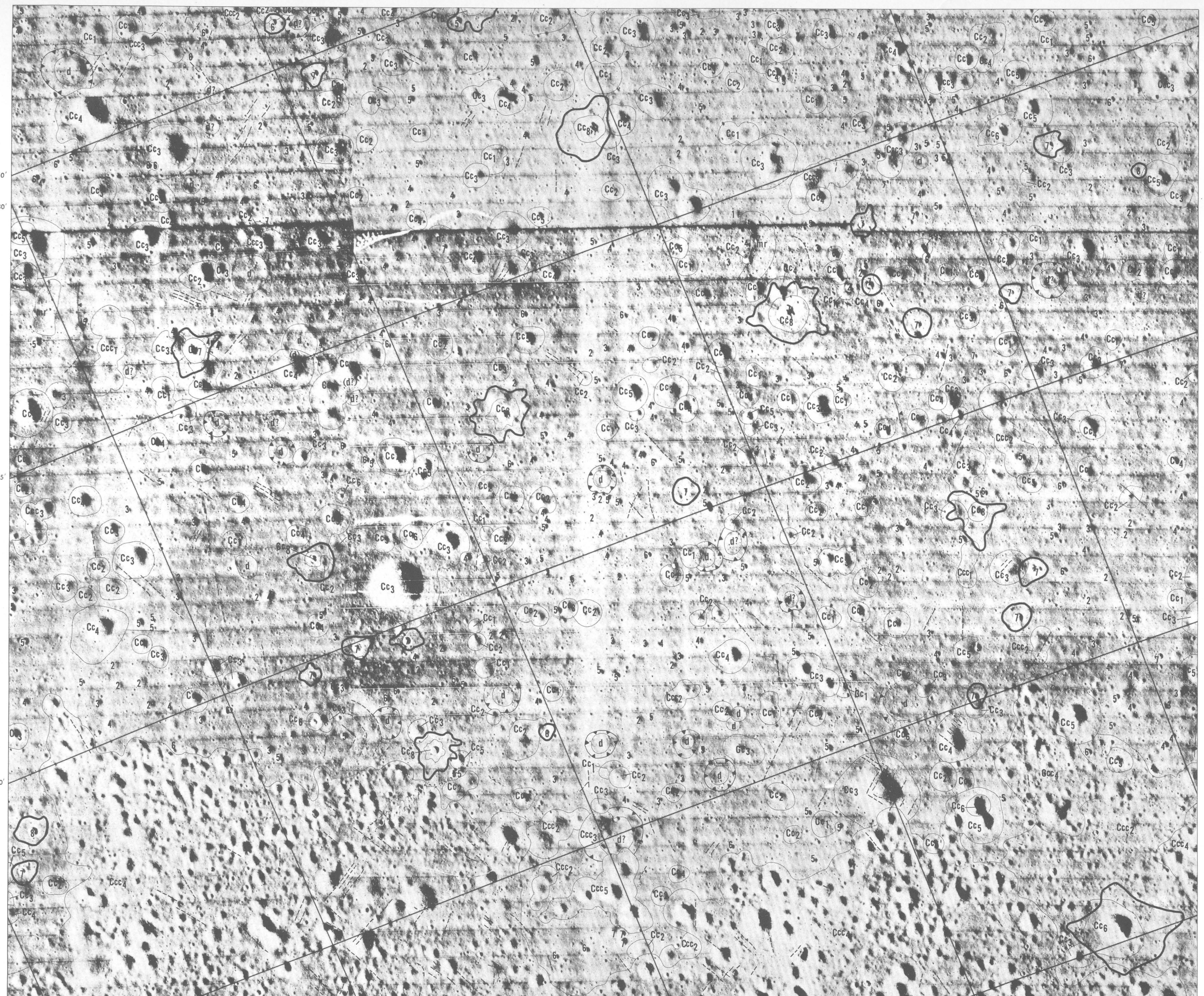
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
Manned Spacecraft Center,
National Aeronautics and Space Administration

ORB III-12-1



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SCALE 1:25,000 (APPROXIMATE)

KILOMETERS

NAUTICAL MILES

Principal sources of geologic information: Lunar Orbiter III and IV photographs (Langley Research Center, NASA, 1966, 1967); albedo data from Pohn and Wildey (1966) and from full-Moon plates 5818 and 5819 taken at U.S. Naval Observatory, Flagstaff, Ariz.

PRELIMINARY GEOLOGIC MAP OF ELLIPSE III-12-1 AND VICINITY

By
Jerry Harbour
1967

Mercator Projection

NOTE: Craters older or younger than cluster are not shown within Ccc_4.

Contact

(d)
Buried contact

Lineament
Shallow linear depression.

Crest of rim surrounding small dome
Short solid lines indicate isolated segments; dashed where indistinct. Line drawn at crest; barbs point downslope to annular valley.

Crest of small ridge

Scarp
Line drawn at base; barbs point down slope.

Block field
Indicates limits of discontinuous deposits mapped independently of other crater rim deposits. Blocks generally superposed on all other units.

COPERNICAN SYSTEM

Crater materials, undivided

NOTE: Crater materials occupying larger areas are outlined by geologic contacts; materials occupying smaller areas are assigned numbers only.

Characteristics

8	Cc_8

8, rim crest diameter 50-100 meters. Includes very bright ray material; abundant blocks present; materials inside crater are hummocky; crater rim crest sharply raised.
Cc_8, rim crest diameter greater than 100 meters. Includes very bright ray material and satellitic crater material; abundant blocks present; abundant structure occurs within crater; crater rim crest raised.

7	Cc_7

7, rim crest diameter 50-100 meters. Includes ray material; either wall material is terraced or floor material is mounded; crater rim crest slightly subdued.
Cc_7, rim crest diameter greater than 100 meters. Includes ray material; abundant blocks present; abundant structure occurs within crater; crater rim crest sharp.

6	Cc_6

6, rim crest diameter 50-100 meters. Unit is not bright; crater density on rim material lower than that of surroundings; crater rim crest slightly subdued.
Cc_6, rim crest diameter greater than 100 meters. Unit is bright; blocks moderately abundant on rim; abundant structure occurs within crater; crater rim crest slightly subdued.

5	Cc_5

5, rim crest diameter 50-100 meters. Crater density on rim material slightly lower than that of surroundings; associated crater is cup shaped; crater rim crest subdued.
Cc_5, rim crest diameter greater than 100 meters. Unit is not bright; few scattered blocks occur outside crater and numerous blocks occur within it; slightly subdued structure occurs within crater; crater rim crest subdued but well defined.

4	Cc_4

4, rim crest diameter 50-100 meters. Crater density on rim material same as that of surroundings; associated crater has shape of shallow bowl; crater rim crest slightly raised.
Cc_4, rim crest diameter greater than 100 meters. Blocks absent or very sparse outside crater and few blocks occur within it; subdued structure present in floor and wall materials and concentric structure present in rim material; crater rim crest strongly subdued.

3	Cc_3

3, rim crest diameter 50-100 meters. Associated crater is gentle pan-shaped depression.
Cc_3, rim crest diameter greater than 100 meters. Blocks absent outside crater and sparse inside; slight concentric structure present in rim material; crater density on rim material same as that of surroundings; associated crater has shape of shallow bowl; crater rim crest slightly raised.

2	Cc_2

2, rim crest diameter 50-100 meters. Associated crater is barely discernible gentle depression; crater rim crest is virtually complete.
Cc_2, rim crest diameter greater than 100 meters. No blocks visible within crater; patterned ground occurs in wall and floor materials; no strong shadows present; associated crater is gentle pan-shaped depression.

Cc_1

Rim crest diameter greater than 100 meters. No blocks visible within crater; shadows very weak and gray; associated crater is barely discernible gentle depression; crater rim crest virtually complete.

Interpretation
Materials of both primary and secondary impact craters; the youngest is Cc_8 and the oldest is Cc_1. All craters are interpreted to have originally had the morphology of Cc_8 and to have been degraded to their current form as a result of erosion and infilling from micrometeoroid bombardment and from slumping and creeping of rim and wall materials because of seismic shaking.

Interpreted engineering properties
Poorly sorted, weakly cohesive, granular debris occurs in floor and rim deposits; blocky debris or bedrock exposures occur in wall material, especially in Cc_5 through Cc_8 craters. Slopes greater than 15° occur within almost all Cc_3 through Cc_8 craters.

Scientific interest
Crater deposits provide a variety of shock-metamorphosed and weakly shock-metamorphosed samples of subsurface materials. Craters of different ages provide samples of different ages of weathering. Projectile fragments, although scarce, will provide exotic samples of extralunar materials and materials from distant areas on the Moon.

Ccc

Crater cluster material
[Subscript indicates relative age of crater materials within cluster.]

Characteristics
Material of terrain covered with at least three contiguous craters of approximately the same age.

Interpretation
Materials of impact craters, probably mostly of secondary origin; youngest Ccc_4, oldest Ccc_1. Superposition relations within cluster are unclear. Mutual interference during cratering process that formed the clusters may have caused more rapid initial degradation of individual craters within the cluster.

Interpreted engineering properties
Terrain of crater clusters is rougher than that of individual craters of same age because contiguous rim crests of adjacent craters preclude broad intercrater areas.

Scientific interest
Because most crater clusters probably are of secondary impact origin, the alinement direction of clusters may indicate primary source crater. Projectile materials associated with such crater clusters may be identified as to locality of origin. Distance from primary source may provide data on projectile velocity and energy.

ERATOSTHENIAN SYSTEM

mr

Mare ridge material

Characteristics
Occurs as two small areas of slightly elevated ridge material whose characteristics are similar to those of the principal mare unit described below. Ridge in north-central part of map is slightly arcuate in outline and occurs in an area marked by a higher than normal frequency of small (<20 m) craters; ridge surface, however, has slightly lower crater density than immediate surroundings.

Interpretation
May be of structural origin, or may represent build-up of volcanic materials around fissures through which mare materials erupted. If of structural origin, ridge materials are identical to adjacent mare material. If ridges are constructional, material may be different, at least in texture and age from adjacent mare flows.

Interpreted engineering properties
Hard volcanic rocks. Slopes estimated as slightly steeper (10° to 15°) than adjacent mare material.

Scientific interest
If ridges are constructional, their materials may provide a slightly younger sample of mare-type volcanic materials than adjacent area.

d

Mare dome materials

Characteristics
Small domes, about 100 to 300 meters in diameter, commonly encircled, or partly encircled, by a shallow, almost V-shaped valley. Relief is very low, and the tops of the domes are near, or possibly slightly below the level of the surrounding mare materials. Dome contact is drawn at the low point of the encircling valley.

Interpretation
Small volcanic centers, possibly pipes or vents. If domes are sources of surrounding mare materials, the low topographic relief indicates that ejection was not violent or explosive.

Interpreted engineering properties
Hard, possibly brecciated volcanic rock. Slopes are estimated to be less than 15° on most domes, except possibly near the floor of the encircling valley. Crater density essentially the same as that of surrounding surface.

Scientific interest
May be an important vent for extruded mare materials and may provide data as to their method of extrusion.

m

Mare materials

Characteristics
Undulating regional mare fill, moderately cratered to locally highly cratered. Almost all of the ellipse area is underlain by this unit, of which about 20 to 25 percent is covered by craters 10 meters in diameter and larger. Lineaments are fairly common and generally concentrated within poorly defined belts. Most lineaments are nearly straight and the preferred orientations are approximately northwest or northeast.

Interpretation
Possibly layered volcanic lava flows or ash flows of low viscosity, that emanated from several centers. Straight lineaments generally reflect the regional lunar grid; sparse arcuate lineaments may indicate segments of buried craters.

Interpreted engineering properties
Hard, moderately jointed rock; covered in intercrater areas by a regolith to a depth of 2-8 meters. Slopes in intercrater areas are estimated to average about 2°, but slopes of 5° are fairly common. Craters 10 meters in diameter and larger would present hazards to landing.

Scientific interest
Mare fill of young age. Comparison with mare fill of older ages at other ellipses will provide information relating to possible differentiation of lunar magmas or to possible methods of magma formation and extrusion. If near-surface layers are thin enough, an age range of mare-fill materials may be sampled from the ejecta of different craters of different depths.

Ellipse III-12-1 is in the northwestern part of the Flamsteed P ring, about 35 km north-northeast of the crater Flamsteed E. The area is a moderately cratered, undulating mare plain. The uppermost mare-fill materials appear to be continuous with those to the south which, within the Flamsteed P ring, overlap ejecta from the crater Flamsteed. Since Flamsteed is Eratosthenian in age, the uppermost mare-fill materials within the ring are considered to be Eratosthenian or younger.

Many units of mare materials probably occur in the area, but their similar chemical and physical characteristics, optical properties, and age of emplacement make identification of the units difficult. Possible details of topographic expression of individual units have been obscured by the smoothing effect of the lunar regolith and the cratering processes that caused its formation. The preservation of large angular blocks ejected several hundred meters from craters which excavated the mare materials is evidence that the underlying mare-fill units are hard rock. Evidence for the Eratosthenian age of the mare materials is cited above.

The mare materials, which underlie the entire area, appear to be nearly homogeneous. The principal regional mare unit probably consists of volcanic flows; only two mare ridges are mapped within the area, but undulations of the surface may be due to other, very low ridges. Small domal features having low relief occur in the area. Many of these are encircled by a shallow, almost V-shaped valley, and the centers of most are at, or below, the level of the surrounding mare surface. This topographic relationship and the fact that a few domes are older than the oldest recognizable craters suggest that the domes are contemporaneous with the surrounding regional mare materials. They are interpreted as small volcanic vents, or pipes, through which some of the surface flow materials quietly emanated.

Many of the craters within the area probably resulted from secondary impacts of material ejected from the crater Kepler, about 350 km to the north-northeast. Telescopic and Lunar Orbiter IV photographs show prominent rays from Kepler that pass near the ellipse, and the intensely cratered area along the southern margin of the map may be part of one of these rays. Other secondary craters within the area may be related to the crater Copernicus, about 720 km to the northeast.

Superposition relations indicate that fresh-appearing craters are degraded with time. Accordingly all craters are mapped on the basis of interpreted relative age. The crater morphology and details of the rim, wall, and floor are used to estimate age; gradation is present between adjacent categories (fig. 1). Figure 2 shows relation between age and frequency distribution of craters larger than 100 meters.

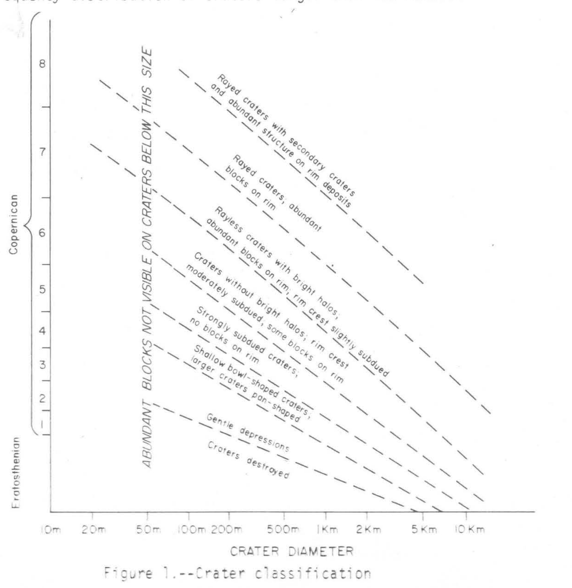

Figure 1.--Crater classification

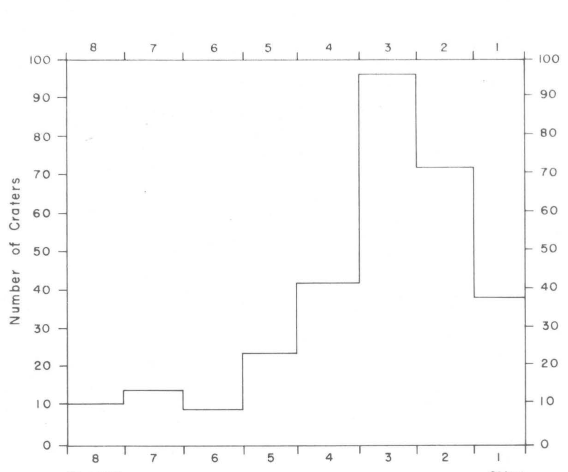

Figure 2.--Histogram of age-frequency distribution of craters larger than 100 meters in map area (clusters of more than three craters not included).

Engineering Geology

A thin (2-8 m) surficial layer of debris--the lunar regolith--occurs throughout the area. Blocks can be resolved around a few craters as small as 15 meters in diameter, and concentric ledges or terraces are visible in some craters as small as 5 or 6 meters in diameter, about the smallest size in which a terrace could be resolved. The smallness of craters that have features indicative of the presence of cohesive materials below the regolith is cited because this ellipse is in the general area studied by Oberbeck and Quaide (1967). Using only moderate-resolution photographs, they estimated the thickness of the regolith as 5 to 15 meters by noting the morphology of fresh craters larger than 40 meters in diameter. However, craters much smaller than those they observed possess the same morphologic features, and at least five different conclusions concerning the relationship between crater morphology and size are possible. If their general conclusions are correct, multiple layers may occur in the area, and they may affect the morphology of craters bottoming near their upper boundaries. Alternatively, crater morphology may be governed more by velocity and density of the projectile than by layering in the target material. Another possibility is that their conclusions are essentially correct, but that the thickness of the regolith varies within very short distances. Similarly, cohesion of mare materials may vary within short lateral distances, and these variations, in addition to those of the lunar regolith, may control crater morphology. These and other alternatives cannot be evaluated as yet. However, the variety of morphology of fresh craters in this area, and the variety in size of craters of similar morphology, indicate the size and morphology relationships cannot be applied in any simple way to determine depth of the lunar regolith.

About 45 km to the east, at the Surveyor I landing site, the regolith was subjected to a dynamic loading of between 4 and 10 psi (3×10^5 and 7×10^5 dynes/cm^2) during the spacecraft touchdown (Natl. Aeronautics and Space Adm., 1966, p. 13). Properties of surface materials in ellipse III-12-1 are probably similar to those at the Surveyor I site. Large blocks that left tracks in surface material have been ejected from at least two craters within the ellipse. One of these blocks is about 4 meters across, and its curved track is about 100 meters long. The block came to rest apparently without significant burial. Blocks are abundant around fresh craters, indicating that the surface is at least strong enough to bear their weight. The abundance of small secondary craters around some fresh craters, is additional evidence of the presence of a regolith. The presence of the impacting block in some of the secondary craters indicates considerable cohesion of the block.

The regional slope of the mare plain in this area is very gentle, probably less than 1°. However along slopes 10 meters or less in length, the surface is moderately rough. Slopes of 5° are fairly common in the undulating intercrater areas, and slopes of 10° and 15° are typical of the interiors of Cc_1 and Cc_2 craters. Slopes in excess of 15° are rare in Cc_2 craters, but are typical of Cc_3 through Cc_8 craters. Numerous small craters, less than 20 meters in diameter, will make landing and travel difficult at many places in the ellipse.

Resolvable blocks (larger than 1 meter) extend outward to 3 or 4 crater diameters around the larger Cc_7 and Cc_8 craters (more than 100 meters in diameter) and out to about 2 crater diameters around smaller ones. Resolvable blocks occur on the exterior rim deposits of most Cc_5 through Cc_8 craters, and on crater walls of most Cc_3 through Cc_8 craters. Resolvable blocks are absent, even within the crater, in most Cc_1 and Cc_2 craters. Blocks too small to be resolved, but large enough to present a hazard to landing, undoubtedly occur beyond the limits of the resolvable blocks. However, they probably are widely dispersed or concentrated only near the fresher craters, as at the Surveyor I site.

Scientific Interest

The relatively youthful age of the uppermost mare materials within the Flamsteed P ring provides an opportunity to study the features, methods of emplacement, and materials of mare fill. Petrologic comparison with older (Procellarum-age) mare materials might shed light on the petrologic differentiation of lunar magmas. Study of the domal features to determine their relationship to surface flows might establish at least one method of emplacement of the mare flows. It is possible that the domes are a general and fundamental source of mare materials and are preserved here only because of the relative youthfulness of the materials. Furthermore, sublimates, or even volatiles, might be sampled from the annular valleys around the domes if the domes are surface expressions of pipes tapping a recently active magma chamber.

Exotic fragments from the crater Kepler may be found in or around some of the Cc_4 or Cc_5 craters, while fragments ejected from Copernicus may be found near Cc_3 craters.

The thinness of the regolith will facilitate sampling of the underlying rock. Ease of sampling of the relatively unshocked substratal rocks, study of the effects of shock metamorphism upon them, and study of the effects of solar radiation and shock compression upon the regolith materials in the ellipse may provide key parameters to petrologic interpretations of samples from older areas.

The relatively greater bearing strength which may result from the younger and thinner regolith, and the scientific advantages derived therefrom, may be offset to some extent by the more undulating topography and the probably greater abundance of blocks on the surface. Therefore, it seems unlikely that this site should be considered as a first priority candidate for early landing. However, as soon as engineering and pilot constraints can be relaxed, the potential value of the site for scientific evaluation of the mare filling process would recommend its consideration for landing.

References

Oberbeck, V. R., and Quaide, W. L., 1967, Estimated thickness of a fragmental surface layer of Oceanus Procellarum: Jour. Geophys. Research, v. 72, p. 4697-4704.
National Aeronautics and Space Administration, 1966, Surveyor I, a preliminary report: NASA Spec. Pub. 126, 39 p.