SPATIALLY EXTENSIVE UNIFORM STRESS FIELDS ON VENUS INFERRRED FROM
RADIAL DIKE SWARM GEOMETRIES: THE APHRODITE TERRA EXAMPLE. Eric B.
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Overview: The high resolution and near global coverage of Magellan radar images is facilitating
attempts to systematically investigate the stresses that have deformed the venusian crust. Here we continue
earlier efforts to utilize 170 large, radially lineated structures interpreted as dike swarms to assess the
orientation of the regional maximum horizontal compressive stress (MHCS) which existed in their
vicinities during emplacement. Examination of swarms near the equator reveals a link to broad scale
regional structures, such as Aphrodite Terra, across distances in excess of 1000 km, suggesting the
existence of first order stress fields which affect areas of more than 10^6 km^2 in a uniform fashion.

Focusing further upon the Aphrodite Terra region, the MHCS field in the surrounding lowlands inferred
from radial swarms is oriented approximately normal to the slope of the highland topography. This stress
configuration appears, at a simple level, to be incompatible with that expected during either upwelling or
downwelling construction of the highlands. In addition, the relatively undeformed geometry of the radial
structures within the highlands implies that these dike swarm features formed more recently than their
highly deformed surroundings. We therefore conclude that the differential stresses which existed during
emplacement of the dike swarms within and adjacent to the Aphrodite Terra highlands are related to the
gravitational relaxation of pre-existing topography.

Basic Principles: Application of continuum mechanical principles has shown that terrestrial dikes
propagate perpendicular to the least compressive stress direction. Thus, when intruded laterally at shallow
levels within the crust, dikes are expected to align with the direction of MHCS. Given geologically
contemporaneous formation or a temporally persistent far field stress configuration, therefore, dikes will
orient perpendicular to folds and other structures formed by compressive buckling and parallel to extensional features such as rift zones. This kind of behavior has provided data for recent attempts to characterize the global organization of shallow stress fields on Earth at a continental scale. The success of this paleostress analysis suggests that a similar approach can be utilized for other terrestrial planets as well.

Application to Venus: Ongoing consideration of radial dike swarms and wrinkle ridges suggests
that Venus is a good candidate for spatially extensive shallow stress analyses. Across equatorial domains
many 10^6 km^2 in area the behavior of radially lineated swarms indicates that sequential stress fields are
recorded in the geologic record, and that careful structural mapping may provide insight into their origin at
the regional level. One interesting example, discussed in further detail below, occurs within and adjacent to
the Aphrodite Terra highlands.

Aphrodite Terra: Radial dike swarms associated with Aphrodite Terra (Figure 1) adopt two general
geometric configurations. The first is comprised of swarms with almost purely radial geometries. From
this configuration, dominant within the highland areas and along their southern margin, we infer that the
swarms were emplaced in the presence of a low differential far field stress. In addition, these swarms
appear to have undergone far less strain than their highly deformed surroundings, and thus are interpreted to
have formed subsequent to construction of the highland areas. The second geometric configuration is one
in which swarms that are radial near their focus gradually become unidirectional at greater radial distances.
From this we infer that, as the dikes increase in length, the influence of the local intrusive stresses at the
swarm's focus gradually diminishes, causing the dikes' orientations to realign with the far field MHCS
direction. This type of geometry dominates in a broad, stratigraphically indeterminate swath north of
Aphrodite Terra which curls around to the east of Atlas and then terminates along its southern border. For
all swarms within this swath, as well as one isolated example south of and intermediate to Ovda and Thetis
Regions, the direction of MHCS indicated is oriented nearly perpendicular to the highland topography.

At present there is an ongoing debate about whether hotspot upwelling or coldspot downwelling,
each described briefly below, is the more likely explanation for formation of the Aphrodite Terra highlands.
One obvious course of action is to compare the stress states recorded by the radial swarms with those
predicted by the two models. The hotspot model predicts uplift, rifting, and shield volcanism followed by
invasion and continued intrusive volcanism that thicken the crust. The coldspot model predicts
downward flexure and small strains followed by thickening of the lower crust through inwardly directed
ductile flow. The post-constructional stages of both models involve gravitational relaxation of the
highland topography, producing increasingly extensional stresses in the interior portions of the plateau and
radially directed compressional stresses near the margins.

Ascent of molten material through the thickened crust and formation of dike swarms will be aided
by the extensional stresses developed in the interior as the topography relaxes. The abundance of swarms
in Thetis Regio relative to Ovda Regio suggests, therefore, that Ovda is the younger and least relaxed of the
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two regions, in agreement with predictions based upon the superposition of graben upon older compressional structures\(^2\). In addition, the overall strain predicted to accumulate in the highlands through relaxation is minor\(^3\); combined with the swarms' lack of structural disruption relative to their surroundings, this further supports the contention that the radial dikes were emplaced preferentially during the post-constructional phase of the highland's evolution. If, as suggested, the highland's construction is essentially complete at the present time, this may help explain the lack of a distinguishing correlation between Ovda and Theis Region and either upwelling or downwelling plumes\(^1\). As deduced for the highlands, neither model's constructional phases appear to account for the behavior of swarms in the surrounding lowlands. Stresses resulting from dynamic uplift, such as that produced by impingement of a mantle plume, should not extend any significant distance beyond the resultant rise\(^2\). Similarly, at a simplistic level the inward flow of material and compression caused by downwelling must, at some distance, disperse through strain induced by compensating extensional stress oriented normal to the highland topography, producing unidirectional swarm orientations perpendicular to their current alignment. Stress orientations induced in the surrounding lowlands by gravitational relaxation, however, are similar to those inferred from the dikes swarms' behavior and should pass from highland to lowland. Thus we postulate that topographic relaxation is currently controlling the differential stress state in the lowland areas, and that tesa formation within the highlands has effectively ceased.

**Conclusion:** The geometry of radial dikes swarms within and adjacent to the Aphrodite Terra highlands appear to record differential stress fields controlled primarily by the gravitational relaxation of pre-existing topography. Similar to the results from mapping of wrinkle ridges across broad regions\(^3\), the MHCS direction recorded by the dikes swarms surrounding Aphrodite Terra implies that shallow stress fields on Venus, as on Earth, are capable of uniformly affecting areas of more than \(10^6\) km\(^2\). We are presently examining other portions of Venus to assess the extent and character of the differential stress fields recorded by radial dikes swarms in order to decipher their relationship to regional structure and stratigraphy.

**References:**

This material is based upon work supported under an NSF Graduate Fellowship.