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Lunar Surface Strength Estimate from Orbiter II Photograph

Abstract. *Lunar Orbiter II photographed a 13-meter boulder which has rolled down the inner slope of a 3-kilometer crater leaving a track 6 meters wide. A static-bearing strength of 4 × 10*^{6} *dynes per square centimeter at 75-centimeter depth is estimated from these data if certain assumptions are made.*

A portion of western Mare Tranquillitatis photographed in high resolution mode (Frame H-76, resolution ~ 1 meter) by Lunar Orbiter II (*1*) contains the small crater Sabine D (23°40′W; 1°20′N). The crater is about 3 km in diameter and has no ray pattern or ejecta field; it has only a low rim rising above the mare surface.

Around the rim crest and on the inner portions of the rim, clusters of rocks as large as 15 m in diameter are exposed (Fig. 1). Some appear half buried, while others appear to rest almost completely on top of the surface. A few rocks are seen scattered about the inner slope of the crater, and many of these appear also to rest on the surface.

During early screening of photographs at the Jet Propulsion Laboratory, it was noted that one of these rocks appeared to have a track leading to the rock (*A′*) from a point higher up the slope (*A*). It was suggested that the rock had become dislodged and had rolled down the inner slope. The boulder, approximately 13 m in diameter, apparently traveled about 650 m along a line roughly radial to the crater center.

The portion of crater wall down which the rock rolled has a slope of ~ 25° at *A* (which decreases to *A′*) as estimated from considerations of Sun angle (27.4° from horizontal) and crater depth and diameter.

The track left by the boulder varies in width from 5 to 8 m (average 6 m) and passes through a 15-m crater (*B*). A 3-m rock lies in the track at *C*. Some portions of the track are missing, suggesting three possible conditions: (i) the boulder bounded down the slope and left the surface at certain spots, (ii) subsequent processes have erased portions of the track, or (iii) the surface at certain points is so strong that the boulder made no imprint. The boulder has come to rest on the downslope rim of a 10-m crater; the presence of the crater coupled with the decreasing slope apparently prevented the boulder from rolling further.

An estimate of the static-bearing strength of the inner slope of Sabine D along *A-A′* can be obtained if cer-

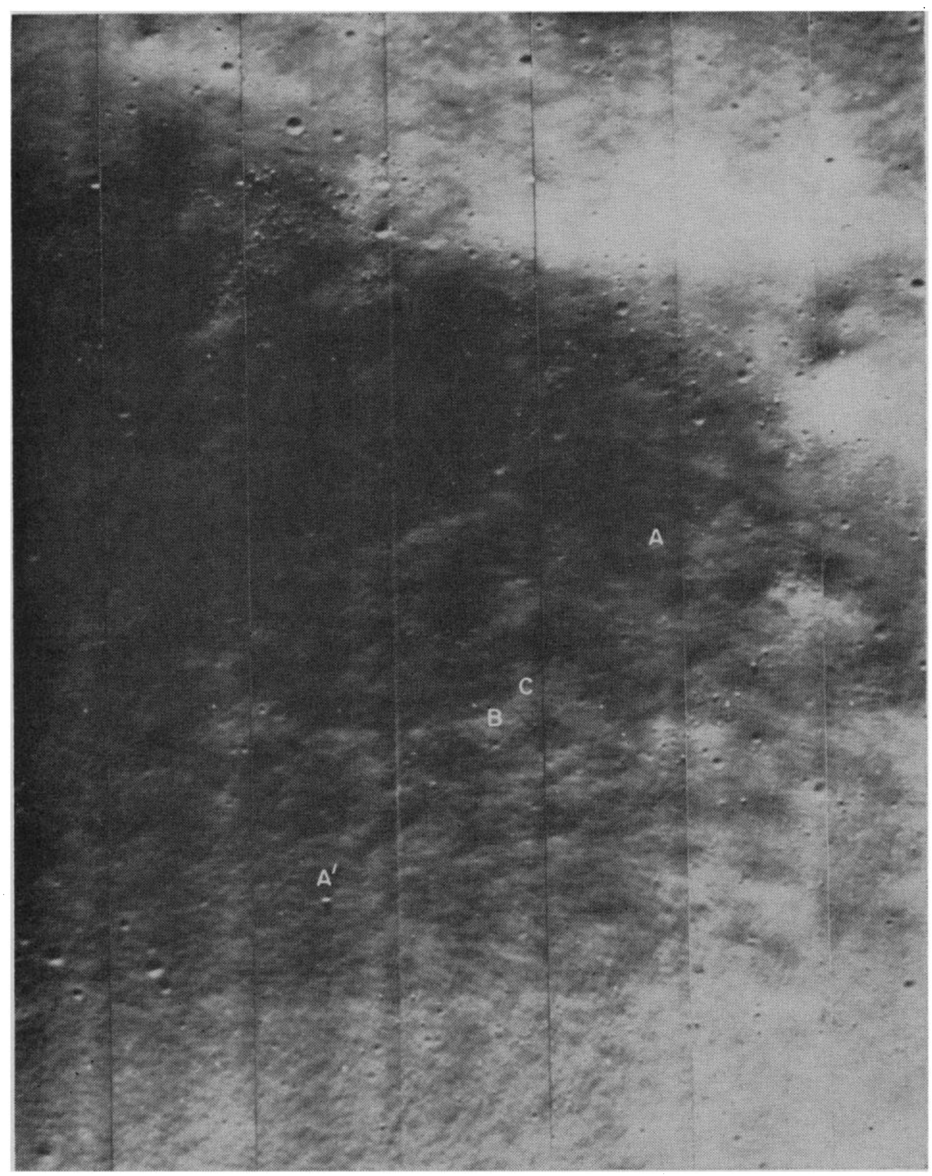

Fig. 1. Portion of Lunar Orbiter II frame H-76.

tain assumptions are made. Assume (i) that the boulder is spherical with radius $r = 6.5$ m, (ii) that it has an average density $\rho = 3.0$ g/cm^3, and (iii) that the average width w of the track (6 m) approximates the diameter of a semicircle equal to the projected area supporting the boulder. The use of an average width of the track gives a reasonable estimate, since the moving boulder probably left a larger imprint than would be the case if it were set down gently on the surface. Measurements of boulder size and width of track to the nearest meter were made from a 3× enlargement of Fig. 1.

The ratio of the mass of the boulder to the area of its semicircular base of support is

$$(4/3)\pi\, r^3\, \rho / \frac{\pi}{2} \cdot \left(\frac{w}{2}\right)^2 = 2.4 \times 10^4 \text{ g/cm}^2$$

Under lunar gravity (162 cm/sec^2) the corresponding effective bearing strength is 4×10^6 dyne/cm^2.

Jaffe (*2*), in an analysis based on Earth, Ranger, and Surveyor I observations, finds that the static-bearing capacity of the lunar maria with no sinkage is 4×10^5 dyne/cm^2 and that it increases at a rate of 2×10^4 dyne/cm^3 for some undetermined depth.

A calculation of the weight necessary to make the observed semicircular indentation in a material with this bearing strength yields 1.6×10^{11} dyne, in good agreement with the calculated boulder weight of 1.8×10^{11} dyne. The results suggest, at least roughly, that Jaffe's expression for the bearing strength in this area is valid up to 75 cm. The measurement of Sabine D is valuable because it can be used as a lower limit of bearing strength over a length of 650 m as opposed to the small-footpad type of measurement from a landed spacecraft. Also, a measurement in western Mare Tranquillitatis is important because this area is a potential landing site for both Surveyor and Apollo missions to the Moon.

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Strontium-90 Deposition in New York City

Abstract. *Measurements of strontium-90 deposited in New York City over the past 12 years make for broader understanding of the fallout phenomenon. The data indicate a stratospheric half-residence time of 8 to 10 months. The seasonal oscillation of strontium-90 fallout is very symmetrical and consistent from year to year and completely independent of the timing and magnitude of nuclear tests. The predicted fallout of strontium-90 in 1970 is less than 1 percent of that during the peak year 1963.*

Twelve-year accumulation of ^{90}Sr data from the New York City collection site (*1*) suggests some important characteristics of fallout. The stratospheric half-residence time of about 10 months (*2*) is corroborated. Normalization of monthly data leads to clear definition of seasonal variation independent of nuclear detonations. By mid-1966 the peak of deposition of ^{90}Sr on Earth's surface passed, and radioactive decay now exceeds fallout; deposition continues to decrease and in 1970 will amount to less than 1 percent of that in 1963.

The New York City station collects fallout monthly with steep-walled stainless steel pots and plastic-funnel, ion-exchange column collectors (*3*). Special large-area collections also are made, and from time to time experimental collection devices are tested. Results of analyses of these collections are reported quarterly (*4*), and interpretive reports are published periodically (*5–7*).

In calculation of cumulative deposit, it is assumed that deposition before 1954 was negligibly small. Analyses of soil samples provide the only direct measurement of cumulative fallout; six such samples from a selected site have yielded values for comparison with the values calculated from the monthly collections (Fig. 1) (*8, 9*); all six are lower in ^{90}Sr content.

The soils were analyzed by leaching directly with HCl. Another procedure, considered to be more accurate, incorporates complete fusion with sodium carbonate before the leach. In a recent study (*10*) with soils collected in 1963, values yielded by straight leaching averaged 90.6 percent of those obtained when fusion was incorporated. The average relation between soil deposit and cumulative monthly deposit (90.7 percent) is in remarkably good agreement. It follows, therefore, that the summing of results from continuously exposed collectors satisfactorily approximates the integrated value derived from analysis of fused soil, and that, at least in New York City, standard collectors of fallout do in fact collect everything. This conclusion may be applicable only to areas of moderate or greater annual precipitation, since dry fallout may constitute a high percentage of total deposition in regions of low rainfall and may not be collected as efficiently as is rain.

The solid curve in Fig. 1 indicates that since about mid-1965 the rate of monthly fallout closely approximates the rate of monthly decay of the deposit. The situation was similar during the first nuclear-test moratorium (1959–61); the deposit never measurably decreased, although during the latter half of 1960 and the first few months of 1961 this condition was closely approached. The current deposit of about 82 mc/km^2 is decaying at about 0.16 mc/month, a rate substantially higher than that anticipated in fallout subsequent to the middle of 1966. Thus, barring any large injections of ^{90}Sr into the atmosphere, the cumulative deposit should begin visibly to decrease; by the end of 1967 a little less than 81 mc/km^2 is expected for New York City.

In contrast with the general features shown by the cumulative deposit, the monthly rate of fallout reveals more dynamic characteristics such as the stratospheric half-residence time and seasonal variations in deposition. Figure 2 shows the monthly fallout in New York City during the last 12 years.

The effects on the deposition rate of the two periods of cessation of atmospheric tests may be related to stratospheric fallout processes. After 1 year, the initial moratorium, from November 1958, very obviously affected deposition of ^{90}Sr. The test ban now in effect since the end of 1962 caused a much less rapid decrease. From 1959 to 1960, annual fallout decreased by more than a factor of 5, while during the same relative period of the current cessation (1963 to 1964) the decrease was less than a factor of 2; between 1964 and 1965 it was by a little less than a factor of 3, and probably did not differ between 1965 and 1966.

These fallout values may be used to infer the stratospheric half-residence