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OREGON STATE MONOGRAPH

Reprint No. 54

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Reprinted from

THE AMERICAN MIDLAND NATURALIST

Vol. 27, No. 2, pp. 523-534, March, 1942

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Post-Mount Mazama Forest Succession on the East Slope of the Central Cascades of Oregon[1]

Henry P. Hansen

Introduction

The eruption of the prehistoric volcano, Mount Mazama, that formed the caldera holding Crater Lake in the Cascade Range of southern Oregon, occurred between 5,000 and 10,000 years ago (Williams, 1941). This volcanic activity resulted in the deposition of a pumice mantle, that extends with diminishing thickness to the east and north of Crater Lake. The depth of the pumice varies from more than 10 feet in the vicinity of Crater Lake to several inches about 100 miles to the north. The pumice lies chiefly on the east slope of the Cascade Range. This cataclysmic event and the enormous amount of pumice and other types of ejecta deposited in this region must have had a profound effect upon the forests that existed at the time of the eruption. Forests in the immediate vicinity of Mount Mazama were probably instantly destroyed by the fragmental ejecta and the incandescent gases that descended the slopes of the mountain. Forests growing beyond the influence of these factors were probably less precipitately destroyed by the pumice mantle and the sudden change in the edaphic conditions. In areas still farther removed from Mount Mazama the forests were not killed, but the change in the edaphic conditions must have inhibited the growth of seedlings of those species that composed the existent forests. Eventually, as the trees of these forests died of old age or were destroyed by wind, fire, or disease, they were replaced by other species less exacting as to soil requirements. Such species were further benefited by lack of competition.

Location and Characteristics of the Bogs

The peat deposit of this study located nearest to Crater Lake lies in Munson Valley on the south slope of the mountain. Munson Creek rises near the south rim of the caldera and flows directly south to empty into Annie Creek, about 4 miles beyond the rim of Crater Lake. The bog is located in section 17 of T. 31 S., R. 6 E., and at an elevation of about 6200 feet. It comprises several acres and is covered chiefly with sedge (*Carex* spp.) and willow. Lodgepole pine *(Pinus contorta)* is the pioneer forest tree invader followed by alpine fir *(Abies lasiocarpa)*. The depth of the pollen-bearing sediments in the area of sampling is 2 meters, which was the deepest point located. The lowest level is composed of a fine, gray, silty sediment, which upon examination under the microscope was found to consist of almost pure volcanic glass. The presence of pollen

1 Published with the approval of the Monographs Publication Committee, Oregon State College, as research paper No. 54, School of Science, Department of Botany.

at this level suggests that the glass was transported into ponded water rather than having been deposited *in situ* during the eruption. The glass grades upward into fibrous peat. Pure fibrous peat is present from 1.2 meters to the surface. It is impossible to estimate the amount of time that elapsed between the eruption of Mount Mazama and the initiation of the pollen-bearing sedimentation. Munson Valley was eroded in Mount Mazama volcanic material. The depth of the peat, however, suggests that from 5,000 to 7,000 years were required for its deposition. The average rate of sedimentation in post-Pleistocene peat bogs in the Pacific Northwest has been about one foot per thousand years. In a bog located near Bend, Oregon, two layers of pumice occur at 2 and 4.5 meters respectively in a 7-meter profile (Hansen, 1942b). It seems probable that the upper stratum owes its origin to the eruption of Mount Mazama, because this bog lies in a zone where the pumice mantle is several inches thick. The depth of the peat above the upper layer of pumice is about the same as the entire Munson Valley profile.

Another peat profile was obtained from Big Marsh, which is located 30 miles north of Crater Lake. This bog has developed on the floodplain of Big Marsh Creek, and is about 3 miles long and 1 mile wide. The surface is covered largely with sedge (*Carex* spp.) and willows. In addition to the sluggish stream that flows through the bog, there are several sloughs supporting various stages of hydrarch plant succession. The sloughs suggest a meandering stream, which may have removed some of the peat in certain areas. There is no topographic map of the region, but the bog lies at an elevation between 4,000 and 5,000 feet. Peat samples were obtained in section 18 of T. 25 S., R. 7 E. The depth of the bog in the area of sampling is 1.8 meters. The peat rests directly upon coarse pumice which the peat borer would not penetrate. The thickness of the pumice mantle in this area varies from 5 to 10 feet.

Peat samples were obtained from a third bog located about 50 miles north of Crater Lake and about 22 miles northwest of Big Marsh. It is located in section 28 of T. 22 S., R. 5 E. at an elevation of 2900 feet, about 10 miles west of the Cascade divide near the Willamette Pass highway. The peat has accumulated at the junction of the South Fork of Salt Creek and a small tributary. The bog comprises an area of about one and one-half acres, and is nearing the climax stage of plant succession. Trees invading the bog in order are Engelmann spruce *(Picea engelmanni)*, mountain hemlock *(Tsuga mertensiana)*, western white pine *(Pinus monticola)*, and alpine fir. On the margin grow mountain alder *(Alnus tenuifolia)* and willow. Lesser vegetation present consists of bog laurel *(Kalmia polifolia)*, blueberry *(Vaccinium uliginosum)*, shooting star *(Dodecatheon jeffreyi)*, star-flower *(Trientalis latifolia)*, twin-flower *(Linnaea borealis)*, bunchberry *(Cornus canadensis)*, mitrewort *(Mitella ovalis)*, paint-brush (*Castilleja* sp.), marsh marigold *(Caltha leptosepala)*, skunk cabbage *(Lysichitum americanum)*, and a few species of sedge (*Carex* spp.). The bog lies in an area where the Mount Mazama pumice mantle is several inches thick. The depth of the peat at the deepest point that could be found is 2.75 meters. The peat is underlain with coarse sand rather than

pumice. A stratum of pumice is present at 2.5 meters, which suggests that the eruption of Mount Mazama occurred just after the beginning of sedimentation. Fibrous peat is present from 2.25 meters to the surface.

Peat samples were also obtained from a fourth bog located on the margin of Mud Lake, about 70 miles north of Crater Lake and 20 miles west of Bend. Mud Lake is about one and one-half miles long and shaped like a dumb-bell. Both ends of the lake support various stages of hydrarch plant succession. Borings were made near the south end where there are several well-defined zones of hydrophytic vegetation. A floating sere of yellow pondlily *(Nymphozanthus polysepala)*, is followed shoreward by a zone of pondlily and bulrush *(Scirpus validus)*, which in turn is succeeded by a zone composed of bulrush, sedge *(Carex* sp.), and buckbean *(Menyanthes trifoliata)*. The last grades into a more mesophytic zone consisting chiefly of sedge, purple marshlocks *(Potentilla palustris)*, and bog laurel. A few specimens of lodgepole pine have gained a foothold in the mesophytic areas. Samples were obtained in section 4 of T. 19 S., R. 8 E. where the profile is 1.8 meters deep. The peat is underlain with coarse pumice which was impenetrable with a Hiller peat borer. Mud Lake lies at an altitude of 5,000 feet and in an area where the pumice mantle is between one foot and six inches thick. Bachelor Butte, an extinct volcanic cone, reaching an elevation of more than 9,000 feet, is situated about 4 miles to the east.

In the preparation of the peat for microscopic analysis, the potassium hydrate method was used. From 100 to 200 pollen grains were identified from each level. Pollen of species not considered as indicators of forest succession was also identified as to genus and listed in the tables. The identification of the winged conifer pollen was based upon the size-range method which has been described in previous papers (Hansen, 1941a, 1941a, 1941c). As stated in these papers, it is not possible to separate all of the species of Pinus and Abies. In this study the most significant inseparable species are western white pine and white bark pine *(Pinus albicaulis)*. Pollen of these species is listed under white bark pine. In the Munson Valley bog, most of the pollen thus listed is probably of this species. In the Willamette Pass bog, however, it seems probable that most of the pollen is that of western white pine because of the moister climate and lower elevation of adjacent areas. In the Big Marsh and Mud Lake bogs it is not possible to say which species of pollen is predominant. Other indistinguishable species of less importance, because of low proportions of their pollen present, are white fir *(Abies concolor)* and noble fir *(A. nobilis)*, and lowland white fir *(A. grandis)* and silver fir *(A. amabilis)*. The first two are listed as white fir and the last two are recorded as lowland white fir. Sugar pine *(Pinus lambertiana)* and yellow pine *(P. ponderosa)* are inseparable to some extent because a small percentage of the former's pollen is within the size-range of that of yellow pine. The feasibility of the size-range is substantiated by the consistencies of pollen profiles from the same bog or bogs located within the same forest climax. In four sediment profiles from Lower Klamath Lake of Oregon and California, a remarkable similarity is present for the general trends of lodgepole, yellow, and white pine pollen spectra

(Hansen, 1942a). In other peat deposits the relative pollen proportions of the several species represented at the surface seem to correlate fairly well with their relative abundance in adjacent areas.

Forests in Adjacent Areas

The four peat deposits of this study lie near the crest of the Cascade Range. The Willamette Pass bog is located a few miles to the west of the divide, whereas the other three are situated just east of the summit. The Munson Valley bog lies practically astride the border of the Hudsonian and Canadian life zones, and the others are located within the Canadian zone (Bailey, 1936). All peat deposits are in proximity to both the Hudsonian and Arctic-alpine life zones, and pollen from the forests of these zones is recorded in the peat profiles. The timbered Arid Transition lies about 10 miles south of the Munson Valley bog, 25 miles east of Big Marsh, 5 miles east of Mud Lake, and 25 miles east of the Willamette Pass bog. The boundary of the Humid Transition is located only 10 miles west of the last bog, and the same zone is about 10 miles west of Crater Lake. The Canadian zone is the most extensive in proximity to the peat deposits, and the timbered Arid Transition is next in extent of area. The borders of life zones, forest climax regions, and climatic provinces are irregular in mountainous areas, extending upward or downward beyond the general limits where the conditions are favorable.

The most abundant species of conifers in the Canadian zone are western white pine, western hemlock *(Tsuga heterophylla)*, Engelmann spruce, noble, silver, lowland white, and white fir, and sugar and white pine. Lodgepole pine is confined largely to the pumice-covered areas and is more abundant east of the Cascade divide than it is to the west. On the west slope of the Cascades, Douglas fir *(Pseudotsuga taxifolia)*, western hemlock, and silver and lowland white fir become more abundant. The timbered Arid Transition, from the latitude of Crater Lake to 100 miles north, is forested about equally with western yellow and lodgepole pine. It is this area that has the greatest thickness of pumice, which extends east and north of Crater Lake in diminishing depth. Lodgepole probably persists here as a subclimax, because the climate of this area is such as normally to support forests of the Canadian zone in its upper part, and yellow pine forests in the areas at lower elevations. Forest type maps (1936) show that yellow pine forms a continuous zone to the east of the lodgepole pine forests and as far north as Bend. Still farther north, yellow pine forms a solid, continuous, but narrowing belt, almost to the Columbia River. The lodgepole pine zone gradually tapers to nothing northward, and is practically absent for the last 100 miles to the Columbia River. This may be due to both the absence of pumice and a difference in climate. The yellow pine forests here lie closer to the Cascade divide.

The Hudsonian, immediately above the Canadian zone, is forested with alpine types including mountain hemlock, white bark pine, alpine fir, and Alaska cedar *(Chamaecyparis nootkatensis)*. Lodgepole also is abundantly

present in this zone. In general it can be said that lodgepole pine is the chief dominant over almost one-half of the timbered belt on the east slope of the Cascade Range for a distance of 100 miles north of Crater Lake. It is also present in greater or lesser proportions in forests of adjacent areas. The altitude of the site of the Munson Valley bog is the highest and the forests of the Hudsonian zone are best represented in this peat profile. A detailed study of the life zones and flora of Crater Lake National Park has been made by Wynd (1941). His observations show that the Hudsonian forests consist largely of mountain hemlock and white bark pine, and those of the Canadian zone are composed chiefly of lodgepole pine.

The bogs of this study are located within a climatic province designated as having a humid, microthermal climate, with adequate precipitation at all seasons (Thornthwaite, 1931). The mean annual precipitation, however, varies considerably in the four areas. The greatest occurs at Crater Lake with about 53 inches (Weath. Bur., U.S.D.A., 1936). At Crescent, 12 miles northeast of Big Marsh but at a lower elevation, it is 19.25 inches. At Sisters, 25 miles northeast of Mud Lake, the mean annual precipitation is 16.65. At Crater Lake, 16 per cent occurs from May to September inclusive, and at Crescent and Sisters 24 and 21 per cent respectively occurs during the same period. The growing season is thus relatively dry, and the porosity of the pumice probably permits rapid drainage, thereby decreasing the benefits of rain during the growing season. It should be noted that the precipitation in the vicinity of Mud Lake and Big Marsh is greater than at Sisters and Crescent respectively, because of their higher elevation. The prevailing wind direction during the period of anthesis is westerly, which is reflected by the relatively low proportions of yellow pine pollen in the peat profiles. This is probably due to the existence of the yellow pine belt to the leeward of the bogs.

Post-Mount Mazama Forest Succession

The location of the bogs in relation to the climate and the depth of the pumice mantle is well reflected by their pollen profiles. Those of Big Marsh and Mud Lake are similar in their general trends. This is to be expected because of the location of the peat deposits in similar floristic and climatic provinces. The pollen profiles of the Munson Valley bog differs from the others because of its higher elevation and different climate. The Willamette Pass bog also records different forest succession because of its location west of the Cascade divide in an area of moister climate and where the pumice mantle is not as thick. On the slopes below Crater Lake lodgepole and white bark pine have been predominant as recorded by their pollen spectra (Fig. 1). These species contributed 67 and 18 per cent respectively of the pollen in the lowest level. Lodgepole pine shows a general decline from the lowest level to the surface where it is recorded to 35 per cent, whereas white bark pine marks a general increase upward to be recorded to 41 per cent at the surface. The lowest percentage of lodgepole pine pollen in the profile is 30, whereas the highest for white bark pine is 47 at 0.6 meter. Other conifers appreciably recorded in order are yellow pine, mountain hemlock, and white fir (Fig. 1).

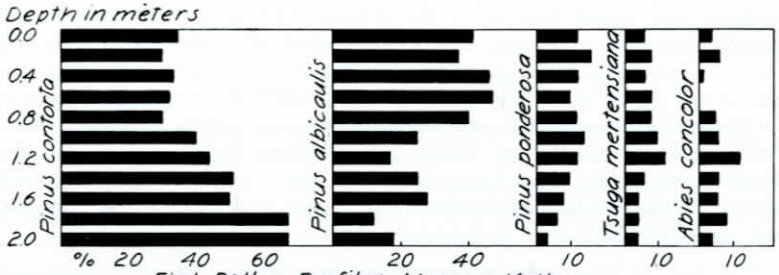

Fig. 1. Pollen Profiles. Munson Valley.

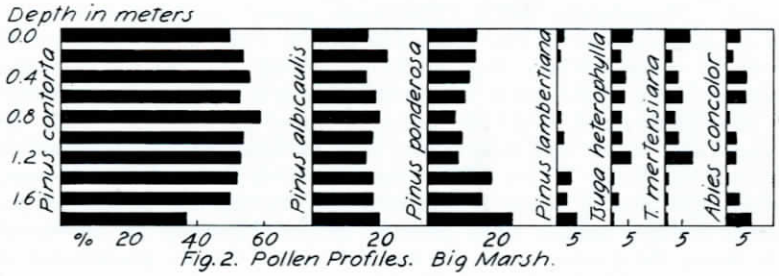

Fig. 2. Pollen Profiles. Big Marsh.

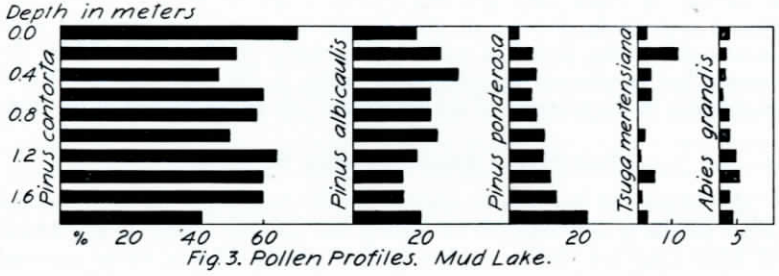

Fig. 3. Pollen Profiles. Mud Lake.

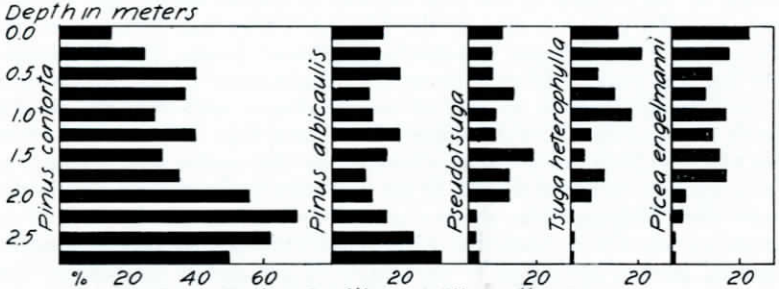

Fig. 4. Pollen Profiles. Willamette Pass.

In the Big Marsh peat profile, lodgepole pine is recorded as having been predominant by a wide margin during all of post-Mount Mazama time (Fig. 2). It contributed 37 per cent of the pollen present in the lowest stratum, shows a gradual increment to 59 per cent at 0.8 meter, and then slightly declines to the surface where it is recorded to 50 per cent. White bark and white pine, whose pollen is inseparable, is next in abundance to lodgepole. These species apparently remained rather constant in their abundance during

TABLE 1.—Percentages of Fossil Pollen. Munson Valley Bog.

Depth in meters	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2	0.0
Pinus contorta	67	67	50	51	44	40	30	32	33	30	35
P. albicaulis	18	12	28	25	17	25	40	47	46	37	41
P. ponderosa	3	6	8	10	12	14	12	10	12	16	12
Tsuga mertensiana	4	4	4	6	12	10	8	8	6	8	6
Abies grandis	..	2	2	..	1	4	4	1	..	1	1
A. concolor	4	8	6	6	12	6	5	..	1	6	4
A. lasiocarpa	4	1	2	2	2	..	1	2	1	2	..
Picea engelmanni	..	..	..	..	..	1	..	..	1	..	1
Pinus spp.*	8	14	23	10	15	11	10	13	19	11	17
Abies spp.*	4	1	4	3	4	3	2	2	2	..	1
Gramineae*	..	..	1	1	..	..	1	..	..	..	..
Compositae*	..	4	1	1	..	..	1	4	..	..	1
Chenopodiaceae*	..	..	..	..	..	..	..	1	..	..	..
Alnus*	..	1	3	1	..	..	1	..	..	..	..
Acer*	..	1	..	1	1	1	..	1	..	..	..
Salix*	..	..	3	3	..	..	..	..	1	2	1
Cyperaceae*	2	8	10	12	13	13	25	34	59	22	23

* Number of pollen grains; not computed in the percentages.

TABLE 2.—Percentages of Fossil Pollen. Big Marsh Bog.

Depth in meters	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2	0.0
Pinus contorta	37	50	52	53	54	59	53	56	54	50
P. albicaulis	20	18	18	16	18	20	19	16	22	16
P. ponderosa	25	16	19	9	10	8	11	10	12	12
P. lambertiana	6	3	4	..	2	1	..	..	1	2
Pseudotsuga taxifolia	1	1	1	1	3	1	1	3	3	2
Tsuga heterophylla	1	2	1	6	3	3	4	4	3	6
T. mertensiana	1	1	1	8	4	3	5	4	2	7
Abies grandis	..	1	1	..	1	..	..	..	..	1
A. concolor	7	4	1	3	3	1	6	6	2	4
A. lasiocarpa	1	1	2	2	1	..	..	1	..	..
Picea engelmanni	1	2	..	..	1	4	1	..	1	..
Larix occidentalis	..	1	..	2	..	..	..	..	..	..
Pinus spp.*	18	11	14	11	11	10	13	11	13	15
Abies spp.*	2	..	..	4	1	1	6	1	3	2
Compositae*	2	1	2	..	1	1	..	1	1	6
Alnus*	1	..	..	..	1	..	1	..	1	1
Acer*	3	..	..	..	..	..	..	..	..	1
Salix*	..	..	..	..	1	..	2	..	..	18
Cyperaceae*	16	17	32	37	44	37	77	72	70	85
Nymphozanthus*	1	1	..	..	..	..	..	..	..	..

* Number of pollen grains; not computed in the percentages.

the time represented by the peat profile. They are represented by 20 per cent of the pollen at the bottom, and fluctuate between 16 and 22 per cent throughout the rest of the spectrum. Yellow pine is third in importance. It is recorded to 25 per cent at the lowest level, declines to 8 per cent at 0.8 meters, and then increases slightly to 12 per cent at the top. Mountain and western hemlock and white fir are also recorded by appreciable proportions. The first two species probably existed in moister areas to the west, windward to the site of the sediments.

TABLE 3.—Percentages of Fossil Pollen. Mud Lake Bog.

Depth in meters	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2	0.0
Pinus contorta	42	60	60	64	50	58	60	47	52	70
P. albicaulis	20	15	15	19	25	23	23	31	26	19
P. ponderosa	23	14	12	10	10	8	7	8	7	3
P. lambertiana	2	1	..	..	2	2	..	..	..	..
Pseudotsuga taxifolia	1	3	1	..	2	2	1	..	1	..
Tsuga heterophylla	2	2	1	..	2	1	1	3	..	1
T. mertensiana	3	1	5	1	2	..	4	4	12	3
Abies grandis	4	3	6	5	3	3	1	2	2	3
A. concolor	2	..	..	..	1	2	1	1	..	..
A. lasiocarpa	..	..	..	1	2	..	1	3	..	1
Picea engelmanni	1	1	..	..	1	1	1	1	..	..
Pinus spp.*	15	10	16	11	15	10	19	12	11	16
Abies spp.*	2	1	1	2	3	1	1	1	3	2
Compositae*	..	..	..	..	..	1	..	1	..	..
Alnus*	1	..	2	..	1	..	3	..	1	..
Acer*	..	..	..	..	1	1	1	..	..	..
Cyperaceae*	34	46	14	14	23	40	45	30	60	16
Nymphozanthus*	4	1	..	..	..	2	1	1	..	..

* Number of pollen grains; not computed in the percentages.

TABLE 4.—Percentages of Fossil Pollen. Willamette Pass Bog.

Depth in meters	2.75	2.5	2.25	2.0	1.75	1.5	1.25	1.0	0.75	0.5	0.25	0.0
Pinus contorta	50	62	70	56	35	30	40	28	37	40	25	15
P. albicaulis	32	24	16	12	10	16	20	12	11	20	14	15
P. ponderosa	4	4	1	..	1	1	1	1	1	4	2	2
P. lambertiana	..	1	3	..	3	1	1	..	..	1	2	..
Pseudotsuga taxifolia	3	2	2	12	12	19	8	8	13	7	7	10
Tsuga heterophylla	1	1	1	6	10	4	6	18	13	8	21	14
T. mertensiana	6	1	..	6	2	..	..	1	1	..	1	3
Abies grandis	..	2	1	..	5	2	8	10	8	10	8	2
A. concolor	3	2	3	4	6	13	4	6	2	3	2	6
A. lasiocarpa	..	..	..	..	..	..	..	..	4	3	2	3
Picea engelmanni	1	1	3	4	16	14	12	16	10	12	17	23
Pinus spp.*	17	13	17	19	10	7	8	12	8	10	15	15
Abies spp.*	2	1	8	2	9	3	5	3	1	3	2	4
Gramineae*	..	..	1	..	..	2	..	..	..	..	..	1
Compositae*	1	..	..	2	2	..	..	..	..	..	1	..
Alnus*	..	1	1	3	12	8	13	5	7	8	6	2
Acer*	1	1	2	..	1	3	2	2	4	1	3	5
Salix*	..	..	1	2	1	..	2	3	1	2	5	11
Cyperaceae*	1	10	5	7	4	3	2	1	4	3	5	1

* Number of pollen grains; not computed in the percentages.

The trends of the pollen profiles recorded in Mud Lake bog are similar to those of Big Marsh. Lodgepole has likewise been the predominant species in its vicinity (Fig. 3). It contributed 42 per cent of the pollen at the bottom, and with several sharp fluctuations it increases to 70 per cent at the surface. White bark and white pine are slightly better represented in Mud Lake bog than in Big Marsh, perhaps because of the former's proximity to the Hudsonian zone along the crest of the Cascade Range. These species are represented by 20 per cent at the bottom, attain 31 per cent at 0.6 meters, and then decline to 19 per cent at the surface. Yellow pine is recorded to 23 per cent at the lowest horizon, and then gradually declines to only 3 per cent at the top. Mud Lake is farther removed from yellow pine forests than Big Marsh. The former lies entirely within lodgepole pine forests, whereas the latter is situated adjacent to yellow pine types. Other conifers most abundantly and consistently recorded are mountain hemlock and lowland white fir (Table 3).

The moister climate and thinner pumice-mantle in the vicinity of the Willamette Pass bog is reflected by the forest succession as recorded in the peat profile. As previously stated, sedimentation of the peat was initiated just prior to the eruption of Mount Mazama. Lodgepole pine is recorded to 50 per cent at the lowest level and then increases sharply to 70 per cent at 2.25 meters. The eruption of Mount Mazama apparently occurred some time during the deposition of the lower one-half meter of peat. The pronounced predominance of lodgepole pine, however, was short-lived, as it shows a sharp decline to 30 per cent at 1.5 meters (Fig. 4). It then fluctuates between 28 and 40 per cent to 0.5 meters, and makes a final decline to 15 per cent at the surface. The last proportion is the lowest for lodgepole in any of the profiles. The general decline of this species from 2.25 meters to the surface is suggestive of rapid modification of the pumiceous soil favorable for the development of other species. The moister climate probably augmented the rate of soil modification. White bark and white pine decline from 32 per cent at the bottom to 10 per cent at 1.75 meters, from which horizon they vary from 11 to 20 per cent to the uppermost stratum (Fig. 4). The general trend for these species seems to be similar in the four peat profiles. Other conifers represented by their pollen in appreciable proportions are Douglas fir, Engelmann spruce, and western hemlock. These species thrive better under moister conditions than lodgepole pine, are more tolerant of shade, and also are more exacting as to edaphic conditions. Western hemlock is particularly so, and grows best where there is considerable humus in the soil. These species show a general increase from 2.25 meters to the surface (Fig. 4). Douglas fir, spruce, and hemlock are recorded to 1, 3, and 2 per cent respectively at this level, and are represented by 10, 23, and 14 per cent at the surface. Yellow pine is sparsely recorded throughout the profile with a maximum of only 4 per cent. Other conifers recorded in low proportions are sugar pine, mountain hemlock, and lowland white, white, and alpine fir (Table 4).

There seems to be little or no evidence for climatic trends in the pollen profiles during the period of time represented by the peat profiles. The existence of the pumice has apparently been unfavorable for the maintenance of

yellow pine as the climatic climax over most of this region. Lodgepole pine, which is a subclimax species that thrives in edaphically disturbed areas, was able to gain predominance due to lack of competition. This species was the chief postglacial pioneer invader of deglaciated regions in other parts of the Pacific Northwest (Hansen, 1938, 1939a, 1939b, 1940a, 1940b, 1041a). It was gradually replaced entirely or partially by other species as the rigorous conditions left in the wake of the glacier were ameliorated. In the Puget Lowland of western Washington it was replaced by Douglas fir, in eastern and north central Washington by yellow pine, and in northern Idaho by western white pine. In the vicinity of Mud Lake, it is probable that lodgepole existed as the predominant species before the eruption of Mount Mazama. This is indicated by pollen profiles of a peat deposit at Tumalo Lake, 13 miles to the northeast (Hansen, 1942c). Lodgepole pine gained predominance soon after a volcanic eruption as denoted by a stratum of pumice at 4.5 meters, which it was able to maintain until and after a second eruption recorded at 2 meters. This upper pumice stratum presumably owes its origin to Mount Mazama, and the recorded forest succession above it is similar to that of the entire profiles of both Big Marsh and Mud Lake bogs. The source and extent of the lower pumice layer is unknown, but it may be localized in the vicinity of the Three Sisters.

There are several lines of evidence suggesting that the eruption of Mount Mazama occurred during or soon after a recorded dry period between 4,000 and 7500 years ago. Pollen profiles from Lower Klamath Lake indicate a period of desiccation about this time as based upon the forest succession and the depth of sediments (Hansen, 1942a). This is further evidenced by an artifact horizon underlying 6 to 8 feet of peat (Cressman, 1940). Apparently the lake dried up and early man built his camp sites upon the lake bed. A moister climate resulted in re-inundation of the lake bed and the subsequent deposition of 6 feet of peat. Although Lower Klamath Lake is located beyond the range of air-borne pumice from Mount Mazama, the highest proportions of lodgepole pine pollen in three out of four profiles are attained just after the yellow pine maximum and above the artifact horizon in each of the profiles. This suggests that the eruption of Mount Mazama occurred during or soon after the dry period denoted by the maximum attained by yellow pine. The thickness of the peat above the artifact horizon is also correlative with the depth of the peat profiles of this study. Peat profiles in the lower Willamette Valley have a pumice stratum immediately above the maximum of white oak *(Quercus garryana)*, which is sufficiently high to indicate a period of desiccation in this area (Hansen, 1942b). The source of the pumice is not known, but if it is from Mount Mazama it shows significant correlation with the interpretations of the Lower Klamath Lake profiles. The existence of a dry period about this time is also suggested by the salinity of certain lakes in the Great Basin (Antevs, 1938), and the oscillations of montane glaciers in some of the western mountains (Matthes, 1939).

Summary

Forest succession on the east slope of the central Cascades in Oregon since the eruption of Mount Mazama has been influenced largely by the thick pumice mantle that extends north and east of Crater Lake. The pollen profiles of four peat bogs lying directly upon Mount Mazama pumice show trends of forest succession that reflect each bog's location with respect to climate and the thickness of the pumice in adjacent areas.

In all profiles lodgepole pine was predominant when deposition of the pollen-bearing sediments began. In the Mud Lake and Big Marsh bogs, lodgepole is recorded as having been predominant throughout the entire period represented by the peat profiles. In the Munson Valley bog, the high elevation and cooler climate is reflected by an increase in white bark pine to supersede lodgepole pine about half-way up in the profile. In the Willamette Pass bog, lodgepole pine decreases from the time of the pumice eruption to the present. Douglas fir, western hemlock, and Engelmann spruce show a general increase from bottom to top. Their greater abundance here may have been a result of more rapid modification of the thinner pumice mantle in this area.

There is little evidence for climatic trends. The Munson Valley and Willamette Pass pollen profiles suggest a slight increase in moisture, and possibly some cooling to a maximum during post-Mount Mazama time. The depth of the peat profiles, and the rate of peat formation in the Pacific Northwest suggest that the eruption of Mount Mazama occurred between 5,000 and 7500 years ago.

ACKNOWLEDGEMENTS

The author thanks Dr. Howel Williams, Department of Geology, University of California, for reading the manuscript and for his suggestions concerning the geological aspects of the paper.

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