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POLLEN ANALYSIS AND THE AGE OF PROBOSCIDIAN BONES NEAR SILVERTON, OREGON [1]

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The discovery of mammoth bones about 3 miles east of Silverton, Oregon, Marion County, during the summer of 1946 represents the richest find of proboscidian bones yet reported from western Oregon, and their occurrence indicates a late date of entombment. The specimens were found by Mr. Paul Pinson while excavating a catchment basin below a large spring, located in the S W 1/4, Sec 36, T 6 S, R 1 W at an elevation of about 625 feet as shown on the Mollala quadrangle (fig. 1).

Occurrence of the Bones

A swamp of about one acre extends below the spring and drains into Evans Creek. The spring is situated on the southeast side of a small but relatively broad alluviated valley which has been but slightly dissected.

The valley appears to have been developed in soft dark colored shale, a few fragments of which were brought up with the shovel during excavation of the basin. The shale is lithologically similar to fossiliferous marine sediments, outcropping farther north within the same quadrangle, which have been named the Butte Creek formation of Oligocene-Miocene Age (Harper, '46).

The fossil bones occur on, and partially imbedded within, a greenish-gray silt, of unknown thickness, which apparently overlies the marine shale. This silt, as revealed in the cavities of the specimens, contains comminuted plant remains, including fragments of wood coated with vivianite. Overlying this silt are the swamp deposits, composed of the usual fragments of roots, stems, and leaves of plants not unlike those now living in the swamp.

The organic deposit is about 0.9 m. thick as judged by the bank of the newly excavated basin and by the several sections that were made.

Unfortunately the presence of four to six feet of water in the catchment basin has prevented obtaining a more accurate section and precise location of the bones.

The topographic position of this bog, within this small valley, the lack of evidence of much dissection of the valley fill and the limited thickness of the swamp deposits are in accord with the evidence of a late post-Wisconsin age indicated by the study of the pollen profiles.

Discovery of Bones

A number of years ago this locality yielded a proboscidian tooth, but it was

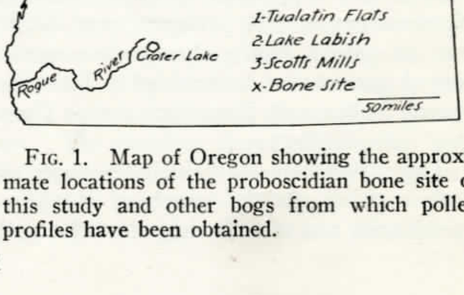

Fig. 1. Map of Oregon showing the approximate locations of the proboscidian bone site of this study and other bogs from which pollen profiles have been obtained.

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not until 1946, when Mr. Pinson procured a power shovel and developed two catchment basins with a connecting ditch, in front of the spring, totaling as much as 3000 square feet of water surface and averaging more than four feet in depth below the water level, that additional material was found.

The shovel brought to the surface a portion of a mammoth skull with at least one upper molar tooth in place. Parts of a lower jaw, teeth, and broken tusks were later exhumed, indicating that a nearly complete skull had been interred.

Dr. Warren Smith, University of Oregon, the first geologist known to have arrived before the excavation was completed, noted in the easternmost bank of the basin a large limb bone in place, lying approximately horizontally about three feet below the water line. He then advised that it be left until it could be removed by hand. A few weeks later the second author first visited the locality and also saw that same bone. Later it was reported that still another large bone, which may have been a scapula, was exposed near the leg bone. Those bones are presumed to be in place yet, but a recent search failed to detect them because of depth of the water, slumping, and the rank vegetation.

Description of the Bones

The specimens collected were removed to the nearby barn, with little regard for their significance. When the writers first examined them, the two tusks were quite complete, although broken, and already beginning to check. The other bones were lying unsorted and no attempt had been made to classify or clean them. Only a very superficial list of the skeletal elements can now be presented and, without laboratory study, the species represented cannot be determined. The following bones and fragments are at Oregon State College.

The incomplete skull includes parts of both incisive sheaths, much of the premaxillaries and maxillaries, one orbit and a portion of the left zygomatic arch. The palatine region back of the pterygoid and a well-preserved third molar will afford important diagnostic characters. Another fragment, presumably belonging to the same individual, consists of the posterior portion of the basi-cranial region, including the occipital condyles. Four incomplete tusks, possibly representing two pair, were obtained. The largest has a diameter at the root of 17.5 centimeters and is over two meters long. Fragments of badly decomposed upper molars also indicate several individuals were entombed in the same locality. The collection also includes the proximal half of a ramus, three lower molars showing 16 to 18 plates, a well-preserved humerus, the distal articulation of a femur, fragments of other limb bones, five fused vertebrae comprising the sacrum, and a number of ribs.

Although Hay ('27) and more recently Osborn ('23) have reported several species of mammoths from the Pacific Northwest, no detailed study of the rather large number of specimens of teeth, now in the educational institutions and museums of the region, has been made. Osborn ('23) described *Parelaphas Washingtonii* from eastern Washington and Elftman ('31) has reported *P. colombi* Falconer from the late Pleistocene deposits of Fossil Lake in eastern Oregon. Osborn ('22) also described *P. jeffersonii* and showed that many specimens previously referred to *P. colombi* belonged to his new species. It now appears that the Silverton mammoth belongs to one of these species of *Parelaphas* and that they were associated with the mastodon.

Characteristics of the Sediments

The peaty sediments cover about one-half acre, although black organic soils of paludal origin occupy a considerably greater area. The organic sediments are thickest near the base of the slope from which issue the springs that are responsible for the development of the swamp. The peaty sediments thin out northward and down-valley from the base of the slope, and grade into mucky silt where the water table becomes lower. Natural drainage of the swamp probably has prevented water from standing except during the winter and spring when the spring flow is greatest and the volume of the water is increased by runoff from the adjacent slopes. The fluctuating water table undoubtedly has kept hydrarch succession at a minimum, while a low water table during the dry summer, especially during dry climatic cycles, has caused some compaction, oxidation, and subsidence of the organic sediments. The rate of organic deposition apparently has been much slower than under the more optimum conditions which have existed elsewhere in the Pacific Northwest. The peat grades downward into peaty clay, clay, silty clay, silt, and silty sand, the last two layers being heavily stained with iron oxide. At present the swamp is covered with vegetation consisting largely of cat-tail, nettle, speedwell, water smartweed, water hemlock, and other swamp species. Six peat sections were taken over the area with a Hiller peat borer, to determine the stratigraphy and the best preserved sediments for pollen analysis. The section used for pollen analysis was taken about 100 feet west of the bone site, because of disturbance and covering of the surface at the site during the excavation. The stratigraphy apparently is similar across the entire swamp.

Methods

A 1.5-meter section, extending 0.5 m. into silt and clay, was analyzed at decimeter intervals for pollen. In preparation for microscopic analysis, a portion of about 2–4 cc. of sediments was boiled for about 10 minutes in a 1 per cent solution of KOH with a few drops of gentian violet stain. It was then washed and strained, and the liquid was centrifuged. The residue was mixed with hot glycerin jelly and mounted on slides. In samples from the lower, more inorganic levels, silt and sand were removed by decanting before the boiling. One hundred or more pollen grains were identified at each level, except at 1.4 and 1.3 m. where only 50 significant pollens were found. No pollen was noted at 1.5 m. but it became more abundant upward as the amount of organic material increased. Pollen was abundant in the organic sediments and it was possible to count 200 pollens at many horizons. Cattail pollen first appeared at 1.2 m., indicating that the area was occupied by swamp vegetation at an early stage of sedimentation. Well defined glass fragments apparently of primary volcanic origin were common at 0.4 m. It is assumed that this glass represents the same source and time as a layer of pumice occurring at 1.85 m. in the organic sediments at Lake Labish about 15 miles northwest of the site of the present study (Hansen, '47). This source may be Mount St. Helens in southwestern Washington and the pumice is dated at about 5000 years. Its occurrence affords a valuable chronologic marker which will be considered later.

Postglacial Climate and Chronology in the Pacific Northwest

Correlation of climatic trends and chronology as recorded by the pollen profiles of this study with those interpreted from other pollen profiles in the Willamette Valley and the Pacific Northwest provides an important source of evidence in dating the proboscidian bones.

The time represented by the pollen profiles, which is here termed generally post-Wisconsin, is divided into four climatic stages. The first, from the time of deglaciation or soon thereafter, was cool and moist and persisted until about 15,000 years ago. The second period was one of warming and drying as the influence of glaciation became more remote, and lasted until about 8000 years ago. The dividing time between the first and second intervals is arbitrarily chosen, as the climate probably began to warm and dry with glacial retreat. The third climatic stage was apparently one of accelerated warming and desiccation which attained its maximum sometime between 8000 and 4000 years ago. The maximum has been set at about 6000 years in the Pacific Northwest (Hansen, '47). The final stage, from 4000 years ago to the present, saw a return to a moister and cooler climate. The occurrence of a postglacial xerothermic stage throughout the north temperate zone is substantiated by pollen profiles and peat stratigraphy from northern Europe, England, eastern North America, the Great Lakes region, northern Montana, and western Canada (Blytt 1881; von Post '30, '33; Godwin '40; Deevey '44; Antevs '45, '48; Sears '48; Hansen '47, '48, '49). The estimates for the duration of the warm, dry interval by these various workers range from 6500 to 2500 years. Other evidence for the xerothermic stage includes fluctuations of Great Basin lakes (Antevs, '45, '48; Allison '45) and the history of modern glaciers in the western mountains (Matthes '39, '42). In the Pacific Northwest, the xerothermic interval is best reflected in eastern Oregon and Washington, where pollen profiles reveal a pronounced influx of grasses, chenopods, and composites at the expense of forests (Hansen, '47). Contraction of grassland and expansion of forests during the past 4000 years are well shown in the upper part of the profiles.

Pollen profiles from sedimentary columns in the Willamette Valley also reveal a warm, dry interval, correlated chronologically with regional trends recorded in bogs throughout the Pacific Northwest. The warm, dry period is best revealed in the Willamette Valley by pollen profiles of peat sections from Lake Labish and Tualatin Flats (fig. 1). The former site is located about 8 miles north of Salem and 15 miles west of the site of the present study, while Tualatin Flats is about 25 miles to the northwest (Hansen, '42). The xerothermic stage is well depicted by an influx of Oregon white oak (*Quercus garryana*) to partially replace Douglas fir (*Pseudotsuga taxifolia*) in the upper-half of the sections. Western yellow pine (*Pinus ponderosa*) is significantly recorded concurrently with oak, particularly in the Labish sections, to further support the role of oak as a xerothermic indicator (fig. 2). Yellow pine is common in the Willamette Valley, but it prefers the higher, better drained sites,

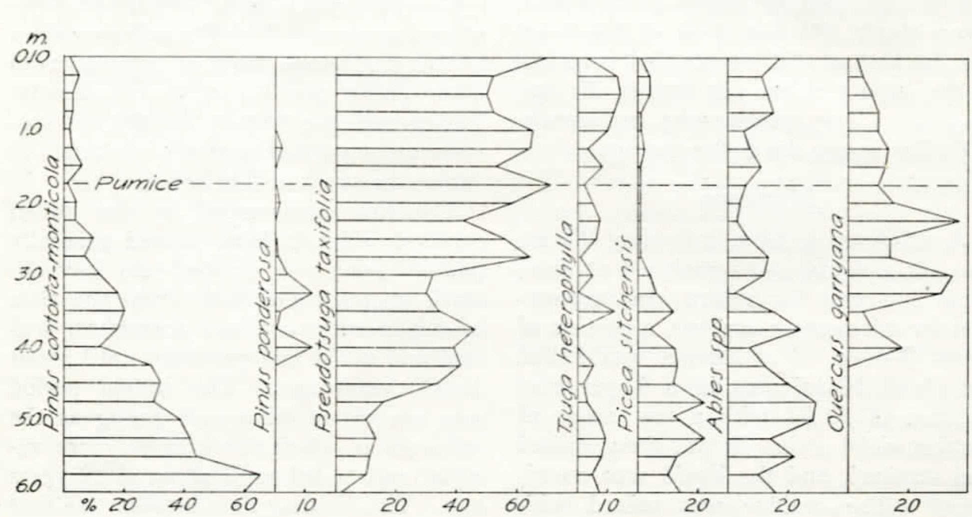

FIG. 2. Pollen profiles from the Lake Labish peat section located about 15 miles west from the Silverton bone site. Xerothermic interval is probably represented by the *Quercus garryana* and *Pinus ponderosa* maxima below the pumice horizon.

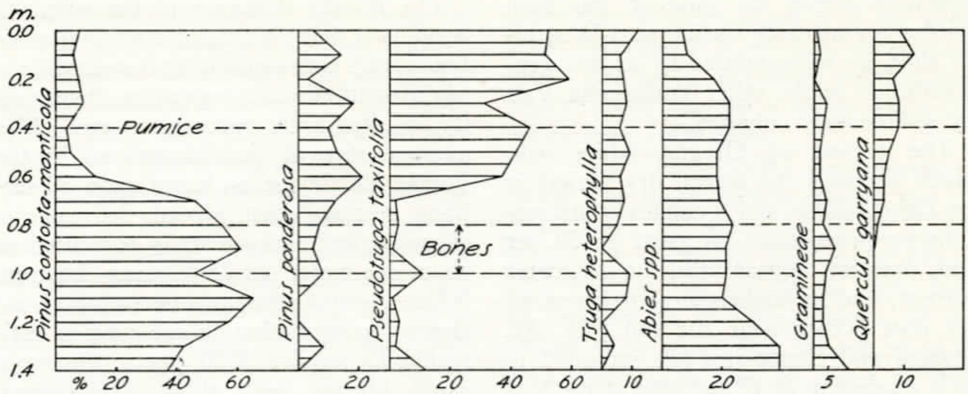

FIG. 3. Pollen profiles of peat section taken about 100 feet from the interred proboscidian bones, showing the stratigraphic position of the bones, the pumice horizon, and the *Pinus ponderosa* maximum which is interpreted as representing the postglacial warm, dry maximum.

and is most abundant along the margins of the valley. White oak thrives on the poorly drained valley floor better than yellow pine, which may explain why oak best records the xerothermic stage in the Labish and Tualatin sections, while yellow pine expresses this climatic trend in the Silverton section. Pollen profiles from a third bog, located near Scotts Mills, about 10 miles southeast of Silverton, however, fail to portray any evidence for a xerothermic stage (fig. 1).

Interpretation of the Silverton Pollen Profiles

The predominant forest trees represented in the lower levels are lodgepole pine (*Pinus contorta*) and one or more species of fir (*Abies*), which are the most abundantly recorded species to a level well above the bone horizon (fig. 3). In the peat sections from Lake Labish, Tualatin Flats, and Scotts Mills lodgepole pine and fir are also predominantly represented in the lower levels, suggesting an early post-Wisconsin regional homogeneity in the forest composition. In the Scotts Mills section, however, fir is more abundant than pine, while in the other two, lodgepole is recorded to greater proportions than fir. This is consistent in view of the relative location of the several sites. Lodgepole pine is predominantly represented at the bottom in practically all peat sections in the Pacific Northwest that rest on glacial drift or its chronological equivalent (Hansen, '47). At Silverton, fir declines gradually and almost constantly from 39 per cent at the bottom to 7 per cent at the top. Lodgepole pine increases from 37 per cent at the bottom to its maximum of 66 per cent at or near the bone horizon, and then sharply declines to its minimum of 4 per cent at 0.4 m. (fig. 3). The persistence of lodgepole in abundance until quite recently in post-Wisconsin time is also denoted in the Lake Labish and Tualatin Flats sections. In the latter it attains its maximum of 55 per cent at 5.75 m. in a 12-meter section and persists in abundance for some levels above (Hansen, '42). In the Silverton section, Douglas fir is poorly represented below the 0.6 meter level, where it sharply increases to 37 per cent (fig. 3). It continues to increase in the next two levels, declines, and then increases again to almost the top. The predominance of lodgepole over Douglas fir, until so recently, suggests a disturbance factor of some kind that favored the former, but the cause of this disturbance is uncertain. Western hemlock (*Tsuga heterophylla*) is only slightly recorded throughout, attaining a maximum of 12 per cent at the top (fig. 3). The climate, especially during the summer, has been too dry for hemlock during post-Wisconsin time, as substantiated by its low representation in the other Willamette Valley sedimentary columns.

The record of Oregon white oak, which portrays the warm, dry period in the Lake Labish and Tualatin Flats sections by proportions as great as 60 per cent, does not appear until the 0.8-meter horizon, and its highest proportion of 13 per cent occurs near the top (fig. 3). Grasses and composites are recorded to their maximum of 17 per cent at the bottom, suggesting their persistence from perhaps a greater abundance during and immediately after the subsidence of the glacial backwaters, which were unfavorable for forests until the waters had permanently subsided. The best indicator of the warm, dry stage and for dating the bone emplacement, is western yellow pine. This species is represented by less than 10 per cent up through 0.8 m. and then sharply increases to its maximum of 21 per cent at 0.6 m. (fig. 3). It then declines with some fluctuation to 5 per cent at the top. The yellow pine maximum is considered to be concurrent with the xerothermic stage, the maximum of which is dated about 6000 years ago in the Pacific Northwest according to the pollen profiles and other supporting evidence. The climatic record manifested in the Silverton sediments, then, is consistent with the regional pattern of post-Wisconsin climatic trends in the entire Pacific Northwest as shown by the pollen profiles of many, widely scattered peat bogs in the region.

Age of the Elephant Bones

In dating the proboscidian bones, several lines of approach may be used. These are (1) the thickness of the sediments overlying the bones and the rate of deposition, (2) the typological succession of the sediments and the stratigraphic position of the pumice, and (3) the stratigraphic position of the bones in relation to the xerothermic interval.

(1) By the thickness of the peat. It is realized that the rate of organic deposition varies considerably under conditions of different climate, vegetation, favorability of hydrarch succession, etc. The average rate of peat deposition in the Pacific Northwest, as based upon 30 sections resting upon glacial drift or its chronological equivalent, is computed at about one meter per 2500 years (Hansen, '47). Accumuation of one meter of the slower accumulating limnic peat is estimated to require 3500 years, the more rapid fibrous peat about 1700 years. However, these rates are based upon more favorable conditions for hydrarch succession than were probably present at the site of the sediments of this study. The mucky character of the sediments, with a high inorganic fraction, suggests a fluctuating water table resulting in oxidation, compaction, and subsidence to a degree greater than normal. The dry summers of the Willamette Valley are unfavorable for rapid peat deposition, except under the most favorable conditions. The sediments overlying the bones are of a slow-accumulating type and their rate of deposition would be perhaps half as great as mentioned above. About 0.9 m. of pollen-bearing sediments overlies the bones, which, computed at half the rate estimated for fine sediments, would represent about 7000 years. This slow depositional rate is not at all unreasonable as shown by the occurrence of 1 m. of organic sediments overlying a 6000-years old layer of volcanic ash in certain Washington bogs, while in others as much as 9 m. overlies the same ash. A similar case is illustrated by the occurrence of Mount Mazama pumice, dated at 10,000 years, at depths varying from less than 1 m. to more than 4 m. in bogs in south central Oregon (Hansen, '47). It is believed that seasonal fluctuation of the water table has been responsible for compaction of slowly-accumulating peat to less than one half of its normal thickness.

As mentioned previously, the bones lie at the surface of the blue clay, or are partially imbedded therein, underlying the more organic sediments. Pollen analysis of peaty clay taken from well within the decayed basal end of one of the tusks reveals more than 60 per cent of pine pollen and about 30 per cent of fir pollen. These proportions are somewhat similar to those at and near the bone horizon, which supports the stratigraphic evidence that the animals were entombed long after the lowest pollen-bearing sediments were deposited (fig. 3). If the bones had been interred during the period of earliest sedimentation, the pollen proportions of sediments within the bone cavities should approximate those near the base of the section. Were the animals mired directly in the clay while drinking at the margin of the pond or did they bog down in the peat and mud while grazing or browsing upon the vegetation in the swamp? If the latter occurred, then the stratigraphic position of the interred bones is lower than the surface at the time of their original emplacement, and they are chronologically younger than their stratigraphic position indicates. A foot or two of peat may have covered the clay, through which the animals sank to become mired in the underlying mud. After the removal of the flesh by predators or by decay, the bones gradually may have worked down through the soft peat to become imbedded at the surface of the firmer inorganic sediments. This interpretation would date the bones at about 7000 years or during the xerothermic period.

(2) By position relative to the pumice. While it cannot be proved that the glass fragments at 0.4 m. are of the same source and synchronous with the pumice of the Lake Labish sections, their depth and stratigraphic position suggest that they may well be. The volcanic activity responsible for the pumice in the Labish and Tualatin pollen profiles is dated at about 5000 years on the basis of its occurrence during the warm, dry maximum (fig. 2). The elephant bones, lying at a depth of more than twice that of the glass, could then be dated at about 10,000 years upon the basis of a constant depositional rate. As this is the more conservative, 10,000 years may be a more reasonable figure than 7000 years.

(3) By relation to the xerothermic interval. In the Silverton section, the climatic maximum portrayed by the highest proportion of yellow pine is at 0.6 m. This horizon lies two-thirds down from the surface to the bone level. If the yellow pine maximum be set at 6000 years, the bones may be dated at 9000 years by the stratigraphy alone. However, the lower sediments undoubtedly are of slower accumulation, so again a figure of 10,000 years may be more acceptable. The persistence of lodgepole with some white pine in high proportions to levels above the bone horizon is also more compatible with the greater antiquity, because lodgepole pine was not replaced by Douglas fir until 10,000 years ago in the Puget Sound region. It should be said, however, that lodgepole evidently persisted longer in the Willamette Valley than in most areas west of the Cascade Range in Oregon and Washington. In conclusion, upon the basis of the above interpretations, the age of the bones would seem to be 10,000 years or probably a little less.

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