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PALEOECOLOGY OF TWO SAND DUNE BOGS ON THE SOUTHERN OREGON COAST [1]

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THE PHYSIOGRAPHIC history of the Oregon Coast during the Pleistocene and Recent has been complex. Most of the physiographic cycles during this time have been the result of eustatic changes in sea level due to advance and retreat of glaciers in other parts of the continent and world. Glaciation and deglaciation apparently lowered and raised the sea level by alternate nourishment and wastage of the ice sheet on the land. In addition to eustatic oscillations of sea level, other factors involved in the modification of the topography to the present day are coastal uplift and warping, formation of marine terraces and their dissection by streams flowing across them, later drowning and filling of the valleys, alternate cutting and filling, development of a low coastal plain, shifting of the stream mouths by shore deposits of sand, the landward migration of sand dunes, and other complications arising from the interplay of diverse forces and agents. Although uplift and subsidence have occurred more than once, the last movement recorded is one of slight subsidence (Fenneman, 1931). This is evidenced by the drowning of the main streams for many miles inland. The final adjustment in the relative positions of the land and ocean has been followed by the erosion cycle of a submerged shoreline.

Along much of the Oregon Coast extends a coastal plain one to several miles wide and ranging in altitude from 200 feet to sea level. On this plain there is considerable shifting of sand, cutting off of bays and estuaries by sandbars, and blocking of stream mouths, resulting in the formation of many freshwater lakes. Continued prograding by shore agents has in some cases separated the lakes from the ocean by wide expanses of beach and dune. The sand is washed upon the beach and carried inland by the wind, where extensive dunes are formed, usually with their long axes parallel with the shore. Some of the lakes are more than a mile inland, with dunes a hundred feet in height between them and the ocean. In other instances, streams flowing parallel with the seashore have been blocked by dunes, forming chains of small lakes. Further shifting of the dunes and progression of the erosion cycle may drain or fill the lakes, so that they may be short-lived. Larger lakes farther inland have existed for some time, as indicated by the depth of peat deposits formed on their margins. Most of the lakes on this coastal plain support various stages of hydrarch succession from submerged to climax bog seres.

LOCATION AND CHARACTERISTICS OF THE BOGS.—Both bogs of this study have been formed in small, sand dune lakes of uncertain age, although the limited depth suggests that they represent only a portion of post-Pleistocene time. One bog is located about twelve miles north of Marshfield, in section 3, T. 24 S., R. 13 W., on the Reedsport quadrangle, Oregon. It lies about one mile from the ocean with intervening dunes, and is one of several lakes in this area that has been entrapped by sand dunes. The bog has been drained and scalped for cranberry cultivation, and the original vegetation is not known. The absence of *Sphagnum* in the peat profile and the presence of *Hypnum* leaves throughout was noted during pollen analysis. An abundance of pond lily pollen in the lower half of the profile with an increase in sedge pollen upward denotes normal hydrarch succession. In uncultivated areas the bog is covered by a dense growth of hairy cap moss (*Polytrichum juniperinum*). The depth of the peat is 2.1 meters, but it is very compact, suggesting that before drainage it was considerably deeper.

The other bog is located about five miles south of Bandon, Oregon, in section 24, T. 29 S., R. 15 W., on the Port Orford quadrangle. It lies about thirty miles south of the Marshfield bog. The Bandon bog has been developed in a shallow lake entrapped by dunes about one mile from the ocean. It comprises about ten acres, a portion of which has been cleared for the cultivation of cranberries. It is in the climax stage with a well developed forest covering a portion. Plants growing on the bog are Labrador tea (*Ledum columbianum*), huckleberry (*Vaccinium caespitosum*), wax myrtle (*Myrica californica*), cotton grass (*Eriophorum Chamissonis*), sedge (*Carex livida*), spike-rush (*Eleocharis acicularis*), violet (*Viola lanceolata*), gentian (*Gentiana Menziesii*), and star-flower (*Trientalis latifolia*). In the damper areas, grow *Sphagnum* sp., purple marshlocks (*Potentilla palustris*), skunk cabbage (*Lysichitum americanum*), buckbean (*Menyanthes trifoliata*), and yellow pond lily (*Nymphozanthus polysepalus*). Trees on the bog in order of their abundance and invasion are lodgepole pine (*Pinus contorta*), Sitka spruce (*Picea sitchensis*), Port Orford cedar (*Chamaecyparis Lawsoniana*), alder (*Alnus rubra*), and cascara (*Rhamnus Purshiana*). The depth of the peat in the deepest part of the bog is 4.4 meters. It is underlain with black sand mixed with fragments of charred vegetation, suggesting that a fire occurred in the region during an early stage of the lake. Sphagnum moss leaves first appear in the profile at 2.4 meters.

In preparation of the peat for microscopic analysis, the potassium hydrate method was used. From 100 to 200 pollen grains of significant species were counted from each level. In the identification of the pine pollen, the size range method was used (Hansen, 1941a, 1941b, 1941c). All of the *Abies* pollen

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is listed under lowland white fir (*Abies grandis*), but a few pollen grains of both noble fir (*A. nobilis*) and white fir (*A. concolor*) were noted. It is remotely possible that spruce pollen, which is listed under Sitka spruce, includes some of weeping spruce (*P. Breweriana*). The latter species is localized in the Siskiyou Mountains of southwestern Oregon.

VEGETATION IN ADJACENT AREAS.—Both bogs lie within the Humid Transition area (Bailey, 1936). The coastal strip of Oregon is designated as a part of the hemlock-cedar association of the Coast Forest (Weaver and Clements, 1938), but western red cedar (*Thuja plicata*) is not as important here as in other areas forested with this climax. Sitka spruce and western hemlock (*Tsuga heterophylla*) are the chief dominants in the northern half of the coastal strip, and it seems logical to designate this zone of vegetation as the spruce-hemlock association. Both of these species thin out eastward into the Coast Range where they are replaced by Douglas fir (*Pseudotsuga taxifolia*). They also become less abundant southward, possibly due to slightly decreased precipitation and more rugged topography adjacent to the ocean. Port Orford cedar makes its appearance about half way down the coast and gradually increases in abundance southward into California and eastward into the Siskiyou Range of southwestern Oregon. Spruce, hemlock, and cedar remain as the chief dominants, but Douglas fir increases in abundance near the ocean on the southern Oregon Coast. This may be due to the change in topography. From Port Orford southward to the California line, the sandy coastal plain is absent, and bluffs and mountains rise directly from the sea. Douglas fir and Port Orford cedar become the chief dominants eastward into the Siskiyous and Coast Range. Along much of the Oregon Coast, lodgepole pine is the most abundant tree in the dune area adjacent to the ocean. It is usually the first arboreal species to invade the dunes after they have been somewhat stabilized by lesser vegetation. In its range, Port Orford cedar is also one of the pioneer arboreal species to encroach on the dunes, often occurring with lodgepole. Other conifers present in the forests of the coastal strip are lowland white fir, western yew (*Taxus brevifolia*), and in the extreme southern part, redwood (*Sequoia sempervirens*). In the Coast Range and Siskiyou Mountains to the east grow western white pine (*Pinus monticola*), sugar pine (*P. Lambertiana*), knobcone pine (*P. attentuata*), white fir, noble fir, weeping spruce, and mountain hemlock (*Tsuga Mertensiana*). Some of these species are sporadically and scantily recorded by their pollen in the peat profiles. It does not seem probable that the ranges of these species have varied much during the interval of time represented by the peat profiles.

Broadleaf species in the vicinity of the bogs are largeleaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), black cottonwood (*Populus trichocarpa*), and willow (*Salix Hookeriana*).

Forest type maps (1936) reveal that both bogs are located within or near lodgepole pine types. Douglas fir types of various size classes cover almost entirely the remainder of the coastal strip, and extend into the Coast Range. Spruce-hemlock types are not common south of the mouth of the Umpqua River, but they increase in extent northward, and form almost a continuous zone several miles wide for the last hundred miles to the Columbia River. The forests of the coastal strip are classified as Pacific Douglas fir by Shantz and Zon (1924).

In general the first plants to invade the dunes in the area of this study are forbs and grasses whose rhizomes, stolons, rootstocks, and fibrous roots help to hold the sand. These are followed by shrubs consisting largely of the ericads salal (*Gaultheria shallon*), manzanita (*Arctostaphylos columbiana*), kinnikinnick (*A. Uva-ursi*), huckleberry (*Vaccinium ovatum*), rustyleaf (*Menziesia ferruginea*), and rhododendron (*Rhododendron macrophyllum* and *R. occidentale*). Additional species of shrubs are tassel bush (*Garrya elliptica*), California lilac (*Ceanothus thyrsiflorus*), wax myrtle, gorse (*Ulex europaeus*), and gooseberry (*Ribes Menziesii*). Simultaneously with the shrubs or later, lodgepole pine or Port Orford cedar or both enter, followed by Sitka spruce. Thickets of lodgepole nearest the ocean are low and rounded due to sand-shear, caused by the abrasive action of landward borne sand. These resemble the Krummholz form of trees at timberline. Farther inland, lodgepole assumes a tall, straight form. After a windbreak has been formed by the pioneer species, and the edaphic conditions have been modified, western hemlock will enter and lodgepole pine gradually lose out because of its intolerance for shade. When the climax forest is disturbed by fire, lodgepole pine may re-enter; or farther from the ocean, Douglas fir often makes its appearance and becomes locally predominant until it is replaced by spruce and hemlock. Lodgepole is also the pioneer invader of climax bogs along the Oregon Coast.

Although the shrubs may be succeeded by forests, the dunes do not always remain stabilized. In some cases, especially near the ocean, dunes seemingly stabilized by plant cover may begin to migrate, burying forests and bogs, and filling lakes and ponds. Later, continued movement of the dunes inland may exhume the forests and bogs, or the bogs may be exposed by stream incision. The movement of dunes and the formation of small lakes goes on continuously, so it is impossible to estimate the ages of the bogs of this study. Upon the basis of the depths of some thirty peat profiles in the Pacific Northwest, the writer has estimated the rate of post-Pleistocene peat depositions to vary from 500 to 1,500 years per foot, depending upon the climate, size of lake, and the type of vegetation contributing to the peat. Along the Oregon Coast the rate has probably been rapid, and 500 years per foot would seem to be a reasonable average figure. At this rate, the Bandon profile, 4.4 meters deep, would represent an interval of about 5,000 to 7,000 years, while the Marshfield profile would represent less. The latter is about one-half as deep as the Bandon profile, but the greater compact-

ing of the peat due to more drainage and the finer sediments indicates that it may be at least 4,000 years old. A bog developed on the margin of Woahink Lake, about thirty miles north of the Marshfield profile, is 12 meters deep, and probably represents most of the post-Pleistocene. This lake is much larger than the bogs of this study and is located several miles from the ocean. The forests adjacent to Woahink Lake have obviously been in a climax stage for a long time, as is indicated by the pollen record in the bog (Hansen, 1941c).

The coastal strip of Oregon is designated as having a wet, microthermal climate, with adequate precipitation at all seasons (Thornthwaite, 1931). The mean annual precipitation at Marshfield is about 65 inches, and at Bandon it is almost 67 inches (Climatic Summary, U. S. D. A.). Along the southern half of the Oregon Coast, the lowest mean annual precipitation is 52 inches at Coquille, whereas the greatest is almost 100 inches at Langlois, about fifteen miles south of Bandon. In spite of this great rainfall, the summers are rather dry, with about 15 per cent of the precipitation occurring during the growing season. It is realized that the interplay of ecological factors determines the amount of water available for the plant, which in the final analysis is the basis for the correlation of plant growth with the precipitation.

Forest succession.—At the beginning of sedimentation in both bogs, lodgepole pine was the predominant species, being recorded to 60 per cent in the Bandon profile and 62 per cent in the Marshfield profile (fig. 1, 2). Western hemlock was next most abundant, with 19 and 21 per cent recorded in the Bandon and Marshfield profiles respectively. Other conifers represented by 10 per cent or less in the

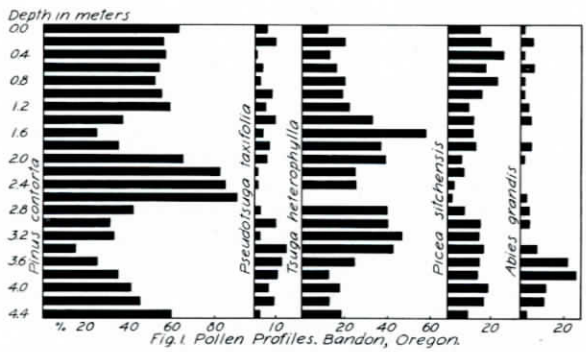

Fig. 1. Pollen Profiles. Bandon, Oregon.

bottom horizon of both profiles are fir, spruce, Douglas fir, and sugar pine. Lodgepole shows a sharp decrease from the bottom upward in both profiles, recording 15 and 30 per cent at 3.4 and 1.8 meters at Bandon and Marshfield respectively. This is the minimum proportion for lodgepole in the former profile. Western hemlock conversely increases to these horizons, while the other species show no significant fluctuations. Lodgepole pine is recorded as making an abrupt increase from these levels, attaining 90 and 66 per cent at 2.6 and 1.5 meters, its maximum proportion in both profiles (fig. 1, 2). Hemlock diminishes to its lowest percentages at these same levels, being entirely absent in the Bandon profile. Other species also decline to their lowest proportions. From these maxima, lodgepole precipitately declines to 25 and 18 per cent at 1.6 and 1.1 meters, and then shows a general increase to the uppermost horizons. The latter trend may reflect its invasion of the bog surface in more recent time. In the Bandon profile, hemlock attains its maximum of 58 per cent at 1.6 meters and in the other it reaches

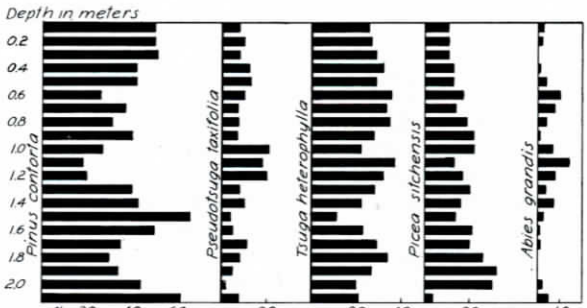

Fig. 2. Pollen Profiles. Marshfield.

37 per cent at 1.1 meters. In the former it shows a sharp decrease from its peak, followed by a more gradual decline to the surface, while in the Marshfield profile hemlock is recorded as decreasing slightly from its maximum, then increasing a little and remaining static to the surface. The other conifers recorded in appreciable proportions throughout both profiles are spruce, Douglas fir, and fir. There seems to be little correlation of the pollen profiles of these species with those of lodgepole and hemlock. Spruce attains the highest proportions in either profile, with 26 and 32 per cent. It is consistently more abundant in the Marshfield profile, reflecting the greater abundance of spruce northward along the coast. The maximum of Douglas fir is 21 per cent in the Marshfield profile, while fir reaches its peak of 26 per cent at Bandon. Port Orford cedar is sporadically recorded in both profiles, but is probably considerably under-represented because of the perishability of its pollen. Broadleaf trees recorded are alder and largeleaf maple, while lesser vegetation whose pollen is present include myrtle, ericads, sedge, pond-lily, willow, pond-weed, grass, and composites.

Interpretation of the pollen profiles.—There are at least two factors that may tend to distort the relative representation of forest trees by their pollen in bogs along the Oregon Coast. The first is the relative amounts of pollen produced by the several species. Not only does lodgepole pine shed more pollen, but it does so at an earlier age. This applies to other areas of the Pacific Northwest as well, where lodgepole is and has been an abundant forest tree. Thus, this species is probably consistently over-represented in Pacific Northwest pollen profiles. The second factor is the location of lodgepole pine forests in relation to that of bogs, the other forests, and to the direction of the prevailing winds

during anthesis. The bulk of the lodgepole pine forests forms a zone on the younger dunes between the bogs and the ocean, so that the prevailing westerly winds carry lodgepole pollen directly to the accumulating sediments. The climax forests, located largely leeward to the areas of hydrarch succession, have their pollen carried away from the site of the accumulating sediments. Pollen analyses of bogs located farther inland and within the spruce-hemlock forests, however, reveal low proportions of lodgepole pollen. On the other hand, Douglas fir, occupying areas largely to the east of the climax forests, is apparently under-represented in the pollen spectra (Hansen, 1941c). This is also true in this study. Port Orford and western red cedar are generally under-represented because their pollen is fragile and apparently not well preserved in peat.

In the interpretation of pollen profiles, the recorded forest succession is usually used as an indicator of climatic trends during the period represented by the peat profile. In fact this is perhaps the major and most important conclusion to be derived from pollen statistics. Whereas many pollen profiles in the Pacific Northwest depict post-Pleistocene climatic trends, some of them are indicative of forest succession due to modification of environmental factors other than climate. The reaction of the vegetation often brings about these modifications through normal forest succession. This is probably more true of areas within range of the moderating influence of the Pacific Ocean than of those east of the Cascades in Oregon and Washington. Causes of changes in the environment other than climate that have evidently altered the course of forest succession in the Pacific Northwest are fire, insect and fungus diseases, volcanic eruptions, and the movement of sand. Climatic trends are more definitely reflected in pollen profiles from east of the Cascades than from further west. Here the annual precipitation is often near a critical minimum, and slight changes over a period of time are instrumental in altering the forest complex. West of the Cascades, especially along the coast, the rainfall is so great and the relative humidity so high, that substantial decreases or increases in the precipitation over a period of time would not affect the forest composition. Moisture is not a limiting factor. This is not to infer, however, that the abundance of moisture has not been the chief controlling factor in determining the composition of the forest. The predominance of spruce and hemlock reflects the influence of a humid climate.

The important rôle of lodgepole pine in the pioneer, postglacial forests in so many areas of the Pacific Northwest was probably due to both the climate and the unstable edaphic and physiographic conditions as the ice retreated. After the climate and edaphic conditions had become ameliorated, other longer-lived and more shade-tolerant species replaced lodgepole. In some areas lodgepole was again able to assume predominance after being supplanted by other species, because of radical changes in the edaphic conditions. The development and persistence of a lodgepole edaphic climax is well illustrated on the east slope of the central Cascades of Oregon (Hansen, 1942a, 1942b). Here, the eruption of Mount Mazama, forming the caldera holding Crater Lake, about 5,000 years ago (Williams, 1942), resulted in the deposition of a thick pumice mantle for a hundred miles north and east of Crater Lake. Soon after this event, lodgepole, which had been replaced in early postglacial time largely by western yellow pine (*Pinus ponderosa*), again assumed predominance which it has retained to the present time. In a peat profile near Mt. Adams, Washington, a stratum of volcanic ash denotes sufficient edaphic disturbances in adjacent areas to permit a temporary influx of lodgepole pine to supersede western hemlock, which otherwise is recorded as predominant throughout the profile (Hansen, 1942e). In areas around the summit of Mt. Constitution on Orcas Island, Washington, glacial scour left so little soil that lodgepole has been able to maintain a marked predominance during all of the postglacial (Hansen, 1943).

Pollen analyses of two bogs farther north on the Oregon Coast show that spruce and hemlock were predominant throughout the time represented by the peat profiles (Hansen, 1941c). One bog, located on the margin of Woahink Lake, about thirty miles north of the Marshfield profile is 12 meters deep and probably represents most or all of post-Pleistocene time. It lies about four miles from the ocean, slightly beyond the dune zone. The forests in adjacent areas at the start of sedimentation were probably of the same composition as those during the latter part of the Pleistocene. The presence of lodgepole on young dunes between this bog and the ocean is not reflected in the pollen profiles. In the other bog, about 100 miles north, and well within the spruce-hemlock climax, similar pollen profiles are revealed but with an influx of lodgepole on the bog surface in recent time strongly recorded in the surface horizon. The constancy of the pollen profiles of these two peat deposits discloses that the forest composition was stabilized beyond the dune zone, possibly before deglaciation to the north. This suggests that lodgepole was confined to a narrow, unstable dune area immediately adjacent to the ocean during the post-Pleistocene.

That sand dunes in the past have become sufficiently stabilized long enough to permit the establishment of a climax forest is shown by pollen analysis of a buried fossil peat stratum on the Oregon Coast near Newport (Hansen and Allison, 1942). A four-foot stratum of peat, inclosed in terrace sands, is exposed in a 125-foot sea cliff, 80 feet above sea level, and about 200 feet from the ocean beach. The peat was formed in a shallow lake on a sandy plain, probably a dune area, and it shows by the preserved pollen an interval of succession from pioneer forests of lodgepole pine to climax forests of spruce and hemlock. The climax forest evidently existed for some time before it was buried by migrating dunes or water-laid sediments. There

is a possibility that this recorded forest dates back to the Pleistocene, and to a time when the ocean shore was several thousand feet to the west.

The climate along the Oregon Coast during the post-Pleistocene has probably been relatively static, although the pollen profiles of Woahink Lake bog suggest a slight drying during the middle third. This same general trend is portrayed by pollen profiles from the Willamette Valley of western Oregon and eastern Oregon and Washington (Hansen, 1939, 1942c, 1942d). The occurrence of a xerothermic period during the middle third or latter half of the postglacial is further suggested by pollen studies in the lake region, the drying and rebirth of lakes in the Great Basin (Antevs, 1938), and the movement of glaciers in some of the western mountain ranges (Matthes, 1939). It is remotely possible that the fluctuation of lodgepole pine and hemlock as recorded in this study, reflects indirectly slight climatic trends in the movement of sand dunes. Periods of increased dune migration may have been caused by increased wind velocity, which in turn resulted from climatic changes here or farther inland. Slight drying of the climate may have started the shifting of sand in localized areas near the shore, and once the movement gained momentum, landward migration of dunes buried forests of small lodgepole pine. This resulted in a decrease of lodgepole pine pollen, and an increase in relative abundance of hemlock pollen. The increase in lodgepole occurred during the less windy periods, when the dunes remained quiescent long enough to develop a vegetation cover. This is highly hypothetical, but possible. Another instigator of dune movement is the possible destruction of the vegetative cover by fire. That fire did occur in this region is evinced by the presence of charred vegetation in the sand immediately underlying the peat in the Bandon profile.

The general trends and major fluctuations of lodgepole pine in the two profiles are in marked agreement with one another (fig. 3). The highs and lows of this species in the two profiles may be synchronous or merely coincidental. As previously stated, the Bandon profile is deeper than the Marshfield profile, but due to the greater degree of compaction in the latter it may represent about the same length of time. If the major fluctuations of lodgepole pine and the other species were a result of climatic changes that occurred generally along the Oregon Coast, then the trends in the two profiles would seem to be synchronous. On the other hand, if the alteration of the forest complex was a result of localized dune movement and lake formation, then the similarities in number and direction of trends may be coincidental. The general trends of western hemlock in the two profiles are also somewhat correlative, but not as noteworthy as those of lodgepole pine. Each of the other species of conifers represented in appreciable proportions do not show much correlation in the two profiles, but the total percentages of all conifers except lodgepole pine disclose similar trends. This is to be expected, as the fluctuations of the total of the other species are merely the converse of lodgepole, since the total of all conifers represents one hundred per cent. The Bandon profile shows much greater extremes of fluctuation, suggesting less stabilization in adjacent

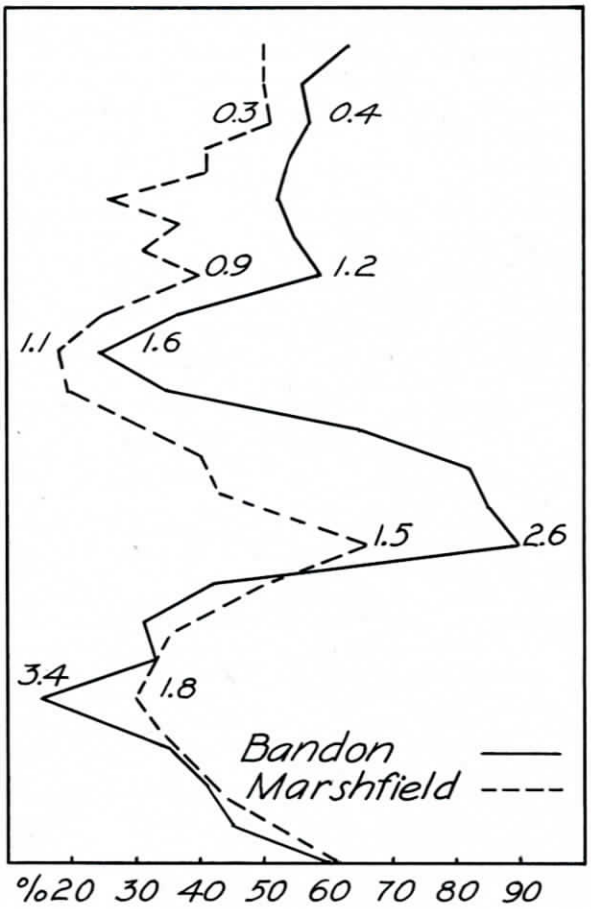

Fig. 3. Pollen profiles of lodgepole pine, showing possible synchronous correlation of major fluctuations and trends. Figures represent in meters the stratigraphic position of the highs and lows for the two profiles.

dune areas. This is further denoted by the greater abundance of Douglas fir and lowland white fir in the vicinity of the Marshfield profile, as these species prefer more stable conditions than lodgepole pine.

SUMMARY

Pollen analyses of two peat bogs, developed in sand dune lakes on the southern coast of Oregon, reveal forest succession for a period of perhaps from 4,000 to 7,000 years. During this time there seems to have been little permanent stabilization of sand dunes along the ocean shore. The chief dominants of the southern coastal strip of Oregon are western hemlock, Sitka spruce, Douglas fir, lowland white fir, Port Orford cedar, western red cedar, and lodgepole pine. The last species is usually the pioneer arboreal invader of stabilized dunes and is replaced

by the others as the environmental conditions are gradually modified.

With exception of two brief periods of hemlock predominance, lodgepole has apparently been the most abundant species during the interval recorded by the peat profiles. Whether the converse trends of lodgepole and hemlock denote changes in actual or relative abundance is difficult to say. It is possible that the recorded increase in hemlock is relative, because of dune migration and burying of lodgepole pine stands near the ocean. If this is true, it may reflect slight climatic changes that were indirectly responsible for renewed dune migration. Temporary stabilization of dunes then permitted lodgepole pine again to flourish. The position of the lodgepole pine forests windward to the site of the sediments, however, suggests that they may be over-represented in the pollen profiles.

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