DURATION OF ACTIVITY ON LOBATE-SCARP THRUST FAULTS ON MERCURY. Maria E. Banks[1], Christian Klimczak[2], Zhiyong Xiao[3,4], Thomas R. Watters[1], Robert G. Strom[3], Sarah E. Braden[5], Clark R. Chapman[6], Sean C. Solomon[2,7], Paul K. Byrne[2,8], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, USA, banksme@si.edu. [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA. [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85719, USA. [4]China University of Geosciences (Wuhan), Wuhan, Hubei, P. R. China, 430074. [5]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281, USA. [6]Department of Space Studies, Southwest Research Institute, Boulder, CO 80302, USA. [7]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA. [8]Lunar and Planetary Institute, Universities Space Research Association, Houston, TX 77058, USA.

Introduction: Contractional crustal deformation on Mercury is expressed by three main types of structure: lobate scarps, high-relief ridges, and wrinkle ridges [e.g., 1–4], with lobate scarps 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. Their formation has been attributed primarily to compressional stresses produced by interior cooling and global contraction [1–3,5]. 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].

The temporal extent of thrust fault activity on Mercury is, however, not well documented. We use data from the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) [6,7] spacecraft to analyze stratigraphic relationships between lobate scarps and other geologic features and units to understand the timing and duration of lobate scarp activity. Determining 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].

Duration of lobate scarp activity: *Constraints on the earliest thrust faulting.* On the basis of size-frequency distributions of impact craters, the oldest surfaces on Mercury are estimated to have been emplaced during or prior to the late heavy bombardment (LHB) of the inner solar system [8]. Widespread volcanic smooth plains were emplaced shortly after the LHB [8], at the end of the Calorian system [9]. The Calorian is followed chronologically by the Mansurian and Kuiperian systems [9]. 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]. However, many scarps are superposed by relatively fresh craters (characterized by crisp morphologies with well-preserved rims and few or no superposed craters) that were formed in the Mansurian and Kuiperian (Fig. 1), whereas other scarps are superposed by partially degraded craters of Calorian age or older (Fig. 2), suggesting that these latter fault segments have been inactive since the early Mansurian.

For some of Mercury's longer scarps (Enterprise, Carnegie, Belgica, Beagle, Eltanin and Duyfken Rupēs), size–frequency distributions were determined for craters that intersect the scarp face and immediately surrounding surface; only craters for which the centers overlapped the count area were included. Preliminary results are consistent with initiation of activity possibly as early as near the beginning of the Calorian and, in areas where a sufficient number of superposing craters could be measured (e.g., for Carnegie, Belgica, Eltanin, and Beagle Rupēs), suggest that activity may have ceased on some scarp segments before the end of the Calorian.

To explore this result further, the northern hemisphere digital elevation model (DEM) derived from Mercury Laser Altimeter (MLA) observations [10] was used to define a larger count area for crater size-frequency distribution analysis that included the back scarp terrain of Carnegie Rupes (58.5°N, 306.8°E; Fig. 1) that had been tilted by movement along the thrust fault. Craters with diameters >10 km (i.e., complex craters) [e.g., 11] were identified that had relatively smooth floors. Under the assumption that crater floors tilted in the direction of the back scarp slope were modified by activity along the fault subsequent to their formation, profiles extracted from the DEM were used to categorize superposed craters as tilted (and so presumably predating the most recent scarp activity) or not tilted (and so presumably postdating activity on parts of the scarp) [e.g., 12]. Results for this second analysis yielded results similar to that from the analysis that included only craters intersecting the scarp face; both analyses indicate that activity on at least parts of Carnegie Rupes occurred in the Calorian near the end of smooth plains emplacement. Although segments of the fault 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 several examples of scarps transecting fresh Mansurian-aged craters [9], indicating that the most recent activity on thrust faults underlying these scarps occurred during or after this epoch (Fig. 3A). Lobate scarps are also observed to transect previously unresolved small (<3 km in diameter) and relatively fresh impact craters (e.g., at Calypso Rupes; Figs. 3B and 3C). On the Moon, fresh craters ≤3 km in diameter, with rims only moderately subdued, are estimated to be Copernican in age (<1 Ga) [13]. Also observed on Mercury are small landforms possibly representative of a population of young lobate scarps only tens of kilometers in length (Fig. 3D). These structures are approximately an order of magnitude smaller than the majority of Mercury's lobate scarps, but they are comparable in scale to Copernican lobate scarps on the Moon [14]. Rates of modification of landforms on Mercury are expected to be higher than those on the Moon, particularly rates of degradation by subsequent cratering. Thus small and relatively fresh lobate scarps and impact craters on Mercury are expected to be Kuiperian and should be generally younger than comparable-scale features on the Moon.

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. Images acquired by MESSENGER also suggest the recent formation of small scarps and the reactivation of earlier, larger scarps (e.g., Calypso Rupes) into the Mansurian and Kuiperian. Altogether, these observations demonstrate that global contraction has been a widespread process on Mercury since the LHB and into the Kuiperian. Continuing analysis of images and topographic data acquired by the MESSENGER spacecraft will provide further insight into the spatial and temporal distribution of tectonic activity, and thus of Mercury's rate of interior cooling through time.

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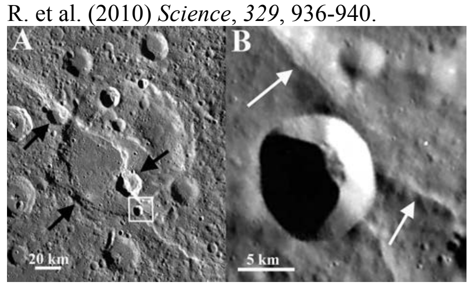

Figure 1. (A) The Carnegie Rupes lobate scarp transects several degraded craters (e.g., Duccio crater) that are Calorian or older (black arrows; MDIS image mosaic). (B) The scarp is itself superposed by a Mansurian crater (MDIS image EW0213286352G). White arrows in (B) point to the earlier-formed scarp; the location of this panel is indicated by the white box in (A).

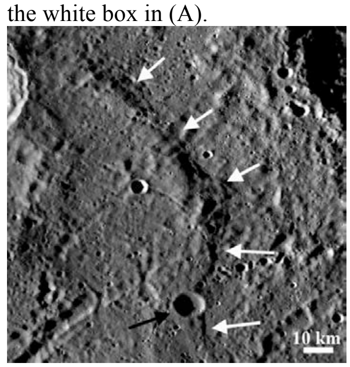

Figure 2. Lobate scarp (white arrows) superposed by a partially degraded crater (black arrow; 33.4°N, 327.7°E; MDIS image mosiac) interpreted to be Calorian or older.

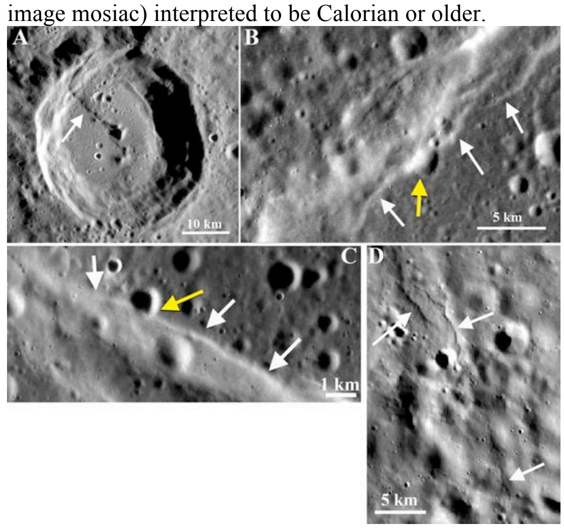

Figure 3. (A) Lobate scarp (white arrow) transecting a Mansurian crater (11.3°N, 0°E; MDIS image EN1015163976M). (B) and (C) lobate scarps (white arrows) transecting relatively fresh craters (yellow arrows) <3 km in diameter (B: 44.8°N, 77.2°E; MDIS image EN0239330240M; C: Calypso Rupes: 19.2°N, 40.1°E; MDIS image EN0250131823M). (D) Series of candidate small scarp segments (white arrows; 63°N, 302°E) each between ~4 and 10 km in length (MDIS image EW0243710157G).