EVIDENCE FOR ANCIENT LUNAR BASALTS, P. H. Schultz, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058; P. D. Spudis, Department of Geology, Arizona State University, Tempe, AZ 85281 and D. Sellers, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.

Mare basalt units on the Moon are generally recognized by their low albedo, a result of the presence of mafic minerals. This fundamental diagnostic observation has been used either implicitly or explicitly to map lunar basalts and basaltic pyroclastics (1). Where mare basalts have been buried by crater ejecta deposits, they may be revealed by dark excavated deposits around smaller craters that post date the burial event. The resulting dark-haloed craters have been recognized by numerous lunar observers (2,3) and are perhaps best illustrated around Copernicus, Theophilus, and Langrenus (4). The dark-haloed impact craters around Copernicus, in particular, not only reveal the low albedo excavated material but also exhibit the same spectral signature as the local pre-Copernicus basaltic surface. The same approach can be used for larger craters that have excavated more deeply buried deposits. If the crater is too large (D >30 km), then near-surface secondary impact ejecta may dilute the photometric signature of primary crater ejecta. However, near-rim ejecta around smaller craters cannot excavate as large quantities of local material owing to the low impact velocities (v <150 m/s) within one crater radius of the rim. The preservation of distinctive spectral signatures characterizing buried units in the near-rim deposits of craters such as Picard and Dionysius strengthen this statement. Although dark-haloed impact craters can be confused with dark-haloed volcanic vents and dark impact melt ponds, such complications are resolved by comparing high and low sun photographs at resolutions sufficient to identify probable vent structures (e.g., elongate pits along rilles) and melt deposits (e.g., highly asymmetric dark deposits around bright-rayed craters). Occurrence of dark-haloed impact craters: The Mare Australe region in the southern lunar hemisphere represents a large circular (1200 km diameter) area containing numerous craters partly inundated by mare basalts. These units exhibit a higher, mottled albedo than most near-side maria and are believed to represent very old units that have lightened with age, at least partly as a result of Humboldt and Jenner crater ejecta (5). Numerous small craters (diameters <15 km) exhibit dark haloes and in a few instances, dark interiors. This contrast between excavated and surface debris suggests that a darker mare basalt unit underlies the exposed higher albedo mare surface. In several examples, dark-haloed craters do not occur on mappable mare units but occur on hummocky lighter plains. Although the dark ejecta deposits might represent a dark mafic unit overlain by lighter mare units, the complex geologic history associated with ejecta deposits from enormous craters such as Humboldt suggest that the dark-haloed deposits more likely correspond to "typical" mare basalts whose surface has lightened with the accumulation and effects of impact ejecta as originally proposed by Hartman and Wood (6).

An inventory of dark-haloed impact craters across both hemispheres of the Moon reveals a wide-spread occurrence. Figure 1 illustrates a region around an unnamed ancient impact basin south of Mare Humorum. At least 14 convincing dark-haloed craters cluster in this general area and typically occur in units mapped as Cayley-type Imbrian Plains material (7). The excavated low-albedo unit clearly pre-dates the Orientale event, as indicated by superposed Orientale secondary craters.

Dark-haloed craters not occurring on mapped mare plains also cluster in other regions of the Moon. The most obvious clusters are north and east of Mare Marginis (Fig. 2), around Mare Crisium, south of Mare Humorum and within Mare Australe, the latter two examples having been discussed above. Most occur on units previously mapped as Imbrian Plains material.

Orbital Geochemistry Data: The nature of dark crater deposits also can be inferred from the orbital Apollo experiments. Detailed maps of Mg/Si values reveal anomalous local increases west and northeast of Mare Smythii (9) that correlate with clusters of small dark-haloed craters. Anomalously high concentrations of Th in terra Cayley-type plains west of Smythii and north of Balmer as seen by the Apollo gamma-ray experiment also correlate with clusters of dark-haloed craters and suggest at least some of these excavated low-albedo deposits may be KREEP-like in composition. More impressive is the pronounced mafic anomaly recognized on the farside (115°, -8°) near Langemak with Mg/Si values approaching typical mare levels with a corresponding decrease in the Al/Si value (10). This geochemical anomaly centers on the crater Vesalius M which exhibits a diffuse, dark ejecta deposit and it is proposed that this crater has excavated mare basalts now buried by old impact debris.

Discussion: Virtually all mare basalts returned from the Moon have been dated radiometrically as younger than ~3.9 b.y. old, thereby leading many authors to conclude that mare volcanism commenced around this time (11). However, a small percentage of the lithic clasts in some Apollo 14 Fra Mauro breccias (~3.95 b.y. old) possess mare basalt chemistry and texture that strongly suggest the existence of pre-Imbrium mare basalt flows perhaps prior to 4.2 b.y. (12). Craters excavating dark materials from below the light highland plains and from below the Orientale ejecta deposits indicate possible examples of such units. Moreover, their widespread occurrence suggests that a large portion of the eastern hemisphere may have been inundated both locally and regionally from southeast of Humboldtianum basin, through Smythii and Balmer basins to Mare Australe. Early topographic studies of light plains units suggested that their origin by non-volcanic processes was supported by the large variations in elevations (13). Figure 3 shows, however, that the distribution of elevations determined from Apollo-based cartographic data is more uniform for light plains units than for the maria in the eastern hemisphere. Such uniformity may reflect pre-Imbrium volcanism that has since been masked by the terminal phases of accretion.

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Fig. 1a. High-sun earth-based view showing dark-haloed impact crater (top arrow) in smooth plains near Schiller (bottom arrow).

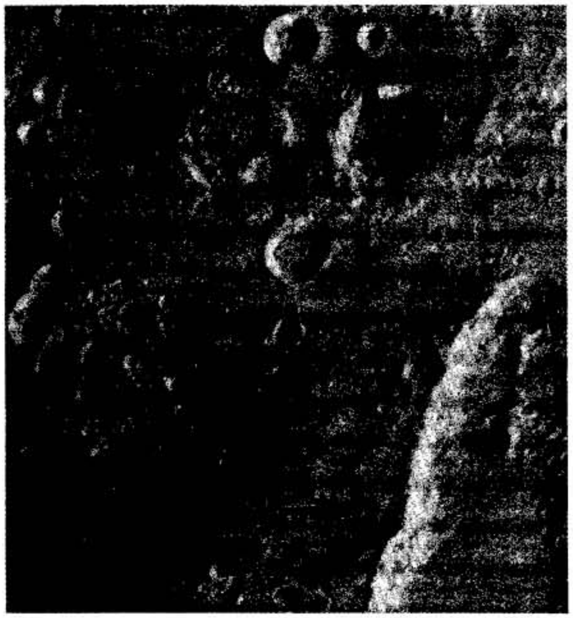

Fig. 1b. Low-sun Lunar Orbiter (IV-160-H1) view showing 8 km-diameter crater identified in Fig. 1a and rim of Schiller.

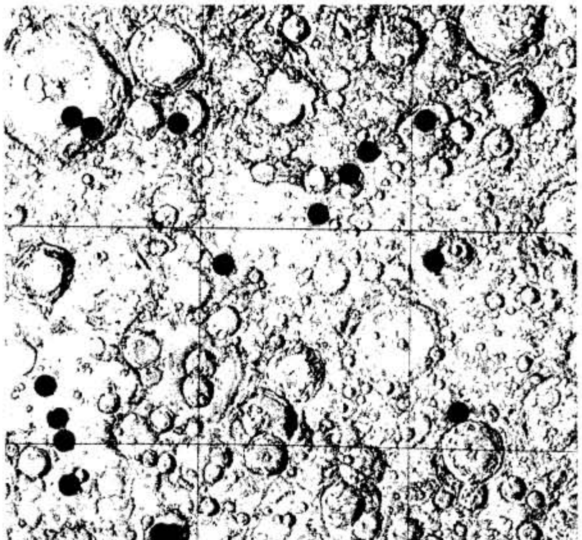

Fig. 2. Location of well-defined dark-haloed impact craters in plains region northeast of Mare Marginis. Plains area may represent buried basalt units.

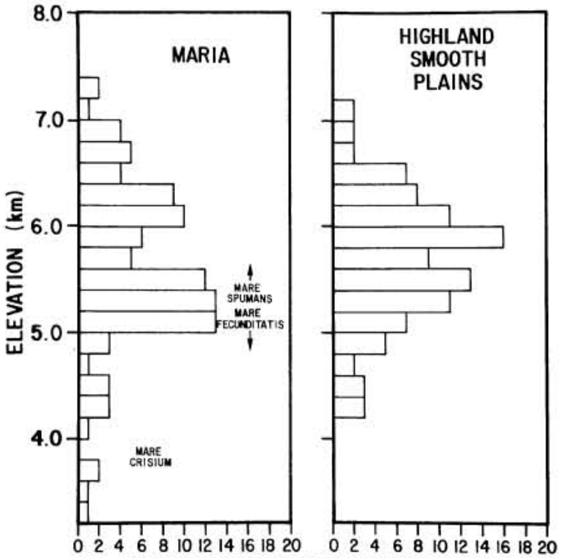

Fig. 3. Elevations of mare units and light plains units in LAC 43, 61, 62, 63, and 80 (from LTO data) as a function of relative mapped area.