MERCURY'S INTERNAL MAGNETIC FIELD FROM MESSENGER. Michael E. Purucker[1], Catherine L. Johnson[2,3], Brian J. Anderson[4], Haje Korth[4], Hideharu Uno[2], David T. Blewett[4], Terence J. Sabaka[1], Sean C. Solomon[5], and James W. Head[6], Raytheon at Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, Greenbelt, MD 20771, michael.e.purucker@nasa.gov; [2]Department of Earth and Ocean Sciences, University of British Columbia, 6339 Stores Road, Vancouver, BC, V6T 1Z4, Canada; [3]Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093-0225; [4]The Johns Hopkins University Applied Physics Laboratory, 11100 John Hopkins Road, Laurel, MD 20723-6009; [5]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, N.W., Washington, DC 20015-1305; [6]Dept of Geological Sciences, Brown University, Providence, RI 02912

Introduction: The internal magnetic field of Mercury, first observed by Mariner 10 during two flybys in 1974 and 1975, was the target of two flybys (M1 and M2) in 2008 by the Mercury MESSENGER spacecraft. These flybys, together consisting of three equatorial and a single polar flyby, invite comparison with the magnetic fields of the other terrestrial planets and the Moon.

Comparison with Earth's magnetic field: The large-scale morphology of Mercury's internal magnetic field (Fig. 1A) is similar to that of Earth (Fig. 1B), although Mercury's surface field is two orders of magnitude weaker than Earth's [1]. Dominantly dipolar and spin-aligned, the fields of both planets possess significant quadrupole components, manifest as polar and equatorial magnetic "lows" in Fig. 1. In the case of Earth, the "low" is referred to as the South Atlantic Anomaly, a region marked by a growing reverse flux patch at the underlying core surface [2]. In contrast, at Mercury the asymmetry between the magnitude of the magnetic field at the north and south poles is the dominant manifestation of the quadrupole field [3].

Only weak constraints have been placed on the time variability of Mercury's core field, although stronger constraints are expected following MESSENGER's insertion in orbit about Mercury. These constraints suggest that the internal field has changed by less than 10% in 30 years [1]. The stronger solar wind at Mercury, and the weaker internal field, mean that magnetic field systems within the magnetosphere play a larger role than at Earth, in a smaller, more dynamic, magnetosphere. Of particular interest is whether the magnetospheric field is capable of affecting core fluid motions and the resultant dynamo [4].

Comparison with the Moon's field: The Moon's internal magnetic field (Fig. 2A) comprises only internal fields of crustal origin [5]. If the internal magnetic field at Mercury is as weak as that of the Moon, it will be difficult to recognize its signature from MESSENGER, even during the orbital phase.

MESSENGER and Mariner 10 observations of magnetic fields are complemented by laser altimetric profiles [6] and high-resolution images. These limited observations indicate that small-scale crustal magnetic fields, if they exist, are near the limit of resolution of the magnetometer [7]. The identification of crustal magnetic fields is complicated by the dynamic magnetosphere [8], and repeat passes over some features will be necessary to establish their origin. One example of a possible crustal magnetic signature is a small feature, 4 nT in magnitude, encountered near closest approach during M1. While the feature is not associated with either enhanced magnetic fluctuations or increased proton plasma count rates [9], its magnetic signature is dominantly east-west. This geometry suggests either a magnetospheric origin or a crustal origin with the spacecraft ground track near the edge of the source body.

One possible location of small- to intermediate-scale magnetic anomalies on Mercury is antipodal to Caloris. Large basin-forming impacts produce a partially ionized vapor-melt cloud. Converging at the antipodes, and interacting with an ambient magnetic field, the cloud may produce a substantial but temporary increase in the magnetic field, as may have happened on the Moon [10]. It will be challenging to view these antipodal regions, however, as they lie in the southern hemisphere, at some distance from closest approach. On the Moon, crustal magnetic fields are associated with swirls [11,12]. Swirls are albedo markings that exhibit winding or sinuous patterns [13]. Examples of possible swirls on Mercury were noted in Mariner 10 images [13], although interpretation of MESSENGER observations suggest that these feature are not analogous to lunar swirls [14].

Comparison with the Martian field: In contrast to Mars (Fig. 2B), and to a lesser extent the Moon, none of the craters profiled by the Mercury Laser Altimeter [6] during M1 or M2 exhibit any magnetic signature. The craters profiled during M1 exhibit a 5.2-km dynamic range in topography [6] and include several significant craters. Impact craters affect crustal magnetic fields through excavation of magnetic material during impact and thermal magnetization and demagnetization. The absence of magnetic features associated with cratering along the two MESSENGER profiles weakens the case for large-scale remanence. Large-scale remanence, with large-scale variations originating from variations in insolation and surface temperature, has been suggested as an alternative explanation for the planet-wide magnetic field at Mercury [15].

Summary: We conclude that the internal magnetic field at Mercury is overwhelmingly of core origin, although small-scale fields of crustal origin may yet be shown to exist. None of the craters profiled during the MESSENGER flybys exhibit any magnetic signature.

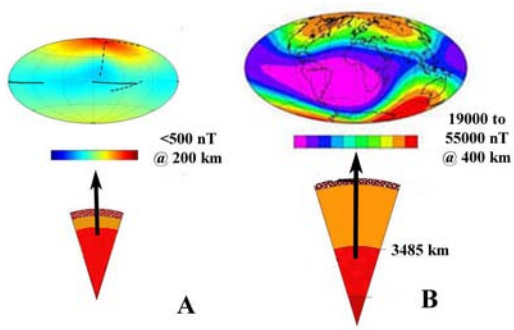

Figure 1. (A) Mercury's internal magnetic field (scalar intensity at satellite altitude) and associated source region. Model structure is restricted by imposing a constraint on the spherical harmonic power spectrum, rather than by restricting the number of model coefficients [16]. Flyby ground tracks are shown as black lines. (B) Earth's internal core magnetic field [17] The core field is from the year 2002 and is the scalar intensity of the main field between spherical harmonic degrees 1 and 13. Hammer projections.

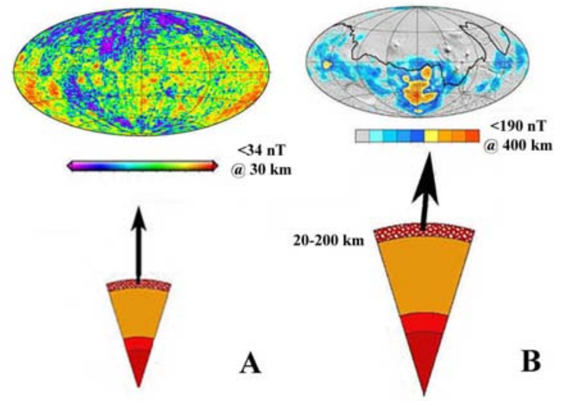

Figure 2. (A) The Moon's internal magnetic field and associated source region. The crustal field shown [5] is the scalar intensity of the magnetic field between spherical harmonic degrees 1 and 150. (B) Mars' internal magnetic field and inferred source region. The crustal field shown is the scalar intensity of the magnetic field between spherical harmonic degrees 1 and 60 [18]. Hammer projections.

References:

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