SPLOTCHES ON VENUS: DISTRIBUTION, PROPERTIES, AND CLASSIFICATION. R. L. Kirk and D. J. Chadwick, U.S. Geological Survey, Flagstaff, AZ.

Introduction

"Splotches," the diffuse, roughly circular features discovered in the Magellan images of Venus and attributed to the disintegration of small impacting bodies in the atmosphere [1], are of interest for several reasons. First, we would like to understand their physical properties and the processes by which they form. Such an understanding is especially desirable because splotches are probably the simplest and easiest to understand of a wide variety of Venusian features formed by impactor-atmosphere interactions. (Other such features are halo craters, parabolic crater deposits, and "butterfly" ejecta patterns.) Second, although the splotches do not shape the landscape in a major way, they are part of the stratigraphic record. Unless they are ephemeral (which has yet to be determined), they will contribute to our understanding of Venus' resurfacing history in the same way as craters [2,3]. Third, unlike craters, splotches appear to be nonuniformly distributed , and splotches of similar types seem to cluster. The distribution of splotches may therefore tell us something about the properties of the surfaces on which they form. Finally, it is possible that a close study of the properties of both splotches and crater halos will reveal patterns that distinguish asteroidal from cometary impactors. This information would tie the cratering records of the terrestrial planets more firmly to the observed numbers of asteroids and comets, improving the absolute accuracy of the cratering timescale.

Splotch Database

Because splotches have yet to be studied systematically in any detail, we expect that considerable insight can be gained by starting with empirical, statistical studies of splotch properties and distributions. We have therefore focused initially on building a splotch database. Schaber et al. [2] described a basic database containing splotch positions, a preliminary classification based on the pattern of concentric dark (D) and light (L) rings outward from the center as well as a possible central "impact" feature (I), and the radii of these rings. We have continually updated this database as new Magellan images have been released; it now contains 401 splotches in 11 different classes. More importantly, we have added considerable information. First, we identified the Magellan image mosaics (C1-MIDRs) in which each splotch occurs and which of the several incidence-angle profiles were used to image the splotch. (We examined the mosaics, many of which contain parts having no data, to be sure that the splotches had actually been imaged in a given mode.) Second, we extracted data values from the Magellan global datasets for altimetry (GTDR), emissivity (GEDR), reflectivity (GREDR), and surface slopes (GSDR), as well as the image data resampled to the same resolution. We recorded the average value within the splotch (out to the outermost radius) and the average in an annulus of equal area surrounding the splotch, converting the data numbers to physical units. The software developed to extract data values from the GxDRs has obvious applications to the study of features other than splotches, and it will be released as part of the Planetary Image Cartography System (PICS).

Spatial and Physical-Properties Distributions

Several types of statistical investigation are possible with the database just described. Our first approach was to analyze the uniformity of the splotch distribution, both spatially and with respect to background values of elevation, emissivity, and so on. One way to do this is to plot the cumulative probability distribution of a property for the set of splotches versus the equivalent distribution for the whole planet (e.g., plot at 1/360 the fraction of splotches between longitudes 0° and 1° , at 2/360 the fraction between 0° and 2°, and so on, or plot the fraction of splotches below a given elevation versus the fraction of the planet's area below that elevation). The resulting plot will be a diagonal line if the chosen parameter does not influence splotch formation; departures from the diagonal are readily visible and their significance can be quantified by powerful statistical tests [4]. We have found that splotches are distributed nonuniformly with respect to all the parameters in our database. To look for patterns in this nonuniformity, we have converted the cumulative plots to a relative density of splotches as a function of the dimensional data values. For example, the density of splotches decreases almost monotonically with elevation (Fig. 1). This trend is not related to Venus having more lowlands than highlands; the uneven distribution of elevations for the planet as a whole has been taken into account in this plot. The other datasets show that splotches are nonuniformly distributed in latitude and longitude and that they prefer intermediate emissivities (0.79 to 0.87); intermediate reflectivities (0.08 to 0.18); intermediate backscatter cross-sections (-3 to 9 db relative to Muhleman's law, peaking at 2 db); and low but not the very lowest slopes (density decreases monotonically with slope except for surfaces with slopes less than 2°, where almost no splotches are present). Slope is the only parameter for which the distributions within and outside the splotches differ (the splotches are typically smoother than the surround). Splotch/surround differences would be expected for backscatter cross-section (the splotches are visible in the backscatter images), but the differences are probably suppressed because we combined all splotch classes and averaged backscatter over all rings out to the outermost radius. We plan to analyze splotch backscatter properties in much more detail by using the C1- MIDRs, which have a resolution 20 times better than the resampled mosaic used here.

An immediate question is whether these trends are interrelated. After all, emissivity varies roughly oppositely with reflectivity, the Venusian highlands tend to be rough and to have high backscatter cross sections and low emissivities, and so on. Perhaps (for example) splotches do not form readily on the highlands, or they are harder to detect in rugged highland terrain. We have tested such hypotheses by comparing maps of the predicted density of splotches based on each dataset individually. The highlands appear as low-density areas in all the maps, supporting the idea that all trends reflect a single cause there. In the lowlands, however, there is little correspondence between the maps, suggesting that the variables have separate and competing effects on the likelihood of splotch formation. The nature of these effects is not yet clear, except that the near-monotonic trend with elevation strongly suggests that splotch formation is favored by high atmospheric pressure. We are currently performing Monte Carlo simulations of splotch distribution to explore the possible correlation between different controlling variables. Another obvious extension of this work will be to examine the dependence of splotch density on geologic unit type, but a global, digital geologic map of Venus is unfortunately not yet available.

Allometry and Classification

A second important area for statistical investigation is the refinement of the initial system of splotch classification, starting with a search for relations between the classes of splotches as initially defined. We are interested in comparing splotch properties and distributions both to discriminate between asteroidal and cometary impactors and to study the effects of different surface properties on splotch formation. These studies are frustrated by the large number of possible combinations of splotch classes and physical parameters, and also because most classes have very few splotches, resulting in poor statistics. A preliminary comparison of the allometry of the splotches (both the statistical distribution of the radius of each ring and the joint distributions of multiple radii) suggests that the rings in different classes can be identified with one another, as shown in Table 1. We hope, ultimately, to understand the processes that create the different light and dark rings.

With this tentative idea of the relations between splotch classes, we have begun to group the classes in different ways and to study the distributions of the groups. For example, splotches with impact scars (classes 5, 6, 11) are biased toward surfaces with lower backscatter crosssection than than those without (classes 1, 2, 10). Splotches with (I)DL rings (classes 1, 6) do not show any such bias in comparison with the corresponding classes (2 and 5) with (I)D only. Had we found the reverse, we might have dismissed a greater abundance of (say) DL splotches on dark terrains as a selection effect having to do with the backscatter contrast between splotch and background. The preference of I splotches for dark terrain is clearly a clue to the conditions that influence the formation of splotches. The task of gathering and understanding all such clues is daunting, but the analyses that we have begun show great promise for increasing our understanding of both the splotch-formation process and the surface properties of Venus.

References Cited
[1] Phillips, R. J., et al. 1991. *Science* **252**, 288-297; Soderblom, L. A., et al. 1992. *Lunar Planet. Sci.* **XXIII**, 1329-1330; Zahnle, K. J. 1992. *J. Geophys. Res.* **97**, 10,243-10,255. [2] Schaber, G. G., et al. 1992. *J. Geophys. Res.* **97**, 13,257-13,301. [3] Phillips, R. J., et al. 1992. 97*J. Geophys. Res.* **97**, 15,923-15,948. [4] D'Agostino, R. B., and Stephens, M. A., eds. 1986. Goodness of Fit Techniques. Statistics: Textbooks and Mongraphs, v. 68, Marcel Dekker, New York and Basel, 560 pp.

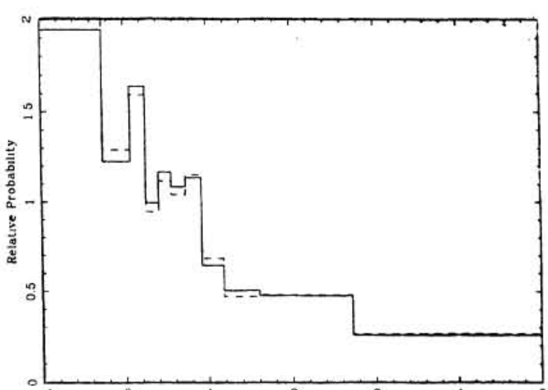

Table 1. Conjectured Relations Between Rings of Different Splotch Classes

Ring	I	L1	D1	L2	D2	L3	
Mean Radius (km)	5	11	25	37	55	105	
% of Splotches w/Ring	15.2	3.7	67.6	5.0	33.4	70.8	
Class							% in Class
1			D			L	54.6
2					D		18.2
3						L	4.0
4		L			D		0.5
5	I				D		7.0
6	I		D			L	8.0
7			D	L	D		3.0
8			D	L	D	L	1.5
9		L	D	L	D		0.5
10		L			D	L	2.5
11	I	L			D	L	0.25

Figure 1. Relative density of Venus' splotches as a function of elevation. Effect of preponderance of area at low elevations has been removed. Data are binned unequally in elevation so that each bin contains an equal number of splotches. Solid line: elevation just outside splotch. Dashed line: elevation within splotches. (Because splotches have no relief, difference between curves reflects errors in measurement.)