VENUS' RADAR-BRIGHT HIGHLANDS: CHLORAPATITE NEAR THE EQUATOR, BUT NOT ON MAXWELL MONTES. A. H. Treiman[1], E. Harrington[2], and V. Sharpton[1]. [1]Lunar and Planetary Institute, 35600 Bay Area Blvd., Houston TX 77058 USA treiman@lpi.usra.edu sharpton@lpi.usra.edu. [2]Simon Fraser University, eliseh@sfu.ca.

Venus' highlands have higher radar backscatter than its lowland plains [1]. On near-equatorial highlands, radar backscatter returns to relatively low values at their highest elevations, with the sharp transition occurring at ~4.5 km elevation (T= ~ 702°K) [2-4]. This is consistent with the presence of a ferroelectric substance, and the only likely candidate is chlorapatite [3]. Backscatter on Maxwell, however, shows a different trend, with an abrupt transition to high backscatter at ~4.5 km elevation – a 'snow line [5,6].' This pattern is consistent with the presence of a semiconductor material, not a ferroelectric [6-8]. The difference between near-equatorial and near-polar highlands implies either different atmosphere properties, or different surface materials.

Data: Using Magellan spacecraft data, we studied radar backscatter as a function of elevation for selected areas in Ovda Regio (near the equator) and Maxwell Montes (~68°N). Backscatter is taken as SAR backscatter coefficient derived from FMIDR images; elevation is from a stereogrammetric DEM [9]. This combination allows spatial resolutions of ~0.4 km, compared to the resolution of ~10 km provided by radar emissivity and altimetry.

Results: Our results for radar backscatter and stereo DEM are consistent with earlier results for radar emissivity and altimetry [1,2]. We confirm that the highest elevations on Ovda Regio have low radar backscatter (equivalent to high emissivity), and that the transition from high to low backscatter going uphill is razor-sharp at ~4.5 km elevation (Figs. 1, 2). This
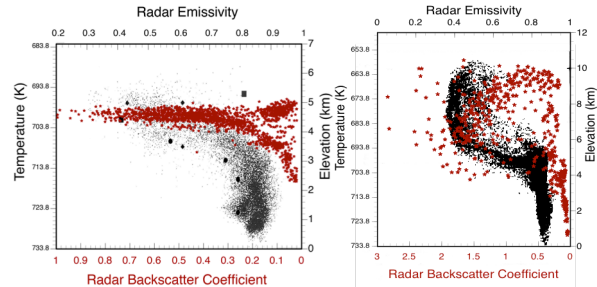
Figure 2. Trends of radar properties with elevation, selected Venus highlands. Red are radar backscatter coefficents [3,4]; black are radar emissivity data. **a.** Ovda Regio. Note the abrupt change in properties at ~4.5 km elevation, very high backscatter (low emissivity) below and low backscatter above. Emissivity data from [2]. **b.** Maxwell Montes. Note abrupt increase in radar backscatter above ~ 4.5 km. Emissivity data from [1].

trend is also seen elsewhere in Aphrodite Terra and on the basaltic shield volcanos of Tepev Montes, but not on all near-equatorial highlands (notably the Maat Mons volcano). We also confirm that Maxwell Montes and other highlands surrounding Ishtar Terra show a radar 'snow line' (Fig. 1); a strong jump in radar backscatter coefficient going uphill at ~4.5 km elevation [1,6]. Approaching the highest elevations on Maxwell, radar backscatter declines to more normal values, a trend which is not strong in current radar emissivity dataset (e.g. Fig. 2).

Ovda Regio: The trend of radar properties with elevation on Ovda Regio is consistent with the presence of a ferroelectric substance [2-4,10], i.e. a material with (or containing domains with) spontaneous electric polarization that can be reversed by the application of an external electric field [11]. The strength of the field needed to reverse the polarization decreases with increasing temperature, and becomes zero at the transition (or Curie-Weiss) temperature. Under the low electrical fields of Venus Magellan radar, a ferroelectric substance has low backscatter coefficient (from low dielectric constant) below the transition temperature. At the transition temperature, backscatter coefficient spikes (dielectric constant is huge), and as temperature increases the backscatter coefficient declines (as does the dielectric constant). This is precisely the radar trend at Ovda, for a ferroelectric transition temperature of ~700K.

Ferroelectric Material. The identity of the ferroelectric material on Venus' highlands has been unclear.
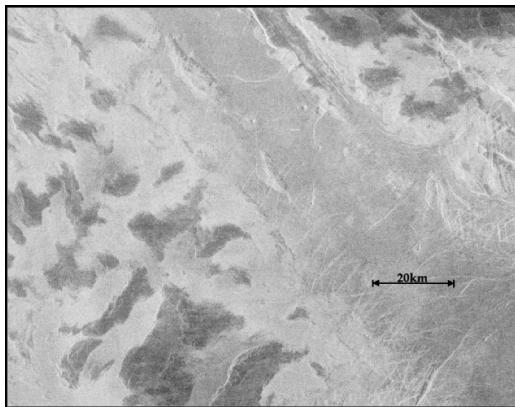

Figure 1. Magellan SAR image of an area in Ovda Terra [3,4]. Elevations above 4.5 km, to lower left and upper right, are dark (low radar backscatter); slightly lower elevations (surrouding the dark areas) have high radar backscatter.
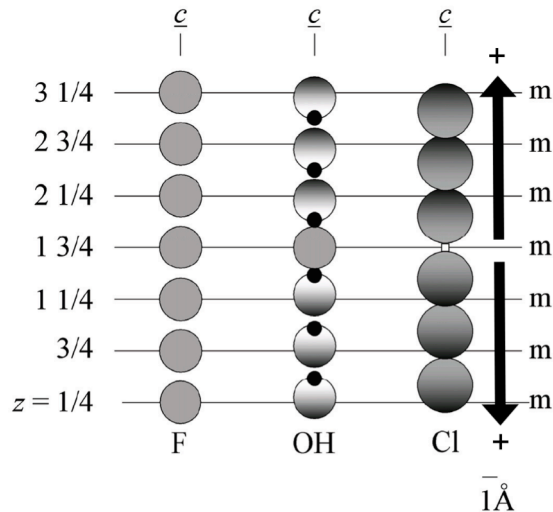
Figure 3. Schematic of arrangement of F⁻, Cl⁻, and OH⁻ ions in the apatite crystal structure (after [12]). Anions are sited in channels parallel to the c axis (*c*); *z* denotes unit cell distances in the *c* direction. In fluorapatite (left column) mirror planes of symmetry are at $z=\frac{1}{4}$, $\frac{3}{4}$, etc., with F⁻ ions on those planes. In chlorapatite (right column), Cl⁻ ions are displaced from those planes, producing domains with permanent electric dipoles (marked by arrows and '+' symbols). .

Shepard and Arvidson [2,10] suggested several substances from the materials science literature, but all involve geochemically uncommon elements or combinations of elements into compounds that are unknown or extremely rare as minerals. None of the common rock-forming minerals are ferroelectric because of their crystal symmetries (olivine, pyroxenes, feldspars, quartz).

Chlorapatite ($Ca_5(PO_4)_3Cl$) is ferroelectric, and is possible as an accessory mineral in both basaltic and granitic rocks. Domains within a chlorapatite crystal can maintain an electrical polarization because the Cl⁻ ions are displaced from symmetry planes in the crystal due to their large size [12], Figure 3. Fluorapatite, the most common phosphate mineral in igneous rocks, is not ferroelectric because F⁻ sits on mirror symmetry planes (Fig. 3). The presence of chlorapatite rather than fluorapatite on Ovda (etc.) and the Tepev volcanos can be rationalized if chlorapatite forms by chemical reaction between original igneous fluorapatite and HCl in the Venus atmosphere (which is consistent with thermochemical constraints). This chemical reaction must be slow on Venus' geological timescales, so that fluorapatite on young volcanos like Maat Mons would not have yet converted to chlorapatite.

Maxwell Montes: On Maxwell Montes and other ranges surrounding Ishtar Terra, radar backscatter is significantly greater above ~4.5 km elevation than below [1] (Fig. 2b), the so-called snow line [6]. This ab-rupt change in radar properties has been attributed to the presence of a conductor or semiconductor material appearing at lower temperature (higher elevation), either precipitated from the atmosphere [5,6] or by atmosphere-surface chemical reactions [7,8]. There is no evidence for an abrupt drop in radar backscatter, as is observed on Ovda (Figs 1, 2a)

Implications: If the rock on Maxwell Montes contains a ferroelectric compound (like chlorapatite), its presence could be obscured by a coating or reaction zone of semiconductor material; in that respect, Maxwell and Ovda could be composed of the same kind of rock, be it basaltic or granitic [13,14]. However, the absence of a semiconductor material on Ovda (and other near-equatorial sites) is more difficult to explain. If the compositions and temperature profiles of the Venus atmosphere are the same above Maxwell and Ovda, both should show the same atmospheric deposits, i.e. a "snow line." So, if the semiconductor material on Maxwell is an atmospheric precipitate, then the atmospheres above Maxwell and Ovda must be significantly different. On the other hand, if Venus' atmosphere is similar across the whole planet, then the absence of a semiconductor coating on Ovda would indicate that the semiconductor material on Maxwell is a chemical reaction product between atmosphere and rock, and the rock on Ovda is different from that on Maxwell. In this case, if the semiconductor reaction product is pyrite (FeS_2 [1,8]), Ovda cannot be made of typical basalt, which is rich in iron.

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