
SUMMARY - The Apollo 14 and 15 core tubes and the Apollo 15 drill core have been tested in layered lunar soil simulants to assess the influence of core geometry and of method of advance on the quantity and quality of lunar sample recovery. The depth in the returned core samples has been related to the original depth in the lunar surface.

INTRODUCTION - The Apollo 11, 12, 14 and 15 missions have returned to earth eleven core tube samples and one drill sample representing a total of 5578 grams of regolith with well-preserved stratigraphy. The core tubes were driven into the lunar surface to various depths ranging from 25 cm for an Apollo 11 single core tube to 70 cm for an Apollo 15 double core tube. The drill core was first used on Apollo 15 and penetrated to a depth of approximately 236 cm; the six sections returned to earth contained 1344 g of lunar sample. Information concerning the true depth from which a core sample originated is of particular importance to investigators studying gradients of such properties as solar wind composition, cosmic-ray track densities, and thermoluminescence. Depth relationships for the Apollo 11 and 12 core tube samples were presented previously (Carrier, et al., 1971); the present paper reports additional results for the Apollo 14 and 15 core tubes and for the Apollo 15 drill core. The simulant and procedures used in obtaining these results are in general as described in our earlier paper; exceptions are pointed out in applicable sections of the paper.

The shapes and dimensions of the bit ends of the Apollo 14 and 15 core tubes and the Apollo 15 drill core are presented in Fig. 1. The Apollo 15 core tube has a much greater diameter and a thinner wall than did the Apollo 14 core tube. As a result, depth relationships established earlier for the Apollo 12 and 14 core tubes do not hold for the Apollo 15 core tube. The drill core is emplaced by a rotary-percussion action. There has previously been some speculation that this motion would cause considerable disturbance of the sample gathered with the drill. One purpose of our investigation has been to evaluate the degree of disturbance.

RESULTS - 1. The depth relationships for 2 of the 3 Apollo 14 core tube samples have been determined and are shown in Fig. 2. The third sample is too disturbed for analysis. In single core sample #2022 material from a depth inside core of 16 cm came from a depth of nearly 29 cm beneath the lunar surface. In the double core (#2045 and #2044), the bit sample was 40 cm deep as measured on the recovered core but represented material from 58 cm beneath the surface. The penetration depth for the single core indicated in Fig. 2 is within ±1.5 cm and that of the double within ±2 cm because no photographs were taken of the tubes after they had been driven into the lunar surface. In addition,
is an experimental error of $\pm 5\%$ of the depth in the core sample. That is, at a depth of 10 cm in the sample, the depth in the undisturbed soil is accurate to $\pm 0.5$ cm; and at 40 cm, $\pm 2$ cm. Individual layers in the Apollo 14 cores are quite well preserved but the sampling process is such that there is some compaction and some material is pushed ahead of the driven core tube so that the recovery ratio is between 49% and 63%.

2. The three core tube samples of Apollo 15, which comprised five core tube sections and returned to earth 3.3 kilograms of material, provide samples of regolith with well-preserved stratigraphy. The depth-in-core-tube versus true depth in the regolith for these three core tubes is practically one-to-one, as shown in Fig. 3. The sample lengths in the upper halves of the two doubles cannot be determined accurately from the X-radiographs, due to image distortion caused by parallax. This introduces an uncertainty in the sample length of $\pm 1$ cm in the case of the first double and $\pm 0.5$ cm in the case of the second double. When the core tubes are eventually opened, this uncertainty will be eliminated. There is, however, an experimental error of $\pm 3\%$ for the depth in the undisturbed soil for all of the Apollo 15 core tube samples. Sample recovery with this new core tube approaches 100%.

3. Contrary to some predictions, the agitation of the Apollo 15 drill core did not greatly disturb the in situ stratigraphy either in our pre-mission simulations or in actual use on the moon. The depth relationship for the drill core sample is probably very close to one-to-one and the densities in the six stems are close to the in situ values, due to the low porosity of the soil encountered at the drill site. Additional tests are planned.

4. Bulk density calculations for Apollo 15 core tube and drill stem samples reveal a range of values from 1.36 grams/cm$^3$ for the top half of a double core tube to 2.15 grams/cm$^3$ for the bottom section of the six-section drill stem. These values for the returned samples are probably close to in situ densities. Bulk density ranges for the Apollo 12 and 14 core tube samples were 1.74 to 1.98 and 1.60 to 1.79, respectively. More investigative effort is needed to ascertain the reason for the bulk density variations with depth and between sites. Variations in both inter-granular and intra-granular porosity as well as compositional variations could produce the variations in density.

5. The approach applied to the Apollo 14 and 15 core tubes and drill samples to determine depth relationships should be extended to samples from subsequent missions as they become available.

REFERENCE:

CORE SAMPLE DEPTH RELATIONSHIPS
W. David Carrier, III

Figure 1. - Comparison of Apollo Core Bits. Shown are cut-away views giving diameters at various sections. The Apollo 12-14 and 15 core tubes are advanced into the lunar soil by manually pushing and, if necessary, hammering. The Apollo 15 drill core is battery-powered and is advanced by a rotary-percussion action.

Figure 2. - Depth-Relationships for the Apollo 14 Core Tube Samples. These curves were prepared by driving core tubes into a lunar soil simulant containing colored layers. The bit sample for the double was returned to earth in Bag 2N and has been designated LRL Sample No. 14411; the bit sample for the single was returned in Bag 18N and is LRL No. 14414.

Figure 3. - Depth-Relationships for the Apollo 15 Core Tube Samples. The new core tubes induce very little sample disturbance and curves are nearly 1:1.