

FORMATION RATES AND MECHANISMS FOR LOW EMISSIVITY MATERIALS ON VENUS MOUNTAINTOPS AND CONSTRAINT ON TESSERA COMPOSITION. M. S. Gilmore, A. J. Stein, A. Treiman² and J. P. Greenwood¹, ¹Wesleyan University, 265 Church St., Middletown CT, 06459 mgilmore@wesleyan.edu, ²Lunar and Planetary Institute, Houston TX.

Introduction and Background: The surface of Venus undergoes changes in Magellan 12.6 cm radar properties that are correlated with altitude. The general case is that at starting at ~3 km above the mean planetary radius (MPR = 6051.84 km), surface materials exhibit lower radar emissivity than do the lowlands (mean emissivity ~0.85), reaching values that range from 0.3-0.8 [1]. At higher elevations, in some regions, there is an abrupt rise in the emissivity back to lowland values. These changes are ascribed to a chemical weathering reaction between the rocks and the local atmosphere, where it is likely that these reactions are facilitated by the lower temperatures at higher elevations. Numerous models have been invoked to explain this phenomenon [2-7], but the nature of these reactions remains equivocal.

Previous work attempting to model the causes of the emissivity changes at high elevations have considered the cumulative emissivity of all surfaces, without exploring potential differences in the emissivity of geologic units. In this study, we leverage bedrock and impact crater ejecta of known relative age to estimate the rate and style of the weathering reactions at the summits of Ovda and Thetis Regio, which together are the 2nd largest tessera occurrence on Venus. Tessera terrain is a heavily tectonized morphologic unit that comprises 8% of the Venus surface [8]. Tessera terrain is stratigraphically older than the volcanic plains and edifices that cover the remainder of the planet [8]. Surface-atmosphere reactions offer the opportunity to constrain the composition of Venus surface materials, particularly in the highland tessera terrain whose composition is inadequately known [9,10].

Methods: We model the size and position of impact deposit parabolas using an empirical formula based on the distribution of visible parabolas [11]. We calculate the radar emissivity and derived dielectric constant of all tessera materials at all elevations using equations 6-8 in [12]; see also [13].

Results: *Units defined by Crater Parabolas.* When a bolide impacts Venus, upper-level winds blow a portion of its lofted ejecta westward, and the ejecta typically settles out as a low-radar-backscatter parabola with the impact crater at its focus [11]. Crater parabolas are modified and removed through time as the ejecta are removed by aeolian processes, volcanism, tectonism, and/or chemical weathering.

We consider two types of crater parabolas on Venus. First are those clearly visible in Magellan left-looking horizontally polarized SAR backscatter data, typically as backscatter-dark parabolas [14]. Second, we assume that all craters >11 km in diameter would have produced dark parabolas, that have since been removed [15, 16]. The tessera surfaces are divided into several physiographic units: Case 1 are surfaces draped by visible radar-dark parabolas of plains craters; Case 2 are surfaces that are inferred to have been draped by parabolas from plains craters; Case 3 are surfaces that are inferred to have been draped by parabolas of craters in tessera terrain; and Case 4 are ‘pristine,’ i.e. inferred to have never been draped by a parabola. It is generally accepted that plains materials are basalts [17], so we assume that parabolas of Cases 1 and 2 consist(ed) of basaltic ejecta, and that Case 3 parabolas and Case 4 surfaces consist(ed) of tessera materials of unknown composition.

Variation in Emissivity Amongst Parabola-Defined Units. Prior studies of radar emissivity (or reflectivity) variations with altitude reported averages for all geographic areas (e.g., a single tessera terrain) [e.g., 7], and an averaged emissivity minimum at ~6055 km altitude. These studies did not consider presence of parabola deposits, which strongly affect radar emissivity. Our data show that emissivity minima are at different elevations for the four parabola-defined Cases. Below ~6052 km elevation, all surface units have emissivities of ~ 0.87 (and inferred permittivities of ~2-7), which are consistent with typical rocks and tightly packed soils. Pristine tessera surfaces (Case 4) show a strong decrease in emissivity up to elevations of 6055 km, above which the emissivity increases again monotonically (Figure 1). On the other hand, surfaces mantled with parabola ejecta from the plains (Case 1) maintain essentially a constant emissivity up to the highest elevations (Figure 1). Case 2, tessera surfaces inferred to have been draped with plains ejecta, are intermediate between Cases 4 and 1; they show generally high emissivity (like but somewhat lower than the tessera), and with minima at 6055 km and >6057 km. Case 3, tessera surfaces draped with tessera ejecta, are quite distinct. Case 3 is similar to Case 4, pristine tesserae, up to elevations of ~6054.4 km – a strong monotonic decrease in emissivity. At higher elevations, though Case 3 surfaces show (with some

exceptions) even lower emissivity values, down to 0.5 at the highest elevations.

Discussion: The fact that surfaces draped by visible parabolas (Case 1) do change emissivity with increasing elevation places critical constraints on the timing of the (uncertain) mechanisms that cause surface materials to have low emissivities. The 49 visible parabolas are 10% of the total number of craters on the plains and thus represent ~10% of the average surface age of Venus, or a model age of ~50-100 Ma. If so, then it takes basaltic materials at least 50-100 Ma to undergo the transition to lower emissivities above at 6052 km elevation. Modeled plains parabolas cover the bulk of the Venus surface and yield ages ~ average model crater age of the planet at 0.5 – 1 Ga [18]. In this time frame, basaltic materials may have reacted to form low emissivity materials. Alternatively, the excursion at 6055 seen for modeled plains craters may be due to overprinting of the plains material on the pristine tessera, where low emissivity signature of tessera terrain is detectable through overlying plains sediments.

The abrupt drop in emissivity at each of the excursions and return to higher emissivity with increasing altitude supports a model where low emissivity minerals are formed due to a temperature-dependent transition of ferroelectric minerals [2,7]. Ferroelectric minerals are electrically polar at low temperature (high elevation) and become paraelectric (non-polar) above the minerals' Curie-Weiss temperature. At or near the Curie-Weiss temperature the dielectric constant increases significantly, followed by a gradual decline in dielectric constant with increasing temperature. *We hypothesize that each case under study has different abundances of ferroelectric materials, where ferroelectric minerals are more concentrated in tesserae than in plains materials.* This accounts for the more rapid rate of change in and lower values of emissivity of the tessera units relative to the plains units.

That the reaction has not occurred in the youngest materials (Case 1, visible crater parabolas) requires a slow mechanism to produce the ferroelectric minerals. We support a scenario proposed by [7], where ferroelectric minerals are created or precipitated in rocks over time by oxidation, sulfidation or halogen reactions of a mineral(s) in the rocks with the atmosphere. That basaltic and tessera parabolas undergo the high permittivity transition at the same altitude requires a ferroelectric mineral that is ubiquitous in igneous rocks [19]. Here we consider the example of one candidate mineral, apatite. We hypothesize that exposed grains of fluorapatite ($\text{Ca}_5(\text{PO}_4)_3\text{F}$), the more common apatite in igneous rocks on Earth [19], will convert to chlorapatite ($\text{Ca}_5(\text{PO}_4)_3\text{Cl}$), a ferroelectric mineral, over a time

frame such that the visible parabolas will not have undergone this reaction in ~50 Ma. The diffusion constant for this reaction predicts that it will react ~50 μm of fluorapatite in ~50 Ma. This model offers a slow process to produce the ferroelectric minerals that then undergo a nearly instantaneous reaction to low emissivity at the Curie-Weiss temperature. We propose as did [7] that the differences in excursion elevations are due to differences in the composition of apatite, where OH^- can occupy the Cl^- or F^- site, or large cations, including rare earth elements, may substitute for Ca.

If we consider apatite, we find that it is more abundant in felsic rocks, which have more incompatible elements including P_2O_5 , relative to basalts [20]. This is also true of the more obscure candidates for the ferroelectric transition (and high dielectric minerals) where many comprise incompatible elements combining with an atmospheric component (S, Cl, F).

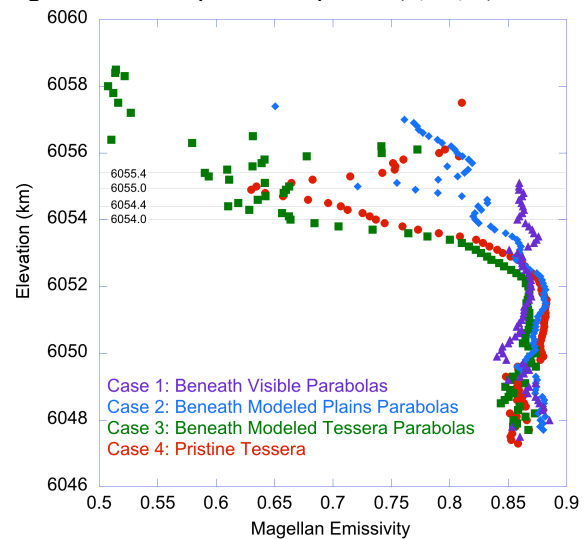


Fig. 1 Binned emissivity of parabola units. Elevations are binned every 0.1 km.

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