DURATION OF ACTIVITY ON LOBATE-SCARP THRUST FAULTS ON MERCURY. Maria E. Banks[1, 2], Nadine Barlow[3], Christian Klimczak[4], Zhiyong Xiao[5, 6], Thomas R. Watters[2], Clark R. Chapman[7].
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Introduction: Contractional deformation on Mercury is expressed by three main types of landforms: lobate scarps, high-relief ridges, and wrinkle ridges [e.g., 1–4], with lobate scarps (rupēs) the most widely distributed of these landforms. Lobate scarps deform all major geologic units, including intercrater plains and smooth plains, thereby providing valuable insight into the history of horizontal shortening on Mercury. Lobate scarps are interpreted to be the expression of low-angle (<45° fault dip) surface-breaking thrust faults, and they can extend more than 500 km in length and display up to ~3 km of relief [1, 3, 5].Their formation has been attributed primarily to compressional stresses produced by planetary cooling and global contraction [1–3, 5]. Understanding the history of crustal deformation provides constraints on thermal history models and insight into the interplay between tectonics and volcanism and the cooling and solidification of the planet's interior [5].

Methods and data: The recent crater production function and inner solar system chronology of [6] indicates that the oldest surfaces on Mercury date from about 4.0–4.1 Ga, during the Late Heavy Bombardment (LHB), and correspond approximately to the pre-Tolstojan and Tolstojan systems [7]. Widespread smooth volcanic plains were emplaced by about 3.55–3.8 Ga [8], at the end of the Calorian system [7]. The Calorian is followed chronologically by the Mansurian and Kuiperian systems [7]. Craters of different ages exhibit different amounts of degradation ranging from sharp morphologies and the presence or absence of high reflectance ejecta and rays (Kuiperian and Mansurian craters, respectively), to moderately degraded (Calorian craters), and heavily degraded (Tolstojan and pre-Tolstojan craters) morphologies, characterized by subdued rims, along with infilling of the crater floor, and superposing craters [7, 9].

Orbital images and mosaics from the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) Mercury Dual Imaging System (MDIS) are used to investigate previously unrecognized stratigraphic relationships between lobate scarps, and impact craters exhibiting a range of degradation states, to gain further insight into the duration of thrust fault activity on Mercury [9]. Here we focus on Mercury's 30 officially named scarps (Fig. 1). For 22 of these lobate scarps, size–frequency distributions were also determined for craters that intersect the scarp face and immediately surrounding surface. This was completed using a modified buffered crater counting technique [e.g., 10–11], and only craters for which the centers overlapped the count area were included. Crater count-derived ages were obtained using the model production function chronology of Mercury from [6]. Age estimates for impact craters that are crosscut by scarp segments provide lower limits on the age of the most recent activity on the underlying thrust faults, but do not constrain the time of formation of those faults. Age estimates for craters that superpose scarp segments provide upper bounds on the age of the most recent detectable activity on the thrust faults associated with the scarp segments, and constrain the time of formation of the fault and the initiation of slip to before the crater-forming impacts [9].

Duration of lobate scarp activity: *Constraints on the earliest thrust faulting.* Any record of crustal deformation prior to or in the early stages of the LHB is unlikely to be preserved. Also, no evidence of embayment of lobate scarps by early-emplaced smooth plains material has been found [4]. Preliminary results from counts of craters crosscut by scarp segments indicate that the majority of the investigated structures formed on surfaces that are Calorian and date back to near the end of the LHB. All of the named scarps collocated with Tolstojan and pre-Tolstojan craters, crosscut and deform the craters (Fig. 2), and all but 7 of the named scarps crosscut Calorian craters. The oldest craters observed to superpose the scarps in this study, or any other scarp segments on Mercury so far, are estimated to have formed during the Calorian system and constrain the time of formation of the associated fault and the initiation of slip to before the end of this system (Fig. 2) [9]. For scarps where a sufficient number of superposing craters could be measured (14 of the investigated scarps), preliminary age estimates also suggest that observable activity may have ceased on some scarp segments before the end of the Calorian.

These collective observations support initiation of shortening of Mercury's surface on at least a regional scale by some time before the end of the Calorian (before ~3.6 Ga), a time interval during which the major expanses of smooth plains were emplaced. Although segments of the faults may have ceased to be active in the Calorian, such a result does not necessarily indicate that the fault has been completely inactive along its entire length since that time.

Evidence for recent activity along thrust faults. Images from MESSENGER show that ~8 of the named scarps crosscut the rims or floors of Mansurian craters, indicating that the most recent activity on thrust faults underlying these scarps occurred during or after this system [9]. Roughly half of the investigated scarps have fewer than 3 superposed craters >4 km in diameter, and for some, only superposing Kuiperian craters have been identified. These observations further support continuing activity on the associated thrust faults into and potentially more recently than the Mansurian. Five of the major lobate scarps are also observed to transect previously unresolved small (<3 km in diameter) and relatively fresh impact craters (Fig. 2) [9]. On the Moon, fresh craters ≤3 km in diameter, with rims sharp to only slightly or moderately subdued, are estimated to be Copernican in age (<1 Ga) [e.g., 12]. On Mercury, by analogy, comparable small and relatively fresh craters are interpreted to have formed during the Kuiperian. Higher degradation rates expected for Mercury compared with the Moon reinforce this interpretation [e.g., 13–14]. Small lobate scarps, less than 10 km in length, and small-scale back-scarp graben have been discovered in close association with a few of the investigated scarps. These small landforms are interpreted to be Kuiperian in age on the basis of expected rates of impact degradation of morphology, and provide supporting evidence that lithospheric contraction on Mercury continued into the Kuiperian [15].

Conclusions: Crater size-frequency distribution analyses and observations of stratigraphic relationships between lobate scarps and craters in various stages of degradation indicate that tectonic activity was initiated and possibly ceased along some scarp segments near the end of the last phase of widespread smooth plains emplacement on Mercury. Evidence of recent activity also suggests the reactivation of or continued activeity on earlier, larger scarps into the Mansurian and Kuiperian. Altogether, these observations demonstrate that global contraction has been a long-lived process on Mercury since near the end of the LHB and into the Kuiperian (Fig. 3).

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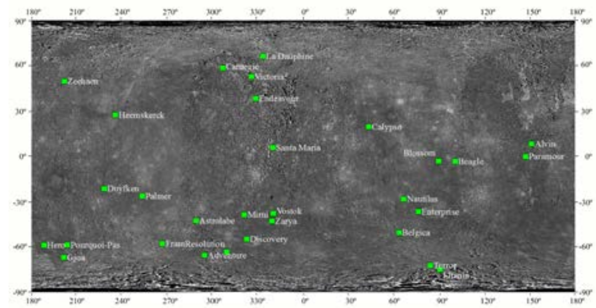

Figure 1. Locations of Mercury's 30 officially named major rupēs (MDIS monochrome map in equirectangular projection).

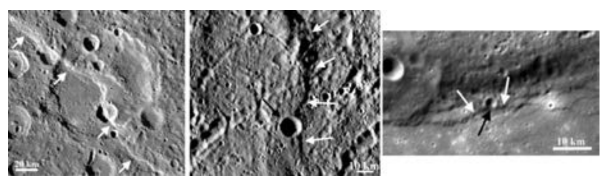

Figure 2. Left panel: Carnegie Rupes (white arrows) transects several degraded craters (e.g., Duccio crater in center) that are Calorian or older (MDIS image mosaic). Center panel: Victoria Rupes (white arrows) superposed by a partially degraded crater (black arrow; 33.4°N, 327.7°E; MDIS image mosiac) interpreted to be Calorian or older. Right panel: Enterprise Rupes (white arrows) cutting a small crater ~2.7 km in diameter (black arrow, 37.85° S, 70.85° E; MDIS image EN0252267858M).

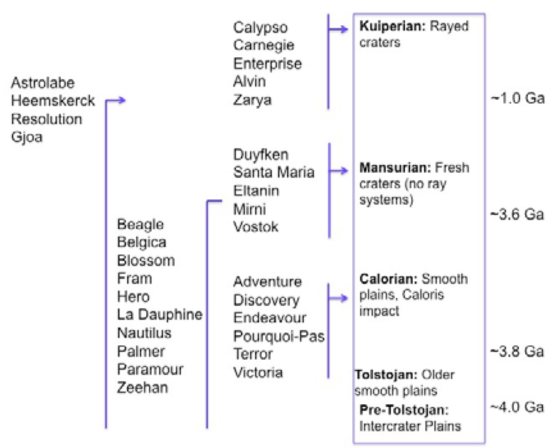

Figure 3. Mercury's named scarps categorized by estimated upper and lower limits for the age of most recent observable activity on the underlying thrust faults.