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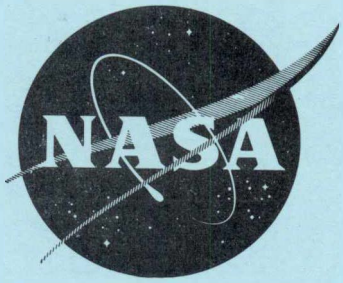

DESCRIPTION OF CORE SAMPLES RETURNED BY APOLLO 12

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ABSTRACT

Three core samples were collected by the Apollo 12 astronauts. Two are single cores, one of which (sample 12026) was collected close to the lunar module during the first extravehicular activity period and is 19.3 centimeters long. The second core (sample 12027) was collected at Sharp Crater during the second extravehicular activity period and is 17.4 centimeters long. The third sample is a double core (samples 12025 and 12028), which was collected near Halo Crater during the second extravehicular activity period. Unlike the other cores, the double-drive-tube core sample has complex layering with at least 10 clearly defined stratigraphic units. This core sample is approximately 41 centimeters long.

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DESCRIPTION OF CORE SAMPLES RETURNED BY APOLLO 12

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INTRODUCTION

Cores collected at both the Apollo 11 and 12 sites by using a drive-tube sampler provide, at present, the most representative samples of lunar soil available. To assist Principal Investigators in interpretation of analyses of subsamples removed from cores of the Apollo 12 mission, the following description of these cores and an index to photographic documentation have been prepared. Photographs of the core tube taken by the astronauts on the lunar surface and photographs taken during the preliminary examination are listed in table I; numbers of individual photographs in which certain features of the cores are shown to best advantage appear in the text. Descriptions and diagrams were prepared at the time cores 12026, and 12025 and 12028 were dissected for subsampling. Color values follow the Munsell system (ref. 1).

CORING METHOD

The core sampler used by the Apollo 12 astronauts consists of an outer aluminum barrel with a detachable bit and handle. The outer barrel contains a core liner, which consists of a thin-walled, anodized aluminum tube split lengthwise and held together by a heat-shrunk tetrafluoroethylene sheath (NASA photograph S-69-23808). As the sampler is driven into the lunar soil (NASA photograph AS12-49-7286), a tetrafluoroethylene follower slides up inside the core liner along with the soil sample. The follower remains in place at the top of the core sample and provides support for the loose soil during transport. After sampling, the core bit is removed and replaced by a cap to retain the sample during transport (NASA photograph S-69-60570). The maximum dimensions of the core sample thus attainable are 31.75 centimeters in length and 1.95 centimeters in diameter. Except for a modification of the coring bit, the drive-tube samplers used on the Apollo 11 and 12 missions were essentially the same (ref. 2).

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DESCRIPTION OF SAMPLES

Three core samples of the lunar regolith were collected by the Apollo 12 astronauts in Oceanus Procellarum. Core sample 12026 was collected during the first extravehicular activity (EVA) period close to the lunar module. The sample is 19.3 centimeters long and is uniformly medium gray in color. No stratigraphic breaks are apparent, probably because the core failed to penetrate the Surveyor Crater ejecta blanket completely. Core sample 12027 was collected at the bottom of a 20-centimeter-deep trench at Sharp Crater. Although the container has not been opened yet, X-ray photography indicates it to contain 17.4 centimeters of sample. The double-drive-tube core (samples 12025 and 12028) was collected near Halo Crater during the second EVA period. The sample is approximately 41 centimeters in length; and at least 10 stratigraphic units, ranging from 1.6 to 9.9 centimeters thick, have been recognized. The stratigraphic units are distinguishable by changes in color, texture, composition, and consistence; and by concentrations of larger particles. Unit VI, which is much coarser than other units and consists largely of olivine grains, is the most distinctive unit.

Descriptions of these three core samples follow. Photographs and reference materials relating to the cores are cited after the descriptions, and studies performed on each sample are noted in coded form with the references. A key to the coding is presented in table II.

Sample 12026

Sample 12026 was collected in drive tube 1 (S/N 2013) near the lunar module (LM) at the end of the first EVA period on the northeast edge of Surveyor Crater (fig. 1). The core was 19.3 centimeters long and contained 106.6 grams of soil (fig. 2). Three small samples were taken from near the top, middle, and bottom of the core for gas analyses; then the core was dissected and split longitudinally. The split was divided into three samples — the top, middle, and lower thirds. Each sample was sieved, then recombined to form part of the bioprime sample (the sample used by biologists in the quarantine area). The median grain size changes from 62 micrometers in the surface sample to 74 micrometers for the middle sample and 110 micrometers for the deepest sample (ref. 3, fig. 3).

The core is uniformly medium dark gray (N4-3) to dark gray (10YR4/1) in color; layering is not apparent in the core. However, the number of rock fragments increases abruptly below a transverse fracture at a depth of 5.9 centimeters. The core was taken close to the rim of Surveyor Crater and appears not to have penetrated the Surveyor Crater ejecta blanket.

Photograph. - See NASA S-69-62760 (postdissection).

References. - See references 4(H) and 5(D).

Sample 12027

Sample 12027 was taken during the second EVA period in the bottom of a 20-centimeter-deep trench at the edge of Sharp Crater (NASA photograph AS12-48-7069). The tube (2, S/N 2011) was driven to an approximate depth of 37 centimeters below the lunar surface and contained 17.4 centimeters of sample (ref. 6). This core has not been opened, but held in reserve by the curator. A stereoscopic pair of X-radiographs is the basis for figure 4. In texture, sample 12027 appears similar to sample 12026 (obtained near the LM) and to the thicker layers in samples 12025 and 12028 (double core taken at Halo Crater).

Photographs. - See NASA S-70-18021 and S-70-18022 (X-radiographs).

Reference. - See reference 6.

The Double-Drive-Tube Core (Samples 12025 and 12028)

The third and final core sample was collected during the second EVA period on the rim of a 10-meter-diameter crater south of Halo Crater. The core was collected by joining two drive tubes and driving them into the surface. The upper tube (1, S/N 2010) contained 9.5 centimeters of core, which was designated sample number 12025 (NASA photograph S-69-23810). The lower tube (3, S/N 2012) contained 31.6 centimeters of core, which was designated sample number 12028 (NASA photographs S-69-64424 and S-69-23734). Unlike sample 12026 and the Apollo 11 cores (ref. 7), the double-drive-tube core sample has easily recognizable stratigraphy (fig. 5). During Lunar Sample Preliminary Examination Team (LSPET) dissection and sampling, 10 morphologic units were identified and numbered sequentially from bottom to top, as I to X. Stratigraphic unit III then was subdivided into four smaller units on the basis of textural breaks. The four subdivisions are labeled A to D, beginning at the bottom. Later study (refs. 8, 9, and 10) indicates that a total of 16 depositional events may be recorded in the sequence sampled by the double-drive tube.

The double-drive-tube core sample is described in the following section on a unit by unit basis. Unit numbers are the same as those used in the original LSPET report (ref. 3). Depths and thicknesses given for units have not been corrected for compaction resulting from the sampling procedure. Information regarding the effects of compaction is given in references 6 and 11. Grain-size data are obtained from reference 8.

Unit I. - Stratigraphic unit I is characterized by the following:

1. Depth - 39.3 to 41.1+ centimeters
2. Thickness - 1.8+ centimeters
3. Color - medium to light gray (N5)
4. Nature of lower contact - not intersected
5. Grain size (median) - 3.10ϕ (116.6 micrometers)

Description: This unit is lighter in color than all other units except unit IX. The soil is homogeneous in color and texture and is somewhat more coarsely textured than the overlying unit.

Photographs: See NASA S-69-23740 (predissection) and S-69-23729 (postdissection).

References: See references 4(H), 5(D), 8(A, B), 9(A, B, C), 12(E), 13(I), 14(G), 15(E), 16(C), 17(B, C), 18(A, B, C), 19(G), 20(I), and 21(E).

Unit II. - Stratigraphic unit II is characterized by the following:

1. Depth - 35.7 to 39.3 centimeters

2. Thickness - 3.6 centimeters

3. Color - medium gray (N3 to N4)

4. Nature of lower contact - sharply defined

5. Grain size (median) - 3.46ϕ (90.9 micrometers)

Description: The soil of unit II is inhomogeneous in color and texture and contains more particles 1 millimeter or larger in diameter than most units. Generally, the particles are distinctly angular, and several white particles were quite friable and disintegrated when picked up. The soil is slightly coarser than that of the overlying unit.

Photograph: See NASA S-69-23730 (postdissection).

References: See references 8(A, B), 9(A, B, C), 10(A), 13(I), 15(E), 17(B, C), 18(A, B, C), 21(E), 22(E), 23(D), 24(C), 25(E), 26(C), 27(C), 28(G), and 29(C).

Unit III-A. - Stratigraphic unit III-A is characterized by the following:

1. Depth - 30.7 to 35.7 centimeters

2. Thickness - 5.0 centimeters

3. Color - medium gray to dark olive (N3 to 5Y3/1)

4. Nature of lower contact - sharply defined with a concentration of larger particles near the contact

5. Grain size (median) - 3.95ϕ (64.7 micrometers)

Description: The soil of unit III-A is similar in color to stratigraphic units above and below but is more uniform in color and has a coarser texture than the unit above (III-B). The soil is weakly cohesive and forms aggregates up to 3 millimeters in diameter. It contains few particles 1 millimeter or larger in diameter, except near the lower contact where a marked concentration of larger particles is found. Some of these

coarser particles are light in color and disintegrate when picked up. The particles appear to be feldspathic breccias. Particles of a similar nature also are present in unit IX.

Photograph: See NASA S-69-23728 (postdissection).

References: See references 5(D), 13(I), 15(E), 17(B, C), 18(A, B, C), 19(G), 20(I), 21(E), 22(E), 24(C), 26(C), 30(C), and 31(F).

Unit III-B. - Stratigraphic unit III-B is characterized by the following:

1. Depth - 28.0 to 30.7 centimeters

2. Thickness - 2.7 centimeters

3. Color - medium gray to dark olive (N3 to 5Y3/1)

4. Nature of lower contact - poorly defined, marked mainly by change in texture

5. Grain size - not determined

Description: The lower portion of unit III-B is homogeneous in color and texture and weakly cohesive. The upper centimeter of the unit, however, contains lighter colored (N5) masses with the same cohesive properties as the surrounding darker colored soil. The noncoherent masses are 1 to 2 millimeters in diameter and are associated with a slight coarsening of the texture of the soil. The unit contains nine particles 1 millimeter or larger in diameter. Unit III-B, like some other stratigraphic units in the sequence, is probably a composite and consists of soil deposited by at least two events. The second event resulted in the deposit of a thin layer of light-colored soil, which was disrupted by subsequent micrometeorite reworking (ref. 8) as inferred previously for similar features in the Apollo 11 cores (ref. 32).

Photograph: See NASA S-69-23758 (postdissection).

References: See references 9(A, B, C), 13(I), 15(E), 16(C), 21(E), 22(E), 27(C), 33(I), and 34(G).

Unit III-C. - Stratigraphic unit III-C is characterized by the following:

1. Depth - 25.7 to 28.0 centimeters

2. Thickness - 2.3 centimeters

3. Color - medium gray to dark olive (N3 to 5Y3/1)

4. Nature of lower contact - poorly defined textural change

5. Grain size - not determined

Description: The lower portion of unit III-C is homogeneous in color and texture. The upper 0.5 centimeter of the unit contains lighter colored (N5), incohesive masses

of soil up to 2 millimeters in diameter, suggesting that, like unit III-B, unit III-C probably was formed by more than one depositional event. This unit contains a higher density of particles 1 millimeter or larger in diameter than units III-A and III-B. The particles are distributed uniformly throughout the unit.

Photograph: See NASA S-69-23731 (postdissection).

References: See references 8(A, B), 12(E), 13(I), 15(E), 17(B, C), 18(A, B, C), 20(I), 21(E), 22(E), 27(C), and 35(H).

Unit III-D. - Stratigraphic unit III-D is characterized by the following:

1. Depth - 22.0 to 25.7 centimeters

2. Thickness - 3.7 centimeters

3. Color - medium gray to dark olive (N3 to 5Y3/1)

4. Nature of lower contact - poorly defined textural change

5. Grain size (median) - 3.00ϕ (125.0 micrometers)

Description: The soil forming unit III-D is weakly cohesive and forms aggregates up to 3 millimeters in diameter, which readily break into subrounded masses 1 millimeter in diameter when probed. The unit is characterized by faint color mottling throughout, suggesting incomplete mixing during deposition. In texture, the unit is homogeneous except for a concentration of 1 millimeter and larger particles 1.5 to 3.0 centimeters below the upper contact.

Photograph: See NASA S-69-23757 (postdissection).

References: See references 8(A, B), 9(A, B, C), 13(I), 15(E), 19(G), 20(I), 21(E), and 22(E).

Unit IV. - Stratigraphic unit IV is characterized by the following:

1. Depth - 18.3 to 22.0 centimeters

2. Thickness - 3.7 centimeters

3. Color - light medium gray (N4)

4. Nature of lower contact - gradational over approximately 3 millimeters, distinct color change

5. Grain size (median) - 4.03ϕ (61.2 micrometers)

Description: Unit IV is lighter in color than adjacent stratigraphic units and consists of loose, weakly cohesive soil which formed angular to subangular aggregates up to 4 millimeters in diameter during sampling. Unit IV contains subrounded masses of lighter colored soil ($\approx$N5) approximately 1 centimeter below the upper contact. The

masses are up to 1 millimeter in diameter and have the same cohesive properties as the soil. Texturally, it is similar to unit III-D but is noticeably less cohesive. Particles 1 millimeter and larger are concentrated between 1.5 and 3.0 centimeters below the upper contact.

Photograph: See NASA S-69-23732 (postdissection).

References: See references 5(D), 8(A, B), 12(E), 13(I), 15(E), 17(B, C), 18(A, B, C), 20(I), 21(E), 22(E), 23(D), 24(C), 26(C), 27(C), 29(C), 30(C), 31(F), and 36(F).

Unit V. - Stratigraphic unit V is characterized by the following:

1. Depth - 14.8 to 18.3 centimeters

2. Thickness - 3.5 centimeters

3. Color - medium gray to dark olive (N3 or N4 to 5Y3/1)

4. Nature of lower contact - abrupt but slightly irregular

5. Grain size (median) - 3.36ϕ (97.4 micrometers)

Description: Texturally, unit V is relatively homogeneous, although a slight increase in grain size is apparent toward the upper contact of the unit. There is also a general lightening of the soil color upward. (See NASA photograph S-69-23733.) A few light-colored patches are present near the base of the unit and toward the top of the unit.

The lower-contact demarcation of unit V is defined well by a color change. Consequently, it is possible to study the irregularities of the contact in some detail. In cross section, the contact is not smooth but consists of a series of wavelike projections of lighter material from unit IV which extend 1 to 2 millimeters above the general level of the contact into unit V. Several patches of lighter colored material from unit IV are isolated in the darker soil of unit V. Apart from a 1-millimeter zone at the edges, the contact appears relatively undisturbed by the coring. The waves and projections appearing in cross section at the contact are similar to flame structures found in turbidite sequences, which suggests that they may be the result of drag at the depositional interface as unit V was deposited.

Photograph: See NASA S-69-23733 (postdissection).

References: See references 5(D), 8(A, B), 12(E), 15(E), 16(C), 18(A, B, C), 19(G), 20(I), 21(E), 22(E), and 27(C).

Unit VI. - Stratigraphic unit VI is characterized by the following:

1. Depth - 12.6 to 14.8 centimeters

2. Thickness - 2.2 centimeters

3. Color - olive (10Y3/1)

4. Nature of lower contact - sharply defined with an abrupt textural change

5. Grain size (median) - 0.75ϕ (595 micrometers)

Description: Unit VI is unique in composition and grain size. It consists of angular rock and mineral fragments, many of which approach 1 centimeter in longest dimension. Many of the grains are roughly oblate or flake shaped and lie with their a/b planes parallel to the bedding planes (figs. 5 and 6). The particles are mostly olivine with smaller proportions of pyroxene, plagioclase, and basaltic rock fragments (ref. 8). Dark-brown glass is present in small amounts. The well-defined upper contact and the lack of mixing across this boundary suggest rapid burial, which is consistent with exposure ages (ref. 15).

Photographs: See NASA S-69-23409 (predissection) and S-69-23755 (postdissection).

References: See references 5(D), 8(A, B), 9(A, B, C), 10(A), 12(E), 13(I), 15(E), 18(A, B, C), 19(G), 20(I), 21(E), and 24(C).

Units VII and VIII. - Stratigraphic units VII and VIII are characterized by the following:

1. Depth - 3.1 to 12.6 centimeters

2. Thickness - 9.2 centimeters (+0.3-centimeter gap between tubes) (9.5 centimeters, total)

3. Color - medium gray to dark olive (N3 to 5Y3/1)

4. Nature of lower contact - well defined, but mixing occurs over a zone 1 millimeter thick

5. Grain size (median) - unit VII, 3.32ϕ (100.2 micrometers); unit VIII, 3.75ϕ (74.4 micrometers)

Description: Units VII and VIII are parts of what may have been a single unit, but which lay across the junction of the two drive tubes. The combined unit (VII and VIII) is the thickest unit encountered by the core tubes. In color and texture, it appears homogeneous. The soil is weakly cohesive and formed loose aggregates 1 to 2 millimeters in diameter during LSPET sampling. In general, the soil contains few particles 1 millimeter or larger in size. However, this unit contained one rock fragment 1.2 centimeters in diameter, the largest single particle encountered in the core sample. (See NASA photograph S-69-23806.)

Photographs: For unit VII, see NASA S-69-23754 (postdissection); for unit VIII, S-70-21309 (postdissection).

References: See references 5(D), 9(A, B, C), 13(I), 15(E), 16(C), 17(B, C), 18(A, B, C), 19(G), 20(I), 21(E), 22(E), 23(D), 25(E), 27(C), 28(G), 30(C), 31(F), 33(I), and 34(G).

Unit IX. - Stratigraphic unit IX is characterized by the following:

1. Depth - 1.6 to 3.1 centimeters

2. Thickness - 1.5 centimeters

3. Color - medium gray (N5)

4. Nature of lower contact - gradational over 1 millimeter, but well defined

5. Grain size (median) - 3.40ϕ (94.8 micrometers)

Description: Unit IX is markedly lighter in color than stratigraphic units above and below. It contains five angular fragments that are larger than most particles encountered except those in unit VI. Some of these particles are light in color and appear to be feldspathic breccias. The unit is homogeneous in color, but the texture is slightly coarser in the uppermost centimeter.

Photograph: See NASA S-70-21309 (postdissection).

References: See references 5(D), 8(A, B), 9(A, B, C), 15(E), 16(C), 19(G), 20(I), 21(E), 22(E), 24(C), 26(C), 29(C), and 31(F).

Unit X. - Stratigraphic unit X is characterized by the following:

1. Depth - 0 to 1.6 centimeters

2. Thickness - 1.6 centimeters

3. Color - dark gray to dark olive (N3 to 5Y3/1)

4. Nature of lower contact - sharply defined

5. Grain size (median) - 3.43ϕ (92.8 micrometers)

Description: In general, unit X is homogeneous in color and texture but appears slightly coarser grained in the lower 4 millimeters. The soil is loose and weakly cohesive.

Photograph: See NASA S-70-21309 (postdissection).

References: See references 8(A, B), 9(A, B, C), 10(A), 13(I), 15(E), 16(C), 17(B, C), 18(A, B, C), 21(E), 30(C), 31(F), 33(I), and 36(F).

CONCLUSIONS

Core samples, collected during the Apollo 12 mission to the Oceanus Procellarum, penetrated more deeply into the lunar surface and are more complexly layered than those obtained during the Apollo 11 mission. Especially in the double core collected at

Halo Crater, unmixed layers of distinctive color, texture, consistence, and lithology appear to represent discrete depositional episodes; other layers in all three cores show mixing of unlike materials.

Dissection and subsampling of the cores included removal of material for biological study, organic gas analysis, and distribution of samples to Principal Investigators for detailed study of chemical and physical properties of the regolith. Although still in progress, these studies show complex variation of many properties with depth and in close relationship to stratigraphic position and depositional history within the regolith.

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TABLE I. - APOLLO 12 CORE-TUBE PHOTOGRAPHY

Sample	Lunar-surface photographs	LSPET photographs
12026	NASA AS12-47-7007 to AS12-47-7008	NASA S-69-60356 to S-69-60362 NASA S-69-60477 to S-69-60481 NASA S-69-60488 to S-69-60493 NASA S-69-61191 to S-69-61195 NASA S-69-62744 to S-69-62762
12027	NASA AS12-48-7068 to AS12-48-7070 NASA AS12-49-7279 to AS12-49-7280	NASA S-70-18021 to S-70-18022
12025	NASA AS12-48-7077 NASA AS12-49-7285 to AS12-49-7288	NASA S-69-23722 to S-69-23727 NASA S-69-23803 to S-69-238-8 NASA S-70-20400 NASA S-70-21302 to S-70-21309
12028	NASA AS12-48-7077 NASA AS12-49-7285 to AS12-49-7288	NASA S-69-23396 to S-69-23412 NASA S-69-23728 to S-69-23758 NASA S-69-60570 to S-69-60572 NASA S-69-62763 to S-69-62765 NASA S-69-64424

TABLE II. - EXPLANATION OF REFERENCE LETTER CODE

Type of study	Code
Size analysis	A
Mineralogy	B
Chemistry	C
Rare gases	D
Particle tracks	E
Physical properties	F
Organics	G
Biological	H
Thermoluminescence	I

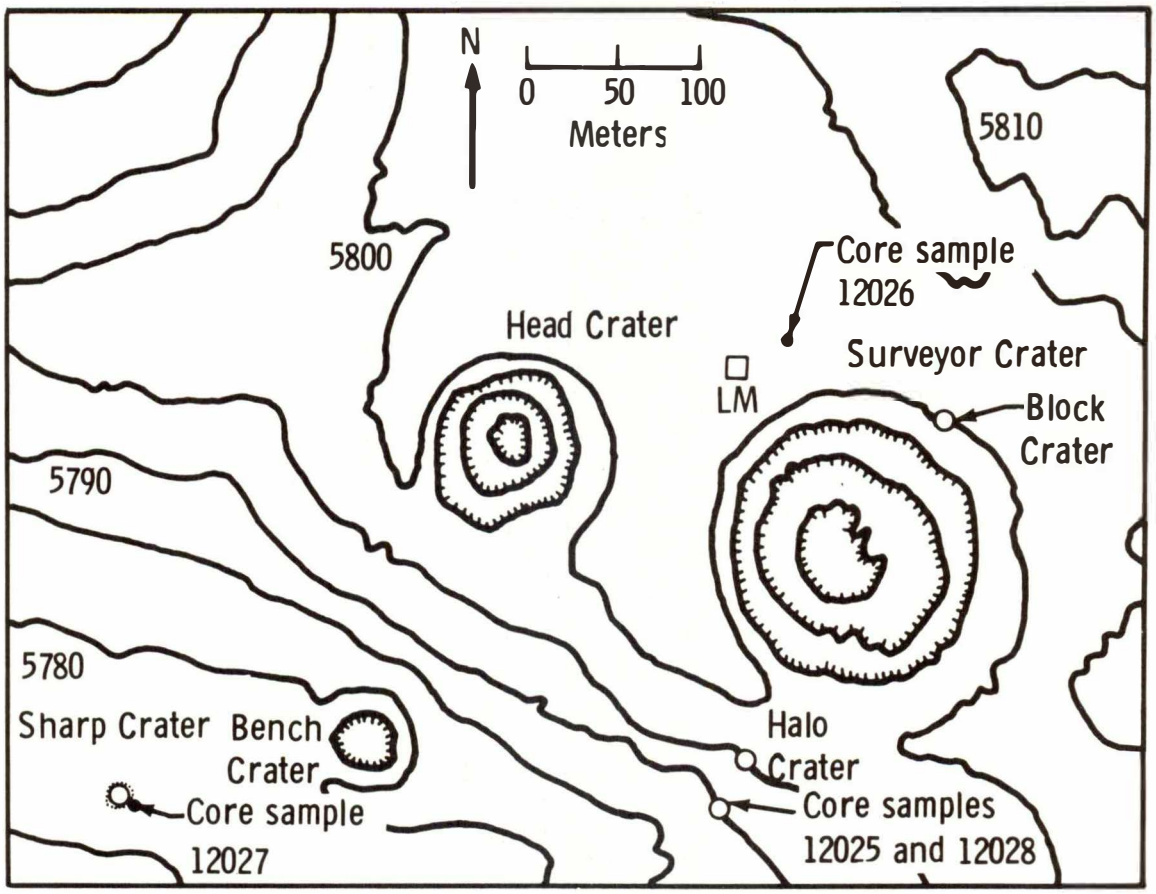
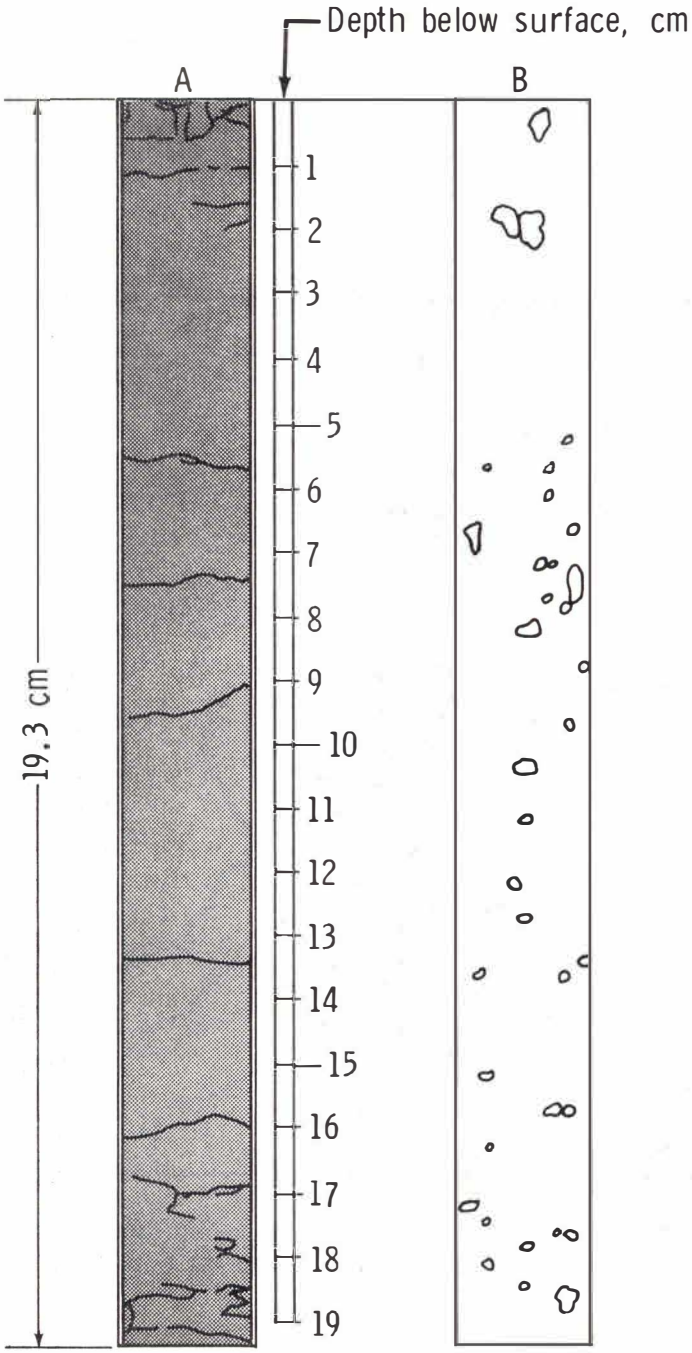


Figure 1. - Apollo 12 landing site, showing the location of the core samples (contour interval 5 meters).



A Core sample before dissection, showing fractures observed after removal of core liner

B Location and orientation of soil particles greater than 1 mm diameter in the half of the core sample dissected

Figure 2.- Core sample 12026, showing the location and orientation of all soil particles larger than 1 millimeter.

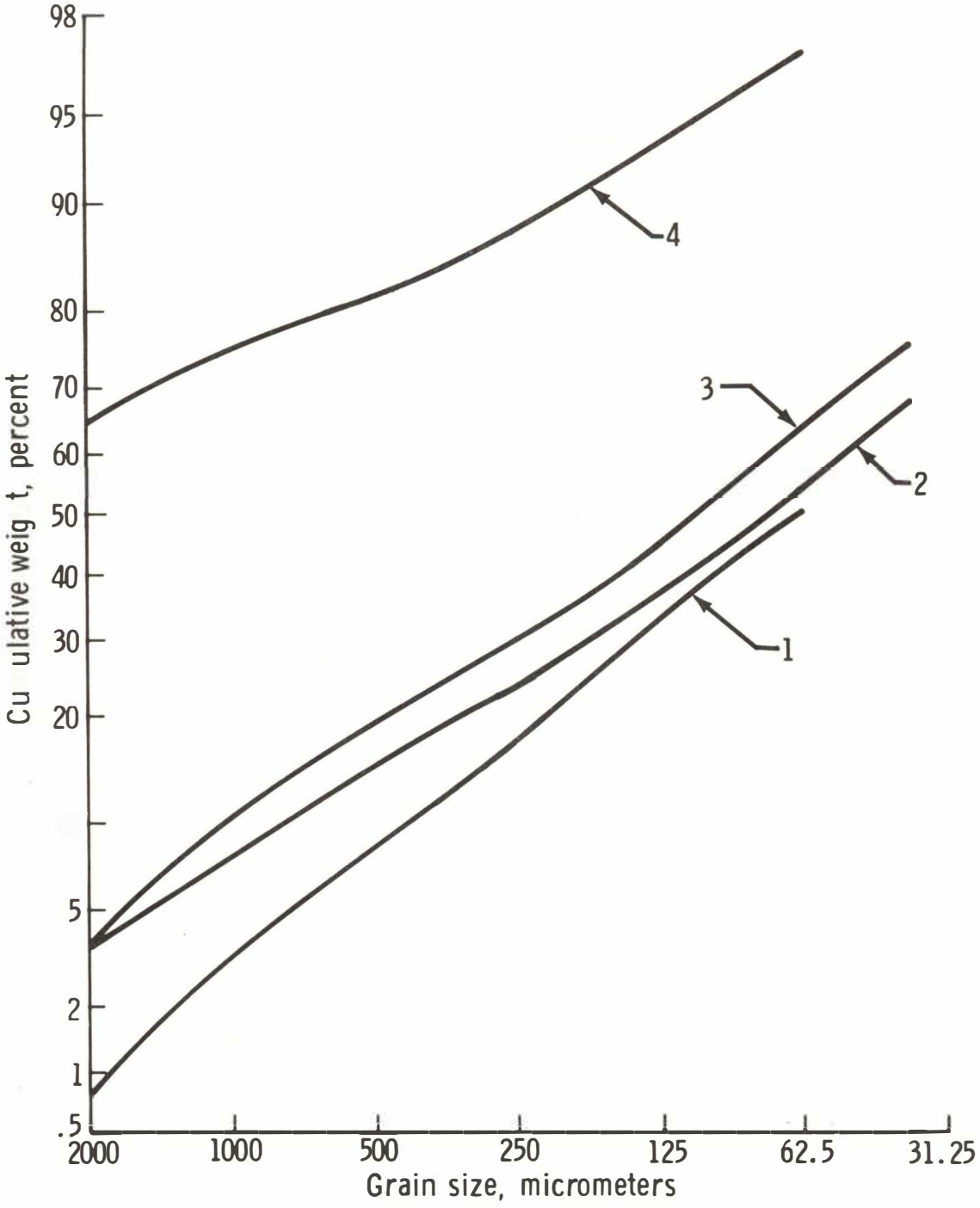


Figure 3. - Grain-size distribution of soil samples from (1) top, (2) middle, and (3) bottom of core sample 12026 and (4) from the coarse layer of the double-drive tube (core sample 12028, daughter sample 16).

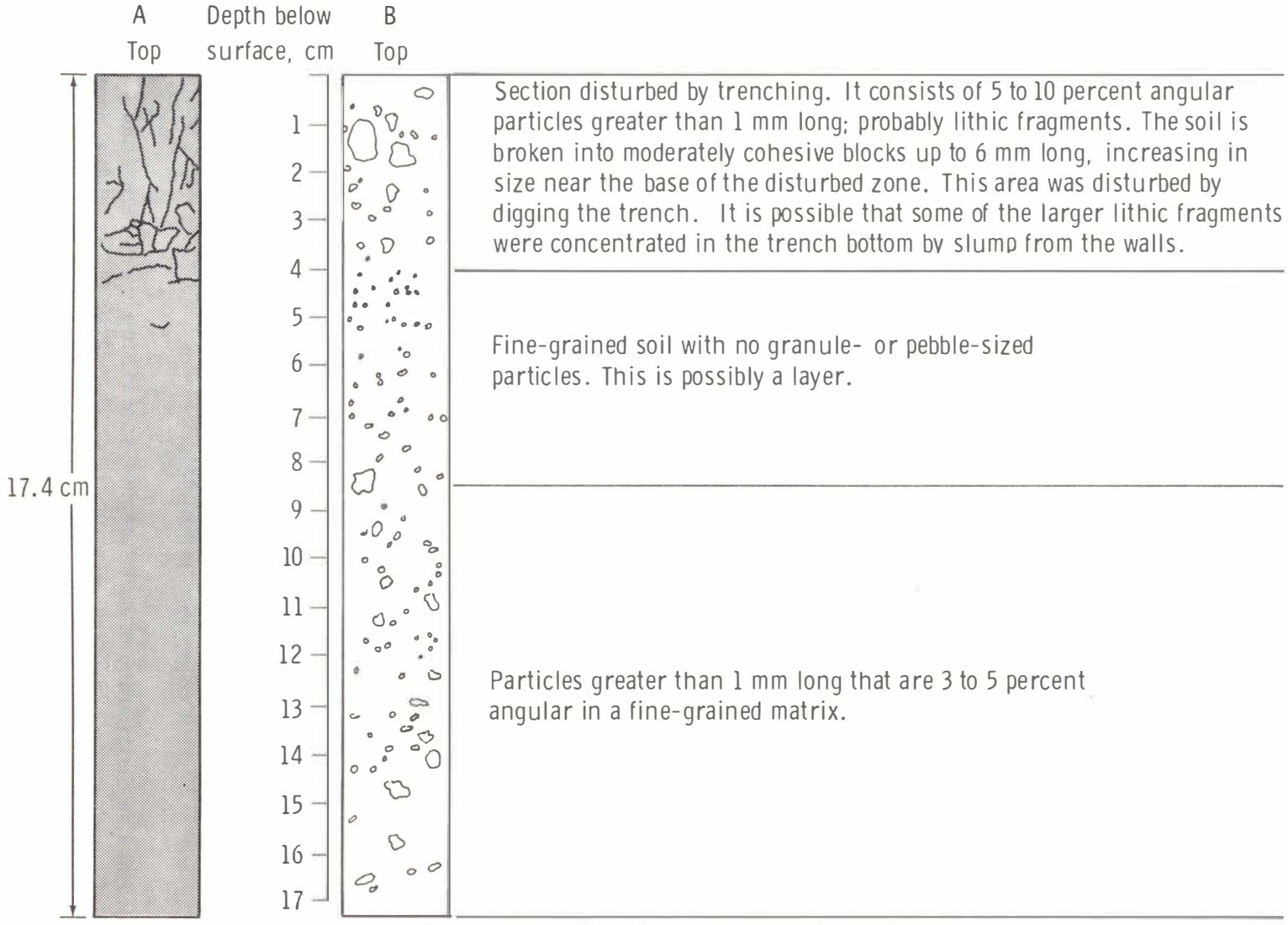
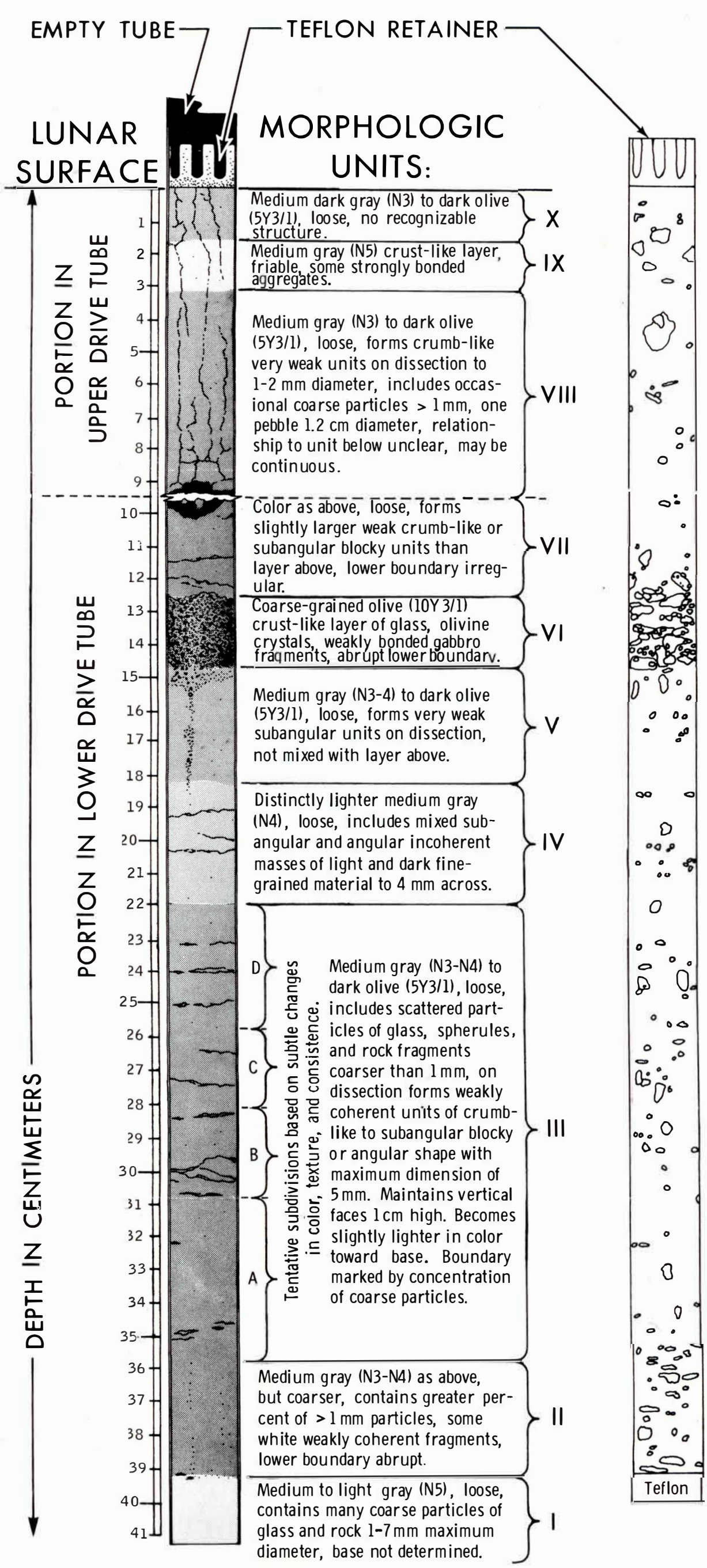


Figure 4. - Core sample 12027, showing the location and orientation of all soil particles larger than 1 millimeter. Diagram is based on X-ray photograph of unopened core.



Note: Teflon is tetrafluoroethylene.

A Core sample prior to dissection, showing fractures developed after removal of core liner and color variations indicating stratigraphy

B Location and orientation of soil particles greater than 1 mm diameter in the half of the core tube dissected (Note relationship between stratigraphy and clusters of larger particles.)

Figure 5. - Stratigraphy of the Apollo 12 double-drive-tube core (samples 12025 and 12028).

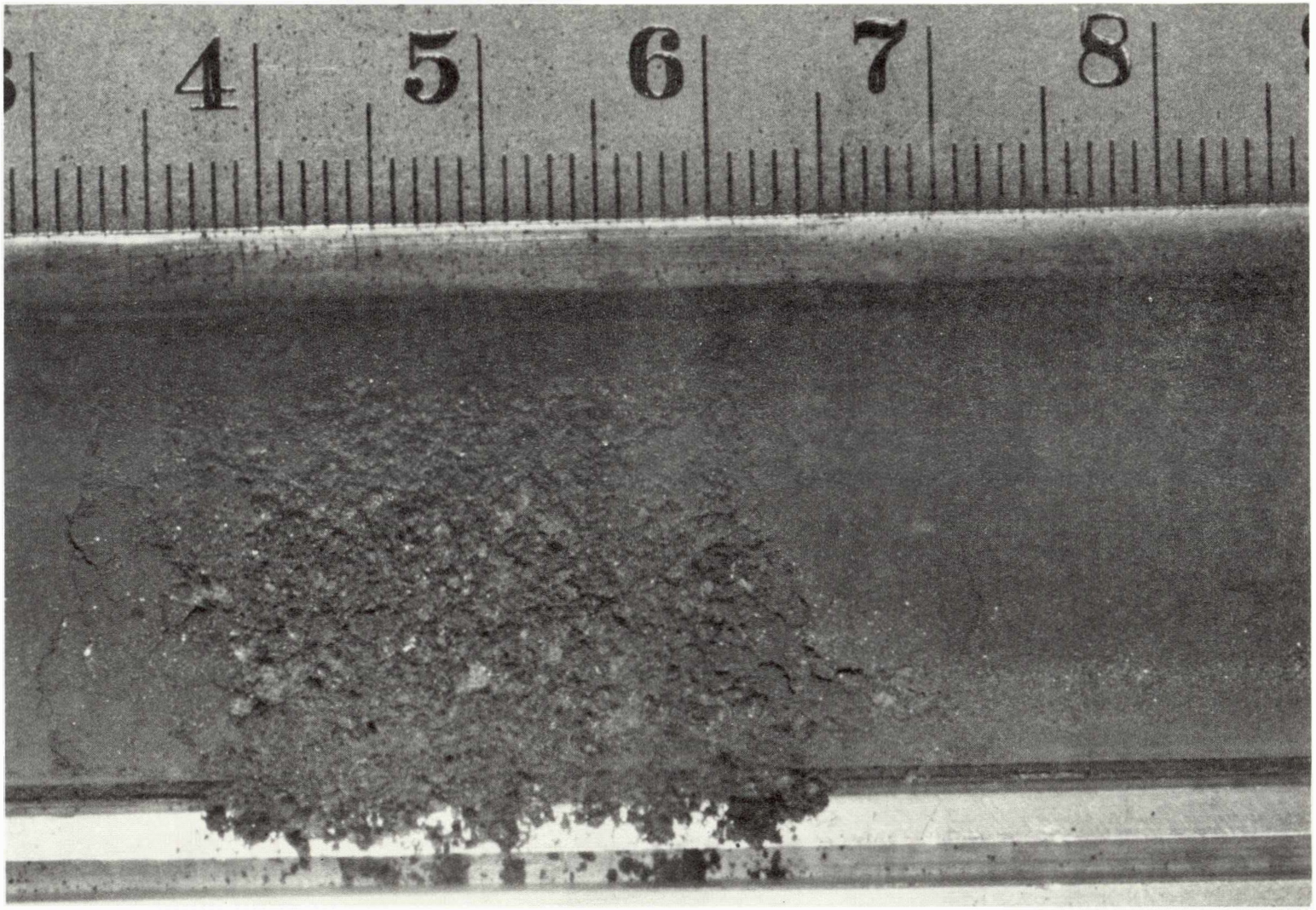


Figure 6. - Unit VI of core sample 12028. Note the coarseness of the soil in this layer.