

HOLOCENE ENVIRONMENTAL HISTORY OF THE WILLAMETTE VALLEY,
OREGON: INSIGHTS FROM AN 11,000-YEAR RECORD FROM
BEAVER LAKE

by

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Holocene vegetation and fire history of the mid-Willamette Valley were investigated in a sediment core from Beaver Lake, Oregon. During the early Holocene, the mid-WV featured a mixed woodland containing Quercus and Pseudotsuga, with Alnus and Corylus also occurring in surrounding foothills. The development of riparian vegetation types began around 7300 calendar years BP, and coincided with regional cooling/moistening and altered valley-floor drainage patterns. Pollen signals remain

relatively unchanged during the middle and late Holocene, with Quercus and Pseudotsuga prominent on drier sites, and riparian vegetation types persisting until present.

Analysis of fossil charcoal suggests burning around Beaver Lake was most prominent between ca. 2900 and 550 cal yr BP. Short core sediments record reduction of the local Salix swamp and introduction of Juglans, commercial grass and Brassicaceae. Additional work is needed to detail spatial variation in burning on the WV floor, and potential roles of Kalapuyan cultural burning.

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CHAPTER I

INTRODUCTION

Presettlement vegetation patterns in western Oregon's Willamette Valley and the importance of fire in their maintenance have been a topic of much interest and speculation (Morris 1934, Habeck 1961, Johannessen et al. 1971, Boyd 1986, and others). Personal accounts of early Euro-American trappers and botanists and General Land Office (GLO) surveys in the early 1850s provide relatively specific descriptions of the Willamette Valley (WV) landscape. Many of these reports described a heterogenous mosaic of vegetation types, including broad flat prairies, savannas of mature Oregon white oak, and riparian gallery forests. Some descriptions include references to burning patterns associated with grasslands and savannas, which was frequently attributed to use of fire by the Kalapuyan Native Americans that populated the region prior to Euro-American settlement (diaries of D. Douglas 1826, Adamson 1926, Smith 1949, and others). Meany's (1841) passages are not atypical of early pioneer descriptions:

One of the most striking appearances of the Willamette Valley is the flatness of its Prairies in some instances a dead level for miles in extent--and it becomes a problem of some difficulty to solve how they have been produced. Fire is no doubt the cause of their being kept clear of an under growth and may have been the original cause of them but the way the forests are growing round them would almost preclude this supposition as but (a) thin belt of wood frequently occurs between extensive ones.

Edmond S. Meany, June 9, 1841
Diary of Wilkes in the Northwest

Aside from such snapshots of presettlement conditions and several geomorphological studies (e.g. Balster and Parsons 1968, 1969, Freidel 1989, McDowell 1991, Reckendorf 1993), relatively little information exists regarding the Holocene development of this complex WV landscape. Paleoecological methods allow investigation of vegetation patterns and disturbance regimes over an expanded temporal window, and can be critical to understanding regional vegetation history. Paleoecological research around western Oregon's Willamette Valley has thus far been limited to early pollen studies of the valley floor (Hansen 1941, 1942, 1947), a vegetation and fire history analysis from the Central Coast Range (Worona and Whitlock 1995, Long et al. 1998), and two vegetation records from the central Cascade Range (Sea and Whitlock 1995). The studies of H. P. Hansen (1941, 1942,

1947) provided the first descriptions of postglacial vegetation change and general landscape development in the Pacific Northwest (PNW). However, his analyses were of limited utility, as they preceded radiocarbon dating and addressed only a subset of the region's floral diversity.

Fire regimes have been important determinants of pre- and post-settlement vegetation patterns in many different sub-regions within the PNW (Agee 1993, Cwynar 1987, Martin 1982 and others). To date, no paleoecological research has examined the Holocene fire history of the WV, or its potential importance in shaping the province's vegetation. I present findings from a ca. 11,000-year sediment record from a mid-WV lake, which is the first study to employ modern radiometric dating and fossil pollen and charcoal techniques to analyze vegetation and fire history in the region. This thesis represents a portion of the total research effort, which will ultimately be published with co-authors.

The objectives of this thesis include the following:

1. Provide an overview of regional climatic and vegetation changes over the Holocene.
2. Summarize the methodology and results of our paleoecological analysis of a mid-WV sediment record, and discuss possible relationships between burning, vegetation

change, and Native American population patterns in the WV.

3. Recommend future research directions that could advance our understanding of Holocene environmental change in the WV.

CHAPTER II

OVERVIEW OF REGIONAL CLIMATE AND VEGETATION HISTORY IN WESTERN OREGON AND WASHINGTON

Understanding the complex environmental history of the Willamette Valley requires knowledge of regional climatic changes during late Pleistocene and Holocene time. The Puget Lobe of the Cordilleran ice sheet achieved its maximum extent in western Washington ca. 15 km south of Olympia between 17,400 and 16,800 calendar years before present (cal yr BP)¹ (Porter 1970, Hibbert 1979). The Puget Lobe retreated rapidly after reaching its maximum position, and was north of the Canadian border by ca. 15,450 cal yr BP (Wiatt and Thorson 1983). Maximum extent of Cascade glaciers was also achieved before 11,100 cal yr BP (Davis 1988). Significant postglacial warming was not evident in the Portland Basin until ca. 13,100 cal yr BP (Barnosky 1985a). The WV and Coast Ranges of western Oregon did not

¹ = all C¹⁴ radiocarbon years have been converted to cal yr BP using the program of Stuiver and Reimer (1993).

support glacial ice at any time during the Quaternary (Davis 1988).

Throughout the PNW, the early Holocene was the period of greatest postglacial warming, due to amplification of the seasonal cycle of solar radiation (Thompson et al. 1993). This change in seasonality was due to differences in earth's tilt and occurrence of perihelion during summer, as opposed to its current timing in winter. The amplified seasonal radiation cycle reached its maximum between 10,000 and 9000 cal yr BP, and has steadily declined to present (Kutzbach 1987, COHMAP 1988). Summer insolation during this maximum period was ca. 8% higher than present, and winter insolation was ca. 10% lower (Kutzbach et al. 1993). Climate modeling suggests that the early Holocene (sometimes referred to as 'hypsiathermal' or 'altithermal' period) was characterized by higher temperatures and decreased effective moisture during summer (Barnosky et al. 1987, Kutzbach 1987, COHMAP 1988). Summer drought was likely intensified as a result of expansion of the seasonal high-pressure system over the northeastern Pacific Ocean (Heusser et al. 1985, Barnosky et al. 1987).

As summer radiation decreased in the middle and late Holocene, the north Pacific high pressure system weakened, resulting in less severe summer drought and cooler

temperatures than in the early Holocene (Thompson et al. 1993). Modern coniferous forests in many parts of the PNW formed within the last 5100 cal yr BP (Barnosky 1985a, Dunwiddie 1986, Sea and Whitlock 1995). Within this general pattern of mid- and late-Holocene cooling are included shorter sub-millennial-scale changes, such as the Medieval warm period (ca. 950-1350 AD) (Tausch et al. 1993) and the 'Little Ice Age' cool period (ca. 1400-1850 AD) (Graumlich 1993).

These general Holocene climatic patterns are reflected in paleo-vegetation changes throughout the PNW. Exact timing and magnitude of changes in vegetation varies by site, and was influenced by elevation, microclimate, aspect, and fire regime (Sea and Whitlock 1995). The WV represents perhaps the largest gap in our understanding of western PNW postglacial vegetation patterns, with the only published paleoecological vegetation data gathered before radiocarbon dating techniques were available. Figure 1 depicts paleoecological study sites discussed in the following sections.

Pre-Euro-American Vegetation and Fire Regimes in the Willamette Valley

The strong seasonality of precipitation and lack of

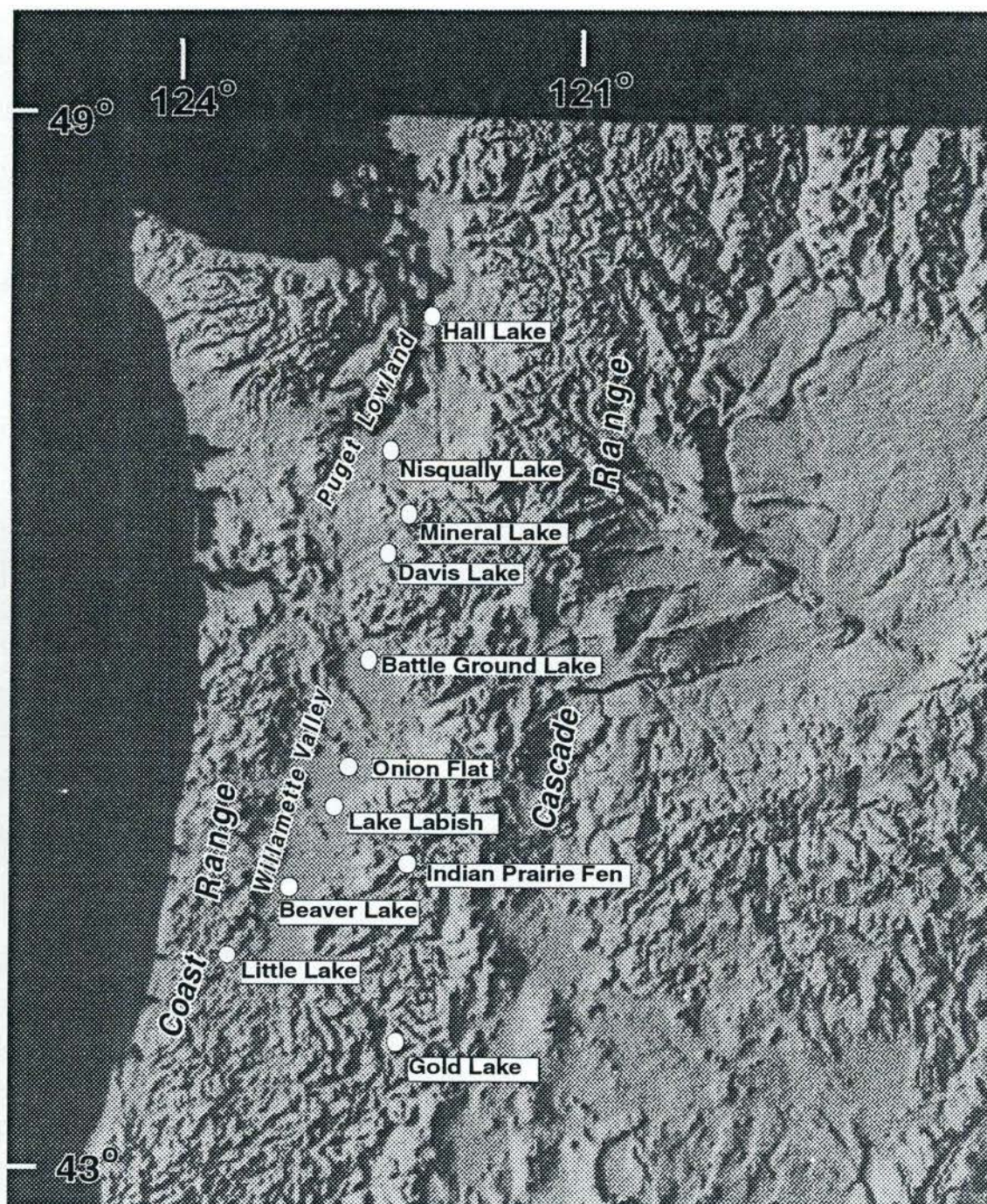


Figure 1. Regional map of Pacific Northwestern U.S., including paleoecological sites discussed in text.

glaciated undrained depressions in the WV have resulted in a scarcity of continuous Holocene stratigraphies suitable for paleoecological studies (Hansen 1947). Most of the organic deposits in the valley were formed under swamp conditions, as evidenced by relatively high inorganic sediment components, as well as layers of compressed organic matter. Such organic layers often result from the seasonal lowering of water tables and consequent oxidation and decomposition of recent deposits. Despite these conditions, H. P. Hansen (1941, 1942, 1947) was able to locate and examine four records spanning the Holocene. Two of the four sites (Onion Flats and Lake Labish) are ancient oxbow channels/marshes in the northern WV, and two (Noti and Scotts Mills) are Sphagnum bogs. The Noti bog is located in the foothills of the Coast Range, while the Scotts Mills site is located in the foothills of the Cascade Range (Hansen 1947). Both these foothill sites receive greater precipitation than the WV floor.

Onion Flat and Lake Labish lie in former river channels associated with the Tualatin and Willamette rivers, respectively. They both were shallow lakes/emergent marshes before conversion to agricultural fields (Hansen 1947). Lake Labish, located 7 km northeast of Salem, was an extensive marsh (> 10 km in length) in a former channel of

the Willamette River that was isolated from the main river by sand deposits at the confluence of several tributaries (Hansen 1947, Orr et al. 1992). Onion Flat is located in Sherwood, Oregon, approximately 50 km north of Lake Labish. Due to their proximity to active floodplains, both Onion Flat and Lake Labish were periodically influenced by high waters (Hansen 1942).

Interpretation of Hansen's (1947) Willamette Valley cores is limited to general trends due to lack of radiocarbon dates and coarse resolution of pollen identifications. However, the general trends deserve mention. The Onion Flats and Lake Labish profiles exhibit high percentages of Pinus contorta (lodgepole pine) during late-glacial time, similar to Puget Lowland sites. This high Pinus period persists longer in both these WV sites than farther north, remaining prominent until the pre-Mazama increases in Pseudotsuga (Douglas fir) and Quercus (Hansen 1942). Pinus contorta pollen was less abundant in records from the Noti and Scotts Mills foothill sites. Hansen (1942) thus concluded that the WV was dominated by P. contorta in the late Pleistocene, likely a reflection of the species' tolerance of surface water (from melting snow and ice in higher elevations) and its ability to colonize unstable, poorly developed substrates.

In both the Onion Flats and Lake Labish profiles, Pseudotsuga increases as P. contorta declines, perhaps a combined result of soil development (as result of P. contorta colonization) and climatic warming (Hansen 1947). Pseudotsuga pollen increases in both records above the Mazama ash layer (since ca. 7630 cal yr BP), providing general evidence of a regional warming and drying trend. Quercus is absent from the lower Onion Flat and Lake Labish profiles, but increases rapidly after its first appearance, reaching maximum percentages before the Mazama ash layer (Hansen 1947). The expansion of Quercus came at the expense of Pseudotsuga and the mesophytic (moderately moisture tolerant) species. These trends and the tolerance of Quercus for xeric sites are strong indications of a drying and warming phase (Hansen 1947). Both of Hansen's (1947) valley floor sites were missing portions or all of their upper profiles as a result of modern agriculture, so information on Quercus' post-Mazama decline is lacking. In the Noti and Scotts Mills profiles, Quercus occurs at very low abundances.

Frequency and severity of burning are important factors affecting vegetation patterns across a variety of different landscape types in the PNW (Agee 1991, Agee 1993). Frequencies of major fire events have varied with climate

and vegetation type through the Holocene (Cwynar 1987, Millspaugh and Whitlock 1995, Long et al. 1998). Large-scale burning has been proposed as an important determinant of forest composition in various PNW sub-regions (Tsukada et al. 1981, Sugita and Tsukada 1982, Cwynar 1987).

Examinations of fire history in the PNW generally address three different chronological windows. Journal entries and General Land Office survey notes taken by early Euro-American pioneers and settlers provide detailed accounts of vegetation patterns in the WV in the early and mid-19th century. Analysis of fire scars and dendrochronology extend the reconstruction window ca. 200-400 years preceding Euro-American settlement. Paleoecological analyses of charcoal particles in lake sediments allow analysis of fire occurrence on millennial time scales.

References to Native American burning of WV lowlands are common among diaries and journals of early Euro-American pioneers in the region (e.g. David Douglas 1823-1827, John Work 1834, W. D. Brackinridge in 1841, Wilkes in 1841, and others). It is widely assumed that seasonal burning was a regular practice by the Kalapuyans indigenous to the lowlands of western Oregon (Johannessen et al. 1970, Boyd 1986, Zybach 1988, Teensma et al. 1991, and others). A variety of management benefits of late summer burning have

been suggested, including moving and providing browse for game animals, maintaining open landscapes for easier travel and lines of sight, and enhancing conditions for staple food sources, such as camas lily (Camassia quamash and C. leichtlinii), oak acorns (presumably Quercus garryana), hazelnut (Corylus sp.) and tarweed (Madia sp.) (Zenk 1976, Boyd 1986, Cheatham 1988, Zybach 1988, and others). However, the temporal and spatial extents of such anthropogenic burning in prehistoric time remain incompletely known, as does the influence on regional vegetation patterns.

Although a Holocene record of fire history from the WV floor is lacking, analyses of fire scars on trees and stand inception patterns in adjacent Coast and Cascade ranges elucidate general burning patterns over the last several centuries. Changes in the foothill forests have led a number of researchers to conclude that the suppression of natural fires has resulted in denser stands and different vegetation composition (Cole 1977, Towle 1982, Reigel et al. 1992). During the centuries prior to Euro-American settlement, Mean Fire Return Intervals were shorter in the foothills surrounding the WV than in higher elevations of the Coast and Cascade ranges. After studying stumps in the Cascade foothills, Weisberg (1998) concluded that fires were

more frequent before (ca. every 52 yrs between 1545-1849 AD) and during early settlement years (ca. every 28 yrs between 1849-1910 AD), than in this century (ca. every 310 yrs 1910 to present). Impara (1998) found the same general pattern of more frequent fires during presettlement and along the foothills than in the more western portions of the central Coast Range. Sprague and Hansen (1946) arrived at a similar conclusion based upon an examination of tree ring growth in the Coast Range foothills. Their investigation suggested that the area was 'frequently burned since around 1647,' and that fires were less severe and less frequent between 1848 and 1946. An evaluation of General Land Survey notes, Land Classification Maps, and timber cruising records, led Teensma et al. (1991) to conclude that 'Recently burned' Coast Range forests (stand inception within the previous 25-50 years) were more prevalent in 1850 than in 1890, 1920, or 1940. In 1850, young forest stands occurred more widely along the margin of the WV than in the central and western areas of the Coast Range (Teensma et al. 1991). Such a pattern is consistent with the decreasing moisture gradient from Pacific Ocean east to the WV, as well as with the potential for WV fires to spread by summer winds from the northeast (Teensma et al. 1991). In the central Oregon Cascades, Teensma (1987) found Mean Fire Return Intervals

(MFRI) of approximately 113 years. Morrison and Swanson (1990) documented central Cascade Range MFRI's varying between 90-150 years on wet sites to 200-275 years on dry sites.

Lightning ignitions are presently uncommon in the WV relative to the surrounding Cascade and Coast ranges (see Impara 1998). Several authors have suggested that lightning has not been a particularly significant ignition source for fires in the WV or Oregon Coast Range since Euro-Americans settlement (Kirkpatrick 1939, Zybach 1988). Towle (1982) found no references in the historical literature to WV fires initiated by means other than Kalapuyan or settler ignition, and considered the frequency of thunderstorms in the WV among the lowest in North America. Moderate and higher elevations in the Cascade Range presently experience no such shortage of lightning ignition, usually associated with late-summer convective thunderstorms. Several researchers have speculated that the more frequent fires in foothills relative to moderate and higher elevations on Coast and Cascade ranges could have been result of escaped valley fires (Thilenius 1968, Johannessen et al. 1970).

These studies based on historic notes and fire-scarred tree ring records provide some information regarding the importance and recurrence of burning within the last 300-400

years. Analysis of particulate charcoal fragments sequestered within lake sediments extends the temporal window of fire history reconstruction to millennial and Holocene time scales. The only published analysis of this type proximal to the WV comes from Little Lake in the central Coast Range. From their examination of macroscopic charcoal, Long et al. (1998) concluded that fire frequencies varied continuously throughout the last 9000 years associated with climatic changes. While the highest background charcoal accumulation rates occur within the last ca. 4000 years, the separation of discrete peaks from this background signal suggested that frequency of large fires around Little Lake has declined through the Holocene (Long et al. 1998).

Many researchers have suggested that anthropogenic burning directly affected vegetation in the WV and surrounding Coast and Cascade Range foothills (Thilenius 1968, Boyd 1986, Teensma et al. 1991, Riegel et al. 1992, and others). Archaeological evidence is widespread demonstrating Native American occupation of the Willamette Valley throughout the Holocene (O'Neill 1987, Freidel et al. 1989, Connolly et al. 1997, and others). WV Native American population estimates range to as high as 12,000 to 16,000 in the late Holocene prior to contact with Euro-American explorers (Cheatham 1988, Boyd 1990). Still,

little is known of how representative the observations of Kalapuyan burning and its subsequent effects on vegetation by early travellers are of a wider temporal window.

Parallel investigations of Kalapuyan population levels, distribution, and cultural burning techniques, in tandem with paleoecological evidence of patterns of vegetation and fire history are needed to detail these interactions and relationships.

CHAPTER III

STUDY REGION AND SITE

The Willamette Valley of western Oregon is a broad structural depression between the Cascade Range on the east and Coast Range on west. It is the largest interior valley in the Pacific Northwest (Cheatham 1988) and measures 190 kilometers long and averages 40 kilometers in width. The Willamette River is a ninth-order channel that drains ca. 29,300 square kilometers, two thirds of which is in the Cascade Range immediately to the east (Sedell and Frogatt 1984). The valley can be defined as the lowland between the confluence of the Middle and Coast forks of the Willamette River at the upstream end near Eugene (elevation ca. 135 m) and the confluence of the Willamette and Columbia Rivers in Portland (elevation ca. 6 m). Commercial agriculture dominates land use in the WV at present. The valley receives an average of 105 centimeters of precipitation annually, more than two thirds of which falls as rain between October and May (Taylor 1993). Precipitation in the Coast Range and Cascade Range follows a similar seasonal

pattern, but averages approximately 380 cm per year at middle to higher elevations (Taylor 1993, Reckendorf 1973).

Beaver Lake is centrally located in the Willamette Valley in Linn County, Oregon (latitude $44^{\circ} 33' 01''$ N, longitude $123^{\circ} 11' 00''$ W, elevation ca. 65 m) (Figure 1). The lake lies approximately 16 km east of the Coast Range, and 35 km west of the Cascade Range foothills. Beaver Lake itself occupies an oxbow/meander bend that is ca. 1.2 km in length, and has an average width of ca. 50 meters. At the end of summer, the deepest part of the lake is generally less than 1.5 m. Beaver Lake and its meander bend are associated with the Winkle geomorphic surface, an alluvial terrace through which the Willamette River and its tributaries have incised over the last 5,000 to 12,000 years (Balster and Parsons 1968).

Modern Vegetation

The Willamette Valley is considered a distinct vegetation province by most biogeographers (Franklin and Dyrness 1988, Hitchcock and Cronquist 1973, and others). Due to reduced precipitation, summer warmth, and moisture stress, the vegetation on the valley floor differs markedly from the Tsuga heterophylla Zone that characterizes the

lower elevations of adjacent Coast and Cascade ranges (Franklin and Dyrness 1988). Franklin and Dyrness (1988) consider the present vegetation in the valley a semi-natural mosaic, also referred to as the Interior Valley or Pinus-Quercus-Pseudotsuga Zone. Cultivated grass fields presently occupy all upland Winkle surfaces surrounding Beaver Lake. A narrow belt of non-cultivated land around the lake is composed predominantly of Populus trichocarpa (black cottonwood), Salix spp. (willows), Fraxinus latifolia (Oregon ash) and Quercus garryana (Oregon white oak), with understory of Oemleria cerasiformis (Indian plum), Rhus diversiloba (poison oak) and Symphoricarpos albus (snowberry). Beaver Lake is presently a shallow eutrophic system, with the littoral zone dominated by wetland vegetation, including Phalaris arundinacea (reed canarygrass), Spiraea douglasii (hardhack), Ludwigia palustris (water-purslane), Nuphar polysepalum (yellow pond-lily), and Lemna sp. (duckweed). Larger strips of bottomland hardwood forest, composed largely of Acer macrophyllum (bigleaf maple) and Populus trichocarpa, occupy floodplains along the Willamette River (ca. 5 km to the west) and the Calapooya River (ca. 2 km to the east).

Pre-Euro-American Vegetation

Survey notes from the early 1850s by the General Land Office (GLO) provide detailed documentation of vegetation types existing immediately before large-scale settlement by Euro-Americans. These notes have been used by a number of researchers to examine pre-Euro-American vegetation in portions of the Willamette Valley (Habeck 1961, Johannessen et al. 1971, Towle 1982, Christy et al. 1997, Whitlock and Knox, in review). Vegetation preceding settlement was a complex mosaic of Quercus woodlands and savannas, coniferous forests, grasslands (ranging from moist to dry), and extensive riparian gallery forests. The 1853 GLO survey notes indicate that Beaver Lake and the rest of the meander bend supported a large Salix/hardwood swamp. Based on the digitized GLO maps (see Christy et al. 1997), a 10.3 km² area centered on Beaver Lake supported ca. 82% prairie (mostly on the upland surface immediately east of the lake), 13% oak savanna, 2% shrub land (which included hardwood swamp), 0.8% closed bottomland forest, and 2.2% unknown composition. The presettlement Salix swamp was significantly reduced, and the surrounding area converted to intensive agriculture by the time of the first aerial photography in 1935.

CHAPTER IV

METHODS

Field Procedures

Sediment cores were recovered from Beaver Lake from a floating platform in summer of 1993. A 5-cm-diameter modified Livingstone corer was used to obtain one long core, which was collected from the center of the oxbow lake. Water depth at time of coring was 0.79 m. An 8-cm-diameter plastic gravity sampler was used to recover recent flocculant sediments and the mud-water interface, referred to as the short core. The long core (complete record of lake sediments to bedrock) was extruded as 1 meter drive lengths on site and wrapped in plastic and foil. The short core was sectioned into 1-cm-long intervals on-site, and samples were stored in plastic bags. All recovered sediments were refrigerated at the University of Oregon Paleoecology Laboratory, in the Department of Geography.

Laboratory Procedures

Lithological characteristics of each meter segment of the long core were described upon observation of longitudinally sliced sections. Color, presence of tephra layers, sand lenses, and organic layers were noted. Differences in particle size composition, and matrix coloration were used to separate lithologic units.

Fourteen sediment samples from the upper 45 cm of the short core were submitted to D. R. Engstrom of the Limnological Research Center, University of Minnesota for ^{210}Pb age determinations. Chronologic control in the long core was provided by one AMS ^{14}C date, eight bulk sediment radiocarbon dates, and the well-dated Mazama ash layer (Bacon 1983, Hallett et al. 1997).

Magnetic susceptibility measures erosion associated minerogenic inputs, and can also quantify iron magnetic minerals that are formed from high iron soils during heating (Rummery 1983, Thompson and Oldfield 1986). MS was measured in the long core at 2-cm intervals between 0.00 and 1.35 m depth, and at 1-cm intervals between 1.35 m and the Mazama ash layer at 4.96 m depth. Unrecovered gaps occurred at 1.87 - 2.22 m and 4.21 - 4.34 m depth. Subsample of 8 cm³ from each cm of the core were measured in a cup-coil

magnetic susceptibility sensor made by Sapphire Instruments. The Magsus.pas software program developed by David Adam (USGS) (pers. comm. 1993) and modified by S. L. Shafer (pers. comm. 1994) was utilized. Four repeated measures were averaged for each sample, and air calibration separated each sample. Output was converted to concentration values of electromagnetic units (emu/cm^3). Magnetic susceptibility was not analyzed on the short core.

Analysis of pollen followed standard techniques described in Faegri et al. (1989). The long core was sampled for pollen at 4 cm intervals above Mazama ash, and 8-30 cm intervals below Mazama. The short core was sampled for pollen every 5 cm in the upper 60 cm. Tablets with known amounts of Lycopodium spores were added to samples to allow calculation of pollen concentrations ($\text{grains}/\text{cm}^3$) and pollen accumulation rates ($\text{grains}/\text{cm}^2/\text{yr}$). Pollen was identified and tallied at magnifications of 400x and 1000x. M. A. Worona identified grains to lowest possible taxonomic resolution and tallied pollen abundances. Pinus monticola-type pollen included the haploxylon pines (western white pine [P. monticola], sugar pine [P. lambertiana], and potentially whitebark pine [P. albicaulis]). P. contorta-type pollen included diploxylon pines (lodgepole pine [P. contorta] and ponderosa pine [P. ponderosa]).

Pseudotsuga/Larix-type pollen was considered to be from Pseudotsuga menziesii, since Larix grows on the east slope of the Cascade Range (Franklin and Dyrness 1988). Botanical nomenclature follows Hitchcock and Cronquist (1973).

Methods of charcoal analysis on the long core follow those outlined in Millspaugh and Whitlock (1995) and Long et al. (1998). Charcoal abundance was tallied in alternating centimeter samples from the top of the long core. Samples were disaggregated by soaking for ca. 12 hours in sodium hexametaphosphate (Calgon). Sediment was gently washed through two nested screens, of 0.250 and 0.125 mm mesh size. Sample volumes of 2.5 cm³ were examined from the upper 1.34 m. Sample volumes were reduced to 1.25 cm³ below 1.34 m, due to high charcoal abundance. Charcoal particles were tallied with a binocular microscope at 50x magnification for all samples, and expressed as concentrations (number of charcoal particles/cm³).

Data Analysis

Pollen percentages of terrestrial taxa were calculated based on a sum of all non-aquatic taxa in the pollen sums. Percentage curves for aquatic taxa are based upon a combined sum that includes both terrestrial and aquatic taxa. A

constrained cluster analysis program (CONISS: Grimm 1988) was used to delineate 6 pollen zones. Pollen zones are characterized by within-cluster dispersion greater than 1.0. Accumulation rates were calculated for pollen (PARs), charcoal, and MS by dividing concentration data by deposition times (yr/cm) as calculated from the long core age-depth model. MS accumulation rates are expressed as $\text{emu}/\text{cm}^3/\text{yr}$. Charcoal accumulation rates are expressed as number of particles/ cm^2/yr . Due to very high background charcoal abundances and likelihood that fires may have occurred frequently, we did not attempt to identify peaks associated with discrete fire events, as has been done in forested systems characterized by infrequent burning regimes (Clark 1990, Millspaugh and Whitlock 1995, Long et al. 1998).

CHAPTER V

RESULTS

Core Lithology

The Beaver Lake long core was 7.87-meters long, and was collected in 8 drives before reaching basal gravel substrate (Figure 2). No discontinuities in the long core exceeded 5 cm in length. The upper ca. 14 cm of flocculant sediments were analyzed only in the short core.

Sediments above approximately 4.00 m depth in the long core were yellowish brown gyttja (10 YR 2/2, 5 YR 2/2) mixed with peat. Distinct layers of coarse organic detritus occurred at ca. 3.20, 3.50, and 3.75 m depth. Between depths of ca. 4.00 m and 5.75 m, sediments were yellowish brown (10YR 4/2) clay and silt mixed with gyttja. The ash layer associated with the eruption of Mt. Mazama occurred between depths of 5.72 and 5.74 m depth. Sand lenses occurred at depths of 4.52, 5.02, 5.26, and 5.59 m. Thin transverse sand/silt striations were abundant between depths of 5.78 m and 7.55 m. These striations were fine silt and clay (10 YR 2/2, 10 YR 5/4, and 10 Y 4/2) in a mixed matrix

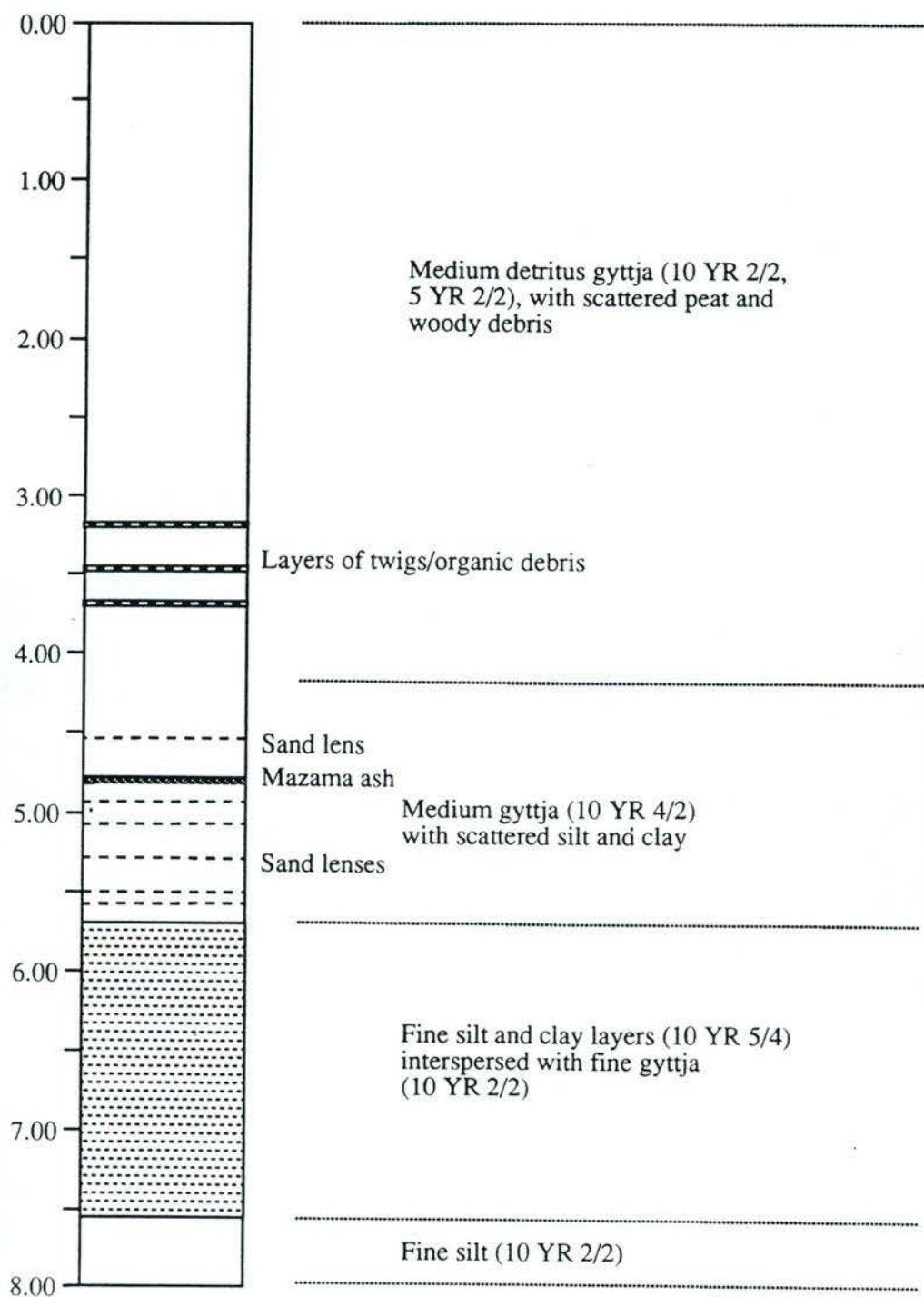


Figure 2. Lithology of long core, Beaver Lake, Oregon.
 (Soil codes from Munsell Color Charts, Kollmorgen Instrument Corp. 1994).

of clay and gyttja (5 Y 3/2).

The long core is similar in length to the six WV sediment cores (mean depth 7.0 m.) studied by Hansen (1947). General lithology was similar between Beaver Lake and Hansen's three valley floor sites of meander/fluvial origin (Hansen 1947). These valley floor sites demonstrate similar depositional histories, which include initial fluvial inputs (reflected in sand and silt components) and accumulations of open-water sediments (gyttja, limnic peat), followed by emergent wetland remains (fibrous peat). Layers of sands and silts likely transported by moving water appear in bottom of Lake Labish (6.0-7.0 m depth), and Onion Flat sediments (9.0-12.0 m depth) (Hansen 1947), as well as at Beaver Lake. Upper sediments are fibrous peats at all these sites.

Chronological Models

Nine radiocarbon dates and the accepted age of Mazama ash were incorporated into a weighted, third-order polynomial function (as per Grigg and Whitlock 1998) for development of the long core age-depth model (Table 1 and Figure 3). All dates were converted to calendar years

before present (Stuiver and Reimer 1993). Dates were weighted from 0-1, with highest confidence value (1.0) assigned only to the well-dated Mazama ash (Hallett et al. 1997). Each radiocarbon date was weighted based on the ratio of standard deviation of measured ^{14}C age to calibrated age: i.e., the AMS date from 6.75 m depth (std. dev. = 101 yr; calibrated age = 10,250 cal yr BP; std. dev./age = 0.0098) received a weighting of 0.90, and the bulk sediment date from 0.68 m depth (std. dev. = 65 yr; calibrated age = 1,290 cal yr BP; std. dev./age = 0.05) was assigned a weight of 0.10. The age-depth curve suggests high sedimentation rates during the very early Holocene and again during Euro-American settlement, with slower deposition rates in the middle Holocene. This pattern is supported by lithologic evidence: fluvial (likely allochthonous) inputs during the early Holocene, and highly organic sediments (likely associated with shallow, eutrophic lake of historical time) during the late Holocene. The basal date of the long core is 10,998 cal yr BP (9860 ^{14}C yr BP), while correlation with the short core suggests the top of the long core dates ca. 50 cal yr BP (1945 AD).

The short core chronology is based on ^{210}Pb dating of the upper organic sediments (Table 2 and Figure 4). Standard deviations increase with depth and age, with the

TABLE 1: Radiocarbon dates and assigned weights used to establish age-versus-depth relations for long core, Beaver Lake, Oregon.

Depth below top of core (m)	Material Dated	Uncalibrated ¹⁴ C age (¹⁴ C yr BP)	Calibrated age +/- 1 s.d. (cal yr BP) ^a	Assigned weight	Lab number or reference
0.63-0.70	Bulk sed.	1370 +/- 80	1320 (1290) 1190	0.10	Beta-85262
1.01-1.11	Bulk sed.	1130 +/- 60	1070 (1050, 1040, 990) 960	0.25	Beta-81660
2.18-2.28	Bulk sed.	2570 +/- 60	2750 (2740) 2550	0.25	Beta-72836
2.39-2.49	Bulk sed.	2920 +/- 60	3200 (3060) 2950	0.25	Beta-109116
2.91-3.01	Bulk sed.	2940 +/- 60	3210 (3070) 2970	0.10	Beta-81661
3.90-4.00	Bulk sed.	5710 +/- 90	6640 (6480) 6410	0.25	Beta-81662
4.20-4.30	Bulk sed.	6070 +/- 120	7150 (6900) 6780	0.25	Beta-109117
4.79-4.81	Mazama ash	6840 +/- 50	7660 (7630) 7580	1.00	Bacon 1983
6.70-6.80	Std. AMS	9290 +/- 50	10350 (10291,10250,10220) 10150	0.90	Beta-109118
7.09-7.19	Bulk sed.	9860 +/- 360	12020 (11000) 10480	0.25	Beta-72837

^a Calibration to calendar years based on Stuiver and Reimer (1993).

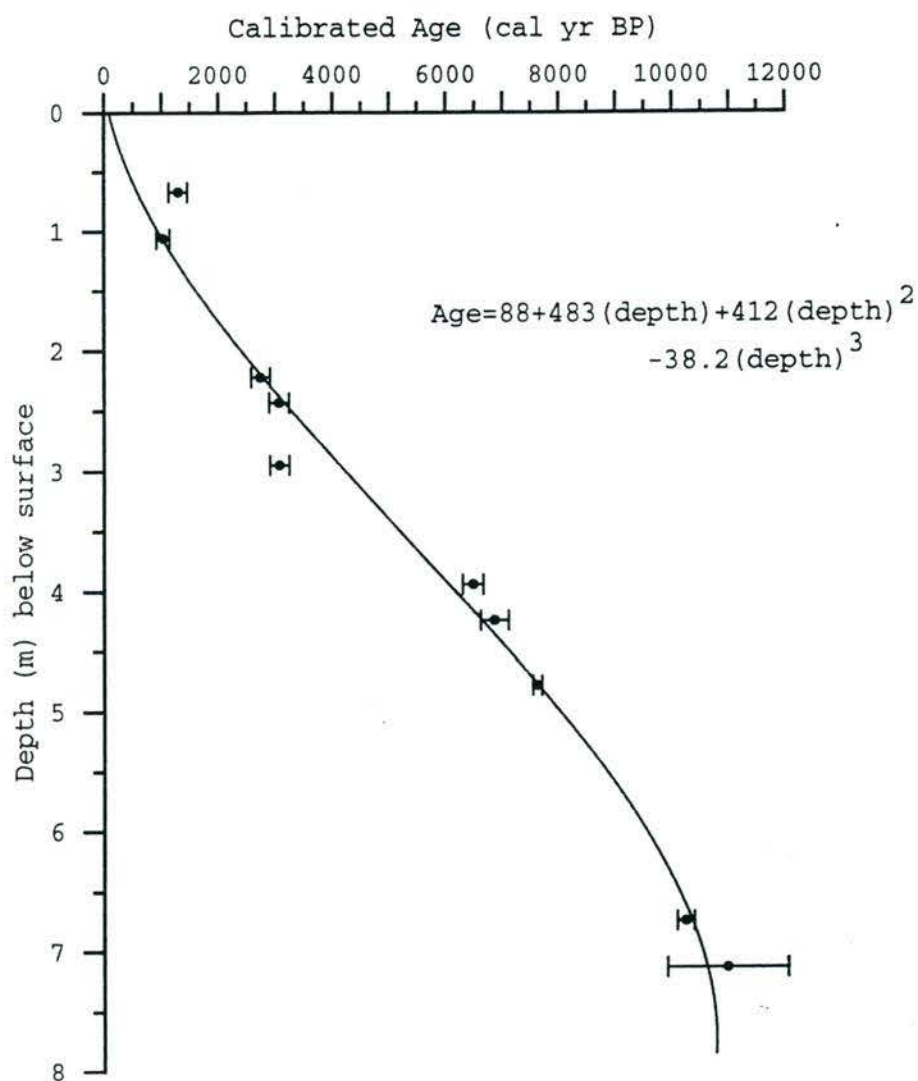


Figure 3. Age-versus-depth model for long core, Beaver Lake, Oregon. (See Table 1 for radiocarbon dates).

greatest deviation (± 59.65 yrs) associated with the deepest sample. The deepest sample analyzed (45 cm) yielded an estimated date of 1844 AD. Sedimentation rates vary from 0.0211 to 0.839 grams/cm²/yr.

Magnetic Susceptibility

Magnetic susceptibility (MS) provides a measure of magnetized particles or iron minerals in sediments, and offers a means of quantifying relative erosion inputs to a basin (see Rummary 1983, Thompson and Oldfield 1986). Other paleoecological researchers have used MS to examine erosional processes that may be associated with burning around lake basins (Millspaugh and Whitlock 1995, Long et al. 1998). At Beaver Lake, MS accumulation rates are highest immediately above the Mazama ash layer (ca. 4.78 m depth; ca. 6800-5200 cal yr BP). From ca. 5200-4300 cal yr BP, MS remains moderately high before declining to its lowest values through most of the late Holocene (ca. 4300-250 cal yr BP). Within the last ca. 250 years (uppermost 0.10 m of the long core), MS accumulation rates attain highest levels in the record (ca. 5 emu/cm²/yr). This peak coincides with the modern peak in Poaceae pollen, and likely indicates conversion of the area surrounding Beaver Lake to

TABLE 2: ^{210}Pb dates, standard deviations, and accumulation rates, Beaver Lake, Oregon.^a

Depth (cm)	Date (AD)	Std. Dev. (yr)	Sed. accum. rate (g/cm ² /yr)
1-2	1992.9	1.39	0.0791
5-6	1988.8	1.48	0.0745
9-10	1983.5	1.61	0.0704
13-14	1976.7	1.85	0.0561
15-16	1973.4	1.96	0.0710
17-18	1970.2	2.10	0.0776
21-22	1963.8	2.32	0.0839
25-26	1957.7	2.69	0.0691
29-30	1948.4	3.44	0.0487
33-34	1935.4	4.87	0.0391
35-36	1924.4	6.74	0.0326
37-38	1912.4	9.60	0.0316
41-42	1883.6	20.02	0.0245
45-46	1843.5	59.65	0.0211

^a Data from Limnological Research Center (D. R. Engstrom, University of Minnesota).

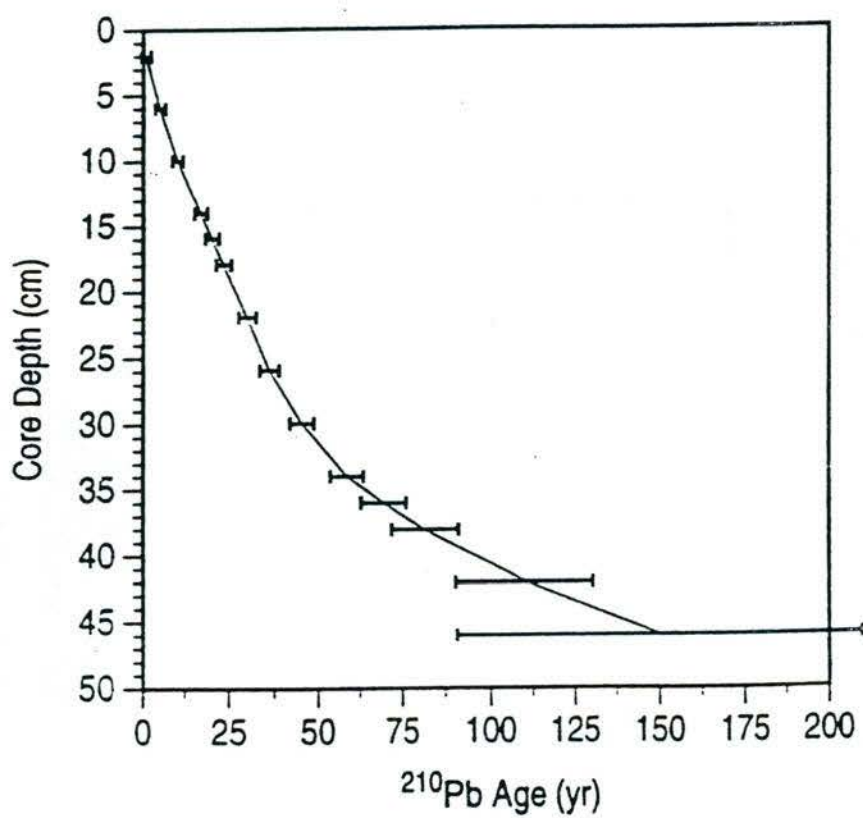


Figure 4. Age-versus-depth model for short core, Beaver Lake, Oregon. (See Table 2 for ^{210}Pb dates).

industrial grass-seed farming.

Long Core Pollen Record

The Beaver Lake record was divided into six pollen zones based on constrained cluster analysis of pollen percentage data (Figure 5). Pollen accumulation rates (PARs) are presented in Figure 6.

Zone BL-1 (7.78-4.57 m; ca. 10,998 to 7250 cal yr BP)

Alnus rubra (red alder) dominates Zone BL-1, but declines from ca. 45% at bottom of the record to ca. 15% at top of the zone. Corylus (10-25%), Pseudotsuga (10-20 %) and Quercus (5-15%) are also prominent. These taxa achieve their highest percentages and pollen accumulation rates (PARs) in this zone. Poaceae (grasses), Tsuga heterophylla (western hemlock), Thuja-type (western red cedar), Spiraea and Salix are characterized by very low PARs. Total arboreal PARs (350-450 grains/cm²/yr) are the highest in the record, while aquatic PARs are the lowest (< 50 grains/cm²/yr). Total PARs (< 2000 grains/cm²/yr) are the lowest of the record.

Quercus and Pseudotsuga figured prominently in the

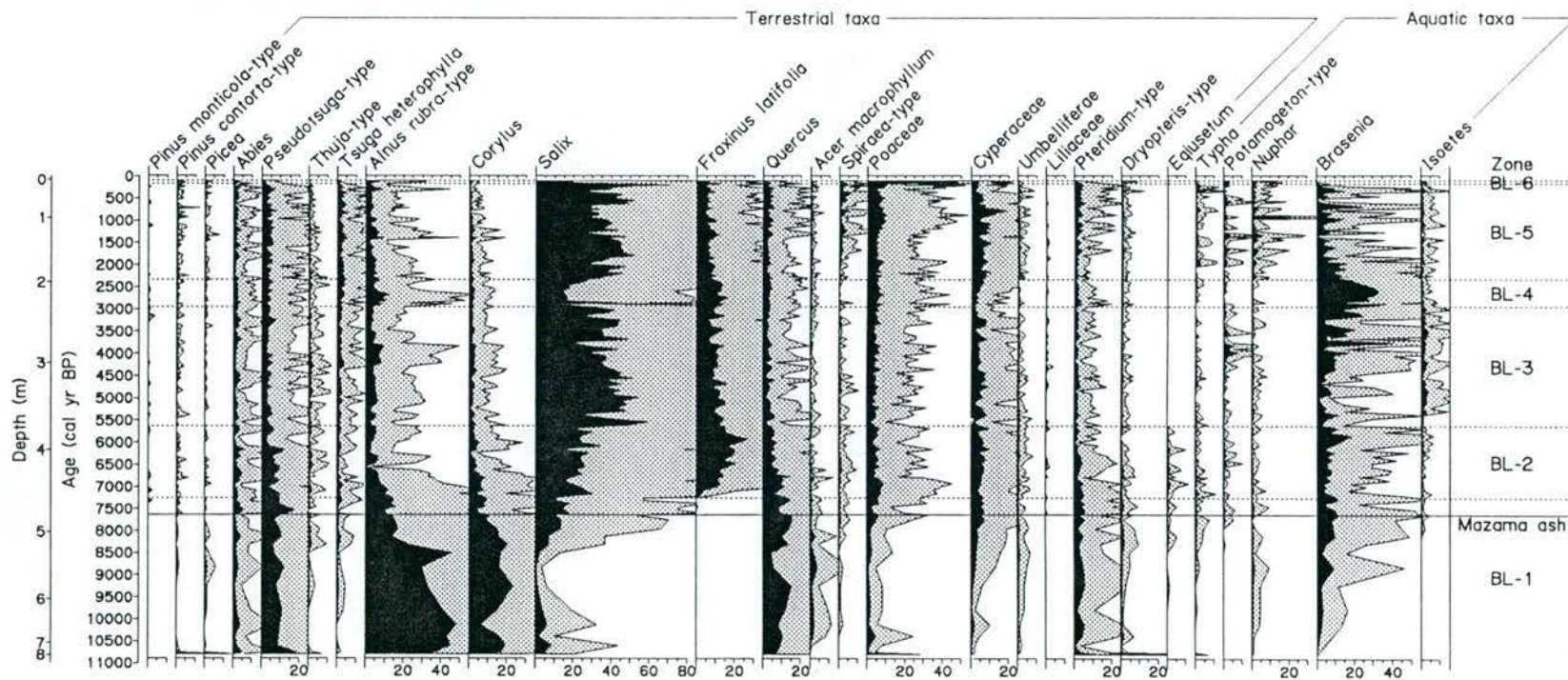


Figure 5. Selected pollen percentage data from long core, Beaver Lake, Oregon. (Shading denotes 5x exaggeration).

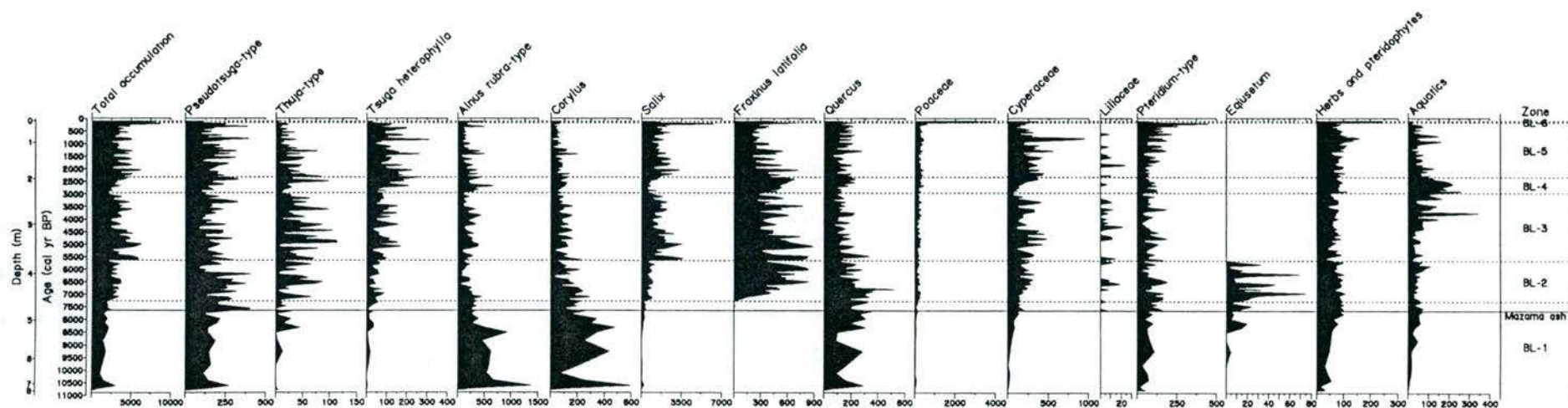


Figure 6. Selected pollen accumulation rates (PARs; grains/cm²/yr) from long core, Beaver Lake, Oregon.

drier-than-present valley floor woodland, and Alnus rubra and Pteridium (bracken fern) were probably common in disturbed areas and surrounding foothills. The abundance of Corylus and Alnus rubra, both of which produce abundant pollen that travels well (Faegri et al. 1989), suggests their presence in the local valley floor as well as in foothills of the surrounding Coast and Cascade ranges. High arboreal PARs and low herbaceous PARs indicate a relatively closed canopy of the aforementioned taxa near Beaver Lake.

Zone BL-2 (4.57-3.73 m; ca. 7250 to 5640 cal yrs BP)

Fraxinus (Oregon ash) first appears and increases through the zone (up to 25% at top of zone; PARs 0-750 grains/cm²/yr.). Salix increases from 15 to 25% through BL-2, but PARs remain consistent at ca. 1000 grains/cm²/yr. Quercus percentages decline through the zone from 10 to 5% at top, and PARs at the base of the zone are the highest in the core (ca. 475 grains/cm²/yr). Alnus rubra-type and Corylus decline in percentage and PARs toward the top of zone. Poaceae increases (steadily above 5%, PARs 150-200 grains/cm²/yr) over BL-1 levels. Liliaceae pollen first appears in this zone (5-15 grains/cm²/yr). Equisetum (horsetail) percentages are low (<5%), but PARs are the

highest in the core (10-70 grains/cm²/yr). Total herb and pteridophyte PARs are high (80-100 grains/cm²/yr), and total PARs (3000-4000 grains/cm²/yr) are above those in Zone BL-1.

Zone BL-2 documents the transition to a more mesic landscape in the mid-WV. The increasing abundance of Fraxinus and Salix, both of which produce pollen that is not widely dispersed (Faegri et al. 1989), indicate the development of mesic forests in riparian zones near Beaver Lake. Elevated Spiraea (25-50 grains/cm²/yr) and Cyperaceae (100-300 grains/cm²/yr) also suggest increased available moisture in the immediate area. Pseudotsuga and Quercus, both of which are near their highest PARs and percentages at the base, decline to the top of Zone BL-2, as PARs of mesic taxa (e.g. Fraxinus and Cyperaceae) increase. Increased Poaceae and total nonarbooreal pollen (NAP) suggest decreased overall canopy coverage in the local landscape toward the top of Zone BL-2.

Zone BL-3 (3.73-2.32 m; ca. 5640 to 2950 cal yr BP)

High Salix percentages (25-60%) characterize Zone BL-3. The Quercus percentage is largely unchanged, and PAR may decline very slightly through the zone. Fraxinus percentage and PAR decline slightly through the zone. Thuja PARs (max.

100 grains/cm²/yr) are generally the highest in the record. Aquatic PARs increase to 150 grains/cm²/yr toward top of zone. Total PARs ranges between ca. 2500 and 5500 grains/cm²/yr.

The high percentages of Salix and Fraxinus indicate the prominence of these riparian taxa close to Beaver Lake. During this time, Thuja plicata, a modest pollen producer/disperser (Heusser 1978, Faegri et al. 1989), may have been more abundant than before on the mid-WV floor near Beaver Lake. Lower Pseudotsuga and Quercus PARs and percentages than in Zone BL-2 may reflect an opening of the mixed woodland on drier sites, and more Quercus-savanna coverage.

Zone BL-4 (2.32-1.96 m; ca. 2950 to 2330 cal yr BP)

Zone BL-4 spans approximately 600 years and is characterized by steep declines in Cyperaceae percentage and PARs (ca. 375-100 grains/cm²/yr), and Salix percentage (down from 40 to 15 %) and PARs (2000 to 1000 grains/cm²/yr). Brasenia (water shield) increases from 20 to 35%, and its PARs reach a maximum exceeding 150 grains/cm²/yr. Fraxinus PARs are high (300-500 grains/cm²/yr) relative to BL-5, and Fraxinus and Cyperaceae increase sharply toward the top of

the zone. Spiraea PARs are low (ca. 25 grains/cm²/yr). Total PARs are low at the base of Zone BL-4 (ca. 2000 grains/cm²/yr) and increase toward the top (ca. 4000 grains/cm²/yr). Total aquatic PARs increase from ca. 100 to 210 grains/cm²/yr, then retreat to 100 grains/cm²/yr at the top of the zone.

Zone BL-4 probably records a period of low water or short term drying at Beaver Lake. Changes in littoral hydrophytes can be considered indicators of water level variation (Barnosky 1981, Singer et al. 1996). High PAR and percentage in Brasenia and other aquatic taxa suggests more littoral zone and decreased water depths in the lake basin. Decreased Salix (PAR and percentage) and Spiraea (PAR) also suggest decreased available moisture. The small increase in Quercus PAR is consistent with slightly increased oak coverage in response to short-term drying in the mid-WV around Beaver Lake.

Zone BL-5 (1.96-0.14 m; ca. 2330 to 160 cal yr BP)

Pollen zone BL-5 is generally similar to Zone BL-3, with Salix dominating the zone by percentage (25-60%). Fraxinus is also prominent, and declines from base to top of zone (10 to 5%, and 700 to 300 grains/cm²/yr). Tsuga and

Spiraea achieve their highest PARs in the record (both > 250 grains/cm²/yr). Quercus, Alnus rubra, Pseudotsuga, and Poaceae remain steady at ca. 5-10%. Nuphar is present in low amounts (< 5%). Thuja and Fraxinus PARs are lower than in Zone BL-3. Pteridium PARs increase through the zone to reach its highest values (ca. 450 grains/cm²/yr) at the top. Tsuga, while not a prolific pollen producer, can be transported relatively long distances on prevailing winds (Minckley 1999), and is likely a regional signal from slopes of Cascade and Coast ranges (Sea and Whitlock 1995, Worona and Whitlock 1995). Total PARs range between ca. 3000 and 5000 grains/cm²/yr.

Salix and Fraxinus remain common around Beaver Lake through Zone BL-5. The late Holocene pollen signal suggests the area around Beaver Lake was a heterogeneous mix of vegetation types similar to the landscape first described by the 1853 General Land Office survey notes. Included in this mosaic were areas of mixed upland forest (Quercus and Pseudotsuga, with Alnus), more open savanna (Quercus, Pteridium and Poaceae), riparian woodlands (Fraxinus and Salix), and prairie (Poaceae, with some Liliaceae).

Zone BL-6 (0.14-0.01 m; ca. 160 to 60 cal yr BP)

The thin uppermost pollen zone is dominated by a discrete peak in Poaceae ($> 40\%$, >3500 grains/cm²/yr). Pteridium declines steeply to ca. 100 grains/cm²/yr from its maximum. Total PARs increase steeply to > 8000 grains/cm²/yr. Salix is well represented (ca. 20%), but less than in the preceding BL-5 zone. Pseudotsuga, Fraxinus, Alnus rubra and Quercus are all present in small amounts (3-10%), as are Spiraea, Cyperaceae, and Nuphar. Total arboreal PARs drop steeply to their lowest values in the record (ca. 200 grains/cm²/yr).

The uppermost long core sediments illustrate changes in mid-WV vegetation associated with mid-19th century Euro-American settlement. The Salix swamp in the Beaver Lake meander bend, as well as total woodland around the lake were reduced during this period. The conversion of the region to an intensely cultivated grass landscape is evident in the sharp increase in Poaceae pollen.

Short Core Pollen Record

Pollen percentage data in the short core (most recent sediments) reveal two trends associated with settlement of

the mid-Willamette Valley surrounding Beaver Lake (Figure 7). Most arboreal taxa (Quercus, Alnus rubra, Thuja, Pseudotsuga, Tsuga, Pinus, Abies, Fraxinus) remain stable throughout the short core strata at < 10%. Salix and Poaceae comprise 50 to 60% of grains throughout, but trade off in dominance from base to top of the short core. The base of the core (0.60-0.47 m depth) is dominated by Salix (ca. 35%), and Poaceae is subordinate (ca. 20%). Between 0.40 and 0.47 m depth (A.D. 1890-1843), Salix declines sharply and Poaceae increases toward the top of the record, where Salix occurs at low percentages (ca. 10%) and Poaceae reaches 55-60%. Ornamental/cultigens Juglans and elevated Brassicaceae appear in the short core record ca. A.D. 1940.

Charcoal

Absolute charcoal abundance and charcoal accumulation rates from the Beaver Lake long core are depicted in Figure 8. Charcoal accumulation rates are consistently low (2-6 particles/cm²/yr) above the Mazama ash until approximately 4100 cal yr BP. Between approximately 4100 and 2900 cal yr BP, charcoal accumulation rates alternate between periods of high accumulation (20-25 particles/cm²/yr), and periods of low accumulation (4-7 particles/cm²/yr). Charcoal

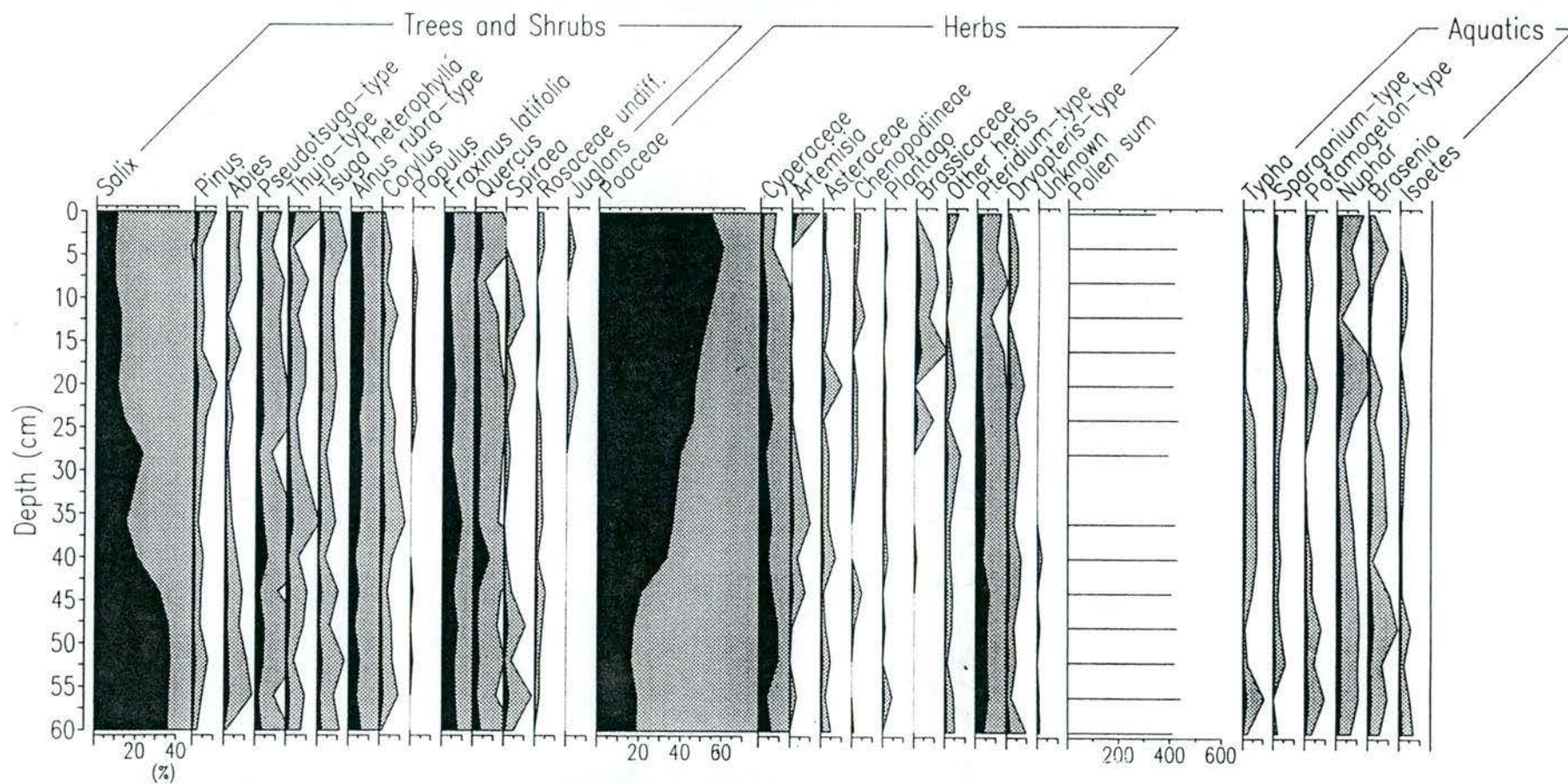


Figure 7. Selected pollen percentage data from short core, Beaver Lake, Oregon. (Shading denotes 5x exaggeration).

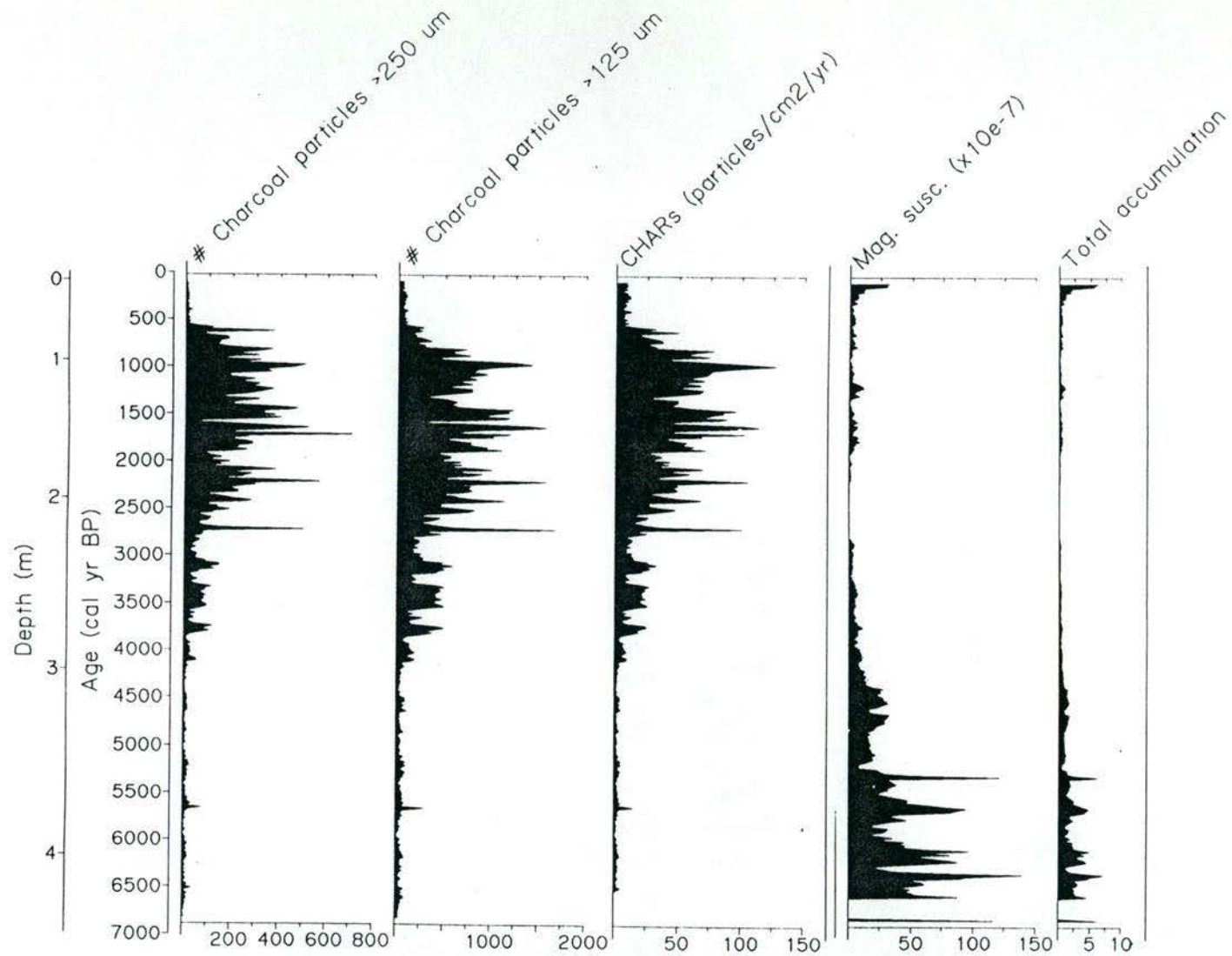


Figure 8. Long core charcoal accumulation rates (CHARs) and magnetic susceptibility, Beaver Lake, Oregon.

accumulation rates are highest (25-130 particles/cm²/yr) between ca. 2900 and 550 cal yr BP, and increase throughout that zone until ca. 1000 cal yr BP. Accumulation rates drop steeply following this maximum (between ca. 1000 and 550 cal yr BP). The last ca. 550 cal yr are characterized by steady, low accumulation rates (1-2 particles/cm²/yr).

Burned and unburned herbaceous material was abundant in middle and late Holocene sediments, and particularly within the period of high charcoal accumulation (2900 to 550 cal yr BP). The abundance of large particle charcoal (>250 μ m) indicates that the source of the burned materials was autochthonous and/or very local. The late-Holocene period of high charcoal accumulation at Beaver Lake is not paralleled by an elevated MS signal, as has been described in studies in other geologic regions (e.g. Millspaugh and Whitlock 1995). This may be a function of surrounding shallow slopes of Bashaw silty clays and Willamette silt loam soil types (SCS 1987), or it may relate to proximity, extent, or intensity of the burning (see MacDonald et al. 1991). If burning occurred on the surrounding flat geomorphic surfaces during the middle or end of summer dry season (with no pronounced precipitation to erode and transport surface soils), a low MS signal could be expected.

CHAPTER VI

DISCUSSION

The Beaver Lake record offers information on vegetation and fire history in the Willamette Valley that can be compared with other paleoecological studies and archaeological records from the Pacific Northwest (PNW), as well as with paleoclimatic model simulations that elucidate the nature of regional climatic changes (e.g. Thompson et al. 1993). The broad-scale climatic changes in the PNW during Holocene time are relatively well known, and have been attributed to changes in the amplitude of the seasonal cycle of insolation (Kutzbach and Guetter 1986, Kutzbach 1987). Maximum summer insolation and attendant drought were experienced throughout the PNW during the early Holocene (Whitlock 1992, Thompson et al. 1993). As summer insolation steadily decreased, regional climate shifted to late-Holocene conditions that were cool and effectively more moist than before (Whitlock 1992, Thompson et al. 1993). Modern climatic conditions were probably reached in the last 3000 years, although this timing varies within sub-regions (Whitlock 1992, Worona and Whitlock 1995).

Responses of local vegetation to these broad-scale changes in climate were probably mediated by local changes in disturbance regimes, as well as by a variety of site-specific characteristics. Cwynar (1987) and Long et al. (1998) demonstrated that climatic changes may initiate changes in fire frequencies, but whether a site burns may be contingent upon site location and vegetation. While vegetation-climate relationships on millennial time scales are relatively clear over the span of the Holocene, shorter-term climate changes, vegetation adjustments, and forcing mechanisms are less completely understood (Green 1982). I compare the mid-WV reconstruction based on Beaver Lake sediments with published reconstructions of Holocene environmental histories of the adjacent Coast Range, Cascade Range, Portland Basin, and Puget Trough (see Figure 9), and suggest patterns and mechanisms of vegetation change within the WV.

Early Holocene (ca. 10,998 to 7250 cal yr BP)

Throughout the Pacific Northwest, the early Holocene was a period of higher-than-present mean temperatures and decreased effective moisture (Barnosky et al. 1987, Kutzbach 1987). Warmer, drier conditions in the early Holocene at

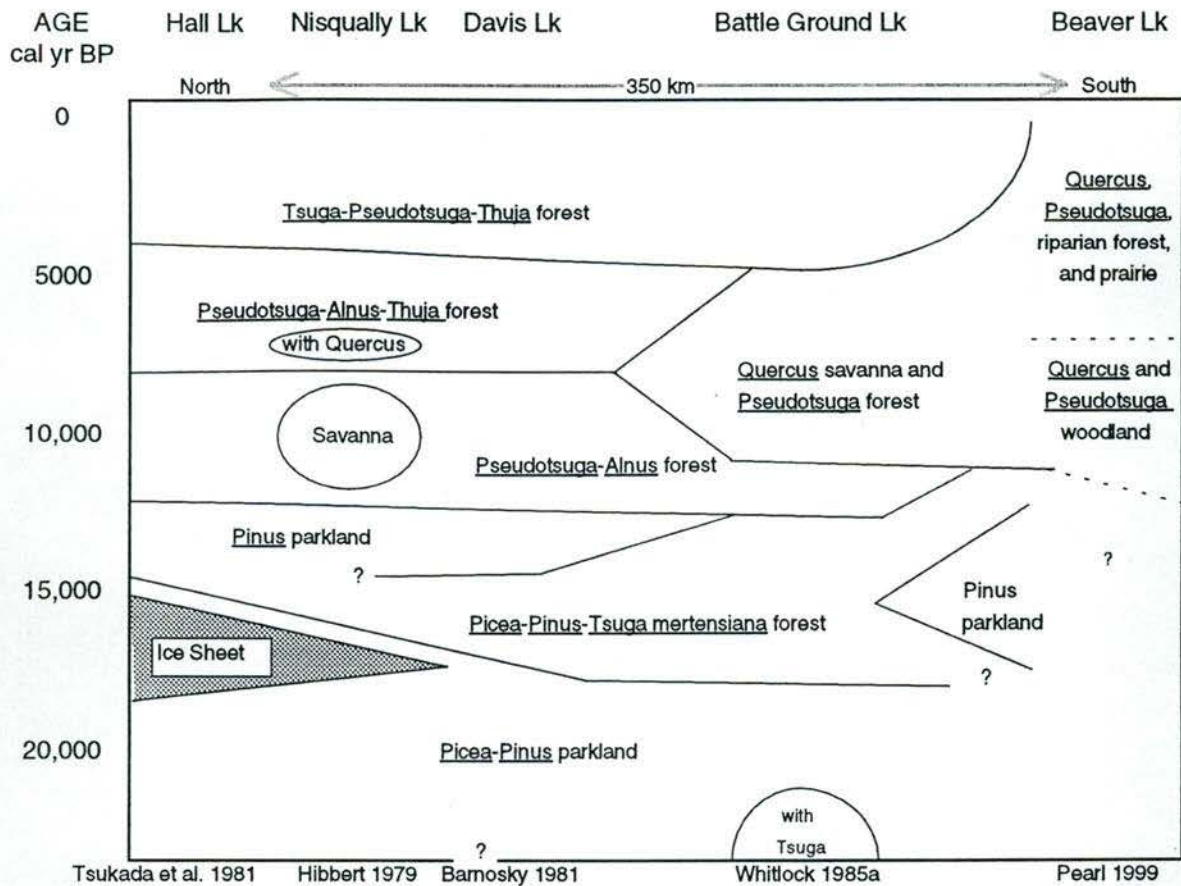


Figure 9. Holocene vegetation interpreted from five lowland lakes in the Pacific Northwest (modified from Barnosky (1985a) with authors permission).

Beaver Lake are evidenced by a suite of xerophytic (drought tolerant) taxa, including Quercus and Pseudotsuga (Minore 1979, Reigel et al. 1992), and disturbance-tolerant taxa, such as Corylus, Alnus rubra, Quercus, and Pseudotsuga (Thilenius 1968, Cole 1977, Reigel et al. 1992, Agee 1993, Rebertus and Burns 1997). These same taxa feature prominently throughout the PNW in the early Holocene. In the central Puget Trough, Pseudotsuga and Alnus rubra replaced late-glacial assemblages that included Pinus contorta and Picea engelmannii (Hibbert 1979). Quercus and Corylus appear in the early-Holocene woodlands, but attain their highest percentages in the middle Holocene (Hibbert 1979). These general patterns appear in two undated records from the WV floor, where the expansion of Pseudotsuga and Quercus follows periods of high Pinus contorta and Picea (Hansen 1947).

The same drought/disturbance-tolerant taxa (as well as Abies and Tsuga in lower abundance) are prominent near Little Lake in the central Coast Range between ca. 12,400 and 6800 cal yr BP, with Quercus reaching its highest percentages in the Holocene between 11,100 and 7800 cal yr BP (Worona and Whitlock 1995). Similarly, these taxa achieved maximum percentages in the early to middle Holocene

in the central Cascade Range, indicating that Quercus and Corylus may have extended their elevational ranges as much as ca. 500 meters above the valley floor (Sea and Whitlock 1995).

While the mid-Willamette Valley around Beaver Lake probably supported a xerophytic woodland during the early Holocene, the western Washington lowlands developed a more open Quercus-savanna/prairie landscape that persisted through the middle Holocene (Barnosky 1985a, Hibbert 1979). Records from the Portland Basin (Battle Ground Lake; Barnosky 1985a) and central Puget Trough (Nisqually Lake; Hibbert 1979) suggest that these regions were characterized by Quercus, Pseudotsuga, and a savanna/prairie herbaceous component. Such assemblages differ from the early-Holocene xeric woodland of the mid-WV. The early-Holocene savanna/prairie signature in the Portland Basin is characterized by low Corylus and conspicuous forbs of mesic prairies, such as Camassia, Umbelliferae, and Compositae (Barnosky 1985a). In contrast, the Beaver Lake pollen record lacks Compositae and Umbelliferae, and Liliaceae does not appear until after ca. 7500 cal yr BP. Furthermore, Poaceae is very poorly represented in the mid-WV during this time, and PARs of nonarboreal taxa are the lowest of the record. Thus, the Beaver Lake pollen data indicate a

partially closed woodland canopy within a relatively xeric landscape, while canopy coverage appeared to be less in the Portland Basin farther north.

While the early Holocene portion of the Beaver Lake charcoal record was not examined, records from other regions of the PNW suggest relatively frequent fires during that period. The prevalence of seral and disturbance-tolerant taxa could indicate more frequent fires in the Portland Basin around Battle Ground Lake (Barnosky 1985a) and in the central Cascade Range (Sea and Whitlock 1995). At Little Lake in the Coast Range, a similar pollen signal (Worona and Whitlock 1995) was associated with the shortest fire return intervals in the Holocene (Long et al. 1998).

Sedimentation rates at Beaver Lake were rapid (ca. 1.6 mm/cal yr) during the very early Holocene, equaled only by those of the most recent post-settlement strata. Magnetic susceptibility accumulation rates were the highest of the record, which likely reflects deposition of allochthonous minerals associated with a periodically-flooded environment. Abundant sand and silt layers between 10,500 and 9000 cal yr BP are consistent with greatest fluvial influence at Beaver Lake during the early Holocene. A sand lens above the Mazama ash suggests that high-energy fluvial inputs may have continued sporadically until after ca. 7000 cal yr BP.

Similar evidence of fluvially transported sediments during the late-glacial and early Holocene was also documented in Hansen's (1947) two sites in the northern Willamette Valley.

Middle Holocene (ca. 7250 to 4000 cal yr BP)

Paleoclimatic model simulations for the PNW suggest that the continued decrease in summer insolation between 6800 and 3200 cal yr BP resulted in cooler and moister conditions than in the early Holocene, but still warmer and drier conditions than today (Thompson et al. 1993). Coincident weakening of the Pacific subtropical high-pressure system also resulted in increased winter precipitation (Barnosky et al. 1987). Throughout the PNW, pollen records suggest that mesophytic (moderately moisture tolerant) vegetation expanded during the middle Holocene (Dunwiddie 1986, Cwynar 1987, Barnosky 1981, and others).

Stratigraphic and archaeological evidence suggest that the WV experienced a pronounced shift in drainage and active floodplain surfaces during the middle Holocene. An examination of bedding patterns around the transition between Winkle and Ingram geomorphic surfaces led Balster and Parsons (1968) to conclude that the shift in primary floodplains for the Willamette River and major tributaries

coincided with a period of significant erosion.

Archaeological evidence suggests that these changes occurred in the middle Holocene prior to 5500 cal yr BP (Cheatham 1988, Freidel et al. 1989, Connolly et al. 1997). Two of the most thoroughly radiocarbon-dated Kalapuyan settlement clusters further suggest that these environmental changes may have been valley-wide in geographic scope, and could have affected Native American settlement patterns (Cheatham 1988, Connolly et al. 1997). The Mill Creek archeological site cluster (38 dates, near Salem in the mid-WV) spans pre-settlement to ca. 5700 cal yr BP (Connolly et al. 1997). The Veneta/Long Tom River (southern WV) sediments have been radiocarbon-dated between present and ca. 5500 cal yr BP, but lack sediments between ca. 5500 and 8000 cal yr BP (O'Neill 1987, Freidel et al. 1989). Based on the age distributions of artifacts from these archeological study sites, Connolly et al. (1997) have hypothesized that these changes in drainage were sufficient to alter Kalapuyan settlement patterns. The timing of these changes may be associated with what Worona and Whitlock (1995) suggested was the onset of a cooler- and moister-than-present period in the central Coast Range in the middle Holocene (Connolly et al. 1997).

Several attributes of the Beaver Lake sediment record

are consistent with the hypothesis that the transition of active floodplain from Winkle to Ingram surface was associated with an important environmental/geomorphic change. Sand and silt lenses, which occur intermittently in the older sections of the core, are not evident above ca. 4.50 m depth. This lithological transition to more uniform gyttja and organic sediments suggests the Beaver Lake meander bend was not significantly fluvially influenced after ca. 7000 cal yr BP. High MS accumulation rates also characterize sediments between 3.60 and 4.50 m depth, indicating that allochthonous mineral inputs were probably more substantial between ca. 7600 and 5500 cal yr BP than later. Increased local prominence of Equisetum sp. (horsetails) coincides with the elevated MS, and provides supporting evidence for a period of fluvial activity and/or substrate change. Equisetum species, which are practically absent at Beaver Lake with the exception of this period between 5600 and 7200 cal yr BP, are proficient colonizers of newly exposed substrates.

The decreased summer drought of the mid-Holocene, perhaps in tandem with the redefined drainage system, allowed the expansion of local mesophytic and hydrophytic taxa near Beaver Lake. High percentages and PARs of Salix (willow), Fraxinus (Oregon ash), Spiraea (hardhack),

Equisetum (horsetails), and Cyperaceae all reflect a general increase in available moisture. Salix and Fraxinus are relatively poor pollen producers and dispersers (Heusser 1978, Faegri et al. 1989), and such an increase in pollen likely represents increasing coverage close to Beaver Lake. Both remain prominent local taxa through the middle and late Holocene to present.

With the exception of Quercus, Hansen (1942, 1947) limited his paleoecological analysis to coniferous taxa. Consequently, almost nothing is known of the Holocene history of other arboreal taxa in the WV. One of the most striking features of the Beaver Lake record is the establishment and rapid rise to dominance of Fraxinus, which reaches ca. 25% and PARs as high as 800 grains/cm²/year almost immediately after its appearance in the region. The immigration of Fraxinus into lowland landscapes of western Oregon and Washington within the Holocene makes it unique among prominent PNW arboreal taxa. Late-Quaternary pollen stratigraphies throughout the PNW fail to document its presence prior to the early Holocene (Barnosky 1981, Barnosky 1985a, Worona and Whitlock 1995), and its initial occurrence is relatively synchronous across a wide geographic range.

The early and middle Holocene increases in available

moisture may also have resulted in the initial development of wet prairie habitats in the mid-WV. Overall herbaceous PARs are consistently higher through the mid- and late Holocene than during the more xeric early Holocene. Poaceae percentages and PARs are 2 to 3 times higher in the middle Holocene than in the early Holocene. The increase in Poaceae, which occurred ca. 7200 cal yr BP, coincides with increases in other open-canopy mesic herbaceous taxa, including representatives of the Cyperaceae (sedges and allies), and Liliaceae. After being absent in the early Holocene, pollen of Liliaceae (now split into several families) is consistently present in low amounts through post-Mazama time. This contrasts with records from the western Washington lowlands, where vegetation types indicative of open prairie/savanna occurred in the early and mid-Holocene (ca. 9000 to 5000 cal yr BP at Battle Ground lake in Portland Basin). The family Liliaceae is well-represented in remaining native prairie remnants (including genera Allium, Camassia, Zigadenus, Dichelostemma, Tritelea, and Calochortus). Pollen of Camassia or Zigadenus, both entomophilous genera, were not found in the Beaver Lake record.

Due to its sensitivity to fire and keystone position in savanna landscape types (Thilenius 1968, Minore 1979, Plumb

and McDonald 1981, Riegel et al. 1992), the development of Quercus-savanna/prairie in Pacific Northwestern lowlands has been a subject of interest to paleoecological and anthropological researchers in the region (Hansen 1947, Barnosky 1985a, Leopold 1987, Cheatham 1988, Franklin and Dyrness 1988, Connolly et al. 1997, and others). The Beaver Lake sediments suggest that the Holocene history of Quercus in the mid-WV is quite different from the lowlands of western Washington. Quercus maxima and post-peak declines occur later in the Portland Basin and Puget Trough, and late Holocene Quercus coverage (based on percentage and PAR) was lower in those regions than in the mid-WV. Quercus percentages remain high in the Portland Basin from ca. 10,300 to 5000 cal yr BP (Barnosky 1985a), whereas the decline of Quercus in the mid-WV occur soon after its maxima around 7000 cal yr BP. At Nisqually Lake in the Puget Lowlands, Quercus influx and percentage reach their maxima after ca. 7000 cal yr BP (Tsukada 1981). Additionally, the magnitude of the decline is less at Beaver Lake, where percentages drop from ca. 10 to 5%, PARs decrease from ca. 300 to 200 grains/cm²/yr, and Quercus averages 4 to 5% through the late Holocene to present. Near Battle Ground Lake in the Portland Basin, Quercus declined from ca. 9 to 2%, and remained ca. 1% through the late Holocene (Barnosky

1985a). Farther north in the Puget Trough (Nisqually Lake), Quercus reached a maximum of ca. 11%, after which it declined to a stable 3% through the late Holocene (Hibbert 1979). Thus, the history of Quercus in the lowland PNW has been spatially complex, and while its overall geographic range appears not to have changed over the Holocene, it has probably retreated substantially from foothill environments in the northern segments of its range (Puget Trough and Portland Basin). The WV has remained the center of its range through Holocene time to present.

Other xerophytic and disturbance-favored taxa (e.g. Corylus and Alnus rubra) also decrease in abundance in the middle Holocene, declining more substantially in percentages and PARs between 9500 and 6500 cal yr BP. Pseudotsuga may decline very slightly in the last ca. 5500 cal yrs. Given the moderate pollen production of Quercus and Pseudotsuga (Faegri et al. 1989, Sugita and Tsukada 1982), both taxa probably were relatively common on drier mid-WV microsites through the middle Holocene, though not as dominant as in the early Holocene.

Beaver Lake also records increases in other taxa that probably represent changes in regional vegetation. Tsuga heterophylla (western hemlock) produces pollen that can travel long distances (Heusser 1978). The pollen record of

Tsuga at Beaver Lake begins a gradual increase in abundance around 7000 cal yr BP, which is consistent with regional cooling and increasing moisture in the middle Holocene. This gradual increase in Tsuga also occurs in the central Puget Trough and adjacent foothills (Hibbert 1979, Barnosky 1981), Portland Basin (Barnosky 1985a), and the central Coast Range (Worona and Whitlock 1995). Cupressaceae-type (predominately Thuja plicata) reaches its maximum PAR (albeit low percentages ca. 2-3%) between ca. 5000 and 3500 cal yr BP in the Beaver Lake record. Similarly, its highest PARs and percentages (12-15%) in the central Coast Range occur between 6800 and 4400 cal yr BP (Worona and Whitlock 1995). In the central Cascade Range, it occurs only in trace percentages (< 5%) (Sea and Whitlock 1995). While a portion was probably from the proximal Coast Range, the relatively low pollen production of Thuja (Minckley 1999) and its limited capacity for dispersal suggest it grew in limited amounts near Beaver Lake at the end of the middle Holocene.

Late Holocene (ca. 4000 to 300 cal yr BP)

The late Holocene in the PNW is generally characterized by a cooler, more humid climate regime, as summer insolation

reached its lowest levels, and seasonal differences in insolation attenuated (Whitlock 1992, Thompson et al. 1993). During this period, modern coniferous forests became established in the Puget Trough (Hibbert 1979, Barnosky 1985), Cascade Range (Heusser 1977, Dunwiddie 1986, Sea and Whitlock 1995), and Olympic Mountains (Heusser 1977). While most regions within the PNW appear to have experienced concurrent cool, moist conditions during the late Holocene, the central Coast Range may been slightly drier over the last 1500 years, as evidenced by the increase in Pseudotsuga (Worona and Whitlock 1995).

Beaver Lake pollen percentages and PARs suggest that the primary arboreal taxa of the mid-WV have changed little over the last ca. 5500 years. The middle and late Holocene are characterized by the persistence of the Salix-Fraxinus riparian forests close to the site, and Pseudotsuga and Quercus contributions from surrounding areas of the valley. The low (relative to the early Holocene) abundance of Alnus and Corylus (prolific producers of well-dispersed pollen; Faegri and Iversen 1975, Heusser 1978), likely reflects vegetation from surrounding valley areas and Coast and Cascade range foothills. Tsuga (western hemlock) gradually increased in importance from ca. 5500 to 2200 cal yr BP, and declined slightly in the last two millennia. Thuja (western

red cedar), which may have occurred in localized populations on the WV floor, reached a maximum ca. 5000 cal yr BP, and has declined slightly to present. These declines, along with generally high herbaceous PARs and slight increases in Quercus and Pteridium PARs in the recent millennia of the late Holocene, imply slight drying over the last ca. 1500 cal yr BP. Drying or increased fires is also implied by an increase in Pseudotsuga and a concurrent decrease in Thuja in the central Coast Range during the last ca. 1900 yrs (Worona and Whitlock 1995).

The late Holocene at Beaver Lake is also characterized by high charcoal accumulation rates, suggesting that local burning was not prominent until after ca. 4100 cal yr BP. Between ca. 4100 and 2900 cal yr BP, charcoal accumulation rates fluctuated through three periods of low and high influxes. The highest charcoal accumulation rates occurred between ca. 2900 and 1000 cal yr BP. Between ca. 1000 and 550 cal yr BP, charcoal accumulation rates decreased sharply to a low rate which is maintained to present. A very similar charcoal signal is evident at Little Lake (central Coast Range) during the late Holocene (Long et al. 1998). Background charcoal levels at Little Lake increased between ca. 4000 and 2000 cal yr BP, remained high until ca. 1100 cal yr BP, and steadily declined from ca. 1100 cal yr BP to

present (Long et al. 1998). In contrast with Little Lake, MS accumulation rates at Beaver Lake were low throughout the late Holocene, which suggests that allochthonous erosion inputs were not significant. Long et al. (1998) attribute coincident high charcoal and MS accumulation during the late Holocene to more efficient transport of secondary burned material.

The reasons for this increase in charcoal production are not easily explained by available pollen data and our understanding of environmental conditions at that time. That much of the charcoal in the Beaver Lake core is relatively large in size (>250 μm), and the pattern of large charcoal mirrors the pattern of smaller particle sizes (>125 μm) (Figure 8) underscores this record of burning being quite local. This may be partially due to successional changes in the immediate Beaver Lake basin, as it developed into a shallower, more heavily vegetated habitat from a deeper, more open one. The changing character of Beaver Lake is evidenced by the increased peat component of the sediments in the upper 3 meters of the core. A heavily vegetated habitat that experienced summer drought would have ample fuels to carry late summer fires, regardless of the ignition source.

Climatic conditions may also have been more favorable

for initiating and carrying fires in the late-Holocene. Lightning is presently rare in the WV floor compared to the Cascade and Coast ranges, but positive ignitions do occur (see Impara 1998). The frequency of lightning in the mid- and late Holocene is not well known.

Increased local burning at Beaver Lake could also be related to native Kalapuyan cultural practices. Accounts of early Euro-Americans in the Willamette Valley imply that anthropogenic burning was important in shaping the presettlement WV landscape (Adamson 1926, Johannessen et al. 1971, Boyd 1986, and others). The record of increased burning at Beaver Lake chronologically parallels inferred Kalapuyan population growth in the late Holocene. Several researchers have used distribution of radiocarbon dates from cultural contexts to infer that populations in the mid- and southern Willamette Valley increased during the late-Archaic Period (ca. 2000 yr BP) (White 1975, Beckham et al. 1981, Cheatham 1988). From an examination of radiocarbon dated cultural artifacts at southern WV archeological sites, Cheatham (1988) concluded that populations in the southern WV remained stable from ca. 8000 to 3000 cal yr BP, and subsequently increased exponentially. Charcoal accumulation rates from Beaver Lake demonstrate a similar trend, remaining low from ca. 7000 to 4000 cal yr BP, and

maintaining high levels between ca. 2900 and 550 cal yr BP. While such parallels are obviously intriguing, at least two data limitations are important to consider: both spatial resolution of burning history and detailed knowledge of Kalapuyan population distribution are at present incomplete. The history of burning reflected in the Beaver Lake sediments is very likely a local record, and may not be indicative of the WV as a whole. Moreover, an expanded examination of age distributions associated with archaeological sites suggests an earlier period of high site occupancy during the middle Holocene, between ca. 5500 and 4000 cal yr BP (Connolly et al. 1997). Thus, while the general charcoal pattern is consistent with what is known of native American population trends, the chronologies do not match exactly. Whether the deliberate use of fire by Kalapuyans was consistent during their entire occupancy of the WV is presently unresolved. Clearly, a better understanding of spatial extent of late-Holocene burning in the WV, as well as further resolution of Kalapuyan population sizes and occupancy patterns will help clarify the relationships between the two.

Pre-Settlement and Historic Time
(ca. 300 cal yr BP to Present)

The uppermost sediments at Beaver Lake provide a signal of local landscape changes associated with Euro-American settlement. The shift in dominance between Poaceae (grass) and Salix (willow) pollen serves as a chrono-stratigraphic marker linking long and short core records. Between 0.50 and 0.35 m depth in the short core, Poaceae increases from 20 to 35%, and Salix declines from 35 to 20%. This transition is also reflected in the upper long core, where Poaceae increased from ca. 15 to 45% and Salix declined from 65 to 25%. The ^{210}Pb chronology for the short core places this transition between ca. 1844 AD and 1905 AD. The lower date of ca. 1844 is consistent with early Euro-American settlement in the mid-WV. The maximum in Poaceae pollen in the uppermost long core also coincides with the MS peak in the uppermost 20 cm of the long core. The changes in the pollen and MS profiles document the reduction of the Salix swamp within the Beaver Lake meander bend (still relatively extensive in the 1853 General Land Office survey notes), and the increase in erosion into the basin associated with grass agriculture, wheat production, and livestock grazing. Throughout the southern WV, cultivated grasses became a dominant crop through the mid- and late-19th century

dominant crop through the mid- and late-19th century (Reynolds 1977). Production of wheat in surrounding Linn County increased steadily from ca. 40,000 bushels in 1849 to almost 1,200,000 bushels in 1885 AD (Reynolds 1977) (Figure 10). Aerial photographs of the Beaver Lake vicinity indicate that distribution of agriculture and Quercus and riparian hardwoods have changed little since 1935 AD, confirming that the transition to an agricultural landscape was complete well before that year.

Elevated levels of Brassicaceae (the mustard family) and Juglans (walnut) pollen above ca. 0.27 m depth in the short core (^{210}Pb dated to ca. 1945 AD) are consistent with the conversion of much of the Willamette Valley to a landscape dominated by intensive agriculture. Domesticated Brassicaceae (mostly Brassica sp.) have been widely planted as agricultural crops in the WV, particularly for green feed for dairy cows or hogs (Reynolds 1977). Juglans was imported for nut production and as an ornamental tree from California and the eastern U.S.

Early explorers and botanists describe Native American burning during the early years of the settlement period (see Introduction), but the Beaver Lake record suggests that the immediate area produced much less charcoal after ca. 550 cal yr BP than it generated between 4100 and 550 cal yr BP.

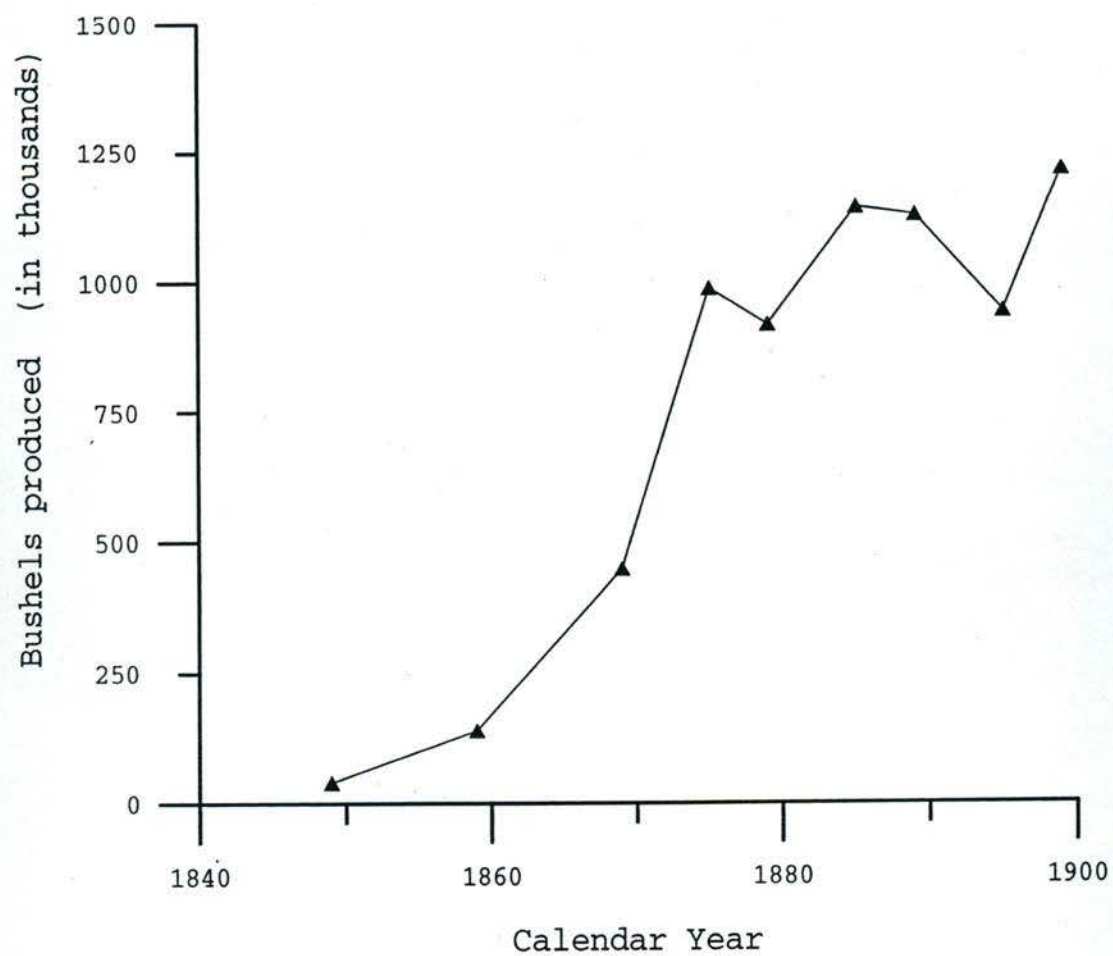


Figure 10. Wheat production in Linn County, Oregon, 1840-1900 (based on Halbakken 1948, and Reynolds 1977).

Several non-exclusive influences could have contributed to this low local charcoal production over the last ca. 550 years. Short-term climatic changes, in particular, the onset of the 'Little Ice Age' (ca. 1475-1890 AD; Mahaney et al. 1984, Richmond 1986, Graumlich 1993), may have affected environmental conditions of the WV. Any change that altered local fuels or fire weather conditions for supporting burning, or in the case of domesticated use of fire, altered settlement patterns or use by Kalapuyans, could result in decreased influx of burned particles. Paleoecological studies of fire history in the western U.S. (Agee 1993, Swetnam 1993, Millspaugh and Whitlock 1995) and midwestern U.S. (Clark 1988) suggest fewer fires occurred during the 'Little Ice Age' as a result of cooler climatic conditions. Such conditions in the PNW may have reduced the natural fire frequency in the WV, or reduced the consumable biomass in fires that did occur. Either of these 'Little Ice Age' cooling consequences could explain the decreased charcoal inputs into Beaver Lake during the last ca. 550 years.

Second, since this represents a record of local burning, the reduction of charcoal at Beaver Lake may represent shifting spatial and short-term temporal patterns of burning on the valley floor and margins. Weisberg (1998) concluded that fires were more frequent before (ca. every 52

yrs between 1545-1849 AD) and during early settlement years (ca. every 28 yrs between 1849-1910 AD), than in this century (ca. every 310 yrs 1910 to present). Similarly, an analysis of tree ring growth of stumps in the Coast Range foothills near Corvallis suggested that the study area was frequently burned between ca. 250 and 150 cal yr BP (ca. 1647 AD and 1848 AD, the hundred years before intensive settlement), and that fires were less frequent since settlement (Sprague and Hansen 1946). Since the Beaver Lake record is most likely a local record, these different studies may suggest significant spatial variation in burning patterns in the very late Holocene. Again, additional fire history records are necessary to sufficiently address this question.

Third, and relevant if the Beaver Lake signal was in part related to cultural burning, Native American populations are known to have been suffered after introduction of diseases by early Euro-American explorers (Mackey 1974, Boyd 1975, 1990). The timing of this decline is not completely known, although it has been suggested that Kalapuyan populations were reduced from an estimated high of 12,000-16,000 to approximately 600 individuals by the 1830's (Cheatham 1988, Boyd 1990). Thus, the cessation of high charcoal influx to Beaver Lake ca. 550 cal yr BP (ca. 1420

AD) is probably not fully explained by the population declines alone. Further, the burning observed by some of the early Euro-American travellers in the WV may not have been representative of their pre-contact practices (see Whitlock and Knox, in review).

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

Beaver Lake sediments record the first radiocarbon-dated, high-resolution Holocene vegetation and fire history from the Willamette Valley. The record suggests that vegetation in the mid-WV responded to changes in regional climate in the PNW that were caused by variations in the seasonal cycle of insolation over the last 10,000 years. During the drier- and warmer-than-present early Holocene (ca. 10,800 to 7000 cal yr BP), the mid-WV landscape featured a relatively xeric woodland mosaic containing Quercus and Pseudotsuga, with Alnus rubra and Corylus on the valley floor as well as on the foothills. Around 7500 cal yr BP, riparian gallery forests and wetland habitats began to develop, during and after a discrete period of environmental/geomorphic change that likely represents the Winkle-Ingram floodplain transition. Pollen signals remain relatively unchanged through the middle and late Holocene, with the exception of a period of local dryness/lowered lake surface between ca. 3000 and 2400 cal yr BP, and a slight drying during the last ca. 1500 years. Local burning around

Beaver Lake was greatest during the late Holocene, with highest charcoal accumulation rates occurring between ca. 2900 and 550 cal yr BP. This study cannot establish causative agents in the charcoal increase and decline. Hypotheses regarding the late-Holocene charcoal period include increased biomass and fuel as Beaver Lake succeeded into a shallow, heavily vegetated water body; short-term climatic conditions that altered fire weather and general fuel availability; and changes in cultural uses of fire by the native Kalapuyans. The short core record of the last ca. 150 years documents the reduction of the Salix swamp around Beaver Lake, the increasing cultivation of commercial grass crops, and the introduction of non-native Juglans and Brassicaceae.

The Beaver Lake record underscores the need for further paleoecological investigations of the lowlands in the Pacific Northwest, particularly in the WV. Future work at WV Holocene sites could benefit from the inclusion of multiple paleoecological proxy data (such as examinations of diatoms and sediment particle-size distributions) that could further differentiate between local/within-basin processes from fluvial influences and other exogenous processes. Additional analysis of Holocene lake stratigraphies may also clarify the chronology, spatial extent, and mechanistic

nature of the geomorphic event(s) associated with the Winkle-Ingram floodplain transition. A regional alteration of drainage efficiency could have significant implications for mid-Holocene vegetation patterns, as well as settlement patterns of Native Americans in the WV.

Holocene vegetation development in PNW lowlands generally deserves further research attention. In particular, data from the WV, Portland Basin, and Puget Lowlands suggest different Quercus-savanna/prairie histories along a North-South axis (this study, Hibbert 1979, Barnosky 1985a, Sugita and Tsukada 1982). If the Beaver Lake Quercus record is representative of the valley floor, investigation of latitudinal differences (e.g. fire regimes, differences between centers and edges of species geographic ranges) may provide a clearer picture of lowland vegetation changes. Holocene fire history data from other lowland sub-regions within the PNW is presently sparse. Once developed, comparative analysis of sub-regional records will assist in understanding the history of such culturally and biologically important vegetation types.

Since the Beaver Lake record likely represents a local record of burning, analyses of additional records are needed to clarify the spatial extent of the late-Holocene Beaver Lake burning maximum. Based on very limited data, spatial

patterns of burning on the valley floor may have been complex. Spatially shifting burning regimes could have important implications for distribution of vegetation types, as well as direct relevance to Kalapuyan settlement patterns.

The specific temporal (as well as spatial) relationship between Kalapuyan populations and lowland burning regimes requires further investigation as well. This study suggests that elevated burning around Beaver Lake generally coincided with the increasing Kalapuyan population densities of the late Holocene. In addition to continued work on population distributions and densities, archaeological evidence of cultural burning practices across the lowlands will be helpful. Coordination of workplans, techniques and information needs between paleoecological and anthropological research will be necessary to better define these relationships.

APPENDIX A

KEY TO APPREVIATIONS USED IN APPENDICES B, C, AND D
IN ORDER OF APPEARANCE

Pollen Count Abbreviations

H	<u>Pinus monticola</u> -type
E	<u>Pinus contorta</u> -type
P	<u>Pinus</u> undifferentiated
\$P	<u>Pinus</u> total
I	<u>Picea</u>
AB	<u>Abies</u>
LX	<u>Pseudotsuga</u>
J	<u>Thuja</u> -type
TX	<u>Taxus brevifolia</u>
TS	<u>Tsuga heterophylla</u>
AR	<u>Alnus rubra</u> -type
B	<u>Betula</u>
CY	<u>Corylus</u>
S	<u>Salix</u>
PU	<u>Populus</u>
FU	<u>Fraxinus</u>
Q	<u>Quercus</u>
SM	<u>Sambucus</u>
RH	<u>Rhamnus</u>
AM	<u>Acer macrophyllum</u>
AC	<u>Acer circinatum</u>
RS	<u>Spiraea</u>
PR	<u>Prunus</u> -type
TP	<u>Potentilla</u>
RO	Rosaceae undifferentiated
CE	<u>Ceanothus</u>
SH	<u>Shepherdia</u> -type
AX	<u>Arceuthobium</u>
CS	<u>Cornus</u>
SR	<u>Sarcobatus</u>
GC	Cereal type
G	Poaceae
Y	Cyperaceae
R	<u>Artemesia</u>
M	<u>Ambrosia</u> -type
V	Other Compositae
K	Chenopodiinae
TH	<u>Thalictrum</u>
RA	Other Ranunculaceae
UM	Umbelliferae
CR	Cruciferae
PB	<u>Polygonum bistortoides</u> -type
PO	<u>Polygonum</u> undifferentiated
ON	Onagraceae

GA	<u>Galium</u>
ST	<u>Stellaria-type</u>
LI	<u>Liliaceae</u>
LU	<u>Leguminosae</u>
t	<u>Pteridium-type</u>
dy	<u>Dryopteris-type</u>
EQ	<u>Equisetum</u>
*H	Other herbs
ty	<u>Typha</u>
LY	<u>Lysichitum</u>
sg	<u>Sparganium-type</u>
UP	<u>Potamogeton-type</u>
MY	<u>Myriophyllum</u>
SG	<u>Sagittaria</u>
NU	<u>Nuphar</u>
LM	<u>Lemnaceae</u>
BR	<u>Brasenia</u>
IS	<u>Isoetes</u>
Sum B	Herbs and pteridophytes
Sum C	Aquatics
Sum D	Pinus
Sum X	Other trees and shrubs
Sum A	Trees and shrubs
Sum P	Pollen sum
Sum T	Total pollen and spores

JU	<u>Juglans</u>
PN	<u>Plantago</u>

Charcoal and Magnetic Susceptibility Measures

Lg C >250 u	Large Charcoal, > 250 microns
Sm C >125 u	Small Charcoal, > 125 microns
C/cm ²	Charcoal concentration
CHAR C/cm ² /yr	Charcoal accumulation rate
MS/cm ²	Magnetic susceptibility concentration (10 ⁻⁶ emu)
MSAR MS/cm ² /yr	Magnetic susceptibility accumulation rate (10 ⁻⁶ emu)
Depos yr/cm	Deposition time
n.m.	not measured

APPENDIX B

LONG CORE POLLEN COUNTS
FOR BEAVER LAKE

Depth (m)	Age (cal yr BP)	H	E	P	\$P	I	AB
0.00	163.3	0	3	3	6	0	0
0.04	206.9	0	1	4	5	3	3
0.08	250.5	0	4	5	9	0	1
0.12	294.0	0	2	3	5	1	8
0.16	337.6	0	1	0	1	0	2
0.20	381.1	0	1	3	4	1	2
0.24	424.7	1	4	8	13	3	9
0.28	468.3	0	0	4	4	2	15
0.32	511.8	0	1	1	2	0	8
0.36	555.4	0	2	4	6	0	3
0.40	598.9	0	3	6	9	1	11
0.44	642.5	0	3	12	15	3	13
0.48	686.1	0	2	4	6	0	10
0.52	729.6	0	2	6	8	1	13
0.56	773.2	0	3	6	9	1	11
0.60	816.7	0	0	2	2	0	6
0.64	860.3	1	0	1	2	0	5
0.68	903.9	1	1	6	8	1	1
0.72	947.4	0	2	9	11	0	3
0.76	991.0	0	3	2	5	4	8
0.78	1012.8	0	12	5	17	2	12
0.80	1034.5	0	1	7	8	2	10
0.84	1078.1	0	0	6	6	2	14
0.88	1121.7	0	4	10	14	2	8
0.92	1165.2	0	0	3	3	2	11
0.96	1208.8	0	7	8	15	1	12
1.00	1252.3	0	1	1	2	0	10
1.04	1295.9	0	1	4	5	0	3
1.08	1339.4	0	0	4	4	0	7
1.12	1383.0	2	4	7	13	1	4
1.16	1426.6	0	5	4	9	3	12
1.20	1470.1	0	1	5	6	2	16
1.24	1513.7	0	3	7	10	2	8
1.28	1557.2	0	1	5	6	7	9
1.31	1589.9	0	4	5	9	0	6
1.32	1600.8	0	2	5	7	1	8
1.36	1644.4	0	3	6	9	3	7
1.40	1687.9	0	0	5	5	0	7
1.44	1731.5	0	2	4	6	0	17
1.48	1775.0	0	1	1	2	1	11
1.52	1818.6	0	0	6	6	0	4
1.56	1862.2	0	1	3	4	1	11
1.60	1905.7	0	3	2	5	0	14
1.64	1949.3	0	2	10	12	2	14
1.68	1992.8	0	3	1	4	2	7
1.72	2036.4	0	3	3	6	1	7
1.76	2080.0	0	0	3	3	1	5
1.80	2123.5	0	2	2	4	2	6
1.84	2167.1	0	1	4	5	2	7
1.86	2188.9	0	0	2	2	1	4

Depth (m)	Age (cal yr BP)	H	E	P	\$P	I	AB
1.88	2210.6	1	4	6	11	0	4
1.89	2221.5	0	6	6	12	0	6
1.90	2232.4	0	2	4	6	1	6
1.92	2254.2	0	1	3	4	2	14
1.94	2276.0	0	2	4	6	3	16
1.98	2319.5	0	4	5	9	0	7
2.02	2363.1	0	1	6	7	1	14
2.06	2406.7	1	2	6	9	1	12
2.10	2450.2	1	0	7	8	1	15
2.14	2493.8	0	2	7	9	0	10
2.18	2537.3	0	1	7	8	1	15
2.22	2586.5	1	1	1	3	2	12
2.25	2635.8	0	0	3	3	0	18
2.26	2652.3	0	4	4	8	0	17
2.30	2718.1	1	3	2	6	1	13
2.34	2784.0	1	1	5	7	1	10
2.38	2849.8	0	2	2	4	1	7
2.42	2915.6	4	5	4	13	2	11
2.46	2981.5	1	0	7	8	0	19
2.50	3047.3	0	0	2	2	0	13
2.54	3113.2	0	3	4	7	4	15
2.58	3179.0	0	2	1	3	0	6
2.62	3244.8	0	2	3	5	1	11
2.66	3310.7	0	2	5	7	1	10
2.70	3376.5	0	1	3	4	0	19
2.74	3442.3	0	7	1	8	0	16
2.78	3508.2	0	1	2	3	1	10
2.82	3574.0	0	3	3	6	0	7
2.86	3639.8	0	4	2	6	1	8
2.90	3705.7	0	2	4	6	0	7
2.94	3771.5	0	1	2	3	0	7
2.98	3837.4	1	2	4	7	1	6
3.02	3903.2	0	4	3	7	1	7
3.06	3969.0	0	1	1	2	0	5
3.10	4034.9	0	2	12	14	0	15
3.14	4100.7	0	1	9	10	1	18
3.16	4133.6	0	2	2	4	1	12
3.18	4166.5	0	1	7	8	1	20
3.22	4232.4	1	0	6	7	0	9
3.26	4298.2	0	1	3	4	1	9
3.30	4364.0	0	3	0	3	1	2
3.34	4429.9	0	0	2	2	0	6
3.38	4495.7	0	0	2	2	0	6
3.42	4561.6	0	0	2	2	1	7
3.46	4627.4	1	1	3	5	1	12
3.50	4693.2	0	2	2	4	2	8
3.54	4759.1	0	2	3	5	0	8
3.58	4824.9	1	7	1	9	0	10
3.62	4890.7	0	0	3	3	0	15
3.66	4956.6	0	0	1	1	0	4

Depth (m)	Age (cal yr BP)	H	E	P	\$P	I	AB
3.70	5022.4	0	1	2	3	0	8
3.71	5038.9	0	0	2	2	0	13
3.74	5088.2	1	0	5	6	0	16
3.78	5154.1	1	0	3	4	1	13
3.82	5219.9	0	2	7	9	1	3
3.86	5285.8	0	1	1	2	2	4
3.90	5351.6	0	2	8	10	0	6
3.94	5417.4	0	1	6	7	0	7
3.98	5483.3	0	2	7	9	0	26
4.02	5549.1	0	0	7	7	0	12
4.06	5614.9	0	0	3	3	0	21
4.10	5680.8	0	5	7	12	2	7
4.14	5746.6	0	1	6	7	0	8
4.18	5812.5	0	2	10	12	2	10
4.22	5878.3	0	0	6	6	0	18
4.26	5944.1	1	3	2	6	1	22
4.30	6010.0	1	2	2	5	0	18
4.31	6026.4	1	6	6	13	2	14
4.34	6075.8	0	0	8	8	0	16
4.38	6141.6	0	0	6	6	3	4
4.42	6207.5	0	1	10	11	0	4
4.46	6273.3	2	0	5	7	0	11
4.50	6339.1	0	2	8	10	0	10
4.55	6421.4	0	2	4	6	0	12
4.58	6470.8	2	1	5	8	1	8
4.62	6536.7	0	2	2	4	0	18
4.66	6602.5	0	0	7	7	1	18
4.70	6668.3	0	1	11	12	1	27
4.74	6734.2	0	3	8	11	0	16
4.76	6767.1	0	1	6	7	0	4
4.82	6852.3	0	0	5	5	0	8
5.26	7427.7	0	1	4	5	2	7
6.16	8604.6	0	0	6	6	1	8
7.06	9781.5	0	1	2	3	1	10
7.76	10696.9	0	3	4	7	2	1

Depth (m)	Age (cal yr BP)	LX	J	TX	TS	AR	B
0.00	163.3	8	1	0	2	28	0
0.04	206.9	6	0	0	0	26	0
0.08	250.5	8	0	0	3	23	0
0.12	294.0	9	0	0	3	9	0
0.16	337.6	12	1	0	6	9	0
0.20	381.1	15	0	0	9	10	0
0.24	424.7	21	2	0	9	20	0
0.28	468.3	22	0	0	16	24	0
0.32	511.8	33	1	0	5	42	0
0.36	555.4	18	1	0	4	15	0
0.40	598.9	22	0	0	24	11	0
0.44	642.5	18	2	0	20	14	0
0.48	686.1	10	2	0	8	14	0
0.52	729.6	14	1	0	18	14	0
0.56	773.2	19	1	0	9	16	0
0.60	816.7	13	3	0	9	13	0
0.64	860.3	12	1	0	13	13	0
0.68	903.9	12	1	0	18	14	0
0.72	947.4	28	3	0	23	21	0
0.76	991.0	16	3	0	11	15	0
0.78	1012.8	15	0	0	17	23	0
0.80	1034.5	21	1	0	8	12	0
0.84	1078.1	35	1	0	13	14	0
0.88	1121.7	19	3	0	25	11	0
0.92	1165.2	24	1	0	8	11	0
0.96	1208.8	27	3	0	15	17	0
1.00	1252.3	9	1	0	5	29	0
1.04	1295.9	26	2	0	8	23	0
1.08	1339.4	25	3	0	12	11	0
1.12	1383.0	20	2	0	15	15	0
1.16	1426.6	30	5	0	12	25	0
1.20	1470.1	18	0	0	11	19	0
1.24	1513.7	25	6	0	11	32	0
1.28	1557.2	20	1	0	19	27	0
1.31	1589.9	20	2	2	15	24	0
1.32	1600.8	24	4	0	23	44	0
1.36	1644.4	27	3	0	17	11	0
1.40	1687.9	26	3	0	12	10	0
1.44	1731.5	30	5	0	12	12	0
1.48	1775.0	12	4	0	10	23	0
1.52	1818.6	13	4	0	15	13	0
1.56	1862.2	20	0	0	9	15	0
1.60	1905.7	25	1	0	5	17	0
1.64	1949.3	18	4	0	15	24	0
1.68	1992.8	27	6	0	12	26	0
1.72	2036.4	28	3	0	18	24	0
1.76	2080.0	9	2	0	15	24	0
1.80	2123.5	23	5	0	17	24	0
1.84	2167.1	21	1	0	17	22	0
1.86	2188.9	15	4	0	12	30	0

Depth (m)	Age (cal yr BP)	LX	J	TX	TS	AR	B
1.88	2210.6	20	5	0	16	19	0
1.89	2221.5	17	2	0	18	19	0
1.90	2232.4	24	6	1	16	17	0
1.92	2254.2	12	10	0	17	31	0
1.94	2276.0	23	3	1	24	40	0
1.98	2319.5	32	3	0	17	29	0
2.02	2363.1	23	13	0	25	26	0
2.06	2406.7	22	5	0	13	30	0
2.10	2450.2	36	3	0	21	41	0
2.14	2493.8	16	3	0	24	75	0
2.18	2537.3	25	5	0	16	51	0
2.22	2586.5	29	3	0	8	64	0
2.25	2635.8	13	2	0	15	22	0
2.26	2652.3	19	3	0	5	61	0
2.30	2718.1	24	2	0	15	23	0
2.34	2784.0	22	5	0	14	20	0
2.38	2849.8	23	3	0	9	24	0
2.42	2915.6	19	10	0	14	19	0
2.46	2981.5	34	3	0	9	17	0
2.50	3047.3	29	5	0	6	15	0
2.54	3113.2	20	4	0	5	15	0
2.58	3179.0	18	4	0	16	12	0
2.62	3244.8	17	8	0	12	27	0
2.66	3310.7	19	8	0	9	27	0
2.70	3376.5	16	2	0	8	22	0
2.74	3442.3	25	4	0	20	29	0
2.78	3508.2	14	4	0	6	51	0
2.82	3574.0	14	6	0	13	40	0
2.86	3639.8	15	1	0	7	43	0
2.90	3705.7	29	8	0	11	33	0
2.94	3771.5	14	6	0	14	38	0
2.98	3837.4	29	10	0	18	39	0
3.02	3903.2	18	12	0	17	23	0
3.06	3969.0	12	5	0	4	22	0
3.10	4034.9	22	10	0	4	17	0
3.14	4100.7	23	2	0	6	24	0
3.16	4133.6	17	0	0	5	24	0
3.18	4166.5	18	6	0	9	24	0
3.22	4232.4	12	7	0	7	21	0
3.26	4298.2	25	4	0	10	24	0
3.30	4364.0	13	11	0	10	25	0
3.34	4429.9	17	11	0	15	29	0
3.38	4495.7	15	1	0	4	27	0
3.42	4561.6	14	0	0	13	29	0
3.46	4627.4	15	8	0	6	26	0
3.50	4693.2	22	6	0	4	15	0
3.54	4759.1	22	3	0	7	13	0
3.58	4824.9	30	5	0	11	28	0
3.62	4890.7	12	3	0	6	23	0
3.66	4956.6	16	5	0	7	12	0

Depth (m)	Age (cal yr BP)	LX	J	TX	TS	AR	B
3.70	5022.4	21	5	0	6	15	0
3.71	5038.9	24	0	0	8	26	1
3.74	5088.2	31	6	0	11	25	1
3.78	5154.1	27	8	0	8	28	0
3.82	5219.9	15	5	0	4	25	0
3.86	5285.8	13	2	0	6	23	0
3.90	5351.6	17	5	0	7	16	0
3.94	5417.4	20	1	0	10	14	0
3.98	5483.3	53	1	0	8	13	0
4.02	5549.1	49	9	0	6	13	0
4.06	5614.9	26	9	0	1	33	1
4.10	5680.8	35	4	0	4	28	0
4.14	5746.6	32	10	0	4	25	0
4.18	5812.5	41	8	0	5	2	0
4.22	5878.3	43	5	0	2	26	0
4.26	5944.1	33	2	0	3	32	1
4.30	6010.0	30	3	0	9	29	0
4.31	6026.4	33	0	0	10	33	0
4.34	6075.8	42	1	0	3	34	0
4.38	6141.6	31	2	0	12	36	0
4.42	6207.5	18	6	0	12	45	0
4.46	6273.3	32	8	0	6	55	0
4.50	6339.1	44	3	0	7	45	0
4.55	6421.4	46	1	0	11	71	0
4.58	6470.8	45	3	0	13	72	0
4.62	6536.7	43	2	0	7	60	0
4.66	6602.5	61	4	0	5	77	0
4.70	6668.3	83	0	0	2	52	0
4.74	6734.2	63	0	0	1	49	0
4.76	6767.1	52	6	0	7	68	0
4.82	6852.3	32	0	0	4	74	0
5.26	7427.7	31	0	0	1	204	0
6.16	8604.6	47	0	0	3	174	0
7.06	9781.5	41	0	0	1	209	0
7.76	10696.9	3	1	1	0	20	0

Depth (m)	Age (cal yr BP)	CY	S	PU	FU	Q	SM
0.00	163.3	3	85	0	31	11	0
0.04	206.9	4	79	0	23	7	0
0.08	250.5	4	78	0	22	11	0
0.12	294.0	3	191	0	52	16	0
0.16	337.6	3	299	0	17	6	0
0.20	381.1	2	235	0	21	7	0
0.24	424.7	2	195	0	24	13	0
0.28	468.3	2	159	0	33	26	3
0.32	511.8	4	191	0	33	18	0
0.36	555.4	1	73	1	22	10	0
0.40	598.9	5	155	0	43	22	0
0.44	642.5	4	191	0	24	15	0
0.48	686.1	5	197	0	27	16	0
0.52	729.6	7	200	0	25	26	0
0.56	773.2	3	187	0	29	15	0
0.60	816.7	6	222	0	25	18	0
0.64	860.3	2	204	0	34	20	0
0.68	903.9	6	225	0	24	12	0
0.72	947.4	3	151	0	27	28	0
0.76	991.0	7	160	0	32	20	0
0.78	1012.8	8	140	0	42	32	1
0.80	1034.5	7	156	0	31	13	0
0.84	1078.1	0	130	0	23	9	0
0.88	1121.7	0	154	0	20	16	0
0.92	1165.2	6	151	0	28	13	0
0.96	1208.8	8	150	0	35	18	0
1.00	1252.3	9	188	1	48	26	0
1.04	1295.9	4	180	1	48	24	0
1.08	1339.4	6	182	0	23	15	0
1.12	1383.0	0	174	0	33	22	0
1.16	1426.6	6	160	0	30	10	0
1.20	1470.1	13	174	0	37	11	0
1.24	1513.7	9	118	0	43	22	0
1.28	1557.2	5	173	0	55	23	0
1.31	1589.9	6	209	16	34	13	0
1.32	1600.8	17	170	0	41	12	0
1.36	1644.4	10	207	0	35	11	0
1.40	1687.9	3	203	0	27	9	0
1.44	1731.5	5	209	0	29	12	0
1.48	1775.0	7	220	2	39	12	0
1.52	1818.6	6	222	1	28	12	0
1.56	1862.2	8	212	0	32	13	0
1.60	1905.7	8	235	1	30	11	0
1.64	1949.3	7	190	0	45	17	0
1.68	1992.8	12	171	0	27	14	0
1.72	2036.4	8	145	0	47	22	0
1.76	2080.0	5	223	2	48	11	0
1.80	2123.5	6	204	1	45	12	0
1.84	2167.1	4	172	6	39	9	0
1.86	2188.9	11	219	1	34	16	0

Depth (m)	Age (cal yr BP)	CY	S	PU	FU	Q	SM
1.88	2210.6	5	189	1	46	16	0
1.89	2221.5	6	180	2	49	17	1
1.90	2232.4	8	185	0	43	14	0
1.92	2254.2	11	183	7	39	24	0
1.94	2276.0	12	153	3	51	18	0
1.98	2319.5	9	135	1	66	22	0
2.02	2363.1	8	107	0	84	22	0
2.06	2406.7	16	113	0	80	30	0
2.10	2450.2	17	91	0	82	19	0
2.14	2493.8	12	95	1	59	21	0
2.18	2537.3	14	98	2	94	15	0
2.22	2586.5	11	100	2	82	22	0
2.25	2635.8	8	203	3	47	14	0
2.26	2652.3	10	46	1	97	26	0
2.30	2718.1	15	176	0	61	22	0
2.34	2784.0	7	209	0	46	17	0
2.38	2849.8	10	206	0	52	14	0
2.42	2915.6	11	144	4	89	23	0
2.46	2981.5	8	199	0	28	8	0
2.50	3047.3	8	203	1	36	14	0
2.54	3113.2	8	208	0	38	14	0
2.58	3179.0	17	194	0	81	16	0
2.62	3244.8	11	190	0	59	12	0
2.66	3310.7	8	186	1	44	11	0
2.70	3376.5	7	219	0	31	12	0
2.74	3442.3	10	150	2	58	30	0
2.78	3508.2	19	149	0	73	25	0
2.82	3574.0	15	197	1	51	11	0
2.86	3639.8	14	161	1	57	17	0
2.90	3705.7	15	182	2	57	17	0
2.94	3771.5	12	180	0	50	24	0
2.98	3837.4	15	170	0	55	7	0
3.02	3903.2	11	182	0	57	24	0
3.06	3969.0	20	208	0	44	23	0
3.10	4034.9	15	204	0	42	12	0
3.14	4100.7	9	200	0	43	9	0
3.16	4133.6	5	228	1	35	11	0
3.18	4166.5	6	172	0	49	28	0
3.22	4232.4	11	194	0	68	11	0
3.26	4298.2	14	175	1	41	17	0
3.30	4364.0	6	215	0	58	13	0
3.34	4429.9	11	192	0	61	12	0
3.38	4495.7	8	249	0	52	7	0
3.42	4561.6	10	211	0	68	17	0
3.46	4627.4	8	217	0	67	18	0
3.50	4693.2	3	193	0	47	18	0
3.54	4759.1	9	218	0	43	16	0
3.58	4824.9	16	125	0	58	31	0
3.62	4890.7	7	181	2	67	27	0
3.66	4956.6	10	259	1	58	8	0

Depth (m)	Age (cal yr BP)	CY	S	PU	FU	Q	SM
3.70	5022.4	17	213	1	53	13	0
3.71	5038.9	10	178	0	69	22	0
3.74	5088.2	12	97	2	73	26	0
3.78	5154.1	11	142	0	73	29	0
3.82	5219.9	17	127	1	106	30	0
3.86	5285.8	14	115	0	130	22	0
3.90	5351.6	28	121	0	110	37	0
3.94	5417.4	18	157	0	76	25	0
3.98	5483.3	19	70	0	89	28	0
4.02	5549.1	4	137	0	98	19	0
4.06	5614.9	8	114	0	88	30	0
4.10	5680.8	16	111	1	66	31	0
4.14	5746.6	16	120	0	97	23	0
4.18	5812.5	19	110	0	70	25	0
4.22	5878.3	12	101	0	56	40	0
4.26	5944.1	26	113	2	62	29	0
4.30	6010.0	26	92	0	62	63	0
4.31	6026.4	41	88	2	54	47	0
4.34	6075.8	32	72	0	51	48	0
4.38	6141.6	27	84	0	55	42	0
4.42	6207.5	27	103	0	46	49	0
4.46	6273.3	36	118	0	19	41	0
4.50	6339.1	18	136	1	13	27	0
4.55	6421.4	45	55	1	0	64	0
4.58	6470.8	46	54	2	0	71	0
4.62	6536.7	34	80	2	0	51	0
4.66	6602.5	42	74	2	1	45	0
4.70	6668.3	22	72	0	0	41	0
4.74	6734.2	28	80	0	0	45	0
4.76	6767.1	53	50	0	0	74	0
4.82	6852.3	42	66	0	0	73	0
5.26	7427.7	76	12	0	0	22	0
6.16	8604.6	64	16	1	0	50	0
7.06	9781.5	90	41	3	0	44	0
7.76	10696.9	4	3	0	0	4	0

Depth (m)	Age (cal yr BP)	RH	AM	AC	RS	PR	TP	RO
0.00	163.3	0	0	0	9	0	0	8
0.04	206.9	0	2	0	6	0	0	4
0.08	250.5	1	0	0	8	0	0	4
0.12	294.0	1	0	0	18	2	0	0
0.16	337.6	0	2	0	4	0	0	0
0.20	381.1	1	0	0	17	0	0	0
0.24	424.7	0	4	0	5	0	0	1
0.28	468.3	0	2	0	10	0	0	8
0.32	511.8	0	3	0	8	0	0	0
0.36	555.4	0	2	0	4	0	0	3
0.40	598.9	0	0	0	30	0	0	1
0.44	642.5	0	0	0	26	0	0	0
0.48	686.1	0	0	0	22	0	0	1
0.52	729.6	0	3	0	14	0	0	2
0.56	773.2	1	1	0	15	0	0	1
0.60	816.7	0	1	0	18	0	0	2
0.64	860.3	0	0	1	9	0	0	3
0.68	903.9	0	1	0	7	0	0	2
0.72	947.4	0	4	0	9	0	0	3
0.76	991.0	0	4	0	3	0	0	4
0.78	1012.8	0	2	0	3	1	0	1
0.80	1034.5	0	1	0	6	0	0	1
0.84	1078.1	0	0	1	24	0	0	6
0.88	1121.7	0	6	0	13	0	0	2
0.92	1165.2	0	2	0	12	0	0	2
0.96	1208.8	0	0	0	3	0	0	0
1.00	1252.3	0	2	0	5	0	0	1
1.04	1295.9	0	1	0	3	0	0	1
1.08	1339.4	0	2	0	8	0	0	1
1.12	1383.0	0	2	0	11	0	0	0
1.16	1426.6	0	1	0	9	0	0	1
1.20	1470.1	0	0	0	15	0	0	1
1.24	1513.7	0	3	0	16	0	0	0
1.28	1557.2	0	1	1	5	0	0	0
1.31	1589.9	0	0	0	0	0	0	5
1.32	1600.8	0	2	0	5	0	0	0
1.36	1644.4	0	1	0	9	0	0	0
1.40	1687.9	0	3	0	8	0	0	1
1.44	1731.5	0	2	0	7	0	0	0
1.48	1775.0	0	2	0	7	0	0	1
1.52	1818.6	0	1	0	11	0	0	0
1.56	1862.2	0	1	0	5	0	0	0
1.60	1905.7	0	1	0	3	0	0	0
1.64	1949.3	0	1	0	5	0	0	0
1.68	1992.8	0	5	0	0	0	0	0
1.72	2036.4	0	1	0	4	0	0	0
1.76	2080.0	0	2	0	4	0	0	0
1.80	2123.5	1	2	0	1	0	0	0
1.84	2167.1	1	0	0	2	0	0	0
1.86	2188.9	2	5	0	3	0	0	0

Depth (m)	Age (cal yr BP)	RH	AM	AC	RS	PR	TP	RO
1.88	2210.6	0	2	0	0	0	0	0
1.89	2221.5	0	3	0	1	0	0	0
1.90	2232.4	0	4	0	5	0	0	0
1.92	2254.2	0	1	1	4	0	0	1
1.94	2276.0	0	0	1	2	0	0	2
1.98	2319.5	0	3	0	2	0	0	0
2.02	2363.1	0	2	0	1	0	0	0
2.06	2406.7	0	4	0	0	0	0	1
2.10	2450.2	0	0	0	0	0	0	0
2.14	2493.8	0	3	0	1	0	0	1
2.18	2537.3	0	5	0	0	0	0	0
2.22	2586.5	0	2	0	1	0	0	0
2.25	2635.8	0	4	0	7	0	0	0
2.26	2652.3	0	6	0	1	0	0	1
2.30	2718.1	0	1	0	4	0	0	1
2.34	2784.0	0	3	0	1	0	0	2
2.38	2849.8	0	2	0	0	0	0	0
2.42	2915.6	0	3	0	1	0	0	2
2.46	2981.5	0	0	0	4	0	0	0
2.50	3047.3	0	4	0	6	0	0	0
2.54	3113.2	0	3	0	1	0	0	0
2.58	3179.0	0	3	0	2	0	0	2
2.62	3244.8	0	1	0	2	0	0	0
2.66	3310.7	0	2	0	1	0	0	0
2.70	3376.5	0	0	0	4	0	0	0
2.74	3442.3	0	2	0	1	0	0	1
2.78	3508.2	0	1	0	4	0	0	0
2.82	3574.0	0	1	0	0	0	0	0
2.86	3639.8	0	1	0	2	0	0	1
2.90	3705.7	0	1	0	1	0	0	0
2.94	3771.5	0	2	0	4	0	0	0
2.98	3837.4	0	3	0	2	0	0	0
3.02	3903.2	0	1	0	1	0	0	0
3.06	3969.0	0	2	0	2	0	0	2
3.10	4034.9	0	4	0	1	0	0	0
3.14	4100.7	0	2	0	7	0	0	0
3.16	4133.6	0	2	0	5	1	0	0
3.18	4166.5	0	2	1	0	0	0	1
3.22	4232.4	0	3	0	7	0	0	0
3.26	4298.2	0	1	1	4	0	0	0
3.30	4364.0	0	0	0	10	0	0	0
3.34	4429.9	0	2	0	4	0	0	0
3.38	4495.7	0	2	0	1	0	0	6
3.42	4561.6	0	3	0	1	0	0	3
3.46	4627.4	0	1	0	1	0	0	0
3.50	4693.2	0	1	0	5	0	0	2
3.54	4759.1	0	2	0	5	0	0	0
3.58	4824.9	0	6	0	3	0	0	0
3.62	4890.7	0	3	2	4	0	0	0
3.66	4956.6	0	2	1	0	0	0	0

Depth (m)	Age (cal yr BP)	RH	AM	AC	RS	PR	TP	RO
3.70	5022.4	0	1	0	2	0	0	0
3.71	5038.9	0	0	0	6	0	0	1
3.74	5088.2	0	5	0	3	0	0	0
3.78	5154.1	0	5	0	8	0	0	1
3.82	5219.9	0	3	0	3	0	0	0
3.86	5285.8	0	0	0	4	0	0	0
3.90	5351.6	0	0	0	2	0	0	0
3.94	5417.4	0	2	0	4	0	0	0
3.98	5483.3	0	0	0	2	0	0	1
4.02	5549.1	0	4	0	4	0	0	1
4.06	5614.9	0	1	0	4	0	0	2
4.10	5680.8	0	2	0	6	0	0	0
4.14	5746.6	0	2	0	7	0	0	0
4.18	5812.5	1	0	0	6	0	0	0
4.22	5878.3	0	8	1	9	0	0	2
4.26	5944.1	0	1	0	4	0	0	0
4.30	6010.0	0	3	0	4	0	0	1
4.31	6026.4	0	11	0	4	0	0	2
4.34	6075.8	0	6	0	6	0	0	0
4.38	6141.6	0	2	0	3	0	0	0
4.42	6207.5	0	4	0	3	0	0	1
4.46	6273.3	0	1	0	2	0	0	0
4.50	6339.1	0	0	0	4	0	0	0
4.55	6421.4	0	5	0	4	0	0	1
4.58	6470.8	0	6	1	5	0	0	1
4.62	6536.7	0	3	0	5	0	0	1
4.66	6602.5	0	5	0	3	0	0	1
4.70	6668.3	0	5	0	3	1	0	0
4.74	6734.2	0	6	1	4	0	0	0
4.76	6767.1	0	5	0	4	0	0	1
4.82	6852.3	0	3	1	6	0	0	0
5.26	7427.7	0	9	0	0	0	0	4
6.16	8604.6	0	8	0	1	0	2	1
7.06	9781.5	0	1	0	0	1	0	0
7.76	10696.9	0	0	0	0	0	0	1

Depth (m)	Age (cal yr BP)	CE	SH	AX	CS	SR	GC	G	Y
0.00	163.3	0	0	0	0	0	0	200	7
0.04	206.9	0	0	0	0	0	0	195	18
0.08	250.5	0	0	0	0	0	0	207	9
0.12	294.0	0	0	0	0	0	0	44	18
0.16	337.6	0	0	0	0	0	0	16	7
0.20	381.1	0	0	0	0	0	0	46	17
0.24	424.7	0	0	0	0	0	0	30	16
0.28	468.3	0	0	0	0	0	0	39	13
0.32	511.8	0	0	0	0	0	0	18	14
0.36	555.4	0	0	0	0	0	0	17	6
0.40	598.9	0	0	0	0	0	0	34	17
0.44	642.5	0	0	0	0	0	0	24	22
0.48	686.1	0	0	0	0	0	0	30	28
0.52	729.6	0	0	0	0	0	0	36	25
0.56	773.2	0	0	0	0	0	0	40	27
0.60	816.7	0	0	0	0	0	0	27	28
0.64	860.3	0	0	0	0	0	0	35	25
0.68	903.9	0	0	0	0	0	0	30	18
0.72	947.4	0	0	0	0	0	0	33	39
0.76	991.0	0	0	0	0	0	0	39	39
0.78	1012.8	0	0	0	0	0	0	42	29
0.80	1034.5	0	0	0	0	0	0	37	64
0.84	1078.1	0	0	0	0	0	0	36	85
0.88	1121.7	0	0	0	0	0	0	35	64
0.92	1165.2	0	0	0	0	0	0	48	50
0.96	1208.8	0	0	0	0	0	0	41	40
1.00	1252.3	0	0	0	0	0	0	45	25
1.04	1295.9	0	0	0	0	0	0	44	22
1.08	1339.4	0	0	0	0	0	0	39	45
1.12	1383.0	0	0	0	0	0	0	32	39
1.16	1426.6	0	0	0	0	0	0	36	45
1.20	1470.1	0	0	0	0	0	0	22	28
1.24	1513.7	0	0	0	0	0	0	30	44
1.28	1557.2	0	0	0	0	0	0	20	24
1.31	1589.9	0	0	0	0	0	0	28	14
1.32	1600.8	0	0	0	0	0	0	22	24
1.36	1644.4	0	0	0	0	0	0	20	30
1.40	1687.9	0	0	0	0	0	0	26	45
1.44	1731.5	0	0	0	0	0	0	20	40
1.48	1775.0	0	0	0	0	0	0	26	31
1.52	1818.6	0	0	0	0	0	0	23	31
1.56	1862.2	0	0	0	0	0	0	24	32
1.60	1905.7	0	0	0	0	0	0	25	29
1.64	1949.3	0	0	0	0	0	0	21	31
1.68	1992.8	0	0	0	0	0	0	40	41
1.72	2036.4	0	0	0	0	0	0	42	38
1.76	2080.0	0	0	0	0	0	0	29	26
1.80	2123.5	0	0	0	0	0	0	27	26
1.84	2167.1	0	0	0	0	0	0	35	47
1.86	2188.9	0	0	0	0	0	0	16	31

Depth (m)	Age (cal yr BP)	CE	SH	AX	CS	SR	GC	G	Y
1.88	2210.6	0	0	0	0	0	0	34	38
1.89	2221.5	2	1	0	0	0	0	33	40
1.90	2232.4	3	0	0	0	0	0	38	36
1.92	2254.2	0	0	0	1	0	0	26	37
1.94	2276.0	0	0	0	0	0	0	33	33
1.98	2319.5	0	0	0	0	0	0	26	36
2.02	2363.1	0	0	0	0	0	0	34	34
2.06	2406.7	0	0	0	0	0	0	45	27
2.10	2450.2	0	0	0	0	0	0	34	26
2.14	2493.8	0	0	0	0	0	0	53	14
2.18	2537.3	0	0	0	0	0	0	38	24
2.22	2586.5	0	0	0	0	0	0	32	14
2.25	2635.8	0	0	0	0	0	0	21	18
2.26	2652.3	0	0	0	0	0	0	58	11
2.30	2718.1	1	0	0	0	0	0	28	14
2.34	2784.0	0	0	0	0	0	0	31	10
2.38	2849.8	1	0	0	0	0	0	23	20
2.42	2915.6	0	0	0	0	0	0	32	16
2.46	2981.5	0	0	0	0	0	0	24	35
2.50	3047.3	0	0	0	0	0	0	32	37
2.54	3113.2	0	0	0	0	0	0	20	37
2.58	3179.0	0	0	0	0	0	0	22	11
2.62	3244.8	0	0	0	0	0	0	20	20
2.66	3310.7	0	0	0	0	0	0	27	27
2.70	3376.5	0	0	0	0	0	0	23	39
2.74	3442.3	0	0	2	0	0	0	30	28
2.78	3508.2	0	0	0	0	0	0	38	21
2.82	3574.0	0	0	0	0	0	0	25	22
2.86	3639.8	1	0	0	0	0	0	38	23
2.90	3705.7	0	0	0	0	1	0	18	22
2.94	3771.5	0	0	0	0	0	0	27	22
2.98	3837.4	0	0	0	0	0	0	20	27
3.02	3903.2	0	0	0	0	0	0	21	18
3.06	3969.0	0	0	0	0	0	0	36	19
3.10	4034.9	0	0	0	0	1	0	14	37
3.14	4100.7	0	0	0	0	0	0	23	32
3.16	4133.6	0	0	0	0	0	0	19	36
3.18	4166.5	0	0	0	0	0	0	23	37
3.22	4232.4	0	0	0	1	0	0	16	23
3.26	4298.2	0	0	0	0	0	0	28	42
3.30	4364.0	0	0	0	0	0	0	23	24
3.34	4429.9	0	0	0	0	0	0	27	24
3.38	4495.7	0	0	0	0	0	0	15	30
3.42	4561.6	0	0	0	0	0	0	22	16
3.46	4627.4	0	0	0	0	0	0	12	11
3.50	4693.2	0	0	0	0	0	0	28	27
3.54	4759.1	0	0	0	0	0	0	20	31
3.58	4824.9	0	0	0	0	1	0	25	42
3.62	4890.7	0	0	0	0	0	0	18	25
3.66	4956.6	0	0	0	0	0	0	9	10

Depth (m)	Age (cal yr BP)	CE	SH	AX	CS	SR	GC	G	Y
3.70	5022.4	0	0	0	0	0	0	19	19
3.71	5038.9	1	0	0	0	0	0	20	26
3.74	5088.2	0	0	0	0	0	0	32	45
3.78	5154.1	0	0	0	0	0	0	26	18
3.82	5219.9	0	0	0	0	0	0	29	26
3.86	5285.8	0	0	0	0	0	0	22	33
3.90	5351.6	1	0	0	0	0	0	16	34
3.94	5417.4	0	0	0	0	0	0	21	31
3.98	5483.3	0	0	0	0	0	0	31	44
4.02	5549.1	0	0	0	0	0	0	20	23
4.06	5614.9	1	0	0	0	0	0	25	36
4.10	5680.8	0	0	0	0	0	0	29	37
4.14	5746.6	1	0	0	0	0	0	21	29
4.18	5812.5	0	0	0	0	0	0	28	31
4.22	5878.3	2	0	0	0	0	0	19	34
4.26	5944.1	0	0	0	0	0	0	22	31
4.30	6010.0	0	0	0	0	0	0	15	27
4.31	6026.4	0	0	0	0	0	0	27	27
4.34	6075.8	0	1	0	0	0	0	35	26
4.38	6141.6	0	0	0	0	0	0	39	24
4.42	6207.5	0	0	0	0	0	0	34	20
4.46	6273.3	0	0	0	1	0	0	32	18
4.50	6339.1	0	0	0	0	0	0	34	21
4.55	6421.4	0	0	0	0	0	0	27	33
4.58	6470.8	0	0	0	0	0	0	27	26
4.62	6536.7	0	0	0	0	0	0	28	31
4.66	6602.5	1	0	0	0	0	0	12	27
4.70	6668.3	1	0	0	0	1	0	15	35
4.74	6734.2	1	0	0	2	0	0	19	33
4.76	6767.1	0	0	0	0	0	0	32	25
4.82	6852.3	0	0	0	1	0	0	23	36
5.26	7427.7	0	0	0	2	0	0	12	14
6.16	8604.6	0	0	0	0	0	0	7	2
7.06	9781.5	1	0	0	0	0	0	7	2
7.76	10696.9	0	0	0	0	0	0	4	0

Depth (m)	Age (cal yr BP)	R	M	LG	V	K	TH	RA	UM
0.00	163.3	3	0	2	3	1	0	2	1
0.04	206.9	5	0	0	1	0	0	2	1
0.08	250.5	0	0	3	4	2	0	2	2
0.12	294.0	1	0	0	1	1	1	1	2
0.16	337.6	0	0	0	2	1	0	0	1
0.20	381.1	0	0	0	1	1	0	1	0
0.24	424.7	0	0	1	2	2	0	3	2
0.28	468.3	2	0	0	2	0	0	1	4
0.32	511.8	3	0	0	2	0	0	1	6
0.36	555.4	1	0	0	2	1	0	0	5
0.40	598.9	3	0	1	3	1	0	0	0
0.44	642.5	0	0	0	3	0	0	0	2
0.48	686.1	1	0	0	3	0	0	1	2
0.52	729.6	0	0	0	3	0	0	0	8
0.56	773.2	0	1	0	0	0	0	1	2
0.60	816.7	1	0	0	1	0	0	0	1
0.64	860.3	0	0	0	1	0	0	0	1
0.68	903.9	0	0	0	2	1	0	1	0
0.72	947.4	1	0	0	1	0	0	0	0
0.76	991.0	0	0	0	2	0	0	0	4
0.78	1012.8	1	0	0	2	0	0	2	2
0.80	1034.5	2	0	1	4	0	0	2	6
0.84	1078.1	0	0	0	5	0	0	0	4
0.88	1121.7	0	0	0	0	0	0	0	2
0.92	1165.2	0	0	0	1	0	0	0	6
0.96	1208.8	0	0	0	5	0	0	0	3
1.00	1252.3	0	0	0	3	0	0	3	0
1.04	1295.9	3	0	0	0	0	0	2	2
1.08	1339.4	1	0	0	4	0	0	0	5
1.12	1383.0	3	0	0	1	0	0	0	5
1.16	1426.6	1	0	0	5	1	0	0	0
1.20	1470.1	0	0	0	2	1	0	0	3
1.24	1513.7	1	0	0	2	0	0	0	4
1.28	1557.2	1	0	0	0	0	0	0	2
1.31	1589.9	0	1	0	1	1	0	0	0
1.32	1600.8	1	0	2	3	0	0	0	3
1.36	1644.4	0	0	0	4	1	0	0	1
1.40	1687.9	2	1	0	1	0	0	0	2
1.44	1731.5	1	0	0	5	0	0	0	4
1.48	1775.0	2	0	0	2	0	0	0	6
1.52	1818.6	1	0	0	1	1	0	0	5
1.56	1862.2	1	0	0	3	0	0	0	2
1.60	1905.7	1	0	0	0	1	0	0	4
1.64	1949.3	3	0	0	2	0	0	0	3
1.68	1992.8	4	0	0	2	0	0	0	3
1.72	2036.4	0	0	0	1	0	0	0	4
1.76	2080.0	1	0	0	1	0	0	0	0
1.80	2123.5	0	0	0	2	0	0	0	2
1.84	2167.1	1	0	0	1	0	0	1	5
1.86	2188.9	1	0	0	1	1	0	0	0

Depth (m)	Age (cal yr BP)	R	M	LG	V	K	TH	RA	UM
1.88	2210.6	0	0	0	1	0	0	0	3
1.89	2221.5	1	0	0	2	1	0	0	2
1.90	2232.4	0	0	0	1	0	0	0	1
1.92	2254.2	2	0	0	2	0	0	0	4
1.94	2276.0	1	0	0	2	0	0	0	0
1.98	2319.5	0	0	0	0	0	0	0	0
2.02	2363.1	2	0	0	1	0	0	0	0
2.06	2406.7	0	0	0	1	1	0	0	1
2.10	2450.2	0	0	0	1	0	0	0	1
2.14	2493.8	0	0	0	2	1	0	0	0
2.18	2537.3	1	0	1	1	0	0	0	1
2.22	2586.5	2	0	0	2	1	0	0	1
2.25	2635.8	0	0	0	2	0	0	1	3
2.26	2652.3	1	0	0	3	0	0	0	2
2.30	2718.1	2	0	0	0	0	0	0	1
2.34	2784.0	0	0	0	2	0	0	0	0
2.38	2849.8	0	0	0	1	0	0	0	1
2.42	2915.6	0	0	0	1	0	0	0	3
2.46	2981.5	1	0	0	1	0	0	0	3
2.50	3047.3	1	0	0	0	0	0	0	1
2.54	3113.2	0	0	0	3	1	0	0	1
2.58	3179.0	0	0	0	2	0	0	0	0
2.62	3244.8	0	0	1	1	0	0	0	3
2.66	3310.7	1	0	0	3	0	0	0	4
2.70	3376.5	2	0	0	1	0	1	0	2
2.74	3442.3	2	0	0	1	0	0	0	2
2.78	3508.2	2	0	0	0	0	0	0	1
2.82	3574.0	0	0	0	2	0	0	0	2
2.86	3639.8	1	0	0	4	0	0	0	3
2.90	3705.7	1	0	0	3	0	0	0	1
2.94	3771.5	1	0	0	2	0	0	0	3
2.98	3837.4	1	0	0	2	0	0	0	0
3.02	3903.2	1	0	1	4	0	0	0	2
3.06	3969.0	1	0	0	1	0	0	0	4
3.10	4034.9	1	0	0	0	0	0	0	1
3.14	4100.7	0	0	0	0	0	0	0	5
3.16	4133.6	0	0	0	1	1	0	0	3
3.18	4166.5	0	0	0	2	0	0	0	5
3.22	4232.4	1	0	0	2	0	0	0	3
3.26	4298.2	0	0	0	0	0	0	0	1
3.30	4364.0	1	0	0	0	0	0	0	0
3.34	4429.9	0	0	0	0	2	0	0	4
3.38	4495.7	0	0	0	2	0	0	0	1
3.42	4561.6	1	0	0	0	0	0	0	2
3.46	4627.4	1	0	0	0	0	0	0	3
3.50	4693.2	1	1	0	3	0	0	0	3
3.54	4759.1	1	0	0	1	0	0	0	5
3.58	4824.9	1	0	0	3	0	0	0	0
3.62	4890.7	1	0	0	0	2	0	0	7
3.66	4956.6	0	0	0	0	0	0	0	4

Depth (m)	Age (cal yr BP)	R	M	LG	V	K	TH	RA	UM
3.70	5022.4	2	0	0	1	0	0	0	4
3.71	5038.9	2	0	0	1	1	0	1	5
3.74	5088.2	0	0	0	0	0	0	0	4
3.78	5154.1	0	0	0	3	0	0	0	4
3.82	5219.9	1	0	0	3	1	0	0	4
3.86	5285.8	1	0	0	0	0	0	0	6
3.90	5351.6	0	0	0	3	1	0	0	3
3.94	5417.4	2	0	1	0	0	0	0	4
3.98	5483.3	0	0	0	1	0	0	0	4
4.02	5549.1	2	0	0	2	1	0	0	4
4.06	5614.9	0	0	0	1	0	0	0	8
4.10	5680.8	1	0	0	0	0	0	0	4
4.14	5746.6	2	0	0	0	0	0	0	3
4.18	5812.5	0	0	0	2	0	0	0	2
4.22	5878.3	1	0	0	1	0	0	0	4
4.26	5944.1	1	0	0	1	0	0	0	4
4.30	6010.0	0	0	0	1	0	0	0	2
4.31	6026.4	1	0	0	2	0	0	0	6
4.34	6075.8	1	0	0	2	0	0	0	5
4.38	6141.6	0	0	1	2	1	0	0	0
4.42	6207.5	1	1	0	0	0	0	0	5
4.46	6273.3	1	0	0	3	0	0	0	6
4.50	6339.1	1	0	1	2	0	0	0	2
4.55	6421.4	1	0	0	2	0	0	0	3
4.58	6470.8	2	0	0	3	0	0	1	0
4.62	6536.7	2	0	0	1	0	0	0	1
4.66	6602.5	3	0	0	3	0	0	0	4
4.70	6668.3	1	0	0	1	1	0	0	4
4.74	6734.2	1	0	1	2	2	0	0	2
4.76	6767.1	3	0	0	3	0	0	0	1
4.82	6852.3	1	0	0	5	0	0	0	4
5.26	7427.7	1	0	0	0	1	0	0	6
6.16	8604.6	0	0	1	1	1	0	0	3
7.06	9781.5	0	0	0	0	1	0	0	2
7.76	10696.9	0	0	0	3	1	0	0	0

Depth (m)	Age (cal yr BP)	CR	CF	PB	PO	ON	GA	ST	LI	LU
3.70	5022.4	0	0	0	0	0	0	0	0	0
3.71	5038.9	0	0	0	0	0	0	0	0	0
3.74	5088.2	0	0	0	0	0	0	0	2	0
3.78	5154.1	0	0	0	0	0	0	0	0	0
3.82	5219.9	0	0	0	0	0	0	0	0	0
3.86	5285.8	0	0	0	1	0	0	0	0	0
3.90	5351.6	0	0	0	1	0	0	0	0	0
3.94	5417.4	0	0	0	0	0	0	0	0	0
3.98	5483.3	0	0	0	0	0	0	0	0	0
4.02	5549.1	0	0	0	0	0	0	0	0	0
4.06	5614.9	0	0	0	1	0	0	0	0	0
4.10	5680.8	0	0	0	1	0	0	0	1	0
4.14	5746.6	0	0	0	0	0	0	0	1	0
4.18	5812.5	0	0	0	0	0	0	0	2	0
4.22	5878.3	0	0	0	2	1	0	0	0	0
4.26	5944.1	1	0	0	0	0	0	0	0	0
4.30	6010.0	0	0	0	0	0	0	0	1	0
4.31	6026.4	0	0	0	1	0	0	0	0	0
4.34	6075.8	0	0	0	2	0	0	0	0	0
4.38	6141.6	0	0	0	1	0	0	0	0	0
4.42	6207.5	0	0	0	0	0	0	0	0	0
4.46	6273.3	0	0	0	0	0	0	0	0	0
4.50	6339.1	0	0	0	0	0	0	0	0	0
4.55	6421.4	0	0	0	0	0	0	0	1	0
4.58	6470.8	0	0	0	0	0	0	0	0	0
4.62	6536.7	0	0	0	0	1	0	0	0	0
4.66	6602.5	0	0	0	0	1	0	0	0	0
4.70	6668.3	0	0	0	1	0	0	0	0	0
4.74	6734.2	0	0	0	0	0	0	0	1	2
4.76	6767.1	0	0	0	0	0	0	0	0	1
4.82	6852.3	0	0	0	0	0	0	0	0	0
5.26	7427.7	0	0	0	1	0	0	0	0	0
6.16	8604.6	0	0	0	1	0	0	0	0	0
7.06	9781.5	0	0	0	0	0	0	0	0	0
7.76	10696.9	0	0	0	1	0	0	0	0	0

Depth (m)	Age (cal yr BP)	t	dy	EQ	*H	X	W	ty
0.00	163.3	4	7	0	2	0	0	0
0.04	206.9	5	7	0	3	0	2	1
0.08	250.5	9	1	0	0	0	3	1
0.12	294.0	14	2	0	1	0	1	1
0.16	337.6	21	1	0	2	0	0	1
0.20	381.1	23	0	0	3	0	1	2
0.24	424.7	19	4	0	1	0	0	11
0.28	468.3	13	4	0	4	0	2	9
0.32	511.8	22	2	0	0	0	0	2
0.36	555.4	8	7	0	1	0	0	14
0.40	598.9	14	3	0	0	0	0	2
0.44	642.5	16	3	0	5	0	0	2
0.48	686.1	14	1	0	1	0	0	3
0.52	729.6	11	1	0	1	0	0	7
0.56	773.2	19	3	0	2	0	0	2
0.60	816.7	11	2	0	4	0	0	2
0.64	860.3	18	3	0	9	0	0	2
0.68	903.9	25	2	0	3	0	0	4
0.72	947.4	16	5	0	1	0	1	4
0.76	991.0	14	4	0	7	0	0	4
0.78	1012.8	7	2	0	4	0	0	10
0.80	1034.5	10	2	0	3	0	0	9
0.84	1078.1	14	4	0	9	1	0	11
0.88	1121.7	13	5	0	3	0	0	4
0.92	1165.2	20	5	0	6	0	0	5
0.96	1208.8	11	1	0	6	0	0	3
1.00	1252.3	9	3	0	1	1	0	4
1.04	1295.9	5	1	0	1	0	0	1
1.08	1339.4	16	2	0	0	0	1	4
1.12	1383.0	19	1	0	2	0	1	3
1.16	1426.6	8	4	0	1	0	0	3
1.20	1470.1	17	3	0	2	0	0	0
1.24	1513.7	14	7	0	1	0	2	1
1.28	1557.2	9	2	0	2	0	0	1
1.31	1589.9	4	5	0	0	0	0	3
1.32	1600.8	3	3	0	1	0	0	6
1.36	1644.4	7	1	0	0	0	0	7
1.40	1687.9	13	3	0	1	0	1	8
1.44	1731.5	11	3	0	0	0	1	7
1.48	1775.0	5	5	0	0	0	0	0
1.52	1818.6	19	0	0	0	0	1	1
1.56	1862.2	12	5	0	1	0	0	3
1.60	1905.7	4	4	0	1	0	0	4
1.64	1949.3	8	5	0	0	0	2	2
1.68	1992.8	7	2	0	0	0	0	11
1.72	2036.4	8	3	0	0	0	0	12
1.76	2080.0	5	2	0	0	0	1	0
1.80	2123.5	5	2	0	1	0	0	0
1.84	2167.1	8	4	0	1	0	1	0
1.86	2188.9	5	2	0	0	0	0	1

Depth (m)	Age (cal yr BP)	t	dy	EQ	*H	X	W	ty
1.88	2210.6	6	3	0	1	0	0	0
1.89	2221.5	1	1	0	1	0	2	1
1.90	2232.4	7	3	0	3	0	1	0
1.92	2254.2	8	3	0	0	0	0	1
1.94	2276.0	4	1	0	1	0	3	4
1.98	2319.5	7	5	0	0	0	1	4
2.02	2363.1	10	5	0	2	0	0	5
2.06	2406.7	15	4	0	2	0	2	1
2.10	2450.2	11	5	0	0	0	1	1
2.14	2493.8	14	0	0	1	0	2	3
2.18	2537.3	8	3	0	0	0	1	1
2.22	2586.5	21	5	0	3	0	3	2
2.25	2635.8	7	1	0	1	0	0	0
2.26	2652.3	26	9	0	1	0	0	0
2.30	2718.1	8	2	0	0	0	0	0
2.34	2784.0	4	2	0	4	0	1	0
2.38	2849.8	12	4	0	2	0	0	0
2.42	2915.6	10	2	0	0	0	2	0
2.46	2981.5	10	4	0	1	0	0	1
2.50	3047.3	6	1	0	0	0	0	3
2.54	3113.2	11	2	0	4	0	0	0
2.58	3179.0	6	0	0	0	0	1	0
2.62	3244.8	11	2	0	0	0	1	0
2.66	3310.7	15	2	0	2	0	1	2
2.70	3376.5	7	4	0	1	0	0	0
2.74	3442.3	4	2	0	1	0	4	1
2.78	3508.2	6	2	0	1	0	1	0
2.82	3574.0	11	1	0	1	0	1	3
2.86	3639.8	10	0	0	0	0	1	0
2.90	3705.7	9	6	0	0	0	0	1
2.94	3771.5	3	1	0	1	0	1	3
2.98	3837.4	5	4	0	1	0	0	0
3.02	3903.2	11	2	0	0	0	2	2
3.06	3969.0	12	2	0	0	0	0	3
3.10	4034.9	8	3	0	0	0	1	3
3.14	4100.7	13	6	0	1	0	0	2
3.16	4133.6	5	2	0	1	0	0	5
3.18	4166.5	12	6	0	2	0	0	2
3.22	4232.4	11	2	0	0	0	0	1
3.26	4298.2	16	2	0	0	0	0	3
3.30	4364.0	2	0	0	0	0	0	1
3.34	4429.9	9	4	0	1	0	0	0
3.38	4495.7	9	2	0	1	0	0	0
3.42	4561.6	8	2	0	1	0	0	0
3.46	4627.4	8	2	0	1	0	0	2
3.50	4693.2	10	3	0	1	0	0	2
3.54	4759.1	7	3	0	0	0	0	1
3.58	4824.9	14	5	0	1	0	0	3
3.62	4890.7	6	3	0	0	0	1	4
3.66	4956.6	5	2	0	0	0	0	1

Depth (m)	Age (cal yr BP)	t	dy	EQ	*H	X	W	ty
3.70	5022.4	12	4	0	1	0	2	6
3.71	5038.9	5	0	0	1	0	0	3
3.74	5088.2	11	5	2	0	0	0	1
3.78	5154.1	14	2	4	5	0	0	3
3.82	5219.9	7	0	0	1	0	0	1
3.86	5285.8	12	0	1	0	0	0	2
3.90	5351.6	2	1	2	2	0	0	3
3.94	5417.4	12	3	2	1	0	0	1
3.98	5483.3	9	4	9	0	0	0	3
4.02	5549.1	11	2	4	2	0	0	2
4.06	5614.9	17	3	1	0	0	1	0
4.10	5680.8	18	4	1	1	0	1	2
4.14	5746.6	22	2	1	3	0	0	1
4.18	5812.5	15	5	5	2	0	0	2
4.22	5878.3	15	7	7	1	0	1	5
4.26	5944.1	12	6	1	3	0	1	3
4.30	6010.0	9	7	4	2	0	0	0
4.31	6026.4	5	1	0	2	0	1	6
4.34	6075.8	14	4	5	0	0	0	1
4.38	6141.6	22	5	10	0	1	0	5
4.42	6207.5	16	1	5	0	0	1	2
4.46	6273.3	20	3	3	0	0	0	3
4.50	6339.1	24	2	3	0	0	0	10
4.55	6421.4	25	4	2	0	0	0	1
4.58	6470.8	17	4	1	2	0	0	4
4.62	6536.7	26	6	3	3	0	0	1
4.66	6602.5	20	9	5	1	0	0	3
4.70	6668.3	28	5	3	4	0	0	3
4.74	6734.2	27	3	2	4	0	0	0
4.76	6767.1	13	6	1	0	0	1	2
4.82	6852.3	27	1	2	2	0	0	7
5.26	7427.7	14	4	0	0	0	4	1
6.16	8604.6	9	1	0	6	0	0	1
7.06	9781.5	3	0	0	0	0	0	0
7.76	10696.9	9	9	0	0	0	2	1

Depth (m)	Age (cal yr BP)	LY	sg	UP	MY	SG	NU	LM
0.00	163.3	0	0	3	0	0	13	0
0.04	206.9	0	2	1	0	0	4	0
0.08	250.5	0	1	3	0	0	14	0
0.12	294.0	0	0	0	0	0	9	0
0.16	337.6	0	0	1	0	0	6	0
0.20	381.1	0	1	3	0	0	13	0
0.24	424.7	0	0	1	0	0	10	0
0.28	468.3	0	1	0	0	1	6	1
0.32	511.8	0	0	0	0	0	5	1
0.36	555.4	0	0	1	0	0	6	0
0.40	598.9	0	1	0	0	0	9	0
0.44	642.5	2	0	0	0	0	4	0
0.48	686.1	0	0	2	0	0	10	0
0.52	729.6	0	0	6	0	0	9	0
0.56	773.2	0	0	9	0	0	8	0
0.60	816.7	0	0	5	0	0	3	0
0.64	860.3	0	0	20	0	0	17	0
0.68	903.9	0	0	9	0	0	5	0
0.72	947.4	0	0	1	0	0	4	0
0.76	991.0	0	0	1	0	0	1	0
0.78	1012.8	0	0	1	0	0	16	0
0.80	1034.5	0	0	0	0	0	15	0
0.84	1078.1	0	0	1	0	0	10	0
0.88	1121.7	0	0	1	0	0	7	0
0.92	1165.2	0	0	1	0	0	5	0
0.96	1208.8	0	0	9	0	0	119	0
1.00	1252.3	0	0	0	0	0	6	0
1.04	1295.9	0	1	2	0	0	4	0
1.08	1339.4	0	0	1	0	0	6	0
1.12	1383.0	0	0	4	0	0	8	0
1.16	1426.6	0	1	7	0	0	9	0
1.20	1470.1	0	0	0	0	0	0	0
1.24	1513.7	0	8	0	0	0	8	0
1.28	1557.2	0	0	16	0	0	26	0
1.31	1589.9	0	0	0	0	0	23	0
1.32	1600.8	0	0	14	0	0	9	0
1.36	1644.4	0	0	4	0	0	17	0
1.40	1687.9	0	0	2	0	0	5	0
1.44	1731.5	0	0	2	0	0	6	0
1.48	1775.0	0	0	0	0	0	3	0
1.52	1818.6	0	0	13	0	0	20	0
1.56	1862.2	0	0	3	0	0	12	0
1.60	1905.7	0	0	0	0	0	8	0
1.64	1949.3	0	0	4	0	0	2	0
1.68	1992.8	0	0	10	0	0	11	0
1.72	2036.4	0	0	11	0	0	15	0
1.76	2080.0	0	0	0	0	0	6	1
1.80	2123.5	0	0	0	0	0	4	0
1.84	2167.1	0	0	2	1	0	7	0
1.86	2188.9	0	0	3	1	0	2	0

Depth (m)	Age (cal yr BP)	LY	sg	UP	MY	SG	NU	LM
1.88	2210.6	0	0	2	0	0	1	0
1.89	2221.5	0	0	0	0	0	3	0
1.90	2232.4	0	0	3	3	0	10	0
1.92	2254.2	0	0	2	2	0	10	0
1.94	2276.0	0	0	4	2	0	3	0
1.98	2319.5	0	0	1	2	0	3	0
2.02	2363.1	0	0	2	2	0	5	0
2.06	2406.7	0	0	1	2	0	1	0
2.10	2450.2	0	0	2	0	0	1	0
2.14	2493.8	0	0	0	0	0	1	0
2.18	2537.3	0	0	0	0	1	1	1
2.22	2586.5	0	0	1	1	0	4	0
2.25	2635.8	0	0	0	1	0	7	0
2.26	2652.3	0	0	6	0	0	0	0
2.30	2718.1	0	0	7	0	0	2	0
2.34	2784.0	0	0	3	0	0	4	0
2.38	2849.8	0	0	8	0	0	0	0
2.42	2915.6	0	0	5	0	0	1	0
2.46	2981.5	0	1	2	0	0	4	0
2.50	3047.3	0	0	1	0	0	7	0
2.54	3113.2	0	0	3	0	0	7	0
2.58	3179.0	0	0	8	1	0	1	0
2.62	3244.8	0	1	16	4	0	2	0
2.66	3310.7	0	0	1	2	0	2	0
2.70	3376.5	0	1	2	1	0	0	0
2.74	3442.3	0	1	7	4	0	1	0
2.78	3508.2	0	0	30	1	0	4	0
2.82	3574.0	0	0	5	0	0	1	0
2.86	3639.8	0	0	43	0	0	1	0
2.90	3705.7	0	0	11	1	0	6	0
2.94	3771.5	0	0	7	0	0	5	0
2.98	3837.4	0	0	2	1	0	0	0
3.02	3903.2	0	0	8	0	0	3	0
3.06	3969.0	0	1	4	0	0	7	0
3.10	4034.9	0	0	0	0	0	3	0
3.14	4100.7	0	1	3	0	0	8	0
3.16	4133.6	0	0	0	0	0	3	0
3.18	4166.5	0	0	2	0	0	3	0
3.22	4232.4	0	0	0	0	0	5	0
3.26	4298.2	0	0	2	1	0	1	0
3.30	4364.0	0	0	1	0	0	5	0
3.34	4429.9	0	0	0	1	0	3	0
3.38	4495.7	0	0	0	1	0	4	0
3.42	4561.6	0	0	3	2	0	2	0
3.46	4627.4	0	0	1	1	0	2	0
3.50	4693.2	0	1	1	0	0	3	0
3.54	4759.1	0	0	4	1	0	0	0
3.58	4824.9	0	0	4	1	0	6	0
3.62	4890.7	0	0	2	1	0	4	0
3.66	4956.6	0	1	2	0	0	1	0

Depth (m)	Age (cal yr BP)	LY	sg	UP	MY	SG	NU	LM
3.70	5022.4	0	0	0	0	0	2	0
3.71	5038.9	0	0	0	0	0	2	0
3.74	5088.2	0	1	1	0	0	5	0
3.78	5154.1	0	0	3	0	0	3	0
3.82	5219.9	0	0	2	0	0	0	0
3.86	5285.8	0	0	1	0	0	1	0
3.90	5351.6	0	0	6	0	0	3	0
3.94	5417.4	0	0	4	0	0	4	0
3.98	5483.3	0	1	0	0	0	1	0
4.02	5549.1	0	1	7	0	0	2	0
4.06	5614.9	0	0	6	0	0	2	0
4.10	5680.8	0	0	1	0	0	4	0
4.14	5746.6	0	0	10	0	0	4	0
4.18	5812.5	0	0	0	0	0	3	0
4.22	5878.3	0	0	3	0	1	3	0
4.26	5944.1	0	0	3	1	0	2	0
4.30	6010.0	0	0	3	0	0	0	0
4.31	6026.4	0	1	0	0	0	1	0
4.34	6075.8	0	2	2	0	0	4	0
4.38	6141.6	0	0	2	0	0	1	0
4.42	6207.5	0	0	1	1	0	3	0
4.46	6273.3	0	0	0	0	0	7	0
4.50	6339.1	0	0	3	0	0	2	0
4.55	6421.4	0	0	2	0	2	3	0
4.58	6470.8	0	1	1	0	0	2	0
4.62	6536.7	0	1	2	0	0	4	0
4.66	6602.5	0	3	4	1	3	9	0
4.70	6668.3	0	5	6	2	0	7	0
4.74	6734.2	0	3	4	0	0	4	0
4.76	6767.1	0	3	4	0	0	2	0
4.82	6852.3	0	2	5	0	1	0	0
5.26	7427.7	0	4	0	0	0	2	0
6.16	8604.6	0	0	0	0	0	4	0
7.06	9781.5	0	0	0	0	0	1	0
7.76	10696.9	0	0	0	0	0	0	0

Depth (m)	Age (cal yr BP)	BR	IS	EU	Sum B	Sum C
0.00	163.3	0	0	105	232	16
0.04	206.9	1	3	64	238	12
0.08	250.5	1	2	111	239	22
0.12	294.0	6	3	93	86	19
0.16	337.6	0	1	59	51	9
0.20	381.1	12	3	98	92	34
0.24	424.7	15	5	107	80	42
0.28	468.3	47	3	173	82	68
0.32	511.8	39	8	106	69	55
0.36	555.4	43	11	182	48	75
0.40	598.9	37	4	150	76	53
0.44	642.5	16	3	129	76	27
0.48	686.1	19	4	134	81	38
0.52	729.6	33	7	160	87	62
0.56	773.2	2	6	147	95	27
0.60	816.7	4	4	111	75	18
0.64	860.3	8	5	219	92	52
0.68	903.9	30	7	142	83	55
0.72	947.4	91	6	157	96	106
0.76	991.0	136	6	171	110	148
0.78	1012.8	72	4	203	91	103
0.80	1034.5	31	7	139	132	62
0.84	1078.1	6	8	111	159	36
0.88	1121.7	39	9	101	122	60
0.92	1165.2	32	6	136	137	49
0.96	1208.8	25	5	241	107	161
1.00	1252.3	73	6	156	90	89
1.04	1295.9	45	7	154	80	60
1.08	1339.4	23	9	145	112	43
1.12	1383.0	17	12	156	103	44
1.16	1426.6	21	4	160	102	45
1.20	1470.1	0	0	138	78	0
1.24	1513.7	33	2	98	103	52
1.28	1557.2	1	2	147	60	46
1.31	1589.9	1	1	120	54	28
1.32	1600.8	3	2	109	62	34
1.36	1644.4	35	12	191	65	75
1.40	1687.9	19	5	179	95	39
1.44	1731.5	19	3	120	86	37
1.48	1775.0	52	9	106	77	64
1.52	1818.6	30	7	171	81	71
1.56	1862.2	23	6	139	80	47
1.60	1905.7	14	3	116	69	29
1.64	1949.3	56	5	106	75	69
1.68	1992.8	23	9	177	99	64
1.72	2036.4	88	1	200	97	127
1.76	2080.0	46	3	83	64	56
1.80	2123.5	82	8	142	65	94
1.84	2167.1	39	5	131	104	54
1.86	2188.9	54	3	100	57	64

Depth (m)	Age (cal yr BP)	BR	IS	EU	Sum B	Sum C
1.88	2210.6	62	2	110	86	67
1.89	2221.5	48	6	139	82	58
1.90	2232.4	88	3	124	90	107
1.92	2254.2	55	2	145	82	72
1.94	2276.0	101	4	116	75	118
1.98	2319.5	111	3	120	75	124
2.02	2363.1	161	6	166	89	181
2.06	2406.7	196	4	167	96	205
2.10	2450.2	206	8	189	79	218
2.14	2493.8	193	1	143	85	198
2.18	2537.3	156	3	205	77	163
2.22	2586.5	172	9	163	81	189
2.25	2635.8	42	8	129	54	58
2.26	2652.3	244	6	165	112	256
2.30	2718.1	133	10	152	56	152
2.34	2784.0	70	16	149	53	93
2.38	2849.8	123	1	90	63	132
2.42	2915.6	145	13	132	64	164
2.46	2981.5	21	8	111	80	37
2.50	3047.3	22	14	73	79	47
2.54	3113.2	53	3	108	79	66
2.58	3179.0	114	16	86	42	140
2.62	3244.8	74	19	102	58	116
2.66	3310.7	85	18	67	82	110
2.70	3376.5	15	8	95	80	27
2.74	3442.3	312	18	109	71	344
2.78	3508.2	39	11	98	71	85
2.82	3574.0	14	10	92	66	33
2.86	3639.8	94	11	132	80	149
2.90	3705.7	40	5	146	60	64
2.94	3771.5	51	8	105	61	74
2.98	3837.4	47	18	95	60	68
3.02	3903.2	48	12	154	64	73
3.06	3969.0	50	10	120	76	75
3.10	4034.9	26	4	78	65	36
3.14	4100.7	16	3	81	80	33
3.16	4133.6	21	2	66	69	31
3.18	4166.5	23	10	123	87	40
3.22	4232.4	0	10	75	59	16
3.26	4298.2	28	8	71	90	43
3.30	4364.0	35	18	81	50	60
3.34	4429.9	40	16	79	71	60
3.38	4495.7	6	11	57	60	22
3.42	4561.6	10	14	63	52	31
3.46	4627.4	13	10	85	38	29
3.50	4693.2	25	4	131	77	36
3.54	4759.1	14	13	98	68	33
3.58	4824.9	58	1	106	91	73
3.62	4890.7	27	1	66	62	39
3.66	4956.6	19	1	58	31	25

Depth (m)	Age (cal yr BP)	BR	IS	EU	Sum B	Sum C
3.70	5022.4	12	1	60	62	21
3.71	5038.9	32	0	179	62	37
3.74	5088.2	56	3	138	101	67
3.78	5154.1	34	2	100	76	45
3.82	5219.9	97	7	119	72	107
3.86	5285.8	72	2	130	76	78
3.90	5351.6	58	6	108	65	76
3.94	5417.4	36	3	143	77	48
3.98	5483.3	21	4	107	102	30
4.02	5549.1	47	1	159	71	60
4.06	5614.9	28	4	122	92	40
4.10	5680.8	39	1	97	97	47
4.14	5746.6	28	1	95	84	44
4.18	5812.5	25	2	89	92	32
4.22	5878.3	37	0	147	92	49
4.26	5944.1	35	2	103	82	46
4.30	6010.0	20	2	99	68	25
4.31	6026.4	28	0	149	72	36
4.34	6075.8	35	1	109	94	45
4.38	6141.6	16	1	110	106	25
4.42	6207.5	23	1	134	83	31
4.46	6273.3	15	2	101	86	27
4.50	6339.1	30	5	124	90	50
4.55	6421.4	53	1	168	98	62
4.58	6470.8	50	2	181	83	60
4.62	6536.7	20	1	169	102	29
4.66	6602.5	31	1	178	85	55
4.70	6668.3	50	1	168	98	74
4.74	6734.2	48	2	141	99	61
4.76	6767.1	57	4	190	85	72
4.82	6852.3	39	1	276	101	55
5.26	7427.7	14	0	227	55	21
6.16	8604.6	14	0	305	32	19
7.06	9781.5	4	0	157	15	5
7.76	10696.9	0	0	172	27	1

Depth (m)	Age (cal yr BP)	Sum D	Sum X	Sum A	Sum P	Sum T
0.00	163.3	6	186	192	424	440
0.04	206.9	5	163	168	406	418
0.08	250.5	9	163	172	411	433
0.12	294.0	5	313	318	404	423
0.16	337.6	1	361	362	413	422
0.20	381.1	4	320	324	416	450
0.24	424.7	13	308	321	401	443
0.28	468.3	4	322	326	408	476
0.32	511.8	2	346	348	417	472
0.36	555.4	6	157	163	211	286
0.40	598.9	9	325	334	410	463
0.44	642.5	15	330	345	421	448
0.48	686.1	6	312	318	399	437
0.52	729.6	8	338	346	433	495
0.56	773.2	9	309	318	413	440
0.60	816.7	2	336	338	413	431
0.64	860.3	2	317	319	411	463
0.68	903.9	8	324	332	415	470
0.72	947.4	11	303	314	410	516
0.76	991.0	5	287	292	402	550
0.78	1012.8	17	299	316	407	510
0.80	1034.5	8	269	277	409	471
0.84	1078.1	6	272	278	437	473
0.88	1121.7	14	279	293	415	475
0.92	1165.2	3	271	274	411	460
0.96	1208.8	15	289	304	411	572
1.00	1252.3	2	334	336	426	515
1.04	1295.9	5	324	329	409	469
1.08	1339.4	4	295	299	411	454
1.12	1383.0	13	299	312	415	459
1.16	1426.6	9	304	313	415	460
1.20	1470.1	6	317	323	401	401
1.24	1513.7	10	295	305	408	460
1.28	1557.2	6	346	352	412	458
1.31	1589.9	9	352	361	415	443
1.32	1600.8	7	351	358	420	454
1.36	1644.4	9	341	350	415	490
1.40	1687.9	5	312	317	412	451
1.44	1731.5	6	340	346	432	469
1.48	1775.0	2	351	353	430	494
1.52	1818.6	6	330	336	417	488
1.56	1862.2	4	327	331	411	458
1.60	1905.7	5	351	356	425	454
1.64	1949.3	12	342	354	429	498
1.68	1992.8	4	309	313	412	476
1.72	2036.4	6	308	314	411	538
1.76	2080.0	3	351	354	418	474
1.80	2123.5	4	349	353	418	512
1.84	2167.1	5	303	308	412	466
1.86	2188.9	2	357	359	416	480

Depth (m)	Age (cal yr BP)	Sum D	Sum X	Sum A	Sum P	Sum T
1.88	2210.6	11	323	334	420	487
1.89	2221.5	12	324	336	418	476
1.90	2232.4	6	333	339	429	536
1.92	2254.2	4	358	362	444	516
1.94	2276.0	6	352	358	433	551
1.98	2319.5	9	326	335	410	534
2.02	2363.1	7	326	333	422	603
2.06	2406.7	9	327	336	432	637
2.10	2450.2	8	326	334	413	631
2.14	2493.8	9	321	330	415	613
2.18	2537.3	8	341	349	426	589
2.22	2586.5	3	338	341	422	611
2.25	2635.8	3	356	359	413	471
2.26	2652.3	8	293	301	413	669
2.30	2718.1	6	359	365	421	573
2.34	2784.0	7	357	364	417	510
2.38	2849.8	4	352	356	419	551
2.42	2915.6	13	352	365	429	593
2.46	2981.5	8	329	337	417	454
2.50	3047.3	2	340	342	421	468
2.54	3113.2	7	335	342	421	487
2.58	3179.0	3	371	374	416	556
2.62	3244.8	5	351	356	414	530
2.66	3310.7	7	327	334	416	526
2.70	3376.5	4	340	344	424	451
2.74	3442.3	8	350	358	429	773
2.78	3508.2	3	357	360	431	516
2.82	3574.0	6	356	362	428	461
2.86	3639.8	6	330	336	416	565
2.90	3705.7	6	364	370	430	494
2.94	3771.5	3	351	354	415	489
2.98	3837.4	7	355	362	422	490
3.02	3903.2	7	354	361	425	498
3.06	3969.0	2	349	351	427	502
3.10	4034.9	14	347	361	426	462
3.14	4100.7	10	344	354	434	467
3.16	4133.6	4	347	351	420	451
3.18	4166.5	8	337	345	432	472
3.22	4232.4	7	351	358	417	433
3.26	4298.2	4	327	331	421	464
3.30	4364.0	3	364	367	417	477
3.34	4429.9	2	360	362	433	493
3.38	4495.7	2	378	380	440	462
3.42	4561.6	2	377	379	431	462
3.46	4627.4	5	380	385	423	452
3.50	4693.2	4	326	330	407	443
3.54	4759.1	5	346	351	419	452
3.58	4824.9	9	325	334	425	498
3.62	4890.7	3	352	355	417	456
3.66	4956.6	1	383	384	415	440

Depth (m)	Age (cal yr BP)	Sum D	Sum X	Sum A	Sum P	Sum T
3.70	5022.4	3	355	358	420	441
3.71	5038.9	2	359	361	423	460
3.74	5088.2	6	308	314	415	482
3.78	5154.1	4	354	358	434	479
3.82	5219.9	9	340	349	421	528
3.86	5285.8	2	335	337	413	491
3.90	5351.6	10	350	360	425	501
3.94	5417.4	7	334	341	418	466
3.98	5483.3	9	310	319	421	451
4.02	5549.1	7	356	363	434	494
4.06	5614.9	3	339	342	434	474
4.10	5680.8	12	313	325	422	469
4.14	5746.6	7	345	352	436	480
4.18	5812.5	12	299	311	403	435
4.22	5878.3	6	325	331	423	472
4.26	5944.1	6	331	337	419	465
4.30	6010.0	5	340	345	413	438
4.31	6026.4	13	341	354	426	462
4.34	6075.8	8	312	320	414	459
4.38	6141.6	6	301	307	413	438
4.42	6207.5	11	318	329	412	443
4.46	6273.3	7	330	337	423	450
4.50	6339.1	10	308	318	408	458
4.55	6421.4	6	316	322	420	482
4.58	6470.8	8	328	336	419	479
4.62	6536.7	4	306	310	412	441
4.66	6602.5	7	340	347	432	487
4.70	6668.3	12	311	323	421	495
4.74	6734.2	11	296	307	406	467
4.76	6767.1	7	324	331	416	488
4.82	6852.3	5	310	315	416	471
5.26	7427.7	5	370	375	430	451
6.16	8604.6	6	376	382	414	433
7.06	9781.5	3	443	446	461	466
7.76	10696.9	7	40	47	74	75

APPENDIX C

SHORT CORE POLLEN COUNTS
FOR BEAVER LAKE

Depth (m)	\$P	I	AB	LX	J	TS	AR	CY	S
0.01	7	0	5	8	12	6	20	1	36
0.05	7	0	5	6	2	2	21	4	39
0.09	5	0	6	11	8	0	25	2	40
0.13	10	0	1	10	4	6	30	7	56
0.17	3	0	6	10	7	6	26	3	52
0.21	10	1	1	12	7	7	26	3	45
0.25	7	0	3	16	4	6	19	6	61
0.29	6	0	1	6	5	3	23	5	93
0.37	4	0	3	16	13	7	22	10	65
0.41	7	0	5	25	5	3	14	5	89
0.45	6	1	7	9	8	8	20	3	129
0.49	5	0	6	19	7	5	14	5	155
0.53	8	1	9	17	3	11	23	5	155
0.57	9	1	12	8	8	7	18	8	161
0.61	3	0	1	14	6	9	26	1	149

Depth (m)	PU	FU	Q	SM	AM	RS	PR	TP	RO
0.01	0	15	9	0	0	0	0	0	2
0.05	0	21	16	0	1	0	0	0	3
0.09	2	12	4	1	0	5	0	0	0
0.13	1	18	10	0	2	8	0	0	1
0.17	1	20	10	0	3	1	0	0	1
0.21	1	24	12	0	1	4	0	0	0
0.25	2	24	14	0	0	1	0	0	2
0.29	0	18	11	0	0	2	0	0	2
0.37	0	40	10	0	0	0	0	0	3
0.41	0	33	35	0	3	1	0	0	1
0.45	1	23	11	0	5	3	0	0	4
0.49	0	34	10	0	0	9	0	0	3
0.53	1	27	13	0	0	3	0	0	2
0.57	0	29	10	0	1	12	0	0	2
0.61	0	33	17	0	4	4	0	0	0

Depth (m)	JU	PN	G	Y	R	M	K	RA	UM
0.01	0	0	184	5	9	1	2	0	2
0.05	0	0	255	5	0	0	2	0	0
0.09	0	0	236	11	0	0	1	1	2
0.13	0	1	237	17	1	0	5	2	2
0.17	2	0	205	13	0	0	0	0	11
0.21	0	1	193	17	1	0	2	2	1
0.25	2	1	200	28	1	0	2	1	0
0.29	0	1	158	13	3	0	2	0	6
0.37	0	1	153	25	8	0	0	0	1
0.41	2	0	143	20	3	0	0	0	1
0.45	0	0	86	27	6	1	4	0	2
0.49	0	1	75	39	1	0	1	0	1
0.53	0	0	68	39	0	0	0	0	1
0.57	1	4	86	18	3	0	0	0	3
0.61	0	0	79	26	0	0	1	0	2

Depth (m)	ON	GA	*H	t	dy	EQ	ty	sg	UP
0.01	0	0	4	8	1	0	0	1	3
0.05	0	0	1	8	4	0	2	1	1
0.09	1	0	11	12	4	0	1	3	3
0.13	0	0	6	6	0	0	2	1	1
0.17	0	0	2	11	4	0	1	3	1
0.21	0	0	4	12	7	0	1	5	5
0.25	0	0	1	17	4	0	5	4	3
0.29	0	1	6	18	5	0	5	2	0
0.37	0	1	2	18	3	0	6	2	1
0.41	0	0	2	14	6	0	6	3	3
0.45	1	0	3	28	5	0	4	2	3
0.49	0	0	3	24	3	0	1	3	7
0.53	0	0	1	24	4	0	2	5	4
0.57	0	0	4	28	2	0	10	0	9
0.61	0	0	4	17	8	0	2	2	3

Depth (m)	MY	SG	NU	LM	BR	IS
0.01	0	0	9	2	2	0
0.05	0	0	6	0	8	0
0.09	1	0	9	0	2	3
0.13	0	0	11	0	1	3
0.17	0	0	12	0	1	0
0.21	1	0	14	0	6	2
0.25	0	0	7	0	3	4
0.29	0	0	3	2	6	2
0.37	0	0	7	0	8	1
0.41	0	0	8	1	2	1
0.45	0	0	9	1	9	1
0.49	0	0	10	0	13	5
0.53	0	0	9	0	6	2
0.57	0	0	10	0	9	5
0.61	0	0	6	0	5	6

APPENDIX D

LONG CORE CHARCOAL AND MAGNETIC SUSCEPTIBILITY
CONCENTRATION AND ACCUMULATION RATES
FOR BEAVER LAKE

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
0.01	92.9	2.5	49.5	41.6	8.2
0.03	102.9	1.5	45.5	37.6	7.4
0.05	113.2	3.5	54.5	46.4	8.9
0.07	123.8	7.0	43.5	40.4	7.5
0.09	134.8	7.5	56.0	50.8	9.1
0.11	146.1	2.5	43.0	36.4	6.4
0.13	157.7	5.5	54.0	47.6	8.1
0.15	169.6	5.0	59.0	51.2	8.5
0.17	181.8	6.0	28.0	27.2	4.4
0.19	194.4	7.5	50.5	46.4	7.3
0.21	207.2	7.5	66.0	58.8	9.0
0.23	220.4	8.0	65.5	58.8	8.8
0.25	233.9	14.5	78.0	74.0	10.9
0.27	247.7	8.5	87.0	76.4	11.0
0.29	261.8	14.5	86.5	80.8	11.3
0.31	276.2	6.5	53.0	47.6	6.5
0.33	290.9	14.5	76.0	72.4	9.8
0.35	305.9	6.0	47.0	42.4	5.6
0.37	321.2	5.0	68.5	58.8	7.6
0.39	336.8	12.0	65.0	61.6	7.8
0.41	352.7	10.0	55.0	52.0	6.5
0.43	368.8	8.5	46.0	43.6	5.3
0.45	385.3	10.0	51.5	49.2	5.9
0.47	402.1	28.0	101.0	103.2	12.2
0.49	419.1	7.5	70.0	62.0	7.2
0.51	436.4	14.0	53.5	54.0	6.2
0.53	454.0	6.0	69.0	60.0	6.8
0.55	471.9	7.5	53.0	48.4	5.4
0.57	490.1	18.0	82.5	80.4	8.8
0.59	508.5	10.5	53.0	50.8	5.5
0.61	527.3	19.5	94.0	90.8	9.6
0.63	546.3	7.0	57.5	51.6	5.4
0.65	565.5	37.5	126.0	130.8	13.5
0.67	585.1	114.0	271.0	308.0	31.3
0.69	604.9	92.0	190.5	226.0	22.7
0.71	624.9	372.0	254.5	501.2	49.6
0.73	645.3	74.0	156.0	184.0	18.0
0.75	665.9	98.5	188.0	229.2	22.1
0.77	686.7	176.5	189.5	292.8	27.9
0.79	707.9	185.0	294.5	383.6	36.1
0.81	729.2	147.0	354.0	400.8	37.3
0.83	750.9	147.0	187.5	267.6	24.6
0.85	772.8	137.0	284.5	337.2	30.6
0.87	794.9	184.5	286.0	376.4	33.8
0.89	817.3	366.0	724.5	872.4	77.5
0.91	839.9	317.5	579.0	717.2	63.0
0.93	862.8	213.5	610.0	658.8	57.3
0.95	885.9	309.5	768.5	862.4	74.2
0.97	909.3	134.5	368.0	402.0	34.2
0.99	932.9	316.0	740.0	844.8	71.2
1.01	956.8	245.0	1263.5	1206.8	100.7

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
1.03	980.8	505.0	1432.0	1549.6	128.1
1.05	1005.2	458.0	1022.5	1184.4	96.9
1.07	1029.7	338.0	851.5	951.6	77.1
1.09	1054.5	362.5	800.0	930.0	74.7
1.11	1079.5	188.5	947.0	908.4	72.3
1.13	1104.8	191.5	733.0	739.6	58.3
1.15	1130.2	292.5	833.5	900.8	70.4
1.17	1155.9	233.0	638.0	696.8	54.0
1.19	1181.8	311.0	789.0	880.0	67.6
1.21	1208.0	283.0	516.5	639.6	48.7
1.23	1234.3	371.5	785.0	925.2	69.9
1.25	1260.9	320.5	788.0	886.8	66.5
1.27	1287.7	259.0	512.5	617.2	45.9
1.29	1314.7	132.5	287.0	335.6	24.8
1.31	1341.9	313.5	533.0	677.2	49.6
1.33	1369.3	225.0	624.5	679.6	49.4
1.35	1396.9	194.0	577.5	617.2	44.5
1.37	1424.8	399.0	649.0	838.4	60.1
1.38	1438.8	472.0	885.0	1085.6	77.4
1.39	1452.8	452.0	1228.0	1344.0	95.5
1.40	1466.9	339.0	1141.0	1184.0	83.9
1.41	1481.0	332.0	1186.0	1214.4	85.7
1.42	1495.2	330.0	1041.0	1096.8	77.1
1.43	1509.5	378.0	956.0	1067.2	74.8
1.44	1523.8	277.0	952.0	983.2	68.7
1.45	1538.1	403.0	1190.0	1274.4	88.7
1.46	1552.5	333.0	1140.0	1178.4	81.7
1.47	1567.0	157.0	692.0	679.2	47.0
1.48	1581.4	147.0	661.0	646.4	44.5
1.49	1596.0	252.0	1023.0	1020.0	70.0
1.50	1610.6	397.0	1443.0	1472.0	100.7
1.51	1625.2	519.0	1577.0	1676.8	114.4
1.52	1639.9	447.0	1303.0	1400.0	95.2
1.53	1654.6	349.0	903.0	1001.6	67.9
1.54	1669.4	209.0	678.0	709.6	47.9
1.55	1684.2	212.0	626.0	670.4	45.1
1.56	1699.1	704.0	1192.0	1516.8	101.8
1.57	1714.0	275.0	921.0	956.8	64.0
1.58	1729.0	262.0	1024.0	1028.8	68.6
1.59	1744.0	202.0	496.0	558.4	37.1
1.60	1759.1	219.0	584.0	642.4	42.6
1.61	1774.2	260.0	680.0	752.0	49.7
1.62	1789.3	283.0	783.0	852.8	56.2
1.63	1804.5	283.0	760.0	834.4	54.8
1.64	1819.7	227.0	806.0	826.4	54.2
1.65	1835.0	224.0	951.0	940.0	61.4
1.66	1850.3	199.0	799.0	798.4	52.0
1.67	1865.7	262.0	1107.0	1095.2	71.1
1.68	1881.1	193.0	668.0	688.8	44.6
1.69	1896.6	86.0	408.0	395.2	25.5
1.70	1912.1	99.0	493.0	473.6	30.5

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
1.71	1927.7	115.0	558.0	538.4	34.6
1.72	1943.2	156.0	565.0	576.8	36.9
1.73	1958.9	118.0	516.0	507.2	32.4
1.74	1974.6	116.0	456.0	457.6	29.2
1.75	1990.3	188.0	669.0	685.6	43.6
1.76	2006.0	122.0	483.0	484.0	30.7
1.77	2021.8	159.0	677.0	668.8	42.3
1.78	2037.7	97.0	472.0	455.2	28.7
1.79	2053.6	275.0	785.0	848.0	53.3
1.80	2069.5	384.0	1004.0	1110.4	69.6
1.81	2085.5	265.0	649.0	731.2	45.7
1.82	2101.5	191.0	702.0	714.4	44.6
1.83	2117.5	284.0	899.0	946.4	58.9
1.84	2133.6	256.0	789.0	836.0	51.9
1.85	2149.8	245.0	553.0	638.4	39.5
1.86	2165.9	130.0	480.0	488.0	30.1
1.87	2182.1	406.0	937.0	1074.4	66.2
1.88	2198.4	568.0	1580.0	1718.4	105.6
1.89	2214.7	283.0	1138.0	1136.8	69.7
1.90	2231.0	299.0	637.0	748.8	45.8
1.91	2247.4	244.0	781.0	820.0	50.0
1.92	2263.8	196.0	746.0	753.6	45.9
1.93	2280.2	209.0	779.0	790.4	48.0
1.94	2296.7	227.0	796.0	818.4	49.6
1.95	2313.2	225.0	698.0	738.4	44.6
1.96	2329.8	91.0	424.0	412.0	24.9
1.97	2346.4	122.0	613.0	588.0	35.4
1.98	2363.0	171.0	646.0	653.6	39.2
1.99	2379.7	207.0	816.0	818.4	49.0
2.00	2396.4	283.0	1138.0	1136.8	68.0
2.01	2413.1	260.0	891.0	920.8	54.9
2.02	2429.9	109.0	456.0	452.0	26.9
2.03	2446.7	102.0	473.0	460.0	27.3
2.04	2463.6	138.0	442.0	464.0	27.5
2.05	2480.5	136.0	619.0	604.0	35.7
2.06	2497.4	191.0	821.0	809.6	47.8
2.07	2514.4	126.0	770.0	716.8	42.2
2.08	2531.4	118.0	530.0	518.4	30.5
2.09	2548.4	58.0	322.0	304.0	17.8
2.10	2565.4	85.0	256.0	272.8	16.0
2.11	2582.5	113.0	454.0	453.6	26.5
2.12	2599.7	108.0	415.0	418.4	24.4
2.13	2616.8	95.0	336.0	344.8	20.1
2.14	2634.0	62.0	244.0	244.8	14.2
2.15	2651.3	67.0	354.0	336.8	19.5
2.16	2668.5	81.0	448.0	423.2	24.5
2.17	2685.8	150.0	632.0	625.6	36.1
2.18	2703.2	501.0	1685.0	1748.8	100.8
2.19	2720.5	106.0	370.0	380.8	21.9
2.20	2737.9	75.0	292.0	293.6	16.9
2.21	2755.4	79.0	468.0	437.6	25.1

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
2.22	2772.8	72.0	320.0	313.6	17.9
2.23	2790.3	39.0	158.0	157.6	9.0
2.24	2807.8	59.0	202.0	208.8	11.9
2.25	2825.4	67.0	237.0	243.2	13.8
2.26	2843.0	51.0	239.0	232.0	13.2
2.27	2860.6	41.0	200.0	192.8	10.9
2.28	2878.2	31.0	181.0	169.6	9.6
2.29	2895.9	51.0	224.0	220.0	12.4
2.30	2913.6	30.0	156.0	148.8	8.4
2.31	2931.3	28.0	190.0	174.4	9.8
2.32	2949.1	35.0	156.0	152.8	8.6
2.33	2966.9	52.0	255.0	245.6	13.8
2.34	2984.7	53.0	222.0	220.0	12.3
2.35	3002.6	48.0	270.0	254.4	14.2
2.36	3020.4	51.0	276.0	261.6	14.6
2.37	3038.4	87.0	270.0	285.6	15.9
2.38	3056.3	92.0	487.0	463.2	25.8
2.39	3074.3	147.0	452.0	479.2	26.7
2.40	3092.2	148.0	601.0	599.2	33.3
2.41	3110.3	90.0	447.0	429.6	23.8
2.42	3128.3	128.0	510.0	510.4	28.3
2.43	3146.4	58.0	439.0	397.6	22.0
2.44	3164.5	62.0	421.0	386.4	21.3
2.45	3182.6	23.0	151.0	139.2	7.7
2.46	3200.8	33.0	168.0	160.8	8.9
2.47	3218.9	37.0	192.0	183.2	10.1
2.48	3237.1	58.0	208.0	212.8	11.7
2.49	3255.4	28.0	136.0	131.2	7.2
2.50	3273.6	40.0	218.0	206.4	11.3
2.51	3291.9	69.0	433.0	401.6	22.0
2.52	3310.2	117.0	511.0	502.4	27.4
2.53	3328.5	86.0	435.0	416.8	22.7
2.54	3346.9	90.0	469.0	447.2	24.3
2.55	3365.3	68.0	448.0	412.8	22.4
2.56	3383.7	78.0	403.0	384.8	20.9
2.57	3402.1	93.0	417.0	408.0	22.1
2.58	3420.5	80.0	420.0	400.0	21.7
2.59	3439.0	85.0	480.0	452.0	24.5
2.60	3457.5	73.0	391.0	371.2	20.1
2.61	3476.0	78.0	410.0	390.4	21.1
2.62	3494.6	94.0	467.0	448.8	24.2
2.63	3513.1	96.0	504.0	480.0	25.8
2.64	3531.7	76.0	310.0	308.8	16.6
2.65	3550.3	47.0	190.0	189.6	10.2
2.66	3569.0	15.0	90.0	84.0	4.5
2.67	3587.6	51.0	177.0	182.4	9.8
2.68	3606.3	23.0	114.0	109.6	5.9
2.69	3625.0	41.0	277.0	254.4	13.6
2.70	3643.7	43.0	213.0	204.8	10.9
2.71	3662.4	16.0	134.0	120.0	6.4
2.72	3681.2	28.0	145.0	138.4	7.4

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
2.73	3700.0	45.0	173.0	174.4	9.3
2.74	3718.7	122.0	431.0	442.4	23.5
2.75	3737.6	93.0	506.0	479.2	25.5
2.76	3756.4	82.0	416.0	398.4	21.1
2.77	3775.2	108.0	303.0	328.8	17.4
2.78	3794.1	70.0	378.0	358.4	19.0
2.79	3813.0	26.0	257.0	226.4	12.0
2.80	3831.9	16.0	110.0	100.8	5.3
2.81	3850.8	10.0	84.0	75.2	4.0
2.82	3869.8	12.0	69.0	64.8	3.4
2.83	3888.7	17.0	89.0	84.8	4.5
2.84	3907.7	32.0	143.0	140.0	7.4
2.85	3926.7	14.0	133.0	117.6	6.2
2.86	3945.7	26.0	135.0	128.8	6.8
2.87	3964.8	28.0	145.0	138.4	7.3
2.88	3983.8	27.0	167.0	155.2	8.1
2.89	4002.9	32.0	198.0	184.0	9.6
2.90	4022.0	26.0	156.0	145.6	7.6
2.91	4041.1	21.0	105.0	100.8	5.3
2.92	4060.2	35.0	156.0	152.8	8.0
2.93	4079.3	54.0	195.0	199.2	10.4
2.94	4098.4	54.0	155.0	167.2	8.7
2.95	4117.6	12.0	60.0	57.6	3.0
2.96	4136.8	11.0	71.0	65.6	3.4
2.97	4156.0	20.0	89.0	87.2	4.5
2.98	4175.2	11.0	62.0	58.4	3.0
2.99	4194.4	11.0	39.0	40.0	2.1
3.00	4213.6	8.0	56.0	51.2	2.7
3.01	4232.8	11.0	58.0	55.2	2.9
3.02	4252.1	7.0	38.0	36.0	1.9
3.03	4271.4	4.0	49.0	42.4	2.2
3.04	4290.7	16.0	34.0	40.0	2.1
3.05	4309.9	4.0	52.0	44.8	2.3
3.06	4329.3	6.0	52.0	46.4	2.4
3.07	4348.6	4.0	32.0	28.8	1.5
3.08	4367.9	5.0	38.0	34.4	1.8
3.09	4387.2	6.0	30.0	28.8	1.5
3.10	4406.6	7.0	24.0	24.8	1.3
3.11	4426.0	7.0	52.0	47.2	2.4
3.12	4445.3	8.0	32.0	32.0	1.7
3.13	4464.7	16.0	42.0	46.4	2.4
3.14	4484.1	14.0	88.0	81.6	4.2
3.15	4503.5	18.0	88.0	84.8	4.4
3.16	4523.0	16.0	99.0	92.0	4.7
3.17	4542.4	12.0	49.0	48.8	2.5
3.18	4561.8	16.0	90.0	84.8	4.4
3.19	4581.3	18.0	54.0	57.6	3.0
3.20	4600.7	18.0	78.0	76.8	3.9
3.21	4620.2	19.0	116.0	108.0	5.5
3.22	4639.7	8.0	51.0	47.2	2.4
3.23	4659.2	5.0	26.0	24.8	1.3

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
3.24	4678.7	9.0	52.0	48.8	2.5
3.25	4698.2	5.0	29.0	27.2	1.4
3.26	4717.7	5.0	40.0	36.0	1.8
3.27	4737.2	3.0	38.0	32.8	1.7
3.28	4756.7	10.0	52.0	49.6	2.5
3.29	4776.2	9.0	51.0	48.0	2.5
3.30	4795.8	8.0	50.0	46.4	2.4
3.31	4815.3	13.0	58.0	56.8	2.9
3.32	4834.9	16.0	87.0	82.4	4.2
3.33	4854.4	5.0	43.0	38.4	2.0
3.34	4874.0	4.0	24.0	22.4	1.1
3.35	4893.6	8.0	40.0	38.4	2.0
3.36	4913.2	7.0	51.0	46.4	2.4
3.37	4932.7	5.0	54.0	47.2	2.4
3.38	4952.3	11.0	51.0	49.6	2.5
3.39	4971.9	3.0	42.0	36.0	1.8
3.40	4991.5	2.0	38.0	32.0	1.6
3.41	5011.1	2.0	42.0	35.2	1.8
3.42	5030.7	4.0	48.0	41.6	2.1
3.43	5050.3	11.0	46.0	45.6	2.3
3.44	5069.9	10.0	34.0	35.2	1.8
3.45	5089.5	8.0	83.0	72.8	3.7
3.46	5109.2	16.0	60.0	60.8	3.1
3.47	5128.8	5.0	51.0	44.8	2.3
3.48	5148.4	23.0	103.0	100.8	5.1
3.49	5168.0	23.0	81.0	83.2	4.2
3.50	5187.7	29.0	107.0	108.8	5.5
3.51	5207.3	17.0	72.0	71.2	3.6
3.52	5226.9	13.0	51.0	51.2	2.6
3.53	5246.6	20.0	88.0	86.4	4.4
3.54	5266.2	16.0	97.0	90.4	4.6
3.55	5285.9	18.0	78.0	76.8	3.9
3.56	5305.5	20.0	79.0	79.2	4.0
3.57	5325.1	7.0	49.0	44.8	2.3
3.58	5344.8	16.0	53.0	55.2	2.8
3.59	5364.4	11.0	36.0	37.6	1.9
3.60	5384.1	2.0	34.0	28.8	1.5
3.61	5403.7	9.0	57.0	52.8	2.7
3.62	5423.3	11.0	48.0	47.2	2.4
3.63	5443.0	8.0	51.0	47.2	2.4
3.64	5462.6	11.0	62.0	58.4	3.0
3.65	5482.3	10.0	67.0	61.6	3.1
3.66	5501.9	11.0	72.0	66.4	3.4
3.67	5521.5	10.0	62.0	57.6	2.9
3.68	5541.2	23.0	81.0	83.2	4.2
3.69	5560.8	17.0	60.0	61.6	3.1
3.70	5580.4	22.0	89.0	88.8	4.5
3.71	5600.1	36.0	85.0	96.8	4.9
3.72	5619.7	18.0	62.0	64.0	3.3
3.73	5639.3	78.0	298.0	300.8	15.3
3.74	5658.9	25.0	84.0	87.2	4.4

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
3.75	5678.5	16.0	58.0	59.2	3.0
3.76	5698.2	9.0	56.0	52.0	2.7
3.77	5717.8	10.0	75.0	68.0	3.5
3.78	5737.4	5.0	41.0	36.8	1.9
3.79	5757.0	13.0	59.0	57.6	2.9
3.80	5776.6	5.0	29.0	27.2	1.4
3.81	5796.2	4.0	37.0	32.8	1.7
3.82	5815.7	5.0	30.0	28.0	1.4
3.83	5835.3	6.0	53.0	47.2	2.4
3.84	5854.9	3.0	31.0	27.2	1.4
3.85	5874.5	12.0	41.0	42.4	2.2
3.86	5894.0	8.0	28.0	28.8	1.5
3.87	5913.6	0.0	16.0	12.8	0.7
3.88	5933.1	5.0	8.0	10.4	0.5
3.89	5952.7	9.0	30.0	31.2	1.6
3.90	5972.2	13.0	53.0	52.8	2.7
3.91	5991.8	8.0	42.0	40.0	2.0
3.92	6011.3	15.0	30.0	36.0	1.8
3.93	6030.8	22.0	65.0	69.6	3.6
3.94	6050.3	14.0	44.0	46.4	2.4
3.95	6069.8	12.0	51.0	50.4	2.6
3.96	6089.3	17.0	50.0	53.6	2.8
3.97	6108.8	8.0	66.0	59.2	3.0
3.98	6128.3	21.0	71.0	73.6	3.8
3.99	6147.7	18.0	85.0	82.4	4.2
4.00	6167.2	20.0	94.0	91.2	4.7
4.01	6186.6	17.0	45.0	49.6	2.6
4.02	6206.1	12.0	52.0	51.2	2.6
4.03	6225.5	6.0	51.0	45.6	2.3
4.04	6244.9	9.0	50.0	47.2	2.4
4.05	6264.3	12.0	75.0	69.6	3.6
4.06	6283.7	7.0	45.0	41.6	2.1
4.07	6303.1	10.0	71.0	64.8	3.3
4.08	6322.5	6.0	45.0	40.8	2.1
4.09	6341.9	13.0	42.0	44.0	2.3
4.10	6361.2	7.0	28.0	28.0	1.4
4.11	6380.6	10.0	57.0	53.6	2.8
4.12	6399.9	15.0	57.0	57.6	3.0
4.13	6419.2	7.0	35.0	33.6	1.7
4.14	6438.5	10.0	35.0	36.0	1.9
4.15	6457.8	20.0	38.0	46.4	2.4
4.16	6477.1	11.0	45.0	44.8	2.3
4.17	6496.4	39.0	89.0	102.4	5.3
4.18	6515.6	10.0	48.0	46.4	2.4
4.19	6534.9	9.0	71.0	0.0	0.0
4.20	6554.1	22.0	45.0	0.0	0.0
4.21	6573.3	10.0	85.0	0.0	0.0
4.22	6592.5	18.0	92.0	0.0	0.0
4.23	6611.7	17.0	60.0	0.0	0.0
4.24	6630.9	9.0	57.0	0.0	0.0
4.25	6650.1	11.0	57.0	0.0	0.0

Depth (m)	Age (cal yr BP)	Lg C >250 u	Sm C >125 u	C/cm2	CHAR C/cm2/yr
4.26	6669.2	11.0	41.0	0.0	0.0
4.27	6688.3	6.0	52.0	0.0	0.0
4.28	6707.4	9.0	40.0	0.0	0.0
4.29	6726.5	7.0	43.0	0.0	0.0
4.30	6745.6	1.0	32.0	0.0	0.0
4.31	6764.7	4.0	37.0	0.0	0.0
4.32	6783.7	3.0	36.0	0.0	0.0
4.33	6802.8	9.0	38.0	0.0	0.0
4.34	6821.8	0.0	0.0	0.0	0.0

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
0.01	92.9	31.4	6.2	5.1
0.03	102.9	30.0	5.9	5.1
0.05	113.2	29.3	5.6	5.2
0.07	123.8	29.8	5.5	5.4
0.09	134.8	22.4	4.0	5.6
0.11	146.1	9.4	1.6	5.7
0.13	157.7	12.4	2.1	5.9
0.15	169.6	9.2	1.5	6.0
0.17	181.8	12.0	1.9	6.2
0.19	194.4	7.3	1.2	6.4
0.21	207.2	6.3	1.0	6.5
0.23	220.4	6.9	1.0	6.7
0.25	233.9	6.8	1.0	6.8
0.27	247.7	6.7	1.0	7.0
0.29	261.8	4.3	0.6	7.1
0.31	276.2	2.1	0.3	7.3
0.33	290.9	5.3	0.7	7.4
0.35	305.9	5.7	0.7	7.6
0.37	321.2	0.4	0.0	7.7
0.39	336.8	1.6	0.2	7.9
0.41	352.7	2.5	0.3	8.0
0.43	368.8	2.8	0.3	8.2
0.45	385.3	2.8	0.3	8.3
0.47	402.1	1.3	0.1	8.4
0.49	419.1	3.3	0.4	8.6
0.51	436.4	3.1	0.4	8.7
0.53	454.0	3.7	0.4	8.9
0.55	471.9	4.2	0.5	9.0
0.57	490.1	3.8	0.4	9.2
0.59	508.5	4.6	0.5	9.3
0.61	527.3	4.0	0.4	9.4
0.63	546.3	1.9	0.2	9.6
0.65	565.5	1.8	0.2	9.7
0.67	585.1	2.8	0.3	9.8
0.69	604.9	2.5	0.2	10.0
0.71	624.9	3.9	0.4	10.1
0.73	645.3	5.4	0.5	10.2
0.75	665.9	1.0	0.1	10.4
0.77	686.7	3.1	0.3	10.5
0.79	707.9	3.3	0.3	10.6
0.81	729.2	4.6	0.4	10.8
0.83	750.9	3.3	0.3	10.9
0.85	772.8	6.4	0.6	11.0
0.87	794.9	2.1	0.2	11.1
0.89	817.3	1.8	0.2	11.3
0.91	839.9	2.0	0.2	11.4
0.93	862.8	2.0	0.2	11.5
0.95	885.9	0.8	0.1	11.6
0.97	909.3	0.3	0.0	11.7
0.99	932.9	1.3	0.1	11.9
1.01	956.8	1.6	0.1	12.0

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
1.03	980.8	2.3	0.2	12.1
1.05	1005.2	1.8	0.1	12.2
1.07	1029.7	3.1	0.3	12.3
1.09	1054.5	3.9	0.3	12.4
1.11	1079.5	2.4	0.2	12.6
1.13	1104.8	2.8	0.2	12.7
1.15	1130.2	2.1	0.2	12.8
1.17	1155.9	6.2	0.5	12.9
1.19	1181.8	10.0	0.8	13.0
1.21	1208.0	11.8	0.9	13.1
1.23	1234.3	6.6	0.5	13.2
1.25	1260.9	4.3	0.3	13.3
1.27	1287.7	8.6	0.6	13.4
1.29	1314.7	2.0	0.1	13.6
1.31	1341.9	0.9	0.1	13.7
1.33	1369.3	0.4	0.0	13.8
1.35	1396.9	1.6	0.1	13.9
1.37	1424.8	2.3	0.2	13.9
1.38	1438.8	2.1	0.2	14.0
1.39	1452.8	3.9	0.3	14.1
1.40	1466.9	4.3	0.3	14.1
1.41	1481.0	4.3	0.3	14.2
1.42	1495.2	3.3	0.2	14.2
1.43	1509.5	2.8	0.2	14.3
1.44	1523.8	1.7	0.1	14.3
1.45	1538.1	4.4	0.3	14.4
1.46	1552.5	4.9	0.3	14.4
1.47	1567.0	7.2	0.5	14.5
1.48	1581.4	4.2	0.3	14.5
1.49	1596.0	3.4	0.2	14.6
1.50	1610.6	6.7	0.5	14.6
1.51	1625.2	6.5	0.4	14.7
1.52	1639.9	6.0	0.4	14.7
1.53	1654.6	4.3	0.3	14.8
1.54	1669.4	3.6	0.2	14.8
1.55	1684.2	3.5	0.2	14.8
1.56	1699.1	2.6	0.2	14.9
1.57	1714.0	5.9	0.4	14.9
1.58	1729.0	7.4	0.5	15.0
1.59	1744.0	6.2	0.4	15.0
1.60	1759.1	6.1	0.4	15.1
1.61	1774.2	8.4	0.6	15.1
1.62	1789.3	5.3	0.3	15.2
1.63	1804.5	5.4	0.4	15.2
1.64	1819.7	4.1	0.3	15.3
1.65	1835.0	3.5	0.2	15.3
1.66	1850.3	4.4	0.3	15.4
1.67	1865.7	3.3	0.2	15.4
1.68	1881.1	3.0	0.2	15.4
1.69	1896.6	1.4	0.1	15.5
1.70	1912.1	0.5	0.0	15.5

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
1.71	1927.7	0.6	0.0	15.6
1.72	1943.2	0.5	0.0	15.6
1.73	1958.9	0.4	0.0	15.7
1.74	1974.6	1.2	0.1	15.7
1.75	1990.3	1.7	0.1	15.7
1.76	2006.0	2.0	0.1	15.8
1.77	2021.8	1.5	0.1	15.8
1.78	2037.7	0.3	0.0	15.9
1.79	2053.6	0.9	0.1	15.9
1.80	2069.5	0.9	0.1	15.9
1.81	2085.5	1.1	0.1	16.0
1.82	2101.5	1.2	0.1	16.0
1.83	2117.5	1.2	0.1	16.1
1.84	2133.6	1.5	0.1	16.1
1.85	2149.8	1.3	0.1	16.2
1.86	2165.9	1.1	0.1	16.2
1.87	2182.1	1.5	0.1	16.2
1.88	2198.4	n.m.	n.m.	16.3
1.89	2214.7	n.m.	n.m.	16.3
1.90	2231.0	n.m.	n.m.	16.3
1.91	2247.4	n.m.	n.m.	16.4
1.92	2263.8	n.m.	n.m.	16.4
1.93	2280.2	n.m.	n.m.	16.5
1.94	2296.7	n.m.	n.m.	16.5
1.95	2313.2	n.m.	n.m.	16.5
1.96	2329.8	n.m.	n.m.	16.6
1.97	2346.4	n.m.	n.m.	16.6
1.98	2363.0	n.m.	n.m.	16.7
1.99	2379.7	n.m.	n.m.	16.7
2.00	2396.4	n.m.	n.m.	16.7
2.01	2413.1	n.m.	n.m.	16.8
2.02	2429.9	n.m.	n.m.	16.8
2.03	2446.7	n.m.	n.m.	16.8
2.04	2463.6	n.m.	n.m.	16.9
2.05	2480.5	n.m.	n.m.	16.9
2.06	2497.4	n.m.	n.m.	16.9
2.07	2514.4	n.m.	n.m.	17.0
2.08	2531.4	n.m.	n.m.	17.0
2.09	2548.4	n.m.	n.m.	17.0
2.10	2565.4	n.m.	n.m.	17.1
2.11	2582.5	n.m.	n.m.	17.1
2.12	2599.7	n.m.	n.m.	17.1
2.13	2616.8	n.m.	n.m.	17.2
2.14	2634.0	n.m.	n.m.	17.2
2.15	2651.3	n.m.	n.m.	17.2
2.16	2668.5	n.m.	n.m.	17.3
2.17	2685.8	n.m.	n.m.	17.3
2.18	2703.2	n.m.	n.m.	17.3
2.19	2720.5	n.m.	n.m.	17.4
2.20	2737.9	n.m.	n.m.	17.4
2.21	2755.4	n.m.	n.m.	17.4

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
2.22	2772.8	n.m.	n.m.	17.5
2.23	2790.3	n.m.	n.m.	17.5
2.24	2807.8	1.9	0.1	17.5
2.25	2825.4	1.9	0.1	17.6
2.26	2843.0	3.8	0.2	17.6
2.27	2860.6	4.4	0.2	17.6
2.28	2878.2	4.3	0.2	17.7
2.29	2895.9	3.9	0.2	17.7
2.30	2913.6	1.6	0.1	17.7
2.31	2931.3	2.6	0.1	17.7
2.32	2949.1	3.1	0.2	17.8
2.33	2966.9	3.8	0.2	17.8
2.34	2984.7	2.8	0.2	17.8
2.35	3002.6	2.7	0.2	17.9
2.36	3020.4	2.5	0.1	17.9
2.37	3038.4	2.8	0.2	17.9
2.38	3056.3	2.2	0.1	17.9
2.39	3074.3	2.7	0.2	18.0
2.40	3092.2	3.3	0.2	18.0
2.41	3110.3	3.1	0.2	18.0
2.42	3128.3	2.3	0.1	18.1
2.43	3146.4	2.1	0.1	18.1
2.44	3164.5	2.6	0.1	18.1
2.45	3182.6	0.9	0.1	18.1
2.46	3200.8	2.5	0.1	18.2
2.47	3218.9	2.2	0.1	18.2
2.48	3237.1	3.4	0.2	18.2
2.49	3255.4	4.2	0.2	18.2
2.50	3273.6	4.4	0.2	18.3
2.51	3291.9	5.3	0.3	18.3
2.52	3310.2	4.7	0.3	18.3
2.53	3328.5	6.5	0.4	18.3
2.54	3346.9	6.0	0.3	18.4
2.55	3365.3	6.7	0.4	18.4
2.56	3383.7	7.1	0.4	18.4
2.57	3402.1	6.4	0.3	18.4
2.58	3420.5	4.3	0.2	18.5
2.59	3439.0	5.2	0.3	18.5
2.60	3457.5	4.8	0.3	18.5
2.61	3476.0	4.7	0.3	18.5
2.62	3494.6	5.7	0.3	18.6
2.63	3513.1	5.4	0.3	18.6
2.64	3531.7	4.3	0.2	18.6
2.65	3550.3	4.1	0.2	18.6
2.66	3569.0	3.9	0.2	18.6
2.67	3587.6	4.2	0.2	18.7
2.68	3606.3	5.0	0.3	18.7
2.69	3625.0	6.0	0.3	18.7
2.70	3643.7	4.1	0.2	18.7
2.71	3662.4	5.2	0.3	18.7
2.72	3681.2	6.8	0.4	18.8

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
2.73	3700.0	7.1	0.4	18.8
2.74	3718.7	10.3	0.5	18.8
2.75	3737.6	11.1	0.6	18.8
2.76	3756.4	7.4	0.4	18.8
2.77	3775.2	7.0	0.4	18.9
2.78	3794.1	7.6	0.4	18.9
2.79	3813.0	7.6	0.4	18.9
2.80	3831.9	6.3	0.3	18.9
2.81	3850.8	4.6	0.2	18.9
2.82	3869.8	6.4	0.3	19.0
2.83	3888.7	7.7	0.4	19.0
2.84	3907.7	4.8	0.3	19.0
2.85	3926.7	4.8	0.3	19.0
2.86	3945.7	7.2	0.4	19.0
2.87	3964.8	8.8	0.5	19.0
2.88	3983.8	8.7	0.5	19.1
2.89	4002.9	10.0	0.5	19.1
2.90	4022.0	9.8	0.5	19.1
2.91	4041.1	10.4	0.5	19.1
2.92	4060.2	10.5	0.6	19.1
2.93	4079.3	10.4	0.5	19.1
2.94	4098.4	8.1	0.4	19.2
2.95	4117.6	7.9	0.4	19.2
2.96	4136.8	8.0	0.4	19.2
2.97	4156.0	8.9	0.5	19.2
2.98	4175.2	9.2	0.5	19.2
2.99	4194.4	13.0	0.7	19.2
3.00	4213.6	12.5	0.6	19.2
3.01	4232.8	11.4	0.6	19.2
3.02	4252.1	14.0	0.7	19.3
3.03	4271.4	13.6	0.7	19.3
3.04	4290.7	12.1	0.6	19.3
3.05	4309.9	14.1	0.7	19.3
3.06	4329.3	13.4	0.7	19.3
3.07	4348.6	14.9	0.8	19.3
3.08	4367.9	19.1	1.0	19.3
3.09	4387.2	27.8	1.4	19.3
3.10	4406.6	24.5	1.3	19.4
3.11	4426.0	26.1	1.3	19.4
3.12	4445.3	22.7	1.2	19.4
3.13	4464.7	24.8	1.3	19.4
3.14	4484.1	27.3	1.4	19.4
3.15	4503.5	28.1	1.4	19.4
3.16	4523.0	30.3	1.6	19.4
3.17	4542.4	31.4	1.6	19.4
3.18	4561.8	26.2	1.3	19.4
3.19	4581.3	23.8	1.2	19.5
3.20	4600.7	16.5	0.9	19.5
3.21	4620.2	16.6	0.9	19.5
3.22	4639.7	20.2	1.0	19.5
3.23	4659.2	32.2	1.7	19.5

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
3.24	4678.7	30.9	1.6	19.5
3.25	4698.2	30.0	1.5	19.5
3.26	4717.7	27.7	1.4	19.5
3.27	4737.2	29.2	1.5	19.5
3.28	4756.7	26.0	1.3	19.5
3.29	4776.2	22.0	1.1	19.5
3.30	4795.8	21.4	1.1	19.5
3.31	4815.3	19.4	1.0	19.5
3.32	4834.9	14.7	0.8	19.6
3.33	4854.4	17.6	0.9	19.6
3.34	4874.0	15.0	0.8	19.6
3.35	4893.6	15.9	0.8	19.6
3.36	4913.2	16.3	0.8	19.6
3.37	4932.7	16.2	0.8	19.6
3.38	4952.3	17.2	0.9	19.6
3.39	4971.9	17.4	0.9	19.6
3.40	4991.5	16.2	0.8	19.6
3.41	5011.1	17.6	0.9	19.6
3.42	5030.7	18.2	0.9	19.6
3.43	5050.3	19.1	1.0	19.6
3.44	5069.9	21.6	1.1	19.6
3.45	5089.5	18.1	0.9	19.6
3.46	5109.2	19.6	1.0	19.6
3.47	5128.8	19.3	1.0	19.6
3.48	5148.4	14.7	0.7	19.6
3.49	5168.0	9.7	0.5	19.6
3.50	5187.7	8.5	0.4	19.6
3.51	5207.3	8.6	0.4	19.6
3.52	5226.9	22.8	1.2	19.6
3.53	5246.6	24.8	1.3	19.6
3.54	5266.2	29.0	1.5	19.6
3.55	5285.9	49.0	2.5	19.6
3.56	5305.5	121.1	6.2	19.6
3.57	5325.1	31.3	1.6	19.6
3.58	5344.8	33.6	1.7	19.6
3.59	5364.4	35.9	1.8	19.6
3.60	5384.1	38.5	2.0	19.6
3.61	5403.7	34.9	1.8	19.6
3.62	5423.3	30.9	1.6	19.6
3.63	5443.0	31.5	1.6	19.6
3.64	5462.6	26.6	1.4	19.6
3.65	5482.3	23.1	1.2	19.6
3.66	5501.9	30.5	1.6	19.6
3.67	5521.5	36.0	1.8	19.6
3.68	5541.2	46.4	2.4	19.6
3.69	5560.8	47.3	2.4	19.6
3.70	5580.4	45.8	2.3	19.6
3.71	5600.1	64.8	3.3	19.6
3.72	5619.7	77.3	3.9	19.6
3.73	5639.3	94.6	4.8	19.6
3.74	5658.9	85.6	4.4	19.6

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
3.75	5678.5	81.7	4.2	19.6
3.76	5698.2	41.5	2.1	19.6
3.77	5717.8	33.0	1.7	19.6
3.78	5737.4	38.1	1.9	19.6
3.79	5757.0	46.0	2.3	19.6
3.80	5776.6	35.5	1.8	19.6
3.81	5796.2	26.9	1.4	19.6
3.82	5815.7	18.8	1.0	19.6
3.83	5835.3	20.7	1.1	19.6
3.84	5854.9	31.7	1.6	19.6
3.85	5874.5	30.1	1.5	19.6
3.86	5894.0	27.8	1.4	19.6
3.87	5913.6	16.8	0.9	19.6
3.88	5933.1	27.4	1.4	19.5
3.89	5952.7	35.3	1.8	19.5
3.90	5972.2	23.7	1.2	19.5
3.91	5991.8	44.3	2.3	19.5
3.92	6011.3	40.6	2.1	19.5
3.93	6030.8	45.1	2.3	19.5
3.94	6050.3	45.2	2.3	19.5
3.95	6069.8	60.4	3.1	19.5
3.96	6089.3	96.2	4.9	19.5
3.97	6108.8	61.9	3.2	19.5
3.98	6128.3	81.2	4.2	19.5
3.99	6147.7	53.2	2.7	19.5
4.00	6167.2	65.3	3.4	19.5
4.01	6186.6	80.8	4.2	19.4
4.02	6206.1	87.6	4.5	19.4
4.03	6225.5	64.0	3.3	19.4
4.04	6244.9	32.4	1.7	19.4
4.05	6264.3	19.3	1.0	19.4
4.06	6283.7	26.9	1.4	19.4
4.07	6303.1	34.7	1.8	19.4
4.08	6322.5	73.6	3.8	19.4
4.09	6341.9	139.2	7.2	19.4
4.10	6361.2	95.8	4.9	19.3
4.11	6380.6	88.8	4.6	19.3
4.12	6399.9	46.5	2.4	19.3
4.13	6419.2	57.3	3.0	19.3
4.14	6438.5	60.5	3.1	19.3
4.15	6457.8	53.5	2.8	19.3
4.16	6477.1	40.8	2.1	19.3
4.17	6496.4	49.0	2.5	19.3
4.18	6515.6	46.0	2.4	19.3
4.19	6534.9	50.1	2.6	0.0
4.20	6554.1	53.1	2.8	0.0
4.21	6573.3	87.5	4.6	0.0
4.22	6592.5	n.m.	n.m.	0.0
4.23	6611.7	n.m.	n.m.	0.0
4.24	6630.9	n.m.	n.m.	0.0
4.25	6650.1	n.m.	n.m.	0.0

Depth (m)	Age (cal yr BP)	MS/cm2	MSAR MS/cm2/yr	Depos yr/cm
4.26	6669.2	n.m.	n.m.	0.0
4.27	6688.3	n.m.	n.m.	0.0
4.28	6707.4	n.m.	n.m.	0.0
4.29	6726.5	n.m.	n.m.	0.0
4.30	6745.6	n.m.	n.m.	0.0
4.31	6764.7	n.m.	n.m.	0.0
4.32	6783.7	n.m.	n.m.	0.0
4.33	6802.8	n.m.	n.m.	0.0
4.34	6821.8	116.4	6.1	0.0

BIBLIOGRAPHY

- Adamson, T. (1926). "Chehalis (Salish): Sources of Ethnobotany." Jacobs Collection, University of Washington, Seattle.
- Agee, J. K. (1991). "Fire history of Douglas-fir forest of the Pacific Northwest." PNW-GTR-285, pp. 25-33, U.S. Department of Agriculture, Forest Service, Portland, Oregon.
- Agee, J. K. (1993). "Fire ecology of Pacific Northwest forests." Island Press, Washington, D. C.
- Aikens, C. M. (1983). Environmental archaeology in the western United States. In "Late Quaternary environments of the United States. Vol. 2" (H.E. Wright, Jr., Ed.), pp. 239-251, University of Minnesota Press, Minneapolis.
- Bacon, C. R. (1983). Eruptive history of Mount Mazama and Crater Lake caldera, Cascade Range, U. S. A. Journal of Volcanology and Geothermal Research 18, 57-115.
- Balster, C. A. and R. B. Parsons. (1968). "Geomorphology and Soils of the Willamette Valley, Oregon." Report 265, Oregon State University Agriculture Experiment Station, Corvallis.
- Baldwin, E. M. (1981). "Geology of Oregon." 3rd Edition. Kendall/Hunt Publishing. Dubuque, Iowa.
- Balster, C. A. and R. B. Parsons. (1969). Late Pleistocene stratigraphy, southern Willamette Valley, Oregon. Northwest Science 43, 116-129.
- Barnosky, C. W. (1981). A record of the late Quaternary vegetation from Davis Lake, southern Puget Lowland, Washington. Quaternary Research 16, 221-239.
- Barnosky, C. W. (1985a). Late Quaternary vegetation near Battle Ground Lake, southern Puget Trough, Washington. Geological Society of America Bulletin 96, 263-271.
- Barnosky, C. W. (1985b). Late Quaternary vegetation in the southwestern Columbian Basin, Washington. Quaternary Research 23, 109-122.

- Barnosky, C. W., Anderson, P. M., and Bartlein, P. J. (1987). The northwestern U. S. during deglaciation: vegetational history and paleoclimatic implications. In "North America and Adjacent Oceans During the Last Glaciation" (W.F. Ruddiman, and H. W. Wright, Jr., Eds.), pp. 289-321, Geological Society of America, Boulder, Colorado.
- Beckham, S. D. (1976). Map of Indian distribution in Oregon, 1850. In "Atlas of Oregon" (W. Loy, Ed.). University of Oregon Books, Eugene.
- Beckham S. D., Minor, R., and Toepel, K. A. (1981). "Prehistory and History of BLM Lands in West-Central Oregon: A Cultural Resource Overview." University of Oregon Anthropological Papers 25, Eugene.
- Berreman, J. V. (1937). Calapuyan tribes. In "Tribal Distribution in Oregon." Memoirs of the American Anthropological Association 47, 20-23.
- Boyd, R. T. (1975). Another look at the "Fever and Ague" of Western Oregon. Ethnohistory 22, 135-154.
- Boyd, R. T. (1986). Strategies of indian burning in the Willamette Valley. Canadian Journal of Anthropology 5, 65-86.
- Boyd, R. T. (1990). Ethnographic History, 1774-1874. In "Handbook of North American Indians, vol. 7." (W. Suttles, Ed.), pp. 135-148, Smithsonian Institution, Washington D. C.
- Cheatham, R. D. (1984). "The Fern Ridge Lake Archaeological Project, Lane County, Oregon, 1982-1984." Report to the Portland District U. S. Army Corps of Engineers. Department of Anthropology, University of Oregon, Eugene.
- Cheatham, R. D. (1988). "Late Archaic settlement pattern in the Long Tom sub-basin, Upper Willamette Valley, Oregon." University of Oregon Anthropological Papers No. 39, Eugene.

- Christy, J., Alverson, E. R., Daugherty, M. P., and Kolar, S. C. (1997). "Presettlement vegetation of the Willamette Valley, Oregon, Version 1." Oregon Natural Heritage Program, The Nature Conservancy of Oregon, Portland.
- Clark, J. S. (1988). Drought cycles, the 'little ice age', and fuels: a 750-yr record of fire in northwestern Minnesota. Nature 334, 233-235.
- Clark, J. S. (1990). Fire and climate change during the last 750 years in northwestern Minnesota. Ecological Monographs 60, 135-159.
- Clark, J. S. and Royall, P. D. (1995). Transformation of a northern hardwood forest by aboriginal (Iroquois) fire: charcoal evidence from Crawford Lake, Ontario, Canada. The Holocene 5, 1-9.
- COHMAP Members. (1988). Climatic changes of the last 18,000 years: Observations and model simulations. Science 241, 1043-1052.
- Cole, D. (1977). Ecosystem dynamics in the coniferous forest of the Willamette Valley, Oregon, U.S.A. Journal of Biogeography 4, 181-192.
- Connolly, T. J., Hodges, C. M., Tasa, G. L., and O'Neill, B. L. (1997). Cultural chronology and environmental history in the Willamette Valley, Oregon. Paper presented at the 50th Annual Northwest Anthropological Conference, Ellensburg, Washington.
- Cwynar, L. C. (1987). Fire and forest history in the north Cascade Range. Ecology 68, 791-802.
- Davis, P. T. (1988). Holocene glacier fluctuations in the American Cordillera. Quaternary Science Reviews 7, 129-157.
- Deevey, E. S. (1943). Additional pollen analyses from southern New England. American Journal of Science 241, 717-752.
- Douglas, D. (1959). "Journal Kept by David Douglas During His Travels in North America 1823-1827." Antiquarian Press, New York.

- Dunwiddie, P. W. (1986). A 6000-year record of forest history on Mount Ranier, Washington. Ecology 67, 58-68.
- Faegri, K., and Iverson, J. (1975). "Textbook of Pollen Analysis." Hafner Press, New York.
- Faegri, K., Kaland, P. E., and Krzywinski, K. (1989). "Textbook of Pollen Analysis." John Wiley and Sons, New York.
- Franklin, J. F. and Dyrness, C. T. (1988). "Natural Vegetation of Oregon and Washington." U. S. Forest Service Gen. Tech. Rep. PNW-8. Portland, Oregon.
- Freidel, D. E. (1989). "Alluvial Stratigraphy in Relation to Archeological Features on the Long Tom River Floodplain, Veneta, Oregon." M.A. thesis, University of Oregon, Eugene.
- Freidel, D. E., Peterson, L., McDowell, P. F., and Connolly, T. J. (1989). "Alluvial stratigraphy and human prehistory of the Veneta area, Long Tom River valley, Oregon." Report to the National Park Service, U. S. Department of Interior, Washington, D.C.
- Glenn, J. L. (1965). "Late Quaternary sedimentation and geologic history of the north Willamette Valley." Ph.D. dissertation, Oregon State University, Corvallis.
- Graumlich, L. J. (1993). A 1000-year record of temperature and precipitation in the Sierra Nevada. Quaternary Research 39, 249-255.
- Green, D. G. (1982). Fire and stability in the postglacial forest of southwest Nova Scotia. Journal of Biogeography 9, 29-40.
- Grigg, L. D. and Whitlock, C. (1998). Late-glacial vegetation and climate change in western Oregon. Quaternary Research 49, 287-298.
- Grimm, E. C. (1988). Data analysis and display. In "Vegetation History" (B. Huntley and T. Webb, III, Eds.), pp. 43-76, Kluwer Academic, Dordrecht, Netherlands.

- Habeck, J. R. (1961). The original vegetation of the mid-Willamette Valley, Oregon. Northwest Science 35, 65-79.
- Halbakken, D. S. (1948). "A history of wheat-growing in Oregon during the nineteenth century." M.A. thesis, University of Oregon, Eugene.
- Hallett, D. J., Hills, L. V., and Clague, J. J. (1997). New accelerator mass spectrometry radiocarbon ages for the Mazama tephra layer from Kootenay National Park, British Columbia, Canada. Canadian Journal of Earth Sciences 34, 1202.
- Hansen, H. P. (1941). Paleoecology of a peat deposit in west central Oregon. American Journal of Botany 28, 206-212.
- Hansen, H. P. (1942). A pollen study of lake sediments in the lower Willamette Valley of Western Oregon. Bulletin of the Torrey Botanical Club 69, 262-280.
- Hansen, H. P. (1947). Postglacial forest succession, climate, and chronology in the Pacific Northwest. Transactions of American Philosophical Society 37, 1-121.
- Heusser, C. J. (1960). "Late Pleistocene Environments of North Pacific North America." American Geographical Society, New York.
- Heusser, C. J. (1978). Modern pollen spectra from western Oregon. Bulletin Torrey Botanical Club 105, 14-17.
- Heusser, C. J. (1983). Vegetational history of the northwestern United States including Alaska. In "Late-Quaternary Environments of the United States: Volume 1" (S.C. Porter, Ed.), Chapter 13. University of Minnesota Press, Minneapolis.
- Heusser, C. J., Heusser, L. E., and Peteet, D. M. (1985). Late-Quaternary climatic change on the American North Pacific Coast. Nature 315, 485-487.
- Hibbert, D. M. (1979). "Pollen Analysis of Late-Quaternary Sediments from Two Lakes in the Southern Puget lowland, Washington." M.S. thesis, University of Washington, Seattle.

- Hitchcock, C. L., and Cronquist, A. (1973). "Flora of the Pacific Northwest." University of Washington Press, Seattle.
- Hoerauf, E. (1969). "The Willamette River: river lands and boundaries." M.A. thesis, University of Oregon, Eugene.
- Impara, P. C. (1998). "Spatial and Temporal Patterns of Fire in the Forests of the Central Oregon Coast Range." Ph.D. dissertation, Oregon State University, Corvallis.
- Ingram, F. C. (1964). Realities of flooding in the Willamette Valley. In "Spatial Organization of Land Use: The Willamette Valley" (J.G. Jensen, Ed.), pp. 79-89, Oregon State University Press, Corvallis.
- Johannessen, C. L., Davenport, W. A., Millet, A. and McWilliams, S. (1971). The vegetation of the Willamette Valley. Annals of the Association of American Geographers 61, 286-302.
- Keeler, E. L. (1985). "Willamette River Valley Towns and Steamboats." M.A. thesis, University of Oregon, Eugene.
- Kirkpatrick, D. (1942). "A History of the Siuslaw National Forest, Oregon, as of December 31, 1939." Corvallis, Oregon.
- Kollmorgen Instrument Corporation, Macbeth Division. (1994). "Munsell Soil Color Charts." New Windsor, NY.
- Kutzbach, J. E. (1987). Model simulations of the climatic patterns during the deglaciation of North America. In "North America and Adjacent Oceans During the Last Deglaciation" (W. F. Ruddiman and H. E. Wright, Jr., Eds.), pp. 425-446, Geological Society of America, Boulder, Colorado.
- Kutzbach, J. E. and Guetter, P. J. (1986). The influence of changing orbital patterns and surface boundary conditions on climate simulations for the past 18,000 years. Journal of Atmospheric Sciences 43, 1726-1759.

- Kutzbach, J. E., Guetter, P. J., Behling, P. J., and Selin, R. (1993). Simulated climatic changes: results of the COHMAP climate-model experiments. In "Global Climates Since the Last Glacial Maximum" (H. E. Wright, Jr., J. E. Kutzbach, W. F. Ruddiman, F. A. Street-Perrott, T. Webb, III, and P. J. Bartlein, Eds.), pp. 24-93, University of Minnesota Press, Minneapolis.
- Leopold, E. B. (1987). An ecological history of old prairie areas in southwestern Washington. University of Washington Arboretum Bulletin 50, 14-17.
- Long, C. J. (1995). "Fire History of the Central Coast Range, Oregon: A ca. 9000 Year Record from Little Lake. M.A. thesis, University of Oregon, Eugene.
- Long C. J., Whitlock, C., Bartlein, P. J., and S. H. Millspaugh. (1998). A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study. Canadian Journal of Forest Research 28, 774-782.
- MacDonald, G. M., Larsen, C. P. S., Szeicz, J. M., and Moser, K. A. (1991). The reconstruction of boreal forest fire history from lake sediments: a comparison of charcoal, pollen, sedimentological, and geochemical indices. Quaternary Science Reviews 10, 53-71.
- Mackey, H. (1974). "The Kalapuyans: A Sourcebook on the Indians of the Willamette Valley." Mission Hill Museum Association, Inc., Salem, Oregon.
- Maenza-Gmelch, T. E. (1997). Holocene vegetation, climate, and fire history of the Hudson Highlands, southeastern New York, USA. The Holocene 7, 27-37.
- Mahaney, W. C., Boyer, M. G., Halvorson, D. L., and Sanmagudas, K. (1984). Glacial chronology of the Rocky Mountains: some problems from observations in western Wyoming. In "Correlation of Quaternary Chronologies" (W. C. Mahaney, Ed.), pp. 225-241, Geobooks, Norwich.

- Martin, R. E. (1982). Fire history and its role in succession. In "Forest Succession and Stand Development Research in the Northwest" (J. E. Means, ed.), Forest Research Laboratory. Oregon State University, Corvallis.
- McDowell, P. F. (1991). Quaternary stratigraphy and geomorphic surfaces of the Willamette Valley, Oregon. In "Quaternary Nonglacial Geology: The Geology of North America, Co-terminous U.S., Vol. K-2" (R. B. Morrison, Ed.), pp. 156-164, Geological Society of America, Boulder, Colorado.
- McDowell, P. F. (1984). Geomorphic setting of archaeological sites, southern Willamette Valley, Oregon. In "Geoarchaeology in the Northwest: Recent Applications and Contributions" (J. A. Willig, Ed.). Tebiwa: The Journal of the Idaho Museum of Natural History 21, 35-44.
- Millspaugh, S. H. and Whitlock, C. (1995). A 750-year fire history based on lake sediment records in central Yellowstone National Park. The Holocene 5, 283-292.
- Minckley, T. A. (1999). "Spatial Variation of Modern Pollen Rain in Oregon and Southern Washington." M.A. thesis, University of Oregon, Eugene.
- Minor, R. (1978). "Survey for cultural resources in portions of the Fern Ridge Reservoir Area, Lane County, Oregon." Report to the Oregon Department of Fish and Wildlife. University of Oregon, Eugene.
- Minore, D. (1979). "Comparative Autoecological Characteristics of Northwestern Tree Species: A Literature Review." Gen. Tech. Rep. PNW-87. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.
- Morris, W. G. (1934). Forest fires in western Oregon and Washington. Oregon Historical Quarterly 35, 313-339.
- Morrison, P. and Swanson, F. J. (1990). "Fire History and Pattern in a Cascade Range Landscape." Gen. Tech. Rep. PNW-GTR-254. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

- O'Neill, B. L. (1987). "Archeological Reconnaissance and Testing in the Noti-Veneta Section of the Florence-Eugene Highway, Lane County, Oregon." Oregon State Museum of Anthropology, University of Oregon, Eugene.
- Orr, E. L., Orr, W. N., and Baldwin, E. M. (1992). "Geology of Oregon." Kendall/Hunt Publishing, Dubuque, Iowa.
- Overpeck, J. T., Rind, D., and Goldberg, R. (1990). Climate-induced changes in forest disturbance and vegetation. Nature 343, 51-53.
- Pendergrass, K. L. (1996). "Vegetation Composition and Response to Fire of Native Willamette Valley Wetland Prairies." M.S. thesis, Oregon State University, Corvallis.
- Peterson, E. M. (1934). "Oregon Indians and Indian Policy, 1849-1871." M.A. thesis, University of Oregon. Eugene.
- Peterson, L. (1989). "9,000 Years of Human Occupation in Relation to Geomorphic Features and Processes in the Long Tom River Sub-basin, Willamette Valley, Oregon." Oregon State Museum of Anthropology Report, University of Oregon, Eugene.
- Porter, S. C. (1970). Glacial recession in the southern and central Puget Lowland, Washington, between 14000 and 13000 before present. In "American Quaternary Association, Abstracts for 1970", p. 107.
- Rebertus, A. J. and Burns, B. R. (1997). The importance of gap processes in the development and maintenance of oak savannas and dry forests. Journal of Ecology 85, 635-645.
- Reckendorf, F. (1993). Geomorphology, stratigraphy, and soil interpretations, Willamette Valley, Oregon. In "Proceedings of the Eighth International Soil Management Workshop" (J. M. Kimble, Ed.), pp. 178-200, Soil Conservation Service, U. S. Department of Agriculture, Portland.
- Reynolds, W. L. (1977). "The Evolution of the Grass Seed Landscape: A Historical Geography of Agriculture in the Southern Willamette Valley." M.A. thesis, University of Oregon, Eugene.

- Richmond, G. M. (1986). Stratigraphy and chronology of glaciation in Yellowstone National Park. Quaternary Science Reviews 5, 83-98.
- Riegel, G. M., Smith, B.G., and Franklin, J.F. (1992). Foothill oak woodlands of the interior valleys of southwestern Oregon. Northwest Science 66, 66-76.
- Rigg, G. B. and Richardson, C. T. (1938). Profiles of some Sphagnum bogs of the Pacific Coast of North America. Ecology 19, 408-434.
- Rummery, T. A. (1983). The use of magnetic measurements in interpreting the fire histories of lake drainage basins. Hydrobiologia 103, 53-58.
- Schlicker, H. G. and Deacon, R. G. (1967). "Engineering Geology of the Tualatin Valley Region, Oregon." Oregon Department of Geology and Mineral Industries Bulletin, Salem, Oregon.
- Sea, D. S. and Whitlock, C. (1995). Postglacial vegetation and climate of the Cascade Range, central Oregon. Quaternary Research 43, 370-381.
- Sedell, J. R. and Froggatt, J.L. (1984). Importance of streamside forests to large rivers: The isolation of the Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal. Verhandlungen Internationale V. Limnologie 22, 1828-1834.
- Singer, D. K., Jackson, S. T., and Wilcox, D. A. (1996). Differentiating climatic and successional influences on long term development of a marsh. Ecology 77, 1765-1777.
- SCS (Soil Conservation Service). (1987). "Soil survey of Linn County area, Oregon." U. S. Department of Agriculture, Washington, D.C.
- Sprague, F. L. and Hansen, H. P. (1946). Forest succession in the McDonald Forest, Willamette Valley, Oregon. Northwest Science 20, 89-98.
- Stuiver, M. and Reimer, P. J. (1993). Extended ^{14}C data base and revised CALIB 3.01 ^{14}C age calibration program. Radiocarbon 35, 215-230.

- Sugita, S. and Tsukada, M. (1982). The vegetation history in western North America. I. Mineral and Hall Lakes. Japanese Journal of Ecology 32, 499-515.
- Swetnam, T. W. (1993). Fire history and climate change in giant Sequoia groves. Science 262, 885-889.
- Tausch, R. J., Wigand, P. E., and Burkhardt, J. W. (1993). Plant community thresholds, multiple steady states, and multiple successional pathways: legacy of the Quaternary? Journal of Range Management 46, 439-447.
- Taylor, G. H. (1993). "Normal annual precipitation, state of Oregon." Oregon State Climate Service, Corvallis.
- Teensma, P. D. A. 1987. "Fire History and Fire Regimes of the Central Western Cascades of Oregon. Ph.D. dissertation, University of Oregon, Eugene.
- Teensma, P. D. A., Rienstra, J. T., and Yeiter, M. A. (1991). "Preliminary Reconstruction and Analysis of Change in Forest Stand Age Classes of the Oregon Coast Range from 1850 to 1940." Technical Note OR-9. U.S. Department of Interior, Bureau of Land Management, Oregon State Office, Portland.
- Thilenius, J. F. (1968). The Quercus garryana forests of the Willamette Valley, Oregon. Ecology 49, 1124-1133.
- Thompson, R. and Oldfield, F. (1986). "Environmental Magnetism." Allen and Unwin, London.
- Thompson, R. S., Whitlock, C., Bartlein, P. J., Harrison, S. P., and Spaulding, W. G. (1993). Climatic changes in the western United States since 18,000 yr B.P. In "Global Climates Since the Last Glacial Maximum." (H. E. Wright, Jr., J. E. Kutzbach, W. F. Ruddiman, F. A. Street-Perrott, T. Webb, III, and P. J. Bartlein, Eds.), pp. 468-513, University of Minnesota Press, Minneapolis.
- Towle, J. C. (1982). "Changing Geography of the Willamette Valley Woodlands." Oregon Historical Quarterly Vol. LXXXIII, No 1. Portland.

- Toepel, K. A. (1985). "Archaeological Survey in the Long Tom Sub-basin, Upper Willamette Valley, Oregon." Report to the State Historic Preservation Office from the Oregon State Museum of Anthropology, University of Oregon, Eugene.
- Tsukada, M., Sugita, S., and Hibbert, D. M. (1981). Paleoeecology in the Pacific Northwest. I. Late-Quaternary vegetation and climate. Verhandlungen Proceedings: International Association of Theoretical and Applied Limnology 21, 730-737.
- USACOE (U.S. Army Corps of Engineers). (1967). "Technical Appendix to Flood Plain Information, Willamette River Basin, Lane County, Oregon." Portland District, Portland, Oregon.
- Weisberg, P. J. (1998). "Fire History, Fire Regimes, and Development of Forest Structure in the Central Western Oregon Cascades." Ph.D. dissertation, Oregon State University, Corvallis.
- Wiatt, R. B., Jr., and Thorson, R. M. (1983). The Cordilleran Ice sheet in Washington, Idaho, and Montana. In "Late Quaternary Environments of the United States; Volume 1." (S. C. Porter, Ed.), pp. 53-70, University of Minnesota Press, Minneapolis.
- Wilson, M. V., Alverson, E. A., Clark, D. L., Hayes, R. H., Ingersoll, C. A., and Naughton, M. B. (1995). The Willamette Valley Natural Areas network: a partnership for Oregon prairie. Restoration and Management Notes 13, 26-28.
- White, J. R. (1975). A proposed typology of Willamette Valley sites. In "Archaeological studies in the Willamette Valley, Oregon" (C. M. Aikens, Ed.), pp 17-140, University of Oregon Anthropological Papers 8, Eugene.
- Whitlock, C. (1992). Vegetational and climatic history of the Pacific Northwest during the last 20,000 years: Implications for understanding present-day biodiversity. Northwest Environmental Journal 8, 5-28.

- Whitlock, C., Thompson, R. S., and Bartlein, P. J. (1990). "Climatic Assessment of the Last Deglaciation in the Pacific Northwest as Inferred from Paleobotanical Data." Abstract in Proceedings of the Geological Society of America Annual Meeting. Dallas, Texas.
- Worona, M. A. and Whitlock, C. (1995). Late-Quaternary vegetation and climate history near Little Lake, Central Coast Range, Oregon. Geological Society of America Bulletin 107, 867-876.
- Zenk, H. B. (1976). "Contributions to Tualatin Ethnography: Subsistence and Ethnobiology." M.A. thesis, Portland State University, Portland.
- Zybach, R. (1988). "The Great Fires of the Oregon Coast Range: 1770-1933." Unpublished manuscript.