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LUNAR SOIL POROSITY AND ITS VARIATION AS ESTIMATED FROM FOOTPRINTS AND BOULDER TRACKS

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A number of estimates of lunar soil porosity have been made based on core tube samples obtained during the Apollo 11-15 Missions. The self-recording penetrometer, used during Apollo 15, provided data from which an additional porosity estimate could be made. While some adjustment of core tube porosity values is required to account for disturbance during sampling, the wide range in observed porosities (about 32% to 58%) suggests that lunar soil porosity may best be described in terms of statistical parameters. Unfortunately, however the number of values obtained using core tube samples alone is somewhat too small to yield a statistical variation in porosity--especially at any one landing site.

A statistical study of porosity variations has been made using two sources of lunar data: (1) Astronaut footprints - Apollo Missions 11, 12, 14 and 15 and (2) Boulder tracks - Lunar Orbiter Missions II, III, and V.

Photographic coverage of a large number of footprints is available for each landing site and these footprints have been analyzed as indicators of soil porosity within the top 10 to 20 cm of lunar soil. Through an extensive model testing program using a lunar soil simulant and theoretical analysis of footprints as plateload tests (including an account of the effect of reduced gravity), the correlation shown in Figure 1 was developed between astronaut footprint depth and soil porosity. The analysis of the footprint data was accomplished by comparing the behavior of the actual lunar soil to that of a lunar soil simulant prepared at the University of California, Berkeley. Model tests on other simulants have provided a basis for adjusting the curve in Fig. 1 as needed to account for variation in soil gradation. The correlation in Fig. 1 has been used to estimate the variation in soil porosity at each of the Apollo sites and at different locations within each of the landing areas.

Additional data on the variation of porosity of lunar soil has been obtained from the study of tracks made by rolling boulders. Theoretical analyses of the deformation mechanism associated with rolling boulders have led to the development of a relationship between the boulder track geometry and the mechanical properties of the soil. Sixty-nine lunar boulder tracks from 19 different locations on the moon have been examined using Lunar

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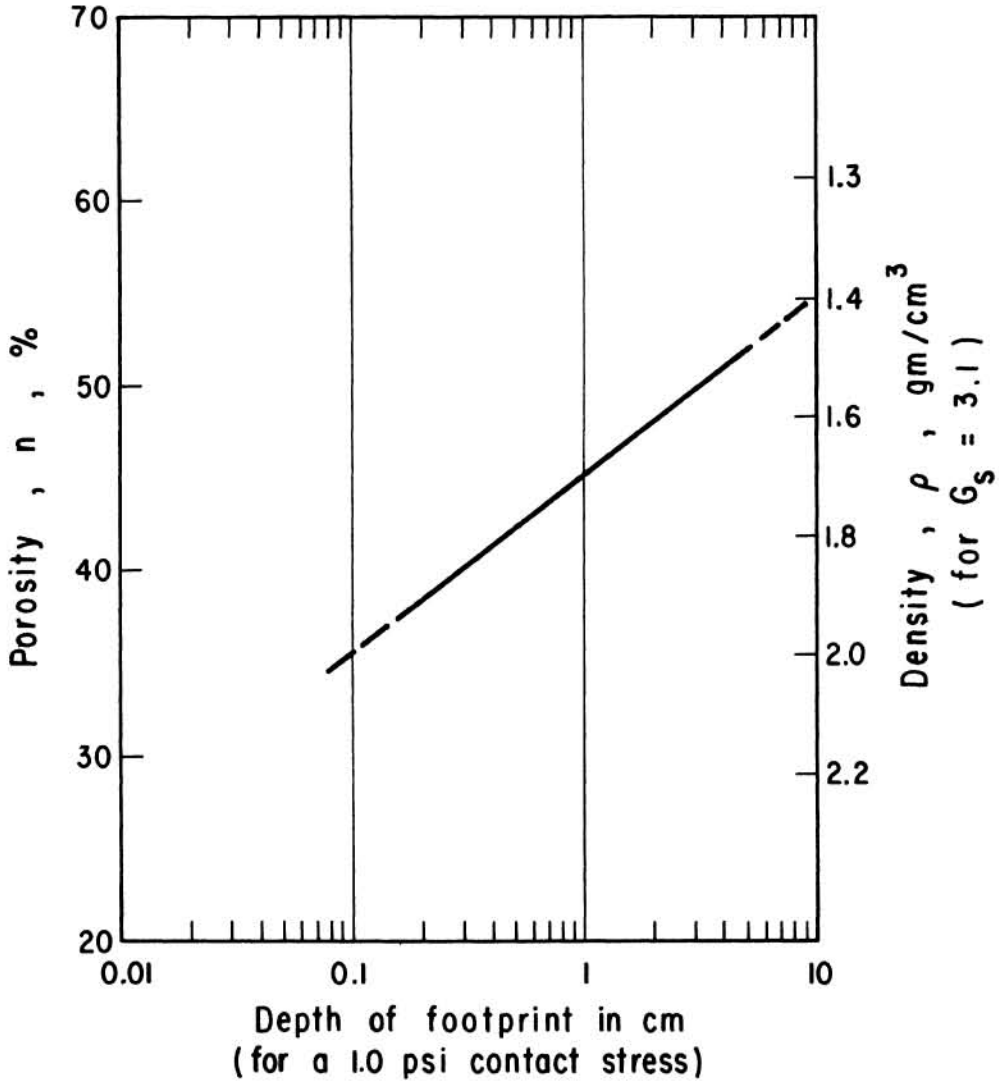

FIG. 1. PREDICTED VARIATION OF FOOTPRINT DEPTH WITH POROSITY.

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Orbiter photography. Measurements of the track widths indicate that some of the boulders sank considerably deeper than others. It is suggested that the lunar surface materials vary from place to place and that the state of compaction as reflected by porosity is probably one of the controlling variables. Using bearing capacity theory, the friction angle of the lunar soil was estimated to range from 19° to 53° with an arithmetic average of 37°. Most of the values were between 24° and 47° and this range suggests a corresponding porosity range of 60 to 35 percent for a specific gravity of 3.1

Porosities from footprints and boulder tracks have been compared with core tube porosities to develop a comprehensive statistical description of the lunar soil porosity.

A direct correlation between the existing porosity and the most probable mode of soil formation (deposition) is still being sought. However, available data showing the wide range in soil porosity indicate that several mechanisms of soil formation may have been operative--often within a relatively small region. The magnitude of local variability in soil porosity suggests that a loosening process (such as impacting meteors) may have often been super-imposed on a soil formation process which produced a soil profile which was initially very dense.