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Geoarchaeological Record of the AD 1700 Cascadia Subduction Zone Earthquake and Tsunami at the Salmon River Wet Site, Central Oregon Coast

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Abstract

Coseismic subsidence is a major contributor to the scarcity of evidence in the archaeological record of prehistoric earthquakes along coasts of the Cascadia subduction zone. The stratigraphy of suddenly subsided tidal wetlands, in places overlain by tsunami-deposited sand, records a long history of great (magnitude 8–9) earthquakes over the last 3,000–7,000 years. The most recent of these great earthquakes and its accompanying high tsunami occurred on January 26, 1700. Here we synthesize geologic and archaeological investigations in the Salmon River estuary on the central Oregon coast. Following coastal subsidence of 1.4 ± 0.4 m during the AD 1700 earthquake, the site of a prehistoric settlement was submerged and covered by tsunami sand and tidal mud, creating an archaeological "wet site" subject to erosion in the tidal zone. Excavations in the last remnants of the eroding cultural deposits recovered evidence of a Tillamook Indian hunting camp occupied within a few hundred years before the AD 1700 earthquake. The Salmon River Wet Site, and similar submerged archaeological deposits in other estuaries, constitute rapidly disappearing evidence of coseismic subsidence during the AD 1700 earthquake along the Cascadia subduction zone on the north Pacific coast.

Keywords: coseismic subsidence, Pacific Northwest archaeology, prehistoric earthquakes and tsunamis

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Introduction

Archaeologists have long been aware of the presence of submerged cultural deposits at prehistoric settlements along the Pacific coast of Oregon and Washington (Cressman 1952, Newman 1959). Submerged at high tide and often accessible for only a few hours each day, these settlements are known as archaeological “wet sites” (Croes 1976, Bernick 1998). The submergence of prehistoric coastal sites was initially attributed to the general rise in sea level during the Holocene which inundated much of the coastal margin (Engelhart et al. 2015). With the first publications of evidence (buried soils of coastal wetlands that suddenly subsided) for great Holocene earthquakes (Atwater 1987, Darienzo and Peterson 1990, Clarke and Carver 1992, Nelson 1992), earthquake-induced subsidence has been identified as a factor in the submergence of cultural deposits at coastal archaeological sites along the Cascadia subduction zone (Figure 1). Archaeologists began noting that radiocarbon ages at some prehistoric settlements roughly correlated with times of great earthquakes. But direct stratigraphic evidence tied to specific earthquakes and tsunamis has proven difficult to document in the archaeological record (Woodward et al. 1990, Hall and Radosevich 1995, Cole et al. 1996, Hutchinson and McMillan 1997, Byram and Witter 2000, Losey et al. 2000, Losey 2002).

In this paper we synthesize archaeological and coastal geologic investigations documenting coseismic subsidence during the AD 1700 earthquake at the Salmon River estuary on the Oregon coast (Figures 1 and 2). The main source of archaeological evidence comes from the Salmon River Wet Site (35LNC64), where some of the most convincing stratigraphic evidence of coseismic subsidence at an archaeological site was first reported (Grant and Minor 1991, Minor and Grant 1996). We review the history of research at the Salmon River, detail the geoarchaeological context of this wet site, and summarize for the first time the results of excavations in the eroded remnant cultural deposits (Figures 2, 3, and 4). Four other archaeological wet sites with evidence of coseismic subsidence have been documented by geologists. None has been subject to archaeological investigations beyond initial recording. Interdisciplinary research at the Salmon River Wet Site illustrates why so few archaeological sites containing evidence of prehistoric earthquakes and tsunamis are preserved along the North Pacific coast. With our focus on the past 500 years, we quote ^{14}C ages as age intervals (95% confidence intervals) in calibrated years (cal yr) AD (approximate solar years; Reimer et al. 2013). Laboratory numbers and ages are listed both in cal yr AD and in ^{14}C years BP in Table 1.

Great Earthquakes and Accompanying Tsunamis

A long and detailed stratigraphic record of great (magnitude 8–9) subduction-zone earthquakes and accompanying high tsunamis occurs along the coast of the Cascadia subduction zone, extending 1,100 km from northern California to Vancouver Island (Figure 1) (Nelson et al. 2021, Walton et al. 2021 and references therein). Geologists have identified stratigraphic contacts marking sudden coastal subsidence of approximately 0.1–2.0 m during these earthquakes, and for some contacts the overlying deposits of tsunamis. Dozens of locations along the subduction zone's coast expose evidence of as many as 8 great earthquakes and/or tsunamis in the past 3,500 years in northern Oregon and southern Washington (Hutchinson and Clague 2017), and as many as 17 great earthquakes and/or tsunamis over 6,700 years in Oregon and northern California (Nelson et al. 2021; Padgett et al. 2021; Walton et al. 2021). The average recurrence interval for the greatest earthquakes is approximately 500 years, but evidence at individual coastal sites suggests intervals between earthquakes from about 50 years to 850 years (Hutchinson and Clague 2017, Nelson et al. 2021).

Coastal stratigraphic evidence of the youngest, most extensive, and so best studied of Cascadia's great earthquakes and tsunamis pointed to an age within decades of 1700 (Atwater et al. 1991, Nelson et al. 1995). Despite the lack of historical records of this earthquake in North America, modeling of the transit of the earthquake's tsunami westward across the Pacific and study of detailed Japanese written records pinpoint the tsunami and its parent moment-magnitude 8.8–9.2 earthquake to January 26, 1700, probably about 2100 local time (Satake et al. 1996, 2003; Atwater et al. 2005). During the earthquake, parts of the coasts of Oregon and Washington subsided by differing amounts (Kemp et al. 2018; Nelson et al. 2020b, 2021), consistent with proposed heterogeneous slip on the subduction-zone fault offshore (Wang et al. 2013, Walton et al. 2021). By analogy with similar great subduction-zone earthquakes in subduction zones in Alaska (1964), Chile (1960), Sumatra (2004), and Japan (2011), shaking too strong for people to remain standing lasted for minutes followed by tsunamis with run up heights of 5–40 m (Witter et al. 2013). References to earthquakes and/or tsunamis that may correlate to this or earlier events occur in the oral traditions of Native American groups along the North Pacific Coast of North America (McMillan and Hutchinson 2002, Ludwin et al. 2005, Ludwin and Smits 2007).

Archaeological and Ethnographic Context

The Salmon River estuary is within the traditional territory of the Tillamook people who lived in the southern part of the Northwest Coast culture area (Seaburg and Miller 1990). These people spoke the southernmost language in the extensive Salish language family, a continuum of dialects including, from north to south, Nehalem, Nestucca, Nechesne or Salmon River, and Siletz. The names of these dialect groups became attached to the most prominent bays or estuaries along this section of the Pacific coast. The Tillamook and other Native peoples of the central Oregon coast left few oral traditions relating to earthquakes

(Losey 2001). The one Tillamook oral tradition, related by Clara Pearson, which can be tied to prehistoric earthquakes refers to tsunami flooding at Nehalem Bay (Jacobs 1934) However, it is uncertain if this account describes the AD 1700 earthquake (Losey 2002:148-150).

As with other Northwest Coast peoples, the primary settlements of the Tillamook were along the shores of the bays and estuaries at the mouths of the principal rivers where their inhabitants could exploit resources in marine, estuarine, riverine, and terrestrial environments (Lyman 1991:82). The one Tillamook village where the most extensive archaeological investigations have taken place, 35TI1 at Netarts Bay, featured large plank houses in a deep and dense shell midden deposit (Newman 1959, Losey 2002). Less intensively occupied camps represented by shallower accumulations of cultural debris were spread out at strategic locations for seasonal fishing, hunting, and plant harvesting (Seaburg and Miller 1990:560, Seaburg 2003:2).

Twelve archaeological sites have been recorded around the Salmon River estuary (Figure 2). Sixteen ^{14}C ages are available from 7 of these sites, reflecting occupation around the estuary over roughly the last 2,000 years (Table 1). Most of these sites are shell middens, inferred to have been at or near villages along the south flank of Cascade Head above the estuary. Very limited investigations have been undertaken at these sites, and reports of the work are incomplete (as reviewed by Connolly et al. 2011). At the one village where excavations have been reported in some detail, Site 35LNC33 on a terrace on the north shore of the estuary, evidence of a plank house was found in the deep shell midden (Murray and Marrant 1983). Identified animals among the vertebrate faunal remains recovered from this shell midden include elk, bear, sea lion, dog, birds, and fish. Mussels (*Mytilus* spp.) and barnacles (*Balanus* spp. and *Mitella polymerus*) characteristically found on rocky ocean shores are the dominant constituents of the shell midden. The apparent absence of bay clams suggests that, as at Nehalem Bay to the north, the mouth of the Salmon River did not contain an environment suitable for estuarine shellfish during the approximately 900-year occupation at 35LNC33 (Becker 2008:72).

Earthquake Stratigraphy at the Salmon River Estuary

The Salmon River estuary, one of the smaller estuaries in Oregon (800 ha), is the drowned reach of a 40-km-long river that drains a watershed of 194 km^2 (Figures 1 and 2). As the name implies, the lower Salmon River is a productive anadromous fish spawning and rearing habitat, notably for Coho salmon (*Oncorhynchus kisutch*), spring Chinook salmon (*O. tshawytscha*), summer and winter steelhead (*Salmo gairdneri*). The lower reaches of the river flow along the south side of Cascade Head, a massive headland of Miocene basalt that rises 232 m above sea level (Figure 2a). Most of Cascade Head has been preserved as a scientific study area for native prairie grassland communities and coastal Sitka spruce (*Picea sitchensis*)-western hemlock (*Tsuga heterophylla*) forests, once abundant along the Oregon coast. Dikes built in the early 1960s to create pasture south of the headland on both sides of the river were removed between 1978 and 1987, and tidal marsh has redeveloped in these areas (Mitchell 1981, Flitcroft et al. 2016). Although the soils of some of the lowest diked pastures compacted as much as 0.4 m (Moran and Frenkel 1992), surface disturbance was largely limited to areas adjacent to dikes.

Grant and McLaren (1987) and Grant (1989) mapped the sharp stratigraphic contact at the top of the youngest buried O or A horizons of a peaty wetland soil along the banks of the Salmon River from near its mouth to 3 km upstream at Highway 101, and in transects of gouge cores extending from the river across restored marshes to the forest edge (Figure 2a) (Nelson et al. 2004). From stratigraphic evidence of subsidence (a tsunami-deposited sand sharply overlying an A horizon and, in turn, overlain by tidal mud), and 10 ^{14}C ages on herb rhizomes and bulk peat from the O horizon (Table 1), Grant (1989) inferred that the upper contact of the horizon recorded subsidence during a large subduction-zone earthquake about 400 ^{14}C years ago. Nelson et al. (1995) later used 7 accelerator mass spectrometer (AMS) ^{14}C ages on the stems of herbs at the contact poking up into overlying sand on the south bank of the river, with inferences from 19th-century records, to restrict the age of contact burial to AD 1660–1800 (site III on Figure 2a).

While surveying the banks of the estuary for evidence of coseismic subsidence in 1988, geologists by accident discovered evidence of prehistoric occupation on a former surface marked by hearths or firepits dug into the A horizon on the south bank of the river approximately 500 m northwest of the later AMS dating site (Nelson et al. 1995). Grant and Minor (1991) and Minor and Grant (1996) attributed the burial of the A horizon containing the hearths to subsidence during the AD 1700 earthquake. In Coon Lake inlet, a small finger of tidal marsh south of the dune complex along the Salmon River (Figure 2a), Grant and McLaren (1987) and Grant (1989) mapped 4 older, deeper buried wetland A horizons, 3 of which Grant (1989) dated with 5 ^{14}C ages on bulk A-horizon peat (Nelson et al. 2004:1279). Nelson et al. (2004) then traced the upper contacts of a stratified sequence of 5 buried wetland horizons in Coon Lake inlet in greater detail and dated them with 7 additional AMS ^{14}C ages on plant fragments at the contacts, such as herb stems and conifer needles. They concurred with the earlier correlation of the uppermost wetland horizon contact with the AD 1700 earthquake and tsunami, and used fossil pollen assemblages and changes in lithology across the contact to estimate the amount of subsidence during the earthquake at 0.3–1.0 m. Hawkes et al. (2011) used a statistical transfer function based on a calibration data set of 91 modern foraminiferal samples from 5 Oregon marshes to estimate subsidence in 1700 at the

Salmon River (near Nelson et al.'s [1995] site III; Figure 2a) at 0.6 ± 0.3 m (mean ± SD). Kemp et al. (2018), using the same fossil data from the Salmon River but with a much larger calibration data set (393 samples from 19 sites), used a Bayesian transfer function to revise this estimate to 1.4 ± 0.4 m.

Evidence for the sudden earthquake subsidence and burial of the 4 older wetland horizons in the Coon Lake inlet is more equivocal because their upper contacts were mapped only over the small area of the inlet (100 by 300 m). But ^{14}C ages for 3 of the 4 older contacts were similar to ages for better studied earthquake contacts at sites to the north and south of the Salmon River (Nelson et al. 2004). The fifth and oldest contact was inferred to have "formed by slow tidal flooding of an upland soil followed by marsh aggradation during gradual late Holocene sea-level rise rather than by sudden flooding during coseismic subsidence" (Nelson et al. 2004:1287).

Archaeological Fieldwork

The Salmon River Wet Site (35LNC64), encompassing the prehistoric hearths or firepits dug into the A horizon discovered by geologists in 1988, is located on the southwest bank of the Salmon River, just downstream from the diked section of the estuary, about 2 km upstream from the sea. The site lies at the eastern end of "a small dune complex of limited extent" (Cooper 1958:86) that has been stabilized by introduced shore pines (*Pinus contorta*); the surrounding restored tidal marshes are backed by second-growth forest (Figure 2).

Stratigraphic and/or archaeological evidence of the AD 1700 earthquake and tsunami at 35LNC64 was assembled during 7 field sessions over 25 years, with the primary archaeological data recovery undertaken in 2001 and 2004 (Figures 3 and 4). The buried A horizon on which prehistoric occupation occurred developed in dune sand. As erosion has undercut the riverbank, chunks of the A horizon have fallen onto a sandflat rather than a mudflat. The extent of the archaeological deposits at the site was initially defined by the distribution of fire-cracked rock from Native American hearths or firepits among the chunks of A horizon exposed on the sandflat at low tide. A tidal inlet where an intermittent stream flows into the river is the reference point used to relate different sessions of fieldwork as the riverbank eroded (Figures 3 and 4).

Grant and Minor (1991) noted that riverbank stratigraphy at the site consisted of 5 depositional layers: (1) a lowest dune sand unit; (2) a buried, 10- to 15-cm-thick, organic-rich A horizon, formed in a wet meadow near the upper edge of a marsh, containing hearths and fire-cracked rock; (3) a tsunami sand bed sharply overlying the A horizon; (4) a tidal mud deposit, divided into a lower bed deposited by gentle currents and a coarser upper bed reflecting stronger flows; and (5) a youngest overlying dune-sand unit (Figures 4 and 5). The lower gradational contact between the lowest dune sand and the A horizon reflected the gradual development of the soil over hundreds of years, with fire-cracked rock and culturally-modified sediments compressed by the site's inhabitants into the A horizon and underlying sand. In contrast, the upper contact of the A horizon was abrupt, with the overlying tsunami sand bed filling in irregularities in the surface of the horizon. The contact between the sand bed and the overlying tidal mud was also abrupt, suggesting that tides and the river were depositing sediment at the site immediately following deposition by the tsunami.

In 1988, when 35LNC64 was first recorded, fire-cracked rock was scattered for 180 m along the base of the riverbank at low tide. Although initially referred to as remnants of hearths, in most occurrences the fire-cracked rock concentrations extended below the base of the buried A horizon into the dune sand and are more accurately interpreted as firepits (Figure 5). Grant (with Brian Atwater, U.S. Geological Survey, Seattle) reported ages on two bulk samples from the upper 3 cm of the buried A horizon at site 35LNC64 that yielded ^{14}C ages of 1421–

1950 cal AD and 1414–1793 cal AD (Grant 1989). Later, Minor and Grant (1996) reported ages on charcoal of 1313–1630 cal AD and 1295–1444 cal AD from two "hearth" features extending below the buried horizon into the dune deposit (Table 1).

Later testing with an auger in November 2000 recovered a small number of stone tools, debitage, vertebrate faunal remains, and fire-cracked rock from archaeological deposits eroded by then to a narrow strip along the riverbank. In July 2001 when mapping of the archaeological deposits along the eroding shoreline was undertaken, most of the fire-cracked rock was limited to an 8-m-long section just downstream from the tidal inlet. The stratigraphic sequence exposed in the riverbank—tsunami-deposited sand and tidal mud overlying the cultural deposits in the A horizon—was faced and multiple peels were collected (Figure 4a); these were later exhibited at the University of Washington's Burke Museum. The remains of firepits like those observed in 1988 were reduced by riverbank erosion to only two locations. Charcoal collected from the base of these firepits yielded ^{14}C ages of 1294–1411 cal AD (Feature 1) and 1206–1380 cal AD (Feature 2).

In September 2001 and September 2004, fire-cracked rock dislodged by erosion was systematically collected and weighed for density distribution, and fallen chunks of A horizon were water-screened to recover cultural remains. Overlying dune sand was shovelled off, the A horizon excavated with trowels and placed in buckets, and the sediments water-screened in the river through 1/8-inch mesh (Figure 4 b–c). Controlled excavations with water-screening were undertaken in 31 units of various sizes (100 × 100 cm, 100 × 50 cm, 100 cm × width of eroding bank) along the bank face just north of where the stratigraphic peels had been taken (Figure 3). The only cultural feature encountered was a hearth containing a concentration of burned large mammal bones, the most intact elements identifiable as elk (*Cervus elaphus)* (Figure 6). Charcoal from this concentration (Feature 3) yielded a ^{14}C age of 59–239 cal AD.

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By August 2010, when 35LNC64 was revisited with Rob Witter (US Geological Survey, Anchorage), very few pieces of fire-cracked rock had eroded onto the sandflat. An exception was a concentration of them representing another firepit (Feature 4) 16 m downstream from the tidal inlet, charcoal from which yielded a ^{14}C age of 1455–1638 cal AD. The site was visited for the last time in August 2013 when, as part of the Cascadia Earthscope Earthquake and Tsunami Education program funded by the National Science Foundation, Brian Atwater and Rick Minor led a tour for teachers highlighting geoarchaeological evidence of the AD 1700 earthquake and tsunami at 35LNC64. The only preserved stratigraphic profile was exposed upstream of the tidal inlet. No evidence of occupation remained downstream where excavations had been conducted in 2001 and 2004.

Interpretation

The primary indicator of occupation at the Salmon River Wet Site was abundant fire-cracked rock, most of which appears to have originated in firepits in the buried A horizon. As the riverbank eroded, fire-cracked rock falling out of these features became lag deposits along the riverbank. Situated 2 km up the estuary from the main concentration of settlements, 35LNC64 lacks the shell-midden deposits found at most archaeological sites around the estuary. The stone tools, debitage, and vertebrate faunal remains recovered point to primary use of 35LNC64 as a seasonal camp from which elk were hunted in the marshes along the south shore of the Salmon River estuary. This wet site is the only one of the 12 recorded archaeological sites around the Salmon River estuary with stratigraphic evidence of the AD 1700 earthquake and its tsunami.

Charcoal recovered from the firepits or hearths was dated by 8 ^{14}C ages (Table 1). All dated charcoal was collected from the 8–15-cm-thick soil A horizon capped by tsunami-deposited sand. Despite their large errors and broad calibrated time intervals, most of the ^{14}C ages from the cultural features are consistent with occupation within a few hundred years before the AD 1700 earthquake and tsunami. The much older ^{14}C age of 59–239 cal AD, on charcoal within the concentration of elk bone fragments (Feature 3), is probably an example of the “old wood problem” in which wood from a long-dead tree yields a ^{14}C age older than the time that the wood was used (Schiffer 1987). The much younger ^{14}C ages from the firepits, and the stratigraphic evidence for subsidence concurrent with deposition of tsunami sand, suggest the charcoal age from the bone concentration reflects the use of old driftwood for fuel.

The cultural materials recovered indicate use of 35LNC64 as a campsite at which hunting was the main activity. Fire-cracked rock from firepits was the most common evidence of occupation; almost 200 kg of this material was collected during the field sessions. Formed tools were limited to 8 items of flaked stone, 9 cobble tools, and a single 2.1-cm-long bone awl tip fragment. The flaked stone items included 4 projectile points, 3 bifaces, and 1 flaked pebble. The 4 projectile points were small contracting stem specimens with narrow neck widths (57–76 mm) made from chert (Figure 7). The cobble tools included 7 hammerstones and 2 anvil stone fragments. The 1,515 pieces of flaked stone debitage consisted of 1,505 (99.3 %) chert flakes, 8 (0.5%) obsidian flakes, and 2 (0.1%) angular chunks of what appears to be siltstone. The debitage was characterized by small flakes and flake fragments, almost all lacking cortex, a majority of which measured < 20 mm in maximum dimension.

Although the location of 35LNC64 appears ideal for stretching a net across the river to catch fish, the 1,129 vertebrate faunal remains recovered consisted largely of unidentifiable mammal remains. These remains were highly fragmented, and approximately one-third of the fragments were calcined or whitened, probably during exposure to fire. Mammal bone identified to genus and/or species included 15 pieces of tooth enamel, 5 molars, 2 metapodials, 2 scapula, 3 podials, and 1 phalange, all identifiable as elk. Among the

Tillamook people, elk were hunted with bow and arrow by men at least 18 to 20 years of age, and successful hunters gained prestige in the village. Elk could be hunted by individuals throughout the year, but men sometimes assembled in groups for a large catch in the fall (Jacobs 2003:75, 80). Additional identifiable faunal remains included one inner ear bone from deer (*Odocoileus* sp.), the sternum bone of a harbor seal (*Phoca vitulina*), and 19 non-diagnostic fragments of whale bone. Fish were represented by only 5 bones, including one vertebra fragment diagnostic to the Salmonidae (salmon and trout) family. While some smaller bones might have fallen through the 1/8-inch mesh screens, more fish remains should have been recovered if fish were a target of subsistence activities at this site.

Discussion

Discovered in 1988, the Salmon River Wet Site provides a graphic example of impacts from subsidence, inundation, burial, and erosion on the archaeological record after a great earthquake (magnitude 8–9) along the Cascadia subduction zone. This site has been previously used as something of a geoarchaeological “type site” to illustrate the consequences of coseismic subsidence and tsunami inundation of low-lying coastal areas as recorded in the deposits at a prehistoric coastal settlement (Atwater et al. 1999:15, Atwater et al. 2005:20). The discovery by geologists of the archaeological wet site at Salmon River in 1988 was important in calling attention to the potential presence of evidence of prehistoric occupation in subsided wetland stratigraphic sequences in other estuaries along the Cascadia subduction zone (Grant and Minor 1991, Minor and Grant 1996).

Archaeological materials in subsided wetland stratigraphic sequences, some of them including tsunami-deposited beds, were subsequently reported during field surveys by geologists at 4 other wet sites along Cascadia’s coast (Figure 1). One of these wet sites, 35TI56, is on the North Fork Nehalem River 4 km upstream from Nehalem Bay on the

Oregon coast (Minor and Grant 1996:775–776, Nelson et al. 2020a:supplemental files part 7). The other 3 sites, which continue to erode, are on the southern Washington coast on the Copalis River (45GH104), the Niawiakum River (45PC102), and the Sewer Locality on Willapa Bay (45PC103) (Cole et al. 1996, Atwater and Hemphill-Haley 1997). Several years ago, a man-made levee undercut by erosion collapsed onto the Copalis River wet site, and erosion during winter 2022 cut back into the mud bank at the Niawiakum River wet site a half meter or more (Brian Atwater, US Geological Survey, personal communication). Altogether, 5 wet sites (including 35LNC64 at Salmon River) where archaeological deposits occur within stratigraphic sequences with evidence for coseismic subsidence have been recorded on the central Cascadia coast. At all 5 wet sites, the top of the uppermost buried soil horizon correlates with coseismic subsidence during the AD 1700 earthquake, and at 3 sites (45GH104, 45PC102, and 35LNC64) overlying sand provides evidence of subsidence closely followed by a tsunami. Not surprisingly, there is no evidence that any of these sites was reoccupied after subsidence and burial during the AD 1700 earthquake and tsunami. Whether any of these wet sites were actually occupied at the time of the AD 1700 earthquake cannot be determined from available evidence. Six ^{14}C ages available from 3 of these 4 wet sites all fall within 500 years before the earthquake, providing only maximum limiting ages for this event. Laboratory errors on the ^{14}C ages are at least many decades and the radiocarbon calibration curve forms a plateau during this time period resulting in unusually long calibrated-age intervals for most ages from this time period (Table 1) (e.g., Nelson et al. 1995). Thus, at all wet sites the link between the AD 1700 earthquake and evidence of Native American occupation is primarily stratigraphic rather than directly chronologic.

Evidence of earlier earthquakes along the Cascadia subduction zone has been reported in the form of tsunami-deposited sand interbedded with cultural deposits at archaeological site

35TI74 at the base of Cape Lookout at the south end of the Netarts Bay sand spit (Minor and Peterson 2016), and at the ancestral Klallam village of Č̓ix̣ʷicən on the shore of Port Angeles Harbor (Hutchinson et al. 2018, Campbell et al. 2019). These prehistoric settlements were not affected by coseismic subsidence, and therefore offered more favourable contexts for preserving intermingled tsunami and archaeological deposits than do conditions at archaeological wet sites submerged in the intertidal zone.

In contrast to 35TI74 and Č̓ix̣ʷicən where evidence from the last several earthquakes is represented, there is stratigraphic evidence only for the most recent AD 1700 earthquake at the 5 archaeological wet sites that subsided coseismically. Submergence into the intertidal zone exposed the cultural deposits at archaeological wet sites to erosion from tidal fluctuations, river currents, seasonal floods, and the continuing gradual rise of late Holocene sea level (Engelhart et al. 2015). At the Salmon River Wet Site, the archaeological deposits in the eroding riverbank first discovered in 1988 had disappeared by 2013. In view of these effective erosional processes, it is likely that there were many more prehistoric settlements along Cascadia's coasts before the last great earthquake more than 300 years ago than appear in the archaeological record today (Cole et al. 1996).

Implications

Coseismic subsidence during prehistoric subduction-zone earthquakes is a major contributor to the scarcity of evidence in the archaeological record of prehistoric earthquakes along the Oregon and Washington coasts. As a result of coseismic subsidence, prehistoric settlements along the shores of estuaries became archaeological wet sites subject to ongoing erosional processes in the intertidal zone. Rapid erosion is clearly illustrated at the wet site on the Salmon River, where subsidence of 1.4 ± 0.4 m during the AD 1700 earthquake exposed cultural deposits to longer tidal inundation, resulting in persistent erosion that led to the complete disappearance of all evidence of this late prehistoric Tillamook Indian hunting camp within 25 years. While additional archaeological wet sites created as a result of coseismic subsidence coupled with sea-level rise undoubtedly remain to be discovered, geoarchaeological evidence along this coseismically subsided coast is disappearing rapidly as a result of erosion since the last great earthquake along the Cascadia subduction zone in AD 1700.

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Literature Cited

Atwater, B. F. 1987. Evidence for great Holocene earthquakes along the outer coast of Washington state. Science 236:942-944.

Atwater, B. F., and E. Hemphill-Haley. 1997. Recurrence intervals for great earthquakes of the past 3,500 years at northeastern Willapa Bay, Washington. US Geological Survey Professional Paper 1576, Washington. https://doi.org/10.3133/pp1576.

Atwater, B. F., Cisternas, M. Bourgeois, W. C. Dudley, J. W. Hendley II, and P. H. Stauffer. 1999. Surviving a tsunami—lessons from Chile, Hawaii, and Japan. US Geological Survey Circular 1187, Reston, Virginia. https://pubs.usgs.gov/circ/c1187/.

Atwater, B. F., M. R. Satoko, S. Kenji, T. Yoshinobu, U. Kazue, and D. K. Yamaguchi. 2005. The orphan tsunami of 1700: Japanese clues to a parent earthquake in North America. US Geological Survey Professional Paper 1707. University of Washington Press, Seattle, WA. https://doi.org/10.3133/pp1707.

Atwater, B. F., M. Stuiver, and D. K. Yamaguchi. 1991. Radiocarbon test of earthquake magnitude at the Cascadia Subduction Zone. Nature 353:156-158.

Becker, T. E. 2008. Analysis of shellfish remains from 35LNC33: A site in the Salmon River estuary, Lincoln County, Oregon. *In* G. L. Tasa and B. L. O'Neill (editors). Dunes, Headlands, Estuaries, and Rivers: Current Archaeological Research on the Oregon Coast. Association of Oregon Archaeologists Occasional Papers No. 8, Eugene, OR. Pp. 65-72.

Minor, R., and A.R. Nelson. 2023. Geoarchaeological record of the AD 1700 Cascadia Subduction Zone earthquake and tsunami at the Salmon River Wet Site, central Oregon coast. Northwest Science 97(1): *in press*.

Bernick, K. (editor) 1998. Hidden Dimensions: The Cultural Significance of Wetland Archaeology. UBC [University of British Columbia] Press, Vancouver, BC.

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. Radiocarbon 51:337-360.

Byram, S., and R. Witter. 2000. Wetland landscapes and archaeological sites in the Coquille estuary, Middle Holocene to Recent times. *In* R. J. Losey (editor), Changing Landscapes, Proceedings of the Third Annual Coquille Cultural Preservation Conference, 1999, Coquille Indian Tribe, North Bend, Oregon. Pp. 60-81.

Campbell, S. K., S. L. Sterling, and D. E. Lewarch. 2019. Building a landscape history and occupational chronology at Čḯxʷicən, a coastal village on the Strait of Juan de Fuca, Washington state, U.S.A. Journal of Archaeological Science: Reports 23:1104-1130.

Clarke, S. H., Jr. and G. A. Carver. 1992. Late Holocene tectonics and paleoseismicity, Southern Cascadia Subduction Zone. Science 255:188-192.

Cole, S. C., B. F. Atwater, P. T. McCutcheon, J. K. Stein, and E. Hemphill-Haley. 1996. Earthquake-induced burial of archaeological sites along the southern Washington coast about A.D. 1700. Geoarchaeology 11:165-177.

Connolly, T., J. Marrant, T. Becker, and G. Burtchard. 2011. A review of archaeology in the Salmon River estuary. Current Archaeological Happenings in Oregon 36(2–3):5-9.

Cooper, W. S. 1958. Coastal Sand Dunes of Oregon and Washington. Geological Society of America Memoir 72, Waverly Press, Inc., Boulder, CO. https://doi.org/10.1130/MEM72.

Cressman, L. S. 1952. Grant No. 48—Reserve Fund (1951), $1,800. Oregon coast prehistory. Year Book of the American Philosophical Society, 1952, Philadelphia, PA. Pp. 256-260.

Croes, D. R. (editor) 1976. Excavation of Water-Saturated Archaeological Sites (Wet Sites) on the Northwest Coast of North America. University of Ottawa Press, Ottawa, Ontario. https://doi.org/10.2307/j.ctv16xdd.

Darienzo, M. E., and C. D. Peterson. 1990. Episodic tectonic subsidence of Late-Holocene salt marshes, northern Oregon Central Cascadia Margin, USA. Tectonics 9:1-22.

Engelhart, S. E., M. Vacchi, B. P. Horton, A. R. Nelson, and R. E. Kopp. 2015. A sea-level database for the Pacific coast of central North America. Quaternary Science Reviews 113:78-92.

Flitcroft, R. L., D. L. Bottom, K. L. Haberman, K. F. Bierly, K. K. Jones, C. A. Simenstad, A. Gray, K. S. Ellingson, E. Baumgartner, T. J. Cornwell, and L. A. Campbell. 2016. Expect the unexpected: place-based protections can lead to unforeseen benefits. Aquatic Conservation: Marine and Freshwater Ecosystems 26:39-59.

Grant, W. C. 1989. More evidence from tidal-marsh stratigraphy for multiple late Holocene subduction earthquakes along the northern Oregon coast. Geological Society of America Abstracts with Programs 21:86.

Grant, W. C., and D. D. McLaren. 1987. Evidence for Holocene subduction earthquakes along the northern Oregon coast. EOS 68:1239.

Grant, W. C., and R. Minor. 1991. Paleoseismic evidence and prehistoric occupation associated with late Holocene sudden submergence, northern Oregon coast. EOS 72:313.

Hall, R., and S. C. Radosevich. 1995. Geoarchaeological analysis of a site in the Cascadia Subduction zone on the southern Oregon coast. Northwest Anthropological Research Notes 29:123-140.

Hawkes, A. D., B. P. Horton, A. R. Nelson, C. H. Vane, and Y. Sawai. 2011. Coastal subsidence in Oregon, USA, during the giant Cascadia earthquake of AD 1700. Quaternary Science Reviews 30:364-76.

Hutchinson, I., and J. J. Clague. 2017. Were they all giants? Perspectives on late Holocene plate-boundary earthquakes at the northern end of the Cascadia subduction zone. Quaternary Science Reviews 169:29-49.

Hutchinson, I., and A. D. McMillan. 1997. Archaeological evidence for village abandonment associated with Late Holocene earthquakes at the northern Cascadia subduction zone. Quaternary Research 48:79-87.

Hutchinson, I., V. L. Butler, S. K. Campbell, S. L. Sterling, M. A. Etnier, and K. M. Bovy. 2018. Impacts of resource fluctuations and recurrent tsunamis on the occupational history of Čḯxʷicən, A Salishan village on the southern shore of the Strait of Juan de Fuca, Washington state, U.S.A. Journal of Archaeological Sciences: Reports 23:1131-1142.

Jacobs, E. D. 1934. Unpublished Nehalem Tillamook Ethnographic Notes, Box 84, Notebook 105, page 120. Melville Jacobs Collection, University of Washington Libraries, Seattle, WA.

Jacobs, E. D. 2003. The Nehalem Tillamook: An Ethnography. Oregon State University Press, Corvallis, OR.

Kemp, A. C., N. Cahill, S. E. Engelhart, A. D. Hawkes, and K. Wang. 2018. Revising estimates of spatially variable subsidence during the A.D. 1700 Cascadia earthquake using a bayesian foraminiferal transfer function. Bulletin of the Seismological Society of America 108:654-673.

Losey, R. J. 2001. Oral tradition of earthquakes and tsunamis on the central Cascadia Coast: variation of accounts and relations to historically observed patterns across the Northwest Coast. *In* J. Younker, M. A. Tveskov, and D. G. Lewis (editors), Changing Landscapes "Telling Our Stories," Proceedings of the Fourth Annual Coquille Cultural Preservation Conference, 2000. Coquille Indian Tribe, North Bend, Oregon. Pp. 3-15.

Losey, R. J. 2002. Communities and catastrophe: Tillamook response to the AD 1700 earthquake and tsunami, northern Oregon coast. Ph.D. Dissertation, University of Oregon, Eugene.

Losey, R. J., J. M. Erlandson, and M. L. Moss. 2000. Assessing the impacts of Cascadia subduction zone earthquakes on the people and landscapes of the Northwest Coast. *In* R. J. Losey (editor), Changing Landscapes, Proceedings of the Third Annual Coquille Cultural Preservation Conference, 1999, Coquille Indian Tribe, North Bend, Oregon. Pp. 124-142.

Ludwin, R. S., R. Dennis, D. Carver, A. D. McMillan, R. Losey, J. Clague, C. Jonientz-Tisler, J. Bowechip, J. Wray, and K. James. 2005. Dating the 1700 Cascadia earthquake: great coastal earthquakes in native stories. Seismological Research Letters 76:140-148.

Ludwin, R. S., and G. J. Smits. 2007. Folklore and earthquakes: Native American oral traditions from Cascadia compared with written traditions from Japan. Geological Society, London, Special Publications: Myth and Geology 273:67-94.

Lyman, R. L. 1991. Prehistory of the Oregon Coast: The Effects of Excavation Strategies and Assemblage Size on Archaeological Inquiry. Academic Press, San Diego, CA.

McMillan, A. D., and I. Hutchinson. 2002. When the mountain dwarfs danced: aboriginal traditions of paleoseismic events along the Cascadia subduction zone of western North America. Ethnohistory 49:41-69.

Minor, R., and W. C. Grant. 1996. Earthquake-induced subsidence and burial of late Holocene archaeological sites, northern Oregon coast. American Antiquity 61:772-781.

Minor, R., and C. D. Peterson. 2016. Multiple reoccupations after four paleotsunami inundations (0.3–1.3 ka) at a prehistoric site in the Netarts littoral cell, northern Oregon coast, USA. Geoarchaeology 32:248-266.

Mitchell, D. L. 1981. Salt marsh reestablishment following levee breaching in the Salmon River estuary. Ph.D. Dissertation. Oregon State University, Corvallis.

Moran, J. C., and R. E. Frenkel. 1992. The Salmon River estuary: How well can we do? Restoration and Management Notes 10:21-23.

Murray, T. A., and J. Marrant. 1983. Preliminary sampling of the Three Rox site, 35LNC33, on the Oregon coast. *In* D. E. Dumond (editor). Contributions to the Archaeology of Oregon, 1981-1982. Association of Oregon Archaeologists Occasional Papers No. 2, Eugene, OR. Pp. 47-55.

Nelson, A. R. 1992. Holocene tidal marsh stratigraphy in south-central Oregon—evidence for localized sudden submergence in the Cascadia subduction zone. *In* C. P. Fletcher and J. F. Wehmiller (editors). Quaternary Coasts of the Unites States—Marine and Lacustrine Systems, Society for Sedimentary Geology Special Publication 48, Tulsa, OK. Pp. 287-301.

Nelson, A. R., A. C. Asquith, and W. C. Grant. 2004. Great earthquakes and tsunamis of the past 2000 years at the Salmon River estuary, central Oregon coast, USA. Bulletin of the Seismological Society of America 94:1276-1292. https://doi.org/10.1785/012003210.

Nelson, A. R., B. F. Atwater, P. T. Bobrowsky, L. Bradley, J. J. Clague, G. A. Carver, M. E. Darienzo, W. C. Grant, H. W. Krueger, R. Sparks, T. W. Stafford, Jr., and M. Stuiver. 1995. Radiocarbon evidence for extensive plate-boundary rupture about 300 years ago at the Cascadia subduction zone. Nature 378:371-374.

Nelson, A. R., C. B. DuRoss, R. C. Witter, H. M. Kelsey, S. E. Engelhart, S. A. Mahan, H. J. Gray, A. D. Hawkes, B. P. Horton, and J. S. Padgett. 2021. A maximum rupture model for the central and southern Cascadia subduction zone—reassessing ages for coastal evidence of megathrust earthquakes and tsunamis. Quaternary Science Reviews 261:106922. https://doi.org/10.1016/j.quascirev.2021.106922.

Nelson, A. R., A. D. Hawkes, Y. Sawai, S. E. Engelhart, R. Witter, W. C. Grant-Walter, L.-A. Bradley, T. Dura, N. Cahill, and B. Horton. 2020a. Identifying the greatest earthquakes of the past 2000 years at the Nehalem River estuary, northern Oregon coast, USA. Open Quaternary 6:2-30. https://doi.org/10.5334/oq.70

Nelson, A. R., A. D. Hawkes, Y. Sawai, B. P. Horton, R. C. Witter, L. Bradley, and N. Cahill. 2020b. Minimal stratigraphic evidence for coseismic coastal subsidence during 2000 yr of megathrust earthquakes at the central Cascadia subduction zone. Geosphere 17:171-200. https://doi.org/10.1130/GES02254.1.

Newman, T. M. 1959. Tillamook prehistory and its relation to the Northwest Coast culture area. Ph.D. Dissertation, University of Oregon, Eugene.

Padgett, J. S., S. E. Engelhart, H. M. Kelsey, R. C. Witter, N. Cahill, and E. Hemphill-Haley. 2021. Timing and amount of southern Cascadia earthquake subsidence over the past 1,700 years at northern Humboldt Bay, California, USA. Geological Society of America Bulletin 133:2137-2156. https://doi.org/10.1130/B35701.1.

Reimer, P. J., E. Bard, A. Bayliss, J. W. Beck, P. G. Blackwell, C. Bronk Ramsey, C. E. Buck, H. Cheng, R. L. Edwards, M. Friedrich, P. M. Grootes, T. P. Guilderson, H. Haflidason, I. Hajdas, C. Hatté, T. J. Heaton, D. L. Hoffman, A. G. Hogg, K. A. Hughen, K. F. Kaiser, B. Kromer, S. W. Manning, M. Niu, R. W. Reimer, D. A. Richards, E. M. Scott, J. R. Southon, R. A. Staff, C. S. M. Turney, and J. van der Plicht. 2013. IntCal13 and marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55:1869-1887.

Minor, R., and A.R. Nelson. 2023. Geoarchaeological record of the AD 1700 Cascadia Subduction Zone earthquake and tsunami at the Salmon River Wet Site, central Oregon coast. Northwest Science 97(1): *in press*.

Rockwell, C. 1887. Topographical reconnaissance of the coast of Oregon from Yaquina Head to Cascade Head. US Coast and Geodetic Survey map, Register No. 1776, scale 1:40,000. Available online at https://nosimagery.noaa.gov/images/shoreline_surveys/survey_scans/T-1776.jpg (accessed 16 April 2019).

Satake, K., K. Shimazaki, Y. Tsuji, and K. Ueda. 1996. Time and size of a giant earthquake in Cascadia inferred from Japanese tsunami records of January 1700. Nature 379:246-251.

Satake, K., K. Wang, and B. F. Atwater. 2003. Fault slip and seismic moment of the 1700 Cascadia earthquake inferred from Japanese tsunami descriptions. Journal of Geophysical Research: Solid Earth 108(B11):ESE 7-1–7-17. https://doi.org/10.1029/2003JB002521.

Schiffer, M. B. 1987. Formation Processes of the Archaeological Record. University of New Mexico Press, Albuquerque.

Seaburg, W. R. 2003. Editor's introduction. *In* E. D. Jacobs (author), The Nehalem Tillamook: An Ethnography, Oregon State University Press, Corvallis. Pp. 1-63.

Seaburg, W. R., and J. Miller. 1990. Tillamook. *In* W. Suttles (editor). Handbook of North American Indians Vol. 7 Northwest Coast, Smithsonian Institution, Washington, DC. Pp. 560-567.

USDA-FSA-APFO Aerial Photography Field Office. 2014. FSA 10:1 NAIP Imagery Downloadable Data Collection from The National Map. USGS National Geospatial Programs Office, Reston, VA. Available online at https://www.sciencebase.gov/catalog/item/51355312e4b0e1603e4fed62 (accessed 18 May 2022).

Walton, M. A. L., L. M. Staisch, T. Dura, J. K. Pearl, B. Sherrod, J. Gomberg, S. Engelhart, A. Tréhu, J. Watt, J. Perkins, R. C. Witter, N. Bartlow, C. Goldfinger, H. Kelsey, A. E. Morey, V. J. Sahakian, H. Tobin, K. Wang, R. Wells, and E. Wirth. 2021. Toward an integrative geological and geophysical view of Cascadia subduction zone earthquakes. Annual Review of Earth and Planetary Sciences 49:367-398. https://doi.org/10.1146/annurev-earth-071620-065605.

Wang, P., S. E. Engelhart, K. Wang, A. D. Horton, B. P. Horton, A. R. Nelson, and R. C. Witter. 2013. Heterogeneous rupture in the great Cascadia earthquake of 1700 inferred from coastal subsidence estimates. Journal of Geophysical Research: Solid Earth 118:1-14. https://doi.org/10.1002/jgrb.50101.

Witter, R. C., Y. J. Zhang, K. Wang, G. R. Priest, C. Goldfinger, L. Stimely, J. T. English, and P. A. Ferro. 2013. Simulated tsunami inundation for a range of Cascadia megathrust earthquake scenarios at Bandon, Oregon, USA. Geosphere 9:1783-1803. https://doi.org/10.1130/GES00899.1.

Woodward, J., J. White, and R. Cummings. 1990. Paleoseimicity and the archaeological record: areas of investigation on the northern Oregon coast. Oregon Geology 52:57-65.

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Figure Captions

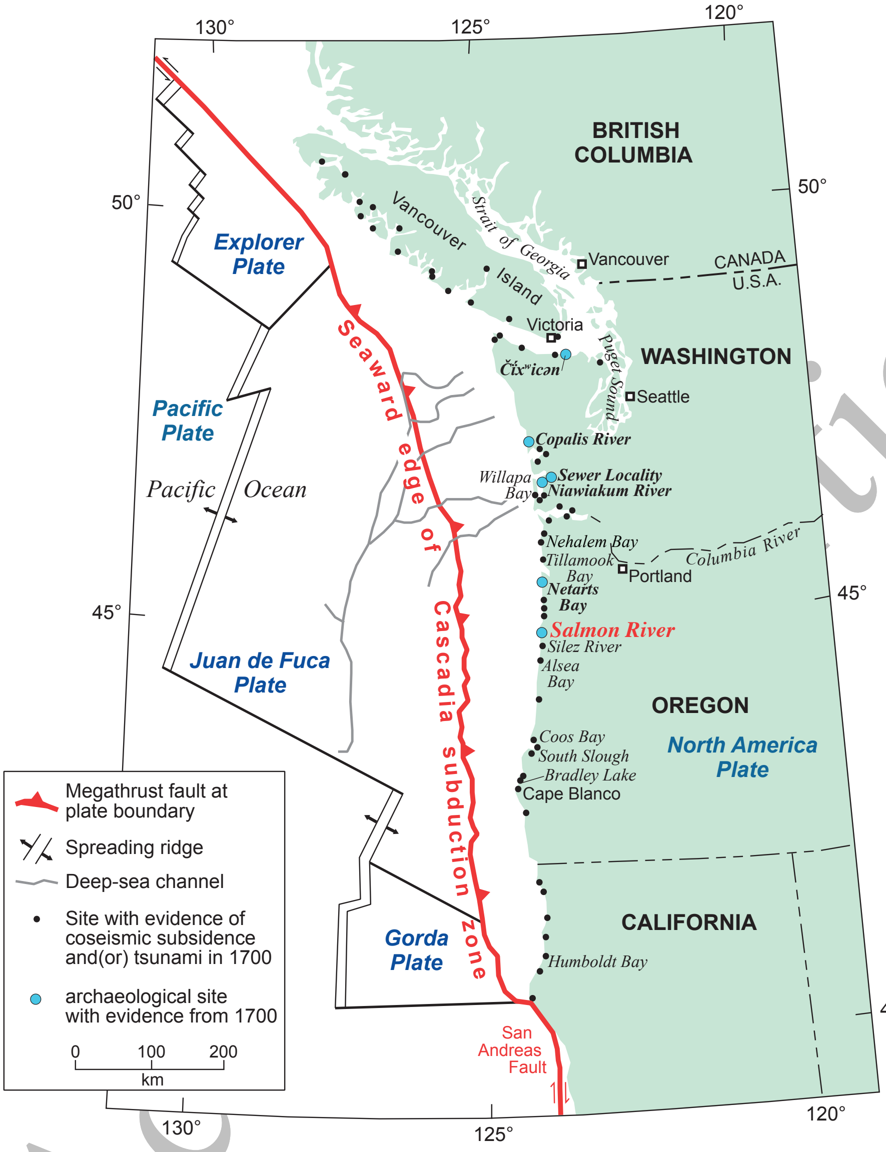

Figure 1. Major features of the Cascadia subduction zone showing the location of the Salmon River estuary on the northern Oregon coast. The trace of the Cascadia thrust fault (red barbed line) is placed at the bathymetric boundary between the continental slope and abyssal plain. Small dots mark coastal sites with evidence of coastal subsidence or a tsunami in 1700 (as compiled by many, e.g., Engelhart et al. 2015, Hutchinson and Clague 2017).

Sites with archaeological materials associated with earthquake or tsunami stratigraphy are marked with large dots.

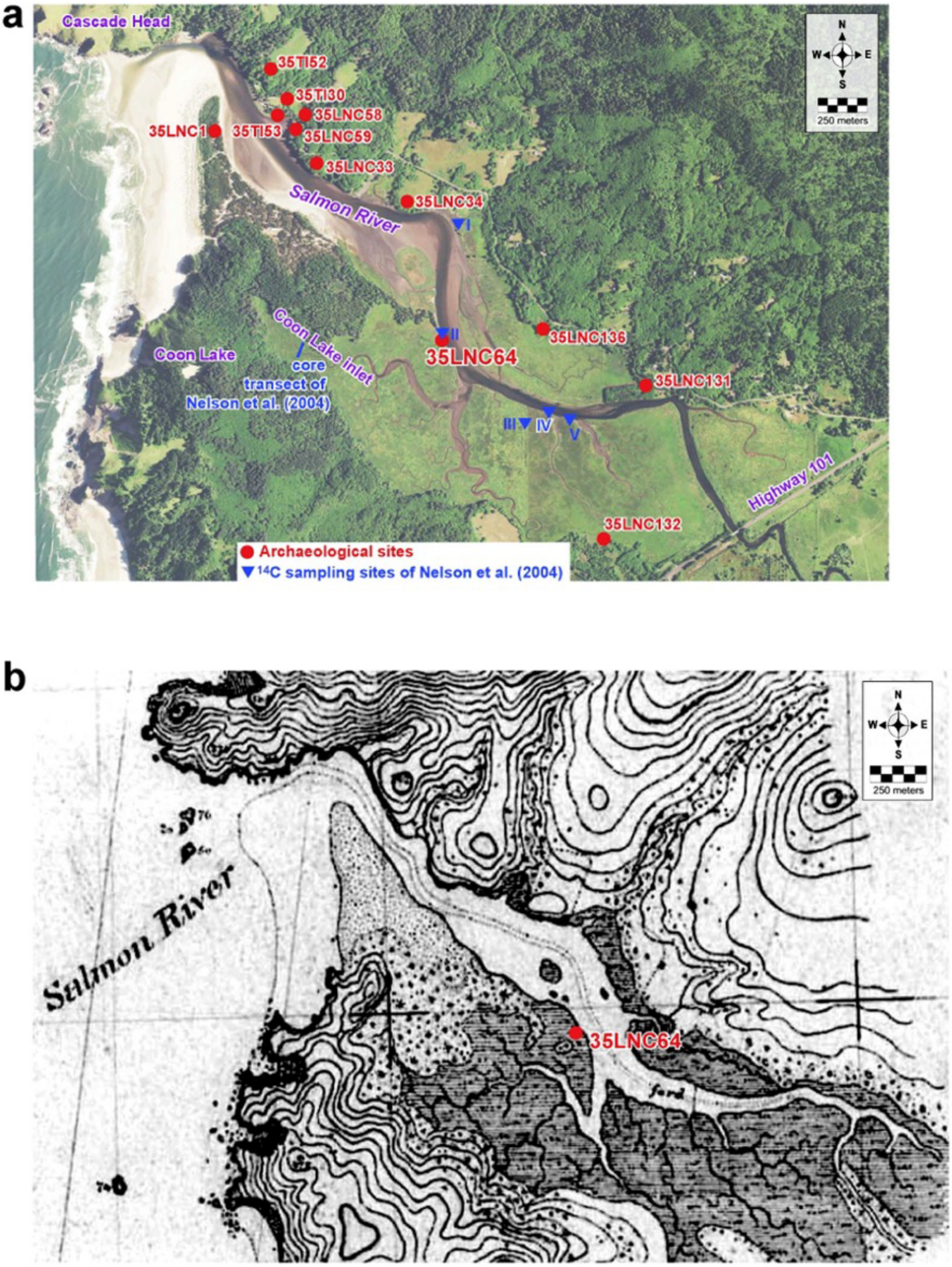

Figure 2. (a) Aerial photograph of the mouth of the Salmon River estuary (USDA-FSA-APFO Aerial Photography Field Office 2014) showing the location of the Salmon River Wet

Site (35LNC64), other archaeological sites mentioned in the text, geologic ^{14}C age sampling sites, and the core transect in Coon Lake inlet, as described by Nelson et al. (2004). (b) Section of reconnaissance map surveyed by Cleveland Rockwell in 1887 (Rockwell 1887) showing the setting of site 35LNC64 in the early historic period. Scale of map is approximately the same as map in (a) but attempts to georeference the 1887 map suggest errors in the positions of landforms by at least ± 10 m. Darker ruled areas with grass symbols show areas of tidal marsh (compare with light green areas of marsh in (a) above). If small symbols on hillslopes mark individual trees on 1887 map, forests on slopes bordering the marsh were very spare in 1887 compared with modern forests (2014).

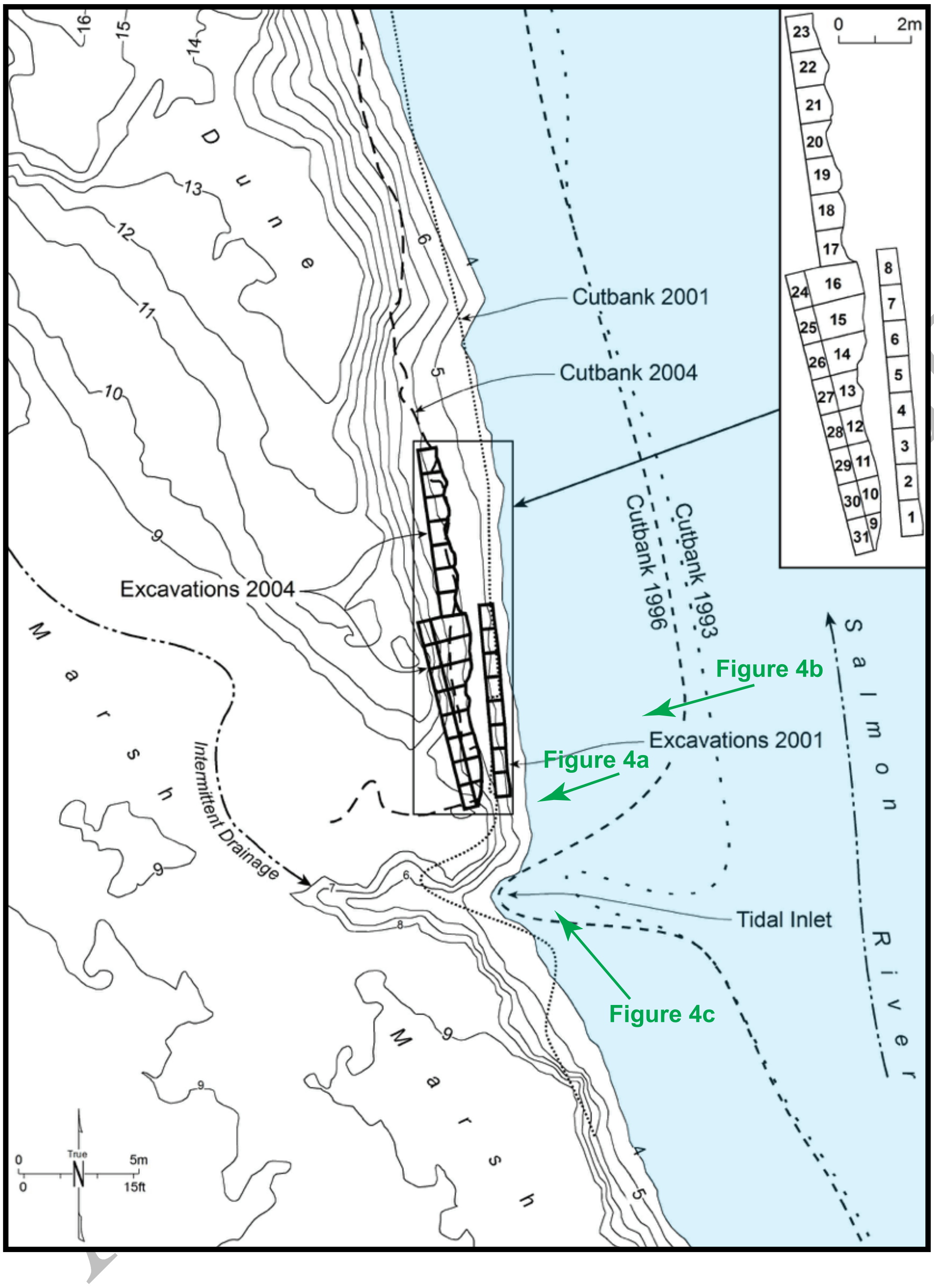

Figure 3. Topographic map of the area around the Salmon River Wet Site (35LNC64) showing the progression of riverbank erosion and location of test units excavated in 2001 and 2004. Topographic map is based on surveys in the field using a laser transit and stadia rod.

Inset shows excavation unit numbers. Arrows show the direction of view of the photographs in Figures 4a, 4b, and 4c.

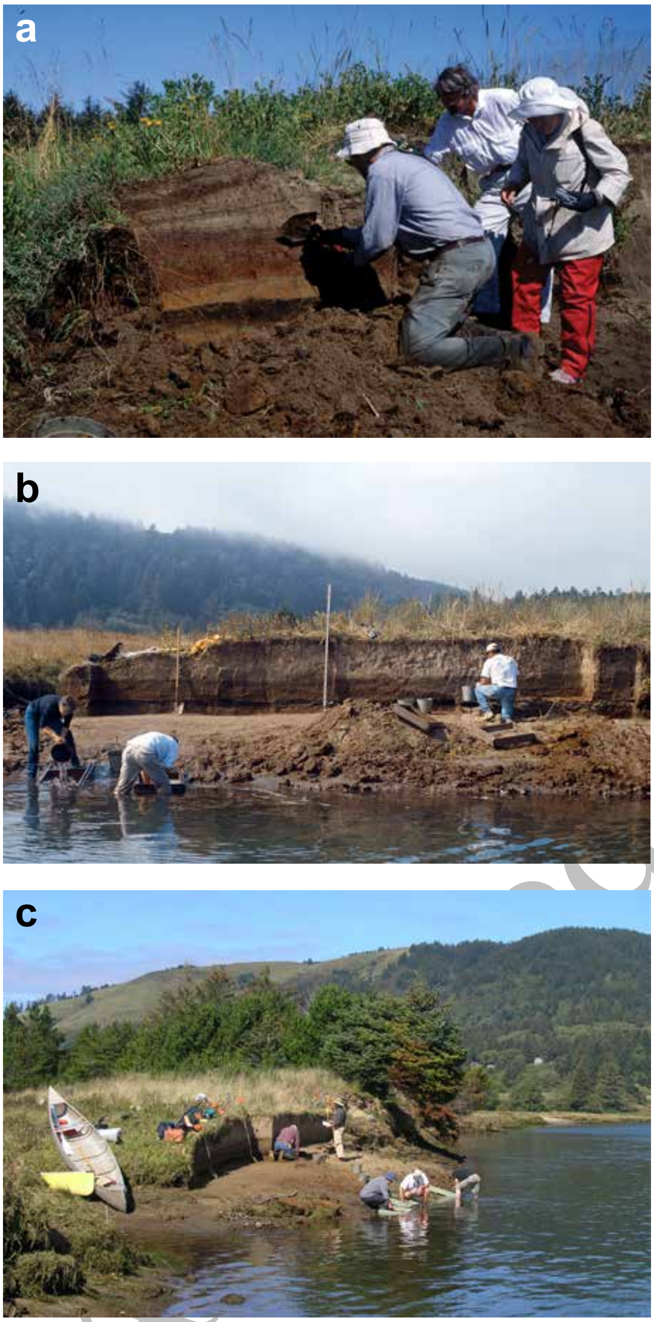

Figure 4. Views of fieldwork at the Salmon River Wet Site (35LNC64). (a) Facing the riverbank in preparation for taking a stratigraphic peel on 26 July 2001 located immediately downstream from the tidal inlet; left to right, Brian Atwater (US Geological Survey), paleontologist Bruce Crowley, and Japanese physical geographer Yoko Ota. (b) The culture-bearing deposit visible in 2001 as a black buried A horizon just above the base of profile was

water-screened in the river (left). (c) View looking downstream showing the maximum extent of excavations in 2004, with the tidal inlet in the foreground, and the massive basalt headland of Cascade Head in the background.

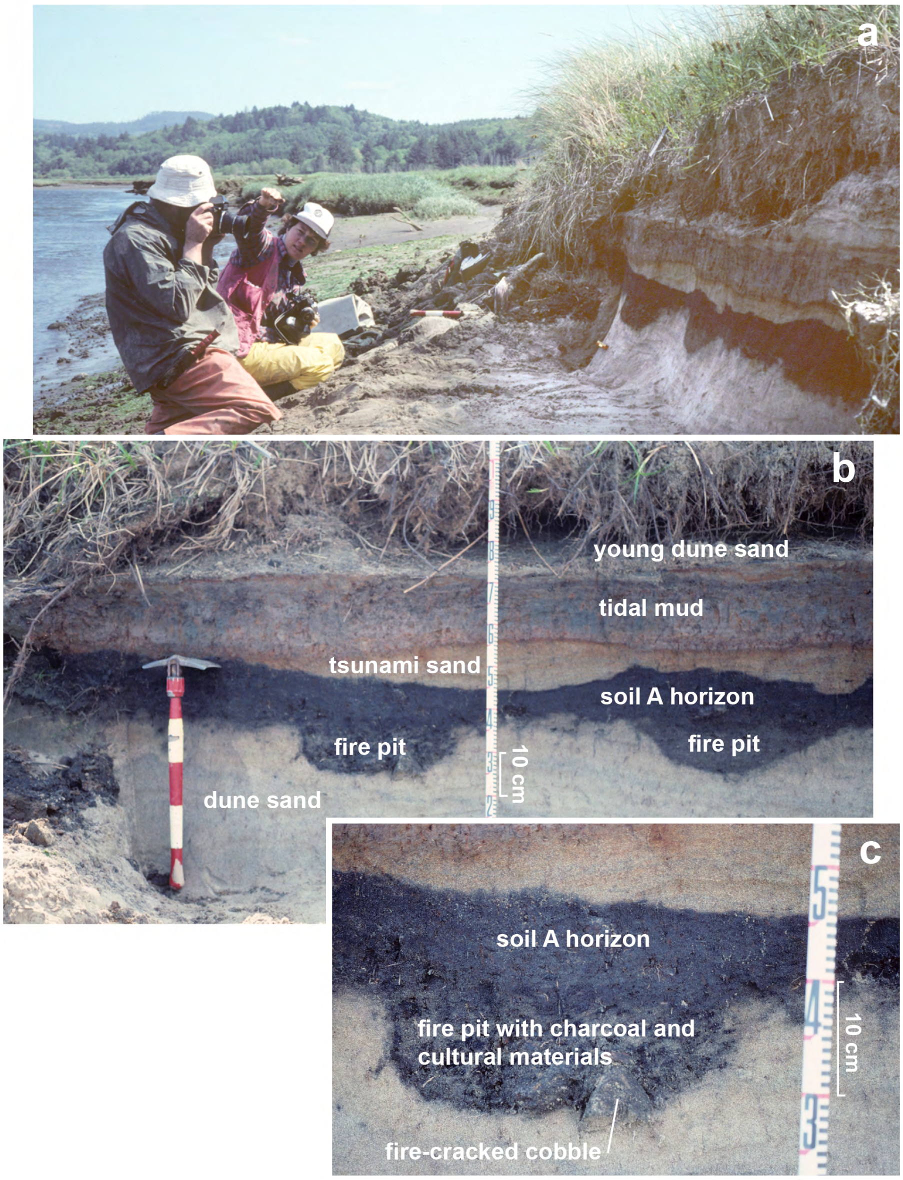

Figure 5. Views from geological fieldwork at 35LNC64 in 1991. (a) Brian Atwater and Wendy Grant photographing the riverbank stratigraphic section. (b) The two firepits containing cultural materials and fire-cracked rock described in 1991. (c) Close-up view of the firepit on the left. The main stratigraphic units are labeled following Minor and Grant (1996) and Atwater et al. (2005:20).

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Figure 6. Concentration of large mammal bones, mostly elk, in the submerged buried black A horizon; overlying gray sand was deposited by the AD 1700 tsunami. Scale labeled every 10 cm.

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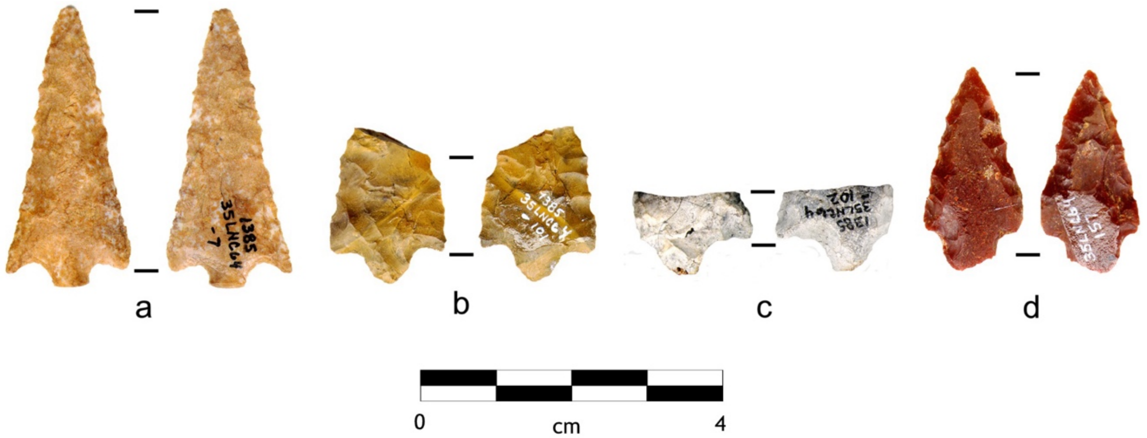

Figure 7. Projectile points recovered from the Salmon River Wet Site (35LNC64).

Tables

Table 1. Radiocarbon data for near-surface samples from archaeological and earthquake stratigraphy sites along the Salmon River, Oregon, USA.

Geologic/ archaeological site	Age (cal yr AD/BC 95% CI)[a]	Lab-reported age ± SD (^{14}C yr BP at 1σ)[b]	Radiocarbon laboratory no.	Sample location[c]	Depth (cm)	Description of dated material[d]
Salmon River Wet Site						
Sites II and 35LNC64	1421–1950	340 ± 80	Beta-23205	G12B	75	Upper 30 mm of fibrous tidal-marsh peat below 1700 contact
35LNC64	1414–1793	370 ± 80	Beta-27877	G140E	75	Upper 30 mm of fibrous peaty sand below 1700 contact
35LNC64	1313–1630	470 ± 60	Beta-27876	G140A	87	Charcoal from fire pit 0.12 m below 1700 contact
35LNC64	1295–1444	550 ± 60	Beta-45954	G140-91	87	Charcoal from fire pit 0.12 m below 1700 contact
35LNC64	1294–1411	600 ± 40	Beta-220512	Unit 5	110–120	Charcoal
35LNC64	1206–1380	750 ± 40*	Beta-220513	5 m north of Unit 23	114–117	Charcoal
35LNC64	59–239	1,870 ± 40*	Beta-289068	Unit 4	99–109	Charcoal
35LNC64	1455–1638	350 ± 40*	Beta-289069	Near Unit 23	103–113	Charcoal
Geologic locations						
Site I	1665–1950	130 ± 70	Beta-27881	G153A	78	*Triglochin maritima* rhizomes rooted 50 mm above 1700 contact
Site I	1417–1644	400 ± 70	Beta-27880	G151B	85	Top 30 mm of fibrous tidal-marsh peat below 1700 contact
Site III	1667–1949	157 ± 17* [b]	GX (notes)	G144	50	Leaf bases and subaerial stems of

						Argentina egedii and *Juncus* cf. *J. balticus*.[d]
Site III	691–1013	1,160 ± 70	Beta-27873	G144A	53	Horizontal stick in mud 0.25 m above 1700 contact
Site III	1449–1950	260 ± 90	Beta-27879	G144B	54	*Triglochin maritima* rhizomes rooted in sand 20 mm above 1700 contact
Site IV	1668–1948	100 ± 70	Beta-23204	G09A	70	*Triglochin maritima* and *Juncus* sp. rhizomes 0.14 m above 1700 contact
Site V	1665–1950	120 ± 70	Beta-23203	G01B	94	Upper 50 mm of muddy marsh peat below 1700 contact
Site V	1286–1451	550 ± 70	Beta-23202	G01A	145	Bed of *Triglochin maritima* rhizomes 0.5 m below 1700 contact
Coon Inlet	1471–1950	240 ± 70	Beta-29066	G126	33	Upper 30 mm of fibrous tidal-marsh peat below 1700 contact
Coon Inlet	1441–1950	310 ± 70	Beta-29069	G133	29	Upper 30 mm of fibrous tidal-marsh peat below 1700 contact
Archaeological sites around Salmon River estuary						
35TI30	1499–1950	230 ± 50	Beta-133203	3S/1E	30–40	Charcoal
35LNC58	1034–1220	890 ± 40	Beta-133202	0S/5W	50	Charcoal
35LNC58	695–1166	1,070 ± 100	WSU-3502	2N/4W	68	Charcoal
35LNC59	969–1260	940 ± 80	Beta-12068	26.5S/7W	130	Charcoal
35LNC33	1263–1620	550 ± 95	WSU-3503	S5/E7	89	Charcoal
35LNC33	1040–1291	810 ± 70	Beta-133201	S5/E7	70	Charcoal
35LNC33	1026–1262	880 ± 70	Beta-2422	S7/E0	150–160	Charcoal
35LNC132	92BC–65AD	2,010 ± 30*	Beta-466893	AP1	14–24	Cervid molar
35LNC132	191–3BC	2,080 ± 30*	Beta-466894	AP8	56–66	Charcoal
35LNC136	137–335	1,780 ± 30*	Beta-466895	SP3	0–20	Marine shell

[a] Ages in calibrated (approximate solar) years AD (BC shown for 2 ages) calculated using OxCal (version 4.3, Bronk Ramsey 2009; probability method) with the INTCAL04 dataset of Reimer et al. (2013). Calibrated ages show time intervals of 95% probability distribution (confidence intervals). Sites with roman numerals (blue on Figure 2) are ^{14}C sampling sites of Nelson et al. (2004). Sites with labels beginning with “35” (red on Figure 2) are recorded archaeological sites. Ages from the Salmon River Wet Site (site II; 35LNC64) are also discussed by Minor and Grant (1996).

[b] Accelerator mass spectrometer (AMS) ages (marked with asterisks) or radiometric ages (no asterisk; Beta-ages are liquid-scintillation ages) in radiocarbon years ± standard deviation as reported by laboratory on materials described in the rightmost column. Dry sample weights for radiometric ages were 35–100 g. Quoted errors for AMS ages are the larger of counting error or target reproducibility error. Geochron Laboratories (GX) age is the mean of 7 AMS ages (GX-17834, 17839, 17849, 17924, 17938, 17943, and 17948) on seven herbs in growth position at the contact as explained in Nelson et al. (1995). This is the most precise ^{14}C age for the 1700 contact at the Salmon River.

[c] Cores and exposure labels beginning with “G” are those described by Grant in 1987-1992 (Grant 1989); labels following the “G” are field numbers. Archaeological proveniences vary depending on investigator and include units of various sizes designated by numbers at 35LNC64, units designated by grid location (e.g., 3S/1E), auger probes (AP), and shovel probe (SP) identified by numbers.

[d] Where samples are referenced relative to a “contact,” it is the upper contact of the A horizon inferred to have subsided during the earthquake and(or) been covered by a deposit of the accompanying tsunami in 1700. Age of 157 ± 17 (discussed by Nelson et al. 1995) is the most precise ^{14}C age for the 1700 contact at the Salmon River.