AGE AND ORIGIN OF THE CRUSTAL DICHOTOMY IN EASTERN MARS H. V. Frey, Geodynamics Branch, Goddard Space Flight Center, Greenbelt, MD 20771, frey@core2.gsfc.nasa.gov.

Summary: The topography associated with the fundamental crustal dichotomy in much of eastern Mars can be largely ascribed to a single event: the very large impact which produced the Utopia Basin. Subsequent internal and surficial processes have been unable to remove the topographic signature of this basin. In particular, endogenic processes appear to have been ineffective in contributing to the basic dichotomy in eastern Mars since the basin formed. Also, if earlier endogenic processes occurred, their signatures were obliterated by the impact. Early Noachian buried impact basins superimposed on the Utopia Basin, and the superposition of the Early Noachian Isidis Basin on the dichotomy boundary on the southern side of Utopia, constrain the Utopia impact to be very Early Noachian in age. The Utopia basin may be the oldest preserved large scale structure on Mars. The crustal dichotomy in eastern Mars dates from the earliest epoch of martian history.

Introduction: The fundamental unsolved problem in martian crustal evolution is also the oldest: origin of the two-fold division of ancient, high-standing, mostly southern cratered terrain and the contrasting, smooth and sparsely cratered younger lowland terrain in the north. The northern lowlands of Mars are covered with plains units that are mostly Hesperian age and younger [1,2,3]. Little is known about what underlies these plains, and pre-MGS explanations for the origin of the lowlands allow both an older surface as well as the possibility that the entire crust is similar in age to the younger surface units. How the lowlands formed and precisely when the crustal dichotomy was established remained uncertain until recently. Large impacts have been suggested as one way to form the northern lowlands early in martian history [4,5]. Internal processes, including plate tectonics, have also been proposed [6,7,8,9,10]. The recent discovery of buried impact basins in the northern lowlands of Mars [11,12] provides a strong constraint on the age of the northern lowlands, and perhaps on their origin as well.

Buried Basins and the Age of the Lowlands: Mars Orbiter Laser Altimeter (MOLA) data have shown the existence of a very large population of Quasi-Circular Depressions (QCDs) in both the highlands and lowlands of Mars [11,12]. Most of these circular depressions are not readily visible in Viking-era imagery. We believe the MOLA-found QCDs without visible structural expression to be buried impact basins [12]. This is supported by: the widespread distribution of the features; lack of association with obvious tectonic and volcanic centers; generally circular shape, softened profiles and subdued relief; and perhaps most convincingly, the similarity of shape of their cumulative number versus diameter curves to that for known impact basins. Comparison of cumulative frequency curves for visible and buried basins in the highlands and lowlands [12] shows that, over the diameter range 200 to 500 km, visible and buried highland basins and buried lowland basins follow a -2 power law slope, as might be expected for impact craters. At smaller diameters, non-visible highland and lowland basins fall off this trend, as expected for a buried population of impact craters. Buried lowland basins have *higher* cumulative numbers than visible highland basins for diameters > 100 km. The nominal interpretation would be that the buried surface represented by the hidden lowland basins (below the lowland plains) is *older* than the visible highland surface [12]. The highland surface on average is Middle Noachian age [1,2,3]. Therefore, the lowlands beneath the plains are Early Noachian, dating from the earliest period of martian history, and pre-dating most of what is seen on the martian surface [11, 12]. This is a fundamental constraint on the age of the lowlands (below the plains) which was not previously available. Not only are the lowlands extremely old, but apparently they have been stable (as a surface to preserve craters) for nearly all of martian history. This temporal constraint may limit the plausible mechanisms for the formation of the dichotomy, and certainly does favor processes which operate quickly and early.

Buried Basins in Utopia: Figure 1 shows the distribution of QCDs in the northern lowlands of Mars, superimposed on colored MOLA topography and on geologic units background. The globes are centered on the Utopia Basin, which McGill [13] first correctly described as an ancient impact basin. His interpretation, based on geologic mapping of knobs, mesas and polygonal terrain, suggested a basin over 3000 km across which had persisted since the Noachian. Schultz and Frey [14] adopted this interpretation but suggested the basin might be 4700 km in diameter if the circumferential arc along the crustal dichotomy boundary in Ismenius Lacus and Amenthes were the rim of the impact. MOLA topography certainly supports the impact structure interpretation of this basin [15,16]. Although lower in the north than in the south and slightly smaller than previously suggested [13,14], the overall character is bowl-like with a depth of ~4950m below the MOLA datum and ~5250m below the dichotomy boundary.

McGill [13] noted the implications of the persistence of such a large feature dating from some time in the Noachian. But the Noachian has Early, Middle and Late subdivisions [1,2,3] and could span 700 to 1000 million years, depending on the absolute chronology adopted. A stronger constraint is now available. Buried impact basins of apparently Early Noachian age lie on the Utopia Basin (Figure 1), which means this larger basin is even older and must have formed in the early part of the Early Noachian. This is consistent with the superposition of the Isidis Basin on Utopia and on the crustal dichotomy boundary zone (Figure 1), which may be an outer ring of the Utopia impact basin [14]. The Isidis rim material is mapped as Early Noachian [2]. Therefore the Utopia impact occurred in the earliest part of martian history, and the Utopia Basin may be the oldest preserved large scale structure on Mars.

Age and Origin of the Crustal Dichotomy in Eastern Mars: The Utopia Basin largely accounts for the topography and present day structure of the crustal dichotomy in much of eastern Mars. Therefore the dichotomy in this part of Mars can be explained by large scale impact in the early

part of the Early Noachian. The preservation of the Utopia Basin since its formation [13] means subsequent processes (both internal, if any, and surficial) were unable to remove the topographic signature established by the impact. Despite obvious resurfacing by a variety of processes [16] and volcanic construction within Elysium, the ancient structure is largely intact. Plate tectonic [8,9] or other internal processes [6,7,10], if they operated after the impact, had essentially no effect on the large scale topography of the dichotomy in this part of Mars, and therefore cannot be invoked to explain the origin of the lowlands.

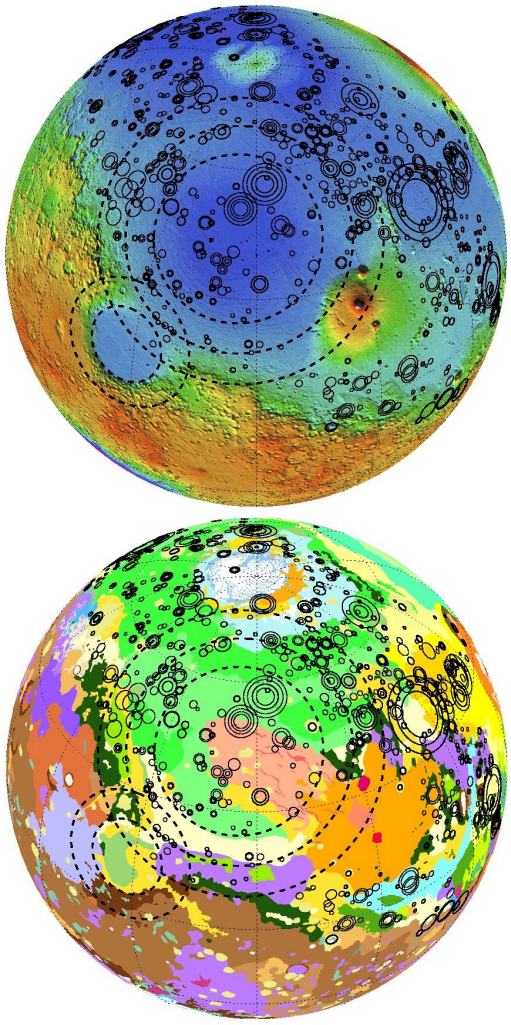

Figure 1. QCDs in the northern lowlands of Mars larger than 50 km diameter based on MOLA data. 644 features are shown, ranging up to over 1000 km across. Most of these (>85%) are hidden (MOLA-found). At least two areas near major volcanic features (N of Alba, SW of Olympus Mons) have no detectable QCDs. Note the QCDs superimposed on the Utopia Basin, and the Isidis Basin superimposed on both Utopia and the crustal dichotomy boundary.

Likewise, if internal processes operated in the short time before the Utopia impact, they had so little effect that any signature they may have produced was erased. This, combined with the very brief time interval that may have been available from the formation of the martian crust to its dramatic rearrangement by the Utopia impact, calls into question whether internal processes ever had any significant role in the formation of the dichotomy in eastern Mars.

Conclusions: The large scale structure and topography of the crustal dichotomy in eastern Mars can largely be attributed to the formation of the Utopia Basin by impact in the earliest epoch of martian history. Superimposed Early Noachian buried impact basins and the Early Noachian Isidis Basin demonstrate the primordial age of the Utopia Basin. Even if internal processes had occurred in the short time available before the impact, their effects were completely overwhelmed by the Utopia impact event. The preservation of the impact structure over the rest of martian history means that internal processes have been largely insignificant in shaping the crustal dichotomy in this part of Mars. There is no compelling evidence for an internal origin for the crustal dichotomy, and very compelling evidence that a major impact was responsible in eastern Mars.

As attractive as it may be from our terrestrial experience to extend the concept of plate tectonics from Earth to Mars [8, 9] and to argue for unusual mantle convection that might be associated with it [10], the fact is there is no observational evidence for such processes, no apparent need for such processes (at least in eastern Mars), and apparently very little time for them to have occurred. On the contrary, there is clear evidence for large-scale impacts (Hellas, Argyre, Chryse, Utopia), and at least in the case of Utopia, the connection between such an impact and the formation of the martian crustal dichotomy seems inescapable.

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