THE TECTONICS OF MERCURY: A NEW VIEW FROM MESSENGER.

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Introduction: The Mariner 10 mission revealed widespread evidence of crustal deformation on Mercury. Only half the story of Mercury's tectonic evolution can be told, however, because the same hemisphere was sunlit during each of Mariner 10's three flybys. A significant portion of the hemisphere unseen by Mariner 10 will be imaged in the first flyby of Mercury by the MESSENGER spacecraft [1]. With images from the Mercury Dual Imaging System (MDIS) [2, 3], tectonic landforms will be identified and characterized, and the first near-global assessment of tectonics on Mercury will provide new constraints on the magnitude and timing of deformation. The flyby will also yield data for more rigorous evaluation of models for the origin of tectonic stresses and their relationship to the interior and thermal evolution of Mercury.

View of Mercury Tectonics from Mariner 10: Tectonic landforms are distributed throughout the hemisphere imaged by Mariner 10. They are found in the ancient intercrater plains, in the youngest smooth plains, and on the floor of the Caloris basin. Crustal shortening is the dominant form of deformation, and it is expressed by three landforms: lobate scarps, wrinkle ridges, and high-relief ridges. Lobate scarps are the most widely distributed tectonic landform on Mercury. Evidence of offset crater floors and walls indicates that lobate scarps are the expression of surface-breaking thrust faults (Fig. 1) [4-8]. The distribution of lobate scarps in the imaged hemisphere is not uniform; more than 50% of the area-normalized cumulative length of lobate scarps occurs south of 30°S [8, 9]. Wrinkle ridges are complex morphologic landforms interpreted to be the result of folding and thrust faulting. They are predominantly found in smooth plains, both within and surrounding the Caloris basin [4, 6, 9]. Landforms described as high-relief ridges have greater relief than wrinkle ridges and may transition into lobate scarps, suggesting that they, too, are the result of thrust or high-angle reverse faults [9, 10]. Evidence of extension in the imaged hemisphere is absent outside the Caloris basin. Subtle evidence of extension may be expressed by lineaments described as a tectonic grid [6, 11]. A network of linear and sinuous extensional troughs forms a series of giant polygons in the floor material of the Caloris basin [12]. These troughs crosscut basin-concentric and basin-radial wrinkle ridges and are thus the youngest tectonic features in Caloris (Fig. 2) [4, 6, 11, 12].

Timing of Deformation: The timing of lobate scarp formation can be constrained by the age of the units they deform. Lobate scarps deform intercrater plains, the oldest (pre-Tolstojan) plains material emplaced near the end of the period of heavy bombardment, as well as younger Tolstojan and Calorian-aged smooth plains units. It has been suggested that lobate scarp formation began near or after the end of heavy bombardment and continued after the formation of the Caloris basin and the emplacement of the youngest smooth plains [4, 6]. However, the following evidence suggests a Calorian age for much of the development of the lobate scarps: (1) there is no evidence of embayment of scarps by ancient intercrater plains [6] or by younger Tolstojan and Calorian smooth plains materials [8], (2) lobate scarps often cut across and offset the floors and rim walls of large impact craters (Fig. 1), (3) there are no large craters superimposed on lobate scarps, and (4) there is no obvious degradation or partial burial of lobate scarps by Caloris ejecta [8]. These relationships suggest that the lobate scarps in the hemisphere imaged by Mariner 10 were active after the emplacement of the Calorian smooth plains [8, 9]. Thus, the lobate scarps may be among the youngest landforms on Mercury, even younger than the youngest smooth plains.

Origin of Tectonic Stresses: Models for the origin of compressional stresses responsible for the formation of lobate scarps include global contraction due to interior cooling, tidal despinning, a combination of thermal contraction and despinning, and the interaction of thermal stresses and stresses related to the formation of the Caloris basin [4-6, 13-23]. Thermal contraction of the planet from interior cooling would result in global, horizontally isotropic compression. The onset of lithospheric contraction is predicted before the end of the period of heavy bombardment [14, 17]. Tidally induced despinning and the relaxation of an early equatorial bulge will induce stresses in the lithosphere [6, 20, 21]. The predicted stresses are E–W compression in the equatorial zone and N–S extension in the polar regions [20]. Stresses from despinning and thermal contraction may have been coupled if the two processes overlapped in time [6, 22]. Stresses associated with the formation of the Caloris basin may have interacted with existing lithospheric stresses from thermal contraction, resulting in Caloris-radial thrust faults [23]. Each of these scenarios has limitations in explaining the spatial and temporal distribution of the lobate scarps. Few lobate scarps in the imaged hemisphere are radial to the Caloris basin. Extension in Mercury's polar regions predicted by tidal despinning has not been observed [6, 8, 15, 17]. Thermal contraction, absent other influences, should generate a uniform distribution of thrust faults with no preferred orientation and no preferred thrust slip direction [8]. Another source of stress that may have contributed to the formation of the lobate scarps is convective downwelling in Mercury's mantle [8, 9].

Models for the origin of the extensional stresses that formed the polygonal troughs in the Caloris basin involve exterior annular loading or lateral crustal flow. Exterior annular loading due to the emplacement of the expansive smooth plains adjacent to Caloris results in basin-interior extensional stresses [6]. Lateral crustal flow of a relatively thick crust toward the basin center results in late-stage basin uplift and extension [12].

The New View of Mercury Tectonics: MESSENGER's first Mercury flyby will fill in a much-needed missing piece in our knowledge of tectonic history. Among the major tectonic questions that will be addressed are (1) what types of tectonic landforms are present in the hemisphere not seen by Mariner 10, (2) what is their spatial and temporal distribution, (3) what is the full extent of deformation of the floor materials of the Caloris basin, and (4) what is the extent of the annulus of deformed smooth plains surrounding Caloris? In addition to a more comprehensive view of the distribution, magnitude, and timing of deformation that will help constrain existing models for tectonic stresses, the flyby results should provide new insight into the thermal and mechanical evolution of Mercury's lithosphere.

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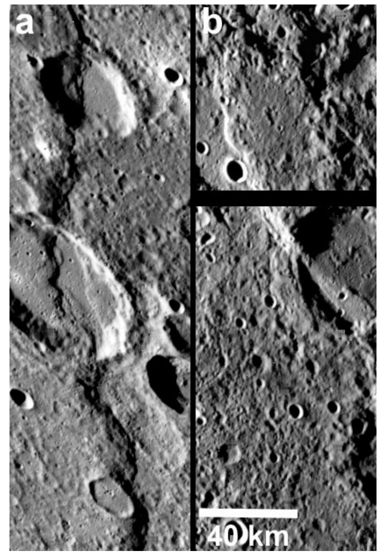

Figure 1. Lobate scarps on Mercury. Discovery Rupes (a) and Vostok Rupes (b) are landforms interpreted to be the surface expressions of thrust faults.

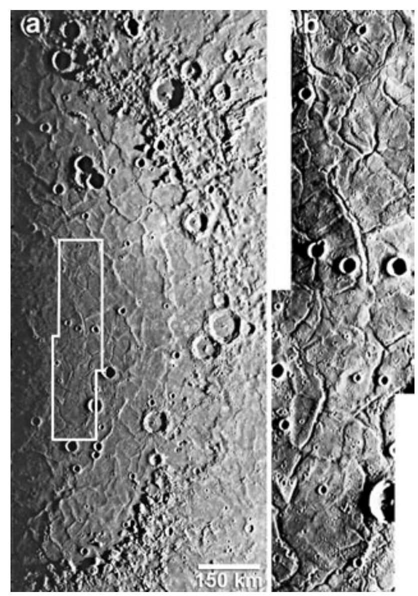

Figure 2. The Caloris basin on Mercury. (a) The interior plains of the Caloris basin show evidence of contractional (wrinkle ridges) and extensional (troughs) deformation. (b) High-resolution image mosaic of a portion of the interior plains showing extensional troughs that form giant polygons (Mariner 10 images 0529055 and 0529056; the maximum width of the mosaic is ~115 km).