GIANT RADIATING DIKE SWARMS: EVIDENCE FOR THE NATURE OF A GLOBAL RESURFACING EVENT ON VENUS  
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Overview:  Where giant radiating dike swarms have formed on the surface of Venus [1], stratigraphic relationships reveal that these structures predate 85% of nearby impact craters [2]. When combined with interpretation of the cratering record [3], this suggests that the global stress field recorded by the dikes postdates and may provide insight into the nature of global resurfacing. The stress configuration is consistent with predictions of resurfacing through mantle overturn [4], and our data indicate that during and just after the waning phases of this event mantle convection was organized into a limited number of upwelling and downwelling sites located beneath the equatorial Beta-Atla-Themis and Aphrodite Terra regions.

Observations:  Examination of the global population of 118 giant radiating dike swarms on Venus [1], in agreement with wrinkle ridge data [5], reveals that the surface of the planet is broadly characterized by coherent stress fields which extend across thousands of kilometers (Figure 1A). Adjacent to Aphrodite Terra, the maximum horizontal compressive stress directions inferred from the dike swarm geometries align predominantly normal to the existing highland boundaries. In contrast, horizontal compressive stress orientations in the Beta-Atla-Themis region are independent of the long wavelength topography, and instead are more closely linked to the presence and orientation of rift zones which have undergone limited extension.

Interpretation of the venusian impact crater population reveals that, though local stratigraphic sequences clearly occur [6], the mean age of the current planetary surface was apparently reset through global resurfacing approximately 300 M.y. ago [3]. Where giant radiating dike swarms have formed, observed stratigraphic relationships indicate that the swarms predate nearby impact craters 85% of the time, postdate all nearby tessera and regional plains deposits, and postdate nearby wrinkle ridges 58% of the time [2]. We are presently placing firmer constraints upon the mean age of the swarms by evaluating the density of impact craters superimposed upon them.

Discussion:  The observation that giant radiating dike swarms on Venus formed prior to the majority of the nearby impact craters but subsequent to the regional plains implies that they were emplaced during or just after the waning phases of the proposed global resurfacing event. This is significant because it means that the stress field recorded by the swarms also originated during this time, and thus may provide insight into the resurfacing process.

Theoretical calculations illustrate that one way to achieve rapid global resurfacing is through overturn of a shallow, gravitationally unstable mantle layer [4]. According to this model, crustal production through partial melting results in a shallow mantle residuum whose stability relative to the underlying undepleted mantle, assuming an absence of convective entrainment, is governed by the balance between compositional and thermal buoyancy forces within the evolving layer. As cooling progresses and a thick crust develops, the thermal evolution within the associated depleted mantle layer eventually produces a state of buoyant instability, initiating mantle overturn driven by negative diapirism. While the scale(s) at which this predicted exchange of material occurs are not addressed by current theoretical models, it is possible to place general constraints upon the process using the observed surface geology.

As one extreme of the overturn model, the depleted mantle layer could sink into the underlying mantle material as a distributed system of small negative diapirs, inducing a similarly dispersed system of localized return flow. Melting of the ascending material and associated resurfacing through magmatic eruption in this scenario is likely to produce a random, patchwork system of volcanic deposits. This situation is inconsistent with observations, however, as it is unlikely to produce laterally extensive stress fields and has been shown to be inconsistent with the observed modification of the cratering record [7].

At the opposite extreme, larger scale foundering at a limited number of sites may drive overturn and whole mantle convection (Figure 1B). Negative diapirism and associated mantle downwelling at this scale will generate compressive stress at the surface focused upon central regions [8] which undergo complex topographic and structural evolution to produce a
tessera-dominated, plateau-shaped highland [9]. In response to this process, concomitant return flow should drive undepleted mantle material toward the surface, a situation which favors concentration of volcanism and rifting above the upwelling site(s). This wholesale mantle overturn endmember is broadly consistent with the stress data preserved in the geologic record. Compressive stress orientations which extend thousands of kilometers across the plains are focused upon Aphrodite Terra, where ~30% of the tessera on Venus exists in the form of elevated plateaus. In combination with other evidence [3,10,11], this supports the interpretation that generation of the stress field is linked to construction and support of topography via broad scale mantle downwelling during or just subsequent to the time of global resurfacing. As a complement to this downwelling, the stress field and geologic record preserved within the Beta-Atla-Themis region support the interpretation that this heavily volcanic area was produced by broad scale mantle upwelling [12] which continued to induce local rifting and volcanism subsequent to cessation of the global resurfacing event [13]. Overall it thus appears that the stress field dictating the observed configuration of surface deformation during and subsequent to the time of global resurfacing was dominated by downwelling beneath Aphrodite Terra and upwelling beneath the Beta-Atla-Themis region, consistent with the interpretation that resurfacing may have occurred through large scale convective overturn of a depleted mantle layer.


**FIGURE 1.**

A) Global distribution of giant radiating dike swarms on Venus (adapted from [1]). Swarms that are depicted as circles formed in low differential stress, while those shown as hourglasses formed in higher differential stress and are aligned with the direction of maximum horizontal compression. Diamonds with lines show general wrinkle ridge trends [5]. The 6051 and 6053 km contours are shown; elevations above 6053 km are stippled. AT = Aphrodite Terra, B = Beta Regio, A = Atla Regio, and T = Themis Regio. B) Schematic of mantle convective system inferred from dike swarm stresses (adapted from [8]).