TECTONIC RESURFACING OF VENUS. Michael C. Malin, Malin Space Science Systems, 3535 General Atomics Court, Suite 250, San Diego CA 92121, Robert E. Grimm, Dept. of Geology, Arizona State University, Tempe AZ 85287-1404, and Robert R. Herrick, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058.

Introduction. Impact crater distributions and morphologies have traditionally played an important role in unraveling the geologic histories of terrestrial objects, and Venus has proved no exception. The key observations are[1,2]: (i) mean crater retention age about 500 Ma, (ii) apparently random spatial distribution, (iii) modest proportion (17%) of modified craters, and (iv) preferential association of modified craters with areas of low crater density. The simplest interpretation of these data alone is that Venus experienced global resurfacing (assumed to be largely volcanic) prior to 500 Ma, after which time resurfacing rates decreased dramatically[1]. This scenario does not totally exclude present geological activity: some resurfacing and crater obliteration is occurring on part of the planet, but at rates much smaller than on Earth.

An alternative endmember model holds that resurfacing is also spatially randomly distributed[2]. Resurfacing of about 1 km^2/yr eliminates craters such that a typical portion of the surface has an age of 500 Ma, but actual ages range from zero to about 1000 Ma. Monte Carlo simulation indicates that the typical resurfacing "patch" cannot exceed about 500 km in diameter without producing a crater distribution more heterogeneous than observed. Volcanic or tectonic processes within these patches must be locally intense to be able to obliterate craters completely and leave few modified.

In this abstract, we describe how global geologic mapping may be used to test resurfacing hypotheses. We present preliminary evidence that the dominant mode of resurfacing on Venus is tectonism, not volcanism, and that this process must be ongoing today. Lastly, we outline a conceptual model in which to understand the relationship between global tectonics and crater distribution and preservation.

Approach. Although craters are randomly distributed around the planet, their distribution with respect to *terrain type* is unknown. Observations of impact crater location, size, modification state, and surrounding terrain[3] may be used as a basis for prediction. For a uniform population of craters that has changed very little since a global resurfacing event, each terrain type should contain a number of craters proportional to its area. To the extent that the actual areal abundances differ, the terrain is younger or older than the global mean and thus provides a first-order measure of the average age of each terrain.

A complete test of this hypothesis first requires a global geologic map from which the areas of each terrain type may be estimated. We are presently compiling a 1:20 million geologic map using data from C2 and C3 MIDRs. For now, we present one preliminary result using an automated mapping procedure. We are interested in testing the specific hypothesis that faulting - whether in the form of tesserae, ridge or mountain belts, coronae, rifts, or plains fractures - dominates crater obliteration on Venus. Faulted units typically have both high radar backscatter and RMS slope. Although use of either quantity alone is problematic, backscatter is more sensitive to variations in local morphology and chemical composition, so we adopt RMS slope as a general indicator of faulting as manifested by meter-scale roughness (e.g., 4). Recognizing that other processes such as blocky lava flows could also contribute to high RMS slopes, a trial-and-error cutoff value was established by visually comparing the RMS slope map to selected tectonic zones visible in backscatter and shaded relief. The adopted contour of 2.5° is shown in Figure 1. These criteria show Venus as a planet dominated by tectonism: approximately 60% of the planet may be characterized as faulted, 45-50% if fractured plains are neglected. Yet only 40% of the craters with $D > 30$ km are contained within faulted regions. Since there are nearly 200 samples (craters), the probability of this distribution occurring by chance is very small. There are fewer craters in tectonized zones because they are being destroyed.

Further evidence for tectonic obliteration comes from crater preservation states. Within the plains areas defined by Figure 1., none of the craters is tectonically deformed. Within the fractured plains, however, nearly half of the craters are cut by faults. Returning to the existing crater data base, 60% of craters in rift areas and 40% in tesserae are faulted. All tolled, 75% of all craters occur on the 50% of the planet covered by plains (either disturbed or undisturbed), and the vast majority of these craters are undeformed. In contrast, over a third of the remaining 25% of craters are tectonically deformed. Although craters may be uniformly distributed geographically, such variances in crater abundances and modification, scaled as they are to global areas, are clear indications of non-uniform geologic distribution. These results clearly indicate that a substantial portion of the planet is undergoing modification.

Interpretation. If craters are being tectonically obliterated but are spatially randomly distributed, then tectonism must be widespread, recurrent, and operating at a variety of scales. Although the eye is drawn in radar backscatter images to major deformation zones such as the Equatorial Highlands and Ishtar Terra, faulted areas occur across the planet (Fig. 1). Resurfacing models[2] still constrain the size of a typical "patch" to less than about the mean intercrater distance in order to preserve spatial homogeneity.

These requirements are in good agreement with the emerging picture of global tectonics on Venus both from theory and Magellan observations. On Earth, plate decoupling focuses deformation in narrow zones a few hundred km across separated by undeformed regions thousands of km in size. On Venus, direct coupling to mantle convection results in more pervasively distributed deformation, but in patterns coherent over length scales of several hundred kilometers[5]. This is precisely the patch size required by crater resurfacing models (although new simulations incorporating belt-like deformations in addition to equant ones may be necessary). Vigorous mantle convection will ensure that resurfacing patterns are both spatially and temporally variable since the time scale for reorganization of convective patterns is small compared to the crater retention age of 500 Ma.

Conclusion. Tectonic resurfacing of Venus is supported both by the distribution of impact craters with terrain type and by the statistical associations of crater preservation states. Widespread and pervasive tectonic deformation of Venus is a natural consequence of "standard" geophysical models of surface-interior interactions and is geologically straightforward.

References. [1]G. Schaber et al, *JGR. 97*, 13257 (1992). [2]R. Phillips et al., *JGR, 97*, 15923 (1992). [3]R. Herrick, Ph.D. Thesis, SMU (1993). [4]D. Bindschadler et al., *GRL, 17*, 171-174 (1990). [5]S. Solomon et al., *JGR 97*,13199 (1992).

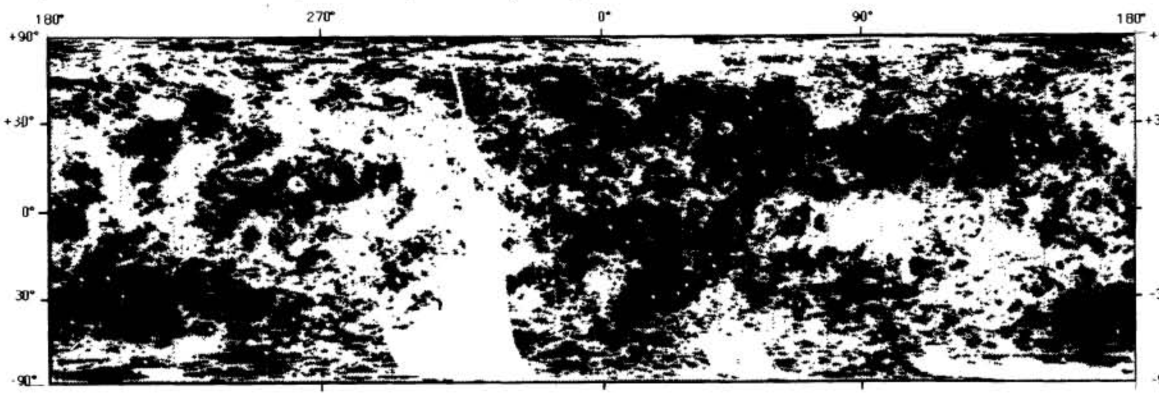

Fig. 1. Cylindrical equal-area map of Venus showing areas above 2.5° RMS slope in gray, roughly corresponding to faulted regions of the planet. Undeformed areas in black; white areas not imaged. Impact crater locations shown as white dots. Tectonized regions comprise 60% of the planet yet contain only 40% of the craters, providing clear evidence for ongoing resurfacing.