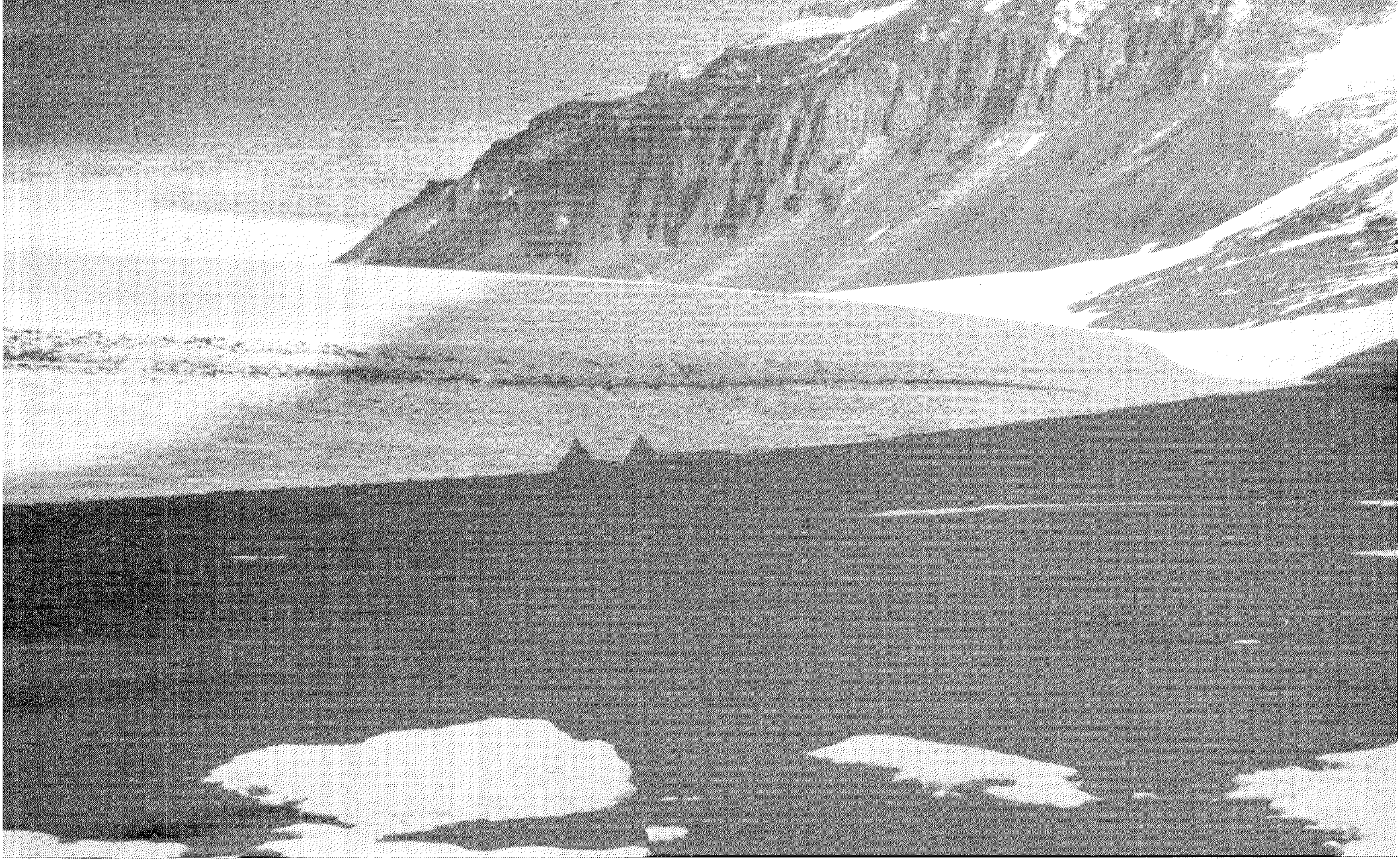


Searching For Life in Antarctica

by Charles David and Jonathan King

During the past winter in the northern hemisphere, we were given the opportunity to take a three-month summer vacation in the southern hemisphere—on the Antarctic Continent. As graduate students in Caltech's biology division, we received this invitation from the Desert Microflora Program of Caltech's Jet Propulsion Laboratory. This program, headed by Roy Cameron, is part of the JPL bioscience section's effort to discover microbiological factors relevant to detection of life on other planets—specifically that which may be found on Mars. Since Mars is a cold desert and life there is almost certainly microorganismic and soil-dwelling, JPL is particularly interested in discovering the characteristics and factors that govern the distribution and physiology of desert microorganisms.

The Antarctic may seem a poor place to look for desert microorganisms, since the continent is principally covered with thousands of feet of glacial ice. There are, however, around the periphery of the polar ice cap, a number of small areas where the seaward flow of the ice cap has been stemmed by a mountain chain. Since the annual precipitation of snow is very low, these areas have not accumulated a covering of snow or ice but have remained as large expanses of

The search for life on Mars takes two Caltech biologists, oddly enough, to Antarctica for a summer.

sandy soil and rock. The dry valleys, as they are called, are in effect cold deserts. Although these dry-valley areas are small compared with the size of Antarctica, they are still impressive. The largest, in Victorialand, covers about 1,000 square miles, and it was there that we "summered."

The trip to Antarctica is made in two jumps, first to New Zealand and from there 2,500 miles due south to the main American Antarctic station at McMurdo Sound. This base is on Ross Island, only 80 miles east of the dry valleys in Victorialand. Navy helicopters cover the distance in less than an hour whereas an overland expedition would take several days.

McMurdo is the headquarters for the American effort in the Antarctic. In summer it is accessible by sea to ships accompanied by icebreakers, so it is the principal supply depot from which inland research stations are supplied by air. The Navy provides most of the support facilities for the scientific community, which consists of about 100 men at all stations together. The scientists come from many universities and industries, both in the U.S. and abroad, and are members of the U.S. Antarctic Research Program (USARP). Biology is the principal activity at McMurdo, while atmospheric physics, glaciology, and geology are studied at inland stations on the polar plateau.

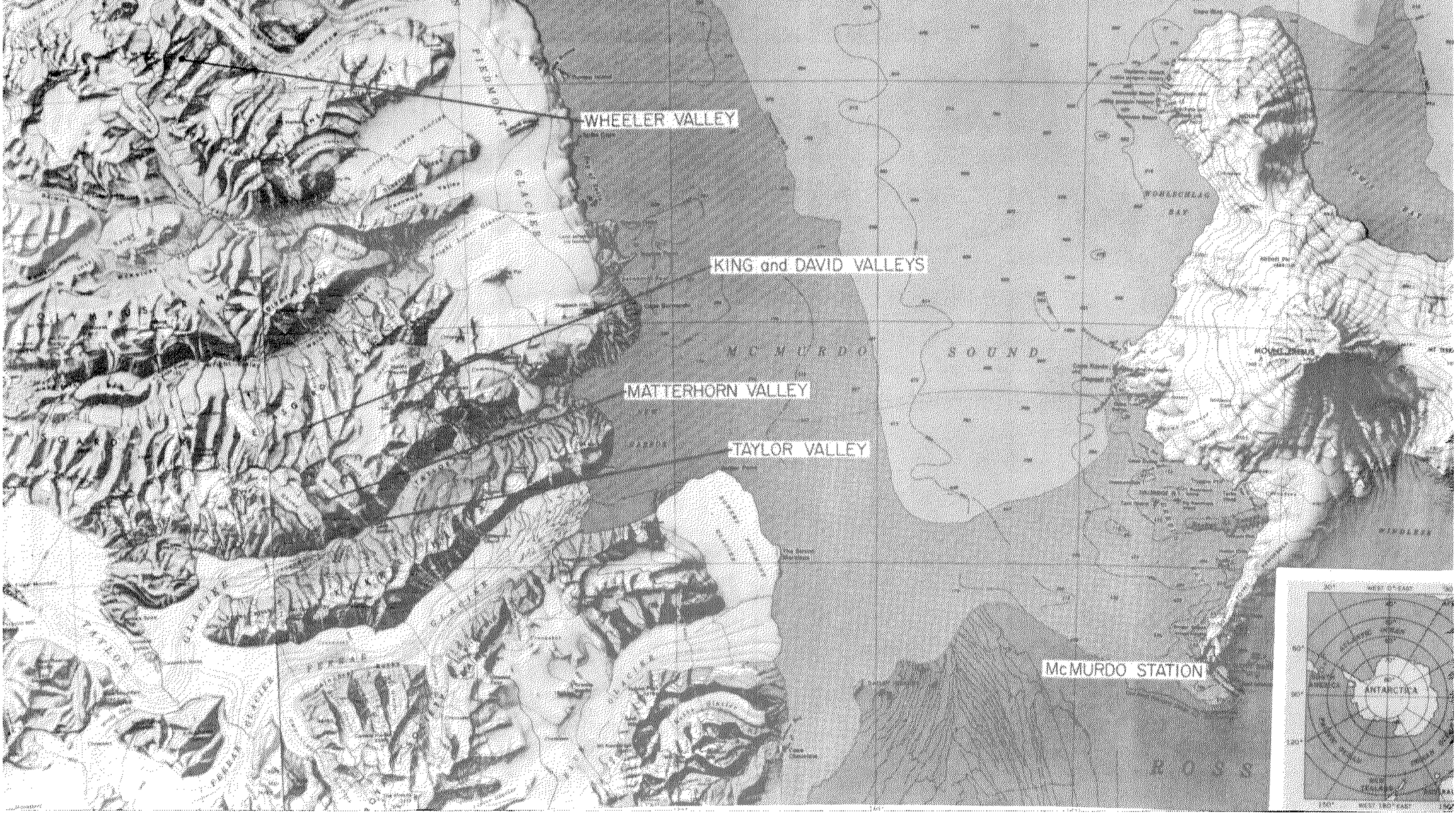
Our own scientific program in the dry valleys was three-pronged. One, we identified and classified the kinds of microflora present in soil samples taken from various locations; two, we examined the physical and chemical properties of these soil samples; and three, we collected meteorological data. The essential effort was to correlate the soil properties and meteorological data with the abundance and variety of the microflora in order to determine what factors critically limit microbial growth in Antarctica.

We established our base camps at three locations in the dry-valley region—Taylor Valley, Wheeler Valley, and King and David Valleys—each picked for specific geographical properties. Helicopters flew us and our equipment from McMurdo to the base camps and deposited us there for five- to ten-day periods. We set up meteorological equipment and recorded data every three hours around the clock. The chief measurements were of the temperature and humidity of the air and soil at various heights from three feet above the soil surface to several feet below it. Total and net solar radiation at the soil surface, evaporation rates, and wind velocity were also measured.

Although the sun never sets in Antarctica during the summer months, it does rise and fall in the sky during the day, providing abundant radiation at noon and dusk-like illumination during the midnight hours. This diurnal radiation cycle is reflected in variations in temperature and humidity in the soil and air. The air temperature fluctuates just below freezing. The soil, by comparison, absorbs solar radiation and is above freezing during the day, often reaching temperatures of 60°F at noon. Deeper in the soil the maximum temperature is just above freezing—cool but certainly adequate to support life. At night the soil cools off and may even go below freezing.

Similarly, while the air frequently has a low relative humidity, the soil has a high relative humidity. The humidity is correlated with the wind velocity and dryness. The floor of Taylor Valley, which is exposed to drying winds, has dry soil compared to areas of Wheeler Valley where there is very little wind and the soils have relative humidities approaching saturation. Since water is essential for life, areas protected from drying winds are likely to be more hospitable. Thus, although the environment in which the scientist lives may indeed be severe, the surface layers of the soil constitute a microenvironment which is *not* hostile to life.

In addition to taking meteorological data at

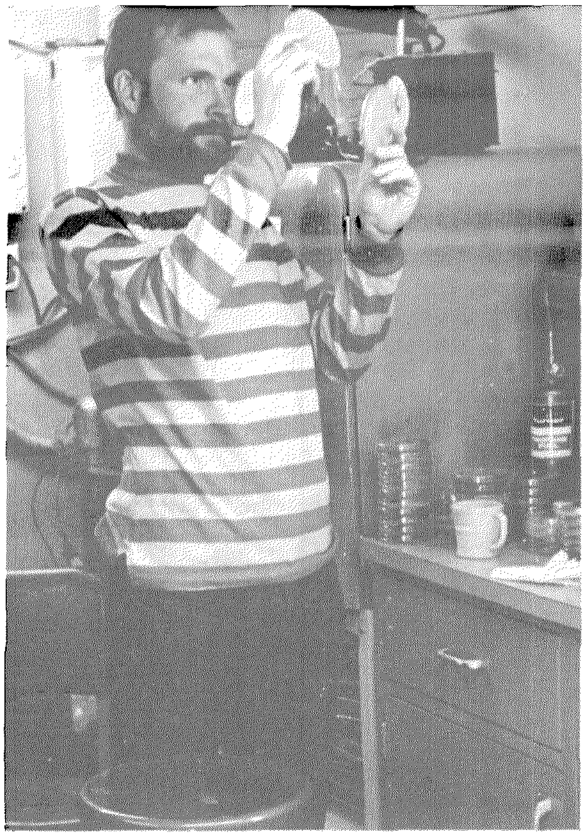


Caltech biologists established camps in four widely separated valleys in Victorialand, Antarctica. The miniscule black dot on the insert map shows the location of Victorialand in relation to the entire Antarctic continent.

the base camps, we took soil samples there and at a number of other sites in the vicinity—up to five miles away. These samples were collected aseptically from the surface and from one inch to four inches below the surface or deeper, depending on the depth of the permafrost. The samples were taken for analysis of microbial life and also for analysis of the physical and chemical properties of the soil. In making the physical and chemical analyses we were concerned principally with the available ions and organic matter in the soil as well as its texture and moisture content—all factors which strongly influence the ability of soil to support the growth of microorganisms.

Back in the biological lab at McMurdo, we ran microbiological analyses on the soil samples. A water suspension was made of soil and used to inoculate a number of different nutrient media which selectively permit the growth of various groups of microorganisms. For instance, an inorganic medium was used to assay for photosynthetic algae. Since it contains no source of organic carbon except the soil itself, this medium does not usually support the growth of bacteria and fungi. With such techniques we assayed the total number of microorganisms per gram of soil and also got an idea of the diversity of groups (algae, fungi, and bacteria) and physiological types (nitrate reducers, anaerobes, and others). A number of these assays were carried out at both high and low temperatures to find organisms especially adapted to live in a cold environment.

Numerically, we found the dominant group of microflora in the dry valleys to be the heterotrophic bacteria. It was the only group present in very poor soils. As sites increased in richness and total abundance of microorganisms, there was also an increase in the diversity of groups and physiological types present. Rich samples contained more than 100,000 organisms per gram of soil, while poor sites contained less than 1,000 and sometimes essentially none. We found that the most conspicuous feature of the distribution of microorganisms



Charles David checks soil samples for microbial life in the biology laboratory at McMurdo Station.

in the dry valleys was the variation between sites geographically close together. Why in the bottom of the main valleys can the population be generally low at many sites, when at 4,000 feet, in the "hanging" valleys on the sides of these main valleys the population is found to be generally rich? We cannot yet offer a complete explanation for all the differences observed, but the results of last summer's work certainly implicate several meteorological factors.

The bottom of Taylor Valley had low abundances of microorganisms. Its soil has very low humidity due to the dry wind that blows through it off the polar plateau to the west. The Matterhorn Valley—a hanging valley 4,000 feet above the floor of Taylor Valley and oriented at right angles to Taylor—has a very high abundance of microorganisms. It is out of the reach of the drying winds. Wheeler Valley has a similar orientation and a high microbial population. We have extensive meteorological data which show that Wheeler Valley is successfully cut off from the dry west wind. The soil in Wheeler is very moist, and, in fact, there were frequently pools of liquid water at noon on sunny days.

In pursuit of the theory that high abundances of microorganisms are found in valleys protected from the dry west wind, we searched the maps for another high valley oriented like Wheeler and Matterhorn. We chose a site in the Asgard Range for which we modestly suggested the names King Valley and David Valley. Once again the mobility provided by the Navy's helicopter support enabled us to get into the selected area for a quick four-day stay just to get the necessary data. Although the area was generally fairly rich in microbial life, the total abundances were not as high as Wheeler and Matterhorn. However, King and David Valleys are not as well isolated from the dry west wind as the maps had led us to hope. Among the sites in the valleys, though, it was clear that those out of the principal wind pattern were richer than sites exposed to the wind.

The analysis of the effects of chemical and physical properties of soil on microbial abundances are not complete. An example, however, will demonstrate the importance of these factors. One site in the Matterhorn, close to several of the rich sites, had virtually no detectable life. This was puzzling at first. Further study, however, showed that this soil was toxic for Antarctic bacteria, and chemical analysis showed that it contained high concentrations of boron, an element known to inhibit microbial growth.

To get aseptic soil samples, Jonathan King and Charles David work downwind from the digging area, using a sterilized trowel and sterile containers.

The results of our work represent only an introduction to the microbiology of the Antarctic deserts. They raise many interesting questions: What are the rates of growth of these bacteria in the natural environment? What do the heterotrophic bacteria use for food? What is the origin of the bacteria present in the permafrost? Are they "ancient" bacteria from an earlier era? How many of the bacteria in poor areas are windblown contaminants from richer areas? How closely related are the Antarctic species to species in the temperate zone? What is the sequence in colonization of initially abiotic areas in the dry valleys—bacteria, then algae, then fungi?

Our results show the need to study all the possible factors that can affect the environment, from the soil properties to the micrometeorology, in order to fully understand the distribution and presence or absence of microbial growth. The results also emphasize the enormous capability of life to find and populate small favorable niches amid a vast hostile area. In terms of extraterrestrial life detection, this fact is very encouraging, since the surface of Mars is without doubt a hostile place. On the other hand, the chance that a space vehicle would land on one of the rare areas favorable for life is small, and it is discouraging to think that a good life detector must be a complicated robot capable of intelligently seeking out such areas.

Although the scientific part of our three-month "vacation" took most of our time and energies, leisure had its challenging, and at times frustrating, aspects. Initially we were attracted to the Antarctic program more for personal adventure than for scientific purposes. Ironically, we came back very much frustrated in the former and very enthusiastic about the latter.

Life at McMurdo is essentially low-grade despite the fact that it is physically very comfortable. We were provided with pleasant private sleeping quarters and four meals a day. Nevertheless, the availability of such amenities does not remove a real sense of malaise among the men. Perhaps boredom is a better word. The environment is monotonous, and there is an extreme lack of imagination on the base. When not working, the men have nothing to do except to go to one of the three movies shown every evening or go to the bar, which serves drinks for almost nothing—a paradise for alcoholics. No effort is made to enrich life with, for example, various sporting possibilities which the Antarctic presents, such as ice hockey or skiing.

In frustration over the dearth of activities, we organized a four-man touch football league by putting up a sign in the mess hall. Overnight we had six Navy teams signed up to play, and we found more scientists to round out a USARP team. The games were played on the only clear level area—the unpaved helicopter landing pad. After a series of playoff games, the Penguin Bowl was held between the two top teams, USARP's Big Kahuana and his Bonzai Pipeliners and the day crew of Seabees, the Saints.

The Kahuanas staged a spectacular comeback in the second half to win 18-12, upholding the honor of the scientific community, to the chagrin of the Navy.

In a more serious vein, we set up a weekly seminar program in the biology lab in order to learn more about the research projects being done by other scientists in Antarctica and to share some of our findings with them. Despite the success of the seminars and the football games in bringing various groups of men together, these activities were insignificant compared to the need. Contacts between the scientists and the Navy and between the scientists themselves were almost nonexistent. Even though it is axiomatic among scientists that contact between persons of divergent interests can be very fruitful, the bureaucracy at McMurdo discourages this contact on the theory that a man is brought there to do a specific job and any time not spent doing that job is "wasted." The weight of bureaucracy at McMurdo is perhaps no heavier than in any other big organization, but it is tragic there since it stifles the imagination so badly needed at an isolated station.

To a great degree it was the prospect of seeing a large part of the continent and learning about the other research projects that initally enticed us to go to Antarctica. In this we were thwarted. What kept us sane and happy was the fact that the scientific project we were attached to proved much more interesting than we anticipated.