CHRONOLOGY OF LOBATE SCARP THRUST FAULTS AND THE MECHANICAL STRUCTURE OF MERCURY'S LITHOSPHERE

T. R. Watters[1], **F. Nimmo**[2] and **M. S. Robinson**[3], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560 (twatters@nasm.si.edu); [2]Department of Earth Sciences, University College London, Gower St, London, WC1E 6BT, England, UK. (nimmo@ess.ucla.edu); [3]Department of Geological Sciences, Northwestern University, Evanston, Illinois 60208 (robinson@eros.earth.nwu.edu).

Introduction: The timing of the thrust faulting that formed lobate scarps on Mercury is important in constraining the mechanical and thermal structure of Mercury's lithosphere. Previous estimates suggest that thrust faulting initiated after the emplacement of the pre-Tolstojan intercrater plains and continued through the Calorian Period [1, 2, 3]. Refined estimates of the timing of lobate scarp formation are reported based on mapping of the tectonic features on the hemisphere of Mercury imaged by Mariner 10. Estimates of the elastic thickness of Mercury's lithosphere from modeling constrained by depth of faulting are also presented.

Chronology of Lobate Scarps: Relative ages of the lobate scarps were determined by plotting their locations, digitized from Mariner 10 image mosaics with improved geometric rectification [4], overlaid on a geologic map of Mercury [5, 6] (Figure 1). Lobate scarps occur in pre-Tolstojan intercrater plains, and Tolstojan and Calorian smooth plains units (Figure 1) [5, 6]. Younger Tolstojan and Calorian aged smooth plains overlay intercrater plains (Figure 2), estimated to cover up to ~40% of the hemisphere imaged by Mariner 10 [6]. If lobate scarps formed only in the older intercrater plains, the distribution of these structures would be influenced by the areal extent of smooth plains (by burial). Lobate scarp thrust faults, however, deform both Tolstojan and Calorian aged smooth plains units, including the smooth plains surrounding the Caloris basin (Figure 2). No evidence of embayment of lobate scarps by Tolstojan and Calorian smooth plains materials has been found. While lobate scarp thrust faults often deform impact craters, some as large as 60 km in diameter, there are no examples of large impact craters superimposed on lobate scarps. These observations suggest that lobate scarps are younger than Calorian smooth plains, the youngest endogenic unit on the planet. The absence of significant degradation or partial burial of lobate scarps in the northern hemisphere by Caloris ejecta is further evidence of a relatively young age [5]. Lobate scarps in intercrater plains adjacent to the Caloris Basin appear as well preserved as those formed in the surrounding Calorian smooth plains.

Structure of Lithosphere: The mechanical and thermal structure of Mercury's early lithosphere is being investigated by modeling the lobate scarp thrust faults [7,8]. Elastic dislocation modeling of the largest of the known lobate scarps, Discovery Rupes, suggests the underlying thrust fault has a planar geometry and a depth of faulting of 30-40 km [7]. The similar across-strike widths of the other large-scale lobate scarps to Discovery Rupes [9,10] suggest similar depths of faulting. This modeling suggests the depth of the brittle-ductile transition (BDT) at the time the thrust faults formed was 30-40 km [8]. The BDT depth may be related to the effective elastic thickness T_e of the lithosphere if the curvature of the lithosphere is known [11]. The curvature K scales as $K = l / L^2$, where l is the vertical distance and L is the horizontal lengthscale. The three largest lobate scarps have mean values of l and L of 1.2 km and 50 km, respectively, so an appropriate value of K is 5×10^{-7} m^{-1}. The observed curvature and a BDT depth of 30-40 km imply a T_e of roughly 25-30 km (Figure 2). This suggests the value of effective elastic thickness was 25-30 km at the time the thrust faults formed.

Implications: Based on the style of faulting within the Caloris basin, the elastic thickness at the time of smooth plains emplacement has been estimated to be on the order of 75-125 km [3]. The results presented here suggest that the elastic thickness at the time thrust faults cut Calorian smooth plains (<3.9 Gyr ago) may have been no more than ~30 km. The modeling also suggests that the crustal thickness on Mercury is unlikely to exceed 140 km, compatible with estimates of h<200 km based on viscous crustal relaxation [12]. Thus the elastic thickness of Mercury's lithosphere during the Calorian Period may have been significantly less than previously thought.

References: [1] Strom R.G., Trask N.J. and Guest J.E. (1975) *J. Geophys. Res., 80,* 2478-2507. [2] Cordell B.M. and Strom R.G. (1977) *Phys. Earth Planet. Inter., 15,* 146-155. [3] Melosh H.J. and McKinnon W.B. (1988) *in* Mercury, 374-400. [4] Robinson M.S., Davies M.E., Colvin, T.R. and Edwards, K.E. (1999) *J. Geophys. Res., 104,* 30847-30852. [5] Watters, T.R., Robinson M.S., Bina, C.R., and Spudis, P.D. (2004), *Geophys. Res. Letts.,* in press. [6] Spudis, P.D. and Guest, J.E. (1988) *in* Mercury, 118-164. [7] Watters T.R., Schultz R.A., Robinson M.S. and Cook A.C. (2002) *Geophys. Res. Letts*., *29*, 37-1—37-4. [8] Nimmo, F. and Watters, T.R. (2004) *Geophys. Res. Letts.,* in press. [9]

Watters T.R., Robinson M.S. and Cook A.C. (1998) *Geology*, *26*, 991-994. [10] Watters T.R., Robinson M.S. and Cook A.C. (2001) *Planet. Space Sci. 49 (14-15)*, 1523-1530. [11] Watts, A.B. (2001) Cambridge Univ. Press, Cambridge. [12] Nimmo, F. (2002) *Geophys. Res. Letts.*, *29*, 7-1—7-4.

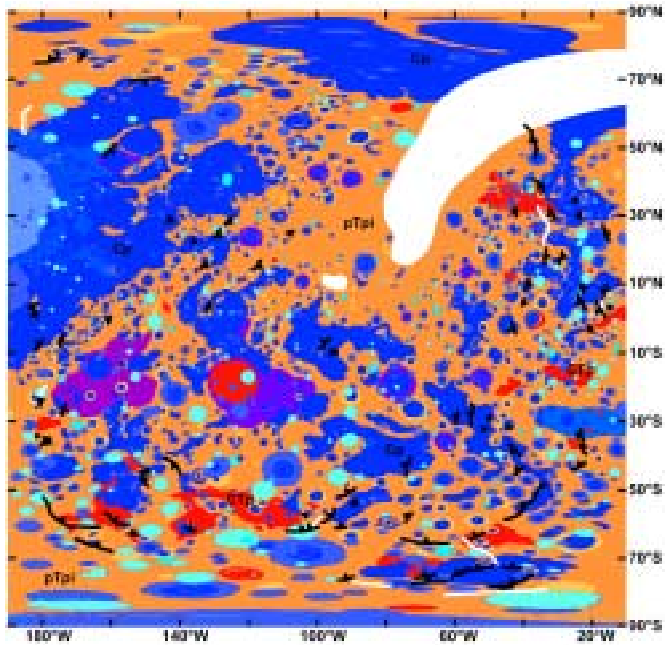

Figure 1. Location of lobate scarps and high-relief ridges on Mercury. Digitized segments of lobate scarps (black) and high-relief ridges (white) are overlaid on the geologic map of Mercury [6]. The major geologic units are intercrater plains material pTpi (tan), Calorian-Tolstojan plains material CTp (red), and Calorian plains material Cp (blue). Black triangles indicate the dip directions of the thrust faults.

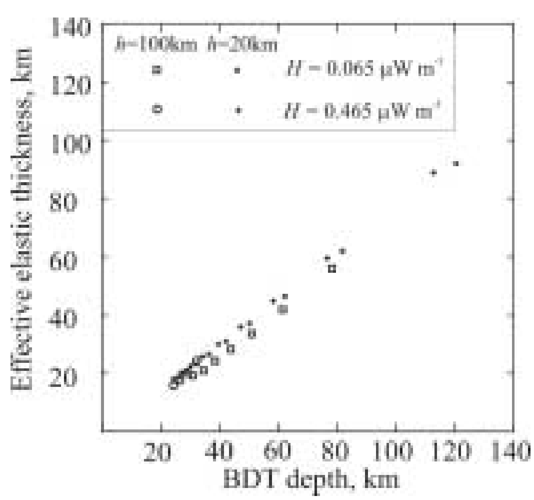

Figure 2. Predicted effective elastic thickness T_e and BDT depth as a function of crustal thickness *h* and crustal heat generation rate *H*. For each combination of *h* and *H* points were generated by increasing the heat flux into the base of the crust F_b in 5 mWm^{-2} increments from 10 mWm_2 (except for *h*=100 km, *H*=0.065 μWm^{-3}, which starts from F_b=15 mWm^{-2}). More details of the methods employed may be obtained from [8].