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Resurfacing styles and rates on Venus: assessment of 18 venusian quadrangles

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Abstract

We have quantitatively assessed the resurfacing sources and styles in eighteen mapped venusian quadrangles, about 30% of the venusian surface. Each quadrangle was split into 0.5° by 0.5° boxes, which were then identified as corona materials, large volcano materials (> 100 km diameter), intermediate volcano materials (10–100 km), small edifice materials (< 10 km), flow materials from rifts or fractures, plains without an identifiable source, impact crater materials and highly deformed materials, or data gaps. We find that coronae resurface approximately 21%, small edifices 22% and large volcanoes about 6% of the surfaces analyzed. Plains with no identifiable source account for an average of 35% of the surface assessed. Small edifices resurface on a scale of 10–100 s of 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 small scales (10^2 km^2) to large scales ($> 10^5$ km^2). 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 than 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. All of the units that we quantified occur throughout the histories of the regions mapped. We favor plains resurfacing to have occurred over at least 100 myr, which implies terrestrially reasonable resurfacing rates.

Keywords: Venus, surface; Surfaces, planets; Geological processes

1. Introduction

As part of the NASA/US Geological Survey Planetary Mapping Program, we have mapped 8 Venus quadrangles, covering approximately 6.0×10^7 km^2 (Table 1). These quadrangles cover different types of terrain, including topographic rises (western Eistla, Laufey, and Themis Regiones), plains regions (Tinatin and Sedna Planitiae) and chasmata regions (portions of Hecate, Parga, and Juno Chasmata) (Stofan et al., 1993, 2000; Crown et al., 1994; Copp, 1998; Stofan and Guest, 2003; Copp and Guest, 2004; Brian et al., 2004a, 2004b; Guest and Tapper, 2004). The portions 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 (Guest and Stofan, 1999).

Table 1
Venus quadrangles mapped by authors

Quadrangle	Latitude range		Longitude range
V19, Sedna Planitia	25°–50°	N	330°–0°
V28, Hecate Chasma	0°–25°	N	240°–270°
V30, Guinevere Planitia	0°–25°	N	300°–330°
V31, Sif Mons	0°–25°	N	330°–0°
V33, Scarpellini	0°–25°	S	30°–60°
V39, Taussig	0°–25°	S	210°–240°
V46, Aino Planitia	25°–50°	S	60°–90°
V53, Themis Regio	25°–50°	S	270°–300°

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Table 2
Other Venus quadrangles included in this study

Quadrangle	Latitude range		Longitude range	Reference
V5, Pandrosos Dorsa	50°–75°	N	180°–240°	Rosenberg and McGill (2001)
V9, Bell Regio	25°–50°	N	30°–60°	Campbell and Rogers (2002)
V20, Sappho Patera	0°–25°	N	0°–30°	McGill (2000)
V25, Rusalka Planitia	0°–25°	N	150°–180°	Young and Hansen (2003)
V37, Diana Chasma	0°–25°	S	150°–180°	Hansen and DeShon (2002)
V40, Galindo Planitia	0°–25°	S	240°–270°	Chapman (1999)
V43, Carson	0°–25°	S	330°–0°	Bender et al. (2000)
V44, Kaiwan Fluctus	25°–50°	S	0°–30°	Bridges and McGill (2002)
V55, Lavinia Planitia	25°–50°	S	330°–0°	Ivanov and Head (2001)
V59, Barrymore	50°–75°	S	180°–240°	Johnson *et al.* (1999)

In light of the controversy over venusian stratigraphic history (e.g., Basilevsky et al., 1997; Basilevsky and Head, 2002; Guest and Stofan, 1999; Hansen, 2000), 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 (http://astrogeology.usgs.gov/Projects/PlanetaryMapping/) (Table 2). The combined eighteen quadrangles cover about 30% (1.3×10^8 km^2) of the planet, giving us what we consider to be a representative view.

2. Background

Multiple models have been put forward to attempt to explain the surface of Venus as revealed by the Magellan radar mapping mission (1990–1994). Initial studies of the impact crater population indicated that it is indistinguishable from a random population, with very few embayed craters (Schaber et al., 1992). End-member models developed to explain the relatively pristine crater population ranged from: (1) a period of catastrophic resurfacing (perhaps cyclical) at $\sim$ 750 myr bp, followed by relatively small amounts of resurfacing since that time (Schaber et al., 1992; Strom et al., 1994) and (2) patch-style resurfacing, with small areas being resurfaced at a relatively constant rate over time (Phillips et al., 1992). Basilevsky and Head (1995, 2000, 2002) in a series of papers developed a stratigraphic model consistent with catastrophic resurfacing, with geologic activity at low levels since the resurfacing event, and certain types of geologic activity (e.g., wrinkle ridge formation, small edifice-style volcanism) confined to specific time periods. Phillips and Hansen (1998) present an alternative view, where crustal plateaus represent an earlier, thin-lid regime, followed by the present day, thick-lid regime characterized by the production of coronae, chasmata, volcanic rises and plains basins.

However, ongoing studies of the surface of Venus have indicated that the initial crater results are more complex than originally thought. Several workers have demonstrated that it is not possible to use the impact crater population to age date surfaces (Hauck et al., 1998; Campbell, 1999), ruling out the use of the impact population as a support of any resurfacing model. In addition, a study by Herrick and Sharpton (2000) of crater morphology and morphometry suggests that there is greater population of embayed impact craters than previously identified. Mapping studies have pointed out that a more nondirectional stratigraphic history for the planet is also possible (Guest and Stofan, 1999; Addington, 2001). Bullock and Grinspoon (2001) modeled the resurfacing event as an exponentially decaying impulse producing a 1 or 10 km thick layer in a timeframe of 10 or 100 myr. They illustrated that high rates of volcanism associated with a putative large-scale resurfacing event have the ability to alter the venusian climate, perhaps raising the surface temperature to as much as 900 K. They interpret the low water abundance in the venusian atmosphere to be most consistent with a resurfacing event that produced an integrated 1-km-thick layer, with recent (10–50 myr) outgassing necessary to support the SO_2 levels in the clouds. While the global-scale resurfacing event originally proposed now seems unlikely, the climate models do suggest that quantifying the rates of resurfacing from surface geology is highly desirable, in order to understand the evolution of the Venus climate, which in turn has the possibility of affecting the nature of the surface (e.g., Anderson and Smrekar, 1999; Solomon et al., 1999; Smrekar et al., 2002).

3. Method

In order to quantify the styles and sources of resurfacing, we required a number of easily identifiable, widely accepted types of 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. Most outcroppings of these plains are deformed by wrinkle