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 catalalques 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 concert 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,
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

Redwood-Douglas fir forest
Bishop pine forest
Pygmy forest
Grassland
Dunes
Hardpan
Wave cut platforms
Sandstone
Beach deposits
Nickpoint
Sea

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.

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 sud-
denly 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 blonish 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 musky-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.

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, 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.
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, butternut, 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
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 grayish 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-resinous 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 only half kidding, maybe even serious, when he suggested the selenium-tainted wetlands of Central California into Selenium State Park. The tainting, after all, is the root of the natural leaching of a trace element when irrigated water is poured over the soils.

Leaving the car beside a rut, we walked through the scrubby path of conifers into another world. The tall trees were scarcely taller than a man, and many rose higher than our waists, though they were decades or even centuries old. Their trunks were as slender as a mummified wrists. Here grew dwarfed, twisted versions of the pines and cypresses on lower steps of the staircase. A few we 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 dying. When they perished, they remained standing, rotting in place.

From above, who could ever say what had caused the 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 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 process 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 he began down in the forest as a light gray horizon as wispy 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 the 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 o 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
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 scabbled 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 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 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."

William Bryan Logan is writer in residence at the Cathedral of St. John the Divine in New York City. He is writing a book on soil.