a good indication of the order of the penetration and its relative magnitudes in the different soils.

It would seem, therefore, from the penetration analysis, that the successful landing and operation of Luna 9 (penetration less than 30 cm) occurred on a surface that was harder than that represented by an incompressible cohesive soil having a cohesive shearing strength of, say, 5×10^4 dyne/cm^2, corresponding to a bearing capacity of 2 to 3×10^5 dyne/cm^2 and a mass bearing capacity of about 1000 g/cm^2. This value is consistent with that given by the energy approach. (The pressure exerted by an astronaut standing on the lunar surface ranges from 3 to 7×10^4 dyne/cm^2; supported mass, 200 to 500 g/cm^2.)

It must be noted, however, that a shock-absorbing system was used to cushion the capsule impact (*3, 6*); accordingly, some of the energy did not go into the soil. Moreover, the velocity vector at impact was not necessarily vertical. For both these reasons the dynamic treatments used are not conservative. Thus the bearing capacity may be less than the 1 to 2×10^5 dyne/cm^2 given by the dynamic analyses, and only the value of 5×10^3 dyne/cm^2, derived from static considerations, seems a truly safe lower bound; the latter value (corresponding to 30 g/cm^2 mass bearing capacity) is no higher than one derived from Ranger-7 data (*10*).

The bearing capacities of hard terrestrial rocks are of the order of 10^9 dyne/cm^2. Available information on the Luna 9 landing thus provides no basis for statements that the lunar surface is hard rock; on the contrary, the landing statics and dynamics are not inconsistent with the properties expected under lunar conditions for highly porous fairy-castle structures (*11*).

We may point out that more information on the mechanical properties of lunar-surface material will be obtained if an upper bound can be established; this would require observation of surface displacement or yielding under the application of a known force under known conditions.

This report should not be taken to advocate the view that the lunar surface consists of unsintered fine particles having low cohesion; more probably the particles show high cohesion (*11*) and need not be fine (*12*). It is not evident, however, that the successful landing of Luna 9 clarifies these questions.

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Atmospheric Gases and Particulates in Panama

Abstract. *The concentrations of trace gases in tropical air from samples taken on the Isthmus of Panama are compared with those reported by others. The role of a tropical land mass as a sink or source of atmospheric components is discussed.*

The National Center for Atmospheric Research and the Tropic Test Center of the U.S. Army Test and Evaluation Command have undertaken a cooperative study of the atmosphere of the Isthmus of Panama to characterize the sinks and sources for trace atmospheric components in the tropics. The results obtained so far are sufficiently unexpected that we are reporting our findings. While the total number of measurements is limited, they are sufficiently spread in time, and the range is sufficiently small, that it seems unlikely that further data would qualitatively change our conclusions.

We have taken samples in Panama during three periods, each about 2 weeks in length. One period was during the rainy season, in November 1965, and the other two were during the dry season, in February 1965 and the same month in 1966.

The orientation of the Canal Zone and the Isthmus of Panama is shown in Fig. 1. The predominant wind direction across the Isthmus is northerly. This wind stems from the Bermuda high, and its direction shifts between the dry and rainy seasons, reflecting the shift of the Bermuda high over the Caribbean.

There were three major sampling sites. The first was at Fort Sherman, on the Caribbean (northern) side of the Isthmus. All samples from this area were collected a short distance from the shore and thus represent tropical maritime air typical of the Caribbean. The second sampling site was a meteorological tower in Albrook Forest near the Pacific (Bay of Panama) side of the Isthmus, a semideciduous tropical rain forest. The tower is about 50 m high, permitting sampling both above and below the forest canopy. The third sampling site was on the north side of the Pearl Islands Archipelago in the Bay of Panama. Typical air trajectories to this site have traversed the Isthmus and then a short distance over the ocean surface. They do not cross the Canal Zone, and thus are not influenced by the human activity of the Zone.

A few samples were collected at a subsidiary site on Madden Ridge Road. This site is on the Continental Divide, in the path of Caribbean air which has traversed 50 km of virgin forest.

Although the samples collected thus far are considered preliminary, some reliable estimates of concentrations of gases and particles in the atmosphere have been obtained. Junge (*1*) summarizes previous measurements and gives a range of probable concentrations in the atmosphere. These concentrations are admittedly uncertain owing to the paucity of previous measurements, and it is interesting to compare Junge's data (converted approximately into consistent units) with our estimates for various gases and particulates.

Junge cites the few formaldehyde measurements which have been made, and gives a probable ground-level concentration range from 0 to 10 ppb (parts per 10^9). He points out that these measurements were made in Europe and that the formaldehyde may be of anthropogenic origin. We did not measure formaldehyde specifically, but used the method of Hauser and Cummins (*2*) to estimate total aliphatic aldehydes. We found a mean concentration of 1.1 ppb as formaldehyde (range from <0.2 to 2.7 ppb). No statistically significant differences were found between samples collected during the rainy and dry seasons, or between those collected on the Pacific and Caribbean sides.

These results were corroborated by use of a specific and ultrasensitive method for particulate formaldehyde developed by Lodge and Frank (*3*). Although this test is qualitative in character, it showed the presence of formaldehyde at all stations including the Caribbean coast.

Junge cites ground-level concentrations of nitrogen dioxide as 0 to 3 ppb. Using a specific method for nitrogen dioxide (*4*), we found that our results corroborated Junge's data. During the dry season, the maritime air from the Caribbean had a mean concentration of 0.9 ppb (range from <0.5 to 1.4 ppb). During the rainy season, with mixed sunshine and thunderstorm activity, the mean concentration was 3.6 ppb (range from 2.6 to 5.0 ppb). Our samples from the forest site gave a mean concentration of 1.3 ppb (range from <0.5 to 2.7) below the forest roof, and 2.2 ppb (range from 1.2 to 4.0) above the forest. Three samples collected 20 miles out in the Bay of Panama (Pearl Islands site) gave a mean concentration of 1.6 ppb (range from 1.5 to 1.7).

By a method involving oxidation to nitrogen dioxide (*5*), we found concentrations of nitric oxide ranging up to 6 ppb. Although the data are too few for an average to be meaningful, they appear to show a somewhat higher concentration of nitric oxide than of nitrogen dioxide.

The method used to determine ammonia (*6*) has not yet been validated for part-per-billion air samples. However, the data obtained appear to lie somewhat above the range given by Junge (0 to 20 ppb). The lowest concentrations found, including those in the Caribbean samples, were higher than 20 ppb.

In one isolated sample on the Caribbean coast the concentration of hydrogen sulfide was 4 ppb. All other samples showed only traces or less than the minimum detectable amount of 1 ppb. Although the method (*7*) requires additional checking, corroborative evidence indicates that the ground-level range of 2 to 20 ppb given by Junge is too high for tropic regions.

Sulfur dioxide concentrations were measured by an adaptation of the West-Gaeke method (*8*). The values found ranged from <1 to 5 ppb, with no general pattern being clearly evident. This contrasts with Junge's worldwide ground-level concentrations of 0 to 20 ppb.

Despite the apparent availability of free ammonia in the atmosphere, sulfuric acid droplets were found to be present at all sites, as shown by a specific technique developed by Lodge and Frank (*9*). The Caribbean coast samples showed a minimum number of droplets, but appreciable quantities of ammonium sulfate. The Madden Ridge Road samples showed the highest levels of droplets. In accordance with other findings elsewhere (*10*) total sulfate remained fairly constant, but showed a progression from ammonium sulfate to sulfuric acid with greater distance inland and greater altitude.

We expected to find that the tropic rain forest was a major source of atmospheric hydrogen sulfide and other reduced chemical species. However, extremely low levels of hydrogen sulfide were found both under the canopy in the forest environment and above the canopy in the ambient atmosphere. We conclude that tropical land is not usually a source of atmospheric hydrogen sulfide. Further, all of the data collected indicate that the atmospheric constituents associated with tropical forest are characterized by partially or completely oxidized chemical species. We postulate that reduced species formed by anaerobic processes will only be found, except where localized extreme conditions exist, well below ground surface, and that they are partially oxidized in the upper soil strata, presumably by aerobic bacteria.

Although the precise results of ammonia measurements are questionable, their relative values are probably meaningful. The values tended to be high for fresh Caribbean air, intermediate beneath the forest canopy and low above the forest canopy. Electron microscopy showed that the Caribbean aerosols are characterized by the presence of ammonium sulfate and the virtual absence

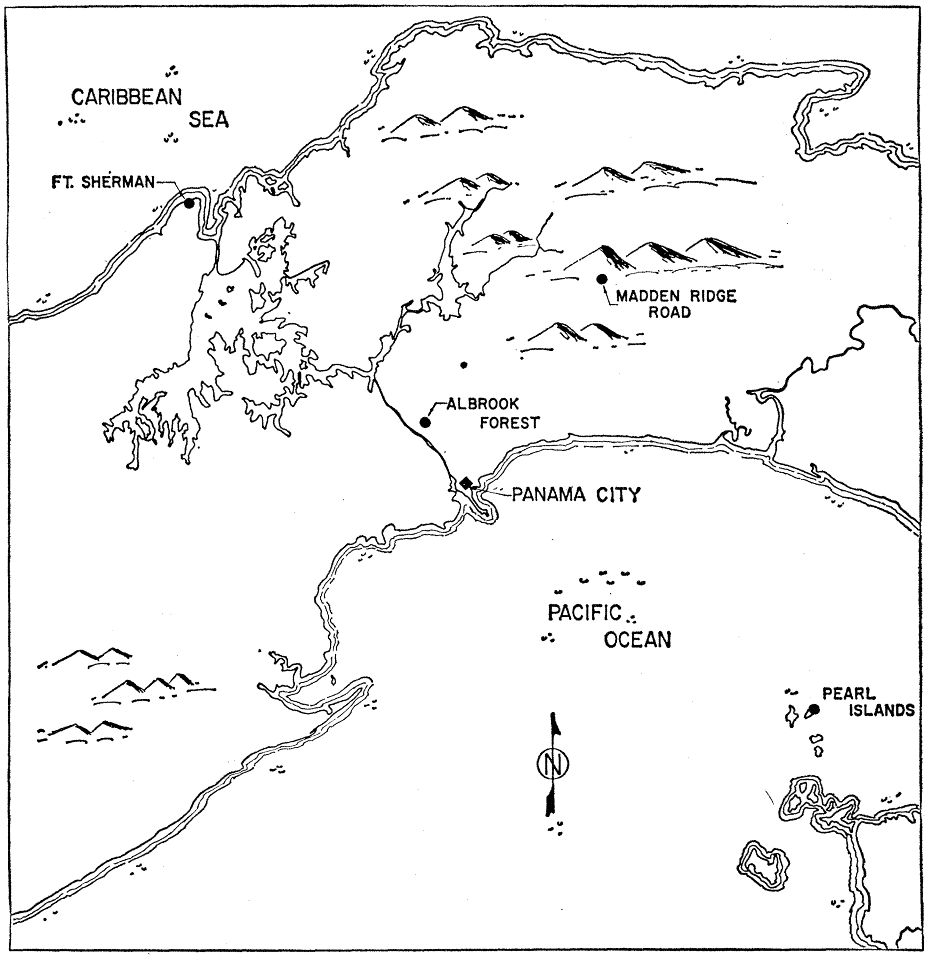

Fig. 1. Sampling sites in Panama.

of sulfuric acid. This seems to corroborate previous suggestions that the Atlantic is an ammonia source. On the other hand, samples from all other sites showed that sulfuric acid was present in substantial amounts as a characteristic aerosol.

If all the sulfate found in unpolluted tropospheric air by a number of investigators is free sulfuric acid, the resulting sink for ammonia cannot exceed 10^{-13} g cm^{-3}. Ambient ammonia concentrations, whether from Junge's data or from our data, are at least two or three orders of magnitude greater than that required to convert all sulfuric acid to ammonium sulfate. The progressive decrease of ammonium sulfate and the increase of sulfuric acid droplets over the land indicates that another sink for ammonia must exist, and that the replenishment rate of sulfuric acid must exceed the rate of the reaction between sulfuric acid and ammonia for these concentrations.

The apparent enrichment of nitrogen dioxide levels over the land and the rapid decrease to a lower level over the sea indicate that processes may occur on land which oxidize ammonia. Our data suggest that nitric oxide could be the oxidation product, and that nitrogen dioxide is a transient product of further oxidative reactions.

To summarize, we present the hypotheses that a forested tropic land mass is not a source of atmospheric ammonia or hydrogen sulfide because these are oxidized in the forest environment; that the land mass is a source of atmospheric oxides of nitrogen; that sulfuric acid aerosol is an atmospheric sink for ammonia over the Atlantic (an atmospheric ammonia source); and that oxidation is a major ammonia sink over land and sulfuric acid aerosol is not.

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Vacuum Welding of Olivine

Abtstract. *Welding of olivine was demonstrated by grinding it in a ball mill in an atmosphere of about 2 × 10^{-7} torr. Most of the sample adhered strongly to the container and grinding balls although adhesion in air is only slight. Similar adhesion should be expected on the lunar surface and may account for the roughness needed to explain the optical properties of the moon and the detail of the Luna 9 photographs.*

An experiment demonstrated the substantial self-welding to be expected when dusts (powdered solids) come in contact under conditions such that their surfaces are at least partially free from gas films (*1*). This process could be expected to occur on the lunar surface when debris from a meteorite collision returns to the surface.

A 10-g sample of coarsely ground (147 to 177 μ) olivine (*2*) was placed in a 10-cm-diameter stainless steel container with 57 18-mm irregular porcelain balls (Fig. 2*b*); the container was rotated about a nearly horizontal axis at about 95 rev/min in the manner of a ball mill. With the container at atmospheric pressure, a run of 22.5 hours produced substantial grinding of the olivine sample. There was some difficulty in removing the material from the container; it adhered weakly to the surface and to the balls; it was mostly removed from the balls by vigorous brushing with a camel-hair brush. To remove the material from the interior of the container, about 20 g of (about 20) freshly broken glass fragments were placed inside and moved over the interior by slow rotation of the tank in various directions by hand; this procedure removed most of the sample, which was sieved (Table 1).

A similar sample was then ground with the container evacuated. The vacuum equipment consisted of a 5-liter/sec sputter-ion pump sealed to the container with a copper gasket. Container, pump, and pump magnet were mounted as a unit in a cradle, with the high-voltage lead of the pump protruding through the axial bearing so that high voltage could be applied during the grinding operation (Fig. 1). The system and sample at room temperature were evacuated overnight by a mechanical pump. The ion pump was then started and the valve to the mechanical pump was closed. The container was heated to 100°C for 18 hours and a considerable amount of gas (presumably mainly water) was evolved. The temperature of the sample was then raised to 200°C for an additional 6.5 hours, with further evolution of much less gas. When the heater was removed the pressure in the system fell rapidly; after 15 hours it was well below 10^{-8} torr.

The container at room temperature was then rotated slowly, with bursts of pressure to as great as 10^{-6} torr; mean pressure was about 2 × 10^{-7} torr. When the system was operated at full rotation speed, the pressure rose to about 7 to 8 × 10^{-7} torr, with the pressure bursts rapidly diminishing. At the end of the 22.5 hours of grinding the pressure was about 2 ×10^{-7} torr; it then fell to 1 × 10^{-7} torr within 2 minutes and to 5 × 10^{-8} torr within 20 minutes.

The container was then opened to the atmosphere and the porcelain balls were extracted. A thick coating of olivine was bound to the balls and unattached olivine was negligible (*3*). Very vigorous brushing of the balls yielded a total of 2.04 g of sample powder, which was sieved (Table 1). Rotation within the container of a 20-g sample of about 20 glass fragments removed a negligible amount of olivine.

The container was then halved with a tubing cutter. Olivine was found uniformly attached to the surface, except for a narrow ring at the joint between end cap and wall (where a ball could not touch the surface of the container) and a ring around the pump tube, which also could not be reached by the balls because of the slight tilt of