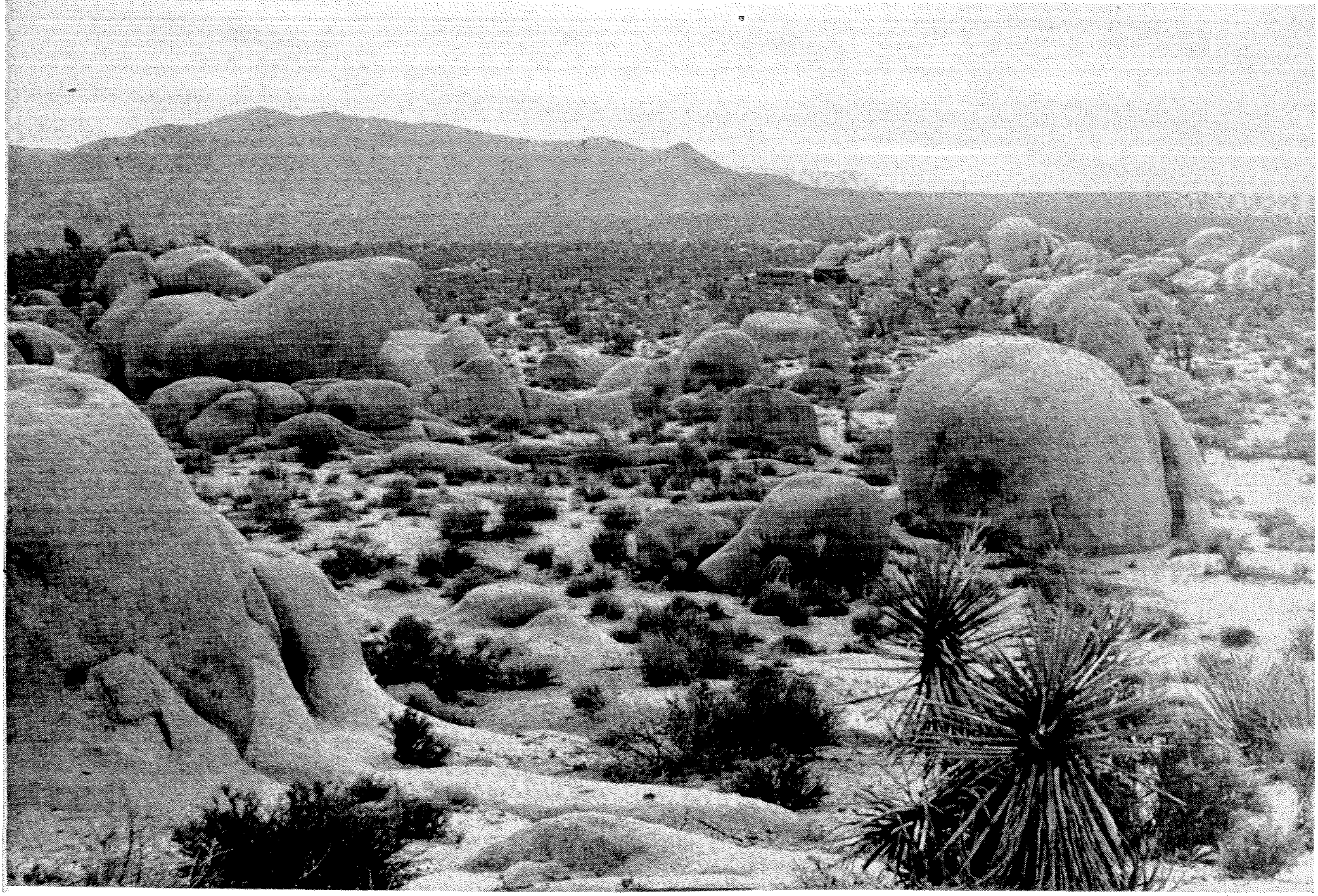


The mobile desert laboratory, dwarfed by its research material

CALTECH'S ROVING LABORATORY

by LLOYD TEVIS, JR.

This new mobile laboratory spurs studies of how plants and animals survive under desert conditions

THE EARHART LABORATORY at Caltech is one of the outstanding botanical research centers of the world. By manipulating artificial conditions of weather, its botanists have learned a great deal about growth and reproduction of plants. But although control of environmental factors is essential for solving many biological problems, study of life under entirely natural and uncontrollable conditions is equally important and interesting.

Towards that end, Caltech recently acquired another unique laboratory—one on wheels, especially designed for exploring the severe and demanding habitat of the desert. Using the facilities of this Mobile Desert Laboratory, investigators are experimenting with an intriguing aspect of evolution: the ability of some plants and animals to survive the heat, dryness, violent winds and cloudbursts of arid places.

Because plants were first cultivated in Egypt some ten thousand years ago, we might expect to find the protype of a desert laboratory in the ancient civilizations of the Middle East. But the agriculture of those days was entirely empirical.

A related people, the Nabataeans, who, at the time of Christ, built an empire in the desert without benefit of a Nile, were forced to adopt a more experimental approach. In fact, their agriculture—based on a system of terracing the wadis or canyons—was so ingenious that it is being studied today by archaeologists for possible application in Israel.

Coming to the modern era, we find that, although there are many botanical field stations in humid areas, they are comparatively rare in the desert. This seems strange when one considers that nearly a fifth of the total land area of the world is arid, and that the desert is a particularly favorable habitat for ecological research.

The challenge of the desert

Its extreme conditions impose a challenge that is met by comparatively few species. The outstanding attribute of aridity is accentuated by long droughts or broken briefly by torrential and destructive rains; daily fluctuations in temperature are tremendous, winds and sandstorms violent, sunlight and ultra-violet radiation intense, and the soils generally charged with salts.

Because plants cannot fly away or retreat into burrows, as animals do, they often show striking adaptations to these extremes. The botanist, Daniel Trembley MacDougal, who for many years was director of the famed Desert Laboratory at Tucson, once said:

" . . . Though we may not recognize it as such, the peculiar plant life of the desert is part of the fascination for us. The panorama of wind-swept expanses, blazing sunlight, and shimmering mirages, all bathed in a swirl of heat and color, suggests an elemental and as yet unconquered world. Into this hostile environment, armed forms of vegetation have forced their way, showing by toughened leaves, indurated stems, and stored-up water, the means by which they have gained a foothold in a region so widely different from their ancestral origin in the seas . . . "

When Frederick Coville explored Death Valley in 1891, he was so impressed by the botany of arid places that he conceived a plan for a permanent laboratory somewhere in the Southwest "to ascertain the methods by which plants function under the extraordinary conditions existing in deserts."

His plan was accepted by the newly-formed Carnegie Institution of Washington, and he and MacDougal were asked to select a site for buildings in what was then the Territory of Arizona.

Among the many visitors who came to use the facilities of the Carnegie Institution's Desert Laboratory at Tucson were Eduard Schratz of the Kaiser Wilhelm Institute, who investigated the suction tension of desert perennials; Henrich Walter, who studied the osmotic value of sap; and Dice and Blossom, who compared the coloration of rodents with the environment.

Almost from its inception, the Laboratory also undertook projects that involved travel to distant places. In 1905, the rampaging Colorado created a great inland body of water 300 miles to the west. This fired the imagination of the botanists, who, accordingly, went to the new Salton Sea to begin an investigation, lasting many years, of the movements of plants along the changing shoreline.

A study of the Mohave Desert was initiated in 1915. Much later, Forrest Shreve, then in charge of the Laboratory, undertook a comprehensive survey of the entire Sonoran and Chihuahuan Deserts. This project, which previously had been impractical because of the frequent revolutions that swept Mexico, was designed to carry the study of the Tucson plants to their distributional limits—to determine how they had originated and differentiated under the impact of aridity. But the geographical scope was so ambitious that before long most of the work of the Laboratory was being accomplished far from the home base at Tucson.

So in 1939, after a fire had destroyed one of the buildings, the Desert Laboratory was given up, and its facilities were transferred to the United States Forest Service.

Shreve's recent monograph, "Vegetation of the Sonoran Desert," published after his death, is a fitting and logical culmination to an impressive list of publications that stemmed from the Carnegie Institution's study of the desert: over 400 articles, monographs, and books.

Now that the Tucson Laboratory has long been out of existence, we might look at the deserts of the world, outside of North America, to see what laboratories are in operation today.

Desert laboratories today

There are none in Australia and South America. The Sahara has two small stations with primitive facilities, and there are two in the Kalahari of South Africa. The vast Asiatic deserts, from Suez to the Gobi, are a little more fruitful in this regard. Israel has three observation sites in the Negev and a small laboratory at Beersheba. India is establishing a Desert Research Institute at Jodhpur. And Russia is experimenting with a number of semi-permanent stations, one of which traces the effect of sandstorms on vegetation.

All of these stations or laboratories are small, and none of them is strictly comparable to the one at Tucson. The Tucson Laboratory was devoted to pure science while the others are concerned with economical applications.

In thinking about the need for a center in this country to continue the traditions of the Arizona Laboratory, we notice that in the desert, in particular, the most interesting situations are likely to develop far from headquarters. The Laboratory at Tucson had hardly

Professor of biology Frits Went (right) and lab workers count seedlings that have survived desert temperatures.

come into being when the Salton Sea attracted the staff members to a distant region, where they had to make their studies without the instruments assembled at Arizona.

Again, when Maximov, the Russian plant physiologist, visited the Imperial Valley in 1926, he was amazed to find the creosote bushes alive after a long period without rain. But, as he wrote with much regret, "The absence of a laboratory in the neighborhood prevented my determining the water content of this interesting plant when in a condition of permanent drought." And by the time he got to Arizona, rains had fallen—so he returned to Russia without ever being able to investigate the survival of creosote.

Desert rains, which so profoundly stimulate the flora and fauna, are notoriously local. A single site may be dry for years while cloudbursts are frequent nearby.

In order to overcome difficulties of this sort, which are encountered by conventional field stations, Frits Went of Caltech has long advocated the construction of a laboratory that would be mobile—one which, like the nomadic Tibu of the Libyan Desert, could follow the rains from place to place.

His idea was realized last summer. Through the generosity of Mrs. Austin McManus of Palm Springs—whose father more than 70 years ago pioneered that now glamorous town in the desert—funds were provided for a truck and house-trailer.

The trailer has been modified into a biological laboratory with work tables and instruments, such as microscopes and balances. Since desert conditions require that the investigators be comfortable, the kitchen stove, refrigerator, hot water heater, and shower have all been retained—and for summer operations there is both an air conditioner and an evaporative cooler. The utility department and key to the whole operation is the truck. It carries 500 gallons (or about two tons) of water under pressure, a 4000-watt generator, and an air compressor. Because it is equipped with its own electricity and running water, the truck-trailer unit is independent of a fixed site.

Known as the California Institute of Technology Mobile Desert Laboratory, it is based at the Rancho Senora del Lago in the desert near Palm Springs.

Probably no other area in the world could offer a mobile laboratory such a diversity of arid terrain to explore. The white sands of the valley floor, bounded to the southeast by the Salton Sea and the dunes of the Algodones, are rimmed by bajades, canyons, and mountains culminating in the 10,000-foot peak of San Jacinto. The only opening from the west, the Gorgonio Pass, is a funnel for almost constant, sand-blasting winds. The palm oases of the foothills, with their peculiar insect fauna, are relicts of a moister age; while the Delta of the Colorado has a climate that is one of the driest and hottest on earth; and across the Sierra Juarez is a fog desert where xerophytes are festooned with moisture-loving lichens. Though much of this great land is under invasion by the works of man, large areas have been set aside for permanent protection—Anza and Borrego State Parks, Death Valley, and Joshua Tree National Monument in the Mohave.

At present, the desert is suffering one of the most prolonged droughts of recent times. Animal numbers are at a low; and many shrubs, which once had grown to a fair height, are dead or dying. Under these circumstances we are particularly interested to know how species of animals and plants survive.

An obvious and easy animal to investigate is the black harvester ant of the genus *Veromessor*, whose colonies, although rare, can still be found in the white sand desert. This species depends on seeds for food, yet for the last three years there has not been enough rain to bring up the annual vegetation; and there has hardly been a really good flower year for a decade.

Robbery pays

Our method of study is to mark a number of colonies and then follow their fate from month to month. And we investigate the food that the ants carry to their nests by the simple expedient of robbing the workers. It is as though a giant were to post himself outside a supermarket and, with huge tweezers, tease all persons who came out until they dropped their bundles. In this way, without seriously upsetting the life of the colony, we are able to get a picture of the amount and kind of food that it collects every week of the year.

An interesting supplementary method would be to uncover the underground granaries of non-marked colonies. But our last attempt had to stop at a depth of 12 feet. At that depth, which made further excavation impractical, we had not reached any of the main chambers, and the passageway was still spiralling down at a steep angle. We did find, however, a small store of seeds at 8 feet, and, although it is often said that ants bite off the radicles to prevent germination, these seeds sprouted when given light and moisture.

One reason that the black harvester ant digs such deep nests is that its temperature tolerance is extraordinarily narrow for a desert insect. In summer, although it may be sluggishly active all night, dumping sand and refuse on the middens, it does not forage until sufficiently warmed by the sun—around 6 a.m. Then food is hunted at top speed, for by 8 a.m. the sand is so hot that the workers have to go below, not to reappear again until the cool of evening. If a wind should arise while the ants are foraging, all wheel around and hurry back to the formicary.

The more familiar one becomes with the black harvester ant the more surprised one is that so sensitive a creature succeeds so well in the desert. The one other harvester occupying the white sands, a large red variety of the genus *Pogonomyrmex*, would seem to be better suited. It is aggressive, it inflicts a severe sting, and it forages all day, even on sand that is 150°F. or hotter. Yet its colonies are the least numerous. Should the present drought continue, it will be interesting to see which species can truly survive the extreme aridity—and how and why it is able to do so.

In studying the food of the black harvester ant, we found that the amount and variety collected by a particular colony each day was quite constant for a number of weeks. Then, when seeds apparently became increasingly rare the workers would disappear, and drifting sands would close the abandoned hole. The colony seemingly had failed. But always within a few days a new hole would be opened—fifty feet or so away—and a new territory invaded for food.

Altogether, we found that the ants brought as many as 15 different kinds of seeds to their nests, though two species comprised 90 percent of the total.

One came from a small insignificant plantain of the genus *Plantago;* the other from a small, insignificant comb-bur of the genus *Pectocarya.* Were it not for the fact that more than three years ago these drab little plants had sprouted and seeded in abundance, the ant colonies probably would not be able to keep alive today. Interestingly enough, cheek pouches of kangaroo rats also yielded only these same kinds of seeds—indicating that rodents, too, are depending upon them for survival.

The ants found very few seeds of those plants which are so colorful in wet years. Sand verbena and desert-gold each made up only one percent of the total, and there was no primrose.

It would seem, then, that possibly because of the toll levied by ants and rodents, seeds of some of the desert annuals in this particular area are becoming scarce, and more than one wet season may be needed to replenish the supply.

Artificial rain

In order to get more exact information about numbers of seeds in the sand, we set up an experiment in which a different but comparable area of the desert was sprinkled with artificial rain each month. After each area had received the one wetting, it was given no additional water. Whatever plants came up had to grow without further moisture. We were interested also in determining the kinds of seeds that might germinate at different times of the year, and in following the fate of seedlings.

In spite of the fact that ants had collected some 15 species of seeds in the sand, the only kinds to germinate during the hot summer months—July, August, and September—were a sand-mat of the genus *Euphorbia* and sand verbena of the genus *Abronia.*

As these plants were not supplied with additional water, most of the verbena perished very quickly. But the sand-mat proved itself a true "summer annual." Without apparent water and growing in full sunlight on white sand—which reached a temperature of 140°F. daily, one inch below the surface—most of the plants thrived. They increased their spread (that is, their diameter) at the phenomenal rate of three-quarters of an inch a day until flowering, lived for as long as four months, and produced copious amounts of seed.

It may be that the plants obtain their moisture from dew. Professor Duvdevani of the Hebrew University in Jerusalem has found that certain plants can draw dew-water through their leaves into the roots and even into the soil for storage. But we know almost nothing about the occurrence of dew—if it occurs at all—on our California deserts during summer. Fortunately, this deficiency can be overcome now by using an instrument for measuring dew-fall developed by Profesor Duvdevani, Caltech's Desert Laboratory is equipped with one.

The end of September saw an abrupt change in weather last year. The heat of summer gave way to mild temperatures, and in contrast to results achieved by summer watering, that done in October and November produced thirteen species of "winter annuals"—but no sand-mats.

Besides this striking difference between the vegetation of the hot and cooler months, there was also a difference between October and November. In October, which was relatively mild, one of the kinds of seeds that are so important now to the black harvester ant sprouted four times more abundantly than all other species combined. This was plantain.

But in November, when minimum temperatures fell below freezing, plantain was rare; while a mallow of the genus *Malvastrum*, which previously had been scarce, was abundant.

Obviously, then, the kind of weather following a desert rain goes a long way towards determining the composition of the flora that subsequently arises. And, hence, even in wet years, the annual vegetation of one year may be quite different from that of another.

So far, our watering experiments have not met the conditions required for germination of the second species that is important to the ants, for not a single comb-bur has appeared.

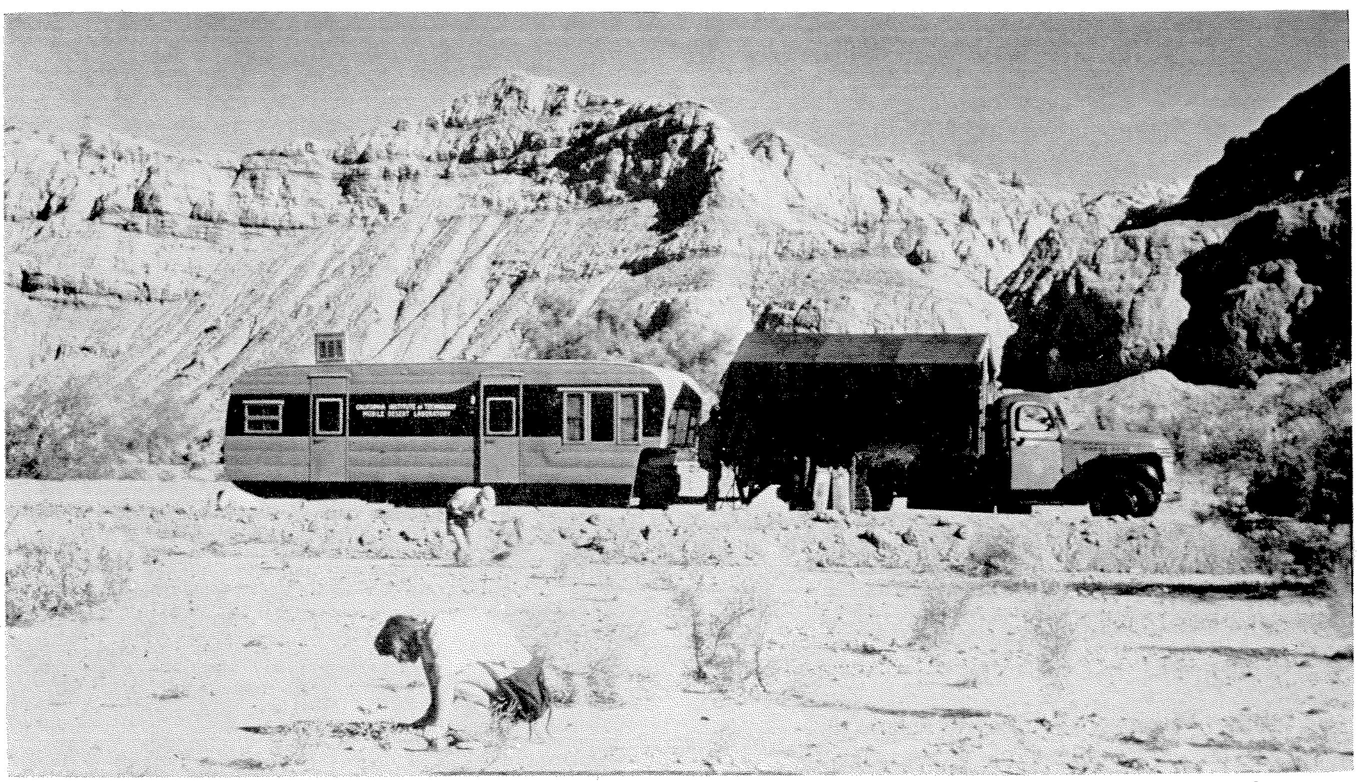
Except for moisture deficiency, the chief cause of mortality during the summer was rabbits, which ate verbena but not sand-mat—the latter being protected by a milky juice that is said to have protein-digesting powers. In October and November, wind was very destructive to seedlings because of the sand-blasting that acompanied it.

Research, such as this on the ants and the annual vegetation of the white sand desert, requires fairly continuous, long-time study of a single area, and might not seem appropriate for a mobile laboratory. But we intend that such studies are to be part of the program in order to provide continuity.

Another idea is that the mobile laboratory should not operate only for the benefit of Caltech. Rather, we would like to see it used as was the Desert Laboratory at Tucson, which attracted workers from all over the world. And, though that laboratory was concerned chiefly with plants, we plan to give equal encouragement to the study of animals.

The relation between animals and plants, as exemplified by harvester ants and seeds, is one of many interlocking factors affecting survival of species. In warm, humid climates, a bewildering array of organisms makes the segregation and evaluation of these factors difficult. But in the desert, where the flora and fauna are limited by aridity, the task is less complex.

That is why Caltech's new research center on wheels is designed particularly to investigate arid regions. The desert itself, with long periods of magnificent weather broken by violent extremes, is an exquisite biological laboratory. There is much to be learned from it, and by studying how its plants and animals survive the climatic extremes, we hope to complement the work that Caltech's Earhart Laboratory is doing with controlled weather.



The mobile laboratory now makes it possible for desert researchers to follow the rains from place to place.