BIOLOGY

Soil Microbial and Ecological Studies in Southern Victoria Land [1]

ROY CAMERON, JONATHAN KING, *and* CHARLES DAVID

Bioscience Section
Jet Propulsion Laboratory
California Institute of Technology

Since 1961, the Jet Propulsion Laboratory (JPL) has conducted a desert-microflora program involving investigations on several continents of desert environments, soils, and microorganisms relevant to the detection and quarantine of life on Mars. The objectives are to study and identify basic groups of microorganisms of extreme environments, especially those of desert soils, and to correlate the environmental parameters with the distribution, abundance, and kinds of microorganisms and their activities.

Antarctic dry valleys have been studied during the austral summers of 1966–1967 (Cameron, 1967) and 1967–1968. Five field sites were established for approximately one-week periods, some in cooperation with the Virginia Polytechnic Institute (VPI) (Benoit *and* Cameron, 1967). Soil samples were collected aseptically from the surface to a level a few inches below the upper surface of permafrost at selected sites throughout the valleys. Measurements or observations were made either continuously or every three hours of soil temperature, solar-radiation flux, net thermal exchange, ultraviolet-radiation flux, light intensity, wind direction and velocity, barometric pressure, evaporation rate, relative humidity, dew point, and gas concentration.

During the past season, 58 surface and subsurface soil samples were collected. Twelve of them were obtained with Dr. James Turnock of NASA, Washington, D.C., for testing at the Lunar Receiving Laboratory. Microbiological analyses of 45 samples from 22 sites were made at the McMurdo biological laboratory. More than 1,000 pounds of frozen samples were sent to JPL's Soil Science Laboratory for further processing and analysis. Sandy, saline soils that are sometimes high in chlorides, nitrates, and sulfates, but quite low in organic matter, yielded few microorganisms.

For the first time in the study of desert-soil microbial ecology, it was found that the abundance and diversity of microorganisms was greatly dependent upon variations of specific ecologic factors. Unfavorable environmental conditions, such as east-west valley orientation, south-facing slopes, low solar-radiation flux, high southerly winds, low humidities, short duration of available water, and salty soils, were observed to restrict greatly the existence and activity of microorganisms. A comparison of favorable and unfavorable ecologic factors important for determining the distribution of life in the antarctic dry valleys is shown in Fig. 1. Under the least favorable conditions, either no microorganisms or only a single population of heterotrophic, aerobic, nonpigmented bacteria was observed. For example, such conditions were observed

[1] This paper presents the results of one phase of research carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract NAS 7–100, sponsored by the National Aeronautics and Space Administration. Logistic support and facilities for the investigations in Antarctica were arranged by the Office of Antarctic Programs, National Science Foundation.

FAVORABLE

N-S ORIENTATION
NORTHERN EXPOSURE
GENTLE, NORTH-FACING SLOPES
HIGH SOLAR RADIATION
MICROCLIMATE ABOVE FREEZING
ABSENCE OF WIND
NORTHERLY WINDS
HIGH HUMIDITIES
SLOW OR IMPEDED DRAINAGE
LENGTHY DURATION OF AVAILABLE H_2O
(PRESENCE OF GLACIERS, LAKES, STREAMS, SNOW AND ICE FIELDS)
TRANSLUCENT PEBBLES
NON-SALTY SOILS, BALANCED IONIC COMPOSITION
APPROX NEUTRAL pH
ORGANIC CONTAMINATION
(SKUAS, SEALS, ETC)

UNFAVORABLE

E-W ORIENTATION
SOUTHERN EXPOSURE
FLAT OR SOUTH-FACING SLOPES
LOW SOLAR RADIATION
MICROCLIMATE BELOW FREEZING
HIGH WINDS
SOUTHERLY WINDS
LOW HUMIDITIES
RAPID DRAINAGE
SHORT DURATION OF AVAILABLE H_2O
(ABSENCE OF GLACIERS, LAKES, STREAMS, SNOW AND ICE FIELDS)
OPAQUE PEBBLES
SALTY SOILS, UNBALANCED IONIC COMPOSITION
HIGH (OR LOW) pH
NO ORGANIC CONTAMINATION
(NO LARGE INCREMENTS OF ORGANIC MATTER)

Figure 1. Ecological factors determining distribution of life in antarctic dry valleys.

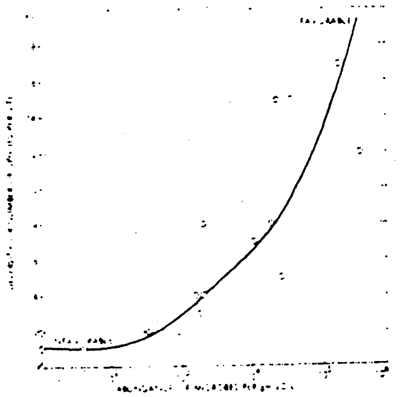

Figure 2. Diversity vs. abundance for surface samples at each soil-collection site in the Asgard Range.

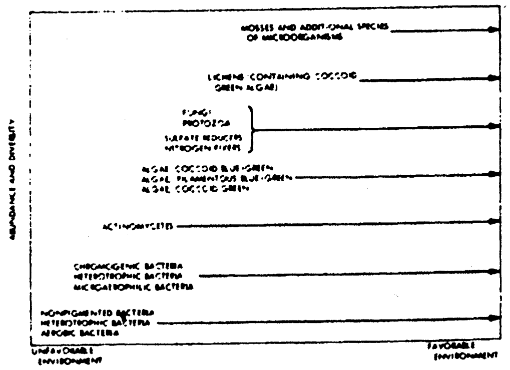

Figure 4. Variability of population density and diversity with variability of ecological factors in antarctic dry valleys.

SAMPLE No.	SAMPLE DEPTH, in.	AEROBIC BACTERIA + ACTINOMYCETES				ANAEROBES	FUNGI	ALGAE	MICROAEROPHILES
		+2°C	+20°C	+2°C	+20°C	ROOM TEMP	+20°C	ROOM TEMP	+20°C
661	SURF. 1	3.7×10^2	3×10^3	3.2×10^2	1.8×10^4	0	2.5×10^2	2×10^2	10^3
662	1 – 4	20	4×10^4	< 10	1.7×10^5	0	3×10^3	20	10^4
663	SURF. 1	0	1.6×10^2	$\sim 10^2$	2×10^3	0	0	20	10^2
664	SURF. 1	0	< 10	0	< 10	0	0	0	0
665	SURF. 1	< 10	2.8×10^3	< 10	2.5×10^4	0	0	0	10^3
666	1 – 4	< 10	2.7×10^3	< 10	1.1×10^3	0	0	20	10^3
667	SURF. 1	< 10	30	0	40	0	0	0	10^2
668	1 – 4	< 10	< 10	0	< 10	0	0	0	10
669	SURF. 1	180	90	< 10	2.7×10^2	0	0	0	10^2
670	1 – 4	3.5×10^4	1.4×10^4	< 10	4.4×10^2	0	0	0	10^3
671	SURF. 1	1.6×10^2	30	0	3.1×10^2	0	2	0	10^2
672	1 – 4	2.5×10^2	90	0	30	0	2	0	10^2
673	SURF. 1	1.2×10^2	10^2	40	1.8×10^3	0	0	20	10^2
674	1 – 4	3.5×10^2	10^2	50	5.5×10^2	0	0	0	10^2
675	SURF. 1	10^2	1.8×10^2	10	9×10^2	0	0	0	10^2
676	1 – 4	2.4×10^3	1.2×10^3	2×10^2	2.4×10^3	0	0	0	10^2
677	SURF. 1	< 10	90	0	< 10	0	0	0	10
678	1 – 4	< 10	< 10	0	< 10	0	0	0	10^2
MEDIA		TRYPTICASE SOY AGAR		SALTS (SIMULATED TAYLOR VALLEY SOIL EXTRACT) + YEAST EXTRACT + NEOPEPTONE		TSA IN CO_2	ROSE BENGAL AGAR (5 gm INOCULUM)	THORNTON'S SALT MEDIUM (10 gm INOCULUM)	FLUID THIOGLYCOLLATE (POSITIVES RECORDED FOR HIGHEST DILUTION)

Figure 3. Microorganisms in Asgard Range soil samples (per gram of soil).

at all locations examined by the authors and Prof. Robert Benoit of VPI during a traverse they made cooperatively along the west side of the Matterhorn Glacier from the glacier's head to Lake Bonney in Taylor Valley.

The abundances of microorganisms determined for 18 samples are shown in Fig. 3. The maximum total abundance did not exceed 10^5/g of soil, and some samples contained few or no microorganisms as determined by culture techniques.[2] In three out of every four sites investigated, the subsurface microflora was more abundant than the surface microflora. Nonpigmented bacteria were generally more abundant than pigmented species and had the ability to grow in a wider variety of culture media. Most of the bacterial isolates were *Bacillus* spp., soil diptheroids, *Micrococcus* spp., and *Mycococcus* spp. The algae were primarily oscillatorioid and coccoid blue-green forms, including *Oscillatoria* spp., *Microcoleus* spp., *Schizothrix* spp., *Anacystis* spp., and *Coccochloris* spp. The fungi included a number of ascomycetous molds and some yeasts. Protozoa were of the flagellated or amoeboid forms. No bacteriophages were found. The absence of anaerobes is especially significant since they have not been found in the harshest of other desert soils (such as those of the Sahara and Atacama Deserts) investigated by JPL.

The relationship of population diversity and abundance of microorganisms in samples obtained from a valley in the Asgard Range is shown in Fig. 2. As indicated in this figure, species diversity and abundance increase with the favorableness of ecological conditions. For this valley, as well as for other valleys investigated, it was predicted and then substantiated that, with a given set of environmental conditions, there would be an ecologic succession as well as a numerical increase in organisms as the environment became more favorable (Fig. 4).

Additional antarctic soil samples will be analyzed and attempts made to correlate the abundance, distribution, and kinds of microorganisms according to pertinent ecological factors operative in the dry valleys. For life-detection purposes, whether terrestrial or

[2] Fifteen antarctic soils were studied by Dr. Jerry Hubbard of the JPL Bioscience Section. Soils were incubated with a substrate mixture containing ^{14}C-glucose and ^{14}C-amino acids. Metabolic $^{14}CO_2$ was then determined. The net CPM was found to correlate to a considerable extent with the absence or presence of microorganisms as determined by culture techniques.

extraterrestrial, it is becoming more evident that the environmental conditions, especially the duration of availability of nonsalty moisture, are extremely important for the existence of life in a harsh environment.

References

Benoit, R. E. *and* R. E. Cameron. 1967. Microbial ecology of some dry valley soils of Antarctica. *Bacteriological Proceedings,* Abstracts, A13, p. 3.

Cameron, R. E. 1967. *Soil Studies—Desert Microflora: XIV, Soil Properties and Abundance of Microflora from a Soil Profile in McKelvey Valley, Antarctica.* California Institute of Technology, Jet Propulsion Laboratory, Space Programs Summary 37–44, vol. IV, p. 224–236.