LAKSHMI PLANUM VOLCANISM: STYLE, ORIGIN, AND RELATION TO OTHER VOLCANIC DEPOSITS ON VENUS; Kari Magee Roberts, James W. Head, Dept. of Geological Sciences, Brown University, Providence, R.I. 02912

Lakshmi Planum, located in western Ishtar Terra, has been interpreted as a highland plain of volcanic origin.[1-6] Lakshmi rises 3-5 km above the datum and is surrounded on all sides by bands of mountains interpreted to be of compressional tectonic origin.[3,11,12] Lakshmi is distinctive and unique on the surface of Venus as an expansive (1.5-2.0 x10^6 km^2), relatively smooth, flat plateau containing two large shield volcanoes in the midst of a region of extreme relief. As a result of our detailed mapping, we have compiled a province map which illustrates some of the basic characteristics and large-scale distribution of surface units on Lakshmi Planum. The map and its units have been described elsewhere;[6] this abstract will focus on the styles and possible origin of the volcanism observed on Lakshmi and how it compares to other volcanic regions on Venus.

We have recognized three styles of volcanism that dominate the surface of Lakshmi. Centralized effusive volcanism is primarily associated with the two major caldera structures (Colette and Sacajawea) and their circumferential low-shield-forming deposits which dominate the plateau. Colette is 130 x 180 km in dimension, elongated in a N-S direction, 1-2 km deep,[2,3,5] and is surrounded by an extensive radiating system of flows having an average width of 15 km and lengths of 100-300 km. The shield structure surrounding Colette is about 500 x 700 km in dimension and descends about 1 km from the rim to the surrounding plains. Sacajawea is a 200 x 120 km oval-shaped depression elongated in a SW-NE direction and approximately 1.5-2 km deep. Sacajawea lacks the distinctive radial lobate flow patterns of Colette,[2,3,5] although mottled deposits surrounding Sacajawea, and distinct from the undivided plains, have been mapped extending about 300 km from the center of the caldera. Adjoining Sacajawea to the SE is a system of linear features interpreted by Pronin[3] to be fault scarps with characteristics similar to graben, at least one of which contains a volcanic dome. The concurrence of these two features suggests the presence of a flanking rift zone similar to those occurring in Hawaii. However, these graben lack the distinctive patterns of lobate flows (eminating at high angles to strike) that characterize eruptions along the rift zones of Mauna Loa and Kilauea. Colette, too, lacks strong evidence for the presence of flanking rift zones that are common among Hawaiian shield volcanoes. Rift zones which form as a result of listric faulting may be unable to develop on Lakshmi due to the low elevation of the shields there. Perhaps rift zones are only able to form in response to regional stresses, such as those associated with the surrounding orogenic belts. This origin is suspected for the rift zone which adjoins Sacajawea to the SE. On the basis of the relative crispness and distinctiveness of the flows and structures comprising the Colette shield it is interpreted to be younger than Sacajawea.[2,3,5]

Distributed effusive volcanism is associated with domes and cones 1-50 km in diameter and smooth plains for which no specific sources can be found. The abundance and extent of smooth volcanic plains which appear to predate the deposits of Colette and Sacajawea suggest that an episode of volcanic flooding occurred earlier in the history of Lakshmi. It is unclear why there was such a dramatic shift from volcanic flooding to extremely centralized, caldera-forming volcanism.

A third style of volcanism on Lakshmi is pyroclastic activity which may be associated with a 50 km diameter feature to the SE of Colette. This feature is surrounded by an elongated halo of deposits that is apparently superimposed on the more distinctive flow deposits of Colette. The diffuse character, the lack of distinctive lobate patterns, the elongation and the superposition of the deposits suggest that they may be of pyroclastic origin. If the classification of this feature is confirmed, and eruption is determined to have occurred under present conditions, then the presence of volatile-rich magmas on Venus is directly implied.[8]

Three primary characteristics distinguish Lakshmi from other volcanic regions known on the planet.[5-7] These are: 1) its high altitude and plateau-like nature, 2) the presence of two very large, low shield volcanoes with very large distinctive central calderas, Colette and Sacajawea, and 3) its compressional tectonic environment. Lakshmi Planum was originally mapped in its entirety as a smooth highland volcanic plain[2] on the basis of its elevation and smooth contrast to the extreme relief of the surrounding mountain belts. However, our mapping[6] has shown Lakshmi to be more complex and varied, containing additional elements of many of the plains types defined by Barsukov *et al.* (1986). Beta and Bell Regiones are volcanic provinces which, like Lakshmi, are characterized by high altitudes. However, unlike Lakshmi, they lack a plateau-like configuration and are not in compressional tectonic environments. The volcanic plains of Sedna, Guinevere, and Niobe Planitiae are similar to Lakshmi in that they are typified by numerous volcanic constructs, lava flows and sheets, and smooth or gently rolling topography. Unlike Lakshmi, they are at very low elevations and lack sharp, well-defined

mountainous boundaries and large volcanic shields. In fact, in the areas imaged by Veneras 15 and 16, there is no other region similar in general characteristics to Lakshmi Planum. While particular aspects of the planum may be observed elsewhere (volcanic regions at high elevations, plains containing numerous volcanic constructs and flows) the combination of features that define Lakshmi is apparently unique on the surface of Venus.

The distinctiveness of Lakshmi Planum is enhanced by the presence of the volcanic shields Colette and Sacajawea, which are themselves quite distinctive structures. Colette and Sacajawea are distinguished by large basal diameters, large, elongate, complex central calderas, and low elevations relative to the surrounding plain. There are numerous large volcanic constructs located outside of Lakshmi Planum but few are the size of Colette and Sacajawea. Theia Mons in Beta Regio is similar in diameter (700 km across) but rises to an elevation of almost 5 km.[15] Like Colette, Theia has a large (60-90 km across) summit caldera, although it does not appear to have as complex a system of concentric fault scarps. The height, steep slopes, and presence of Devana Chasma make Theia Mons, despite a similar basal diameter, presence of bright lava flows, and a large summit depression, fundamentally dissimilar to Colette. Renpet Mons (76°N, 238°) and Tepev Mons (on the SW flank of Bell Regio) have significant basal diameters (~300 km each) but are still smaller than Colette and Sacajawea. As is Theia, they are typified by higher elevations (up to 5.5 km above the surrounding plains) and steeper slopes than Colette and Sacajawea. Both have weakly defined summit depressions and are surrounded by radar-bright flows, although the lobate character of individual flows is not as distinct as that of flows about Colette. Api Mons (NE of Bell Regio), Atira Mons (52°N, 268°), and Melia Mons (SE of Tethus Tessera) are all characterized by radar-bright flows radiating ~200-250 km from complex summit regions. These structures may represent more highly developed calderas than those present at Theia, Renpet, and Tepev Montes. In particular, Melia Mons has an elongate, almost heart-shaped, caldera-like structure 170 km across. Interior to the structure are numerous domes, craters, and linear features suggestive of a caldera that has undergone several episodes of collapse and rejuvenation. In terms of caldera complexity, Melia Mons is most similar to Colette, although in general morphology they are quite distinct.

Our interpretation of the origin of Lakshmi Planum is based on several key observations. The relative synchronism of volcanism on Lakshmi and tectonism in the surrounding orogenic belts is indicated by the following: 1) the calderas of Colette and Sacajawea are not circular, but elongate, and their walls are oriented parallel to major structural trends within the planum and surrounding mountain belts, 2) smooth volcanic plains have been deformed into ridged plains which follow the borders of the plateau and strike parallel to the adjacent orogenic belts, and 3) the plains become increasingly more elevated as they approach some of the surrounding mountain belts. These observations, in conjunction with the topographic elevation of the plateau itself and the evidence for compressional deformation[11,12] and crustal thickening in excess of several tens of km in Akna, Freyja, and Maxwell Montes[9-14] lead us to conclude that volcanism on Lakshmi Planum is linked to melting associated with the processes of convergence and crustal thickening. We are currently investigating the sequence of tectonic deformation, crustal thickening processes, and the implications for crustal melting and differentiation in relation to the evolution of volcanic deposits on Lakshmi Planum.

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