COMPARISON OF 1988 ARECIBO RADAR IMAGES OF WESTERN EISTLA REGIO, VENUS, AND MULTI-POLARIZATION AIRBORNE RADAR IMAGES OF TERRESTRIAL TERRAINS: Bruce A. Campbell: Planetary Geosciences Div., Dept. of Geology and Geophysics, Univ. of Hawaii, Honolulu, HI, and Donald B. Campbell, Nat. Astronomy and Ionosphere Ctr., Cornell Univ., Ithaca, NY

Introduction: Radar images collected in 1988 at Arecibo Observatory [1] have been used in previous work [2] to map the distribution of volcanic deposits in Western Eistla Regio, Venus, and to suggest possible modes of origin for these units. The relative surface roughness of apparently homogeneous regions were inferred from their radar brightness and polarization ratio, but the question remained as to what type (if any) of terrestrial volcanic terrains (such as a'a or pahoehoe) might correspond to the observed deposits on Venus. In order to assess the range of possible surface morphologies within Eistla Regio, we have compared the dual-polarized 1988 Arecibo Observatory data to calculated circular-polarized returns for a variety of terrestrial volcanic and desert areas imaged by JPL aircraft radar systems.

Method: The 1988 Arecibo Observatory images used here consist of 21 averaged "looks" at ~1.5 km spatial resolution. These data were collected at 12.6-cm wavelength in both senses of circular polarization: "polarized" (LR) and "depolarized" (LL) [1]. The aircraft radar images were collected by the JPL CV-990 and DC-8 multi-polarization systems at 24-cm wavelength, and have a spatial resolution at one look of 2-3 m [3]. We studied images of 5 volcanic areas: Craters of the Moon (COM) (Idaho), SP Flow (Arizona), Cima volcanic field (California), Mt. Katmai (Alaska), and Kilauea caldera (Hawaii). An image of Meteor Crater was used to study the smooth desert surface surrounding the crater itself.

Within the Arecibo and aircraft images, we identified apparently homogeneous units and extracted the backscatter data within their boundaries. The aircraft data are collected in "quad-polarization" form, which permits synthesis of any desired combination of transmit and receive polarizations [3]. We calculated LL, LR, and HH returns for each of the aircraft images. Data were grouped into 1° incidence angle bins and averaged. The average polarization ratio for each angle was defined as the ratio between the average depolarized return and the average polarized return. Average HH echoes were calculated for the aircraft images in order to assess the variations in return which might be encountered by Magellan.

Comparisons between the two datasets were limited to some degree by the lack of radiometric calibration between Arecibo and aircraft images, and between the aircraft scenes themselves. For this reason, comparisons were made between backscattered return as a function of incidence angle, and between the observed correlation of depolarized radar brightness and polarization ratio (depolarized/polarized) for each study area.

Results: Figure 1 shows the normalized LR backscatter data for four terrestrial sites and the average backscatter cross-section for Western Eistla Regio (10-30 N, -25 to +10 E). The range of incidence angles is limited by the near range of the Meteor Crater desert area, which cuts off at ~26°, and by the cutoff in the dual-pol Arecibo data used here at 45°. The Carey Kipuka and Little Park flows in Craters of the Moon, Idaho, are very rough a'a surfaces comprised of rubbly vesicular blocks ranging from several cm to ~1m in size. The Blue Dragon flow in COM is a billowy pahoehoe with rounded flow lobes and numerous collapse depressions. The flow toes are covered with a blue glass coating which is extensively cracked to a depth of ~1 cm. Field measurements found that the Blue Dragon flow has an rms slope of 1.4^{o}, while the Carey Kipuka flow has an rms slope of 4.9^{o} [4]. The desert area surrounding Meteor Crater is quite smooth, with a few cm of aeolian mantling and little vegetation. It is evident that the average LR cross-section for Eistla Regio drops more rapidly with incidence angle than the returns from the three COM volcanic deposits. Only the Meteor Crater desert area approximates the Eistla Regio behavior. For each of the study areas, the LL return was observed to have little dependence on incidence angle within this range, so we may interpret the drop in LR power with angle to represent the change in quasi-specular scattering population with viewing

Comparison of Arecibo and Aircraft Radar Data
B.A. Campbell and D.B. Campbell

geometry [5]. The fact that the Eistla Regio average scattering curve is steeper than that of the terrestrial sites, even when imaged at 12.6 cm (as opposed to 24 cm) implies that the general surface morphology of this region on Venus is exceeedingly smooth at scales of meters to hundreds of meters. A close correlation was found between HH and LR echoes for the terrestrial sites, suggesting that Magellan backscatter measurements may correspond well with Arecibo polarized images.

More detailed analysis of apparently homogeneous radar-mapped units in Eistla Regio revealed an important difference between backscatter from volcanic units in this region and those studied with the aircraft systems. For terrestrial sites, greater depolarized brightness is consistently correlated with higher LL/LR polarization ratios. At any given incidence angle within the Eistla Regio study area, brighter (higher LL) deposits have, in general, lower polarization ratios than darker areas. Dark areas which cover a few degrees of incidence angle exhibit rapid decreases in polarized backscatter with angle, suggesting that they are smoother than the average surfaces within Eistla Regio. The very bright deposits near the summits of Sif and Gula Montes, assumed to be regions with high Fresnel reflectivity [2], have polarization ratios which vary over a wide range, suggesting large variations in reflectivity or roughness over scales of a few km.

The trend in polarization ratio with depolarized brightness suggests that returns from dark areas are due to a small population of wavelength-scale scatterers on a very smooth substrate. As the depolarized brightness increases, the lower polarization ratio requires that the quasi-specular scattering cross-section increase at a more rapid rate. Changes in the Fresnel reflectivity would tend to create an opposite effect to that seen here (higher reflectivity leading to higher polarization ratios and brighter terrains), so roughness seems the more likely explanation. It seems unlikely from these observations that any of the larger volcanic deposits in Western Eistla Regio resemble terrestrial a'a morphologies; a progression from very smooth "pavements" to perhaps terrestrial-style pahoehoe structures is suggested. It may be possible to refine these conclusions by comparison of radiometrically calibrated DC-8 SAR images and Magellan data.

References: [1] Campbell, D.B., et. al. (1989), Science 246, 373-376; [2] Campbell, B.A., and Campbell, D.B (1990), GRL 17: 1353-1356; [3] Evans, D.L., et. al. (1989), IEEE Trans. Geosci. Rem. Sens. 26: 774-788; [4] Campbell, B.A., et. al. (1990), Rem. Sens. of Environment 30: 227-237; [5] Hagfors, T. (1968), in Radar Astronomy, McGraw-Hill, pp. 187-216.

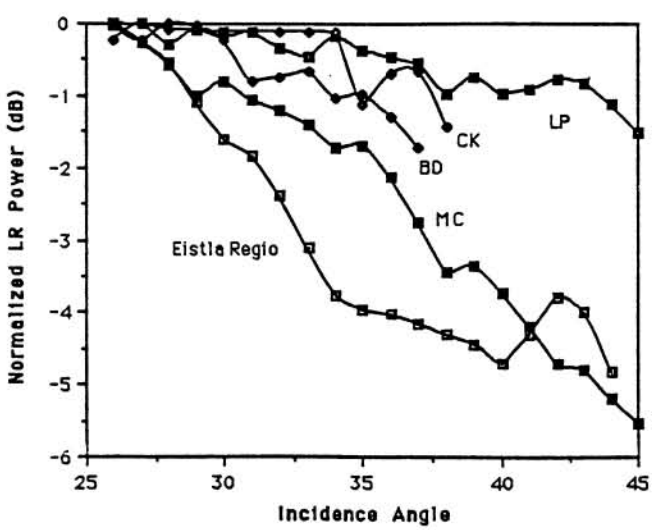

Figure 1: Plot of 10*log(Normalized LR return) vs. Incidence angle for Carey Kipuka (CK) a'a, Little Park (LP) a'a, Blue Dragon (BD) pahoehoe, Meteor Crater desert (MC), and average over Western Eistla Regio (10-30 N, -25 to +10 N). Data normalized to return at 26°. Upturn at far range of Eistla Regio data due to bright terrain in the NW portion of the image. Oscillations with incidence angle in CV-990 data (all COM targets) due to antenna-beam correction errors.