Reprinted from

RESEARCH REVIEWS

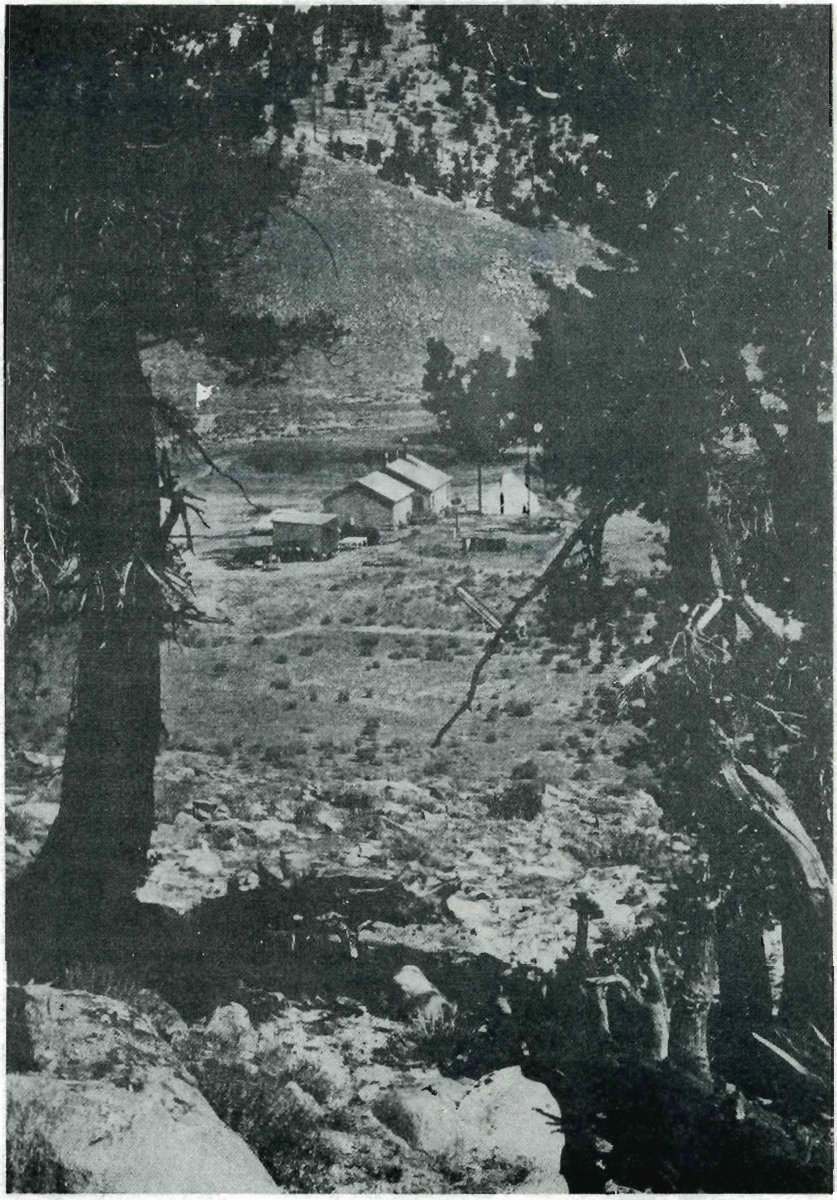
MARCH 1952

California's Laboratory Above the Clouds

by
Nello Pace and S. F. Cook
University of California, Berkeley

OFFICE OF NAVAL RESEARCH

DEPARTMENT OF THE NAVY WASHINGTON, D. C.



As the numerous plants show, this is the "lower" part of California's High-Altitude Research Station--located a mere 10,500 feet above sea level! Some very important high-altitude studies were made here, before the higher installation became available. The bristle cone pine trees through which the photographer took the picture are believed by some to be older than the redwoods. Further up the mountain plant life grows sparser and sparser until finally, above the timber line, the terrain begins to look as if it belonged to another world.

California's Laboratory Above the Clouds

by
Nello Pace and S. F. Cook
University of California, Berkeley

As Alice in Wonderland would have put it, scientists are becoming "curiouser and curiouser" about the regions above the earth's surface. This is probably the result of the huge advances made in the past half-century in man's ability to send men and equipment higher and higher. Soaring planes and electronically guided rockets have torn aside the barriers that once made the sky a romantic mystery, and the new accessibility of its "wide open spaces" has prodded men of science to ask a thousand questions about it. What is the composition of the atmosphere at great distances from the earth's surface? What kind of radioactive particles does it contain? What are the effects of the temperatures and pressures encountered on animals, humans and plants?

Some of the information sought has definite military or other practical applications. Some, on the other hand, is of interest solely as fundamental scientific fact, helpful in guiding man to a better understanding of the universe in which he lives. In either case, the establishment of a new high-altitude research laboratory is a development of very great importance.

Within the past two years ONR has been instrumental in making available a much-needed new year-round, high-altitude research facility for scientists of the United States. This laboratory, open to any investigator interested in the problems of high altitude, is located in the White Mountains of central California near the eastern edge of the state, 200 miles from San Francisco.

Access may be had to the White Mountains by way of Westgard Pass from the little town of Big Pine on the Owens Valley floor (4000 feet above sea level!). A paved road leads from Big Pine through Westgard Pass over into Nevada in the region of Tonopah, Goldfield and Lida—names that recall legends of gold and desert thirst. At the summit of the pass, 13 miles from Big Pine, a good dirt road branches off to the north and winds upward for 30-odd miles along the crest of the White Mountains to an altitude of 13,200 feet and just short of White Mountain Peak itself (at 14,246 feet). Although extension of the road to the top of the peak is quite practical, it has not yet been done.

Nello Pace, Associate Professor of Physiology at the University of California in Berkeley, is Project Director of ONR Unit Number One there. Formerly he headed the Physiology Facility at the Naval Medical Research Institute in Bethesda, Md.

S. F. Cook was formerly a member of the Donner Laboratory Aero-Medical Unit at the University of California, where he is now Professor of Physiology. He is conducting ONR-sponsored research on burn shock.

The road was built in 1948 by the Bureau of Ordnance's Naval Ordnance Test Station at Inyokern, and a laboratory installation erected at an elevation of 10,500 feet. This installation is located on the headwaters of Crooked Creek in the lee of Campito Mountain, an 11,500-foot peak, about 20 miles north of Westgard Pass on the White Mountain Road. The installation consists of a wooden frame building which serves as living quarters and a Quonset hut which houses a weather station and provides laboratory space. At present, a colony of laboratory rats and mice is also located in the Quonset.

Although the original installation was used for classified work by NOTS, it was soon made available to outside investigators for high-altitude research. Thus, in 1949, investigators (led by Dr. Carl D. Anderson under an ONR contract with the California Institute of Technology) discovered the important and still-mysterious V-particles in cosmic radiation. During that same summer Professors R. B. Brode and W. B. Fretter, under ONR contract with the University of California, also made extensive cosmic-ray studies.

A full year's data on relative atmospheric purity of the White Mountain Station was obtained by Dr. Fritz Zwicky of the California Institute of Technology under an ONR contract in 1949. A comparison of these data with similar data from Sacramento Peak in New Mexico and from Climax, Colorado was made by Dr. Walter Orr Roberts, Superintendent of the High Altitude Observatory of Harvard University and the University of Colorado, and it was clear that the White Mountains are definitely the superior site for solar coronal research, although both the other sites are very satisfactory. In the fall of 1949, the White Mountain Station was turned over temporarily to two groups of investigators working under government contracts. One of these groups, comprised of scientists from the University of California at Los Angeles and led by Professors L. P. Delsasso and R. W. Leonard, conducted extensive experiments on the velocity of sound under various conditions.

Thus for the first two years of its existence the White Mountain Station was used exclusively for physical research in a wide variety of fields. During this time, the authors had been seeking a suitable location for investigating the problems of adaptation to high altitudes in animals and man. Although higher altitudes existed in the region of Mt. Whitney (elevation, 14,495 feet) in the Sierra Nevada, the White Mountains possessed marked advantages from the point of view of year-round accessibility and relative gentleness of terrain. Accordingly, plans were formulated for the construction of another installation some nine miles north of the Crooked Creek quarters, and 2,000 feet higher, on the slopes of an unnamed peak just south of White Mountain Peak itself. The peak chosen, reaching 13,023 feet above sea level, has now been officially named Mt. Barcroft in honor of Sir Joseph Barcroft, the British physiologist who pioneered in high-altitude physiology. Many factors influenced the selection of Mt. Barcroft as the site for the second installation, but the chief ones were the presence of an adequate water supply and the matter of protection from the prevailing westerly winds of the region.

In the summer of 1950, the entire Crooked Creek installation was transferred to the cognizance of ONR, and operation of the Station was delegated by contract to the University of California at Berkeley in the fall of 1950. This arrangement is still in effect. Thus the Crooked Creek installation has been kept in continuous operation for over three years.

Maintenance of the Crooked Creek quarters through last winter made it possible to start construction of the Mt. Barcroft quarters at 12,500 feet above sea level in the spring of 1951. The installation here consists of a 40- by-100-ft Quonset hut, erected on a concrete slab and specially reinforced to withstand the high-velocity winds encountered at these elevations, which are well above the timber line. One end of the hut is devoted to a 30- by- 40-ft heated garage, and the remaining two thirds has been partitioned off into a number of rooms on two stories. Besides complete living accommodations for 24 persons there are two laboratory rooms, each 17 by 25 feet, and a third room which houses some of the meteorological instruments and radio equipment. Construction on this building is essentially complete, but numerous finishing details still must be taken care of.

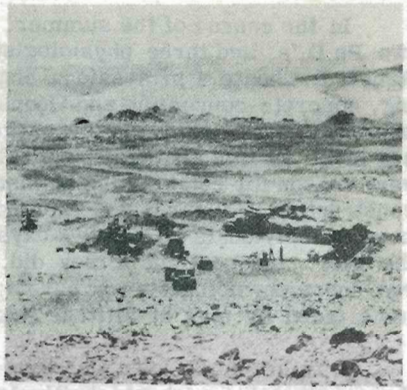


Figure 1. The site for the upper station looked like this in July of last year.

The story of the building of the Mt. Barcroft laboratory, some 45 miles from the nearest human habitation, almost constitutes a saga. It involved the transformation of a poor jeep trail into a good truck road, the development of a water supply, the pouring of almost 100 cubic yards of concrete, the erection of the Quonset building itself, and the roughing-in of a two-floor interior. The pressure of time was constant because of the sharply limited building season (from the middle of June to the end of September) and the accomplishment is a tribute to all who were involved.

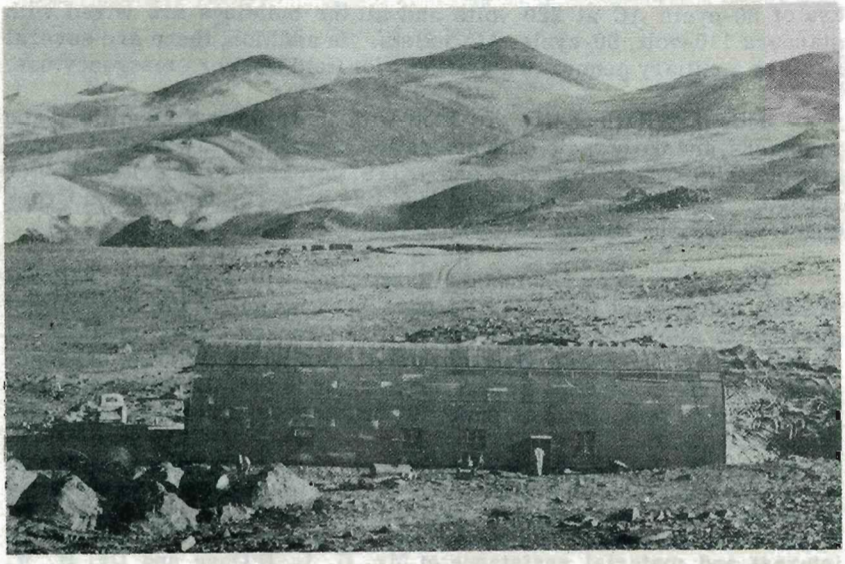


Figure 2. By October plenty of hard work had produced this result.

In the course of the summer, 14 graduate students in physiology, two Ph.D.'s, and three physiologists at the professional level (led by Robert B. Choate, a professional engineer), had learned about road blasting, concrete-concocting and Quonset hut assembly under the very trying conditions of cold and low oxygen encountered at 12,500 feet above sea level. At this altitude, physical exertion becomes difficult, and the very reason for establishing an installation here operates against those constructing it. Moreover, a pronounced mental depression developed in most individuals after a few days, which made it difficult to continue the effort, but continue it they did. Consequently there are now some two-score physiologists who have a far keener appreciation of the problems faced by man at altitude than do their "flatlander" colleagues.[1]

A rather humorous and very fortunate incident occurred during the construction work, which illustrates how adversity may sometimes be turned to advantage. Early in July, when excavation for foundations was begun, the same difficulty that beset Mr. Blanding in building his dream house was encountered--the continual seepage of water into the excavation. It was believed that this was caused by snow melting on the flank of Mt. Barcroft. When the snow was all melted and gone by the end of August, however, the seepage continued. It had been originally intended to pump water for the building from a spring several hundred yards away, but instead, a well-driller was persuaded to bring in his rig and a well 30 feet deep was installed right beside the building. It continues to supply water at this writing, in the dead of winter. It is, possibly, the highest well in the United States, and a much less costly water system than the one originally planned.

Both the Mt. Barcroft and the Crooked Creek quarters boast hot and cold running water and modern plumbing of the indoor variety. Heat is provided by oil stoves, and electric power by Diesel generators. There are two generators at each installation capable of producing 25 kva of 60-cycle AC at 220 volts and all the buildings are wired with standard 110-volt, 60-cycle, AC outlets. In addition, there are several smaller auxiliary generators available for field work or emergency use.

Both installations are provided with short-wave transmitters and receivers, and daily radio communication is maintained with the University of California at Berkeley and NOTS, Inyokern to provide weather reports. In addition, a telephone land line connects the Crooked Creek quarters with the Bishop telephone exchange.

The entire White Mountain Range lies within the Inyo National Forest, and Special Use Permits have been issued by the U.S. Forest Service to allow the construction of the Crooked Creek quarters at 10,500 feet and the White Mountain Road. A slightly different arrangement is in effect with the Forest Service for the Mt. Barcroft installation at 12,500 feet. In this case, a cooperative agreement has been

[1] Considerable assistance was rendered by various Naval facilities in central California in the form of loans of mechanized equipment of all sorts. Great help was also received from the San Francisco Branch of the ONR in making the necessary arrangements. The continuing interest and material assistance of Mr. C. L. D'Ooge and Dr. H. W. Hunter of NOTS, Inyokern was also an integral part of the success of the entire project.

formulated between the Forest Service and the ONR under which an area of 20 square miles has been set aside for purposes of high-altitude research. This area not only includes the Mt. Barcroft site and White Mountain Peak itself, but also is essentially all above 11,000 feet. Furthermore, the terrain is quite gentle with mild to moderate slopes interspersed with numerous broad, flat, grassy alpine meadows. The whole area is of course above timber-line, and in character resembles an altiplano of the Andes.

Because the White Mountains lie just east of the Sierra Nevada, the moisture-laden prevailing westerly winds coming off the Pacific lose most of their water on the latter and as a result a yearly total of only about ten inches of water fall on the White Mountains. Of this, about one-third falls as rain during the summer months and the other two-thirds as snow in the winter. The latter represents a total snowfall of about 100 inches. While the limited precipitation results in a semi-arid environment, it also determines a very marked advantage of the White Mountains as a site for a high-altitude station in that year-round access is possible. The snowfall is, of course, moderately large but can be coped with, and in comparison with other high-altitude regions of the United States it is far less.

Continuous weather observations have been taken at the Crooked Creek site for over three years, and similar observations have just been started at the Mt. Barcroft site. The coldest recorded temperature at Crooked Creek was -19° Fahrenheit. Although this is not as low a temperature as that found on other parts of the earth, the mercury commonly hovers in the vicinity of zero for days at a time during the winter months. The maximum summer temperature has been consistently in the low 70's with 73°F the highest recorded. During July and August the temperature does not fall below freezing at night. The relative humidity fluctuates from about 40 percent in the summer to about 60 percent in the winter, and wind velocities up to 50 knots average for one hour have been recorded during the winter months. The barometric pressure exhibits a regular and rather large cyclic variation over the year. The monthly average pressure falls from a value of about 515 mm Hg in the summer to approximately 506 mm Hg in the winter, which represents a change of about 500 feet in equivalent altitude.

It has been no surprise to find that weather conditions are more severe at the higher White Mountain Station. The limited observations made thus far at the Mt. Barcroft laboratory indicate that the air temperatures are quite consistently about 10° F lower than those at Crooked Creek. Moreover, higher wind velocities are encountered; an average one-hour velocity of 71 knots has already been logged.

The meteorological conditions over the White Mountains appear to be unique. Within the past year or two, it has been discovered that a tremendous updraft exists here, and the town of Bishop in the Owens Valley has become the glider capital of the world. All previous altitude records for gliders have been broken recently, and flights to 45,000 feet have become almost commonplace.

Two maintenance crews, each consisting of two men, live at both the Crooked Creek and Mt. Barcroft quarters throughout the year. The Operations Manager is Mr. Jack Rose. A rotation plan is in effect under

which each man works twenty days and then is off for five; thus, there are four men in residence at all times. It is seldom that they cannot get into Big Pine or Bishop at least once a week for mail and fresh food. Between storms the road is usually kept clear of snow with a bull-dozer, but two snow weasels are also a very important part of the Station equipment.

The duties of the crews are varied and on a 24-hour-a-day basis. In addition to the routine care of the laboratory animal colony and weather observations three times daily, there is a never-ending stream of maintenance and repair problems on the mechanical equipment, together with the task of completing the construction at both installations. In the winter there is the additional burden of snow-clearing, and in the summer of road maintenance and improvement. Then there are the sporadic visits of the "flatlanders" — scientists who arrive to work. While all visitors share in the cooking and k.p. duties, the arrival of eager investigators always means time diverted from the basic maintenance effort. The Station exists solely for them, however, and their needs must be served.

Both the biological and the physical sciences are represented in the research being conducted or planned at White Mountain. In general, the biological research is concerned with the effects of low oxygen and low temperatures on living organisms, and with what kinds of adaptations the organisms can make in combating these environmental extremes. More specifically, experiments are being carried out on the acclimatization of man and laboratory animals, and parallel observations are being made on the native species which have successfully adapted themselves to the extreme conditions over many generations.

The experimental colony of pure-strain laboratory rats and mice was established over a year ago, so that successive generations of these animals may be compared for adaptive changes with the same strains kept at sea level. The native fauna above 10,000 feet include numerous marmots, ground squirrels, deer mice, meadow mice, coneys, snowshoe rabbits, jackrabbits, coyotes, a few mountain lions, deer, wild horses and bighorn sheep. An extensive bird population is also found at these higher altitudes, and a conservative estimate places the number of plant species occurring above the timber-line at least at 500, many of them yet to be described. Thus an amazingly varied native population is available for comparative studies.

The purpose of these researches is to obtain information on how acclimatization of man to these environmental extremes might be hastened or even induced artificially, an objective of great importance in aviation and in cold-weather or alpine operations of either military or civilian nature.

Related experiments are being planned on the effects of cold and low oxygen on domestic stock animals. The broad objective in this case is of economic as well as of fundamental importance in that much of the marginal land of the United States suitable for grazing and farming lies above 5,000 feet. In order to utilize this land more effectively it is essential to know and make allowance for the effects of altitude upon the stock animals involved.

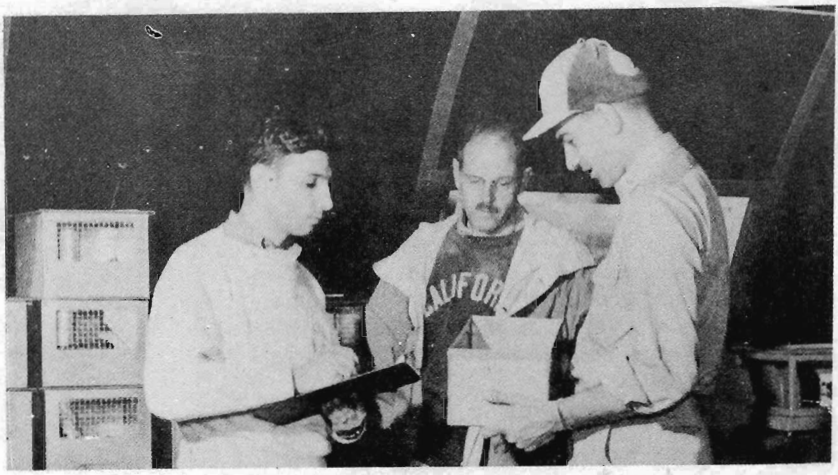


Figure 3. Dr. Cook (center) and Dr. Pace (right) discuss their notes on some experimental white mice with assistant Donald Green.

Another problem of importance being attacked at White Mountain is that of long-term bulk food storage. The "keeping" qualities of rations stored in a cold, low-oxygen environment will be compared to the preservation of those stored in the warmer, relatively high-oxygen environment near sea level. It is possible that less deterioration in foodstuffs may occur under the former conditions.

The researches conducted in the physical sciences are concerned chiefly with the study of cosmic rays. It is becoming increasingly evident that a detailed analysis of the nature of cosmic radiation is one of the keys to a complete understanding of the forces in the atomic nucleus, and hence of the most efficient utilization of atomic energy. The marked superiority of American atom-smashing machines has, in the past few years, resulted in a relative lack of attention in the United States to natural cosmic radiation; however, it is now generally recognized that both approaches to the problem of nuclear forces, used together, will probably be the most fruitful. Since much present-day cosmic ray research must be conducted at high altitudes, the White Mountain Research Station represents an excellent site for some phases of this work.

Although the Station is administered by the University of California, it is open to any qualified investigator interested in high-altitude research. Living quarters and basic laboratory facilities such as power, water, and gas are available, but very little laboratory equipment is on hand at the Station and investigators must bring along their own. It is also necessary to levy a small charge on individuals using the Station to help defray operating costs. Details of such arrangements may be obtained either from the authors or from Dr. Louis Levin, Head of the Biochemistry Branch, ONR, Washington, who has been instrumental in making possible the recent development of the Station.

The White Mountain Research Station represents a significant addition to the high-altitude laboratories of the world. Not only is it the second or third highest but it is one of the very few operating all year long. ONR can well be proud of supporting research not only in institutions of higher learning, but also in this case in an institution of highest learning!