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Late Pleistocene vegetation and sedimentary charcoal at Kilgii Gwaay archaeological site in coastal British Columbia, Canada – with possible proxy evidence for human presence by 13,000 cal BP

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ABSTRACT

Kilgii Gwaay is an early Holocene archaeological wet site located in the intertidal zone of Ellen Island in the southern Haida Gwaii archipelago of coastal British Columbia, Canada. The Kilgii site includes one of the oldest shell middens in western North America and provides evidence of early maritime adaptations by humans. Radiocarbon-dated cultural deposits that surround a small paleopond (Kilgii Pond) include hearth features, abundant lithic, bone and wood artifacts, and a diverse fossil fauna and flora. The known occupation dates between 10,800 and 10,500 cal BP, when relative sea level was 1-3 m lower than today. The site was submerged and capped by marine deposits by 10,500 cal BP as relative sea level rose. We conducted multi-proxy paleoenvironmental analyses (magnetic susceptibility, pollen, charcoal, macrofossils) on Kilgii Pond sediments from a core taken beneath the coarse intertidal deposits. Pollen analysis indicates establishment of herb-shrub tundra by 14,500 cal BP, followed by pine-dominated communities after 13,800 cal BP and spruce forest with abundant ferns from about 13,250 cal BP. Macroscopic charcoal in the core is most abundant during the period of confirmed human occupation; however, significant peaks in charcoal abundance are present well below the known occupation horizon. Since lightning and natural forest fires are infrequent in this wet hypermaritime setting, we consider that the charcoal peaks from Kilgii Pond may serve as a proxy for human presence, potentially as early as 13,000 cal BP, approximately 2200 years earlier than indicated by the AMS-dated cultural deposits and artifacts.

Keywords

Haida Gwaii, charcoal, pollen analysis, archaeology, Kilgii Gwaay, peopling of Americas

INTRODUCTION

The peopling of the New World is a long-standing and controversial problem, especially regarding the timing and route(s) used by early colonists to travel from Beringia to the rest of the Americas. In recent decades, two competing hypotheses have been the focus of this debate, namely the Ice-Free Corridor (IFC) hypothesis, and the North Pacific Coast (NPC) route, as summarized by Potter et al (2018). The development of this debate has a long history, often with a focus on suitable paleoenvironments (Mandryk et al 2001, and references therein). Although Potter and others argue that the weight of evidence is largely consistent with either route, it is clear that deglaciation along the NPC occurred earlier than in the IFC and allowed for human migration as early as 16,000 cal BP, and possibly even earlier, based on recent ^{10}Be dating of deglaciated coastal environments (Lesnek et al 2018; Darvill et al 2018), geomorphological evidence of glacial refugia in southeastern Alaska (Carrara et al 2007), early deglaciation of the Aleutian shelf (Misarti et al 2012), and paleoecological research on the exposed and vegetated Dogfish Bank in Hecate Strait of Haida Gwaii (Lacourse et al 2005).

Archaeological evidence of human presence during the Late Pleistocene and early Holocene of the NPC was rare and scattered until recently, due in part to what Easton (1992) described as a “Mal de Mer” situation, where the maritime environment was seen by many as a barrier to research, based on a historical terrestrial mindset (Mackie et al 2018). Since Easton’s paper, the NPC route has gained considerable traction as an early corridor for human expansion into lands south of the Wisconsin ice sheets, with growing evidence for early human presence along the west coast, particularly on Haida Gwaii and some other coastal islands (Mackie et al 2018). Human footprints dated to ca. 13,100 cal BP on Calvert Island are among a number of recent discoveries that add to the evidence for early coastal occupation and adaptation (McLaren et al 2018).

Our focus in this paper is on the Haida Gwaii archipelago in coastal British Columbia, particularly the Moresby Island area, which lies near the middle of the NPC corridor. The intertidal wet site of Kilgii Gwaay on Ellen Island (52° 9.3'N, 131° 5.7'W), a small (~ 20 ha) island in the southernmost Gwaii Haanas National Park Reserve (Fig. 1), is important for several reasons. The site is significant due to its earliest Holocene occupation age (10,800 to 10,500 cal BP), which is based on radiocarbon dating of wood artifacts, along with charcoal, seeds and mussel shell dates from cultural layers (Electronic Supplementary Material 1), as summarized in Fedje et al (2005b) and Cohen (2014). This single component site is particularly significant for its documentation of early maritime cultural adaptation and marine resource use (Fedje 2003; Fedje et al 2001, 2005b; Mackie et al 2018), as well as archaeobotany (Cohen 2014). The initial discovery of the site in 1991 by Haida archaeologist Captain Gold, who collected more than 1500 stone artifacts, was followed by detailed excavations in 2001, 2002 and 2012 (Fedje et al 2001, 2005b). Recovery of a diversity of fish, shellfish, and marine mammal and bird remains in addition to lithic, bone and wood artifacts has established that Kilgii Gwaay was an important marine hunting and fishing camp. It also records the earliest known evidence for a Northwest Coast shell midden (Fedje et al 2001). The

harvesting of both nearshore and offshore marine resources implies the use of watercraft and knowledge to travel within this rugged coastline.

Figure 2 shows a plan view of the Kilgii Gwaay site surrounding a buried paleopond currently overlain by intertidal deposits. This ancient Kilgii Pond is roughly horseshoe-shaped and about 50 m wide based on exploratory coring. Scattered stone artifacts surround the pond, but are concentrated on the western and eastern edges, where the excavations in 2001 and 2002 recovered over 4000 lithic artifacts as well as hundreds of bone and wood artifacts. Two percussion cores 10 cm in diameter were collected from the paleopond (Fig. 2) by Fedje et al (2001). In this paper, we use multi-proxy paleoenvironmental analyses of Core 2, including magnetic susceptibility, pollen, charcoal and other macrofossils to characterize the early vegetation history of Ellen Island and the ecological context of the Kilgii Gwaay archaeological site.

MATERIALS AND METHODS

Stratigraphy and radiocarbon dating

Core 2 (2.26 m long) was split into two equal halves after retrieval, wrapped in plastic film and aluminum foil for transport and storage, and stored at 4°C until analyzed. Sediment stratigraphy was described on the split core by visual inspection, accompanied by magnetic susceptibility measured at 1 cm intervals using a Bartington MS2E surface sensor. AMS radiocarbon ages were obtained on 12 samples including wood, seeds, conifer needles, or shell (Table 1). The IntCal13 data set (Reimer et al., 2013) was used to calibrate radiocarbon ages to calendar years before present (cal BP). An age-depth model was built using calendar age probability distributions for 10 of the ages using 10,000 iterations of a smooth spline in the ‘clam’ package (Blaauw 2010) in R (R Core Team 2017). Two ages were excluded from the model because they were out of stratigraphic order and considerably younger or older than the ages immediately above and below (Table 1). As determined by Southon and Fedje (2003), a marine reservoir correction of –600 yr was applied to the age on a sea urchin test near the top of the sampled sequence.

Pollen analysis

Prior to subsampling, 0.5 cm of outer sediment was removed from the split core to avoid contamination. Subsamples of 2 cm³ were extracted for pollen analysis at 2 cm intervals using a calibrated brass sampler. Palynomorph sampling began at a core depth of 48 cm where peaty sediments became prominent in mixed intertidal-terrestrial materials, suggesting lagoonal conditions. Volumetric displacement in water was used to take 5 cm³ samples from clay-rich sediment at the base of the core. Palynomorphs were isolated from sediment subsamples using standard processing methods with some modifications (Faegri et al 1989). Subsamples were transferred into 50 mL centrifuge tubes, and each sample received one tablet of exotic *Eucalyptus* pollen (16,180 ± 1460, Batch # 903722). Subsamples were treated with 20% HCl, 10% KOH, acetolysis, and sieved at 250 µm to remove large particles. Samples were also treated with hot 48% HF to remove silicates, followed by a hot 10% HCl rinse to prevent formation of silicofluorides. Residues were

stained red with safranin 'O', dehydrated in successively higher concentrations of EtOH, ending with tertiary butyl alcohol. Samples were mounted on glass slides in 2000 cs silicone oil and coverslips were sealed with nail enamel. Identification and quantification of pollen and spores was conducted using a Zeiss compound microscope at 400× magnification. Oil immersion at 1000× magnification was needed for some identifications.

A minimum sum of 300 pollen and spores was the goal for all samples. Identification of palynomorphs was aided by standard pollen keys (Faegri et al 1989; McAndrews et al 1973; Moore et al 1991) and comparison with a modern pollen and spore reference collection in the Department of Biological Sciences at Simon Fraser University. Pollen and spore taxa were identified to genus or species level when distinguishing features are present. For example, it is possible to separate the shrub alder pollen morphotype (i.e. *Alnus viridis* type) from tree alder (*Alnus rubra* type) based on specific morphological criteria such as size, wall thickness, arci strength, and pore structure (May and Lacourse 2012). The interpretation in this paper of spruce pollen as derived from Sitka spruce (*Picea sitchensis*) is based on this species as the only native spruce present on Ellen Island, and the rest of Haida Gwaii. Cohen (2014) identified wood artifacts and charcoal from Kilgii Gwaay as *Picea sitchensis*, confirming its local presence. Ericales include mostly *Empetrum*-type tetrads, and at least two other unknown ericaceous taxa. Monolete fern spores with absent or non-distinct perines were classified as Filicales. Pollen and spore counts were entered into TILIA software (Grimm 2011) for calculation and pollen diagram plotting. Pollen percentages are based on the sum of all tree, shrub and herb pollen. For spores and pollen from obligate aquatic plants, percentages are based on the main pollen sum in addition to the sum of each group. Cluster analysis (CONISS) was used for numerical zonation of the pollen diagram.

Charcoal analysis

For charcoal analysis, sediment samples were taken at contiguous 1 cm intervals from 45 cm to the base of the core at 226 cm. Sediment sample volume was 2 cm³, except in the basal clays where 1 cm³ was analyzed. Samples were treated with 3% H₂O₂ for 20 h and then sieved through 150 µm mesh with distilled water. The >150 µm fraction was transferred to a Bogorov tray and charcoal particles were enumerated in four size classes (150-250 µm, 250-500 µm, 500-1000 µm, and >1000 µm) under a Zeiss stereomicroscope. Counting charcoal by size classes allows for comparisons of smaller size classes, which may be transported over long distances, with larger sizes that are more likely of local origin (Whitlock and Larsen 2001). Invertebrate remains and plant macrofossils in these samples were also identified and counted.

We tested the statistical significance of peaks in charcoal accumulation rates using CharAnalysis (Higuera et al. 2009). Charcoal data were interpolated to the median sample resolution of 23 yr before analysis, as per Higuera et al. (2009). Model settings for peak analysis included a 500-yr background smoothing window based on a locally-weighted regression robust to outliers and a 99% significance threshold. Analyses run with a 1000-yr window and/or a 95% threshold returned nearly identical results.

RESULTS

Stratigraphy and Dating

The sediment stratigraphy of Core 2 from Kilgii Pond is summarized in Fig. 3, which also shows the stratigraphic position of a small basalt flake (ca. 1.6 cm long, 1 cm wide) near the top of the core that is similar to many other Kilgii artifacts. It was likely incorporated into the disturbed intertidal deposits at the top of the core due to bioturbation or mixing by ocean waters in the intertidal zone. Fedje et al (2005b) note that the Kilgii Pond basin was still fresh water, based on diatom analyses, until at least 11,000 cal BP, soon followed by bioturbation and mixing with intertidal sediments as relative sea level rose.

The base of the core consists of compact silty clay (226-217 cm) and is overlain by brown silty gyttja (217-200 cm) that gradually increases in organic content (Fig. 3). Between 200 and 78 cm, the core consists of coarse woody detrital peat with a large wood fragment at 190-196 cm. Minor increases in magnetic susceptibility at 98-94 cm and 89-87 cm are associated with silty peat and gravelly sand, respectively. Mixed terrestrial and intertidal sediment i.e., sandy silt and peat with occasional gravel, shells and shell fragments occurs between 78 and 40 cm. The uppermost 40 cm consists of shell fragments with sand and gravel, or 'shell hash' and is marked by a large increase in magnetic susceptibility at 20 cm. Ten calibrated radiocarbon dates (Table 1) were used to produce an age-depth model for the Kilgii Pond core (Figure 4). The model predicted an age of 14,540 cal BP (14,380–14,700 cal BP) for the base of the core.

Pollen Analysis

We aimed for a minimum pollen sum of 300, but due to low pollen concentrations in the three uppermost samples, we accepted lower sums of 174 to 227 for these samples. Elsewhere in the core pollen sums consisted of 306 to >1000 grains. The median pollen sum was 460. Summary results of the major pollen and spore types from Kilgii Pond are shown in Fig. 5, which is arranged with the earliest taxa at left. Detailed pollen diagrams showing all taxa can be found in Helmer (2014). Pollen and spore concentrations for the major types are shown in Electronic Supplementary Material 2. Cluster analysis of the pollen percentages identified three main pollen zones and two subzones.

Zone 1a: Sedge-willow (Cyperaceae-*Salix*) subzone, 226 - 215 cm (14,540 - 14,200 cal BP). Although pollen concentrations are low in this basal silt and clay, sedge pollen reaches 60% and willow up to 30%, with other herbaceous taxa comprising the rest of the pollen sum. The heath family (Ericaceae) is also indicated by continuous pollen presence, and confirmed by the seed of *Arctostaphylos* (bearberry) used to radiocarbon-date the basal sediments (Table 1). The continuous presence of planktonic freshwater algae such as *Pediastrum* in combination with lake sediment rather than peat indicates open fresh water in the pond at this time. The presence of pondweed type pollen (*Triglochin*/*Potamogeton* type) supports the freshwater interpretation.

Zone 1b: Ericales subzone, 215 – 199 cm (14,200 - 13,850 cal BP). Pollen tetrads of Ericales including mostly *Empetrum* type, reach peak abundance of up to 70% in this subzone. Prominent but declining values of willow pollen (10-20%), and increases in fern spores (*Polypodium* and Filicales) are also apparent. Both subzones 1a and 1b are mostly treeless and dominated by herbs and dwarf shrubs, although at the top of this zone, pine pollen begins to rise rapidly.

Zone 2: Pine - shrub alder zone (*Pinus-Alnus viridis* type), 199 – 157 cm (13,850 - 13,260 cal BP). *Pinus contorta* type pollen rises to peak values of 90% in this zone, which corresponds with a stratigraphic change from lake sediment to peaty sediment. Pine pollen is joined in the upper half of the zone by *Alnus viridis* type pollen that increases quickly to 30-60% as pine pollen almost disappears. Filicales fern spores increase from 15 to 60% and freshwater algae reach maximum levels here and early in the next zone.

Zone 3a: Spruce (*Picea*) subzone, 157 - 77 cm (13,260 - 11,320 cal BP). An abrupt rise in spruce pollen percentages to 60% marks the beginning of this zone. High spruce values of up to 85% persist throughout along with abundant *Alnus viridis* type pollen and fern spores. Pollen of western hemlock (*Tsuga heterophylla*) makes its first appearance near the middle of zone 3a, and is continuously present after 12,500 cal BP. Freshwater algae, horsetail spores (*Equisetum*) and pondweed pollen (*Triglochin/Potamogeton* type) are also present.

Zone 3b: Shrub alder (*Alnus viridis* type) subzone, 77 – 48 cm (11,320 - 10,260 cal BP). Shrub alder pollen is consistently dominant at 50-80% of the pollen sum, along with spruce and western hemlock pollen and fern spores.

Macrofossils

Macrofossils recovered from the charcoal analysis samples include aquatic indicators such as midge (chironomid) and caddisfly (Trichoptera) remains, as well as abundant mite remains (Fig. 6). Oospores of aquatic green algae (Characeae) and seeds of pondweeds (*Potamogeton*) also confirm early open freshwater conditions. A number of seeds and foliage of terrestrial plant taxa and fungal sclerotia were also recorded and help to supplement the paleoenvironmental interpretation based on the pollen and spore record. *Menyanthes trifoliata* seeds confirm the local presence of this semi-aquatic herb that is also present in the pollen record. Seeds from salmonberry and thimbleberry (*Rubus spectabilis* and *R. parvifolius*) are present between 13,500 and 10,500 cal BP and are particularly noteworthy because these berry-producing shrubs would have been important terrestrial food sources for early occupants of Kilgii Gwaay.

Charcoal Analysis

The detailed results of macroscopic charcoal analysis are summarized in Fig. 7 showing concentrations, total accumulation rates, and statistically significant peaks in charcoal accumulation rates. Charcoal

concentrations in the four size classes follow similar patterns through time; however, particles between 250 and 1000 μm are most abundant. In general, changes in charcoal concentrations and accumulation rates correlate well with changes in overall sediment stratigraphy and pollen assemblages. There is little to no charcoal before 13,700 cal BP, during accumulation of basal clays and the overlying lake sediment, in the herb-shrub tundra zone. A minor increase to 10 charcoal particles/cm³ occurs at ~13,670 cal BP, when *Pinus contorta* pollen percentages reach their maximum. This increase corresponds with the first significant increase in charcoal accumulation rates. Charcoal concentrations increase after 13,300 cal BP, when *Picea* pollen becomes abundant, with intermittent increases to 100-360 particles/cm³ between 13,180 and 11,670 cal BP. Significant peaks in charcoal accumulation rates occur, on average, every 210 yr during this interval; the time between significant peaks in charcoal accumulation rates varies between about 50 and 320 years. Charcoal is continuously abundant after 11,250 cal BP and reaches a maximum concentration of 530 particles/cm³ at 10,900 cal BP, just before the transgressing shoreline reached the elevation of Kilgii Gwaay.

DISCUSSION

Vegetation History and Archaeobotany

The vegetation history of Ellen Island as documented by pollen and spore analysis from Kilgii Pond begins with herb-shrub tundra from 14,500 to 13,850 cal BP, transitioning to open lodgepole pine forest until 13,300 cal BP, followed by Sitka spruce-alder forest with Western hemlock until 10,200 cal BP. This sequence of postglacial vegetation development on Ellen Island is broadly similar to that described in other published pollen diagrams from Haida Gwaii (Heusser 1995, Lacourse 2004, Lacourse and Mathewes 2005, Lacourse et al 2005) although not all lake cores include sediments older than 14,000 cal BP as in Kilgii Pond zone 1a. Pollen diagrams from other sites to the north like Hippa Island (Lacourse et al 2012) off the west coast of Graham Island show a similar pattern of plant succession to Kilgii Pond, beginning with treeless vegetation similar to herb-shrub tundra, a rapid rise of lodgepole pine type pollen with very high pollen frequencies, followed by increases in shrub alder, spruce, and then Western hemlock. The most comparable pollen diagram to Ellen Island is also from the South Moresby region. West Side Pond (Fig. 1) is even older than Kilgii Pond and shows a similar pattern of plant succession (Lacourse et al 2005). The early treeless zone at West Side Pond also has pollen of *Arctostaphylos*, while the basal age at Kilgii Pond (Table 1) is on a rare seed of the same genus. Many other herbaceous taxa or dwarf shrubs, including willows, grasses, wormwood (*Artemisia*), other Asteraceae and Ericales as well as ferns, particularly *Polypodium* show similar abundance patterns at the two ponds. Another pollen diagram from a small forest hollow on nearby Anthony Island, about 10 km west of Ellen Island, describes a similar pattern of early vegetation changes (Hebda et al 2005) although the time resolution is insufficient for a detailed comparison.

The archaeological record from Kilgii Gwaay suggests human occupation 10,800 to 10,500 cal BP, although radiocarbon ages on wood artifacts and from cultural deposits span from ~10,910 to 10,230 cal BP

(Electronic Supplementary Material 1). These intervals correspond with pollen zone 3b (11,320 - 10,260 cal BP), which is dominated by shrub alder along with Sitka spruce, Western hemlock, and ferns. Excavated wooden artifacts have been identified (Cohen 2014) as made from Western hemlock and Sitka spruce, also known from the pollen record (Fig. 5). Shrub alder (also known as green alder, or Sitka alder) is a shrub to small tree most common in open canopy forests on moist sites, and is also characteristic of disturbed sites (Klinka et al 1989). Collectively, the paleoecological evidence suggests wet coniferous forest at Ellen Island during occupation, with understory openings and forest edge vegetation at Kilgii Pond.

In addition to the pollen and spore record, macrofossils from Kilgii Pond also provide information on plant presence. The recovery of a *Pinus contorta* needle at 13,800 cal BP (Fig. 6) confirms that the rapid rise in pine pollen frequencies in pollen zone 2 (Fig. 5) reflect local pine growth and are not due to long distance dispersal of pollen. Sitka spruce seeds at 13,000 and 10,800 cal BP also confirm the local presence of mature Sitka spruce trees. Similarly, the presence of pondweed (*Potamogeton*) endocarps confirms the local presence of this aquatic plant, clarifying the taxonomic uncertainty posed by pollen of the *Triglochin/Potamogeton* type in the pollen diagram.

The plant macrofossil record (Fig. 6) also confirms fossil seeds of two important berry-producing shrubs, salmonberry (*Rubus spectabilis*) and thimbleberry (*Rubus parviflorus*), between 13,500 and 10,500 cal BP. *Rubus* species are insect-pollinated and their pollen is difficult to identify and uncommon, usually only recorded as undifferentiated Rosaceae pollen. These two shrubs often occur together on forest edges and early seral communities, and thimbleberry may also be common on burned or otherwise disturbed sites (Klinka et al 1989). Both the berries and young shoots of these shrubs are well known as important food sources for coastal peoples (Turner 1995, 2004) and their presence during the period of confirmed human occupation and earlier would have been welcomed by the occupants of the hunting and fishing camp in summer. Archaeological investigations at Kilgii Gwaay by Cohen (2014) identified a salmonberry and elderberry (*Sambucus*) processing area that suggests summer occupation when these berries ripen. It is clear that Kilgii Gwaay was used not only for fishing and hunting, but also for harvesting and processing of plant foods.

The Importance of the Charcoal Record

Charcoal is common at Kilgii Gwaay, and is widely distributed in the cultural deposits, as well as in the Kilgii Pond core. Human ignition of fires for purposes like cooking and food processing is demonstrated by the discovery of a hearth complex with charcoal during excavations (Fig. 2) on the west side of the paleopond (Cohen 2014). The detailed record of macroscopic charcoal from Kilgii Pond reveals an interesting pattern of abundances. It is perhaps expected that the most continuous and abundant accumulation of charcoal particles falls within pollen zone 3b, and is centered around the known period of human occupation between 10,800 and 10,500 cal BP (Fig. 7). This pattern is clear in both charcoal concentrations (particles/cm³) and accumulation rates (particles/cm²/cal yr). It is also interesting that the

highest charcoal concentrations occur slightly before the known occupation interval, suggesting the possibility of even earlier occupations.

An unexpected result, however, is the series of frequent peaks of high charcoal concentration that occurs much earlier within pollen zone 3a (13,260 - 11,320 cal BP), which coincides with the sudden increase to dominance of spruce pollen and elimination of pine forest. The combination of high frequencies of Sitka spruce, shrub alder and fern palynomorphs suggests the development of wet coastal forest on Ellen Island by 13,300 cal BP. This change in forest type was likely accompanied by an increase in forest density and therefore fuel availability, although the abundance of shrub alder suggests forests were not entirely closed.

The South Moresby area of Haida Gwaii is located within the very wet hypermaritime Coastal Western Hemlock Zone (Meidinger and Pojar 1991). Mean annual precipitation at Ellen Island is about 2250 mm/yr (Wang et al 2016). Such climatically wet environments are not conducive to natural forest fires and lightning is very rare in the region (Parminter 1983; Stocks et al 2002; BC Ministry of Forests 2003). Climatic conditions during the latest Pleistocene were likely even less conducive to frequent forest fires. Recent paleoclimate reconstructions suggest that the northeast Pacific region was both cooler and wetter relative to the present (e.g. Praetorius et al 2015, Renssen et al 2018) during the Kilgii Pond spruce interval (pollen zone 3a).

Although natural fires do occur in the coastal rainforests of British Columbia, some areas have been free of forest fire over much of the Holocene (Lertzman et al 2002). Unfortunately, there are no charcoal records from elsewhere on the Haida Gwaii archipelago for comparison to Kilgii Pond. On the northern BC coast near Prince Rupert, Turunen and Turunen (2003) found only a few charcoal particles at a single depth in a Holocene peat sequence, suggesting that fire has not been an important agent of disturbance in this adjacent hypermaritime setting for at least the last 8500 years. Hoffman et al (2016a) found little soil charcoal dating to the latest Pleistocene on the hypermaritime central coast of BC, with some areas showing no evidence of fire for the last ~12,700 cal yr. Hoffman et al (2016b) make a convincing case that late Holocene fires in these temperate rainforests are linked to intentional burning by indigenous peoples for land management. Further south, Gavin et al (2003) reconstructed the Holocene fire history of rainforest on the wet outer coast of central Vancouver Island and showed that some areas, particularly stands of Sitka spruce and western hemlock, have not burned for the past 12,000 years. Similarly, Brown and Hebda (2002) found very low charcoal accumulation rates at Whyac Lake on southern Vancouver Island, when forests were composed of spruce, hemlock and alder during the early Holocene. The authors attribute the low charcoal abundance at that site to a wet climate. However, spruce pollen did not exceed 30%, making the comparison to our site somewhat tenuous. Collectively, the available evidence indicates that natural forest fires were infrequent and, in some areas, entirely absent in similar hypermaritime forests elsewhere on the BC coast. Deliberate human ignition is likely the source of most archaeological charcoal at Kilgii Gwaay, and probably also explains the high abundance of sedimentary charcoal in pollen zone 3.

Sea levels were lower prior to formation of the Kilgii Gwaay archaeological record (Fedje et al 2005a, Mackie et al 2018), which would place Kilgii Pond further inland than during the known shoreline

occupation. This would make Kilgii Gwaay a less desirable site for fishing or intertidal harvesting of shellfish, but the pond and its surroundings were likely important sites for fresh water, berry-producing plants, and hunting of terrestrial animals such as black bears, the remains of which are abundant at Kilgii Gwaay (McLaren et al 2005). The earliest well-documented archaeological sites on Haida Gwaii are three bear hunting sites in karst caves (Fig. 1) located 35 km (Gaadu Din caves) and 135 km (K-1 cave) to the north of Kilgii Gwaay (McLaren et al 2005, Fedje et al 2011). These hunting sites date from 12,700 to 10,000 cal BP and demonstrate familiarity with inland landscapes by that time and, by extension, use of other inland resources such as food plants and game animals living around areas such as paleo-Kilgii Pond. Since we know that humans were present elsewhere on Haida Gwaii by at least 12,800 years ago, it is reasonable to speculate on their potential presence on Ellen Island around this time, based on the archaeological evidence (Fedje et al 2001, Fedje et al 2005b, Fedje 2003).

Although located further inland during lowered sea levels, Kilgii Gwaay would have been proximal to any trail leading from the Pacific west coast to Hecate Strait via a low elevation pass – thus avoiding circumnavigation of the highly exposed water of the paleo-peninsula, with better access to uplands and both coasts, especially during storm periods. Calculations based on relative sea level reconstructions (Fedje et al 2005a, Mackie et al 2018) place Kilgii Pond on a terrestrial travel route 7 km from the ancient Hecate shoreline, and 12 km from the Pacific at 13,000 cal BP. Travel by paddling would entail a distance of 60-100 km at that time.

The Pacific Northwest of America has a long history of research addressing the use of fire for environmental and plant management by aboriginal peoples (Boyd 1999, Deur and Turner 2005), mostly based on Holocene and recent food plant management. Late Pleistocene records of human-caused fires in western North America are rare and inherently difficult to identify, so it is also interesting that the presence of humans in eastern Beringia prior to the Last Glacial Maximum has recently been inferred from peaks in charcoal and other bioindicators from lake sediments in Alaska (Vachula et al 2019).

The strong association of a detailed charcoal record with a well-dated archaeological site such as Kilgii Gwaay provides a rare opportunity to consider in greater detail the potential connections between past human presence and small local fires. Kilgii Gwaay has produced such a detailed fire record because of its unusual setting, with human activities on the shores of an ancient small pond that could capture a record of even small local fires for cooking or other activities, rather than representing a more regional record of forest fire activity.

CONCLUSIONS

The vegetation history of Ellen Island and Kilgii Gwaay is consistent with and confirms paleobotanical records from other Late Pleistocene and early Holocene sites on Haida Gwaii. The radiocarbon-dated pollen zonation for Kilgii Pond is consistent with other published sequences, beginning with herb-shrub tundra by 14,500 cal BP, followed by open pine-dominated communities after 13,800 cal BP and spruce-alder forest with Western hemlock and abundant ferns from about 13,250 cal BP.

The macroscopic charcoal record from Kilgii Pond provides a record of frequent fires from the known period of human occupation, between 10,800 and 10,500 cal BP. All size classes of charcoal particles reach their peak concentrations and accumulation rates around this occupation interval. The most surprising finding is the high concentration of charcoal along with multiple statistically significant peaks in charcoal accumulation rates that extend back to at least 13,000 cal BP, below the known occupation period and approximately 2200 years earlier than the beginning of the archaeological record. The forests adjacent to the Kilgii Gwaay wet site during this interval were temperate rainforest composed of a mixture of Sitka spruce, Western hemlock, and alder, in a region that is classified as a hypermaritime biogeoclimatic zone where lightning and natural forest fires are very rare, and essentially absent in some areas. Like the recent charcoal study by Vachula et al (2019), we cannot prove that the unusually frequent record of repeated burning at Kilgii Pond is not related to lightning-induced forest fires, but since people were present at other nearby sites and given the abundance of charcoal in adjacent cultural deposits, human ignition is clearly the most likely explanation. Our charcoal evidence thus supports an earlier human presence at Kilgii Pond than documented at the younger archaeological site and highlights the value of sedimentary charcoal as a potential proxy for human ignition activities.

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TABLES

Table 1 AMS radiocarbon and calibrated ages from the Kilgii Pond core on Ellen Island, British Columbia

FIGURE CAPTIONS

Fig. 1 The Haida Gwaii archipelago showing the location of Kilgii Gwaay (star) at its southern tip and other sites (circles) mentioned in the text including the bear-hunting cave sites of Gaadu Din and K-1. Dashed line shows location of Gwaii Haanas National Park Reserve. Inset shows location on the North Pacific coast of North America

Fig. 2 Outline of Kilgii Pond in light blue at 9400 ^{14}C yr BP (~10,600 cal BP) before it was transgressed by rising sea levels at ~10,400 cal BP. Positions of sediment cores 1 and 2 are shown. Contour lines are 1 m intervals

Fig. 3 Sediment stratigraphy and magnetic susceptibility of the core from Kilgii Pond, Ellen Island. Position of ^{14}C ages (Table 1) are shown as triangles along the y-axis. The lithic flake is shown in the stratigraphy at 7.5 cm

Fig. 4 Age-depth model for the Kilgii Pond core based on 10 AMS dates (Table 1) and a smooth spline using the ‘clam’ package (Blaauw 2010). Grey bands are 95% confidence intervals based on 10,000 model runs. The two ages marked with a red X were not used in model construction

Fig. 5 Percentages of major pollen and spore types from Kilgii Pond with 5× exaggeration for infrequent taxa. Ericales includes *Empetrum* type and undifferentiated Ericaceae pollen. Order of taxa is based on weighted averages. Also shown are concentrations of freshwater algae (*Pediastrum*, *Spirogyra*, *Sigmopollis*). The interval of confirmed human occupation (10,800-10,500 cal BP) based on AMS ^{14}C ages from adjacent cultural deposits and artifacts is indicated by the coloured horizontal band. See Fig. 3 for stratigraphy legend

Fig. 6 Concentrations of insect and plant macrofossils in charcoal samples from the Kilgii Pond core. Note changes in scale on x-axis. The interval of confirmed human occupation (10,800-10,500 cal BP) based on AMS ^{14}C ages from adjacent cultural deposits and artifacts is indicated by the coloured horizontal band. See Fig. 3 for stratigraphy legend. (s) = seeds, (n) = needles

Fig. 7 Macroscopic charcoal concentrations and total charcoal accumulation rates (CHAR) at Kilgii Pond. Concentrations are shown by size class and total concentration. Statistically significant peaks in CHAR are identified by black circles. Note changes in scale on x-axis. The interval of confirmed human occupation (10,800-10,500 cal BP) based on AMS ^{14}C ages from adjacent cultural deposits and artifacts is indicated by the coloured horizontal band

ELECTRONIC SUPPLEMENTARY MATERIAL

Supplemental Table 1 AMS radiocarbon ages relevant to human occupation of Kilgii Gwaay, Ellen Island, British Columbia

Supplemental Figure 1 Pollen and spore concentrations of important taxa from Kilgii Pond, Ellen Island, British Columbia. Note changes in scale on the x-axes. Orange band is the interval of confirmed human occupation (10,800 - 10,500 cal yr BP) based on ^{14}C ages from adjacent cultural deposits and artifacts.

Table 1 AMS radiocarbon and calibrated ages from the Kilgii Pond core on Ellen Island, British Columbia

Depth (cm)	Material	Radiocarbon Age (^{14}C yr BP $\pm 1\sigma$)	2 σ Calendar Age Range ^a (cal yr BP)	Lab Code ^b
20	Sea urchin test	8670 \pm 40 ^c	9540 – 9730	CAMS 79685
74	Wood	9640 \pm 20	10,810 – 11,170	UCIAMS 102667
79	Wood	10,025 \pm 40	11,320 – 11,750	CAMS 95557
110	Wood	10,890 \pm 35	12,700 – 12,810	UCIAMS 116603
161	Wood	11,415 \pm 35	13,150 – 13,330	UCIAMS 116602
199	<i>Pinus contorta</i> needle	12,010 \pm 60	13,740 – 14,040	CAMS 95558
207	<i>Potamogeton</i> seeds	12,420 \pm 60 ^d	14,170 – 14,910	CAMS 79686
216	Unidentified seed	12,190 \pm 60	13,840 – 14,260	CAMS 82214
216	Wood	12,335 \pm 40	14,110 – 14,640	CAMS 87243
219	Unidentified seed	12,455 \pm 40	14,260 – 14,950	CAMS 95559
223	Unidentified seed	11,695 \pm 45 ^d	13,430 – 13,590	CAMS 95560
224.5	<i>Arctostaphylos</i> seed	12,435 \pm 35	14,230 – 14,870	UCIAMS 116604

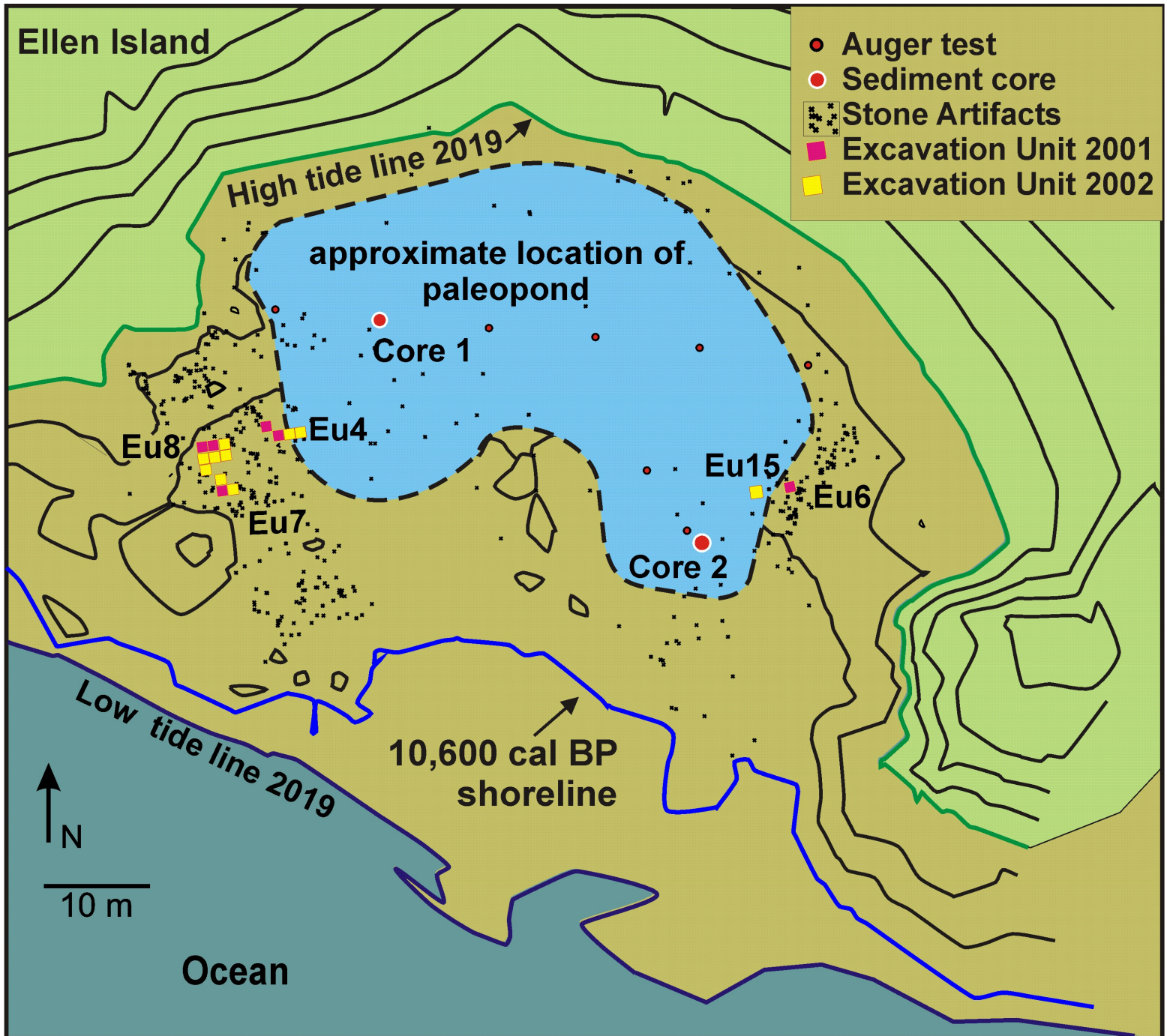
^a Age ranges, rounded to the nearest 10 yr, are from CALIB 7.10 based on IntCal13 (Reimer et al. 2013)

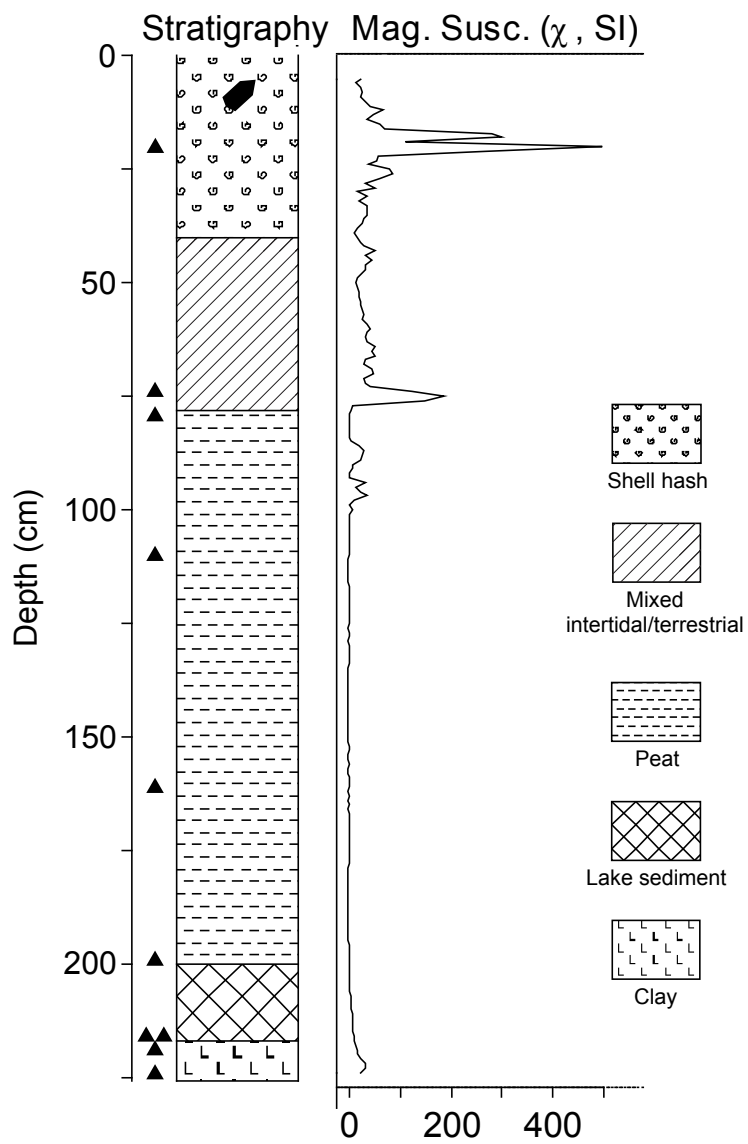
^b CAMS = Center for Accelerator Mass Spectrometry, USA; UCIAMS = University of California, Irvine.

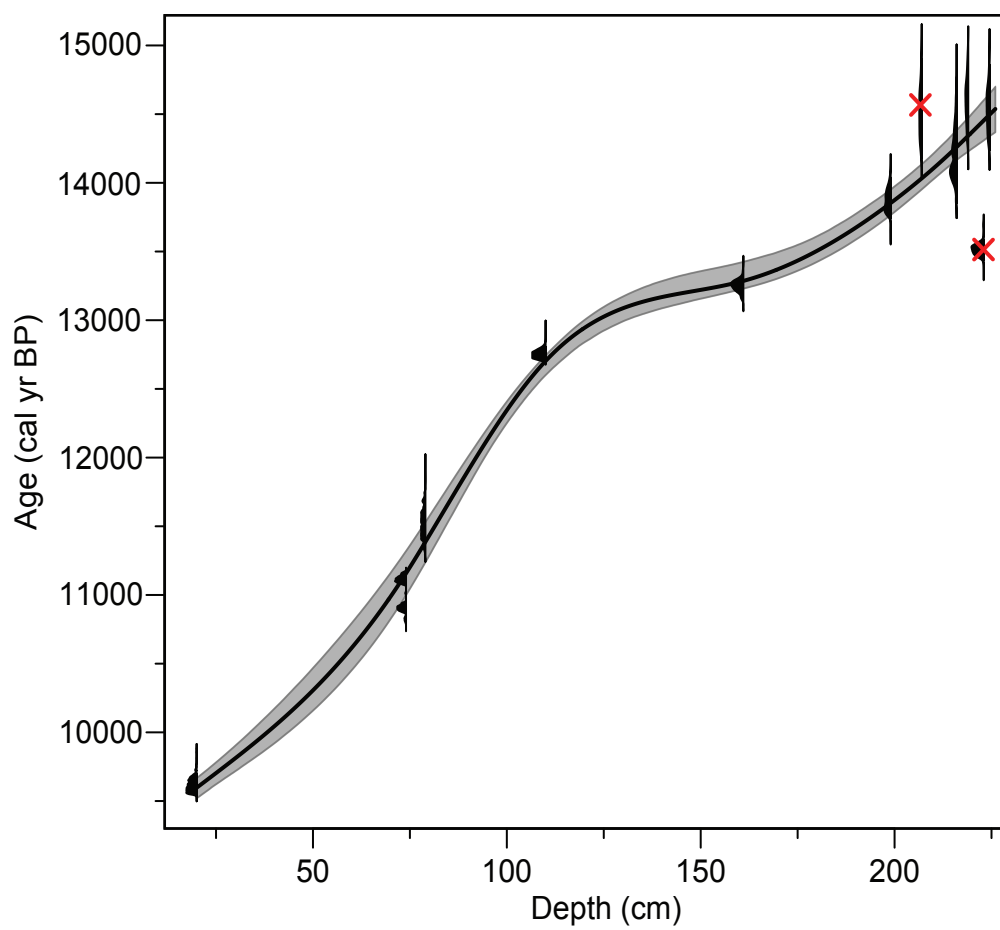
CAMS ages were previously reported by Fedje et al. (2001, 2005)

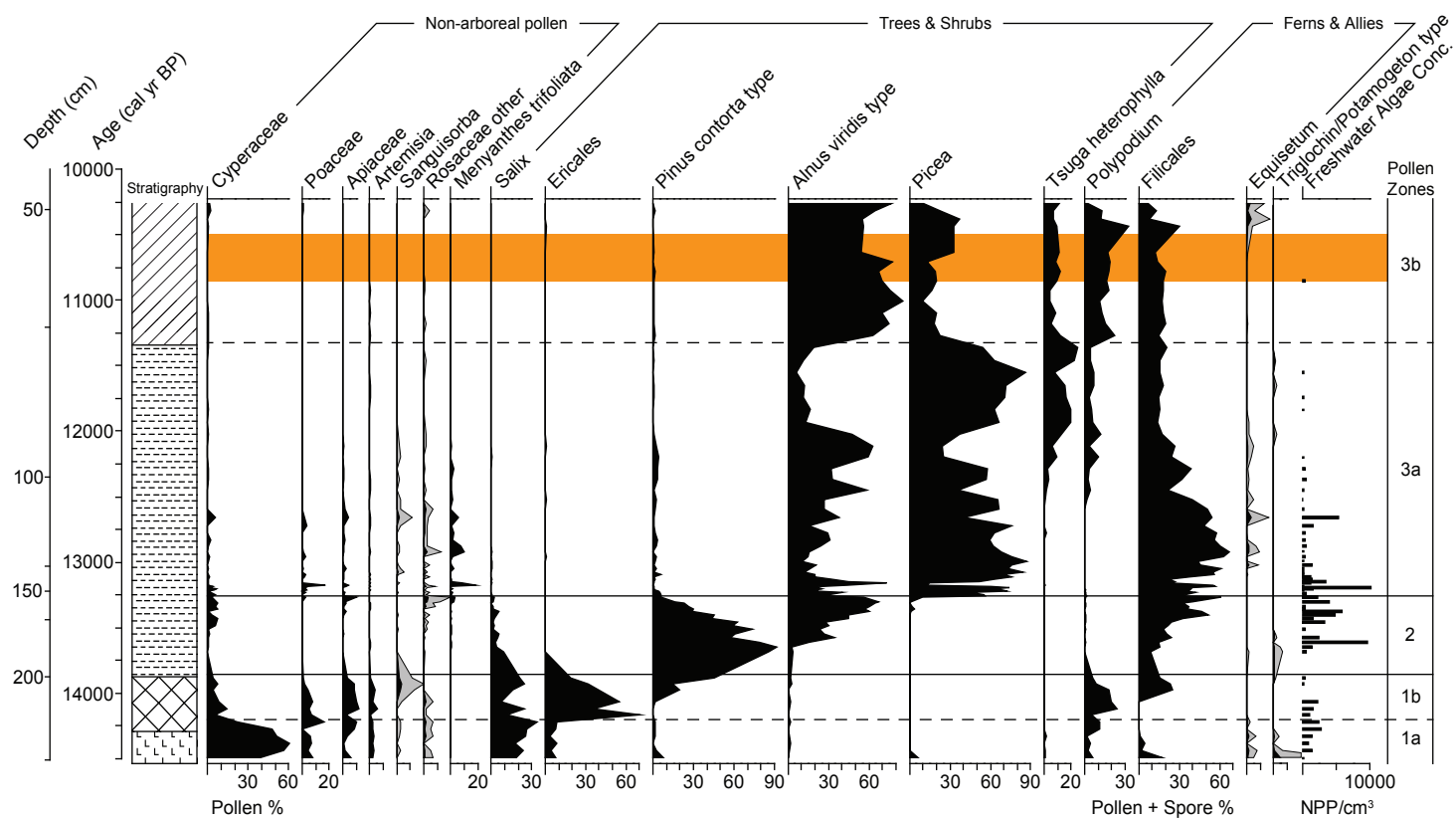
^c Marine reservoir correction of –600 yr applied as per Southon and Fedje (2003)

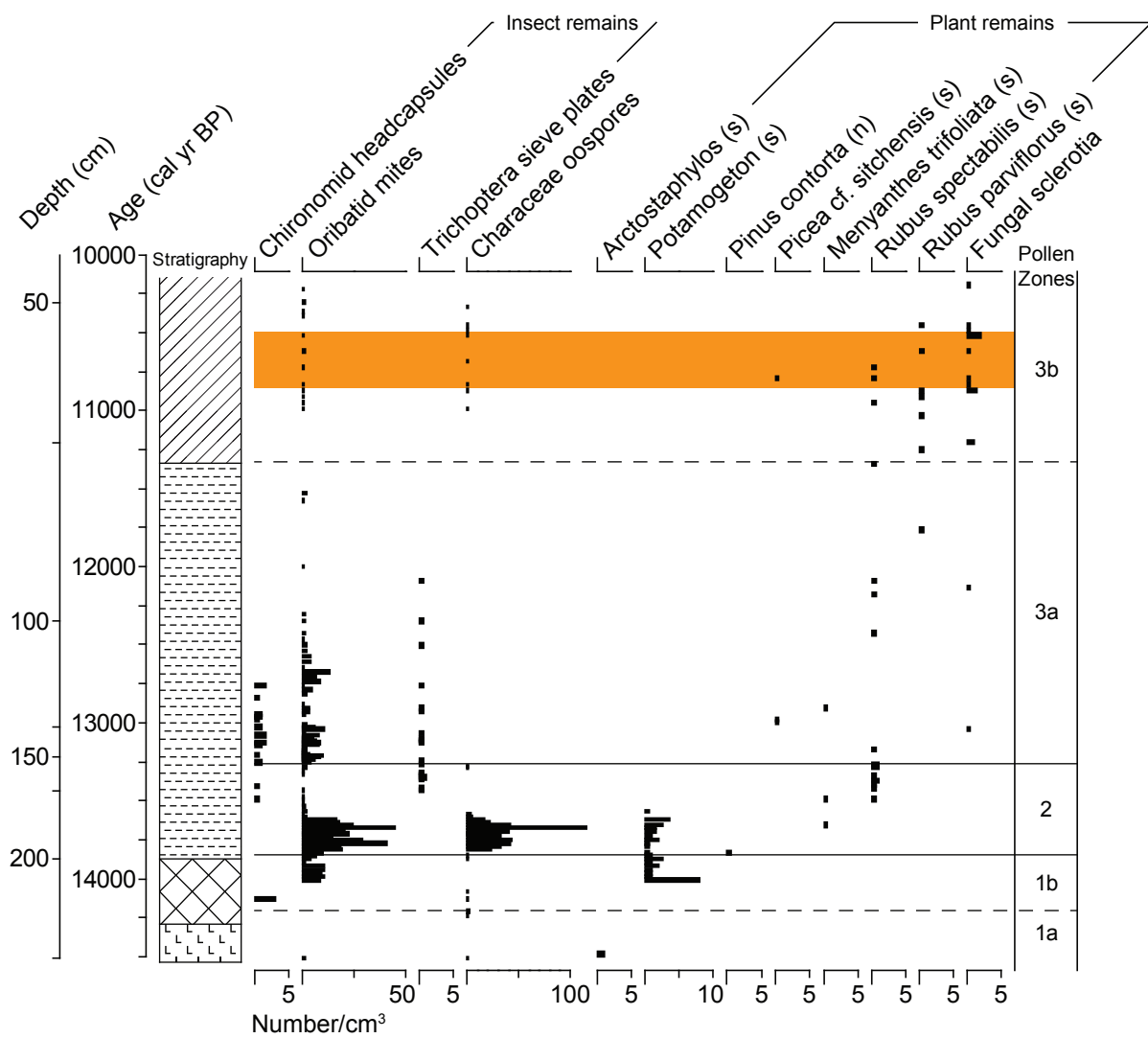
^d Age excluded from age-depth model

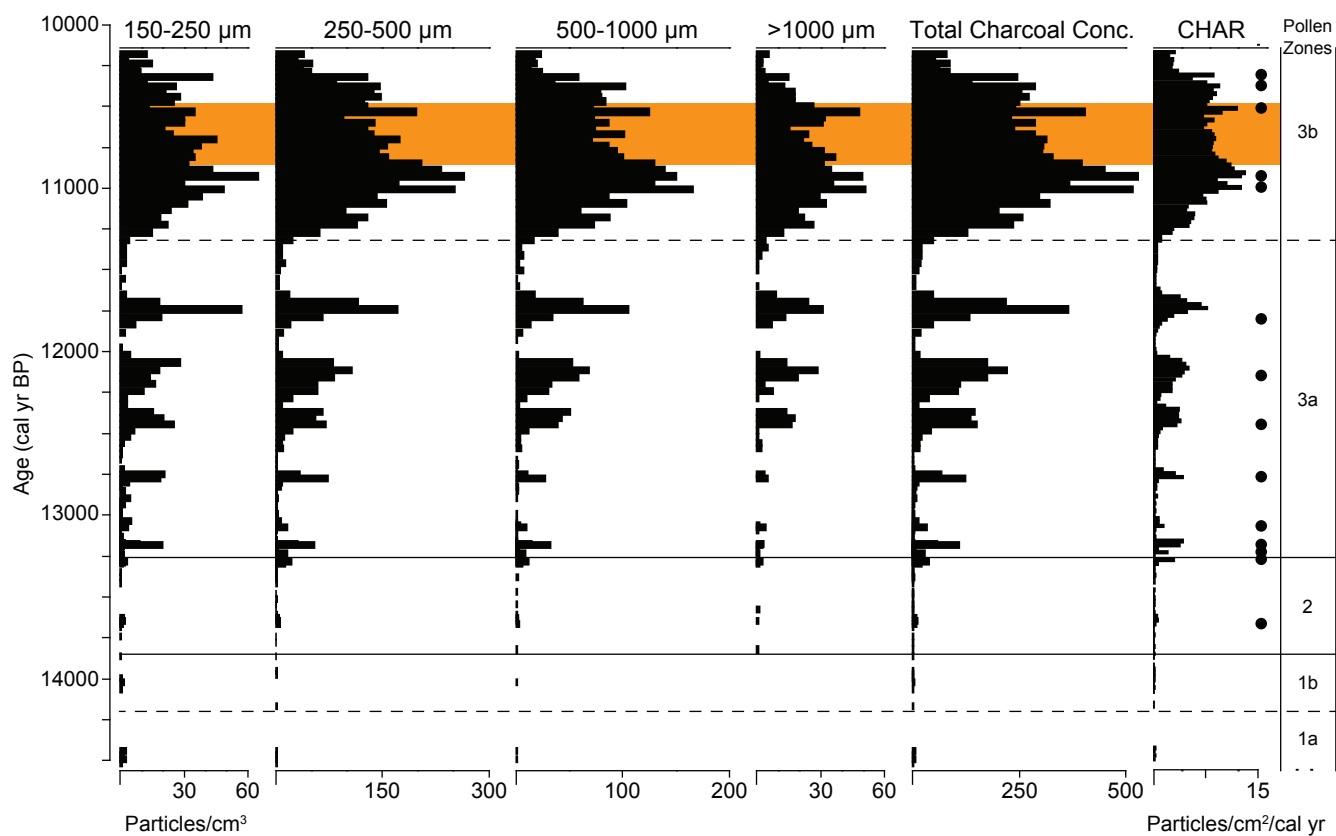












Electronic Supplementary Material for:

Mathewes RW, Lacourse T, Helmer E, Howarth C, Fedje DW (2019) Late Pleistocene vegetation and sedimentary charcoal at Kilgii Gwaay archaeological site in coastal British Columbia, Canada – with possible proxy evidence for human presence by 13,000 cal BP. *Vegetation History and Archaeobotany*.

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Supplemental Table 1 AMS radiocarbon ages relevant to human occupation of Kilgii Gwaay, Ellen Island, British Columbia

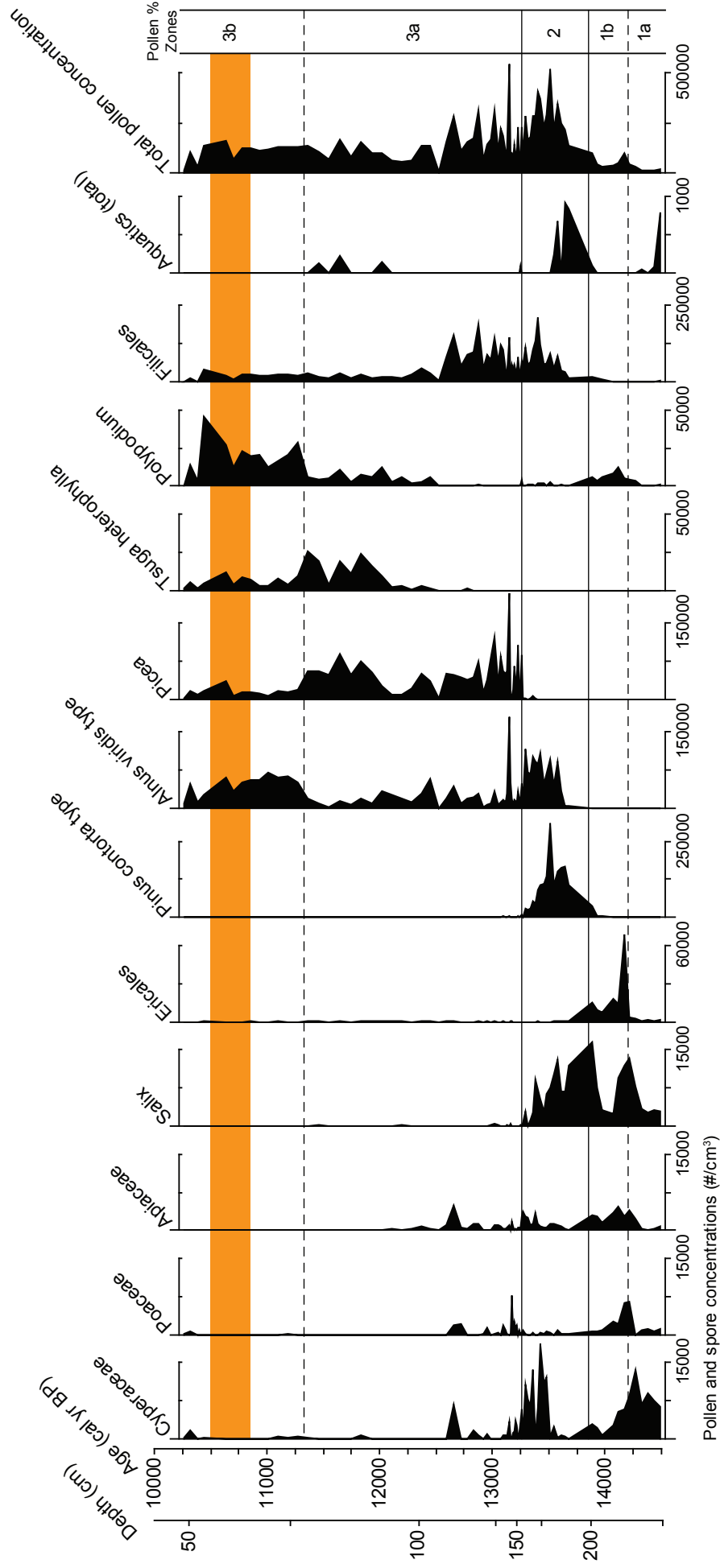
Material and Context	Radiocarbon Age (¹⁴ C yr BP ± 1σ)	Calendar Age (cal yr BP) ^b	Lab Code	Source
<i>Rubus</i> seed from hearth	9075 ± 35	10,230 (10,190–10,270)	UCIAMS 143282	Cohen (2014)
Charcoal from midden	9230 ± 50	10,400 (10,250–10,540)	CAMS 76668	Fedje et al. (2001)
<i>Sambucus</i> seed from hearth	9240 ± 25	10,420 (10,290–10,500)	UCIAMS 143283	Cohen (2014)
Charcoal from midden	9260 ± 40	10,440 (10,290–10,560)	CAMS 79682	Fedje et al. (2001)
Charcoal from cultural layer	9340 ± 40	10,560 (10,430–10,680)	CAMS 79684	Fedje et al. (2001)
Wood stake (artifact)	9380 ± 30	10,620 (10,520–10,690)	UCIAMS 116598	Cohen (2014)
Wood wedge (artifact)	9395 ± 40	10,630 (10,520–10,720)	CAMS 87642	Fedje et al. (2005)
Charcoal from midden	9410 ± 50	10,640 (10,510–10,760)	CAMS 77248	Fedje et al. (2001)
Split root wrap (artifact)	9415 ± 35	10,650 (10,570–10,740)	CAMS 87641	Fedje et al. (2005)
Mussel shell from midden	9420 ± 50 ^a	10,650 (10,510–10,770)	CAMS 79681	Fedje et al. (2001)
Charcoal from midden	9430 ± 50	10,660 (10,520–11,060)	CAMS 76666	Fedje et al. (2001)
Mussel shell from cultural layer	9440 ± 40 ^a	10,670 (10,570–10,770)	CAMS 79683	Fedje et al. (2001)
Mussel shell from midden	9440 ± 50 ^a	10,670 (10,520–11,060)	CAMS 76667	Fedje et al. (2001)
<i>Sambucus</i> seed from cultural layer	9455 ± 30	10,690 (10,590–10,760)	UCIAMS 116599	Cohen (2014)
Bear bone from cultural layer	9460 ± 50	10,700 (10,570–11,070)	CAMS 70704	Fedje et al. (2001)
Mussel shell from midden	9540 ± 40 ^a	10,910 (10,700–11,090)	CAMS 76669	Fedje et al. (2001)
Charcoal from paleosol below midden	9850 ± 40	11,250 (11,200–11,320)	CAMS 76670	Fedje et al. (2001)

^a Marine reservoir correction of –600 yr

^b Median and 2σ age ranges rounded to nearest 10 yr

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Supplemental Figure 1 Pollen and spore concentrations of important taxa from Kilgij Pond, Ellen Island, British Columbia. Note changes in scale on the x-axes. Orange band is the interval of confirmed human occupation (10,800 - 10,500 cal yr BP) based on ^{14}C ages from adjacent cultural deposits and artifacts.

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