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Venus Surface Composition and Weathering

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Abstract

Imagine interpreting the geologic history of the Earth from radar images at ~100 m/pixel, topography with a footprint of ~10 km and major-element analyses at 3 random sites. This is our challenge for Venus after Magellan. This abstract is a summary of a Venus III chapter, which will describe what we have learned about the Venus surface primarily from Venus Express (VEx), which has for the first time provided regional mapping of surface radiance that includes compositional variability. Critical to the interpretation of these data are measurements of the 1 μm emissivity of rocks under Venus conditions and a better understanding of the chemistry of potential Venus surface-atmosphere interactions.

1. Introduction

Mapping of Venus by Magellan synthetic aperture radar (SAR) reveals a planet that can be divided into a number of geomorphic terranes [e.g., 1]. The surface is dominated (~70%) by plains that are relatively smooth at the scale of the radar (12.6 cm) and generally lie at elevations within a kilometer or so of mean planetary radius (MPR). Plains include vents, channels and small shield volcanoes consistent with a volcanic origin. Most or all of the Venera and Vega landers sampled plains materials whose chemistry is basaltic [e.g., 2]. The volcanic highlands 1-9 km above MPR) comprise large (100s km across) volcanic edifices, coronae and associated lava flows, fracturing and rift zones. These highlands are geographically concentrated and interpreted to be sites of mantle upwelling [e.g., 3]. The tessera highlands (1-4 km above MPR) are characterized by high radar backscatter and two or more sets of intersecting structures [4].

Venus has ~950 craters whose distribution is indistinguishable from random. This corresponds to an average surface crater retention age of < 1 Ga [5]. As the plains comprise most of the planet, this suggests that the planet underwent global, presumably dominantly basaltic volcanism in the last 0.5 Ga. Many details of this resurfacing event are poorly known (e.g., punctuated vs. equilibrium resurfacing, source vents), but it is generally agreed that this event is due to large-scale melting of the mantle [e.g., 6].

The tesserae are stratigraphically older than plains materials where they are in contact [7]; this is consistent with their crater age of 1-1.4X the average surface age [8]. Thus the tesserae are oldest rocks on a planet with a young surface age and offer our best (only?) hope at measuring materials from the first 80% of the history of the planet. Due to their topography, the tesserae have been considered candidates for more felsic compositions. If a felsic composition were confirmed for the tesserae, we are forced to envisage a number of formations scenarios including, but not limited to, terrestrial-style plate tectonics on a water-rich planet.

Conversely, the volcanic highlands are stratigraphically younger than the plains and have a paucity of craters compared the average [9]. A major question is whether Venus is presently volcanically active as is predicted by its size. There are several hints of recent geologic activity in the volcanic highlands based on stratigraphic position of flows above geologically recent crater deposits [10] and that the summit of Maat Mons has not undergone a weathering process typical of materials at that elevation [11].

2. Emissivity of the Venus Surface

Emission from the Venus surface can be detected above the atmosphere through atmospheric windows at 1.02, 1.10 and 1.18 μm [12]. Within this signal is the emissivity of surface rocks, thus providing an opportunity to assess the composition of surface materials.

The 1 μm emissivity of minerals is dominated by ferrous iron content where felsic minerals and rocks have a lower emissivity than mafic materials [13]. Relatively low ~1 μm flux values for mapped tessera units have been noted in both VEx VIRTIS [14,15] and VMC data [16]. A trend of lower radiance flux with at higher altitudes measured in integrated Galileo NIMS data [17] and VIRTIS data [18] has been attributed to the dominance of tesserae at high elevations. As the plains are presumed to be basaltic by extrapolation from the Venera lander data the lower radiance values observed for the highlands are consistent with a felsic composition for tessera [e.g., 17].

Volcanic peaks in Themis Regio are associated with anomalously high 1 μm radiance with respect to the global average [19]. Our understanding of Venus via surface measurement [20] and laboratory experiments is that Fe-rich minerals should weather to hematite under Venus conditions [e.g., 21], which would lower emissivity. Thus the higher emissivity is consistent with relatively unweathered Fe-bearing silicates in geologically young basalts [19].

3. Laboratory Measurements

The interpretation of the 1 μm emissivity data requires significant advances in laboratory measurements of rocks under Venus conditions. Absolutely critical is the systematic measurement of the variation of ~1 μm emissivity of minerals with temperature. Over a decade of work has been invested in the Berlin Emissivity Database which is now beginning to collect and interpret these data [22].

Additionally, laboratory work is required to better model weathering reactions and rates of reaction for relevant Venus materials. This requires funding for such endeavors, but also fundamental measurements of the lowermost atmosphere to better constrain relevant chemistry and redox conditions.

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