An Overview of Venus Geology and Geophysics

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Long known as Earth's evil twin, Venus is the planet most like Earth in terms of its size and bulk density. The global radar data set from Magellan indicates that Venus has many geologic processes in common with Earth as well as many that are unique. The high surface temperature alone on Venus would suggest that rocks would deform more readily than on Earth. However, the assumption that rocks are extremely dry more than offsets the temperature effect, making crustal rocks on Venus even stronger than those on Earth. On the global scale, Venus lacks plate tectonics. On Earth, plate tectonics provides the driving force for most geologic activity. Venus has five major plateaus that have been high deformed into 'tessera' terrain, which is defined by having multiple, intersecting sets of deformation features. Additionally, there are nine major topographic rises that are geologically similar to terrestrial 'hotspots' on Earth such as Hawaii. The gravity field produced by the Magellan mission provides key constraints on the origin of these majot topographic features. The large volcanic rises, or hotspots, have large positive gravity anomalies, which has been interpreted as the presence of a mantle plume at depth. In contrast, the gravity and topography signature at the major topographic plateaus indicates shallow, crustal compensation. The origin of these tessera highlights remains enigmatic, with models suggesting they form over both mantle upwellings and downwellings. Neither model fits with all observations.

An additional constraint on the interior comes from the lack of a magnetic field. Estimates of the Love number indicate the presence of a liquid core. The absence of a magnetic field is consistent with the idea that a stagnant lid convection mode does not allow for sufficiently rapid heat loss to produce a dynamo. However, it is possible that Venus had both plate tectonics and a dynamo early in its history.

A key constraint on the geologic evolution of Venus comes from the study of its impact craters. Venus has only ~1000 craters, which leads to a resurfacing age of 300-1000 my (McKinnon, et al. 1997). The additional observation that few of the craters are modified suggested an early interpretation that Venus experienced catastrophic resurfacing perhaps 500 my ago, followed by little geologic activity since then. Geodynamic models have tried to explain how Venus could have rapidly resurfaced via episodic mantle overturn and sinking of the lithosphere or melting in a hot mantle insulated by a stagnant lid.

Alternative models have suggested that Venus has resurfaced at a more moderate pace based on the observations of variations in crater density and how impact craters are modified over time. Impact craters start out with radar-dark parabolas that extend out 1000s of km and halos 100s of km in diameter. There is an evolutionary sequence of dark deposits: parabolas → partial-parabolas → complete-halos (no parabolas) → partial-halos→ no-halos. These studies show that there are areas of different age on Venus, and suggests that resurfacing has continued in at least some regions. This hypothesis is supported by a number of studies : 1) those that indicate active mantle plumes, 2) those that indicate that volcanism has supplied SO_2 to the atmosphere in the last 30 my., and 3) studies that interpret high surface emissivity in VIRTIS data as indicating relatively recent, less weathered flows. The relatively constant resurfacing scenario implies that the interior of Venus operates in a more Earth-like manner, with out a need for rapid global resurfacing. However, the fact that Venus has a stagnant lid indicates that it differs significantly from Earth with respect to rheology.