average surface radar properties best reflect the character of the various venusian plains. The mean planetary radius is 6051.9 km, a value slightly above that previously reported [*Masursky et al.*, 1980; *Pettengill et al.*, 1982]; we have referenced all elevations to a datum of 6051.0 km in order to be compatible with topographic provinces defined by *Masursky et al.* [1980]. Table 1 compares the topographic provinces proposed by *Masursky et al.* [1980] with ρ values for each elevation interval.

The α values are derived from fitting discrete templates to the altimetric measurements in a two-stage process [*Pettengill et al.*, 1980*a*; *Garvin et al.*, 1984*c*]. These templates are approximations to the observed radar echo distribution as a function of time delay. Templates for a wide variety of altitudes and roughnesses (α) were used in a weighted least squares comparison to obtain good estimates of the radar parameters [*Pettengill et al.*, 1980*a*]. Unlike roughness, ρ is linear in equation (1) and can be fit in a continuous sense to the observed data. Surfaces poorly fit by the templates because of their nonstandard quasi-specular scattering behavior often have ρ values with low relative errors. This is because ρ serves only as a scaling parameter and does not affect the shape of the quasi-specular scattering curve. As such, ρ is a relatively model-independent parameter, in contrast with α, which totally defines the shape of the curve, and is thus model dependent.

GEOLOGIC INTERPRETATION

In order to interpret the radar ρ in terms of the material properties of a surface, several assumptions must be made. We adopt a single-layer model with a magnetic permeability of unity in order that ρ is a function of the complex dielectric discontinuity at the reflecting interface (typically the uppermost surface) [*Pettengill et al.*, 1982]. It is then possible to express ρ in terms of the complex dielectric constant ε as follows

$$\rho = |(1 - \varepsilon^{1/2})/(1 + \varepsilon^{1/2})|^2 \quad (2)$$

where

$$\varepsilon = \kappa + j\{L + S/(\varepsilon_0\omega)\} \quad (3)$$

for $j = (-1)^{1/2}$. The real component κ dominates the radar ρ for dry lunar and terrestrial rocks and soils [*Krotikov and Troitsky*, 1963; *Campbell and Ulrichs*, 1969; *Olhoeft and Strangway*, 1975; *Pettengill et al.*, 1982]. The imaginary component $\{L + S/(\varepsilon_0\omega)\}$ depends on the dielectric loss L, the volume conductivity S, the permittivity of free space ε_0, and the angular frequency of the incident radiation ω (here ω is 1.76 GHz); for our purposes none of these factors affect ε very much, and $\varepsilon \approx \kappa$ for typical terrestrial and lunar geologic materials [*Olhoeft and Strangway*, 1975; *Pettengill et al.*, 1982].

The bulk dielectric constant κ is directly dependent upon the porosity and electrical properties of geologic materials, and indirectly on composition (e.g., Fe and Ti content) and bulk density γ. The dielectric properties of typical terrestrial and lunar rocks, soils, and minerals at radar frequencies ($\sim 10^9$ Hz or 3.8–70 cm wavelengths) have been determined [*Krotikov*, 1962; *Krotikov and Troitsky*, 1963; *Evans and Hagfors*, 1968; *Campbell and Ulrichs*, 1969; *Olhoeft and Strangway*, 1975] and empirical relationships between these properties and density [*Krotikov and Troitsky*, 1963; *Olhoeft and Strangway*, 1975] as well as composition [*Hansen et al.*, 1973; *Saint-Amant and Strangway*, 1970] have been derived. *Krotikov* [1962] and *Krotikov and Troitsky* [1963] found that for a wide range of naturally occurring rocks and soils (e.g., from tuff to dunite), the relationship

$$\gamma = (\kappa^{1/2} - 1)/0.5 \quad (4)$$

for density γ and dielectric constant κ was accurate to within 10% at 4 cm and 12 cm radar wavelengths. All samples were dried. Equation (4) can be related to radar ρ via equation (2) so that

$$\gamma = 4\rho^{1/2}/(1 - \rho^{1/2}) \quad (5)$$

or, inversely,

$$\rho = \gamma^2/\{4(2 + 0.5\gamma)^2\} \quad (6)$$

Note that this is a quadratic relationship that empirically applies only for dry rocks and soils with γ between 1.5 and 3.3 g/cm^3. *Campbell and Ulrichs* [1969] measured κ as a function of γ, T (temperature), porosity (i.e., powder versus solid rock), and frequency (0.45 and 35 GHz). They observed that the Rayleigh mixing formula well modeled the change in κ when the density of a solid was reduced by powdering the sample. Though they did not derive an equation relating bulk density γ and κ, their data fit the *Krotikov* [1962] model (equation (4)) very well (correlation $R^2 > 0.90$).

Olhoeft and Strangway [1975] analyzed a large sample of lunar rocks and soils in terms of κ and derived an empirical relationship between γ and κ for frequencies on the order of 10^6 Hz. For dried samples they found the following power law relationship:

$$\kappa = a^{\gamma} \quad (7)$$

where $a = 1.93 \mp 0.17$ and γ is density in grams per cubic centimeter. This can be written in terms of radar ρ as follows

$$\gamma = (2/\ln a) \ln \{|(1 + \rho^{1/2})/(1 - \rho^{1/2})|\} \quad (8)$$

In order to evaluate differences between the relationships described by equations (5) and (8) and to choose the relationship most appropriate for Venus, a statistical correlation analysis is required. Correlation of the *Krotikov* [1962] relationship (equation (5)) with that of *Olhoeft and Strangway* [1975] using a least squares regression technique demonstrates that

$$\rho_k = 0.64\rho_{os} + 0.54 \quad (9)$$

at a correlation R^2 of 0.99 with $a = 1.87$, where ρ_k is from equation (5) and ρ_{os} is from equation (8). If only solid rocks are considered, the correlation can be improved. In equation (9) the radar ρ values are equivalent for $\gamma = 2.8$ g/cm^3 at $\rho = 0.17$. On the basis of the above analysis, we adopt the relationships

$$\kappa = 1.87^{\gamma} \quad (10)$$

$$\gamma = 3.2 \ln \{(1 + \rho^{1/2})/(1 - \rho^{1/2})\} \quad (11)$$

as those to use when interpreting the radar ρ in terms of density γ. We have chosen to use this combined relationship in favor of either of the two independent models (equations (5) and (8)) because it links the best aspects of both relationships in a single, empirical equation (equation (11)) for the range of γ values of geologic interest.

From equation (11) the following simplified interpretation of the magnitude of reflectivity ρ can be derived: (1) $0.02 < \rho < 0.10$ correspond to $\gamma < 2.0$ g/cm^3 and are likely to be high-porosity materials such as soil, poorly welded tuff, or weakly cemented sediments, (2) $0.10 < \rho < 0.20$ correspond to