would be of great interest, the determination of the composition in the contrasting highland provinces now becomes of paramount importance for clarifying the differentiation that has occurred in the moon.

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Surveyor V: Television Pictures

Abstract. *Surveyor V landed in a small crater, 8.5 meters wide and 12.5 meters long, which was probably formed by drainage of surficial fragmental debris into a subsurface fissure. The lunar surface debris layer is exposed in the walls of this crater. At depths below about 10 centimeters, the debris appears to be composed mainly of shock-compressed aggregates, ranging from a few millimeters up to 3 centimeters in diameter, set in a matrix of less-coherent finer particles. Rocky chips and fragments larger than a millimeter are dispersed as a subordinate constituent of the debris.*

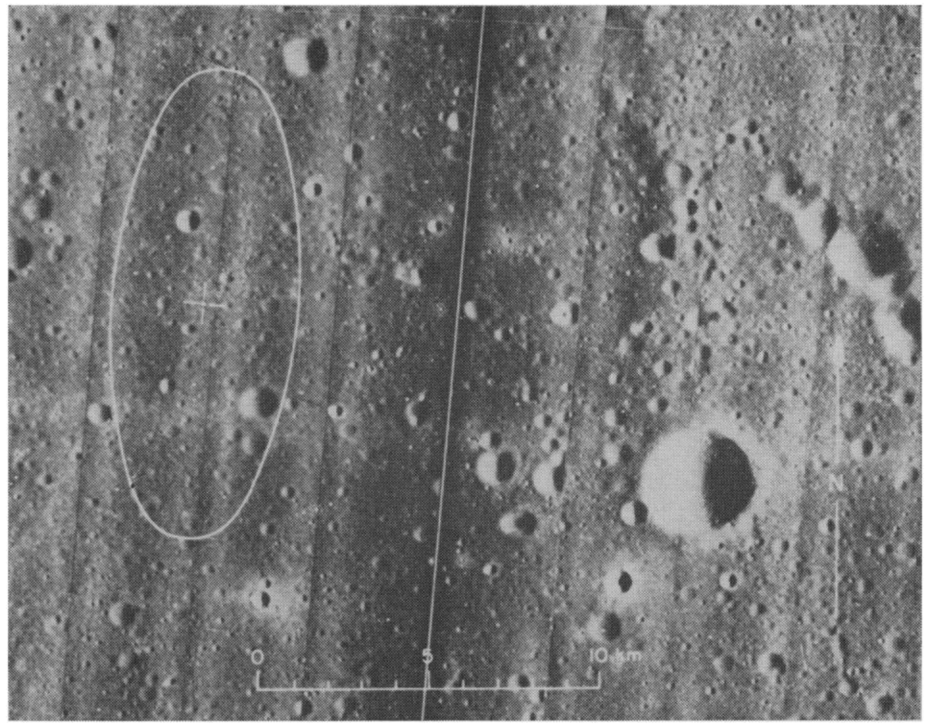

Fig. 1. Lunar Orbiter V medium resolution photograph (M-74) of an area in the southern part of Mare Tranquillitatis. The cross shows the best solution from tracking data for the location of Surveyor V, and ellipse shows 3σ-limit of error of this location. Large crater on the right side of the photograph is Sabine D. The crater in which Surveyor V landed is too small to be resolved in this photograph.

Surveyor V landed on the lunar surface at 00:47 GMT on day 254, 11 September 1967, 35 hours after local sunrise on the moon. Between the time of landing and lunar sunset, 14 days later, more than 18,000 high-quality television pictures of the lunar surface and parts of the spacecraft were acquired. The first results obtained from the television pictures on the physical features of the lunar surface immediately surrounding the spacecraft are presented in this and the foregoing reports.

Landing site of Surveyor V. The landing site of the spacecraft, as determined both from inflight and from after-landing tracking data, is at 1.50°N and 23.19°E (lunar latitudes and longitudes). The 3σ uncertainty ellipse for this solution has a semimajor axis of 6.9 km and a semiminor axis of 2.7 km (Fig. 1). This site is in the southwestern part of Mare Tranquillitatis, about 70 km north of the southern boundary of the mare and a little over 80 km east of the crater Sabine (Fig. 2). It is near the periphery of a complex system of mare ridges, but no known mare ridges occur within 10 km of the most probable position of the landing site. The region is crossed by faint rays associated with the major crater Theophilus, 350 km to the south, and the landing site may be within one of the Theophilus rays.

The highlands to the west of Mare Tranquillitatis are characterized by prominent ridges trending northwest (Fig. 2); these ridges are part of the system of Imbrian sculpture (*1*). Subordinate linear structures in the highlands, such as the Ariadaeus rille, trend about N 20°W. In the immediate vicinity of the landing site, high-resolution pictures taken by Lunar Orbiter V reveal many small craters about 10 m across which are aligned in a northwest direction. Typically, these small craters occur as pairs, with the line between the centers of the craters trending northwest; in a few instances, a single crater is markedly elongate in this same direction. This alignment follows the dominant trend on this part of the mare of the lunar patterned ground, which consists of gentle ridges and troughs of very low amplitude. Both the aligned craters and the lunar patterned ground probably reflect a subsurface system of fissures and joints related to the Imbrian sculpture.

Topography and structure of area around spacecraft. The data obtained from the television pictures (*2–4*) have been used to prepare a preliminary topographic map of a small area on the lunar surface surrounding Surveyor V. The orientation of the spacecraft and of the camera has been determined from television observations of stars, planets, and the lunar horizon and also from the angular settings of the solar-panel sun sensor and positional tuning of the planar array antenna of the spacecraft. The stars Sirius, Arcturus, Agena, and Capella and the planets Venus and Jupiter were observed. Preliminary reduction of these observations showed that the spacecraft was tilted 19.7° at an azimuth of N17°E. Observations of the lunar horizon, on the other hand, indicate that the spacecraft was tilted 19.4° at an azimuth of N13°E. The amount of tilt of the spacecraft, at the time of these observations, is known within a few tenths of a degree, but the present solution for the azimuth of tilt has a probable error of several degrees. The camera's 0° azimuth was found, from the stellar and planetary observations, to be oriented approximately N24.7°E. This solution is accurate to within a degree. Near the end of the lunar day the shock absorbers on legs two and three collapsed, and the spacecraft was tilted about 3 degrees further to the northeast. The final attitude of the spacecraft and camera at the end of the lunar day is not accurately known.

The positions of points on the lunar surface, relative to the television camera, were obtained from angular position measurements derived from potentiometers on the elevation and azimuth axes of the camera mirror, and from range measurements based on the solution for points of best focus in pictures taken at many different focus settings. This method of topographic mapping is essentially new; we refer to the technique as *focus ranging*. Focus-ranging surveys were taken at each available camera elevation position along camera azimuth lines 18° apart. Available line-of-sight elevation angles are separated by increments of 4.96°. Partial focus-ranging surveys also were taken along several intermediate azimuths. The technique utilizes pictures taken at 8 to 10 different focus settings at each camera elevation position along a given azimuth. Small areas in best focus in each picture were located on a mosaic of pictures taken at specific focus settings, and the azimuth and elevation of the centers of each small area in best focus were deter-

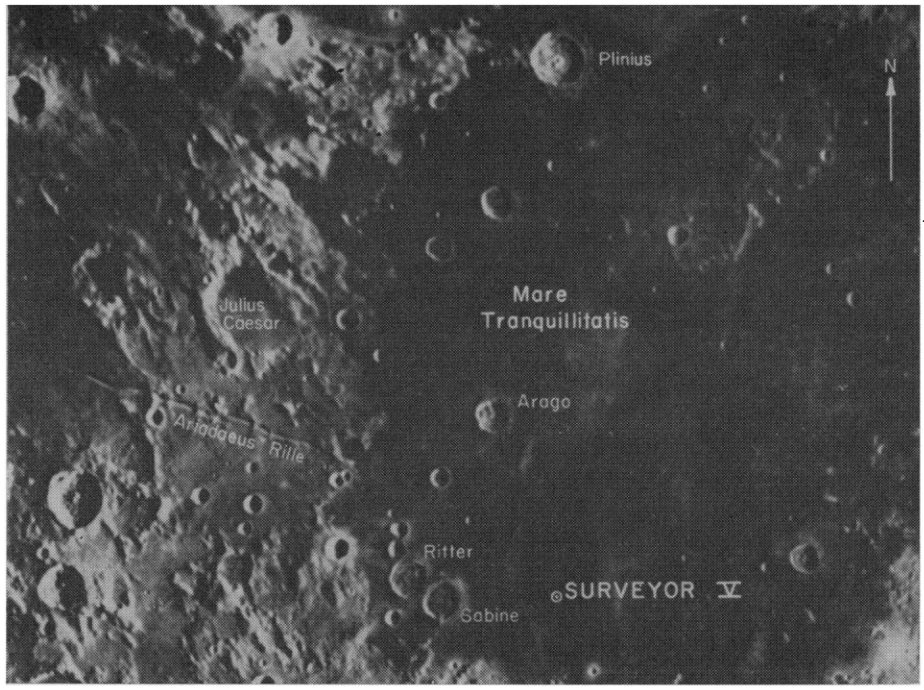

Fig. 2. Earth-based telescopic photograph of Mare Tranquillitatis and the highlands to the west of Mare Tranquillitatis. Prominent northwest-trending ridges and valleys in the highlands are part of Imbrian sculpture.

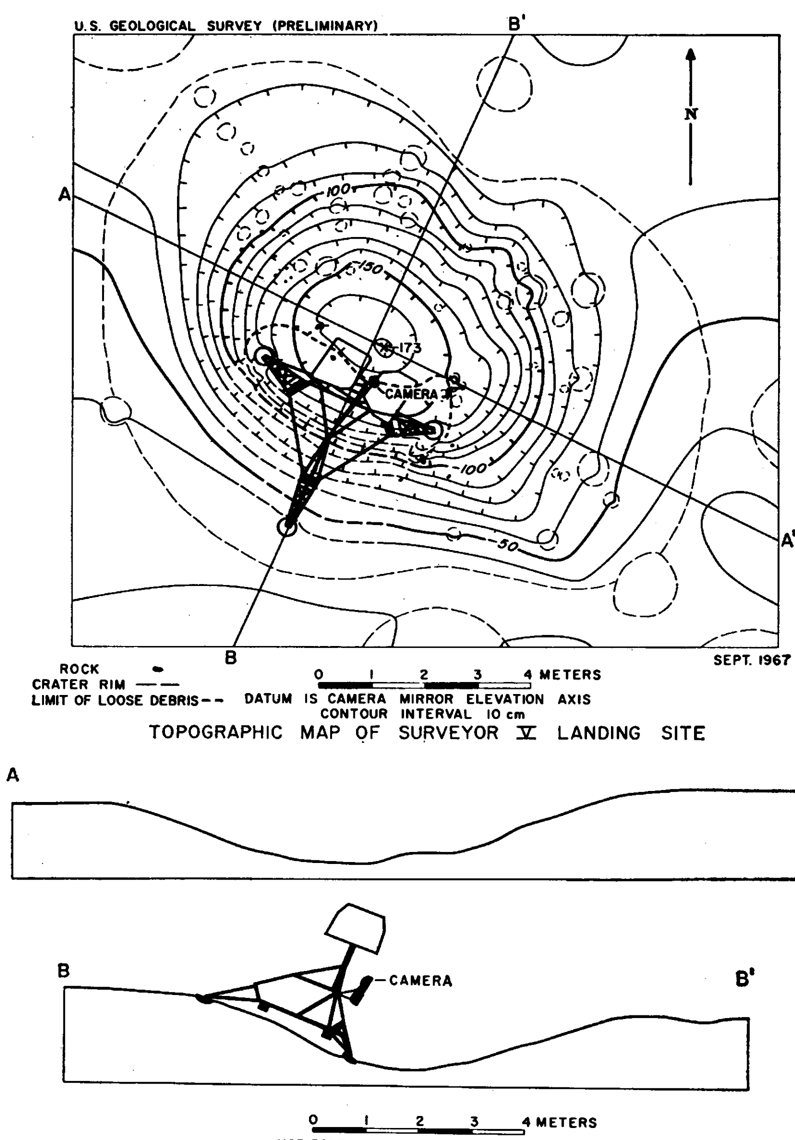

Fig. 3. Topographic map and profiles of the Surveyor V landing site.

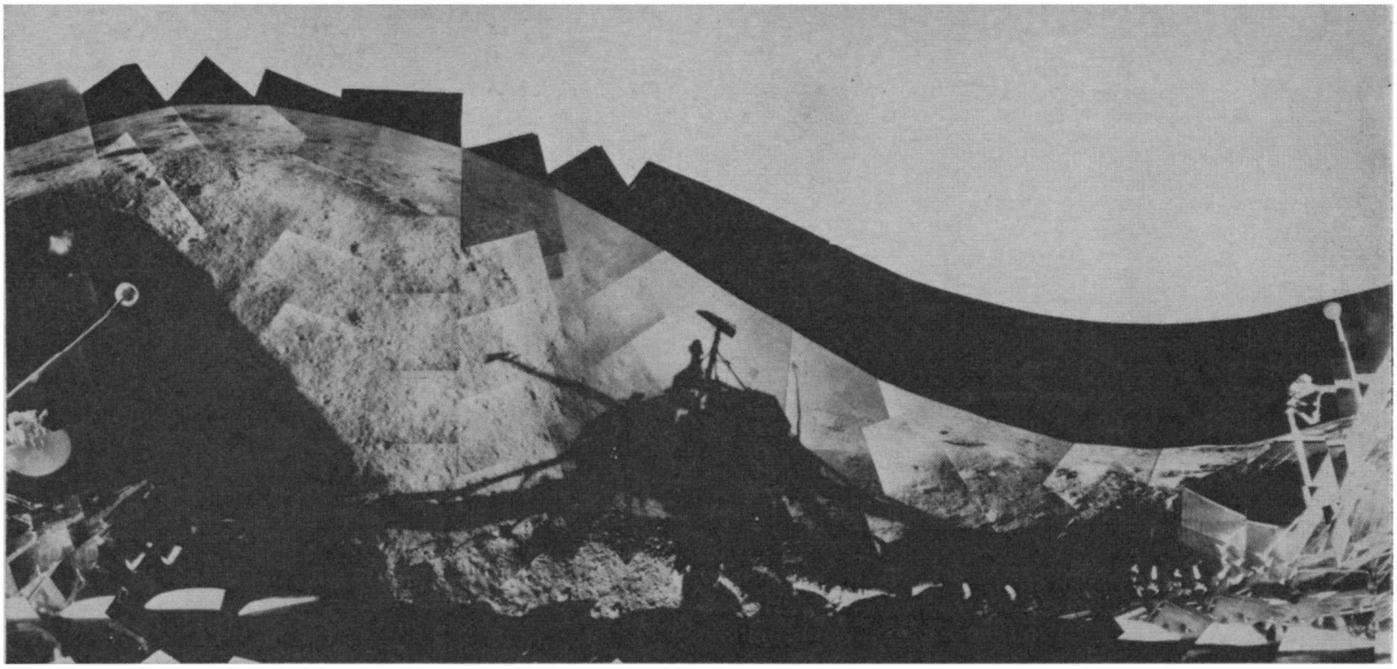

Fig. 4. Mosaic of wide-angle pictures (GMT day 266; 11:20:24 to day 266; 11 : 47 : 54) from Surveyor V taken the day before lunar sunset. The horizon follows a sinusoidal curve because the camera is tilted. The shadow of the west wall of the Surveyor V crater partially fills the crater at the left. Rounded edge of the Surveyor V crater follows the horizon, but lies approximately one-half the width of one wide-angle picture below it.

mined by graphical measurement. The location of a point on the lunar surface with respect to the intersection of the camera mirror rotation axes was computed from azimuth, elevation, and calibrated focus distance.

More than 3000 focus-ranging pictures were taken during the first lunar day, from which more than 300 data points were computed for compilation of the preliminary topographic map (Fig. 3). The map shows that the Surveyor V spacecraft is located on the southwest wall of a crater that is more than a meter deep and about 12.5 m long by 8.5 m wide. Footpads 2 and 3 of the spacecraft came to rest at the foot of the crater wall, and footpad 1 rests on the rim of the crater. For convenience of reference, we call this crater the Surveyor V crater.

Because the camera is inclined toward the floor and far wall of the Surveyor V crater, more than 80 percent of the field of view below the horizon is occupied by parts of the lunar surface and the spacecraft that are not more than 6 m from the camera. The rim or edge of the crater, as seen from the camera, lies about 8° to 10° below the horizon and follows a sinusoidal curve approximately parallel to the horizon in the panoramic mosaics prepared from the pictures (Fig. 4). Under high-sun illumination, the edge of the crater can be observed (in another series of pictures) as a region of abrupt change in the apparent eccentricity of very small craters, which reflects the change in surface slope. A rather abrupt change in the observable texture of the surface and in average photographic density or tone also occurs at the edge of the crater (Fig. 5). At very low angles of solar illumination, the edge of the crater was easily distinguished as the upper edge of the shadow filling the crater.

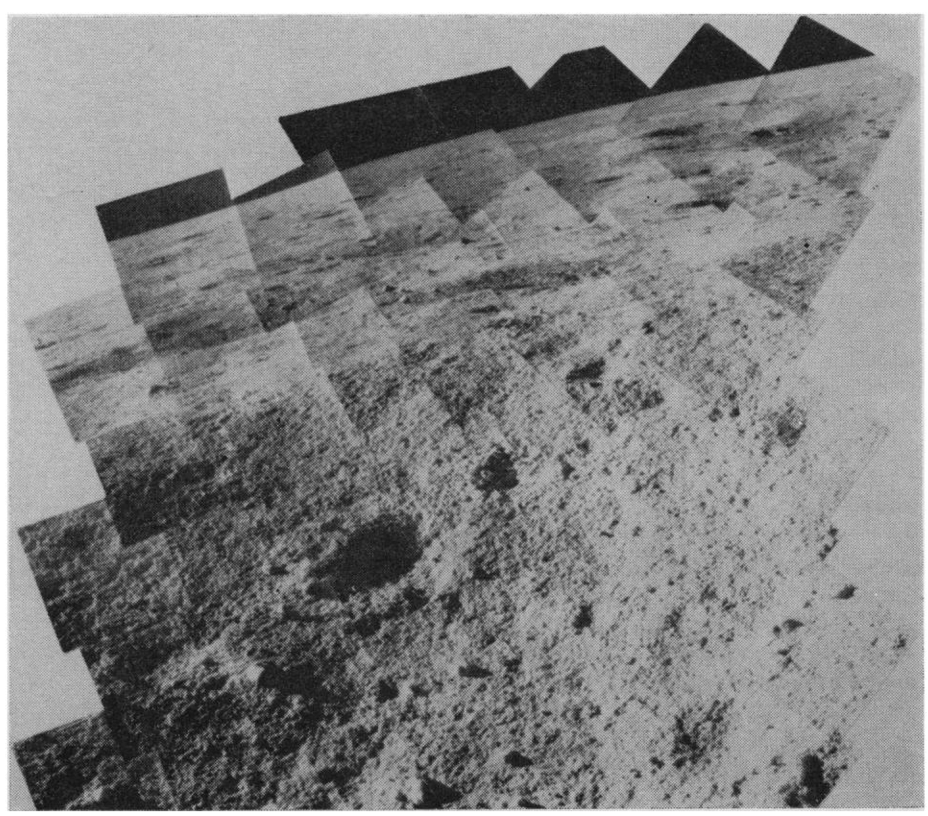

Fig. 5. Mosaic of narrow-angle pictures from Surveyor V showing the northwest wall of the Surveyor V crater, and the far field beyond the rim of the crater extending to the horizon. Differences in texture of the crater wall and the far field are due to differences in the distance from the camera and inclination of the surfaces.

As revealed by the topographic map (see Fig. 3), the Surveyor V crater is elongate in the northwest direction. It is, in fact, the largest local member of a chain of small craters trending northwest, and it appears to be a compound crater consisting of two partially merged smaller craters or components separated by a subdued northeast-trending septum or low ridge. Thus the Surveyor V crater appears to be a member of the family of elongated craters and crater pairs observed on the Lunar Orbiter V high-resolution pictures in the vicinity of the Surveyor V landing site.

The floor of the southeast component of the Surveyor V crater is about 20 cm higher than that of the northwest component, but the rim of the compound crater is also 20 to 30 cm higher on the southeast than on the northwest. The camera elevation axis rises more than 50 cm above the north rim of the crater but only about 30 cm above the south rim.

In profile (Fig. 3), the Surveyor V crater is dimple-shaped; it lacks a raised rim, and the slope of the crater walls increase gradually toward the center of the crater. It has a distinct small concave floor, however, about 2.5 m wide. Both in plane view and in profile, the Surveyor V crater resembles other craters observed on Ranger and Orbiter pictures, which are inferred to have been formed by drainage of surficial debris into subsurface fissures (*5*). We infer the Surveyor V crater has been formed by drainage of surficial fragmental debris into a fissure that passes beneath the center of the crater and extends for some distance both northwest and southeast beneath the crater chain.

Along the northwest wall of the Surveyor V crater is a chain of very small craters ranging in diameter from 20 to 40 cm (Fig. 3 and Fig. 6). The trend of this chain is nearly parallel to the long axis of the Surveyor V crater and lies very nearly on the axis. This group of small craters probably has been formed by recent renewed drainage into the underlying fissure. Other very small craters are scattered over the walls and floor of the Surveyor V crater. Many have low raised rims. Most of these probably were formed by impact.

An unsuccessful attempt was made to locate the Surveyor V landing site on Orbiter V high-resolution frame number 78. The coordinates of the landing site obtained from the tracking data were plotted on U.S. Air Force Aeronautical Chart and Information Center (ACIC) lunar chart AIC 600, and transferred to the Orbiter photograph. As the resolution of this photograph is about 2.5 m, the chances of identifying the Surveyor V crater by its size and shape alone were remote. However, the study of the distant features shown in narrow-angle photographs of the horizon, taken near sunset, should ultimately lead to the identification of the crater in which Surveyor V landed.

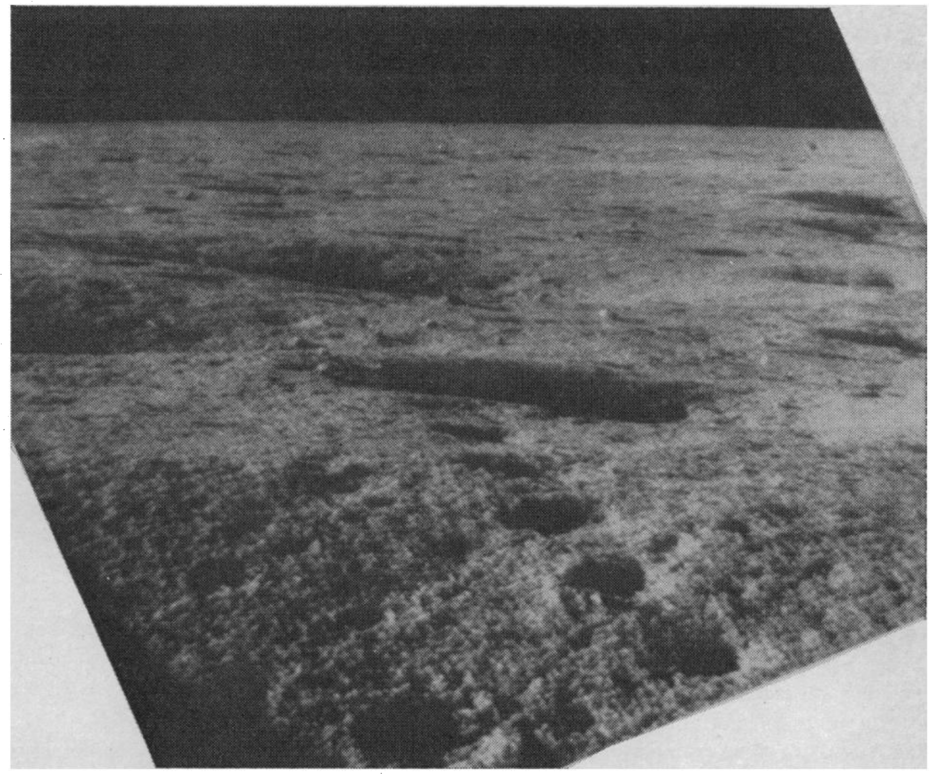

Fig. 6. Wide-angle picture (GMT day 266; 11:26:28) of the northwest wall of the Surveyor V crater. Chain of small craters 20 to 40 cm in diameter extends from the center to the bottom of the picture.

Beyond the rim of the Surveyor V crater, the lunar surface is visible to distances of the order of a kilometer to the north and west. The horizon to the east and south is closer. In one sector, south of the spacecraft, the horizon is only about 100 m distant, where it is occupied by the raised rim of a nearby crater. The horizon lies slightly above the horizontal line of sight in all directions, and is 0.4° high on the average. These data suggest the landing site lies within and on the southeast flank of a very broad, shallow depression on the order of 1 km in width and about 10 m or a few tens of meters deep.

The surface of this depression is pock-marked with hundreds of craters visible from the vantage point of the Surveyor V camera. They range in diameter from a few tens of centimeters to more than 20 meters. About 10 m northwest of the Surveyor V camera there is another rimless crater about 4 m in diameter. This crater has probably been formed by drainage of debris into a subsurface fissure, like the Surveyor V crater, and is probably localized over the same or a parallel fissure. Many other craters observable in the middle distance are of similar rimless form and may have been formed by drainage of surficial debris.

A few craters in the middle distance have distinct raised blocky rims. One, lying about 200 m to the north of the spacecraft (Fig. 7), is about 15 m in diameter, and another, which lies about 100 m to the south, is about 20 m in diameter. A strewn field of blocks surrounds each of these craters; the strewn field associated with the crater to the south extends almost to the position of the spacecraft. If the blocky rimmed craters have depth-to-diameter ratios between 1 to 3 and 1 to 4, ratios characteristic of small primary lunar craters, the presence of blocks on their rims indicates the depth to coarse blocky or coherent material is locally not greater

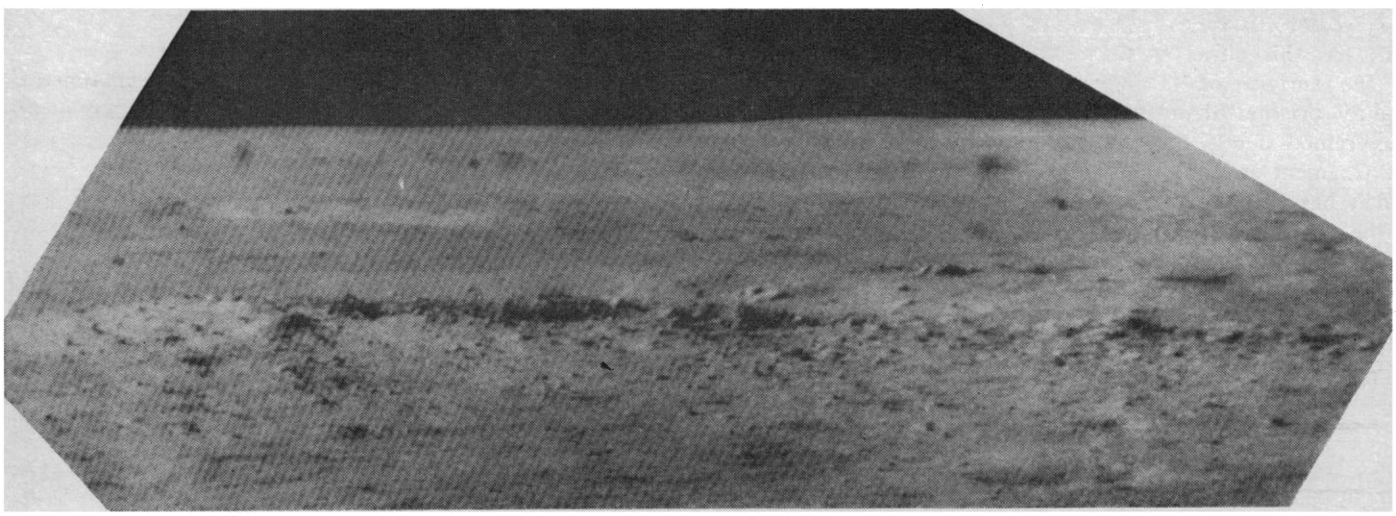

Fig. 7. Narrow-angle picture (GMT day 265; 15:30:48) showing blocky rimmed crater about 15 m in diameter approximately 200 m north of Surveyor V.

than about 5 m. The scarcity of blocky ejecta around most smaller craters, however, indicates that at least the upper few meters of material consist predominantly of fine-grained debris with little or no cohesion (see *6*).

Surficial debris. An unusually detailed view of the surficial debris layer is provided by the close-up pictures of the walls and floor of the Surveyor V crater. The spacecraft initially touched down on the upper part of the south wall of the crater; footpad 1 touched first outside of the crater and footpads 2 and 3 part way down the crater wall. As the spacecraft rebounded, it slid down the crater wall and stopped with footpads 2 and 3 close to the edge of the concave crater floor. A one-meter-long furrow or trench plowed by footpad 2 in sliding downward is shown in Fig. 8. This furrow is about 10 cm deep and is partly filled with loose debris. A good exposure of the fragmental material lining the crater wall can be seen for about 60 cm along the wall of this trench.

As the spacecraft slid down the crater wall, loose debris was thrown out in front of each footpad, and formed distinct low piles that extend out on the crater floor in front of footpads 2 and 3 (Fig. 3). In addition, a considerable amount of loose material cascaded down the slope ahead of footpad 1 and is visible on the floor of the crater directly beneath the camera.

Many individual fragments rolled a short distance, leaving tracks on the original surface (Fig. 9a). Some of these tracks, which are a millimeter to a few millimeters deep, were formed by fragments no more than 2 cm across. On the assumption that the density of the fragments does not exceed 3 g/cm^3, the development of the tracks shows the bearing strength of the uppermost few millimeters of the fine-grained debris on the lunar surface is less than 10^4 $dyne/cm^2$, for surface areas of about 3 cm^2. This fragile uppermost layer was disturbed not only by fragments set in motion during landing of the spacecraft, but also by the scouring effect of the gases exhausted from the vernier engines, when they were turned on to conduct an erosion experiment on the 3rd day after landing. At distances more than a meter from the vernier engines, the surface has a marked swept appearance with many low parallel grooves. These grooves probably were formed mainly by the sliding and rolling of loose fragments on the surface, ranging in size from a few millimeters to a few centimeters across. It can be shown that many loose fragments thrown out during the landing of the spacecraft were moved again during the firing of the vernier engines.

A remarkable variety of fragments is revealed in the pictures of the debris dislodged by the spacecraft and in pictures of the undisturbed surface as well. In the debris pile around footpad 2 (Fig. 9b) there are (i) bright angular fragments, which are inferred to be pieces of dense rocky material, (ii) dark rounded objects, which are probably aggregates of very fine-grained particles, and (iii) curious dark lumpy objects, which appear to be aggregates of aggregates. This last-named characteristic of some of the loose chunks thrown out is well demonstrated by the presence of bright angular chips set in a dark fine-grained matrix (Fig. 10, a and b). The surface texture of one fragment several centimeters across, which was originally lying on the southeast wall of the crater (Fig. 10c), suggests that it, too, is made up in part of resolvable pieces and chips, each a few millimeters across. Its surface is made up of numerous small angular protuberances and indentations. Similar, but slightly more rounded, protuberances 1 to 3 mm across were observed on a dark rounded object exposed in the wall of the trench plowed by footpad 2 (Fig. 10d).

Material exposed in the trench plowed by footpad 2 is closely similar to the rubble or debris exposed in many of the small craters a few tens of centimeters across that dot the walls and floor of the Surveyor V crater. Most of the debris appears to be clods or aggregates of fine particles. A subordinate number of objects in the debris appear to be complex aggregates or individual bright angular pieces of rocky material.

New photometric evidence obtained from the Surveyor V pictures indicates that the bright angular fragments are more dense or at least less porous than the dark fine-grained surface material and dark aggregates. Figure 11 illustrates a bright angular fragment about 12 cm across and 2 m from the camera, under two different angles of solar illumination. The shadow of one of the omnidirectional antennas on the spacecraft passed over this fragment during the lunar day, and we have referred to it as the "omni rock." In Fig. 11a, this object is seen as it appeared in the late lunar morning at a small phase angle (angle between the vector from the object to the camera and vector from the object to the sun). At this phase angle, most parts of the surface of the fragment are slightly brighter than the surrounding fine-grained debris but some parts of the fragment are covered with material which has nearly the same brightness as the nearby fine-grained debris. These covered parts of the fragment are depressions which appear to be partly filled with dark very fine-grained material. In Fig. 11b, the fragment is shown as it appeared in the late lunar afternoon, at a large phase angle. Here the exposed surfaces of the fragment are much brighter than the surrounding fine-grained debris and much brighter than the fine-grained material resting in the depressions on its surface. The difference in contrast in the two pictures is due to differences in the photometric function of the fine-grained debris and the photometric function of the surface of the angular fragment. Much more light is scattered from the surface of the angular fragment at large phase angles than from the dark fine-grained material, whereas the luminance of the angular fragment and the fine-grained debris are more nearly equal at low phase angles. This indicates the surface of the fragment is more like a lambertian scattering surface than is the dark fine-grained surface material. It is, therefore, less porous or less rough at a scale below the resolution of the television pictures.

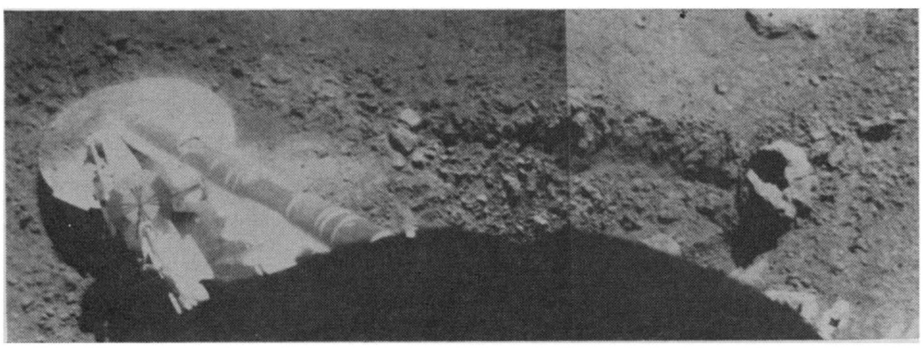

Fig. 8. Mosaic of two wide-angle pictures (GMT day 258; 03:24:59 to GMT day 258; 03 : 40 : 28) showing footpad 2 and trench dug when the spacecraft skidded down the inner slope of the Surveyor V crater. The trench is about 1 m long and 10 cm deep.

SURVEYOR V

Many other bright angular objects in the field of view around Surveyor V show photometric properties similar to that observed for the "omni rock." The top of an angular block about 11 cm across and 6 m from the camera is seen to be much brighter at large phase angles than the nearly parallel surface of the fine-grained debris surrounding the block (Fig. 12). A bright but rounded object, which rolled into the head of the trench formed by footpad 2, was also conspicuously bright at large phase angles compared with the surrounding dark clods and rubble. This object may have been partly broken by impact of footpad 2 before rolling into the trench and, if so, some of the surfaces observed may have been freshly formed. It may be inferred that all bright objects which exhibit a photometric function more like that of a lambertian surface than like most other parts of the lunar surface are composed of relatively dense, coherent material. Probably they are either rocks or compacted aggregates of fine particles that have rock-like mechanical properties. Some such compacted aggregates may have been formed by shock compression during impact cratering.

The blocks on the raised rims of

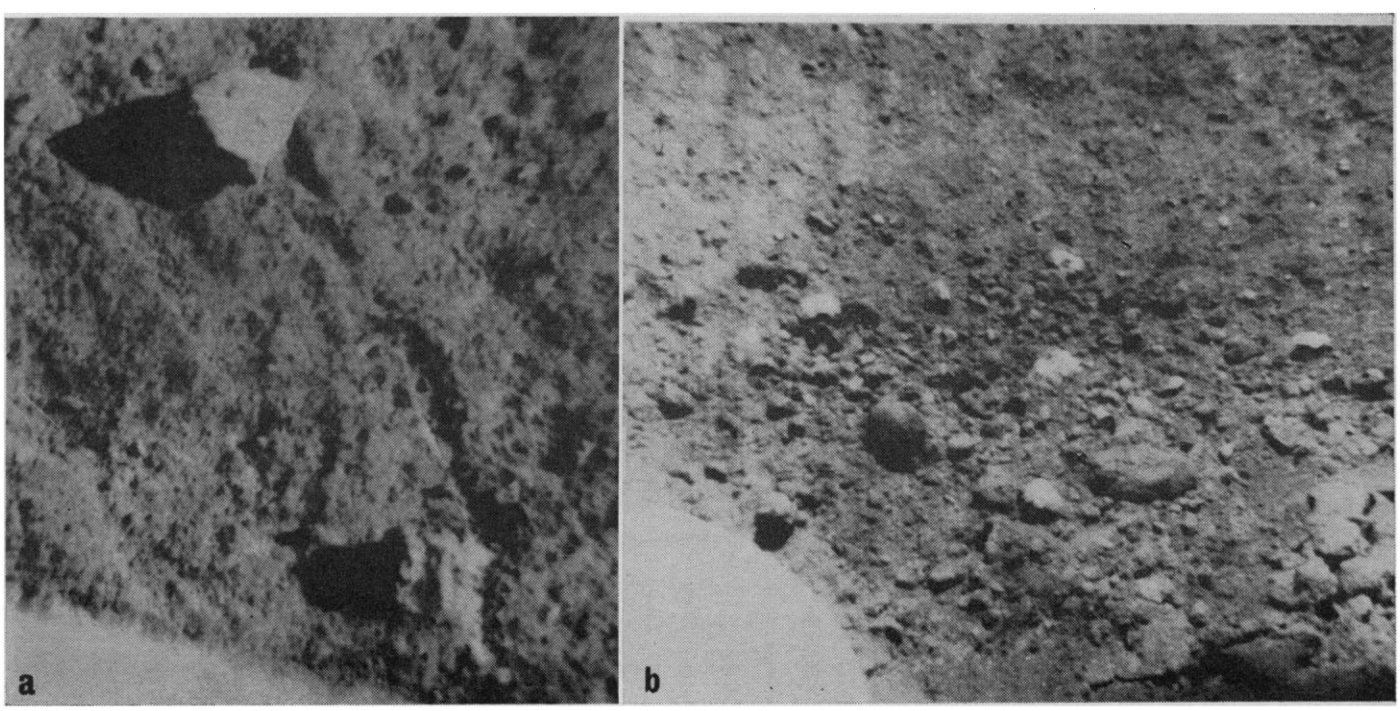

Fig. 9. (a) Track produced by a fragment 3 cm wide. The fragment was disturbed by Surveyor V during landing (GMT day 255; 06:07:26). (b) Fragmental material thrown onto the lunar surface in front of footpad 2 during the landing of Surveyor V. Most of the fragments are aggregates of fine particles. The bright fragments probably are pieces of coherent rock (GMT day 258; 08 : 40 : 04).

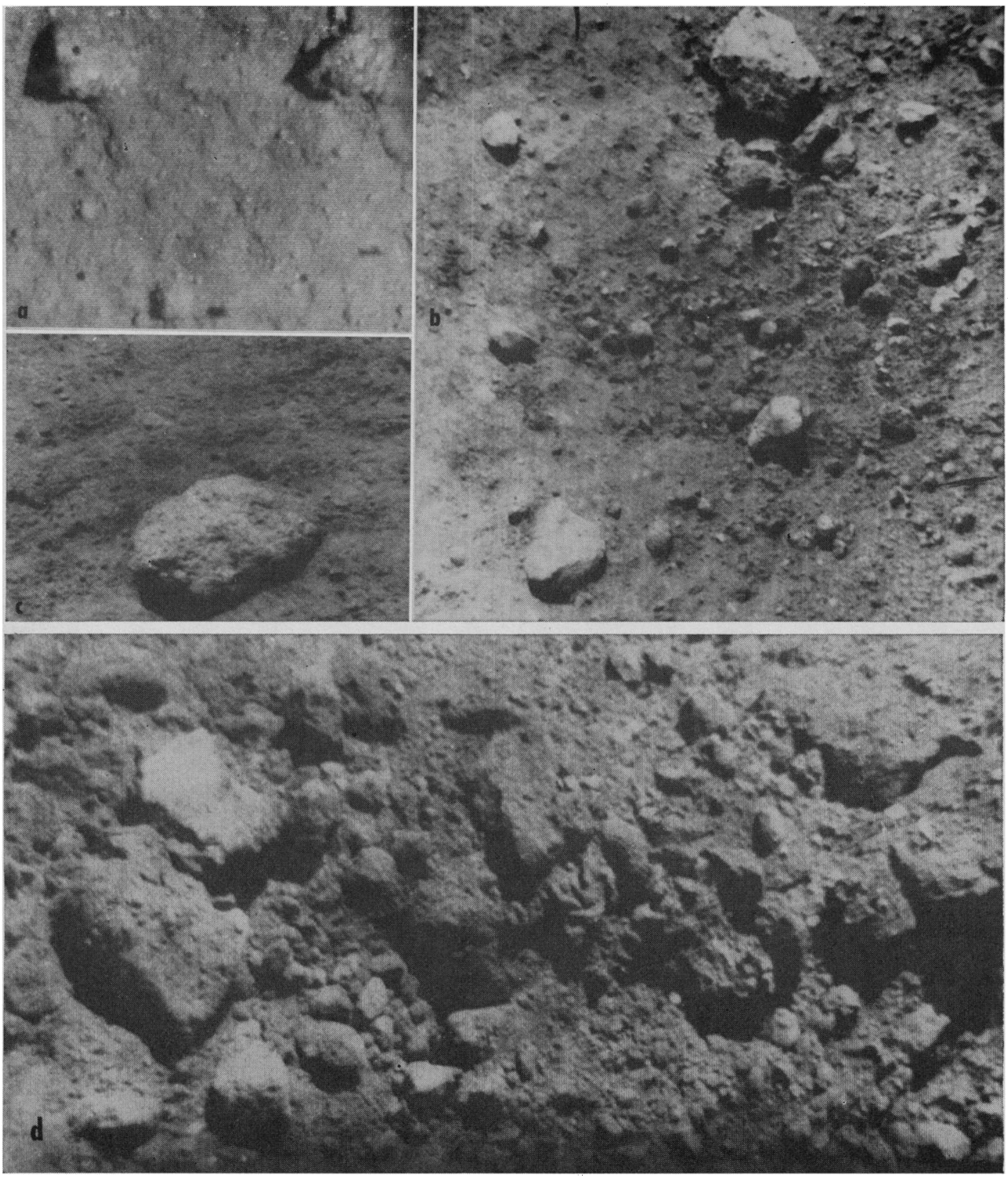

Fig. 10. Narrow-angle pictures illustrating various types of aggregate fragments observed in the Surveyor V crater. (a) Two fragments, each about 2 cm across, thrown out during landing of the spacecraft. Bright spots with angular outlines on these fragments are probably tiny bright rock fragments embedded in a very fine-grained dark matrix (GMT day 264; 11 : 47 : 56). (b) Fragments thrown out of furrow made by footpad 2 during landing of spacecraft. Angular fragment (4 cm long) at top has bright and light gray spots, which may represent rocky chips and compacted aggregates of fine-grained particles. The whole fragment appears to be a complex aggregate composed of rock chips and smaller aggregates (GMT day 258; 01 : 41 : 27). (c) Fragment 10 cm across lying on southwest wall of Surveyor V crater. Surface of fragment exhibits numerous small, angular protuberances and indentations which suggests it is a conglomerate or breccia composed of resolvable pieces and chips. (d) Wall of furrow dug by footpad 2 of Surveyor V spacecraft during lunar landing. Largest dark rounded object to left has rounded protuberances 1 mm to 3 mm across, each of which may be an aggregate of fine particles. The entire object appears to be an aggregate of smaller aggregates (GMT day 258; 08:39:28).

some of the larger craters in the middle distance are too numerous for all of them to have been formed by shock compaction of weakly coherent fine-grained fragmental material. Impact experiments in weakly coherent targets show that the amount of rocky material produced by shock compression is a small fraction of the total debris ejected from the impact craters, and that the rocky pieces so formed are small compared with blocks ejected from craters of comparable size formed in targets of coherent rock (7). Probably the blocky fragments in the strewn fields around the raised-rim craters north and south of the spacecraft are derived from a rocky substratum that underlies the surface debris layer.

Blocks in the strewn field south of the spacecraft are close enough to be observed in some detail in the narrow-angle high-resolution Surveyor V pictures (Fig. 13). They are angular to subrounded in shape and generally do not exceed a quarter-meter to half-meter maximum observable dimension. When observed at low phase angles, they appear slightly brighter than the surrounding fine-grained debris on the lunar surface (Fig. 13) and some of them are distinctly mottled with irregular bright spots 1 to 2 cm across. In this respect, these fragments resemble a mottled angular to subrounded block a half-meter across that was observed near Surveyor I, over a thousand kilometers to the west of the Surveyor V landing site (3). This widespread distribution of mottled rocks suggests they may be an important lithologic component of the maria.

The Surveyor V pictures show two fragments of unique appearance that may once have been melted or partially melted by shock. One fragment lies on the wall of the Surveyor V crater just above the trench plowed by footpad 2. It is about 3 cm long and irregular to knobby in shape. A picture of this object taken in the late lunar morning (Fig. 14) suggests its upper surface is partly specular. Various parts of the fragment are either much brighter or much darker than the surrounding fine-grained debris.

The other fragment is about a centimeter long and was deposited on the floor of the Surveyor V crater during the firing of the vernier engines, the third day after landing. This fragment is exceedingly ragged in outline and appears to be pierced by holes, as indicated by gaps in the shadow it casts (Fig. 15). It is probably a natural object blown out of the crater wall by the vernier rocket exhaust, but there is a possibility that it is simply an artifact created by the interaction of the rocket fuel or oxidizer or the exhaust with the lunar surface material. Both this object and the partly specular fragment may be comparable to shock-formed glasses and impactites shown in Fig. 16. Specular surfaces and irregular shapes are common characteristics of impactites, and we suggest these two unusual lunar fragments may be impactites.

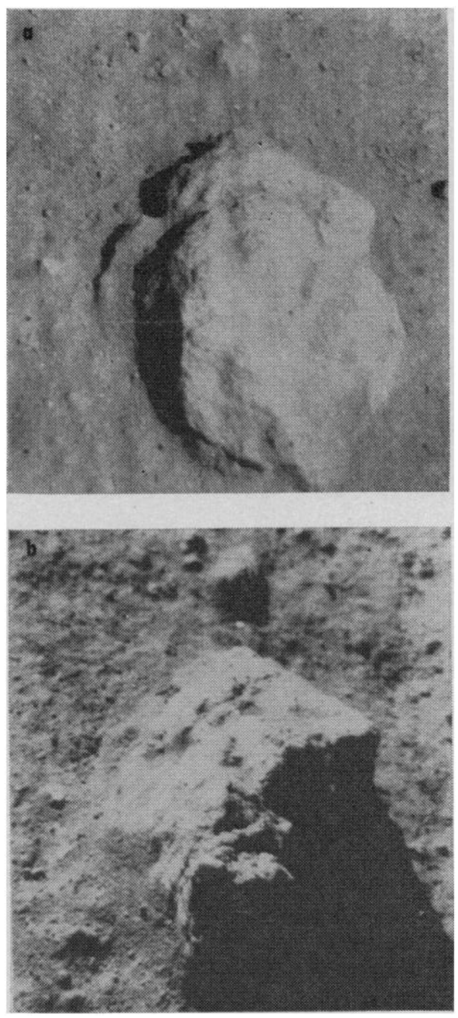

Fig. 11. Two narrow-angle pictures showing angular fragment 12 cm across lying 2 m from the television camera on the floor of the Surveyor V crater. (a) Picture taken in late lunar morning (GMT day 257; 02:47:27). Exposed parts of fragment are slightly brighter than surrounding surface debris. Parts of the fragment covered with fine-grained debris appear as slightly darker patches. (b) Picture taken in late lunar afternoon (GMT 264; 04:22:25). The exposed parts of the fragment are conspicuously brighter than the surrounding fine-grained debris on the lunar surface and also brighter than the small patches of debris lying in depressions on the upper surface of the fragment.

SURVEYOR V

Size-frequency distribution of fragmental debris. The size-frequency distribution of the fragmental debris was studied in four sample areas close to the Surveyor V spacecraft. One sample area, near footpad 2, was entirely in the loose material thrown out in front of the footpad, and a second sample area is on the floor of the Surveyor V crater between footpads 2 and 3. The other two sample areas are on the northeast wall of the crater. A total of 1962 fragments was counted, the sizes ranging from 1 mm to 3.2 cm.

The cumulative size-frequency distribution of the measured fragments, normalized to an area 100 m^2 for each of the sample areas may be compared with the average size-frequency distribution of fragmental debris on undisturbed parts of the lunar surface at the landing sites of Surveyor I and Surveyor III (Fig. 17). The lumpy fragmental material kicked out on the surface by the footpads during landing is clearly much coarser than the particles observed on the undisturbed surface, as was the case at the Surveyor I landing site (3). This ejected material is interpreted as consisting mostly of clods or aggregates of fine-grained material. Most of the clods are irregular to rounded in shape and have an albedo that is similar to, or slightly lower than, the surrounding undisturbed surface material.

The size-frequency distribution of the fragmental material in the area studied on the floor of the crater between footpads 2 and 3 is similar to the size-frequency distribution of particles on undisturbed parts of the crater wall except for fragments larger than a centimeter. Fragments 1 cm to 3 cm across have rolled or have been kicked out onto the floor of the crater by the impact of the spacecraft's footpads.

The size-frequency distribution of the fragmental material on the undisturbed walls of the Surveyor V crater is similar to that observed at the Surveyor I and Surveyor III sites. The size-frequency distribution curves for the debris on the wall of the Surveyor V crater have a steeper slope, however, than do the curves obtained for fragmental debris at the Surveyor I and Surveyor III sites. Thus, there are fewer coarse fragments per unit area around Surveyor V. No blocks larger than 15-cm across were observed in the Surveyor V crater. This paucity of coarse fragments may be the result of two related factors, (i) a greater thickness of the fragmental debris layer at the Surveyor V landing site, compared with the Surveyor I and Surveyor III landing sites, and (ii) a greater distance from Surveyor V to the nearest raised rim craters with associated strewn fields of coarse blocks.

Study of the fragmental material in the Surveyor V crater has shown that many of the fragments, up to a few centimeters grain size, are aggregates of finer particles. Almost certainly. many of the small fragments and grains counted on the wall of the crater in the study of fragment size distribution are aggregates. This probably accounts for the large number of particles in the size range of a few millimeters observed on the wall and for the steepness of the size-distribution curves. A considerable number of aggregate fragments probably were also included in the counts of small particles at the landing site of Surveyor III, but we believe that most of the small particles counted at the Surveyor I landing site are individual rocky chips. Care was taken in the study of the fragmental debris at the Surveyor I landing site to count only bright angular objects. Nearly all the fragments counted at all three Surveyor landing sites that are larger than a few centimeters are believed to consist of fairly dense rocky material.

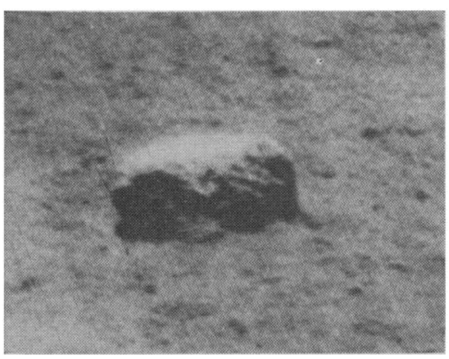

Fig. 12. Angular block 11 cm in diameter on the east rim of the Surveyor V crater. The nearly level upper surface of this block is much brighter at large phase angles than the surrounding fine-grained debris (GMT day 258; 08:44:16).

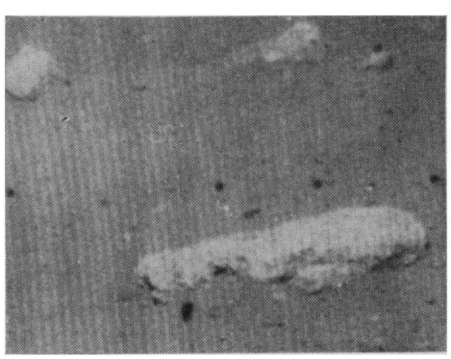

Fig. 13. Fragments in strewn field of blocks south of spacecraft. Mottled subrounded fragments, largest of which is about 20 cm across, lying 5 m to 6 m from Surveyor V cameras. These fragments exhibit bright spots, 1 cm to 2 cm across and are similar to those on one of the large rocks observed at the Surveyor I landing site (GMT day 264; 11:37:01).

Albedo of undisturbed surface and of ejected debris. Photometric reduction of 16 measurements of the undisturbed lunar surface near the Surveyor V spacecraft indicates that the photometric function of this site is similar to that observed at the Surveyors I and III landing sites. The estimated normal albedo (normal luminance factor) of undisturbed parts of the lunar surface near the spacecraft is 7.9 ± 1.0 percent. Telescopic photometric measurements of the normal albedo of an area several kilometers in diameter around the landing site by Pohn and Wildey (*8*) averaged about 9.4 percent. Apparently Surveyor V landed in a dark spot or patch within a relatively bright area. This bright area is part of the ray system of Theophilus, and the dark patch may simply be a gap in the ray.

The debris kicked out on the floor of the Surveyor V crater in front of the footpads has a photometric function similar to that of the undisturbed material, but it is slightly darker. The normal albedo of this material is estimated to be 7.5 percent, a value lower by about one-twentieth than that of the undisturbed surface. Dark rubbly material exposed in the wall of the trench plowed by footpad 2 also has a normal albedo that is lower by one-twentieth than that of the undisturbed surface. Although the contrast in albedo between the ejected debris and the undisturbed surface is less than that observed at the Surveyor I and Surveyor III sites (*3, 4*) the albedo of the dark ejected material is nearly the same at the Surveyor III and Surveyor V sites (*4*).

Parts of the floor and walls of the trench plowed by footpad 2 have been smoothed by the pressure and sliding of the footpad (Fig. 8). As observed in the footpad imprints at the Surveyor III landing site (*4*) these smoothed surfaces are brighter than the undisturbed parts of the lunar surface at certain phase angles. This effect is a result of the difference in photometric function between the rough undisturbed surface and the smoothed surface. The smoothed floor of the trench plowed by footpad 2 of Surveyor V is about 10 percent brighter than the undisturbed lunar surface in the mid-lunar morning, and a small part of this smoothed surface is about 20 percent brighter.

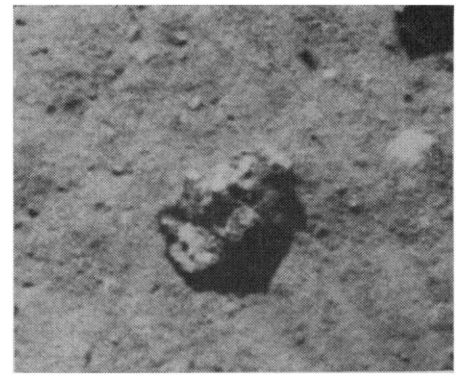

Fig. 14. Small, irregular fragment about 3 cm across close to Surveyor V spacecraft. Various parts of fragment are either much brighter or much darker than surrounding fine-grained debris, which suggests this fragment is partly glassy. It resembles impactites from Meteor Crater, Arizona, and shock-melted ejecta from nuclear craters (GMT day 258; 08:30:15) (see Fig. 16).

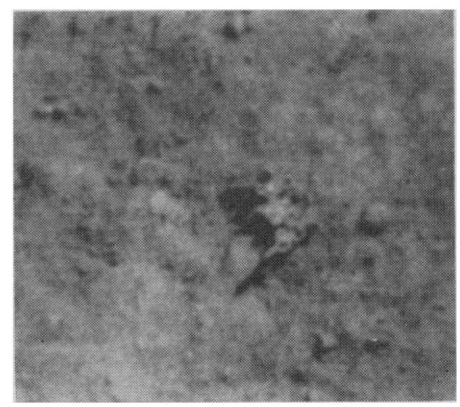

Fig. 15. Strange, ragged object on floor of Suveyor V crater. This object is about 1 centimeter across and apparently has holes through it. It arrived in its present position during or after firing of the spacecraft's three vernier rocket engines. This object may be an impactite or it may be an artifact produced during engine-firing (GMT day 257; 02:49:46).

Discussion. Several lines of evidence support the interpretation that the small crater in which the Surveyor V spacecraft landed was formed by drainage of surficial fragmental debris into a subsurface fissure. The absence of a raised rim and the dimple shape of this crater suggest it was not formed by impact, as experimental impact craters in this size range have raised rims and most have a profile that is concave upward. The elongated shape and compound character of the Surveyor V crater and the fact that it is a member of a small chain of craters suggest it has been localized by a linear subsurface structure. This suggestion is strengthened by the fact that the Surveyor V crater and the crater chain are parallel with the major linear features of this region of the moon and that there are a large number of similarly aligned small craters and crater pairs in the vicinity.

Both the shapes of small craters in the vicinity of Surveyor V and the interaction of the spacecraft footpads with the lunar surface show that the near surface material is composed of relatively fine-grained debris which has very low cohesion. The mechanical properties of this debris are similar to the properties inferred for the lunar surface material at the Surveyor I and Surveyor III landing sites (*9*). The cohesion of the debris is sufficiently low that, if a cavity or fissure were opened beneath the debris, it would tend to flow or drain into the cavity, particularly if agitated by impact events or shaken by moonquakes.

As indicated by the size of the smallest craters with coarse blocky rims in the area around Surveyor V, the thickness of the fragmental debris which might flow is several meters. Thus, it would be possible for a crater the size of the Surveyor V crater to be formed by the drainage mechanism. It is probably significant that the characteristic dimension of the aligned crater pairs and elongate craters in the vicinity of Surveyor V is about 10 m. If all of these craters have been formed by drainage, it suggests the thickness of the debris that flows is about 3 m, a result consistent with the evidence derived from craters with blocky rims. The small concave floor of the Surveyor V crater probably was formed after most of the drainage had ceased. Small craters on the moon tend to fill up fairly rapidly with ballistically deposited debris produced by meteoritic bombardment.

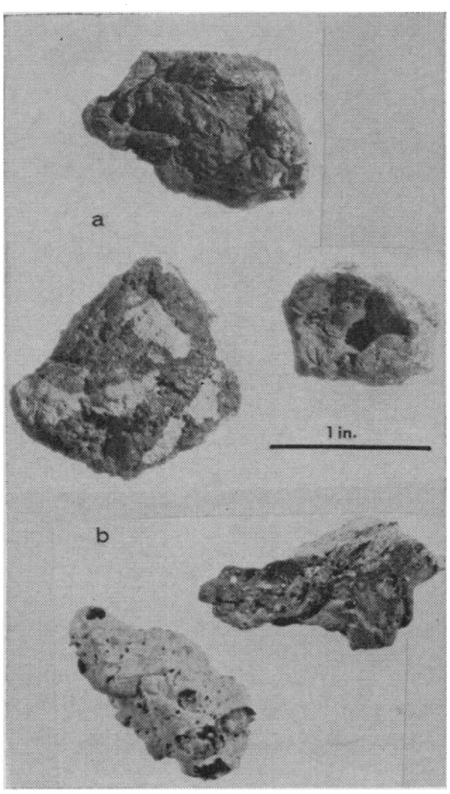

Fig. 16. Terrestrial impactites and shock-melted ejecta from nuclear crater. (a) Impactites from Meteor Crater, Arizona, formed from shock-melted Kaibab dolomite. (b) Shock-melted ejecta from the small nuclear crater, Teapot ESS, at the Nevada Test Site of the United States Atomic Energy Commission. These specimens are largely glass derived from melted alluvium.

The walls of the Surveyor V crater provide a natural exposure of material that originally lay at depths of as much as a meter beneath the surface of the debris layer. Much of this material appears to consist of clods or aggregates of fine particles. Many clods appear to be complex objects composed of smaller aggregate units and, in some cases, angular chips of rock. Observable differences in the photometric properties of various clods suggest that they vary in porosity or have been compacted to various degrees. Both the aggregates and complex aggregates probably have been formed by shock compression of finer fragmental material in the course of repetitive impact cratering.

A clearer picture of the subsurface structure of the lunar surface debris layer or regolith has thus emerged from our study of the Surveyor V television pictures. At depths below about 10 cm, the regolith is probably composed mainly of shock-compressed aggregates ranging from a few millimeters up to 3 cm in diameter, set in a matrix of less coherent finer particles.

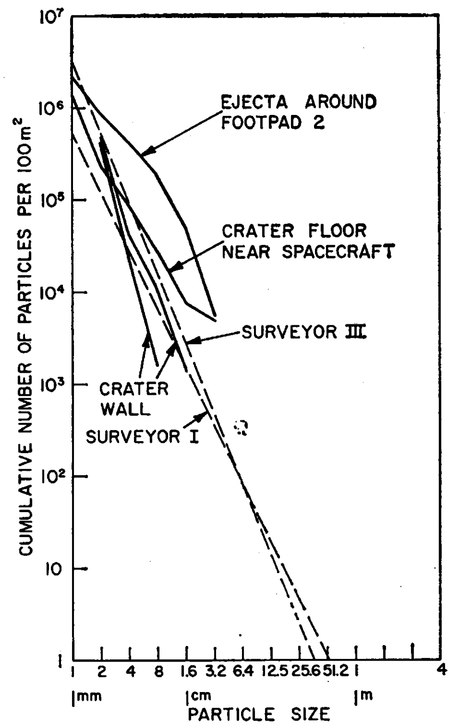

Fig. 17. Size-frequency distribution of fragments on the lunar surface around Surveyor V. Average size distribution of fragments at the Surveyor I and Surveyor III landing sites (*4*) is shown with dashed lines for comparison. Ejecta around footpad 2 consists mainly of aggregates. Some clods or aggregates kicked up by the footpads during landing of the spacecraft also rolled out onto the floor of the crater near the spacecraft.

Rocky chips and fragments larger than a millimeter are dispersed as a subordinate constituent of the debris. Most fragments larger than 3 cm, however, are rocky material. Both the fragmentation and the aggregation of the material in the debris are probably the direct result of prolonged meteoritic bombardment of the lunar surface.

It is important to recognize the complicated history of the lunar surface debris in evaluating the chemical analysis provided by the alpha-scattering instrument on Surveyor V (*10*). The instrument was lowered from the spacecraft and came to rest on loose debris that had been kicked out on the wall of the Surveyor V crater during landing of the spacecraft. This debris is composed mostly of aggregates of fine particles; the particles of which the aggregates are composed probably have been derived from a wide region on the lunar surface and transported ballistically to the Surveyor V crater. The analysis does not, therefore, represent a single rock but a mixture of rock particles which are possibly of diverse origin. The bulk of the particles probably have not been transported more than a few kilometers, however, so that the analysis represents, for the most part, a mixture of rocks derived from a small area on Mare Tranquillitatis.

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Ribonucleic Acid: Control of Steroid Synthesis in Endocrine Tissue

Abstract. *Ribonucleic acid extracted from either adrenal or testis altered the enzyme activity of adrenals and ovaries maintained in organ culture. The pattern of steroid hormone synthesis of the cultured endocrine tissue reflected the origin of the RNA.*

Preparations of ribonucleic acid from adrenals or gonads altered the pattern of steroid hormones synthesized in endocrine tissues maintained in organ culture. Ribonucleic acid was extracted from adrenals or gonads with phenol and dodecyl sulfate by the method of Hiatt (*1*). After precipitation from 0.1*M* NaCl with ethanol, the RNA was treated twice with deoxyribonuclease at room temperature for 5 minutes and then was precipitated with ethanol. The final precipitate was washed once with 95 percent ethanol and twice with a mixture of ethanol (95 percent) and ether (2:1). The RNA was dissolved in water, and its absorption was measured spectrophotometrically over the range 220 to 290 mμ. For each RNA preparation used, the ratios of the absorption at 260/280 and 260/230 mμ were very nearly two.

Adrenal glands can be maintained in organ culture in a histologically and biochemically differentiated state for short periods of time (*2*). Explants of ovaries or adrenals weighing no more than 5 mg were cultured sterilely on stainless steel rafts in a chemically defined medium (Parkers 1066) containing RNA extracted from either adrenal or testis. The concentration of the RNA in the medium ranged from 25 to 250 μg/ml. The cultures were maintained at 26°C for 24 hours with 95 percent oxygen 5 percent carbon dioxide as gas phase. The explants were then removed from the chamber and assayed for enzyme activity by one of two methods. In one method the explants were placed in fresh chambers containing nutrient medium plus pregnenolone-7α-^{3}H (0.25 μc per milligram of tissue) and cultured for an additional 24 hours. The radioactive products in the tissue and medium were isolated and characterized by reverse isotope dilution. In all such experiments only 10 to 20 percent of the radioactive substrate was metabolized. In the second method, the explants after exposure to RNA were homogenized in phosphate buffer and incubated in a Dubnoff shaker for 1 hour at 37°C with an excess of substrate (pregnenolone-7α-^{3}H), NAD, NADP (nicotinamide adenine dinucleotide and the phosphate), and glucose-6-phosphate. Radioactive products were isolated as in the first method of assay. After separation of the steroid products on thin-layer chromatography, radiochemical homogeneity of radioactive products and carrier steroids was achieved by crystallization of the carrier steroids to constant specific activity followed by the formation of a derivative of the steriod and crystallization of the derivative.

Table 1. Radioactive steroid products, expressed as counts per minute per milligram of adrenal, isolated from cultures of rat adrenals previously exposed to RNA from either rat adrenal or rat testis. The substrate was pregnenolone-7α-^{3}H (0.5 μc per milligram of adrenal).

Product	Yield (count min^{-1} mg^{-1})	
	Adrenal + adrenal RNA	Adrenal + testis RNA
Progesterone	2950	4000
Testosterone	72	114
Deoxycorticosterone	1920	3820
Corticosterone	2080	1250

The influence of RNA from rat testis on steroid synthesis in rat adrenals in culture was significant (Table 1). Adrenals previously exposed in organ culture to RNA from rat testis produced more radioactive progesterone, testosterone, and deoxycorticosterone, but less corticosterone when subsequently cultured in the presence of pregnenolone-7α-^{3}H. These results might be explained by assuming that RNA from rat testis led to a greatly increased activity of 3β-hydroxysteroid dehydrogenase in the adrenal gland in culture. One must also assume that the RNA led to some inhibition of the 11β-hydroxylase in the adrenal.

Ovaries previously exposed to RNA from the adrenal formed more radioactive deoxycorticosterone and corticosterone from pregnenolone-7α-^{3}H than did control ovaries or ovaries previously exposed to RNA from the testis (Table 2). Those ovaries from a pregnant rat synthesized a large amount of testosterone and perhaps for this reason, RNA from rat testis produced no effect on their synthesis of testosterone. However, ovaries from nonpregnant rats were clearly affected by testis RNA, and when subsequently cultured