RESURFACING STYLES AND RATES ON VENUS: ASSESSMENT OF 18 VENUSIAN QUADRANGLES.
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Introduction: As part of the NASA/U.S. Geological Survey Planetary Mapping Program, we have mapped 8 Venus quadrangles, covering approximately 6.0 x 10^7 km^2, representing about 30% of the planet. These quadrangles cover different types of terrain, including topographic rises (western Eistla (V31), Laufey (V30) and Themis Regiones (V53)), plains regions (Tinatin (V33) and Sedna Planitiae (V19)) and chasmata regions (portions of Hecate (V28), Parga (V39) and Juno Chasmata (V46)). The areas of Venus that we have mapped show a diversity of stratigraphic histories, resurfacing styles and degrees of resurfacing, and led us to assess end-member models of the geologic history of Venus [1].

In light of the controversy over venusian resurfacing rates (e.g., 1-3) and the potential effects of widespread resurfacing (e.g., 4), we were motivated to attempt to quantify the sources and significance of resurfacing in our quadrangles. In order to broaden our results, we also assessed the resurfacing sources and significance in ten other quadrangles that have been published under the Planetary Mapping Program (refs. at [5]) (quadrangles V5, 9, 20, 25, 37, 40, 43, 44, 55, 59). These quadrangles avoided large expanses of tessera highlands, in order to more fully characterize the plains that make up over 80% of the Venus surface.

Our results indicate that the majority of plains resurfacing by volcanism can be tied to an identifiable source, that fields of small edifices contribute more to resurfacing that we had anticipated, and that resurfacing styles do not appear to have evolved over the time period represented by the surface geology in the mapped quadrangles.

Method and Results. In order to quantify resurfacing, we required a number of easily identifiable, widely accepted units. The current surface of Venus has formed from the accumulation of lava flows and deposits from a number of different source vents. A virtual consensus among those who study Venus recognize these source vents as broadly being; coronae, large volcanoes (>100 km diameter), intermediate volcanoes (10-100 km), small edifices (<10 km), and materials from rifts or fractures. In addition, widespread plains units have been identified that are interpreted to be sheet flows of volcanic origin, but cannot be tied to a source. Other units that have altered the surface include areas of deformed materials (‘tessera’, ridge belts, fracture belts, rift zones) and impact craters and their associated deposits. Due to the lack of water on Venus, none of these surfaces have been subjected to extensive erosion.

Each quadrangle was divided into 0.5 x 0.5-degree boxes. Each box was then assigned to a particular material unit class (i.e. Corona materials, Large volcano materials, Intermediate volcano materials, etc.) dependant on whether we were confidently able to identify the type of source that the material came from. Materials with no apparent source were counted as ‘plains no source materials’.

Where an individual 0.5-degree box was made up of different types of material, we added ‘half’ boxes to make up the total. We added both structure (including impact crater materials) and data gap categories in order to take into account small outcrops of tessera, belts of deformed materials and impact crater deposits, and areas of data loss. Heavily deformed materials associated with coronae (e.g. fractured annuli and interiors) were included within the corona category. F-Maps and digital image data were used to identify the different materials, and the where possible, published or preliminary versions of each quadrangle were consulted to allow consistency with the interpretations of other mappers. Given that we used radar image data, only units with radar backscatter characteristics differing from surrounding units will be identifiable, even if the units were emplaced at different times from different sources. Therefore, we are likely to have underestimated deposits from identifiable sources, misclassifying them as ‘plains no source’.

Results of our survey of eighteen quadrangles are shown in Figure 1. All percentages discussed below are of the areas surveyed, not the planet as a whole. By percent area, volcanic units with no identifiable source cover an average of 35% of the area surveyed, while volcanic units that can be tied to a specific source cover an average of about 52%. Of the identifiable sources, coronae (20.8%) and small edifices (22%) are the most significant in areal extent. Large volcanoes contribute about 6% to resurfacing. Tectonic processes, including areas mapped as ridge belts, fracture belts and tessera, have modified about 10% of the surface. Data gaps covered an average of 4% of the areas surveyed.

We can also assess the data by examining the overall geologic settings of the quadrangles surveyed. Four of the quadrangles cover major portions of topographic rises interpreted to be hotspots and six of the quadrangles lie along chasmata. The other eight quadrangles are in the plains isolated from major highland plateaus, chasmata or topographic rises. As seen in Figure 2, coronae are a major contributor to resurfacing along chasmata (38%), with plains with no identifiable source covering only 21% of these regions. At topographic rises, large volcanoes cover 11%, as opposed to 1.4% in isolated plains regions. In isolated plains regions and at topographic rises, small edifices cover approximately 25% of the terrain. In all regions, flows originating from rift fractures provided negligible contributions to resurfacing, even in chasmata regions (1.56%). Large flow fields in these regions instead tend to emanate from coronae and volcanoes.

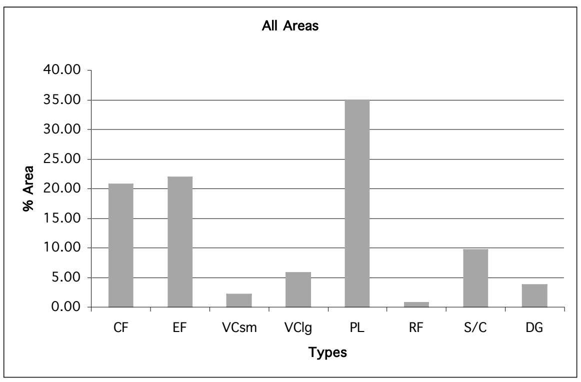

Figure 1. Results for all areas.

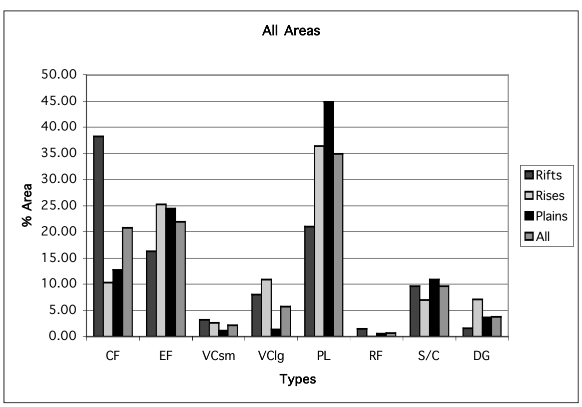

Figure 2. Result grouped by geologic setting.

In conducting this survey, we also were able to assess the scales at which various types of features resurfaced. Small edifices resurface areas on a scale of 10s-100s of km^2, with intermediate volcanoes producing flows that cover areas of 10^2-10^4 km^2. Large edifices resurface areas of 10^4-10^5 km^2. Coronae have greatly varying amounts of associated volcanism, with some coronae producing negligible flow deposits and others producing deposits of 10^4-10^6 km^2. The areas identified as plains with no visible source occur on very small scales (10^2 km^2) to very large scales ($>10^5$ km^2). In contrast, areas of terrestrial flood basalts are from 10^5-10^6 km^2 with thicknesses up to 8000 m (e.g., 6).

Conclusions: We have taken a quantitative approach to assessing resurfacing on Venus. Volcanism has dominated resurfacing in the regions we have examined, with approximately 2/3 of the area resurfaced by deposits from identifiable sources (coronae and small to large edifices). The remaining 1/3 of volcanic deposits ('plains no source') are likely to have erupted from fissures, or from coronae or volcanoes but obscured by having backscatter similar to that of surrounding plains.

All of the units that we quantified occur throughout the histories of the regions mapped. We see no evidence of directionalism in volcanic resurfacing over the mappable history of Venus (~750 my). Small edifices, which are not confined to a single period of venusian history (1, 7), resurface a significant portion of the surface, although their patch-scale of resurfacing is relatively small.

References: [1] Guest J.E. and Stofan E.R. (1999) *Icarus, 139,* 55. [2] Basilevsky A.T. et al. (1997), in *Venus II*, eds. S. W. Bougher, D. M. Hunten, R. J. Phillips, *Univ. of Ariz. Press, Tucson*, 1047. [3] Basilevsky A.T. and Head J.W. (2002) *Geology, 30*, 1015. [4] Bullock M.A. and Grinspoon D.(2001)*Icarus,150*,19037.; [5]http://astrogeology.usgs.gov/Projects/PlanetaryMapping/; [6] Tolan T.L. and others (1989) GSA Spec. Paper 239, 1-20.; [7] Addington E.A. (2001), *Icarus* 149, 16.