GEOLOGICAL CONSTRAINTS ON THE TIMING OF THE EXTREME WARMING CLIMATE TRANSITION ON VENUS.

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Extreme warming climate transition on Venus: According to recent global circulation models, Venus underwent a climate transition from Earth-like conditions for most of its history to the current extremely warm conditions (surface temperature of ~450ºC) with the transition perhaps occurring at ~700 Ma [1,2]. We have been investigating the geological implications of this dramatic change in climate [3,4] and consider whether traces of the transition are recorded in the tesserae and/or in the old plains units.

Pre-warming fluvial erosion in tesserae: A implication of these global circulation models is that tesserae, the geologically complex and stratigraphically oldest preserved terrains on Venus (e.g. [5]), could have experienced erosion. From this perspective, we examined the topographic patterns in tesserae and compared them with stream drainage patterns on Earth [4]. Since topography is poorly constrained on Venus [6,7], we used a proxy method to locate topographic lows in tesserae. The margins of tesserae are often flooded by younger mafic plains volcanism in an embayed pattern suggesting that the lava is emplaced upstream along older river patterns. In a preliminary survey, we matched the tesserae valley patterns with 4 types of terrestrial stream drainage patterns [4], which is consistent with the hypothesis of the presence of fluvial erosion in pre-warming times.

Post-warming units and structures: Based on these observations, the climate transition must have occurred in post-tesserae time. Some types of stratigraphically younger units and structures on Venus show no sign of erosion. This includes features such as flow fields (e.g. [8, 9]) which exhibit simple superimposition of flow units, widespread shallow thrust faults called wrinkle ridges [10,11], graben-fissure systems [12], and lava channels (including canali and sinuous rilles) [13, 14]. All these features have surface topographic signatures that would have been lost if water erosional processes had been active.

Syn-warming units and structures: The timing of the climate transition is thus constrained to have occurred after the formation of tesserae and prior to the uneroded features described in the previous section. We next consider any evidence for erosion in the stratigraphically oldest mafic volcanic units and consider both intra-tessera plains units and the earliest plains units, using examples from Alpha Regio (V-32) Quadrangle [15].

***Intra-tessera plains units*:** Within the tesserae are isolated patches of mafic volcanism (e.g. [5]); these areas are distinct from the lava embayments discussed above and are not fed from lavas from the adjacent younger plains units (Fig. 1). It is generally interpreted that intra-tessera plains units originate from local sources such as small shield volcanoes. Some intra-tessera plains units, however, lack any obvious sources (Fig. 1). They are therefore likely either fed from fissure systems (dykes, as is common for flood basalts associated with terrestrial large igneous provinces [16]) or erosion has removed evidence of sources in which case the intra-tessera plains could be erosional remnants of originally more extensive areas of mafic volcanism.

Earliest plains units: Could the climate transition have occurred during the period of early plains volcanism? Of particular interest are the volcanic plains that in part overlap onto the edges of tesserae. They are stratigraphically the oldest plains units and exhibit lateral changes in radar brightness.

1) Sharp sudden changes in radar brightness indicate a boundary between flows (Fig. 2). In some cases, relative chronology can be interpreted from the apparent partial flooding of earlier structures (grabens or wrinkle ridges) by the younger flows. These relationships would not require erosion.
2) The other texture is a patchy pattern with diffuse boundaries between areas of differing radar brightness (Fig. 3). An origin for this texture involving erosion is plausible.

Individual subaerial basaltic flows can have pahoehoe and a'a surface textures, and in cross-section can exhibit entablature-colonnade structures [17,18]. If flows are emplaced sub-aqueously, they can have a pillowed morphology with hyaloclastite texture. Furthermore, a sequence of flows can exhibit different facies types and associations, including tabular and compound braided [19]. As a consequence differential erosion through a single flow, or a package of flows, would exhibit lateral variations in radar brightness.

Summary: We hypothesize that the extreme warming climate transition left marks in the Venusian geological record in the intra-tessera plains units and/or earliest plains units.

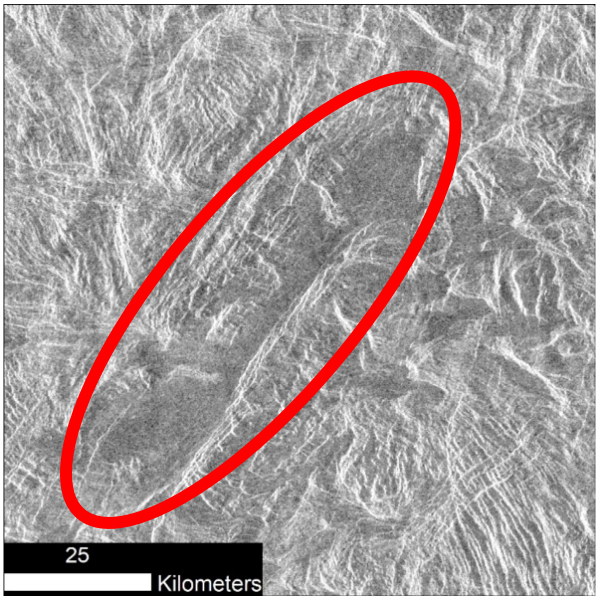

Figure 1 Patch of intra-tessera plains unit (irregular radar dark region) lacking any obvious feeder source. Coordinates of image centre are 3.5° E, 22.7° S.

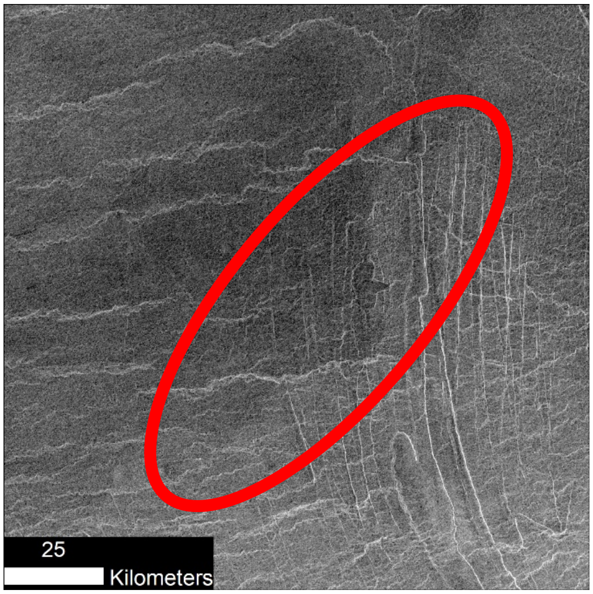

Figure 2. Sharp boundary (particularly inside red oval) between radar dark (smooth plains material unit 1) and light (intermediate plains material unit 7) old plains units; these two units are interpreted as separate flows. Younger ENE-trending wrinkle ridges are present throughout the area and younger NNW-N-trending grabens are concentrated on the right side of the image. Coordinates of image centre are 18.0 ° E, 7.4 ° S.

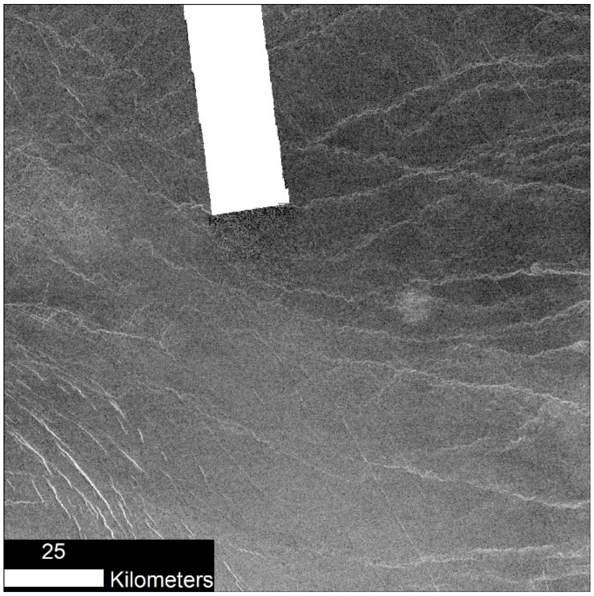

Figure 3. Gradational transition between radar dark (smooth plains material unit 1) and bright (intermediate plains material unit 1) areas possibly reflecting erosion; see discussion in text. Younger wrinkle ridges are present throughout the area, and younger NW-trending grabens are concentrated in the lower left of the area. Coordinates of image centre are 12.6° E, 9.9° S.

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