

aters rs occur- raters gentle	<pre>tively recent time; material has encroached on shallow craters along the base of the ridge. Interpreted engineering properties Thick accumulation of loose material. May be unstable; slopes a hazard in early missions. Scientific interest One of the few terraces mapped along a mare ridge and relatively accessible in an early mission. Ground examination and photography may provide evidence for or against proposed origin as mass-wasted material derived from higher ground; information would have bearing on origin of larger terraces occurring at the</pre>	 subsurface fracture. Interpreted engineering properties Depend on mode of origin. Possibility of collapse dictates that these features be avoided in early missions. Scientific interest Probably the same as for other impact craters of comparable age. Determination of whether or not features are collapse pits is of significance in establishing the extent and mechanism of collapse in the uppermost layers of lunar material. 	shallow bowl. Cc3, rim crest diameter 75-250 meters. Pat- terned ground present in wall mate- rial; associated crater has shape of shallow bowl and crater rim crest is rounded but raised. Rim crest diameter greater than 250 me- ters. No blocks present in rim de- posits, blocks present in wall, especially near tops of slopes; strongly patterned ground present in wall material; crater rim crest strongly subdued.
sed rim. 11 and segments lel to ble blocks in mostly shape tem.' If rrounded rrounded	base of steep slopes in the terra. Material of terrace may provide samples of mare ridge material that have moved downslope.	Ccc _{1.2}	2 Cc2 2, crater materials undivided. Rim crest dia- meter 75-250 meters. Associated crater is gentle depression or shallow-bowl- shaped depression. Cc2, crater materials undivided. Rim crest diameter greater than 250 meters. Pat- terned ground present in wall material; blocks present in wall material of larger craters: associated crater is nan shaped
rned ground on blocks to early may be source of er craters origin		Characteristics Material in terrain covered with shallow cra- ters 100 to 400 meters in diameter; craters contiguous in much of unit. Intercrater areas gently undulating and relatively smooth; den- sity of small craters (10 to 20 meters in dia- meter) the same as on mare material (unit m ₁). Patterned ground occurs on the slopes of cra- ters; other lineaments sparse. No resolvable blocks around craters.	and has distinct break in slope at rim crest. Crater materials undivided. Rim crest dia- meter greater than 100 meters. Patterned ground present in floor material of larger craters; associated crater is very gentle de- pression.
		 Interpretation Debris in and around a cluster of secondary impact craters. Origin of crater-forming pro- jectiles uncertain. Relatively fine-grained material with no blocks greater than 2 meters in diameter. Blocks rounded by erosion; de- bris largely mixed with fragmental mare mate- rial. Interpreted engineering properties Numerous slopes caused by high density of sub- dued craters are a landing hazard. Unit may be a problem for radar approach. Fragmental material at the surface may be slightly thick- er than on mare material because surface has been more intensely churned by impact. Unit probably has more subresolution blocks than less cratered mare material. Scientific interest Similar to craters of age Cc1 and Cc2. If cra- ters are secondary impact craters, their ejecta may contain fragments derived from depth at the site of large primary impact craters, but craters are old and such fragments may not be 	Interpretation Materials of both primary and secondary impact craters; youngest Ccg, oldest Ccl. Craters with lower numbers formed from craters with higher numbers by micrometeorite erosion and by slumping and downhill creep caused by seis- mic shaking. Crushed rock, poorly sorted de- bris, and impactite occur in the rim deposits of all but the oldest craters; materials were probably shock metamorphosed to varying degrees but shock phases if originally present may have reverted to normal forms in oldest craters. Blocks most angular around youngest craters becoming progressively rounded and buried in older craters. Walls and floors of younger craters consist of highly fractured bedrock, possibly impactite in smaller craters; shatter cones possibly present. These features pro- gressively obliterated in older craters whose floors and walls are covered with fragmental debris much like the ground outside the crater rims.
		TGENTITIADIE	Interpreted engineering properties In general, all large craters are landing haz- ards; hazards become less severe with decreas- ing diameter and increasing age of craters. Subresolution blocks are probably present a- round all Cc4 and younger craters, Cc2 and Cc3 craters larger than 100 meters in diameter, and possibly around Cc1 craters larger than 200 meters in diameter. All Cc2 and younger craters larger than 100 meters in diameter have undesirable slopes for landing and walk- ing. Depth to bedrock probably greater in the floors of subdued craters than on the rim. Scientific interest
			provide a means of sampling bedrock in the ejected blocks surrounding them; possible var- iations in bedrock chemistry and mineralogy may be mappable by collecting ejected blocks from several craters. Ejected blocks will have been exposed to the space environment for differing periods of time depending on the age of the crater from which they are collected. Collection from craters with a wide range of ages is desirable for determining the radiation history of the Moon and may also resolve pos- sible ambiguities in the determination of radiometric ages of the bedrock. The younger craters will provide the clearest evidence on crater originprimary volcanic features or shock phases and shock induced structures both microscopic and macroscopic. Craters with flat floors should be compared with craters with normal geometry to determine if the former are caused by the impact of low density ob- jects such as comets. Evidence as to which craters are primary and which secondary is not apparent on the ground; secondary impact craters may include in their ejecta fragments derived from considerable depth at the sites of large primary imp&ct craters.
		mr2 mr1 Mare ridge material	m ₂ Mare material
	Characte mr2 mr1	ristics , elevated mare material occurring on connected linear segments and having numerous scarps and lineaments within segments. Contact with the mare material is an abrupt scarp in places and a gentle transitional slope in others. Slopes up to 5°. Subdued craters between 50 and 200 meters in diameter fewer than on mare material; density of small craters, 10 to 20 meters in diameter, the same as on mare material except where patterned ground is strongly developed. Small fields of resolvable blocks on higher parts. , similar to mr2 but narrower, with more gentle slopes and less patterned ground; no fields of resolvable blocks.	Characteristics Forms plain due south of west end of mare ridge (unit mr2) with which it may be associated; has fewer resolv- able craters of all types and sizes than unit m1; few lineaments except near large craters; appears lower than m1 to west and slightly higher than m1 to east. Interpretation Lavas or ash flows, probably basaltic, stirred and com- minuted by impact; younger than m1; flows may have issued from vent along east-west mare ridge and filled a struc- tural depression that was deeper on west side with flow overflowing on east. Deficiency of large old craters may have been caused by blanketing effect of flow but
	Interpre Seg all mat the by c as of of or is Interpret Frag cent of c high solv stee impe	tation nents of the mare material uplifted along faults par- al to the lunar grid. Areas transitional to mare wrial may be flows that came from feeder dikes along ridge. Lower crater density on steeper parts caused downslope movement of material. Unit mr ₁ interpreted older and more worn down than mr ₂ but the two types ridges may be the same age and differ only in their jinal size. ted engineering properties mental material at surface is thinner than on adja- t mare on ridge crests and thicker on.slopes because lownslope movement of material. Average grain size ner on ridge crest as indicated by presence of re- vable blocks. May be unstable on gentle slopes; eper scarps and slopes are landing hazards as well as adiments to traverses. Hazards greater on unit mr ₂	<pre>deficiency of young small craters is probably random. Interpreted engineering properties Fragmental material at the surface generated by the im- pact of small projectiles. Surveyor VI landed on this unit at 0°30.5' N., 1°24.5' W., outside the ellipse and northwest of a prominent mare ridge. The landing site may be anomalous in having a substantial amount of loose material derived from the surrounding mare ridge. Ejected blocks occur on only one relatively fresh cra- ter but unit is of limited extent; blocks up to 3 meters in diameter around this crater appear to be only slight- ly buried; one may have made a shallow skid mark indi- cating soil-like properties in the uppermost layer. Flat floors are present in some craters as small as 10 meters in diameter, as on unit ml to the east. The uppermost layers of unit m2 have behaved similarly to those of unit m1 during the cratering process.</pre>
	than Scientifi Subr pact May and in t	on unit mr ₁ . c interest esolution blocks of bedrock, not excavated by im- , probably present at the foot of the steeper slopes. be the site of extrusion of relatively young lavas of the ascent of volatiles along numerous fractures he ridge materials.	Scientific interest Possibly relatively young mare material with chemical and mineralogical properties that may be different from those of more typical mare material in this and other sites.
			mı (Mare material
			Characteristics Gently rolling to level material, highly cratered with abundant subdued craters. Percentage of area covered by craters ranges from 15 to 25. Sinuous scarps sparse; lineaments moderately abundant. Area outlined by short- dashed line has more lineaments than the average of unit m1 and fewer subdued craters.
Ţ			Interpretation Basaltic lavas or ash flows stirred and comminuted by impact. Sinuous scarps probably flow fronts. Unit probably made up of many overlapping flows but individ- ual flows are not traceable. Interpreted engineering properties
elipse	area). Jeob. 1:2.	N. S. GEOLOGICAL WASHINGTOWEL IBRARY S,000. 1967.	Fragmental material at the surface generated by repeated impact. Ejected/blocks up to 3 meters in diameter around fresh craters within the ellipse appear to rest on the surface and suggest a static bearing capacity of at least 1 x 10 ⁵ dynes/cm ² . Ejected blocks around a fresh crater on the same unit 15 km northwest of the ellipse have made a few shallow gouges indicating the presence of material grossly similar in its behavior to terrestri- al soils, at least to a depth of 1 meter. Very small flat-bottomed craters and craters with well-developed terraces (concentric craters of Oberbeck and Quaide, 1 ⁹⁶⁷) suggest that material with strengths considerably above that of the surface material lies at depths of from 1.5 to 6 meters with a median depth of 3 meters. (Statistics on the geometry of small craters are sum- marized in figure 2.) Craters of this size, which be- cause of their geometry are believed to have penetrated a substrate stronger than the surface layer, do not in general have resolvable blocks surrounding them in con- trast to craters in some other areas such as III P-12 where such blocks are conspicuous. The substrate ap- parently breaks into smaller fragments in this site than in III P-12. Fresh craters 100 meters in diameter and larger are surrounded by resolvable blocks; these blocks may be derived from a layer of hard rock estimated by the author to lie at depths of from 5 to 10 meters from figure 4 of Oberbeck and Quaide (1967). Area outlined by dashed line may have been seismically active to de- stroy subdued craters by shaking and slight movement along numerous coll defined the meter and slight movement
teet .	2-8-3,	M(200) R290	a rong nummerous well-defined lineaments. This area may be hazardous but geometry of small craters suggests that material with low cohesion has the same depth as in adjacent areas. Scientific interest
10 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	USGS LIBRARY - RESTON	ho 69-170	the Moon Probably as old as that in any other site

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Mare material typical of much of the equatorial belt of the Moon. Probably as old as that in any other site. Surface material may contain exotic blocks derived from large primary impact craters such as Copernicus and Tycho.

On a regional scale, the map area is part of a large tract of dark level mare material crossed by several low ridges. The mare material is probably a series of volcanic flows that have been intensely cratered; vast numbers of craters smaller 100 -Ľ _____ 10 75 -⊙ Normal geometry Flat-bottomed and concentric geometry 25 — 30 40 50 60 Diameter, D, in meters Figure 2.--Apparent geometry of small fresh craters as a func-tion of crater diameter. Depth to cohesive substrate >D/6.5 for normal craters, <D/6.5 for flat-bottomed and concentric craters. Sun angle 28°. rial along a broad area of slightly elevated ground (Rowan, 1967). Unit m2, on which Surveyor VI landed, may be such a flow unit, although distinct flow fronts are not visible. Engineering properties.--The properties of level mare material and gently rolling mare ridge material are apparently similar throughout the map area; more rugged parts of the mare ridges may have different properties. Fragmental mate-rial in which shallow gouges form under the impact of very low velocity fragments, extends to a depth of at least 1 meter on the level and gently rolling surfaces. The material is broad-ly similar to that at the Surveyor III and V sites. Surveyor VI landed successfully on unit m₂ in an area surrounded on three sides by mare ridge material. Results from Surveyor VI should be extrapolated with caution, since the landing spot may contain a substantial amount of loose debris eroded from the surrounding ridges. Material stronger than that at the surface lies at depths ranging from 1.5 to 6 meters, and a substrate of solid rock apparently lies at depths of from 5 to 10 meters. These depth estimates are based on a study of the morphology of small, relatively fresh craters (fig. 2), using the method described by Oberbeck and Quaide (1967). Part of unit m₁ in the eastern part of the map area has an un-

Scientific interest.--Samples of any of the mare material will be of great interest in early missions. Age, chemical composition, and physical properties may differ from place to place within the ellipse, especially across the contact be-tween units m₁ and m₂ and across the sinuous scarps that may be flow fronts. Unit m₂ may be younger than unit m₁, and material along the mare ridges may be younger still. 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. Rowan, L. C., 1969, Preliminary geologic map of Lunar Orbiter site ORB II P-8: U.S. Geol. Survey map (in prep.) open-file report.

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have been intensely cratered; vast numbers of craters smaller than those shown at the map scale cover the surfaces shown in Surveyor photographs. The cratering process has apparently comminuted and stirred the original surface of the mare mate-rial so that it is now covered with a layer of fragmental de-bris; any original volcanic textures and most boundaries be-tween individual flows are no longer discernible. A small tract of the mare material in the western part of the area (unit m₂) is distinctly deficient in craters of all types. It probably consists of flows that are slightly younger than the rest of the mare material (unit m₁), although the crater deficiency may be partly due to a random lack of secondary impact craters (Rowan, 1967). Several low sinuous scarps within unit m₁ may be vestiges of individual flow fronts that were once more extensive. were once more extensive.

Mare material

A well-defined mare ridge with a zigzag pattern crosses the northern part of the map area but is wholly outside land-ing ellipse II-8-3. A second, lower and less well-defined ridge with the same trend occurs in the western part of the ellipse. It was recognized for the first time on high-resolu-tion Orbiter V photographs which provided convergent stereop-sis. The ridges appear to be uplifted segments of mare mate-rial; patches of patterned ground on the ridges are probably the result of downslope movement of fragmental material. New mare material may have been extruded along the peripheral parts of some ridges where they merge with adjacent mare mate-rial along a broad area of slightly elevated ground (Rowan,

using the method described by Oberbeck and Quaide (1967). Part of unit m_1 in the eastern part of the map area has an un-usually high density of strong lineaments and a relative lack of subdued craters. Loose material on this surface may have undergone extensive compaction because of jiggling along sub-surface fractures. On mare ridge crests, fragmental material is probably thinner than that on level mare; on ridge flanks it is probably thicker. Downslope movement of material on the choose where have occurred relatively recently.

the steeper ridges may have occurred relatively recently.

10m 20m 50m 100m 200m 500m 1Km 2Km 5Km 10Km CRATER DIAMETER Figure 1.--Graph showing assumed relations among crater dia-

meter (measured from rim crest to rim crest), crater pro-perties, and crater age. Width of intervals on abscissa carries no implication as to length of intervals of lunar geologic time.

Engineering properties.--All large craters (>500 m in diameter) constitute hazards to landing because of their large surrounding blocks and steep slopes. Hazards diminish as crater size decreases and crater age increases. Ccl and Cc2 craters that are 200 meters and less in diameter prob-ably present only minor hazards. Fields of resolvable blocks are shown on the map with a heavy line; additional blocks that are below the limit of resolution probably occur around

that are below the limit of resolution probably occur around

most craters.

Scientific interest. --Ejected blocks around craters will be prime objects of scientific interest in early missions. The chemistry, mineralogy, and physical aspects of these blocks can be compared with blocks from the general lunar re-golith; and blocks from craters of widely differing ages can be compared to size information on the offects of exposure be compared to give information on the effects of exposure over various periods of time. Evidence bearing on the origin of craters is most likely to be found in the youngest craters.

This map is one of a series showing the geology of potential early Apollo landing sites. It was prepared largely from high-resolution photographs taken by Lunar Orbiters II and V. Ellipse II-8-3, in the central part of Sinus Medii, is an area of relatively heavily cratered mare near the subterrestrial point of the lunar disk. A map of Orbiter site II-P-8 at a scale of 1:100,000 (Rowan, 1967) includes the ellipse and its regional setting. It shows a large number of crater clusters superposed on very heavily cratered mare material (unit m_1). Many of the clusters lie along well-defined rays from Copernicus and Tycho and probably belong to the widespread fields of secondary impact craters around these large craters. Ellipse II-8-3 lies between the large crater clusters and includes a small patch of mare material with below-average crater density (unit m_2).

Crater materials

Craters are the most obvious and readily mappable topographic features in the map area. Surveyor I and III photo-graphs show that many craters larger than a certain size are surrounded by distinctive blocky deposits. These deposits may not be visible on Orbiter photographs. Study of crater rim deposits is of high priority for early missions. A morphologic range exists from sharply sculptured, blocky, high-rim craters to gentle depressions. The continu-um of crater types in this and other areas indicates that um of crater types in this and other areas indicates that with time, fresh craters are degraded to gentle depressions. Crater materials are therefore assigned numbers according to their relative age; highest numbers are for youngest, fresh-est craters, and lowest numbers for oldest craters. Numbers are assigned on the basis of diameter and morphology accord-ing to the scheme outlined in figure 1. Craters classified on the basis of details of the rim and floor deposits fall into a well-defined age sequence, but greater uncertainty attaches to the craters classified mainly on the basis of denth-diameter ratio-raminly Cr_Coc craters at this scale attaches to the craters classified mainly on the basis of depth-diameter ratio--mainly Ccl-Cc3 craters at this scale (fig. 1). This is because craters that form at the same time may differ in depth-diameter ratio; after degradation such craters would appear to be of different ages according to figure 1. Also, the rate of crater degradation may have dif-fered from place to place, so that craters assigned the same number are not actually equivalent. For example, in this area downslope movement of material on the mare ridges may have degraded craters at a faster rate than on the level mare material: old-annearing subdued craters on the ridges may material; old-appearing subdued craters on the ridges may thus be younger than similar-appearing craters on the mare. It seems probable, however, that Cc1-Cc3 craters are all re-latively old members of the total population.