EVALUATION OF THE ORIGIN HYPOTHESES OF PANTHEON FOSSAE, MERCURY.

C. Klimczak[1], A. L. Nahm[1] and R. A. Schultz[1], [1]Geomechanics-Rock Fracture Group, Department of Geological Sciences and Engineering/172, University of Nevada, Reno, NV 89557-0138, USA (klimczak@unr.nevada.edu).

Introduction: Since its discovery during the first flyby of the MESSENGER spacecraft, the origin of Pantheon Fossae (PF), a complex structure consisting of radial graben in the center of the Caloris Basin, Mercury, has been intensely debated. Several studies looked at the larger context for its formation, where three different formation theories have been suggested, i.e. basin-interior uplift [1, 2, 3], graben formation as surface expressions of dike intrusions [4], and an origin associated with the 40km- diameter Apollodorus crater [5], located near the center of PF.

Basin-interior uplift was proposed to have occurred as the result of loading by an external annular load [2, 6] with a bull´s-eye gravity anomaly (central positive anomaly surrounded by a ring of lower gravity and another ring of high gravity) [2]. Furthermore, lateral crustal flow [3], caused by a horizontal pressure gradient associated with thinner crust beneath the basin than beneath the surrounding areas, is also suggested to have caused basin-interior uplift.

Graben formation as a result of dike intrusions would be explained by the formation of a magma reservoir below the surface of PF. Over-pressurization of the reservoir would have resulted in the radial intrusion of dikes, which then caused the grabens to form at the surface [7].

The location of the Apollodorus crater near the center of the PF structure raised the question of a connection between them. The Apollodorus impact is believed to have caused a sudden change of the stress state. Stress changes traveling at seismic speeds are suggested to have caused the faulting to propagate with rupture propagation speeds (in km per second). The relative timing of the impact and graben faulting at PF are demonstrated by the observable ejecta cover on the graben closest to the crater [5].

We test these hypotheses with a detailed study of the graben pattern on MESSENGER image PIA10397, a strain analysis along 5 concentric traverses, and an analysis of the loading of the Mercurian lithosphere [8].

Graben Geometry: An inspection of the graben pattern shows two distinct generations of normal faults (Fig. 1). The first (set 1; red) consists of evenly spaced graben with uniform graben width, consistent with stratigraphic restriction of these faults [9]. This shows that the crater floor of the Caloris basin is layered stratigraphically and a calculation of graben depths from throws (calculated from shadow-length measurements) and fault dip angles (inferred from basalt frictional strength) points to faulting for set 1 graben (Fig. 1) to occur to depths of approximately 1.2 to 2.1 km.

The second set (white) of graben is younger; these graben crosscut and curve into the graben of set 1. Graben of set 2 are generally wider and their widths are not uniform, with graben width decreasing towards the ends. They do not appear to be stratigraphically restricted, and the faulting occurs to depths of approximately 5.6 km.

It appears that the ejecta blanket of the Appolodorus crater covers parts of the graben of set 2 and, to an extent, also graben of set 1. If set 2 graben formed after set 1 graben but ejecta covers set 2 graben, the very short timing of the formation of PF according to the Appolodorus impact hypothesis becomes unlikely.

Furthermore, the graben linkage pattern does not appear to be consistent with the magmatic origin hypothesis. Igneous intrusions are likely to cause segmented, en echelon geometries [e.g. 10, 11]. However, most of the pattern of PF reflects a more random distribution of the mapable radial graben with stepovers of varying senses and minimal to no overlaps of graben segments. This pattern points more likely to the uplift hypothesis. Both sets of graben are consistent with a concentric extensional stress field supporting a doming at the center of the Caloris basin. Graben widths of set 1 graben, however, stay constant throughout these graben which is an indication that doming extends well outside the area of PF shown on PIA10397.

Strain analysis: By means of shadow length measurements and sun angles, the amount of extension at a total of 73 graben from both sets was calculated in order to quantify the magnitude of horizontal fault-normal strain along concentric traverses. These traverses are shown in Fig. 1, with three north and two south of the Apollodorus crater. Results indicate an increase in strain towards the center of PF. This is, again, in qualitative accordance with an origin of PF from broad uplift of the center of the Caloris basin.

Loading of lithosphere: To evaluate if the Caloris basin-forming event influenced the formation of PF, we use the pattern of faulting due to excavation of the Caloris basin. The general pattern of faulting due to a broad load on a relatively thin lithosphere [12] is determined using the membrane response to loading.

Here, a broad load has been defined as one with an angular width of ~90º (corresponding to ~3800 km on the surface of Mercury) and a thin lithosphere has been defined as H/R_p = 0.02, or ~50 km [8], where *H* is the lithospheric thickness and R_p is the radius of Mercury (2439 km [8]). The pattern of tectonics from unloading due to an impact has the same magnitude, but opposite sign, to that produced by the pattern due to loading [8]. Working radially outwards, the pattern of faulting at the center of the basin should be disorganized normal faults, then a region of concentric normal faulting, and finally a region of strike-slip faulting [8] if only stress orientations but not their magnitudes or crustal strength are considered [13, 14]. The pattern of faulting near the center of the Caloris basin near PF and Apollodorus crater is not consistent with that predicted by the membrane response due to unloading of a broad load on a thin lithosphere [12], and therefore PF is likely not the result of the Caloris impact event.

Late stage normal faulting, like that seen at PF, may have formed as a result of emplacement of smooth plains exterior to the Caloris basin [2]. Emplacement of these presumably volcanic plains occurred in an annular zone that extends 1 to 3 basin radii (between 750 and 1800 km) from the basin rim [2]. The external plains load must have been thick (at least 5 km) to have modified the dominantly compressional stress field to a dominantly extensional stress field [2].

Conclusions: The full range of proposed origin hypotheses, such as dike intrusions that form grabens as their surface expressions, doming and uplift in the center of the Caloris basin, and the Apollodorus impact theory, for the PF structure in the center of the Caloris basin have been evaluated by using observations and measurements of the grabens themselves. A detailed analysis of the graben geometries, strain calculations of 5 concentric traverses, and the analysis of loading/unloading of the lithosphere were used to investigate the plausibility of the origin hypotheses.

The study of graben geometry revealed 2 sets of graben with different relative ages. Both sets appear to be covered by ejecta from the Appolodorus impact, which stands in contradiction with the sudden formation of PF due to the Apollodorus impact. Also, the pattern of the 2 sets of graben including their segmentation and linkage argue against the dike intrusion hypothesis. This and the increasing extensional strain towards the center of PF point to an origin of PF due to uplift of the central Caloris basin.

References: [1] Murchie S. L. et al. (2008) *Science, 321*, 73–76. [2] Kennedy P. J. et al. (2008) *JGR, 113*, E08004, doi: 10.1029/2007JE002992. [3] Watters T. R. et al. (2005) *Geology, 33,* 669–672. [4] Head J. W. et al. (2008) *Science, 321*, 69–72 [5] Freed A. M. et al. (2008) *in revision, EPSL*. [6] Melosh H. J. (1988) in *Mercury*, Vilas F., Chapman C. R., Matthew M. S., Eds. (Univ. of Arizona Press, Tucson, AZ.1988), 374-400. [7] Pollard D. D. et al. (1983) *Tectonophysics*, *94*, 541–584. [8] Janes D. M. and Melosh H. J. (1990) *JGR, 95,* 21,345–21,355. [9] Soliva R. et al. (2005) *GRL*, *32*, L16302, 10.1029/2005GL023007. [10] Delaney P. T. and Pollard D. D. (1981) *U.S. Geological Survey Professional Paper* 1202. [11] Klügel A. et al. (2005) *Bull. Volcano., 68,* 37–46. [12] Schenk P. and Melosh H. J. (1994) *LPS XXV*, 1203-1204. [13] Schultz R. A. and Zuber M. T. (1994) *JGR*, *99*, 14,691–14,702. [14] Andrews-Hanna, J. et al. (2008) *JGR*, *113*, E08002, doi:10.1029/2007JE002980.

Acknowledgements:

We thank Dr. Andrew Freed for providing a preprint of [5].

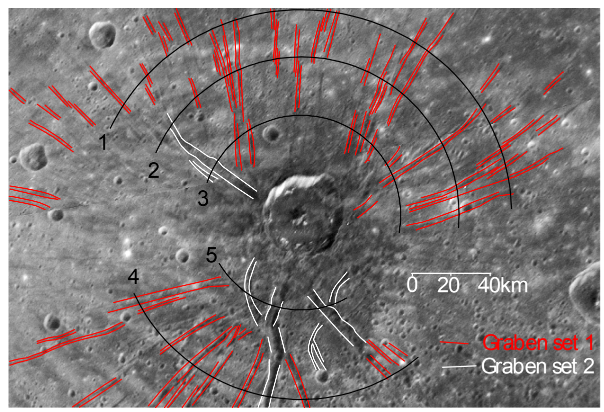

Fig.1. Pantheon Fossae structure with the Apollodorus crater in the center of the image, showing 2 different sets of graben (red, white) and the 5 strain traverses (black).