

GEOLOGIC MAPPING OF THE NIOBE AND APHRODITE 1:10M MAP AREAS, VENUS: INSIGHTS FOR MAPPING METHODOGY AND IMPLICATIONS FOR VENUS EVOLUTION. V. L. Hansen¹ and I. López², ¹University of Minnesota Duluth, Duluth, MN 55812 (vhansen@d.umn.edu), ²Departamento de Biología y Geología. Universidad Rey Juan Carlos. 28933. Mostoles. Madrid (ivan.lopez@urjc.es).

Introduction: Earth currently cools through plate-tectonic processes, however such processes likely depend on conditions that did not exist on early Earth. Archean tectonic processes are widely debated, in large part due to the extremely poor geological record, due in large part to late plate tectonic processes. Our ability to understand first-order processes of terrestrial planet evolution requires taking advantage of geological clues across the solar system, yet ancient terrestrial planet records are particularly poorly preserved and rare. Earth's ancient record is disrupted/destroyed by plate tectonic and surface processes; Mars' early history is obscured by bolide impact, surface burial, and/or reworking by volcanic, hydrologic, or atmospheric processes; whereas Mercury records dominate impact crater processes. In contrast, Venus' surface likely preserves a rare record of early terrestrial planet evolution due to an absence of both plate tectonics and a hydrologic cycle, and a dense atmosphere that shields the surface from extensive bolide impact [1-3]. In addition, Venus is the most Earth-like of the terrestrial planets based on first-order geophysical and geochemical properties. Thus, although Venus' evolution and operative geodynamic processes remain elusive, Venus may hold critical clues about early terrestrial planet evolution, and renewed study of Magellan's spectacular global data sets has the potential to reveal such a history preserved across Venus' surface.

We are conducting a detailed and comprehensive geologic, structural, and volcanic synthesis of Niobe Planitia (0-57°N/60-180°E, *I-2467*), Aphrodite (0-57°S/60-180°E, *I-2476*), and the immediate surroundings, herein referred to as Niobe Map Area and Aphrodite Map Area, respectively, and Niobe-Aphrodite, collectively. Geologic analysis was carried out using NASA Magellan S-band synthetic aperture radar (SAR) and altimetry data [4]. Data include: 1) browse to full resolution (275m/pixel to 75-100 m/pixel) right- and left-illuminated SAR; 2) Magellan altimetry (8 km along-track by 20 km across-track, ~30-m average vertical accuracy); and 3) synthetic stereo images constructed after [5] using NIH-Image macros developed by D.A. Young.

Geologic mapping is compiled at 1:10M-scale, although results are informed by full-resolution Magellan SAR data. Herein we summarize some of the first-order preliminary results to emerge from regional and

detailed geologic mapping; results are divisible into two major groups: 1) insights for geologic mapping methodology on Venus, and 2) implications for regional geologic relations and evolution.

Insights for geologic mapping methodology: A critical first step in mapping is delineation of the distribution and trends of different structural elements or suites of structural elements, particularly in lowland regions. For example, we recognize different suites of wrinkle ridges from the most regional extensive suite concentric to Artemis, defining a region >13,000 km in diameter [6], to suites concentric to individual coronae, to changes in wrinkle ridge trends spatially associated with deformation belts. Wrinkle ridge patterns can also be used to highlight or identify provinces of varying mechanical anisotropy, as well as to record the relative temporal evolution of regional-scale features, such as deformation belts, and regional strain field associated with spatially remote features, such as Artemis.

The regional distribution of suites of lineaments can be used to infer the nature of surface burial, including minimum spatial extent and thickness of cover material. The nature of lineament suites (including lineament character, spacing, length, etc.) can also provide clues about the mechanical nature of deformed cover material, even if the nature of material emplacement processes are elusive. Fundamentally it seems that mapping on Venus typically allows one to differentiate different mechanical units, which may or may not correspond to geologic units emplaced through singular events.

In addition, examples of structural reactivation are common, and occur at a wide range of scales, highlighting the important role that data resolution plays in both geological mapping and geologic history interpretation.

Implications for geological relations and evolution: Detailed geologic mapping over regional scales leads to a host of emerging first-order observations and/or implications for geological relations and general evolutionary trends.

Detailed mapping of lowland ribbon tessera terrain, Venus's locally oldest surface unit [7], and a major focus of our mapping efforts, reveals that RTT preserves both incredibly wide-spread coherence in structural trends between kipukas preserved over extensive regions, and, seemingly contradictory, regions marked by relatively sharp, spatially localized, changes in

structural fabric orientation. Similar patterns emerge from detailed structural mapping of RTT structural fabrics within crustal plateau, Tellus Regio [8]. It seems clear that ultimately we will be able to identify distinct RTT packages or provinces, although these patterns will only emerge with regional scale mapping conducted employing the highest resolution data.

Detailed mapping of RTT structural fabrics also reveals that more than one episode of ribbon structure formation may have occurred within some spatial locations, with relatively late formed suites of periodic ribbon-like ridges and troughs displaying extremely length:width aspect ratios.

A possible cousin of RTT, lineated terrain (LT), marked by extremely penetratively-developed parallel-lineaments, is commonly (but not in all cases) spatially associated with lowland RTT. Unit LT, which in some cases corresponds to the material unit defined as densely lineated plains [7], is defined as a terrain, rather than a material unit, given that it is defined by structural elements, which clearly formed after the material unit(s) fabric deformed [9]. Where unit LT occurs adjacent to RTT, the lineament fabric typically parallels one of the linear fabric trends in adjacent RTT; in some cases LT appears to wrap around parts of adjacent RTT. In some cases RTT and LT appear to represent gradational structural facies of one another. Potential genetic relations between RTT and LT are unclear, but warrant further study.

Shield terrain [10-11], which may also be genetically related to RTT and LT, occurs extensively across the lowlands, and broadly post-dates the formation of adjacent RTT and LT structural fabrics, although lineaments parallel to RTT or LT fabric elements locally cut individual shield structures, presumably the result of structural reactivation. The formation of shield terrain remains elusive, yet critical to understanding Venus evolution.

Geologic mapping to date across the Niobe map area leads us to challenge the widely accepted proposal that lowland RTT represents collapsed crustal plateaus [e.g., 2, 12-14]. Although the structural fabric of RTT preserved in both crustal plateaus and lowland inliers is similar, as noted in numerous published studies, we have found no evidence and/or relationships that require lowland RTT to have once been elevated, or that indicate lowland RTT exposures experienced tectonic collapse. This point seems worth noting given that mechanisms to accommodate crustal plateaus collapse (to accommodate widespread RTT within the lowland) have eluded modeling efforts to date [e.g., 15-17]. Thus, it is possible that lowland RTT exposures do not represent remnants of crustal plateaus. This point has

implications for models of both RTT and crustal plateau formation, as well as Venus evolution models.

Map relations across a wide range of scales indicates that at least across the Niobe-Aphrodite map area, Venus lacks thick (i.e., several km) regionally extensive material units; as a result, the Venus surface preserve a potentially rich geohistorical record, although delineating the details of the surface histories is a challenging undertaking.

Several regionally defined suites of wrinkle ridges are emerging as a result of the mapping efforts. As noted above, the regionally most extensive suite is concentric to Artemis (Artemis wrinkle ridges, AWR), defining a suite >13000 km in diameter [6?]. At the northern limit of the map area wrinkle ridges defined patterns that differ from AWR; the regional pattern of this suite or suites is, as yet, undefined as it lies mostly outside the map area. As a suite, AWR appears to generally postdate the formation of lowland circular lows (isolated corona defined by circular topographic lows rather than topographic domes). Lowland deformation belts, preserved only in the northern part of the map area, also predate the formation of AWR. In contrast, wrinkle ridge suites concentric to Bell Regio and Eastern Eistla Regio postdate the formation of AWR.

The Diana-Dali coronae-chasmata chain preserves a rich history of interaction with the spatially extensively greater-Artemis structure. The deep chasmata generally post-date AWR formation, with clear evidence of regional truncation of AWR wrinkle ridge patterns, however, AWR deform some flows which have been mapped as coronae-related flows. Two north-trending coronae chains that extend north of the Diana-Dali coronae-chasmata chain are deformed by, and thus predate formation of, AWR. Volcanic rise Atla Regio, which lies too the east outside the map area, and forms the termination of the Diana-Dali chain, clearly post-dates AWR formation, as Atla-related flows bury AWR structures.

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