LESSONS LEARNED FROM LARGE IMPACT BASINS ON MARS H. V. Frey, Geodynamics Branch, Goddard Space Flight Center, Greenbelt, MD 20771, Herbert.V.Frey@nasa.gov,

Summary: Impact basins on Mars > 1000 km in diameter number over 30. Crater retention ages for these show they may have formed in a relaltively short period of time, indicate the Mars global magnetic field disappeared rapidly, and provide a minimum age for the recently re-proposed "Borelais Basin". Thickness at basin centers demonstrate that the lowland region of Mars was already thin at the time the large basins formed there, so some earlier process had a major role in the formation of the crustal dichotomy.

Introduction: Very large impact basins on Mars, those with diameters > 1000 km, may number 31, based on 11 new candidates found [1] using a recent crustal thickenss model [2]. The distribution and crater retention ages of these very large and mostly very old impacts provides important information on the origin of the crustal dichotomy on Mars [3,4], the demise of the global magnetic field [5], the character of the Late Heavy Bombardment on Mars and possibly elsewhere in the inner solar system [6], and the age [4,7] of the recently re-proposed "Borealis Basin" [8]. Below we summarize these results, which, taken together, imply that the earliest history of Mars was dominated by these impacts and the effects derived from them.

Large impact basins and the crustal dichotomy. We previously suggested [3] the crustal thickness at the centers of large impact basins of similar size in the lowlands and highlands of Mars suggested that the region in which the large lowland basins formed was already thinner than the highlands at the time the basins formed. A more recent crustal thickness model [2] and the larger number of very large basins now recognized on Mars supports this idea [4]. Figure 1 shows a plot of central basin crustal thickness versus basin diameter for basins older than Hellas.

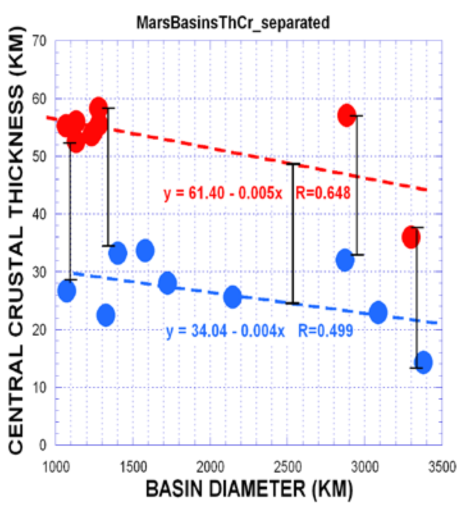

Figure 1: Crustal thickness at basin center vs basin diameter for large highland (red) and lowland (blue) basins. Both areas show the same trend of thinner crust for large basins, as expected, but the two trends are systematically offset by about 25 km in this crustal thickness model [2].

The Late Heavy Bombardment on Mars. N(300) craster retention ages of the 20 largest impact basins on Mars [6] showed a peak between 2.5 and 5 [6]. When converted to a Hartmann-Neukum model chronology, the "absolute ages" suggested most of the basins had formed in a relatively short time, perhaps 150-200 MY (if the crater retetion ages are formation ages). Newly identified large impact basins [1] reinforce this apparent brief duration of very large basin formation, as shown in Figure 2. Though some of the new candidate basins are the oldest yet seen (N(300) CRA > 7), the model absolute ages are not significantly older and the sharp peak remains. As we previously suggested [6] this may support a Nice-type Late Heavy Bombardment on Mars and throughout the inner solar system.

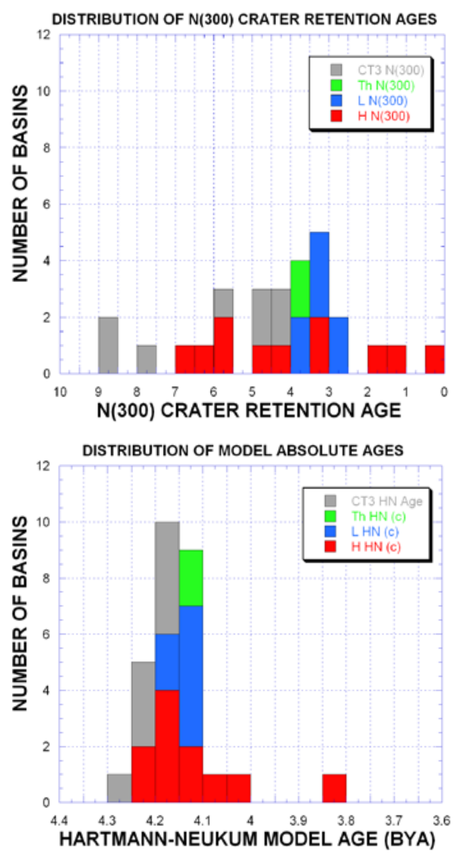

Figure 2. N(300) crater retention ages (top) and inferred Hartmann-Neukum model ages (bottom) for 28 large basins > 1000 km diameter on Mars. Red = highland basins, blue= lowland basins, green = Tharsis basins, grey = candidate basins newly identified in a more recent crustal thickness model [2].

Demise of the global magnetic field. Lillis et al. [5] showed that the ages of the large impact basins were closely correlated with their magnetization: old basins had high magnetization suggesting they were remagnetized following the impact. The youngest 5 basins had very low magneitzation, suggesting they were not remagnetizaed because they formed after the global magnetic field disappeared. The newly identified large basins [1] reinforce this: all the new candidates are old [see above] and all have high magnetization [1,4], as shown in Figure 3 below.

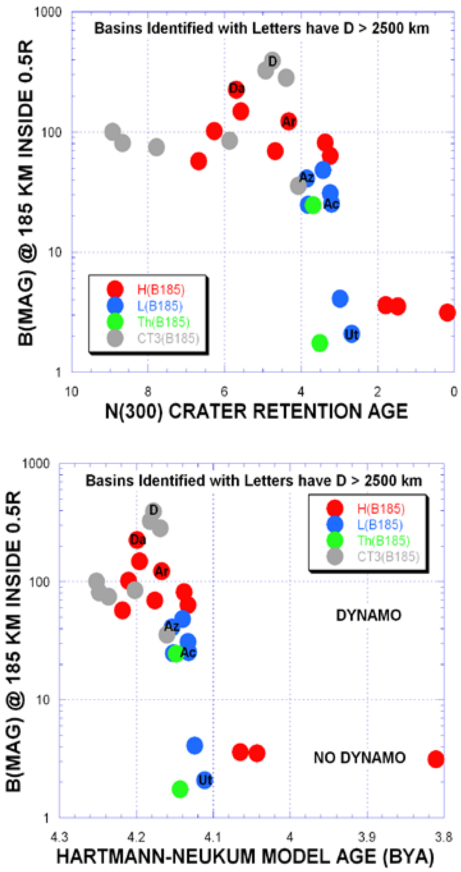

Figure 3: Magnetization at centers of large basins vs basin age. Top: N(300) crater retention age. Bottom: Hartmann-Neukum model age. Color code as in Figure 2. As shown in Lillis et al. [5], there appears to be an abrupt change from dynamo to non-dynamo conditions on Mars, perhaps at about 4.13 BYA.

Age of the Borealis Basin. As indicated above, there is good reason to believe that the crust in the region where the lowlands exist today was already thinner than that in the highlands at the time the large basins formed [3,4]. Some earlier mechanism must have operated. If a process like the formation of a very large, elliptical "Borealis Basin" [5] resulting from a giant, oblique impact, it is possible to put constraints on the minimum age of the basin. As shown in a companion abstract [7], the Borealis Basin must be older than the oldest large basin which is superimposed on it. That basin, candidate "F" found in the most recent crustal thickness model [2], has an N(300) CRA of 4.08 and an inferred model age of 4.16 BYA. But the cumulative frequency curves for basins > 1000 km diameter inside and outside the Borealis Basins are, within their errors, the same, suggesting the Borealis Basin likely formed before all of the currently recognized large impacts basins, both inside and outside it. If true, the N(300) age of the Borealis Basin is > 8.93 (the age of the oldest smaller basin, "B") or 4.25 BYA in the Hartmann-Neukum chronology.

A puzzling latitude vs age distribution. Figure 4 below shows a plot of the latitude of the largest basins vs their N(300) CRA and the inferred model absolute age. Symbols indicate basin diameter. For nearly all the basins larger than 2000 km diameter, there appears to be a systematic change in latitude from north-to-south-to-north-to south over time [4]. The one glaring discrpency is Scopolus, a large basins which has the most uncertain age because the much more recent Isidis Basin covers more than 2/3 of the older basin. Given that large basins should generally form near the equator, this systematic pattern is puzzling and, unless there has been significant polar wander on Mars, hard to explain.

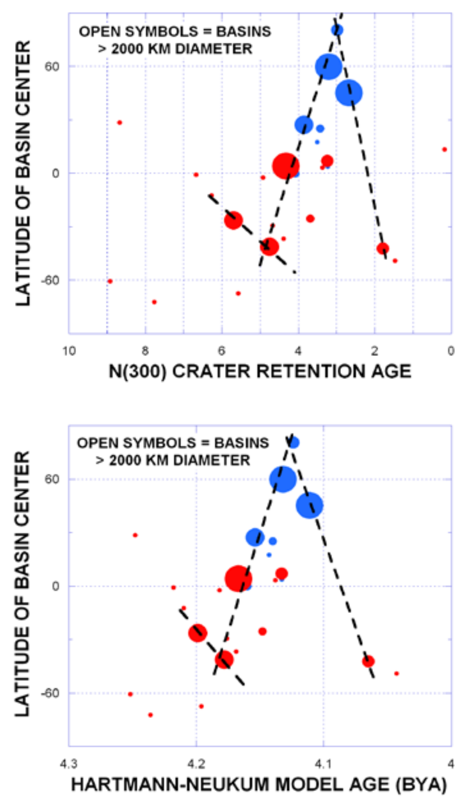

Figure 4. Latitude vs time for large basins on Mars. Top = N(300) CRA. Bottom = inferred Hartmann-Neukum model age. Red = highland basins, blue = lowland basins.

References. [1] Frey, H.V. (2009) LPSC 40, abstract #1123. [2] Neumann G.A. et al. (2008) LPSC Abstract # 2167. . [3] Frey, H.V. (2008) LPSC 39 abstract # 1342. [4] Frey, H.V. (2009) GSA Annual Meeting Paper 135-4. [5] Lillis, R., H. V.Frey and M. Manga (2008) GRL 35, L14203, doi: 10.1029/2008GL034338. [6] Frey, H.V. GRL 33, L08S02, doi:101029/2005GL024484. [7] Frey, H. (2010) LPSC 41, abstract #1136 (this meeting). [8] Andrews-Hanna, J. et al. (2008) *Nature*, *453*, 1212-1215.