

The PYGMY FOREST ECOLOGICAL STAIRCASE

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Summary of proposal

A sequence of five elevated marine terraces along Jug Handle Creek in coastal Mendocino County constitues a nationally and internationally famous ecological staircase. So outstanding is the combination of canyons, terraces and ancient dunes, tall redwoods and firs, bishop pine forest and dwarfed pines and cypresses that the upper terraces already have been declared in 1969 a Registered National Landmark by the Department of Interior, Washington, D.C.

As urged by many people, it is proposed to extend this protected area in Jackson State Forest as a narrow strip of land clear to the sea cliff and thereby preserve a natural landscape segment that is ecologically unique not only along the entire California coast but in all of North America and Europe put together.

The Staircase is deserving the esteemed status of a federal <u>National Monument</u> within the National Park System. Already it is being visited annually by some 2,000 nature-oriented people from all walks of life, young and old.

The present Preserve comprises about 300 acres and some 600 acres would have to be purchased by the Federal Government from private owners. They are anxious to sell, hence action is urgent.

The Staircase, declared a nature museum, will become an enduring tourist attraction of national scope.

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Introduction

Along the coast of northern California, about 160 miles north of San Francisco, occur well-developed marine terraces that were carved by the sea ages ago and that have since been gently uplifted by geologic forces. The plateaus are scattered between Fort Bragg and Navarro River at various elevations in step-like fashion, but there is no better sequence than the five terraces that make up the <u>Pygmy Forest Ecological Staircase</u> along Jug Handle Creek. It has become a Mecca for naturalists, botanists, ecologists, pedologists (soil scientists), geographers and nature-oriented laymen. It is being praised as the best preserved ecological showplace of coastal landscape evolution anywhere in the northern hemisphere. It has been explored scientifically in many directions.

The presentation here given follows the outline of topics proposed by the National Park Service for evaluating a Registered National Landmark.

Location

The Staircase is about five miles south of the city of Fort Bragg, and about the same distance north of the town of Mendocino. During summertime it is accessible by way of Gibney Lane (4.3 miles south of Fort Bragg) which traverses its entire length in winding course. During the rainy season the middle portion of Gibney Lane is not passable and the eastern portion of the Staircase is reached via Simpson Lane (2.3 miles south of Fort Bragg) and Mitchell Creek Road.



Fig. 1 The five marine terraces south of Fort Bragg (5). Insert shows position and altitude of terraces along Jug Handle Creek (in red) where all five are well represented and preserved.

The Staircase follows Jug Handle Creek and is a narrow strip of land about one half a mile wide (north-south) and about three miles long, extending from the seashore on the west end to the 600 foot contour line on the eastern border (Fig. 2). It comprises 900-1000 acres of multidimensional landscape composed of terraces, ancient beach deposits and sand dunes, covered by diverse grass, pine and redwood vegetations and pygmy forest. The eastern portion of the Staircase, some 300 acres, is irregularly shaped and has already been declared in 1969 by the National Park Service a Registered Natural Landmark. It contains the three highest terraces and associated ancient dunes.

Ownership

The aforementioned Landmark is part of the Pygmy Forest Reserve of the State of California's <u>Jackson State Forest</u>. Honorable Ronald Reagan is Governor, Norman B. Livermore, Jr. is Administrator of the Resources Agency, and Ray B. Hunter is Director of Conservation, Department of Conservation, Sacramento, California. Mr. Hunter has been informed of the proposal of preserving the entire Staircase, possibly as a National Monument. The Reserve and Landmark used to have identical boundaries but two years ago the former was enlarged by about 60 acres to include a portion of Mitchell Creek watershed as well as a transition zone from pygmy forest to regional forest along the rim of Jug Handle Creek Canyon. It is proposed that the entire Reserve

Size







Fig. 2 Approximate boundaries of proposed Staircase Monument.

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Fare

Holiday Lodge and Man in Nature south of creek not available.

Secondary in Exciting Sensors Concerns Activity (and Concerning Secondary), 2018. as well as its extention into the canyon be included in the Staircase.

East of the Jackson State Forest Reserve, between its boundary and Mitchell Creek Road, is a narrow strip of land of sphagnum bog (slightly disturbed), belonging to <u>Cecil Gorra</u>, that should be included in the Staircase as a buffer zone against septic tank effluents from proposed housing developments. The entire Gorra property is 94 acres.

The territory directly west of the Landmark is part of <u>Caspar</u> <u>Lumber Company</u>, owned by Mrs. Abigail Fout of San Francisco. It combines the middle terraces and merges with portions of Jug Handle Canyon, a total area of 298 acres.

Further west, the frontal segment of the second terrace belongs to the <u>California Institute of Man in Nature</u>. Its portion north of Jug Handle Creek is the former Hyman property (60 acres) where forest and grassland meet, whereas south of the creek is the Institute proper with the old red farmhouse built by the Tregoning family (55 acres).

The western terminus of the Staircase extends to the seashore and is all on the first terrace. It is a grassy plain of 80 acres. The piece north of the creek (47 acres) belongs to Mrs. <u>Elizabeth</u> <u>Burger</u>, of Berkeley, California, and the south portion (33 acres) to the owners of the proposed <u>Pacific Holiday Lodge</u>, Fort Bragg, California. The ownerships are shown in Fig. 2.

Correspondents

Aside from the owners listed above, a committee headed by the writer is active in promoting the preservation of the entire Staircase. Address correspondence to Professor Hans Jenny, 582 Euclid Avenue, Berkeley, California 94708.

Dangers to the integrity of the area

One of the characteristic features of the higher terraces of the Staircase is the dwarf-vegetation known as <u>pygmy forest</u>. Not long ago there were some 4,000 acres of it between Fort Bragg and Mendocino. The area has declined at a rapid rate because of lowcost housing developments, airport construction, corporation yards and city and county disposal dumps. Undisturbed tracts are still held by lumber companies, especially Masonite and Boise-Cascade. It was fortunate and commendable that the State established in collaboration with University people the Pygmy Forest Reserve in Jackson State Forest. There is pressure from local landowners to sell the Reserve to private developers and to convert Gibney Lane, which bisects the Reserve lengthwise, to a through-highway to the coast.

At the northeastern border of the Reserve existing rare <u>sphagnum</u> bogs are threatened, as already mentioned, by future pollution from the adjacent Gorra properties.

The ecologically valuable <u>coastal grasslands</u> on the first terrace are rapidly being taken over by housing, recreational activities and motels. The Burger property, relatively undisturbed,

has already been offered for sale; north of it a large home has been hurriedly erected just prior to passing of the Coastal Bill No. 20, and south of the creek the case of the projected Pacific Holiday Motel is still in the courts.

The fine stands of bishop pine forests on the second and third terraces are key witnesses for the silvicultural question why and where pines occur on the coast. Past lumbermen did not touch the non-commerical pines, but now interest in firewood and furniture is threatening them. Extensive areas of pine forests are owned by the Caspar Lumber Company and they are on the market as a large block; but Mrs. A. Fout, reportedly has consented to sell the Staircase portion separately for purposes of preservation.

The canyon walls of Jug Handle Creek harbor the once primeval, magnificent <u>regional forest</u> of redwoods, Douglas fir, hemlock and Sitka spruce. Many beautiful specimens survived the early logging and second growth has been spectacular. Very recently the canyon portion belonging to Jackson State Forest has been re-logged, against wide protests, and it will not be long before the Caspar Lumber Company portion succumbs too.

The part of the second terrace belonging to the Institute of Man in Nature is being managed ecologically and like the Jackson State Forest Reserve presents the least threat to the Staircase.

Land use, past and present

The Mendocino coast was occupied at a few river mouths during the 1850's as a result of lumbering activities that chose redwoods and a few Douglas firs. The pine forests were not touched except

that occasional stray fires from logging camps are said to have done some damage here and there. The Staircase, especially Jug Handle Creek Canyon, was logged by Caspar Lumber Company during 1880-1885. The eastern portion within Jackson State Forest was selectively logged again in 1970. The coastal grasslands were used by the Tregoning family for sheep grazing. Earlier in this century the settlers sometimes set light fires in the pygmy forest area to encourage growth of huckleberries.

Importantly, the above brief vegetational disturbances did in no way alter the extent and character of the terraces and the sand dunes on them, and foremost not the soil profiles that determine the lasting vegetational cover, as will be shown. There are few signs of man-made erosion.

Present-day land use of the Staircase is in a non-exploitive lull. Grasslands and pygmy forest are subjected to experimentation by faculty members of the University of California, Berkeley, by a team from Cornell University, and sporadically by members of the California State Universities.

Local hunters roam the area and fishermen trespass the fenced grassland, and there is persistent vandalism to research installations and equipment. It is estimated that in recent years conducted ecological tours brought some 2000-3000 people into the area annually.

Description of natural values

The overall integration of the landscape forms and the vegetation mantle visualizes ecosystem evolution that starts on



Fig. 3 Looking north. Schematic illustration of Staircase, landforms and vegetation. Gr - grassland, RW, DF - redwood-Douglas fir forest, Bi - bishop pine forest, Py - pygmy forest. Horizontal distance is 3 miles, vertical distance 600 feet above sea level. the first terrace with rich parent materials covered by grassland and culminates on the higher terraces in extremely impoverished and acidic soils carrying dwarfed and endemic species and ecotype subspecies. It has been contended that the pygmy forest and its underlying podsol soil come as close to a final stationary ecosystem as can be expected to be found in nature (9).

The word ecosystem is especially appropriate here because the whole of plant kingdom, animal life, microbes and soil and their interactions and feedbacks have transformed themselves in continuous, orderly fashion.

1) Landforms of the Staircase

In the distant past, when glaciers expanded and disappeared again a number of times (the Pleistocene age), the sea level fell whenever precipitation stayed on land as ice and rose again when the glaciers melted away.

A slowly <u>rising sea level</u> cuts world-wide <u>terraces</u> or platforms into the country rock. In the Graywacke sandstone of the greater Fort Bragg area the terraces reach widths of several hundred feet. Subsequent to the cutting, geological forces slowly uplifted the lands by hundreds of feet. Five terraces have been identified (5) at altitudes of 100, 300, 425 and 650 feet, known as first, second, third, fourth and fifth terrace (Fig. 3). The heights are not measured at the land surface but at the buried "nickpoint" where rock plateau and vertical cliff meet. A zero terrace is being carved presently and can be recognized at low tide as a rough, rubbled bedrock surface harboring the tidal pools.



Fig. 4 Wave action near mouth of Jug Handle Creek. Birds are Brandt Cormorants.



Fig. 5 Example of first terrace (house on it) near Mendocino. Sea waves are cutting zero-terrace and deposit beach materials at their front. Forest in background is on second terrace.

A slowly <u>falling</u> <u>sea level</u> receeds from the shoreline and leaves in its wake deposits of rock, gravel, diverse sands and clay, known as <u>beach</u> <u>material</u>. There is beach material up to 20 and 30 feet thick on every one of the five terrace platforms, as ascertained by well drilling and seismographic testing (1).

Along the coast the elevation sequences of the nearly level terraces are dissected by creeks and rivers that flow from the inland mountains westward to the sea. In the Staircase it is Jug Handle Creek, back-cutting into Graywacke sandstone. The <u>steepwalled canyon</u> has features of a drowned valley, most so at the river's mouth, for during periods of interglacial low sea levels (some 300 feet below present) the canyon floor was bedrock with water rushing over it, but as the ocean rose the river stalled, dropped its sediment load and is now crawling over its own debris, bypassing little swamps and marshes.

Today, the fierce winds along the shoreline pick up sand grains from the beach material and drop the load on the first terrace as <u>dunes</u>. It is a continual process that persisted throughout the Pleistocene; hence, dunes, large and small, are squatting frontally on all five terraces.

These diverse landforms, the terraces, the beach deposits, the dunes and the canyons possess an intrinsic similarity that is not found elsewhere: they have the <u>same mineralogical</u> <u>composition</u>. The ratio of feldspar crystals (F) to quartz crystals (Q) is in the proportion of 18 to 100 in all of them because the mineral assemblies of both beach and dune have a

common origin: the Graywacke sandstone (5). This likeness has pertinent scientific implications, as will be shown later.

As a further advantage the Staircase displays an <u>evo-</u> <u>lutionary history</u> that is said to be singular in its occurrence, for the higher a terrace is positioned in the landscape the older it is and the older are its beach materials and dunes. Oldness implies long-time soil and vegetation genesis, which in a coastal cool and wet climate is accompanied by intense weathering of minerals and leaching of nutrients. Although the young and the old terrace deposits possess the same mineralogical "parent material," the soils that nourish the vegetation are strikingly differentiated.

That in the Staircase all these landforms are in a superb state of preservation attests to great surface stability during hundred thousands of years and is a gratifying feature of the entire project.

2) Broad vegetation and soil patterns

For a century now the coastal vegetation mosaic has intrigued botanists, ecologists and pedologists alike, without, however, leading to accepted clarification of its origin. Interest was stimulated by the surveys of the State of California Department of Natural Resources (15, 16, 17). From what has been said, it comes as no surprise that the grasslands, the redwood-Douglas fir forests, the pine- and the pygmy forests are geographically related to the landforms and their ages and their soils (see Fig. 3).

The Jug Handle Staircase area discloses the intricate web of ecological causes and effects so plainly and so beautifully that it has become an evolutionary bench mark of national and international renown. Odum (12) records it in his authoritative textbook of Fundamentals of Ecology and discussions have been held in as far away places as Australia and Europe, and a review appeared in a Russian scientific journal.

The story to be told begins with the coastal grassland on the first terrace and continues with two development series of ecosystems, one on dunes and the other on beach materials. It is followed by a section on transitions and the canyon slope.

a) The coastal grassland

Near the cliff of the Burger property the soils are shallow and sandstone bedrock is reached within a few inches. Prominent among the low-creeping plant species are the soil-enriching lupines that have root nodules in which bacteria fix nitrogen from the air.

Farther inland, the soils are thick beach materials covered in parts by 1-3 feet of dune sands.

The bulk of the vegetation is a tree-less grassland, which is typical of much of the California coast. Occasionally clumps of struggling pines are seen, and some people conclude that the grasslands have been created by logging by the white <u>settlers</u>. There exist, however, in the Bancroft Library and elsewhere, early large photographs by C. E. Watkins showing that some of the very same grassy areas existed already in the early 1860's when

logging and agriculture had barely gotten started. No charcoaled tree roots, which are common in the Sierra Nevada forests, have been encountered.

Most importantly, the soils under the grass cover are true <u>prairie soils</u> (mollisols), rich in organic matter content that slowly diminishes with soil depths (Fig. 6). It takes many thousands of years of continuous grass sod to build up such a soil; a permanent pine forest would not be associated with it.

<u>Pomo Indians</u> dwelled along the coast, and a small mound has been sighted on the Burger property. The natives might have maintained a grass cover by burning, if they lived there long enough. Carbon-14 dates and plant opal studies are urgently needed.

The most obvious of <u>natural causes</u> of coastal grasslands are heavy winds and salt spray. Indeed, systematic plantings of pines, redwood and Douglas fir on the Burger property at various distances from the cliff, as seen in Fig. 7, show that near the sea all trees succumb, that pines gradually get a foothold farther inland and that redwood and Douglas fir barely keep alive. Analyses of salt content of grasses, of needles, and of soil samples disclose a marked sodium gradient from the cliff to the east end of the terrace (1).

Today, the Jug Handle grasslands are no longer virgin throughout, but the soils are essentially intact and reconstruction of the virgin sod appears feasible. Once the Staircase preservation becomes a reality, some of the newly planted Monterrey pine thickets will have to be removed.



Fig. 6 Rich prairie soil (Mollisol) on first terrace of Burger property.



Fig. 7 Planting experimental trees on first terrace (Burger property).

b) Ecosystem genesis on dunes

When a sea cliff is low or altogether missing and the sand supply from a river is abundant, as near Ten-Mile River north of Fort Bragg, dune accumulation is rapid and the dunes are thick, unstable and on the move. But when a cliff is high and river sand is limited, as at Jug Handle Creek, deposition of wind blown sand is infrequent and creates a slow accruement process into existing grass and lupine vegetation which thereby rises gradually, protecting under it a deep, rich prairie soil (Fig. 6).

Not enough is known today of the Staircase dunes on the first terrace to identify the dune regime of the post-glacial, altithermal period, which seems recognizable a little farther north. Quite generally, the slightly older, deep dunes on the back portion of the first terrace and on the front of the second are light-brown, moderately weathered with an abundance of mild humus, a rich supply of nutrient bases (8-10 units in the first foot) and advantageous quantities of soil acidity (9). Their once luxurious giant forest was, and its second-growth successor still is, populated by redwood (<u>Sequois sempervirens</u>), Douglas fir (<u>Pseudotsuga Menziesii</u>), grand fir (<u>Abies grandis</u>) and hemlock (<u>Tsuga heterophylla</u>). Many botanists consider it the climax forest of the California Coast Range (7).

The dunes on the higher and older terraces have undergone profound transformations in the prevailing humid, cool oceanic climate. During the hundred-thousand-year-spans the fresh dune

minerals weathered to clay, the stock of bases (Ca+Mg+K+Na) was depleted to 1-3 units by percolating waters, and mineral acidity increased greatly (9). The surface soil developed a bleached, gray A2 horizon and the soil profile is known as <u>Noyo</u> soil (Fig. 8). And though there is good drainage even during the rainy season numerous vertical pipes (piezometers) driven to 12 feet depth have not registered a free water table in years (1) - the fertility of the soil has fallen so low that the nutrient-demanding redwoods and Douglas firs cannot compete with frugal bishop pines, and the proportion of redwoods to pines gradually increases in favor of pines, as indicated in Fig. 3. In turn, the favorable humus reservoir is reduced to one-half as a consequence of altered litterfall, soil animal populations and microbe assembly (9).

The cldest dune on the highest terrace at the eastern terminal of the Staircase (Mitchell Road) is an extreme case of Noyo soil. Under small-leaf manzanita (A. Nummularia) it has a nearly white A2 horizon underlain by concretionary pebbles of sand grains cemented by iron oxide. The deeper subsoil exhibits reddish-colored reticulate mottling that some pedologists (but not this writer) interpret as signs of a past subtropical climate. Bishop pines, and not very striking specimens at that, dominate the vegetational aspect and only occasionally is a dwarfed, yellow-leafed struggling redwood tree encountered. If climax is defined (3) as a terminal plant community which is in dynamic equilibrium with the prevailing climate then bishop pine rather than redwood would be climax on the dunes.

Fig. 8 Old, highly weathered dune (Noyo soil) under bishop pine. Bleached A2 horizon below salal leaves, underlain by rust-brown B horizon. Reddish-brown reticulate mottling near shovel.





Fig. 9 Tall bishop pine forest on second terrace along Gibney Lane.

e.

This development series or chronosequence of ecosystems on young to old dunes carries conviction because of the morphological and mineralogical similarity of the original dune parent materials, which leaves time as the principal variable. The sequence explains the puzzling perpetuation of coastal pine forest (2, 10) against the aggressive invaders from the continental forest.

c) Ecosystem genesis on terraces proper

The terraces differ from the dunes in their nearly level surface configuration and in their great variety of textures that range from coarse sands to silts and clays. These degrees of mineral fineness acted from the very earliest as species differentiating media. A further prominent departure from the dunes is the hydrologic condition because the basal sandstone strata impede percolating waters and induce in wintertime a rising water table that creates wet, even flooding conditions. The subterranean water bodies slowly drain downhill along the slightly inclined terrace platform and in doing so maintain a horizontal soil-leaching regime. For reasons not yet fully understood the seasonal fluctuating water table enhances the mobility of ferrous iron freed by weathering and in turn podsolization becomes intense. Along Gibney Lane it is clearly visible on the second terrace of the Staircase where redwoods, Douglas firs and bishop pines still grow well side by side. These trees are able to withstand seasonally high water tables (11). The interplay of soil conditions and former logging practices on pine growth needs further clarification (Fig. 10).

As podsolization advances, the regional forest of redwoods and Douglas firs is gradually being displaced by bishop pine forest. Already at the western front of the third terrace, which Gibney Lane intersects, a pure stand of pines maintains itself and is devoid of old redwood stumps that might point to a mixed forest at the time of first logging a century ago; yet, a few hundred feet away on the upper canyon slopes of Jug Handle Creek, redwoods are prospering on the better drained and less-leached soils.

Following Gibney Lane eastward, an observer encounters <u>pygmy</u> <u>forest</u> on the back portion of the third terrace, and this stunted vegetation extends clear to the fourth and fifth terraces of the Reserve.

It should be said that dwarfed trees by themselves are not a rarity in nature. In Alaska they have been sighted on permafrost soils in which ice layers severly restrict root penetration; in Florida they are associated with shallow calcareous iron strata, in the New Jersey pine barrens they are attributed to white man's frequent fires, and in parts of California they can be seen on rubble of nutrient-unbalanced serpentine rock. The Staircase pygmy forest is in a class by itself. Rather than a freak situation it is the culmination of uninterrupted ecosystem evolution that commenced in mid- and early Pleistocene. Fire played a minor role (19).

Extreme pygmy forest is species-poor and space unsaturated with as much as 25 per cent of the ground area bare or covered with colonies of lichens. Slender cypresses (Cupressus pygmaea) and

gnarled bishop pines (<u>Pinus muricata</u>) and Bolander pines (<u>Pinus</u> <u>Bolanderi</u> Parl. or <u>Pinus contorta</u>, ssp. <u>Bolanderi</u>), many decades old and some passing the century mark, are only 5-10 feet tall. Their trunk thicknesses do not exceed the diameter of a human wrist or arm. Dwarfs over 300 years old have been claimed to exist. Likewise dwarfed are the prominent ericaceous shrub companions like Labrador-tea (<u>Ledum glandulosum</u>), rose-bay (<u>Rhododendron macrophyllum</u>), salal (<u>Gaultheria shallon</u>), the two manzanitas (<u>Arctostaphylos Nummularia and A. columbiana</u>) and huckleberry (<u>Vaccinium ovatum</u>).

Trees and shrubs exhibit die-back symptoms and fungus-gall infestations suggestive of specific nutrient deficiencies. Some of these have been confirmed by pot tests and needle analyses (9). Redwood, Douglas fir and other tall non-pines are totally absent though they prosper nearby. Their planted seedlings die (1).

One of the soils that support this extreme plant community is the highly acidic <u>Aborigine</u> soil derived from clayey beach material. A foot below the surface it has a rust-stained clay pan with as much as 61 per cent clay that effectively restricts root penetration (9).

More common is the <u>Blacklock</u> soil on coarse sandy beach deposit, seen in Fig. 11. It is an extreme podsol with whitish A2 horizon underlain by a concrete-like, iron-cemented hardpan or B horizon (Bmir). In the newest U.S.A. system of soil classification Blacklock is a Spodosol, specifically a Typic Sideraquod, but since

Fig. 10 Cane-like pygmy cypress with zebra-type lichen markings (white stripes), and lichencovered open ground.





Fig. 11 Hardpan podsol soil under pygmy forest. Dark humus layer with roots, followed by bleached A2 horizon. Below is rust colored hardpan of various degrees of induration. the international system still retains the time-honored word podsol (ash-gray), its usage is continued here.

The soil is highly weathered and leached. Bases are less than one unit (9) and pH is 2.8-3.9. Whereas at lower depth (parent material) the ratio of felspar to quartz is still 18, as mentioned, in the A2 horizon it has been reduced to less than 0.0003 (5), meaning that the horizon is essentially non-weatherable, inert quartz flour. Samples brought to the greenhouse will not support a standard test plant like barley unless heavily fertilized as seen in Fig. 12. It supports previous fertility studies (12).

According to modern pedologic theory the acid-tolerant pines and ericaceous shrubs synthesize organic chelates that, upon reaching the soil, mobilize its inorganic iron and thereby bleach the surface soil. In the subsoil the released iron, as positive iron hydroxide, cements the negative quartz grains to an indurated hardpan. This view treats the vegetation as the cause of the podsol. Botanists, on the other hand, take it for granted that the endemic Bolander pine-manzanita association reflects the presence of the podsol and they pronounce the pygmy forest as an edaphic (edaphon = soil) climax. The contradiction is resolved if the entire ecosystem is chosen as the focal point of evolution, as has been attempted here.

d) Transitions and the canyon slope

To walk within a distance of 50-100 feet from puny pygmy forest into majestic regional forest is an unforgettable experience



Fig. 12 Left (check): barley seedlings on A2 horizon; growth stops as soon as nutrient supply in seed is used up. Right: fertilized A2 soil (9).



Fig. 13 Nutrient-poor bogs on high terraces attract insecteating plants. (Sundew)

(Fig. 15). Two monitered transects reveal the hidden factors responsible from the sharp contrast.

In the first transect the trail leaving the pygmies ascends a short, gentle slope and reaches 50 feet above the terrace a broad ridge studded with beautiful redwood trees. Depth probing with augers records the site as well-drained dune of moderate weathering. Evidently the dune, as a later addition, sits on the edge of the terrace and a buried hardpan may be under it, as has been observed elsewhere (5).

The second transect leads from the edge of the pygmy forest to the steep canyon slopes of Jug Handle Creek. Rapidly the water table descends, providing more aeration, and the stone-like hardpan crumbles to a fragile, pebble layer which is permeable to roots. The bishop pines grow tall and downslope give way to hemlocks and impressive redwoods. These trees are anchored in the deep weathering mantle of Graywacke sandstone which is rich in minerals. Its seepage waters and springs are ten to a hundred times richer in calcium than the plateau ground waters and the pH is higher.

Although in its upper course Jug Handle Creek is back-cutting and side-cutting into bedrock, terraces and dunes, this geologic erosion and rejuvenation of the soil is exceedingly slow, hence the slopes are stable. Tall, old trees stand perfectly straight on steep slopes, which they would not be able to do if sliding and slipping were noticeable. The canyon is deserving of detailed reFig. 14 Pygmy forest during rainy season. Puddles form above hardpan. They are colored coffee brown from dissolved humus.





Fig. 15 Sharp transition to regional forest. Pygmy forest in foreground, tall pines and redwood in back. search on erosion and sedimentation loads under undisturbed and logging conditions.

The stiff climb from the lush greenery of the canyon bottom through tall forests to the gray-colored dwarf-pine forest at the rim, over an elevation difference of some 300 feet, brings one into enjoyable contact with some of nature's most extreme ecosystems.

3) Discussion

Mendocino county in general and the Staircase in particular offer unique opportunities for exploring grand-scale ecological problems such as the causes of coexistence of redwood, pine and pygmy forests along the Pacific Coast. Conventionally, presence of redwood forest is attributed to climate, its coolness and fog, and pygmy forest to an edaphic component. Since both occur in the Staircase under the same climatic regime the interplay of factors needs further resolution.

Presumably, the ecotype Bolander pine evolved its genetic constitution in conjunction with Blacklock and Aborigine soil genesis, but how is unknown. The exploration of genetic changes in organisms tied to progressive soil development still awaits its investigator (18).

Natural vegetation changes of the magnitude envisioned for the Staircase are customarily linked to climatic shifts. Undoubtedly, climatic changes have occurred along the coastal area during the Pleistocene and Post-Pleistocene times involved, but they are not believed to have been critical as they have merely temporarily



Fig. 16 Lushious vegetation in bottom of canyon.



Fig. 17 Vigorous new thirdgrowth on upper canyon slopes. accelerated or retarded the long-time podsolic trend that molded soils and associations of species (9). The thesis advanced views the lower terraces with their vegetations and soils as presenting the past history of the upper terraces.

Europeans are intensely impressed by the Staircase because all over northern Europe, the British Isles, even Siberia, podsols are an important type of soil formations, but these Eurasian podsols are all young, younger than the last glaciation. The spectacle of seeing dwarfs and old, extreme podsols of the Blacklock type is to Europeans an education in itself.

The many ideas presented in this appraisal are not put down as claims to scientific finality but to illustrate the far-reaching research and teaching possibilities of the proposed National Monument.

Eligibility

The Pygmy Forest Ecological Staircase deserves to be preserved as an ecological National Monument because of its undisturbed land forms and soils and existing and regenerating vegetation, and for its tremendous potential for observation, experimentation, teaching and education.

Although scenic values have not been stressed because most people believe grasslands and pygmy forests to be non-photogenic, the writer expects a change in attitude once the conventional picture of beauty in nature is broadened (8). Already the famous midwestern painter Grant Wood has artistically lauded the grassland

soil profile in his Arbor Day, and Europeans like Schmidt-Rotloff and Jean Dubuffet have painted podsol profiles and horizons that hang in museums and command high prices. As more and more perceptive photographers focus their cameras on wavy grass expanses, graygreen sedge bunches, twisted pines and zebra-stripped cypress stems, an enlarged aesthetic appreciation of the Staircase is in the making.

It is fair to say that the Staircase constitutes a new dimension in nature preservation. Emphasis is not so much on scenic values, or on the saving of an endangered species or on recreation, but rather on the spectrum of genesis of an entire earth segment and its life mantle during a million years.

The Staircase is an outdoor museum that satisfies the growing awareness of people regarding their natural environment and their desire to sense its inner workings and achieve rapport with it.

Literature cited

- (1) Arkley, R. J., H. Jenny and A. M. Schultz, 1973. Unpublished material.
- (2) Axelrod, D. I., 1967. Evolution of the California closed-cone pine forest. In: R. N. Philbrick, Proc. Symp. Biol. Calif. Islands, Santa Barbara.
- (3) Cain, S. A., 1944. Foundations of plant geography. Harper and Broth. New York.
- (4) Clark, B., 1970. Plant-soil relationships in the pygmy forest of the Mendocino coast. Unpublished report and M. A. thesis.
- (5) Gardner, R. A., 1967. Sequence of podsolic soils along the coast of northern California. Ph.D. thesis, Univ. of California, Berkeley. 226 pp.
- (6) Gardner, R. A. and K. E. Bradshaw, 1954. Characteristics and vegetation relationships of some podsolic soils near the coast of northern California. Soil Sci. Soc. Amer. Proc. 18:320-325.
- (7) Heusser, C. J., 1960. Late-Pleistocene environments of North Pacific America. Amer. Geogr. Soc. Publ. 35.
- (8) Jenny, H., 1968. The image of soil in landscape art, old and new. Pont. Acad. Sci. Scripta Varia, 32: 947-979.
- (9) Jenny, H., R. J. Arkley and A. M. Schultz, 1969. The pygmy forest-podsol ecosystem and its dune associates of the Mendocino coast. Madroño 20: 60-74.
- (10) Mason, H. L., 1934. Pleistocene flora of the Tomales Formation. Publ. Carnegie Inst. Wash. 415: 81-180.
- (11) McGuire, K. B., formerly in charge of logging operations of Caspar Lumber Co.; depositions made to H. Jenny on file at University of California (1973).
- (12) McMillan, C., 1956. The edaphic restriction of Cupressus and Pinus in the Coast Ranges of central California.

- Odum, E. P., 1972. Fundamentals of ecology. 3d ed.
 W. P. Saunders Co., Philadelphia. Penna.
- (14) Rigg, G. B., 1933. Notes on a sphagnum bog at Fort Bragg, California. Sci. 77: 535-536.
- (15) State of California, Dept. of Natural Resources. 1948. Timber stands and vegetation elements (maps), Mendocino County.
- (16) State of California, Dept. of Natural Resources. 1950. Vegetation-soil (maps), Mendocino County.
- (17) State of California, Dept. of Natural Resources. 1951. Upland soils of Mendocino County (colored map).
- (18) Stebbins, G. L. and J. Major., 1965. Endemism and speciation in the California flora. Ecol. Monogr. 35: 1-35.
- (19) Westman, W. E., 1971. Production, nutrient circulation, and vegetation-soil relations of the pygmy forest region of northern California. Ph.D. thesis, Cornell Univ. 411 pp.

Appendix

Species List of Pygmy Forest including boggy areas, from various sources. Starred species are endemic.

Trees

200

*Cupressus pygmaea, Mendocino cypress *Pinus contorta var. Bolanderi, Bolander pine Pinus muricata, Bishop pine

Shrubs

*Arctostaphylos Nummularia, Fort Bragg manzanita Arctostaphylos columbiana, Hairy manzanita Vaccinium ovatum, Huckleberry Gaultheria shallon, Salal Ledum glandulosum, Labrador tea Rhododendron macrophyllum, Rose-bay Myrica californica, Wax myrtle Ceanothus gloriosus, California lilac

Herbs (incomplete)

Whipplea modesta, Yerba de Selva Gentiana oregana, Oregon gentian Gentiana sceptrum, King's gentian Carex californica, California sedge Lilium maritimum, Coast lily Xerophyllum tenax, Bear grass Habenaria maritima, Rein orchid Spiranthes romanzoffiana, Ladies' tresses Viola sempervirens, Evergreen violet

Veratrum fimbriatum, False-hellebore

Agrostis hallii, Bent grass

Drosera rotundifolia, Sundew

Helenium bolanderi, Sneezeweed

Sphagnum species

Pygmy Forest. Depth to Hardpan. (revisit)



Variations in depth to hardpan within a small area (30m x 30m) of pygmy forest. Depth from soil surface to beginning of hardpan varies from 20 to over 65 inches. Pines and cypresses appear to be randomly distributed (4).

Glossary of terms

aeration (p. 18), infiltration of air into soil pores.

- altithermal (p. 12), meaning high, warm. A period, some 4,000-6,000 years ago that was warmer than today, accompanied by a somewhat higher sea level.
- bases (p. 12), non-acid compounds like lime, ammonia, magnesia and potash.
- <u>chelates</u> (p. 17), from the Greek word claw. Water-soluble organic molecules, as in humus, that hold iron atoms, making them mobile.
- die-back symptoms (p. 16), leafless, stunted twigs because of malnutrition.
- ecotype (p. 7), a subspecies of plants or animals confined to certain areas, like Bolander pine on Blacklock soil.
- edaphic (p. 17), from edaphon = soil; pertaining to soil effects on vegetation, as contrasted with climatic or human influences on plant cover.
- endemic (p. 7), plant species that are confined to a certain geographic area, like coast redwood or Fort Bragg manzanita.
- ericaceous (p. 16), being a member of Erica, the heath family of plants.
- indurated (p. 17), very hard, enduring in time.
- microbe assembly (p. 13), a population of various microbes (bacteria, tiny molds).
- mollisol (p. 11), a dark, humus-rich grassland soil, from mollis or soft, easy to handle.
- morphological (p. 14), pertaining to form, structure and shape of bodies.
- opal (p. 11), plant opal; grasses take up silica and convert it in the leaves to the mineral opal, of microscopic size. Plant opal in soil indicates grass cover, past or present.
- <u>podsol</u> (p. 7, 17), used internationally for soils having leached, grayish surface layers (horizons), underlain by iron-rich layers. A Russian word meaning ash-gray.

podsolization (p. 14), the process of creating podsols.

reticulate mottling	(p.	13),	network-like	patches	of	brown	and	gray
spots.								

silvicultural (p. 5), related to producing and managing forests.

sodium gradient (p. 11), increasing amounts of soda in plants and soil with nearness to cliffs.

soil profiles (p. 6), vertical soil cut, as in Fig. 6.

sphagnum bog (p. 4), accumulation of peat mosses of the sphagnumkind.

spodosol (p. 16), new American word for podsol.

transect (p. 18), a chosen line or cut.

Typic Sideraquod (p. 16), a new American name for iron-hardpan soil (podsol).