EVIDENCE FOR A CRUSTAL MAGNETIC SIGNATURE ON MERCURY FROM MESSENGER MAGNETOMETER OBSERVATIONS. Michael E. Purucker[1], Catherine L. Johnson[2,3], Reka M. Winslow[2], Joseph B. Nicholas[1], Brain J. Anderson[4], Haje Korth[4], James W. Head[5], Maria T. Zuber[6], Sean C. Solomon[7], James A. Slavin[8], Igor I. Alexeev[9], Roger J. Phillips[10], and David A. Paige[11] [1]Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, Greenbelt, MD, 20771, USA, Michael.E.Purucker@nasa.gov. [2]Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada, cjohnson@eos.ubc.ca. [3]Planetary Science Institute, Tucson, AZ 85719, USA. [4]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [5]Department of Geological Sciences, Brown University, Providence, RI 02912, USA. [6]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA. [7]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA. [8]Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI 48109, USA. [9]Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow 119991, Russia. [10]Planetary Science Directorate, Southwest Research Institute, Boulder, CO 80302, USA. [11]Department of Earth and Space Sciences, University of California, Los Angeles, CA, 90095, USA.

Introduction: We examine residual magnetic fields from low-altitude MESSENGER observations over the northern pole of Mercury to test for signatures of crustal and core magnetic fields. Crustal magnetic fields may be associated with spatial variations in the depth to specific Curie temperatures resulting from variations in insolation, with impact craters or basins, or with geologic features that possess a magnetic contrast with their surroundings. The presence of crustal magnetic fields can help elucidate the geologic history of the planet and the history of its magnetic field. The residual fields used here are obtained by subtracting the predictions of a paraboloid magnetospheric model [1] from vector observations at latitudes north of 30°N. The paraboloid model includes the offset dipole [2] and large-scale magnetospheric fields and is described in a companion abstract [3]. Other expected residual fields include those from Mercury's magnetospheric cusp and other plasma signatures [4,5], possible closure current systems, and higher-order core fields.

Results: Analysis of the magnetic field residuals in solar-centric coordinates reveals the presence of repeatable, organized magnetic fields that are dominated by the cusp fields, possible closure fields, and fields possibly related to the downtail misfit of the magnetopause boundary [3]. Analysis of the magnetic field in Mercury bodyfixed (MBF) coordinates indicates repeatable, organized magnetic fields only in the radial component (Fig. 1). In order to characterize these MBF-organized fields, we first removed observations in regions affected by the cusp, and we then calculated the magnetic field expected at a constant altitude from the remaining observations (>60000) utilizing an equivalent source-dipole approach [6]. The grid of dipoles is located at Mercury's surface, and dipoles are arranged on an equal-area mesh with a spacing of 1.5°. The equivalent source-dipole model (Fig. 2) reveals a series of magnetic features centered on a topographic rise near the north pole and extending along 45° longitude.

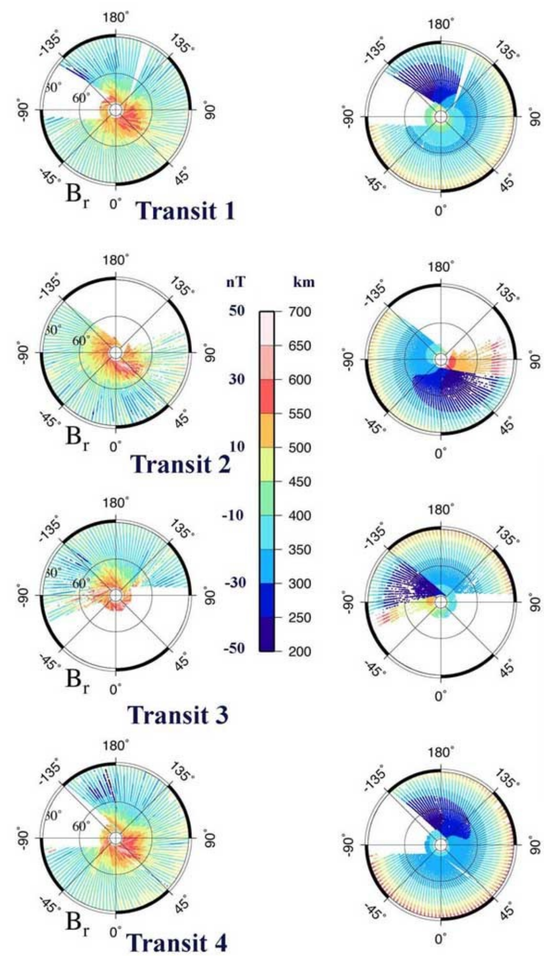

Figure 1. Radial magnetic field residuals (left) and measurement altitudes (right) in planet-centered coordinates for the four transits of the planet through day 326 of 2011. Observations affected by the northern magnetic cusp have been removed.

The model is most robust between 45°N and the north pole. The root mean square misfit of the model is small (typically less than 6 nT) relative to the observations, which are up to 45 nT at 300 km altitude. We used ideal body analysis [7] to place bounds on the distribution of magnetization, and we calculated the minimum magnetization required for a given layer thickness, irrespective of the magnetization direction.

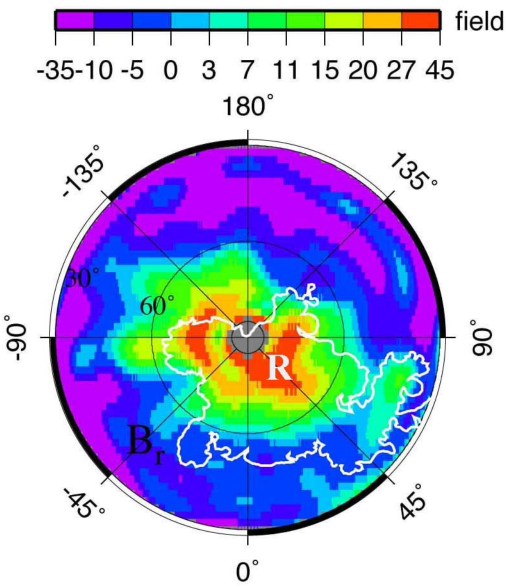

Figure 2. Residual radial magnetic field (nT) of internal origin normalized to 300 km altitude. Observations are from days 83-326 in 2011 at altitudes of 200-700 km. White line outlines the extent of the northern volcanic plains [8]. The white R locates the center of the topographic rise in the northern volcanic plains [10].

Interpretation: The observed residual magnetic field can be reproduced with a crustal layer magnetized in a direction opposite to that of the present main field. There is a trade off between layer thickness and magnetization; for instance, a magnetization in excess of 1 A/m is needed for a layer thickness of 15 km (Fig. 3). This interpretation of the residual field implies that the magnetization is a remanent magnetization acquired during a period when Mercury's magnetic field was of the opposite polarity, and possibly stronger, than the present field.

The boundaries of the magnetized region correspond closely to that of the northern volcanic plains [8]. The plains are not likely to be regionally thicker than 2 km, although they may be locally somewhat thicker in the region of a broad topographic rise ([10] R in Fig. 2), where magnetic fields are strongest. On the basis of the style of volcanism and the inferred state of stress in the crust when the volcanic plains were emplaced, dikes feeding these eruptions are likely to be numerous, long (tens to hundreds of kilometers), and wide (many tens to hundreds of meters) [10]. The northern plains are contemporaneous with large expanses of smooth plains within and exterior to the Caloris basin that were emplaced shortly after the end of the late heavy bombardment of the inner solar system [8]. An association of the residual field with the northern plains would therefore indicate that Mercury's dynamo has been long-lived. The northern plains appear to be more basaltic and less magnesian than the adjacent more heavily cratered terrain [9]. Corresponding differences in the abundances of iron and titanium remain to be determined.

A dipolar inducing field should preserve the signature of an increasing magnetic field with increasing geomagnetic latitude, as seen in Fig. 2. A latitudinal dependence on insolation will also produce a similar effect, and we expect that the effects will be additive. We cannot exclude the possibility that some fraction of the observed magnetic signature has a core source, but the correspondence of the feature with the northern volcanic plains and the decrease of the field with decreasing latitudes are both suggestive of a crustal source. On the basis of the high sulfur contents of the surface rocks [9], highly reducing conditions applied during the generation of northern plains magma. We infer, therefore, that the magnetic carrier may be native iron. The low average iron content of surface material (<4%) [9] is compatible with the strength of the observed, long-lived remanent field, as long as native iron is in a single-domain state.

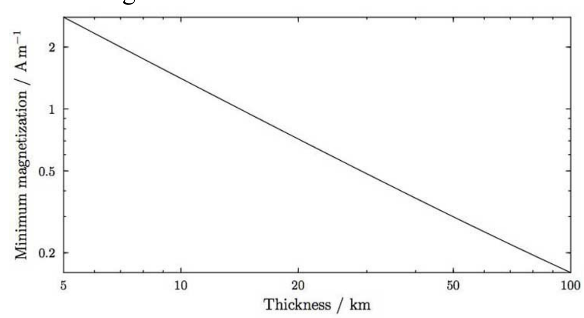

Figure 3. Minimum magnetization for a specified layer thickness.

References: [1] Alexeev I. I. et al. (2010) *Icarus, 209,* 23-39. [2] Anderson B. J. et al. (2011) *Science*, *333*, 1859-1862. [3] Johnson C. L. et al. (2012) *LPS, 43*, this meeting. [4] Korth H. et al. (2011) *GRL*, *38*, L2201, 10.1029/2011GL049451. [5] Winslow R. M. et al. *GRL*, submitted. [6] Purucker M. E. et al. (1996) *GRL 23*, 507-510. [7] Parker R. L. (2003) *JGR,* 108, 5006, 10.1029/2001JE001760. [8] Head J. W. et al. (2011) *Science, 333*, 1853-1856. [9] Nittler L. R. et al. (2011) *Science, 333*, 1847-1850. [10] Dickson, J. L. (2012) *LPS, 43*, this meeting.