**A MINIMUM CRATER RETENTION AGE FOR THE PROPOSED "BOREALIS BASIN" ON MARS** H. V. Frey, Geodynamics Branch, Goddard Space Flight Center, Greenbelt, MD 20771, Herbert.V.Frey@nasa.gov,

**Summary:** A minimum (N1000) crater retention age (CRA) for the proposed "Borelais Basin" (BB) on Mars can be derived from the cumulative number of very large (D>1000 km) impact basins on Mars that lie within the BB. Also, the N(300) CRA of the BB must be older than the N(300) CRA of the earliest large basin which formed within it. We find that the BB most likely predates all the very large basins on Mars, including those outside it, suggesting that, if real, the formation of this proposed dichotomy-forming impact likely resurfaced the entire planet and effectively reset the crustal ages over the entire surface. The BB likely has N(300) > 9 and a model absolute age > 4.3 BY.

**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]. N(300) crater retention ages for 28 of these basins based on superimposed basins (both visible and revealed in topography or crustal thickness data) suggest they all formed in a relatively short period of time [1,3], perhaps supporting a Nice-like Late Heavy Bombardment on Mars.

The idea that the crustal dichotomy on Mars was formed by a giant impact [4] has been re-invoked, with the further suggestion that this was a low angle oblique impact [5], which better accounts for the likely pre-Tharsis shape of the lowlands of Mars. If real, this "Borealis Basin" (BB) impact must pre-date all the large impact basins in the lowlands of Mars. The lowlands cannot be explained entirely by the large impacts seen there, as previously suggested [6, 7], because the crust in that region must have already been thinned by some earlier process to explain the systematic thinner basin-center crust found in large impact basins there compared with that in basins of the same size in the highlands of Mars [3, 8, 9, 10 this meeting]. But the fact that large lowland basins are superimposed on the BB provides a way to determine a minimum crater retention age for the BB.

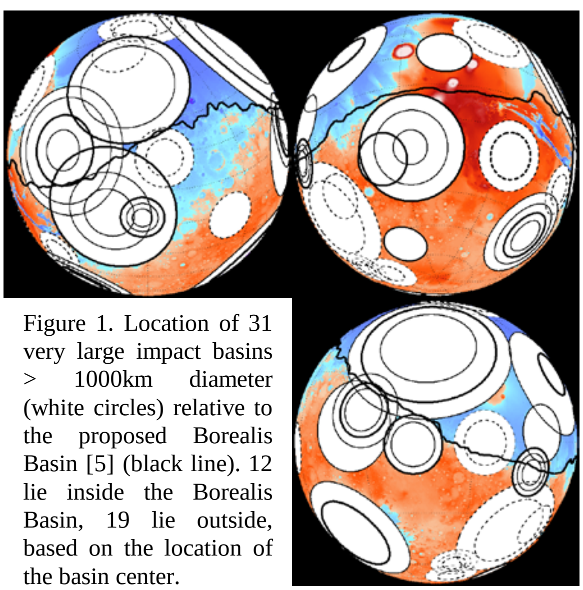

Figure 1. Location of 31 very large impact basins > 1000km diameter (white circles) relative to the proposed Borealis Basin [5] (black line). 12 lie inside the Borealis Basin, 19 lie outside, based on the location of the basin center.

**Large basins inside and outside the Borealis Basin.** Figure 1 shows the distribution of 31 very large basins (D > 1000 km) currently recognized on Mars [1] compared with the proposed Borealis Basin [5]. Based on the centers of the large impacts, there are 12 that lie inside the BB and 19 that lie outside. Obviously those basins which lie inside the BB must have formed after it. There are in addition several that lie on the edge or "rim" of the BB which are also likely younger it. Below we show that even those large basins which lie outside the propose rim of the BB are likely to post-date the impact which formed the BB, which has implications for the extent of the effects of this giant impact.

**Ages of large impact basins on Mars.** N(300) crater retention ages for 28 of the basins are shown in Figure 2, separated by those inside (blue) and those outside (red) the proposed Borealis Basin. Also shown are model absolute ages based on a Hartmann-Neukum [11] chronology. All the basins appear to have formed in a relatively short period of time, if the CRAs and the inferred model absolute ages do in fact represent formation ages. Those inside the BB tend to be on the whole younger than others, and group rather tightly at N(300) < 4.5, or <4.2 BYA in model absolute age. The oldest of the "inside BB group" is basin "F", found [1] in the most recent crustal thickness model [2]. It's N(300) CRA is 4.08 and the inferred model absolute age is 4.16 BYA.

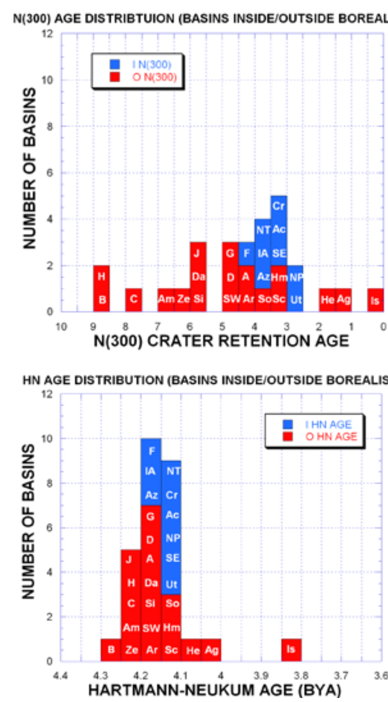


Figure 2. N(300) crater retention age (top) and Hartmann-Neukum model absolute age for 28 basins on Mars > 1000 km diameter. Blue = basins with centers inside the Borealis Basin, Red = basins with centers outside the Borealis Basin.

Because the Borealis Basin must be older than the oldest smaller basin superimposed on it, it is tempting to suggest that basin "F" provides a minimum age for the larger dichotomy-forming impact. That is, the BB would have an N(300) CRA > 4.08 and an inferred model absolute age > 4.16 BYA. But most of the very large basins (older than Hellas) formed in a relatively narrow interval of time before 4.3 BYA in the model absolute chronology (N(300) CRA < 9.0). For an impact of the size that would produce the BB it is likely the interior of the basin would take somewhat longer to stabilize than the regions outside the immediate impact. An obvious question is: Is it possible the clustering of ages for the "inside BB" group reflects this, and the basins just slightly older may also post-date the Borealis impact?

The largest basins can be used to determine an N(1000) crater retention age for the area inside and outside the basin, although with poor statistics. Note that the ratio of basins with centers inside the BB (12/31 = 39%) compared with those outside the BB (19/31 = 61%) is close to the ratio of the area inside BB (41%) or outside BB (59%) to the whole surface area of Mars. That is, the density of basins > 1000 km diameter inside and outside the BB is approximately the same. Figure 3 shows a more careful accounting in the form of a cumulative frequency curve for the basins inside and outside the Borealis Basin, compared with that for the entire surface area of Mars.

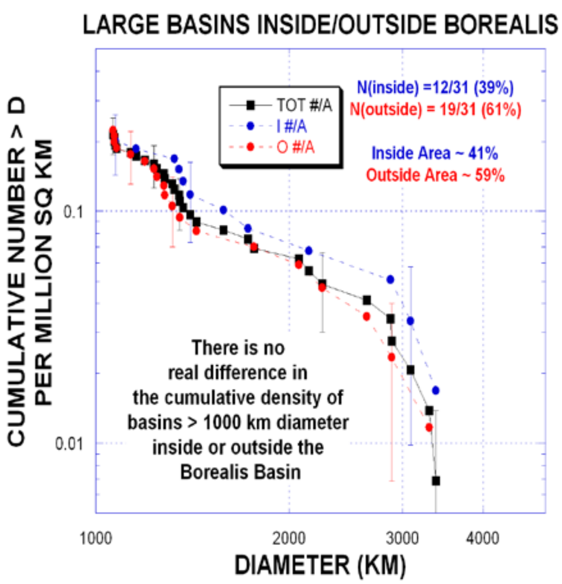


Figure 3. Cumulative frequency curves for very large basins with centers inside (blue) or outside (red) the Borealis Basin, compared with that for the whole of Mars (black). Although the curves for inside and outside appear separable, within their errors they are the same. The N(1000) cratere retention age inside the BB (0.202 +/- 0.058) and outside the BB (0.233 +/- 0.051) are essentially identical.

The N(1000) crater retention ages (cumulative number > 1000 km diameter per million square km) inside and outside the BB are essentially the same, within their errors (inside = 0.202 +/- 0.058, outside = 0.233 +/- 0.051). Based on the density of the largest impact basins, the entire surface area of Mars has the same N(1000) CRA, roughly 0.218.

This suggests the Borealis Basin likely predates ALL the very large basins recognized in both the highlands and lowlands of Mars. That is, the BB is older than the oldest recognized smaller basin anywhere on Mars, not just older than the oldest one inside the BB. Using this measure, the BB has an N(300) CRA older than basin "B", that is, > 8.93, or 4.25 BY in the model absolute chronology.

**Discussion:** If real, the Borealis Basin must predate all smaller basins superimposed on it. Overall the density of very large basins inside and outside the BB is the same: all of Mars has roughly the same N(1000) surface age. This may in fact be due to the formation of the Borealis Basin: an impact of this size could well completely resurface the entire planet and reset the crater retention ages. The large basins inside BB tend to have younger N(300) CRAs than most of those outside it (except for the youngest Hellas, Argyre and Isidis). This tight age clustering of "inside BB" basins suggests the interior of the basin may have stabilized slightly later (~ 50 MY?) than the area outside the BB, which seems reasonable for an impact of this size. Thus the formation of the crustal dichotomy, if due a a giant oblique impact [5], may have had the additional effect of resetting the surface ages for the entire planet. If true, the BB impact is the oldest structure we see and can see on Mars.

**Conclusions:** Based on the density of very large impact basins inside and outside the proposed Borealis Basin, the N(1000) CRA for the giant impact is > ~0.218, which is the average surface CRA everywhere on Mars. The N(300) CRA of the oldest basin inside Borealis is 4.08, with an inferred model absolute age of 4.16 BY. But given the likelihood that Boreals formed before all of the very large basins currently recognized, its N(300) CRA is > 8.93 and the inferred model absolute age is > 4.25 BY.

**References.** [1] Frey, H.V. (2009) LPSC 40, abstract #1123. [2] Neumann G.A. et al. (2008) LPSC Abstract # 2167. [3] Frey, H.V. (2009) GSA Annual Meeting Paper 135-4. [4] Wilhelms, D.A. and Squyres (1984) Nature 309, 138-140. [5] Andrews-Hanna, J. et al. (2008) *Nature*, *453*, 1212-1215. [6] Frey, H.V. and R.A. Schultz (1990) J. Geophys. Res. 95, 14,203-14,213. [7] Frey, H.V. GRL 33, L08S02, doi:101029/2005GL024484. [8] Frey, H.V. (2008) LPSC 39 abstract # 1342. [9] Frey, H.V. (2010) LPSC 41 abstract this meeting. [10] Frey, H.V. ((2009) LPSC 41, this meeting. [11] Hartmann, W.K and G. Neukum (2001) Space Sci. Rev. 96, 165-194.