DISTRIBUTED POINT SOURCE VOLCANISM: A MECHANISM FOR ‘REGIONAL PLAINS’ RESURFACING, VENUS.

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Introduction: The mechanism(s) responsible for Venus plains volcanism remain mostly elusive. Although coronae comprise a dominant source of “plains” lava, many plains lack coronae or obvious volcanic sources. Thus plains resurfacing is typically attributed to flood-type lava, presumably leaked to the surface though distributed cracks and fractures; but this mechanism has been accepted mostly due to a lack of viable models. Ongoing geologic mapping of ~15 million km^2 of equatorial plains (0-25N/90-150E) reveals clues to plains evolution and resurfacing.

Although plains have been described as smooth and featureless, FMIDR SAR images reveal extensively developed primary and secondary ‘micro’structures that provide critical clues for resurfacing processes. The area hosts abundant small shields across >10x10^6 km^2. Shields record shallow point-source volcanism over extensive regions, likely the result of incipient point-source partial melting of the crust leaked to the surface along penetratively developed fractures. Individual shields coalesced into a thin layer of shield “paint”, which formed time transgressively relative to local deformation and/or reactivation.

Data: We are in the process of mapping the V23 (Niobe Planitia) and V24 (Greenaway) regions using R- and L-look full-resolution SAR 2°x2° F-tiles viewed in normal and inverted modes (many features are more visible in inverted SAR). We interactively stretch images to highlight primary and secondary ‘micro’structures. Regional synthetic stereo (following published methods and macros [1,2]), and mosaiced C1 SAR provide regional context.

Niobe, Sogolon and Llorona planitiae lie north of elevated tessera terrain of Aphrodite Terra. These regions host regionally extensive E-trending wrinkle ridges, and N- to NW-striking fractures, faults and graben. Locally preserved concentric ridges mark corona-related structures. Digitate flow boundaries record local volcanic flows from central locations, but generally evidence of flow direction is rare. However, tens of thousands of shields decorate ~10 x 10^6 km^2.

Shields are small (1-15 km diameter) quasi-circular to circular radar-dark or -bright features with or without topographic expression (shield, dome, cone, flat-topped, or flat), and with or without a central pit [3-6]. Shields typically occur in clusters (~50-350 km diameter regions, 100-150 km mode; covering ~10,000 km^2) called shield fields [6]. Some workers believe shields formed during a specific time predating “regional plains” [7], whereas others propose that shield fields both predate and postdate regional plains [6, 8]. Detailed mapping of 7 dispersed regions indicates that shield fields are time transgressive with respect to local “regional plains” emplacement and deformation [9]. Aubele [10] delineated a morphologic unit, ‘shield plains’ that covers ~2.3 million km^2 and hosts small shields at a density of ~4500/10^6 km^2 within northern Niobe Planitia (V11, V12). Aubele proposed that the shield plains’ unit might extend from 7N to 67N. Indeed this unit occurs across most of V23-24.

Shields across the map area are distinguished based on the characteristics noted above, as well as by quasi-circular to circular regions of relatively homogenous texture on an otherwise penetratively textured region, interpreted as a region of local volcanic cover on surface marked by a delicate penetrative deformation fabric. Shields are distributed across Niobe, Sogolon and Llorona planitiae with no discernable patterns at any scale. The shields are not aligned along local fractures, nor are they clustered. What makes these shields so striking is their pervasive distribution across >10x10^6 km^2 across V23-24.

Shields locally cover, and therefore postdate fractures, wrinkle ridges or polygonal fabrics, yet they are also locally cut by structures of the same morphology and orientation. The delicate nature and the regionally extensive distribution with little change in orientation of the secondary structures, indicates that shield material forms an extremely thin (locally absent) ‘layer’. The layer forms a sort of volcanic veil with varying visibility of (underlying) tectonic structures. Shields coalesce into a thin mechanical layer—a ‘shield-paint layer’—that is locally deformed by parallel or polygonal wrinkle ridges, or parallel closely-spaced extension fractures. The layer also locally records reactivation in which surface fractures filled with ‘paint’ and later contraction resulted in inversion of the shield paint.

Specific locations highlight key shield-tectonic relations. In southern Llorona Planitia (9N/141), shields show little evidence of structural reactivation. The pattern of shields and older tectonic fabric delineates an extremely detailed contact over a 150 km transition; shield flows fill local fracture topography to the scale of data resolution, indicating that the shield layer is extremely thin. In regions dominated by the older penetratively fractured morphologic unit shields locally cover the delicate tectonic fabric. In the shield dominated region shield coalesce forming coherent layer; individual shields can be difficult to delineate, even with stretched and inverted SAR data.

Because shields occur apparently to the scale (and below) of SAR, their numbers are difficult to assess. Mapping of four representative 2°x2° F-tiles lacking craters, coronae, and tesserae allows estimation of shield density. Each F-tile was mapped using R- and

L-look data, and normal and inverted SAR. We delineated "obvious shields (OS)" and shields (S).

F-tile	OS	S	OS/10^6km^2	S/10^6km^2
23N/103	402	626	10,500	15,650
21N/113	167	1,080	4,175	27,000
13N/111	142	1,347	3,550	33,675
23N/117	251	1,005	6,275	25,125

Shield densities are similar to shield plains [10], and shield areas are much larger than that of shield fields.

At 23N/103 ENE-trending wrinkle ridges deform the shield-paint layer yet shields also locally overprint wrinkle ridges. Shields cover NNW-striking fractures, yet are cut by reactivation of these same structures. Similar relations occur across 21N/113. Fine-scale polygonal wrinkle ridge fabric domains with parallel fabric trends and gradational boundaries likely represent regions of extremely thin shield-paint. Within 13N/111 and 23N/117 fracture density is higher, although wrinkle ridges and fractures show similar regional structural orientations. Fractures are also locally covered or filled by shield material, and have subsequently been inverted to ridges as result of contraction similar to processes described by DeShon et al. [11]. 23N/117 also hosts a group of small ribbon-bearing [12] tessera inliers. Shields form on and around the tessera as they do elsewhere in V23-24.

The shield paint layer can display a mottled appearance, or it can appear extremely homogeneous similar to "homogeneous plains", "smooth plains" or "wrinkle ridge plains" of some workers. Thus it is possible that other plains regions are actually comprised of a composite layer of thousands of individual shields.

Resurfacing: Small shield size, close spacing, thinness of the shield-paint layer, a lack of discernable patterns, time-transgressive nature of the shields, and the distribution across >10x10^6 km^2 indicates that these shields record local point-source volcanism, which occurred across incredibly expansive regions. Each shield represents a small volume of melt as evidenced by its limited surface area. Individual shields presumably reflect single point sources of magma. The depth of the magma generation is likely shallow and regionally distributed. If the shields were spawned from a single large deep source of magma the shields would describe a pattern above the magma body, and presumably the region would have been elevated by the thermal mass of magma at depth resulting in a discernable pattern in resulting tectonic structures. The regional patterns of the tectonic fabrics do not describe a coherent magma source, nor do the shields. If the magma traveled from deep depths one would expect large volcanic constructs rather than tiny edifices.

Thus the distribution of shields across the study area seem to require point sources of melt formed at very shallow levels in the crust. The melt was presumably low viscosity and formed time transgressively across millions of km^2. Melt could rise due to capillary action, or due to buoyancy driven by density contrast between the magma and the surrounding material. Density contrasts can result from thermal or compositional differences, or both. However, given that shields represent such small volumes of melt, an unreasonably high ΔT between melt and host would be require for buoyancy [13]; given that the melt must form at shallow crustal levels a large ΔT is unlikely. Thus it seems most plausible that the shields represent a different composition than the material they are derived from, and presumably built on.

Regionally extensive, time transgressive, shallow, incipient point-source partial melting in the Venusian crust could perhaps be induced or enhanced by elevated surface T, geotherm or radioactive element concentration. We constructed numerical conductive heat flow models to investigate the relevance of specific variables responsible for crustal temperatures. Assuming theoretically derived Venusian solidus temperatures [14,15], variations of geothermal gradient, thermal conductivity, radioactive content and distribution, and surface T can result in significant perturbations of the local geotherm sufficient to cause the generation of upper crust partial melt.

Although not required for partial melting, the greatest deviation from the background geotherm occurs when surface T is high, thermal conductivity is low, and radioactives are abundant. This situation is not difficult to imagine given thermal conductivity's dependence on temperature [16]. A significant rise in atmospheric T may result in a decrease in the thermal conductivity of the surface rocks; this in turn allows radioactive heat to build up adding to the heat initially provided by the atmospheric increase. Transient variations and related feedback systems as above may provide a mechanism for generating local, limited sources of melt that leak to the surface.

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