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A few words from the Director of the NRS

The thin layer of soil covering the earth's surface represents the difference between survival and extinction for most terrestrial life. — John W. Doran and Timothy B. Parkin (in "Defining and assessing soil quality," pp. 3-21. From: J.W. Doran et al., eds., *Defining soil quality for a sustainable environment*. SSSA Special Publication No. 35. Madison, WI: Soil Science Society of America, 1994.)

Historically, the study of soils has emphasized aspects important to agriculture. Within four years of the signing of the Declaration of Independence, an Act of the Legislature of Massachusetts on May 4, 1780, incorporated the American Academy of Arts and Sciences, asserting that "the Arts and Sciences are the foundation and support of agriculture,

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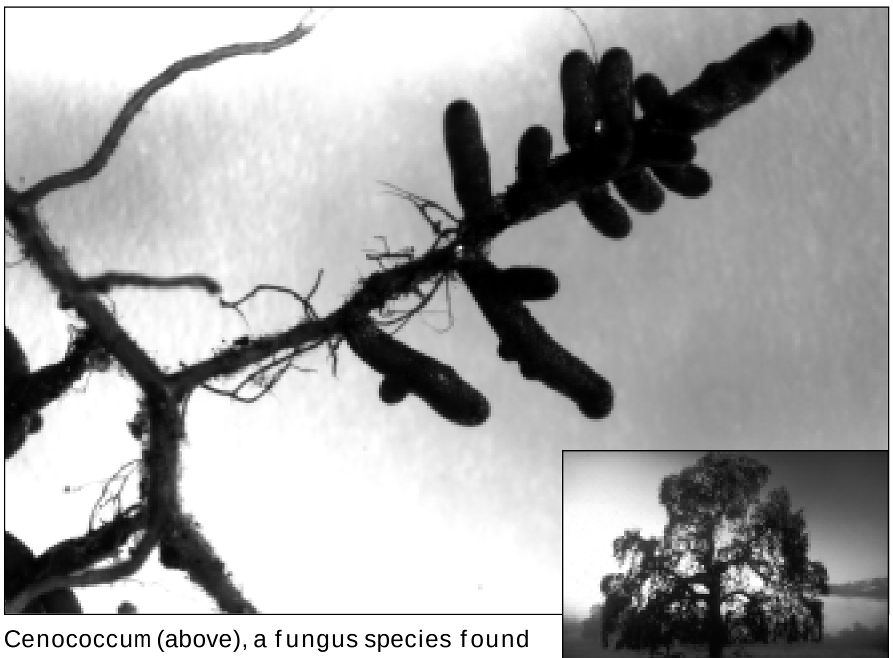

Cenococcum (above), a fungus species found in and on oak tree roots at the NRS's Emerson Reserve. Now that plant-fungus mutualism is being studied in the field, mycorrhizal fungi are understood to form extensive underground networks that support not only huge individual plants, but entire landscapes. Photo of Cenococcum by Amy Lindahl; inset of valley oak at the NRS's Hastings Natural History Reservation by Galen Rowell

(Field) notes from underground reveal the true nature and extent of flora-fungi relations

Like a moth to a flame, UC biology professor Michael Allen is drawn to disasters, natural or human-caused. Whether he's investigating the barren landscape of a Wyoming strip mine, the devastated slopes of Mount St. Helens, or the fate of Mayan civilization, Allen seeks to understand the impact of disturbances on ecosystems and the processes by which they recover. Even the thick smog darkening the sky outside his Riverside campus office attracts his interest as he ponders the impact of the nitrogen that it rains down upon the desert ecosystem.

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(Field) notes from underground

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By studying disrupted ecosystems, Allen has discovered the importance of mycorrhizal fungi. Many people don't realize that plant roots are not especially efficient in extracting resources from soil. Much of the work is actually done by these small, often microscopic, fungi that live on and in the plant's roots. Over hundreds of millions of years, fungus and plant have evolved a mutualistic relationship that benefits both organisms. The fungi extract nutrients from the ground and supply them to the plants; the plants extract carbon from the atmosphere and provide it to the fungi.

Scientists have long regarded the relationship as a perfect example of mutualism in nature. Now, however, Allen and his colleagues are developing an expanded vision of the role that mycorrhizae play in natural ecosystems. They realize that the fungi often don't simply share a relationship with a single tree or plant. Instead, they form underground networks that link plants and trees across a landscape. Rather than simply provide nutrients for a single plant, they allow plants separated by many meters to share moisture, carbon, and nutrients. Scientists call this system the Common Mycorrhizal Network (CMN).

Allen is fascinated by the idea that tiny organisms can form a network that physically links plants at great distances. "Fungal hyphae [threads] are often considered microscopic," he notes, "mainly because we look at them through a microscope. But they're really macro-organisms that are distributed in microscopic units. One hypha may be only 2 to 20 microns in diameter, but it meanders across a large area,

Mycorrhizae 101

Almost all plants are mycorrhizal — meaning, they have ongoing associations with one or more fungi. The only exceptions are some annual weeds that tend to thrive in disturbed areas. Old strip mines, for example, are covered with annual weeds until mycorrhizae reestablish themselves. At Mount St. Helens, recovery first focused in small areas at the edge of the blast, where surviving pocket gophers carried mycorrhizal spore up from their burrows.

Hundreds of different species of mycorrhizae exist, but all can be divided into two predominant types. Ectomycorrhizae (EM) species are found on the surface of a root and within the root, but not within the root's cortical cells. EMs are visible to the naked eye and are the dominant form in woody plants. Arbuscular mycorrhizae (AM) species, on the other hand, are microscopic; their hyphae penetrate the root's cortical cells to exchange nutrients. AMs are the dominant type in grasslands, shrublands, and agricultural ecosystems.

Though a Common Mycorrhizal Network (CMN) may connect plants of many different species, it is formed by the hyphae of a single fungal species. It is often difficult to tell exactly which plants are part of a CMN, because the network is both dynamic and patchy. Burrowing animals can clip through some branches, cutting off specific plants or whole parts of the landscape. Moisture pooling under a rocky patch of ground might lead to the development of a thick patch of mycorrhizae. Some fungi live for years, but most turn over every few months. One arbuscular mycorrhizal unit completes a life cycle every seven days.

How do plants benefit from the CMN? Is a forest ecosystem some sort of socialist paradise where the trees and plants share nutrients, each according to its need? It's been established that they do indeed share resources. When an oak tree taps into a good supply of groundwater, for example, it uses hydraulic lift to pull the water up. Then, once the tree is full, its stomata close and water begins flowing sideways through the roots into the mycorrhizal hyphae. Once the water reaches the tips of the mycorrhizae, it can be released to help extract nutrients from dry soil, or it can be transported via the CMN to other plants.

Beneficiaries of this movement include oak seedlings that remain dormant for many years under their host tree. UC Riverside graduate student Amy Lindahl recently demonstrated at the NRS's Emerson Reserve that the seedlings share a great number of mycorrhizae with the mature tree. The closer they are to the host, the more species they share. Consequently, although the seedlings remain the same size for years, they are able to persist through dry years by drawing moisture from the host via the CMN. And when the host tree topples over or dies, dozens of well-established seedlings suddenly emerge, each one a potential replacement for the fallen host.
— *JB*

wrapping around itself to form bunches that can stretch meters and meters across the landscape."

Much remains to be discovered about CMNs and their role in the environment. Are they simply passive conduits through which plants exchange resources? Do the fungi actively control the flow to support their own development? Or do plants and fungi together control the flow to benefit both organisms? Allen is now working with other scientists from UC Riverside, UC Davis, and Southern Oregon University to investigate CMNs in hopes of finding answers to these questions.

Knowledge of mycorrhizae is best acquired through fieldwork, as they are extremely difficult to grow in the laboratory. Allen and his students often work at NRS sites — most notably, Emerson Oaks Reserve in the Temecula Valley — but the initial stages of a CMN project are conducted outside of a reserve for a very simple reason: a lot of destructive digging is required. Allen notes, a bit ruefully: "After a few years of study, a place can look like Swiss cheese when we're done, and we don't do that in a reserve."

The CMN group faces a daunting task that has as much to do with a computer scientist's network theory as it does with species diversity. In a sense, they're trying to decipher an unseen, constantly evolving, network by marking resources in one plant and then tracing them to neighboring plants. But they aren't sure which species transfers what resources, nor do they know how efficient each fungus is. To top it all off, this entire process is happening in three dimensions throughout the soil column, and, periodically, entire strands of the network die away and re-form again.

For now the group's first goal is to determine how the fungi are distributed at each of their research sites. Then they will use isotope signatures to follow moisture and nutrient movement among the plants. Once they understand the distribution patterns throughout the landscape and which species of mycorrhizae are present, they will still face the difficult task of figuring out who is moving what, where, and when.

"It's a mess!" Allen notes with a chuckle. "But what we're learning by looking at network theories is that the CMN's very mass is what makes it a stable system. If a collembolan [springtail] chops off one strand of the network, it doesn't matter. There are 39 others hanging around ready to take its place."

New technology promises to facilitate a number of major breakthroughs in our understanding of mycorrhizae and CMNs. Rather than dig up, and thus destroy, a mycorrhizal network to observe it, Allen is working with engineers in the CENS Project (Center for Embedded Networked Sensors) at UCLA and the NRS's James San Jacinto Mountains Reserve near Idyllwild to develop noninvasive sensors that can monitor the network in situ.

Field researchers use a minirhizotron camera system to spy on plants and fungi underground. Images that are collected using such technology are more complex and subtle (and, thus, more difficult to interpret) than photographs of bits of individual species taken in the lab using an electron microscope. However, real-time, in situ minirhizotron camera images are essential to understanding the real workings and full extent of fungal networks. Photo courtesy of Bartz Technology Corporation, Santa Barbara, CA

To monitor an entire landscape, Allen envisions a wireless network of "minirhizotron probes" — basically, tiny cameras inserted into clear plastic tubes and observing the development of plant roots. Each minirhizotron camera system might include not only cameras, but also CO_2 and nitrate sensors, as well as temperature and moisture probes that allow scientists to monitor the network nondestructively over time. "We can use molecular analysis to identify the fungi and the plants involved. Then we'll build up a collection of images and data that will allow us to observe the CMN over time. The minirhizotron technology is already good enough that we can identify and track individual fungi down to about 10 microns."

In a few years, advanced monitoring technologies like those being developed by CENS may help Allen and his colleagues untangle the story of the CMNs. Until then, they will continue the backbreaking fieldwork and painstaking lab work that are just beginning to reveal the functioning of this long-hidden underground world. — *JB*

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The upper crust surviving nicely at NRS desert site

When Jayne Belnap talks about the NRS's Jack and Marilyn Sweeney Granite Mountains Desert Research Center in the Eastern Mojave, she tends to focus on what's *not* there — namely, hoofprints and tire tracks. Belnap is a scientist with the U.S. Geological Survey (USGS), based in Moab, Utah. She travels throughout the world, searching for undisturbed biological soil crusts, which she believes play a key role in desert ecosystems.

The crusts, which are composed of microscopic cyanobacteria, algae, mosses, and lichens, form slowly and damage easily. Consequently, undisturbed crusts are essential to Belnap's research. She compares what she finds when she's working in nonreserve areas with what she finds at reserves: "In areas *near* the [Sweeney Granite Mountains] reserve, when I don't see lichen (the most distinctive element in most crusts), I often can't tell if they aren't there because the environment didn't support them or because the cows smashed them. *On* the reserve, if they're not there, it's *not* because someone ran over them five years ago. It's invaluable to have places like that. And, with time, it's going to get even more so."

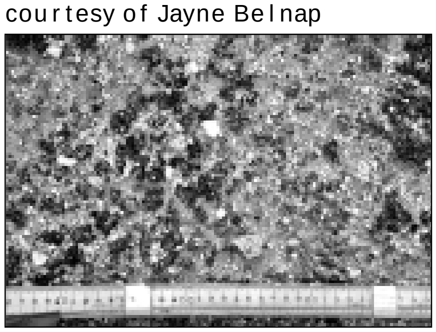
Belnap's interest in biological soil crusts grew out of her fascination with the factors that structure plant communities. Throughout graduate school, even when she was studying butterflies and birds, she found herself wondering why grass grew in one area while sagebrush dominated another, or why trees flourished on one hillside, but left another barren?

These questions became particularly insistent after she joined the USGS and began exploring the Colorado Plateau around Moab. That's when her focus first turned to soils, and soon she became convinced that — in this area, at least — the answers to all her questions lay in the top few millimeters of soil, where the thin crusts modulate everything that enters the soil.

Composed of living, mostly photosynthetic organisms, biological soil crusts range in thickness from 10 millimeters to 10 centimeters. They can occur wherever plant cover is sparse so that light reaches the soil surface. Crusts are found in the pine barrens of the eastern United States, for example, where the infertile soil ensures sufficient surface exposure. They're also common on some parts of the Great Plains where the grass is not especially thick. But they're particularly prevalent in arid and semi-arid areas like the western United States.

Undisturbed soil crusts at the NRS's Sweeney Granite Mountains Reserve in the Eastern Mojave Desert. Photo by Jayne Belnap

Belnap toils away at the edge of a soil crust in the Great Basin. Photo courtesy of Jayne Belnap



Bomber lichens thrive on intact soil crusts in the Mojave Desert. Photo by Jayne Belnap

Belnap can quickly list all the crucial roles soil crusts play in desert ecosystems. "The organisms and their by-products bind the soil to prevent wind erosion. They change the pH of the soil surface. They fix nitrogen. They add carbon. They influence water infiltration. They influence water evaporation. I'm convinced that they really are the driver of many desert systems."

Her explorations around Moab soon evolved into more extensive trips to find out whether soil crusts performed these functions in all deserts or only at certain latitudes. She traveled throughout the Great Basin and the Mojave Desert, trying to determine the extent of their biological soil crusts, how their species compositions varied, and how the roles they play in the ecosystem changed. It wasn't long before her search brought her to the Sweeney Granite Mountains Desert Research Center.

It wasn't just the untrampled crusts of this NRS site that attracted Belnap. The reserve's precipitation records are valuable in helping her gauge the crusts' response to rainfall. Also, the year-round presence of a knowledgeable on-site staff provides a context for understanding the things she sees in her sporadic visits. "It's invaluable to have people around who can show me where the annual grasses are located,"she notes, "or tell me what happened to the yuccas last year."

The work that Belnap's team conducts at the Granites has proceeded on several levels. One effort focuses on developing a regional model for the entire western United States that predicts the locations of biological soil crusts. A number of plots established at the Sweeney Granite Mountains Reserve feed into this model.

Another research focus asks similar questions, but on a local level. What factors specific to a site lead to crust formation? Do crusts favor locations next to washes? Do they prefer younger soils over older soils? Do they like being next to plants, or do they favor the open spaces between plants? Again, plots at the Granites are a major part of this investigation for the Eastern Mojave.

How crusts vary

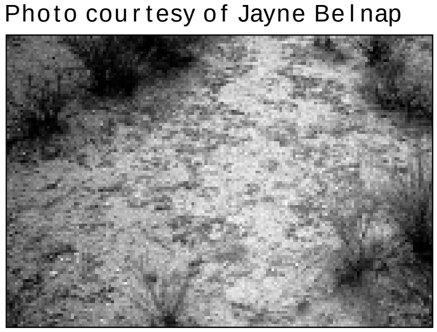
Biological soil crusts teem with life, but the exact composition of a crust varies from location to location. Near Boise, Idaho, for example, the soil crusts are very thick and dominated by 20 to 30 species of lichens and mosses. As they move south, however, species begin to drop out, one by one, until in the Mojave Desert, crusts are much less obvious and consist of only two or three species of lichens and mosses. And in the extreme heat of the Sonoran Desert, crusts are difficult to see and dominated completely by cyanobacteria. This variation in composition from area to area also means changes in the role a crust plays from area to area.

In the Mojave, for example, biological soil crusts play a major role in protecting the soil against wind erosion. The long distances between plants and the presence of few plant roots at the surface make this crucial. The organisms in the crust bind the soil particles and thus limit erosion; damage to the crusts is a major factor in erosion.

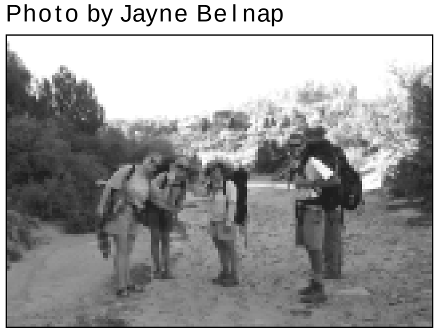
Much remains to be discovered about soil crusts. Belnap is convinced that they modulate water infiltration and evaporation in the Mojave, but she's not sure how they do it. While pores in the crusts might clog, preventing water from penetrating into the soil below, the rough surface texture of crusts also slows runoff, giving the water more time to soak into the ground. The exact outcome of this balancing act remains to be determined.

Another big area that remains poorly understood is the role that soil crusts play in making nitrogen available to plants. In northern areas of the western United States, where the weather is colder and damper, lichens and mosses in the crusts play a major role in fixing nitrogen. In the Sonoran Desert, cyanobacteria play that role. But in the Mojave, where the crusts contain only two or three species of lichens and mosses, the predominant strains of cyanobacteria are not as efficient at converting nitrogen. Belnap believes their role in fixing nitrogen is limited.

Crust team members at work in a soil pit, demonstrating that soil scientists are not afraid to get dirty. Photo courtesy of Jayne Belnap



A real find: Mojave interspace with soil crust beautifully intact. Photo by Jayne Belnap



Belnap (left) and her team of self-described "dirtbags" in the Mojave. Photo courtesy of Jayne Belnap

The crusts also play a heretofore largely unexplored role in the soil food webs — the community of nematodes, mites, bacteria, and fungi that make nutrients available to plants. The crusts' rough surfaces capture seeds and organic matter for these animals, but Belnap believes they also play a much larger role in supporting such micro-environments.

Difficult to study

One reason so many questions about biological soil crusts remain unanswered is that they are incredibly difficult to study. Though scientists in Europe have known about them since the 1500s, it took over 400 years, until the 1960s, for anyone to pay much attention to them. Even today, Belnap estimates, perhaps no more than ten scientists work on them full-time.

Only half in jest, Belnap curses the day her professor at Brigham Young University introduced her to the subject. "Identification is terribly difficult," she complains. "All the organisms that make up the crusts are tiny and embedded in dirt. Processes that normally take a plant researcher a week take me two to three years because I have to develop the machine to do it!"

The good news is that probes being developed for other purposes can now be adapted for use with soil crusts. Belnap's dream is that some day DNA testing will develop to the point where she can run a quick test to determine the composition of crusts. Until then, rather than identify individual species,

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The upper crust

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she deals with the entire community as a single entity as she tries to gauge its impact on the surrounding environment.

Save the crusts

The presence of soil crusts is a good indicator of a healthy desert ecosystem. An intact soil crust means that the soil below is also functioning well: the nutrient cycles are intact, and water infiltration and evaporation are occurring normally.

To Belnap, our current approach to the desert is akin to an uncontrolled experiment on a grand scale that covers 250 million acres of the western U.S. landscape. We drive all over it in cars and tanks. We graze cattle and sheep on it. With the federal government's support, ranchers are continually adding new water so that cattle, along with deer and other wildlife, can move into ever more remote areas. And everywhere we go, we're converting lichen- and moss-dominated crusts into cyanobacteria-dominated crusts.

The result, she fears, could have major implications: nitrogen and carbon input are reduced, and the color of the soil surface is changed from dark to light. And because light surfaces absorb less energy than dark surfaces, this cools an area. One study showed the change could be as much as a 14°C difference — more than enough to interrupt plant function and soil food webs. The disruption might not be significant on a small scale, but when it happens over thousands of acres, regional processes, such as rainfall and cloud cover, could very likely be affected. — *JB*

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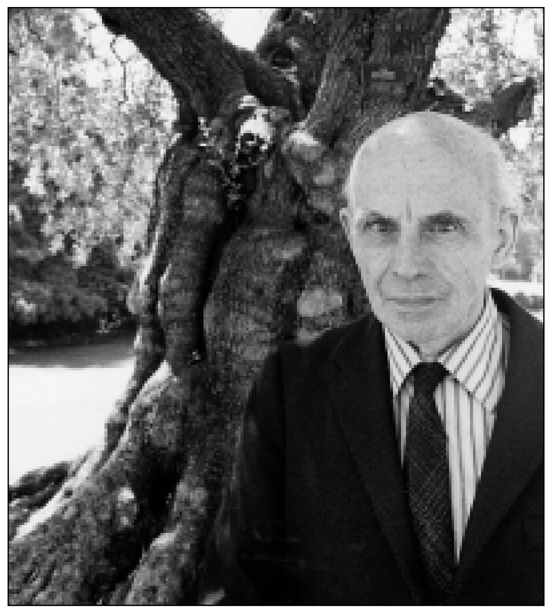
A search for Hans Jenny awakens new appreciation for the legacy of this world-class soil scientist

Society grants human beings a right to exist, regardless of whether we are useful or not…. I wish we would extend the same right to soils. — Hans Jenny



Hans Jenny, UCB professor emeritus of soil science. Photo by Dennis Galloway/UCB

The Hans Jenny Pygmy Forest, one of seven original NRS reserves, is a dirty little treasure waiting to be rediscovered. The area receives limited use these days. Though groups from local schools do occasionally tour the 70-acre site, its remote location in Mendocino County and facilities-free status do not encourage visits from researchers or university students taking field courses.

But, for anyone ready to notice, the Jenny Pygmy Forest has a special role to play in illustrating the interdependence of soil and plants in ecosystem formation. Located on ancient marine terraces, the sandy soils of this site are underlain by an impermeable hardpan of iron and graywacke sandstone. Neither plant roots nor water can penetrate the hardpan, and, over hundreds of thousands of years, acid leached from nearby trees has built up in the infertile soil. Very few species can eke out a living in this impoverished environment; those that do must struggle mightily. A 75-year-old Mendocino cypress, its needles brown from lack of nutrients, may stand only three feet tall.

Even in its underused state, the Jenny Pygmy Forest Reserve serves an important purpose, preserving one of the last remnants of a unique ecosystem. Ecologist Pam Huntley, who oversees an adjoining Nature Conservancy preserve, has acted as the volunteer caretaker for this NRS reserve since 1985. "At one point there were 32 different pygmy forest sites between Ten Mile Creek and the Navarro River," she recalls, "but wherever people build roads and houses, they break through the hardpan that underlies the forest. And once the trees have access to more nutrients, they grow big. So now there are only a few places with stunted pygmy trees."

In the 1940s, most local residents didn't think too much of these places with the stunted trees and bad-tasting water. Such sickly trees couldn't be logged, and the areas flooded every winter. Whenever someone was looking for a spot to dump garbage or build a community airport, the easy solution was to dig up a pygmy forest terrace.

Honey, I shrunk the trees! Adult man stands next to adult tree in the Hans Jenny Pygmy Forest Reserve. Photo by Susan Gee Rumsey

Then along came Hans Jenny, noted UC Berkeley professor of soil science, who realized that here was one of the few places in the world where one could track the complete evolution of soils from their origin to near-depletion. The Swiss-born Jenny, who passed away in 1992 at the age of 93, is considered a giant in the field. "He was a great physical chemist," notes Ron Amundson, faculty manager for the Jenny Pygmy Forest Reserve. "His book, *Factors of Soil Formation*, totally revolutionized the field with a concept that looks simple, but is filled with subtlety and depth. A lot of professional soil scientists to this day really don't have a grasp of the intellectual depth of that concept."

The Jenny concept to which Amundson refers is the idea that just a handful of important factors determine the character of soils in nature. Jenny expressed his concept as a relationship: CLORPT — which stands for Climate (CL), Organisms (O), Relief (R), Parent Material (P), and Time (T). Even today — 63 years since Jenny released his CLORPT relationship in 1941 — the concept is hotly debated by soil scientists, ecologists, and students around the globe.

Jenny's passion for soils was legendary. Amundson recalls that, as a graduate student at UC Riverside in the 1970s, he invited Jenny to speak to his department. "His talk traced the role of soils in landscape painting," Amundson recalls, "and people were stunned by the breadth of his knowledge. He could speak authoritatively about both soils and art. He opened up everyone's eyes to how nature and soils were being portrayed."

Huntley saw the same traits in a very different context when she asked Jenny to address a third-grade class in Mendocino in the 1980s. "The students were captivated by his enthusiasm as he talked about the colors, textures, and age of soils. Here's this 80-year-old man with his Swiss accent who just oozed excitement for his topic. The kids loved it!"

Jenny and a few colleagues, most notably forestry professor Arnold Schultz, spent years investigating the pygmy forest, piecing together its story and publishing their findings. Schultz recalled in a tribute to his friend: "Hans Jenny showed me how to have fun doing research, how to strive for powerful theories, and how to insure that whole ecosystems remain for others to enjoy and study."

Much has changed since those days. The Department of Soil Science at UC Berkeley has been subsumed into the Department of Environmental Science, Policy, and Management. Most of the scientists who worked on the pygmy forest have retired. Arnold Schultz now lives in Scottsdale, Arizona, where he's still working on a book on the subject. Jenny's papers languish in 52 boxes stored at UC Berkeley's Bancroft Library, their contents largely uncatalogued.

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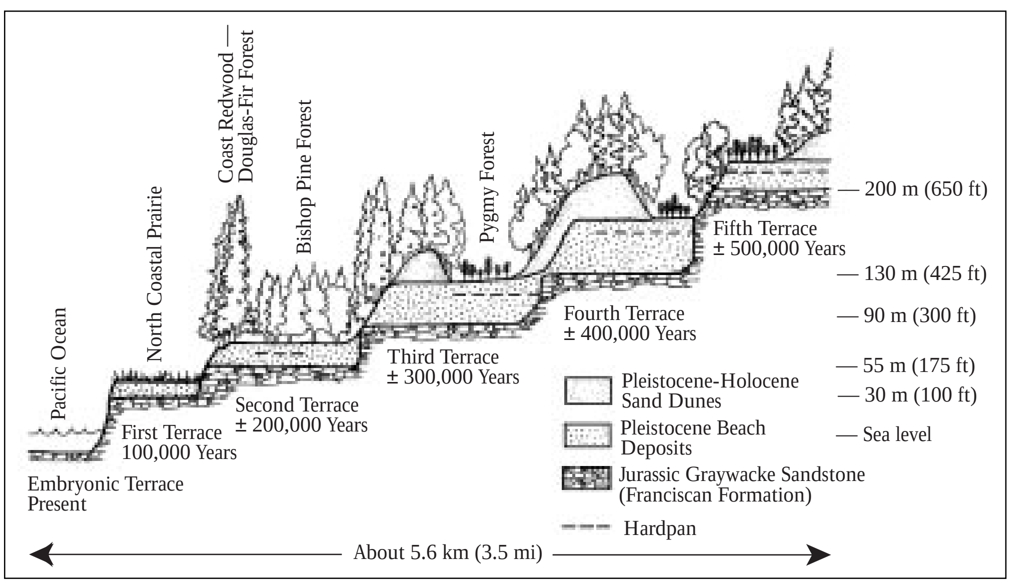

Hans Jenny's conception of the Pygmy Forest Ecological Staircase on the Northern California coast. The Jenny Pygmy Forest Reserve is located on the fifth terrace, an ecosystem that Jenny believed was the oldest in North America. Illustration by Kirsten Englund (1985, after Jenny, 1973)

A search for Hans Jenny

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But a little investigation reveals that Jenny's legacy remains strong.

The Jenny papers at the Bancroft are the expression of a keen scientific mind. Jenny filled journals with pages of equations, showing how he was constantly working on the details behind the CLORPT relationship. Interspersed among these journal pages are drafts of essays, correspondence with students, and scientific papers that reveal Jenny's wide range of interests. Amundson recalls his mentor's Socratic method for exploring topics: "He was always interested in what you thought. He'd listen very carefully and then slowly take control of the conversation, asking probing questions that tested the logic of your ideas. It was always a very interesting experience."

UC Berkeley's Biosciences Library holds several well-used copies of Jenny's classic *Factors of Soil Formation*. More revealing, however, is another book that hasn't been checked out since 1975. Titled *Pygmy Forest Ecological Staircase*, this 26-page, velobound booklet was produced by Jenny in 1973 to advocate national recognition for the area. The book was, obviously, a labor of love. The cover is hand-printed and illustrated in thick felt pen by the author. Inside, the hand-typed pages and carefully trimmed and glued-down color snapshots present both the site's unique characteristics that make it worthy of receiving national recognition and the dangers that threaten its integrity. The book is an effort altogether in keeping with Jenny's view of himself: "I like to think that this is my greatest contribution to soil science — the preservation of natural areas giving an opportunity for future generations of soil scientists to see what nature did with soils prior to human disturbances."

Jenny's legacy also remains strong in the area of public education. Each year thousands of students and public visitors hike the "Ecological Staircase Trail" at the Jug Handle State Reserve, learning the story that Jenny, Schultz, and others painstakingly pieced together. Pam Huntley regularly takes students on the hike, amazing them with the history of the area. She explains: "Each coastal terrace is approximately 100,000 years old. So when you reach the fourth and fifth terraces where the pygmy forests are located, the students suddenly realize that this land has been here largely unchanged for half a million years."

Many current trends in soil science research are based on Jenny's ground-breaking ideas developed during his 50-year career. Amundson's recently published national survey of endangered soils recalls Jenny's efforts to preserve "benchmarks of soil origin and evolution." And Jenny's work on the impoverished soils of the pygmy forest are reflected on a much larger scale in current research into the exhausted soils of the oldest islands in the Hawaiian chain, soils so depleted that the only nutrients available to the area's flora are those blown in on the wind.

And then there's the NRS's Hans Jenny Pygmy Forest Reserve. The site may be quiet today, but it is still *there*. Jenny had the right idea: preserving a site so that, generations from now, a curious researcher might rediscover a hidden part of the North Coast where the trees struggle for existence and humans learn to look a little deeper into their conceptions about how ecosystems function and what constitutes beauty. — *JB*

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Hans Jenny's wife, Jean Kramer Jenny, was a conservationist in her own right and a tireless environmental activist well into her eighties. In addition to supporting her husband's efforts to preserve the pygmy forest in Mendocino County, she was important in helping to secure protected status for the Jepson Prairie Reserve in Solano County and was also involved in the creation of the McLaughlin Natural Reserve in Napa, Lake, and Yolo Counties, two NRS sites administered through UC Davis. This photograph of her was taken at the dedication of the Hans Jenny Pygmy Forest on October 10, 1992. Jean Jenny died in December 2002 at the age of 94. Photo by Susan Gee Rumsey

Old-growth reserve plans new-growth future

Environmental scientists are seeking understanding of natural processes over larger spatial and longer temporal scales than ever before, in order to address urgent questions about ecosystem change. The Heath and Marjorie Angelo Coast Range Reserve, along with the other 33 NRS reserves, supports long-term studies and manipulative experiments needed for the "understanding and wise management" of California's diverse ecosystems.

With this in mind, scientists from across the country were invited to the Angelo Reserve on September 5-7, 2003, for a planning workshop sponsored by the National Science Foundation (NSF). They were asked the following questions:

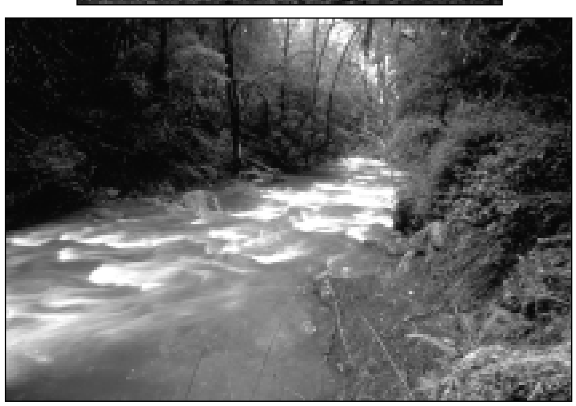
• *What new questions could or should be addressed at the Angelo Reserve that have not yet been addressed? What promising new research directions could be well-served by this reserve?*

• *What other research programs are studying environmental change in rivers and watersheds along California's North Coast? How might changes over the larger region influence the future of Angelo Reserve ecosystems? How might the reserve participate in coordinated regional studies to expand the spatial extent of our knowledge of landscape-ecosystem-organism interactions?*

• *What long-term commitment should be made to monitoring at the Angelo Reserve? What variables would be most valuable to measure? What emerging technologies are available to support monitoring? Who might fund or support such efforts? What are successful models from other institutions or programs?*

In short, the goal was to chart the future of scientific research at this rugged, remote Mendocino County reserve.

Participating scientists represented a range of different specialties, from plant evolution and landscape ecology to hydrology and geomorphology. They came from states as diverse as Wyoming, New Jersey, and Kentucky, and represented a wide spectrum of governmental and nongovernmental organizations, as well as universities. UC Berkeley's Vice Chancellor for Research Beth Burnside attended the meeting to familiarize herself with the reserve, while also contributing her experiences as a researcher who has done extensive work at other field stations.



Two habitats at the Angelo Reserve: old-growth forest and Elder Creek. Photos by Liza Riddle (top) and Bill Trush (bottom)

The meetings took place at the reserve's recently completed Environmental Science Center. Built with a gift from the Richard and Rhoda Goldman Fund, the center includes a meeting room, a library, a computer lab, other laboratories, and a screened lathe house. These facilities were completed in 2002 and represent a major addition to the reserve, providing a cornerstone around which future improvements will be constructed.

The group's challenge was to develop an understanding of the reserve, identify new areas of research that might lend themselves to the site, and compile a list of infrastructure improvements that would be needed to support this research.

Angelo's assets are many. Located in California's rugged Coast Range, the reserve includes one of the largest remaining uncut, old-growth Douglas-fir forests left in the state. Participants were impressed by the reserve's size — approximately 8,000 acres (4,500 owned by UC and 3,500 acres jointly managed with the U.S. Bureau of Land Management) — and its diversity, which includes seven small streams in addition to 5 kilometers of the South Fork of the Eel River. Earlier studies provide a background of 25 years of biological, ecological, geomorphological, and cultural data, while meteorological and stream runoff data have been collected at a U.S. Geological Survey's gauging station on Elder Creek for 36 years and by Angelo researchers from the South Fork Eel since 1990. Participants also commented on the reserve's favorable location, noting that an absence of major upwind pollution

Continued on page 10

Old-growth reserve

Continued from page 9

sources facilitated the study of atmospheric pollutants flowing from China and other Pacific Basin countries.

After touring the reserve in cars and on foot, and hearing presentations about ongoing research, the committee engaged in two days of animated discussion. In the end, they recommended four new research directions that build on past programs at the reserve, while starting some new initiatives, particularly in ecosystem science and biogeochemistry, that take advantage of the natural setting. These include:

• Cross-habitat linkages between channel and terrestrial food webs and ecosystems. Two interface areas were identified as particularly promising: (1) between river channels and terrestrial watersheds, and (2) between the forest canopy and the atmosphere. The reserve's existing canopy walkway provides a good beginning for these latter studies.

• Use of remote and automated sensing devices to monitor ecologically relevant environmental conditions and corresponding habitat use and movements of organisms. U.S. Forest Service researchers, for example, noted that they have developed sensors for monitoring suspended sediment in streams to help determine their capacity to support salmon. They are using these sensors in other northern California watersheds and expressed interest in including study sites in the Angelo Reserve.

• Dynamics of species of critical concern in fluctuating, heterogeneous environments. Salmonids, foothill yellow-legged frogs, Townsend's long-eared bats, and spotted owls are all declining in the region, and the reserve's undisturbed watersheds provide an excellent baseline for studying how these organisms interact with the environment.

• Feedback from organisms and climate to the physical and chemical forcers of landscape evolution. This work builds on several decades of field ecology research already completed at the reserve. The committee noted that the area's simple underlying geology and variety of watersheds with different sizes and slopes facilitate the study of how slope, drainage area, aspect, and local microclimate influence biogeochemistry and biota.

The committee then developed a prioritized list of the facilities and equipment that would be required to support a major increase in research at the reserve:

• The most pressing need is for upgraded housing. At the end of each day, many conference participants journeyed an hour over a winding road out to the coast because the reserve lacks adequate housing for visitors. The committee envisions one building with two to four small apartments for researchers, as well as a second building that could host ten to twelve students or individual researchers attending conferences.

• Improved communications within the reserve, including satellite and wireless technology, to serve both in case of emergency and as a backbone for real-time environmental monitoring at remote sites.

• Secure storage and shop facilities for creating and repairing field gear. Inexpensive solutions were proposed for both of these needs.

• Significant spatial augmentation of automated sampling and sensing devices for environmental and biological monitoring. UC Berkeley professor Todd Dawson [Department of Integrative Biology] described his work developing a wireless network of remote sensors for studying redwood ecophysiological dynamics and discussed how such technology could be used at Angelo.

• Essential scientific equipment for laboratories at the new Environmental Science Center.

• Improved access to the forest canopy through additions to the canopy walkway. Participants envisioned a system of cables and pulleys for deploying sensors, insect traps, or cameras.

• Improved access to remote sections of the reserve. High water in the winter restricts access to one-third of the reserve and also prevents channel studies in the river. A sampling platform spanning the Eel River could address both of these needs.

With the assistance of the NSF funding for this planning workshop, the Angelo Reserve has taken a major step forward in planning for expanding its contributions to long-term and larger scale ecological research. Based on the committee's input, reserve researchers are planning to write an NSF facilities grant application for funding to address the most pressing facilities needs.

— *Mary Power*

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Editor's Note: The Angelo Reserve is protected by The Nature Conservancy (TNC) and constitutes part of the California Coast Ranges Biosphere Reserve, in UNESCO's Man and the Biosphere Programme. (The NRS's Landels-Hill Big Creek Reserve on the Big Sur coast is another part of that same biosphere reserve.) More information available on the Internet at: <http://www.unesco.org/mab/>.

The bad news—and good news—about Elliott Reserve

Teaching and research parameters at the NRS's Elliott Chaparral Reserve were altered significantly last fall when fire raged through the 183-acre, San Diego County site administered by UCSD.

The Cedar Fire, which started October 25, 2003, would turn out to be Southern California's largest conflagration of this past fire season, burning more than 280,000 acres, requiring the efforts of nearly 1,500 personnel, killing 13 civilians and one fire fighter, destroying more than 2,200 homes, and costing the state over $27 million.

When the damage to Elliott Chaparral is viewed in this sorry context, it seems the reserve got off easy: since the site had no facilities, no facilities were lost. Moreover, since fire is a natural part of the Mediterranean ecosystem, field scientists do expect a portion of wildlands — including natural reserves — to burn periodically. The bottom line is: although a big fire like the Cedar disrupts the usual studies in place at a site, it also gives researchers an opportunity to study how populations, habitats, and ecosystems recover after fire.

Elliott Reserve turned to toast during the 2003 fire season in Southern California. Photo by Larry Cozzens

It sometimes happens that the ecosystem of a natural area has a harder time recovering from desperate firefighting efforts employed to save on-site facilities, including bulldozing fire lines, safe havens, and interception troughs, applying large amounts of water or fire-retardant, as well as post-fire application of non-native grasses. However, Elliott Chaparral burned at the height of the Santa Ana winds on the first day of the fire, a time when firefighting was of limited use and not generally employed to slow the fire, but only to protect structures. At the structure-free Elliott Chaparral Reserve, no major fire-fighting efforts were apparently taken — thus, it will be possible to observe a natural recovery of the site over the next few years. — *SGR*

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Remote reserve set to welcome new on-site manager

The NRS's site at Big Sur is due for a big change when Kurt Merg takes up the position of resident director/manager for the Landels-Hill Big Creek Reserve early this year. Big Creek's last change of on-site directors occurred 17 years ago.

Merg joins the NRS upon completion of a postdoctoral research commitment at UCLA in the Department of Organismic Biology, Ecology, and Evolution and Institute of the Environment. There he worked at another NRS site, the Sedgwick Reserve, conducting investigations that included genetic analyses to assess the conservation implications of limited pollen flow in the valley oak (*Quercus lobata*). This deciduous oak is endemic to California and was once widely distributed throughout the state's riparian forests, valleys, and foothills, but now is reduced to a small remnant of its former population.

Merg was an education coordinator for the Organization for Tropical Studies, a research and teaching consortium of more than 65 universities worldwide, and has experience operating in remote settings. He built and administered a solar-powered research station in Papua, New Guinea. He grew up in Wisconsin, working on his family's conservation-oriented farm and learning all aspects of farm operations.

He earned a bachelor's degree in natural resources from Cornell University, a master's in zoology from University of Florida, Gainesville, and a doctorate in botany from Washington State.

Kurt Merg moves into his new NRS position February 1, 2004. Meanwhile, John Smiley, who had managed the Big Creek Reserve since 1986, has already gone on — along with his wife, Kim Smiley, and their two daughters, Rosie and Sonrisa — to Bishop, CA, to become Field Stations Associate Director for UC's White Mountain Research Station. — *SGR*

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Sweeney Granite Mountains Desert Research Center.
Photo by Susan Gee rumsey

NRS desert reserve celebrates its first quarter of a century and an NRS elder

In recent years, research use of the Sweeney Granite Mountains Desert Research Center has grown faster than at any other site in the NRS.

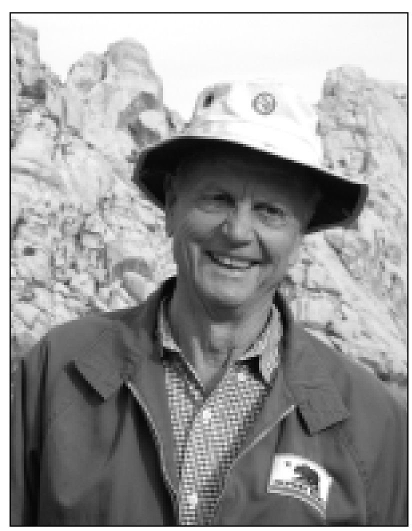
The 9,000-acre reserve was established in 1978, and it would take the site's first 20 years for the number of active research projects conducted there to reach 45. But then, in just the next five years, that statistic would more than double (it now stands at about 108). So far, approximately 380 scientists have conducted 240 research projects at the Sweeney Granite Mountains Reserve and, in the process, they have generated more than 370 scientific publications.

This major achievement of use and productivity was celebrated last fall with a full-day symposium, hosted by the reserve, that encompassed the wide range of disciplines practiced at Sweeney Granite Mountains and reflected the rich history of academic accomplishments supported by this NRS reserve over the past quarter of a century.

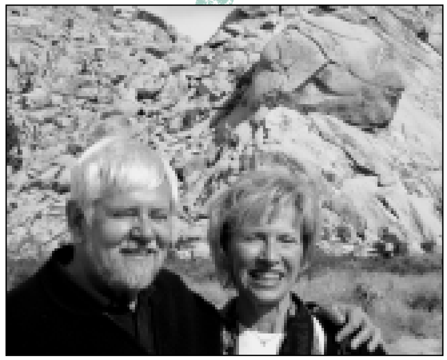
On Friday, November 7, 2003, 120 scientists, artists, lecturers, graduate and undergraduate students, NRS staff, and land management agency professionals gathered at UC Riverside's Extension Center to listen to talks about the reserve and what it takes to maintain it as a resource for research and education, as well as the reserve system to which it belongs. The core of this symposium, however, was comprised of presentations by eleven scientists whose research has depended upon the Sweeney Granite Mountains Reserve:

• Sharon Coe, UC Riverside, on *How does water availability influence reproductive success in desert birds*?
• Brad Coupe, Ohio State University, on *Three generations of sidewinder rattlesnake (*Crotalus cerastes*) spatial ecology*
• Julie Evens, California Native Plant Society, *Research and education from the Granite Mountains Reserve: vegetation in watercourses of the Eastern Mojave Desert, California*
• CJ, Fotheringham, UCLA, *Two studies of community structure in the Mojave Desert*
• Chris Giorni, Tree Frog Treks, *Planting a seed at the GMDRC: How I was inspired to use the field experience to propagate biodiversity awareness to the public*
• Wyatt Korff, UC Berkeley, *Comparative biomechanics of sand-locomotion in lizards*
• Mary Price, UC Riverside, *Community ecology of seed-eating desert rodents: insights from the Granite Mountains*
• Philip Rundel, UCLA, *A tale of three winter rainfall deserts: the Mojave, Succulent Karoo, and Atacama*
• James Russell, UC Riverside, *Parasites of parasites: selfish genes and genetic conflict in* Trichogramma
• Kelly Thomas, UCLA, *Distribution, diversity, and isolation of montane small mammals in the Mojave National Preserve*
•John Wehausen, UC White Mountain Research Station, *Resource predictability for desert bighorn sheep: an analysis of long-term data sets from the Eastern Mojave Desert.*

The symposium's successful conclusion marked the end of the first of three days of celebration of the Sweeney Granite Mountains Desert Research Center. The following day, Saturday, November 8, many of the symposium's participants made



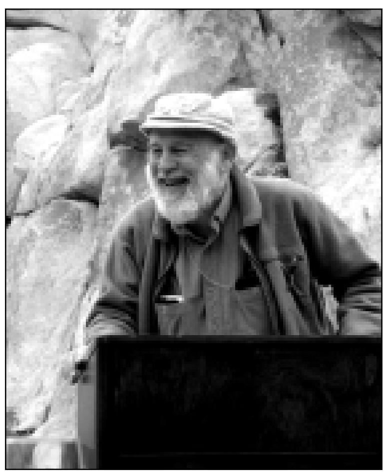
NRS Elder Bob Norris.
Photo by Susan Gee rumsey

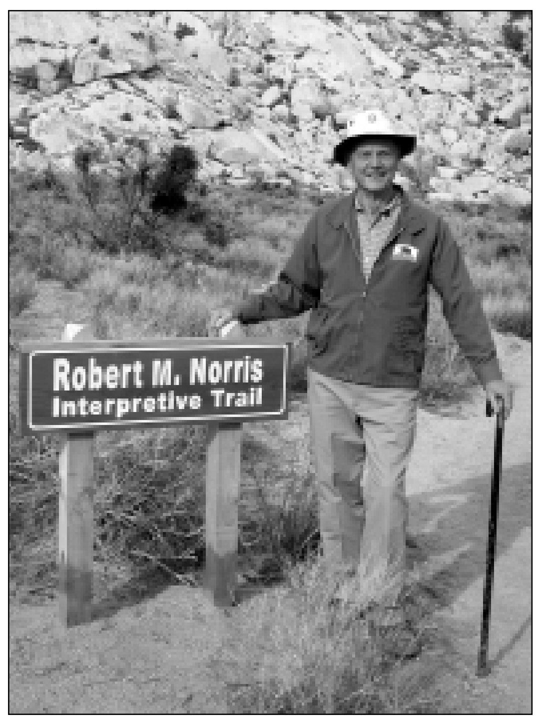


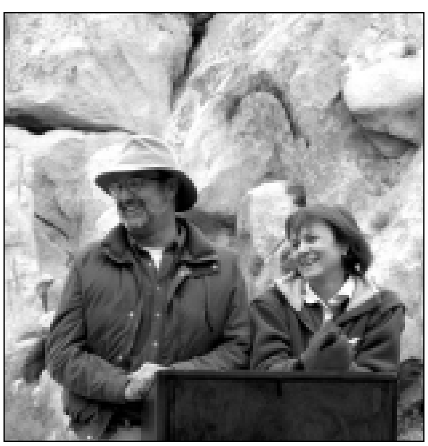
Some who celebrated at Sweeney Granite Mountains Reserve on November 8-9, 2003:
(far left) UC Riverside Chancellor France A. Córdova. Photo by Susan Gee rumsey
(near left) Jack and Marilyn Sweeney, benefactors of the NRS reserve that bears their name. Photo by Chris Foster
(below and clockwise from top) Reserve director Jim André and Bob Norris (photo by Alex Glazer); Bob Norris at the head of the new trail named for him; Bob Norris's son Don; Bob Norris's son Jim and his daughter, Betsy; researcher and long-time friend of the Norris family Evan C. Evans (photos by Susan Gee rumsey).

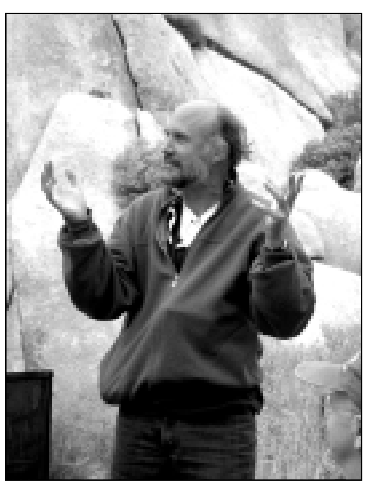
the three-hour car-trek from UC Riverside to the reserve, located adjacent to the Mojave National Preserve established in 1994. There they were joined for a VIP lunch by UC Riverside Chancellor France Córdova and her husband, Christian Foster, Marilyn and Jack Sweeney, who endowed the reserve, many members of the Norris family, who first enabled the land to be brought into the UC reserve system, and numerous other people who have played key roles at the reserve. The highlight of that afternoon was the official opening of the Robert M. Norris Interpretive Trail. Robert (Bob) Norris, professor emeritus of geology at UC Santa Barbara and brother of the late NRS founder Ken Norris, was present to celebrate the reserve and to be celebrated himself for a belated 80th birthday.

And on the final day of the weekend, Sunday, November 9, family members and friends of Bob Norris stayed on to lunch together one more time, toasting and roasting the octogenarian scientist and professor who has contributed so much to the NRS. — *SGR*









Frank Pitelka, distinguished ecologist and longtime NRS scientist, academic, and administrator, dies at 87

Frank Alois Pitelka, UC Berkeley professor emeritus of zoology who served for many years as faculty reserve manager of the NRS's Hastings Natural History Reservation and a member of the NRS University-wide Advisory Committee, died on October 10, 2003, at the age of 87.

NRS old-timers remember Pitelka fondly for his funny little field hat, great Shakespearean-style delivery, and remarkable ear for both bird calls and Verdi operas. For decades, he conducted extensive research in the Alaskan tundra, exploring the effects of food availability on the brown lemming population and on the behavior of arctic birds. He also contributed to the classification of jays and documented the behavior of acorn woodpeckers and hummingbirds. In the process, he helped to establish a field of study that documents how environmental factors affect animal behavior.

During his career, Pitelka published more than 200 scholarly papers. At UC Berkeley, he received the Distinguished Teaching Award and the Berkeley Citation. In 1980, the American Ornithologists' Union conferred upon him its highest honor, the Brewster Medal. In 1992, the Ecological Society of America presented him with its Eminent Ecologist Award.

Pitelka contributed greatly to UC Berkeley's Museum of Vertebrate Zoology (MVZ). He was MVZ's curator of birds from 1949 until 1963 and served for many years as its associate director. The Hastings Reserve is administered through MVZ.

Pitelka was born in Chicago in 1916. He earned a B.S. from the University of Illinois in 1939 and a Ph.D. from UC Berkeley in 1946. Soon thereafter, he joined the faculty of UC Berkeley's zoology department. From 1963 to 1966 and from 1968 to 1971, he served as department chair. Although he retired from teaching in 1985, he continued to oversee the Hastings Reserve until 1997.

A man of exacting literary standards and an exquisite eye for detail, he served on the editorial boards of numerous journals, on the editorial committee of University of California Press for nine years, and on numerous federal committees and panels, including the National Science Foundation, the U.S. Atomic Energy Commission, and the National Academy of Sciences.

He met his wife, Dorothy Riggs Pitelka, when they were fellow graduate students at UC Berkeley; they married in 1943. A cancer researcher and a professor of zoology at UCB, she died in 1994. Pitelka is survived by his two sons, Louis and Vince; his daughter, Kazi; five grandchildren and two great-grandchildren.
— *SGR*

Clark Kerr, legendary UC president and NRS visionary, dies at 92

Many people knew Clark Kerr as UC Berkeley's first chancellor (1952-1957), as the UC system's twelfth president (1958-1967), as chief architect of the California Master Plan for Higher Education (a 1960 blueprint for ensuring access to college for all Californians), and as one of the nation's leading figures in higher education.

Few realize it was Clark Kerr whom Ken Norris approached in 1963 with a dream of building a natural reserve system. And it was Clark Kerr who, being as much a visionary university president as Norris was a visionary scientist, first embraced the NRS dream. Kerr encouraged the idea, helped to fund it, and initiated the administrative process that would be needed to create a UC reserve system.

Kerr would later recall, with satisfaction, his efforts to make the NRS a reality:
One of our major accomplishments during my tenure as president was starting a natural reserve program to preserve one example of every kind of California terrain… . This is a state with enormous variety; identifying the ecological areas and preserving them forever under University control is something that in the long run will loom as having been of increasing importance over the years.

Kerr was born in May 17, 1911, in Stony Creek, Pennsylvania, and raised on a farm. Ninety-two years later, on December 1, 2003, he died in his home in El Cerrito, CA, survived by his wife of 69 years, Catherine; their two sons, Clark and Alexander; their daughter, Caroline; seven grandchildren and one great-grandchild. — *SGR*

UC reserve system premieres on UC TV channel

A diverse and far-flung viewing audience has multiple opportunities this year to learn about the NRS, its resources and uses, through a series of half-hour programs being shown on the University of California's television channel, UCTV.

In the first months of 2004, UCTV viewers can get acquainted with the reserve system through a series of five new programs, each of which highlights a different NRS site. After the initial program about the Hastings Reserve, which aired in December 2003 and was repeated throughout January 2004, each subsequent program airs for a month, rotating through the UCTV schedule to maximize exposure in different communities.

The five featured NRS reserves and their scheduled months of airing on UCTV are:

- Hastings Natural History Reservation (December/January)
- Landels-Hill Big Creek Reserve (February)
- James San Jacinto Mountains Reserve (March)
- Sedgwick Reserve (April)
- Coal Oil Point Reserve (May).

All five programs were created by the video group of Communications Services in UC's Division of Agriculture and Natural Resources (ANR), located at UC Davis. Systemwide Senior Science Writer Jerry Booth co-produced the series for the NRS, working with reserve staff to organize the shoots, conducting the on-camera interviews, reviewing the video footage, writing the scripts, and working with the editor on the completed programs.

Jim O'Brien, ANR Communications Services producer/director, has been documenting activities at NRS reserves for two years. Photo by Jerry Booth

In October and November 2003, the NRS was featured in a six-minute segment on UCTV's newsmagazine "State of Minds." This segment also served as an introduction to the series of half-hour programs focusing on individual NRS reserves. This "State of Minds" show featuring the NRS (the same show that introduced incoming UC President Bob Dynes) remains available for viewing on-demand at the UCTV website. The direct Internet link is: <http://www.uctv.tv/library-test.asp?showID=8138>. (The NRS segment within the 28-minute newsmagazine starts about 12 minutes, 45 seconds into the program.)

For a complete UCTV schedule and to discover "where to watch UCTV," go to:

<http://www.uctv.tv>.

UCTV is available to over 12 million homes nationwide via the following:

- Direct Broadcast Satellite: 24 hours a day on Dish Network, channel 9412
- Cable Television: Local cable throughout California and the country (for details, visit: <http://www.uctv.tv/cable>)
- Internet: Live webcast and subsequent "video-on-demand" streaming video at: <http://www.uctv.tv>. — *SGR*

Ray Lucas, ANR Communications Services producer/director, grabs a panoramic shot at the James San Jacinto Mountains Reserve. Photo by Jerry Booth

A few words

Continued from page 1

manufactures, and commerce….” A committee “appointed to arrange several subjects, which in their opinion should principally engage the attention of the Academy,” gave as their first recommendation that a group of Academy members “examine the various soils of the Country, what are their respective qualities; which are most prevalent, the substances best adapted to improve them, what are their natural growths….” (Reprinted from the *Records of the American Academy of Arts and Sciences*, Volume 1, Meeting of May 29, 1781, pp. 44-45. With permission of the American Academy of Arts and Sciences.)

This emphasis still held some 100 years later. Soil scientist Eugene Hilgard, who arrived at the University of California in 1875 to become a “one-man College of Agriculture,” collected and characterized soil samples from throughout California, studying ways to farm on these soils. In his biography of Hilgard, soil scientist Hans Jenny, who arrived at the University of California in 1936, commented: “Unmistakably, Hilgard [became] the scientific conquistador of the soils of the arid region, a region that comprises over half of the earth's surface.”

This *Transect* describes the Hans Jenny Pygmy Forest Reserve (p. 6) and the dramatic dwarfing of the plants that eke out a living on its acidic, nutrient-poor soil. This issue also examines less well-understood aspects of soil science. Studies of mycorrhizae (p. 1) aim at an understanding of the specific interactions between plants and mycorrhizal fungi, while studies of microbiotic crusts (p. 4) explore the role played by these assemblages of organisms, such as cyanobacteria, algae, mosses, and lichens, commonly found in arid and semiarid environments around the world, including the Eastern Mojave.

As Hans Jenny rightly asserted: “Each soil is an individual body of nature, possessing its own character, life history, and powers to support plants and animals” (H. Jenny, “The Making and Unmaking of a Fertile Soil,” in W. Jackson et al., eds., *Meeting the Expectations of the Land*, San Francisco: North Point Press, 1984). Over time, soil study at NRS sites is fulfilling the original first priority of the American Academy of Arts and Sciences and doing its part to ensure the continued survival of life on Earth.

— Alexander N. Glazer
Director, Natural Reserve System

Transect

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