

PHYSICAL PROPERTIES OF VOLCANIC DEPOSITS ON VENUS FROM RADAR POLARIMETRY. Lynn M. Carter, *Center for Earth and Planetary Studies, Smithsonian Institution, PO Box 37012, Washington, DC 20013, (carterl@nasm.si.edu)*, Donald B. Campbell, *Department of Astronomy, Cornell University, Ithaca NY 14853*, Bruce A. Campbell, *Center for Earth and Planetary Studies, Smithsonian Institution, PO Box 37012, Washington, DC 20013*.

Introduction. Studies of the morphology and radar properties of volcanic deposits can aid in understanding their differences and formation. On Venus, volcanoes range in size from large highland edifices, such as Theia Mons, to small shields and domes which are often found in groups of tens to hundreds. In plains regions, windstreaks are sometimes found near shield fields, suggesting that there may be fine grained deposits associated with the volcanoes [1]. Previous studies of Bell Regio suggest the presence of fine-grained material in a low dielectric constant triangular-shaped region on the flank of Tepev Mons, which may be crater ejecta or a pyroclastic deposit spread westward by wind [2]. The eastern caldera on Tepev Mons shows a steep trend in backscattered power with incidence angle and has high RMS-slopes, implying a fine-grained covering such as ash [2].

Radar waves can easily penetrate smooth mantling layers such as ash and aeolian deposits. If a radar system can measure two orthogonal polarizations, it is possible to detect subsurface scattering and infer the presence of surficial deposits. The Magellan spacecraft could only measure one polarization and was therefore not able to fully characterize the polarization state of the radar echoes. We compare Arecibo dual-polarization data for Venus to Magellan images and emissivity data to investigate the physical properties of volcanic deposits.

Interpreting Measurements of Linear Polarization. Mapping the degree of linear polarization (m_l) can reveal areas where there is subsurface scattering of the radar wave. A circularly polarized wave can be thought of as a combination of two orthogonal linear vectors that are vertically (V) and horizontally (H) polarized. If the circularly polarized wave refracts into a surface that is smooth at wavelength scales, the V component of the wave will be preferentially transmitted and the radar echo will acquire a net linear-polarized component (it will become elliptically polarized). The fraction of the echo that is linearly polarized depends on the incidence angle, dielectric constant of the surface material, relative amounts of surface and subsurface scattering, and whether the scattering is quasi-specular (mirror-like) or diffuse.

Terrestrial radar data provide a good demonstration of this technique. The NASA/JPL AIRSAR system records the full Stokes scattering matrix and can therefore be used to generate linear polarization maps. In AIRSAR data, areas of high m_l values typically correspond to smooth mantling deposits. One particularly good example occurs near a small cinder cone northeast of Sunset Crater volcano in Arizona and shown in Figure 1. A radar dark deposit to the north of the cone produces m_l values of around 30% at L-Band (24 cm). Photos of the area show that the radar dark region is covered in welded cinders with fine-grained ash filling in to produce a fairly uniform surface. Short grasses grow in patches on the deposit,

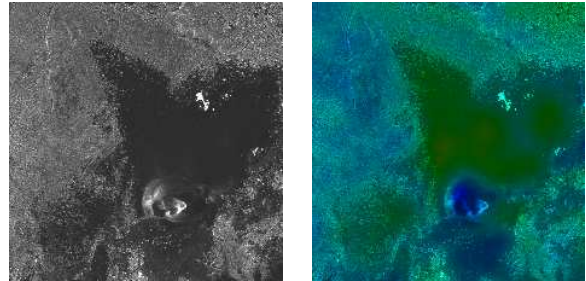


Figure 1: *Left:* AIRSAR L-Band (24 cm) radar image of a cinder cone and dark deposit northeast of Sunset Crater volcano. *Right:* A degree of linear polarization overlay of the same region. The degree of linear polarization is stretched to a linear color scale, where blue represents $m_l = 0$ and green represents $m_l = 0.3$.

but there are almost no trees or shrubs that would produce a strong reflection at 24 cm wavelength. Another area that produces a strong linear polarization signature is the Lunar Lake playa (Nevada), where the radar waves penetrate through the desiccated upper layer and reflect from the subsurface.

Radar polarimetry has been also used to study lunar impact craters and regolith properties [3,4], and to investigate deposits associated with craters on Venus [5]. In particular, the Arecibo Venus data used in [5] show that the terrain around many impact craters on Venus has an enhanced linear polarization signature. The high degree of linear polarization values are usually correlated with diffuse, radar bright areas in the Magellan imagery. The increase in backscatter cross section is likely due to sub-surface scattering from buried rocks or from a rough, mantled substrate. The Arecibo data also show evidence of mantling deposits associated with shield fields, volcanoes, and highland areas.

Arecibo Dual-Polarization Data of Venus Volcanoes.

We use the degree of linear polarization maps from [5], which were created using the Arecibo 12.6 cm wavelength radar system. The data have resolutions of 12 km per pixel or 16 km per pixel depending on the radar datataking parameters. The Arecibo maps are compared to the higher-resolution Magellan SAR imagery, as well as Magellan altimetry and radiometry, to investigate the geologic context of the inferred sub-surface scattering.

Clusters of small (several km in diameter) shield volcanoes are ubiquitous on the volcanic lowland plains, and most of the fields visible with Arecibo are correlated with an enhanced degree of linear polarization. An example of one such area can be seen in Figure 2. The degree of linear polarization is greatest in the immediate vicinity of the volcanoes and drops to zero (blue) on the surrounding plains. High m_l values correspond

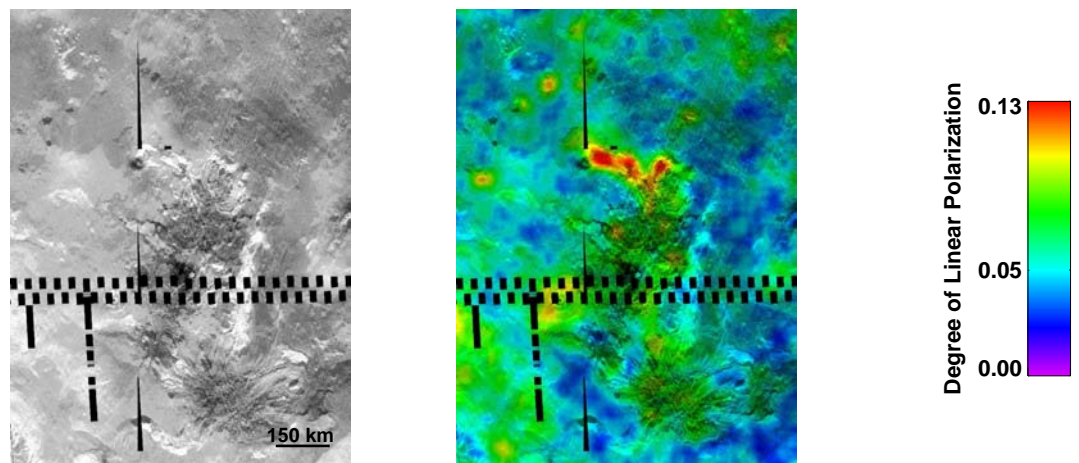


Figure 2: Images of a volcanic field in Guinevere Planitia at 17.5° N, 313° E. *Left*: A Magellan radar image. *Right*: A color overlay of the same area created by combining the Arecibo degree of linear polarization map, stretched to a color scale, with the Magellan image. A color bar shows the degree of linear polarization values.

to both dark and bright lava flows. In another dome field at 22° N and 332° E (near the crater Aurelia), individual shield volcanoes have concentric regions of low radar return that brighten (to the level of the surrounding plains) with distance from the volcanic center. Radar bright, triangular patches south of a few of the shields have been interpreted as wind-scoured areas, and dark margins around the bright triangles suggest that material piles up at the edges of the scoured regions [6]. This dome field shows up clearly in the degree of linear polarization maps, with m_l values of up to 0.16, which is additional evidence that there are smooth mantling layers in this area.

High degree of linear polarization values are also seen in some highland areas. Two volcanoes associated with highland regions (Theia and Tepev Montes) show enhanced linear polarization from high-altitude summit areas, as does part of Maxwell Montes near Cleopatra crater. In these cases, the areas with high m_l values partially or completely overlie high-reflectivity, low emissivity regions thought to be covered in a high dielectric constant semi-conducting or conducting material [7].

On Beta Regio, portions of the radar bright, low emissivity flows on the summit of Theia Mons show enhanced linear polarization. The highest m_l values correspond to some of the lowest emissivity areas, where the emissivity values drop to 0.35. On the eastern flank of Theia, the areas with high m_l values have slightly higher emissivity values (0.55).

Tepev Mons also has a high reflectivity summit region, with two large calderas that may contain fine-grained ash or dust [2]. The highest m_l values occur in a region between

the two calderas that is characterized by Fresnel reflectivity slightly lower than the average across the summit region. The dark, low dielectric constant mantling deposit [2] does not show any linear polarization signature, nor does the large, eastern caldera that is thought to be filled with debris.

Conclusions. Volcanic fields on Venus are typically associated with a high degree of linear polarization, and we infer that the radar wave is penetrating into smooth surficial deposits surrounding the volcanoes. Highland volcanoes also have patches of high m_l , but inference of a mantling deposit is less certain due to the high-dielectric surface coating. In general, a high Fresnel reflectivity will tend to increase the surface echo from rough terrain, and reduce the signature of any subsurface returns. The highland areas with enhanced m_l values must therefore be smooth at the scale of the radar wavelength. Further comparison of these regions with Magellan emissivity data may help to determine the characteristics of any mantling layers.

Acknowledgments: Photos of the Sunset Crater area were provided by K. Williams and R. Ghent. Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under cooperative agreement with the NSF and with support from NASA.

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