TECTONIC FEATURES ON MERCURY: AN ORBITAL VIEW WITH MESSENGER. Thomas R. Watters[1], Sean C. Solomon[2], Mark S. Robinson[3], James W. Head[4], Robert G. Strom[5], Christian Klimczak[2], Paul K. Byrne[2], Andrew C. Enns[3], Carolyn M. Ernst[6], Louise M. Prockter[6], Scott L. Murchie[6], Jürgen Oberst[7], Frank Preusker[7], Maria T. Zuber[8], Steven A. Hauck, II[9], and Roger J. Phillips[10]. [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560 (watterst@si.edu); [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015; [3]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85251; [4]Department of Geological Sciences, Brown University, Providence, RI 02912; [5]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; [6]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723. [7]German Aerospace Center, Institute of Planetary Research, D-12489 Berlin; [8]Department of Earth, Atmospheric and Planetary Sciences, MIT, Cambridge, MA 02139; [9]Department of Earth, Environmental and Planetary Sciences, Case Western Reserve University, Cleveland, OH 44106; [10]Planetary Science Directorate, Southwest Research Institute, Boulder, CO 80302.

Introduction: The first view of the tectonics of Mercury was provided from images of one hemisphere obtained by Mariner 10 during three flybys in 1974-75 [1]. With MESSENGER's three Mercury flybys more than 30 years later, about 98% of Mercury's surface had been imaged by spacecraft. Although the flyby images revealed many of Mercury's tectonic landforms [2], their true global spatial distribution remained poorly defined because the images were of variable spatial resolution and many were obtained under lighting geometries less than ideal for the identification and characterization of tectonic features. With the successful insertion of MESSENGER into orbit about Mercury in March 2011, the tectonics of Mercury may be studied anew. Global monochrome mosaics and targeted high-resolution images obtained with the Mercury Dual Imaging System (MDIS) wide-angle and narrow-angle cameras [3] are revealing tectonic landforms in unprecedented detail. Combined with topography from the Mercury Laser Altimeter (MLA) and from stereo imaging, the morphometry and topographic settings of Mercury's tectonic landforms can now be analyzed. Topographic data also reveal broad, long-wavelength features that may be evidence of large-scale deformation of Mercury's lithosphere [4].

Distributed Tectonics: Tectonic features on Mercury can be generally divided between distributed and basin-localized. The broadly distributed tectonic landforms are mostly contractional in origin and include lobate scarps, high-relief ridges, and wrinkle ridges. Among these, lobate scarps are the dominant contractional feature and accommodated the greatest strain (Fig. 1). These widely distributed thrust fault scarps and the closely related, rarer high-relief ridges are the result of global-scale stresses.

Models for the origin of compressional stresses include global contraction due to interior cooling, tidal despinning, a combination of thermal contraction and despinning, and a combination of thermal contraction and mantle convection [e.g., 5, 6]. A key test of these models is the spatial distribution, orientations, and timing of formation and reactivation of the lobate scarps. The distribution of recognized lobate scarps is not uniform. In the currently available imaging, concentrations of lobate scarps and high-relief ridges occur in uneven longitudinal bands, separated by intervening bands in which there are distinctly fewer tectonic features (Fig. 1). In the flyby images, these gaps were correlated with areas of the surface imaged under poor lighting conditions (low incidence angles) [5]. In orbital imaging, some longitudinal bands with fewer lobate scarps occur within areas having favorable illumination to recognize the scarps, but other bands correspond to regions with unfavorably low solar incidence angles. Comparison with topography obtained from MLA profiles and stereo images suggests that some scarps within these bands follow the boundaries of areas of high elevation and greater crustal thickness [7]. The distribution of lobate scarps within broad bands may be seen as support for an origin by mantle convection in combination with global contraction [8, 9], but prior such models must be reconciled with new and lesser estimates for the thickness of Mercury's mantle [10].

Basin-localized Tectonics: Two large impact basins, Caloris (centered at 30°N, 165°E) and Rembrandt (33°S, 88°E), exhibit complex arrays of contractional and extensional tectonic landforms (Fig. 1). The interior plains of the Caloris basin have both basin-concentric wrinkle ridges and graben [11, 12]. A system of basin-radial graben, Pantheon Fossae, radiates outward from a zone near the basin center, and some of those graben extend outward to basin-concentric graben to form polygonal patterns along the basin margin [2, 11, 12]. Orbital imaging shows that basin-concentric wrinkle ridges, previously thought to be restricted to the outer floor, extend to the center of the basin. The Rembrandt basin also displays myriad basin-radial and basin-concentric wrinkle ridges and graben that form a wheel-and-spoke-like pattern in its interior plains [13]. The stresses in these basins were likely the product of some combination of subsidence-induced contraction and uplift-induced extension. Uplift might have resulted from inward lateral flow of the lower crust [6, 14] or loading by volcanic plains exterior to the basin to induce flexural elevation of the basin interior [15, 16].

Three smaller basins, Raditladi, Rachmaninoff, and Mozart, have graben confined to smooth plains material interior to their peak rings [2, 8, 17, 18]. Rachmaninoff and Mozart also have wrinkle ridges in their interior plains. It is now clear that multiple basins on Mercury are sites of localized deformational activity.

Tectonic Systems on Volcanic Plains: Many of the smooth plains units on Mercury, the largest expanses of which are found northern high latitudes and exterior to the Caloris basin, consist of flood volcanic deposits [19-21]. These volcanic plains are deformed predominantly by wrinkle ridges (Fig. 1), likely formed by stresses resulting from some combination of subsidence and global contraction [6, 8, 21]. Within many areas of volcanic plains encircled by rings of wrinkle ridges localized over the rims of buried impact structures are graben, commonly in polygonal patterns. The diameters of buried craters and basins hosting such graben range from ~40 to 300 km. These graben and associated wrinkle ridges form contractional and extensional tectonic systems not seen elsewhere [22, 23]. The mix of contractional and extensional stresses that formed these distinctive fault systems may result from a combination of thermal contraction of thick lava flow units and global contraction [22].

Large-scale Tectonics: Topographic maps derived from MLA and stereo imaging have revealed long-wavelength topographic variations on Mercury that may be at least partly tectonic in origin. Stereo-derived topography, for instance, shows a broad ~500-km-wide trough outward of the southwestern rim of Rembrandt basin [24]. Two southwest–northeast-oriented lobate scarps bound the trough; one of the scarps is the longest found on Mercury and crosscuts Rembrandt [13]. The maximum relief of this fault-bounded trough is over 2 km, and the trough is contiguous to a low-relief area of Rembrandt's rim and interior floor. The trough may be the result of a long-wavelength lithospheric fold [25]. Another long-wavelength feature revealed in stereo-derived [22, 26] and MLA [27] topography is a broad rise in the northern portion of the Caloris basin interior and a lesser rise in the southern section separated by a trough extending across the interior basin floor and oriented approximately east-west. The elevation of the northern section (>3 km) is greater in some areas than the basin rim [5, 24, 26]. The area of convergence of the Pantheon Fossae graben is located within the trough [26].

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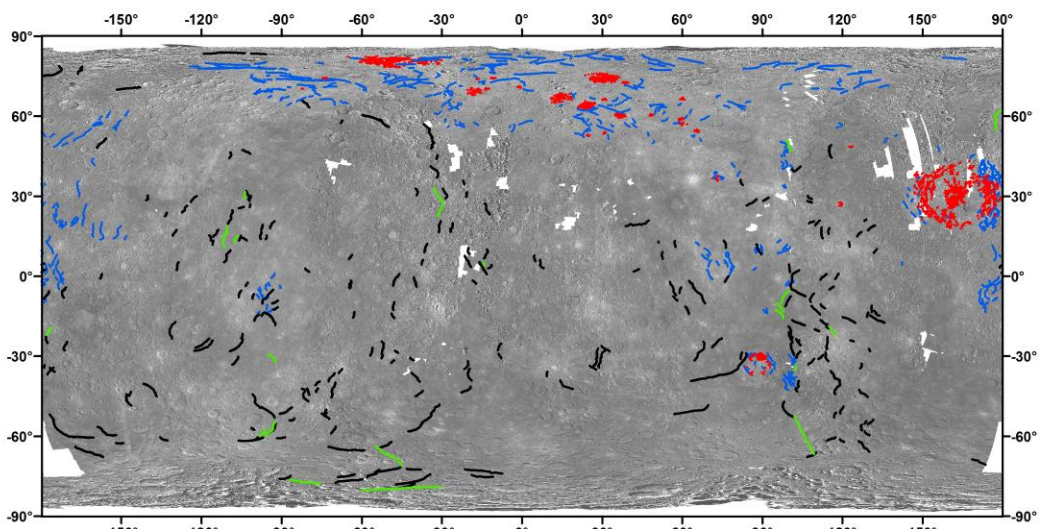

Figure 1. Preliminary tectonic landform map of Mercury. Lobate scarps (black) and high-relief ridges (green) are distributed in broad, longitudinal bands, wrinkle ridges (blue) are found in volcanic plains, and graben (red) are found in the interior plains of impact basins and within some basins and craters buried by volcanic plains.