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Revealing Mercury's geology with observations by the MESSENGER spacecraft

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The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft, developed under NASA's Discovery Program, launched in August 2004. En route to insertion into orbit about Mercury in 2011, MESSENGER flies by Mercury three times. The first and second of these encounters were accomplished in January and October of 2008. These flybys viewed portions of Mercury's surface that were not observed by Mariner 10 during its reconnaissance of somewhat less than half of the planet in 1974-1975. All MESSENGER instruments operated during each flyby and returned a wealth of new data. Many of the new observations were focused on the planet's geology, including monochrome imaging at resolutions as high as 100 m/pixel, multispectral imaging in 11 filters at resolutions as high as 500 m/pixel, laser altimetry tracks extending over several thousands of kilometers, and high-resolution spectral measurements of several types of terrain.

Here we present an overview of the first inferences on the global geology of Mercury from the MESSENGER observations. Whereas evidence for volcanism was equivocal from Mariner 10 data, the new MESSENGER images and altimetry provide compelling evidence that volcanism was widespread and protracted on Mercury. Color imaging reveals three common spectral units on the surface: a higher-reflectance, relatively red material occurring as a distinct class of smooth plains, typically with distinct embayment relationships interpreted to indicate volcanic emplacement; a lower-reflectance, relatively blue material typically excavated by impact craters and therefore inferred to be more common at depth; and a spectrally intermediate terrain that constitutes much of the uppermost crust. Three more minor spectral units are also seen: fresh crater ejecta, reddish material associated with rimless depressions interpreted to be volcanic centers, and high-reflectance deposits seen in some crater floors. Preliminary measurements of crater size-frequency distribution suggest that smooth plains on Mercury's surface range in age from the end of the period of heavy impact bombardment to as young as perhaps 1 billion years; these ongoing measurements are helping to elucidate the volcanic history of the planet. Mercury's global tectonic history is also revealed by the MESSENGER image and laser altimeter data. Significant evidence for global contraction was seen in Mariner 10 images in the form of widespread lobate scarps. The MESSENGER images show that contractional features are the dominant tectonic landform globally, and the inferred average contractional strain is at least one third greater than previously inferred from Mariner 10 observations. Only three exceptions to the dominance of contractional deformation have been found to date: extensional troughs that include prominent basin-radial systems documented in two basins, the Pantheon Fossae within the 1500-km-diameter Caloris basin and a similar set of features within a newly-imaged 700-km-diameter basin, and a circumferential trough system within the smaller, younger Raditladi basin. That these extensional tectonic features are rare on Mercury, and that they are not seen within basins elsewhere in the Solar System, pose important constraints on the thermal and mechanical evolution of Mercury's interior.