VENUS RESURFACING RATES: CONSTRAINTS PROVIDED BY 3-D MONTE CARLO SIMULATIONS

M. A. Bullock, D. H. Grinspoon, University of Colorado, Laboratory for Atmospheric and Space Physics and the Department of Astrophysical, Planetary and Atmospheric Sciences, Boulder, CO 80309, J. W. Head, Department of Geological Sciences, Brown University, Providence, RI 02912

We have implemented a 3-D Monte Carlo model that simulates the evolving surface of Venus under the influence of a flux of impacting objects and a variety of styles of volcanic resurfacing. For given rates of impact events and resurfacing, the model predicts the size-frequency and areal distributions of surviving impact craters as a function of time. The number of craters partially modified by volcanic events is also calculated as the surface evolves. We find that a constant, global resurfacing rate of approximately 0.4 km^3/yr is required to explain the observed distributions of both the entire crater population, and the population of craters partially modified by volcanic processes.

An examination of the Venus impact cratering record revealed by Magellan thus far suggests interesting implications for its resurfacing history. In particular one feature of the observed crater population demands an explanation: The total density of craters suggests a surface which is approximately 500 million years old, yet the craters themselves are nearly all apparently in a state of perfect preservation [1]. The surface is young compared with the age of the planet, therefore some process is removing craters. Yet there are very few partially degraded, or partially buried craters observed. Schaber *et al.* [2] report only 4-6 % partially embayed craters. Any process that was removing craters gradually such as chemical or physical weathering, aeolian erosion or burial, viscous relaxation or volcanic flooding would be expected to leave a suite of craters in various states of degradation. Two hypotheses have recently been presented to explain the observed crater population.

The first hypothesis, the single production age or "spasmodic volcanism" model, is that resurfacing rates on Venus were quite high up to some point in the past and then rapidly declined, allowing subsequent crater preservation in pristine form [2,3,4]. The age of this change in surface activity may be roughly constrained by crater densities. The second hypothesis is that there has been a relatively constant rate of "regional resurfacing" [1,4]. Although statistical analyses of the spatial distribution of observed craters reveals that they are consistent with complete spatial randomness, ruling out extensive resurfacing events over large areas in the last 5 - 10 x 10^8 years, this hypothesis suggests that the characteristic scale of the resurfacing events which dominate the steady-state evolution of the surface is smaller than the scale of randomness of the craters.

The resurfacing of Venus is modeled as the time evolution of the competing processes of impact cratering and volcanism [5]. The computer simulation of the planetary surface is represented on a 3-D grid, with a surface resolution of 5 km and a vertical resolution of 100 m. The total grid represents an area of 4 X 10^8 km^2, the approximate surface area of Venus. Monte Carlo methods are used to randomly place impact craters, at rates and diameters derived from the observed mass distribution of Earth and Venus crossing asteroids and comets [6]. Rim heights are calculated from the diameter/height relationships for lunar impact craters [7]. A wide range of volcanic features are represented on the planet. The observed size-frequency distribution for volcanic features on Venus [4] is used to randomly select volcanic forms and to place them on the planet. Again, the observed distribution is fit to a power law for the Monte Carlo simulation. The areal extent of shield fields, large volcanoes, and lava floods is determined in the simulations by sampling the appropriate distributions for the feature type from Magellan data [4]. Lava flow features are modeled using an energy minimization technique to simulate the effects of local topography on the shape and extent of flows. By performing simulations with a wide range of resurfacing rates, we have seen that no fewer than 30% of the surviving craters are partially embayed by lavas, for resurfacing rates greater than 2 km^3/yr. At these resurfacing rates, the model also shows that a steady state between crater impacts and volcanic resurfacing is established in less than 600 m.y. We therefore conclude that an equilibrium regional resurfacing is inconsistent with the observed number of partially embayed craters.

A unique solution to the problem of a constant resurfacing rate is provided by the constraints of the total number of impact craters, their spatial randomness, and by the number of partially embayed craters. The evolution of the crater population for a constant global resurfacing rate of 0.37 km^3/yr is shown in the two figures below. Figure 1 is a plot of the total number of surviving impact craters as a function of time. The low diameter cut off is 16 km, selected to adjust for the fall-off of low diameter impact craters due to atmospheric effects. A total of approximately 900 craters survive after 500 m.y., as shown by the solid line. The evolution of a pure production surface is shown by the dotted straight line. Figure 2 shows that the total number of partially embayed craters is about 5% of the total population.

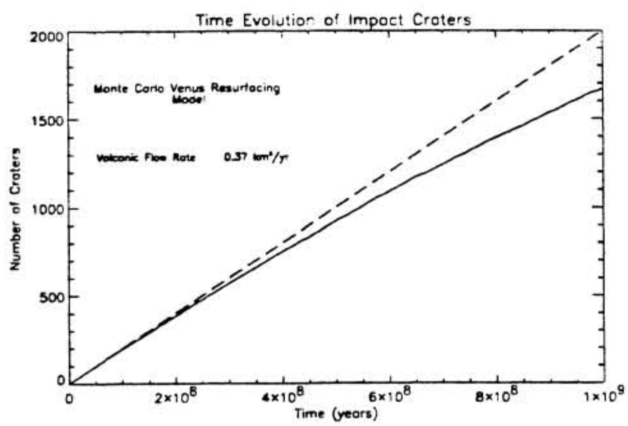

Figure 1. Time Evolution of Impact Craters

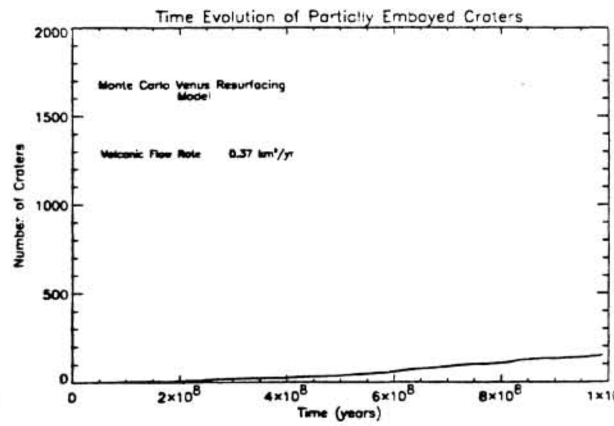

Figure 2. Time Evolution of Partially Embayed Impact Craters

Our results thus far suggest that the most likely scenario for the history of Venus' surface is that the observed crater population is the record of a relatively pristine surface that has undergone volcanic resurfacing on a regional scale at an average rate of about 0.4 km^3/yr. If the present crater population is one that has accumulated after some global catastrophic event, the age of the surface, as constrained by the spatial randomness and number of partially embayed craters is slightly greater than the crater production age, and is estimated to be about 500 m.y.

References: [1] Phillips, R.J. *et al.* (1991) *Science*, **252**, 288. [2] Schaber, G.G. *et al.* (1992) *JGR*, **97**, 13,257. [3] Head, J.W. *et al.* (1992) *JGR*, **97**, 13,153. [4] Phillips, R.J. *et al.* (1992) *JGR*, **97**, 15,923. [5] Bullock, M.A. *et al.* (1992) *Lunar and Planetary Science XXIII*, 175. [6] Shoemaker, E.M. *et al.* (1989)*Reports of the planetary geology and geophysics program: 1988.* [7] Melosh, H.J. (1989) *Impact Cratering*, Oxford University Press, New York.