TESTING THE TIMING AND RATE OF GLOBAL CONTRACTION ON MERCURY AGAINST ITS CRATERING RECORD. Kelsey Crane1 (kelsey.crane@uga.edu), Christian Klimczak1 (klimczak@uga.edu), Structural Geology and Geomechanics Group, Department of Geology, University of Georgia, 210 Field Street, Athens, GA, USA.

Introduction: Mercury experienced a reduction in volume due to secular planetary cooling [1], a process referred to as global contraction. Such decrease in volume, and thus radius, led to shortening and brittle failure in the lithosphere accommodated by thrust faults, which formed prominent positive relief landforms [2]. Although the amount of radius change on Mercury has been estimated from detailed mapping of thrust fault-related landforms to be ~5-7 km [3], the timing and rate of contraction has been less rigorously studied. Based on observations of faults in old, heavily cratered units [4], the onset of contraction must have occurred soon after the end of the Late Heavy Bombardment (LHB) and continued through much of the planet’s history [5]. Variations in the rate of contraction have not been studied in detail using geologic techniques. Thermal evolution models show that a wide range of boundary conditions produce different temporal solutions that lead to the observed planetary radius change [6-8], and thus, a more thorough understanding of the rate at which global contraction operated through geologic time is essential to further characterize Mercury’s geologic history.

Faults and Craters on Mercury: Several thousands of thrust fault-related landforms caused by global contraction occur on Mercury’s surface [3]. Impact structures are also globally distributed (Fig.1), differing in size and degradation stage [5], attesting to a long history of varied magnitude impacts. Because impact cratering and thrust faulting operated contemporaneously across the entire surface for the majority of Mercury’s geologic history, the stratigraphic relationships between craters and thrust fault-related landforms preserve information about the timing [5] and rate of global contraction. For our analysis, we utilized and extended a global crater dataset with diameters greater than 40 km [9] to include craters as small as 20 km in diameter (Fig. 1). Geospatial analysis between faults and the crater dataset (n=7835) reveals that 1938 craters spatially coincide with faults (Fig. 2, blue circles). Of these craters, 1590 were cut by faults and 348 were not cut by faults (Fig. 1, insets). The oldest and youngest deformed craters bound the maximum range in which global contraction was active. The population of craters that are deformed or superpose thrust faults, along with the crater degradation stages [5] can then be used to obtain better insights into the rate at which global contraction operated.

Models for Cratering and Contraction Rate: Mercury’s cratering rate is closely tied to that derived for the Moon [10-11]. In the first 1 Ga of Mercury’s formation, impacts were larger and more numerous, decreasing in size and frequency exponentially with time. We integrated Mercury’s cratering model [11] to achieve a simple analytical solution (over 0 to 4.1 Ga) and numerical solution (over 4.1 to 4.5 Ga) for cumulative cratering rate (Fig. 2, red curve).

Heat from differentiation caused Mercury to initially expand followed by long, sustained cooling and contraction over the remainder of its geologic past [e.g., 1]. Thermal evolution models produce a wide array of solutions for global contraction, but

Figure 1. Global map of craters on Mercury shown in equirectangular projection. Craters displayed in red are not spatially associated with a thrust fault whereas the ones marked in blue spatially coincide with thrust faults.
among them contraction rates generally show two primary trends: one follows a relatively constant rate and the other expresses an initial sharp increase, followed by a mostly constant rate [e.g., 1,6,8]. Accordingly, we chose a constant model with onset at 3.7 Ga [5] and one representative of a non-constant contraction rate approximated from thermal model results [6] with onset at 4.5 Ga (Fig. 2). Both curves are shown as cumulative plots with the slopes indicating contraction rate.

In Fig. 2, the cratering and contraction rates are both expressed as the cumulative percentage that has occurred through time. Multiplication of these curves provides the probability of craters to be cut as a function of time. If the sub-population of craters coinciding spatially with faults is representative of Mercury’s total crater population, then this calculated probability allows for the statistical determination of the percent of faulted craters as a function of time for different rates and onset times of thrust faulting.

Preliminary Results and Conclusions: Mercury’s geologic history is divided into five systems: the pre-Tolstojan (> 4.0 Ga), the Tolstojan (4.0 to 3.9 Ga), the Calorian (3.9 to −3.5 to 3.0 Ga), the Mansurian (~3.5−3.0 to 1.0 Ga), and the Kuiperian (< 1.0 Ga) [see 5]. Recent studies indicate that the Kuiperian may be shorter and more recent than 1 Ga [12]. Global contraction operated gradually through most of these systems. Craters emplaced in the earlier time-stratigraphic systems have a greater probability of being deformed by faults and conversely younger craters have a greater probability of superposing a fault and being undeformed for both studied examples of contraction rates (Fig. 2). Global contraction in the constant model (Fig. 3, dark gray) did not commence until 3.7 Ga, so 100% of craters emplaced before the Calorian, if spatially coinciding with a fault, are expected to be cut by that fault. The probability of being cut drops steeply from 100% in the Calorian to 87% in the Mansurian and 27% in the Kuiperian. The non-constant model (light gray) shows a decrease from the pre-Tolstojan 100%, Tolstojan 78%, Calorian 75%, Mansurian 66%, to Kuiperian 21%. Note that because the cratering rate sharply decreased during the Kuiperian, this percentage accounts for very few craters. In future work, a detailed analysis of degradation stages of the 1938 craters will enable us to gain a better understanding of the contraction rate on Mercury.

Figure 3. Probabilities of craters being cut by thrust faults for two representative contraction rates. Both the constant (dark gray) and non-constant models show decrease in probability of being cut by a fault with age. PT=pre-Tolstojan, T=Tolstojan, C=Calorian, M=Mansurian, K=Kuiperian.