**LARGE-DIAMETER VISIBLE AND BURIED IMPACT BASINS ON MARS: IMPLICATIONS FOR AGE OF THE HIGHLANDS AND (BURIED) LOWLANDS AND TURN-OFF OF THE GLOBAL MAGNETC FIELD** H. V. Frey, Geodynamics Branch, Goddard Space Flight Center, Greenbelt, MD 20771, Herbert.V.Frey@nasa.gov.

**Summary:** The global populations of visible and buried impact basins > 200 diameter revealed by high resolution gridded MOLA indicate: (a) a small (~10) number of very large basins (D=1300-3000km), most of which have remained visible over martian history; (b) a much larger population of smaller basins (D=200-800 km) with many more buried than visible (on images); (c) a depletion of visible basins at intermediate diameters which may be a signature of some global-scale event (formation of the lowlands? origin of Tharsis?); and (d) a crater retention age for the buried lowlands greater than that of the visible highlands but less than that of the total (visible + buried) highlands. Crustal magnetic anomalies are generally not present in the interiors of the largest basins with two exceptions: these two (which appear to be the oldest) may predate the demise of the global magnetic field.

**Introduction:** The discovery of a large population of "Quasi-Circular Depressions" in MOLA data which have little or no visible appearance in image data has been interpreted to suggest there exists a significant population of buried impact basins on Mars [1,2]. These basins have led to a number of important conclusions about the very early age of the buried lowlands and what mechanisms could produce the crustal dichotom. Recently we have also used buried basins found in the earliest Noachian terrain to show there is (buried) crust on Mars older than the oldest observed surface units and therefore Early Noachian terrain visible at the surface must be younger than 4.6 BY [3,4]. These earlier regional studies used MOLA data with less resolution than is currently available. In this paper we present results of a global survey of large QCDs using high resolution MOLA data and suggest there is a slight difference in the ages of the highlands and lowlands of Mars. We also show that the disappearance of the global magnetic field can be placed within a temporal sequence of formation of the very largest impact basins.

**QCDs > 200 km Diameter:** We systematically searched 64 pixel/degree MOLA data for Quasi-Circular Depressions > 200 km diameter. The diameter cut-off for this global survey was motivated by several factors: (a) the total number found (~560) was tractable; (b) features of this size are difficult to bury completely (rim heights 1-1.5 km, depths ~4 km [5]) and therefore might be expected to survive over all of martian history; and (c) this is an appropriate size for comparison with other data such as the distribution of gravity and magnetic anomalies [6-8]. Figure 1 shows polar views of the visible, buried and combined (visible+buried=total) QCDs. The buried population is much greater the visible population in both the northern lowlands and in the southern highlands. The density of all (visible+buried) basins is also much greater in the highlands than in the lowlands, by roughly a factor 4 (much larger than their areal ratio). Finally, there is a population of very large basins (D>1000km) which is equally divided between the two hemispheres. This includes at least one and likely two Utopia-size buried features, one near but not identical to an earlier proposed Daedalia basin [9,10] and the other centered near 4N, 16W. This "Ares" basin, determined from MOLA data, has independent support. The Uzboi-Ladon-Arden Valles through Margaritifer-Iani Chaos depressions form a nearly continuous northward channel system that is radial toward the exact center of the Ares Basin. Ares Valles drains exactly radially away from this center NW into Chryse.

**Cumulative Frequency Curves and Crater Retention Ages:** Whole planet cumulative frequency curves and curves separated by highland/lowland populations show similar characteristics. There is a small (~10) population of very large basins (D=1300-3000km) which follow a –2 power law slope on the log-log cumulative frequency plots. At diameters smaller than ~500 km the total populations in both highlands and lowlands again follow a –2 slope; for the planet-wide visible population this is the same slope as for the very large diameter basins. On a regional basis, the total population for D<600 km for the lowlands lies above the visible highland population, but below the buried (and also below the total) highland population in the cumulative frequency plot. This suggests the lowland crust is slightly younger than the highland crust.

At intermediate diameters (1200 to about 600km) the global visible population of basins falls off the –2 slope before recovering at smaller diameters. The visible and total populations of the highlands have a similar depletion, but the buried population in the highlands does not. We speculate that this depletion of intermediate size basins is the signature of some global-scale event very early in martian history. Two obvious candidates are the formation of the slightly younger lowlands, and the growth of Tharsis, both of which could have removed a small but significant

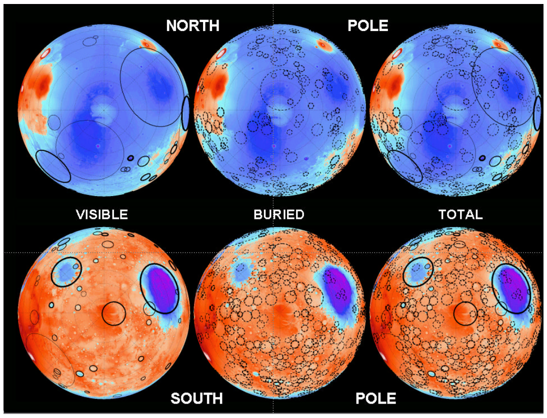


Figure 1: North and South polar views of visible, buried and total (= visible + buried) QCDs > 200 km diameter. Note the larger number of buried basins in both hemispheres, and the larger total number in the south.

percentage of pre-existing intermediate-size basins.

**Comparison with Magnetic Anomalies:** We compared the distribution of QCDs (both buried and visible) with the distribution of magnetic anomalies, both modeled [11,12] and directly observed [7,8]. Very few of the basins <1000km coincide with anomalies, and the small number that do could be just chance coincidence, given the large number and high density of basins (Figure 1). Most of the very large basins do not have prominent magnetic anomalies lying within their main ring, as had been previously suggested for the obvious Hellas and Argyre Basins [7,8]. This is also true for many of the less obvious large basins detected in this study, and consistent with earlier suggestions that these basins may have formed after the global dynamo died [7,8,13]. But two very large basins, Daedalia and especially Ares, do have prominent anomalies lying within their main rings (Figure 2). These two are also likely the oldest of the population, based on their much more subdued nature and larger number of superimposed smaller basins. It may be that Daedalia and Ares predate the disappearance of the global magnetic field.

**A Chronology of Major Events in the Early History of Mars:** We use the cumulative number of basins larger than 200 km diameter per million square km [N(200)] to place the large diameter basins in a chronology that includes the crater retention ages of the highlands and lowlands (Figure 3). The total highland N(200) age is [4.53], based on visible and buried basins. The very ancient Ares Basin is slightly older [3.98] than the buried highland surface [3.89]. The three basins which contribute most to the topography of the lowlands ("lowland-making" basins, Acidalia, Utopia, and Chryse) are all older [N(200) > 2.50] than the buried lowland crust [2.39-2.47], as they should be. Argyre and Isidis formed after the lowland crust, but Hellas may have formed before, just after Chryse. Utopia and Acidalia [3.12-3.27] are older than Hellas [2.68], but like Hellas and the other later basins, may have formed after the global magnetic field died .

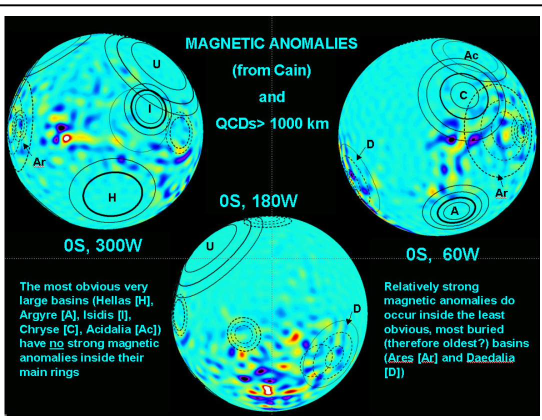


Figure 2. Crustal magnetic anomalies from Cain [11] with QCDs > 1000 km diameter superimposed. Note only Daedalia [D] and Ares [Ar] have prominent anomalies lying inside their main (darker) rings. These two may have formed when the global magnetic field was still present.

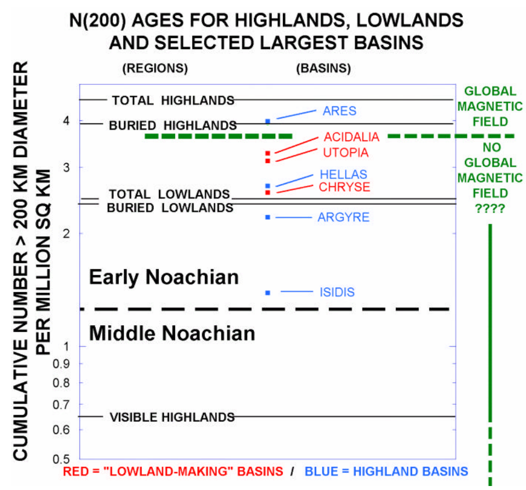


Figure 3: Possible chronology of early events in martian history, including formation of major impact basins before and after presence of global magnetic field, based on crater retention ages for D>200 km.

The relative sequence of basins seems fairly secure and appears consistent with the regional ages based on counts of superimposed impact basins. The line dividing the magnetic field/no-magnetic field eras is less so. It is based on the assumption that basins without anomalies formed after the field disappeared. If some process other than impact demagnetized the crust [e.g., 14], then this line could be substantially lower in Figure 3 and later in martian history.

**Conclusions:** The (visible and buried) large diameter crater populations suggest the buried lowlands are slightly younger than the buried highlands, but significantly older than the exposed highland surface. Formation of the lowlands may have caused a depletion in the intermediate size global population of visible basins. Buried basins outnumber visible basins for all diameters < 500 km, implying a significant hidden but recoverable early history for Mars. Very large basins appear to have separable crater retention ages and the existence or absence of magnetic anomalies in their interiors may suggest that the oldest large basins formed before the magnetic field died.

**References.** [1] Frey, H. et al., GRL 26, 1657-1660, 1999. [2] Frey, H. et al., GRL 29, 10.1029/2001GL013832, 2002. [3] Frey, E.L. et al., GSA Fall 2002 Meeting paper 26-2, 2002. [4] Frey, H. et al., LPSC 34 (this volume), 2003. [5] Garvin, J.B. et al. LPSC 33, abstract 1255, 2002. [6] Smith, D.E. et al., Science 286, 94-97, 1999. [7] Acuna, M.H., et al., Science 284, 790-793, 1999. [8] Connerney, J.E.P. et al., GRL 28, 4015-4018, 2001. [9] Craddock, R.A. et al., JGR 95, 10729-10741, 1990. [10] Schultz, R. A. and H.V. Frey, JGR 95, 14,175-14,189,1990. [11] Purucker, M.E. et al., GRL 27, 2449-2452, 2000. [12] Cain, J. unpublished data, 2001. [13] Hood, L.L. et al., LPSC 33, abstract 1125, 2002. [14} Solomon, S.C. et al., LPSC 34, this volume, 2003.