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SMALL-DIAMETER MARTIAN CRATERS: APPLICABILITY FOR CHRONOLOGY – OR NOT. J. B. Plescia, Applied Physics Laboratory, Johns Hopkins University, 11100 Johns Hopkins Road, Laurel MD 20723, jeffrey.plescia@jhuapl.edu.

Introduction: Crater counting has historically been used to establish relative and absolute chronologies on planetary surfaces and to develop global stratigraphies. Typically, craters in the size range ≥1 km have been used. This diameter was chosen as a convenient balance between image resolution and a diameter that would indicate a formation age. Craters at larger diameters might be craters protruding from an underlying surface; smaller diameters might be affected by local resurfacing. A limitation of an approach that employs this size crater is that counts must be compiled for large areas in order to reduce the statistical uncertainties associated with comparison of counts. This results in an inability to detect small areas of variable age.

The availability of high resolution MOC, THEMIS and HRSC images provides the ability to examine the population of craters in the <<1 km size range. Because the production function of craters follows a log distribution, the number of craters in the meters to hundred of meters diameter range is several orders of magnitude greater than in the km range. Thus, smaller areas can be counted, in principal, with low statistical uncertainties allowing the recognition of smaller differences in age and smaller areas of different age. [1, 2] proposed absolute chronologies for small scale craters to allow them to be used to establish not only the relative age, but the absolute age of a surface. Such chronologies are established by modifying the lunar chronology (based on returned samples) for martian condidtions (e.g., impact velocities, gravity).

Applicability of Model Isochrons: The isochrons that have been proposed by Hartmann and his colleague have been used by a number of investigators. The observed size-frequency distributions have been plotted with reference to the proposed isochrons and geologic scenarios in the context of absolute time have been proposed (Figures 1 and 2). However, in many cases it is unclear if the proposed chronologies are realistic. This concern arises from the statistics of the observed size-frequency distribution. Additional concerns are raised by issues of the lifetime of individual volcanoes and the thermal evolution of Mars.

In most cases, the plots show that the observed size-frequency distrubiton of impact craters lie along a slope more shallow than that of the isochrons. This results in a diameter-dependent age – that is, for the same surface, the smaller the reference crater diameter under discussion, the younger the surface age. In such cases, it is not at all clear what diameter should be used for a reference.

Figure 1 illustrates this effect for a portion of the southern Elysium plains. The various distributions represent counts made for different MOC images by different people along with counts made on Viking images [3]. The distrubitons clearly lie along lower slopes than the isochrons. Thus, any surface can have any age spanning hundreds of millions to billions of year, depending upon the diameter chosen. The geologic scenario proposed for this area [3], to account for the apparent age variation, is that over time volcanic eruptions repeatedly cover the entire area, but each eruption is successively thinner such it only buries the small diameter craters.

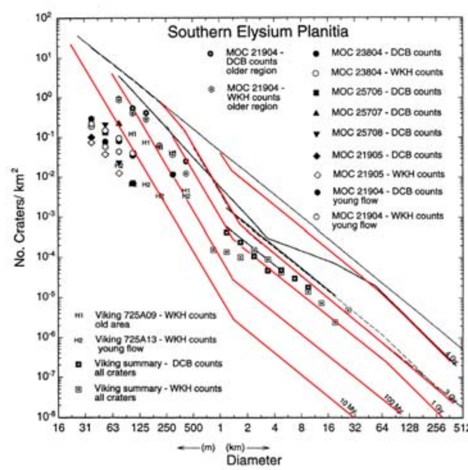

Figure 1. Distribution of craters counted in various images presented by [3]. The red lines denote isochrons. The observed distributions in each case follow a more shallow slope than the isochrons.

Counts have also been published for areas on some of the martian volcanoes suggesting wide variation in the absolute ages of different parts of the same volcano, in some cases ranging over hundred of millions of years [4]. Again, however, the observed size-frequency distributions of impact craters often lie along slopes that are shallower than the isochrons. Such models can produce results (Figure 2) which are inconsistent with the observed geology. Figure 2 shows the caldera complex of Olympus Mons and the absolute ages derived for different portions of the caldera by [4]. On the basis of observed cross-cutting relations, calderas II and V would be the youngest [5]. However, the absolute ages assigned to these surfaces are in fact the opposite; caldeas II and V have the oldest ages.

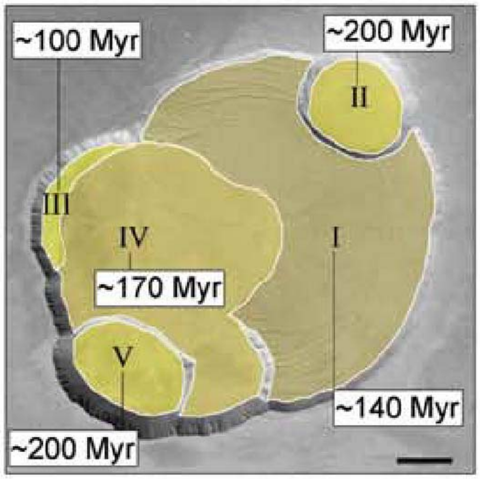

Figure 2. Absolute age estimates by [4] for the Olympus Mons caldera based on craters <1 km in diameter. The geologic sequence based on the stated absolute ages in inconsistent with the observed geologic relations for these surfaces.

Variations In Statistics: Using MOC and THEMIS images, crater counts were compiled for portions of the flank and caldera of Olympus Mons, the calderas of the Tharsis Montes shields, several of the smaller Tharsis volcanoes and for plains in Elysium. Counts have also been compiled for secondary fields. Images show that many surfaces on the volcanoes are extensively mantled (Figure 3). An odd aspect of this mantling is that in many cases, the mantling is more substantial on the volcano than on the surrounding plains. The morphology shows craters filled to varying amounts, rayed craters are nearly absent. and ejecta blankets are not usually observed. This morphology indicates the surfaces and the resulting crater size-frequency distributions do not represent pristine surfaces and production populations. Rather, the distributions probably represent an equilibrium distribution.

The size-frequency distributions of craters on the flanks and caldera surfaces vary widely in terms of both the frequency of craters and the slope of the size-frequency distributions. Slopes range from -4.4 to -1.7 for the flanks of Olympus Mons; -3.9 to -3.3 within the Olympus Mons caldera; and -5 to -1.9 for the caldera of the Tharsis Montes shields. The variation in frequency might be ascribed to differences in age. However, the variations in the slope indicates that these distributions do not represent production populations.

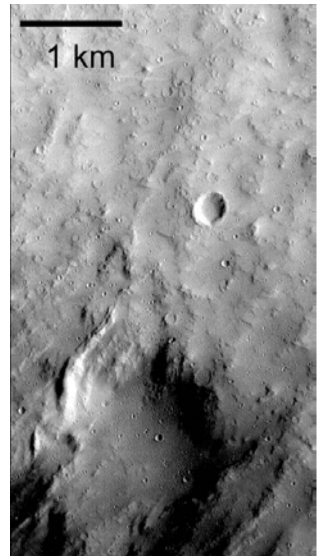

Figure 3. Section of Olympus Mons flank (MOC M1801592) showing extensive mantling and variably buried craters.

There are several mechanisms that might explain the variations: resurfacing processes, atmospheric effects, and secondary cratering. Surfacing processes clearly are active. If the martian atmosphere was appreciably thicker in the past, it could have acted to screen out small diameter projectiles which would cause a shallower distribution than when the atmosphere was thin. [6] has recently proposed that secondary craters contribute significantly and irregularly to the observed distribution of small diameter craters. This would account for the large variations in frequency for surfaces of suspected uniform age and for the variations in slope of the size-frequency distribution (admixtures of different number of secondaries to a given population).

Summary: Craters in the size range of meters to hundreds of meters can not be reliably used for either relative or absolute chronologies on Mars. Processes not well understood result in significant differences in the frequency and statistics of impact craters on surfaces that should be approximatey the same age. Models that suggest volcanic activity on individual volcanoes lasting for hundreds of millions to billions of years are not thermally reasonable.

References: [1] Hartmann, W. (1999) *Meteor. Planet. Sci., 34*, 167-177. [2] Hartmann W and Neukum G (2001) *Space Sci. Rev., 96*, 165-194. [3] Hartmann W. and Berman D. (1999) *JGR, 105*, 15011-15025. [4] Hartmann W. Et al. (1999) *Nature, 397*, 586-589. [4] Neukum et al. (2004) *Nature, 432*, 971-979. [5] Mouginis-Mark P. and Robinson M. (1992) *Bull Volc., 54*, 347-360. [6] McEwen A. (2004) *LPSC XXXV*, Abstract #1756