# Crater Ejecta and the Search for Felsic Material in Maxwell Montes, Venus

B. A. Campbell (Smithsonian), J. L. Whitten (Tulane University)

Maxwell Montes on Venus may preserve evidence of a past water-rich environment. We combine Magellan and Arecibo radar data to characterize surface properties across Maxwell for orbital or landed investigations. Modeling of H-polarized emissivity ($E_H$) shows that the surface undergoes a step-like shift from EH~0.85 to EH~0.35 at 6056.3 km radius, and a second abrupt shift back to $E_H$ >0.6 above 6061.0 km. Earth-based data reveal a region surrounding and west of the 90-km crater Cleopatra with lower radar echoes and circular polarization ratio despite increased surface reflectivity. We propose that fine-grained Cleopatra ejecta mantles much of Maxwell Montes, consistent with Venus distal crater ejecta patterns and the longevity of mantling debris in the highlands. Searches for felsic material formed during a water-rich period must consider the presence of ejecta, the source material at the impact site, and the effects of shock or melting on ejecta mineralogy.

Over a portion of Venus are highland regions shaped by tectonic processes to form mountain belts and tessera terrain. One driving question of current Venus exploration is whether these highland regions preserve compositional or morphological signatures of an era when abundant water was present. Orbital infrared observations show that the emissivity properties of tesserae and plains differ in a way that may imply a felsic composition for the highlands (e.g., 1, 2). Carrying out higher resolution visible/infrared studies that confirm this highlands composition is a key goal of the VERITAS, EnVision, and DAVINCI missions (3, 4, 5). A significant consideration in assessing orbital observations and descent/landed measurements is the degree to which a felsic rock surface has been altered by in-situ weathering and possible later deposition of mantling material. As the highest elevation mountain range on Venus Maxwell Montes is an intriguing locale for possible occurrence of felsic material, but the surface properties may be affected by Cleopatra crater. We use Magellan and Earth-based radar mapping to study the extent of Cleopatra ejecta across Maxwell.

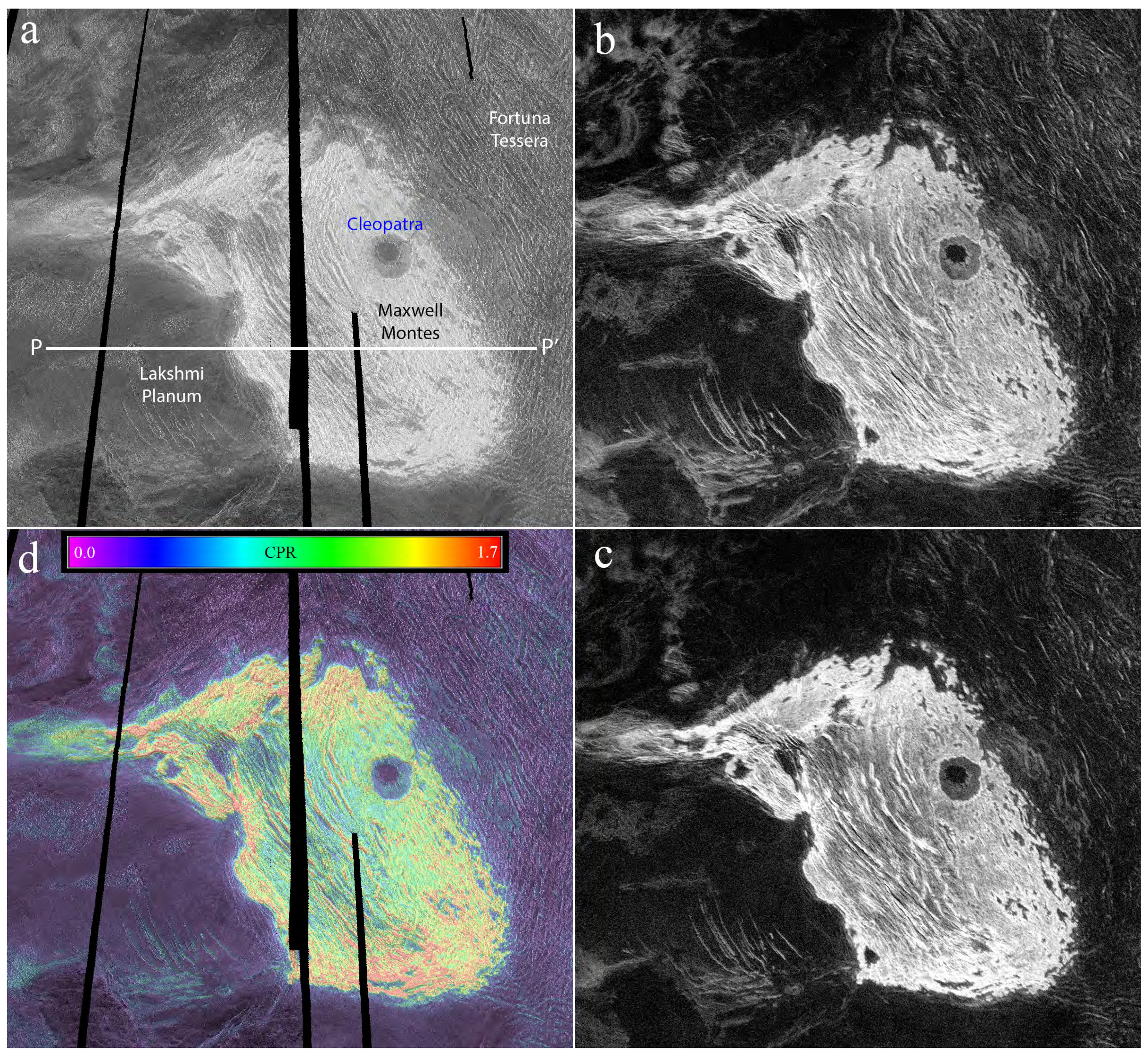


Fig. 1. Radar images for Maxwell Montes. (a) Magellan horizontal-transmit, horizontal receive echo; (b) Arecibo opposite-sense circular echo; (c) Arecibo same-sense circular echo; (d) Arecibo circular polarization ratio as color overlay on Magellan image. Note the low SC echo over much of Maxwell, despite the apparently high surface dielectric constant. We propose that this is due to mantling by Cleopatra ejecta.

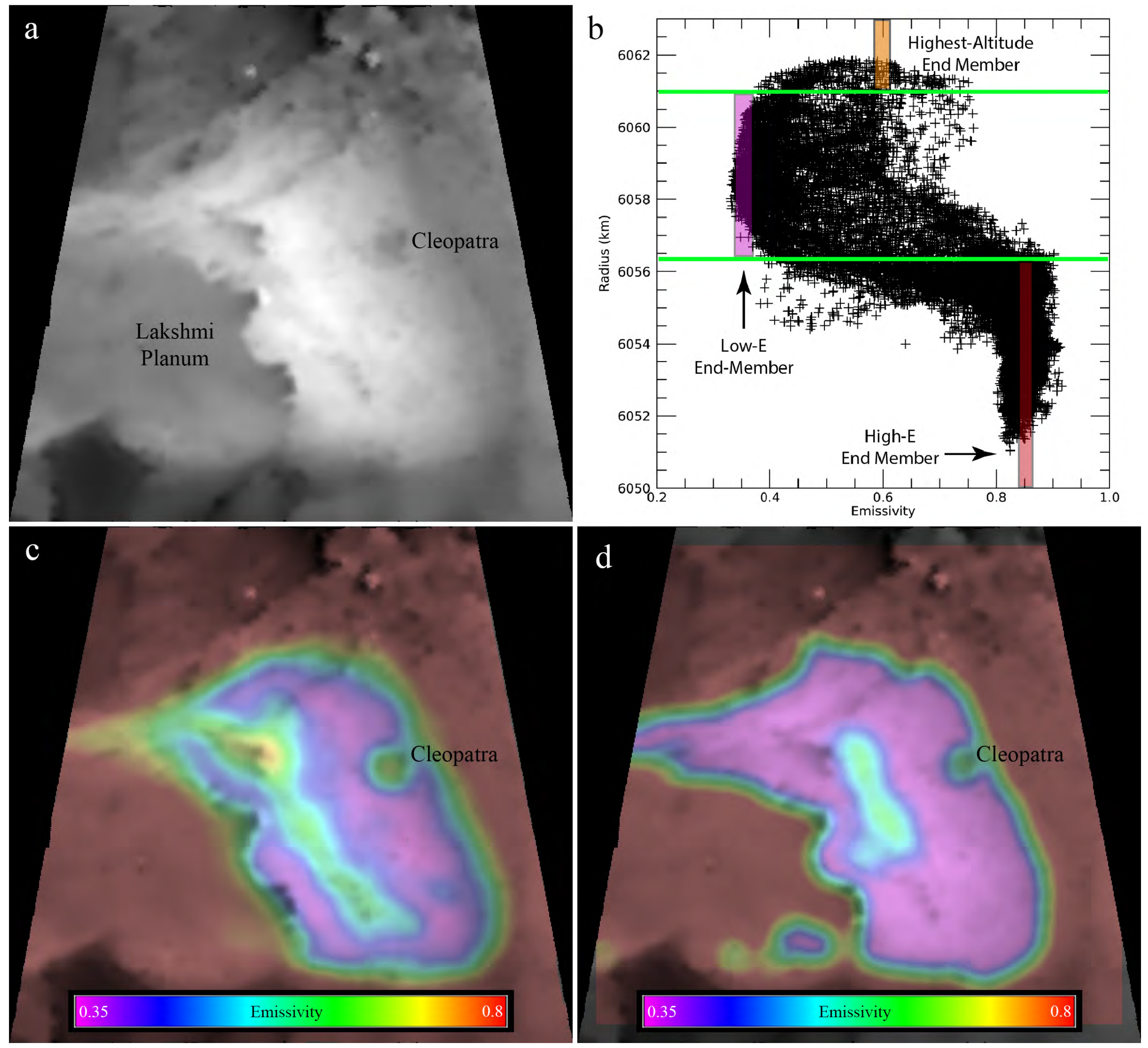


Fig. 2. (a) Magellan altimetry. Range of values 6051 to 6062 km planetary radius. (b) ARCDR emissivity values (not from the GeDR) and radius from interpolated altimetry. Lower green line denotes lower critical elevation of 6056.3 km; upper green line at 6061.0 km denotes proposed upper critical elevation. (c) Magellan H-emissivity on altimetry background. (d) Emissivity simulated from interpolated altimetry with fixed values of 0.85 up to 6056.3 km (red bar), 0.35 from 6056.3 km to 6061.0 km (purple bar), and 0.6 above 6061.0 km (orange bar). Radiometer footprint ~40 km.

Most areas of Venus above a regionally-varying critical elevation have much lower horizontal-polarized emissivity, E, than the plains, with a correspondingly high Fresnel reflectivity and radar echo (6). This change likely reflects a stable metallic or semi-conducting surface coating that is in equilibrium with the atmosphere only above the critical radius (7, 8, 9). There is evidence of a second critical elevation above which E increases again, and may be accompanied by intense in-situ erosion of the surface material (10, 11). Because the altimetry and radiometry footprints are large, it is not clear whether the change in dielectric constant is a continuous function of altitude or two nearly step-function changes. Magellan radar images show a dramatic change in backscatter strength over a small horizontal scale at the boundary, suggesting that the low-emissivity material certainly begins as a step-function within an elevation band of a few hundred meters or less. The images do not, however, resolve the question of a continuous versus punctuated change in surface dielectric constant with altitude above this first shift.

Figure 2b presents a scatter plot of H-polarized emissivity values versus altitude across Maxwell. A value of EH near 0.85 represents terrain up to ~6054 km, at which point some portion of the footprints begin to exhibit lower values as the terrain within the footprint becomes a mix of low-dielectric and high-dielectric areas. The lower critical elevation appears to be at ~6056.3 km. From 6058 to 6060 km the low-emissivity footprints settle near E~0.35, and above 6060 km there is a shift upwards toward a maximum of E~0.6. We test a model for step-wise E changes based on critical elevations of 6056.3 km and 6061.0 km (Fig. 2c). General correlation with the Magellan observations is good. The simulated values do not fully capture the extent of the higher-emissivity band in central Maxwell, likely due to an upward bias of topography and shedding of high-dielectric material. Results for a linear model for the decline in E yielded poorer fits. Per (7), the gentle transition of E with altitude (Fig. 2b) is a consequence of mixing properties within the radiometer footprints, and we can infer two step-function changes in surface dielectric properties.

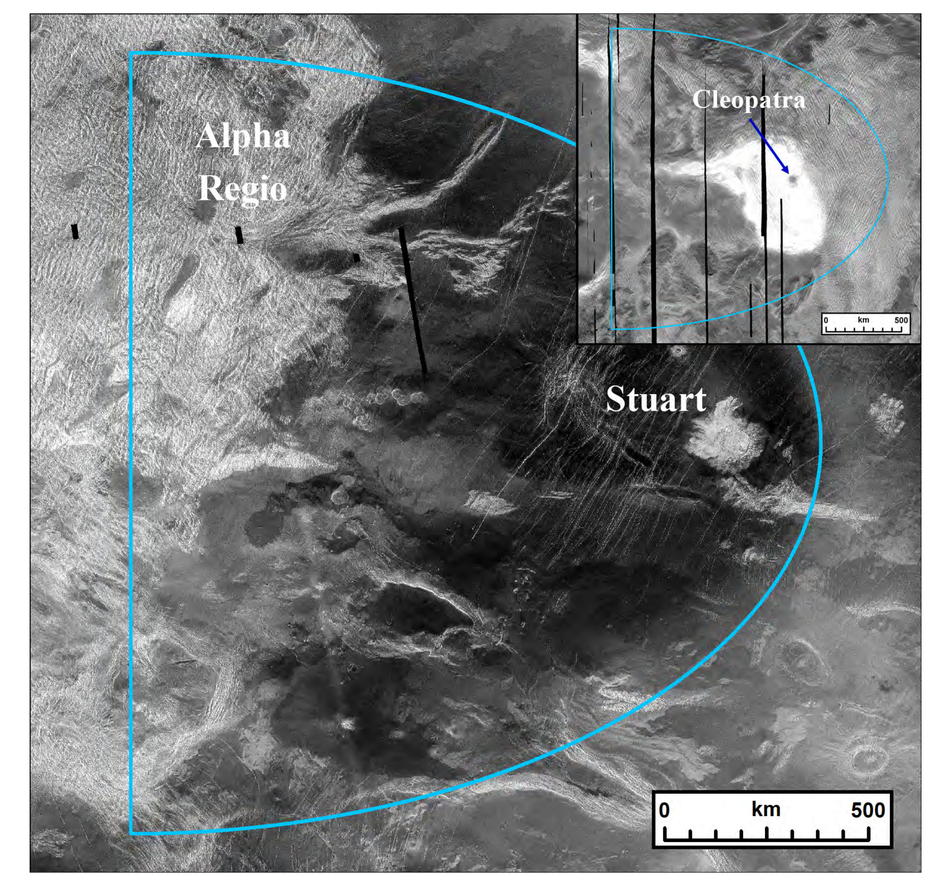


Fig. 3. Outline of predicted extent of parabolic ejecta (blue lines) from Stuart crater (69 km diameter), showing overlap with Alpha Regio. Inset shows Maxwell Montes with outline of predicted parabolic ejecta pattern from Cleopatra crater (90 km diameter). Note that the region of low-SCP radar echo from Maxwell (Fig. 1c) lies within the central area of predicted fine-grained debris.

If E does not change with altitude between critical elevations, then variations in SCP and CPR (Fig. 1) must reflect surface properties on wavelength scales. A primary cause of reduced SCP is a smaller population of scattering objects through variations in rock population or by mantling by fine-grained material. Craters on Venus form two major types of fine-grained deposits. "Haloes" are near-circular, low-radar-return units just outside the proximal ejecta blanket. "Parabolic" ejecta deposits form when fine ejecta is carried to the west, mantles surfaces, and lowers radar backscatter (Fig. 3). These are eroded over time by the wind, but the material may be trapped in tesserae for longer periods (12). Based on other crater deposits and ejecta modeling, Cleopatra must have emplaced a significant fine-grained halo and parabola. We propose that this fine material, trapped by the ridged topography, mantles the terrain and reduces the radar-visible rock population. Investigations of the role of felsic material will need to consider the presence of ejecta (particularly in topographic lows), the source material at the Cleopatra impact site, and the effects of shock or melting on the mineralogy of the mantling material.

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