THE CRATER PRODUCTION FUNCTION FOR MARS: A -2 CUMULATIVE POWER-LAW SLOPE FOR PRISTINE CRATERS >5 KM IN DIAMETER BASED ON CRATER DISTRIBUTIONS FOR NORTHERN PLAINS MATERIALS. K.L. Tanaka[1], J.A. Skinner, Jr.[1], and N.G. Barlow[2]. [1]Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ 86001 (ktanaka@usgs.gov); [2]Dept. of Physics and Astronomy, Northern Arizona U., Flagstaff, AZ 860011-6010.

Introduction. The random bombardment of planetary surfaces by asteroids and comets has enabled the application of crater densities as a primary measure of relative ages of surfaces on Mars and other cratered bodies. Diameters of craters are a function primarily of impact energy determined by the velocity and mass of the projectiles [e.g., 1]. Over time, collections of craters for an otherwise undisturbed surface can be used as a statistical sample to define an idealized size-frequency distribution, known as a crater production function (CPF).

In spite of extensive previous work, consensus has not been reached yet as to the form of the CPF for Mars, especially in the ~2 to 20 km size range. We feel that much of the problem may be due to complex resurfacing that has resulted in non-ideal crater populations over much of Mars. Based on revised geologic mapping and an improving crater database, we present preliminary results that indicate that the CPF follows closely a -2 power low in the 5 to ~100 km diameter range.

Crater counts of northern plains units. Recent geologic mapping of the northern plains of Mars using MOLA, THEMIS, and MOC data has defined the boundaries of widespread Hesperian and Amazonian units whose geologic relations indicate that they likely define surfaces of uniform age [2-3]. The most expansive are the Vastitas Borealis marginal and interior units (1.8×10^6 km^2 combined), which possibly relate to deposition within a paleo-ocean [4]. In addition, we include the Chryse 3 and 4 units, which consist of the youngest outflow materials in Chryse Planitia, cover 8.8×10^5 km^2, and are embayed by the Vastitas Borealis units [2-3].

Our crater database [5] is restricted to craters larger than 5 km in diameter, a size range which is sufficiently large such that secondary craters are not likely to contaminate the crater populations [6]. We include counts of pristine only and total craters in order to isolate the superposed craters and to examine how inclusion of craters pre-dating the units affect the crater distributions.

Vastitas Borealis units. The morphologies within the Vastitas Borealis units, including thumbprint terrain, sinuous valleys with medial ridges, and polygonal fractures, indicate that the units' surfaces have been modified, in association with or soon following their formation [e.g., 2-3]. However, we do not observe on these units any significant degradation of craters >5 km in diameter, nor signs of substantial resurfacing or mixing of surface ages, such as flow lobes, that may have altered the crater population. Younger units that partly bury the Vastitas units have been identified and mapped separately. Some of these younger units are thin and illustrate how resurfacing can preferentially bury smaller craters. For example, flows from the western flank of the Elysium rise bury eastern and central Utopia Planitia. They have buried all but the larger craters tens of kilometers in diameter. Some of these craters have large ejecta ramparts that provided topographic obstacles to the Utopia flow materials. MOC images and MOLA topography demonstrate that the flows postdate the crater ejecta, whereas Viking images could not resolve these relations.

We use the latest Viking-based version of the crater database of Barlow [5] to define crater locations, sizes, and degradation state. In Vastitas Borealis, the population of pristine craters having discernible ejecta blankets is generally quite distinctive from the population of modified "ghost" craters that are nearly rimless, flat-floored, and lack preserved ejecta [e.g., 7]. We find that the pristine crater distribution follows a –2 power law slope between 5 and 16 km diameter (Figure 1, Table 1). The slope is not constant but steepens slightly with increasing diameter. Werner et al. [8] find even steeper distributions (~-2.2 to -2.3) for counts within parts of the Vastitas units where polygonal terrain is present. The general consistency of the crater counts across varying elevation and latitude ranges that we have explored thus far indicates that the Vastitas Borealis units essentially reflect the same distribution and relative age throughout. The total crater population shows a -1.67 slope in this size range, which apparently reflects that the ghost crater population is skewed toward larger diameters.

Chryse units. Crater densities for the Chryse units have been produced with a partly updated crater database that uses a new crater degradation ranking system. This system has degradation states assigned from 0 to 7, where the higher the number, the more pristine [9]. Craters ranked 4 to 7 have preserved ejecta blankets and thus generally appear to be superposed on surrounding geologic units and are considered pristine in this study. We interpret the non-pristine craters to be those that predated the flooding; the flooding and (or) other earlier activity destroyed their ejecta blankets. We arrive at a crater distribution slope of ~-2 for pristine, superposed craters and a -1.6 slope for total craters (Table 1).

Discussion. Both the Vastitas Borealis and Chryse units contain pristine crater populations having a -2 power-law slope, whereas their total crater populations show significantly shallower slopes. Non-pristine craters either had their ejecta removed prior to deposition

of the units or were modified by local activity after deposition. However, we find no evidence for the latter. Although Werner et al. [8] speculated that target property effects led to different crater morphologies and sizes to explain the steep crater distributions in Vastitas Borealis, no real explanation has yet been provided.

Previous results for the form of the Mars CPF range significantly, particularly in the ~2 to 20 km diameter size range for intermediate age surfaces on Mars. Results by Tanaka [10] suggested a -2.0 cumulative CPF power-law slope between 1 and 5 km diameter and a -1.8 slope between 5 and 16 km diameter. The Hartmann CPF [11] as calculated from his lunar CPF by Ivanov [1] yields a slope of -1.72 for the 1 to 32 km diameter range; that slope increase to -2.2 at larger diameters. The Neukum CPF [11] shows a much shallower slope of ~-1.2 in the ~6 to 14 km size range, steepening to ~-2.5 slope at larger diameters. Frey [12] finds for densely cratered regions on Mars a slope of -2 for combined large craters and quasi-circular depressions inferred to be craters at diameters >25 km; the slope in this case might be related to crater saturation.

In all cases, our counts of pristine craters reflect a steeper CPF in the 5 to 14-32 km size range than indicated by previous workers. We suspect that those studies have included partly obliterated crater populations predating the surfaces. Such contamination would result in inaccurately high cumulative crater densities with slopes shallower than -2. Previous CPFs relied principally on craters superposed on lava-flow fields consisting of individual flows that vary in age, area, and thickness. In such cases, at least several to dozens of flows of varying age are likely combined to define a surface. Because of this, the crater population will include partly buried craters that poke through the uppermost flows; their diameters will be skewed to larger sizes.

Conclusion. Given the apparent uniform crater size-frequency distribution across the broad Vastitas units and the lack of evidence for crater obliteration in the >5 km diameter size range, we propose that the –2 slope power law between 5 and 16 km diameter, extending with less precision to ~100 km (Fig. 1), represents the true CPF for that diameter range for post-Noachian Mars.

Future work. We plan to update the crater database further using the crater preservation classification system applied to the Chryse units to refine the counts for the Vastitas Borealis units. As the database is completed planetwide, we will be able to isolate superposed and partly buried crater populations more accurately, which will permit estimates of resurfacing rates based on crater height/diameter relations. In turn, a more accurate estimate of total age range for composite units such as lava-flow fields could then be calculated, rather than just a mean relative age as is generally the case at present.

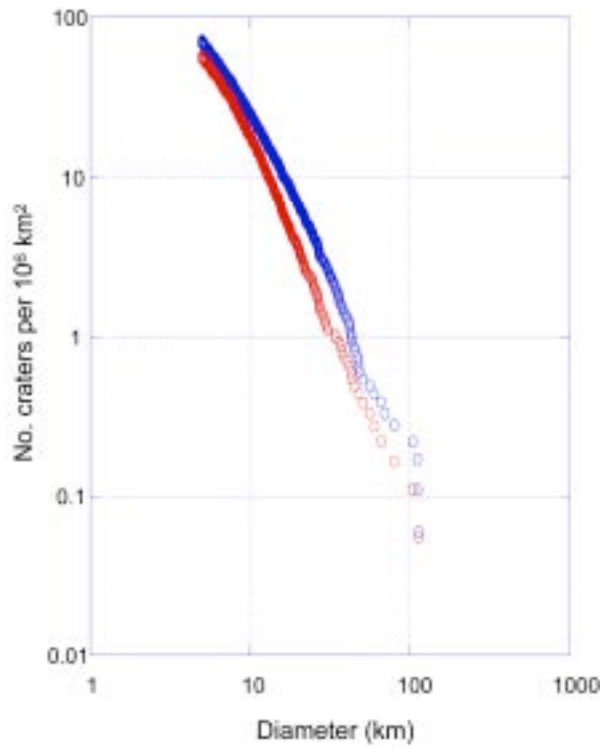

Figure 1. *Log-log plot of cumulative crater density for Vastitas units on Mars. Red, pristine craters only; blue, total craters.*

Table 1. Crater counts for northern plains units.

Unit[a]	Slope[b]	N(5)[c]	N(16)[c]
VB (p)	1.96±0.13	57.6±1.8	5.9±0.6
VB (t)	1.67±0.10	72.1±2.0	10.3±0.8
Chryse (p)	1.98±0.56	64.7±8.6	6.8±2.8
Chryse (t)	1.59±0.37	97.7±10.5	10.3±0.8

[a]Pristine (p), total (t) craters; Vastitas Borealis (VB)
[b]Power-law fit for N(5)/N(16)
[c]N(x)=no. craters >x km diameter per 10^6 km^2

References. [1] Ivanov B.A. (2001) *Space Sci. Rev. 96, 87*. [2] Tanaka K.L. et al. (2003) *JGR 108*, 8043. [3] Tanaka K.L. et al. (2004) *USGS Sci. Invest. Map*, submitted. [4] Parker T.J. et al. (1989) *Icarus 82*, 111. [5] Barlow N. G. (2003) *6th Inter.Conf. Mars*, Abs. #3073. [6] Chapman C.R. (2004) *2nd Conf. Early Mars*, Abs. #8028. [7] Head J.W. III et al. (2002) *JGR 107*, 10.1029/2000JE001445. [8] Werner S.C. et al. (2004) *LPSC XXXV*, Abs. #1905 (CD-ROM). [9] Barlow N.G. (2004) *GRL 31*, 10.1029/2003GL019075. [10] Tanaka K.L. (1986) *JGR 91*, E139. [11] Hartmann W.K. and Neukum G. (2001) *Space Sci. Rev. 96*, 165. [12] Frey H.V. (2003) Sixth Intl. Conf. Mars, LPI Cont. 1165, Abs. #3104 (CD-ROM).