EVIDENCE OF EXTENSION ON MERCURY UNRELATED TO IMPACT BASIN DEFORMATION.
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Introduction: Mariner 10 images of Mercury showed widespread evidence of contractional deformation. The only clear evidence of extension was found in the interior plains of the Caloris basin [1, 2]. The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft has completed three flybys of Mercury [3], and 98% of the surface has now been imaged by spacecraft. The areas imaged by MESSENGER with lighting geometry favorable for the detection of tectonic landforms support the view that crustal deformation on Mercury is predominantly contractional. During MESSENGER's first flyby, additional evidence of extensional deformation was found in the Caloris [4, 5] and Raditladi [3, 6] basins. The Rembrandt basin, imaged during the second flyby, was found to have a complex pattern of extensional features in its interior plains [7]. Until MESSENGER's third flyby, no evidence of extension outside of large impact basins had been seen on Mercury.

Newly Viewed Evidence of Extension: Images obtained during the third MESSENGER flyby in October 2009 revealed an additional ~6% of Mercury's surface. The approach images showed a fourth large impact basin with evidence of extensional landforms, a peak-ring basin similar in size to the Raditladi basin [8]. Also revealed were contractional landforms that had not been imaged or resolved in the previous flybys. Chief among these are lobate scarps, the most widely distributed tectonic landform on Mercury [1-3, 5]. Lobate scarps are interpreted to be the expression of surface-breaking thrust faults [1-3, 5]. In plan view, lobate scarps are generally linear, curvilinear, or arcuate features. There are also lobate scarps that exhibit substantial curvature. The most notable of these is Beagle Rupes [3, 5]. With its approximately north-south-trending central segment, its NW-SE-trending southern segment, and NE-SW-trending northern segment, Beagle Rupes has a bow-like shape. Another unusually arcuate lobate scarp was revealed in the third flyby approach images (Fig. 1). This landform is characterized by a scarp approximately 200 km in length with an approximately N-S-trending central segment, a NE-SW-trending southern segment, and a short NW-SE-trending northern segment, forming a bow-like shape similar to that of Beagle Rupes. The scarp face of this structure has substantial relief along much of its length (Fig. 1). A preliminary digital terrain model (DTM) derived from stereo images obtained during MESSENGER's second and third flybys [9] indicates that the fault scarp has a throw of as much as ~1.5 km. The N-S-trending scarp segment is cut by a linear trough that extends ~6 km to where it intersects the rim and walls of an irregularly shaped impact crater (Fig. 2). The trough can be clearly traced down the eastern wall of the crater. The western rim of the crater is cut by two (and possibly more) parallel troughs. Other approximately NE-SW-trending trough segments extend up to ~50 km westward from the scarp. About 130 km west of the scarp, two other linear, approximately parallel NE-SW-trending troughs over 30 km in length crosscut a NW-SE-trending contractional high-relief ridge (Fig. 3). These troughs are interpreted to be graben on the basis of their crosscutting relations, uniform along-length widths, and lack of a beaded morphology such as that characterizing troughs formed by chains of secondary craters. There is also evidence that some of the troughs are segmented with echelon steps, indicating that the faults grew by segment linkage [10]. These troughs thus are the first evidence of extensional tectonics outside of an impact basin on Mercury.

Origin of the Extensional Stresses: The nearly general absence of extension outside of major basins on Mercury has been attributed to global compressional stresses associated with cooling and contraction of the planet's interior [3, 5]. The graben documented here, on the basis of crosscutting relations, postdate the lobate scarp and the high-relief ridge. The scarp segments intersect at angles >100° without an evident overlap of fault trends (Fig. 1), characteristics that have been attributed in the case of Beagle Rupes to listric bounding faults that sole in a basal decollement [11]. The DTM shows a rise associated with the scarp face and suggests that the terrain west of the scarp described here is elevated, possibly forming a plateau bounded to the east and south by the scarp segments. However, the quality of the DTM is poor west of the scarp because the area was near the limb during the second flyby. The high topographic relief along most of the scarp face hints that the shallowest portions of the bounding faults may be high-angle thrust or reverse faults. A possible mechanism for graben formation in this area is relaxation of topographic relief by lateral flow of the crust, a process well documented in mountain belts and plateaus on

Earth [12]. The nearly orthogonal relation between the graben and the contractional features they crosscut is consistent with this scenario. Ascertaining whether the relaxation and lateral flow involved the entire crust or only the volume above a mid-crustal decollement will require both detailed modeling and additional information from high-resolution imaging and stereo-derived topography to be obtained during MESSENGER's orbital mission phase.

References: [1] Strom R.G., Trask N.J., and Guest J.E. (1975) *J. Geophys. Res., 80,* 2478-2507. [2] Melosh H.J. and McKinnon W.B. (1988) in *Mercury,* Univ. Arizona Press, Tucson, 374-400. [3] Solomon S.C. et al. (2008) *Science,* 321, 59-62. [4] Murchie S.L. et al. (2008) *Science,* 321, 73-76. [5] Watters T.R. et al. (2009) *Earth Planet. Sci. Lett.,* 285, 309-319. [6] Watters T.R. et al. (2009) *Earth Planet. Sci. Lett.,* 285, 283-296. [7] Watters T.R. et al. (2009) *Science,* 324, 618-621. [8] Prockter L.M. et al. (2010) *Lunar Planet. Sci., 41,* this volume. [9] Preusker F. et al. (2010) *Lunar Planet. Sci., 41,* this volume. [10] Schultz R.A. et al. (2009) in *Planetary Tectonics,* Cambridge Univ. Press, 457-510. [11] Rothery D.A. and Massironi M. (2009) *Lunar Planet. Sci., 40,* 1702. [12] Dewey, J.F. (1988) *Tectonics, 7,* 1123-1139.

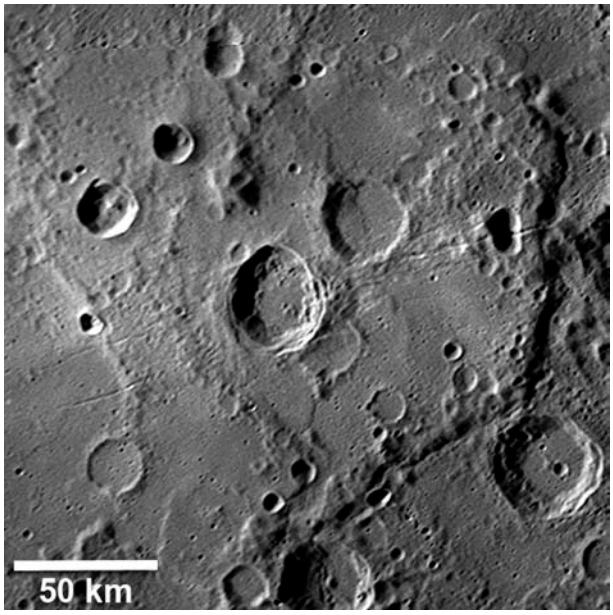

Figure 1. The Mercury Dual Imaging System (MDIS) narrow-angle camera (NAC) images obtained during MESSENGER's third flyby revealed an unusually arcuate lobate scarp. Several impact craters are crosscut by the NE-SW-trending southern segment of this lobate scarp. Mosaic is centered at ~26.6°S, 66.4°E.

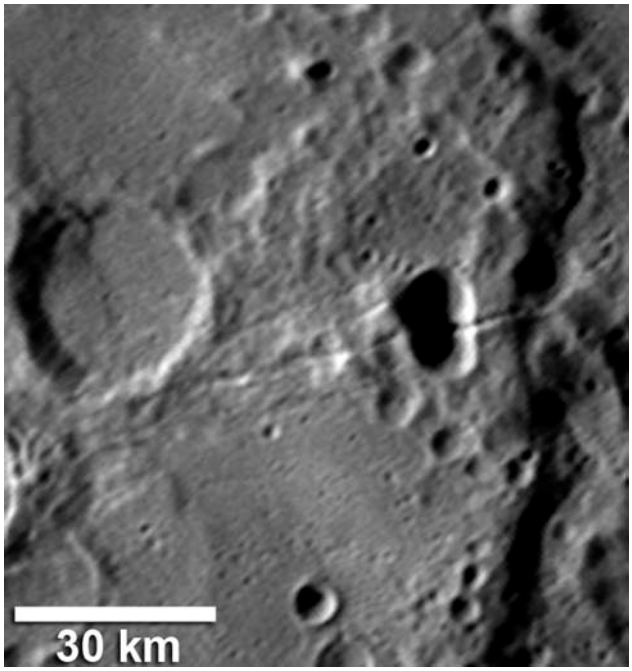

Figure 2. A series of narrow troughs crosscut the rim and walls of an irregularly-shaped impact crater and the scarp face. Other troughs extend westward from the crater.

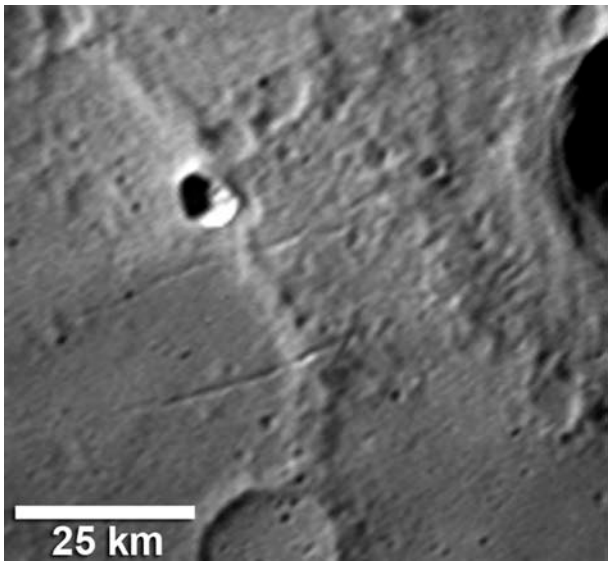

Figure 3. Two approximately parallel NE-SW-trending troughs crosscut and are therefore younger than a contractional high-relief ridge to the west of the lobate scarp. The angular relation between the troughs and the ridge is nearly orthogonal.