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Editorial

Introduction to the special issue of *Icarus* on "Mercury after Two MESSENGER Flybys"

More than three decades ago the Mariner 10 spacecraft visited Mercury, revealed 45% of the planet's surface, and provided hints of a strikingly dynamic planet inside and out. Subsequent ground-based observations built on the foundation of knowledge provided by Mariner 10 and helped to raise new questions. The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission was conceived as a means to carry out a comprehensive investigation of our Solar System's innermost planet, within the budget of NASA's Discovery Program. The papers collected in this special issue of *Icarus* present findings from the spacecraft's first and second encounters with Mercury and reveal that MESSENGER is well on its way to successfully meeting its mandate and stimulating a new generation of modeling studies and ground-based observations. Indeed, this collection of papers unveils fresh insights into the composition of Mercury and its surface and interior, the geological history of the surface, and the composition and dynamics of its extended atmosphere and magnetosphere.

Mercury's reflectance spectrum at ultraviolet to near-infrared wavelengths has been frustratingly difficult to interpret. High-resolution observations by MESSENGER's optical instruments, along with theoretical work and telescopic data collected by Earth-based telescopes, are permitting new compositional information to be teased from the reflectance properties of the planet's surface. The photometric analysis by Domingue et al. is key for normalizing spectra collected under differing viewing conditions to a common geometry and also provides clues to the textural properties of the regolith. Papers by Holsclaw et al., Warell and Davidsson, Warell et al., and Vernazza et al. apply different approaches to the problem of extracting compositional information from reflectance spectra. These authors all agree that Mercury's surface must have a low abundance of ferrous iron in its silicates and that opaque minerals likely play an important role in governing the reflectance.

MESSENGER's elemental chemical sensors provide important information complementary to that from spectral analysis. A paper by Lawrence et al. reports on neutron absorption by Mercury's surface, found to be similar to that of lunar soil samples from Mare Crisium. This result suggests the presence of iron or titanium in abundances equivalent to 7–18 wt% ilmenite. High-spatial-resolution monochrome and multispectral images returned by MESSENGER continue to provide new information on the geology of the surface. Blewett et al. report a study of the antipodes of major impact basins in search of unusual modified terrain and analogs to the enigmatic albedo patterns seen on the Moon known as lunar swirls. No swirl-like markings have been identified, and modified terrain is found only at the Caloris antipode. Ernst et al. describe the use of color units exposed in impact crater deposits as probes of variation in composition with depth; the complex stratigraphy so revealed hints that volcanism played a key role in building the planet's upper crust.

Images from Mariner 10 provided tantalizing hints of the physical connections between surface features and Mercury's interior. A paper by Smith et al. combines measurements of the equatorial shape and the low-degree gravity field as measured during the flybys to investigate the properties of the interior. The global network of long, high-relief structures known as lobate scarps on Mercury has been interpreted to be the result of planetary contraction. Zuber et al. report on the first precise altimetric profiles across lobate scarps and other tectonic features from MESSENGER's laser altimeter and on the results of modeling to understand the formation of these features. Rothery and Massironi describe how Beagle Rupes, a spectacular lobate scarp discovered by MESSENGER, may indicate the importance of a basal décollement in the formation of some scarps. Klimczak et al. evaluate formational hypotheses for the set of extensional features known as Pantheon Fossae, unique because of both its radiating pattern of faults and its curious location near the center of the largest known impact structure on Mercury – the Caloris basin. Oberst et al. present the first stereo topographic measurements from MESSENGER images, with a particular focus on the morphology of the Caloris basin and the identification of several potential pre-Caloris basins. New 70-cm Earth-based radar measurements of Mercury by Black et al. place additional constraints on the thickness and extent of the radar-reflective polar deposits in the floors of craters near the planet's north pole.

Mercury's dipole moment of 200–400 nT R_M^3, where R_M is Mercury's radius, was inferred previously from magnetic field observations by Mariner 10 and MESSENGER. The wide range in the estimate for the planetary moment is due at least in part to differences in the consideration of magnetospheric current systems, which create magnetic fields that contribute to the measurements. A good quantitative understanding of these external magnetic fields is therefore important for the determination of the strength and geometry of the planet's intrinsic magnetic moment, and a corresponding model is presented in a paper by Alexeev et al. The external magnetic field may also have influenced the evolution of the weak-field dynamo believed to exist at Mercury, via a feedback mechanism that is examined in a paper by Gómez-Pérez and Wicht.

Mercury's surface, exosphere, and magnetosphere constitute a strongly coupled system in which neutral and ionized particles interact with each other and electric and magnetic fields govern the motion of charged particles. Remote and in situ observations revealed the existence of metallic species at high altitudes that are removed from the planet's surface through interactions of the

0019-1035/$ - see front matter
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surface–exosphere–magnetosphere system with solar radiation, the solar wind, and the interstellar medium. Monte Carlo simulations by Burger et al. show that photon-stimulated desorption is the dominant source mechanism ejecting sodium from the surface, while impact vaporization and ion sputtering play minor roles in the creation of the exosphere. The complex distribution of the metallic species and implications for the source and loss processes are described in a paper by Killen et al. Detailed insight into the solar wind interaction with Mercury's surface–exosphere–magnetosphere system can be obtained with physics-based simulations, which augment the observations by providing three-dimensional pictures of the environment sampled sparsely by in situ observations. Several approaches to the simulation of Mercury's space environment during the times of the MESSENGER flybys are presented in papers by Benna et al., Trávníček et al., and Wang et al. Although the modeling techniques in these studies differ, their results show many features in common, including pronounced differences in magnetospheric dynamics under northward and southward interplanetary magnetic field, conditions encountered during the first and second flybys, respectively. Lyatsky et al. report on a new model to explain closure of field-aligned currents in Mercury's magnetosphere that can be tested with MESSENGER observations.

Mercury was once nicknamed "the elusive planet" (Strom, 1987). Earth-based study, the Mariner 10 mission, and now MESSENGER have begun to reveal Mercury as a surprisingly complex and dynamic object. As we await the onset of MESSENGER's orbital phase, set to begin on 18 March 2011, we can look forward to a sustained investigation of Mercury and the new discoveries and understanding that it will reveal. After completion of both MESSENGER and the European and Japanese BepiColombo dual orbiter mission now in development, Mercury will surely be elusive no longer.

Reference

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