THE APOLLO 11 DRIVE TUBES

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24 March 1978

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APPENDIX

THE APOLLO 11 DRIVE TUBES

PROCEDURES AND METHODS OF STUDY

1. Lunar Surface Procedures and Sampling Rationale

The Apollo 11 Lunar Module landed in an area relatively free of large rocks between rays of blocky ejecta from a sharp-rimmed crater 400 m to the west and of 180 m in diameter called West Crater (Shoemaker, et al., 1969). Cores 10004 and 10005 were collected about 4 meters apart and up to 3-5 meters north-northwest of the Apollo 11 Lunar Module (see Fig. 1). Astronaut Aldrin took 5 minutes and 50 seconds to collect both cores (Shoemaker, et al., 1969). The sampling of core 10005 was photographed (NASA photo AS 11-40-5963), but the sampling of core 10004 was out of the range of the camera. Both tubes had to be hammered into the lunar surface after they had penetrated the first few centimeters. Core 10005 was located near the solar wind composition experiment. Only the general area from which core 10004 was taken is known. The extension handle could not be separated from the plug on the upper end of core tube 10004 after the sample was taken. Therefore, the plug was removed leaving only the follower to hold the sample in the tube (Apollo 11 Mission Rep., 1971). The cores were packed into the documented sample box which was made of aluminum, lined with stainless steel mesh, and had seals made of indium and of synthetic rubber. This box maintained a pressure substantially less than atmospheric pressure (170 μHg) until opened in the Lunar Receiving Laboratory (Kramer, et al., 1977).

The original purpose for collecting the two core samples was not as sophisticated as it was in later missions when cores were taken to sample specific areas like crater rims or rille rims. The Apollo 11 cores were collected to provide an aseptic and stratified sample near the Lunar Module (Apollo 11 Lunar Surface Operations Plan, 1969). The photo showing astronaut Aldrin driving core tube 10005 into the lunar surface (NASA photo AS 11-40-5963) also shows the light and dark color patchiness of the surface soil (a patch of light colored soil about 1 meter in diameter lies near the sample). Soil texture patterns shown in this photograph are probably evidence of erosion by the Lunar Module descent engine. Some erosion effects were thought to extend at least tens of meters (Costes, et al., 1969). Part of the soil resistance to the core tube was due to bit design which, in retrospect, was poor for the more compact soil encountered. Since the Field Geology Team considered the possibility of fluffy, uncompacted soil on the lunar surface, the bit finally chosen for flight was one which could compact fluffy material into the core tube so the tube could be removed from the lunar surface with sample intact (U. Clanton, personal communication, 1978). More information is given on bit design in the section on Coring Hardware below.

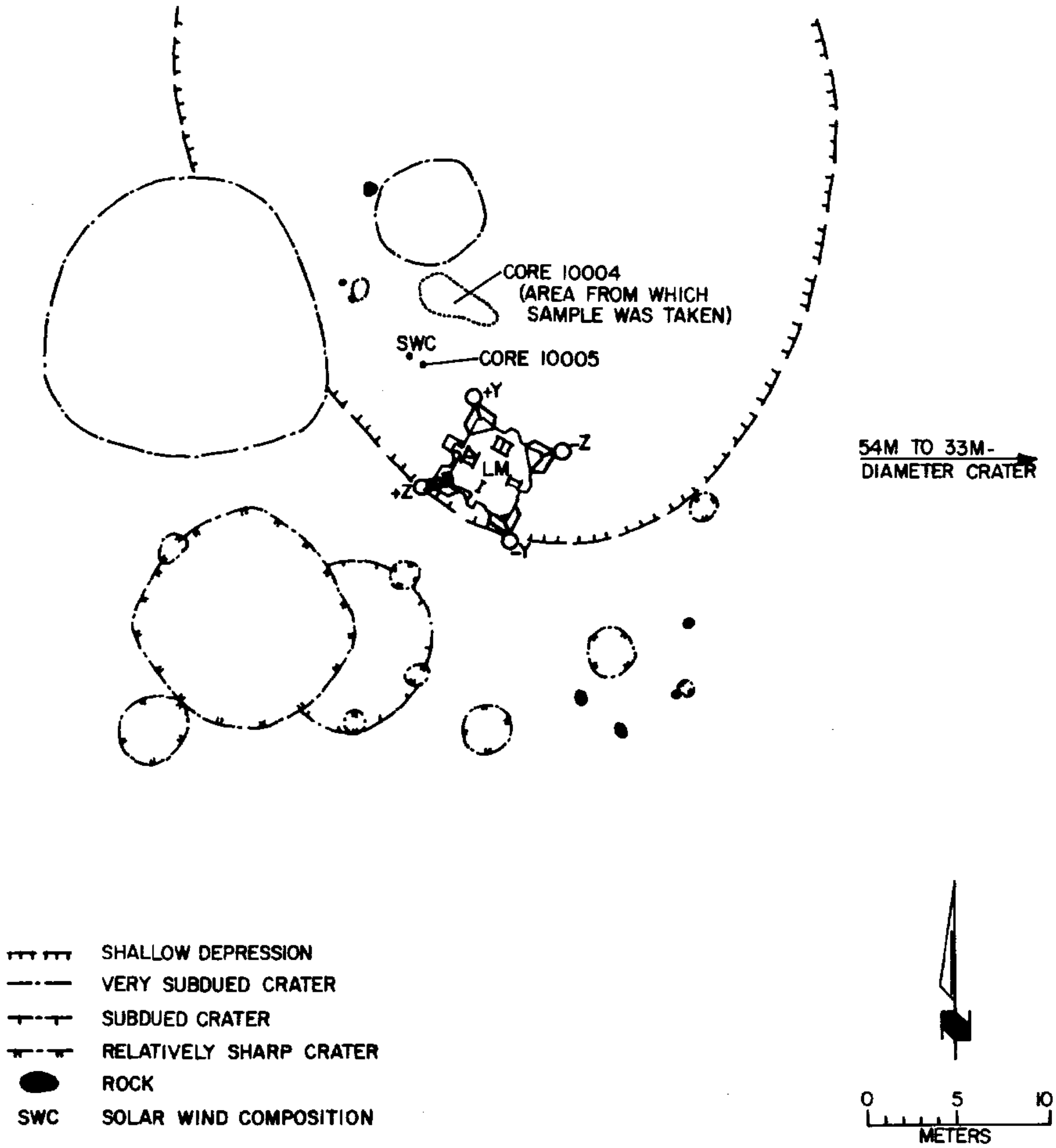


FIGURE 1. Map of landing site modified from Apollo 11 Preliminary Science Report, p. 52, (NASA SP-214).

2. Coring Hardware

Apollo 11 drive tubes were members of the family of early Apollo drive tubes which had extractable liners. The 1.95 cm (interior diameter) anodized aluminum liner was split lengthwise so the core could be exposed in the laboratory by lifting off half of the liner. The two halves were held together during sampling by a snugly fitting teflon sheath. This assembly was housed in an aluminum core barrel onto which a hard anodized aluminum bit was screwed. The bit flared outward to an interior diameter of 2.92 cm, and the resulting taper to the 1.95 cm liner diameter made the sampling like pushing the large end of a funnel into the soil first.

The design of the hardware caused distortion of the sample as it entered the tube. The type and amount of distortion, described by Carrier and Johnson (1971), was based on simulation. The center of the soil column traveled farther than the sides. The depth to which the core was driven was much greater than the depth of sample obtained. The bit of core 10005 penetrated to about 25 cm, and the tube recovered material only from about 12 cm. A similar depth relationship was not developed for 10004 since it was believed disturbed.

3. Initial Processing in the Bio Preparation Laboratory

Both 10004 and 10005 were opened July 28-29, 1969, in the same cabinet. Each core was processed as follows:

The aluminum liner was removed from the core barrel. While the core was held horizontally, the teflon sheath was cut off, and the exposed half of the aluminum liner was lifted off. Sample 10004 was found to contain 13-14 cm of soil, and sample 10005 was found to contain about 10 cm of soil. Photographs and descriptions were made by R. Fryxell and W.R. Greenwood. Their data are incorporated in this report. Several 0.05 g organic gas analysis samples were removed (see Appendix, Tables 6 & 7 for location). Then the exposed half of the core was troweled off level with the edges of the bottom liner. This material was sieved for size analysis and then set aside for the biology team to investigate. These size analyses, reported by Costes et al., (1969), are given in the appendix (Fig. 5).

4. Initial Weights and Sample Numbering

There was some confusion of sample numbers and weights in the original processing records. These documents were generated during brisk activity in order to obtain samples rapidly for biological analyses. Mix-ups may have resulted from "core #1" and "core #2" collected on the lunar surface being confused with "first core" and "second core" processed in the Bio Prep Laboratory. The core identifications used in the references cited in this paper are believed correct (except for the core weights given in the Apollo 11 Lunar Sample Information

Catalogue, 1977). Core 10004 is identified as core #2, 13-14 cm long, weighing 65.1 g. Core 10005 is identified as core #1, 10 cm long, weighing 52.0 g. The collection weight for 10005 is recorded as 67.5 g, because 15.5 g of soil reportedly fell out of the core tube cap when it was removed. The 52.0 g weight actually represents the weight of 10 cm of core material. This spilled material presents a problem, since documentation attributed the source of the 15.5 g as core 10005. Photos of the core tube showed 10005 was filled flush to the cap end, and measurements of the cap suggest that there was no void from which 15.5 g could have come. This 15.5 g of soil (numbered ,33) was sent to V.I. Oyama for testing for viable organisms and has since been returned.

5. Subsequent History of Handling

At some time after the initial halving of the cores and before June, 1971, the core halves retained for geological study were transferred in their aluminum liners to plexiglas boxes. Gummed labels were placed on the inside of these boxes next to the core to indicate strata noted by early observers. The teflon plug in 10004 and the follower in 10005 were each replaced with a wad of aluminum foil. The soil was not well confined in these containers as there was a 1-2 mm void space above the planed-off surface. The cores were moved from the Lunar Receiving Laboratory, Building 37, to the Returned Sample Processing Laboratory, in Building 31, where they were stored in air. Probably during this time both the plastic storage boxes were inverted. When the cores were transferred to the special core storage facility (Sample Storage and Preparation Laboratory) in 1972, this inverted box configuration was noticed and correct orientation was restored. Although the cores were stored in nitrogen from 1972 until dissection, the soil was in contact with plexiglas, gummed paper labels, and air. Therefore, they cannot be regarded as pristine.

6. Allocations Prior to Final Dissection

In addition to the allocations for biological studies of a lengthwise half of each core and for organic gas analyses, as described above, the following allocations were made:

10004:

Small allocations (about 0.2 g) of material were made to G. Arrhenius, G.W. Reed, G.J. Wasserburg, J.R. Arnold, J.H. Reynolds, R. Geake, and D. Lal in late 1969 and early 1970. Each investigator's sample included material from 0.0 cm, 3.3 cm, 6.6 cm, 9.9 cm, and 13.2 cm depths in the core. R. Walker received 5 single-depth samples from 2.0, 3.0, 6.0, 9.0, and 12.0 cm depths in the core.

10005:

Small allocations (about 0.2 g) of material were made to J.R. Arnold, H.C. Urey, R. Weeks, J. Geiss, R. Fleischer, D.S. McKay, P.B. Price, D. Lal, and R.A. Schmitt in late 1969 and early 1970. Each investigator's sample included material from 0.0 cm, 2.6 cm, 5.2 cm, 7.8 cm, and 10.5 cm depths in the core. V. Oyama was allocated 15.5 g which fell out of the cap when the tube was opened. Two samples were removed for the USSR in June, 1971. These consisted of a half gram each from the 3 and 9 cm depths.

The allocations with what locations are known, are summarized in Tables 6 and 7 of the Appendix.

7. Dissection Procedure

In 1977 the samples remaining in the bottom halves of the core tube liners were dissected according to Sample Processing Procedure 134. Dissections were done in a nitrogen cabinet. Each half-centimeter of soil was removed and passed through a 1 mm sieve. Thus, for each half-centimeter of core, a sample of fine material <1 mm and a sample of fragments >1 mm were created. Some larger fragments, which were not entirely contained within the interval assigned to them, were included in the interval where most of their mass was located. Drawings were made showing the location of the larger fragments in each interval. Special samples were created to isolate particular or fragile samples or for very large fragments spanning more than one depth interval.

The material <1 mm was described and weighed. Several characteristics of this material were noted and some were quantitatively compared to other intervals. These included color, grain size, cohesiveness, amount and orientation of light colored mottles and particles, and amount and kind of reflective particles (point source, planar source).

Particles larger than 1 mm were grouped according to rock type, photographed and weighed. Eight compositional categories were used to classify these particles for the purpose of constructing a rock type distribution. The categories, described in the paragraph below, were soil breccia, recrystallized or high grade breccia, basaltic or crystalline rock fragments, vesicular glass, partially crystallized glass, anorthositic breccia, recrystallized anorthosite, and agglutinates. Notation was made of the number of particles of each rock type in each of the following size groups: 1-2 mm, 2-4 mm, >4 mm.

Since the stratigraphy was disrupted in collection and storage as described in the section on the History of Handling, all of the core material was dissected and none was preserved by epoxy impregnation.

8. Compositional Descriptions Used For >1 mm Fragments

The soil breccias are lithified clastic material. The material includes very small dust grains, glass, basalt fragments, and breccia clasts. This category includes soft, friable breccias up through tough breccias, as long as clasts retained their original angular shapes. Very fine glass-welded soils (dark, sintered-looking fragments) are also placed in this group. Recrystallized or high grade breccias are the tough breccias where clasts exhibit flow structure up through material that had recrystallized. The recrystallized material typically has a fine-grained, waxy appearance. Crystalline material that is not heavily shocked, including single mineral grains such as plagioclase, are grouped together and called basaltic and crystalline rock fragments. Vesicular glass refers to fresh, vitreous glass which occurs as beads, shards or coatings. Partially crystallized glass refers to dark, fine-grained devitrified material often of similar shape to vesicular pieces or with conchoidal fracture. For the Apollo 11 cores, the term anorthositic breccia in most cases means shocked plagioclase, some with greenish maskelynite. However, also included with anorthositic breccias are a few highly shocked fragments with a white matrix and containing dark inclusions. These may have been very fine, very shocked crystalline rock. The white and very light gray fine-grained, homogeneous, waxy luster fragments are classified as recrystallized anorthosite. Agglutinates are spindly pieces of soil welded by many small glass splatters. This glass cementing agent is usually dust-coated, and therefore, not shiny. Soil splashed with glass (classified by some observers as agglutinates), was apportioned between the vesicular glass and soil breccia categories.

Classification errors resulted from this "pigeonholing" and from dust and glassy patina which obscure the fragments.

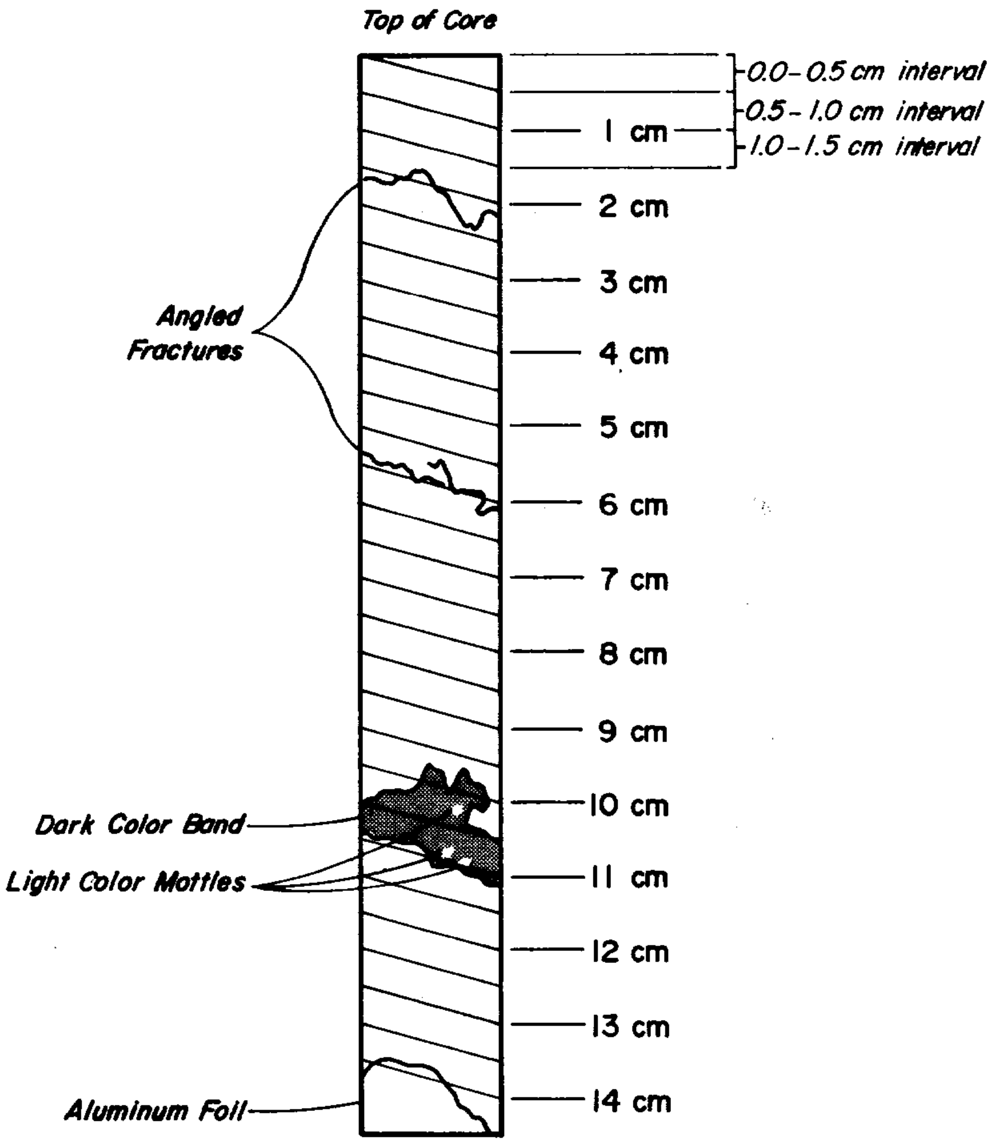
The full descriptions of fragments, recorded in the sample data packs, were not restricted to these eight categories and so reflect more precisely the nature of each fragment. Soil breccias were differentiated into friable or medium grade types or welded soils. Unusual composition of clasts was noted. Group photographs taken of these >1 mm fragments aid in the characterization of each fragment.

9. Analysis of Data

The collected quantitative data consists of the weights of the fine fraction (<1 mm) and of the coarse fraction (>1 mm) for each interval, the weights of the special samples, and, for each coarse fraction, the weights of each compositional group.

The distribution of rock type with depth in the core for the coarse fraction was characterized by two methods, weight abundance and

Figure 2
CORE 10004
DESIGNATION OF INTERVALS



numerical abundance. For each interval, the weight of each compositional group was compared. In the second method, the number of particles of each type in the 1-2 mm, 2-4 mm, and >4 mm size ranges were compared (as done by Waltz for the Apollo 17 drill string). In both methods distributions were normalized to the average weight of a standard dissection unit of 0.5 cm for each core.

Graphs were generated comparing the following parameters to depth in the core:

1) weights of each rock type for 8 compositions
2) frequency of rock types for each of three size ranges: 1-2 mm, 2-4 mm, >4 mm
3) frequency of rock types for combined size ranges (scale factors were used to give weight to the larger size ranges). This frequency distribution should compare to the weight distributicn.
4) frequency of particles, in each of 3 size ranges: 1-2 mm, 2-4 mm, >4 mm
5) frequency of particles in combined size ranges (scale factors were used to weight the larger size ranges).
6) weight percent of coarse fraction (coarseness)

Information from graph types 1 and 6 was the main data used in the interpretation.

Tables 2 and 3 in the Appendix contain the raw data for the amounts of different rock types by weight.

10. 10004 Dissection Procedure Notes

Core 10004 was dissected in April, 1977, in a Lunar Curatorial Laboratory nitrogen cabinet. Beginning at the top of the core, soil in each half centimeter interval was removed and passed through a 1 mm sieve. Unlike other cores, where the boundary between intervals was normal to the core length, these dissection units were taken at an angle (Fig. 2). A dark color patch and two prominent fractures having similar angles indicated this technique would better preserve any differences occurring with depth.

An attempt was made to preserve separately samples of material from light mottles and from dark mottles encountered in the core. Many more light gray mottles became apparent as dissection proceeded, so only representative samples were taken. In addition, many of the light mottles were cohesive clods classified as soil breccias. The large or unusual fragments, as well as these light and dark soil samples were preserved as special samples.

11. 10005 Dissection Procedure Notes

Core 10005 was dissected in January, 1977. Beginning at 11.0 cm, the bottom of the core, each half centimeter of soil was removed, sieved and described.

RESULTS AND DISCUSSION

1. Preservation of Lunar Stratigraphy

Since the history of the handling of the Apollo 11 cores indicates possibility of major disturbances of soil, observations made of the core should be evaluated two ways: 1) extent of disturbances due to collection and laboratory handling, and, 2) evidence of stratification from lunar deposition.

Handling disturbances happened in two time periods: 1) from the time of collection up through the opening and initial sampling of cores in the Bio Prep Lab, and, 2) during storage in Lunar Receiving Lab and Lunar Curatorial Lab until the dissection.

The first period of disturbance is of special interest for core 10004 where the 14 cm of soil was found in the top half of the core tube unconfined and free to move throughout the length of the tube. In this case Fryxell observed, upon opening the core, a lighter gray layer with sharp boundaries. For the other core, 10005, which was secured at both ends in the core tube, Fryxell initially recorded observing mottling. He could not tell whether this mixing had occurred during deposition on the lunar surface or during transport to earth. After having troweled off half of each core for biological samples, Fryxell had another core surface to observe. He finally concluded that both cores appeared "essentially undisturbed in their primary characteristics" (Fryxell et al., 1970).

10004: Initial Core Description

Fryxell described the color of the unsplit core 10004 as N3 to N4 on the gray value scale and 10YR 3/1 to 4/1 on the Munsell Color Scale. He reported the texture as silty fine sand with admixed angular rock fragments, glass spherules, and aggregates of glass up to 3 or more mm in diameter. The soil was loose and weakly cohesive (Fryxell et al., 1970). Weak very fine aggregates <1 mm with crumb-like structure were observed. A lighter gray, wedge-shaped layer with distinct boundaries was noted at 6.2-7.0 cm. About 10% of the surface area was covered with very fine reflective particles. The consistency of the core was loose. (Fryxell's original core descriptions can be found in the Lunar Curator's data packs for 10004 and 10005.) Sieving of the biology core sample at this time yielded an average grain size of 100μ (Costes, N.C., et al., 1969).

10005: Initial Core Description

Fryxell described the unsplit core 10005 as a uniform medium gray between N4-N3, estimated 10YR 4/5. The basal 1.5 cm had mottled light gray (N7) areas. Grain size ranged from very fine silt up to 1 cm. Except the mottling in the basal 1.5 cm, no bedding or changes were noted. The core material was weakly cohesive and contained 15-20% very small reflective particles. Sieving of the biology core sample yielded an average grain size of 100μ (Costes, N.C., et al., 1969).

Allocations were made of Apollo 11 core material about 3-5 months after the cores were opened in July, 1969. Analyses done on samples taken at 3.3 cm intervals in 10004 and 2.6 cm intervals in 10005, might reflect the existence of core stratigraphy at that time, but elemental analyses by Reed and Jovanovic (1971) for 10004 and Wakita et al., (1970) for 10005 show no trends. Fleischer et al., (1970) reports that track densities for 10005 were chaotic instead of showing a regular decrease with depth. However, he felt that the mixing he observed was a lunar process due to the strong, electrostatic cohesiveness of the soil in the laboratory. A decrease with depth of Mn^{53} was shown in both cores by Finkel et al., (1971). Dalrymple and Doell (1970) saw an increase in thermo-luminescence with depth for core 10005, and Hoyt et al., (1970) reported a similar trend in core 10004. Crozaz et al., (1970) observed decreasing track densities with depth (with one anomaly at 9.0 cm) for 10004, and Lal et al., (1970) observed a similar decrease for both cores.

Extent of disturbance of the cores during storage in the Lunar Receiving Lab and the LCL may be indicated by comparing Fryxell's description in 1969 with the pre-dissection core description in 1977. It was during this time period that the cores were transferred to plastic boxes. The material of core 10004 was originally located from 3 to 16 cm in the core liner and subsequently moved to the 0 to 14 cm interval in the core liner. Both cores were turned upside down and then later restored to correct orientation.

10004: 1977 Core Description

The bulk of the core appeared 5Y 6/1 in color on the Munsell Color Scale. A band at 10.5 cm, the darkest in the core was 5Y 5/1. Lighter gray (5Y 7/1) small mottles, totaling 3-5 in number, were found in this dark band and from 5 to 7 cm. Aside from the dark band and the light mottles, the bulk color of the core (about 5Y 6/1) changed in about 5 very small gradations from darkest at the top to lightest at the bottom. These colors were viewed under fiber conducted tungsten-halogen light. This dark color band and 2 prominent fractures were angled away from the perpendicular to the core tube length (see Fig. 2). The greatest surface concentration of glass spheres was from 2-5 cm. The bulk of the spheres were black, although some were clear (about 3/1 black to clear) and a very few were orange. Concentrations of particles reflecting light and appearing to sparkle were found at 2.5-5.5 cm and 8.0-10.5 cm. These most concentrated areas contained about 20% reflectives, and other regions contained

10-20% reflectives.

Material from core 10004 had shifted in the box leaving a partially empty space at the bottom of the core (from 10.5-13.5 cm on one side). The grain size distribution seemed to reflect handling disturbance. Regions containing grains up to 500μ were located on one side of the core, rather than being associated with depth. The 100μ average grain size reported in 1969 appeared to be correct.

10005: 1977 Core Description

Just prior to dissection, the color of core 10005 appeared to be 10YR 3/1 tending toward 4/1. The color, which appeared homogeneous throughout the length of the core, was perceived with fiber conducted tungsten-halogen light. No mottling nor stratification by color was observed. The 100μ average grain size reported in 1969 appeared to be correct.

The most evident difference between the photographs taken in 1971 and 1976 (NASA photos S-71-35062 and S-77-20660) is the upward movement of core material. Material had filled in and engulfed the aluminum plug. A much larger void was created at the bottom (8.5-11.0 cm). The large centimeter-size rock fragment observed at 1.5-2.5 cm in 1971 was found at 1.0-2.0 cm in 1976. The rock had also rotated 90° counterclockwise. More subtly, larger grains distributed on the surface had moved from a left-side pocket to a linear arrangement of the right side. At three times during dissection a very faint stratification was thought to exist at 6.8, 3.9, and 2.8 cm. On the dissection face as viewed from the bottom of the core, the laminae looked like this:

This layering probably reflects the rotary movement made when the cores were turned upside down, and when they were returned to right-side-up.

During the trip from the lunar surface to the Lunar Receiving Laboratory, core 10005 seems to have been undisturbed. Core 10004, however, probably slid along the length of the tube at least once. This action seemed not to have destroyed gross stratigraphy because a light layer survived, and also the track and thermoluminesence data previously cited showed expected trends. During laboratory storage both cores were slopped in their containers to about the same degree. It appears from dissection data given below, that relative position of units in soil was maintained in core 10005 and perhaps in core 10004 also.

2. Description of Units 10004

Core 10004 was composed of 3 units (see Fig. 3). The main determination of units was based on color and presence of light-colored mottles. The top unit was slightly darker and homogeneous in color. A thicker middle unit contained light-colored mottles, and the bottom unit was a homogeneous gray which was lighter than the top unit.

Unit III: 0.0-3.5 cm

Although soil breccias were the most abundant rock type in all units, this unit had the lowest percentage of soil breccia (53% based on non-normalized weight ratios) and the highest percentage of basalt (20%). Particles greater than 1 mm constituted 9% of the soil weight. The lower half of the unit was characterized by an increase in basalt and vesicular glass fragments.

Unit II: 3.5-12.0 cm

The thick middle unit was the most varied. Mainly it was characterized by a medium gray matrix containing 5-10% light gray mottles. Most of the mottles were cohesive clods of light gray from which marbled streamers extended. Many of the clods were saved as soil breccias which partially explains why soil breccias dominated the >1 mm fraction of this unit (64% soil breccia, non-normalized weight ratios). Twelve percent of the soil weight was particles greater than 1 mm. This abundance of coarse particles was greater than other units, and it was also more variable within the unit. About one third down into the unit a sharp peak in coarseness occurred. It gradually decreased to a low level, and another large peak occurred at the bottom of the unit. There was a greater abundance of small (1-2 mm) anorthositic fragments in this unit than in the others. They are particularly concentrated at 3.5-6.0 cm. There was significant variation in basalt abundance and in vesicular glass abundance. The ragged band of dark material seen between 9.5 and 11.0 cm prior to dissection was found to be only a thin crust 1 mm thick.

Unit I: 12.0-14.0 cm

Soil breccias composed 62% of the >1 mm fraction and are evenly distributed throughout the unit. A small peak of vesicular glass abundance occurred near the middle of the unit. Immediately below this is a larger peak in basalt abundance due to one piece of shocked basalt. Nine per cent of the soil was particles >1 mm. This unit had 3-4 very small light mottles and it had a small pocket of dark material at 13 cm.

Orange clasts and glass were observed in soil breccias in most intervals below 4.0 cm in the core. A sharp peak in the occurrence of orange clasts was found at 9.5-10.0 cm. This peak gradually declined toward the bottom of the core.

FIG. 3. DISTRIBUTION OF SOME ROCK TYPES IN CORE 10004 BY WEIGHT CONTENT NORMALIZED TO AN AVERAGE WEIGHT OF 1.045g FOR A STANDARD DISSECTION INTERVAL OF 0.5cm

THIS GRAPH IS DIRECTLY COMPARABLE WITH FIG. 4, CORE 10005

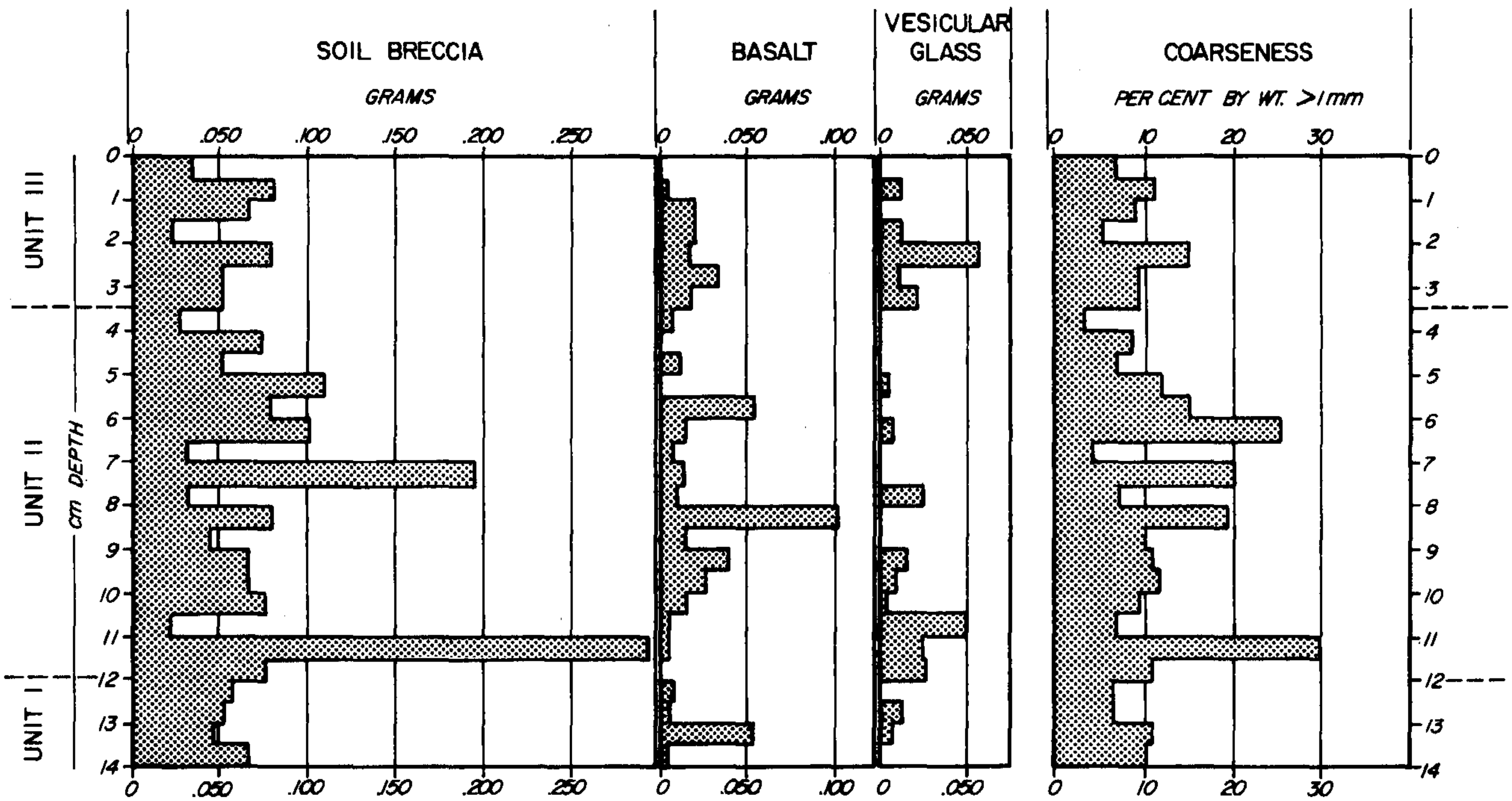
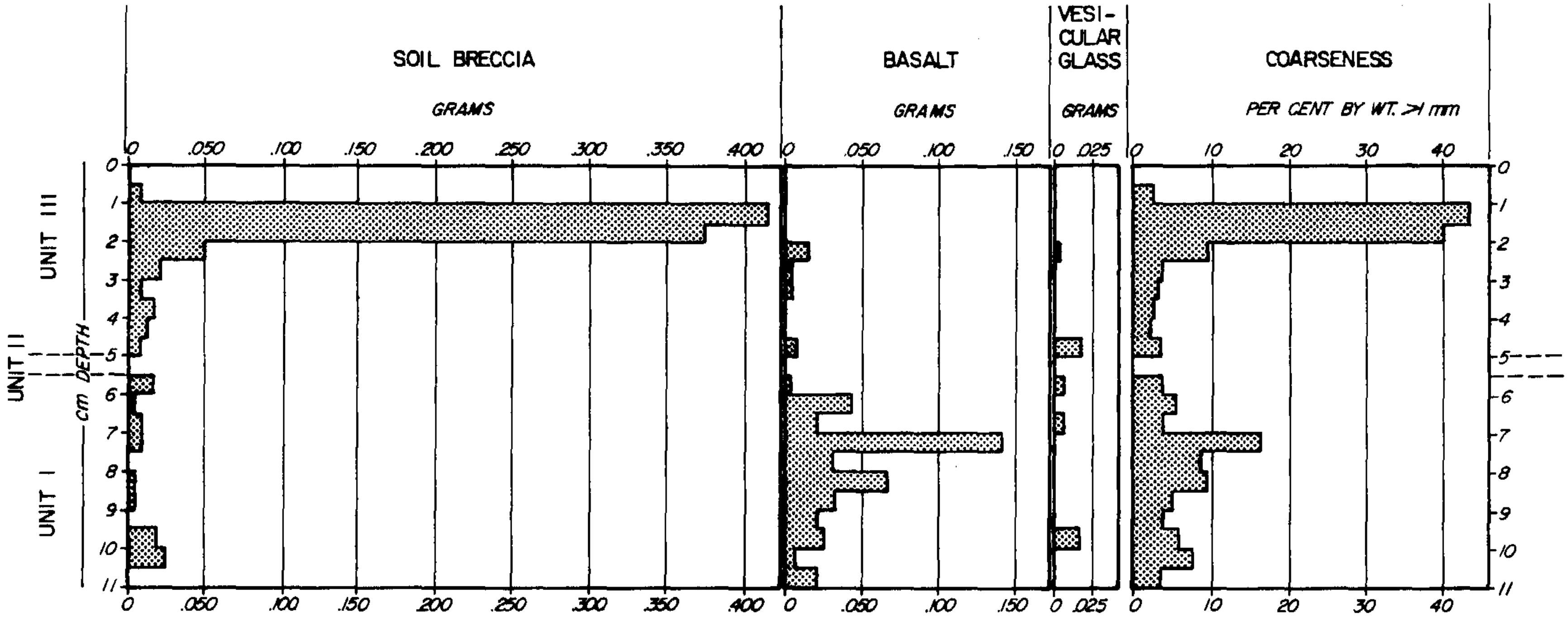


FIG. 4. DISTRIBUTION OF SOME ROCK TYPES IN CORE 10005 BY WEIGHT CONTENT

NORMALIZED TO AN AVERAGE WEIGHT OF .960g FOR A STANDARD DISSECTION UNIT OF 0.5 cm

THIS GRAPH IS DIRECTLY COMPARABLE WITH FIG. 3, CORE 10004



3. Description of Units 10005

Core 10005 was composed of 3 units which remained distinct despite known movement of soil at the top and bottom ends of the core (see Fig. 4). The uppermost unit was dominated by soil breccias and had very few basalt fragments. The lowermost unit was mainly basalt fragments with some vesicular glass at the top of the unit. The middle unit, only a half centimeter thick, contained only a very few particles >1 mm.

Unit III: 0.0-5.0 cm

This unit contained the largest abundance of soil breccia and the smallest abundance of basalt. (Based on non-normalized weight ratios, the >1 mm fraction of unit III was 88% soil breccia and 3% basalt.) Thirteen percent of the weight of the soil was particles >1 mm. This high percentage of coarse particles was due to a large one-gram fragment located at 1.0-2.0 cm intervals. This particle was a soil breccia which graded into a glass-welded soil. A large number of >1 mm particles, including a significant number of agglutinates, was found at 2.0-2.5 cm. (In early processing photographs the large one-gram fragment was located in this coarse interval at 1.5-2.5 cm. It was found during dissection at 1.0-2.0 cm indicating some upward movement had occurred in the core.) A significant amount of vesicular glass occurred at the bottom of this unit.

Unit II: 5.0-5.5 cm

This inverval formed a boundary between upper and lower units. It had very few particles >1 mm (<1%).

Unit I: 5.5-11.0 cm

This unit was characterized by predominance of basalt fragments and scarcity of soil breccia fragments. (Based on non-normalized weight ratios, the >1 mm fraction of unit I was 13% soil breccia and 61% basalt.) The 5.5-6.0 cm interval at the top of the unit has a relative abundance of agglutinates and vesicular glass. Below this, the abundance of basalt increased, peaked at 7.0-7.5 cm and gradually declined. With increasing depth in the core, a sharp peak in coarseness (16%) occurred at 7.0-7.5 cm and gradually declined. Six percent of the weight of the soil was particles greater than 1 mm.

4. Comparison of 10004 and 10005

Since they were taken only 3 meters apart, cores 10004 and 10005 provide an opportunity to examine the extent of stratigraphic continuity. Visually, the surface in the vicinity of the cores does not appear continuous in soil color as a 1 meter diameter patch of light soil surrounded by dark soil indicates (NASA photo AS 11-40-5963).

The Apollo 11 cores indicate no similarity of units between cores by color, structure or composition of coarse fraction. The mottling observed in Unit II, core 10004, was not seen in 10005. The percent composition of the two major rock types, soil breccia and basalt, in the >1 mm fraction in each unit is shown in Table 1. No correlation could be made from this data. Possible causes of this lack of correlation are: 1) lateral discontinuity, 2) Lunar Module exhaust disturbance, 3) incomplete sampling due to hardware problems, and 4) lack of vertical comparability, especially a problem with such short cores on uneven terrain.

CORE 10004		CORE 10005	
Unit III	53% soil bx 20% basalt	Unit III	88% soil bx 3% basalt
Unit II	64% soil bx 14% basalt	Unit II	N/A
Unit I	62% soil bx 19% basalt	Unit I	13% soil bx 61% basalt

TABLE I. Weight Percent Composition of >1 mm Fraction

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The Apollo 11 Drive Tubes

APPENDIX

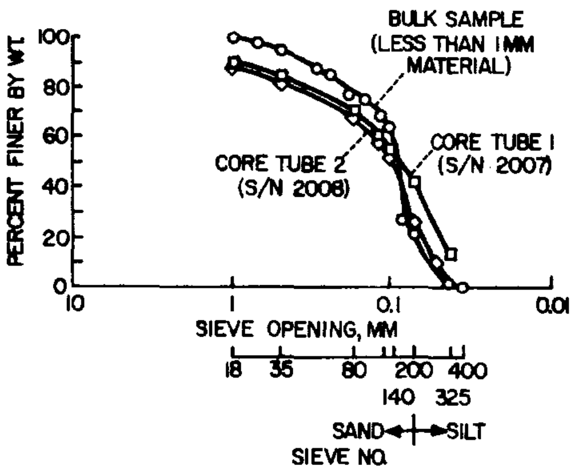


FIGURE 5. Size analyses of Apollo 11 fines from Apollo 11 Preliminary Science Report, p. 117. (NASA SP-214). Core tube 1 is sample 10005, and core tube 2 is sample 10004.

TABLE 2.

RAW DATA FOR CORE 10004

Depth in Cm	Wt. in Grams < 1 mm Fines	Wt. in Grams > 1 mm Fragments	Wt. in Grams by Rock Type for Fragments > 1 mm: Agglutinates	Basalt	Anorthositic Breccia	Devitrified Glass	Recrystallized Breccia	Soil Breccia	Vesicular Glass	Recrystallized Anorthosite
0.5- 0.0	.425	.032	.000	.000	.000	.015	.000	.017	.000	.000
1.0- 0.5	.716	.094	.002	.004	.000	.009	.000	.064	.011	.000
1.5- 1.0	.886	.093	.001	.018	.000	.000	.008	.063	.001	.000
2.0- 1.5	.987	.059	.000	.020	.000	.000	.000	.021	.016	.000
2.5- 2.0	.874	.166	.000	.017	.000	.008	.020	.083	.060	.000
3.0- 2.5	1.295	.135	.000	.046	.000	.000	.000	.071	.017	.000
3.5- 3.0	.931	.095	.000	.017	.000	.005	.000	.052	.021	.000
4.0- 3.5	.892	.034	.000	.008	.000	.002	.000	.025	.000	.000
4.5- 4.0	1.056	.093	.000	.002	.002	.011	.000	.073	.004	.000
5.0- 4.5	1.068	.048	.000	.011	.003	.000	.000	.030	.004	.000
5.5- 5.0	1.099	.131	.000	.000	.004	.000	.001	.118	.007	.000
6.0- 5.5	1.027	.183	.000	.066	.004	.015	.003	.091	.002	.000
6.5- 6.0	1.072	.073	.000	.018	.000	.000	.000	.044	.012	.000
7.0- 6.5	.921	.039	.000	.007	.000	.000	.000	.032	.000	.000
7.5- 7.0	.823	.089	.000	.014	.000	.005	.002	.066	.000	.000
8.0- 7.5	1.117	.057	.000	.012	.002	.000	.000	.017	.028	.000
8.5- 8.0	.833	.207	.000	.106	.008	.003	.003	.084	.003	.008
9.0- 8.5	.861	.081	.000	.014	.000	.004	.024	.039	.002	.000
9.5- 9.0	1.036	.132	.000	.043	.000	.002	.003	.073	.017	.000
10.0- 9.5	.747	.117	.001	.023	.003	.027	.000	.060	.009	.000
10.5-10.0	.841	.065	.000	.011	.000	.000	.000	.046	.005	.000
11.0-10.5	.959	.082	.000	.006	.000	.006	.003	.019	.051	.000
11.5-11.0	.665	.289	.000	.006	.000	.005	.000	.275	.022	.000
12.0-11.5	.968	.126	.000	.000	.000	.010	.013	.080	.028	.000
12.5-12.0	.684	.053	.000	.006	.004	.000	.000	.044	.003	.000
13.0-12.5	.775	.057	.000	.005	.000	.000	.000	.045	.012	.000
13.5-13.0	.554	.049	.000	.010	.000	.000	.000	.027	.006	.000
14.0-13.5	.671	.078	.000	.004	.000	.002	.021	.049	.003	.000

RAW DATA FOR SPECIAL SAMPLES, CORE 10004.
These are not included in the regular samples listed above.

Depth in Cm	Wt. in Grams < 1 mm Fines	Wt. in Grams > 1 mm Fragments	Type of Sample
4.0- 3.5	.020		
4.5- 4.0	.076		
4.5- 4.0	.012		
4.5- 4.0		.005	Soil Breccia
4.5- 4.0		.009	Soil Breccia
5.0- 4.5		.031	Soil Breccia
5.5- 5.0		.021	Soil Breccia
6.0- 5.5		.007	Soil Breccia
6.5- 6.0		.099	Soil Breccia
6.5- 6.0		.196	Soil Breccia
7.5- 7.0		.131	Soil Breccia
8.0- 7.5		.024	Soil Breccia
9.0- 8.5		.020	Soil Breccia
10.0- 9.5	.039		
10.5-10.0	.024		
10.5-10.0		.026	Soil Breccia
11.0-10.5	.017		
12.0-11.5		.003	Soil Breccia
13.5-13.0	.002		
13.5-13.0		.025	Basalt
14.0- 0.0	.221		Miscellaneous
14.0- 0.0	.089		Miscellaneous
14.0- 0.0	.636		Miscellaneous

Weights of individual rock types may not sum to the exact weight of the >1 mm fragments total weight because separate weighings were taken and balance tolerance is $\pm$.05 g.

TABLE 3.

RAW DATA FOR CORE 10005

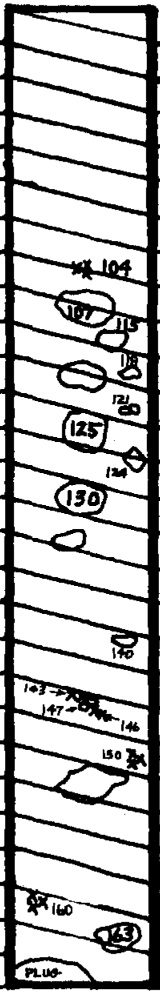
Depth in Cm	Wt. in Grams <1 mm Fines	Wt. in Grams >1 mm Fragments	Wt. in Grams by Rock Type for Fragments >1 mm:							
			Agglutinates	Basalt	Anorthositic Breccia	Devitrified Glass	Recrystallized Breccia	Soil Breccia	Vesicular Glass	Recrystallized Anorthosite
0.5- 0.0	.291	.000	.000	.000	.000	.000	.000	.000	.000	.000
1.0- 0.5	.709	.017	.002	.001	.008	.000	.000	.006	.000	.000
1.5- 1.0	.660	.016	.001	.000	.000	.000	.000	.014	.001	.000
2.0- 1.5	.798	.019	.001	.000	.000	.000	.002	.014	.001	.000
2.5- 2.0	1.136	.121	.026	.023	.000	.001	.000	.065	.007	.000
3.0- 2.5	1.182	.045	.000	.008	.000	.000	.002	.027	.005	.000
3.5- 3.0	1.112	.036	.000	.007	.000	.003	.010	.013	.003	.000
4.0- 3.5	1.222	.033	.004	.002	.000	.000	.005	.021	.004	.000
4.5- 4.0	1.090	.027	.001	.003	.006	.000	.004	.014	.000	.000
5.0- 4.5	.925	.034	.000	.008	.000	.000	.005	.007	.015	.000
5.5- 5.0	1.048	.005	.002	.000	.000	.003	.000	.000	.000	.000
6.0- 5.5	.920	.034	.012	.005	.004	.000	.000	.017	.008	.000
6.5- 6.0	1.022	.059	.009	.045	.000	.000	.000	.005	.000	.000
7.0- 6.5	1.160	.044	.000	.023	.000	.000	.011	.012	.010	.000
7.5- 7.0	.839	.167	.000	.146	.005	.000	.005	.011	.003	.000
8.0- 7.5	1.074	.097	.000	.038	.001	.012	.045	.004	.000	.000
8.5- 8.0	.677	.071	.003	.052	.001	.000	.009	.004	.000	.000
9.0- 8.5	.831	.043	.000	.030	.000	.000	.006	.005	.000	.000
9.5- 9.0	.587	.022	.000	.012	.008	.001	.000	.001	.000	.000
10.0- 9.5	.497	.035	.000	.013	.000	.000	.002	.010	.009	.000
10.5-10.0	.467	.036	.000	.006	.000	.000	.017	.013	.000	.000
11.0-10.5	.563	.023	.000	.013	.000	.000	.006	.000	.001	.000

RAW DATA FOR SPECIAL SAMPLES FOR CORE 10005
(These are not included in the regular samples listed above.)

Depth in Cm	Wt. in Grams <1 mm Fines	Wt. in Grams >1 mm Fragments	Type of Sample
11.0- 0.0	.366		Miscellaneous
2.0- 1.0		1.002	Soil Breccia*

*This fragment is physically stored with 2.0-1.5 cm sample.

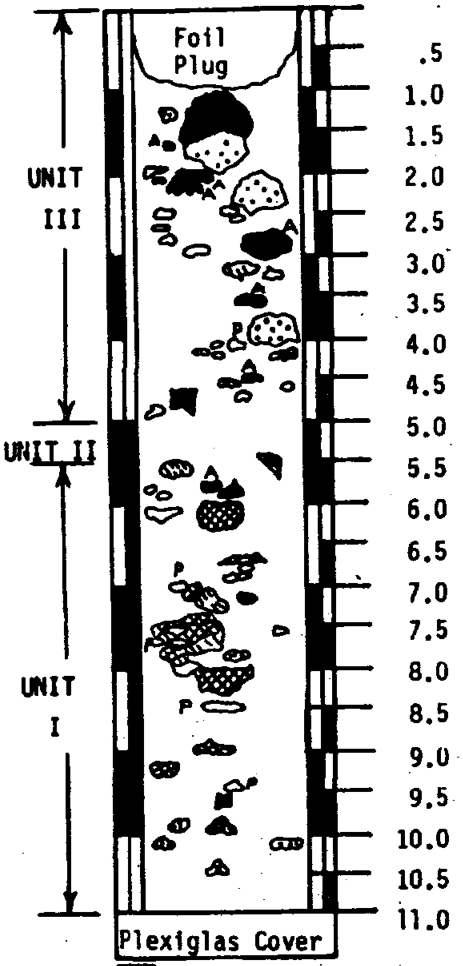
Weights of individual rock types may not sum to the exact weight of the >1 mm fragments total weight because separate weighings were taken and balance tolerance is ±.05 g.



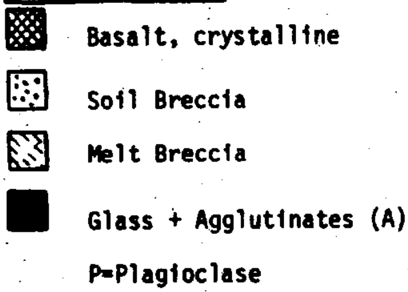
Cm. Depth	Interval Notation	Unit	<1 MM FINES Sample Number	<1 MM FINES Weight (grams)	>1 MM Sample Number	>1 MM Weight (grams)	SPECIAL SAMPLES Interval Notation	SPECIAL SAMPLES Sample Number	SPECIAL SAMPLES Weight (grams)	SPECIAL SAMPLES Description (Location/orientation shown at left XXX=soil)
.5	0.5- 0.0		90	.425	91	.032				
1.0	1.0- 0.5		92	.716	93	.094				
1.5	1.5- 1.0		94	.886	95	.093				
2.0	2.0- 1.5	III	96	.987	97	.059				
2.5	2.5- 2.0		98	.874	99	.166				
3.0	3.0- 2.5		100	1.295	101	.135				
3.5	3.5- 3.0		102	.931	103	.095				
4.0	4.0- 3.5		105	.892	106	.034	4.0- 3.5	104	.020	Light gray soil
4.5	4.5- 4.0		108	1.056	109	.093	4.5- 4.0	107	.076	Light gray soil breccia
5.0	5.0- 4.5		113	1.068	114	.048	4.5- 4.0	110	.012	Light gray soil
5.5	5.5- 5.0		116	1.099	117	.131	4.5- 4.0	111	.005	Dark soil breccia
6.0	6.0- 5.5		119	1.027	120	.183	4.5- 4.0	112	.009	Light gray soil breccia
6.5	6.5- 6.0		122	1.072	123	.073	5.0- 4.0	115	.031	Light gray soil breccia
7.0	7.0- 6.5		126	.921	127	.039	5.5- 5.0	118	.021	Light gray soil breccia
7.5	7.5- 7.0	II	128	.823	129	.089	6.0- 5.5	121	.007	Light gray soil breccia
8.0	8.0- 7.5		131	1.117	132	.057	6.5- 6.0	124	.099	Light gray soil breccia
8.5	8.5- 8.0		134	.833	135	.207	6.5- 6.0	125	.196	Light gray soil breccia
9.0	9.0- 8.5		136	.861	137	.081	7.5- 7.0	130	.131	Light gray soil breccia
9.5	9.5- 9.0		139	1.036	140	.132	8.0- 7.5	133	.024	Light gray soil breccia
10.0	10.0- 9.5		141	.747	142	.117	9.0- 8.5	138	.020	Light gray soil breccia
10.5	10.5-10.0		144	.841	145	.065	10.0- 9.5	143	.039	Dark soil
11.0	11.0-10.5		148	.959	149	.082	10.5-10.0	146	.024	Dark soil
11.5	11.5-11.0		151	.665	152	.289	10.5-10.0	147	.026	Light gray soil breccia
12.0	12.0-11.5		153	.968	154	.126	11.0-10.5	150	.017	Dark soil
12.5	12.5-12.0		156	.684	157	.053	12.0-11.5	155	.003	Soil breccia
13.0	13.0-12.5	I	158	.775	159	.057	13.5-13.0	160	.002	Dark soil
13.5	13.5-13.0		161	.554	162	.049	13.5-13.0	163	.025	Shocked basalt
14.0	14.0-13.5		164	.671	165	.078				
							Misc.	166	.221	Unsieved soil
							Misc.	167	.089	Unsieved soil
							Misc.	168	.636	Unsieved soil

TABLE 4. Drive Tube 10004 Sample Location Information

TABLE 5. SAMPLE LOCATIONS, DRIVE TUBE 10005



< 1mm Fines			> 1mm Coarse Fines		
Sample No.	Container No.	Wt.	Sample No.	Container No.	Wt.
152	9-10544	.291			
150	9-10542	.709	151	9-10543	.017
148	9-10539	.660	149	9-10540	.016
146	9-10537	.798	147	9-10538	1.021
144	9-10535	1.136	145	9-10536	.121
142	9-10533	1.182	143	9-10534	.045
140	9-10531	1.112	141	9-10532	.036
138	9-10529	1.222	139	9-10530	.033
136	9-10527	1.090	137	9-10528	.027
134	9-10525	.925	135	9-10526	.034
132	9-10523	1.048	133	9-10524	.005
130	9-10521	.920	131	9-10522	.034
128	9-10519	1.022	129	9-10520	.059
126	9-10517	1.160	127	9-10518	.044
124	9-10515	.839	125	9-10516	.167
122	9-10513	1.074	123	9-10514	.097
120	9-10511	.677	121	9-10512	.071
118	9-10509	.831	119	9-10510	.043
116	9-10507	.587	117	9-10508	.022
114	9-10505	.497	115	9-10506	.035
112	9-10503	.467	113	9-10504	.036
110	9-10501	.563	111	9-10502	.023
153	9-10545	.366			



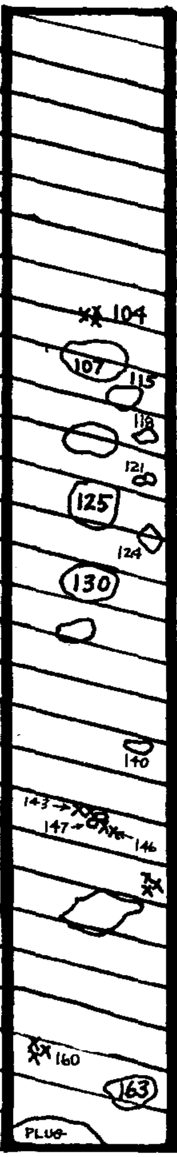
EARLY ALLOCATIONS

RECENT ALLOCATIONS

TABLE 6

10004

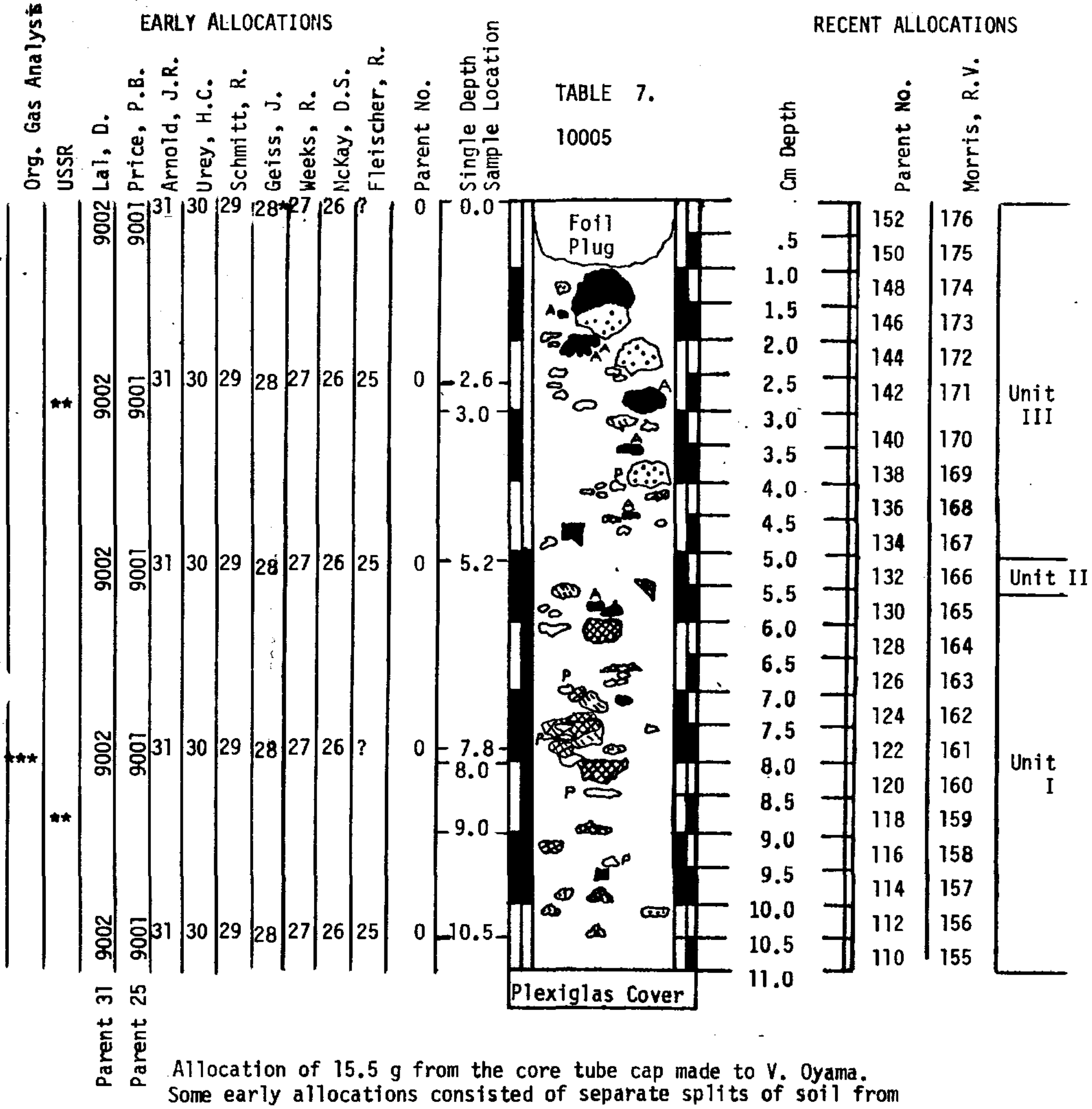
Org. Gas Analysis	Org. Gas Analysis	Lal, D.	Geake, R.	Geake, R.	Reynolds, J.H.	Arnold, J. R.	Wasserburg, G.	Reed, G. W.	Arrhenius, G.	Walker, R.	Parent No.	Single Depth Sample Location	Cm. Depth	Interval Notation	Unit	Parent No.	Morris, R.V.
		9001	32	31	30*	29	28	27	26		0	0.0	.5	0.5- 0.0		90	170
													1.0	1.0- 0.5		92	171
													1.5	1.5- 1.0		94	172
										21	0	2.0	2.0	2.0- 1.5	III	96	173
													2.5	2.5- 2.0		98	174
										22	0	3.0	3.0	3.0- 2.5		100	175
		9001	32	31	30	29	28	27	26		0	3.3	3.5	3.5- 3.0		102	176
													4.0	4.0- 3.5		105	177
													4.5	4.5- 4.0		108	178
													5.0	5.0- 4.5		113	179
2	3											5.5	5.5	5.5- 5.0		116	180
										23	0	6.0	6.0	6.0- 5.5		119	181
		9001	32	31	30	29	28	27	26		0	6.6	6.5	6.5- 6.0		122	182
													7.0	7.0- 6.5		126	183
													7.5	7.5- 7.0	II	128	184
													8.0	8.0- 7.5		131	185
													8.5	8.5- 8.0		134	186
										24	0	9.0	9.0	9.0- 8.5		136	187
													9.5	9.5- 9.0		139	188
		9001	32	31	30	29	28	27	26		0	9.9	10.0	10.0- 9.5		141	189
													10.5	10.5-10.0		144	190
4	5											11.0	11.0	11.0-10.5		148	191
													11.5	11.5-11.0		151	192
										25	0	12.0	12.0	12.0-11.5		153	193
													12.5	12.5-12.0		156	194
		9001	32	31	30	29	28	27	26		0	13.2	13.0	13.0-12.5	I	158	195
													13.5	13.5-13.0		161	196
													14.0	14.0-13.5		164	197



Parent 29

Some early allocations consisted of separate splits of soil from different depths which were given only one sample number for each Principal Investigator.

* This split was designated "top" only, not 0.0 cm.



Allocation of 15.5 g from the core tube cap made to V. Oyama. Some early allocations consisted of separate splits of soil from different depths which were given only one sample number for each Principal Investigator.

* This sample was designated "top" only, not 0.0 cm.

** USSR samples are numbered 34 and 35. Correspondence of sample number to depth is not known.

*** The two Organic Gas Analysis samples taken from 8.0 cm were originally numbered 2 and 3. Shortly afterward they were renumbered 3 and 4. The sample number 4 is presently deleted from the inventory (Apollo 11 PACRAT tape dump).