EVIDENCE FOR BURIED "PRE-NOACHIAN" CRUST PRE-DATING THE OLDEST OBSERVED SURFACE UNITS ON MARS

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Summary: MOLA gridded data shows clear evidence for Quasi-Circular Depressions not visible on images in Early Noachian (EN) terrain units on Mars. We suggest these are buried impact basins that pre-date the superimposed craters whose high density makes these EN units the oldest visible at the surface of Mars. There is crust older than the oldest visible terrain units on Mars, and these EN units cannot date from 4.6 BYA. These and other Noachian units have similar total (visible + buried) crater retention ages, suggesting a common "pre-Noachian" crustal age OR crater saturation beyond which we cannot see.

Introduction: Even though the "Early Noachian" (EN) used in geologic mapping [1,2,3] is undefined at the early end, it is often assumed in absolute chronologies [4,5] to extend back to 4.6 BYA. We explored this assumption by searching for evidence of buried impact basins, [6,7] in the largest occurrences of Early Noachian terrain. The hypothesis is that if such basins exist, they indicate crust which must predate the surface units mapped as the oldest on Mars, and those units must then be less than 4.6 BY old. Alternatively, if no such buried features are seen, then the surface units may represent crust of the same age below, which could in principle be as old as Mars. Here we show the former alternative is true. There must be crust older than the oldest mapped surface units. We also show that a number of Noachian terrains on Mars appear to have a common total (visible + buried) crater retention age. This might be either the age of the original (planet-wide?) crust of Mars, or may indicate crater saturation.

Buried Basins near Hellas and Isidis: The two largest occurrences of EN materials on Mars are the basin rim materials of Hellas (Nh_1, about 1.2 million sq. km) and Isidis (Npl_1, about 0.6 million sq km). Figure 1 shows these units along with Middle Noachian (MN) units near Hellas (Npl_1) and a very large area we call "Arabia", which on average is MN based on its visible crater retention age. We systematically searched 64 pixel/degree MOLA data for Quasi-Circular Depressions (QCDs) >25 km diameter in the Hellas [8] and >15 km in the Isidis [9] areas, and found a significant population of QCDs not visible on images that we assume are buried impact basins. Cumulative frequency curves for the visible, buried and total (visible+buried) populations (Figure 2) have similar shapes, supporting the idea

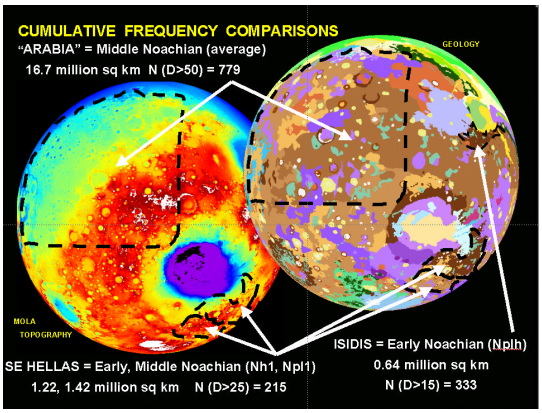

Figure 1: Areas where QCDs were mapped and for which cumulative frequency curves are shown: Early Noachian units SE of Hellas (1.2 M sq km) and south of Isidis (0.6 M sq km) and Middle Noachian units SE of Hellas (1.4 M sq km) and in " Arabia (17 M sq km).

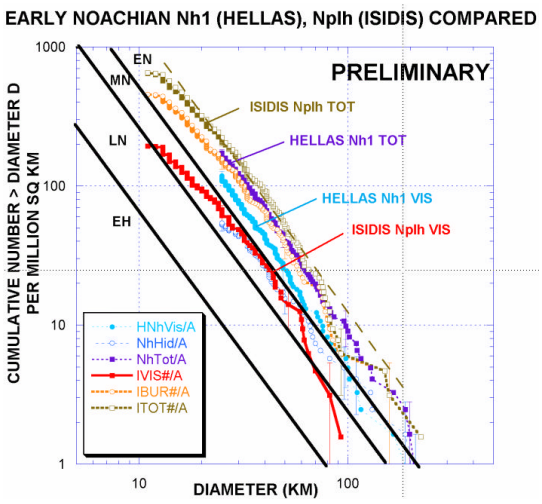

Figure 2: Cumulative frequency curves for the visible, buried and total populations in Early Noachian terrains near Hellas and Argyre. Despite the differences in the ratio of buried to visible basins, the total populations for both regions are nearly the same. Stratigraphic boundaries from Tanaka (1986) counts at D=16 km, extrapolated to larger diameters with a –2 power law.

the not-visible-on-images QCDs are buried impact basins.

We earlier showed that the total (cumulative) population near Hellas is about 1.6 times the visible population [8]. Our recent study at Isidis [9] shows a total population about 3-3.5 times the visible popula-

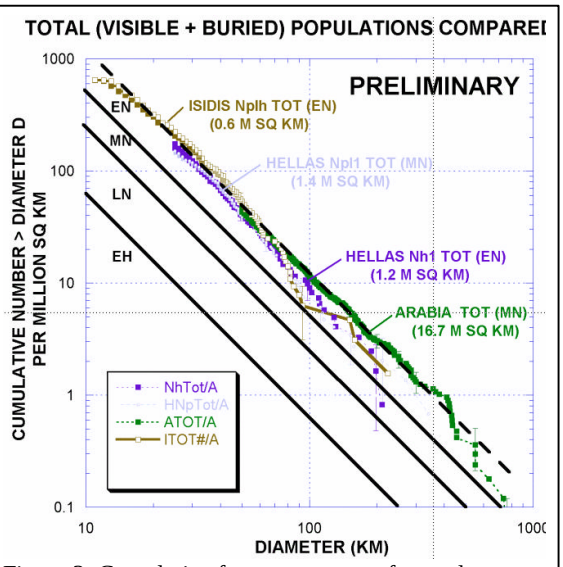

Figure 3: Cumulative frequency curves for total populations in Early and Middle Noachian terrains. See text for details. Note common crater retention age for all areas where good statistics permit comparison.

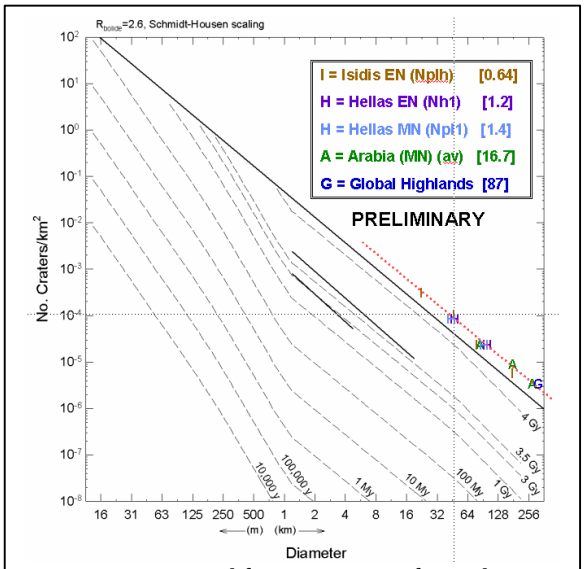

Figure 4: Incremental frequency curves for total populations for several Noachian terrains. All plot on a line (red dots) parallel to but slightly above the saturation line. Curves from [10].

tion over the same diameter range. Our counts suggest Isidis rim material is younger than Hellas rim material in terms of visible crater populations, but has a larger buried population. Note the total populations for Hellas and Isidis rim materials are about the same, implying a common age older than the Early Noachian visible crater retention age (Figure 2).

Total Populations Compared: In Figure 3 we compare these total populations with other Noachian units, including MN Npl_1 near Hellas and the very large "Arabia" area (Figure 1) used previously for comparison with our lowland study [7].

Because of its very large area, the "Arabia" statistics are very good, and the Arabia total population points closely follow a –2 power law over the diameter range 50-500 km. Over a more limited range where their smaller area statistics are also good, the total population curves for EN terrain at Isidis and for EN and MN terrain at Hellas closely overlap and follow the same –2 slope as for "Arabia". In all three regions, despite radically different sampling areas, the total crater retention age is similar.

Similar total crater retention ages could suggest either (a) a common age for the underlying surface which, if not the age of the primordial crust on Mars, is certainly older than the surface units mapped as Early Noachian, or (b) crater saturation. To test the second of these we plot the same total population data in an incremental frequency plot and compare it with curves of martian ages from [5,10]. Over the diameter ranges for which we have data the total population points define a straight line (red in Figure 4) which parallels a saturation curve, but lies above it. However, the curves in Figure 4 depend on a number of model assumptions, especially the scaling factor R. The absolute ages shown are probably accurate to a factor 2 [10]. Note our data does lie within a factor 2 of the saturation line in Figure 4. The total population data shown here may well indicate saturation in the underlying crust. It is interesting to speculate that data such as presented here, if supported by similar results from other Noachian terrains around Mars, could be used to "calibrate" the model curves in Figure 4.

Conclusions: MOLA data provide strong evidence that there exists still older crust underlying the oldest mapped Early Noachian surface units on Mars. These surface units cannot date from 4.6 BYA. There appears to be a recoverable "pre-Noachian" history in many parts of the planet. An apparent common crater retention age may indicate saturation of the underlying surface.

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