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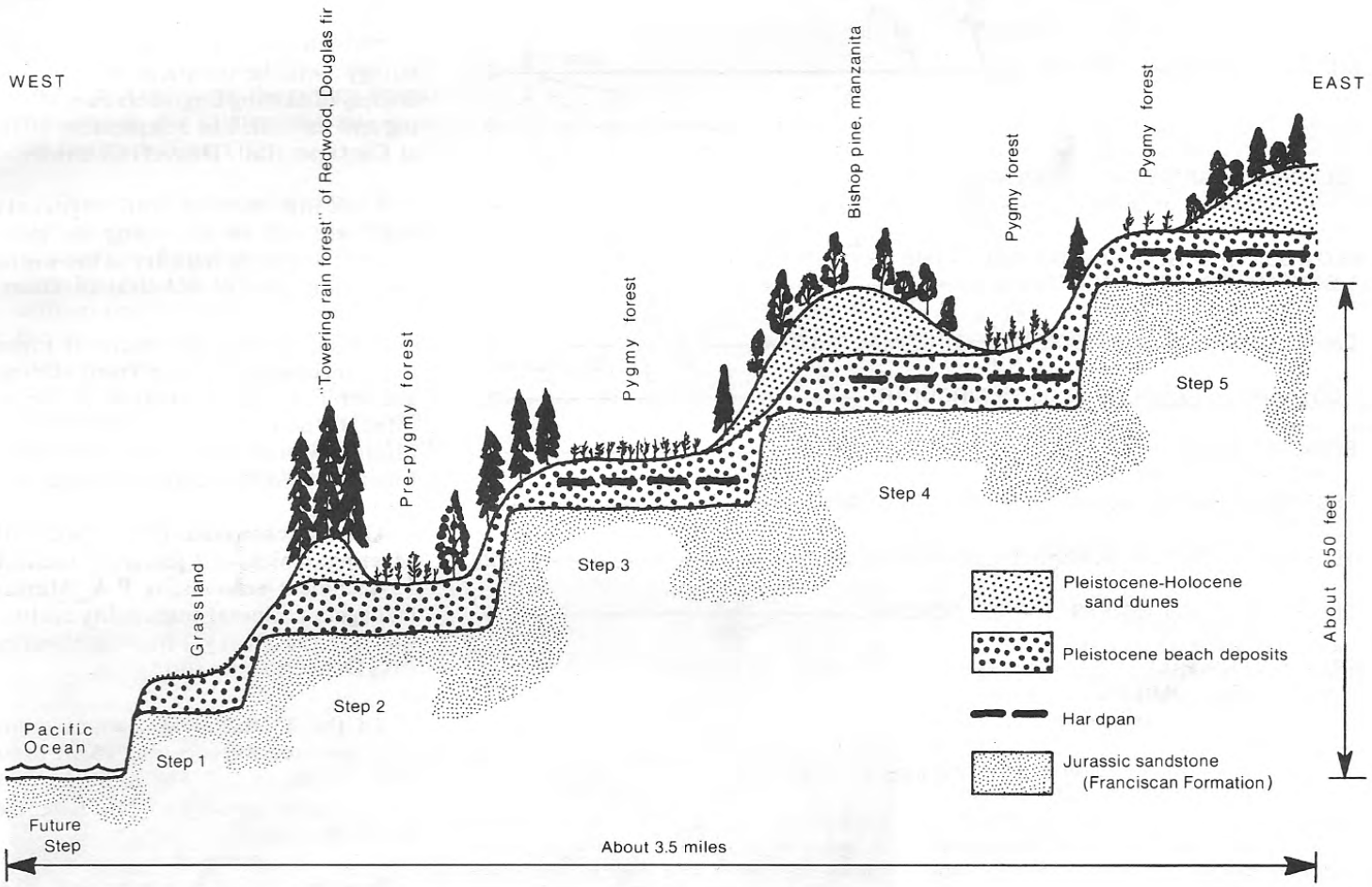

PYGMY FOREST:

AN ECOLOGIC STAIRCASE

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AN ECOLOGIC STAIRCASE

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INTRODUCTION

Discovery in the mid-1800s of nature's own bonsai forests along the Mendocino County coast in the northern Coast Ranges province started a century-long investigation that has exposed a remarkable phenomenon: a complete ecologic staircase, the only one if its kind, with the pygmy forests dominating the climax vegetation on the top steps (figure 1).

The steps are represented by a series of Pleistocene marine terraces uplifted as much as 650 feet above sea level over the last 500,000 years. The half-million year old ecosystem was created through a process of landscape aging that recycles the old into the new through erosion. Jug Handle Creek and other streams draining the area are erosional agents performing part of the task in the pygmy forest (photo I).

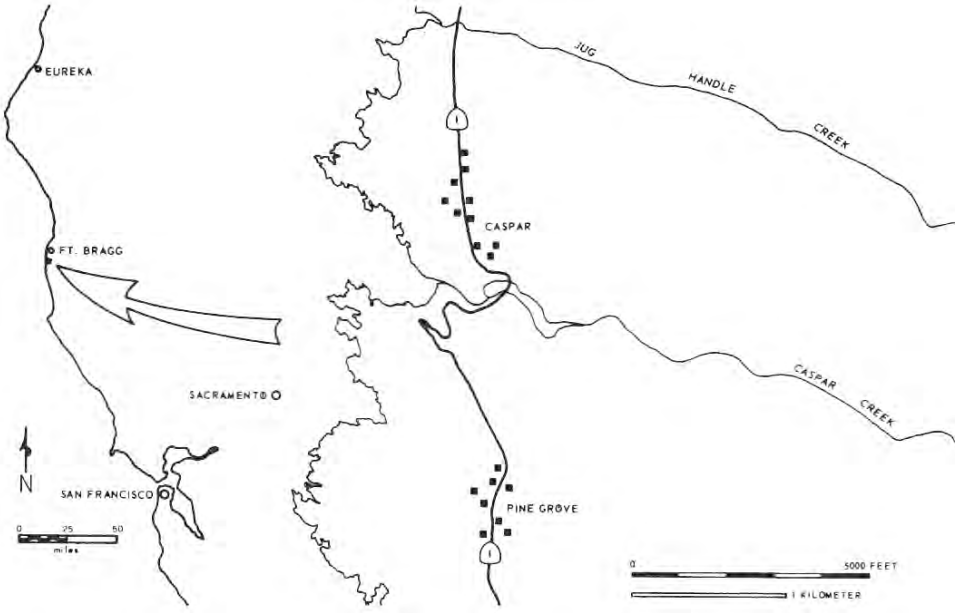

Figure 1. Location of the pygmy forest ecological staircase.

Photo 1. Mendocino County coast. Coastal sediments are the material of the elevated terraces of the future. *Photo courtesy of California Institute of Man in Nature.*

DEFINITIONS*

graywacke: a dark grayish, hard, firmly indurated, coarse-grained sandstone, consisting of poorly sorted, extremely granular grains of quartz and feldspar and a variety of other minerals, in a partly metamorphosed clayey matrix.

illuvial: said of a soil horizon to which material has been added (leached or "washed in") by the process of illuviation.

podzol: a group of zonal soils having a surface layer of mats of organic material and thin horizons of organic minerals overlying gray, leached horizons and dark brown, illuvial horizons. It develops under coniferous or mixed forests or under heath, in a cool to temperate, moist climate. Also spelled: podsol. Russian podsol, "ash soil".

podzolization: the process by which a soil becomes more acid due to the depletion of bases, and develops surface layers that have been leached of clay; the development of a podzol.

Taken from AGI glossary

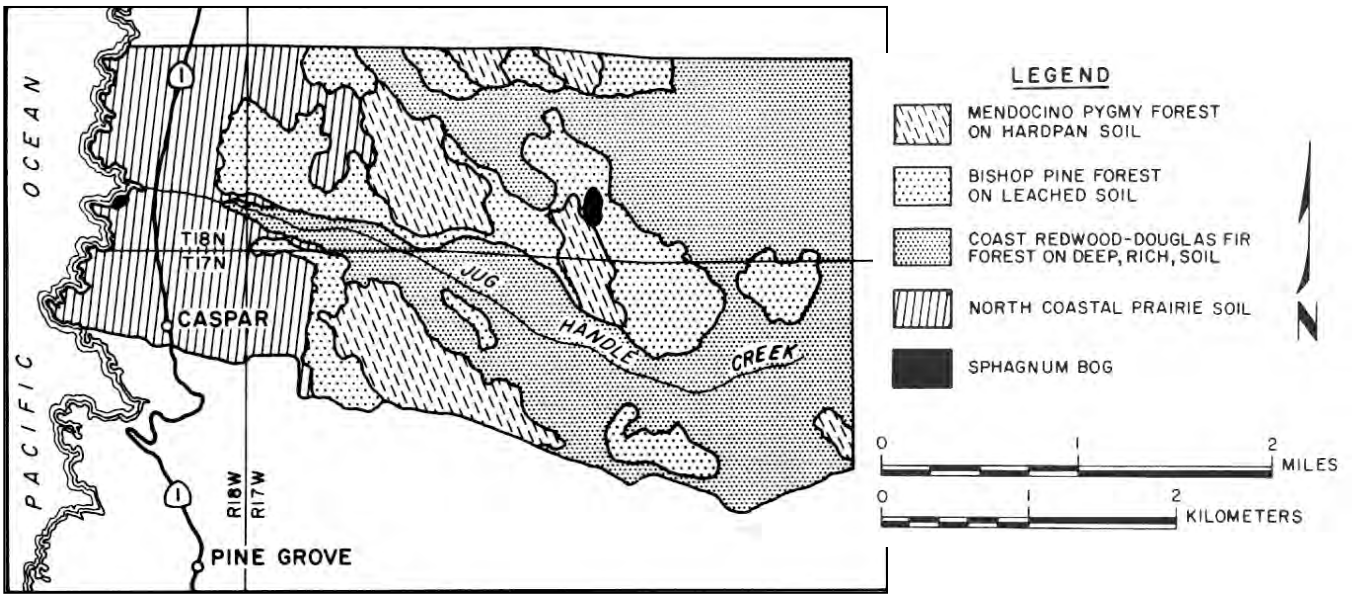

Figure 2. Distribution of soil and vegetation on the ecologic staircase.

From: Pygmy forest ecological staircase feasibility study, Department of Parks and Recreation and Department of Conservation, 1974.

EVOLUTION OF THE STAIRCASE

The five elevated marine terraces constituting the staircase evolved from the same parent Jurassic marine sedimentary rock (Franciscan Formation), under the same climatic regimen. They differ principally in the length of time they have existed as related entities. The age increment separating terraces is, in round numbers, 100,000 years (figure 2).

Changing Sea Level and Tectonic Uplift

Such a staircase structure could have come into being only where a segment of coastline rose slowly and steadily from the ocean. This part of Mendocino County coast has risen for about 500,000 years at a reasonably constant rate averaging 2 to 3 centimeters rise per cenwry. Movement within the San Andreas fault zone, which lies about 3.5 miles offshore, has probably contributed to upward movement of the staircase.

Superimposed upon the relatively constant coastal uplift is the changing sea level, fluctuating about 200 feet or more over periods of thousands of years. With each epoch of glacial melt, the ocean has sent its breakers at ever higher levels crashing against the solid shore, plucking it apart grain by grain to leave vertical sea cliffs and to accumulate debris on the continental shelf.

As the polar ice thickened during the,lce Age, the ocean has receded and withdrawn the attack, permitting the mantle of detritus to ride upward on the sandstone shelf, forming a step in the staircase, which might be compared roughly to an escalator. Thus, step number five was once at the elevation now occupied by step number four, and four was where three is, and so on down. The steps risc in unison and more steps will be formed in turn, as time goes by.

Wind and Sand Dunes

Another active agent in building the structural base for the exhibit of plant succession is the wind. Over the centuries strong coastal breezes have picked up beach sand and dropped it on top of the lowest step to form dunes, often 20 feet or more high. This has happened on each step in turn as the escalator has moved upward.

The term "marching" has often been applied to sand dunes that seem to be randomly distributed on the stairs. A dune deposit can be expected to develop downwind from a sand source, such as at the entry of a stream into the ocean. The wind deposits the sand in a leeward direction, but sand is deposited on an elevated terrace only where the cliff is low or a break in the topography, such as a drainage channel or stream, permits the deposition without a major interruption. When changes over long periods have reduced the source of sand and changed the route of "march", the dune remnants appear to have been scattered without reason.

Future Step

The next step which will form on the staircase is now occupied by tide pools inhabited by anemones, starfish, and myriads of bottom-dwelling animals and plants of the lower littoral zone. Kelp and fish communities populate the shallow water that shifts back and forth above 10 to 15 feet of sand. Underneath is the Jurassic bedrock that makes up the solid land mass and will form the core 'of the terrace as it is elevated.

MINERAL AND SOIL RELATIONSHIP ON THE STAIRCASE

In the pygmy forest sector of the Mendocino coast the mass of Franciscan Formation graywacke sandstone which forms bedrock, has a ratio of about 18 feldspar granules to every 100 quartz granules. Fresh, unweathered sand derived from this graywacke sandstone will have this same proportion. Thus, on the ecologic staircase, quartz, which has no nutrients useful to plant growth, provides physical support, and feldspar provides plants with calcium, sodium, and potassium, all necessary nutrients for their growth.

The First Step

The "riser" of the first step in this staircase ecosystem is the sea cliff where the sandstone is exposed. The "tread" is the broad flat terrace that generally lies along the coastal bluff (photo 2). Where the exposure is fresh and unweathered, the black soil crowning the cliff contrasts with the lighter colored rock underneath. In the language of the soil scientist this black soil is known as prairie soil, like the classic soil on the prairies half a continent away. This prairie soil has the richness imparted by organic matter from the decay of roots, leaves, and stems of lupine, poppy, grass, and other perennial plants, which have renewed themselves annually over the centuries.

It has been suggested that the first terrace is grass-covered because Indians burned the trees off, or the early loggers cut the trees closest to the shore for easy shipping. The latter idea is disproved by photos from the 1860s showing the growth of grass and flowers and neither trees nor stumps. Black prairie soil develops over a long period of time-perhaps longer than the Indians have been around-and does not develop at all under coniferous tree cover.

Tree growth is not encouraged by the lashing salt spray that on-shore breezes bring to the first stair step. Redwoods and Douglas firs are found dotting the eastern edge of the terrace, where soil and wind contain the least amount of salt, and these trees grow up the riser onto the tread of the next step above.

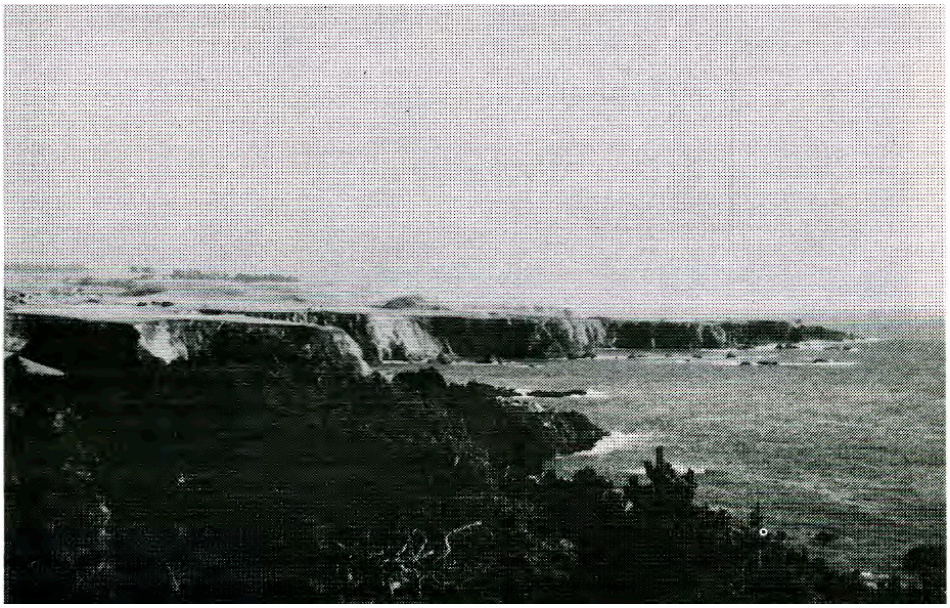

Photo 2. The first terrace, elevated above sea level, extends for many miles along the Mendocino County coast. Trees visible on the horizon (left center) occupy the second terrace. *Photo courtesy of Hans Jenny.*

All along the ocean front, real estate developers rate the first terrace as choice for gracious living. The green carpeting, dotted with blue, pink, and orange blossoms of wild flowers, leads the eye to the white surf and far out over the blue sea beyond. As an ecosystem, however, the first terrace of rich black soil is in a state of alteration and is a thing of the moment that would change before the eyes if one could watch it intently through a hundred millenia.

The Second Step

On the second step, about 200 feet above sea level and nearly 1 mile back from the cliffs, the salty wind no longer determines which plants will survive. Forests dominate this zone, and the soils reflect their presence. Conversely, changes in the soil are beginning to have their influence upon the welfare of the forest. The term "towering rain forest" is better applied here than on any other terrace.

This second step has distinct remains of sand dunes on its seaward edge-distinct in configuration, at least, although internal change has taken place. In the hundre.ds of thousands· of years that the step has been forming, the high rainfall (40 to 60 inches per year) and the constant shower of needles and leaves from the stately redwoods, firs, and hemlocks have masked the sand that blew in long ago.

Weathering has darkened the sand and altered some of the feldspar to clay, changing the ratio of 18 parts feldspar to 100 parts quartz. Decay of the needle-and-leaf compost has made a humus zone on the ground surface that slowly imparts nutrients and a moderately acid reaction ·to the soil body. The dune has become a favorable site for timber, because of the influence of the rainfall and the cover of the awesome giant redwoods, themselves.

The midsection of the second terrace is duneless. The soil is developing directly in the beach deposits that rode the step from the beginning of its ascent. The rim of dunes along the edge has cut off surface drainage from this central area and has even enhanced its wetness by releasing internal moisture onto it through seepage of springs. The result is a prolonged season of soaking until the short summer arrives and everything becomes so parched that one wonders how plants accustomed to moisture could have adjusted.

All of the events that have formed more completely in the midsections of the third, fourth, and fifth steps have begun at the position of the second step. Cypress clumps and bishop pines are present here, but are less obvious than the sphagnum bogs and pygmy forests on the higher steps.

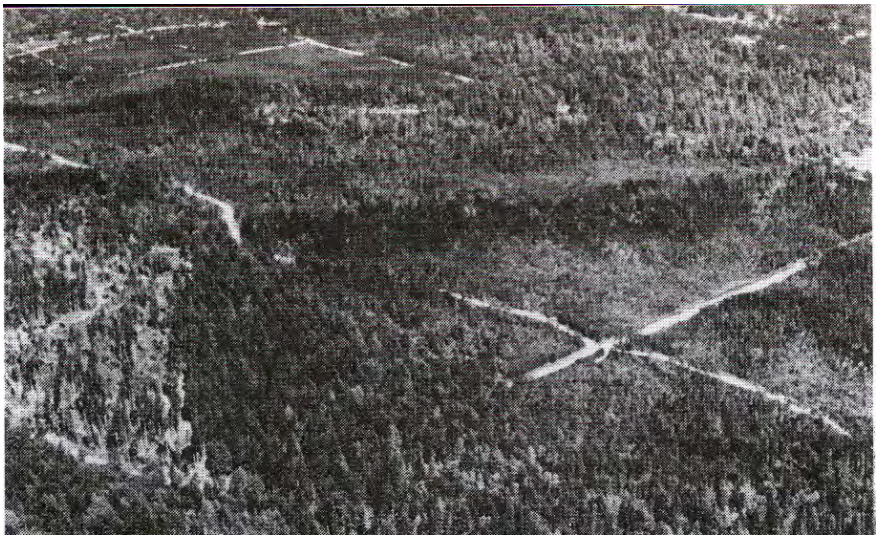

Photo 3. Roads cross near the edge of a pygmy forest. The dark horizontal zone (center) is the riser to the highest pygmy forest terrace. Photo courtesy of California Institute of Man in Nature.

Remaining Steps

Effects of the first and second 100,000 years are readily apparent. Terraces three, four, and five resemble one another in many respects, though they are separated also by time increments of about 100,000 years (photo 3).

SOIL FORMATION

Podzol

Where dunes remain on the higher and older steps their composition departs radically from the fertile dark brownish soil of the younger dunes, reflecting a degree of podzolization.

A podzol is a soil that develops under a combination of rainfall and time that creates a high rate of leach~ ing. Moisture moves down through the surface zone, and chemical elements such as calcium, sodium, and potassium, are dissolved and carried downward in solution. Ultra-fine clay particles, in a state resembling suspension, also filter through the surface zone. After several centuries an ashygray or white layer, which is essentially sterile, develops several inches below the top humus layer. This layer is called the podzol horizon (Russian podsol, "ash soil"). Everything that was leached out of the podzol accumulates in the next zone below, which as a result, slowly hardens into hardpan.

Noyo Soil

The ashy-gray soil that has developed on the dunes of the older terraces is called Noyo soil, and it is only partly podzolized. Downward migration within the soil has made a distinct clay layer with rusty mottling, but it is not cemented like hardpan.

A seedling tree sprouting on Noyo soil will find a fairly good environment in the top layer where it can feed on nutrients in the humus. Roots growing downward, however, soon encounter the nutrient-deficient podzolized zone, and the suddenly disadvantaged plant becomes distinctly retarded.

Bishop pine is the most abundant tree growing on Noyo soil dunes, in company with small-leafed manzanita, and an occasional dwarfed, yellowleafed redwood. This privation-tolerant association compares poorly with the lush growth on the lower steps but has not yet reached pygmy proportions.

Blacklock Soil

Wherever dunes occur on the upper steps they block surface drainage in the same manner as on step number two. Again, localized bogs develop nearby, flooded by winter. rains, and the bogs last into dryer months as they are fed by dune-margin springs.

With or without bogs, complete podzolization has taken place in the flat ocean-beach deposits on these oldest steps. The resulting soil, known as Blacklock soil. is a true podzol with a cemented hardpan, impenetrable to anything short of steel tools in the hands of strong men. The feldspar is gone from the white upper layer, and the fertility of the quartz is no better than that of pulverized glass. This layer of soil is among the most highly acid soils found anywhere; even worms shun it because it contains no organic matter.

The high-terrace bogs form the most southerly habitat of the sphagnum moss, which is common in the north lands. The sterile bogs are so low in oxygen and so nearly devoid of bacteria that the moss compresses itself by its own weight without decaying and becomes peat — youngest of the fossil fuels.

Virtual absence of nutrients in the soil precludes the growth of all but a few plants. Without competition from the usual nitrogen-consuming vegetation, some of nature's oddities have taken a foothold beneath the sparse canopy of swamp cypress. Among them is the colorful sundew — a minute specimen that traps insects on its sticky leaves and takes its nourishment from them.

Where neither dune nor bog prevail, the stair tread is not hummocky and is not submerged, although the subsurface is wet more of the year than it is dry. This is the site of the pygmy forest.

EFFECT OF THE ECOSYSTEM

Dr. Hans Jenny, University of California at Berkeley, is the leading student of the ecologic staircase. He regards the pygmy growth and the podzol as simultaneous cause and effect of one another (Jenny and others, 1969). The forest cover, he believes, has influenced the time~consuming conversion of the rich, black prairie soil to the leached, gray Blacklock soil. The limitation of the Blacklock soil as a nutrient provider has concurrently caused the slow advent of dwarfism in the plants that occupy it.

Jenny cites a vegetal case in point — the Bolander pine, which occurs in nature only in its pygmy state. The Bolander pine retains the major characteristics of its Pinus contorta ancestor, but has evolved from it in the chemistry of its resins and in a structural modification from open to closed cone. When Pinus bolanderi is moved to a better environment it grows vigorously but shows no tendency to revert to the open-cone condition.

Besides the Bolander pine, a pygmy forest typically has bishop pines and cane-like slender Mendocino cypresses striped around with white lichen markings. Two varieties of manzanita are in

the association along with Labrador tea, salal, rhododendron, and huckleberry. All are small, and most of the plant population show further effects of poor nutrition in die-back symptoms, infestations of dwarf mistletoe, and fist-sized orange-colored growths of pine-gall rust.

Here and there among the pygmies is a rarity of bishop pine that has sunk a tap root through a crack in the hardpan and grown to overshadow all else. Without such phenomenal luck the others are rooted only in the top half-foot of soil where they find little sustenance.

Commonly, the pygmy pine that has reached the century mark will lift its tip to a height of 5 to 10 feet on a trunk with a 2.5 inch diameter. A 50-year old cypress may be less than 4 feet high and less than l inch in diameter, anchored by a root system with a breadth of 1 foot (photo 4).

With branch growth measured at 1 inch per year, or even less, the Bolander pine barely paces the 1000- year-old bristlecone pine-the pygmy of the desert mountains (see p. 180, December 1974 CALIFORNIA GEOLOGY). No pygmy Bolander pine is known to be older than 300 years.

The wonder is that so many have lived so long on so little. Pygmy forests sog in winter, sear in summer. They subsist with chronic malnutrition and endure their diseases and infestations in the world's sourest soil. The one thing they are not is crowded.

Dr. Jenny describes the extreme pygmy forest condition on the staircase as species-poor and space-unsaturated with 1/4 of the ground area bare or covered with lichens. He sums up its significance by saying that the little forest and its podzol (soil) come as close to a terminal steady-state ecosystem as can be found in nature.

SOME UNANSWERED QUESTIONS

The pygmy forest anomaly has brought scientists from far places and the opportunity to see, learn, marvel, and teach has attracted over 2000 visitors per year. But the complete story is not known and many questions arc still unanswered.

Why are the podzols of the pygmy forest developed to such an extreme degree, compared to their European counterparts?

Photo 4. Waist-high pygmy trees may be older than the man. *Photo courtesy of Hans Jenny.*

How did Pinus bolanderi accomplish the change in genes that took place while the soil material was becoming a podzol?

How can the towering redwoods and the dwarfed pines with their differing environmental demands exist as such close neighbors?

The questions yet to be answered will continue to intrigue ecologists, and the attraction will grow as long as the pygmy forests continue to ride the escalator intact.

PRESERVATION

The pygmy forest area is currently designated as a "Registered National Landmark", and the California Institute for Man in Nature, along with Dr. Jenny, advocates that a 900-acre Jug Handle Creek National Monument be created to give more protection to the ecologic staircase than the "Registered National Landmark" designation offers. In 1974 passage of a recreation bond issue gave hope that the area will be incorporated into the State Park System.

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