

VENUS: NO CATASTROPHIC RESURFACING, NO PLATE TECTONICS, BUT A RICH ANCIENT HISTORY—RESULTS FROM GLOBAL RIBBON TESSERA TERRAIN MAPPING.

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Introduction: Ribbon tessera terrain (rtt) represents the oldest locally exposed unit across Venus' surface. Unit rtt is characterized by a distinctive tectonic fabric comprised of generally orthogonal ribbons and folds [1,2]. We are creating a global geologic map of rtt outcrops and structural fabrics. Unit rtt represents ~18% of Venus' surface with greater exposure in the northern and eastern hemispheres. Unit rtt displays coherent structural fabric patterns that define individual rtt packages that extend across millions of square kilometers. Individual rtt packages show cross-cutting relationships with one another, and record a rich ancient history of rtt evolution. Unit rtt map relations are difficult to reconcile with catastrophic resurfacing (via either volcanic flooding or lithospheric overturn) or ancient plate tectonic processes.

Background: Venus displays a rich variety of exogenic and endogenic structures that provide clues to its history. Currently, widely accepted hypotheses that dominate textbooks and popular science call for a globally extensive catastrophic volcanic flooding event that purportedly buried >80% of Venus' surface with 1-3 km lava in 10 to 100 m.y. time [e.g. 3-7]. Catastrophic resurfacing involving wholesale lithospheric overturn is also proposed [8]. According to these hypotheses, flooding or lithospheric overturn created a crater-free global surface in the form of lowland plains, effectively erasing (through burial) the recorded geologic history prior to the global catastrophic event. In the case of catastrophic volcanic resurfacing, unit rtt formed prior to the flooding event, representing a globally extensive surface unit across Venus [7,8]. Within the context of this hypothesis exposures of unit rtt represent limited regions that escaped catastrophic volcanic flooding and burial. Subsequent to the catastrophic emplacement of flood lava, colliding bolides created Venus' suite of ~970 well preserved impact craters, which display near random spatial distribution across Venus, with few modified craters [3,9,10]. Given that catastrophic volcanic resurfacing calls for an ~1-3 km thick flows to bury pre-existing impact craters, conservatively, ~80% of the planet's surface, or more, must have been buried to a depth >1 km to accommodate the spatial distribution of impact craters. Additionally, the hypothesis predicts that modified craters should lie along the margin of the buried region—that is, along the rtt-volcanic cover boundary, or the region with <1 km cover.

Given that unit rtt is postulated to form the basal layer for global-scale catastrophic flooding, the hypothesis predictions can be tested through a global rtt map, and isopach surfaces that reflect the possible depth of flood deposits. Unit rtt—variably marked by multiple wavelength contractional (folds), extensional (ribbons), and S-C-like shear structures—characterizes crustal plateaus (2-3 million km² quasi-circular highlands) and is preserved in large and small kipukas [1,2,11,12].

Methods: We employed NASA Magellan SAR and altimetry data in order to create a geologic map of rtt exposures and structural fabric including regional trends of ribbons, folds, and the occurrence and shear sense of S-C-like fabrics. We delineated rtt outcrops and structural fabric trends of individual georeferenced USGS VMap quadrangles, working in an Adobe Illustrator[™] environment with linked data files. Data layers included: USGS VMap SAR image bases, and synthetic stereo images (created using macros by D.A. Young); SAR and stereo images are consulted in both normal and inverted modes. We mapped rtt in VMaps 1-61 (we currently lack SAR data for V-62, the south pole region). We used Map Publisher[™] to create GIS shape and line files for transfer of geological interpretations to an ArcGlobe[™] GIS environment. ArcGlobe[™] allows true global data projection, dissolving cartographic issues (but granting a host of new technical issues!), and enabling comparative analysis of rtt with global data suites. To date ArcGlobe[™] issues are hampering our analysis somewhat.

Construction of a global rtt map, like all geologic mapping, is iterative. Identification of rtt exposures is mostly complete; VMap boundary mismatches is being addressed through iterations, although the initial match between VMaps was surprisingly good. Structural fabric mapping is complete across ~70% of Venus; local structural interpretations are revisited following global projection.

Calculated isopach surfaces delineate the possible depth of burial, or layer thickness above buried rtt. We used a local slope of 0.4° to calculate a global isopach surface, and cover depth >1 km. This slope, taken from rtt exposures in Niobe Planitia in V-23, represent steep slopes, serving to maximize regions with cover >1 km.

Results: Unit rtt is exposed across ~18% of Venus' surface. Perhaps the most striking result to emerge from the global rtt map is the uneven distribution of rtt, with the second being numerous regionally coherent

patterns defined by both rtt exposures and structural trends. Unit rtt outcrops dominantly in the northern and eastern hemispheres, with lower areal extent in the southern and western hemisphere. Local rtt poor regions occur across ~3000 km diameter areas. A huge rtt poor zone occurs across a NE-trending swath (~12,000-15,000 km long, ~7,000 km wide) centered at ~40S/225E. This region spatially overlaps with Atla Regio and Parga Chasma, and overlaps with and extends south of, Artemis, Diana-Dali, and Hecate Chasmata. The region of Venus that might lie beneath >1 km volcanic cover shows a similar (but inverted) global pattern.

If Venus had experienced catastrophic volcanic resurfacing, we would expect that the regions marked by large tracts of rtt (and hence old surfaces that escaped flooding) should show higher impact crater density than regions of poor rtt exposure (that is, young surfaces due to catastrophic flooding and resulting burial of old pre-flooding impact craters). But this is not the case, even for the large NE-trending rtt poor region centered at ~40S/225E. In addition, modified craters would be expected to lie within area of <1 km thick cover, but they do not. Each of these factors is difficult to reconcile with the volcanic catastrophic resurfacing hypothesis, and the catastrophic hypothesis fails the predictive tests imposed by global rtt map relations.

Regionally extensive patterns defined by both rtt exposures and coherent structural patterns among widely separated exposures define individual suites of rtt that are likely genetically related. Examples include: A) rtt is preserved both within and between the northern deformation belts of Atalanta and Vinmara; coherent rtt structural fabrics indicate that there was likely original continuity across a 2-4 million km² region of rtt; rtt formation predated deformation belt formation, yet the preservation of rtt patterns constrains mechanisms of deformation belt formation. B) A large circular feature (1800 km diameter) similar to crustal plateaus, though lacking elevation, within Niobe Planitia; C) an ~4000 km long (parallel to structural trend marked by fold axes) and ~3000 km wide (normal to structural trend) package of rtt trends in a NE fashion across Leda and Akhtamar Plantiae; D) a second NE-trending belt (~4000 km long, up to 600 km wide) divides Lowana and Tilli-Hanum Planitiae from Niobe and Vellamo Planitiae. First order cross-cutting relationships between individual rtt suites indicate that these rtt suites formed diachronously, and might provide means to establish relative temporal relations at the global-scale, forming the basis of a global-scale (relative) time scale. For example, rtt suite D truncates, and hence post-dated the formation of, rtt suite B; crustal plateau Tellus Regio truncates rtt suite C, and likely also formed after rtt suite D.

South of the equator Alpha and Phoebe preserve the largest single tracts of rtt (Phoebe's distinctive tectonic fabric is comprised of rtt broadly overprinted by younger extensional structures related to Devana Chasma); but coherent structural fabric patterns preserved across numerous isolated exposures of rtt over extensive areas indicate that rtt was once exposed across a much greater area. These isolated, but originally continuous exposures occur: 1) SW of Phoebe, 2) between Phoebe and Alpha, and 3) S and E of Alpha. The region east of Alpha hosts relatively large individual exposures of rtt; the structural fabric patterns across these exposures record a host of cross-cutting relations, again indicating diachronous formation of individual packages of rtt. As in the northern hemisphere, detailed mapping of these suites of rtt should reveal spatial and temporal limits of individual rtt packages, providing a means to construct a relative evolutionary history of rtt formation across this extensive region.

Implications: With ~18% exposed rtt, Venus preserves an ancient record that rivals that of Earth. The areal extent of rtt exposure, the limited contiguous area of Venus' surface that could be buried >1 km, and the uneven distribution of rtt and possible buried region are all difficult to reconcile with the catastrophic volcanic resurfacing hypothesis. Mutual crosscutting relations between individual rtt suites indicate that rtt formed diachronously. Although rtt formation may require unique environmental conditions that mark a distinct geological era, rtt it did not form synchronously across Venus. The regionally extensive and coherent patterns defined by rtt tectonic fabrics across millions of square kilometers are incompatible with plate-tectonic processes at any time in Venus' recorded history, and also cannot be reconciled with catastrophic resurfacing via lithospheric overturn. However, careful study of individual suites of rtt (as defined by coherent structural fabric patterns), and first-order temporal relations between individual suites, should provide new and exciting clues about the ancient global evolution of Venus' surface, and may form the basis for a global (relative) time scale.

References: [1] VL Hansen & JJ Willis, 1996, *Icarus*, 123, 296-312; [2] VL Hansen & JJ Willis, 1998, *Icarus* 132, 321-343; [3] GG Schaber et al. 1992, *JGR* 97, 13257-13302; [4] RG Strom et al., 1994, *JGR* 99, 10899-10926; [5] RR Herrick, 1994, *Geology* 22, 703-706; [6] AT Basilevsky & JW Head, 1996, *GRL* 23, 1497-1500; [7] AT Basilevsky & JW Head, 1998, *JGR* 103, 8531-8544; [8] DL Turcotte, 1993, *JGR* 98, 17,061-17,068; [9] DL Turcotte et al., 1999, *Icarus* 139, 49-53; [10] RJ Phillips et al., 1992, *JGR* 97, 15,923-15,948; [11] RR Herrick et al., 1997, *Venus II*, 1015-1046; [12] MA Ivanov & JW Head, 1996, *JGR* 101, 14861-14908; [13] RR Ghent & IM Tibuleac, 2002, *GRL* 29, 994-997.