagnetize the entire depth of crust over an area comparable to the final size of the impact basin [7, 8]. As the central melt pool solidifies, some fraction will crystallize into magnetic minerals (what fraction depends on the oxidation state of the target material). As the mineral cools below its Curie point it acquires a thermoremanent magnetization (TRM) aligned with the direction of, and with a magnitude positively dependent on the strength of the local ambient magnetic field. This magnetization (or lack thereof) is preserved in the crust and can be detected by spacecraft measurements.

**A rough magnetic history** can be constructed if we compare the crater retention age (CRA) N(200) (i.e. the number of craters >200 km per $10^6$ km$^2$, overlaid on the terrain in question) of nine of the oldest large impact basins with the crustal magnetic field magnitude at 195 km inside 0.4, 0.5 and 0.6 basin radii, as shown in figure 2. We make the assumptions that magnetic field is a good proxy for magnetization (a reasonable one for basins 5 or more times larger than our observation altitude) and that remanent coercivity and magnetic coherence scale do not vary globally by factors of more than several, so that magnetic field measured above the basins corresponds approximately to the strength of the magnetizing field at the time of shock remanent or thermoremanent magnetization.

**Rapid end to the Martian Dynamo?** The result is a magnetic timeline with a clear separation between a dynamo era and a post-dynamo era. The Daedalia, Ares and Ladon basins fall well within the dynamo era as they have the largest CRAs and appear to be magnetized. Consistently, the Hellas, Argyre and Isidis basins fall within the post-dynamo era as they have the lowest CRAs and appear to be largely demagnetized. The epoch during which the dynamo 'died' seems to span the formation of the geologically contemporaneous (i.e. they have indistinguishable CRAs) northern lowland basins Utopia, Acidalia and Chryse, which have quite different magnetic signatures, as revealed by the sensitivity of the ER map. Chryse seems as magnetic as Ladon, Acidalia is significantly weaker and Utopia appears the least magnetic of all (simple modeling shows a likely maximum magnetization of 0.03 A/m). Clearly, assigning absolute ages is fraught with errors relating to the absolute calibration of the Martian cratering record [9], but if we convert these CRAs to Hartmann-Neukum model ages, the magnetic signatures of these three ancient lowland basins imply that the global magnetic field went from being significant to almost nonexistent during the geologically short time, <50 million years, between these three impacts, ~4.13 Gyr ago.

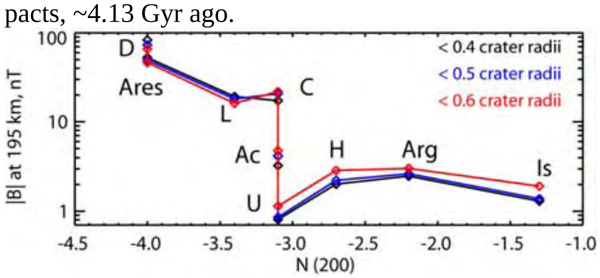


**Figure 2: Martian magnetic timeline. N(200) errors do not overlap except where plotted as identical.**

**References:** [1] M.H. Acuna et al., *Science* (1998), [2] M.H. Acuna et al., *JGR* (2001), [3] J.E.P Con-nerney, *Science* (1999), [4] K.S. Hutchins et al, *JGR* (1997), [5] R.J.Lillis et al, *GRL* (2004), [6] H.V. Frey et al, *GRL* (2002), [7] L.L. Hood et al, *GRL* (2003), [8] J.S. Halekas et al, *JGR* (2001), [9] W.K. Hartmann & G. Neukum, *Space Science Reviews*, (2001)

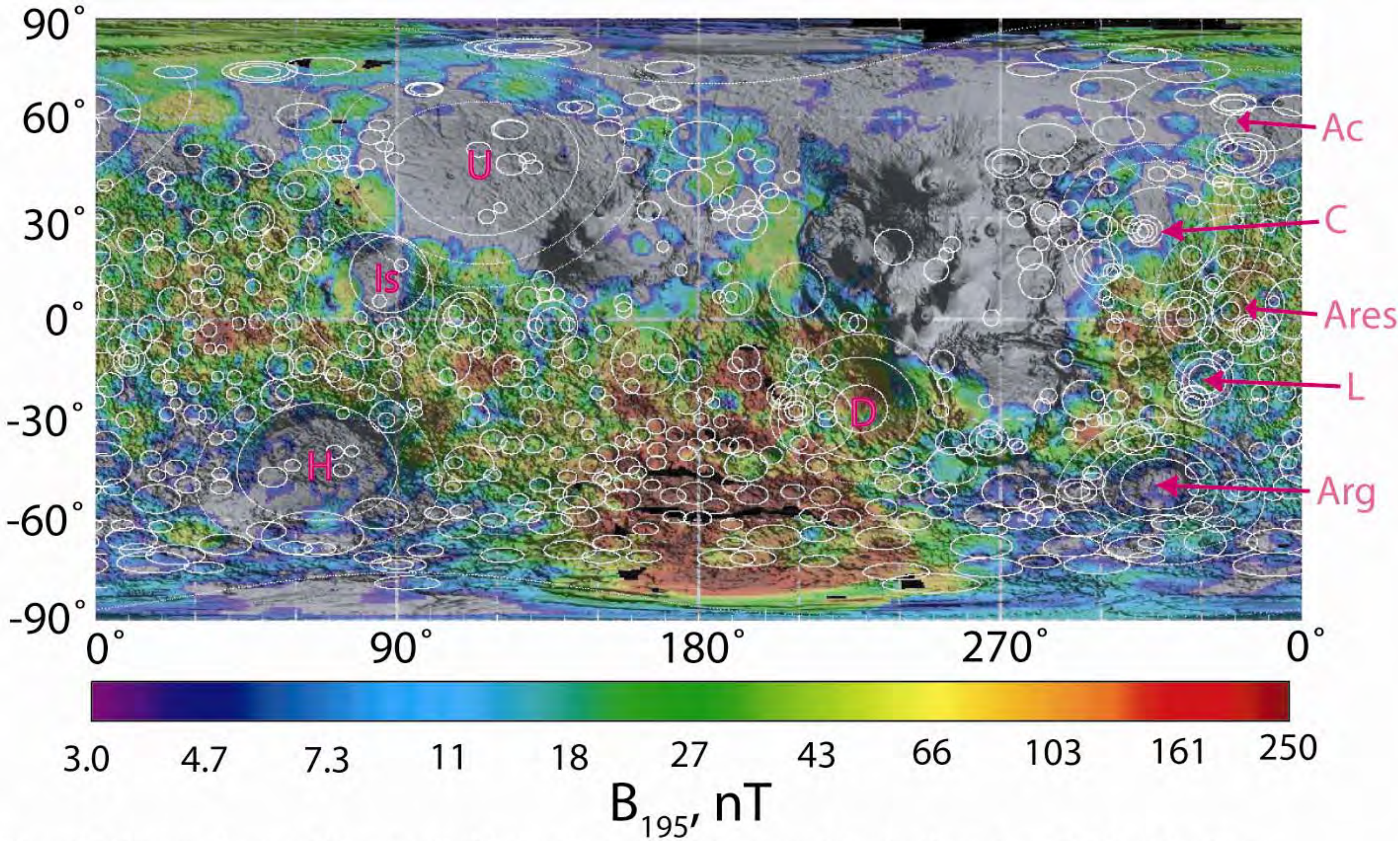


**Figure 1:** ER magnetic map of Mars in cylindrical projection, showing all quasicircular depressions >200 km taken from Frey [2006]. The logarithmic color scale represents the crustal magnetic field magnitude 195 km above the Martian datum and is overlaid on shaded MOLA topography [Smith et al., 2001]. The lower limit of the color scale is the threshold for unambiguously crustal features while the scale saturates at its upper end. Black represents sectors with fewer than 5 measurements within a 100 km radius. the nine basins denoted in pink are, from left to right: Hellas, Isidis, Utopia, Daedalia, Chryse, Argyre, Ladon, Ares and Acidalia.