

LUNAR DARK MANTLE DEPOSITS: POSSIBLE CLUES TO THE DISTRIBUTION OF
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A series of low albedo deposits of varying distribution and areal extent have been mapped on the lunar surface¹. The deposits are characterized by their low albedo relative to other lunar geologic units, their post-Imbrium event but pre-latest mare age, their concentration in and near upland areas adjacent to maria, and their apparent smooth surface which gives the appearance of mantling underlying topography. From east to west, the major occurrences of dark mantle deposits include 1) the Taurus-Littrow region (SE edge of Serenitatis)²; 2) the Sulpicius Gallus region (SW edge of Serenitatis); 3) Mare Vaporum region (primarily to the SE of Vaporum); 4) Rima Bode region; (uplands south of Rima Bode; 5) Sinus Aestuum region (southeast of Sinus Aestuum); 6) Copernicus region (SE of Copernicus), sparsely cratered aspect cited as evidence of Copernican age¹ but this study suggests that the area is simply one of several ray/secondary excluded regions surrounding Copernicus; 7) Alphonsus crater floor; several small dark mantle patches associated with linear rilles and asymmetric craters; upper bounds on age uncertain; 8) Mare Humorum, (near the crater Doppelmayer at SSW edge of Mare Humorum); relation to central mare not clear; 9) Aristarchus plateau; extensive development on plateau in north-central Procellarum around Schroter's Valley.

At the Apollo 17 landing site (Taurus-Littrow area) the majority of soils overlying the subfloor basalts are composed of comminuted basalt fragments, agglutinates, and 5 to 20% of orange and black spheres³. Laboratory reflectance spectra obtained for components of these soils indicate that it is the black spheres which most closely resemble typical telescopic spectra for the Littrow dark mantle area, and that these are somewhat different than the subfloor basalt spectra⁴. These observations are interpreted to mean that it is the admixture of dark spheres which is responsible for the characteristic dark mantle development and that without the dark spheres, the subfloor basalt would resemble the Apollo 11 landing region. The orange and black droplets have been interpreted to have formed in lava fountains of low viscosity lunar basaltic magmas⁵ and it has been shown that lunar pyroclastic deposits should appear as a smooth mantling material rather than typical terrestrial cones because of lunar gravity and lack of atmospheric drag⁶. Age dates and chemical similarities suggest that the orange and black droplets were part of the same period of volcanism, about 3.63 b.y. to about 3.83 b.y. which produced the subfloor basalts⁵. From consideration of the samples and geology of the Apollo 17 region it is concluded that the dark mantle component represents a pyroclastic phase of very early Ti-rich mare basalt flooding at the edge of the Serenitatis basin. The background subfloor basalt is very similar to Apollo 11 type basalts. Subsequently, subsidence occurred in the Serenitatis basin⁷ and a younger, less Ti-rich basalt was emplaced, embaying the dark mantle deposits. The general lack of subsidence of early mare deposits in Mare Tranquillitatis in part precluded their later burial. The subsidence of Serenitatis⁷ was followed by major flooding which buried the more extensive mare deposits which were

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probably similar to Apollo 11 and 17 basalts in composition. Thus the early volcanic dark mantling deposits in the uplands and valleys at the edge of the Serenitatis basin undoubtedly represent more widespread Ti-rich early volcanic deposits which have subsequently been covered. Old upland dark mantling deposits in other areas may therefore be indicators of the distribution and composition of more extensive early mare volcanism.

The distribution of dark mantling material in uplands surrounding mare basins has always been an intriguing characteristic of these deposits and has served to differentiate them from the mare lavas which tend to pond in low areas. Although dark mantle is seen in upland areas surrounding the valleys at Taurus-Littrow, photographic^{6,8,9} and spectral⁴ information suggest that it is less extensive and apparently thinner. Consideration of lunar pyroclastic processes suggests that the thinner upland mantle may not always represent discrete sources in the uplands but may instead often be deposited from sources in the surrounding valleys. Terrestrial lava fountains ranging up to 500m in height have been noted¹⁰. Extrapolation to lunar conditions⁶ suggests that lava fountains of comparable size located in the valleys could easily spread a veneer of dark mantling material over the surrounding highland massifs. Therefore, it is possible that a small number of significant sources associated with the extrusion of mare lavas could as easily be responsible for the dark mantle as a large number of sources spread throughout the adjacent uplands.

Features associated with several dark mantling deposits suggest that they may represent major source regions for lunar lavas. The coincidence of Serenitatis and Imbrium radials and lunar grid directions in the Taurus-Littrow area, and its structural significance has been noted⁷. Associated deep fractures may have localized early lava extrusion. Similarly, fractures and rilles in the Rima Bode area and major sinuous rilles in the Aristarchus Plateau suggest that many dark mantle deposits represent pyroclastic lava fountain deposition associated with major source areas of lunar lavas.

Lunar dark mantle deposits show variations in terms of their spectral reflectivity and radar backscatter characteristics¹¹. In particular, most of the eastern dark mantle deposits show spectral and radar characteristics similar to those at the Apollo 17 site¹¹. However, western dark mantle deposits are relatively redder (Aristarchus Plateau^{12,13}, Alphonsus^{11,13}, and Doppelmayer¹⁴).

The lunar dark mantle deposits discussed here are believed to represent pyroclastic fire fountain deposits localized around source regions (fractures, sinuous rilles) for early mare lavas. In the equatorial belt from Copernicus east to Taurus-Littrow the dark mantle deposits generally share the characteristics of early Ti-rich lavas of the Tranquillity type^{11,15} but are embayed by later "redder" mare of the Serenitatis type. Based on the relationships described above these dark mantle deposits are believed to be indicators of the presence of more extensive Ti-rich early mare deposits underlying the surface of Mare Serenitatis, Mare Vaporum, and Sinus Aestuum.

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The western dark mantle deposits, in particular the Aristarchus Plateau, are interpreted to be pyroclastic source regions for the early "redder" western mare deposition.

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