were then stressed for the first time. Differences in latency to the air from the same rat when stressed and unstressed were comparable to differences found when one rat was stressed and another unstressed. This observation would also suggest that the discriminable odor did not derive from a chronic stress state, but arose immediately from a given stressing.

Neither can the discrimination be reasonably attributed to greater familiarity with odors of the unstressed rats as a group. Air sampled from unstressed animals not previously used did not produce the long latencies associated with S-air. The possibility that a cue might derive from the living cages from which the stimulus air was sampled, was tested by placing U- and S-stimulus rats in completely new cages for 30 of the 100 test trials. Results were indistinguishable from those obtained when air samples were taken from the living cages.

The major finding of this paper that rats can respond differentially to odors of stressed and unstressed rats suggests the need for instituting experimental controls in those studies in which odor from a stressed animal might affect behavior of nearby animals. Previously such controls were not thought necessary. We are presently seeking to locate the odor source in the animal's body to assist us in determining whether the material has pheromonal activity and in its eventual chemical analysis.

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30 April 1968

Surveyor V Landing: the Effect of Slope on Bearing Capacity

Preliminary Surveyor V results (*1*) indicate that the mechanical properties of the lunar surface material at the Surveyor V landing site are generally similar to those determined for the Surveyor I site. The static bearing capacity, however, was reported to be "somewhat lower" than the range of values reported previously. It is to this statement that the authors direct their comments.

An important difference between the Surveyor I and V landings is that the former took place on a virtually flat surface [1.7° ± 0.5° (*2*)], whereas the latter was on a crater slope of approximately 20 degrees. Although there are a number of theories concerning the stability of slopes and foundations embedded in a slope, to our knowledge the bearing strength of a slope loaded over a finite area on the surface has not been treated theoretically. Our theory (*3*) is based on the Prandtl theory of plastic equilibrium. Figure 1 shows the three shear zones which, according to Prandtl's theory, exist at failure in an ideal soil in contact with a smooth footing on a level surface.

The following expression for the ultimate bearing capacity of a level soil loaded over a finite area has been developed from the Prandtl solution by Terzaghi (*4*):

$$q_u = K_1 c N_c + \frac{1}{2} K_2 \gamma_1 b N_\gamma + K_3 \gamma_2 t N_q \quad (1)$$

where q_u is the ultimate bearing strength; K_1,K_2,K_3, the footing geometry coefficients; c, the value of unit

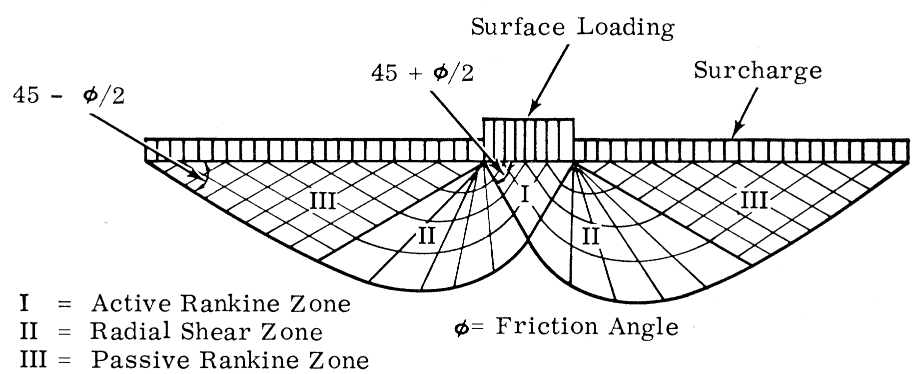

Fig. 1. Slip line field for surface loading and weightless soil according to Prandtl.

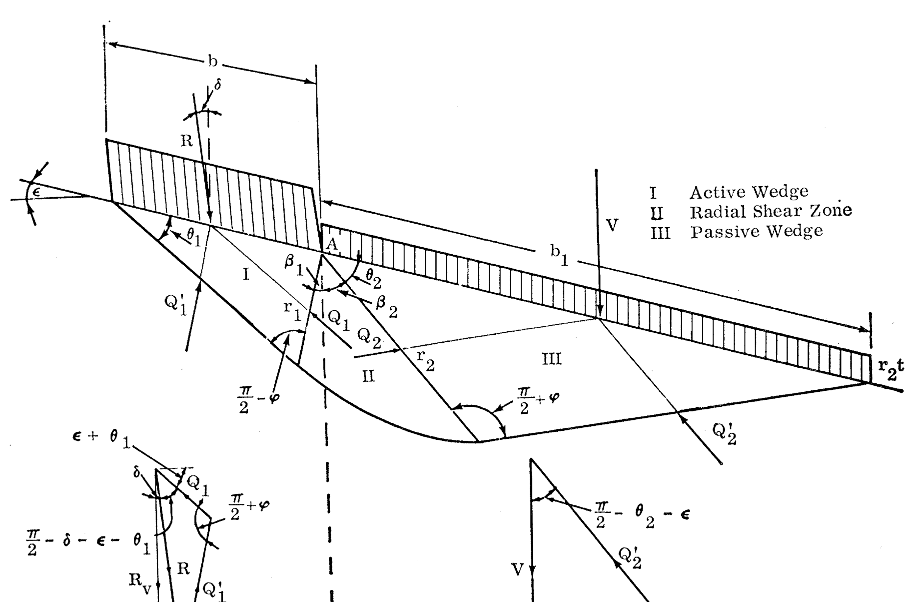

Fig. 2. Assumed shear zone geometry for sloping surface.

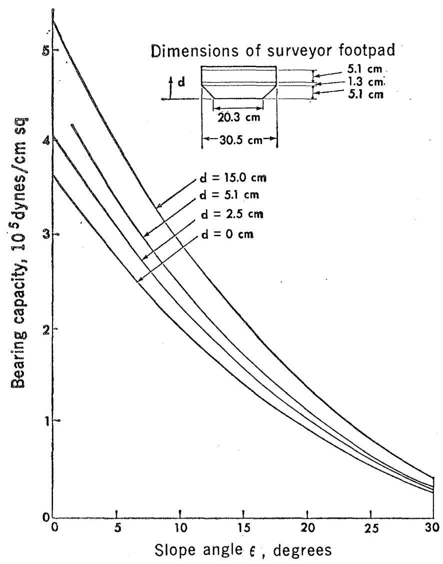

Fig. 3. Theoretical results showing decrease of bearing capacity with increase of slope for various depths of surveyor footpad penetration.

cohesion; b, the width of footing base; t, the depth of surcharge; γ_1, the unit weight of material beneath footing; γ_2, the unit weight of surcharge material; and N_c,$N\gamma$,N_q, the bearing capacity factors.

In our theory, the geometry of the zone of plastic equilibrium is analogous to that of Prandtl's solution, if we take into account the modifications due to the sloping surface as shown in Fig. 2. For even a slight slope, critical plastic equilibrium exists only in the downhill radial shear and passive Rankine zones. Figure 2 also illustrates the internal system of forces resulting from an externally applied load (R) and a surcharge load (V). The N_q bearing capacity factor is determined from the equilibrium of this force system acting on the radial shear zone; the N_c factor is directly related to the N_q factor through the cotangent of the friction angle. If, instead of the surcharge load, the weight of the individual zones is considered as acting on the geometric configuration shown in Fig. 2, a different system of forces results. The $N\gamma$ bearing capacity factor is determined by calculating the moment equilibrium about the pole of the logarithmic spiral (A) of this force system acting on the radial shear zone. It is evident that the bearing capacity factors obtained in this way depend on the strength properties of the soil alone; they account only indirectly for grain shape and size. These factors were used in the Terzaghi equation (Eq. 1) to evaluate the effect of the slope on the bearing capacity of the Surveyor V landing site (Fig. 3).

For all soil parameters constant and consistent with the Surveyor I values, it was found that, in going from a level surface to a slope of approximately 17 degrees, the static bearing capacity decreases from 4×10^5 dyne/cm^2, a value in the range previously determined for the Surveyor I landing (*2*), to 1.4×10^5 dyne/cm^2, a value in the range suggested for the Surveyor V landing (*5*).

If the decrease in static bearing capacity of the Surveyor V landing is due to the fact that the vehicle landed on a 20-degree slope, as both our theory and the mission data suggest, then it may be concluded that the strength properties of the surface material at both sites are almost identical.

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14 April 1968

Mercury's Permanent Thermal Bulges

Liu (*1*) has argued that the capture of Mercury's rotation period into a 3:2 resonance lock with its orbital period (*2*) was "affected by thermal expansion" and, further, that "thermal bulges on Mercury's surface contribute significantly to the dynamic stabilization of the planet's rotation." We find both arguments faulty. The thermal bulges considered by Liu cannot grow until *after* capture takes place: The systematic asymmetrical heating of the surface can persist only for resonance rotation (that is, only well after the apparent circulational motion at successive perihelia has been converted to a librational motion). Only then are the "faces" that Mercury can present to Sun at perihelion restricted to two antipodal ones which can undergo relatively larger thermal expansions because of their greater intercepted insolation. More important, the contribution of the two thermal bulges to the fractional difference $[(B-A)/C]$ in Mercury's principal equatorial moments of inertia is negligible and therefore has no appreciable effect on the dynamics of rotation. Liu's error is attributable to his comparison of a thermally produced $(B-A)/C$ with the minimum value of that fractional difference—about 10^{-10}—for which a resonance lock is possible (*3, 4*). Although perhaps possible, the probability of capture for such a value of $(B-A)/C$ is vanishingly small. The capture probability (*4*) increases approximately with the square root of $(B-A)/C$ (*5*) and is less than 0.1 even for $[(B-A)/C] \approx 10^{-5}$ which is five orders of magnitude larger than the value considered by Liu. According to Liu's calculations, the residence time required in the resonance state to produce a thermal contribution to $(B-A)/C$ of 10^{-10}, is only 6×10^4 years. But the thermal contribution increases only linearly with the residence time. In order for the thermal-bulge effect on $(B-A)/C$ to be even comparable to 10^{-5} would require a residence time longer than the 5×10^9 year estimated age of the solar system.

We conclude that the relatively large value of $(B-A)/C$ required for there to have been a nonnegligible probability that Mercury's spin be captured in the 3 : 2 resonance (*4, 5*) precludes a thermal bulge from playing a significant dynamical role.

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