THE EARLY BOMBARDMENT HISTORY OF MARS REVEALED IN ANCIENT MEGABASINS.

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Introduction: Information regarding the early bombardment of Mars is encoded in its largest basins. Using the record of Mars basins (craters with D_{crat}>300 km) that overprint megabasins (basins with D_{crat}>1000 km), including suspected basins in the form of "Quasi-Circular Depressions" (QCDs) that appear in maps of martian crustal thickness variations [1,2], we show that there are two distinct populations of megabasins on Mars:

1) Ancient basins exist that show evidence of remanant crustal magnetism, subdued crustal thickness expression, and high N(300) Crater Retention Age (CRA).

2) The youngest four basins, Utopia, Hellas, Argyre, and Isidis, show no evidence of crustal magnetism and have large crustal thickness contrast with the surrounding terrain and low N(300) CRA.

Furthermore, we show, using a Monte Carlo basin formation code, that the N(300) CRA of these ancient megabasins is indicative of a population in cratering equilibrium, or saturation.

Megabasins and the Late Heavy Bombardment: Based on the lunar rock record, it has been suggested that the Late Heavy Bombardment (LHB) was a spike in the impact rate onto the terrestrial planets at ~4.1-3.9 Gy ago [3-6]. The similarity of the size-frequency distributions between ancient terrains on the Moon, Mars, and Mercury suggests that the LHB impactors originated in the Main Asteroid Belt and were liberated via a size-independent mechanism, such as resonance sweeping [7,8]. This line of evidence suggests that all ancient terrains are part of a common impactor population, and suggests that LHB-era cratering reached equilibrium, or saturation [9]. In contrast, it has been suggested [10,11] that on the Moon, the heavily-cratered terrains may contain a mix of populations with different SFDs, however this contention has been debated [12,13].

Crustal Thickness and Magnetic Anomolies: Using a crustal thickness model for Mars [2], many large circular depressions that may represent ancient buried basins have been discovered [1]. Using the set of D>300 km basins that overprint the D_{crat}>1000 km megabasins, we calculate the N(300) CRA of several megabasins (Figure 1).

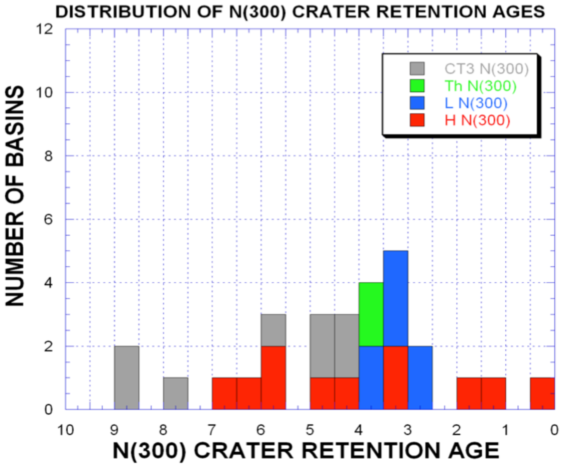

Figure 1 Histograms of N(300) CRA for megabasins on Mars. Red are highland basins, blue are lowland basins, green are basins in the Tharsis region, and grey are new candidate basins derived from the MarsCrust3 crustal thickness model(2).

The four youngest megabasins on Mars (Utopia, Hellas, Isidis, and Argyre) have relatively low N(300) CRA values (<3). These basins are unlikely to be in cratering equilibrium for D_{crat}>300 km craters, and so their N(300) CRA values are related to their ages. These four basins show much more pronounced crustal thickness contrast than the ancient basins. Crustal thickness constrast is measured by taking the ratio between the average crustal thickness, D, at the center of the basin with that outside the rim (Figure 2). In Figure 2 the basin center crustal thickness is defined as the average of D within 0.4 R, where R is crater radius, and the crustal thickness outside the basin rim is defined as the average of D between 1.2 and 1.4 R. The four youngest basins are also distinguished from the ancient megabasins by the weak or non-existent crustal magnetisim associated with them.

The low topographic relief and magnetization of the most ancient megabasins may be a result of formation when Mars had a warmer thermal gradient and a global magnetic field. Models of basin formation into the cooling crust of Mars may help constrain the amount of time that passed between the formation of Utopia basin and the set of ancient megabasins. It is plausible that the timing of both the loss of the martian magnetic field and a change in the rheologic state of the upper mantle that allowed the high crustal thickness contrast of a large basin to persist were concurrent. If this were the case, then the four youngest basins may be a part of a continuous impact flux, and Utopia simply marks the boundary when both the Mars dynamo ended and the upper mantle heat flow become low enough that basins retained substantial inner-/outer crustal thickness contrast. Alternatively, the four young non-magnetized, high contrast basins may represent a population that impacted Mars well after the earlier magnetized basins.

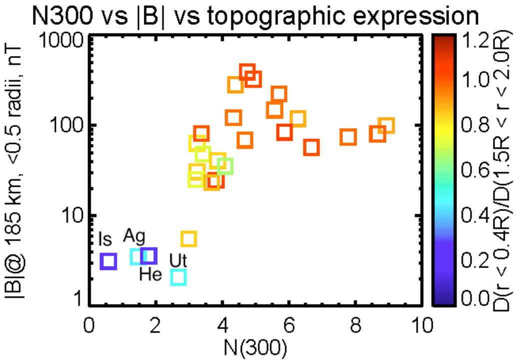

Figure 2 Basin magnetization vs. N(300) CRA age and for megabasins on Mars (D>1000 km). Colors are coded for crustal thickness ratio (inside basin/outside basin). The youngest four basins (Isidis, Argyre, Hellas, and Utopia) show both greater crustal thickness contrast and weaker magnetization than the other basins.

Megabasin Equilibrium Cratering: Using a Monte Carlo basin formation code [14] we show that the population of ancient megabasins shown in Figure 2 that generally have high magnetization, high N(300) CRA, and subdued topography may be in crater equilibrium or saturation. Figure 3 shows the results of our Monte Carlo crater code, plotted has histograms of N(300) CRA values, similar in style to Figure 1. In our code, we track the number of D_{crat}>300 km basins that overprint D_{crat}>1000 km megabasins. The code craters a surface at some rate that is set by the user in arbitrary time interval units. Figure 3 shows the histograms of N(300) CRA for megabasins on the same surface, one set of histograms display 1 time interval after the start of the model and second displays 3 time intervals after the start of the model. The results show that once the surface is in equilibrium total number of megabasins increases, but the peak in the N(300) CRA values remains constant.

The value of the peak of the N(300) CRA histogram depends strongly on the slope of the basin cumulative SFD, where slope refers to the power law index q for a cumulative SFD of the form $N \propto D^q$, as well as the process by which young craters destroy old ones. In equilibrium, the N(300) CRA of individual basins can be modeled as being taken from a normal distribution with a mean that depends on the slope of the basin SFD. The results of our Monte Carlo code also indicate that some change occurred in the most ancient population of impactors recorded on Mars. Two possibilities are that the source region of large impactors was different for these very ancient basins, or that the impactor velocity changed.

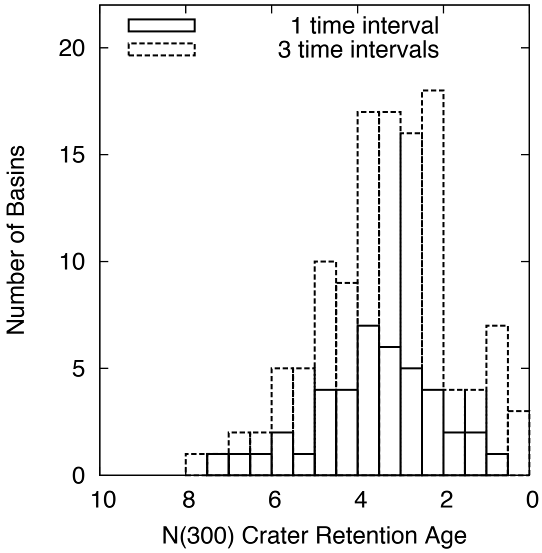

Figure 3 Histograms of N(300) CRA values from a Monte Carlo cratered terrain evolution code. The modeled surface had the same surface area of Mars and the bombardment rate was constant. The solid histogram is the result after one arbitrary time interval, and the dashed line is the result after three time intervals.

References:

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