$K_4Fe(CN)_6$ or α,α'-dipyridyl in thioglycollate.

Extracts of the lunar sample were prepared and analyzed by atomic absorption spectrophotometry. The results (Table 1) showed that minerals containing Fe—the most abundant of the ions analyzed—were not solubilized by water alone, but required H^+ or Na^+. The results are consistent with cation exchange phenomena. The spot-test results obtained on the Type II artifacts support the cation exchange results. The reason for the equivocal response by the type I artifacts to the iron reagents is not known, but it may be that the brown color arising around the particle is an iron mineral at concentrations barely detectable by the two reagents. We believe that the higher concentrations of Fe in some lunar particles may well produce the lobular structures of the type II artifacts.

We conclude for this sample of the moon that there was no viable life present. Our conclusion agrees with that of the biological quarantine team at the Manned Spacecraft Center, Houston.

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References and Notes

1. See A. I. Oparin in "The Origin and Initial Development of Life," *NASA Tech. Trans. NASA TTF-488* (1966), pp. 20–22.
2. C. Sagan, "Organic Matter and the Moon," *Nat. Acad. Sci.–Nat. Res. Counc. Publ. 757* (1961), pp. 13, 14.
3. The medium contained 1.0 g/liter of glycerol, sodium salts of lactate, pyruvate, and acetate, methanol, ethanol, K_2HPO_4, KNO_3, and $(NH_4)_2SO_4$; 0.2 g/liter of 18 DL-amino acids, glycine, 4-hydroxy-L-proline, β-alanine; 0.01 g/liter of seven purines and pyrimidines; and trace quantities of 16 vitamins; *p*H adjusted to 3.0 with HCl.
4. Same as described in (*3*), but with *p*H 7.0.
5. Same as described in (*3*), but with *p*H adjusted to 10–11 with NaOH.
6. Ingredients same as (*4*), but at 1/10 concentration.
7. Synthetic sea salt mixture (Aquarium Systems, Inc., Wickliffe, Ohio).
8. Same as (*7*), supplemented with 1.0 g/liter each of K_2HPO_4, KNO_3, and $(NH_4)_2SO_4$.
9. Same as (*8*), but with *p*H adjusted to 3.0 with H_2SO_4. After the agar solidified, 0.5 ml of a solution containing elemental sulfur (100 g) dissolved in Na_2S solution (180 g of $Na_2S \cdot 9H_2O$ per 330 ml of H_2O) was spread on the surface; elemental sulfur then precipitated.
10. Same as (*8*), supplemented with 10 g of formose sugars per liter. (Prepared by Dr. J. Shapira, NASA SP-134, 1967).
11. Contained 500 ml/liter of a solution prepared by the reaction of CH_4, NH_3, and water vapor in a spark discharge apparatus [J. Rabinowitz, F. Woeller, J. Flores, R. Krebsbach, *Nature* **224**, 796 (1969)] consuming 90 watt-hours. The solution contained (in grams per liter) organic carbon, 2.3; cyanide carbon, 1.3; NH_3-N, 7.3; other N, 1.9.
12. The sieve distributions of the 50-g sample (10089,1) were as follows: 16/35, 6.7%; 35/60, 6.3%; 60/115, 13.1%; 115/250, 15.8%; 250/325, 12.4%; and < 325, 45.7%. The sample color closely matched Munsell color index 5YR.
13. F. Feigl, *Spot Tests in Inorganic Analysis* (Elsevier, Amsterdam, 5th English ed., 1958); Fe (prussian blue reaction, p. 161; α,α'-dipyridyl reaction, p. 162), Cr (diphenylcarbazide reaction, p. 168). Mn (benzidine blue reaction, p. 175), Ti (chromotropic acid reaction, p. 197).
14. Lunar Sample Preliminary Examination Team, *Science* **165**, 1211 (1969).
15. We thank B. J. Berdahl, C. W. Boylen, G. C. Carle, J. O. Coleman, C. C. Davis, G. Hamilton, D. A. Jermany, P. J. Kirk, M. E. Lehwalt, A. K. Miyamoto, E. F. Munoz, G. E. Pollock, B. J. Tyson, and O. Whitfield for assistance; E. L. Craig and C. W. Boylen for photography, and G. E. Peterson and his staff for design and construction of the facility.

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Micropaleontological Study of Lunar Material

Abstract. *Samples of the lunar dust, rock chips, and thin sections of rocks from Tranquillity Base have been examined by use of white light and electron optics. In transmitted and in dark- and bright-field incident light and in the scanning electron beam the material reveals no indication of biological morphology. It is inferred that the lunar regolith has always been devoid of life.*

The hope of finding evidence of a preexistent biosphere, or even of stages in chemical evolution of organic systems, on the moon began to fade even as Astronauts Armstrong and Aldrin's early observations began to return to earth from Tranquillity Base. The assumption that no such evidence would be found has been fully confirmed, at least with respect to microorganic structures that might represent extinct or extant microorganisms on the lunar surface. The conclusion bears the limitation that the lunar maria, of which the Sea of Tranquillity is regarded as typical, are representative of the moon as a whole during its entire history. It can be inferred that the lunar regolith has never possessed life and is inimical to life.

The samples investigated in this study consisted of the following: (i) lunar fines (10086,8) from the bulk sample container, sieved to various size fractions; (ii) rock chips of microbrecciated structure, from an outside chip (10091,6) and an inside chip (10091,7), respectively; and (iii) thin sections of microbreccia (10059,32; 10065,25; 10046,56; 10021,29).

The lunar dust was examined as free powder, on the untreated surfaces of glass slides, by normal and polarized, transmitted, and indirectly reflected light (dark-field illumination), and by transmitted light on whole mounts employing various mounting media, such as microscope immersion oil, gum damar, and diaphane.

Rock chips were examined by scanning electron microscopy after deposition of a 300- to 500-Å layer of gold.

Thin sections were examined by polarized and nonpolarized transmitted light, by polarized and nonpolarized direct incident light, and by polarized indirect reflected light (dark-field illumination). (Thin sections bearing cover glasses can be examined by transmitted light only.)

The morphology and optical properties of discrete objects in the lunar fines and in the thin sections of the rocks, at all magnifications accessible to white-light microscopy, indicate total absence of structure that can be interpreted as biological in origin.

Studies of the rock chips, both of outside and inside surfaces, with the scanning electron microscope likewise demonstrate complete absence of biological morphology.

It is appropriate to note that certain of the ubiquitous glass beads in the Apollo 11 dust, especially those of <10-μm size range and of spheroidal and ellipsoidal shape, curiously resemble microorganisms. These "pseudofossils" occasionally appear to possess double "walls," owing to spherical refraction of light around their surfaces and false "organelles" resulting from minute inclusions within the glass and to minute particles of adhering dust. Their mineral origin can readily be determined by optical properties in different combinations of light response in the white-light microscope.

All samples examined in this study were virtually devoid of terrestrial contaminants, with the exception of occassional birefringent fibers occurring in the bulk dust sample and occasional chemically induced artifacts within the epoxy mounting medium of the thin section preparations.

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References and Notes

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