VENUS VOLCANIC CENTERS AND THEIR ENVIRONMENTAL SETTINGS: NEW DATA FROM MAGELLAN.

J. Head[1], J. Guest[2], G. Schaber[3], K. Roberts[1], D. Senske[1], A. Basilevsky[4], R. Saunders[5], A. De Charon[1], T. Parker[5], B. Klose[6], B. Pavri[1], E. De Jong[5]. [1]Brown Univ. Providence RI; [2]Univ. College London, London UK; [3]USGS, Flagstaff AZ; [4]V. I. Vernadsky Institute; [5]JPL, Pasadena CA; [6]Harvard-Smithsonian Center for Astrophysics, Cambridge MA.

I) Introduction: Pre-Magellan regional image data (e.g.[1,2]) at resolutions of 1-4 km showed widespread plains volcanism and abundant volcanic centers and edifices of a variety of sizes and associations. Geochemical data from Venera sites indicated tholeiitic and alkali basalts[3], and possibly quartz monzonite-quartz syenite[4]. Theoretical studies have assessed the influence of the very high surface atmospheric pressure (4-10 MPa) and surface temperatures (650-750K) on eruption conditions relative to the Earth[5]. Resolution of pre-Magellan image data was insufficient to identify the detailed characteristics of many of the volcanic features and associations, and was not comprehensive enough to assess the global distribution of volcanism and its tectonic relationships. The Magellan mission, with its planned global data sets, is designed to address many fundamental volcanological questions. Here we report on early Magellan data for several examples of volcanic centers and their environmental settings.

II. Lava Flooding in Lavinia Planitia (Mylitta Fluctus): Unusual, extensive regions of isolated radar-bright lava flows have been mapped in Lavinia Planitia from Arecibo and high-resolution Magellan data[6,7]. The largest of the lava complexes (354°, 54°S) extends approximately 900 km N-S and 380 km E-W. The complex is located near the southern boundary of Lavinia Planitia and is surrounded by radar-dark plains. Rough-textured, radar-bright linear deformation zones border the complex to the north and south. The lineaments to the north form ridges and are interpreted to be of compressional and shear origins[6]; the lineaments to the south are more widely dispersed and are interpreted to be zones of extension[7]. The complex is characterized by very long, lobate, radar-bright flow units that extend up to 900 km in length with the widths of individual flow units varying from 15 to 125 km. The lavas in the complex have flowed downhill to the north primarily from a 200 km diameter shield volcano located on the linear extensional deformation zone. These extreme flow lengths suggest very high effusion rates and low magma viscosity[9].

III. Lava Channels: Sinuous Rille: A number of narrow sinuous channels have been discovered in the volcanic plains of Venus. Generally they: 1) are about 0.5-1.5 km wide; 2) are extremely constant in width; 3) do not show evidence for associated flow lobes or lava flow deposits; 4) sometimes empty into low-lying areas to form large plains deposits. In an example in SW Guinevere Planitia, a sinuous radar-dark rille-like feature about 0.75-1.5 km in width extends for hundreds of km and is linked to a fan-shaped area of dark volcanic plains at one end. The sinuous rille winds its way across the plains and between two ridges, turning north and apparently emptying out into the low-lying plains to form a fan-shaped deposit. The rille appears to have been deflected around the ridge, apparently following local topographic slopes. Details of the rille show what appear to be radar-bright levees and local 'breakouts' where the dark material flowing in the interior of the rille has broken through the levees and spilled out to form a new channel. Although the point of origin of this feature is unclear, the lava appears to have flowed over 1000 km before ponding in the low-lying plains. These characteristics are very similar to sinuous rilles on the Moon which are interpreted to have formed when very low-viscosity lava or lava emerging at very high effusion rates becomes turbulent and thermally erodes and incises a channel into the preexisting plains deposits[10]. If these structures are of similar origin, the higher surface temperatures on Venus may enhance thermal erosion processes[5].

IV. Volcanic Edifices: Sif Mons: About 50 large edifices and volcanic centers in the 100-350 km diameter range have been mapped in the 45% of the surface covered by Venera and Arecibo data[11]. One such example is Sif Mons, a 225 km diameter peak rising 1.7 km above the 2 km Western Eistla Regio regional rise. Magellan images reveal the detailed characteristics of Sif Mons and its deposits and have been used to assess local stratigraphy related to the origin and evolution of large volcanoes. Laterally extensive domed plains and dark plains units characterize the flanks of Eistla. The large abundance of small shields suggests that volcanism in this unit is localized and is unrelated to the formation of Sif itself. Uplift of these plains is suggested by the development of small, closely spaced graben developed radially in the NW sector. The edifice itself is made up of radially arrayed digitate and mottled plains extending for distances of 300 to 600 km from the summit region which are interpreted to represent large outpourings of lava associated with initial uplift and formation of the volcano. Superposed on and interleaved within these deposits is a radially textured annulus of flows extending 100-300 km from the summit that form the shield proper. Although flows radiating from Sif extend for distances of hundreds of km, they are of limited extent compared to the overall dimensions of the Eistla Rise (over 2000 km) and they appear to be a relatively thin veneer of material representing only a small portion of the overall topography of this region. On the basis of the observed relationships, a preliminary sequence suggests that extensional fracturing of the background plains units, possibly radially to the Sif Mons region,

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System

was followed by voluminous outpouring of flows from the vicinity of the present Sif Mons. Subsequently, broad aprons of flows were emplaced on the NE and SW flanks, and eventually, the central edifice was built up to an elevation of about 1.7 km from the abundant flows comprising the inner apron or annulus. These relationships, and the occurrence on a broad rise, suggest that a thermal plume or hot spot may have uplifted and fractured Western Eistla[12]. Voluminous melts associated with the plume head may have poured out initially, followed by numerous smaller eruptions building the edifice as the plume evolved.

V) Caldera: Sacajawea Patera: The largest caldera-like structure observed to date is Sacajawea Patera, a 200 x 300 km diameter, 1-2 km deep depression in Lakshmi Planum, Western Ishtar Terra[13]. Magellan data show details of an elongate 120 x 215 km annulus of volcanic plains within the depression, surrounded by concentric graben. The elevation of the northern rim averages 600 m higher than the southern rim and the patera floor is 0.4-1.7 km below the surrounding plains. Very few flow features are observed extending radially from Sacajawea and no shield edifice comparable to Sif Mons is observed in either image or altimetry data. The volume of the depression is approximately 2.4-6.3 x $10^4$ $km^3$, considerably greater than volumes of typical terrestrial calderas. No distinctive, single ridge or scarp sharply defines the rim of Sacajawea and the outer walls are characterized by a wide belt of circumferential, curvilinear graben, rather then the crests of rotated blocks commonly associated with listric faults on collapsed caldera margins. The graben, up to about 100 km in length are typically 1-2 km in width and spaced several km apart. Extending from the SE boundary of Sacajawea is a system of linear features that are approximately 40-140 km long, 0.7-3 km wide and spaced 4-20 km apart. The association of these features with a volcanic edifice and mottled, lobate flows suggests that they may represent a flanking rift zone along which the lateral injection and eruption of magma has occurred. A flow complex on the SW flank of Sacajawea and flow units that embay the concentric fractures suggest that subsidence and extrusion of lava were taking place simultaneously. These relationships suggest the following history for the region: Magma rising from depth reached neutral buoyancy in the upper part of the crust in eastern Lakshmi Planum, creating a large magma chamber.[14] Instead of effusive eruptions contributing to a surrounding edifice, magma was predominantly intruded laterally along dikes into the preexisting crust. Continued lateral eruption began to empty the magma chamber and cause subsidence of the rim. Subsidence was characterized by broad downwarping resulting in an annulus of graben structures. Concurrently with the downwarping, magma injected distally along dikes occasionally erupted to flood the outer edge of the annulus of graben. Sacajawea Patera is thus far unique in terms of its size, location in the highlands, lack of significant edifice deposits, and its annulus of graben.

VI) Morphologic Evidence of Viscosity and Composition Variations: Some structures and edifices observed in the Magellan data have characteristics that suggest higher effective viscosities or more acidic magma compositions. A field of domes in northern Lavinia Planitia (30°S, 338°) shows bright summit pits on low volcanic shields of probable basaltic composition. Nearby a steep-sided, conical volcanic structure 8 km in diameter and hundreds of meters high has a sharp contact with the surrounding plains, suggesting an outflow of viscous magma. The large summit pit, almost 3 km in diameter, is larger than summit pits observed on other steep-sided domes and may be evidence of explosive eruptions or subsidence and collapse of the summit. Located nearby is a group of three steep-sided, generally flat-topped domes 8 to 15 km in diameter, two of which appear to have summit cones and short, stubby flows; the summit pits may be evidence for explosive volcanic activity. The third dome shows no evidence for extrusive activity and probably grew by the intrusion of magma into the dome from below. The general morphology of these domes is very similar to extrusive domes of viscous magmas (rhyolitic, dacitic, andesitic) seen on the Earth in association with continental volcanism and large calderas (e.g., Mono Lake, California; Valles, New Mexico). Terrestrial domes are characterized by both endogeneous activity (magma intruded internally causing expansion and growth of the dome) and exogenous activity (breakthrough of flows or small extrusions, and explosive activity due to gas buildup). The southern dome appears to have formed largely by endogenous activity while the two northern domes appear to have had both types, with exogenous activity forming the summit cones. Additional similar features are seen in a region of volcanic activity in southernmost Guinevere Planitia (5°S, 335°) and a group of seven steep-sided volcanic domes located east of Alpha Regio (30°S, 11-13°) also show similar characteristics[15].

1) V. Barsukov *et al.* (1986) *JGR* **91**, D378; A. Sukhanov *et al.* (1989) *USGS* Map **I-2059**; V. Kotelnikov *et al.* (1989) *Venus Atlas*, ANCCCP; 2) D. Campbell *et al.* (1989) *Science* **246**, 373; 3) Yu. Surkov *et al.* (1987) *JGR* **92** E537; 4) Yu. Surkov *et al.* (1977) *PLSC* **8**, 2665; 5) J. Head and L. Wilson (1986) *JGR* **91**, 3049; 6) D. Campbell *et al.* (1990) *Science*, in press; 7) D. Campbell *et al.* (1991) *EMP*, to be submitted; 8) S. Solomon *et al.* (1991) submitted to *Science*; 9) L. Wilson *et al.* (1990) *LPSC* **XXI**, 1347; 10) M. Carr (1974) *Icarus* **22**, 1; 11) E. Slyuta (1990) *LPSC* **XXI**, 1172; 12) D. Senske and J. Head (1989) *Proc. 28 IGC*, 3-80; 13) K. Roberts and J. Head (1990) *EMP* **50/51**, 193; 14) L. Wilson and J. Head (1990) *LPSC* **XXI**, 1043; 15) B. Pavri *et al.* (1991) this volume.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System