Hans Jenny at the Pygmy Forest

by William Bryant Logan

Dirt isn't respectable. You are dragged down in it, or they dig it up on you, or you command an enemy to eat it, or you say a thing is as cheap as it; you have a dirty mind or a dirty job. The hero has feet of clay; after unseemly revelations, her name is mud.

Tide, All, Joy, Ivory, Whisk, Cascade, and the whole legion of ionic surfactants promise a world purged of dirt, just as those pop-closed catafalques deny the presence of a coffin the moment it has been placed in the ground. True, it is not thought such a bad thing to be an earthy person, the salt of the earth, or to have grit. But these expressions are the sort that rednecks and fundamentalists use. When we speak of grit, we usually mean "gritty reality," and we don't often use "earth" except when we mean the whole ball of wax, *the* earth. Dirt is beneath us to contemplate.

Yet not in all places and in all times has dirt been so shunned. Even into this century, the bride-price of a country•girl in France was determined by the weight of the manure produced on her father's farm. Pilgrims still come to Esquipulas in Guatemala and to Chimayo in New Mexico to worship a Christ whose souvenir is little healing tablets or bags of dirt, which they drink dissolved in tea or water. Even city people like the fresh smell of soil when it first opens in the spring. But for the most part dirt is something we would rather not believe in.

Our willful disregard of dirt is perhaps a subset of our denial of the existence of pain and death, for it is these with which dirt, to a nonagricultural people, is largely identified. We do not like dirt because it means death.

But since the end of the nineteenth century, when the Russian Dokuchaev published his extraordinarily detailed treatises on the origin of the rich soils of the Russian steppes and Winogradsky began to study the life of soil microbes, and when the American Hilgard examined the influence of climate on alkaline and acid soils, we have been moving toward a place where we can see dirt for what it is and appreciate it in the way the ancients did intuitively: as the generative source of all manifestations of existence.

The study of soils is a young science, scarcely a hundred years old. It's hard to find two scientists who even agree on the meaning of the word. Part of the problem is that processes in the soil are orchestral. They deal not with the infinitesimals of chemistry or physics or biology alone but with interacting realms whose concern is the soil's life. At a conference on soil, a soil physicist presented an elaborate mathematical model describing the percolation of water through the soil. As soon as he was done, a soil biologist jumped up and shouted, "But a single one of my earthworms will destroy all of your calculations!"

The story is a favorite of Hans Jenny, a native of Switzerland and for almost three quarters of a century the leading American soil scientist. If there is anyone who knows what a soil really is, it is Jenny. This past year marked the fiftieth anniversary of the publication of his *Factors of Soil Formation*, a book that changed the study of the earth's surface. In it Jenny worked out elegantly and simply the broad factors that govern the development of soils.

Were he not a soil man, Jenny's achievement might have ranked him with Henry Cowles and other pioneers of ecology, but his work has been buried in the obscurity of his profession. The head of the University of Chicago's venerable department of ecology, asked to comment on Jenny's contribution, remarks, "Never heard of him." And to this day, at University of California cocktail parties Jenny will tell a new acquaintance he is a soil scientist only to receive questions about the person's tomato plants. This is like Toscanini being asked to tune someone's guitar.

Such incidents are doubly unjust. Jenny's formula for soil genesis was one of the pioneering works of ecosystems ecology. It is an archetype of whole-systems thinking. Furthermore, it represented a substantial philosophical advance on the work of plant ecologists like Henry Cowles.

In Cowles's 1899 paper on the Indiana dunes, the great Chicago botanist had shown how the succession of plant communities on the dunes could be described in terms of the prevailing climate, the slope of the dunes, and the organisms living there. He pictured a landscape evolving to a steady-state climax dominated by one or more mixed-forest communities. Once the different factors were in balance,

Opposite top: The waves wash into beautiful Jug Handle Cove, near Mendocino, California, breaking the underlying graywacke sandstone into fragments. The current beach will someday be lifted to become a marine terrace.

Opposite bottom: The pygmy forest lies not half a mile up the hill from Jug Handle Cove. Its soils are roughly half a million years older, and it supports only stunted, endemic plants. The mature bolander pine seen here is only 3 feet tall.

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Weathering sandstone on the California coast can be the parent of fertile soils.

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Soils whose parent rock was serpentine are thin and infertile.

a forest would be established that could maintain itself indefinitely. Later students of Cowles's work corrected his optimistic picture, even admitting that soils might run down instead of building up. But it was Hans Jenny who gave the picture a new dimension, with his 1941 formulation of soil process that distinctly linked "deep time" and our time. For Cowles, twenty thousand years was old. That was the age of his oldest dunes. Jenny looked as deep into time as the age of the oldest soil he could find—more than half a million years. By including the factors Time and Parent Material in his equation, along with Climate, Slope, and Organisms, he was able to link biology, geology, and duration in a single mathematical dance.

The shorthand for Jenny's equation is CLORPT. The CL is for climate, the O for organisms, the R for relief (slope or topography), the P for parent material, and the T for time. Knowing these variables, he asserted, one should be able to predict the vegetable, animal, soil, and other properties of the ecosystem in question. The equation is not so easy to solve as it might seem. There are those who say it can never be solved fully because seldom are all the factors amenable to quantification. In other words, you will never be able to plug in values for each of the factors and predict authoritatively the ecosystem that will result. Yet the real measure of the success of Jenny's formula—as it was for Cowles's—is how well it captures the processes that make a landscape.

Ecologists sometimes receive unusual monuments. Cowles's is a bog in the Indiana dunes, named in his honor. He called it "a history book with a flexible cover." Hans Jenny keeps a piece of what may well become his own monument in the lower right-hand drawer of his desk. That is often where a man keeps what he most values and/or fears. It could be a bottle of bourbon, a Bible, or the unpublished novel or poems of his youth. I was therefore flattered and embarrassed when the ninety-two-year-old Jenny pulled open that sacred drawer in his University of California office in Berkeley. "I want to show you something," he said in his clipped Swiss accent.

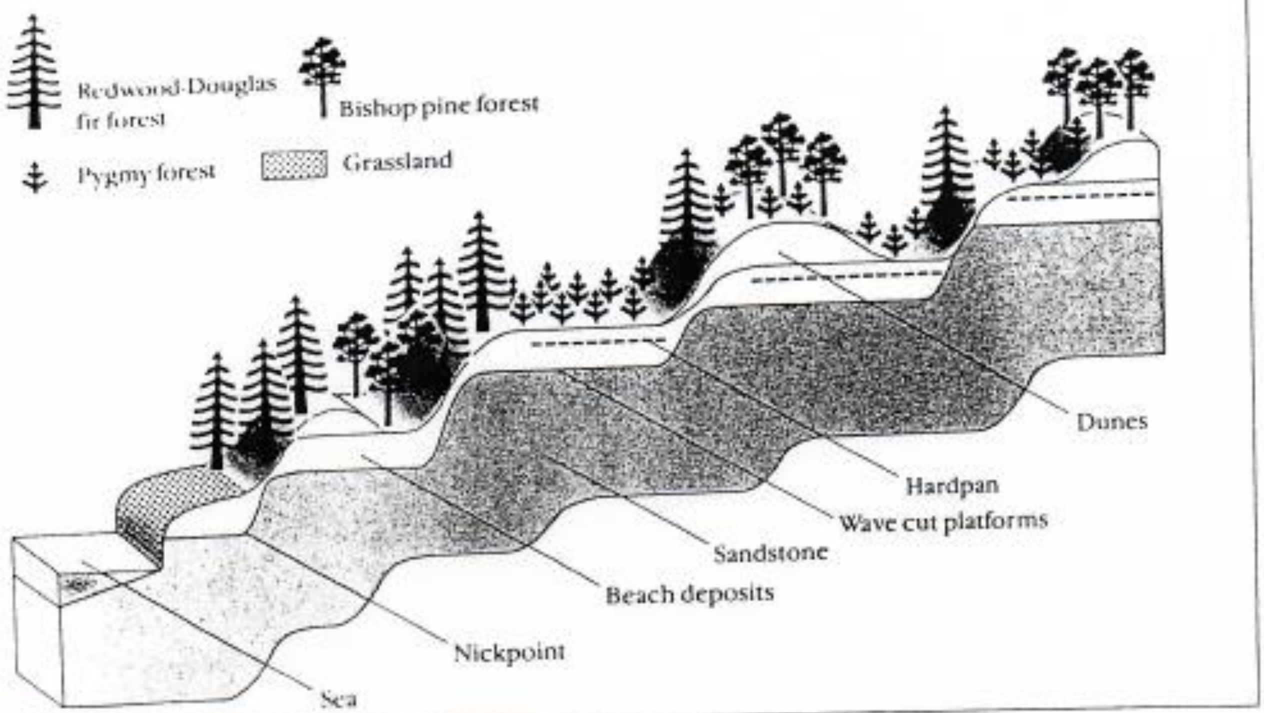
Dressed in a well-used sweater, worn gray wool slacks, and black loafers, Jenny sat in an office taller than it was wide, his slender, stooped body framed in the dull, even light that came through the big window behind him. It was a March day that threatened rain, but the rain dallied and fell just a few drops at a time.

He handed me a white lump the size of a softball, but chalky, as though he had been saving blackboard dust for half a century. "Hold it," he said. "See how heavy it is." It sank in my hand like a shotput. "Now that has hardly any organic matter in it, hardly any nutrients," he observed slowly, choosing his words. "But it is certainly a soil."

Opposite: A resistant sandstone ridge stands far out in the water on the Mendocino coast.

HANS JENNY'S ECOLOGICAL STAIRCASE

Five small steps in space, five giant strides in time



Above: The full ecological staircase, as depicted by Jenny. From a first terrace of meadow, the landscape steps up through mixed forests of redwoods and Douglas fir, to bishop pine forest, and finally to pygmy forest. The forested "bumps" at the front of the higher terraces represent soils formed from windblown sands, which are therefore younger than the underlying terrace soil.

Left: Lupine and tidytips in the coastal meadow.

Opposite: A view from the first terrace meadow, looking over the headland to the sea.

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It was also my introduction to the pygmy forest, and Jenny's understanding of ecosystem evolution.

The heavy chalky lump I hefted was, he told me, ancient, Methusalan. With a pH just this side of lemon juice and a subsoil as hard as a frying pan, the soil it came from grew nothing but a few stunted pines and ericaceous (heath) plants—acid-lovers like manzanita—many of which sickened and died, still standing.

What calamity brought this about, I asked him.

Time, nothing but time. More than half a million years of sitting out in the rain.

Jenny sat regarding the bagged lump with the eyes of a proud father. It represented, I believe, his excursion to the edge of human time, his adventure in truth. For more than two decades since his retirement from active teaching, he had pursued research on this soil, trying to establish how it had come to be. ("I could never have done this while I was teaching," he reflected. "They would never have allowed it.")

What most startled me was that the soil was not from a parched desert but from the area widely regarded as without parallel on the whole California coast for scenic beauty. (They filmed parts of the movie *East of Eden* and the TV series *Murder, She Wrote* there.) This white dust was from Mendocino.

Several months later, Jenny and I were bound north from Berkeley in his station wagon to see this soil in its place. In the back of the car rattled cans of tuna fish and fruit and a jar of coffee, together with a tackle box full of little augers, a hammer, chicken wire, white envelopes, and labels. Somewhere in the wine country of Sonoma, he suddenly indicated I should take the next exit. We scooted off onto a side road, and he told me to stop.

"What do you see?" he asked.

I saw a hillside with some live oaks, some vines, and some pine trees.

"Well, why," he continued imperiously, "does the oak grow over here and then the pine grow there?"

Before I could answer, he was out of the car and swinging off along the roadside. He stooped to pick up some small stones and returned to me. In one palm, he held a blondish sandstone the color of dried grass; in the other, a handful of small, sharp-edged, friable chunks of a deep-green rock called serpentine. "It's the official State Rock," he said of the latter. "Beautiful, isn't it? But it is not good for plants."

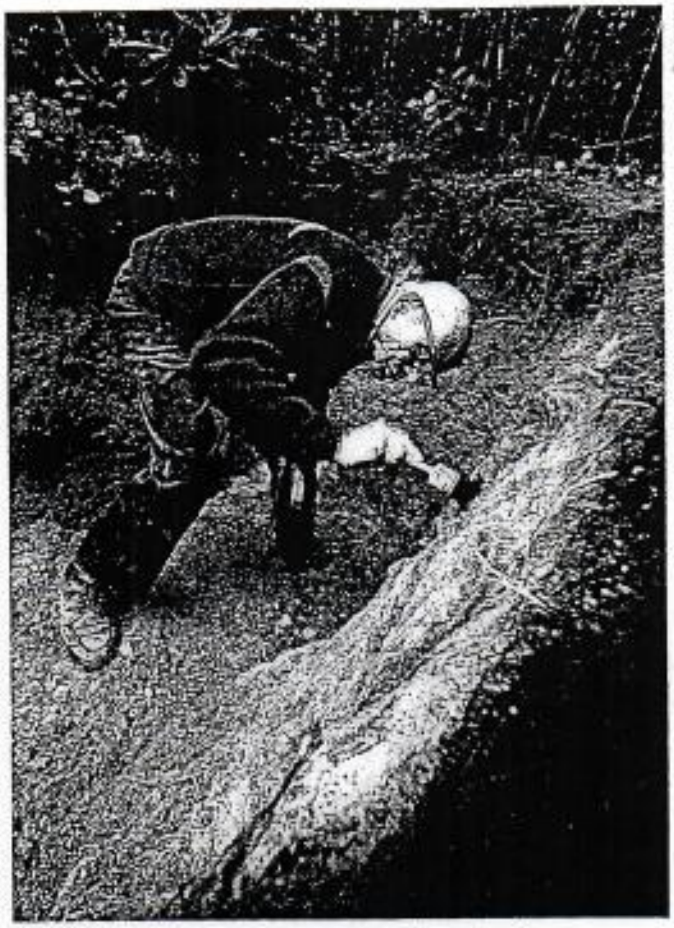
Here in my own native ground, he had shown me a key to the landscape that I had never noticed. Other factors being equal, a soil derived from sandstone will support oaks and vines; a soil that comes from serpentine is covered with scraggly digger pine.

This was fair warning that the soil world has a hard edge. Its admission of diversity also admits danger. As we drove west over the coastal hill toward the sun that hovered above a bed of fog, Jenny explained to me that the pygmy forest soil that we were going to see had deeply affected his idea of ecosystem evolution and caused him to question the unspoken idea of much environmental thinking: that, properly treated, nature balances herself in a way that is beneficial to man.

As we neared Mendocino, he listed for me some of the theories that had been used to try to explain the pygmy forest soil. Some said it was a fire climax, caused by repeated disastrous conflagrations. But then, he pointed out, the soil should be alkaline from the ashes, when in fact it is among the most acid soils in the world. Soils people often said the soil was caused by the strange endemic flora atop it—which, being largely ericaceous and coniferous, would tend to make an acid soil. The plant ecologists, on the other hand, blamed the sparse, struggling plant cover on the poverty of the soil, which they called an edaphic climax (*edaphos* means ground in Greek).

Jenny laughed. To him, to ask whether the soil caused the plants or the plants caused the soil is meaningless. It is a question not of cause and effect, but of the dynamic interaction of factors. His CLORPT equation is, after all, a description of the set of feedback loops that maintain a living system, providing a picture of the world in which this soil takes its rightful place.

He promised that the next morning he would show me systematic proof of how the pygmy forest came to be. That evening, in the musty-smelling clapboard farmhouse that has been his base for decades, he described the staircase of five marine terraces that step up the hill from the town of Mendocino to an altitude of more than six hundred feet above sea level. The top three terraces contain areas of pygmy forest with its dust-and-iron soil. It occurred to me that, like Cowles in the Indiana dunes, Jenny had found a special landscape in which a spatial sequence could reveal the workings of time.



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Hans Jenny examines a soil profile in the mixed forest.

The difference was that whereas Cowles had worked with dunes that moved over the surface of the earth—comparatively young, restless, and ephemeral features—Jenny was dealing with a landscape formed by the interaction of massive glacial and tectonic forces. The underlying rock on which the whole landscape is based is a graywacke sandstone, laid down fast in a deep sea trench about 150 million years ago. It is what geologists call a poorly sorted stuff, which means it contains a variety of minerals—quartzes, feldspars, micas, chlorites, volcanic fragments. Such a parent material is rich in the whole range of mineral elements that, once weathered and made soluble in soil, contribute to plant growth. Serpentine rock, as I had seen with my own eyes, would make a far poorer soil.

This sandstone represented the prehistory, or the emergent possibilities, of the Mendocino landscape. Jenny's picture reaches to a time in the middle Pleistocene, between a half million and a million years ago, when the sea level rose, responding to melting glaciers farther north. As the water rose, waves cut a shelf in the graywacke. Then the glaciers returned, and the sea level fell, the receding water leaving a layer of stones, gravel, and sand on the now-exposed shelf.

Opposite: The luxuriant mixed forest of the second terrace, featuring native rhododendrons, redwoods, and Douglas fir.

Compare these sparser stands in the bishop pine forest with the lush mixed forest of the preceeding page.

The glaciers retreated again, and sea level rose, but at the same time tectonic forces of compression along the San Andreas fault, at the junction of the North American and Pacific plates, lifted this first shelf above the reach of the waves. So the sea began to cut a new shelf, at a lower level than the first. Over the course of the Pleistocene and into the Holocene, this to-and-fro-ing continued, until like a gigantic escalator the landscape had unfolded at least five shelves, each made of roughly the same parent materials and each slightly higher and farther inland than the next. The oldest is perhaps three quarters of a million years old; the youngest is still waiting to be born.

Overlain on this stately sequence of emerging shelves is a corresponding set of fore-edge dunes, not too unlike Cowles's dunes. Each was the result of sand blowing up from the beach and becoming piled on the front edge of the most recently elevated terrace. Thus each shelf has two ages, one belonging to its own materials and the other belonging to the dune that was later blown up onto it.

This, Jenny asserted, was the history of the landscape that made it possible to study the effect of time on the pygmy forest soil. Though fascinated, I found it difficult to imagine why this sequence of events should result in a soil barely able to support life, as Jenny contended it had. The claim became doubly hard to swallow the next morning, when he drove me to the Mendocino headlands.

Down below us on the beach, we could see sloshing beneath the incoming waves the pebbles, the gravel, and the chunks of tough graywacke that would be the raw material for a future soil on a terrace yet to be born. It looked barren enough on the steep slope of the headland, where lupine, iceplant, and pinks were holding on in the crevices. But when Jenny turned around, he plunged his hands into an exposed soil profile that was as black and as rich-looking as the Iowa prairies. The soil of the lowest terrace, on which we were standing, is a grassland soil of the sort we call a mollisol, genetically related to the soils of the midwestern prairies as well as to the famous Russian *chernozem*. The mutual action of organic acids and the chemical and mechanical weathering of potassium- and calcium-rich graywacke sands had turned the sand to clays, and along the edges of the clay particles clung the blackish organic complexes of humus substances. The soil supported a magnificent meadow flora of nodding onion, wild iris, lupine, buttercup, bunch grasses, strawberry, yarrow, and many more species. How was I to believe that this soil was a younger brother to one not three miles distant that supported more lichens than plants? It was like asking someone to believe that in due course an apple will turn into a bomb.

We drove to the next higher terrace. Not only was there no more prairie, we could not even see the prairie because we were deep in a mature forest dominated by majestic redwoods and Douglas fir, with thick stands of rhododendrons, salals, and other ericaceous plants. The dense growth made

Opposite: Dwarf ground covers in the pygmy forest include junipers and rhododendrons. Note the high percentage of dead limbs and soil that is completely bare.

for tough walking, but the acid odor of the conifers, together with the rhododendron flowers and the waxy berries of the salal, was more than adequate compensation for the trouble. So now I was to believe that on its way to becoming a bomb, our apple was first to turn into a skyscraper.

Looking at the soil profile in a six-foot trench, I began to understand. As a soil ages, it becomes like a sky: layers, called horizons, develop, just as they do in the atmosphere, distinguishable by their color, texture, and chemical composition. The younger soil of the prairie below had had a thick black horizon, a grayer horizon beneath it, where the organic matter did not reach, and beneath these, the same beach sands and gravels that one could still see washing in the waves at the shore. The forest soil was a different matter.

Fifty thousand years ago, if Jenny was right, the place where we were standing had itself been a prairie by the edge of the sea. Propelled by tectonic forces, it was now a little higher and much older than its prairie brother below. The soil here was more weathered, and the horizons had become thicker and more distinct. At the bottom of this soil could still be seen the same sands and gravels of the original beach material, but now they were so worn and friable that you could crumble them in your hands.

Mutual interaction of acid-loving plants and a more weathered substrate had created a soil that dissolves and moves its mineral constituents. This soil was a rich one, because nutrients still percolated through the level of the plant roots. But just beneath the surface layer of leaf litter, a gray horizon, like a thin belt of clouds, showed where some minerals had been leached out. Iron and aluminum now formed orange-red teardrops in a mottled layer a foot deep in the soil profile.

At the next step in the staircase, Jenny showed me a forest dominated by towering bishop pine. At first glance, the older soil here seemed to support a plant community as robust as that on the shelf below. But there was less diversity of species, and the forest was less dense. The trees were sending their roots deep, in search of the nutrients that were being leached all the way to the water table, through which they might finally be lost. In this soil, the top gray horizon had thickened, as weathering leached more and more minerals from the surface soil, leaving only the grayish, resistant quartz and kaolinite. The iron drops of the lower horizon had grown more numerous, and some of them were cemented into clusters.

From the above-ground life on the three shelves, I would never have guessed that these landscapes were closely related. Yet in the soils, I could clearly grasp their common origin and their evolution. The soil horizons formed a sequence from simple black uniformity through processes of mobilization and then stabilization. I was therefore prepared for the bomb.

We drove up over the hump onto the next terrace and took a dirt road onto property that belongs to the University of California. Jenny and his wife struggled for years to get anyone interested in preserving this landscape, and eventually won a state park for one strip of the staircase we had ascended as well as this UC study plot in the pygmy forest. "People don't regard soils as beautiful," he lamented, "so it's hard to argue why they should be preserved." He is only half kidding, maybe even serious, when he suggests turning the selenium-tainted wetlands of Central California into Selenium State Park. The tainting, after all, is the result of the natural leaching of a trace element when irrigation water is poured over the soils.

Leaving the car beside a rut, we walked through a scrubby path of conifers into another world. The tallest trees were scarcely taller than a man, and many rose no higher than our waists, though they were decades or even centuries old. Their trunks were as slender as a mummy's wrists. Here grew dwarfed, twisted versions of the plants and cypresses on lower steps of the staircase. A few were endemic species, found nowhere else in the world. Almost a quarter of the area was bare ground or covered with yellow-green lichens. Thirty percent of the trees were dead or dying. When they perished, they remained standing, rotting in place.

From above, who could ever say what had caused this apparent catastrophe? Standing with Jenny in an eight-foot-deep soil trench, I could see the answer. The very bottom of this soil, where it met the unaltered graywacke sliced flat by the rising waves the better part of a million years ago, was the same beach sand as on the other terraces, but the horizons above were the sclerotic developments of the processes that were still in full swing on the levels closer to the beach. Beneath a slender, gray-brown top layer was a bone-white horizon at least one foot thick—the result of what had begun down in the forest as a light gray horizon as wispy as cirrus clouds. Basically, there were no free nutrients left in this layer, only the most resistant, insoluble quartz. It was from this layer that Jenny's lump of dust had come. The metallic elements leached by millennia of rain from that graying surface now formed not teardrops or even clusters of red-brown knots, but a solid, unbreakable hardpan horizon, in places more than three feet thick. To get a piece of it, you had to hit hard with a hammer more than once.

Little could live atop this white-and-red soil. Jenny and his students were still doing experiments to grow other plants here—poppies, grasses, anything. On unaltered soil, nothing at all would emerge. If the soil had been amended with a nitrogen fertilizer, the plants would sprout, use up the fertilizer, and keel over dead.

There was not, in fact, a lack of nitrogen. Indeed, because the hardpan prevented drainage, during the winter rains the whole forest was awash in a coffee-brown liquid of water mixed with humus substances rich in nitrogen. But the nutrients derived from the mineral world, particularly phosphorus, were virtually lacking, having leached away, or having been long since locked up in compounds that were very hard to break and therefore useless to plants. Furthermore, because the soil surface was cut off from the depth, the acidity of the soil had built to such a level that few soil microbes could survive, so that plants growing here would have little access to the nutrients usually produced or converted into usable form by such organisms.

As Jenny and I stood on the slope leading into the soil

On a foggy day, Hans Jenny takes his students on a field trip to the ecological staircase.

trench, the old man was filled with the delight of his knowledge. "You see," he said stooping, "the soil down at the bottom of the trench, *beneath* the hardpan, has more nutrients than the topsoil. If we find a living seedling, it will likely be down there." Down we went, though it occurred to me there was some chance that his body, so old he could scarcely keep his head erect on his neck, would never leave the trench, once in it.

We scrabbled about in the red subsoil until we found a tiny seedling, perhaps two centimeters tall, of the endemic bolander pine.

"Now that is a seedling two years old," he said exultantly. Anywhere else, it should have been inches, not centimeters, high. Jenny whacked off a hunk of the red hardpan and gave it to me.

When he stood up again in the trench, his eyes, like mine, rose just a few inches above the soil surface. "It's beautiful, isn't it," he breathed, looking out over the miniature, contorted landscape.

I wondered what he could mean by that. His theory certainly had the elegance of the true. He had shown me that an apparently random assemblage of landscape features had a deep underlying order which in fact turned prairie to forest to pygmy forest, apple to skyscraper to bomb. Soils, under the influence of time, were largely responsible for the changes.

"Your ideas are beautiful," I told him, "but this landscape is frightening."

Jenny had stood me on the boundary between deep time and our time. It was a place of risk, where I could not avoid the feeling that we are just one experiment in a more ancient world. "What does nature have in mind in making soils?" he had once asked. In light of the pygmy forest, he could not answer with the communitarian optimism of a Cowles or a sanguine environmentalist. Over the long haul, nature was not in the business of making pleasant places for people to live. Quite the contrary, it seemed interested in pushing the limits of the relationship between the organic and inorganic realms, producing new experiments like the bolander pine. Yet to Jenny this is a cause for wonder, not despair. His theory provokes the most difficult beauty, the one that we would often as soon leave buried in that lower right-hand drawer. It is a beauty that admits the underground, the underworld, the soil, the dirt, heat, decay, cold, smells, soluble metals. It may be a hideous, misshapen, twisted, threatening thing on the surface, but musically beautiful in the laws by which it lives. According to the poet Rilke, Orpheus never sang so sweetly as when he went to the land of the dead. As the poet explained, "Only in the double kingdom, there alone,/Do voices become undying and tender."

Certainly, the scientist could accept such a characterization of what he meant by "beautiful." When I said I thought the landscape frightening, Jenny did not even turn his head. He kept looking out across the forest floor, his nose practically resting on the edge of the trench, and growled, smiling, "Ach! You must look with fox's eyes." •

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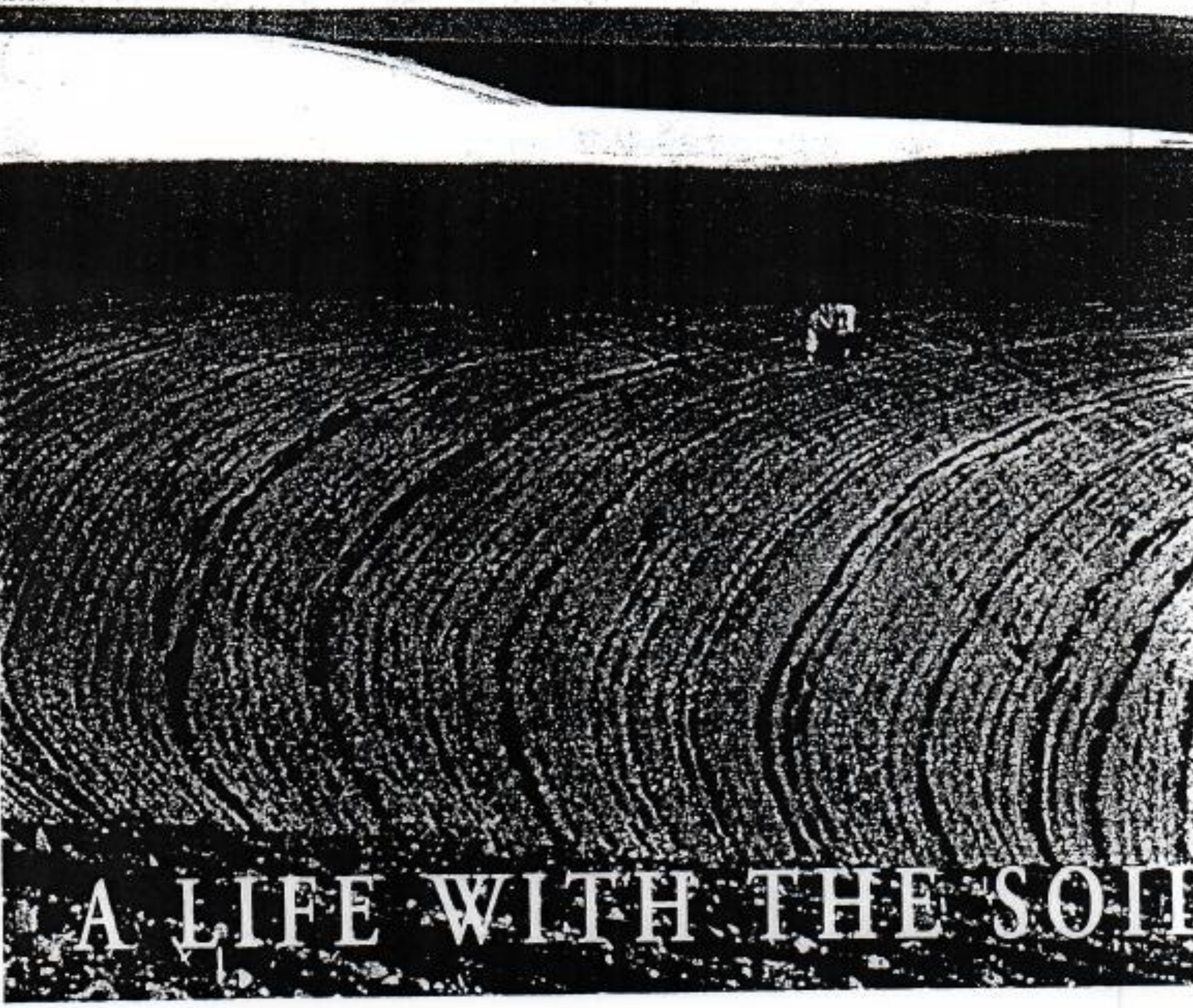


A LIFE WITH THE SOIL

A native of Switzerland, Hans Jenny came to the United States in 1926 as a Rockefeller Fellow. He joined the University of Missouri-Columbia faculty in 1927 and moved to the University of California-Berkeley in 1938. Jenny's early research produced a new, quantitative description of soil genesis. While at Missouri, his work took a practical bent, focusing on problems of declining soil fertility in the Midwest. His well-known text, *Factors of Soil Formation*, was published in 1941.

Jenny was interviewed in 1984 by Kevin Stuart, a graduate student at the University of Hawaii.

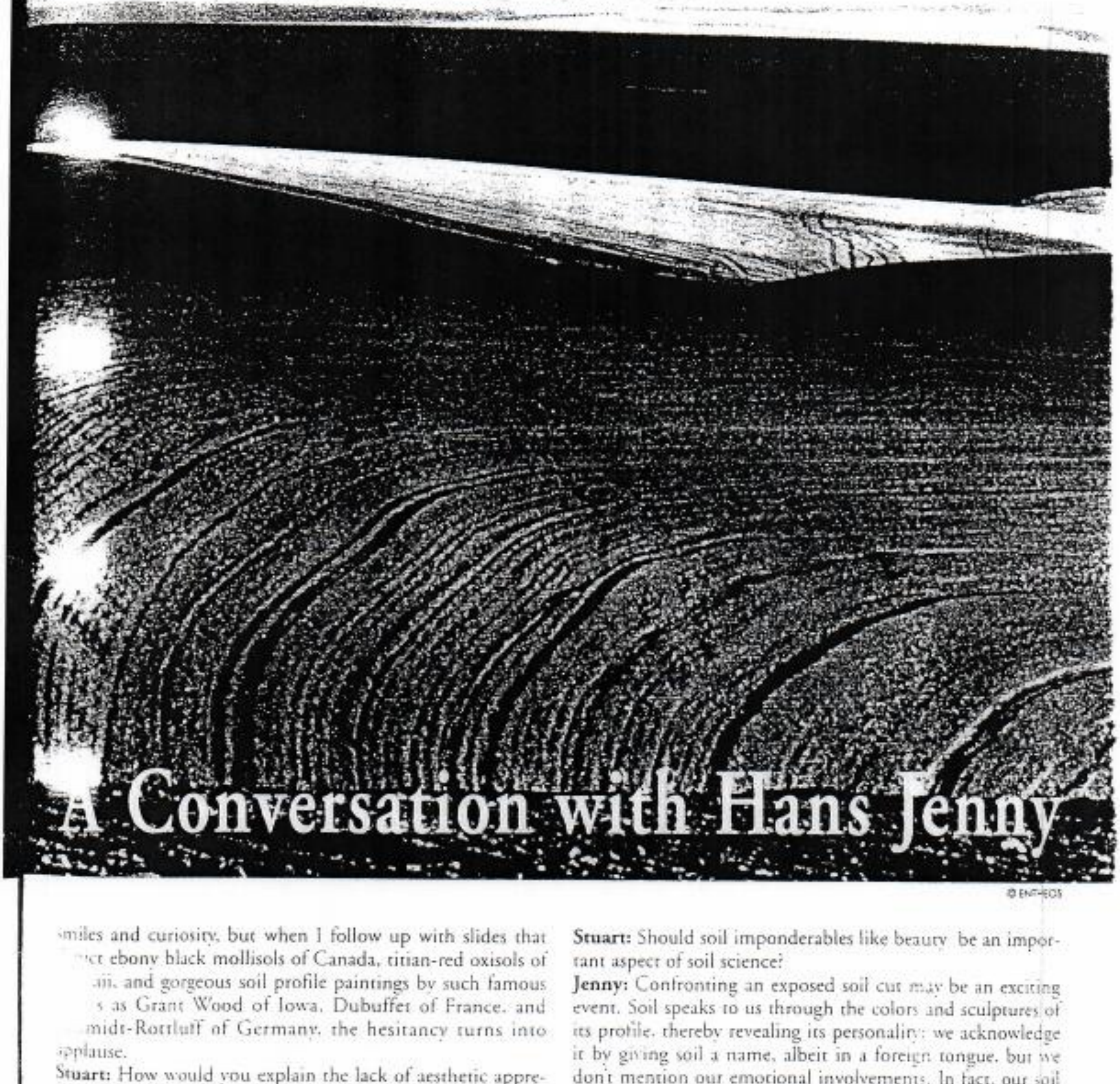
Kevin Stuart: Would you tell me what the basis is for your appreciation of the aesthetics of soil?

Hans Jenny: Soil appeals to my senses. I like to dig in it and work it with my hands. I enjoy doing the soil-texture feel test with my fingers or kneading a clay soil, which is a short step from ceramics or sculpture.

Soil has a pleasant smell. I like to sit on bare, su drenched ground and take in the fragrance of soil. As neither touch nor smell sensations have been accorded a thetic recognition, but colors delight painters, photog phers, and writers, as well as you and me.

In loess country, plowed fields on slopes show w bands of attractive color gradations from dark browns light yellows, caused by erosion of the surface soil. Wa brownish colors characterize fields and roofs in Cézann landscape paintings of southern France, and radiant soils of the tropics dominate canvasses of Gauguin a Portinari. Soil profiles viewed in pits may reveal vivid co and structure patterns of layers or horizons. I have seen many delicate shapes, forms, and colors in soil profiles th to me, soils are beautiful.

Whenever I offer this reaction to an audience, I no



A Conversation with Hans Jenny

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smiles and curiosity, but when I follow up with slides that ...ct ebony black mollisols of Canada, titian-red oxisols of ...aii, and gorgeous soil profile paintings by such famous ...s as Grant Wood of Iowa, Dubuffet of France, and ...midt-Rottluff of Germany, the hesitancy turns into applause.

Stuart: How would you explain the lack of aesthetic appreciation of soil on the part of many soil scientists?

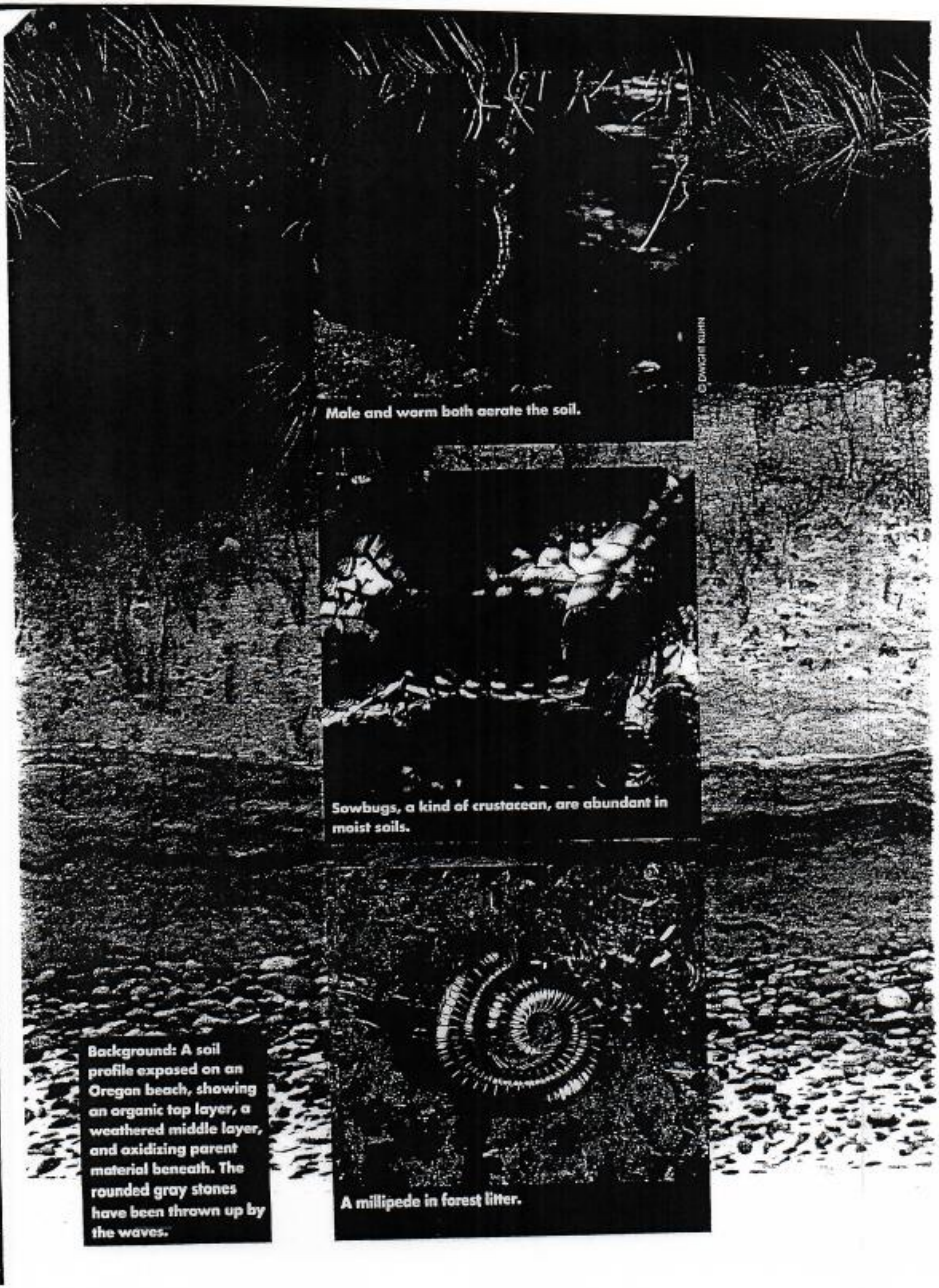
Jenny: I don't know. Maybe they lacked early exposure to art appreciation. My grandfather was a wood-carver, and his ... and daughters kept an interest in art. In high school I ...n art teacher who took us regularly to current art ...its in local galleries and museums. Soil profile art is ...akin to classic paintings with themes; rather, it resembles abstract art; and if you are used to thinking of soil as dirt, which is customary in our society, you are not keyed to find beauty in it.

Stuart: Should soil imponderables like beauty be an important aspect of soil science?

Jenny: Confronting an exposed soil cut may be an exciting event. Soil speaks to us through the colors and sculptures of its profile, thereby revealing its personality; we acknowledge it by giving soil a name, albeit in a foreign tongue, but we don't mention our emotional involvements. In fact, our soil language is lifeless, and the soil descriptions in our publications are utterly boring. Articulation would strengthen our feelings about the soil body. We may even become more interesting persons. We may gain new friends, and they might hold a positive opinion of the soil resource.

Stuart: How would you describe the idea of soil as interpreted by the discipline of soil science?

Jenny: A soil creed that began to spread in the 1920s states that soil is a natural body that deserves scientific study and contemplation, as is accorded other natural bodies, the



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Mole and worm both aerate the soil.

Sowbugs, a kind of crustacean, are abundant in moist soils.

A millipede in forest litter.

Background: A soil profile exposed on an Oregon beach, showing an organic top layer, a weathered middle layer, and oxidizing parent material beneath. The rounded gray stones have been thrown up by the waves.

organisms, rocks, oceans, and stars. This formulation marked a radical change from viewing soil as merely a cog in the agricultural production machine, yet the creed has benefitted farming in many important ways.

To my famous teacher G. Wiegner, soil was an object to apply known principles of colloid chemistry and to discover new ones. He expressed little interest in the contract of humans with soil. My former colleague Richard Bradfield studied soils in the laboratory and field with the aim of helping farmers manage their soils and provide food for humanity in general.

My own approach to soils has changed several times. In my younger years, with my farm background, whenever I thought of "soil" I visualized a plowed field. I used to walk behind the plowman, watching the earth turn over. It was beautiful, smooth and shiny with a brownish tint. You seeded a crop and what yield you got depended a great deal on the nature of the soil.

Later, during my Missouri work on soil humus content, I soon realized that the prime source of organic carbon in soils resides in the organic matter furnished by tree litter fall, grass mats, crop residues, and root production. When my Swiss ancestors took the mould from the forest floors to fertilize their fields, I learned, they were robbing the woods to feed the crops, causing the decline of the forests.

In California, I got involved with pristine and near-pristine grasslands and forests and began thinking in terms of the "larger system" that is composed of soil plus vegetation plus animal life, a combination that is now known as the ecosystem. Hence, I see soil in the context of a living, dynamic ecosystem, either a natural, or an agricultural, or a silvicultural one.

I place natural soils and ecosytems—the nature museums—on a par with art museums, automobile and railroad museums, golf courses, racetracks, music halls, and gambling halls, even colleges and temples.

Stuart: Just what is a soil?

Jenny: Soil scientists do not agree on this. But then, biologists cannot agree on a definition of life, nor can philosophers agree about what is philosophy. Take a granite rock, say. A century later, perhaps a millimeter of its surface has weathered. Is that a soil? If you are a farmer, you say no, because you couldn't grow a crop on it. But from the biological point of view it certainly is a soil. Some of the chemical compounds have been altered by the processes of oxidation and reduction. Thousands of different kinds of bacteria have begun to live on the weathered rind, excreting acids that further dissolve the rock.

If you go into the mountains, you can see this process at work. Much of the rock has patterns on it in tones of red and brown, composed of iron oxides and so forth. The designs are beautiful. Are those soils? Yes. I would say that they are. When a volcano like Mt. St. Helens throws out fresh lava, that is not yet a soil. But the first rainfall starts to change it. It begins to become a soil.

Stuart: You talk about a living system. Why is it important to you to include this aspect?

Jenny: Many ecologists glibly designate soil as the abiotic environment of plants, a phrase that gives me the creeps. Is the bark of a tree the abiotic environment of the tree? And what about the bacteria-rich rhizosphere? Looking at the root-soil boundary under the powerful electron microscope, an observer cannot tell where the biotic part ends and the abiotic part begins.

Soils contain over a thousand different species of lower animals, the earthworms, pill bugs, nematodes, millipedes, termites, ants, springtails, and amoebas, not to mention the millions of molds and bacteria. My late teacher, Professor S. A. Waksman, discovered in soils the microbes that produce the antibiotic streptomycin, which cures tuberculosis, and was awarded the Nobel Prize in medicine; he signed his letters "soil microbiologist."

When I add up the live weight, exclusive of roots, estimated by soil biologists, I find more living biomass below ground than above it, amounting to the equivalent of twelve horses per acre. The soil organisms consume oxygen from the soil air and give off carbon dioxide, and the summation of the multitudes of respirations characterize the metabolism of a soil individual. Hence I designate soil as a living system.

If all the elephants in Africa were shot, we would barely notice it, but if the nitrogen-fixing bacteria in the soil, or the nitrifiers, were eliminated, most of us would not survive for long because the soil could no longer support us. I can't help thinking of the claim that healthy soils make healthy people, and as an extension, I am intrigued by the thought that good soils make good people, but that notion seems untenable. Well, not wholly so. Working in the garden with spade and hoe soothes the minds of many people.

To this day, I cherish an old photograph of a white castle on a rocky promontory in Germany. At the base sits a large farmhouse, telling you that it supports the castle and its folk. But the most beautiful thing in the picture is the well-groomed manure pile beside the stable. The farmer would weave the pile, turning the manure over his boot and stacking it in neat layers like a display of sausages. For me, the photo said that the proud nobleman on the hill owed his daily life to the soil's fertility.

Stuart: You described how Wiegner and Bradfield looked at the soil, but I wasn't sure where you placed yourself.

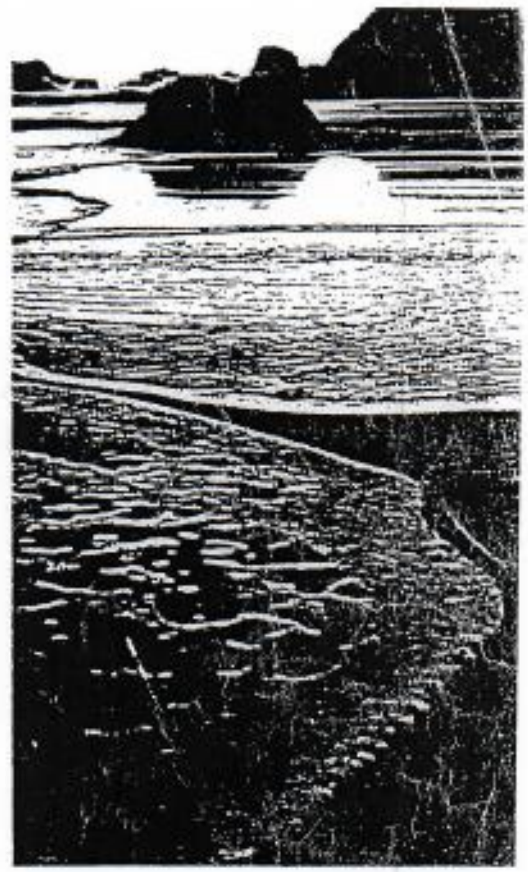
Jenny: Observing soils, studying them, and reflecting on them induces respect, if not wonder. All of us relate to soil

WALK A GIANT STAIRCASE

STEPHEN WHITNEY

ALONG THE WATERSHED of Jug Handle Creek on California's spectacular Mendocino coast, nature has created and preserved a remarkable ecological staircase where the basic processes that inform all landscapes are epitomized and displayed with the elegance and economy of a museum exhibit. Here, five wave-cut terraces formed beneath ancient seas rise from the shore in staircase fashion, each step being about 100 feet higher and 100,000 years older than the one below it, and each supporting a distinctive association of plants, animals, and soil. The staircase provides perhaps the finest record anywhere of the fluctuations in sea level that accompanied the advance and retreat of glaciers during the great Pleistocene Ice Age. It may also constitute the most clear-cut display of ecological succession in the world. In most places, we can only infer the processes that created the particular landscape before us—whether it be forest, or desert, or coastal plain—but at Jug Handle we can follow step-by-step 500,000 years of natural history. Here, the child is indeed father to the man, for the lower—and therefore younger—terraces to a degree represent ecological stages through which the upper and older terraces passed hundreds of thousands of years ago. The story progresses from the colorful tidepools of Jug Handle Cove to grasslands and coastal forest and finally, on the upper terraces, to the unique Mendocino pygmy forest, among the tiniest woods in the world.

The Jug Handle watershed does not contain the only staircase formation or pygmy forest on this coast, merely the finest and most accessible. It is also the only place where the entire staircase remains virtually intact. Scientists have long been aware of the importance of the staircase formation to our understanding of soils and ecosystems, but until recently it has received little attention beyond a few technical articles, which appeared from time to time in professional journals. The sole exception seems to have been a short article written by Dr. Hans Jenny, a soil scientist from the University of California, which appeared in the *Sierra Club Bulletin* exactly 13 years ago. Writing about the pygmy forest in particular, Dr. Jenny then stated what remains the most essential point about the need to preserve the entire staircase, which is that some lands deserve preservation not for their scenic beauty or wilderness qualities, but because they embody unique ecosystems that increase our understanding of the processes that shape natural history. Jenny was to recognize in Jug Handle, in particular, the opportunity to preserve an entire ecological transect, an immense,



Jug Handle Creek meanders through its narrow seabluff corridor.

easily readable storybook to scientists and laymen alike. He had studied the Mendocino sea terraces for many years and knew that of them all, Jug Handle was not merely the finest, but also the only one that could be entirely preserved.

In an attempt to educate the public about the importance of the Jug Handle transect, Dr. Jenny has published articles, talked to conservation groups and scientific gatherings, and worked closely with responsible government agencies to preserve the staircase. The first result of these efforts came in 1962 when State Forester F. H. Raymond set aside 250 acres on the upper three terraces as the Pygmy Forest Reserve. Jenny and his colleagues at the University of California had pointed out the great value of the pygmy forest to soil scientists and ecologists, and the force of their argument was recognized not only by the State Division of Forestry but also by the U.S. Department of the Interior, which designated the reserve as a National Natural Landmark in 1969.

While Dr. Jenny was working on one front, John Olmsted, a young botanist who had been teaching courses in the Mendocino area, began to work on another. He had been fascinated by Jenny's description of the staircase, realized that it comprised a natural schoolroom of great value, and in 1968 founded with others the California Institute of Man in Nature for the purpose of preserving it. Beginning with only $300 and a dream, the institute under Olmsted's direction has since raised over $100,000 for the purchase of lower-staircase property. It now owns 140 acres on the first and second terraces and hopes to purchase more land in the future.

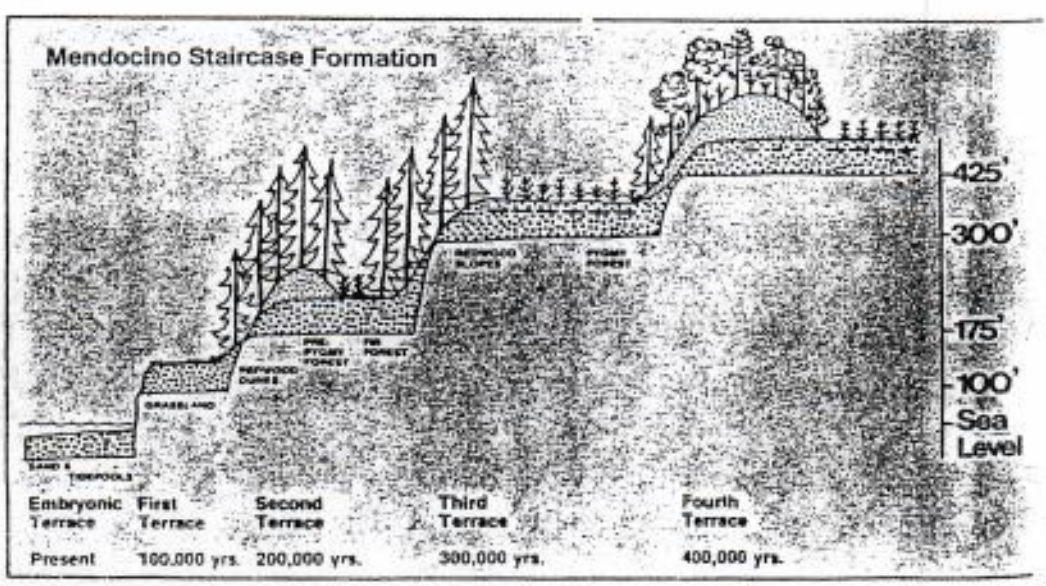
Despite both Jenny's and Olmsted's separate efforts the staircase still remains in private hands. In order that the entire ecological story at Jug Handle can be told, it is essential that at least a major portion of the lower terraces be set aside. The difficulty of doing so, however, has been that of educating the public to values that are not immediately evident. Jug Handle is not scenicly unique—the beauty of the cove, for example, is reproduced all along this coast. Nor is the pygmy forest itself much to look at, being a scrawny, drab tangle of tiny trees and shrubs. We easily respond to the splendor of wilderness, but it is difficult to immediately understand that an area deserves preservation because it is ecologically important.

The process of staircase formation is complex and imperfectly understood, but seems to depend mainly on a steady, uniform uplifting of bedrock possessing just the right physical characteristics, a combination of conditions that in California, at least, obtains most perfectly along the 20-mile stretch of Mendocino coast between Fort Bragg and the Navarro River. Each step of the staircase was cut into sandstone bedrock by the rising seas that marked periods of glacial retreat. Subsequent glacial advances produced receding seas, which then deposited miscellaneous sands, gravels, and clays on the bedrock platform. At the same time, the entire coastal land mass was rising—as it still is—and the terraces were lifted higher and higher, like steps of a giant escalator. Today's interglacial ocean has cut another, embryonic terrace offshore, and if this coast continues to rise, this new step may itself overlook some future sea.

Jug Handle Creek transects the entire staircase, having cut a typical V-shaped canyon through the upper terraces and a narrow corridor through the first-terrace coastal bluff. It flows across a sandbar into Jug Handle Cove only four miles from where it began, high on the fifth terrace. The seabluffs rise about 60 feet above the beach and extend one-half mile eastward along the creek estuary. The beach itself is narrow and is composed largely of quartz sand carried from the upper terraces by Jug Handle Creek. The beach is lighter than others on this coast, where dark sands predominate. Off Jug Handle Point on the south side of the cove, a few seastacks provide nesting sites for cormorants. Beneath the waters of Jug Handle Cove and just off the point exist tidepools and submerged reefs containing an extremely rich variety of sealife, including extensive populations of beautiful urchins and red anemones. The deposition of 5 to 15 feet of sand on the reefs and tidepools would prepare them to be a future uplifted terrace like the seabluff above them.

The first terrace is covered mostly by grasses and herbaceous plants such as lupine, coast poppy, and sea pink, which can withstand the salty air and the seemingly eternal winds that harass this coast. But on the seabluff on the south side of Jug Handle Cove, the southernmost wind-dwarfed Sitka spruces grow in low, sculpted thickets—or krumholtzes—with tanbark oaks, lowland firs, and bishop pines. On the eastern portion of the first terrace, grasslands slowly give way to typical coastal scrub species, which in turn yield to conifers at the beginning of the second terrace. Bishop and shore pines, perhaps remnants of an ancient forest that grew here when the coastline lay farther west, are scattered about most of the first terrace, save that portion nearest the sea. Alder and willow thickets line the creek bottom cut through this terrace.

The beginning of the second terrace is marked by a thick forest of Sitka spruce, lowland fir, and bishop pine, while at the back of the terrace an an-



cient weathered dune supports stands of redwood and Douglas fir. When this terrace overlooked the sea perhaps 100,000 years ago, winds hurled beach sand onto the top of the seabluff, piling it up one mile inland just as they do today at Ten Mile Dunes north of Fort Bragg. Over thousands of years, immense dunes formed, colonized first by grasses and salt-tolerant plants and later by conifers as the terrace rose higher above the sea. At Jug Handle, larger, older, even more weathered dunes mark the beginning of the fourth and fifth terraces. Between, the spruce-fir forest and the second-terrace dune grow mixed stands of tall bishop pine and Mendocino cypress. On the canyon slopes and along the entire stream bottom stands a mixed forest of redwood, Douglas fir, lowland fir, western hemlock, and Sitka spruce, the last species represented by a magnificent 12-foot-diameter tree, which is the largest on the Mendocino coast.

Ecosystems replenish themselves by efficiently utilizing the nutrients bound up in the organic detritus produced in the cycle of life and death. The floor of the coastal forest is covered by a thick carpet of needles and leaves, whose high acidity prevents the incursion of alien species and which, when broken down by micro-organisms, forms the nutrient-rich humus layer on which the forest thrives. On the staircase, however, this recycling of once-living material has been interrupted. Because of the underlying, impenetrable bedrock and flat structure of the terraces, drainage is poor. So during the winter rainy season—when from 40 to 80 inches of rain may fall from October to April—large standing puddles of tea-brown water collect on the older terraces, their color indicating humic acid from the incompletely decayed forest litter.

The standing water on the second terrace has in many places leached nutrients from the surface soil horizon, leaving an ashy white quartz layer known as podsol, a precursor of what is known locally as blacklock soil. In the middle of the second terrace the podsol layer is underlain by a rust-colored hardpan, formed from particles of precipitated iron hydroxide, making it a true blacklock. This podsol and hardpan formation reaches its extreme stage on the higher terraces, where it underlies the Mendocino pygmy forest. Where it has begun to form on the second terrace, a small tract of dwarfed—though not pygmy—bishop pine and Mendocino cypress interrupts the towering splendor of the surrounding forest.

A tall stand of bishop pines and rhododendron grows on the well-drained western face of the third terrace, but soon gives way to a drab, scrubby tangle of plants, looking more like chaparral than forest. This is the Mendocino pygmy forest, drenched in winter, parched in summer, growing in the world's most acid soil. Here, bishop pines and Mendocino cypresses rarely exceed a man's height, and their trunks are seldom bigger than a man's forearm, and often much smaller. Bolander pines, a race of the shore pine and a pygmy forest endemic, are almost as small. One remarkable three-inch-diameter "tree" was found to be a century old. Other pygmy-forest plants include several members of the heath family, including salal, rhododendron, wax myrtle, Labrador tea, huckleberry, and two species of manzanita, one of which is an endemic. In addition, sphagnum bogs—which are rare everywhere and which occur no farther south on the coast—have formed on the upper three terraces where dune springs provide water throughout the summer. Here, too, grow the bizarre, insect-eating sundew plants, whose tiny flypaper leaves can hold large damsel flies.

Longevity is rare in the pygmy forest because disease is common. Pine gall rust, which is an indicator of soil deficiency, forms orange growths on many pygmy forest trees. Soil analyses conducted at the University of California at Berkeley have revealed extreme shortages of potassium, calcium, magnesium, and phosphorus, all necessary minerals to normal plant growth. The process of podsolization that is underway on the second terrace is complete on the third. Only a pygmy humus layer covers the bleached upper soil horizon. Winter flooding continues to leach and sour the soil. Summer drought (almost no rain falls between April and October) produces desert-like conditions in the pygmy forest, and the underlying iron hardpan prevents pygmy roots from tapping the groundwater beneath.

Although no single factor has been found to be the main cause for dwarfing and endemism on the staircase formation, several stand out: poor

drainage, highly acid humus layer, mineral content of underlying sand deposits, climate and rainfall, and the length of time each terrace has existed above the sea. The first terrace is too young and too close to the ocean to support most of the conifers that precede the pygmy forest. On the second terrace, the process of podsolization has, on the geological time scale, only just begun, so tall pines, firs, and spruces still thrive on the waterlogged flats. Only when we get to the third terrace has enough time passed (perhaps 300,000 years) to produce the climax pygmy forest. Given the extreme conditions in which the pygmy forest grows, it seems marvelous that it persists at all, that it doesn't just shrivel up and die. Yet not only does it survive, it comprises, according to soil scientists, a steady-state ecosystem in which plants, animals, water, soil, climate, and the countless other elements that interact to form a natural community have achieved a perfect balance. Only man or a major change in the natural makeup of the region can destroy the pygmy forest. It is the climax, and perhaps the glory, of the staircase.

Forming a backdrop to the third-terrace pygmy forest is a stand of tall bishop pine, growing in the deep soil of the fourth-terrace dune, which was formed when that ancient cliff overlooked the sea almost a half-million years ago. The dunes form mounds rising above the second, fourth, and fifth terraces, providing better drainage and offering deeper, richer soils to full-sized redwoods, firs, and pines. Though formed of much the same material as the terraces themselves, the dunes have evolved their own soil type—called Noyo soil—which achieves its extreme form on the fourth-and-fifth-terrace dunes, indicating that bishop pines may comprise the climax vegetation on the staircase dunes. Extreme pygmy forest recurs on the fourth terrace and, to a lesser degree, on the fifth, and its juxtaposition here to the tall, healthy dune pines elegantly climaxes the staircase's parallel stories of ecological succession.

This remarkable ecological story, which has virtually no parallel anywhere else, has attracted the interest of scientists around the world, who see in the Jug Handle staircase an ideal outdoor laboratory where the processes of soil evolution and ecological succession can be thoroughly studied. Research teams from Cornell and the University of California have both studied the pygmy forest, and scientists from over ten foreign countries have visited the staircase. Last year alone, about 2,000 people visited the staircase, including scientists, teachers, college students, school children, and conservationists. Dr. Jenny continues to conduct research in the pygmy forest, and John Olmsted has conducted numerous nature walks down the staircase.

Jug Handle has also become something of a *cause celebre* to conservationists in Northern California. The Northern California Chapter of the Nature Conservancy lists the Jug Handle staircase as its number-one priority. Early this year, the Sierra Club submitted a friend-of-the-court brief in litigation to block a proposed motel development on the seabluffs overlooking Jug Handle Cove.

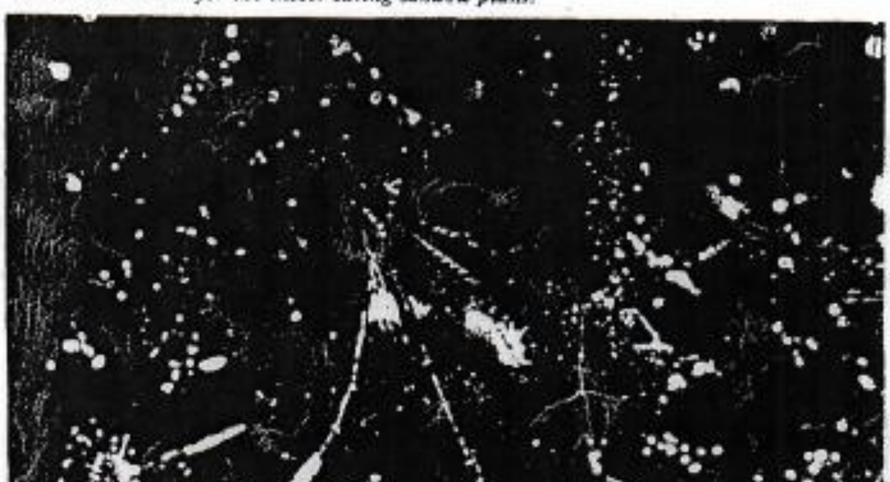
Jug Handle Inn would be a posh 80-unit motel with bar and restaurant designed to accommodate the more affluent of the thousands of tourists who visit the Mendocino Coast each year. Despite the recently passed coastal protection initiative—which has been most upsetting to many Mendocino coastal property owners—the region could still become another Monterey Peninsula or Santa Barbara, still lovely, but without the wildness and openness that presently constitute much of its special charm. North of Jug Handle is the growing town of Fort Bragg; south is the self-consciously quaint and historic village of Mendocino City, the main attraction to the tourists who fill up the motels in the whole area and purchase the town's store of ceramics, macrame wall hangings, wood carvings, leather goods, candles, antiques, and art works. Sandwiched between go-ahead growth and increasingly popular quaintness, it is particularly difficult to insure the protection of the Jug Handle staircase—though the staircase in its natural state could in the future provide one of the main reasons for visiting the area, to the benefit of both the Fort Bragg developers and the Mendocino City artisans.

Since plans for the $750,000 motel complex were announced last September, the fate of half of the sea front terrace land has largely rested in the courts. The litigation has been complex, but to outline it: 1) Mrs. Elizabeth Burger, owner of the other half of the ocean front land, filed suit to prevent construction of the motel on the grounds that no environmental impact statement had been prepared; 2) the motel developers, Holiday Lodge Corporation, asked the court to dissolve its restraining order on the ground that no impact statement was required because of the early date at which building permits had been issued to them; 3) the court dissolved the restraining order, but did *not* vacate the order requiring the impact statement; 4) when the developer did provide an impact statement, Mrs. Burger appealed to the State Court of Appeals, which issued a second restraining order. At this point the county board of supervisors was left with an impact statement, and the implication that it should do something about it, but without any clear course of action.

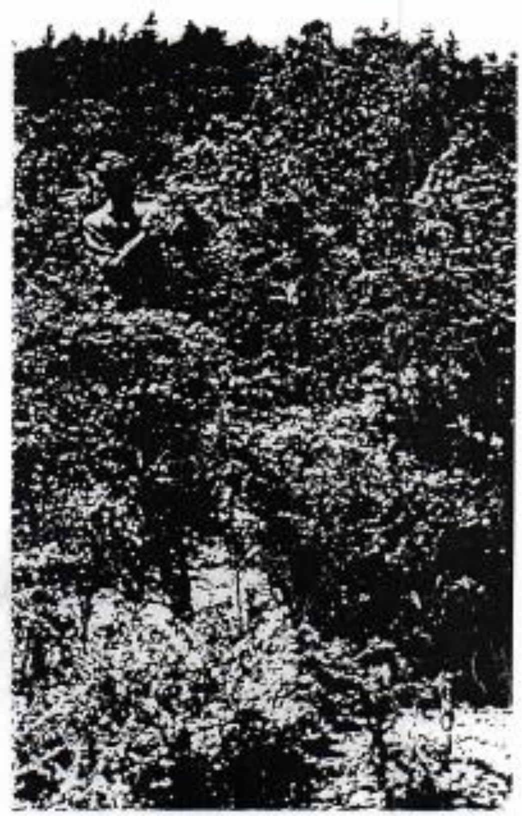
The upshot was that the board held a public hearing, and despite the impact statement's recommendation that an alternative plan be developed decided to support the original building permit. As the state attorney general, the Mendocino planning department, the state park plant ecologist, the developer's own consultant, and those interested in the preservation of Jug Handle for public use and education all opposed the original proposal, the supervisors' decision obviously could not lay the matter to rest.

The impact study for Jug Handle Inn is a curious blend of good intentions, insufficient analysis, and poor logic. It admits that the Jug Handle staircase is "an irreplaceable natural resource," but concludes that a well-planned motel would constitute no greater threat to the environmental integrity of the area than would its designation as a natural preserve. Considering the increased traffic the motel would generate, the large area that would be turned into a parking lot, the possibility of sewage contamination of the Jug Handle tidepools, and the possibly adverse effects on the local water table, the impact study's conclusion seems—to be charitable—ingenuous. The study's alternative, which would have reduced the number of units, minimized the destruction of vegetation, and situated the buildings away from the cliffs seems reasonable only if it is assumed beforehand that the motel must and will

A two-course meal for the insect-eating sundew plant.



Summer fog drapes the second-terrace Sitka spruce forest.



John Olmsted in the third-terrace pygmy forest.

be built. The possibility of making the motel site a public park was apparently rejected on the grounds that it "would most likely result in a very great human use impact which would be detrimental to the vegetation and wildlife." The alternative of leaving the site in its present natural state was dismissed as "academic."

In January of this year, the Sierra Club submitted a friend-of-the-court brief in support of Mrs. Burger's appeal in which it argued, among other things, that the impact study was improperly prepared and insufficient and that the supervisors should not have approved the original motel plan. The brief cites the study's admittedly inadequate treatment of the problems of water supply and sewage disposal and lists several other areas that the study glossed over or ignored, including the impact on local residents of a large tourist facility, the effect of increased usage on the beach and adjacent littoral communities, the damage to plant and animal communities at the motel site, and the impact on local traffic. The brief also points out that the study did not adequately consider its listed alternatives to the proposed motel development and contained no analysis of the need—if any—for further tourist accommodations in the area. (Contrary to a statement in the study, the Mendocino Coast Motel Association is on record opposing the Jug Handle development.)

The brief further argues that, contrary to the provisions of California Environmental Quality Act (CEQA), the impact study was improper because it was written by an agent of the developer and was not subject to proper public supervision to assure its objectivity, comprehensiveness, and accuracy. For example, in his evaluation of the study, the county planning director admitted that the study was "non-technical and generalist in its approach," but did not ask whether such an approach was appropriate and sufficient under the law. "Certainly," the brief states, "such comprehensive technical matters as required by CEQA to be completed in the environmental impact report demand more than a non-technical evaluation before their adoption."

Finally, the brief contends that even if the impact study were proper, the Mendocino County Board of Supervisors' approval of the originally proposed motel project in disregard of the study's recommended alternative violates the intent of CEQA that environmental considerations and feasible alternatives be given serious consideration by the public agency responsible. The brief argued that there was no evidence that such consideration was given.

In March, the appeals court denied part of the Burger appeal, but did so without prejudice, which in effect referred the case back to the superior court for reconsideration. In April, the lower court ruled that the impact statement was sufficient and that the Mendocino County Board of Supervisors acted properly in approving the original motel plan. This decision is now being appealed.

At the same time that John Olmsted

and his immediate supporters have been spearheading the drive to save the south bluff of Jug Handle Cove from motel developers, others have been seeking a far-reaching method of preserving the staircase—the creation of a national monument to protect this whole unique ecosystem at one stroke. While John Olmsted seeks to follow up his earlier successes in raising funds to hold remaining private portions of the staircase, Dr. Hans Jenny has been following up the federal solution suggested several years ago. The national monument that Dr. Jenny and his informal committee of prominent Mendocino County residents and informed laymen and scientists across the nation envisage would combine the presently protected pygmy forest lands with lumber company lands separating them from the parcels owned by the Institute of Man in Nature and would add the seabluff to complete the portrait of the Mendocino staircase. It appears at this time that Representative Don Clausen stands ready to introduce legislation to create the national monument *when* the county supervisors endorse the proposal. The supervisors, in turn, wait on a favorable report from the planning commission.

Time is a serious problem. In the fight to preserve the south seabluff, Olmsted finds that the developers now want $375,000 for the twelve acres that they bought for $150,000 four years ago, a sum that seems completely beyond the reach of the California Institute of Man in Nature, despite its imaginative and successful funding programs. Dr. Jenny argues that even if the south bluff should go, the push to create the National Monument could still succeed in saving an intact terrace system. John Olmsted might reply that if the south bluff goes the north side might soon follow, a depressing eventuality that would indeed demolish all the work that everyone has invested. Furthermore it would take at least a year and a half to get government funds. What is clear is that any program to preserve the entire cross-section of the sea terrace system badly needs the support of the local governmental bodies.

Like so many other irreplaceable natural areas, the Jug Handle staircase could be lost because we Americans have not learned how to weigh those values that elude the accountant's balance sheet. We are beginning to develop a land ethic—the impact studies reflect this progress—but we still have no overriding vision of the best uses to which our various lands should be put, no comprehensive public policy whereby such a vision could be implemented. Willy-nilly our finest resources continue to fall to the bulldozer, the chain saw, and the dragline, despite energetic efforts to save them. Those areas and resources that are preserved from inappropriate uses and thoughtless stewardship are seldom saved by appealing to elusive visions or philosophical positions. The stuff of litigation is facts and logic, and the heart of impact statements is feasibility and compromise. We must use the techniques available and be thankful when they work, but we needn't imagine they embody the highest expression of our intuition or the final justification of our beliefs. The very circumstance of considering and having to debate the possibility of building a motel at Jug Handle Cove argues nothing so much as our own loss of perspective and sensibility.

Perhaps more than any other natural area, this staircase is valuable as a complete, functioning example of ecological succession. The processes here enchant us more than the results. There is an elegance to the story that unfolds here, and if the final result is a scrawny, malnourished cousin to the grand forests of the North Coast, its very oddity impels us to wonder and explore.

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HOW PLANTS AFFECT SOILS: HANS JENNY AND THE "BIOTIC FACTOR" OF SOIL FORMATION

by Garrison Sposito

Everyone knows that soils affect the way plants grow. Passing by a farm whose crops show patchy unevenness in height, or variability in the color of their leaves, we think at once of there being some underlying variability in the soil on which the crops are growing. And soils themselves are replete with living organisms. Soil is not only mineral particles and organic matter in varying stages of decomposition, but also is home to legions of microbes and small animals. In fact, just one pound of fertile soil can contain a population of bacteria alone that is fifty times larger than the entire world population of human beings.

What is perhaps less commonly appreciated is the possibility that plants by themselves – herbaceous plants, shrubs, and trees – can affect soils. Think for a moment about a forest floor. Year after year, leaves, blossoms, fruit, cones, twigs, branches, and bark fall to the ground as litter produced by the forest canopy. This accumulating, dead biomass eventually would bury the living vegetation that produced it, were it not for the small soil animals and microbes that decompose plant debris as they carry out their life cycles. While all this is happening, the soil below receives products from the litter decomposition, particularly finely-divided, dark-colored organic matter and plant nutrients. The organic matter (humus) promotes in soil a myriad of chemical reactions and physical processes that influence the way soil properties will change over time, irrespective of the geologic origin, local climate, or physiographic setting of the soil. Thus, the vegetation growing on soil affects its evolution.

Different environments can lead to very large variations in the properties of litterfall. For example, an old Sierran redwood tree supports a large, circular mat of decomposing litter, whereas in a Colombian rainforest, despite the very high annual rates of litterfall, the soil surface is barely covered with litter because the warm, humid climate accelerates the rate of decomposition. The rate also depends on the composition of litter, which is plant species-specific. At 6000 feet in the Sierra Nevada, litter under an oak tree can decompose at an annual rate more than seven times greater than that for litter under an adjacent pine tree. Thus, in the Sierra Nevada, forest-floor litter tends to be much thicker under pines than under oaks.

Roots, of course, are also parts of plants and they produce decomposable biomass in soil just as the canopy produces litterfall. The annual yield of root biomass within soil can even exceed the annual litterfall. The many fine roots of grasses are the source of the typically higher humus content of meadowland soils as compared to adjacent forest soils. As roots grow, their tips enter soil pores and push soil particles apart; as roots thicken, they compress the soil mass and may even force it upward. A dramatic example is the old Sierran redwood tree that can push, heave, and warp soil over a diameter of several yards, destroying the vertical arrangement of its subsurface layers (called soil horizons).

As a final and perhaps more subtle example of how plants can affect soils, think of what happens when it rains on a forest canopy. As raindrops fall on a tree, some of the drops are intercepted by leaves, twigs, or branches and (if they do not evaporate) are diverted to become stemflow, the remainder passing through the canopy as crown drip. Stemflow and crown drip carry dissolved plant nutrients and deposited dry matter from the canopy surface into the soil below, modifying the chemical and biological processes that cause it to evolve with time.

The Dilemma of Interactions: Enter Hans Jenny

The simplicity of these three examples of plant influences on soil hides the conceptual difficulty one encounters in trying to isolate more precisely the ways in which plant influences actually operate. For example, plants remove nutrients from soil as they grow. During growth, their roots may release acids that help to dissolve the nutrients from soil particles, but whether this release occurs is depends on the forms of nutrients (for example, whether the form of nitrogen is nitrate or ammonium) that the plant has removed and taken up previously. Thus, the way a plant alters soil is apparently conditioned by the way the soil has influenced the plant. A legume like clover grows differently, depending on how successful are the nitrogen-fixing soil bacteria in colonizing its roots. To make matters more complicated, plant effects on soil must depend in some way on local microclimate and water supply, and these factors also act on soil quite separately from vegetation. How is this web of interactions to be untangled?

The solution of this problem was achieved in 1941 with the publication of a book, *Factors of Soil Formation*, by Hans Jenny, then Professor of Pedology (the science of soil development) at the University of California at Berkeley. This remarkable book was the culmination of a brilliant synthesis of earlier work on how soils form, as well as a potpourri of penetrating insights as to the role of external conditioning in the evolution of soil properties. The book has been read widely in the discipline of soil science, compared in influence to that of Darwin's *Origin of Species*, and used as a research reference by students of pedology even to this day. Its author, no less remarkable than his landmark book, enjoyed sixty-five years of scientific research on soils and ecosystems until his recent death in January 1992, just one month short of his ninety-third birthday.

All textbooks on soil science give an account of Jenny's five key factors of soil formation. In the context of plant influences on soil, they can be expressed in an equation now widely referred to as the "*clorpt*" equation.

To understand the "*clorpt*" equation, it is important to know that it is logically akin to the "state relationships" of physical chemistry, the discipline which Hans Jenny emphasized in his formal training in Switzerland before immigrating to the United States in 1926. Much of the thinking implicit in Jenny's *Factors of Soil Formation* (1941), is indebted intellectually to the branch of physical chemistry known as thermodynamics, a lifelong interest of Jenny. This relationship is discussed at length in his book, *The Soil Resource*, published in 1980, but we can summarize it in a less abstract way.

Think again, for a moment, about the Sierra Nevada, and imagine a long, narrow transect laid out in the foothills, running south-north, parallel to the axis of the mountains, and including broad ranges of precipitation and temperature, as well as variable topography and soil parent material. The vegetation canopy changes from arid-zone shrubs to grasslands to pine-fir forests as the annual rainfall increases northward along the transect: clearly, the distribution of observed plants is dependent on the local climate. This dependence can be suppressed by considering only the part of the transect receiving a narrow range of annual rainfall (24-30 inches) in the middle of the whole range of variation (3-80 inches). In this part of the transect, clusters and groves of pines alternate with expanses of grasslands in a seemingly random fashion. If an effort to choose sites of similar topography also is made, one discovers that the humus content of the soils and its degree of enrichment in nitrogen show a striking dependence on whether grasses or conifers are the dominant plants growing on the soils. The surface soils on which the pines grow are those consistently higher in humus and relatively poorer in nitrogen, something that is recognizable at once in the field by the darker color of the soils. If the entire transect is then examined with a careful eye kept on the dominant plant species making up the vegetation canopy, the humus/nitrogen relationship is found to hold regardless of the annual rainfall or the type of geologic material from which the soils have formed. Thus, the vegetation is controlling the humus content and composition in these soils independently of local climate and other soil-forming factors.

The essential premise underlying this way of looking at the effect of plants on soil properties is the idea that, in principle, the grass and pine species have had equal access to the entire Sierran transect given sufficient time. Together they constitute the "biotic factor" common to all areas of the transect — a kind of "species rainfall," as Hans Jenny once put it. The sequence of species that grows along the transect reflects an "effective biotic factor" which, in general, depends on local climate and other variables. It is the *potential* species that are the independent biotic factor, while the actual species are the dependent, effective biotic factor. In the rainfall metaphor, the biotic factor is the "incoming rainfall," whereas the effective biotic factor is the "effective rainfall" that produces erosion and runoff only after it interacts with the soil. The first is an independent variable, the second, a dependent

Hans Jenny standing in a soil pit at the pygmy forest in 198?. Photograph from the Jenny collection courtesy of the British Broadcasting Corporation.

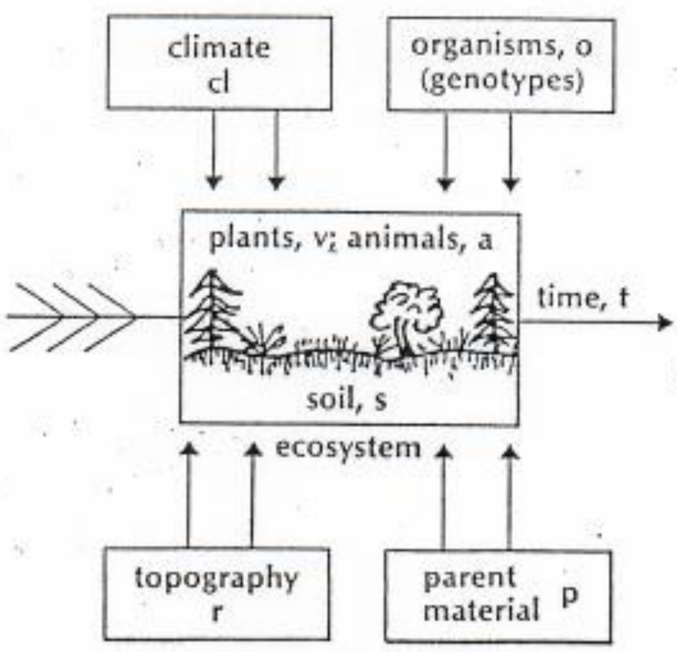
variable. In the more technical language of botany, the genotypes of plants — their genetic constitution as embodied in the multitudes of dispersed nearly everywhere — are biotic factors, but their phenotypes — their expressed features after interaction with the environment as embodied by those seeds which germinate, root and grow thus interacting with the environment — are effective biotic factors. As summarized by Hans Henny, vegetation is not a biotic factor; flora is.

Hans Jenny on the Biotic Factor

The example of the biotic factor at work in the Sierra Nevada foothills is taken from *The Soil Resource*. It represents a distillation of a thought process that was being refined for over forty years in the mind of Hans Jenny. Indeed, the clearest description of that process comes from Jenny himself, who discussed it in his oral history. Following is a pertinent excerpt from a lively discussion in the oral history, *Hans Jenny, Soil Scientist, Teacher and Scholar*, conducted by Douglas Maher and Kevin Stuart in 1979-83, and reprinted with permission by the Bancroft Library, University of California, Berkeley, 1989.

Jenny: The factor of topography wasn't too much of a problem, but the biotic factor, *that* posed a real difficulty; and while people have accepted the parent material as the initial state, there is, I would say, controversy and hesitancy in seeing the biotic factor the way I see it.

A diagram of the widely-used "clorpt equation" by Hans Jenny on the influences on ecosystem properties (soil, *s*; plants, *v*; animals, *a*) by climate (*cl*), organisms (*o*), topography (*r*), parent material (*p*), and the passage of time (*t*). Reprinted by permission of Williams and Wilkins from R. Amundson and H. Jenny, *Soil Science* (1991).



Maher: Why don't you explain the development of your thinking along that line, the first terms that you used, and how you bounced back and forth?

Jenny: It probably goes back to when I worked with J. Braun-Blanquet, the botanist, in the Swiss Alps, and when we discussed how soil and vegetation evolve together. To what extent does soil affect vegetation, to what extent does vegetation affect the soil, and how can the two actions be separated? Later, fancy words appeared in the literature, like loops from the information theory, on how interaction was to be handled.

In the technical literature, a soil formation equation by Professor C.F. Shaw has soil as a function of vegetation, and we have a formula by Txen, a German botanist, in which vegetation is a function of the soil. Hence we have two contrary formulations, switching cause and effect.

It took me quite a while to convince myself — and probably as a result of talking to people like Professor Herbert Mason, who used to teach ecology, to Roy Overstreet and to others like Sauer — to come to the conclusion that vegetation was not the proper word to use for a state factor. The botanists made long ago the fundamental distinction between *vegetation* and *flora* of an area. Zoologists don't have this idea or don't have different words for these two things.

Maher: Where was the difference in your view?

Jenny: According to botanists, the flora of an area is a list of species — how many species and their names — whereas the vegetation refers to the amount of biomass produced — whether the corn plant is tall or small, or in poor shape, or in good shape — this would be vegetation. It would be what the botanists call the *phenotype* compared to the *genotype*, which refers to the genes of an organism. I don't recall how I made that transfer from vegetation to flora as being the biotic factor, and, like the parent material issue, it probably was a gradual thing.

With colleagues and students I discussed pot experiments, where you put seeds in a flower pot containing soil, and the seeds grow and, depending on the soil, you get big plants or little plants, which is the vegetation. The action of putting the seed in the system, that is really the crucial thing. The seed species is the flora-type.

Looking back now, when I wrote *Factors of Soil Formation*, I wasn't a hundred percent sure, or I wasn't consistent in separating vegetation and flora. Certain headings of sections are, I would think now, misleading because I talk about vegetation. I have concluded, therefore, that the vegetation is a dependent variable and flora *can* be the independent variable. I identified the latter with the soil-forming factor as the influx of species, the flora of influx.

Some years later, I discussed that thoroughly with other people, like R.L. Crocker and another Australian, and we agreed that the core of this idea was satisfactory or plausible.

There are several ramifications regarding the "species rain," the influx of the species. For analogy, I call precipitation a "state factor"; the soil-forming factor, precipitation. But from the viewpoint of soil chemistry, that is not necessarily the proper moisture criterion. To a soil chemist, the water regimen inside the soil is the crucial thing. If there is a close correlation between that water in the soil and the precipitation, then the precipitation is a proper state factor to use. On slopes there may be runoff. From the viewpoint of erosion, the runoff part of precipitation would have to be used. This is very clear in R.J. Arkley's "leaching factor"; for the leaching process, the water which percolates the soil is the crucial thing. Both runoff water and percolation water are related to the rainfall, but not necessarily in a simple fashion.

Maher: Had you been thinking about this in the period when you were writing the book?

Jenny: The *Factors of Soil Formation*?

Maher: Yes.

Jenny: No, I bring that out now to explain some of the difficulties, and one such difficulty occurred in the biotic factor, and I argued back and forth with Crocker in the 1950s. All right, the influx of all species; but actually what counts is the species that are growing. That is what will affect the soil. Not just all that comes in, with the exception that you get carbon and nitrogen in seed influxes, and that sort of thing. Crocker restricted the biotic factor to the effective biota. He said the vegetation is the effective biotic factor. I say, it is the flora that is growing.

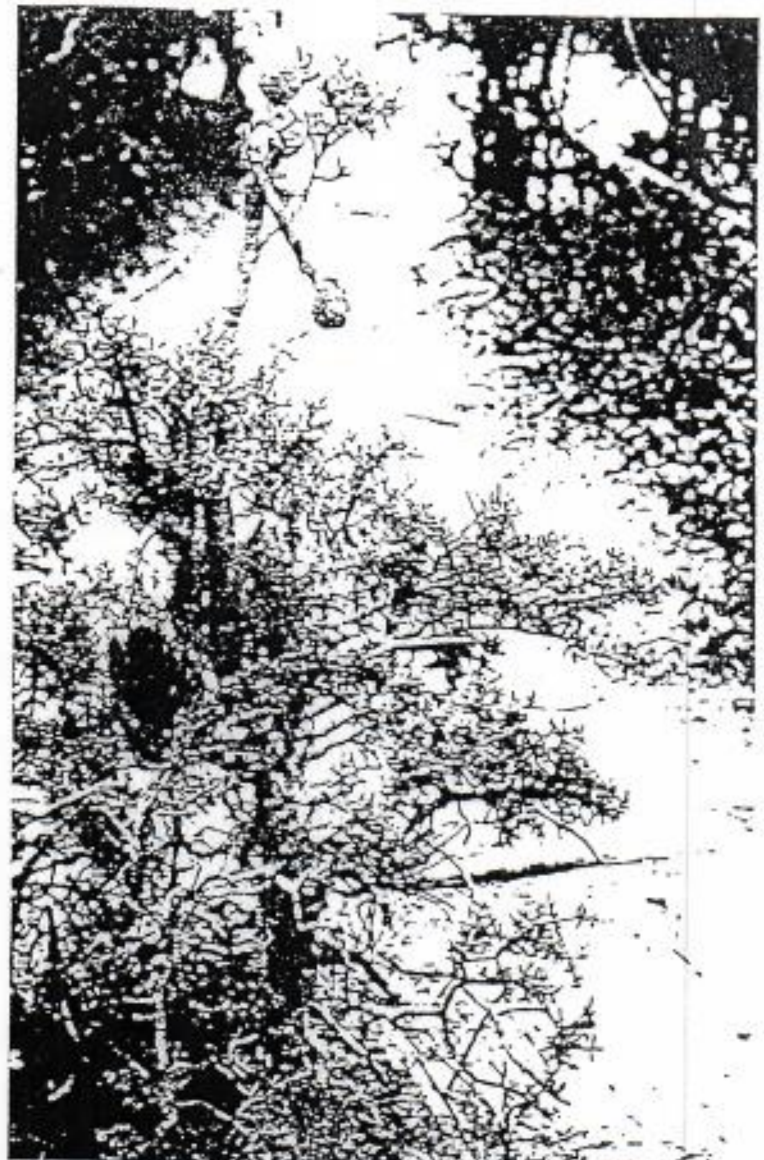
Crocker also thought vegetation was affecting the soil independently, but I don't see it that way. You put a seed in a pot and the seed grows, but how it affects the soil depends entirely on how the environment of the plant, including substrate, controls the behavior of the plant. To me, the "effective biotic factor," meaning vegetation, is a dependent variable. So I could not fully agree with Crocker.

I mention now these terms, dependent and independent variables. They, I think, are the greatest obstacle, and still are the greatest obstacle to the success of the state factor approach to ecosystems and soils, and it includes the misunderstanding – what it means to have an independent variable.

I tried to explain in the original book that independence means that a variable *can* be independent. It doesn't *have* to be independent. For example, the soil, and a plant growing on it, cannot be independent of each other. The soil affects the plant, and every other second, the plant affects the soil. So there is no independence. But for the flora, the soil is not going to affect the genotypes of the seeds that I put on or that are blown in.

Maher: Do you mean it is not going to affect the genetic make-up of that particular seed. It's not going to change into an acorn?

Jenny: Whether that soil grows a pine or an oak depends on the influx of the seeds – what comes in – and that's independent of the soil. The seed comes in independently. So I can say that the potential flora is independent of the soil. The seed that enters, its genetics, is independent of



The gray-ashy color of podzols is characteristic of the terraces of the Mendocino ecological staircase where trees such as this Mendocino cypress (*Cupressus pygmea*) grow. Photograph by Sylvia and Stephen Sharnoff.

the soil, because it was formed *before* it ever reached the soil. In that way, I could conceive the biotic factor as an independent variable, and I have to have independent state factor variables in order to solve the "*clorpt*" equation. Otherwise, it cannot be solved.

Maher: So you were talking about the biotic factor insomuch as it is an independent factor?

Jenny: That's right. It had to be defined that way. All the state factors I had to define – I realized that early – as independent variables so they can change independently of the others. Each one you can change – and I knew that right away with the climate. I can go to an area having a given temperature, and a great variety of moisture values, or I can take a certain moisture range – a certain rainfall range – and I can find localities where the temperatures differ a great deal. So the two need not be related. They *may* be related from the meteorological point of view, but that is not what is of concern in soil genesis.

I don't ask, for example, how were the rocks formed down deep in the Earth, or I don't ask how the weather is formed or how the climate is formed, how the storms are formed. I merely put registration instruments here and there and I take their readings. I exclude all discussions on how the state factors originate.

Maher: You said earlier on you realized that you had to define the independent variables as independent.

Jenny: That's right, as independent.

Maher: When do you mean "early on"? Do you mean when you began teaching this course?

Jenny: Yes, before I started to write the book. When I worked on the definitions I wasn't thinking of a book. But, while I was working on definitions, that was very clear. There had to be dependent and independent variables. I could see that in statistics. If you had a property depending on several variables, and the variables were not independent, you could never understand what was going on. You didn't know what caused what. But that aspect is not well understood, and people think that when I speak of an independent variable that it varies *always* independently. No, it means it *can* vary independently. Very clearly, temperature and precipitation I treat as independent variables. When I ascend a mountain, the two change simultaneously, and in opposite manner, so there they are not independent of each other. I cannot separate these two variables to understand why the soils change as you go up a mountain. That can be done if you get areas or zones in which the two vary independently of each other.

Hans Jenny and friends (Chris Bartlett, her children, and Alice Howard), November 1986, in the Pygmy Forest, one of the many unique ecosystems he and his wife, Jean, have worked to preserve in California. Photograph courtesy of Jean Jenny.

These ideas of Hans Jenny about the biotic factor can be illustrated once again with the results of a field study done on antelope bush (*Purshia tridentata*) and ponderosa pine (*Pinus ponderosa*) growing on the lower slopes of Mt. Shasta. Glacial deposits of rock on this mountain have been subjected occasionally to rare combinations of very heavy snowfall followed by hot spring weather that together trigger massive mudflows that descend the slopes, devastating lower-lying forests and covering them with deep, uniform mud deposits. The latest of the mudflow events occurred in 1924. Forty years later, the soil that was forming on the mud deposits supported the growth of mostly antelope bush and ponderosa pine, among other plant species. Excavations and chemical analyses of both soil and whole plants (including roots) of similar age, showed clearly that antelope bush, through the cyclic processes of growth, litter drop, and litter decay, was enriching the soil in humus and in the plant nutrients, nitrogen and calcium, severalfold more rapidly than was the ponderosa pine. Since the other soil-forming factors (cl, r, p, and t in the "*clorpt*" equation) were uniform, biotic factors are operating to vary the properties of soil as it developed on the mudflow deposits. More information about this and other examples of the biotic factor at work can be found in *The Soil Resource* (1980). In a broader context, this example illustrates the general point, that different plant species engage in nutrient cycling in different ways and this, in turn, produces variations in the properties of the soil on which they grow. This unifying perspective, initiated by Hans Jenny, is finding many applications in modern research on the sustainability of wildland ecosystems under global environmental stress, one good example of which is the Alaskan taiga forest.

That soil and vegetation can be pictured as two interacting natural systems, each affecting the development of the other as an independently-variable factor, is a crowning contribution of the sixty-five years of thought and research by Hans Jenny on the genesis of soils. The richness of this concept, so typical of the ideas that abound in *Factors of Soil Formation* (1941), has been praised in an especially apt way by Professor Paul Day, a former colleague of Jenny at Berkeley in soil science: "Hans Jenny has an unusual capacity for originating ideas, applying them and communicating them to others. In any field of knowledge, truly original ideas are rare, and particularly those which are pursued to the point of stimulating an entire generation of scholars in the field. Hans Jenny has done precisely that for soil science." Our debt to him for this is enormous.

The author wishes to acknowledge the collaborative role of Hans Jenny who prepared the first draft of the opening and closing sections of this article, and his appreciation to Mrs. Jean Jenny for her unfailing cooperation.

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UNDERSTANDING THE PYGMY FOREST THROUGH TIME

by Alice Q. Howard

In late summer of 1986 Hans Jenny, professor emeritus of soil science at the University of California at Berkeley was eager to launch new field experiments in the pygmy forest of coastal Mendocino County, exploring theories to account for the dwarfing of species. His collaborator of twenty-five years, Arnold Schultz, was on sabbatical leave out of the country, so I offered to help Hans get the experiments launched.

Hans also gave me another special assignment – to explore the history of the pygmy forest. He was seeking whatever information there might be about the geographic and temporal continuity of the vegetation for a given tract of pygmy forest. One of the often-heard theories of the origin of any particular tract is that it follows from a fire, which opens the cones of the dwarf cypress and pines, starting an age class of seedlings.

I had spent many weekends on hands and knees getting a rabbit's-eye view of the world while searching for seedlings of the little trees to use in experiments Hans was planning. Though seedlings were seldom abundant, I began to develop a sense of where they were likely to be found. I wondered whether anyone had ever looked at the plentiful open cones of both pines and cypresses at the sites where we were working – sites with no obvious evidence of fire.

Searching the Historic Record

Finding historical information about a specific land tract was much harder than finding seedlings. My years at the University of California Herbarium and my work on the first Rare Plant Committee of the California Native Plant Society had made me aware of some of the more obscure sources of descriptive materials about the California scene. Applying this background to the pygmy forest, I found some tantalizing tidbits.

Following the history of the naming of the two dwarfed conifers was a tangled tale in itself. According to J.G. Lemmon, Henry Bolander had been the first to visit the trees. Presumably, Lemmon meant the first botanist. At the time, Bolander was with the California Geological Survey, where in 1864 he had succeeded William Brewer as botanist.

In October 1865, Bolander presented a paper to the California Academy of Sciences recounting his visit to Mendocino, which was published in the Academy's *Proceedings* in 1866. Bolander said that "a small pine tree" (which he called some kind of *Pinus muricata*) and averaged "only from five to fifteen feet" high, was to be found "on the so-called plains" behind Mendocino. He amended the name a year later to *Pinus contorta*. He spoke of a "mass of little trees covering the plains." Though Bolander also spoke of cypress at Mendocino City, he made no mention here of dwarfed cypress.

Bolander sent specimens of his little pines to DeCandolle in Geneva, who turned them over to a colleague, Parlatore, for study. The pine was described as *Pinus bolanderi* in DeCandolle's *Prodromus* by Parlatore in 1869. Several years later Vasey called it *Pinus contorta* var. *bolanderi*. However, neither of the descriptions included an identifiable locality.

In 1872 Bolander wrote about these little pines in an essay on the coniferous trees of California published in the *Transactions of the Bay District Horticultural Society of California*. Noting how in the Mendocino area the pines made a barrier against drifting sand, he suggested that San Franciscans might find it useful for that same purpose. In passing he also mentioned the dwarfed Mendocino cypress, saying it was "as yet undetermined." J.G. Lemmon took care of that in 1892 in his *Handbook of West-American Cone-Bearers*, in which he named the little cypresses *Cupressus goveniana* var. *pigma*, noting that they were "sparsely found on the ashen 'White Plains' back from the coast, near Mendocino." In that same work Lemmon said the little pines, *P. contorta* var. *bolanderi*, occurred "On the white, ashy, narrow, almost sterile 'Plains' paralleling the coast at Mendocino, a few miles interior" and they contrasted strikingly with the "typical species found abundantly on the near-by coast." Evidently forgetting his 1892 name, Lemmon ten years later gave the cypress yet another name, *C. goveniana* var. *parva*. In 1901 Sargent named it *C. pygmaea*. Lemmon noted that the pygmies had been "First visited by Professor H.N. Bolander [in] 1866" [sic].

In 1894 Lemmon, writing in the botanical journal, *Erythea*, referred to Bolander's original report, which evidently lacked some details when it had appeared in the *Proceedings* of the Academy. "Bolander [had] climbed the long sinuous stairway, reaching from the beach, one hundred and forty feet up to the level summit of the promontory fronting the quaint New England town of Mendocino." Continuing about his own visit, Lemmon wrote, "I shall not soon forget the trip to the so-called 'Plains of Mendocino', or my surprise as the carriage suddenly emerged from the forest of Prickle-cone Pine and entered upon the white, much exposed barrens.

"'O, see those little berry bushes!' exclaimed Mrs.

Lemmon, as I sprang out and pulled up a handful of tiny little cypress trees, four to six inches high, almost leafless, yet bearing one or more shining, globular cones upon or near their summits. Larger trees, straight and slender as walking sticks and knobbed with cones from bottom to top, were near them. But what is that curious thing yonder? A moment after I stood beside a conical little tree resembling the artificial dwarfs in Japanese gardens, and stooped to pluck cones from the top of Bolander's Pine!" The trees occurred in a "poor streak of white clayey barren . . . . parallel with the ocean for miles on miles."

In 1896, writing a three-part article in *Garden and Forest* on the "Flora of the California Coast Range," Carl Purdy, who lived not far away in Ukiah, limited himself largely to a Mendocino perspective. His most extensive descriptions of the region of pygmy forest occur in part two, where he, too, alludes to the local custom of calling the rolling table-lands of the pygmy forest "barrens" or "prairies." "There are thickets almost impenetrable of the north coast Cypress, *Cupressus goveniana*, slender, straight, cone-covered, and mingled with them the north coast scrub pine, equally slender and straight. When this dense growth reaches a height of ten feet perhaps a brush-fire will sweep through it, leaving a denuded space or

From left to right, Professor Gordon Huntington, Penny S. Howard, Mark Akeson, and Professor Hans Jenny with a recovered section corner post in the midst of a tract of pygmy forest. The description of the extent of pygmy forest found here tallied with the description of vegetation encountered on the north-south line through this point by cadastral surveyors establishing grids on land for apportioning taxes in 1866.

skeleton stems, and the fire which consumes the thicket opens the cones and seeds the land abundantly for another tangle. In the hard struggle for existence these little trees fruit when a foot high. Dense tracts of them stretch monotonously away in every direction."

Willis Linn Jepson, too, visited the Mendocino coast, quite probably passing over the Comptche road through Melburne, where the Jennys' ranch house is located, and perhaps even staying overnight there. Melburne, a name still found on the U.S. Geological Survey maps, was then a stage stop, post office, and hotel of sorts for travelers. Jepson's misjudgment of what he saw is permanently enshrined in his *Flora of California*, wherein in 1909 he recorded *Cupressus goveniana* (in part) as being found in "Miniature forests . . . on the Mendocino White Plains, where the alkaline [sic] soil rests on a sandstone hardpan one or two feet below the surface . . . ."

Surveyors Notes Can Help

No matter how evocative these various descriptions might be of the pygmy forest that we know today, none is well enough fixed in locality to assess the permanence in place of any given tract of today's pygmy forest. I knew of only one source that seemed likely to be both descriptive of the vegetation and relocatable: records of the old cadastral surveys which established a grid of township, range, and section for apportionment of taxes. The surveyors had included brief descriptions of the terrain encountered as the lines were run. These records now are housed with the Bureau of Land Management (BLM).

Contemporary U.S. Geological Survey topographic maps of the Mendocino coastal area use a symbol for scrub that seems to coincide well with contemporary or historical areas of pygmy forest. The maps are none too recent and much development has taken place in some of the indicated areas. Using these maps as a guide, I identified section lines passing through such areas, planned which section corners might be both accessible and still relatively unaltered, and asked BLM for the appropriate records of the early surveys.

The records I obtained were of surveys made at various times between 1866 and 1873. "American" society in California was rather an "instantaneous" one following the discovery of gold in 1848 and surveyors were probably from out of state, perhaps, like those of the coast survey, on assignment from the east. Not being botanists, when in doubt they probably used terminology evocative of vegetation they were familiar with in their own places of origin. There are both vague and strange plant names among those mentioned by them.

William H. Carlton, surveying in 1866, made reference to redwood, oak, fir, hemlock, nutmeg, pine, cedar, and skunkwood. Isaac N. Chapman, also working in 1866, referred to redwood, oak, fir (white, red, and yellow), hemlock, alder, pepperwood, poison oak, lilac, pines (also Scotch pine), cedar (and swamp and white cedars), willow, "briers," skunkwood, and manzanita. In surveys done a year later, he mentioned other plants, too, including whortleberry, chestnut oak, and tanbark. Thomas S. Towle, surveying in 1868, referred to pine, coast pine, redwood, whortleberry, rhododendron, oak, fir, and madrona. John M. Ingalls, working in 1869, mentioned pine, redwood, ironwood, oak, fir, yew, huckleberry, ash, lilac, and laurel. H. Savage, working in 1873, recorded oak, fir, redwood, hazel, salmon brush, hemlock, cedar, and manzanita.

I do not mean to imply that all the plants mentioned were found in areas of pygmy forest. At best, these survey lines only pass into and out of such areas. Interspersed through the descriptions are references like "burnt opening of pine and whortleberry," "Balance of Township unfit for cultivation and therefore I consider it unsurveyable," "In many places the underbrush is dense being chiefly whortleberry and briers," "opening or burn of small pines and cedars," "brush on the prairie, manzanita and scrub pine," "prairie is covered with low brush and is worthless." "leave timber enter prairie; timber first half mile redwood and fir; last half mile pine and cedar," "burnt opening of small pines and cedar," "land entirely unfit for cultivation and destitute of timber of any value." Some of these comments seemed clearly to refer to areas of pygmy forest.

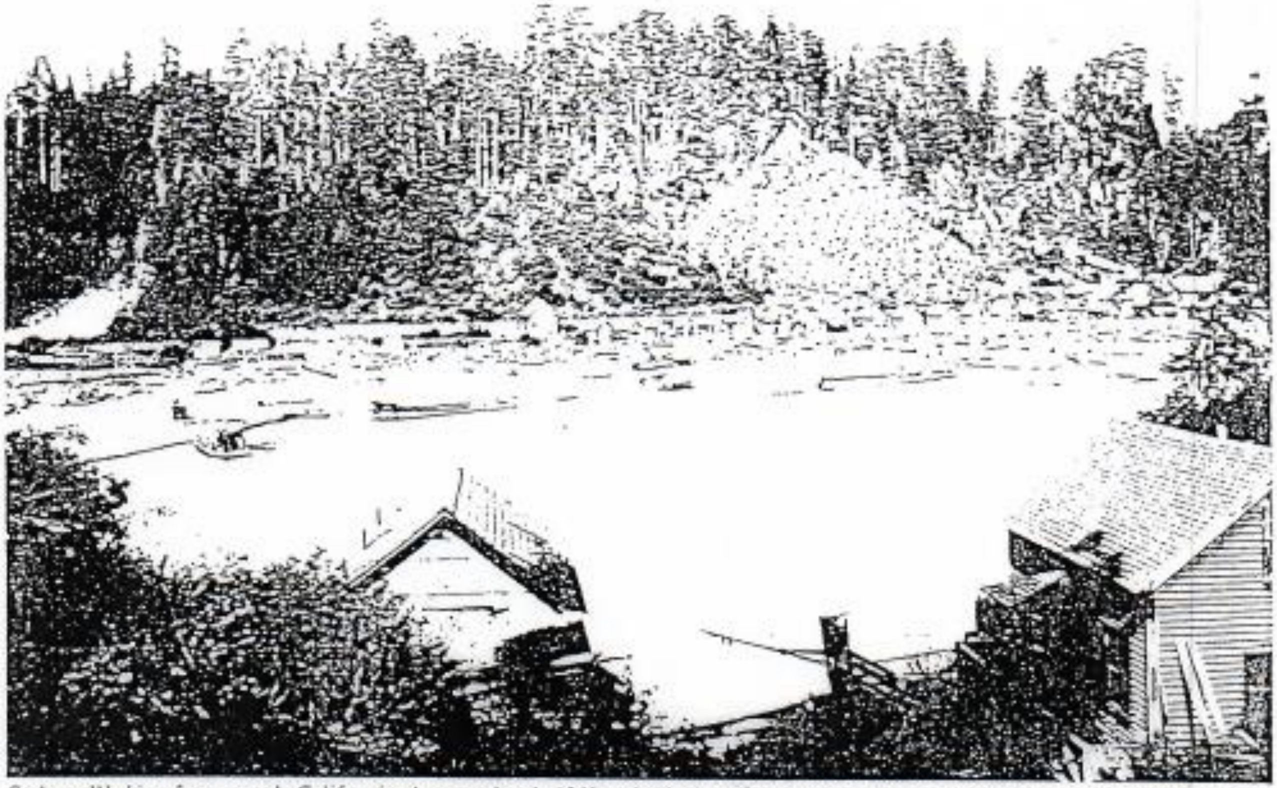
One can see that some of the terms still in use today, such as "prairie" for flat stretches of pygmy forest rather than of grass, go back a long way. One can also speculate whether the reiteration of the use of "ashy" to describe the white, leached E-horizon (remember that Jepson even called it "alkaline," evidently mistaking the white color for salts) might have led to an occasional misconception that there had been a burn.

Jepson notes in his field book in 1903 during a visit to the Mendocino coast, "After the trees come down the area is fired to get rid of brush and tops to facilitate getting out the logs. The working practice here has always been so."

Where Was the Logging Done?

Logging in this region began with the founding of the town of Mendocino in 1852. Several sources bear upon the question of whether logging had appreciably affected the uplands by the time of the cadastral surveys.

For some time logging evidently was concentrated along the rivers and creeks, which were used to float logs to the "doghole" ports for conveyance by coastal schooners to the market. The Mendocino Indian Reservation, set aside in 1856, stretched along the coast from Noyo River to about one mile north of Ten Mile River and from the Pacific Ocean inland to include the first range of hills. Fred B. Rogers, writing in the *Quarterly of the California*



Carleton Watkins, famous early California photographer, in 1863 took this view of the lumber mill and the mouth of Big River, which empties into Mendocino Bay, where the town of Mendocino City is located. Note that the slopes above the river have been logged off, but trees still stand on the uplands. This was only three years before the cadastral survey line discussed in the text was made.

Historical Society in 1951, described the general area of the reservation in 1855: "Along the coast were jutting cliffs, open table lands, patches of scraggly pines and some sand dunes, but farther back, in more protected and more favorable locations, were immense virgin stands of redwood and other timber, as yet virtually untouched by the operations of the two sawmills at the village and bay of Mendocino." In 1867 the surviving Native Americans were removed to Covelo. Presence of the reservation must have inhibited logging the uplands and no doubt contributed to the removal of the Native Americans.

The 1869 edition of the *Coast Pilot* sketches the aspect of Point Arena and Mendocino City from the sea, but to the north skips rapidly to such places as Shelter Cove and Cape Mendocino, indicating that the coastal lumbering trade did not yet involve all the "doghole" ports that existed somewhat later.

The U.S. Coast and Geodetic Survey *Annual Report* for 1872 recounts the progress made on field work in the vicinity of Mendocino City, suggesting the rising need for better navigational information by this time. Resuming work near Mendocino City in May, the survey party was confronted with a stretch presenting "a very narrow margin of cleared country along the water-line, which is bordered by broken bluffs of moderate height, backed by heavily-timbered ridges." Because of the dense vegetation, triangulation of base lines proceeded with difficulty and one of the stations "occupied . . . with the theodolite was upon a tree 103 feet above the ground . . . ."

A.W. Chase, writing in 1874 in the *Overland Monthly* on "Timber Belts of the Pacific Coast," said, "Great inroads have already been made into these mighty forests of the coast, as can be seen along the streams of Mendocino County . . . ."

The Mendocino Lumber Company, whose mill was at the mouth of Big River (present-day Mendocino City), owned some 22,000 acres extending inland twenty-four miles in a straight line. At the time of writing of the *History of Mendocino County, California*, published by Alley, Bowen & Company, San Francisco, in 1880, the company had cut as far inland as eighteen miles. But see Watkins' photograph, which shows logging concentrated along the river.

All this suggests that, at the time of the cadastral surveys, logging had not yet affected the uplands much beyond the immediate vicinity of the streams. Yet the large trees the mills were after could never have grown on the soils that support pygmy forest.

A serendipitous find of a Native American projectile point as we were setting up test plots at one site may have bearing on the extent to which fire was common on these tracts. The point lay *on top* of the ancient crust of lichen covering the soil rather than on the mineral soil beneath. An authority to whom I showed it said it was probably about 1,500 years old from the style of workmanship. Of course, it may have been lost at this site by some intermediate finder.

Relocating an Identifiable Old Section

It seemed time to plan a field search to try to relocate an old section or quarter-section post in a present-day site of pygmy forest and to attempt to match the description of what the surveyors had recorded as they ran their line with what was there today. An early recruit was my daughter-in-law, Penny S. Howard, a civil engineer now with the Office of Water Conservation in the State's Department of Water Resources. Penny had had experience in relocating old corner posts while working for the Division of Dam Safety. She in turn recruited a colleague, Lisa Akeson, and her husband, Mark Akeson, who had completed a doctorate in soil science from the University of California at Davis under Gordon Huntington. They were eager to help the project, and Mark in turn recruited Professor Huntington, an old friend of Hans. By then Hans himself had decided to join our party.

On the fourteenth of July 1989, we set forth for Mendocino to rendezvous at Melburne. The next morning, our party, including five-and-a-half-month-old Graham Akeson, set out to look for the nearest landmark we thought we could locate fairly easily, benchmark 543 along the Comptche Road. We hoped to use our surveying equipment to take a bearing from it and locate a nearby section or quarter-section post. A local resident told us, as we were creeping around in the bushes along the road, that a benchmark had been there in the last couple of years, but though we searched carefully, we could not find it.

What to do? Armed with a map provided us by the caretaker of The Nature Conservancy property along Comptche Road, we set as our substitute prize the section post marking the corner of sections 33, 34, 4, and 3.

Our first attempt took us initially along a partly overgrown old road or firebreak through pygmy forest but then into a gully supporting vigorous forest growth and a thick understory of huckleberry and other shrubs that became very difficult to penetrate. We found some boundary signs of Van Damme State Park, but not the corner post we were seeking.

We next tried a different approach, and headed in along the eastern boundary of The Nature Conservancy property, where there is a new entrance trail to the state park. This trail initially follows the trace of the old Comptche Road and is readily passable. Sharp-eyed Mark, in the lead, spotted our missing corner post lying on the ground at a fence corner in the middle of an area of pygmy forest.

We looked up Isaac Chapman's description of his survey lines to the north and to the south, converting chains to feet: to the north, "Run in burnt opening of small pines" 330 feet to the "trail" (the now abandoned old Comptche Road); to the south through pygmy forest 1,550 feet to the point where Chapman recorded "leave the prairie." The scene matched perfectly with Chapman's suggestions of dwarfed vegetation. (We did not have the east-west survey descriptions.) Thus we know that this particular area of pygmy forest has existed in essentially the same place for 123 years.

What do we know about fire history in this area? Van Damme State Park was founded in 1934, and chief ranger Mike Curry told me in November 1991 that no fires had occurred in our area since that year. He said, further, that fire scars on the big trees in the canyon area not far away suggest a large fire "that probably was regional in scope" at an unknown earlier date.

There is some further anecdotal evidence from other sites of pygmy forest. A property owner adjacent to the lower third terrace site at which Jenny and Schultz have been working fixes a fire at some seventy years earlier based on counting rings of trees he had cut on his own property. Living near our work site on Little Lake Road, an elderly woman said that no fire had occurred in the now forty-five years she had owned her property. Another tract south of the Little River airport was owned by a pair of elderly sisters when Calvin McMillan, a University of California graduate student, worked on his doctoral project there around 1945. They said no fire had occurred there within their mother's memory, and none has since that time. This time line, then, would cover about forty-seven years plus seventy-five (their approximate age) plus, perhaps, another twenty for a total of 142 years without fire. (I am indebted to Arnold Schultz for this information.)

Professors Jenny and Schultz, not having worked in the area of our section corner, have no data as to age of trees there, but they did sample trees not far away. The oldest recorded in their sampling is about seventy-five to eighty years (earliest growth rings are hard to decipher), while the peak age class of individuals was thirty-three years.

Where does all this leave the fire-climax theory? It would appear to need more critical examination than it has had so far.

Alice Q. Howard, 6415 Regent Street, Oakland, CA 94618

The lowest, most recently formed, marine terrace in Mendocino County has relatively young soils, estimated to be about 100,000 years old. Photographs by Sylvia Duran Sharnoff, daughter of the cover photographer, and her husband Stephen unless otherwise noted.

THE PYGMY FOREST OF MENDOCINO

by Robert E. Sholars

The Pygmy Forest

Along the coast of Mendocino County, California occurs a series of marine terraces carved by the sea since the early Pleistocene. The lowest, most recently formed terrace is occupied by coastal prairie. Subsequent terraces display a sequence of soil and vegetation development that culminates on the higher (older) terraces in extremely impoverished, highly acid podzolic soils. Here grow a number of severely dwarfed, endemic species such as Mendocino cypress (*Cupressus pygmaea*) and Bolander's pine (*Pinus contorta* ssp. *bolanderi*). These plants are often decades old, yet only one to two meters tall, with gnarled, lichen-encrusted trunks, a few centimeters in diameter. This pygmy forest has been described as being as close to a final, stationary ecosystem as can be found in nature. It is the culmination of many hundreds of thousands of years of soil-vegetation interaction.

During the Pleistocene epoch, the worldwide sea level fell and rose as continental glaciers formed and melted. This fluctuation of sea level occurred a number of times. For the duration of a glacial stage, the sea would remain at a relatively stable low level; for the duration of an interglacial stage the sea would remain at a relatively high level. As sea levels rose, terraces or platforms were cut into coastal bedrock, while retreating seas covered these platforms with beach materials.

Where coastlines were gradually rising from tectonic forces, successive periods of higher seas cut new platforms below previously created ones, creating elevational sequences of marine terraces. This has happened in many places in the world, particularly in western North America. But in most locations, the terraces have faulted, warped, and eroded and are no longer distinguishable as relatively flat platforms. In western North America, generally only the most recently formed terrace, called the coastal headland, is distinguishable. In Mendicino County, however, a fault block, extending from south to north, approximately from the Navarro River to Ten Mile River, has been uplifted without too much deformation. On this block five distinct terraces still retain the relatively flat positions in which they were sequentially formed.

Because of breaks in the continuity of terraces caused by entrenched streams, the variable widths of the terraces, and the varied density and height of the vegetation, the relationships of the terraces in Mendocino are not always obvious. Elevations of the five terraces range from one hundred feet for the first terrace to six hundred and fifty feet for the fifth terrace, not above sea level, but from the lowest buried "nickpoint" where the terrace floor underlying the beach deposits and the sea cliff meet to the similar points of the higher terraces.

The parent graywacke rock of the inland mountains is continuously weathered and eroded, and the numerous streams and several rivers that dissect the terraces carry the erosional products to the sea, where they are deposited by long-shore currents as beach materials, sometimes twenty to thirty feet deep.

Terraces are dissected by numerous streams and several rivers that flow from the mountains to the sea and continuously erode and weather the parent graywacke rock. Eroded fragments of rock, gravel, sand, and clay are carried to the sea, and deposited by long-shore currents as beach material, where they may accumulate to a depth of twenty to thirty feet.

Soils

Because the source of beach material for each terrace is the same Franciscan graywacke, soils on each of the terraces are also considered to have developed from similar parent material. Soil on the first, lowest terrace, cut before the onset of the Wisconsin glaciation, is estimated to be about 100,000 years old; soil on the highest, oldest terrace is estimated to be on the order of one million years old – an extreme age for a soil!

Many soil scientists have theorized that vegetation has been important in development of the soils upon which the pygmy forest grows. Pines and ericaceous shrubs synthesize chemicals that mobilize inorganic iron in the soil, allowing it to leach downward. In the subsoil this released iron is thought to cement the quartz grains into hardpan. The vegetation, they say, has created the soil. Botanists, on the other hand, say the extreme soils of the pygmy forest have produced the dwarfed vegetation. They label the pygmy forest an edaphic (soil-derived) climax. Jenny and colleagues say, in a third view, that both vegetation and soil develop together, each affecting the other.

On the second terrace above the sea, as podzolization takes place, redwood-Douglas-fir forest, typical of the Mendicino coastal region, is gradually displaced by a Bishop pine forest. On progressively higher and older terraces, the third, fourth, and fifth, the podzolization process becomes completed, and the terraces support a pygmy forest.

There are two types of podzol soil on these terraces, Blacklock and Aborigine. Typically in Blacklock soil, the upper layer, called an A1 horizon, is one-half to four inches deep, dark grey in color, and full of entwined roots and organic matter. Below is a light, bleached, sandy layer, eight to fifteen inches deep, called an A2 horizon, which is underlain by a concrete-like, iron-cemented hardpan, or B horizon, six to fifteen inches thick. Below, at a depth of sixty inches, is unaltered beach deposit which rests on an impervious, sea-cut platform or hard graywacke. Aborigine, a variation of the Blacklock profile has, in place of the iron-cemented hardpan, a dense claypan containing up to 61 percent clay. This claypan, like the iron hardpan, is an effective barrier to both roots and water. Other characteristics of this soil are essentially like those of Blacklock. These podzol soils are some of the most acid soils known, with reported pH values between 2.8 and 4.3. They are very low in macronutrients and micronutrients, though other habitat types, such as coastal sand dune supporting forests of considerable size, fall within a similar low range of nutrients. Vegetative productivity decreases as the degree of acidity of the upper soil levels in the A horizon increases. Soil acidity has a direct effect on the availability of both essential and non-essential elements in the soil. As acidity increases, nitrogen, phosphorous, potassium, calcium, magnesium, sulfur, and molybdenum become less available. Some elements, such as iron, manganese, aluminum, zinc, copper, and boron become more soluble and, therefore, more available to the plant. If an element is present at low levels and soil acidity increases, deficiencies could be improved; if an element is present at high levels, toxicity could result. The extreme acidity may inhibit bacterial activity, perhaps disrupting the availability of nitrogen to the plant from the nitrogen cycle. Nitrification by soil microorganisms decreases as acidity increases below neutrality. High levels of aluminum may decrease nutrient uptake and limit plant growth and may be a factor in creating a pygmy forest.

During the winter, visitors often note standing pools of water throughout the pygmy forest. Because of high rainfall and an impervious hardpan, a perched water table occurs near the surface of the soil for many months each winter. In late fall, after the first winter rains, the deeper groundwater table also begins to rise and during prolonged rains it may reach the height of the hardpan. In spring the upper perched water table gradually disappears by seepage, evapotranspiration of vegetation, and evaporation. This seasonally high water table has existed on each of the terraces since the time of their emergence from the sea and has been fundamental in the development and maintenance of the podzol soils.

In the pygmy forest, the roots of the dwarfed vegetation do not penetrate the hardpan; they are confined to the shallow soil above it. It was long assumed that the pygmy forest is very dry during the summer. The summer visitor often likens the pygmy forest to chaparral, and it seems as if "dry summer conditions" might be critical in excluding species from the pygmy forest. Several investigators have assumed the existence of "extreme xeric conditions" during the summer, and considered this condition as a possible cause of the endemism and the stunted growth of trees in the pygmy forest. Tree crowns are often gnarled and grotesque from the repeated dieback of terminal and lateral branches, growth similar to that in other forests found during recurrent years of severe moisture stress. On a still, cloudless summer day, the pygmy forest certainly *seems* very arid. Interestingly, it has recently been found that the soil of the pygmy forest does not become extremely dry during the summer. Soil moisture stress is actually low in the pygmy forest and does not attain levels that significantly limit growth. In fact, while the *amount* of water available during the growing season in the pygmy forest is limited, the sparse, small-statured vegetation does not fully utilize the water that is present.

Pygmy cypress trees typically grow in cane-like thickets, often heavily encrusted with lichens.

The stunted, gnarled, and lichen-encrusted vegetation of the pygmy forest contrasts sharply with an adjacent luxuriant regional forest of redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and grand fir (*Abies grandis*). The transition (ecotone) from the pygmy forest to the redwood forest of large, undwarfed trees often occurs in only thirty to one hundred feet. The rapid change is quite striking, and occurs where a level terrace of pygmy forest on Blacklock/Aborigine podzol soils adjoins a stream canyon of redwood forest on the slopes. The stream canyon provides soil drainage as well as soil renewal through processes of geologic erosion.

Pygmy Cypress

Pygmy cypress (*Cupressus pygmaea*) is the species most characteristic of the pygmy forest, and its distribution coincides with the boundaries of the pygmy forest. Like other members of its genus, and unlike some other coniferous genera with widespread distribution such as *Juniperus* and *Pinus*, pygmy cypress is restricted to well-defined areas, appropriately termed "arboreal islands." Most of the population occurs between Ten Mile River and the Navarro River. These populations are essentially restricted the Blacklock-Aborigine terrace podzolized soils. Several populations are scattered south of Point Arena, on shallow, very acid, partially podzolized soil.

Pygmy cypress typically grows as a five to ten foot cane-like dwarf tree on acid pozol soils. These trees can be decades to a century old and can grow in dense groves with as many as four trees per square meter. While the name pygmy cypress is appropriate for specimens growing on podzol soils, it definitely is not for specimens growing in low moist sites on better drained soils. Here, in swales surrounded by typical pygmy forest vegetation, pygmy cypress can grow to 100 feet in height with a diameter of three feet near the ground. It, in fact, is the tallest of all cypress species when

Bolander's pine, an endemic species found growing in the pygmy forest on the higher (oldest) terraces, sometimes only reaches one to two feet in height in fifty years.

growing under these conditions. Stands with large individuals of pygmy cypress are not common, but do still exist. Local independent sawmills occasionally sell lumber of pygmy cypress in sizes up to one inch by twelve inches by sixteen feet.

Pygmy cypress is not confined to the pygmy forest because of an inability to grow elsewhere but rather, appears to compete poorly with tall-growing conifers of the regional forest and is thus restricted to areas where competing species cannot grow, namely on acid podzol soils and boggy sites. In addition, pygmy cypress, when grown at sites inland from its natural range, is very susceptible to attack by the cypress canker, *Coryneum cardinale*. It may, in fact, be limited to the coast by this disease. A recent theory speculated that fire may exclude competing three species from boggy sites where pygmy cypress prospers; however, this seems unlikely because the fire resistance of pygmy cypress is poor except possibly for large individuals. It seems more likely that species of the regional forest are excluded from boggy sites by long periods of standing water.

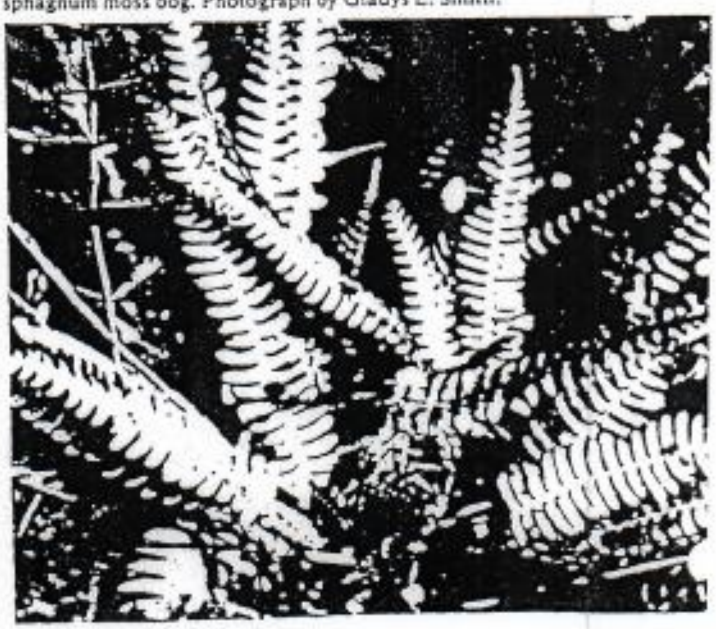
Fire appears to be critical in the perpetuation of pygmy cypress for it is the only effective natural agent both for opening the serotinous cones and for creating light gaps nourished with bare mineral substrate needed for seed germination. The occurrence of occasional fires in the pygmy forest produces numerous relatively even-aged stands of pygmy cypress. A striking feature of pygmy cypress is its miniature size at reproductive maturity. It often bears female cones when one one to two feet tall and at an age of seven years.

Other Plants in the Pygmy Forest

Bolander's pine is endemic to the Mendicino pygmy forest. Its distribution generally coincides with that of pygmy cypress but is somewhat more restricted. In the pygmy forest, Bolander's pine may reach one to two feet in height in fifty or sixty years. Thickets of the stunted cane-like trees are often even-aged, a reflection of their closed-cone habit and their fire origin. Bolander's pine has serotinous cones which remain closed for many years. Large specimens of Bolander's pine are unusual, but when found, grow in boggy areas within the pygmy forest, usually with large forms of pygmy cypress. Unlike pygmy cypress, Bolander's pine does not seem to invade the margins of the redwood forest following fire, logging, or a similar disturbance.

Within the pygmy forest are occasional, small bogs

Deer fern, a common plant of north coast bogs, grows in the sphagnum moss bog. Photograph by Gladys L. Smith.



where an impervious soil plan is absent and a deep accumulation of organic material occurs. Large specimens of pygmy cypress and occasionally of Bolander's pine grow in these places. Dense hummocks of sphagnum are present in some of the boggy areas of the pygmy forest and absent or poorly developed in others. Sundew (*Drosera rotundifolia*), tinker's penny (*Hypericum anagalloides*), and coast lily (*Lilium maritimum*) are all common herbaceous plants. Bunchberry (*Cornus canadensis*) makes its most southerly appearance on the Pacific Coast in this habitat. Bellflower (*Campanula californica*) has been found here [CNPS *Inventory of Rare and Endangered Vascular Plants of California* List Two (Plants Rare and Endangered) 1980].

A typical site in the pygmy forest has pygmy cypress and Bolander's pine, varying height from six to eight feet, growing in profusion. Stunted specimens of bishop pine (*Pinus muricata*) are frequently interspersed. The most common shrubs are California huckleberry (*Vaccinium ovatum*), Fort Bragg manzanita (*Arctostaphylos nummularia*), labrador-tea (*Ledum glandulosum* ssp. *columbianum*), salal (*Gaultheria shallon*), and California rose-bay (*Rhododendron macrophyllum*). Trees and shrubs are all dwarfed, many exhibit dieback symptoms and several have fungus-gall infestations. Occasionally, a lone Bishop pine as high as seventy feet towers above the dwarfs. Hans Jenny excavated one such specimen and found an enormous tap root that penetrated the hardpan and extended into the permeable deeper strata. The low stature and openness of the pygmy forest allows exposure of most of the photosynthetic surfaces to full sunlight. There is twenty-five percent light penetration to the ground in this pygmy forest compared with one percent in a redwood forest and four percent in a Bishop pine forest. As a result, pygmy forest understory vegetation has a very high productive efficiency.

Conservation

The pygmy forest has long fascinated botanists and soil scientists. This fascination has, from the outset, been heightened by the stunning contrast of the diminutive plants in the pygmy forest with the grand giants of the redwood forest, often growing just meters apart.

The pygmy forest is apparently a very stable ecosystem, existing on the same sites, unchanging, for hundred of thousands of years. Ironically, even moderate levels of pedestrian use are very damaging. The amounts of roots, lichens, and organic material at the surface of the soil are dramatically reduced when people continuously walk through an area. Pygmy forest areas "preserved" at Jughandle and Van Damme State

Dwarf mistletoe and fungus-galls infest the stunted trees, here seen on a Bishop pine.

Parks have been severely degraded by trampling. The pygmy forest is thought to have maintained itself because, on the relatively flat terraces, erosion is minimal. Removal of the organic mat encourages erosion. Roadways, of course, are even worse because they accelerate erosion tremendously, and, less obviously, because they alter the level of the water tables, both above bedrock and also above the hardpan. Maintenance of "normal" water tables is essential to the long-term viability of the pygmy forest and water wells, roads, roadcuts, and ditches all alter both water tables. Where rapid runoff of water occurs, erosion takes place. Under these altered soil conditions a regional redwood forest would, over long periods of time, displace the pygmy forest.

At Jughandle State Reserve, ORV activity and intentional road grading and creation of fire breaks have damaged the Pygmy Forest Reserve to the degree that its long-term viability is in doubt. In addition, because of the horizontal movement of water into and within the pygmy forest (on the surface, above the hardpan, and above bedrock), the introduction of nutrient-rich waters poses a major threat to the viability of the pygmy forest. Sources of these waters include septic systems, gardens and landscapes, and concentrations of domestic animals.

Once there were about 4,000 acres of pygmy forest, in twenty-six separate locations. Because of obvious problems in sewage disposal, water supply, and landscaping, there was little development and the pygmy forest areas were relatively undisturbed for many years. Until recently, pygmy forest destruction was principally from government projects such as airports and garbage dump sites. In recent decades, however, the combination of a significant population influx, a lack of alternate building sites, and the low cost of pygmy forest land have resulted in the destruction of extensive amounts of pygmy forest lands for residential purposes. Problems such as septic system failure, contaminated water supplies, and failed landscapes have, of course, resulted from building on the poorly draining hardpan soils of the pygmy forest. Thirteen of the twenty-six areas of pygmy forest have been destroyed. The other thirteen areas have all been affected, some more than others.

The pygmy forest ecosystem, situated on ancient marine terraces that remain intact at this moment in geological time, provide modern man with a rare form of natural museum. To destroy a unique ecosystem that was formed over hundreds of millenia to be in two decades by a series of minor but cumulative events is a senseless tragedy.

Editor's Note: That there will still be a pygmy forest and ecological staircase in Mendicino for future generations to marvel at is so largely because of the vision, leadership, and persistence of the distinguished soil scientist Prof. Emeritus Hans Jenny and his wife Jean. A forthcoming issue of Fremontia *will set forth the story of how their dream became today's reality with the help of many people in efforts that have persisted over twenty-four years. In recognition of their contributions to this and many other conservation battles, Hans and Jean were made fellows of the California Native Plant Society in 1981.*

Cladina is a lichen only found growing in the sphagnum moss bog in the pygmy forest of Mendocino.