THE SURFACE OF VENUS AFTER VIRTIS ON VENUS EXPRESS: LABORATORY ANALOGS AND THE VENUS EMISSIVITY MAPPER.

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Introduction: The permanent cloud cover of Venus prohibits observation of the surface with traditional imaging techniques over most of the visible spectral range. Venus' CO_2 atmosphere is transparent exclusively in small spectral windows near 1 µm. These windows have recently been used successfully by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on the European Space Agency Venus-Express spacecraft to map the southern hemisphere of Venus from orbit [1,2]. VIRTIS is showing variations in surface brightness which can be interpreted as variations in surface emissivity. Deriving from these variations surface composition is a challenging task. Comparison with laboratory analog spectra are complicated by the fact that Venus has an average surface temperature of 730K. Mineral crystal structures and their resultant spectral signatures are notably affected by temperature, therefore any interpretations based on *room temperature* laboratory spectra database can be misleading [3].

In order to support the interpretation of near-infrared data from Venus we have started an extensive measurement campaign at the Planetary Emissivity Laboratory (PEL, Institute of Planetary Research of the German Aerospace Center, Berlin). The unique facilities available at PEL allowed emission measurements covering the 1 to 2 µm wavelength range at sample temperatures of 770K: preliminary results validate the investigation of emissivity within this narrow spectral range. Data from this facility not only allow interpretation of the VenusExpress VIRTIS data by also provide a baseline for considering new instrument designs for future Venus missions, as the Venus Emissivity Mapper (VEM) [4].

Target: With the currently available data from VIRTIS on VenusExpress [1] the whole southern hemisphere is a target area. With a future mission carrying a follow-up instrument [4] this can be extended to global coverage.

The highest priority targets are tesserae to address III.A.2. 50 km spatial resolution has abundant margin for tesserae plateaus, and even permits some tesserae inliers. Many other volcanic and tectonic features can be assessed for compositional variations at this resolution.

Science Goal(s): Near-infrared surface observations from orbit can directly address the science goals II.B.1, II.B.2, III.A.2 and III.A.3 as given in Table 2 of the VEXAG Goals, Objectives and Investigations.

Discussion: Based on the ongoing laboratory work, emissivity derived from near-infrared observations will allow at the very least determining whether Tessera terrain is composed of more felsic material, and whether the plains are formed by more mafic material.

Based on current VenusExpress VIRTIS interpretation, thermal emissivity has to be measured with a relative accuracy of 0.5% at 60km spatial resolution to constrain surface mineralogy and chemistry [1]. Deriving a more detailed mineralogy from the near-infrared data will also depending strongly on the availability of laboratory analog data obtained at Venus surface temperatures and on a better understanding of weathering processes on Venus.

The Planetary Emissivity Laboratory (PEL): PEL currently operates two Bruker Fourier transform infrared (FTIR) spectrometers both located on an optical table and equipped with external chambers for emissivity measurements (Figure 1). The laboratory is located in a temperature-controlled room at the Institute for Planetary Research in Berlin.

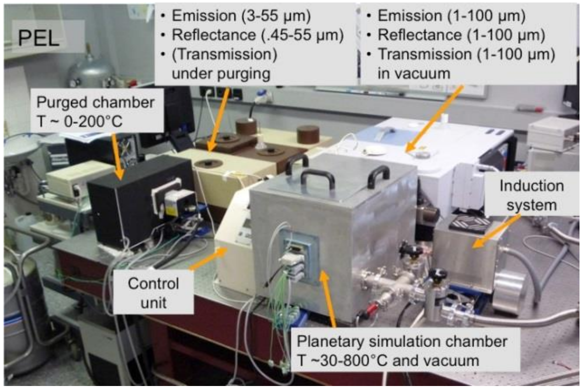

Figure 1. Overview of the setup at the Planetary Emissivity Laboratory (PEL).

For this study a Bruker Vertex 80V was used. The main feature of the PEL is a high-temperature chamber attached to the Vertex 80V that allows heating of samples to temperatures up to 1000K under vacuum conditions (medium vacuum - 10-100pa). Samples are placed in steel cups equipped with type K thermopiles as temperature sensors. A copper induction coil installed in the chamber and connected to a Linntherm 1.5kW induction system allows contactless heating of the ferromagnetic sample cups by induction. Spectral coverage is achieved with a combination of a liquid nitrogen-cooled MCT detector and KBr beamsplitter for the spectral range up to 16 µm and a DTGS detector with a multilayer beamsplitter for the remaining spectral range. In addition, a InSb/MCT sandwich detector is used. This detector provides significantly increased sensitivity in the spectral range from 1-5 µm.

Laboratory experiments: Conciliating the expected emissivity variation between felsic and mafic minerals with Venera and VEGA geochemical data [5,6], we chose to begin our work with single mineral phases, avoiding any possible band superposition.

The diversity of the considered igneous rocks induced us to prepare samples of several different silicates and salts suggested by past workers to be present on Venus. Thus we first collected in quantities spectra of pyroxenes, felspathoids, alkali-feldspars, carbonates, sulfates and sand salinifer (Table 1).

Table 1. Examples of selected minerals

Sample	Classification and Nominal Composition
amazonite	Tectosilicate group, K(Na,Ba) Feldspar subgroup, variety of microcline species $KAlSi_3O_8$
augite	Inosilicates, single-width unbranched chains group,(*C*2/c) Pyroxenes subgroup $(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$
barite	Hydrated Acid and Sulfates group, barite subgroup $BaSO_4$
calcite	Anhydrous carbonate group, Calcite subgroup $CaCO_3$
gypsum	Hydrated Acid and Sulfates group $CaSo_4 \cdot 2H_2O$
kyanite	Nesosilicate group, Kyanite subgroup $Al_2(SiO_5)$
sodalite	Tectosilicate, Feldspathoids Sodalite subgroup $Na_8(Al_6Si_6O_{24})Cl_2$

The potential single-phase samples were manually crushed and sieved to a grain sizes <250 µm selected for measurement. The reduced minerals were placed into steel cups and then into the high-temperature chamber. Emissivity were measured at 770K - the maximum expected temperature on the surface of Venus - focusing the wavelength range between 1 and 2 µm (Figure 2).

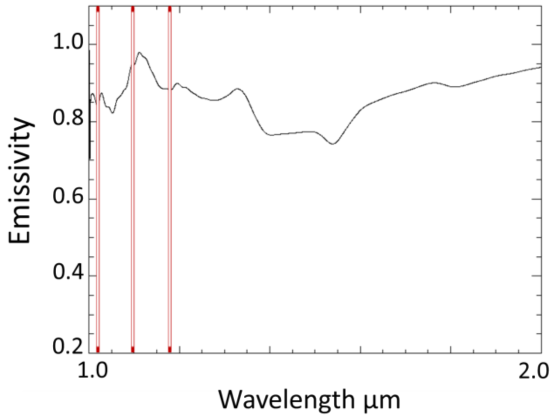

Figure 2. Emissivity spectrum for augite between 1 and 2 µm, collected in vacuum at 737K. Red lines show the filter positions of VEM within this range [4].

Conclusion: Our ongoing laboratory work validates the investigation of emissivity in a narrow spectral window of the near-IR spectrum. Our work on Venus analogs confirm that the high surface temperature of Venus, as other terrestrial planets, can affect the spectral characteristics of the surface materials [3].

Building on this acquired knowledge and in combination with a potential new high-resolution radar mapper, the Venus Emissivity Mapper [4] will be able to determine the large-scale compositional variations of the surface of the planet. The achievable ground resolution of 50-100 km will be oversampled at a spatial resolution of 10 km.

This successful combination of laboratory work and remote sensing will help us to understand better why Venus evolved so differently from Earth, and will provide valuable input for any landing site selections for future Venus lander missions.

References: [1] Müller, N. et al. (2008), *JGR Planets*, *113*, 1-21. [2] Helbert, J. et al. (2008), *GRL*, *35*, 1-5. [3] Helbert, J. et al. (2013), *EPSL*, *371-372*, 252-257. [4] Helbert, J. et al. *this workshop*. [5] Fegley, B., Jr. et al. (1992) *Proc. Lunar Planet. Sci.*, *22*, 3-19. [6] Kargel, J.S. et al. (1993), *Icarus*, *103*, 253-275.