RESULTS OF EQUILIBRIUM RESURFACING MONTE CARLO MODELS ON VENUS. E. E. Bjonnes[1], V. L. Hansen[1], and J. B. Swenson[1]. [1]University of Minnesota Duluth Dept. of Geol. Sci., 1114 Kirby Dr., Duluth, MN 55812. bjonn001@d.umn.edu, vhansen@d.umn.edu, jswenso2@d.umn.edu.

Introduction: The Synthetic Aperature Radar (SAR) images taken of Venus' surface show a planet with ~1000 randomly distributed pristine impact craters [1,2]. Consequently, any viable resurfacing model for Venus must accommodate two key observations: 1) near random spatial distribution of impact craters, and 2) few tectonically or volcanically modified craters [2]. These observations are inconsistent with plate tectonic processes [3, 4], but can be accommodated by catastrophic resurfacing [5,6]. However, catastrophic resurfacing cannot address the preservation of three average model surface age (AMSA) provinces preserved across Venus [7,8], or growing number of geologic relations that favor equilibrium resurfacing processes [9,8, 10].

Strom et al. [5] used Monte Carlo modeling to argue that equilibrium resurfacing is not viable. They tested varying increments of surfacing of Venus' total surface area; increments of 50, 25, 10% resurfacing cannot met the spatial observation (1), whereas 0.03 and 0.003% resurfacing results in far too many modified craters, violating observation 2. Strom et al. [5] failed to test increments between 10 and 0.03%. We used Monte Carlo modeling to test incremental resurfacing of 10, 5, 1, 0.7, and 0.1% surface areas and found that incremental resurfacing of 5, 1, and 0.7% met both observations.

Background: Venus hosts ~970 impact craters; diameters range from 1.5-270 km, (20 km average), and few (169-186) show evidences of tectonic deformation or embayment [11,12]. The number of embayed craters range from 85 to 108, tectonically deformed from 56 to 101, and both tectonically deformed and embayed from 27 to 39 [11,12]. Because of ongoing volcanic processes, we estimate the number of craters deformed or embayed through resurfacing at 100. Venus lacks both plate tectonic and water-driven processes [3], consistent with observations 1 and 2.

Catastrophic resurfacing, which encompasses both tectonic and volcanic mechanisms, is one hypothesis to explain Venus' crater record. Volcanic catastrophic resurfacing requires a layer of lava 1-3 km think was emplaced between 10 and 100 Ma, after which volcanic activity ceased within 10 Ma [13,5] In tectonic catastrophic resurfacing, the lithosphere overturned and created a new surface [14,15,16,6]. Catastrophic resurfacing is not consistent with observations, however; neither volcanic nor tectonic catastrophic resurfacing reconcile with Venus' three major age provinces.

Equilibrium resurfacing, in contrast, proposes that Venus was resurfaced in small increments through time, or time transgressively, and can be achieved through volcanic or tectonic processes [2,17,8]. Strom et al. [5] tested volcanic equilibrium resurfacing in increments of 50, 25, 10% of the total surface area, which did not meet observation 1, as well as 0.03, and 0.003% which did not meet observation 2. They only tested volcanic equilibrium resurfacing, however, and did not consider tectonic processes. They also did not test increments between 10 and 0.03%. Tectonic versions of equilibrium have been proposed and invoke the creation of crustal plateaus as the resurfacing mechanism [17,18,19,20], but these hypotheses have not been statistically tested against the key observations of Venus' impact crater record.

Methods: We simulated randomly emplaced impact craters and resurfacing events on a Venus-sized sphere (Fig. 1). The model tracked the number, location, and condition of craters. We generated Poisson random variables to determine times of both impact crater formation and resurfacing events assuming that at the end of the experiment 1000 craters would remain on the surface and resurfacing would have totaled 100%. Craters could fall into one of three categories depending after a resurfacing event: modified craters lie within a 60-km wide ring centered on the edge of the resurfaced area, destroyed craters lie within this ring, and pristine craters lie outside this ring (Fig. 1). A previously modified crater will remain modified unless it is destroyed by the end of the test run.

We ran two suites of experiments, each considering incremental resurfacing across areas of 10, 5, 1, 0.7, and 0.1%. Each experiment consisted of 1000 test runs to ensure statistical viability and assumed constant bolide and resurfacing fluxes through time. In suite A, both impact crater formation and resurfacing occur throughout the entire test run; impact crater formation and resurfacing occur throughout the first two-thirds of experiments in suite B, after which only impact crater formation continues. Because a mechanism of resurfacing depends on the thickness and strength of the lithosphere, it is more geologically reasonable to impose that at some point before the present Venus could no longer undergo these resurfacing events.

To determine spatial randomness, we found the R^2 value of a histogram of all inter-crater distances to the fitted theoretical relationship **f(x) = m*sin(x)**, where x is the intercrater distance and m is a scaling factor [6]. The R^2 value of an experiment is the average of the 1000 R^2 values of all the runs within that experiment. To determine the number of modified craters in each experiment, the number of modified craters in each run were averaged over the

1000 runs in each experiment; these averages were then compared to the cutoff value of 100.

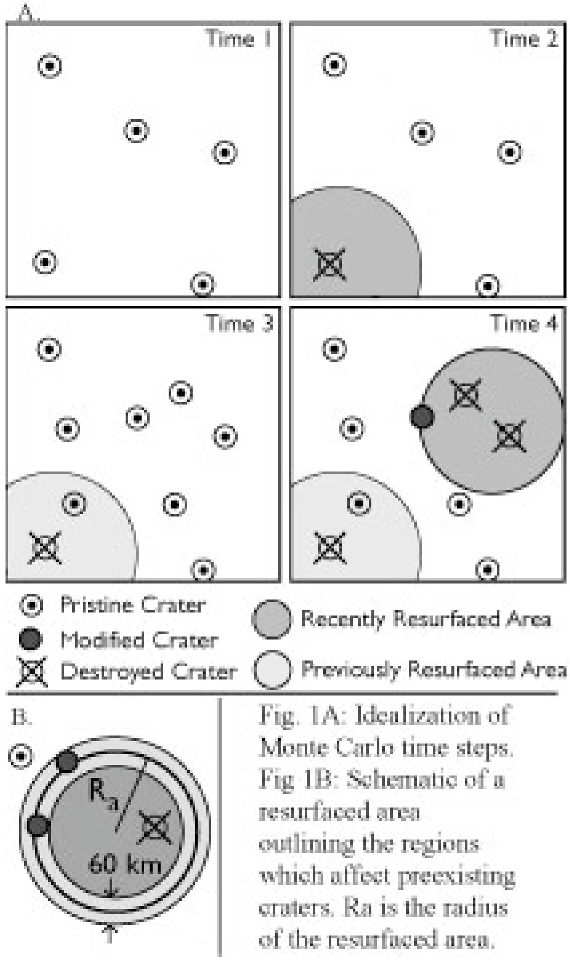

Fig. 1A: Idealization of Monte Carlo time steps. Fig 1B: Schematic of a resurfaced area outlining the regions which affect preexisting craters. Ra is the radius of the resurfaced area.

Results: Table 1 shows the results of spatial distribution and number of modified craters, respectively**.**

Table 1

		Data			Constraint?	
	% Area Resurf.	R^2	# Mod. Crater	# Mod >1	Mod. Crater	Spatial Dist.
Suite A	10	0.905	14	1	Yes	No
	5	0.938	19	1	Yes	Yes
	1	0.965	41	2	Yes	Yes
	0.7	0.969	48	2	Yes	Yes
	0.1	0.981	130	13	No	Yes
Suite B	10	0.968	7	1	Yes	Yes
	5	0.970	10	1	Yes	Yes
	1	0.979	23	1	Yes	Yes
	0.7	0.979	27	2	Yes	Yes
	0.1	0.983	71	7	Yes	Yes

In suite A resurfacing at 5, 1, and 0.7% met both the impact crater spatial distribution (observation 1) and low number of modified craters constraints (observation 2). The 10% and 0.1% resurfacing experiments violated observations 1 and 2, respectively, and therefore serve to bracket the overall result. These results agree with the findings of Strom et al. [5].

For B, all configurations met both observations, and therefore an expanded parameter space should to be considered to determine where this hypothesis is no longer viable. This is important because it is unreasonable to assume that both impact crater flux and resurfacing events act constantly through time.

Discussion: These results indicate that 5 to 0.7% equilibrium resurfacing can satisfy impact crater distributions. Because we lowered the number of acceptable modified craters, 0.1% equilibrium resurfacing may be valid. The number of modified craters existing on Venus is also currently being researched; volcanic embayment may be much more common and harder to detect according to the findings of Herrick and Sharpton [21].

There are new hypotheses trying to incorporate these new possibilities of equilibrium resurfacing. SPatially-Integrated Time Transgressive Equilibrium Resurfacing, or SPITTER, builds on these findings to search for a mechanism to operate within these statistically valid increments [8]. It proposes that Venus may hold a much richer geologic history than was previously thought. More research is needed in these areas through detailed mapping and innovative thought regarding possible resurfacing histories of Venus.

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