25

A POLLEN STUDY OF A FOSSIL PEAT DEPOSIT ON THE OREGON COAST* 1943

HENRY P. HANSEN AND IRA S. ALLISON
Oregon State College, Corvallis

INTRODUCTION

Pollen profiles of a fossil peat bog, enclosed in terrace sands at the north end of Nye Beach, Newport, Oregon, reveal a sequence of plant succession from pioneer to climax forest in a sand dune region. The age of the peat is uncertain, because of the complex physiographic history of the Oregon Coast during Pleistocene and Recent time. The earliest recorded forests, however,, indicate that the sediments of this study had an earlier origin than living bogs in the same general region. The erosion cycle of a submerged shoreline during the post-Pleistocene, has created and is creating favorable topographic conditions for the initiation and continued development of hydrarch plant succession. Many lakes and ponds have been formed as a result of blocked stream drainage by shifting shore-sand and the formation and migration of sand dunes. Some of these lakes are more than a mile inland and separated from the ocean by dunes a hundred feet or more in height. In many cases the sand dunes have become stabilized by plant growth, at least temporarily, and support various stages of xerarch plant succession. Likewise the lakes, entrapped by dunes, support many stages of hydrarch succession, from submerged to climax bog seres. Where sufficiently removed from the interplay of shore agents, the climax forest has been attained on both bog and dune. Nearer the ocean, however, dunes seeminngly stabilized by plant cover may begin to migrate, burying forest and bog, and filling lakes and ponds. Later, continued shifting of the dunes may exhume the buried forests and bogs. Thus, plant succession, both xerarch and hydrarch, may be interrupted, and all traces of its stages obliterated by the shifting sand.

In general the first plants to invade the dunes are forbs and grasses whose rhizomes, stolons, and rootstocks tend to hold the sand. They are followed by shrubs, consisting largely of the ericads salal (**Gaultheria shallon**), manzanita (**Arctostaphylos columbiana**), bearberry (**A. uva-ursi**), huckleberry (**Vaccinium ovatum**), and rhododendron (**Rhododendron macrophyllum**). Wax myrtle (**Myrica californica**) is also common during the shrub stage. Simultaneously with the shrubs or later, lodgepole pine (**Pinus contorta**) is the first arboreal invader, followed closely by Sitka spruce (**Picea sitchensis**). After the edaphic conditions have been modified and a windbreak of pine and spruce formed near the ocean, western hemlock (**Tsuga heterophylla**) may enter, and lodgepole pine gradually lose out because of its intolerance for shade. When the climax forest is disturbed by fire, Douglas fir (**Pseudotsuga taxifolia**) makes its appearance and may become locally predominant until it also is replaced by spruce and hemlock.

Occurrence of the Peat.

The peat is exposed in the fresh face of the sea cliff immediately east of the former site of Jump-off-Joe (a wave-tunneled residual later destroyed by wave erosion) at the north end of Nye Beach at an elevation of about 80 feet above sea level. This peat can be traced along the cliff for a distance of a few hundred feet. It can also be followed northward, eastward and southeastward around a small spur into a ravine leading to the beach. Except as reworked materials it seems to be absent from the other side of the ravine, thus suggesting that the original deposit was relatively small, perhaps occupying only an acre or two, although its former extent seaward is not known.

*Published with the approval of the Monographs Publication Committee, Oregon State College, as Research Paper No. 70, School of Science, Departments of Botany and Geology.

The expenses of the project were defrayed by a grant from the General Research Council of Oregon State College.

Its maximum exposed thickness is about 3 feet; but as it thins toward the limits of the exposures, its average thickness is about half as much.

The bulk of the peat, especially in its lower parts, is relatively compact, fine-grained and apparently structureless. Here and there, however, particularly near the top and near the southern edge of the deposit are well preserved logs, burl, stumps with spreading roots and recognizable bark, aggregates of conifer needles and similar xyloid material. Such wood is merely stained brown, not carbonized. As the logs are prostrate and do not extend into the sands above, the trees evidently were not standing at the time of the deposition of the cover of sand.

Stratigraphic Relations and Age of the Peat.

The major geological problem is to determine the stratigraphic position and geologic age of the deposit. An offhand view suggests that the peat-bearing sands are merely a part of a marine terrace that extends along the greater part of the)Oregon coast and that has generally been referred to some part of Pleistocene time (Diller, 1896; Smith, 1933). The complexities possible along the Oregon coast, involving Pleistocene and Recent eustatic changes of sea level, coastal uplift and warping, trenching of marine terraces by streams extended across them, later drowning and partial filling of these valleys, alternations of cutting and fillinng, deposition of alluvial fans and related deposits on the terraces, shifting of stream mouths by shore deposits of sand, the landward migration of shore dunes and other complications arising from the interplay of diverse forces and agents, make one wary of such a simple explanation. Unfortunately the limited facts available do not permit an unequivocal conclusion.

The terrace sands lie nearly horizontally across the beveled edges of the Nye shales which dip westward at an angle of about 20 degrees. The Nye Shales, carrying **Acila gettysburgensis** Reagen, **Bruclarkia gravida** (Gabb), fish scales, a fe wforamenifera, etc., are Upper Oligocene or Lower Miocene in age (Schenck, 1928; Packard and Kellogg, 1934). The base of the richly fossiliferous marine "Astoria" Miocene beds, formerly passing through Jump-off-Joe, has been transgressed locally by wave erosion and now lies a few hundred feet seaward from the present beach. The base of the terrace sands is about 60 feet above sea level and the edge of the terrace at the top of the sea cliff is about 100 to 125 feet above sea level. Stabilized dune sands are widespread on the terrace in this vicinity. The clayey and impermeable character of the seaward-dipping Nye shales, being undercut by the waves, induces numerous slides so that a jumble of small slip-blocks, some of them including peat, composes the slope between the receding cliff face and the beach.

The sand immediately underlying and overlying the layer of peat is rather even-textured, hence bedding is indistinct but apparently generally parallel and probably subaqueous in origin. Whether it is lacustrine, fluviatile or marine is uncertain. Cross-bedding is local, minor and not diagnostic. No fossils except of plants were found in the sands. Apparently the peat bog was formed on a fairly smooth sandy plain and eventually was buried by a sheet of waterlaid (?) sand. A thin seam of additional peat exposed about two feet above the main layer in the ravine mentioned above suggests a minor repetition of these processes. Stream-laid gravels and wind-laid sands nearby indicate a complexity of origin of the terrace deposits.

The modern analog of these peat-forming conditions is probably best exemplified by bogs associated with the lakes near Florence, Oregon, about 50 miles to the south, where lakes and ponds are numerous—some in drowned valleys blocked by shore drift of sand, some in depressions between or behind dunes, etc. (See Heceta Head and Siltcoos Lake topographic maps, U. S. Geol. Survey.) These lakes, some with bogs at their borders, range in elevation from a few feet above sea level (as

Siltcoos Lake, 5 feet; Tahkenitch Lake, 5 feet) to several tens of feet above sea level (as Threemile Lake, 18; Woahink Lake, 36; Mercer Lake, 39; Clearwox Lake, 82; Munsel Lake, 92; Clear Lake, 98; Collard Lake, 108 feet). Numerous small ponds, potentially the sites of bogs, lie at various intermediate elevations. The present elevation of the peat in the cliff at Newport therefore cannot be used as an argument for uplift of the terrace since the peat was formed. It may have been formed at its present level (or even higher) subsequent to the formation of the terrace. On the other hand it may have been deposited during a temporary low stand of sea level before the cutting of the terrace and deposition of terrace sands had been completed and the terrace uplifted. The corresponding range in age likewise extends from the comparatively recent past (when the shoreline lay perhaps several hundred to several thousand feet or more farther west, say a few thousand years ago) to some indeterminate time in the Pleistocene (tens of thousands of years or more ago).

In the discussion thus far, the sea terrace has been treated as an entity of a single age, whereas actually it appears to be composite. Furthermore one must distinguish between the wave-cut terrace and the deposits on such a terrace. Probably most of the deposits on the terrace are not marine, but are fluviatile, eolian, etc. The principal terrace, a mile or more wide and at its landward edge 250 to 350 feet above sea level, slopes westward toward the sea and has been considerably dissected by streams. It was formerly covered with timber and brush, now partly cleared. Some bench-like areas near the sea lie at lower elevations and appear to be remnants of other, lower terraces (not to be confused with landslides) that originally may have had much greater extent seaward. The peat at Newport is in just such a bench now standing a little more than 100 feet above sea level. If, as seems likely, the peat is younger than a 75 to 100-foot terrace adjacent to older, higher and more dissected terraces, its probable age is correspondingly reduced, but no correlation of such terraces or terrace coverings in Oregon with the Pleistocene stages elsewhere has been attempted or seems justified by present knowledge.

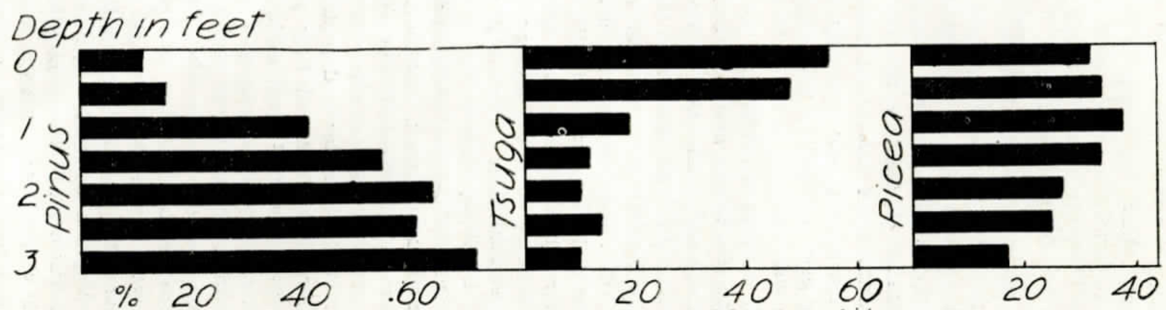
A conservative conclusion is that the peat was formed on an exposed coastal terrace, probably in Recent, but possibly in late Pleistocene time.

Methods and Technique.

Samples were obtained at six inch intervals at two sites. One profile was obtained from an exposed face of the peat stratum **in situ** in the sea cliff. The thickness of this layer, including the pollen-bearing sand underlying the organic peat, is about 3 feet. Another profile was obtained from a four-foot stratum, a block of which had slumped down to the beach, and remained intact. The greater thickness of the slipback suggests that the bog became deeper seaward, and that the major portion of it had been eroded into the ocean with the receding sea cliff. This is further substantiated by the thinning of the layer toward the eastern limits of its exposure as previously mentioned. In preparation of the peat for microscopic study, the potassium hydrate method was used. Although the peat was not carbonized, it was slightly lignitic, and it was necessary to pulverize it with a mortar and pestle before boiling. One-hundred fifty pollen grains were identified from each level, and pollen was very abundant. In the identification of the Pinus pollen, the size range method was employed (Hansen, 1941a, 1941b, 1941c). A few pollen grains were discarded because their dimensions fell within the limits of overlap between those of lodgepole and western white pine (**Pinus monticola**). These, however, were probably also of lodgepole pine. Fir pollen is listed as that of lowland white fir (**Abies grandis**), and is too scanty to be of any significance.

Interpretation of the Pollen Profiles.

The forests within range of pollen dispersal to the bog when the lowest



Pollen Diagram, Cliff Profile.

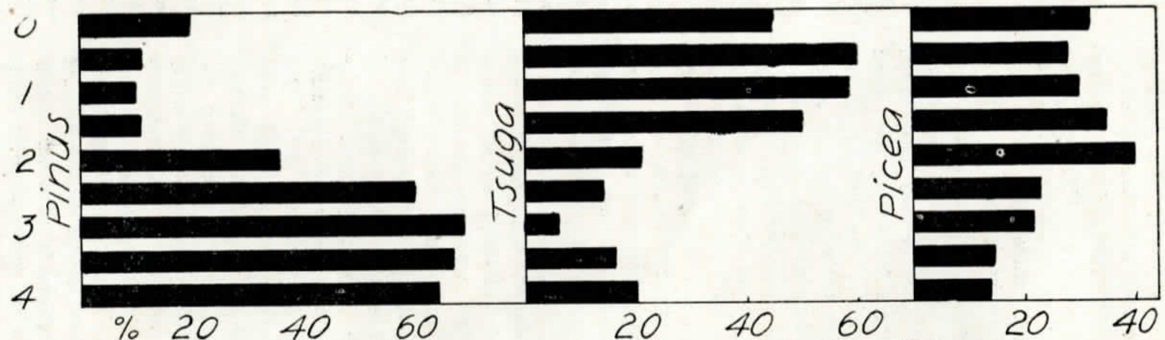


Fig.1 Pollen Diagram, Beach Profile.

sediments were deposited consisted chiefly of lodgepole pine, Sitka spruce, and western hemlock. These species are the principal dominants of the present day forests along the northern half of the Oregon Coast. Lodgepole pine was predominant and is recorded to 71 per cent in the cliff profile and 64 per cent in the beach profile. In the cliff profile, spruce and hemlock are recorded to 17 and 10 per cent, and in the other profile to 14 and 20 per cent respectively at the bottom (fig. 1. Lodgepole declines sharply from its maximum at the bottom to 11 per cent at the top of the cliff profile. In the deeper profile, it increases slightly from the bottom to 3 feet, sharply decreases to 10 per cent at 1 foot, and then increases to 20 per cent at the uppermost level. Spruce increases from its minimum proportions at the lowest level of both profiles to its maximum of 38 and 40 per cent, and then it declines to the top where it is recorded to 32 percent in both profiles. Hemlock remains rather static in the lower half of the cliff profile, then increases to supersede spruce, and is recorded to 55 per cent at the highest horizon. In the beach profile, hemlock decreases from the bottom to 3 feet, then increases to supersede spruce and attains its maximum of 60 per cent at 0.5 feet, and then declines to 45 per cent at the top. Hemlock exhibits the lowest proportions of the three species, but also attains higher proportions than spruce, and is predominant in the uppermost horizon (fig. 1). Thus, from a pioneer forest consisting largely of lodgepole which invaded a sand dune area, forest succession reached a climax composed chiefly of spruce and hemlock, the dominants of the present Oregon Coast forests. Douglas fir, also one of the lesser dominants, is not represented by its pollen in the profiles. Other species recorded in low proportions are lowland white fir, alder, and maple. Sedge, grasses, composites, water-lily, and ericads are also sporadically reprecally represented in low proportions. The presence of water-lily pollen in the lower levels of both profiles, reveals that the hydrarch succession began in a body of water.

That lodgepole pine is a pioneer invader of areas that are physiographically unstabilized is shown by its invasion of recently deglaciated areas in many parts of the Pacific Northwest, and of pumice-mantles in the central Cascades of Oregon (Hansen, 1938, 1939, 1940a, 1940b, 1941a, 1942a, 1942b). In the Willamette Valley of western Oregon, which was unglaciated, lodgepole was also the pioneer invader and was predominant during the early postglacial (Hansen, 1942c). The unstabilized conditions caused by the inundation of the Willamette Valley by backwater from the glacial-swollen Columbia River (Allison, 1935), and the increase in water from melting glaciers in the Cascades were unfavorable for other species. The lack of competition permitted lodgepole to thrive until the physiographic conditions were stabilized and other species gained a foothold. There is no lodgepole in the Willamette Valley today, and it was apparently absent when white man first settled the valley.

The depth of the exposed peat stratum is comparatively thin, but its seaward extent is unknown. If the layer constitutes the eastern border of the original bog, it may have been several times deeper farther west in the center. The presence of tree stumps and roots **in situ**, cones, and conifer needles of spruce and hemlock indicate that this portion of the bog had reached a climax and that little or none of the original surface was truncated by subsequent erosion. The weight of the overlying sand and the normal compaction of the peat itself, suggest that the original thickness was greater than the buried stratum. The amount of time required for its deposition is uncertain. The rate of post-Pleistocene peat deposition in the Pacific Northwest has varied from 500 to 1500 years per foot, depending upon the climate and the type of vegetation contributing to the peat. In the wet climate of the Oregon Coast, the rate has probably been rapid, and 500 years per foot would be reasonable. If the peat stratum has been compacted to one-half of its original thickness, about 4,000 years for its deposition was required. Forest succession from pioneer forests of lodgepole pine to a spruce-hemlock climax during this interval, lends support to these figures.

Another means of dating the past stratum is available. Pollen analyses of two living bogs along the Oregon Coast have been made, and a comparison of their pollen profiles with those of this study shed considerable light on their relative ages (Hansen, 1942c). One of these bogs is located on the margin of Woahink Lake, about 50 miles south of Newport, and the other at Sand Lake, about 50 miles to the north. Both of these bogs and the peat stratum of this study lie within areas of similar physiographic, climatic, and floristic characteristics. The sequence of physiographic events leading to the ponding of water and subsequent hydrarch plant succession also have apparently been similar in the three cases. The depth of the Woahink bog is 12 meters, and spruce and hemlock have been predominant during the time represented by the profile. The greatest proportion to which lodgepole pine is recorded is 21 per cent at .25 meters, and the average for this species in the lower 6 meters is about 5 per cent. In the Sand Lake bog, lodgepole is also recorded in low proportions throughout, with the exception of the surface, where it attains 51 per cent. In both bogs the increase of lodgepole as recorded in the upper levels is probably a result of its invasion of the bog surface and recently denuded areas. This species also occupies young dunes between the bogs and ocean, and prevailing westerly winds should cause an abundance of its pollen to reach the bogs. Its relative absence, however, tends to show that the presence of local stands of lodgepole pine on younger dunes is ont reflected in the pollen profiles sufficiently to distort the normal representation of the climax forests that exist over most of the Oregon Coast area.

The existence of climax forests during the entire period represented by the Woahink and Sand Lake bogs, suggests that they had their inceptions at a later time than the buried peat stratum of this study. This apparently was after most of the coast region had been stabilized sufficiently to support a climax forest, whereas the buried peat was initially deposited when the adjacent areas were still in a pioneer lodgepole pine stage of succession. As previously stated the stratigraphic relationships fail to definitely date the peat stratum. It may have been laid down in Recent or late Pleistocene. The physiographic setting and depth of the Woahink bog, suggest that it represents most or all of the post-Pleistocene (Hansen, 1941c). The existence of climax forests adjacent to Woahink Lake when its lowest pollen-bearing sediments were deposited indicates that the dune area had already been stabilized. Notwithstanding the possibilities of local forest succession on younger dunes being recorded in adjacent accumulating peat, it seems probable that the buried peat had its origin early in Recent or in late Pleistocene time, before the beginninng of the above mentioned living bogs. It is possible that the upper levels of the buried peat stratum overlap in time with the lower horizons of the living peat deposit, as they both record the dominants of the climax forests in about the same proportions. A lapse of considerable time may also have occurred between the cessation of sedimentation in the fossil bog and the beginning of deposition in the modern bogs. If the pioneer invasion-forest of lodgepole pine as recorded in the fossil peat was representative of the entire coastal area at that time, it may indicate that Pleistocene glaciation to the north was previously responsible for a climate unfavorable for forest growth in the dune zone. A lower sea level during the Pleistocene may have provided a wider zone of shifting sand. Winds may have been stronger than today, preventing the stabilization of dunes and development of a forest cover. As the glaciers waned, the climate became more equable, the strong winds subsided, much of the exposed beach was inundated as the sea level rose, and conditions in general became more favorable for stabilization of dunes and forest growth. This may have occurred in late Pleistocene or early Recent time. The fossil peat deposit may have had its origin in late Pleistocene, and its deposition continued into Recent time.

Summary.

A layer of peat imbedded in terrace sands on the central Oregon Coast records by the pollen therein, succession from a pioneer forest of lodgepole pine to a climax forest of Sitka spruce and western hemlock in a sand dune region. The age of the peat is uncertain, but the stratigraphic relations suggest that it was formed on a sandy plain probably during Recent or possibly late Pleistocene time. Pollen analyses of living bogs on the coast that lie within similar physiographic setting, indicate that the fossil peat had its inception as a bog earlier than they. The predominance of lodgepole pine when sedimentation began denotes that unstabilized physiographic conditions due to migrating sand dunes were existent in adjacent areas. It is possible that glaciation in other parts of the continent was indirectly responsible for the absence of forests in the coastal zone during the latter part of the Pleistocene. There is continual shifting of dunes in this coastal area today, but its effect on forest succession has evidently been too localized to be recorded in accumulating peat deposits. This is substantiated by pollen analyses of modern bogs in the same general region. It is possible that the upper levels of the fossil peat stratum is synchronous with the lower horizons of the living bogs, because the latter show that a climax forest existed when they were initiated. There is no evidence for climatic trends during the depositional interval of the fossil peat.

Literature Cited.

Allison, I. S. 1935. Glacial erratics in Willamette Valley. Geol. Soc. Amer., Bull. 46: 615-632.

Diller, J. S. 1896. A geological reconnaissance in Northwestern Oregon. U. S. Geol. Surv., Ann. Rept. 17, pt. 1, pp. 480-483.

Hansen, H. P. 1938. Postglacial forest succession and climate in the Puget Sound region. Ecology 19: 528-543.

——. 1939. Pollen analysis of a bog in northern Idaho. Amer. Jour. Bot. 26: 225-228.

——. 1940a. Paleoecology of two peat bogs in southwestern British Columbia. Amer. Jour. Bot. 27: 144-149.

——. 1940b. Paleoecology of a montane peat deposit at Bonaparte Lake, Washington. Northwest Science 14: 60-69.

——. 1941a. Further pollen studies of post-Pleistocene bogs in the Puget Lowland of Washington. Bull. Torrey Bot. Club 68: 133-149.

——. 1941b. Paleoecology of a peat deposit in west central Oregon. Amer. Jour. Bot. 28: 206-212.

——. 1941c. Paleoecology of two peat deposits on the Oregon Coast. Oregon State Monographs, Stud. Bot. 3: 1-31.

——. 1942a. Post-Mount Mazama forest succession on the east slope of the central Cascades of Oregon. Amer. Midl. Nat. 27: 523-534.

——. 1942b. The influence of volcanic eruptions upon post-Pleistocene forest succession in Central Oregon. Amer. Jour. Bot. 29: 214-219.

——. 1942c. A pollen study of lake sediments in the lower Willamette Valley of western Oregon. Bull. Torrey Bot. Club 69: 262-280.

Packard, E. L. and R. Kellogg. 1934. A new Cetathere from the Miocene Astoria formation of Newport, Oregon. Carnegie Inst. Wash. Publ. No. 447: 4-19.

Schenck, H. G. 1928. Stratigraphic relations of western Oregon Oligocene formations. Univ. of Calif. Publ., Geol. Sci., Bull. 18: 28-31.

Smith, W. D. 1933. Special physiographic features of the Oregon Coast. Pan-Amer. Geol. 59: 190-206.

Reprinted from November, 1942, issue of Northwest Science