km) of a major secondary cluster. This cluster is dominated by two elongate craters that are ~2.5 × 5.5 km in size. V structures from these secondaries extend all across the area covered by the spectral measurements. These secondaries are well preserved with crisp southern rims and deep shadows (and presumably have experienced little infilling). The R2 area just to the north of these secondaries exhibits a textured or disturbed surface on the scale of 100 m. Neither area R2 nor the secondaries to the south exhibit exceptionally strong radar backscatter, even though a larger secondary cluster 10 km to the northwest does. The R2 area is nevertheless moderately bright in radar backscatter, about 10 to 15% of the echo strength of the Copernicus ejecta blanket. There is a minor amount of structure in the radar image, but generally the spot is typical of the diffuse radar characteristics of the ray in this area. The spectral reflectance properties of area R2 follow an apparent progression from the areas closer to Copernicus: The continuum is slightly steeper, the band strength, slightly deeper (but still less than for the mature mare), and a band center, slightly longer, near 0.965 μm, implying a little more of a clinopyroxene component in a two-pyroxene mixture for the mafic component of R2.

Ray 5 (R5). This area is located on the main ray system that extends from spot E3 to spot R7. Area R5 is situated about 25 km west of the mature mare area M1 and lies entirely within the high-albedo ray element, which measures ~21 km in east/west extent at this point. The spot is centered near a cluster of small (<1 km), subdued secondaries which appear mantled by subsequent ejecta. This gives the region a textured appearance on the scale of 100 m. Within 5 km to the south, there are several 1- to 2-km diameter less mantled secondaries. The radar backscatter properties for R5 are relatively undistinguished. The backscatter of the secondary craters to the south and north is somewhat higher than for R5, but the latter nevertheless stands out in relation to the darker maria to the east and especially to the west, the backscatter for material surrounding the crater Pytheas. As with area R2, the reflectance properties for area R5 show an apparent progression away from Copernicus: The continuum is slightly steeper, the band strength is slightly stronger, and the band center is at a slightly longer wavelength. R5 is at approximately the same radial distance from Copernicus as the mare area M1, but its spectral reflectance characteristics are sufficiently distinct from the mare (higher albedo, weaker band, shorter band center) to preclude the possibility that local mare material dominates the surface soil composition. (See Tables 1 and 2.)

Ray 7 (R7). This is an area chosen to represent the properties of secondary craters larger than 1 km in diameter. R7 is located at greater radial distance along the large ray that includes areas R5, R2, and E3. Area R7 is located in the middle of the ray and is centered on an elongated cluster of large secondary craters 10 × 4 km in extent plus several additional secondaries larger than 1 km in diameter. Details of this surface morphology can be seen in Figure 7. V structures and sharp rims are frequently associated with these secondaries. Other large (7 × 2 km) secondaries lie immediately to the south (within 15 km). Area R7 exhibits a notably high radar backscatter, about 25–30% greater than that for the Copernicus ejecta blanket. This high backscatter appears to be typical for such ray areas with large relatively unmantled secondaries, although R7 is the only ray area included in this study with such characteristics. The spectral reflectance properties of R7 are distinct from those of all areas previously discussed: The continuum slope is similar to that of R5, but the strength of the pyroxene absorption band is almost 50% stronger than R5 and even 15% stronger than that for mature mare M1. The band center for R7 is almost 1.0 μm. These characteristics indicate not only that the surface material at R7 is primarily basaltic in composition, but also that a mature soil has not fully developed at that site.

Ray 6 (R6). This area was included in the study because it exhibits one of the highest radar backscatter characteristics for any extended region within the northern ray system of Copernicus. R6 is located in the middle of the ray system to the north and east of the main E3–R7 ray. There are no secondary craters larger than ~0.5 km diameter within the measured area, although there are many near-circular subkilometer craters at this point (Figure 8). While these small craters seem to be associated with the ray, they do not have the morphological appearance of most secondary craters [*Oberbeck and Morrison*, 1973]. The radar image shows a profusion of bright, diffuse features, often (but not always) with circular symmetry, superimposed on a mottled but generally radar-bright background (25–30% of the ejecta backscatter returns of Copernicus). Within 8 km to the east of R6 is a small cluster of <1-km diameter secondaries with subdued V structures, while a cluster of many subdued secondary craters 0.5–1.5 km in diameter is located ~15 km to the northwest of R6. There are no large secondaries within 60 km to the south of the spot, indicating that no tertiary ejecta from other secondary impacts is likely to be found in this area. The spectral reflectance characteristics of R6 are similar to those for R7 but with the absorption band near 1.0 μm slightly stronger. The R6 area thus also exhibits a component of relatively immature mare basalt characteristics.

Discussion

From the above presentation of the data it can be seen that there is no unique way to characterize the Copernicus ray under consideration. It is heterogeneous; different chemical and physical properties are associated with different areas of the ray, and these properties appear to be influenced by the number and size of secondary craters and their deposits at any given site. The complementary information provided in the form of decimeter-scale roughness detected by the radar, the compositional parameters derived from the spectra, and the surface morphology inferred from photographic images does, however, enable many of the properties of the ray to be intercompared and interpreted. Although crater rays are complex and there are no simple rules that describe their properties, there is sufficient information to discern a few systematic trends which govern the nature of this ray system.

For example, a highland component within the rays of Copernicus ray is evident in the reflectance characteristics of areas E5 through R5, the locations of which increase in radial distance from Copernicus along a single continuous ray. For these areas the albedo is seen to be higher, continuum slopes are flatter, and absorption bands are weaker and centered at shorter wavelengths than the local mature mare. All these characteristics indicate a feldspathic component in the soils that includes a low Ca-pyroxene. For areas R2 and R5 in Mare Imbrium this highland component must clearly be of nonlocal origin. On the basis of the spectral data and inferred ejecta ballistics, the origin for the highland component would thus be Copernicus itself. It is also clear from the reflectance data, however, that the second major component at R2 and R5 is the local mare basalt soil, and the amount of this local